CanSat 2025
Critical Design Review (CDR)
Outline

Team #3114
Robotics for Space eXploration

Presentation Outline

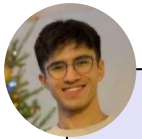
Team Organization

Adam Kabbara
CanSat Team Lead
2nd Year EngSci

Dr. Jonathan Kelly
Faculty Advisor
Professor @ UTIAS

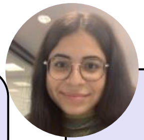
Arthur Goetzke-Coburn
Mechanical Team Lead
4th Year Robotics Eng.

Daniel Yu
Electrical Team Lead
4th Year Computer Eng.



Luke Watson
Software Team Lead
4th Year Computer Eng.

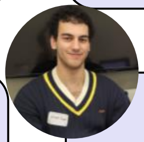
Gianluca Ceccacci
Mechanical Team Member
2nd Year EngSci



Nour Barsoum
Electrical Team Member
4th Year Robotics Eng.

Angelique Liao
Software Team Member
1st Year Electrical Eng.

Alexey Albert
Mechanical Team Member
1st Year Math & Physics



Robert Saab
Electrical Team Member
2nd Year Electrical Eng.

Acronyms (1/4)

Acronym	Definition
A	Analysis
ABS	Acrylonitrile Butadiene Styrene
ADC	Analog-to-digital Converter
AGDS	Auto-Gyro Descent System
API	Application Programming Interface
AT	Transparent
BEM	Blade Element Momentum
CAD	Canadian Dollar
CAL	Calibrate Altitude to Zero
CC	CanSat Container

Acronym	Definition
CCR	CanSat Crew
CDH	Communication and Data Handling
CFD	Computational Fluid Dynamics
CMD	Command
Config	Configuration
CPL	CanSat Payload
CSI	Camera Serial Interface
CX	Payload Telemetry On/Off Command
D	Demonstration
dB	Decibel

Acronym	Definition
dBi	Decibels Relative to Isotropic
dBm	Decibel Milliwatt
DVP	Digital Video Port
EPS	Electrical Power System
FSM	Finite State Machine
FSW	Flight Software Design
FPS	Frames Per Second
g	Gram
G	Acceleration due to Earth’s Gravity

Acronyms (2/4)

Acronym	Definition
GCS	Ground Control System
GNSS	Global Navigation Satellite System
GPIO	General Purpose Input/Output
GPS	General Positioning System
GS	Ground Station
GSC	Ground Station Crew
GUI	Graphical User Interface
HFSS	High-frequency Structure Simulator

Acronym	Definition
hPa	Hectopascal
Hz	Hertz
I	Inspection
I^2C	Inter-Integrated Circuit
ID	Identification
IMU	Inertial Mass Unit
in	Inch
KB	Kilobyte
kg	Kilogram
kHz	Kilohertz
LW	Lightweight

Acronym	Definition
LW-ASA	Lightweight Acrylonitrile Styrene Acrylate
m	Metre
MB	Megabyte
MCO	Mission Control Officer
MEC	Mechanism Actuation Command
MIPI	Mobile Industry Processor Interface
mm	Millimetre
MPa	Megapascal
ms	Millisecond

Acronyms (3/4)

Acronym	Definition
m/s	Meters per Second
mT	Millitesla
mV	Millivolt
N	Newton
NETID	Network Identification
NVS	Non-volatile Storage
OTA	Over the Air
PANID	Professional Area Network Identification
PCB	Printed Circuit Board
PLA	Polylactic Acid

Acronym	Definition
P2P	Peer to Peer
QHA	Quadrifilar Helical Antenna
RAM	Random Access Memory
RC	Recovery Crew
RHCP	Right-hand Circular Polarization
RP	Raspberry Pi
RPM	Revolutions per Minute
RP-SMA	Reverse Polarity SubMiniature Version A
Rqmt Num	Requirement Number

Acronym	Definition
RTC	Real Time Clock
s	Second
SCCB	Serial Camera Control Bus
SD	Secure Digital
SIM	Simulation Mode Control Command
SIMP	Simulated Pressure Data
SMD	Surface-mount Device
SPI	Serial Peripheral Interface
SPIFF	Serial Peripheral Interface Flash File System

Acronyms (4/4)

Acronym	Definition
SRAM	Static Random Access Memory
ST	Set Time
T	Test
THT	Through-hole Technology
uA	Microampere
UART	Universal Asynchronous Receiver /Transmitter
USD	United Stated Dollar
USB	Universal Serial Bus
UTC	Coordinated Universal Time
V	Volt

Acronym	Definition
Wh	Watt Hour
°	Degree
°/s	Degree per Second

System Overview

Nour Barsoum, Gianluca Ceccacci

Mission Summary

Mission Objectives
Build a CanSat consisting of a container (CC), a payload (CPL), nose cone, and a parachute.
The CanSat shall perform a two-stage separation. First separating from the rocket and deploying a parachute at apogee. Then deploying the CPL at 75% apogee that shall descend using an auto-gyro decent system (AGDS).
The CC shall descend with a parachute at 20 m/s and the CPL shall descend using the AGDS at 5 m/s.
CanSat shall transmit sensor telemetry data to a ground station at a 1 Hz rate. The sensor data shall include interior temperature, battery voltage, altitude, auto-gyro rotation rate, acceleration, rate, magnetic field, and GPS position.
One camera shall record the release of the CPL as well and the AGDS in action while a second camera shall be spin stabilized, pointed north and oriented 45 degrees from the CanSat nadir.

External Objectives
Air foils made in-house.
Implement adaptive control system for the ailerons to provide spin stabilized descent.
Participate in the CanSat competition after being absent for 9 years.
AGDS should fall at the target descent rate within a reasonable uncertainty (±10%).

Summary of Changes Since PDR

Subsystem	Changes	Reason
Sensors	Change ground camera orientation sensor (magnetometer)	IMU's built in magnetometer was too inaccurate
Decent Control	No Changes	-
Mechanical	Improved electrical component mounting methods	Structural reliability
	Added soldered standoffs to support sensor boards	Structural reliability
	Reinforced CC release mechanism	Extra weight clearance allows for a sturdier system
Communication and Data Handling	Added system restart command	Allow for more control over CanSat, especially in case of failure during testing
Electrical Power System	Redistributed power to the DS1307 payload real time clock	Allows for a longer lasting real time clock using the same components
Ground Control System	Updated GUI, implemented simulation mode, implemented csv writing	Meet mission requirements, improve UI experience
Flight Software	Updated processor reset recovery flow	Meet mission requirements

System Requirement Summary (1/2)

Priority	Requirement	Requirement #	Verification			
			A	I	T	D
1	At 75% peak altitude, the payload shall be released from the container and deploy an AGDS that descends at 5 m/s ±10%.	C5, C6, C7			X	
2	The nose cone shall be a single piece without any opening and a height greater than 76 mm.	S6, S7	X			X
3	The CanSat must survive 30 G shock and 15 G vibrations.	S8, S9			X	
4	The second video camera shall be spin stabilized, so the ground view is not rotating in the video.	C12			X	
5	A second camera shall record 640 x 480 color video while pointing north and 45 degrees from the CanSat nadir during descent.	C10, C11		X		
6	The payload shall record 640 x 480 color video of its release and the operation of the AGDS.	SN10		X		
7	The payload and container shall descend at 20 m/s when using the automatically deployed parachute.	C4			X	X
8	All mechanisms shall be capable of maintaining their configuration or states under all forces.	M3			X	
9	CanSat mass shall be 1400 ±10 grams.	S1	X			X
10	Above the shoulder, the container shall be 144 mm in diameter, 250 mm in length and its wall shall be at least 2 mm thick.	S12, S13, S14	X			X

System Requirement Summary (2/2)

Priority	Requirement	Requirement #	Verification			
			A	I	T	D
11	The container shoulder's length shall be within 90 and 120 mm and its diameter shall be 136 mm.	S10, S11	X			X
12	Payload shall measure its acceleration, rotation and auto-gyro rotation rate.	SN5, SN6			X	
13	Payload shall measure magnetic field and perform GPS tracking.	SN4, SN11			X	
14	Cost of the CanSat shall be under $1000.	C14	X			
15	The CanSat shall use a 900 MHz XBee Radio to transmit a telemetry signal every second.	X1, X4		X		
16	A portable ground station shall display real time sensor data in SI units as well as send commands to the rocket such as calibration.	G1, G6, G7, G10, G11				X
17	The flight software shall determine the time, packet count, payload altitude, air pressure	F1, F2, F4, F5			X	
18	Must have an easily accessible power switch and power indicator.	E3, E4				X
19	The CanSat payload shall include an audible beacon that functions independently of the CanSat electronics.	C13			X	
20	The audio beacon shall operate on a second battery with an easy to access power switch.	C13			X	

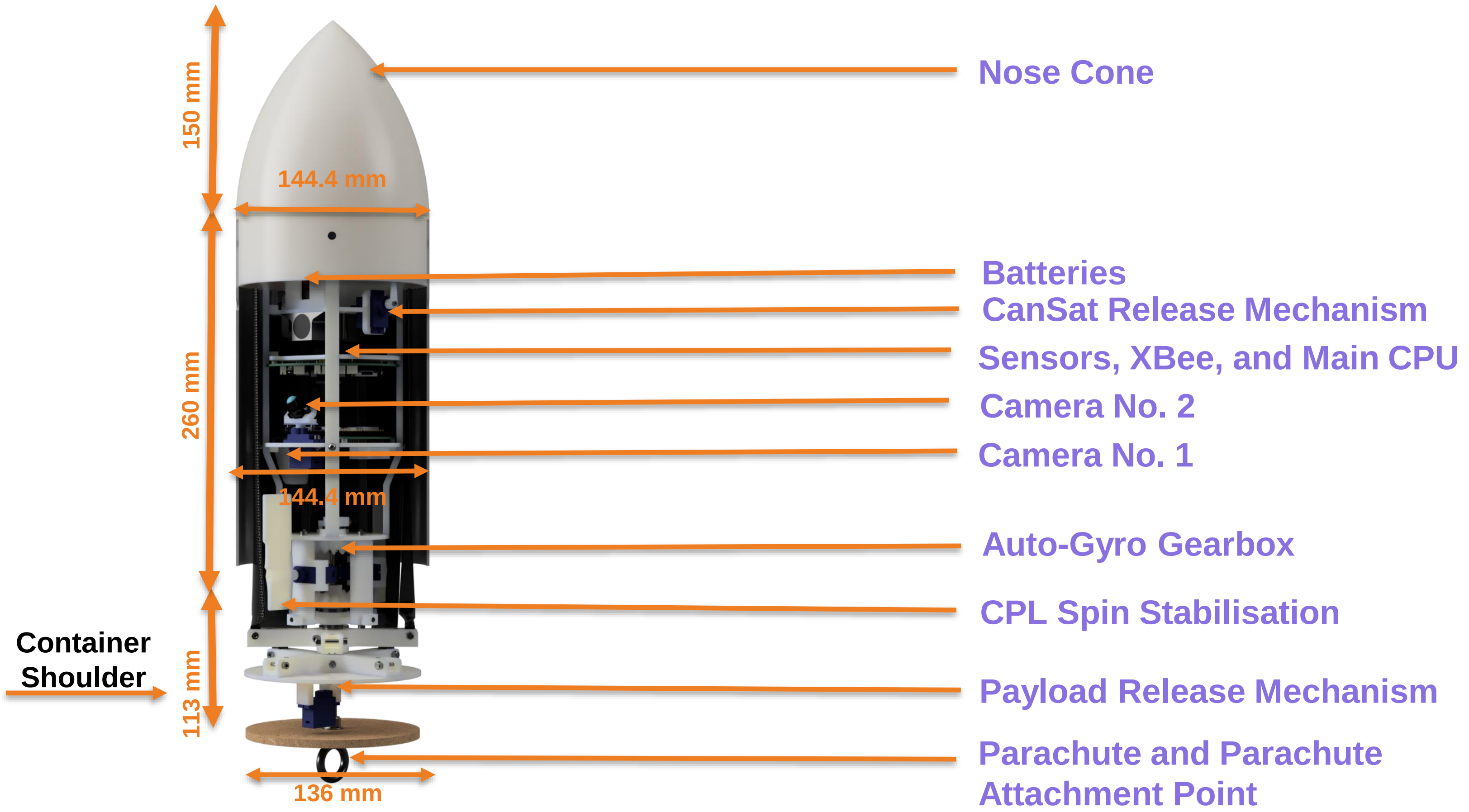
System Concept of Operations (CONOPS)

Operations	
1	CC in rocket and CPL is ready for launch.
2	Moments after rocket launch.
3	Apogee is reached around ~740 m. CC is deployed and descends with parachute. Rocket descends and lands with its own parachute.
4	At 75% apogee CC will deploy the CPL which will descend using the auto-gyro system while CC continues to descend and land with its parachute.
5	CPL lands. Recovery crew retrieves the CPL and CC.
6	Data recovery and processing at GS.

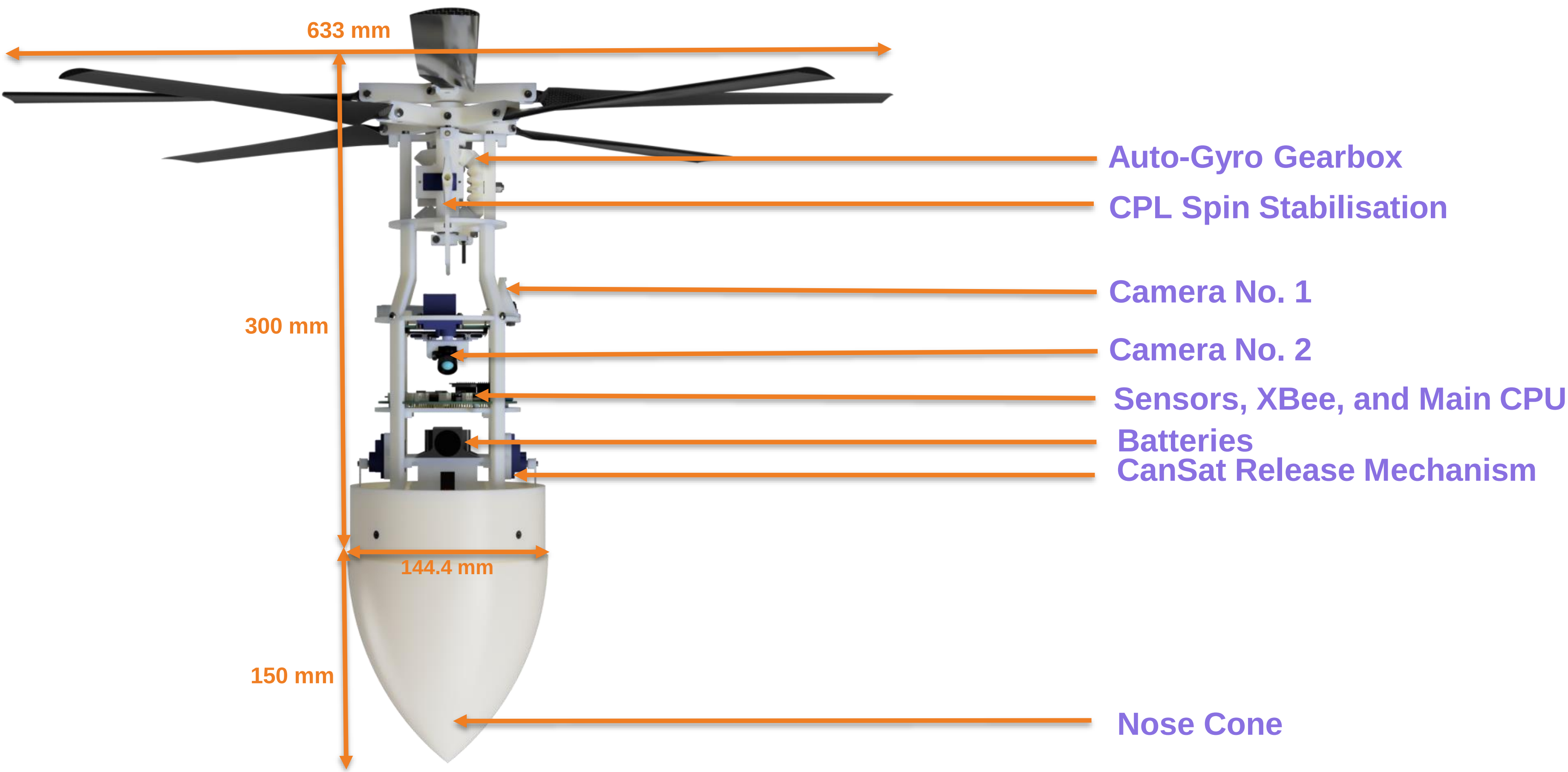
System Concept of Operations (2/2)

<table>
<tr><th>Pre-launch</th><th>Launch</th><th>Post-launch</th></tr>
<tr><td>Set up the ground station, including the GUI and the hand-held communication antenna.</td><td>Rocket launch while still transmitting telemetry and recording video.</td><td rowspan="2">The recovery team scouts for the CanSat using the last known GPS coordinates and the buzzer sound.</td></tr>
<tr><td>Switch on the CanSat (CPL) and the buzzer.</td><td rowspan="2">Apogee is reached around ~740 m (assuming J425 engine). CC is deployed and descends with its parachute. Rocket descents and lands with its own parachute.</td></tr>
<tr><td>Ensure XBee enters running as intended.</td><td>The telemetry data received by the GS and the on board CanSat footage are retrieved</td></tr>
<tr><td>Instruct CanSat crew to integrate the CanSat into the rocket.</td><td rowspan="2">At 75% apogee (~555 m) CC will deploy the CPL which will descend using the auto-gyro system while CC continues to decent and land with its parachute.</td><td rowspan="2">A thumb drive with the telemetry data is prepared and presented to the GS judges.</td></tr>
<tr><td>Calibrate and zero the onboard flight system values, including barometric altitude and roll-pitch-yaw IMU values.</td></tr>
<tr><td>CanSat continuously collects and sends telemetry data at 1 Hz.</td><td rowspan="2">CPL lands and telemetry data streaming and video footage are stopped while the buzzer keeps beeping.</td><td rowspan="2">PFR (includes flight footage) preparation and presentation.</td></tr>
<tr><td>CanSat starts recording and storing video footage from both cameras.</td></tr>
</table>

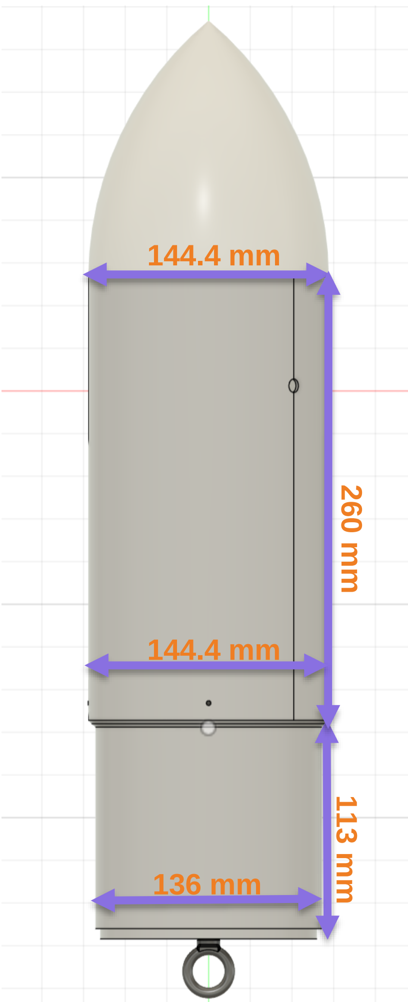
Physical Layout
Launch Configuration



Physical Layout
Deployed Configuration



Launch Vehicle Compatibility



The Competition Guide was followed with precision to determine the dimensions of the CC for proper fit along the shoulder. The length of the CC container above the shoulder was selected to be 260 mm tall. There is a 4 mm tall transitional edge between the shoulder and the main body, a length of 98 mm on the main 3D printed section of the CC shoulder, and a piece of plywood with a thickness of 6 mm, putting us within requirement S10. All structural compatibility requirements are met.

Rocket payload bay dimensions were not given. However, following the exact measurements outlined by the Mission Guide will allow the CanSat to fit with just enough clearance.

Satisfied Launch Vehicle Compatibility Structural Requirements	
S3	Nose cone radius shall be exactly 72.2 mm
S10	The container shoulder length shall be 90 to 120 mm
S11	The container shoulder diameter shall be 136 mm
S12	Above the shoulder, the container (outer) diameter shall be 144.4 mm
S14	The container length above the shoulder shall be 250 mm ±5%

Sensor Subsystem Design

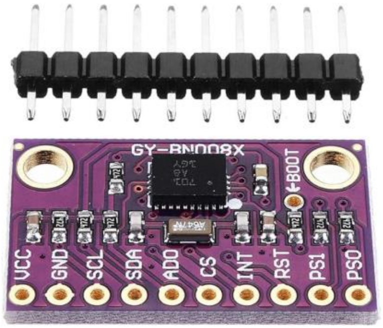
Daniel Yu

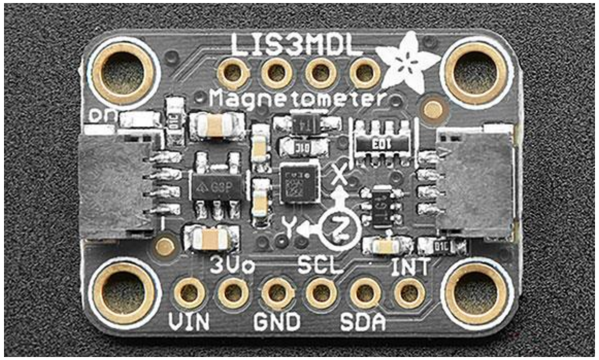
Sensor Subsystem Overview

Type	Model	Functions	Interface
Air Pressure and Temperature Sensor	BME280	Measures temperature, air pressure, and calculated altitude (using air pressure)	I^2C
Battery Voltage Sensor	Voltage Divider Circuit + ESP32 Built-In ADC Pin	Measures battery voltage level	Analog (ADC)
GPS	BN-220	Measures longitude, latitude, altitude, satellite count, and UTC time	UART
Hall Effect Sensor	A3144EU	Measures the auto-gyro rotors' rotation rate	Digital Signal
IMU	BNO085	Measures the angular speed and acceleration of the CanSat's tilt	SPI
Magnetometer	LIS3MDL	Measures the strength of the magnetic field (to determine rocket direction)	I^2C
Camera 1 (Release Camera)	OV5640AF	Records the auto-gyro mechanism	DVP
Camera 2 (Ground Camera)	OV5640	Records the stabilized north-pointing direction during descent	DVP

Sensor Changes Since PDR

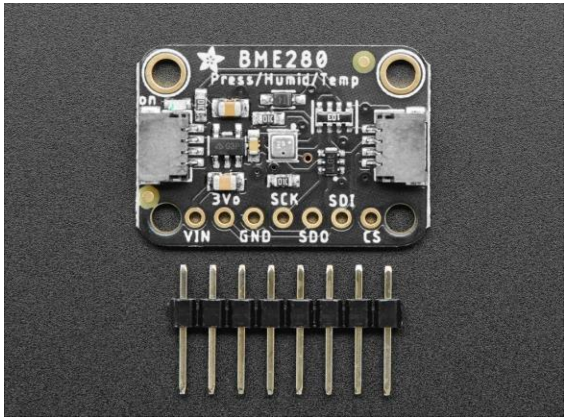
Sensor	PDR	CDR	Rationale
Payload Ground Camera Orientation Sensor (Magnetometer)	**BNO085** (Used as both the tilt and ground camera orientation sensors)	**LIS3MDL** (Dedicated ground camera orientation sensor)	- The LIS3MDL outperformed the BNO085 in overall performance following intensive testing. - It delivered more accurate results with significantly less magnetic drift as a dedicated magnetometer. - Furthermore, our team could accommodate the additional weight, footprint, and cost of the LIS3MDL without compromise to our total CPL.





Payload Air Pressure Sensor Summary

Sensor	Measurement Range [hPa]	Resolution [hPa]	Accuracy[1] [hPa]	Communication Interface	Operating Voltage [V]	Current Consumption [uA]	Cost [USD]	Dimension [mm]	Mass [g]
BME280	300 to 1100	0.0018	±0.12	I²C, SPI	1.71 to 3.6	180[2]	14.95	25.2 x 18.0 x 4.6	2.4



Sensor Accuracy

±0.12 hPa (Pressure)
±1 m (Altitude)[2]

Description

Sensor Calculations: Onboard calculations returns pressure in Pa as an unsigned 32-bit integer in a Q24.8 format after applying calibration compensation parameters which is later divided by 256 to convert its raw bit-valued readings to a readable float Pa.

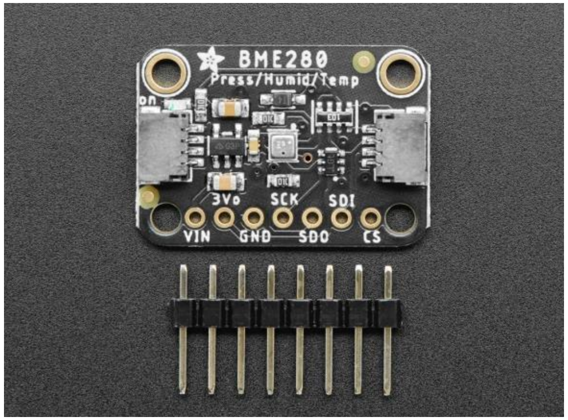
ESP32 Code: Using the *Adafruit_BME280.h* library, our team extracts the air pressure directly using *readPressure() / 1000.0* and the altitude calibrated by the relative pressure before launch using *readAltitude(<Launch Pad Air Pressure>)*; both using *%.1f* format specifiers to convert to one decimal point.

Data Format:
#.# kPa (Pressure stored in onboard memory as a float)
###.# m (Altitude stored in onboard memory as a float)

[1] Accuracy is based off relative pressure accuracy.
[2] Measured by team during testing.

Payload Air Temperature Sensor Summary

Sensor	Measurement Range [˚C]	Resolution [˚C]	Accuracy[1] [˚C]	Communication Interface	Operating Voltage [V]	Current Consumption [uA]	Cost [USD]	Dimension [mm]	Mass [g]
BME280	-40 to +85	0.01	±0.5	I²C, SPI	1.71 to 3.6	180[2]	14.95	25.2 x 18.0 x 4.6	2.4



Sensor Accuracy

±0.5 ˚C

Description

Sensor Calculations: Onboard calculations returns temperature readings with two decimal points in Celsius degrees after applying calibration compensation parameters.

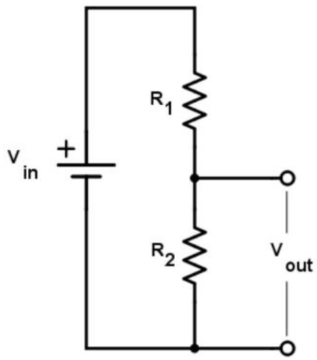
ESP32 Code: Using the *Adafruit_BME280.h* library, our team extracts the temperature directly from the sensor using *readTemperature()* and a C++ format specifier *%.1f* to convert to only one decimal point.

Data Format:
##.# ˚C (Temperature stored in onboard memory as a float)

[1] Accuracy is based off absolute temperature accuracy.
[2] Measured by team during testing.

Payload Voltage Sensor Summary

Sensor	Resolution [mV]	Communication Interface	Voltage Range [V]	Current Consumption [uA]	Cost [USD]	Dimension [mm]	Mass [g]
Voltage Divider Circuit[1] + ESP32 ADC Pin	~0.8[2]	Analog (ADC)	0 to 3.3[3]	~0.43	~0.20	N/A	~0.8



Sensor Accuracy

±0.8 mV[2]

Description

Sensor Setup: Our voltage divider circuit is composed of a R1 = 22 kΩ and R2 = 10 kΩ resistor connected to a 12-bit ADC pin on the ESP32 whose raw readings range from 0 to 4095.

ESP32 Code: Using a basic *analogRead(<ADC Pin>)* function to extract the raw ADC value, we can then follow the two equations below to calculate the measured battery voltage through the ADC resolution formula and the voltage divider formula.

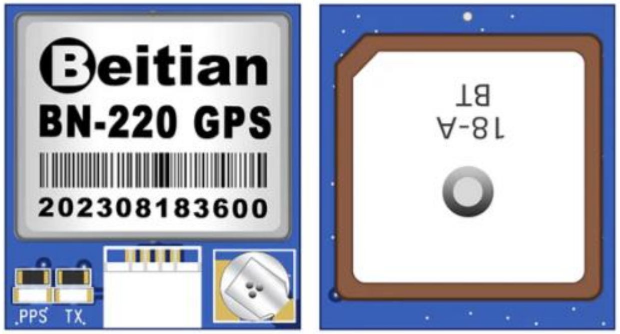
$$V_{ADC} = V_{Reference} \frac{ADC_{Raw}}{2^{12}} \qquad V_{Out} = V_{ADC} \frac{R_2}{R_1 + R_2}$$

Data Format:
#.# V (Battery voltage stored in onboard memory as a float)

[1] Voltage divider circuit was tested using resistor values of R1 = 10.47 kΩ and R2 = 6.75 kΩ.
[2] Calculated using the ADC resolution formula with 12 bits.
[3] Pin directly connected to ESP32.

Payload GNSS Sensor Summary

Sensor	Sensitivity[1] [dBm]	Resolution [m]	Update Rate [Hz]	Communication Interface	Voltage Range [V]	Current Consumption[1] [mA]	Cost [USD]	Dimension [mm]	Mass [g]
BN-220	-167	2.0	1 to 18	UART	3.0 to 5.5	47	12.88	22.0 x 20.0 x 6.0	5.6



Sensor Accuracy

±2.0 m

Description

Sensor Data: Raw GNSS satellite data is received in NMEA format and all relevant message types are parsed through the ESP32 via UART communication protocols.

NMEA Test Example:

```
$GPGSV,4,2,13,21,09,253,40,25,39,061,29,26,29,184,26,28,82,355,33*73
$GNGSA,A,3,73,71,80,88,,,,,,,,,1.32,0.86,1.00*19
$GPGSV,4,1,13,02,12,270,37,03,25,316,35,10,22,165,30,12,08,034,31*76
$GPGSV,4,2,13,21,09,253,41,25,39,061,30,26,29,184,33,28,82,359,30*71
$GPGSV,4,3,13,29,01,101,13,31,57,249,32,32,57,093,29,46,36,206,39*71
$GPGSV,4,4,13,48,17,243,40*40
$GLGSV,2,1,07,70,47,118,24,71,72,358,29,73,79,158,18,74,34,202,*66
```

ESP32 Code: Using the *TinyGPS++.h* library, our team converts these raw NMEA satellite data readings into readable values using various library functions and C++ format specifiers.

Data Format:
##:##:## s (UTC time stored in onboard memory as a string)
###.# m (GPS altitude stored in onboard memory as a float)
##.#### ˚ (Longitude/Latitude stored in onboard memory as a float)
(Satellites tracked stored in onboard memory as an integer)

[1] Taken from tracking and navigation mode measurements.

Auto-gyro Rotation Rate Sensor Summary

Sensor	Measurement Range [mT]	Resolution [mT]	Communication Interface	Operating Voltage [V]	Current Consumption [mA]	Cost [USD]	Dimension [mm]	Mass [g]
A3144EU	7 to 35[1]	~20[2]	Digital Signal	4.5 to 24	6.12	0.06	19.84 x 4.65 x 1.6	~0.1

Sensor Accuracy

±20 mT[3]

Description

Sensor Calculations: One of our rotor blades is fitted with a small neodymium magnet which interacts with a fixed A3144EU Hall effect sensor near the rotor blades' gear box. Each passing of the magnet sends a high digital signal to the ESP32.

ESP32 Code: Using a pulse timer to count the time which passes between each digital high signal the ESP32 receives, we can calculate its RPM. By using the formula below, we can further convert it to a degrees per second reading for each axis.

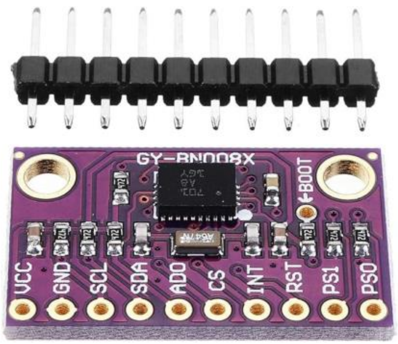
$$\text{RPM} = \frac{360°}{60\ seconds}$$

Data Format:
˚/s (Auto-gyro rotation rate stored in onboard memory as a float)

[1] Unipolar hall effect sensor.
[2] Based off on the minimum hysteresis parameter.
[3] Converts digital signal hits to determine the RPM.

Payload Tilt Sensor Summary

Sensor	Resolution[1] [˚/s]	Range [˚/s]	Communication Interface	Operating Voltage [V]	Current Consumption [mA]	Cost [USD]	Dimension [mm]	Mass [g]
BNO085	~0.061[2]	±2000	I²C, SPI, UART	2.4 to 3.6	14	24.95	25.2 x 15.7 x 1.7	2.1



Sensor Accuracy

±0.061 ˚/s

Description

Sensor Calculations: Onboard sensor fusion and calibration calculations shown at the bottom of the slide help derive the initial measurements of the device.

ESP32 Code: Using the associated *Adafruit_BNO08x.h* library, our team first computes the Euler angles to determine the orientation of the CPL in 3D space. Furthermore, the *gyroIntegratedRV* function directly grabs the angular velocity of the sensor while the angular acceleration can be calculated using the following equation.

$$Angular\ Acceleration = \frac{\Delta Angular\ Velocity}{\Delta Time}$$

Data Format:

#.# ˚/s (Angular velocity stored in onboard memory as a float)

#.# ˚/s² (Angular acceleration stored in onboard memory as a float)

$$\theta_k = \theta_{k-1} + (\omega_k - b_{k-1})\Delta t \quad \text{\{State Prediction\}}$$

$$P_k^- = FP_{k-1}F^T + Q = \begin{bmatrix} 1 & -\Delta t \\ 0 & 1 \end{bmatrix} P_{k-1} \begin{bmatrix} 1 & 0 \\ -\Delta t & 1 \end{bmatrix} + Q \quad \text{\{Covariance Prediction\}}$$

Updating Error Prediction: $P_k = \left(\begin{bmatrix} 1 & 0 \\ 0 & 1 \end{bmatrix} - \begin{bmatrix} \frac{P_{00}}{P_{00}^+ + R} & 0 \\ \frac{P_{10}}{P_{00}^+ + R} & 0 \end{bmatrix} \right) P_k^-$

Determining Final Value: $\theta_{Final} = \theta_k + \begin{bmatrix} \frac{P_{00}}{P_{00}+R} \\ \frac{P_{10}}{P_{00}+R} \end{bmatrix} (\theta_{measured} - \theta_k)$

Linear Acceleration

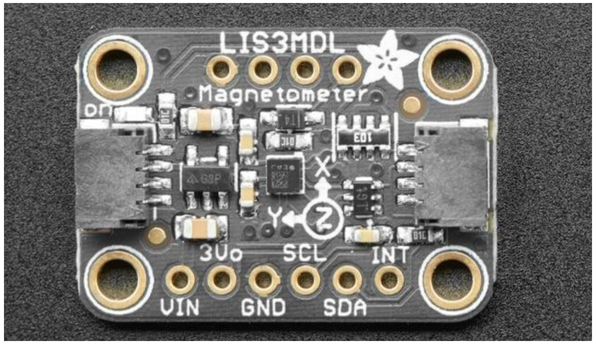
Linear acceleration is also measured in x, y and z axes with an accuracy of ±0.35 m/s^2 and a range of ±78.5 m/s^2

[1] Resolution is the gyroscope measurement for the CPL tilt

[2] Estimated using the ADC resolution formula with 16 bits

Payload Ground Camera Orientation Sensor

Sensor	Resolution[1] [Gauss]	Range [Gauss]	Communication Interface	Operating Voltage [V]	Current Consumption[3] [mA]	Cost [USD]	Dimension [mm]	Mass [g]
LIS3MDL	~0.0001[2]	±4, ±8, ±12, ±16	I²C, SPI	1.9 to 3.6	0.27	9.95	25.7 x 17.8 x 4.6	2.6



Sensor Accuracy

±0.0001 Gauss[1]

Description

Sensor Calculations: Using the default ±4 Gauss range, amplified magnetic field signals are converted into digital signals using an onboard ADC for each axis. Additionally, it uses an internal conversion factor of $\frac{6842\ Least\ Significant\ Bits}{Gauss}$.

ESP32 Code: Our team uses both the *Adafruit_LIS3MDL.h* and *Adafruit_Sensor.h* libraries to directly extract the magnetic field values in microteslas and then convert it to Gauss readings using *event.magnetic.<axis> / 100.0*. Furthermore, we can use these magnetic readin convert into gyro readings using the equation below.[4]

$$\phi_{Roll} = \arctan 2(B_y, B_x)\frac{180°}{\pi}$$

Data Format:
#.## Gauss (Magnetic field stored in onboard memory as a float)

[1] Using the default full-scale range of ±4 G.
[2] Estimated using the 16-bit ADC resolution formula.
[3] For ultrahigh resolution mode.
[4] Roll equation example shown here, pitch and yaw are similar but different.

Ground Camera Sensor Summary

Sensor	Frames Per Second[1]	Resolution[2] [pixels]	Field of View [˚]	Communication Interface	Operating Voltage [V]	Current Consumption [mA]	Cost [USD]	Dimension [mm]	Mass [g]
OV5640	90	2592 x 1944	65 ± 3	DVP, MIPI, SCCB	2.6 to 3.0	45	4.46	13.1 x 21.7 x 24.9	6.4

Camera Resolution
1024 x 768 @ ~60 FPS

Description
Camera Summary: The OV5640 will start recording a landscape shot of the North direction when the CanSat is on the launch pad for both the ascent and descent. Video is be captured in 1024 x 768 at ~60 FPS with colour and stored in a microSD card. **ESP32 Code:** Digital high signals will be sent by the ESP32 to turn on the camera to begin video capture. **Data Format:** AVI Video Format (Captured video saved on a microSD card)

[1] Frames per second listed are at a resolution of at least 640 x 480.
[2] Highest possible resolution of the camera module.

Auto-Gyro Deploy Camera Summary

Sensor	Frames Per Second[1]	Resolution[2] [pixels]	Field of View [˚]	Communication Interface	Operating Voltage [V]	Current Consumption [mA]	Cost [USD]	Dimension [mm]	Mass [g]
OV5640AF	90	2592 x 1944	65 ± 3	DVP, MIPI, SCCB	2.6 to 3.0	45	5.08	8.8 x 8.6 x 4.8	0.7

Camera Resolution
1024 x 768 @ ~60 FPS

Description

Camera Summary: The OV5640AF will start recording the auto-gyro release mechanism using its built-in auto-focus functionality when the CanSat is on the launch pad for both the ascent and descent of the payload. Due to the variability of the auto-gyro deployment system, an autofocus camera is used to ensure the system remains in focus at all times. Video is be captured in 1024 x 768 at ~60 FPS with colour and stored in a microSD card.

ESP32 Code: Digital high signals will be sent by the ESP32 to turn on the camera to begin video capture.

Data Format:
AVI Video Format (Captured video saved on a microSD card)

[1] Frames per second listed are at a resolution of at least 640 x 480.
[2] Highest possible resolution of the camera module.

Descent Control Design

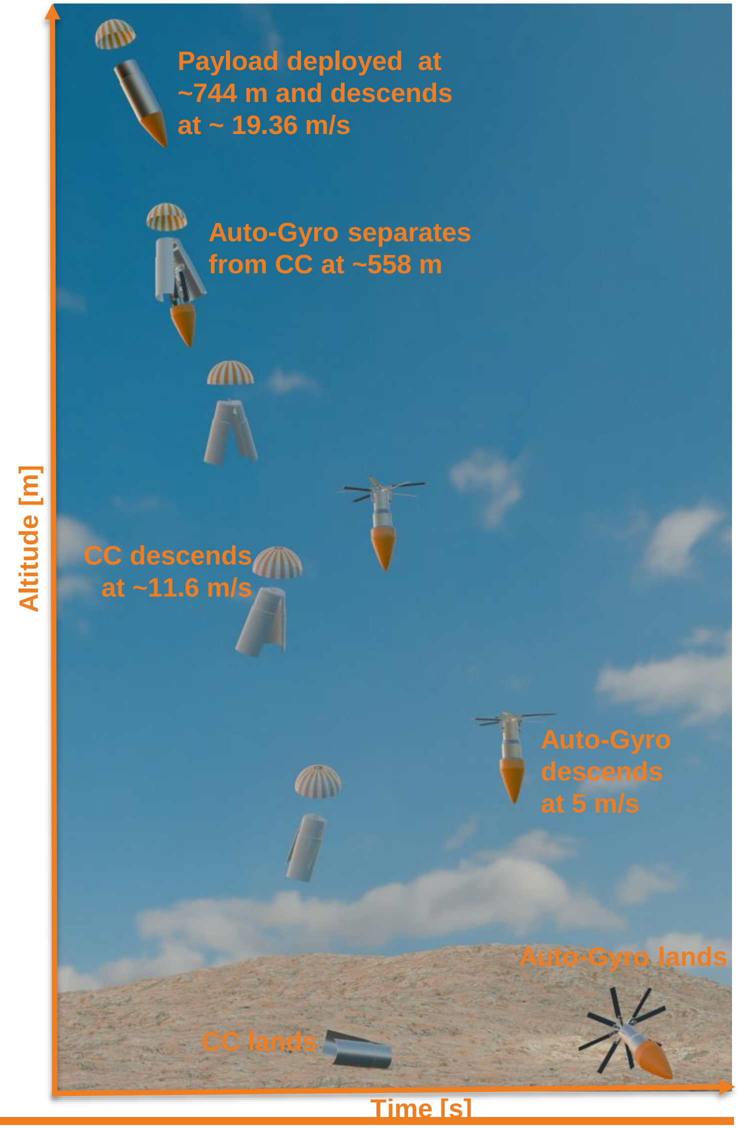
Alexey Albert, Arthur Goetzke-Coburn

Descent Control Overview

CPL and CC Descent Control System Overview

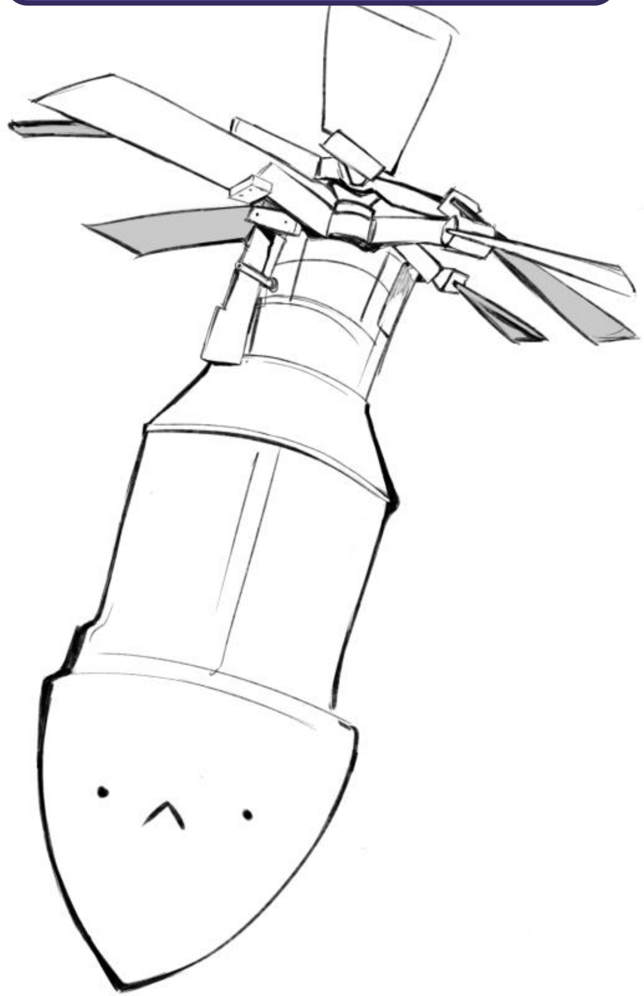
At apogee (~744 m), the CC, CPL, and AGDS decouple together with the CC parachute deployed, descending at 19.36 m/s. At 75% apogee (~558 m), the CPL and AGDS are decoupled and the AGDS descends at 5 m/s. The CC descends separately at ~11.6 m/s. The CC's parachute is 12" in diameter, with a spill hole of 24 mm, regulating the velocity of the CC, CPL, and AGDS.

Title	Time [s]	Final Altitude [m]	Velocity [m/s]
OpenRocket Time to Apogee	11.65	744	-
Parachute Descent (CC, AGDS, CPL	9.637	558	19.3
Auto-Gyro Descent	111.6	0	5
CanSat Container Descent	48.10	0	11.6
Total Flight	**132.9**	-	-



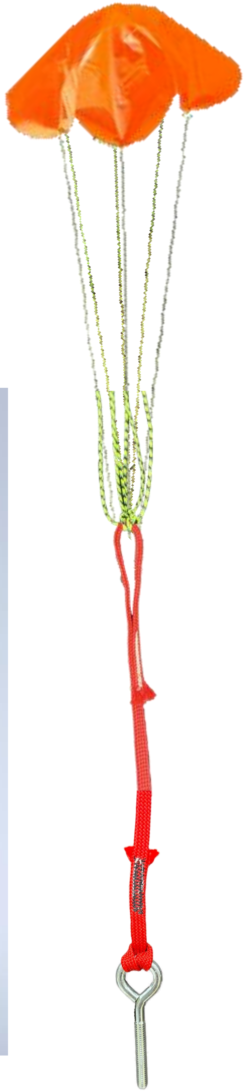
Descent Control Changes Since PDR

No changes have been made to the descent control since PDR



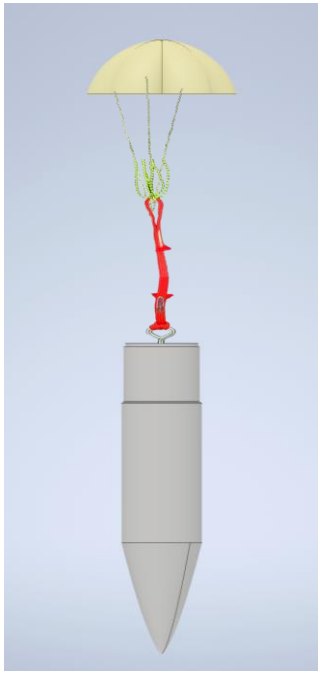
Container Parachute Descent Control Summary

Shape	Material	Diameter [in]	Spill Hole Diameter [mm]	Coefficient of Drag	Terminal Velocity [m/s]	Cost [USD]
Circular	Ripstop Nylon	12	24	1.29	19.36	5.01



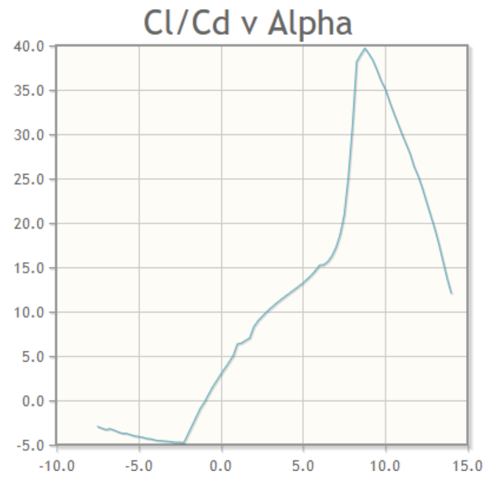
Description

Our final parachute design is a **12-inch circular canopy** with a **24 mm spill hole**, constructed from **ripstop nylon**. This configuration enables an approximate **19.36 m/s** descent rate when combined with the payload; close to the required 20 m/s target; while the spill hole provides added stability and helps prevent oscillations without significantly reducing drag.
We selected **ripstop nylon** due to its proven combination of **durability**, **light weight**, **ready availability**, and **cost-effectiveness**.
The parachute is **bright orange** to ensure high visibility and facilitate post-flight recovery.
Our shroud lines are made of 95#s nylon, with each attached to a looped 3/8" tubular nylon rope, which is in turn looped around the parachute eye bolt and sewn together.



Auto-gyro Descent Control Summary

Descent Control Mechanism	Passive fixed-pitch rotor blades
Airfoil	SG6043 – low Reynolds number airfoil optimized for small-scale horizontal axis wind turbines
Rotor Blade Design	**Twisted rotor blade** – has a non-linear twist from -15.8° to +0.8° to best match the changing relative airflow velocity and angle of attack along the rotor. The steady-state rotation rate is estimated at 613 RPM.

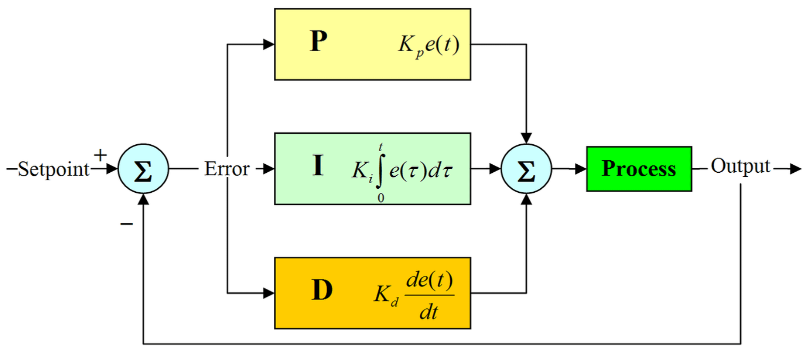


← Lift/Drag ratio vs angle of attack for the SG6043 airfoil at a Reynolds number of 20000

Spin Stabilisation System	Two actively controlled fins that rotate the CanSat towards the northern direction aerodynamically.
Type of Control	Active

Auto-gyro Descent Stability Control Design (1/2)

The equation used to derive the motion of the rotors follow a Proportional-Integral-Derivative system, with the equation as follows:



This can also be interpreted using discrete samples in time, yielding the equations:

$$y[n] = y(nT_s) = K_p e(nT_s) + K_I \sum_{-\infty}^{n} e(nT_s) T_s$$

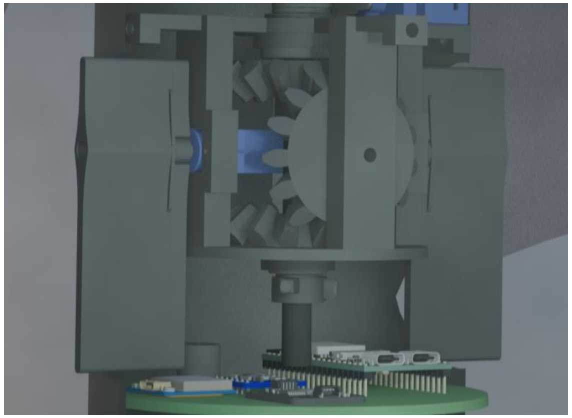
$$= K_p e(nT_s) + K_I \sum_{-\infty}^{n} e(nT_s) T_s + K_d \frac{e(nT_s) - e((n-1)T_s)}{T_s}$$

Active Stability Control

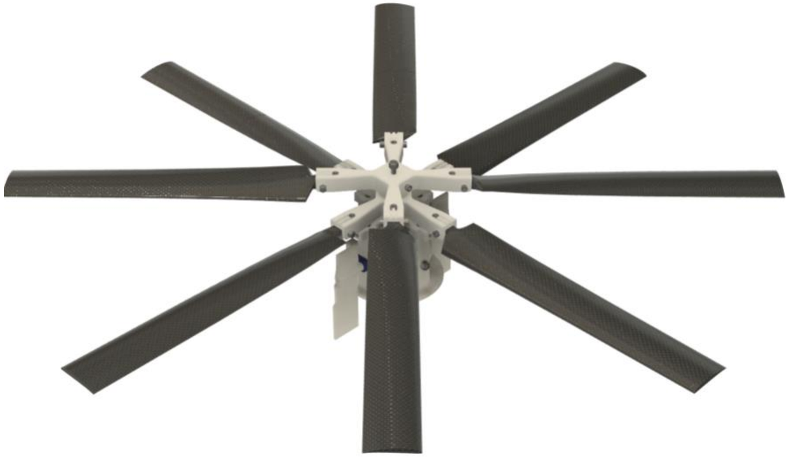
Two adjustable fins connected to servo motors to orient the rocket and keep the **nadir pointing accordingly**. This is done by developing a software based Proportional-Integral-Derivative Control System that has been calibrated to allow the motors to rotate the CanSat clockwise and counterclockwise in whatever direction will lead most quickly lead to nadir stability.

.

Active fins→



Auto-gyro Descent Stability Control Design (2/2)



Passive Stability Control
The auto-gyro subsystem employs **two counter-rotating rotors** to reduce spin, while also providing a roughly **75% increase in lift**. Both rotors are linked by a **1:1 gearbox**, ensuring the second rotor can draw mechanical power from the first rotor to compensate for the reduced airflow it experiences. This approach **increases** the second rotor's thrust, from **1.5 N to 3.9 N**, while reducing the first rotor's thrust by only about 1 N, yielding a net increase in overall lifting force. We employ **fixed-pitch blades** to minimize **mass**, **complexity**, and **cost**. We are using the **SG6043** airfoil due to its **higher lift coefficient** at low Reynolds numbers, which was verified through **Blade Element Momentum (BEM)** analyses and **CFD** simulations. Each blade also features **built-in twist**, which significantly improves lift and efficiency.

Formulas Used:

$$C_D = \frac{2F_D}{\rho v^2 A} \qquad v = \sqrt{\frac{2F_D}{\rho C_D A}}$$

F_D: drag force (N)
ρ: density of air (kg/m^3)
v: speed (m/s)
A: cross-sectional area (m^2)
C_D: drag coefficient

We assumed a ρ of 1.22 kg/m^3 as a general estimate for average conditions. Calculating descent rates with a more realistic ρ of 1.1 kg/m^3 yielded insignificant differences, only differing in the hundred thousandths of a decimal place.

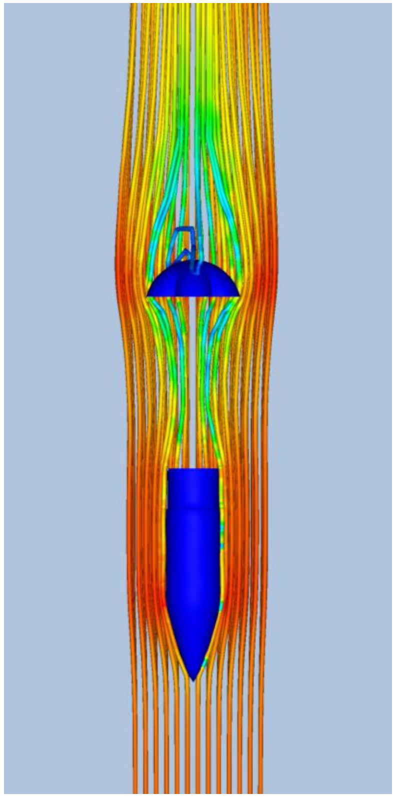
Descent Rate Estimates (Parachute) (2/2)

With $F_D = 14.6642\ N, \rho = 1.22kg / m^3, v = 20m / s, A = 0.04659832559m^3$

$$C_D = \frac{2F_D}{\rho v^2 A} = 1.289728323$$

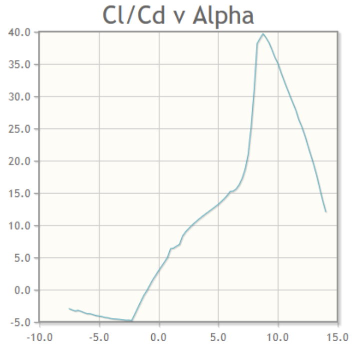
With $F_D = 14.6642\ N, C_D = 1.289728323$

$$v = \sqrt{\frac{2}{\rho C_D A}} = 19.3552746\ m / s$$



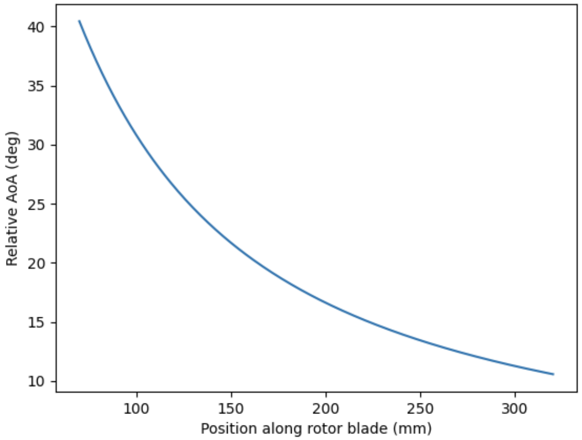
The F_D used in the calculation of the drag coefficient was obtained by running a static fluid simulation of the CPL and parachute in Autodesk CFD against a headwind of 20 m/s.

C_l/C_d vs AoA at R=20000:



Lift/Drag ratio vs angle of attack for an SG6043 airfoil

Effective AoA vs Blade Length at 5m/s airflow and 7 tip speed velocity ratio (achieved at 5m/s steady-state descent):



To estimate the performance of the two-rotor system, we first simulate a single rotor using blade element momentum (BEM) theory.

v_0: **undisturbed wind speed upstream of the turbine**

C_T: **coefficient of thrust of the upstream turbine**

With $v_0 = 5m/s$, using the blade geometry described beforehand we obtained the following results:

- **Thrust = 5.2 N**
- C_T **= 0.97**

Estimated Second Rotor Airflow Velocity:

$$v_1 = v_0 + v_0(\sqrt{1 - C_T} - 1)(\frac{r_0}{r})^2$$

$$r = r_0 + \alpha x$$

v_0: undisturbed wind speed upstream of the turbine
C_T: coefficient of thrust of the upstream turbine
r_0: radius of the upstream turbine blades
x: distance between the upstream and downstream turbine
α: wake expansion factor, ~0.08 for slightly turbulent flow
v_1: estimated wind speed downstream of the turbine

Descent Rate Estimates (Auto-Gyro) (4/9)

With $v_0 = 5m/s, C_T = 0.94, \alpha = 0.08, x = 0.05m, r = 0.32m$

$$v_1 = v_0 + v_0(\sqrt{1 - C_T} - 1)(\frac{r_0}{r})^2$$

$$r = r_0 + \alpha x$$

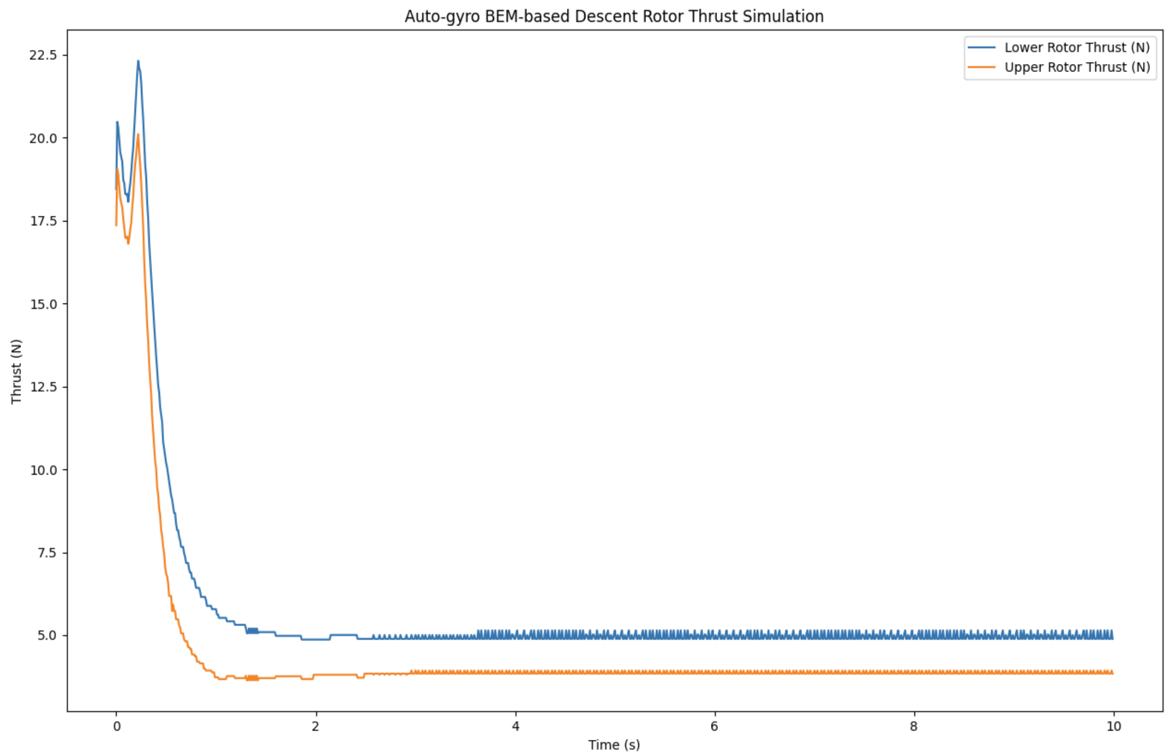
$$v_1 \approx 1.41m/s$$

By using BEM theory again at this estimated airflow speed, we obtain a second rotor thrust of 3.9N. Therefore, the total thrust is 9.1N at 5m/s, allowing us a maximum payload mass of 927.6g.

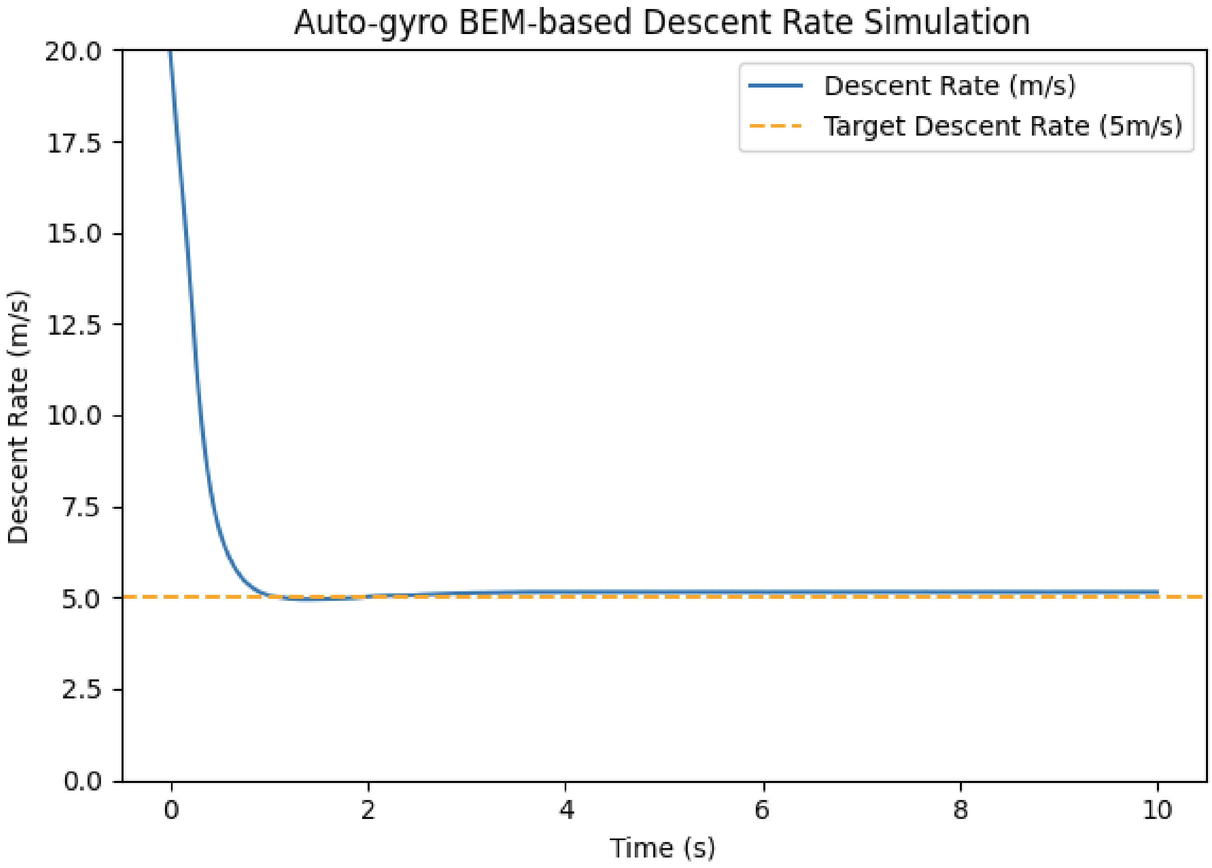
To estimate the descent rate under the auto-gyro, a custom ODE solver was written which assumes the following initial parameters:

$$I_{rotor} = 7.927 * 10^{-3} kg * m^2$$
$$m_{payload} = 0.9kg$$
$$v_0 = 20m/s$$

And uses a lookup table for thrust and RPM, which was generated by the BEM solver.

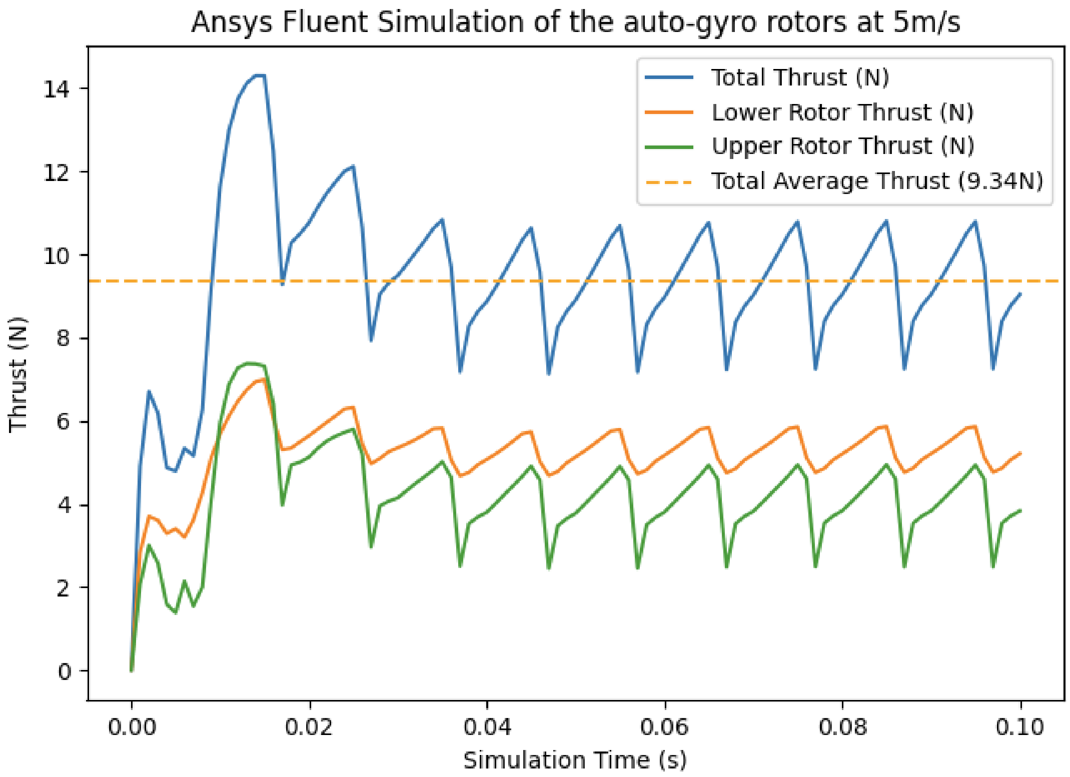


Simulating the entire descent profile with the BEM-based solutions, we obtain the following velocity plot.

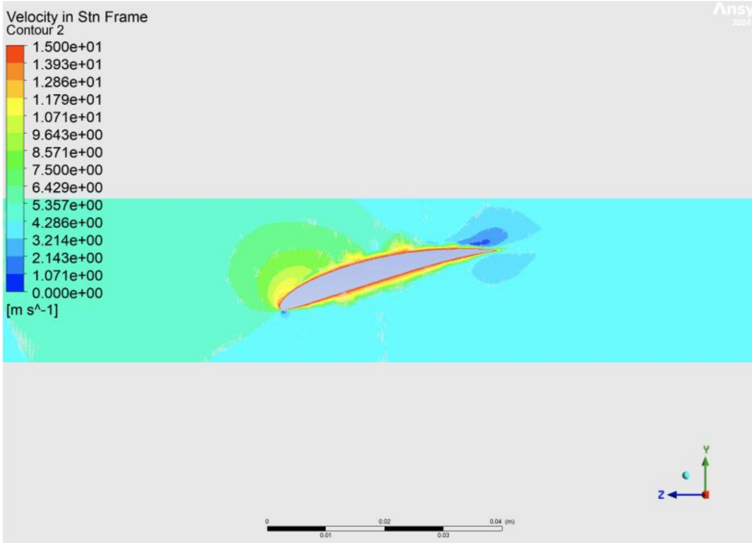


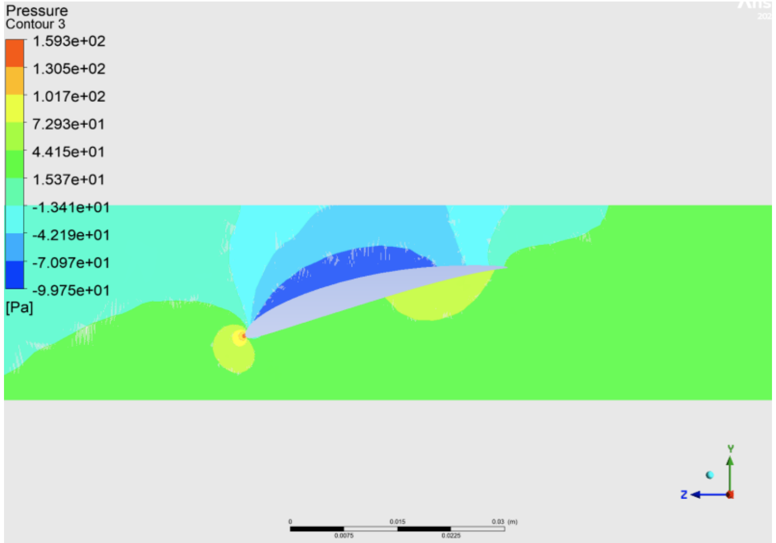
To verify the BEM solver results, a simulation using both rotors was done using Ansys Fluent, with a simplified rotor geometry.

In the Fluent CFD Simulation, the average lift was found to be slightly higher at 9.34 N at 5 m/s, allowing us a maximum payload mass of 952.1g.

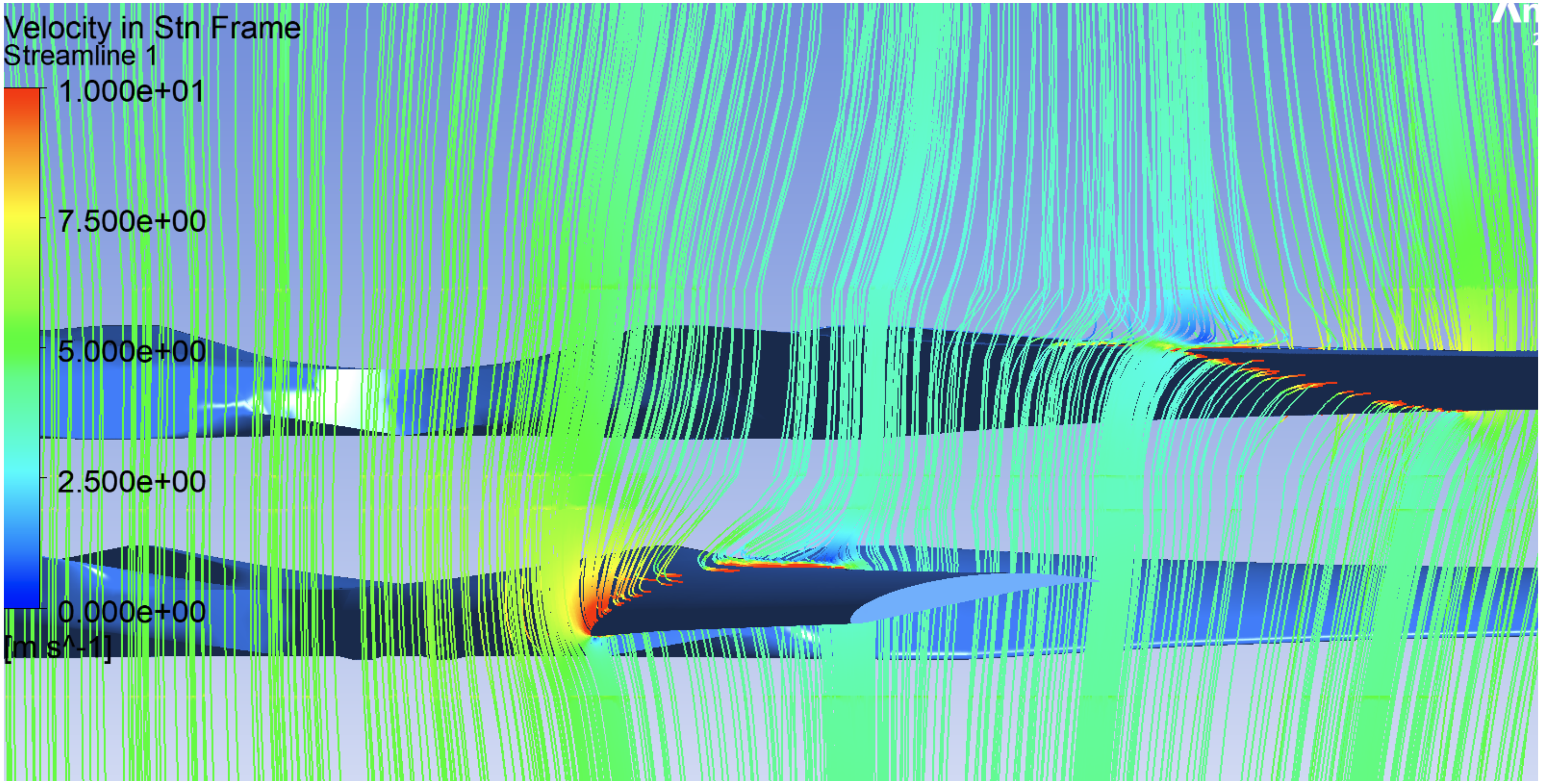


Ansys Fluent results using the final rotor design, showcasing the lift-generating high-speed, low-pressure zone above the airfoil cross-section.



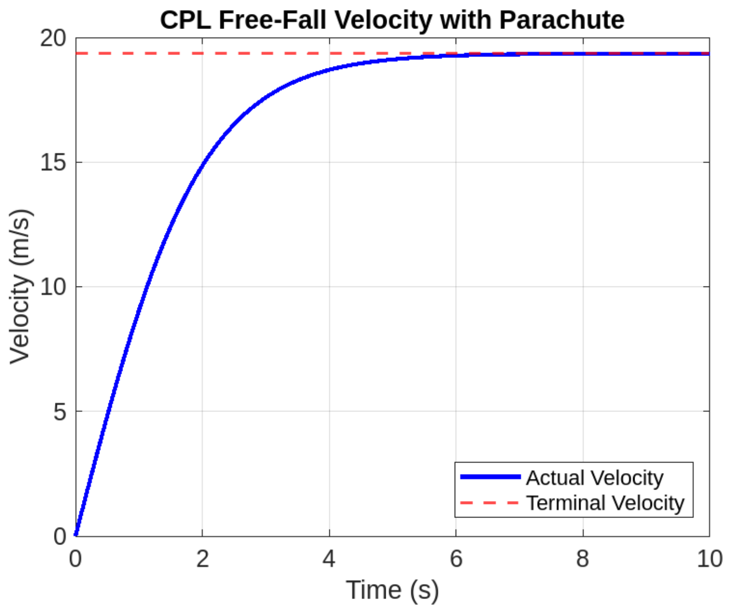


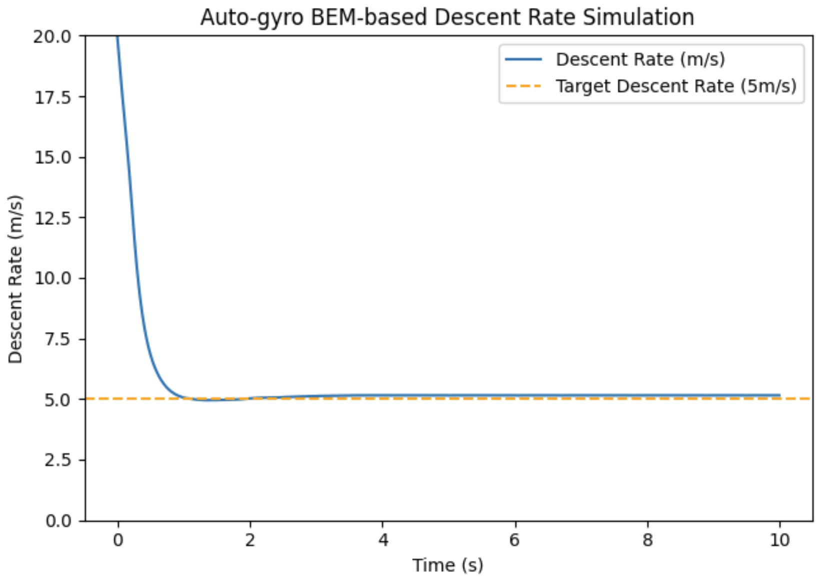
Ansys Fluent pathlines for the dual-rotor simulations, showcasing the flow through both rotors at the target speed of 5 m/s.



Descent Rate Estimates (Summary)

Descent Phase	Speed of Descent [m/s]
Payload Descent with Parachute	19.36
Payload Descent with Auto-Gyro	5.14

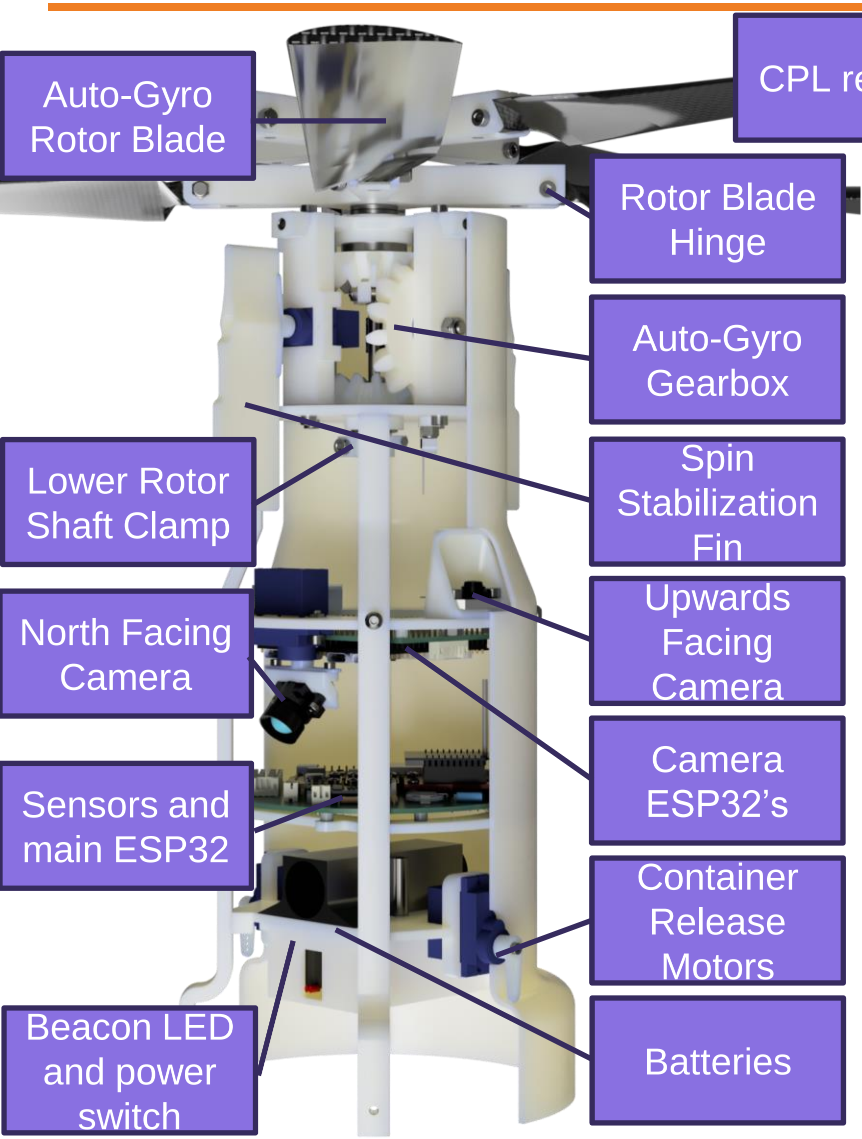


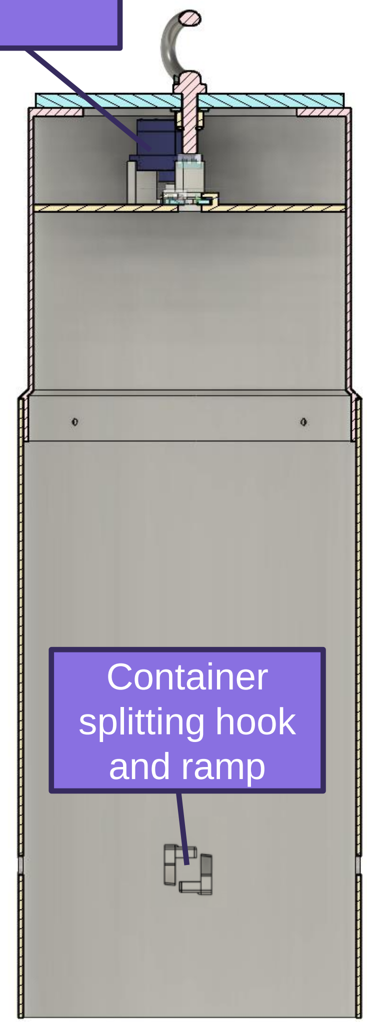


Mechanical Subsystem Design

Arthur Goetzke-Coburn, Gianluca Ceccacci

Mechanical Subsystem Overview





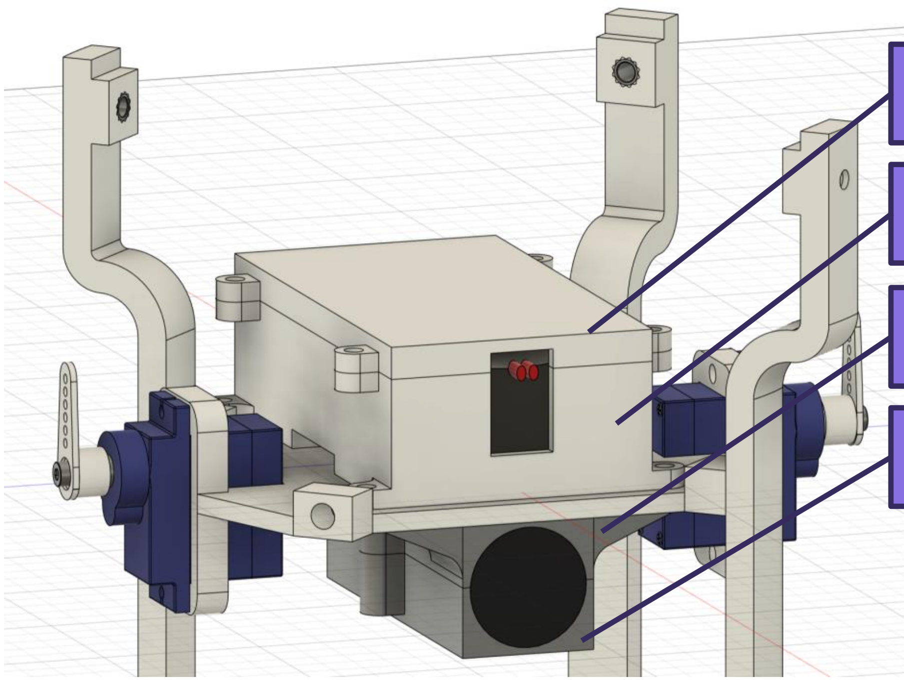
Container Overview

Secures the CanSat Payload during launch
Includes a servo mechanism to deploy the CPL at 75% of apogee
3D printed out of bright orange LW-ASA
¼ thick plywood used as the mount for the ¼ inch eyebolt that the container parachute is attached to, using an anchor bend knot

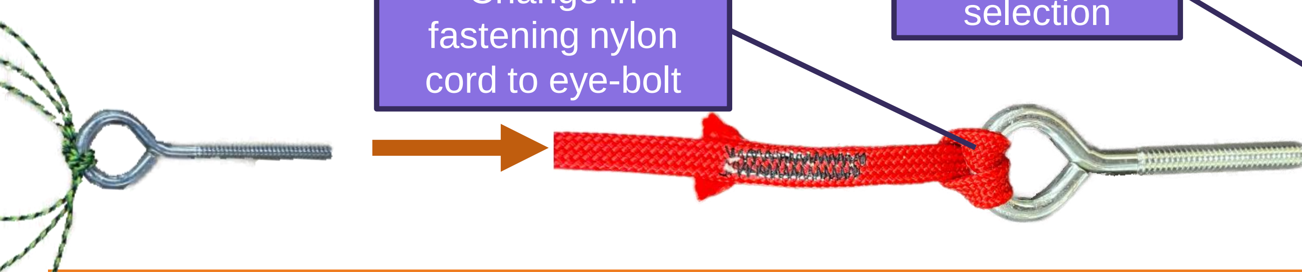
CanSat Payload Overview

Auto-gyro system uses counter-rotating rotors with blades made from a LW-ASA core and 3-ply carbon layup
Gearbox is made out of regular ASA, and synchronizes the speed of the two rotors
Two spin stabilization fins are mounted to servos and will help orient the whole CanSat
Batteries and electronics are placed at the bottom to lower the center of gravity
Main structure is made from LW-ASA to reduce mass
All connections between printed parts are bolted using M3 bolts and heat-set threaded inserts, using threadlocker.
Electronics are hardmounted using M3 bolts or placed in enclosures that are then hardmounted to the structure.

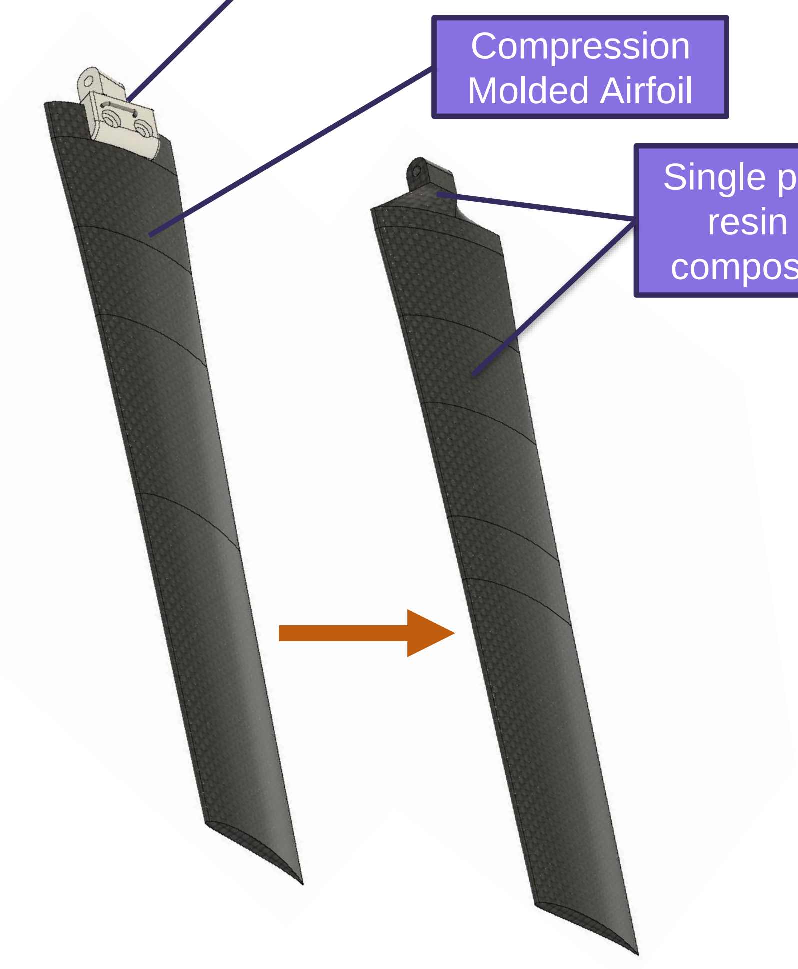
Mechanical Subsystem Changes Since PDR 1/2



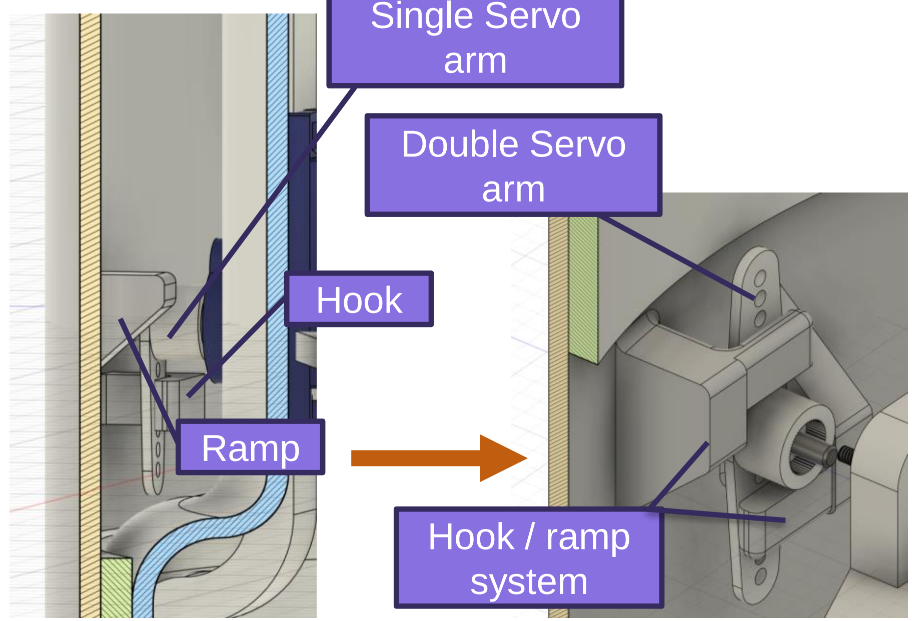
Since PDR, the Mechanical Subsystem has developed in preparation for construction of the CanSat. We have developed enclosures that properly fasten the Lithium ion batteries, fitting between our release mechanism. Additionally, we have selected standoffs for our PCBs, which can be soldered onto the boards directly. With a greater understanding of our physical cord, which possess a sewn loop at its end, we have opted to utilise this loop, providing a more secure and simplistic attachment point.



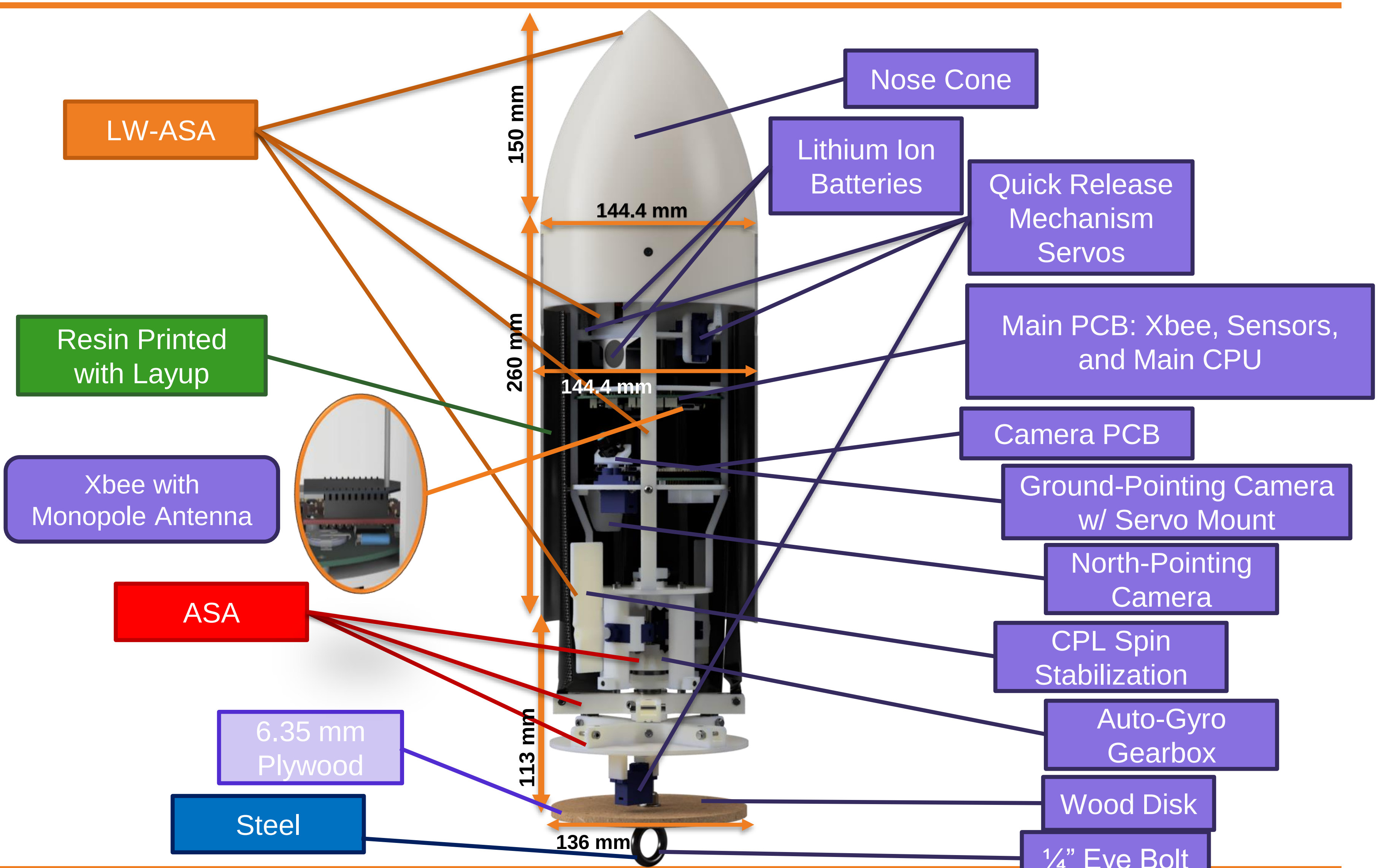
Mechanical Subsystem Changes Since PDR 2/2



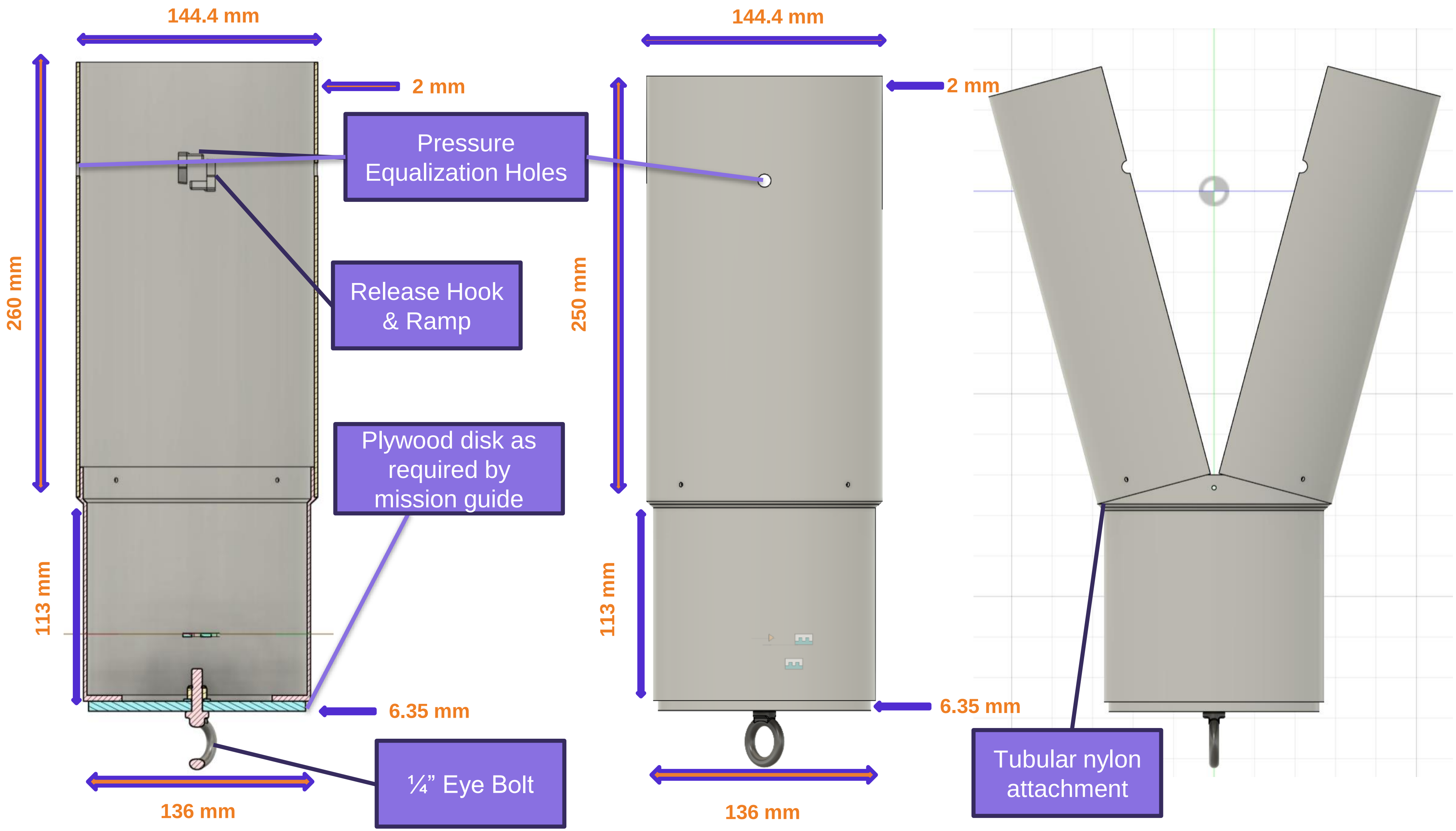
The design for the airfoil was changed from a 2-part mount & blade design to a single composite combined rotor and mount. And finally, the CC release mechanism design was adjusted to ensure the walls of the container are more secured prior to opening by having two integrated hook and ramp systems. The CC will attach at the walls using 3/8" tubular nylon rope.



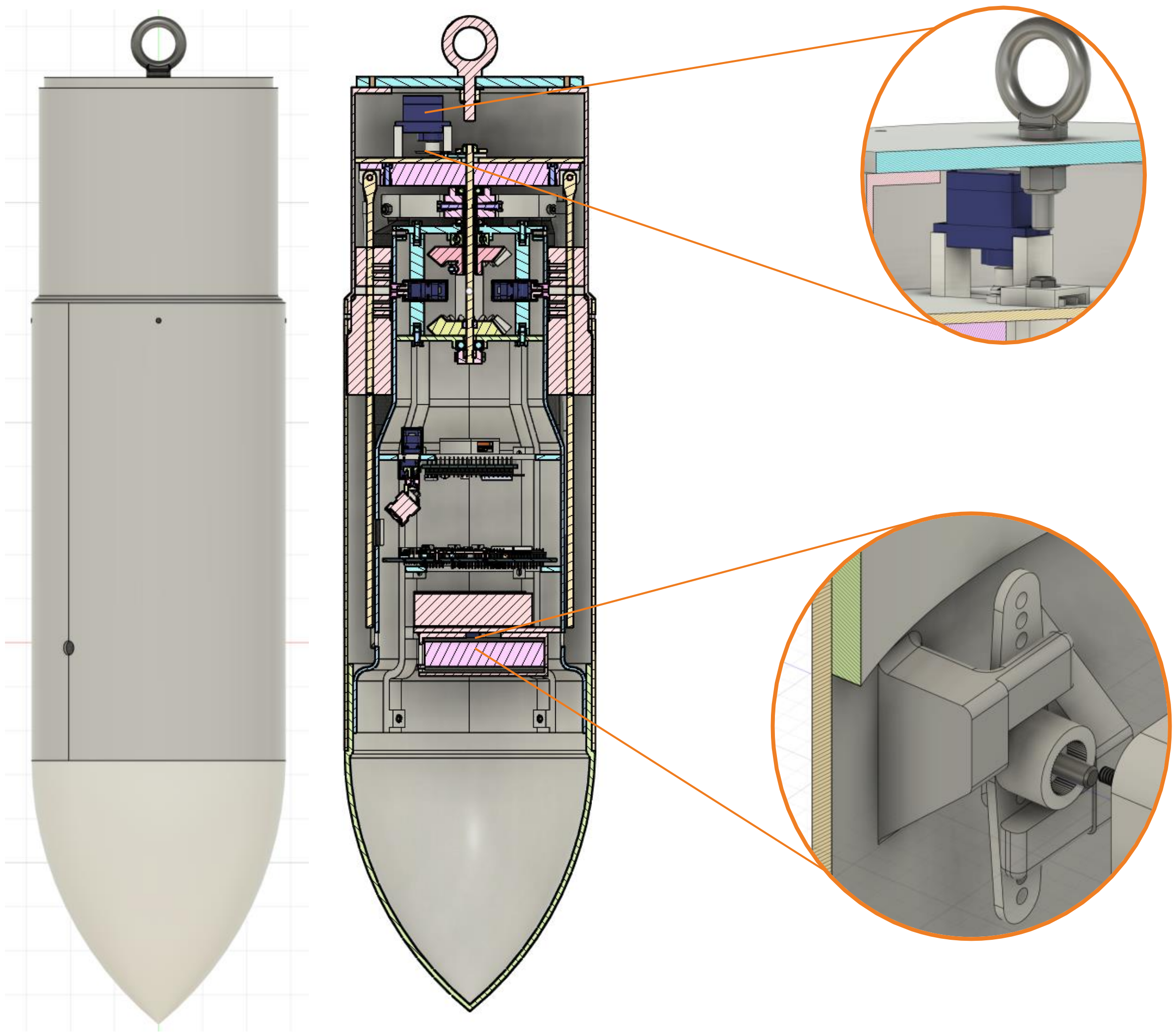
Cansat Mechanical Layout of Components



Container Design

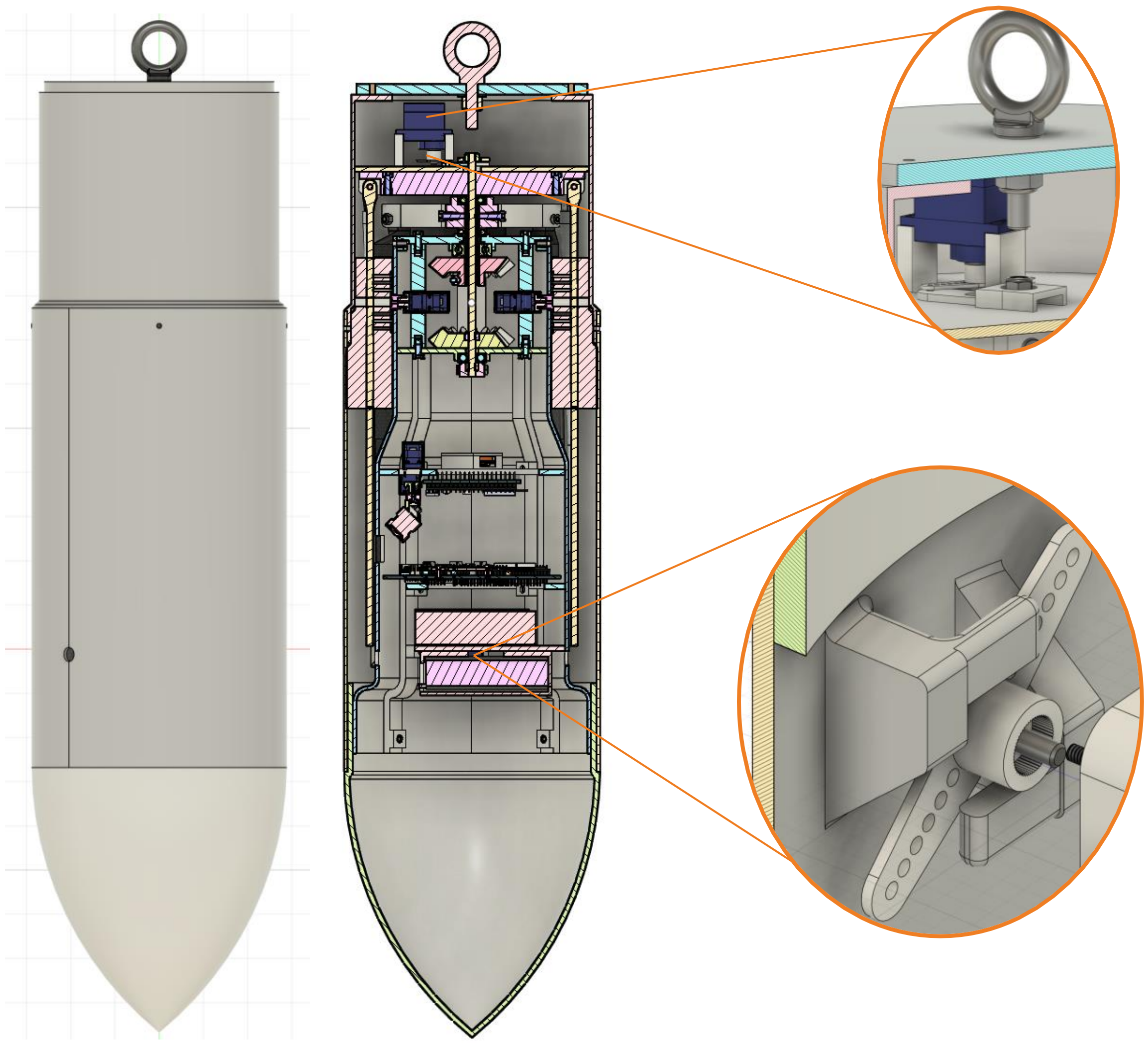


Payload Pre-Deployment Configuration



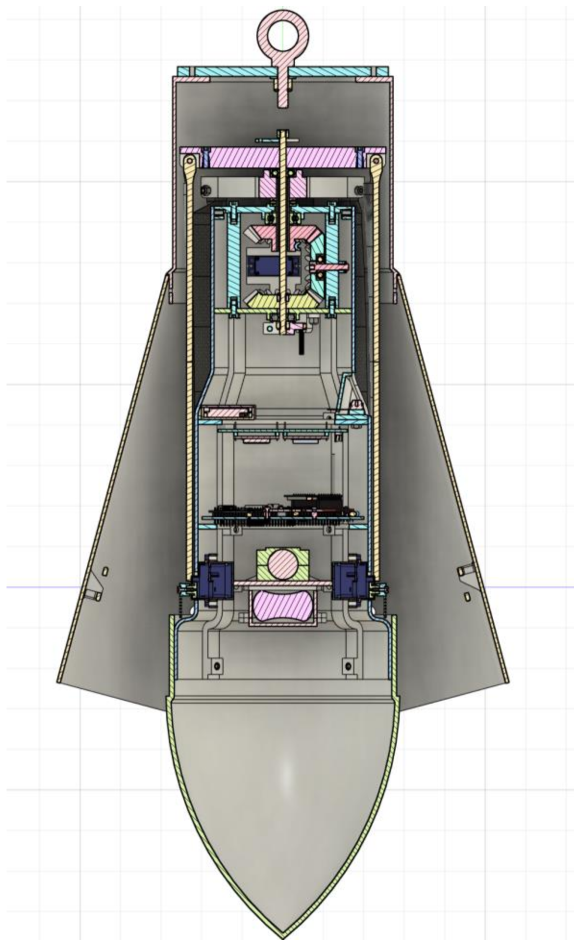
The CPL sits within the CC. The quick release mechanism, a fork-like latch attached to a servo located near the eye-bolt, attaches the AGDS to the CC. This latch sits below a nut fastened to the central shaft of the AGDS. This servo is attached to the CC but powered via wiring from the CPL which easily detaches when the payload is released. Additionally, the CPL is held in place using two units of two hook/ramp systems, depicted below, where a double servo motor arm slots between, halting internal rotation and fixing the CC walls. There are two of these servos (front and back in the cross section).

Payload Release



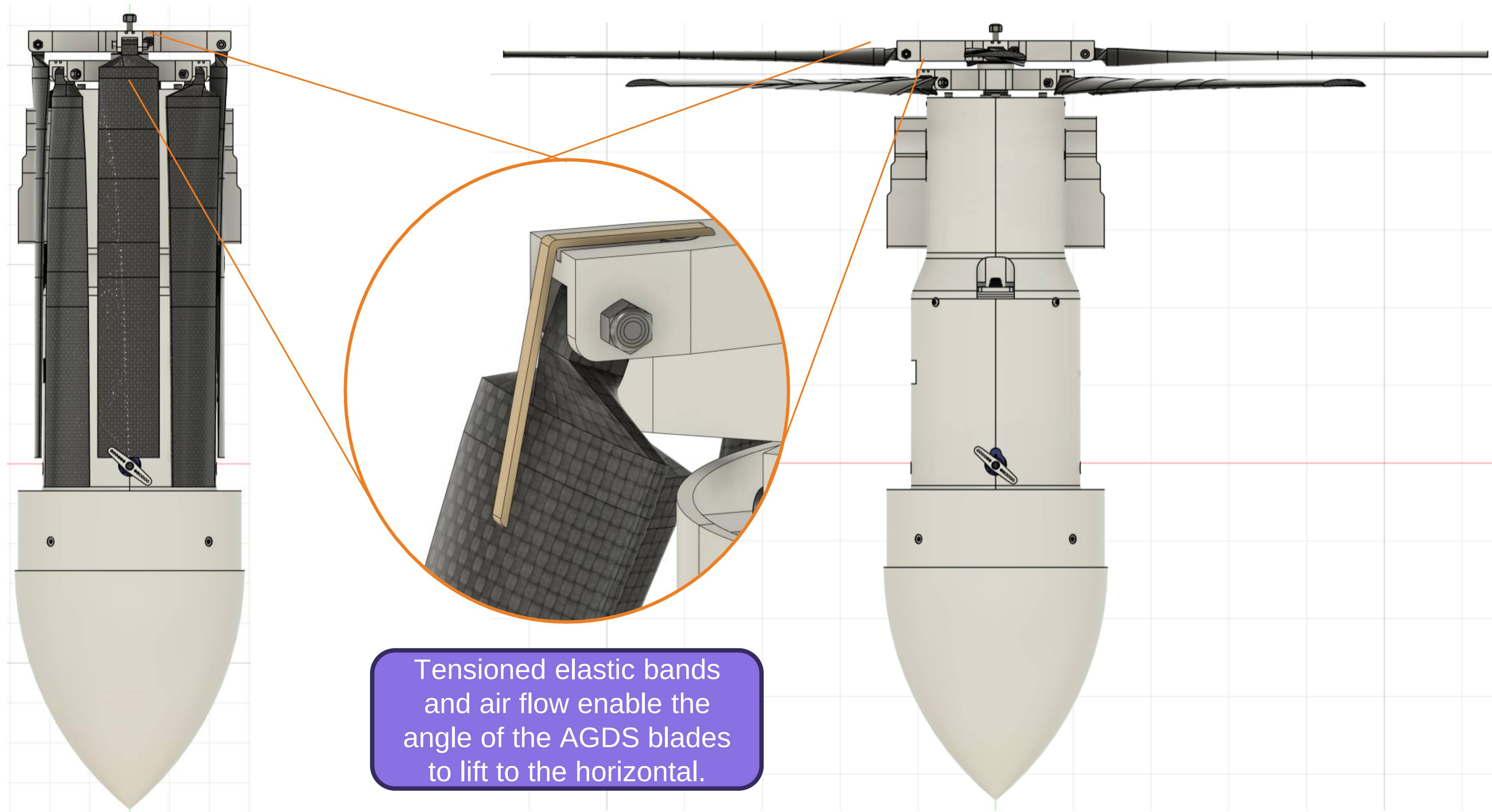
The mechanisms previously described are now used to enable the CPL to detach. The quick release mechanism's servo pulls back from underneath the nut attached to the central dowel of the AGDS, enabling the CPL to fall. The two servos near the nose cone rotate against the triangular ramps, pushing the walls of the midway-opening CC outwards.

Payload Deployment Configuration

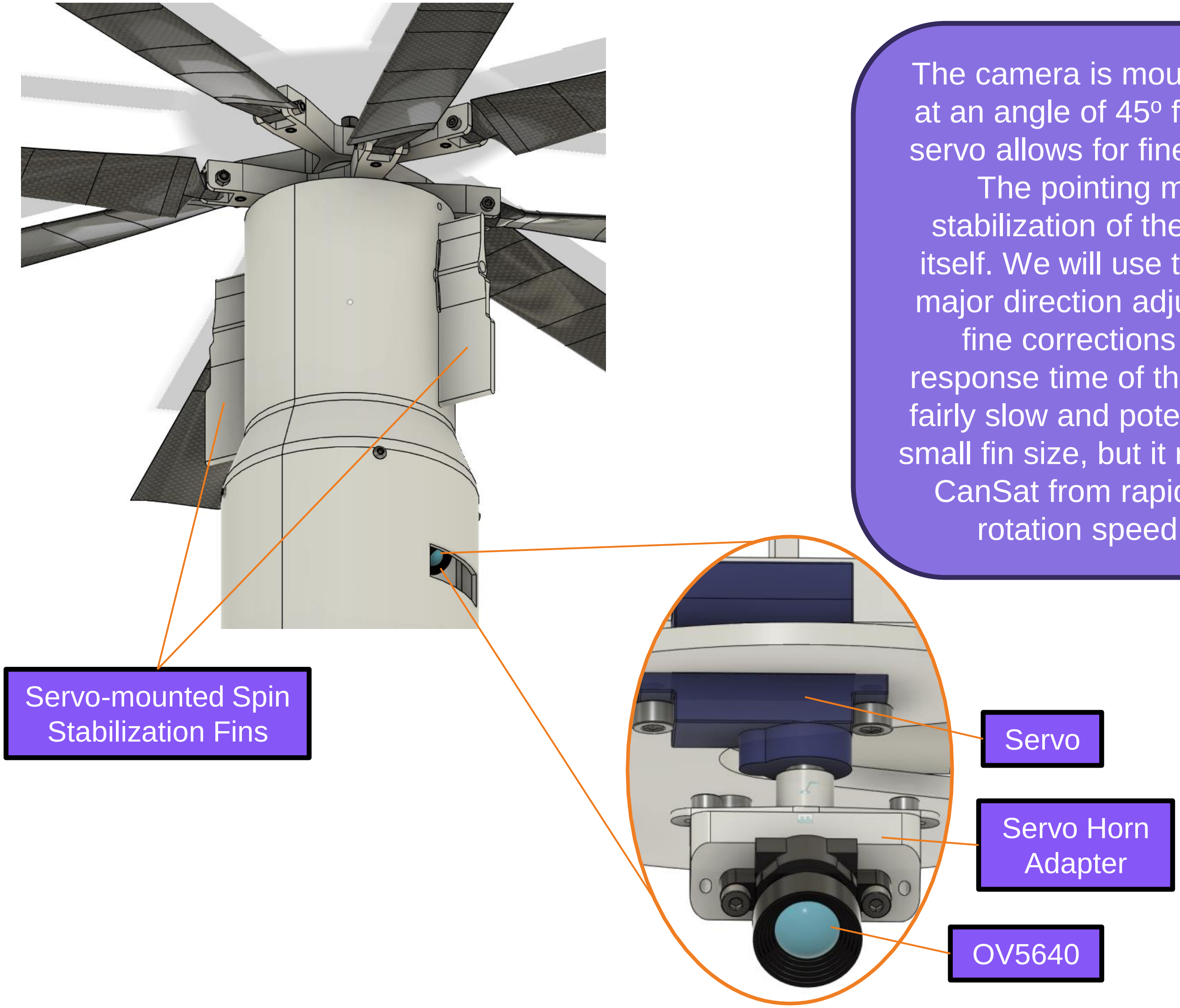


As described previously, upon deployment, the CC opens midway. This is triggered by the two servos near the nose cone having pushed on the triangular nubs, which will let air hit the interior of the CC upon its descent, enabling the payload to fully release. The walls of the CC are held by tubular nylon rope.

Auto-gyro deployment



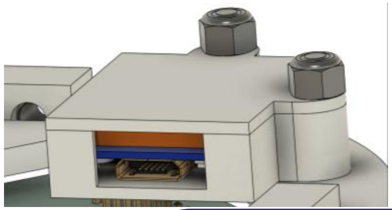
Ground Camera Pointing



The camera is mounted using a servo horn adaptor at an angle of 45º from the horizontal. The use of a servo allows for fine control of the camera direction. The pointing mechanism will use the spin-stabilization of the AGDS in addition to the servo itself. We will use the aerodynamic spin control for major direction adjustments, then use the servo for fine corrections to the camera direction. The response time of the aerodynamic control system is fairly slow and potentially inaccurate because of the small fin size, but it remains necessary to prevent the CanSat from rapidly spinning and exceeding the rotation speed of the camera servo motor.

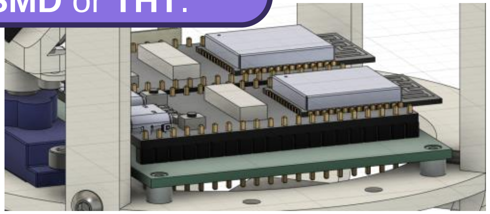
Structure Survivability (1/2)

Electronics Mounting Method	Electronics Enclosure	Electronical Connections
M3 bolt hard-mount	LW-ASA 3D printed box	SMD and THT components and JST connectors

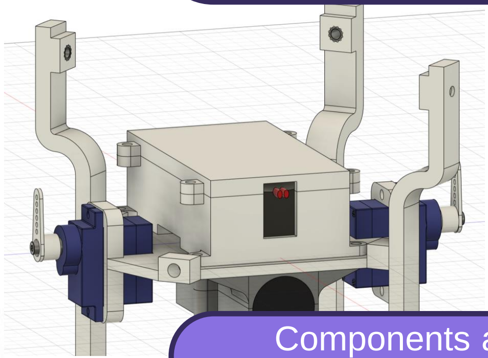


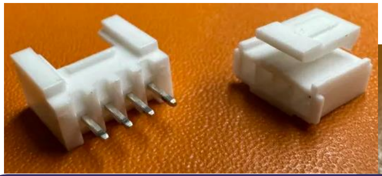
All electronic components and PCBs are hard-mounted to the CPL using **M3 bolts**, ensuring a vibration and shock resistant setup, fixed using multiple mounting points to distribute stress.

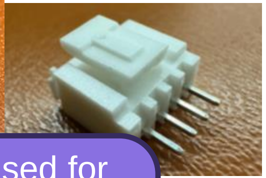
Electrical connections are primarily soldered onto the main PCB, using either **SMD** or **THT**.



The real time chip is powered by a coin cell battery, secured and mounted using a **coin cell battery holder**.





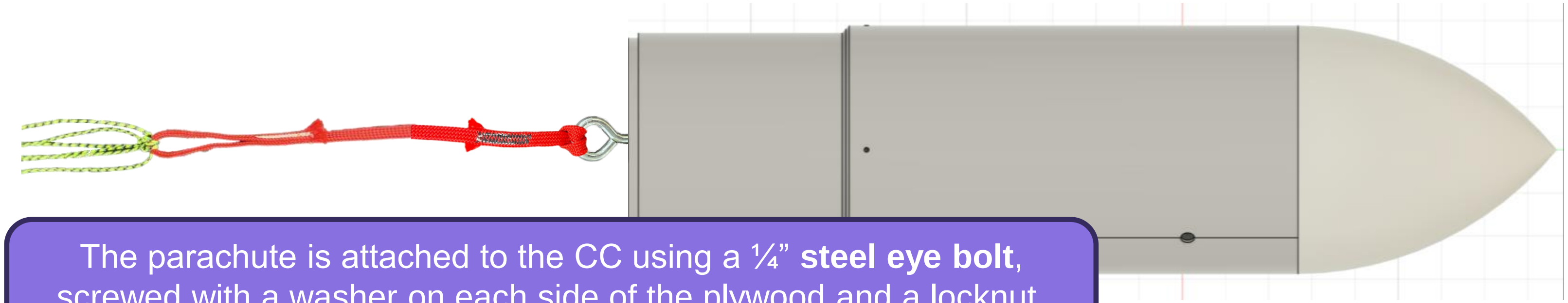


JST Connectors are used for connections between boards, batteries, and motors. They are reliably vibration proof, helping to pass the 15G shock test.

Vibration resistant **standoffs** are soldered directly onto the board to support electrical components.

Components are completely enclosed in **3D-printed LW-ASA** housings with mounting holes if they cannot be directly mounted.

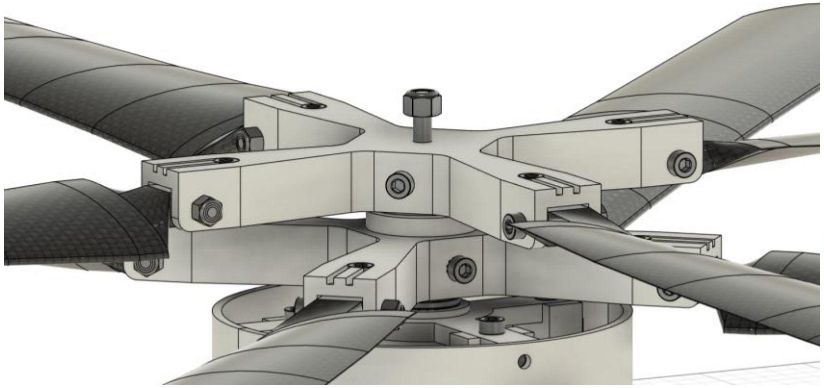
Structure Survivability (2/2)



The parachute is attached to the CC using a ¼” **steel eye bolt**, screwed with a washer on each side of the plywood and a locknut. **3/8” tubular nylon** with shroud lines attached is tied to this eye bolt.

The AGDS is attached via **threaded inserts**. Both rotor holders are attached to the shaft using orthogonally positioned bolts. Each rotor is attached to a holder via threaded inserts and a bolt.

All electronic enclosures are designed for easy judge inspection during pre-flight check-in.



Mass Budget (1/5)

Subsystem	Component	Quantity	Mass per Item [g]	Total [g]	Source	Uncertainty
CanSat Payload 3D-printed Only	Top Rotor Holder	1	25.46	25.46	Estimate	± 0.34
	CanSat Slice Holder	4	3.61	14.44	Estimate	± 0.19
	Northcam Slice	1	21.07	21.07	Estimate	± 0.28
	Nose Cone	1	51.70	51.70	Estimate	± 0.69
	Blade Assembly	8	1.20	9.60	Measured	± 0.80
	Bottom Rotor Holder	1	28.78	28.78	Estimate	± 0.38
	Fins	2	3.01	6.02	Estimate	± 0.08
	Bottom Rotor Shaft Holder	1	13.17	13.17	Estimate	± 0.18
	Top Rotor Shaft Holder	1	40.93	40.93	Estimate	± 0.55
	Shaft Clamp (Upper)	1	5.24	5.24	Estimate	± 0.07
	Bottom Clamp	1	3.44	3.44	Estimate	± 0.05
	Small Shaft Clamp	1	2.43	2.43	Estimate	± 0.03
	Top & Bottom Rotor Shaft + Ball Bearing	1	5.00	5.00	Estimate	± 0.07
	Shroud	1	86.00	86.00	Estimate	± 1.15
	Standoffs	12	0.31	3.72	Estimate	± 1.00
	TOTAL			**317.00**	**-**	**± 5.86**

Mass Budget (2/5)

Subsystem	Component	Quantity	Mass per Item [g]	Total [g]	Source	Uncertainty
CanSat Container	Release Latch Release Slice	1	20.21	20.21	Estimate	± 0.27
	Release Latch	1	0.43	0.43	Estimate	± 0.01
	Release Assembly	1	12.04	12.04	Estimate	± 0.16
	Shoulder	1	55.90	55.90	Estimate	± 0.75
	Side Walls	1	115.35	115.35	Estimate	± 1.40
	Eye Bolt mount	1	45.20	45.20	Estimate	± 0.60
	Steel Parts	1	37.10	37.10	Estimate	± 0.49
	TOTAL			**286.23**		**± 3.68**

Subsystem	Component	Quantity	Mass per Item [g]	Total [g]	Source	Uncertainty
Other Mechanical	Power PCB	1	40.00	40.00	Estimate	± 0.53
	Main PCB	1	40.00	40.00	Estimate	± 0.53
	Parachute Cord	18 inches	12.04	12.04	Estimate	± 0.16
	Parachute	1	6.90	6.90	Measured	± 0.10
	Carbon Fibre Layup	8	2.77	22.12	Estimate	± 0.29
	Steel Parts	-	23.00	23.00	Estimate	± 0.31
	Coin Cell Battery Holder	1	1.00	1.00	Estimate	± 0.13
	Elastic Bands	8	1.50	12.00	Measured	±0.10
	TOTAL			**157.06**		**± 2.05**

Mass Budget (3/5)

Subsystem	Component	Material / Part Number	Quantity	Mass per Item [g]	Total [g]	Source	Uncertainty
Electrical System	Buzzer	MATEK 5V Loud Buzzer	1	2.20	2.20	Measured	± 0.10
	Timer	NE555P	1	0.40	0.40	Measured	± 0.10
	Boost converter	TPS610333	2	1.00	2.00	Measured	± 0.20
	XBee	XBP9B-XCWT-001	1	4.00	4.00	Measured	± 0.10
	Barometer	BME280	1	2.40	2.40	Measured	± 0.10
	GPS	BN-220	1	5.60	5.60	Measured	± 0.10
	Hall Sensor	A3144EU	1	0.10	0.10	Measured	± 0.10
	ESP32	ESP32 S3 WROOM	2	11.80	23.60	Measured	± 0.20
	ESP32	ESP32 S3 WROOM 32D	1	8.30	8.30	Measured	± 0.10
	Watch Crystal	CRYSTAL 32.7680KHZ 12.5PF TH	1	0.17	2.97	Measured	± 0.10
	Magnetometer	LIS3MDL	1	2.60	2.60	Measured	± 0.10

Mass Budget (4/5)

Subsystem	Component	Material / Part Number	Quantity	Mass Per Item [g]	Total [g]	Source	Uncer tainty
Electrical System	Camera (Ground)	OV5640 Camera Module	1	6.40	6.40	Measured	± 0.10
	Camera (Release)	OV5640AF Camera Module	1	0.70	0.70	Measured	± 0.10
	Release Mechanism	SG90	6	10.60	63.60	Datasheet	± 0.60
	IMU	BNO085	1	2.10	2.10	Measured	± 0.10
	Voltage Regulator	LM2596	1	1.00	1.00	Estimate	± 0.10
	Voltage Divider	Resistors	8	0.10	0.80	Estimate	± 0.10
	Power Indicator	C566D-RFF	1	1.00	1.00	Estimate	± 0.10
	TOTAL	-	-	-	**126.97**		**± 2.50**

Mass Budget (5/5)

Subsystem	Component	Material / Part Number	Quantity	Mass Piece [g]	Total [g]	Source
Electrical System	Main Battery	7.4 V 2600 mAh Li-Ion	1	96.00	96.00	Datasheet
	Buzzer Battery	3.7 V 2000 mAh Li-Ion	1	51.20	51.20	Datasheet
	Timer Buzzer	Uline Ultra 2032 Coin Cell Batteries	1	3.00	3.00	Datasheet
	TOTAL	**-**	-	-	**150.20**	-

The total mass is 1037.46 g with total uncertainty of 14.39 g. Since we are currently at least 362.54 g under the maximal mass, it is possible that we will increase the infill and create more carbon fiber layups for a more structurally sound auto-gyro system, as well as add weight as a form of head sinks. These changes will cause a potential increase in our total mass.

Communication and Data Handling (CDH) Subsystem Design

Luke Watson, Robert Saab

CDH Overview

Component	Specifications	Role
Processor	ESP32 ESP-WROOM-32D	• Receives and sends data through UART interface connection to XBee • Reads data from sensors via various interfaces
Telemetry	XBee PRO S3B (XBP9B-XCST-001/XBP9B-XCWT-001)	• Receives data from processor, transmits to ground station • Receives data from ground station, forwards to processor • Uses Digimesh protocol
Real Time Clock	DS1307	• Measures time throughout the mission
Sensors	See Sensor Selection Table	• Sensors will measure external environmental data and battery voltage • Data is read from processor
Storage	ESP32 Flash Memory	• Will backup all data in case of telemetry transmission failure • Memory will be wiped right when mission starts to ensure sufficient space

CDH Changes Since PDR

Component	Change	Reasoning
Payload Commands	Added an additional command, “RR”	• Upon receiving this command the processor will perform a software restart • This is useful in case the processor is not functioning correctly, and we cannot restart in manually

Payload Processor & Memory Selection

Selected Processor Model	Boot Time [s]	Processor Speed [MHz]	Cores	Data Interface	Memory	Operating Power [V]	Average Current Consumption [mA]	Size [mm]
ESP32 ESP-WROOM-32D	~0.3	80 to 240	2	• 34x GPIO, expandable to other interfaces • 2x 12-bit ADC, 6&10 channels • 1x I^{2}C • 2x UART • 2x SPI, 3 slaves each	• 520 KB SRAM • 4MB Flash memory	3.0 to 3.6	80	25 x 48

Selected Memory	Size [mm]	Storage [MB]	Processor Write Speed [MB/s]	Power [V]	Data Interface
ESP32 Integrated SPI Flash Memory	N/A	4*	~10 to 20	3.3	Internal SPI bus

Reasons for Choosing: ESP32

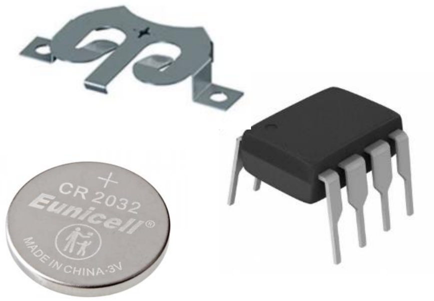
This choice of processor is due to its dual-cores, speed, low power consumption, high speed, sizable SRAM, and interface selection. In addition, it uses a real-time OS. The ESP32 has enough non-volatile memory to store flight data.

Payload Real-Time Clock

Selected Model	Size [mm]	Communication Interface	Operating Power [V]	Clock Crystal [kHz]	Mass [g]	Power
DS1307 Module	25.8 x 21.7 x 5	I²C	5	32	2.3	External Coin Cell, 3.3V

Reasons for Choosing: DS1307

The DS1307 is an accurate RTC that can keep track of mission time over power resets, which the internal RTC on the ESP32 and GPS module are not capable of. It will have it's own backup power source (coin cell).



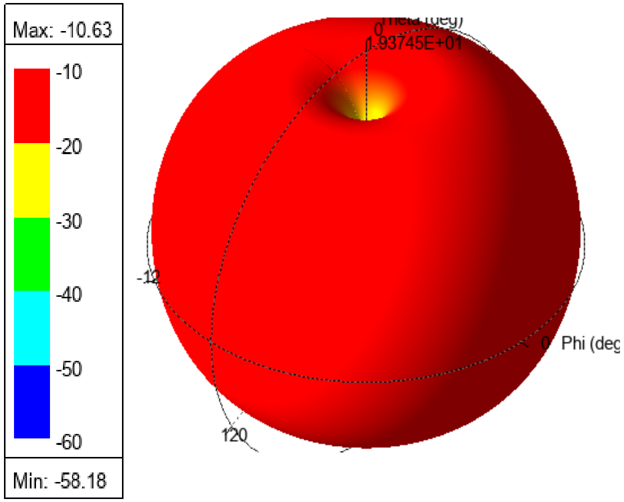
Payload Antenna Selection (1/2)

Model	Type	Radiation Pattern	Frequency Range [MHz]	Size [mm]	Gain [dBi]	Outdoor Range [m]	Mounting
XBee Integrated Wire (XBP9B-XCWT-001)	¼ Wave Wire (Monopole)	Omnidirectional	900	82.6	1.9	1300[1]	Pre-soldered onto PCB

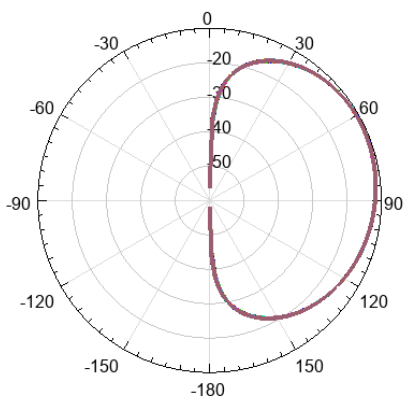
Reasons for Choosing: XBP9B-XCWT-001

We employ an XBee module featuring a pre-installed integrated wire antenna, which meets our required operational range and eliminates the need for additional external antenna components. This compact, factory-soldered solution also ensures reliable compatibility and simplifies the overall radio configuration.

Note the gain is greater than the –14 dB threshold needed to transmit data over 1000 m



Simulation of Antenna Gain (dB)



2D Radiation Pattern (dB)

[1] Estimated based on Digi Whip antenna measurements.

Payload Antenna Selection (2/2)

Ground Station Components

Frii's Transmission Equation (once normalized on the logarithmic scale and put in terms of gain) states:

$$\mathbf{Gt} = 0.5 * \mathbf{Pr} - 0.5 * [\mathbf{Pi} + \mathbf{Gr} + 20\log(\boldsymbol{\lambda} / 4\pi\mathbf{d})]$$

Where:

- **Gt** = Transmitter Antenna Gain (dB)
- **Pr** = Received Power (dBm), we are plugging in the minimum allowable power, i.e. the power sensitivity
- **Pi** = Power inputted to the antenna (dBm)
- **Gr** = Receiver Gain (dB)
- **d** = distance between two antennas (m) = 1000 m
- **λ** = wavelength (m) = 0.333 m

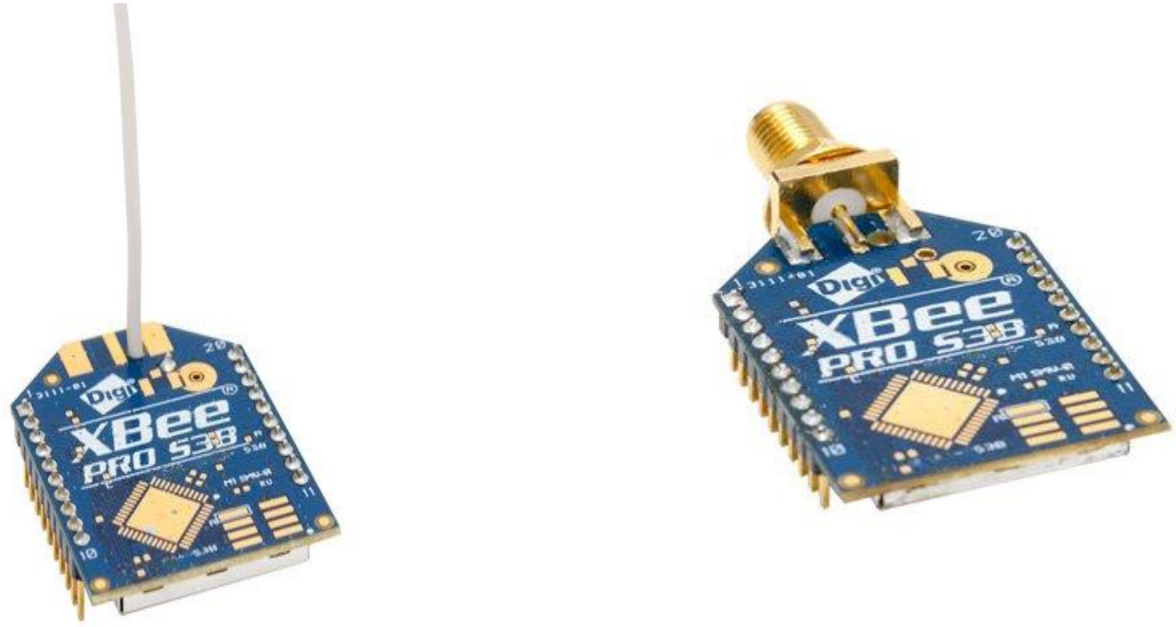
Applying the Formula to our Antennas

For the **Payload Antenna**:
Pr = 110 dBm, Pi = 24 dBm, Gr = -14 dB, thus **Gt = -14.2 dB**

Payload Radio Configuration (1/2)

XBee Radio Selection

We have chosen Digi XBee-PRO® XSC 900 MHz (XBee Pro S3B) Long-Range RF Modules for our ground and payload radios. The payload will hold a XBP9B-XCWT-001 (left) and a XBP9B-XCST-001 (right) will be used for the ground station.



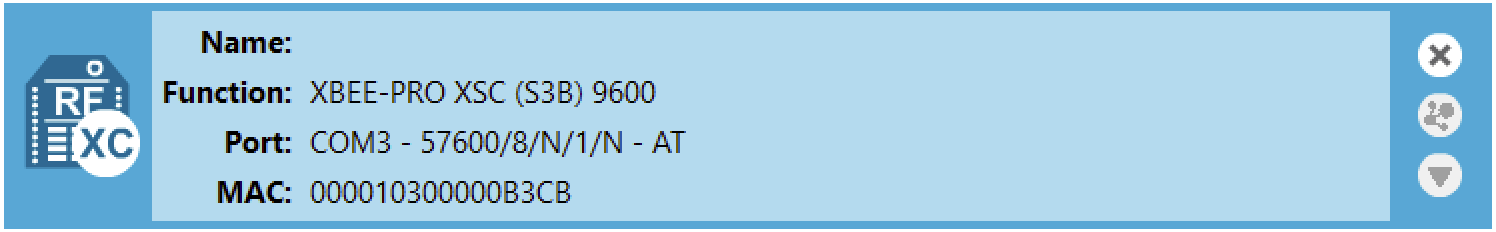
Payload Radio Configuration (2/2)

XBee Configuration

The XBees were configured using Digi's XCTU. The shared NETID is set to our Team ID: 3114. To establish a private P2P connection, the Destination address of one XBee is set to the Source address of the other and vice versa. The command mode is set to AT for simplicity. Interface baud rate is 57600. Lastly, packet delivery attempts is set to 2.

Transmission Control

Upon turning on the payload processor and opening the port on the ground station app, the two XBees will be able to communicate with each other. The operator can send commands, including CX, ON/OFF to activate/deactivate transmission of data packets at a 1 Hz rate. Automatic transmission will also stop once the payload has landed.



Payload Telemetry Format

Data Packet Format		
<TEAM_ID, MISSION_TIME, PACKET_COUNT, MODE, STATE, ALTITUDE, TEMPERATURE, PRESSURE, VOLTAGE, GYRO_R, GYRO_P, GYRO_Y, ACCEL_R, ACCEL_P, ACCEL_Y, MAG_R, MAG_P, MAG_Y, AUTO_GYRO_ROTATION_RATE, GPS_TIME, GPS_ALTITUDE, GPS_LATITUDE, GPS_LONGITUDE, GPS_SATS, CMD_ECHO>	1. Team ID # 2. Mission time in UTC format 3. # of transmitted packets 4. Payload mode 5. Software state based on air pressure 6. Altitude of payload relative to launch site ground 7. Measured temperature in degrees Celsius 8. Measured air pressure in kPa 9. Battery voltage 10. Gyro measurements in ˚/s	11. Accelerometer measurements in $˚/s^2$ 12. Magnetometer measurements in Gauss 13. Auto-gyro rotation rate in ˚/s 14. Time measured from GPS in UTC format 15. Altitude measured from GPS relative to sea level 16. Latitude measured from GPS 17. Longitude measured from GPS 18. Number of satellites tracked by GPS 19. Text of the last command received from ground station

Example Frame
Each packet is sent using Arduino's Serial library, which converts text into an ASCII-encoded format. Each field is comma-separated, and the packet terminates with a newline. A packet is sent every 1 second during transmission. "3114,12:06:32,120,F,LAUNCH_PAD,10.2,1.2,101.3,3.3,0.01,0.00,0.02,0.00,0.00,-9.81,0.25,0.18,0.45,0,12:06:32,11.0,43.6606, -79.3966,7,CXON\n"

Payload Command Formats (1/2)

General Command Format
All commands sent from the ground station follow this ASCII format: "CMD,3114,<COMMAND>,<DATA>"

Command	Data	Example	Description
CX	ON/OFF	"CMD,3114,CX,ON"	Turn on/off telemetry
ST	<UTC_TIME>|GPS	"CMD,3114,ST,12:03:24"	Set mission time to computer time or GPS time
SIM	ENABLE/ACTIVATE/DISABLE	"CMD,3114,SIM,ENABLE"	Control simulation mode
SIMP	<PRESSURE DATA>	"CMD,3114,SIMP,101325 "	Send simulated pressure data

Payload Command Formats (2/2)

Command	Data	Example	Description
CAL	N/A	"CMD,3114,CAL,X"	Calibrate launch altitude to current reading
MEC	DEVICE, ON/OFF	"CMD,3114,MEC,CAMERA,ON"	Turn mechanisms on payload on or off
TEST	N/A	"CMD,3114,TEST,X"	Test connection while payload is idle
RR	N/A	“CMD,3114,RR,X”	Restart processor

Electrical Power Subsystem Design

Adam Kabbara

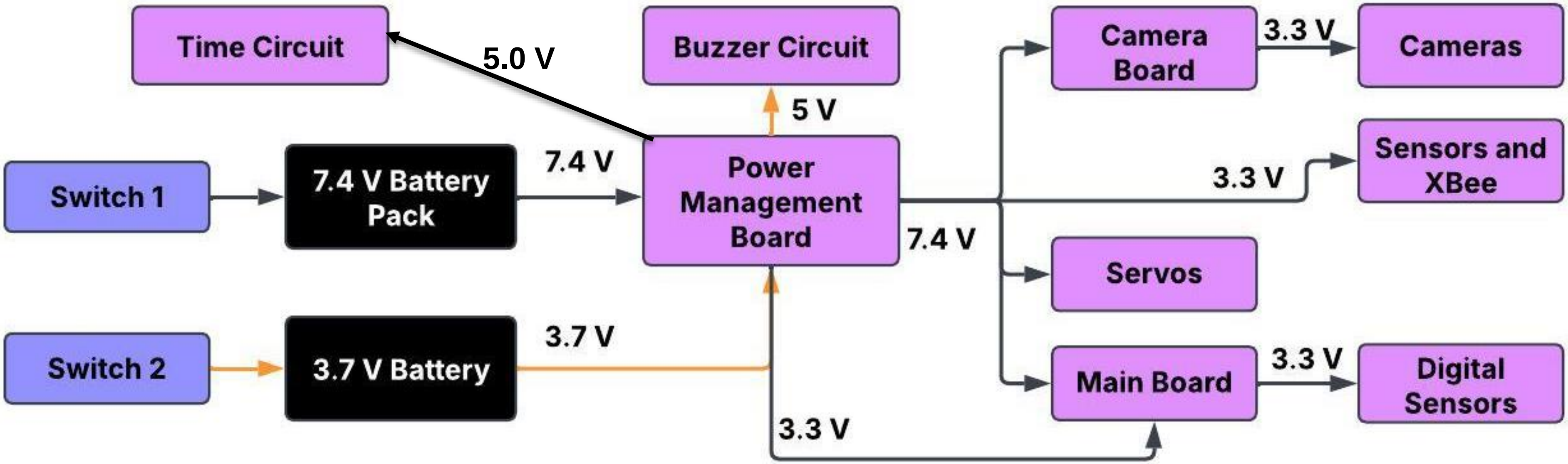
EPS Overview

Power Management Board: This board directs 7.4 V from the battery pack to both the camera board and the main board. It also steps down 7.4 V to 3.3 V to power the XBee and other high-current-consuming sensors, offloading the high-current demand from the ESP32's voltage converter. The servos are powered directly by 7.4 V. The 7.4 V is also stepped down linearly to 3.3 V using a voltage divider circuit, to send power to the ESP32's ADC. Additionally, the 3.7 V battery is stepped up to 5 V to power the buzzer circuit. Finally, the self-sustaining timer circuit is its own self-sustaining circuit that is persistent throughout system restarts.

- **Main Board**: The main board houses an ESP32, which uses its onboard buck converter to regulate 7.4 V down to 3.3 V and supply power to the digital sensors. This ensures that the digital sensors receive a more stable and less noisy signal compared to a direct voltage step-down.
- **Camera Board**: This board contains two ESP32s, each with its own integrated SD card slot. Both ESP32s use their onboard buck converters to regulate 7.4 V to 3.3 V and provide power to the cameras.

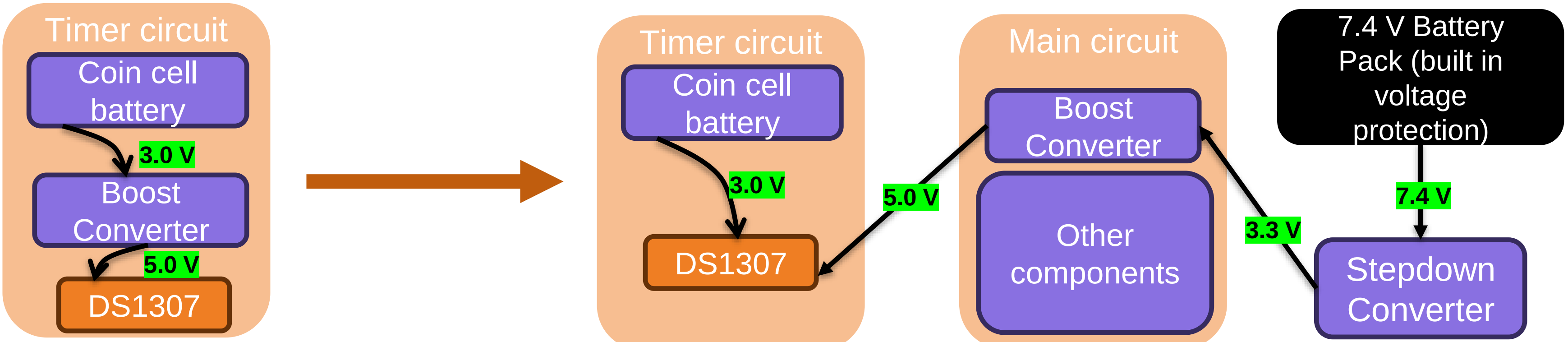
Because of requirement E6 stating that the audio beacon needs to be powered separately the CanSat has 2 **Power Sources:**

- **3.7 V Battery** → Stepped up to 5 V for the buzzer (orange path).
- **7.4 V Pack** (2x 3.7 V cells) → Powers main components (black path).

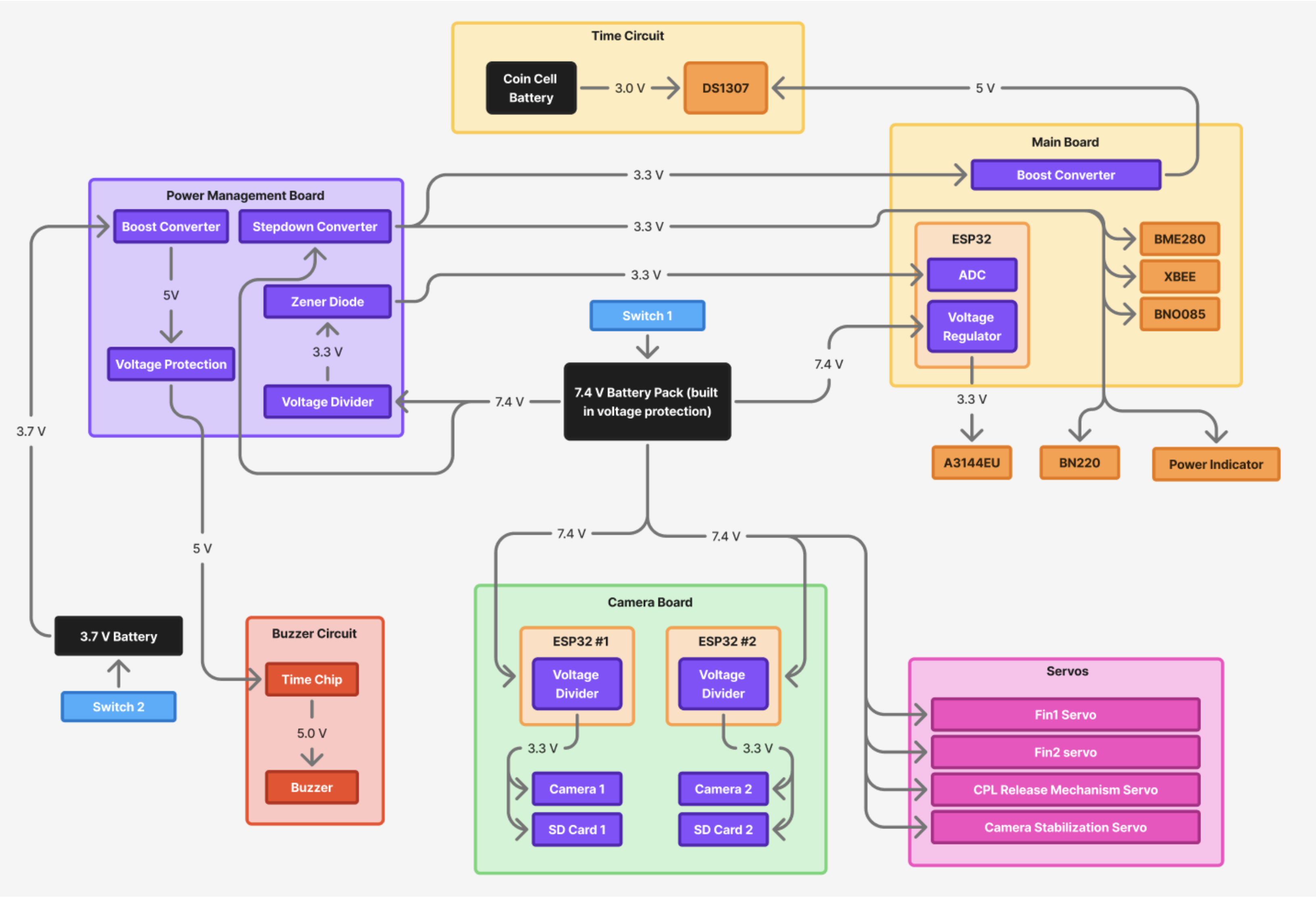


EPS Changes Since PDR

Aspect	PDR	CDR	Rationale
Power to the DS1307 payload real time clock	Coin cell battery voltage stepped up to 5.0V to power the real time DS1307 chip	Instead of being powered from one voltage source, the real time chip uses a unique built in feature that allows it to be used normally (read and write) at 5.0V and when that voltage is no longer being provided, it keeps track of time using the 3.0 V battery	Allows for CanSat to keep track of time for longer as the coin cell battery being stepped up does not last as long as the coin cell being used for backup only. In addition, this builds redundancy in our system, which is an important thing especially in space missions where one thing going wrong can sabotage the whole mission.



Payload Electrical Block Diagram



Payload Power Source

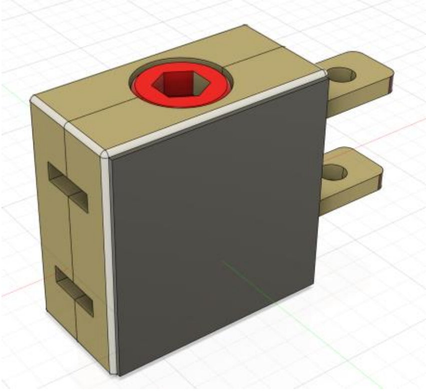
Battery	Units Needed	Total Mass [g]	Total Energy [Wh]	Total Capacity Estimate [mAh]	Total Supplied Voltage [V]	Cost [USD]	C rating
Lithium-Ion Battery Pack	1	96.00	19.24	2600	7.4	16.00	1.5
Lithium-ion Battery Cell	1	51.20	7.4	2000	3.7	7.70	15
C2032	1	3.00	0.705	235	3.0	3.6	0.013

Lithium-Ion Battery Pack for Main Power Source

The singular **7.4 V, 2600 mAh lithium-ion pack** was chosen to power the main system offers:

- **30% lower overall mass** compared with other batteries
- **Built-in protection circuits**
- **Rechargeability** for cost-effective testing
- Sufficient **current delivery** to handle ~4 A peaks without compromising performance.

The two switches that control the buzzer circuit and the main circuit are designed to be easily accessible using Allen keys and be resistant to the high vibrations that the CanSat will be subjected to.



Payload Power Source

Lithium-Ion Battery Cell for Buzzer Circuit

Our **3.7 V lithium-ion cell** provides sufficient capacity to reliably power the **MATEK 5 V buzzer** for the full mission duration. A **step-up voltage converter** boosts the battery's nominal 3.7 V to the **5 V** required by the buzzer, ensuring consistent performance and allowing for cost-effective rechargeability in testing.

Back up Coin Cell Battery for Real Time Clock

A single **3.3 V battery** powers the **DS1307 real-time clock** whenever the primary 7.4 V supply is switched off. This backup arrangement ensures the clock continues tracking time correctly through power cycles or extended storage, supporting accurate mission timing at all stages

Payload Power Budget (1/2)

Function	Component	Quantity	Voltage (V)	Current (mA)	Power (mW)	Duty Cycle (%)	Energy (Wh)	Source
Audio Beacon	MATEK 5V Loud Buzzer	1	5.00	200.00	75	50	0.15	Measured
Buzzer Timer	NE555P	1	5.00	15.00	75	100	0.15	Measured
Communication	XBP9B-XCWT-001	1	3.30	290.00	957	100	1.914	Measured
Temperature & Pressure	BME280	1	3.30	0.18	0.594	100	0.001188	Measured
GPS Location and Time	BN-220	1	3.30	47	155.1	100	0.3102	Measured
Rotor Spin Count	A3144EU	1	3.30	6.12	20.196	100	0.040392	Measured
Camera CPU	ESP32 S3 WROOM	1	5.00	51	255	100	4.46	Measured
Main CPU	ESP32 S3 WROOM 32D	1	5.00	48	240	100	0.6	Measured
Boost Converter	TPS610333	2	3.70	0.023	0.088	100	0.0002	Estimated
Camera 2	OV5640 Camera Module	1	3.30	45	148.5	100	0.297	Measured
Camera 1	OV5640AF Camera Module	1	3.30	45	148.5	100	0.297	Measured
Servos	SG90 (Release Mechanism)	3	7.40	250	1850	0.1	0.46	Measured
Magnetometer	LIS3MDL	1	3.30	0.270	0.89	100	0.0018	Datasheet

Payload Power Budget (2/2)

Function	Component	Quantity	Voltage (V)	Current (mA)	Power (mW)	Duty Cycle (%)	Energy (Wh)	Source
Servos	SG90 (Fins and camera control)	3	7.4	250	1850	37.5	4.44	Measured
Roll, Pitch, Yaw	BNO085	1	3.3	14	46.2	100	0.0924	Datasheet
Voltage Regulator	LM2596	1	7.4	2.956	21.87	100	0.0437	Datasheet
Voltage Divider	Resistor	8 Resistors	7.4	0.4297	3.1	100	0.0508	Measured
Power Indicator	C566D-RFF	1	3.3	20	66	100	0.132	Measured
Time Chip	DS1307	1	5	1.5	7.5	100	0.015	Datasheet

Power Supplies				
Function	**Component**	**Voltage (V)**	**Capacity (mAh)**	**Energy (Wh)**
Main Battery	Lithium-ion Battery Pack	7.4	2600	19.24
Buzzer Battery	Lithium-ion Battery Cell	3.3	2000	7.4
Time Chip Battery	Coin Cell Battery	3.0	235	0.705

	Power (W)	Energy (Wh)
TOTAL	**6.726**	**13.45**

The above calculations were done assuming a time interval of 2 hours. One can see that the Energy used by the system in two hours is less than the main battery's energy. (13.45 < 19.24)

Flight Software (FSW) Design

Luke Watson

FSW Overview

Language	Main Libraries	Development Environment	FSW Tasks
C, C++	Arduino	PlatformIO, VSCode	• Handle restarts • Interface with sensors • Receive/parse commands • Determine flight state • Send data packets to ground at 1 Hz • Save data to memory

FSW Flow

Power ON → **Receive Commands** → **Telemetry Activation** → **Mission** → **Landing**

Power ON: Connection to Ground Station begins

Receive Commands: Receive, parse, and respond to commands From Ground Station

Telemetry Activation: Receive CX,ON command from Ground Station
Begin mission tasks on 2nd core

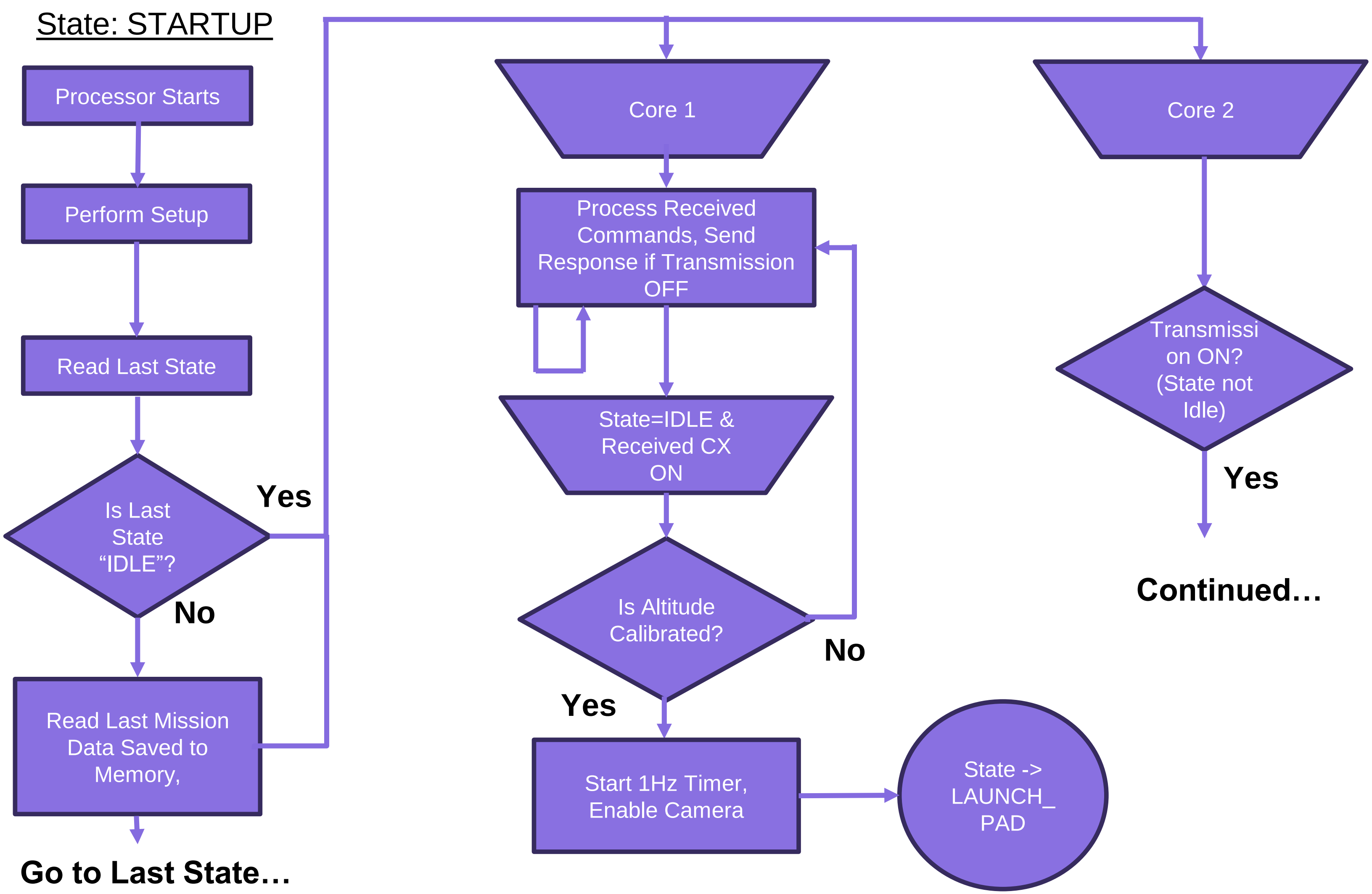
Mission: Collect measurement data from sensors
Trigger video recording
Send data packets to Ground Station
Save data to memory

Landing: End telemetry
Stop video and data collection

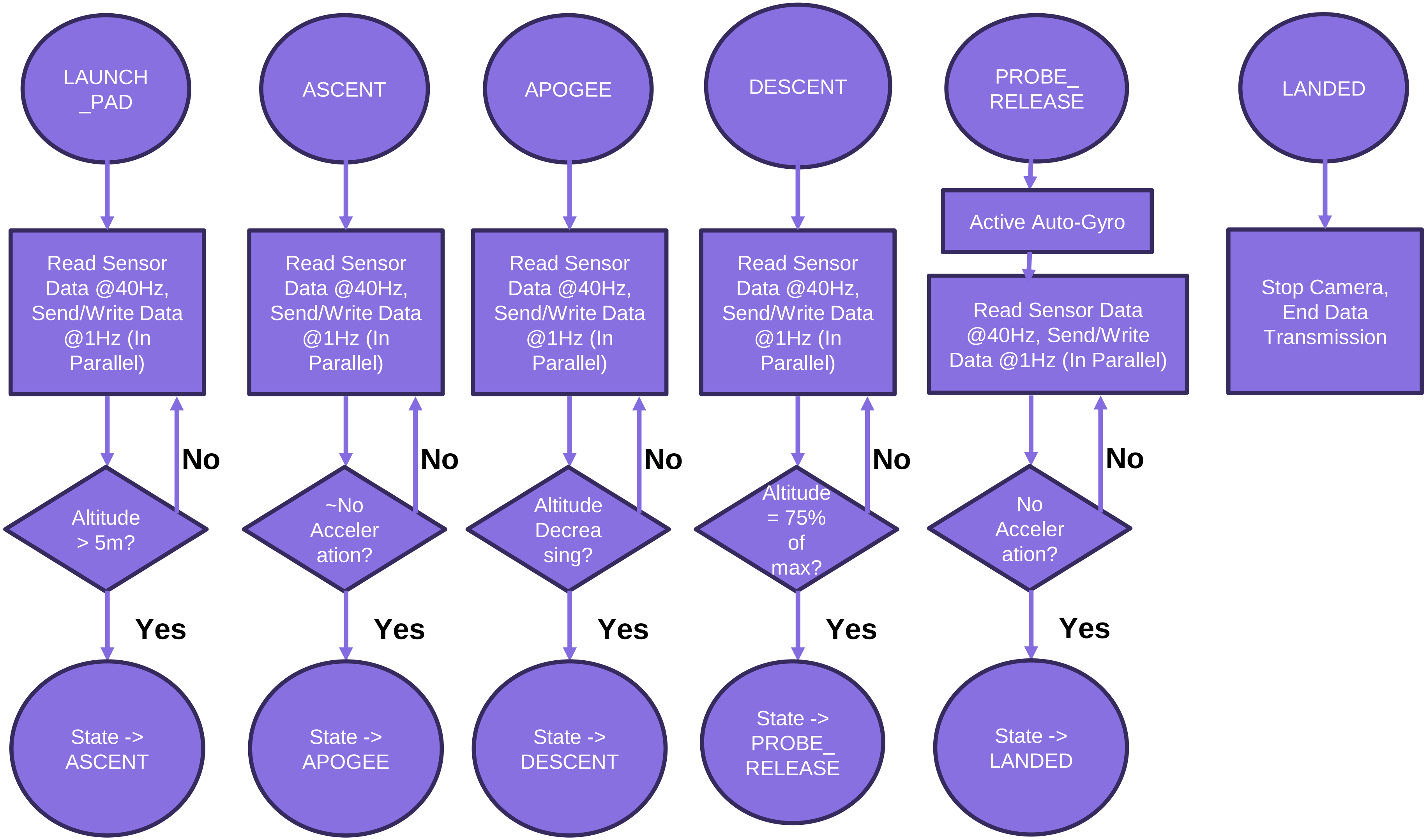
FSW Changes Since PDR

Component	Change	Reasoning
Software	Improved processor reset recovery flow	• Now upon reset, all information needed to continue previous operations will be read from memory based on last state • Reset/Startup information will be sent to Ground Station

Payload FSW State Diagram (1/3)



Payload FSW State Diagram (2/3)



Payload FSW State Diagram (3/3)

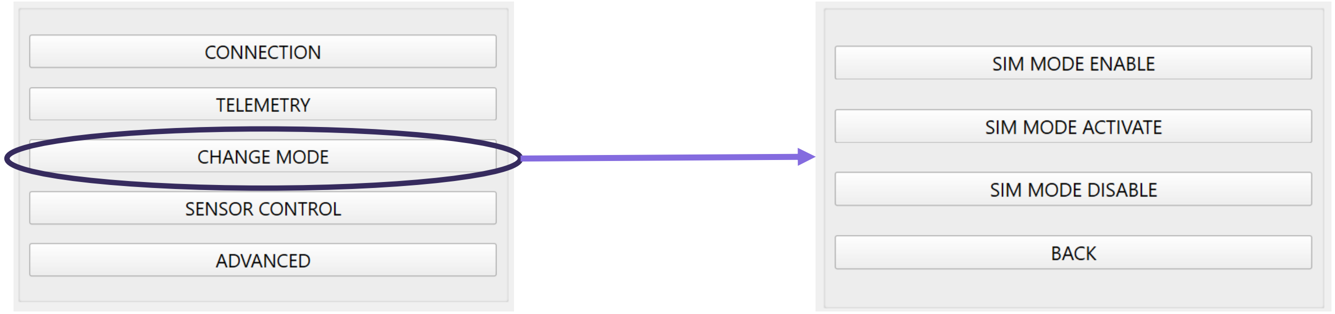
Processor Restart Recovery
On startup, the processor will check the last saved State in the NVS memory. If it is not “IDLE” then the processor will read the following values from NVS memory: • Packet Count • Launch Altitude • Operation Mode (Flight, Simulation) The reason for reset will be transmit to the ground station, and will be one of the following: • Software reset • Power reset • Watchdog reset • Brownout • SDIO reset • Unknown Transmission will then continue from the previous state.

Simulation Mode Software

Simulation Mode

Simulation mode can be started from the ground station, by pressing the buttons in the image below, which will send a command to the payload. The payload must receive the following commands to change to simulation mode: ***CMD,3114,SIM,ENABLE*** and ***CMD,3114,SIM,ACTIVATE***. ***CMD,3114,SIM,DISABLE*** will de-activate simulation mode if it is active.

In simulation mode, once transmission is activated the ground station will send SIMP commands at 1Hz in the format ***CMD,3114,SIMP,<DATA>*** where DATA is a value from the provided .txt file. The processor will use the given pressure data to determine states and altitude instead of reading from the sensors.



Software Development Plan (1/2)

Prototyping	Team	Test Methodology
• Using GitHub branch for prototypes, main branch contains latest working code • Prototyping environment: PlatformIO	• FSW – Luke • GCS – Luke • Sensor Code/Connections/PCB – Daniel • Support – Angelique	• FSW will be developed in parallel with GCS • Logic will first be tested with random numbers in place of sensor readings to simulate mission • Sensors are tested independently and are then integrated with FSW

Development Sequence

FSW Development → Test Individual Prototype Functionality → Test Functionality Together → Update Complete; Verify all Features Bug-Free → Merge into Main Development Branch

GCS Development

(i.e., Test FSW with Latest Stable GCS Release & Vice Versa)

Update Release of Compiled GCS App

Software Development Plan (2/2)

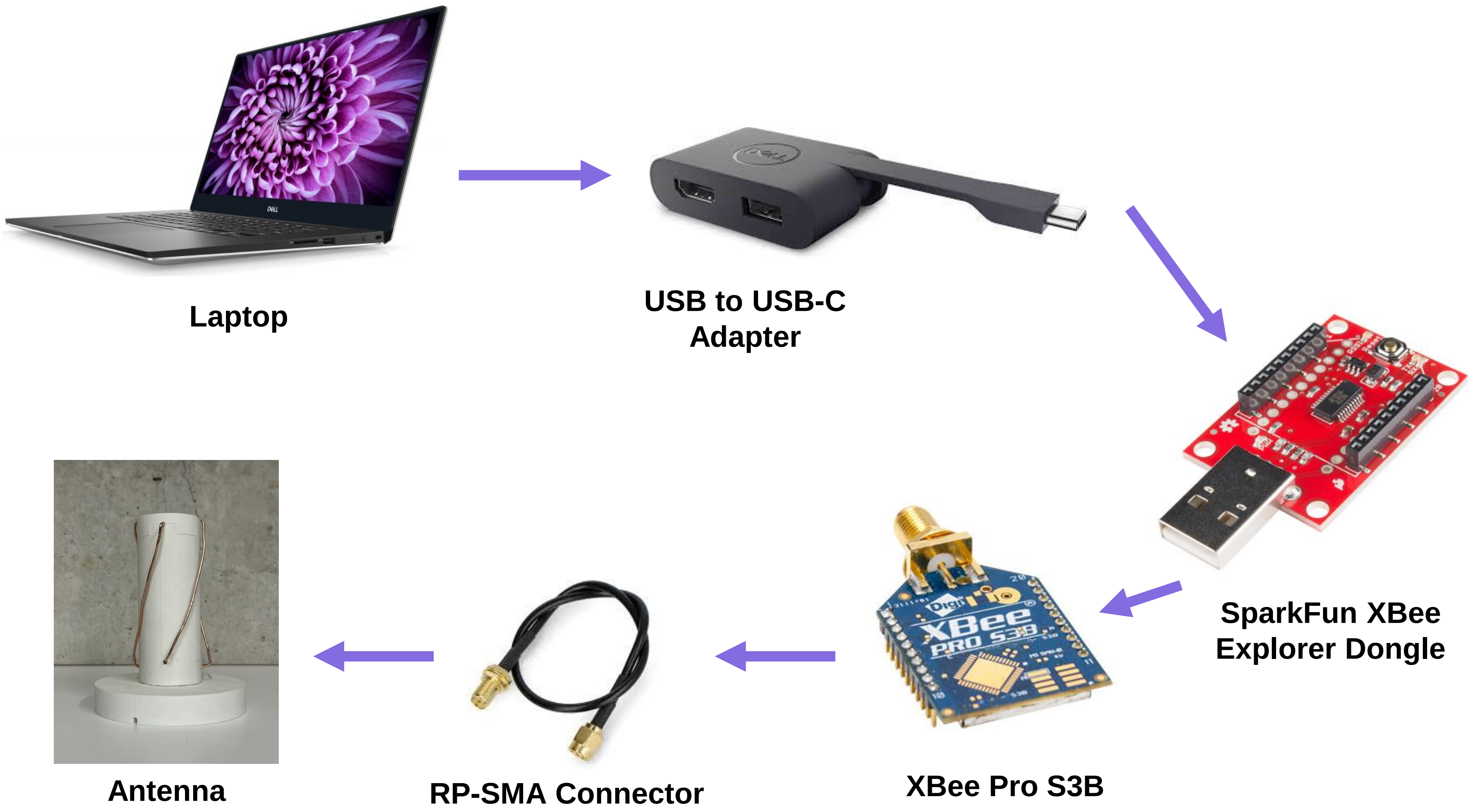
Progress From PDR
Since the PDR, we have started developing a PCB for the electronics. This will allow us to test everything together with much more efficiency. In parallel, most features for the FSW are now completed.

FSW Task	Status
Receive + Process Commands	Complete
Send Data Packets	Complete
Recover From Resets	Complete
Save Data to Memory	In Progress
Integrate With Sensor Code	In Progress

Ground Control System (GCS) Design

Luke Watson, Robert Saab

GCS Overview



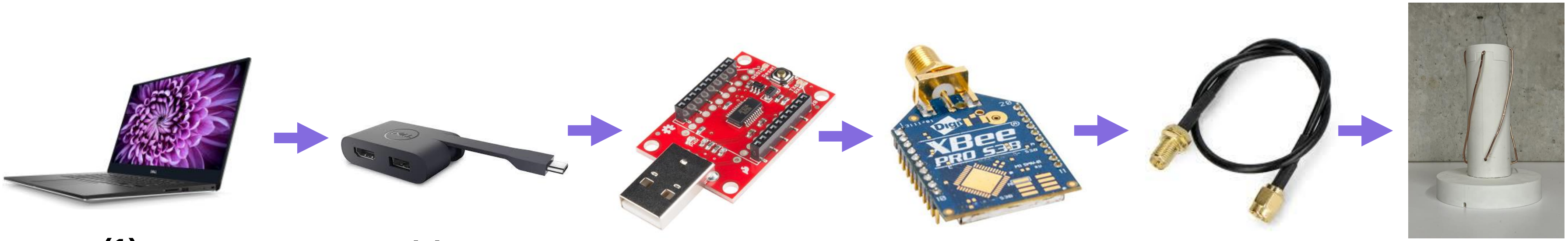
GCS Changes Since PDR

Component	Change	Reasoning
GUI	Improved UI, completed working CSV writing, fully implemented simulation mode, made all fonts 14pt+, increased graph line thickness	• Now all received data will be correctly saved to a CSV file • GUI will now correctly send SIMP data in simulation mode • Using the GUI is easier and more intuitive
Antenna	Refined antenna construction	• On testing connection distance, the transmission would sometimes stop • Improved construction of the GCS antenna to prevent this

GCS Design (1/2)

Ground Station Components

1. Laptop: The device that will be running the GCS app throughout the mission. This is flexible since the app can be downloaded and ran on any Windows computer. Currently using the Dell XPS 15 9520.
2. **USB-A to USB-C Adapter**: Will connect the XBee Explorer Dongle to the Laptop.
3. XBee Explorer Dongle: Breakout board for the XBee with a **USB-A** Male connector.
4. XBee: Receives data to from the Laptop to send to the Payload, and vice-versa, via **UART**.
5. **RP-SMA** Connector: Male to female connector allowing XBee to transmit data through the antenna.
6. Antenna: Sends and receives data from the payload.



(1) (2) (3) (4) (5) (6)

GCS Design (2/2)

Ground Station Design	
Battery	The Dell XPS 15 9520 has an 86 Wh battery, lasting around 9 hours doing low performance tasks. However, given that heat and age both affect the performance, an additional power bank will be brought for backup.
Overheating	The GCS will be setup under a tarp to prevent intense heat from reaching it. In addition, the app will be loaded onto multiple laptops for insurance.
Windows Updates	Laptop will be kept up to date pre-mission and automatic updates will be disabled beforehand.

GCS Antenna (1/3)

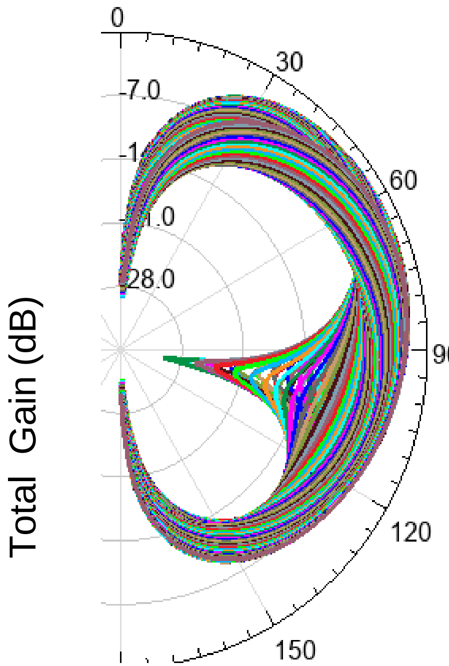
Selected Antenna Type	Design Description	Gain [dBi]	Beamwidth
Handheld - Helical Antenna (QHA - Quadrifilar Helical)	A circularly polarized antenna made of a helical wire wound around a core.	Moderate, typically around 3-5 dBi.	Moderate, providing coverage in a circular pattern.

Reasons for Choosing: Handheld (QHA - Quadrifilar Helical)

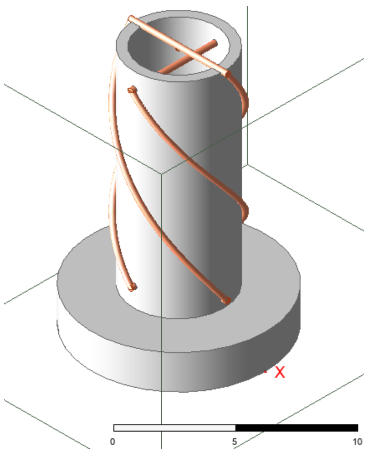
For a **handheld ground station** that must **track the CanSat** during **ascent** and **descent**, the **Helical Antenna** is the best choice due to:

- **Circular polarization,** providing better reliability in maintaining the connection without needing precise alignment.
- **Moderate gain** and beamwidth, offering a good balance between coverage and range, making it easier to track the CanSat.
- **Compact** and **easy to handle design** for a handheld system.

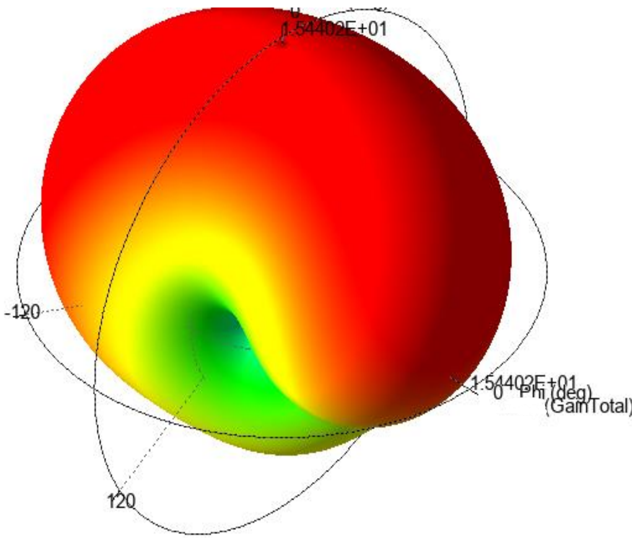
GCS Antenna (2/3)



2D Antenna Radiation Pattern (dB)



Model of Antenna simulated in ANSYS HFSS



Antenna RHCP Radiation Pattern (dB)

This shows that the Antenna is successful in sending all signals in the upward direction with peak gain along the direction where the CanSat is located.

All signals able to reach a range of 1000 m must be greater than -16 dB. With this antenna, all far field signals in the necessary directions are ~14 dB.

Ground Station Components

Frii's Transmission Equation (once normalized on the logarithmic scale and put in terms of gain) states:

$$\mathbf{Gt} = 0.5 * \mathbf{Pr} - 0.5 * [\mathbf{Pi} + \mathbf{Gr} + 20\log(\boldsymbol{\lambda} / 4\pi\mathbf{d})]$$

Where:

- **Gt** = Transmitter Antenna Gain (dB)
- **Pr** = Received Power (dBm), we are plugging in the minimum allowable power, i.e. the power sensitivity
- **Pi** = Power inputted to the antenna (dBm)
- **Gr** = Receiver Gain (dB)
- **d** = distance between two antennas (m) = 1000 m
- **λ** = wavelength (m) = 0.333 m

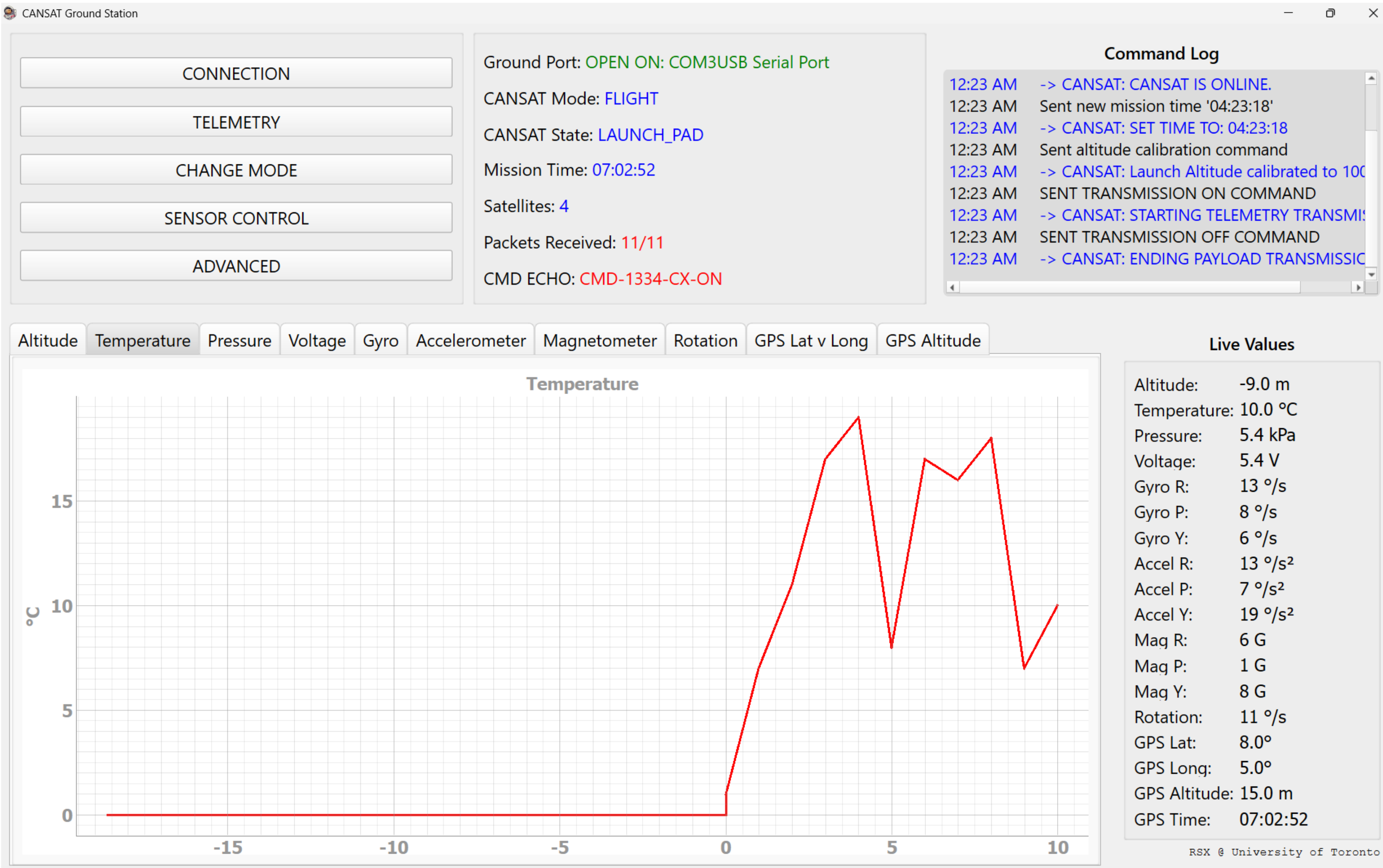
Applying the Formula to our Antennas

For the **Ground Station Antenna**:
Pr = 110 dBm, Pi = 24 dBm, Gr = -10 dB, thus **Gt = -16.2 dB**

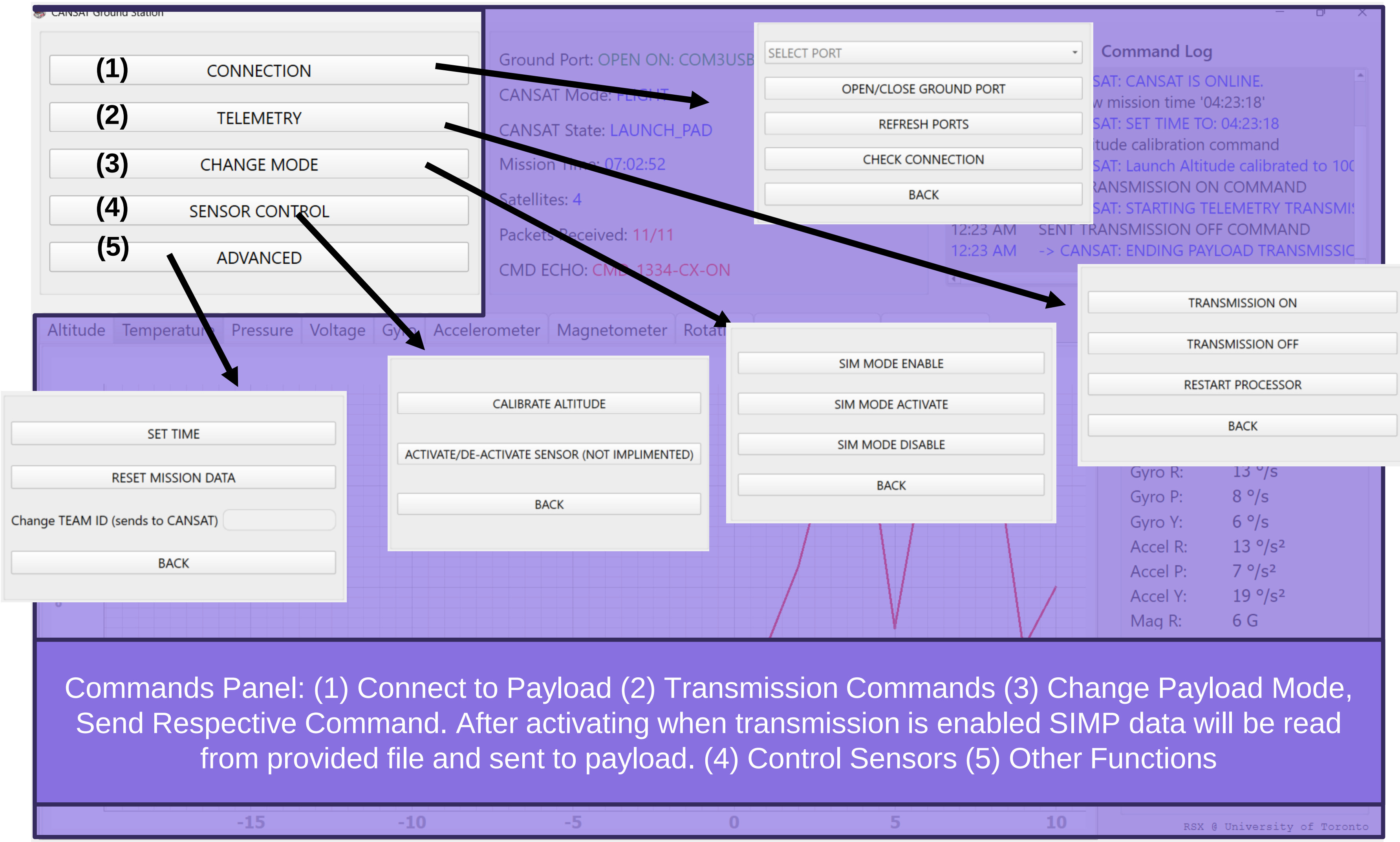
GCS Software (1/6)

GCS Software Overview	
Language	• Python
Major Packages	• PyQt6 for GUI development • PyQtGraph for real-time plotting • QSerialPort for serial interfacing, provides easy integration into GUI
Software Tasks	• Read received data packet and display contents into respective fields or update graphs with contents and write data into respective .csv files • Send all required commands to the payload • Track number of received packets • Send simulated pressure data in simulation mode
Compiling	• Using cx-freeze & bdist-msi to create a downloadable .msi file that can be ran on any Windows computer with no pre-requisites

GCS Software (2/6)

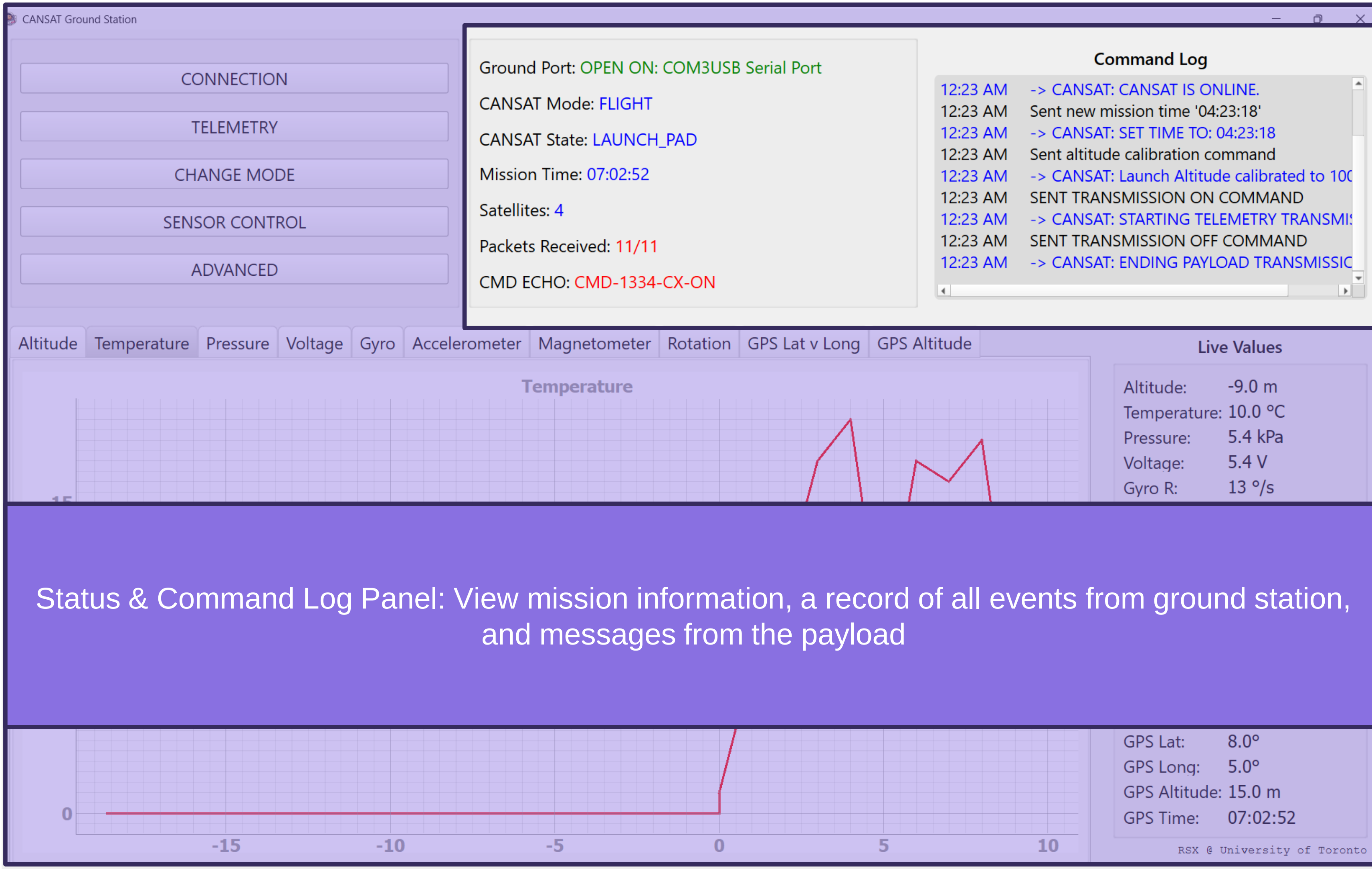


GCS Software (3/6)



Commands Panel: (1) Connect to Payload (2) Transmission Commands (3) Change Payload Mode, Send Respective Command. After activating when transmission is enabled SIMP data will be read from provided file and sent to payload. (4) Control Sensors (5) Other Functions

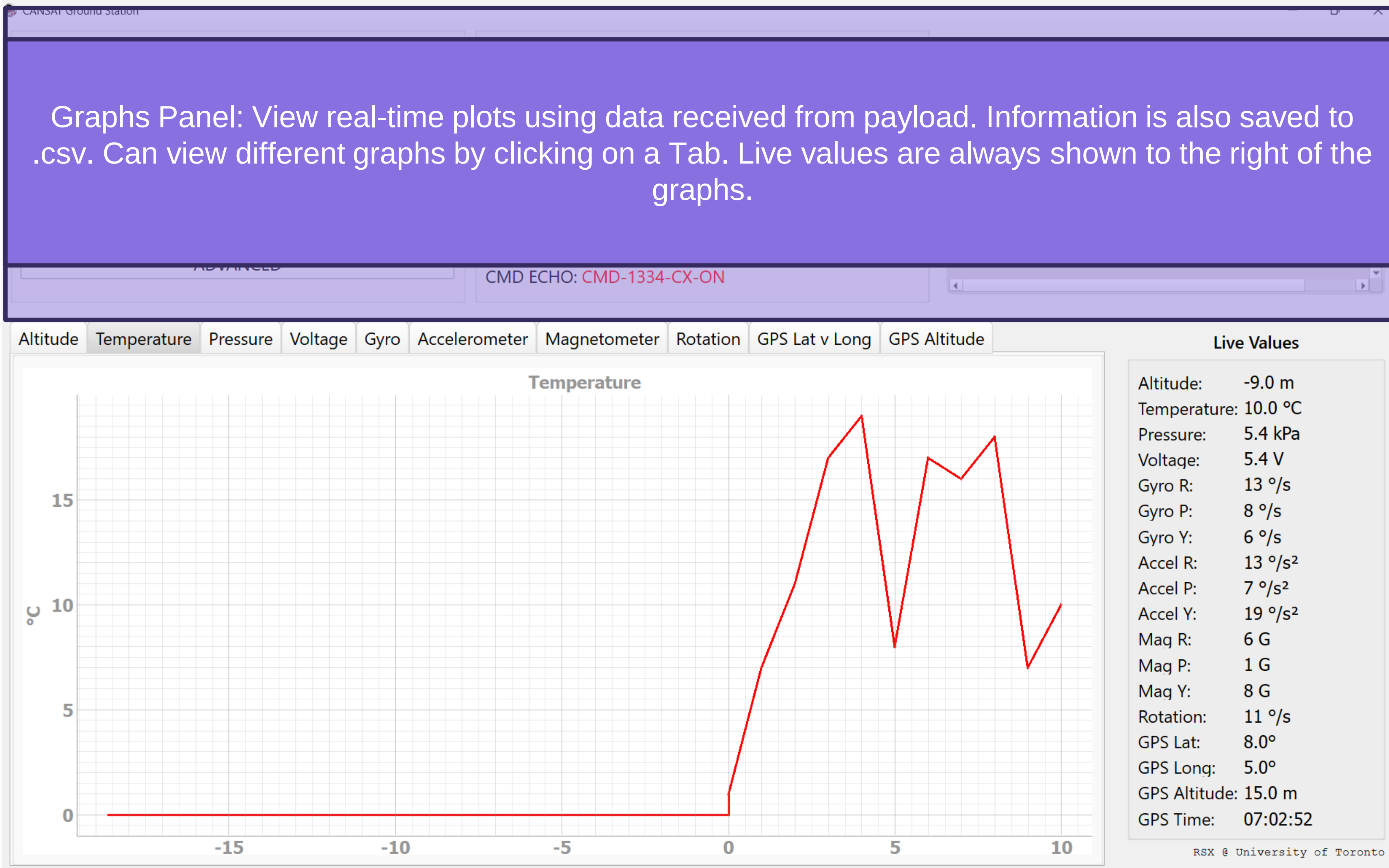
GCS Software (4/6)



Status & Command Log Panel: View mission information, a record of all events from ground station, and messages from the payload

GCS Software (5/6)

Graphs Panel: View real-time plots using data received from payload. Information is also saved to .csv. Can view different graphs by clicking on a Tab. Live values are always shown to the right of the graphs.



GCS Software (6/6)

Progress From PDR
Since the PDR, we have completed most features of the ground station software, specifically the last three tasks in the following table.

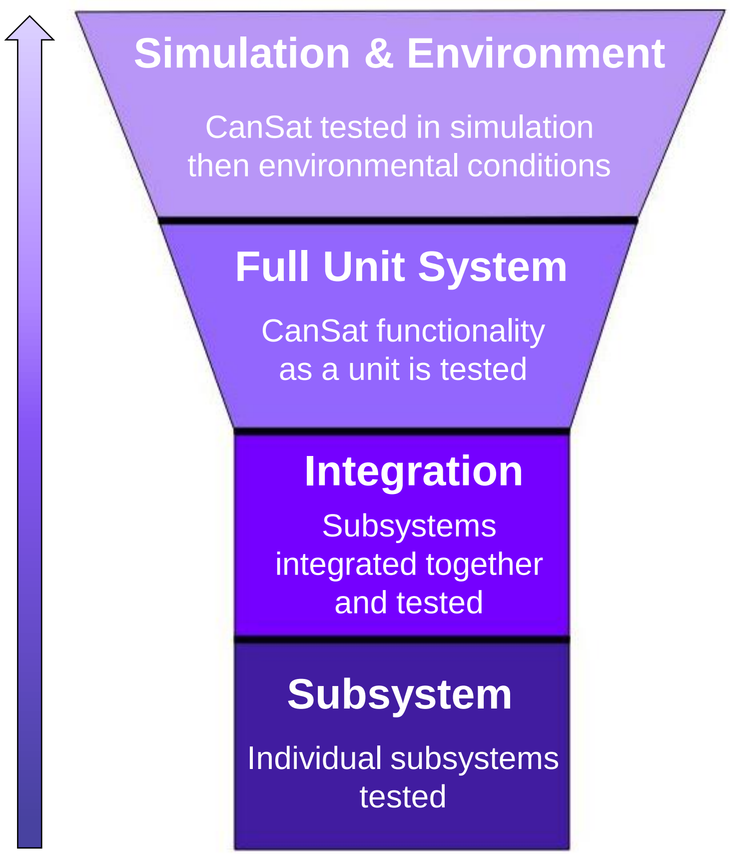
GCS Software Task	Status
Implement All Commands	In Progress (Sensor Controls)
Receive and Display Data in Real-Time	Complete
Write All Data to CSV	Complete
Send Simulated Pressure Data in Simulation Mode	Complete
Match All Visual Requirements (Font Size, Bold Lines, etc.)	Complete

CanSat Integration and Test

Nour Barsoum

CanSat Integration and Test Overview

Goal:
Ensure all subsystems function correctly before launch by testing subsystem functionality, integration, and environmental resilience



Test	Description
Subsystem	Each subsystem individually tested for functionality and expected output. This is necessary to ensure everything works independently so we can localize bugs/issues. For example: We must check the X-bee system works to ensure radio communication quality and data transmission accuracy.
Integration	Each subsystem is tested for functionality with all other subsystems it interacts with. Integrating subsystems together allows us to test the functionality of larger systems. For example: testing the full auto-gyro system functionality, structural durability of the CanSat, or the recovery system.
Full Unit System	Iteration and adjustment done to ensure smooth overall integration of all parts and subsystems on a high level.
Simulation & Environment	CanSat is tested in simulation mode to ensure all algorithms are correctly implemented. Environmental tests will be conducted to test the CanSat's structural durability and performance with respect to mission objectives. For example: The CanSat withstanding 30 G of force.

Subsystem Level Testing (1/4)

Subsystem		Test Case	Rqmnts	Acceptance Criteria	Test Status
Mechanisms	**Mechanical**	Payload remains structurally sound after undergoing shock, vibrations, and simulated landing	S8, S9, S17	No damages to structure (including cracks or lose bolts) after undergoing the tests	**Active**
		Parachute successfully slows down CPL to desired speed	C4	Payload slowed to desired speed	**Verified**
		Successful rotor deployment from the container	C6	All rotors have successfully deployed 90 degrees from their initial position	**Verified**
		Electronics board is isolated from shock and vibrations	S8, S9, S17	Electronics do not reset, and all communications interfaces are working	**Active**
		Stabilizing fins can move unobstructed	M3	Fins can freely rotate 90 degrees	**Active**
	Descent Control	FSM detects flight phase changes between descent and landing	SN5, SN6	State output changes appropriately with the CanSat's states	**Active**
		FSW controls deployment mechanisms using FSM	F2	Parachute is released properly at appropriate time	**Active**
		Parachute maintains appropriate descent velocity for the CanSat	C4	Parachute allows the CanSat to descend at ~20 m/s	**Active**
		Auto-gyro system is functional	C7, SN6	CanSat maintains controlled descent with stable rotation	**Active**

Subsystem Level Testing (2/4)

Subsystem	Test Case	Rqmts	Acceptance Criteria	Test Status
Sensors	IMU, magnetometer, hall effect sensors are successfully initialized – communications enabled	SN5, SN11	Sensor readings are accurate and successfully sent to their respective output interfaces	**Verified**
	Temperature, Pressure and Voltage readings	SN1-SN3	All values are correctly measured and accurate	**Active**
	Buzzer sounds	C13	Buzzer beeps intermittently when connected to the circuit and power	**Verified**
	Both cameras can successfully record and save video	SN7, SN8, SN10	Camera video are taken and stored in the MicroSD card	**Verified**
	Camera pointing due North	C10, SN9	Servo attached to camera moves such that the camera is pointing in the due north direction with a tolerance of ±10 degrees	**Active**
	GPS data decoded from NMEA frame and readable	SN4, X5	Longitude latitude, number of satellites, altitude, UTC time data is outputted and readable by the FSW	**Verified**
	Altitude is properly calculated from barometer	SN1, G1	Altitude measurements are within ±2 (propagated from barometer tolerance) and are relative to ground level (zero'd accordingly)	**Verified**
	GPS altitude data is correct	SN4, X5	GPS altitude output is respective to sea level and within range of the barometer	**Verified**
	High altitude GPS testing	SN4, X5	GPS outputs longitude, latitude, number of satellites, altitude and UTC time data at high altitudes with similar accuracy to when it is at lower altitude	**Verified**

Subsystem Level Testing (3/4)

Subsystem	Test Case	Rqmts	Acceptance Criteria	Test Status
CDH	Format of data sent by FSW is correct and can be accurately parsed by GCS	X5, G2	Commands and telemetry tested	Verified
	Data is sent at 1 Hz	C8, G8	GCS graphs show data points every second	Verified
	Sensor data can be properly read by FSW	SN1-SN11, F1	All sensors can be read	Active
EPS	Servo torque is sufficient for the fins to move	M3, E5	Servos propel the fins 90 degrees in each direction. If operational voltage greater than 6 V is needed, it must be sustained for 2 hours without change in current consumption to be deemed safe.	Active
	CanSat can operate for 2 hours	E5	From fully charged batteries, electrical systems stay operational for 2 hours (high currents concidered)	Active
	PCB circuit is closed with proper soldering	S17	Multimeter on continuity setting beeps when probes are touching soldered points.	Active
	Voltage regulators powered correctly	E3, E4	Voltage measured at relevant pins is accurate	Verified
	Pressure, temperature, voltage sensors powered	SN1-SN3	Voltage measured at relevant pins is accurate	Verified
	Camera, processor, MicroSD card are powered	SN7, SN8, SN10	Voltage measured at relevant pins is accurate	Verified
	IMU and XBee powered	SN5, X1	Voltage measured at relevant pins is accurate and expected output is seen from the device	Verified

Subsystem Level Testing (4/4)

Subsystem		Test Case	Rqmts	Acceptance Criteria	Test Status
Communications	**Radio Communications**	XBee radio can transmit data	X1, X4	Both XBees capable of sending data that can be received on computer using XCTU software	**Verified**
		XBee radio can receive data	G1	Both XBees capable of receiving data send through computer using XCTU software	**Verified**
		Antenna signal range	X1	XBees can communicate at a range of at least 1 km – tested results show appropriate range relative to max apogee	**Verified**
	Flight Software (FSW + GCS)	Software is capable sending and receving commands	G1, G11	All commands tested and working	**Verified**
		Accurate progression through FSM mission states	F7, F4, F6	FSM states represent flight state accurately (initialized, start, ascent, descent phase 1 & 2, landed)	**Active**
		Data can be properly visualized on graphs/text	G6-G8	Random data is properly displayed	**Verified**
		System can survive power cuts	F1-F2	Large capacitor sustains power for 1 to 2 seconds. Logs data alerts of backup power usage	**Active**

Integrated Level Functional Testing (1/2)

CanSat Subsystem Tests (after Integration)		
Descent Testing		Check if the CanSat flight is stable with the rotors and parachute functioning and deployed. To test this, we are deploying the CanSat from a high building/a known height. The drop test will be recorded with a slow-motion camera, allowing us to calculate the descent rate of the CanSat with the parachute. Instead of dropping the CanSat itself, we will be filling the nose cone and container with weights to mimic its weight.
Communications	Telemetry	Test if the telemetry is correct by setting up the CanSat on ground and sending a test data frame. Then we can check if the received data matches what we expect. Afterwards, high altitude testing must be done with the whole system.
	Antenna	Test the antenna's range using a drone to move it up various altitude and lateral distances relative to starting position. This allows us to test the antenna's performance both vertically and at an angle.
	Ground station	Test the range of radio communication by increasing distance between the ground station and the probe on a flat field; this will also ensure successful communication between the probe and ground station can be sustained. Testing of the ground station GUI is done while testing antenna/telemetry functionality to ensure the data received is accurate. The usability of the GUI is tested by having multiple members use it.
Mechanisms		Testing the rotors to ensure they have full range of motion and can deploy appropriately. Ensuring the fins have full range of motion and can stabilize the CanSat during flight.

Integrated Level Functional Testing (2/2)

CanSat Subsystem Tests (after Integration)		
Deployment	Release Trigger	Ensuring the CanSat can easily slide in and out of the container for smooth deployment. Checking that the rotor deployment system works.
	Parachute	Testing from low altitudes is done to ensure the parachute opens successfully. After this, parachute deployment testing will be done using a drone to release the payload from a high altitude and a camera to film the drop. This allows us to ensure the parachute decreases the CanSat's velocity appropriately.
Simulation		Tests ensure the CanSat software, communication system and ground station antenna work using simulated data. This also allows us to test the functionality of the sensors and auto-gyro stabilization

Integrated Level Testing – Detailed Procedures (1/2)

<table>
<tr><th colspan="2">Test</th><th>Test Procedure</th><th>Test Purpose</th><th>Rqmts</th><th>Acceptance Criteria</th></tr>
<tr><td colspan="2">Descent Testing</td><td>1. Fill the CanSat nose cone and container with padded weights to achieve net weight
2. Climb to roof of building and drop the CanSat, making sure it is level with ground
3. Use a slow-motion phone camera to record the drop</td><td>Testing ensures that we achieve desired descent rate for the CanSat and the autogyro system is functioning .</td><td>C5-C12, S16-S20, SN5-SN9</td><td>CanSat deploys smoothly Autogyro system is functional, and we achieve desired descent rate.</td></tr>
<tr><td rowspan="6">Communications</td><td>Telemetry</td><td>1. Setting up the CanSat on ground and sending a test data frame
2. Check if the received data matches what we expect</td><td>Testing ensures that the CanSat can transmit and receive telemetry correctly.</td><td>C8, X4, X5, G6, G7</td><td>Received data matches the data sent.</td></tr>
<tr><td>Antenna</td><td>1. Attach antenna to a drone
2. Fly drone up to various altitude and lateral distances relative to starting position
3. For each altitude, check antenna functionality to determine range</td><td>Tests the antenna’s performance both vertically and at an angle.</td><td>X1, X4, G13, G15</td><td>The antenna range is sufficient for functionality.</td></tr>
<tr><td rowspan="4">Ground Station</td><td>Ground test</td><td rowspan="4">Tests allow us to see the range of effective communication and the usability of the GUI with which we receive and process data.</td><td rowspan="4">G5, G6, G9, G10, G14, G15</td><td rowspan="4">The CanSat is able to communicate with the ground station and the GUI is functional and displays the correct data.</td></tr>
<tr><td>1. Increase distance between the ground station and the probe on a flat field
2. Check at which distance communication becomes unreliable</td></tr>
<tr><td>GUI Testing</td></tr>
<tr><td>1. GUI tested during antenna/telemetry test
2. The usability of the GUI is tested by having multiple members use it</td></tr>
</table>

Integrated Level Test – Detailed Procedures (2/2)

Test		Test Procedure	Test Purpose	Rqmts	Acceptance Criteria
Mechanisms		1. On ground static testing to ensure the rotors deploy and fins have motion range 2. High altitude fin and rotor testing done with deployment testing as follows: a. Attach CanSat to drone b. Fly up to high altitude c. Release the CanSat and observe if the fins can stabilize the CanSat during the drop and the rotors deploy appropriately	Ensuring the fins have full range of motion and can stabilize the CanSat during flight. Check that the rotors deploy	M3, S8, S9	The rotors to they have full range of motion and can deploy appropriately. The fins stabilize the CanSat during flight. All mechanisms in the CanSat are functional and it is structurally stable.
Deployment	Quick Release Mechanism	1. Put CPL inside the container 2. Ensure the trigger is closed 3. Release the CPL from the container 4. Observe if all three servos are functioning and release at the same time, and the CPL slides easily out of the container	Tests allow us to see if CPL can fit inside and slide out of the container easily by ensuring the functionality of the 3 servos.	C1, C5, C6	The 2 servos near the nose cone push the walls of the midway-opening CC outwards and the top servo releases CPL.
	Parachute	1. Fill the CanSat nose cone and container with padded weights to achieve net weight 2. Attach the nose cone container to the drone 3. Fly up and release it; checking if the parachute opens and stays attached to the structure	Tests allow us to check if the parachute deploys appropriately and remains attached to the structure.	C3, C4	Parachute opens at appropriate descent rate and stays attached to the structure. The parachute is structurally sound without tears/rips.

Environmental Testing

CanSat Environmental Tests	
Drop Test	Show if CanSat can survive a sudden shock of 30 G. Using a kevlar cord secured to an eyebolt attached to the celling with ample clearance so the CanSat does not hit the ground. CanSat is powered on, ensuring telemetry is received and with the parachute and the eyebolt level is dropped. Inspect all components for damage and verify that telemetry is still being received.
Thermal Test	Show if CanSat can operate normally at high temperatures. Thermal chamber is composed using an insulated cooler, heaters, and thermometers. Power on the CanSat and put it into the thermal chamber till temperature reaches 60 degrees Celsius turn heaters off and back on when temperature drops to 55 degrees Celsius. Turn off heat source when finished and visually inspect components for damage and while the CanSat is hot, test functionality.
Vibration Test	Show if CanSat structural and mounting integrity is sufficient under vibrational forces using an orbital sander upside down to introduce vibration. The CanSat is powered on, ensuring accelerometer data is being collected. Power on the sander to introduce vibrations. Inspect CanSat for damage and check if accelerometer data is still being collected.
Vacuum Test	To verify deployment operation of the payload using a vacuum chamber. Power on the CanSat and suspend it in the chamber while pulling a vacuum until the telemetry reaches max altitude. Let air enter the chamber and monitor the operation of the CanSat. Collect and saved telemetry and camera video to observe if the CanSat's relevant mechanisms activate with respect to altitude changes.
Fit Check	3D print payload container with specified dimensions, container length of 250 mm (above shoulder), diameter of 144.4 mm and wall thickness of 2 mm. Check if the payload fits within the print.

Environmental Testing – Detailed Procedures (1/2)

Test	Test Procedure	Test Purpose	Rqmts	Acceptance Criteria
Drop Test	1. A 61 cm 1/8 kevlar cord is secured to an eyebolt 2. The chord is attached to the ceiling with ample clearance so the CanSat does not hit the ground. 3. The CanSat is powered on (ensuring telemetry is received) 4. The parachute and the eyebolt are held level and dropped. 5. Check all CanSat components for physical damage such as loose screws or damaged electronics and ensure we are still receiving real time telemetry data	This test showcases if the CanSat can survive sudden shocks and vibrations while remaining functional and structurally sound.	S9, S17, C8	CanSat remains functional after drop sending real time telemetry data and maintaining its mechanical/ structural integrity.
Thermal Test	1. Create a thermal chamber by gathering one insulated cooler, one or two heaters, and one thermometer. 2. Power on the CanSat and put it into the thermal chamber. 3. Turn the heaters on – for 2 hours or until the temperature reaches 60 degrees Celsius 4. At 60 degrees Celsius, turn the heaters off and turn them back on when temperature drops to 55 degrees Celsius 5. Turn off heat source when finished and visually inspect components for damage and while the CanSat is hot 6. Test functionality of the CanSat by checking if it can be powered on, if the telemetry data is accurate, if the battery is sound, and that none of the structural components have melted.	Show if CanSat can operate normally at high temperatures that we may experience during the mission.	E5, SN2, S17	CanSat survives the thermal test as a unit without major damages that inhibit any components from working.

Environmental Test – Detailed Procedures (2/2)

Test	Test Procedure	Test Purpose	Rqmts	Acceptance Criteria
Vibration Test	1. Secure an orbital sander upside down 2. Place CanSat in the area where sandpaper would be 3. Power on the CanSat and ensure accelerometer data is being collected 4. Power on the sander, when it reaches full speed wait 5 seconds to allow the CanSat to experience vibrations 5. Power off the sander and wait till it has fully stopped 6. Repeat 4 times and inspect the CanSat for damage after each trial to gauge the amount of vibration it can tolerate and check if accelerometer data is still being collected for functionality.	Test allows us to check if the CanSat can survive vibrations similar to those expected during the mission while remaining functional and structurally sound.	S8, M3, SN5	No major damages to the CanSat structure, the electrical components remain functional and the CanSat is operational.
Vacuum Test	1. Power on the CanSat and suspend it inside a 5-gallon bucket 2. Cover the bucket with a lid and turn on a vacuum to remove air from the chamber 3. Stop the vacuum when the telemetry reaches max altitude 4. Monitor the CanSat as air enters the vacuum 5. Collect and save telemetry and video data to review and ensure all relevant mechanisms activate with the appropriate altitude changes	Test allows us to check if all appropriate mechanisms activate with altitude changes and verifies FSM functionality.	C8, SN1, SN4, F2, F1, SN7	The CanSat powers on, transmits accurate telemetry, activates mechanisms at the correct altitude, transitions FSM states properly, records retrievable telemetry and video, and remains structurally intact without functional damage.
Fit Check	1. 3D print a payload container with length 250 mm (above shoulder), diameter of 144.4 mm and wall thickness of 2 mm 2. Assemble the CanSat 3. Visually check if the CanSat fits inside the payload	Test allows us to see if CanSat will fit inside the rocket payload,	S1, S11-S14, S16, C2	The CanSat can fit easily inside the rocket payload with no resistance.

Simulation Testing

Simulation Implementation
The simulation mode will test the CanSat by sending simulated pressure data through the ground software. Simulation mode is activated by sending “ENABLE” and “ACTIVATE” SIM commands. The pressure data is sent at 1 Hz through SIMP commands once the “ON” CX command is pressed. On the CanSat, all software will operate as normal except for substituting sensor pressure data for received simulated data. The CanSat will remain in simulation mode until directed by the ground station, through a “DISABLE” SIM command.

Parts Tested
Simulation mode will test the software on the ground station and CanSat. The CDH system, including sensors, will also be tested during the simulated mission as data will be sent to the ground station just like in flight mode. Once integrated with the mechanical parts, simulating will also test the gyro stabilization mechanism.

Simulation Testing – Detailed Procedures

Test	Test Procedure	Test Purpose	Rqmts	Acceptance Criteria
Simulation Mode	1. Send ENABLE and ACTIVATE commands from the GUI 2. FSW changes from FLIGHT mode to SIMULATION mode 3. Data transmission is turned ON from the GUI 4. Pre-determined pressure data is sent from a provided .txt file using SIMP commands at a 1Hz rate 5. Pressure data is received by FSW and used to calculate states and release of auto-gyro stabilization mechanism 6. GUI sends DISABLE command to return FSW to FLIGHT mode	Test will check GCS, CDH, and FSW as they should work in a real mission	C6, C8, C9, C10, C11, C12, X1-5, SN1-11, G1-16, F1-7	Sensor data is transmitted, received, and displayed throughout the duration of the test, and auto-gyro is activated

Mission Operations & Analysis

Alexey Albert, Angelique Liao

Overview of Mission Sequence of Events (1/2)

1. Arrival, Ground Station, and Antenna Setup

- Arriving at the launching site (Whole Team)
- Check and fix any potential damage could happened in the transportation (RC/CCR)
- Ground Control System Assembly (GSC)
- Antenna Assembly (GSC)

2. CanSat Assembly and System Validation

- Battery Charge Level Check (CCR)
- CanSat Assembly Final Integration and System Check (CCR)
- Communication and Sensor Functionality Check (GSC)
- Weight & Size Compliance Verification (MCO/CCR)
- Final Inspection Submission (MCO/CCR)

3. Pre-Launch Checklist

- Positioning Ground Control Station (GSC)
- CanSat Integration Check (MCO).
- CanSat – GCS Communication Verification (GSC).
- Sensor Calibration: Adjust and verify sensor accuracy (GSC)
- Final Safety Inspection (Whole Team)

4. Launch Execution

- Initiating Launch Procedures (MCO/CCR/GSC)
- Monitor CanSat during flight (GSC)
- CanSat Recovery after landing (Whole Team)
- Submit flight data via USB stick to the judge (GSC)

5. Post-Landing Recovery

- Deploy team to locate and recover the CanSat (RC)
- Retrieve the onboard storage device MicroSD (RC)
- Flight data backup after recovery (GSC)

6. Post-Landing Evaluation and Cleanup

- Return to check-in for final assessment (RC)
- Clear the Ground Station area(GSC)
- Process and interpret collected flight data (Whole Team)

Overview of Mission Sequence of Events (2/2)

Role	Members	Responsibilities
Mission Control Officer (MCO)	Adam Kabbara	Launch manager oversees countdown and readiness.
Ground Station Crew (GSC)	Luke Watson, Angelique Liao, Nour Barsoum	Ground station crew monitors telemetry and commands.
Recovery Crew (RC)	Gianluca Ceccacci, Robert Saab	Recovery crew tracks and retrieves CanSat.
CanSat Crew (CCR)	Arthur Goetkze-Coburn, Alexey Albert, Daniel Yu	CanSat preparation and rocket integration team.

- **Antenna Setup and Ground System Preparation**
- Our goal is to make the setup process as straightforward as possible to avoid any delays before launch. The laptop will be linked to our custom-built helical antenna and connected to the XBee Radio using a specialized USB adapter. Before the probe check-in, the CanSat will verify connectivity by establishing communication with the ground station via its onboard antenna.
- **CanSat Testing and Assembly**
- The electronics will be installed, the parachute securely attached, and the MicroSD card inserted. Just before check-in, a final round of communication tests will be performed.

Field Safety Rules Compliance

- The Mission Guide's insights, members' prior experiences, and the remaining test results will all be used to complete the Mission Operations Manual. After the CDR, the Mission Operations Manual will be completed, taking into account any relevant feedback mentioned during the CDR presentation.
- This manual will be arranged in a three-ring binder along with the mission sequence, team roles, and safety instructions.
- With the overview of the Mission Sequence of Events, some crucial points of the Mission Operation Manual are specified in the next slide within detailed description diagram.
- In terms of progress, we have fully designed the CanSat and its associated systems and the team has moved on to putting together the different subsystems. And we will be ready to move into integrated level testing and environmental testing where appropriate.

CanSat Location and Recovery

CanSat Recovery

- Landing zone will be determined by GPS location data after landing
- The buzzer, 90 dB loud, will be active throughout ascent, decent and after landing

Color Selection for Components

- The probe and the parachute will be orange in color so that it can be easily observed

CanSat Return Address Labeling

- The payload and container will be labelled with the team’s contact email address and alternative contact information in case the Recovery Crew is unable to find it

Mission Rehearsal Activities

1. Ground System Radio Link check

- Connect the XBee (XBP9B-XCST-001) to the QHA antenna using an RPSMA coaxial cable.
- Insert the XBee into the XBee SparkFun Adapter.
- Connect the XBee SparkFun Adapter to the laptop using a USB to USB-C cable.
- Access the onboard computer with the XBee by launching the GSC GUI and selecting the corresponding port for the XBee adapter.

2. Electrical Systems

- Processed and read collected flight data
- Sensor calibration involving adjusting and verifying sensor accuracy
- Battery charge level check
- Positioning ground control Station

3. Recovery

- Searched for CanSat using audio beacon in a large field.
- Searched for bright orange parachute in large field.
- Backed up flight data after recovery

Requirements Compliance

Angelique Liao

Requirements Compliance Overview

- All requirements are already fulfilled (100%).
- Management requirements are also met.

- There are no partially completed tasks.
- Previous items—such as real descent rates, survivability under shock, vibration, acceleration, and orientation stability—have been reviewed and fulfilled.

- There are no serious issues, since all requirements were considered and addressed during design process.
- Additional tests to verify functionality and stability will be completed by the Environmental Test Documentation deadline.

Requirements Compliance (1/13)

Rqmt Num	Requirement	Comply / No Comply / Partial	X-Ref Slide(s) Demonstrating Compliance	Team Comments or Notes
C1	The CanSat payload shall function as a nose cone during the rocket ascent portion of the flight.	Comply	15, 16, 53, 116	
C2	The CanSat container shall be mounted on top of the rocket with the shoulder section inserted into the airframe.	Comply	15, 16, 17, 50, 53, 54, 55, 56	
C3	The CanSat payload and container shall be deployed from the rocket when the rocket motor ejection charge fires.	Comply	13	
C4	After deployment, the CanSat payload and container shall descend at 20 m/s using a parachute that automatically deploys.	Comply	33, 38, 48	
C5	At 75% flight peak altitude, the payload shall be released from the container.	Comply	13, 14, 31, 36	
C6	At 75% peak altitude, the payload shall deploy an auto-gyro descent control system.	Comply	13, 14, 31, 36	
C7	The payload shall descend at 5 m/s with the auto-gyro descent control system.	Comply	40, 41, 42, 43, 44, 47, 48	

Requirements Compliance (2/13)

Rqmt Num	Requirement	Comply / No Comply / Partial	X-Ref Slide(s) Demonstrating Compliance	Team Comments or Notes
C8	The sensor telemetry shall be transmitted at a 1 Hz rate.	Comply	14, 75, 88, 114	
C9	The payload shall record video of the release of the parachute and the operation of the auto-gyro descent control system.	Comply	11, 19, 29, 113	
C10	The second video camera shall point in the north direction during descent.	Comply	11, 19, 28, 34	
C11	The second camera shall be pointed 45 degrees from the CanSat nadir direction during descent.	Comply	11, 59	
C12	The second video camera shall be spin stabilized so the ground view is not rotating in the video.	Comply	11, 34, 53, 117, 119	
C13	The CanSat payload shall include an audible beacon that is turned on separately and is independent of the CanSat electronics.	Comply	12, 14, 80	
C14	The cost of the CanSat shall be under $1000. Ground support and analysis tools are not included in the cost of the CanSat. Equipment from previous years shall be included in this cost, based on current market value.	Comply	12, 148, 149, 150, 151, 152	

Requirements Compliance (3/13)

Rqmt Num	Requirement	Comply / No Comply / Partial	X-Ref Slide(s) Demonstrating Compliance	Team Comments or Notes
S1	The CanSat and container mass shall be 1400 g ±10 g.	Comply	11, 62, 63, 64, 65, 66	
S2	The nose cone shall be symmetrical along the thrust axis.	Comply	15, 17, 53	
S3	The nose cone radius shall be exactly 72.2 mm.	Comply	15, 17, 53, 54	
S4	The nose cone shoulder length shall be a minimum of 50 mm.	Comply	14, 15, 16, 17	
S5	The nose cone shall be made as a single piece. Segments are not allowed.	Comply	11, 15, 17, 53	
S6	The nose cone shall not have any openings allowing air flow to enter.	Comply	11, 15, 17, 53	
S7	The nose cone height shall be a minimum of 76 mm.	Comply	11, 15, 17, 53	
S8	CanSat structure must survive 15 G vibration.	Comply	11, 60, 61, 112, 122	
S9	CanSat shall survive 30 G shock.	Comply	11, 60, 61, 111, 120	
S10	The container shoulder length shall be 90 to 120 mm.	Comply	12, 17, 54	

Requirements Compliance (4/13)

Rqmt Num	Requirement	Comply / No Comply / Partial	X-Ref Slide(s) Demonstrating Compliance	Team Comments or Notes
S11	The container shoulder diameter shall be 136 mm.	Comply	12, 17, 53, 54	
S12	Above the shoulder, the container diameter shall be 144 mm.	Comply	12, 15, 17, 53, 54	
S13	The container wall thickness shall be at least 2 mm.	Comply	11, 54, 120	
S14	The container length above the shoulder shall be 250 mm +/- 5%.	Comply	11, 15, 17, 53, 54	
S15	The CanSat shall perform the function of the nose cone during rocket ascent.	Comply	15, 17, 53, 113	
S16	The CanSat container can be used to restrain any deployable parts of the CanSat payload but shall allow the CanSat to slide out of the payload section freely.	Comply	56, 57, 117, 119	
S17	All electronics and mechanical components shall be hard-mounted using proper mounts such as standoffs, screws, or high-performance adhesives.	Comply	50, 51, 60, 61, 112	
S18	The CanSat container shall meet all dimensions in section F.	Comply	15, 17, 53, 54	
S19	The CanSat container materials shall meet all requirements in section F.	Comply	17, 50, 53, 148, 149, 150	

Requirements Compliance (5/13)

Rqmt Num	Requirement	Comply / No Comply / Partial	X-Ref Slide(s) Demonstrating Compliance	Team Comments or Notes
M1	No pyrotechnical or chemical actuators are allowed.	Comply	50, 55, 57	CanSat does not use any pirotechnical or chemical actuators
M2	Mechanisms that use heat (e.g. nichrome wire) shall not be exposed to the outside environment to reduce the potential risk of setting the vegetation on fire.	Comply	50, 55, 57	CanSat not use any heat-based mechanism
M3	All mechanisms shall be capable of maintaining their configuration or states under all forces.	Comply	11, 60, 61, 112, 122	
M4	Spring contacts shall not be used for making electrical connections to batteries. Shock forces can cause momentary disconnects.	Comply	60, 82	

Requirements Compliance (6/13)

Rqmt Num	Requirement	Comply / No Comply / Partial	X-Ref Slide(s) Demonstrating Compliance	Team Comments or Notes
E1	Lithium polymer batteries are not allowed.	Comply	66, 83, 84, 151	
E2	Battery source may be alkaline, Ni-Cad, Ni-MH, or Lithium. Lithium polymer batteries are not allowed. Lithium cells must be manufactured with a metal package similar to 18650 cells. Coin cells are allowed.	Comply	66, 83, 84, 151	
E3	An easily accessible power switch is required.	Comply	12, 50, 80, 82	
E4	A power indicator is required.	Comply	12, 82	
E5	The CanSat shall operate for a minimum of two hours when integrated into the rocket.	Comply	85, 86, 114	
E6	The audio beacon shall operate on a separate battery.	Comply	12, 80, 82, 84	
E7	The audio beacon shall have an easily accessible power switch.	Comply	12, 80, 82	

Requirements Compliance (7/13)

Rqmt Num	Requirement	Comply / No Comply / Partial	X-Ref Slide(s) Demonstrating Compliance	Team Comments or Notes
X1	XBee radios shall be used for telemetry. 2.4 GHz Series radios are allowed. 900 MHz XBee radios are also allowed.	Comply	15, 16, 53, 74	
X2	XBee radios shall have their NETID/PANID set to their team number.	Comply	68, 75	
X3	XBee radios shall not use broadcast mode.	Comply	75	
X4	The CanSat shall transmit telemetry once per second.	Comply	75, 91	
X5	The CanSat telemetry shall include altitude, air pressure, temperature, battery voltage, command echo, and GPS coordinates, including latitude, longitude, altitude, and the number of satellites tracked.	Comply	88	

Requirements Compliance (8/13)

Rqmt Num	Requirement	Comply / No Comply / Partial	X-Ref Slide(s) Demonstrating Compliance	Team Comments or Notes
SN1	CanSat payload shall measure its altitude using air pressure.	Comply	19, 21, 76, 113	
SN2	CanSat payload shall measure its internal temperature.	Comply	19, 22, 76, 103	
SN3	CanSat payload shall measure its battery voltage.	Comply	19, 23, 76, 82, 113	
SN4	CanSat payload shall track its position using GPS.	Comply	12, 19, 24, 76, 113	
SN5	CanSat payload shall measure its acceleration and rotation rates.	Comply	12, 19, 26, 76, 113	
SN6	CanSat payload shall measure auto-gyro rotation rate.	Comply	12, 19, 25, 76	
SN7	CanSat payload shall video record the release of the parachute and deployment of the auto-gyro at 75% peak altitude.	Comply	29	
SN8	CanSat payload shall video record the ground at 45 degrees from nadir direction during descent.	Comply	59	

Requirements Compliance (9/13)

Rqmt Num	Requirement	Comply / No Comply / Partial	X-Ref Slide(s) Demonstrating Compliance	Team Comments or Notes
SN9	The camera video shall be spin stabilized and oriented in the north direction so the view of the ground is not rotating more than 10 degrees in either direction.	Comply	35, 59	
SN10	The video cameras shall record video in color and with a minimum resolution of 640 x 480.	Comply	28, 29	
SN11	The CanSat shall measure the magnetic field.	Comply	27	

Requirements Compliance (10/13)

Rqmt Num	Requirement	Comply / No Comply / Partial	X-Ref Slide(s) Demonstrating Compliance	Team Comments or Notes
G1	The ground station shall command the CanSat to calibrate the altitude to zero when the CanSat is on the launch pad prior to launch.	Comply	78	
G2	The ground station shall generate CSV files of all sensor data as specified in the Telemetry Requirements section.	Comply	98, 104	
G3	Telemetry shall include mission time with 1-second resolution.	Comply	76	
G4	Configuration states such as zero altitude calibration software state shall be maintained in the event of a processor reset during launch and mission.	Comply	92	
G5	Each team shall develop their own ground station.	Comply	97, 104	
G6	All telemetry shall be displayed in real-time during ascent and descent on the ground station.	Comply	105, 108	
G7	All telemetry shall be displayed in the International System of Units (SI), and the units shall be indicated on the displays.	Comply	105, 108	
G8	Teams shall plot each telemetry data field in real-time during flight.	Comply	104, 105, 108	

Requirements Compliance (11/13)

Rqmt Num	Requirement	Comply / No Comply / Partial	X-Ref Slide(s) Demonstrating Compliance	Team Comments or Notes
G9	The ground station shall include one laptop computer with a minimum of two hours of battery operation, XBee radio, and an antenna.	Comply	97, 99, 100	
G10	The ground station must be portable so the team can be positioned at the ground station operation site along the flight line. AC power will not be available at the ground station operation site.	Comply	12, 97, 100	
G11	The ground station software shall be able to command the payload to operate in simulation mode by sending two commands, **SIMULATION ENABLE** and **SIMULATION ACTIVATE**.	Comply	77, 93, 106	
G12	When in simulation mode, the ground station shall transmit pressure data from a CSV file provided by the competition at a 1 Hz interval to the CanSat.	Comply	77, 93, 104	
G13	The ground station shall use a tabletop or handheld antenna.	Comply	97, 99, 101, 102	

Requirements Compliance (12/13)

Rqmt Num	Requirement	Comply / No Comply / Partial	X-Ref Slide(s) Demonstrating Compliance	Team Comments or Notes
G14	Because the ground station must be viewed in bright sunlight, the displays shall be designed with that in mind, including using larger fonts (14-point minimum), bold plot traces and axes, and a dark text on light background theme.	Comply	98, 105	Some font sizes need to be updated, need to add bold axes on plots
G15	The ground system shall count the number of received packets. Note that this number is not equivalent to the transmitted packet counter, but it is the count of packets successfully received at the ground station for the duration of the flight.	Comply	104, 105, 107	
G16	The ground station shall be able to activate all mechanisms on command.	Comply	78, 109	

Requirements Compliance (13/13)

Rqmt Num	Requirement	Comply / No Comply / Partial	X-Ref Slide(s) Demonstrating Compliance	Team Comments or Notes
F1	The flight software shall maintain a count of packets transmitted, which shall increment with each packet transmission throughout the mission. The value shall be maintained through processor resets.	Comply	104	
F2	The CanSat shall maintain mission time throughout the entire mission even in the event of processor resets or momentary power loss.	Comply	71	
F3	The CanSat shall have its time set by ground command to within one second UTC time prior to launch.	Comply	77	
F4	The flight software shall support simulated flight mode where the ground station sends air pressure values at a one-second interval using a provided flight profile file.	Comply	77	
F5	In simulation mode, the flight software shall use the radio uplink pressure values in place of the pressure sensor for determining the payload altitude.	Comply	77, 92, 93, 104, 109	
F6	The flight software shall only enter simulation mode after it receives the **SIMULATION ENABLE** and **SIMULATION ACTIVATE** commands.	Comply	93	
F7	The flight shall include commands to activate all mechanisms. These commands shall be documented in the mission manual.	Comply	106, 128	

Management

Adam Kabbara

Status of Procurements

Subsystem	Part	Status	Subsystem	Part	Status
EPS	ESP32 S3 WROOM	Received 10, 2024	Recovery	MATEK Buzzer	Reused
	Camera ESP32	Received 11, 2024		Timer Chip	Received 10, 2024
	Buck converter	Received 2, 2025		Parachute	Received 12, 2024
	Boost Converter	Received 1, 2025		Ripstop Nylon	Received 12, 2024
	Lithium Ion Pack	Received 1, 2025	Mechanical	SG90	Received 1, 2025
	Lithium Ion Cell	Received 1, 2025		Coin cell holder	Received 2, 2025
	Coin Cell	Received 2, 2025		Eyebolt	Received 3, 2025
	Time Chip	Received 3, 2025		ASA	Received 2, 2025
	Watch Crystal	Received 3, 2025		LW ASA	Received 2, 2025
	PCB boards	Ordered, 3, 2025		Threaded inserts	Received 11, 2025
Sensors	BME280	Reused		Screws and bolts	Ordered 3, 2025
	BN-220	Reused		Standoffs	Ordered 3, 2025
	A3144EU	Received 10, 2024		Resin	Ordered 3, 2025
	OV5640AF Camera	Received 11, 2024		Carbon Fiber	Ordered 3, 2025
	OV5640 Camera	Received 11, 2024	GCS	Xbee	Reused
	Magnetometer	Received 3, 2025		Xbee Adapter	Reused
CDH	Xbee	Reused		Copper Wire	Reused
	SD card	Reused		Coaxial Cable	Received 12, 2024

CanSat Budget – Hardware (1/4)

Currency	USD
Exchange rate	CAD = 0.7 * USD

Slide Total:	**$10.96**

Component	Description	Quantity	Price per Unit [USD]	Total	Source
Printed Mechanical Parts – CanSat Container Payload					
Top Rotor Holder	Light Weight ASA	1	0.89	0.89	Estimated
CanSat Slice Holder	Light Weight ASA	4	0.13	0.51	Estimated
Nose Cone	Light Weight ASA	1	1.81	1.81	Estimated
Blade Assembly	Light Weight ASA	8	0.04	0.34	Estimated
Bottom Rotor Holder	Light Weight ASA	1	1.01	1.01	Estimated
Fins	Light Weight ASA	2	0.11	0.21	Estimated
Bottom Rotor Shaft Holder	Light Weight ASA	1	0.46	0.46	Estimated
Top Rotor Shaft Holder	Light Weight ASA	1	1.43	1.43	Estimated
(Upper) Shaft Clamp	Light Weight ASA	1	0.18	0.18	Estimated
Bottom Clamp	Light Weight ASA	1	0.12	0.12	Estimated
Small Shaft Clamp	Light Weight ASA	1	0.09	0.09	Estimated
Top and Bottom Rotor Shaft	Light Weight ASA	1	0.17	0.17	Estimated
North Camera Slice	Light Weight ASA	1	0.74	0.74	Estimated
Shroud	Light Weight ASA	1	3.01	3.01	Estimated

CanSat Budget – Hardware (2/4)

Slide Total:	$77.99

Component	Description	Quantity	Price per Unit [USD]	Total	Source
Printed Mechanical Parts – CanSat Container					
CanSat Release Latch Slice	Light Weight ASA	1	0.71	0.71	Estimated
CanSat Release Latch	Light Weight ASA	1	0.02	0.02	Estimated
Release Assembly	Light Weight ASA	1	0.42	0.42	Estimated
Container Shoulder	Light Weight ASA	1	1.96	1.96	Estimated
Side Walls	Light Weight ASA	1	3.69	3.69	Estimated

Component	Description	Quantity	Price per Unit [USD]	Total	Source
Non-printed Mechanical Parts					
Carbon Fiber Layup	Rotors layup	8	2.65	21.25	Estimated
PCB Boards	Power and main board	2		13.24	Estimated
Steel Parts (Eyebolt with Shoulder + Locknut + Steel Washer)	Steel	120	-	20.00	Estimated
Cansat Release Sliding Latch	Steel	1	5.50	5.50	Estimated
Eyebolt Mount	6.35 mm Plywood	1	11.20	11.20	Estimated

CanSat Budget – Hardware (3/4)

Slide Total:	$56.36

Component	Description	Quantity	Price per Unit [USD]	Total	Source
Non-printed Mechanical Parts					
Parachute	-	1	4.43	4.43	Actual
3/8" Tubular Nylon 20' with Loops Sewn	Parachute cord (18")	1	7.17	7.17	Actual
Steel Parts (Eyebolt with Shoulder + Locknut + Steel Washer)	Steel	120	-	20.00	Estimated
Coin cell Battery Holder	Time chip battery	1	0.96	0.96	Actual
PCBs	Power and Main PCB	2	-	13.24	Estimated
Round Standoff M2 X 0.4 Steel 3mm	-	12	0.88	10.56	Actual

Note that all items in the budget tables in the slides before and including this one, are items that are new and not reused

CanSat Budget – Hardware (4/4)

Slide Total: **$197.11**

Component	Description	Quantity	Price per Unit [USD]	Total	Source	Status
Electrical Subsystem Continued						
MATEK 5V Loud Buzzer	Buzzer	1	2.90	2.90	Actual	Reused
NE555P	Timer	1	0.36	0.36	Actual	New
XBP9B-XCWT-001	XBee	1	53.85	53.85	Actual	Reused
BME280	Barometer	1	14.95	14.95	Actual	Reused
BN-220	GPS	1	12.88	12.88	Actual	Reused
A3144EU	Hall Sensor	1	0.06	0.06	Estimated	New
Freenove ESP32 S3 WROOM	Camera ESP32	2	5.55	11.10	Actual	New
ESP32 S3 WROOM 32D	ESP32	1	7.70	7.70	Actual	New
OV5640AF Camera Module	Camera (Release)	1	4.46	4.46	Actual	New
OV5640 Camera Module	Camera (Ground)	1	5.08	5.08	Actual	New
SG90	Servos	6	2.24	13.44	Actual	New
BNO085	IMU	1	24.95	24.95	Actual	New
LM2596	Voltage Regulator	1	5.76	5.76	Actual	New
Resistor	Voltage Divider	1	0.20	0.20	Estimated	New
C566D-RFF	Power indicator	1	0.13	0.13	Estimated	New
Lithium-ion Battery Pack	Main battery	1	16.00	16.00	Actual	New
Lithium-ion Cell Battery	Buzzer Battery	1	7.70	7.70	Actual	New
TPS610333	Boost Converter	2	1.04	2.08	Actual	New
DS1307	Time Chip	1	3.00	3.00	Actual	New
CRYSTAL 32.7680KHZ 12.5PF TH	Watch Crystal	1	0.56	0.56	Actual	New
LIS3MDL	Magnetometer	1	9.95	9.95	Actual	New

CanSat Budget – Other Costs

Component	Description	Total Cost [USD]	Source	Status
Ground Control Station				
RP-SMA	Coaxial Cable	3.47	Actual	New
SparkFun XBee Explorer Dongle	XBee Adaptor	27.95	Actual	New
XBP9B-XCST-001	XBee	58.08	Actual	Reused
Coper Wire	Antenna	0.15	Estimated	Reused
Antenna Chassis	3D Printed	2.80	Estimated	New
Computer	Provided by Members	-	-	-

Component	Description	Total Cost [USD]
Other Expenses		
Prototyping	3D Prints and Failed Electronics	50.00
Testing Facilities	Environmental Testing	100.00
GCS Total	GCS Total	92.45
Competition Fee	Registration	200.00
Transportation (Van + Gas)	Faculty Van	567.30
Accommodation	4 Days	600.00
Food	12 Meals	800.00

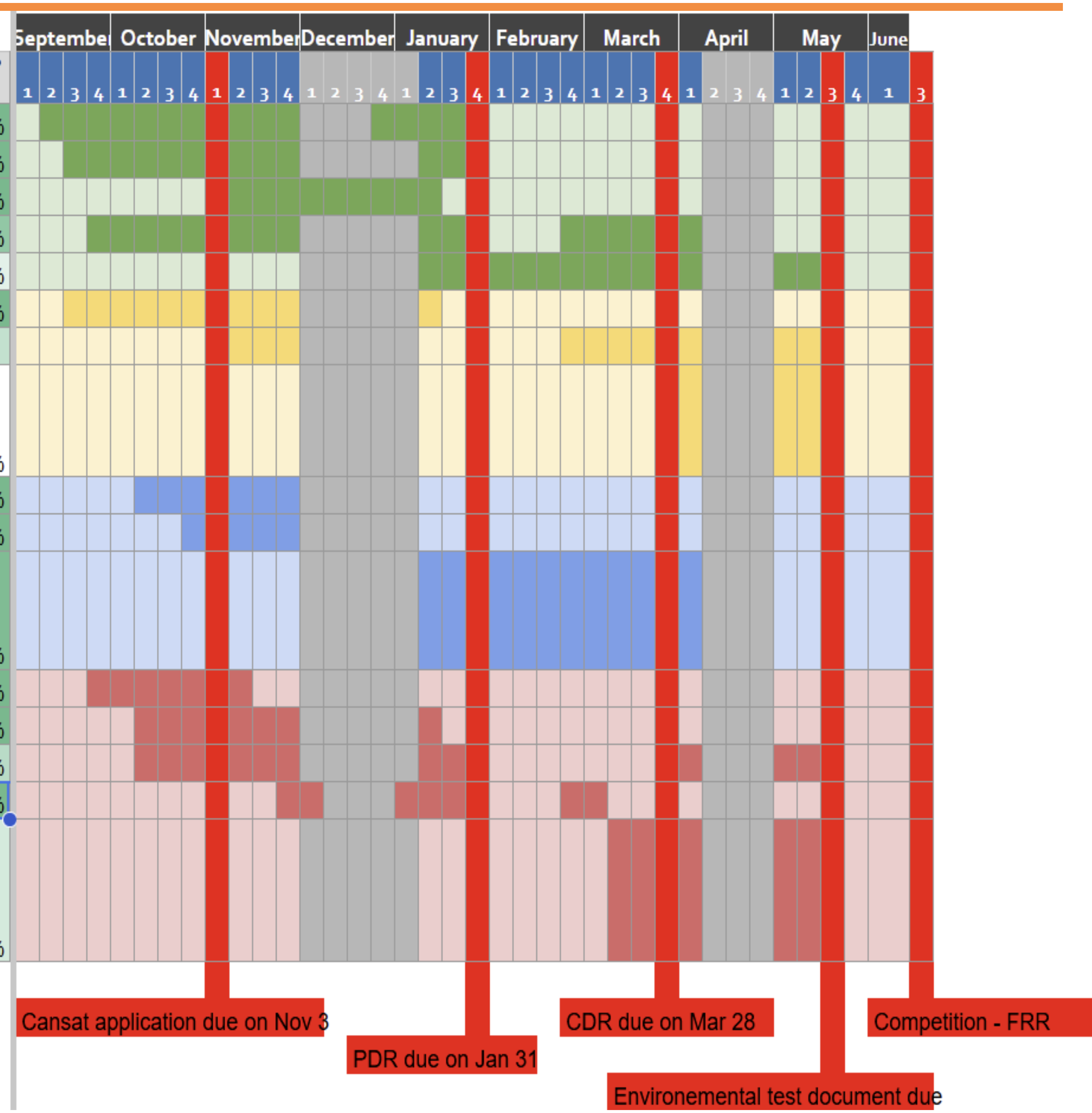
Source of Income [USD]	
University Levy	11,212.02
Department Funding	3,159.00
Sponsorships	2,778.92
Total	**17,149.94**

Budget Summary [USD]	
Credit	17,149.94
CanSat	-342.42
GCS	-92.45
Other	-2,409.75
Balance	**14,305.32**

Program Schedule Overview

CanSat Gantt Chart 2024-2025

	WBS #	TASK TITLE	Assigned people	COMPLETE
MECHANICAL	1	Conceptual Design and Research	AR - GI	100%
	2	Preliminary Design Phase	AR - GI	100%
	3	Design Parachute Deployment	AL	100%
	4	Prototype and Refinement	AR	80%
	5	Final Assembly and Testing	AR - NO	20%
ELECTRICAL	1	Research on Required Sensors	DA - NO	100%
	2	PCB Design	AD	43%
	3	Final Assembly and Validaiton	AD - DA	0%
SOFTWARE	1	Code Research and Exploration	AN	100%
	2	Refinement Phase	LK	100%
	3	Simulation	LK	95%
COMMUNICATIONS	1	Preliminary Design Phase	RO - LK	100%
	2	Validation Phase	LK	100%
	3	Simulation Mode	LK	50%
	4	Antenna Design	RO - AL	100%
	5	Final Design and Integration	LK	30%

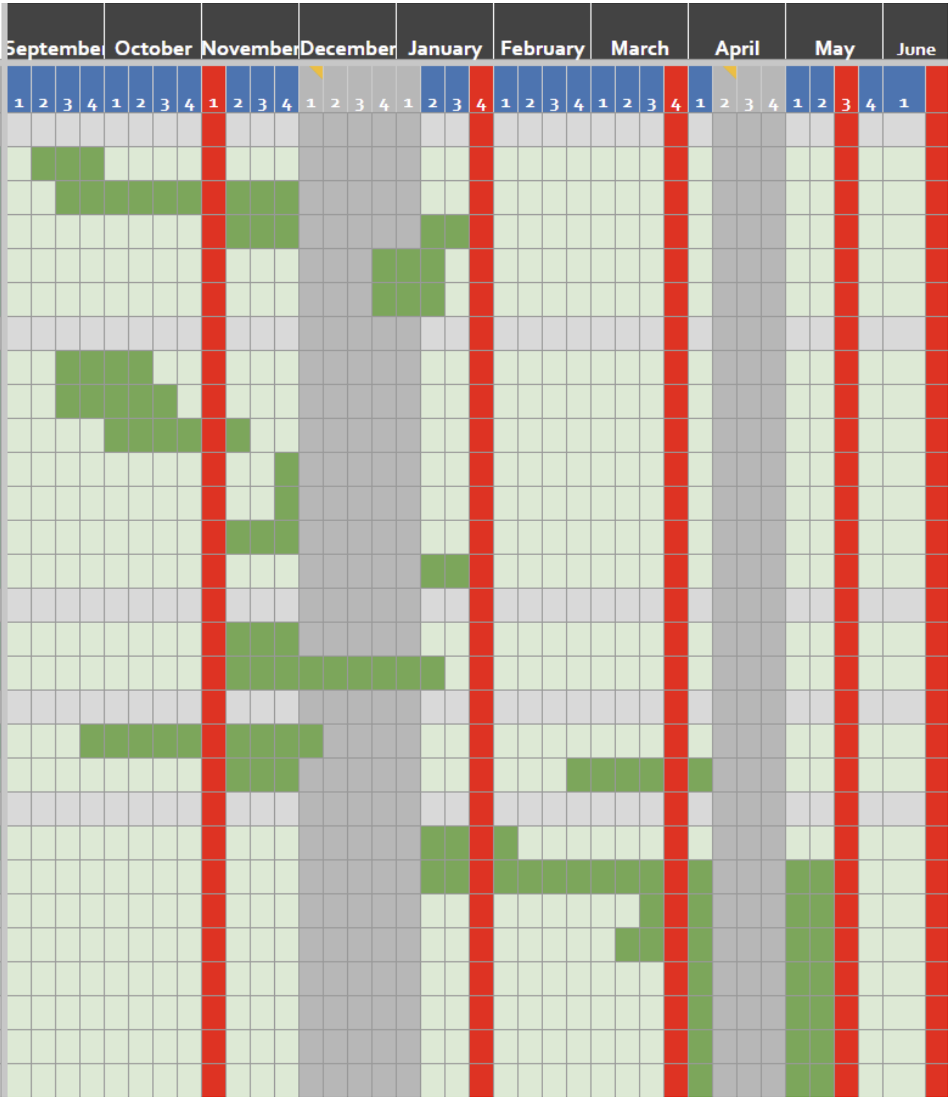


Detailed Program Schedule (1/3)

CanSat Gantt Chart 2024-2025

MECHANICAL

WBS #	TASK TITLE	Assigned people	COMPLETE
1	Conceptual Design and Research		
1.1	Research on requirements and benchmarks	AD	100%
1.2	Preliminary design	AR - GI	100%
1.3	CAD prototype	AR	100%
1.4	CFD analysis	AR - AL	100%
1.5	Marterial research	NO	100%
2	Preliminary Design Phase		
2.1	Design nose cone	GI	100%
2.2	Design autogyro landing system	AR	100%
2.3	Design autogyro landing deployment	AR	100%
2.4	Purchase parachute	AD	100%
2.5	Parachute simulations	AL	100%
2.6	Reasearch parachutes	AL	100%
2.7	Design parachute deployment	AR	100%
3	Design Parachute Deployment		
3.1	Print parts for initial prototype	AR	100%
3.2	Refine design and make iterate until	AR	100%
4	Prototype and Refinement		
4.1	Prototype nose cone	GI	100%
4.2	Intergate final prototypes with structure	AR	60%
5	Final Assembly and Testing		
5.1	Order parts	AD	90%
5.2	Print final parts	AR - NO	40%
5.3	Assemble final design	AR	10%
5.4	Design environemental tests	NR - AN	0%
5.5	Drop test	GI - NO	20%
5.6	Shake test	AL	0%
5.7	Field test and enviromental test	AD	0%
5.8	Improve design and make iterate until	AR	0%



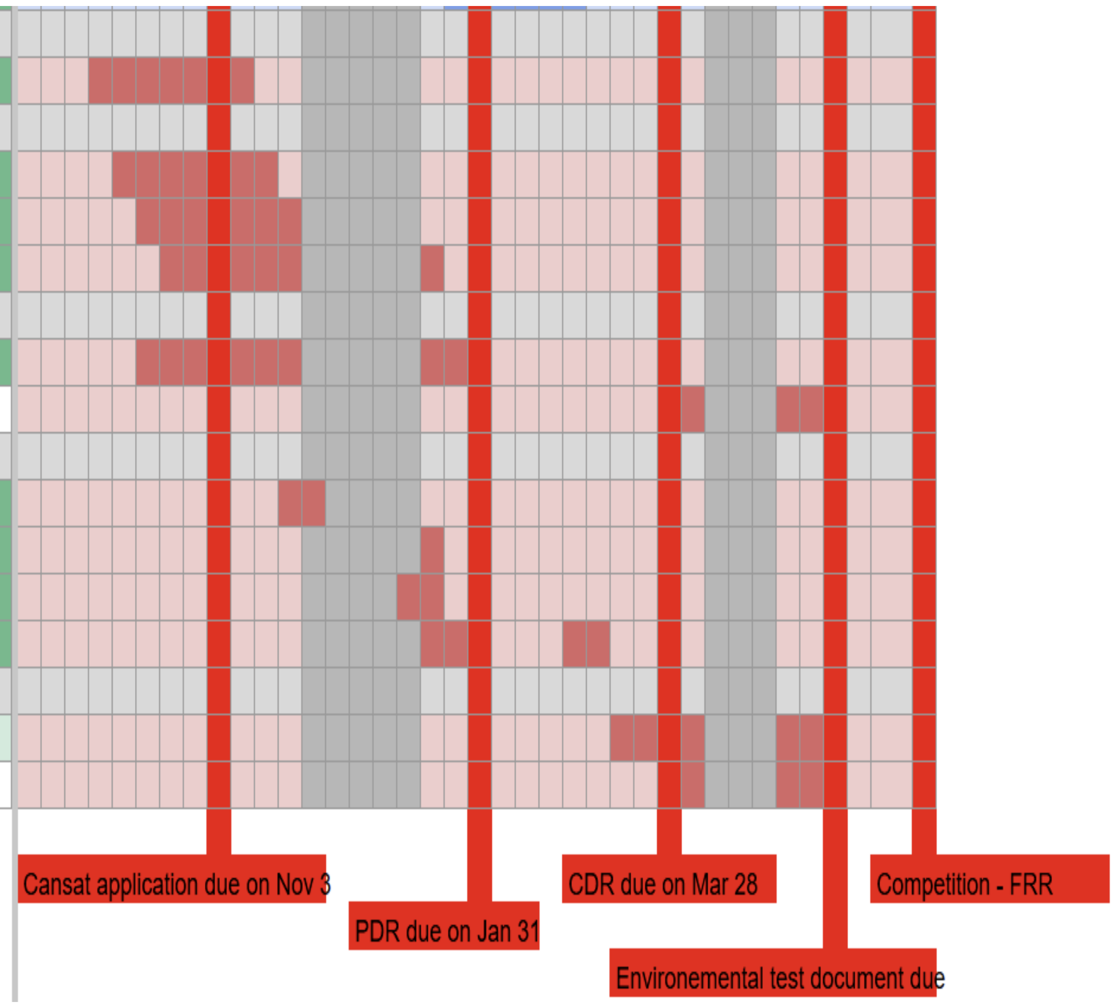
Detailed Program Schedule (2/3)

Area	No.	Task	Assigned	Progress
ELECTRICAL	1	Research on Required Sensors		
	1.1	Sensor investigation	DA - NO- AN	100%
	1.2	Order sensors	AD	100%
	1.3	Sensor testing	DA - NO- AN	100%
	1.4	Sensor integration and telemetry sending	LK	100%
	1.5	Battery investigation	AD	100%
	1.6	Order batteries	AD	100%
	2	PCB Design		
	2.1	KiCad workshop	ALL	100%
	2.2	Preliminary board design & integration with	AD - GI	30%
	2.3	Ordering boards	AD	0%
	3	Final Assembly and Validaiton		
	3.1	Assemble boards	DA - GI	0%
	3.2	Test funcitonality of each part	DA - GI	0%
SOFTWARE	1	Code Research and Exploration		
	1.1	Ensure funcitonality of individual sensors	NO - RO	100%
	1.2	Send data from sensors into telemetry	LK	100%
	1.3	Ground station GUI	LK - AN	100%
	2	Refinement Phase		
	2.1	Sending telemetry and recieving commands	LK	100%
	3	Simulation		
	3.1	Create in-flight logic code	LK	90%
	3.2	Setup SIMP commands with sensors	LK	100%

Detailed Program Schedule (3/3)

COMMUNICATIONS

1	Preliminary Design Phase		
1.1	Investigate XBee and confirm fucntion	LK	100%
2	Validation Phase		
2.1	Ensure Telemetry can be sent with XBee	LK	100%
2.2	Confirm range of XBee	AD - LK	100%
2.3	Confirm loacation within the structure	LK	100%
3	Simulation mode		
3.1	Work on simulation mode	LK	100%
3.2	Test simulation mode	LK	0%
4	Antenna Design		
4.1	Antenna research and design	RO	100%
4.2	Antenna building	AL - GI	100%
4.3	Antenna simulations	RO	100%
4.4	Antenna testing	RO	100%
5	Final Design and Integration		
5.1	Integrate with PCB	LK	30%
5.2	Ensure it can withstand testing	LK	0%



Shipping and Transportation

We plan to drive across the US-Canada border using the University of Toronto's Skule™ van (on June 5th), which helps establish our affiliation as a student team traveling to the CanSat competition. We will carry an official letter from both the University of Toronto and CanSat organizers to present if we encounter customs inquiries. Traveling by van avoids many of the airline carry-on and checked baggage restrictions, allowing us to bring crucial tools and equipment directly. If certain items appear problematic for customs, we will purchase replacements in the United States. Overall, this approach simplifies transportation logistics, reduces the risk of lost hardware, and ensures compliance with international regulations.

Conclusions

Accomplishments
• Ground Station GUI fully completed, providing real-time plotting, command capabilities, and reliable CSV logging. • Performed extensive subsystem tests, including high-altitude trials for telemetry and deployment checks. • 3D-printed rotor blades and a mockup container to validate mechanical fit prior to final, high-quality prints. • Spin stabilization mechanism for the ground camera finalized and demonstrated in this review.
Unfinished Work
• PCB production and subsequent functional testing. • Final 3D printing of the container in LW-ASA for optimized strength-to-weight performance. • Mass production of light weight strong airfoils with carbon fiber layups • Full system integration of all mechanical and electrical components into the flight-ready CanSat.
Testing to Complete
• Environmental testing (shock, vibration, thermal, vacuum) with final hardware. • Integrated descent trials with the final container and rotor assembly to confirm target descent rates. • Full mission rehearsal, ensuring flight software, power systems, and mechanical structures work seamlessly together.
Flight Software Status
• Environmental testing (shock, vibration, thermal, vacuum) with final hardware. • Integrated descent trials with the final container and rotor assembly to confirm target descent rates. • Full mission rehearsal, ensuring flight software, power systems, and mechanical structures work seamlessly together.
Readiness for the Design Stage
• We have clear testing goals to help us achieve mission objectives. • Good team morale and preparation enhances our excitement for the design stage.