CanSat 2025
Preliminary Design Review (PDR)
Outline
Version 1.0

Team #3114

Robotics for Space eXploration

Presentation Outline

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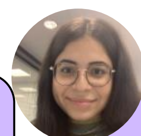

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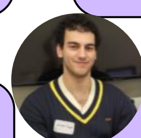

Robert Saab
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Acronyms (1/4)

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

Systems 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
Forged carbon fibre 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%).

System Requirement Summary (1/2)

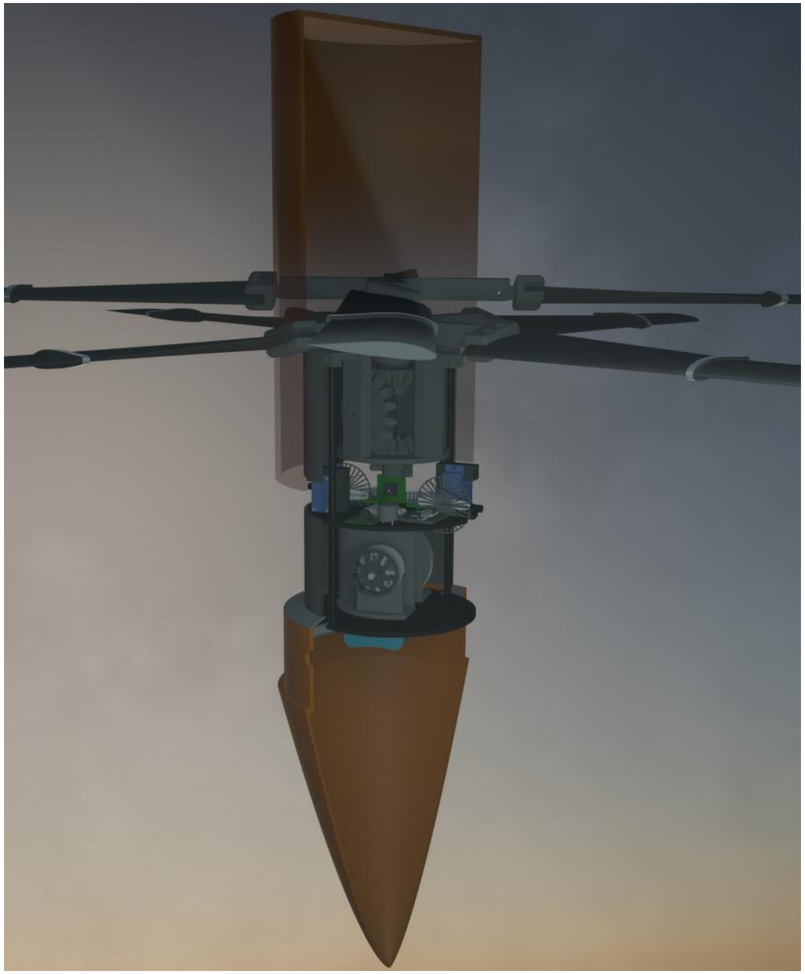
Priority	Requirement	Requirement #	Verification			
			A	I	T	D
1	At 75% peak altitude, the payload shall be released from the container and deploy an AGDS that descends at 5 m/s ±10%.	C5, C6, C7			X	
2	The nose cone shall be a single piece without any opening and a height greater than 76 mm.	S6, S7	X			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 Level CanSat Configuration Trade & Selection (Configuration A)

Rotors	**Two static angle counter-rotating rotors** to ensure the payload doesn't spin uncontrollably in one direction.
CPL Spin Stabilization	**Spin wheel** positioned in the center of the CPL to act as a balancing gyroscope, stabilizing the descent in case of gusts of wind.
Camera Stabilization	**Camera placed on a spinning motor** to provide redundancy, keeping the camera oriented towards the north, while the spin wheel handles more transient changes.
CPL Release Mechanism	**Pistons, controlled by servo motors retract** allowing the payload to **slide out** of the cylindrical container using its own weight.
Electronic Management	A **RP Zero** is chosen to control the on-board flight software, cameras, and run all the sensors all of which runs on a **single board** which also handles power management. It is chosen for its computational power and compact design. A **7.4 V Lithium Ion Battery** is used to power the everything. The battery is held within the volume of the nose cone's shoulder.
Nose Cone	**Not ejected** as it is used by the CPL to achieve the 5 m/s decent rate



- The design does not use any pyrotechnics or chemical actuators, or heat-based mechanisms

System Level CanSat Configuration Trade & Selection (Configuration B)

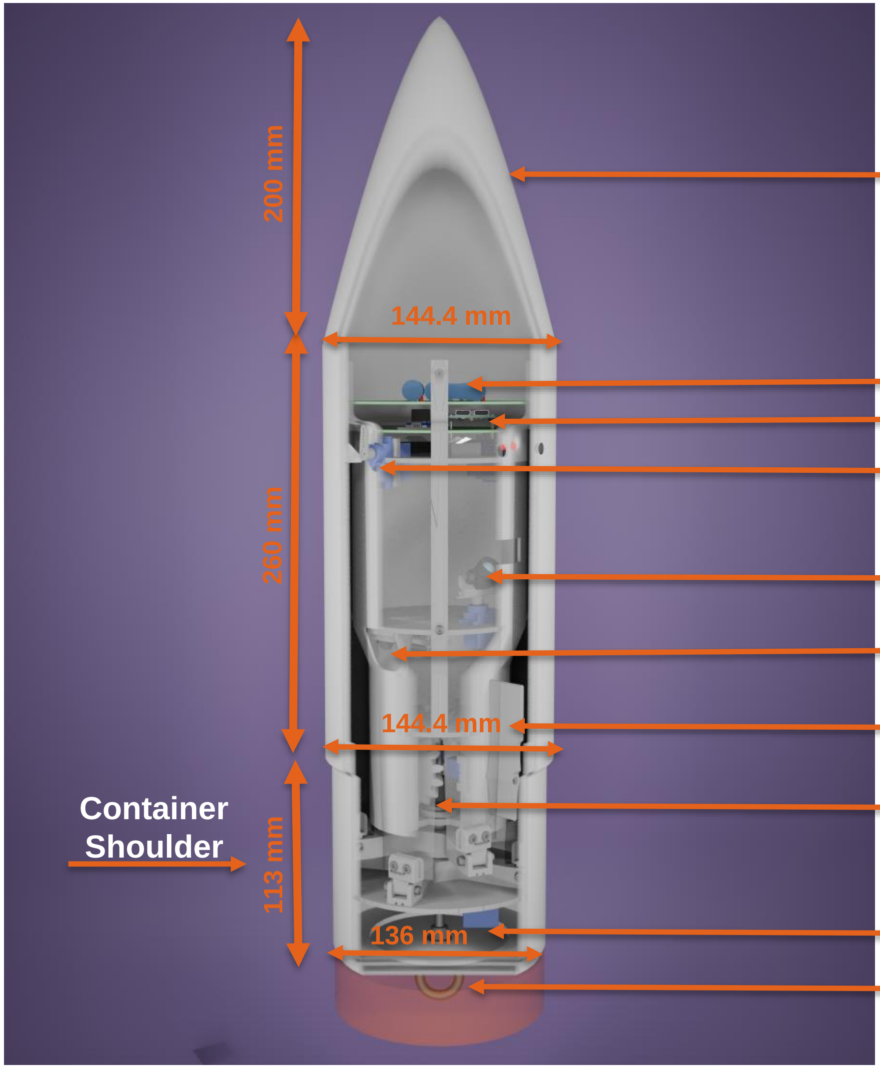
Rotors	**Two variable pitch counter-rotating rotors** to ensure the payload doesn't spin uncontrollably in one direction and allow for precise control of descent speed via a PID system using a single motor that adjusts the pitch of all rotors dynamically.
CPL Spin Stabilization	**Two PID controlled fins** on the side of the CPL to stabilize the roll during descent. Fins are used as variable pitch rotors are only able to change decent rate and not roll.
Camera Stabilization	**Separate 360° camera** placed at the bottom of the CPL, providing an all-encompassing view. This redundancy allows post-processing software to correct orientation, if needed, after landing.
CPL Release Mechanism	**Midway opening** CC allows CPL to easily separate from the CC.
Electronic Management	**ESP32** is chosen as even though it is less computationally capable, it is less power intensive. In addition, the electronics will be spread to **three different boards** (power management, sensors, cameras) allowing for a more **modular design**. The electronics are powered using **three 9V batteries.**
Nose cone	**Ejected** to reveal camera at the bottom of the CPL.

- The design does not use any pyrotechnics or chemical actuators, or heat-based mechanisms

System Level Configuration Selection

	Config A	Config B	Final Config	Rationale
Rotors	Two fixed pitch counter-rotating rotors	Two variable pitch counter-rotating rotors	Config A	Simpler and easier to manufacture; variable pitch rotors require intricate parts, more money and expertise to manufacture.
CPL Spin Stabilization	Spin wheel	Two PID controlled fins	Config B	Allows for more weight efficiency and better control over CP decent.
Camera Stabilization	Camera placed on a spinning motor	Separate 360° camera	ESP32 Camera + Config A	Switching from a RP camera to an ESP32 camera, Config A is much more effective than Config B.
CPL Release Mechanism	Piston retract – CPL slide out of CC	Midway opening CC	Config B	Reduces points of failure compared to Config A, where CPL may get stuck while sliding out of CC.
Electronic Management	RP Zero with one main board	Modular design with ESP32 and three board levels	Config B	ESP32 is more power-efficient. Modular design allows for more batteries and simplifies integration and weight distribution.
Nose Cone	Not ejected	Ejected	Config A	Aids in descent modulation with parachute.

Physical Layout
Launch Configuration



Nose Cone

Batteries

Sensors, XBee, and Main CPU

CanSat Release Mechanism

Camera No. 2

Camera No. 1

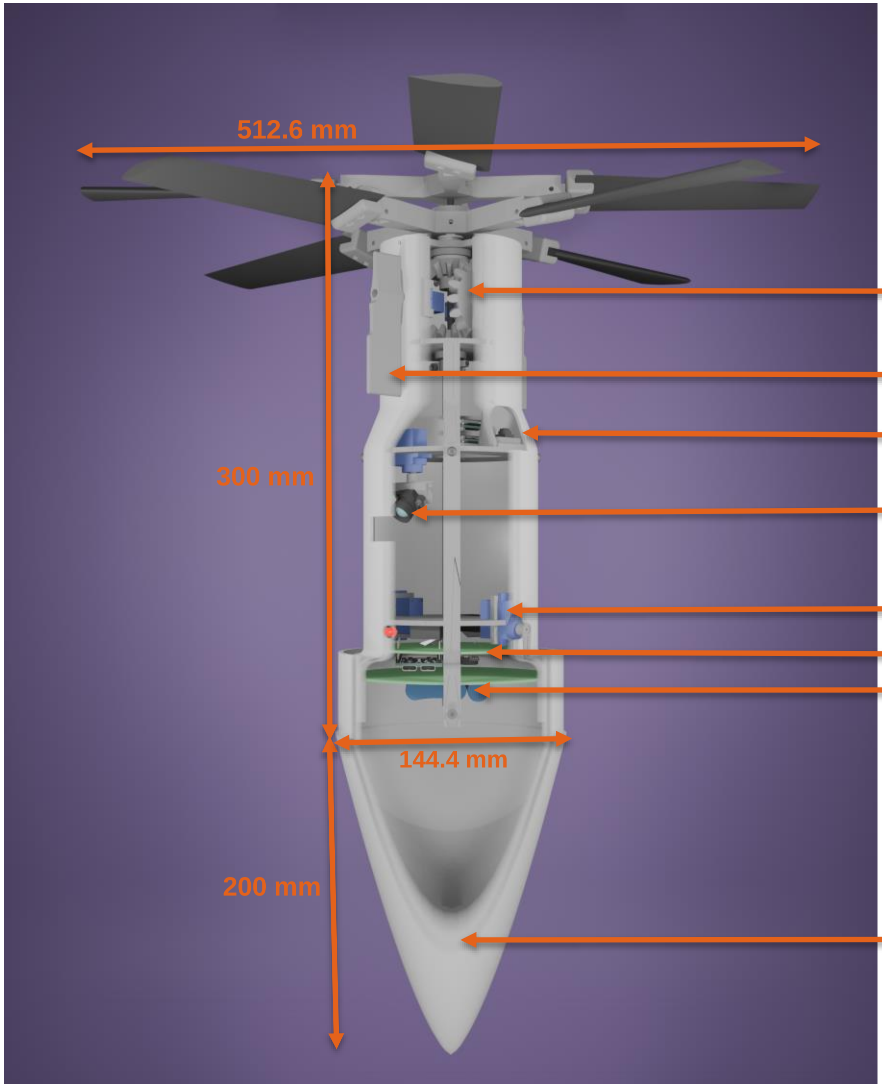
CPL Spin Stabilisation

Auto-Gyro Gearbox

Payload Release Mechanism

Parachute and Parachute Attachment Point

Physical Layout
Deployed Configuration



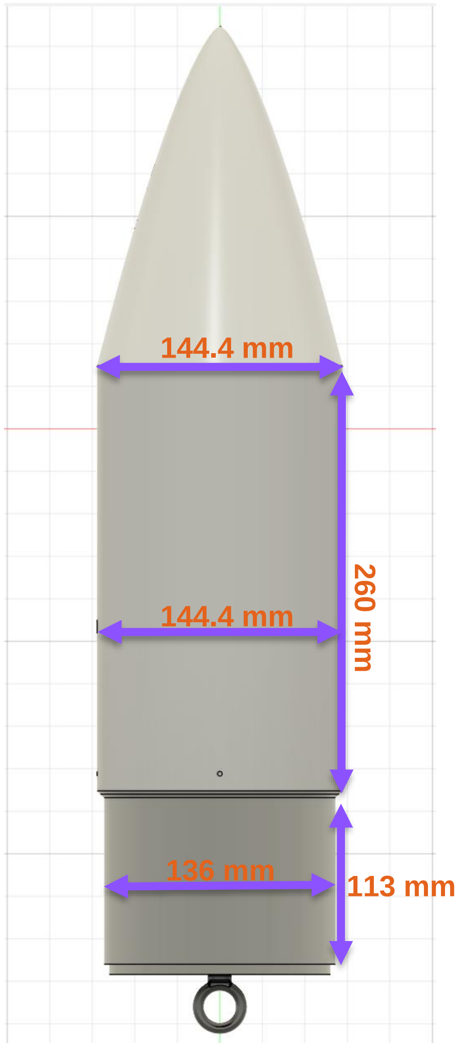
System Concept of Operations (1/2)

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)

Pre-launch	Launch	Post-launch
Set up the ground station, including the GUI and the hand-held communication antenna.	Rocket launch while still transmitting telemetry and recording video.	The recovery team scouts for the CanSat using the last known GPS coordinates and the buzzer sound.
Switch on the CanSat (CPL) and the buzzer.	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.	
Ensure XBee nters running as intended.		The telemetry data received by the GS and the on board CanSat footage are retrieved
Instruct CanSat crew to integrate the CanSat into the rocket.	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.	A thumb drive with the telemetry data is prepared and presented to the GS judges.
Calibrate and zero the onboard flight system values, including barometric altitude and roll-pitch-yaw IMU values.		
CanSat continuously collects and sends telemetry data at 1 Hz.	CPL lands and telemetry data streaming and video footage are stopped while the buzzer keeps beeping.	PFR (includes flight footage) preparation and presentation.
CanSat starts recording and storing video footage from both cameras.		

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

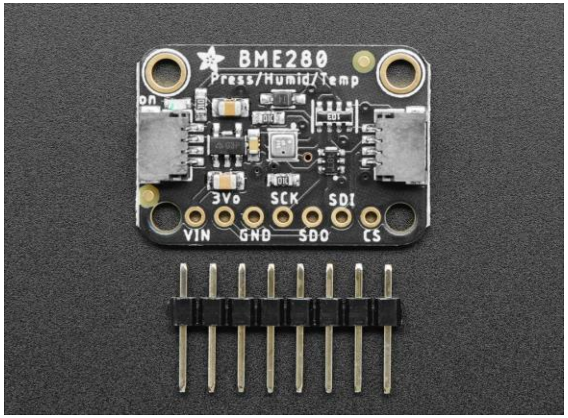
Type	Model	Functions	Interface
Air Pressure and Temperature Sensor	BME280	Measures temperature, air pressure, and calculated altitude (using air pressure)	I²C
Battery Voltage Sensor	Voltage Divider Circuit + ESP32 Built-In ADC Pin	Measures battery voltage level	Analog (ADC)
GPS	BN-220	Measures longitude, latitude, altitude, satellite count, and UTC time	UART
Hall Effect Sensor	A3144EU	Measures the auto-gyro rotors' rotation rate	Digital Signal
IMU and Magnetometer	BNO085	Measures the strength of the magnetic field (to determine rocket direction)	SPI
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

Payload Air Pressure Sensor Trade & Selection

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
DPS310	300 to 1200	0.002	±0.06	I²C, SPI	1.7 to 3.6	1.7	6.95	25.5 x 17.7 x 4.6	~2
BMP180	300 to 1100	0.01	±0.12	I²C	1.8 to 3.6	5	9.95	~19 x ~18 x ~4	~2

Reasons for Choosing: BME280

- Can be used to measure temperature and air pressure
- Best resolution
- Can calculate altitude using air pressure measurement
- Team is already highly familiar with this sensor



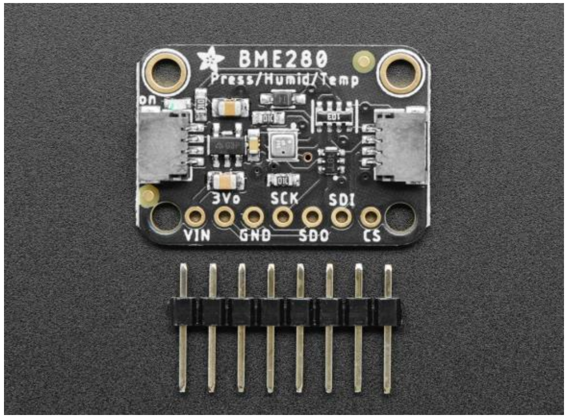
[1] Accuracy is based off relative pressure accuracy.
[2] Measured by team.

Payload Air Temperature Sensor Trade & Selection

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
DPS310	-40 to +85	0.01	±0.5	I²C, SPI	1.7 to 3.6	1.7	6.95	25.5 x 17.7 x 4.6	~2
BMP180	-40 to +85	0.1	±1.0	I²C	1.8 to 3.6	5	9.95	~19 x ~18 x ~4	~2

Reasons for Choosing: BME280

- Can be used to measure temperature and air pressure
- Best resolution and accuracy measurements
- Saves budget and footprint by using the same sensor
- Team is already highly familiar with this sensor



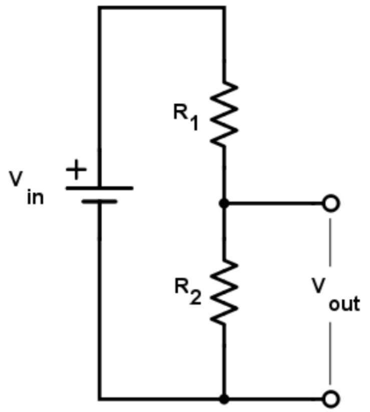
[1] Accuracy is based off absolute temperature accuracy.
[2] Measured by team.

Payload Battery Voltage Sensor Trade & Selection

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
INA219	~6.3[2]	I²C	0 to 26	700	9.95	25.6 x 20.4 x 4.7	~2
BQ25622E	~4.4[2]	I²C	0 to 18	1.5	2.61	2.5 x 3.0 x ~2	~1

Reasons for Choosing: Voltage Divider + ESP32 ADC

- Can be directly integrated into our power PCB
- Best resolution and lowest current consumption
- Simple and cheapest to integrate with a small footprint



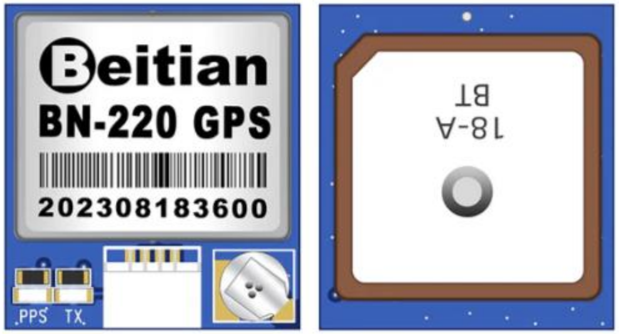
[1] Voltage divider circuit was tested using resistor values of R1 = 10.47 kΩ and R2 = 6.75 kΩ.
[2] Calculated using the ADC resolution formula with 12 bits.
[3] Pin directly connected to ESP32.

Payload GNSS Sensor Trade & Selection

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
NEO-M8N-0	-167	2.5	1 to 10	UART, USB, SPI, I²C	2.7 to 3.6	30	31.50	12.2 x 16.0 x 2.4	1.6
NEO-6M	-161	2.5	1 to 5	UART, USB, SPI, I²C	2.7 to 3.6	37	25.99	25.5 x 31.5 x ~6	~6

Reasons for Choosing: BN-220

- Best resolution, sensitivity, and cheapest sensor
- Performed very accurately during sensor testing
- Team is already highly familiar with this sensor



[1] Taken from tracking and navigation mode measurements.

Payload Auto-Gyro Rotation Rate Sensor Trade & Selection

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[3]	Digital Signal	4.5 to 24	6.12	0.06	19.84 x 4.65 x 1.6	~0.1
US5881LUA	15 to 30[1]	~2[3]	Digital Signal	3.5 to 24	2.5	0.65	17.5 x 4.1 x 1.5	~0.1
SS49E	±65 to ±100[2]	N/A	Analog	2.7 to 6.5	6	3.22	17.99 x 4.1 x1.6	~0.1

Reasons for Choosing: A3144EU

- Measurement range and resolution functions with our magnets and distance[4]
- Cheapest sensor among all of them
- Larger operating voltage does not require an external voltage divider
- Team is already highly familiar with this sensor

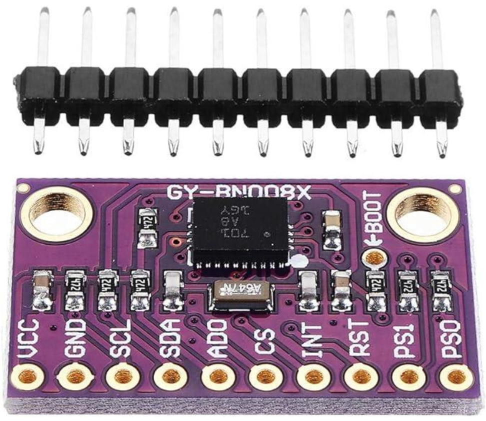
[1] Unipolar hall effect sensor.
[2] Bipolar hall effect sensor.
[3] Based off on the minimum hysteresis parameter.
[4] We determine RPM using the hall effect sensor and convert it to ˚/s.

Payload Tilt Sensor Trade & Selection

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
MPU-6050	~0.0076[2]	±250, ±500, ±1000, ±2000	I²C	2.375 to 3.46	3.9	12.95	26.0 x 17.8 x 4.6	1.8
MPU-9250	~0.0076[2]	±250, ±500, ±1000, ±2000	I²C, SPI	2.4 to 3.6	3.2	21.53	3.0 x 3.0 x 1.0	~1

Reasons for Choosing: BNO085

- Includes a built-in magnetometer
- Handles drift using built in sensor fusion and magnetic interfaces dynamically
- Easy to use breakout board and supports the SPI interface



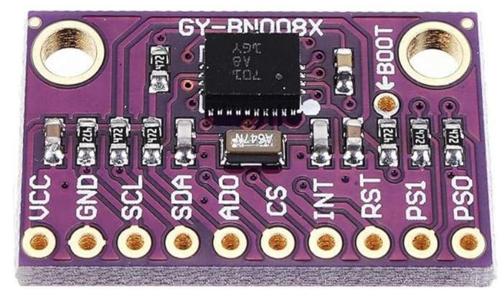
[1] Resolution is the gyroscope measurement for the CPL tilt
[2] Estimated using the ADC resolution formula with 16 bits

Payload Ground Camera Orientation Sensor Trade & Selection

Sensor	Range [Gauss]	Resolution[1] [Gauss]	Resolution[2] [˚]	Communication Interface	Operating Voltage [V]	Current Consumption [mA]	Cost [USD]	Dimension [mm]	Mass [g]
BNO085	±13[3]	0.0004[4]	~0.005	I²C, SPI, UART	2.4 to 3.6	14	24.95	25.2 x 15.7 x 1.7	2.1
BNO055	±13 (x, y), ±25 (z)	0.003	~0.005	I²C, UART	2.4 to 3.6	12.3	34.95	20.0 x 27.0 x 4.0	3.0
MPU-9250	±48	0.006	N/A[5]	I²C, SPI	2.4 to 3.6	3.2	21.53	3.0 x 3.0 x 1.0	~1

Reasons for Choosing: BNO085

- Using an existing sensor to reduce cost and footprint
- Handles drift using built sensor fusion and magnetic interfaces dynamically
- Cheapest breakout board and easy to use



[1] This resolution is the magnetometer readings of the magnetic field.
[2] This resolution determines the compass heading of the CPL orientation.
[3] Estimated based on the range of the BNO055.
[4] Estimated using the ADC resolution formula with 16 bits.
[5] No sensor fusion capabilities internally on the sensor.

Note: After testing, the BNO085's magnetometer did not perform as expected, therefore, further sensor trade and selection is required.

CanSat Payload Release Camera Trade & Selection

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
OV2640	30	1600 x 1200	~65	SCCB, DVP	1.71 to 3.3	30	12.99	35.7 x 23.9 x ~4	6
NoIR Camera V2	90	3280 x 2464	62.2	CSI	3.3	~250	29.95	25.0 x 23.0 x 9.0	3.4

Reasons for Choosing: OV5640AF

- The OV5640AF features built-in auto-focus, ensuring the camera maintains sharp focus as the release mechanism activates, adjusting from close to distant shots.
- Best FPS and field of view
- Lowest priced and lightest camera module

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

Ground Camera Trade & Selection

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
Insta360 GO 3 (x2)	50	2720 x 1536	134	Wi-Fi, Bluetooth, USB Type-C	N/A	N/A	299.99	25.6 x 54.4 x 23.2	35.5
NoIR Camera V2	90	3280 x 2464	62.2	CSI	3.3	~250	29.95	25.0 x 23.0 x 9.0	3.4

Reasons for Choosing: OV5640

- Nearly identical to the OV5640AF in functionality and setup
- Constant focus view is best for long range landscape shots
- Best FPS and lowest priced
- Sufficient field of view to be stabilized and oriented in the North direction with room for error

[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

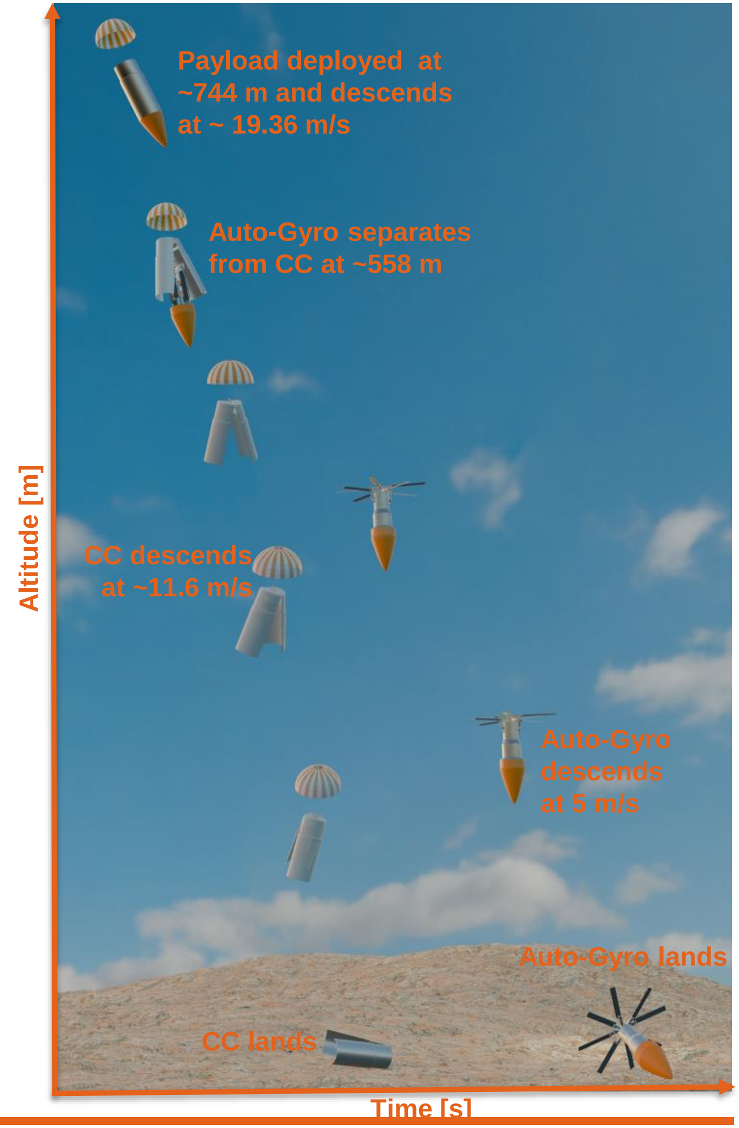
Alexey Albert, Arthur Goetzke-Coburn

Descent Control Overview

CPL and CC Descent Control System Overview

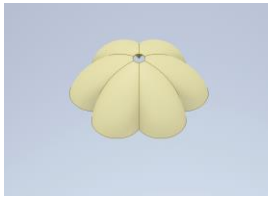
At apogee (~744 m), the CC, CPL, and AGDS decouple together with the CC parachute deployed, descending at 19.36 m/s. At 75% apogee (~558 m), the CPL and AGDS are coupled and descend at 5 m/s. The CC descends separately at ~11.6 m/s. The CC's parachute is 12" in diameter, with a spill hole of 24 mm, regulating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



Parachute Descent Control Strategy Selection and Trade

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
Hexagonal	Ripstop Nylon	36	200	1.49	5.94	43.20
Circular	Ripstop Nylon	14	50	1.29	16.40	8.02
Circular	Ripstop Nylon	9	35	1.14	29.08	4.43



Reasons for Choosing: 12” w/ 24mm Spill

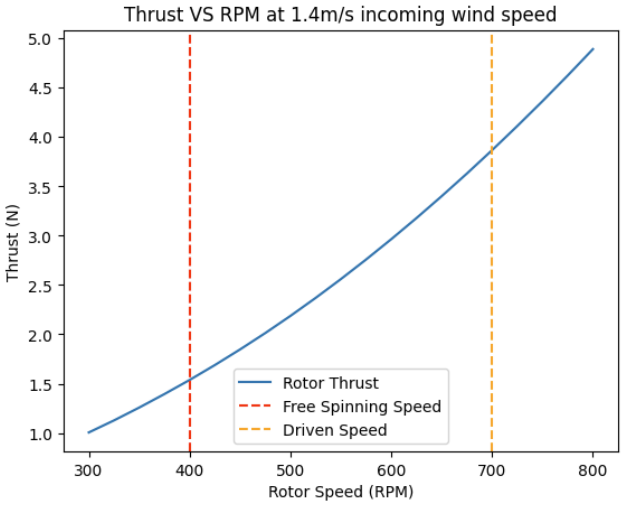
The 12” parachute with a 24 mm spill hole was the best choice since our estimations showed that together with the CPL it would reach a terminal velocity of 19.36 m/s, which was the closest that any of our estimations reached to the required 20 m/s. We also chose to opt for a spill hole as it provides more stability with little drawback. We also chose to use ripstop nylon as the material since it provided the best combination of durability, weight, availability, and cost compared to polyester, mylar, and polyethylene.

We chose to use 6 shroud lines 1.5 ft in length made of 3/8” tubular nylon for our shroud lines due to price and load capacity, and chose 1.5 ft as the length to compensate for the wake caused by CPL.

Auto-Gyro Descent Control Strategy Selection and Trade (1/2)

	Configuration A	Configuration B
Descent Control Mechanism	Single rotor	Dual counter-rotating rotors
Rotor Gearbox	1-1 gearbox linking both rotors	None

Selection Rationale
We chose to use dual, counter-rotating rotors for the auto-gyro, as it not only cancels out the torque from the rotors, which would otherwise cause the CPL to spin, but it significantly increased the lift of the system (~75% increase). We also chose to link both rotors with a 1-1 gearbox, as the airflow velocity at the second rotor is fairly low, limiting its ability to generate lift when spinning freely. By using a gearbox, we harness some power from the first rotor, and use it to spin the second rotor, more than doubling the second rotor's thrust from 1.5 N to 3.9 N, while only reducing the 1st rotor's thrust by ~1N.

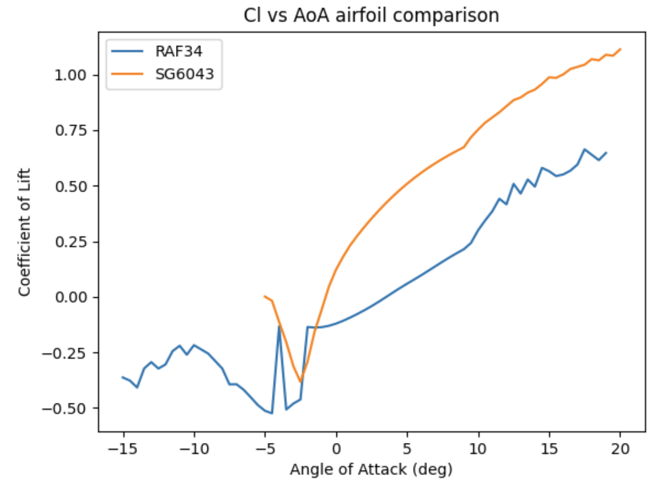


Auto-Gyro Descent Control Strategy Selection and Trade (2/2)

	Configuration A	Configuration B
Descent Control Mechanism	Passive fixed-pitch rotor blades	Active collective pitch control
Airfoil	SG6043 – low Reynolds number airfoil optimized for small-scale horizontal axis wind turbines	RAF34 – Commonly used airfoil on commercial auto-gyro aircraft
Rotor Blade Design	**Twisted rotor blade** – has a non-linear twist to match the changing relative airflow velocity and angle of attack along the rotor	**Straight flat rotor blade** – a flat airfoil with no twist or taper

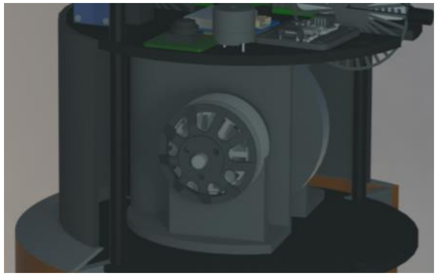
Selection Rationale

We chose passive, fixed-pitch blades for the AGDS, as it avoids the cost, mass and complexity of a collective pitch system. The SG6043 airfoil was chosen as it had a higher coefficient of lift at a low Reynolds number when compared to the RAF34 airfoil. It also performed significantly better in both BEM and CFD simulations. Given a fixed-pitch rotor design was chosen, the rotor blade design incorporates a twist that provided significant efficiency gains.



Auto-Gyro Descent Stability Control Strategy Selection and Trade

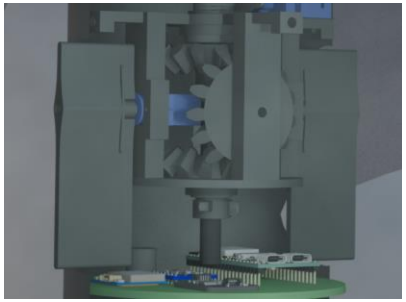
	Configuration A	Configuration B
Spin Stabilisation System	**Spin Wheel**. The rocket would lift off pointed in the northern direction and the spin wheel would provide enough angular momentum such that the rocket does not spin away from north.	**Two actively controlled fins** that rotate the CanSat towards the northern direction aerodynamically.
Type of Control	Passive	Active



← Spin Wheel

Selection Rationale
The spin stabilisation system for configuration B was chosen as it provides more control authority (no saturation or gimbal lock), takes up much less space, uses significantly less power, and weighs significantly less than the spin wheel, which must be heavy to have sufficient control authority.

Active fins →



Descent Rate Estimates (Parachute) (1/2)

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.

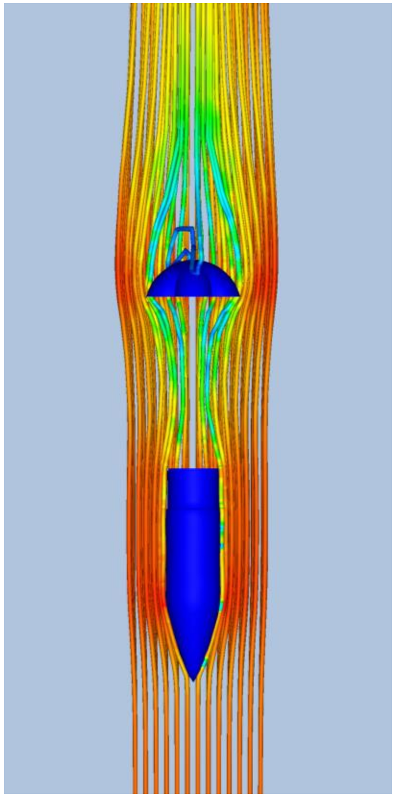
Descent Rate Estimates (Parachute) (2/2)

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 $F_D = 14.6642\ N, C_D = 1.289728323$

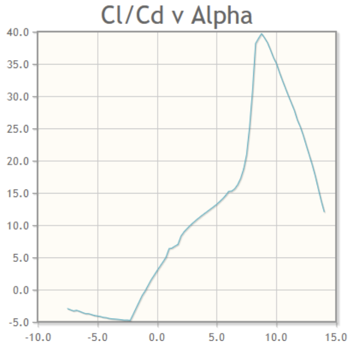
$$v = \sqrt{\frac{2}{\rho C_D A}}$$
$$= 19.3552746\ m\ /\ s$$



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.

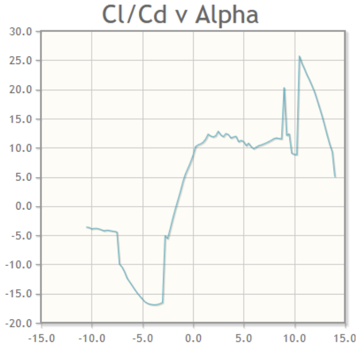
Descent Rate Estimates (Auto-Gyro) (1/9)

C_l/C_d vs AoA at R=20000:

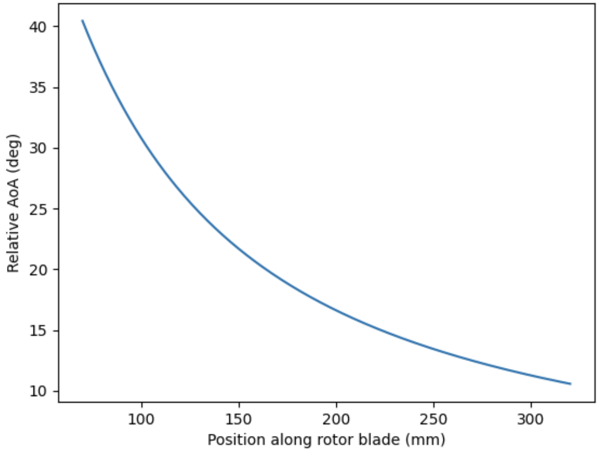


← SG6043 airfoil

RAF34 airfoil →



Relative AoA vs Blade Length at 5m/s airflow and 7 tip speed velocity ratio:



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 same blade geometry for both airfoils, we obtained the following results:

	Thrust (N)	C_T
SG6043	5.2N	0.94
RAF34	3.1N	0.64

Descent Rate Estimates (Auto-Gyro) (3/9)

Estimated Second Rotor Airflow Velocity:

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

$$r = r_0 + \alpha x$$

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

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

$$r = r_0 + \alpha x$$

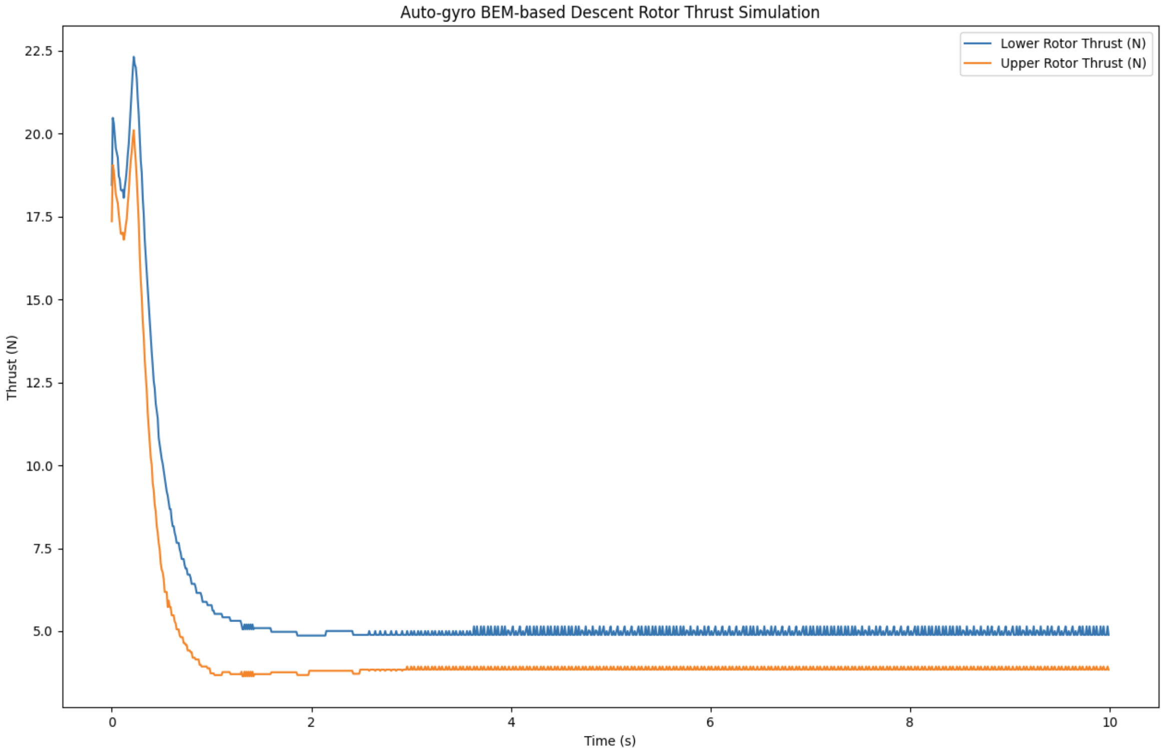
$$v_1 \approx 1.41m/s$$

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. These results were then confirmed in Fluent CFD, where the average lift was found to be slightly higher at 9.34N at 5m/s, allowing us a maximum payload mass of 952.1g.

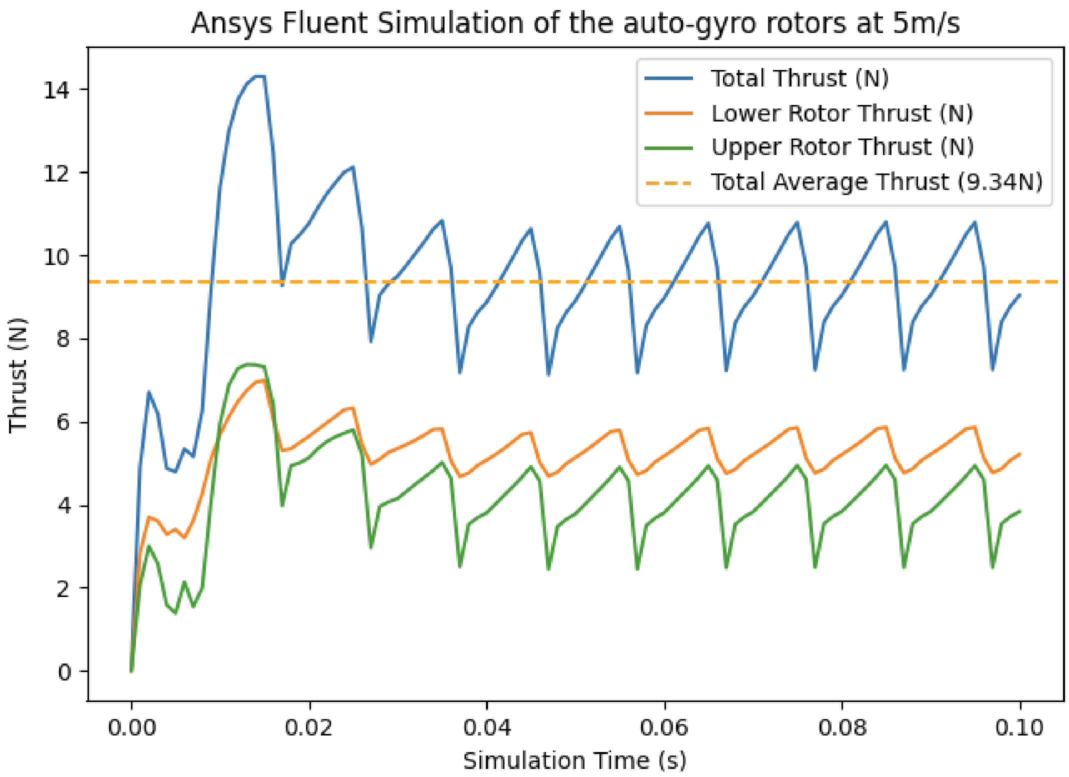
To estimate the descent rate under the auto-gyro, a custom ODE solver was written which assumes the following initial parameters:

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

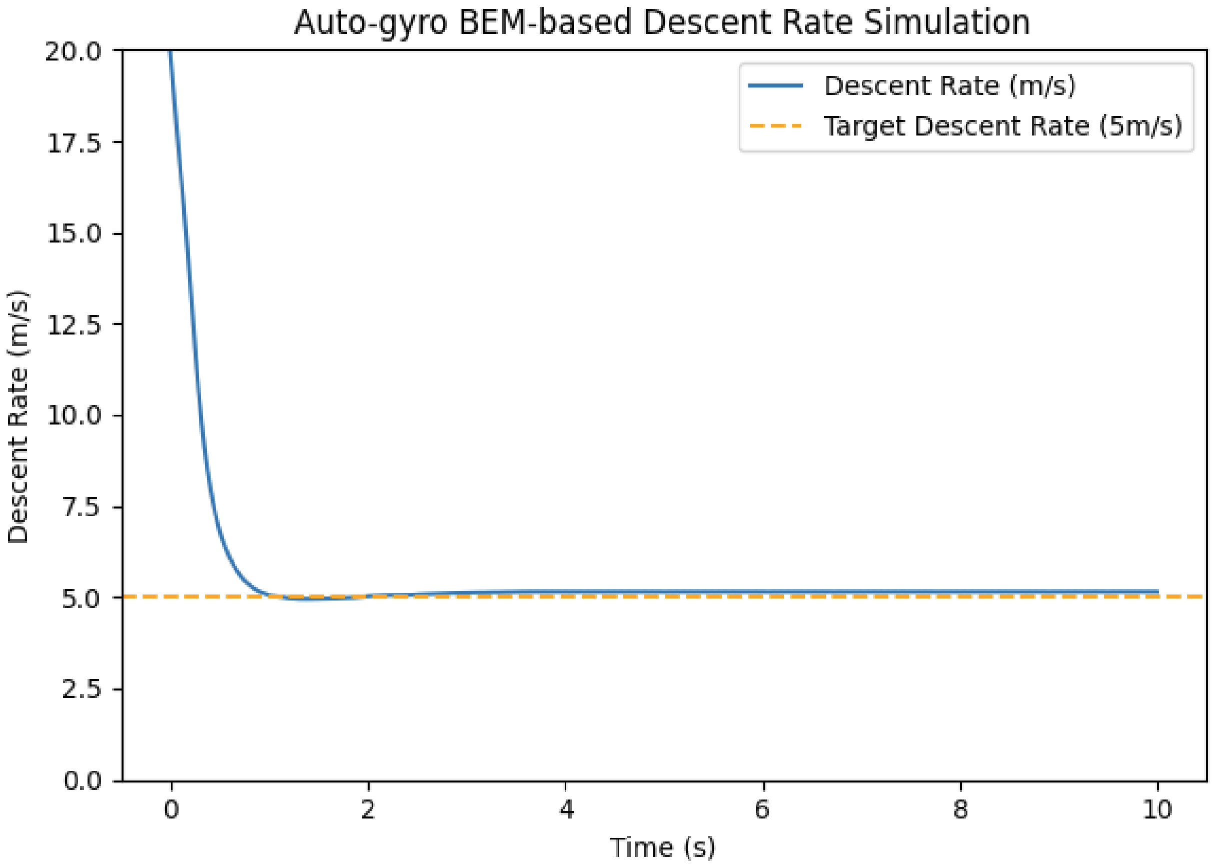
And uses a lookup table for thrust and rpm, which was generated by the BEM solver.



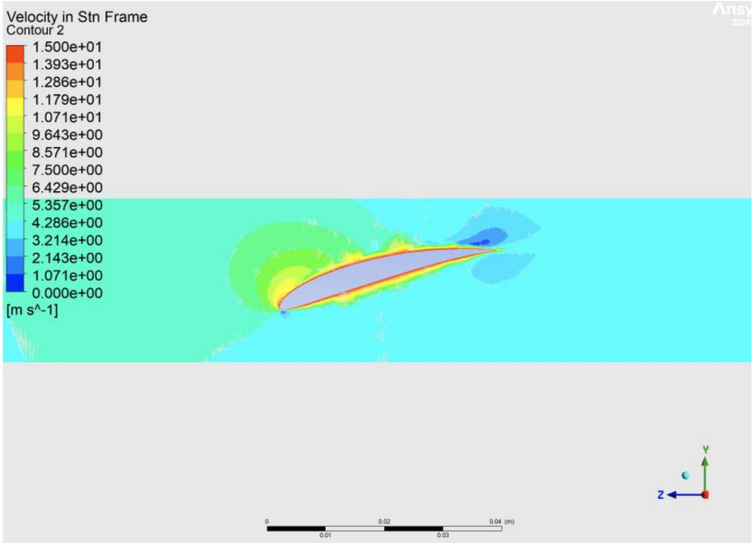
To verify the BEM solver results, a simulation using both rotors was done using Ansys Fluent, with a simplified rotor geometry.

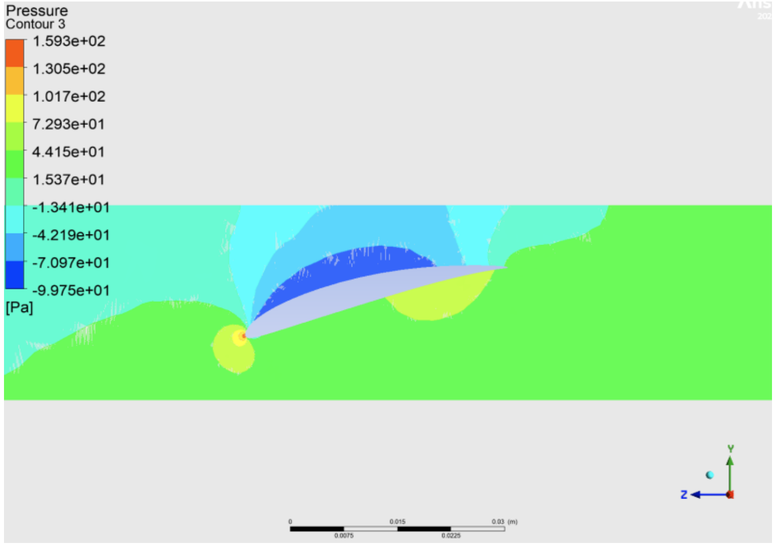


Simulating the entire descent profile with the BEM-based solutions, we obtain the following velocity plot.

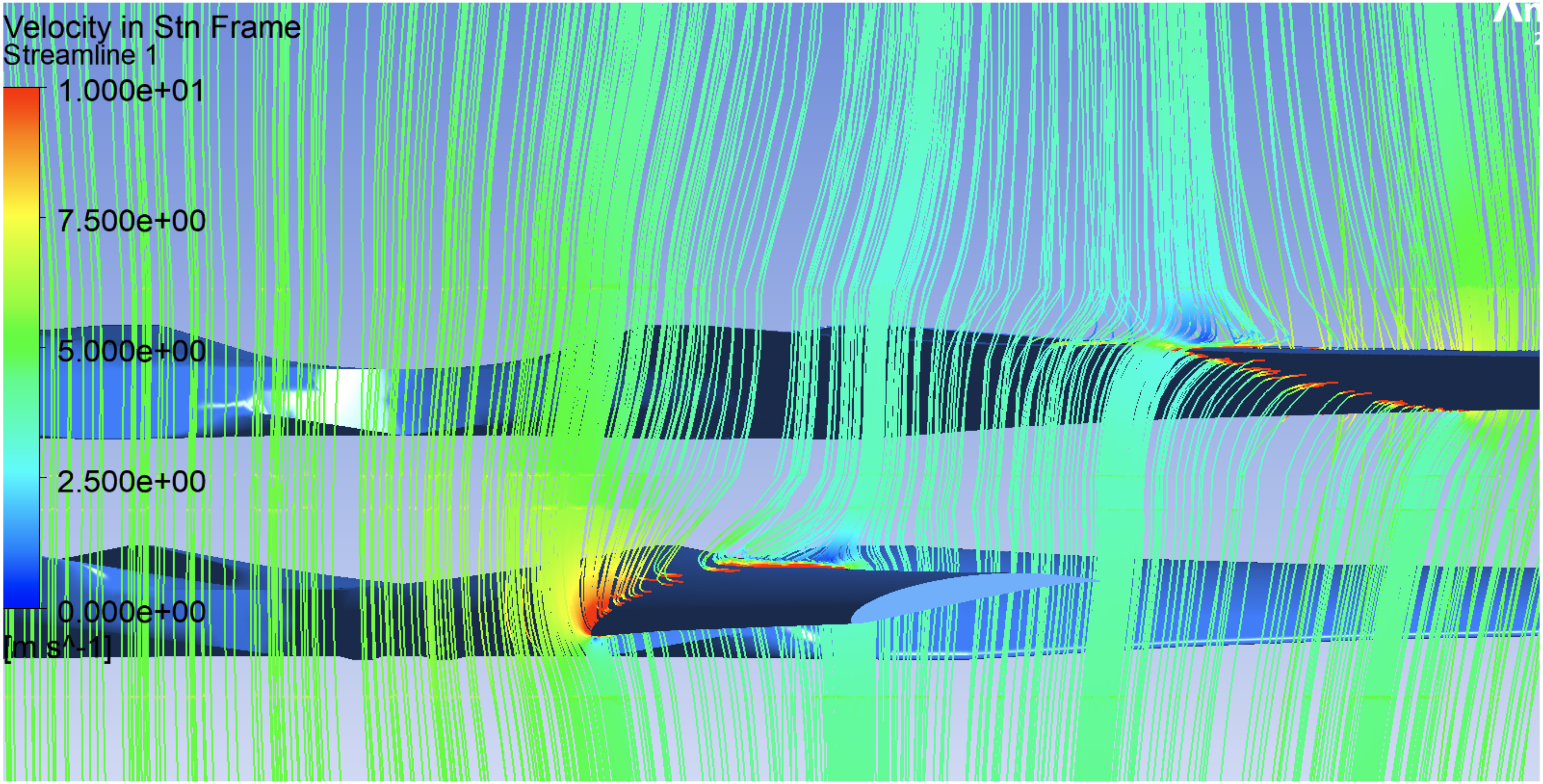


Ansys Fluent results using the final rotor design, showcasing the lift-generating high-speed, low-pressure zone above the airfoil cross-section.



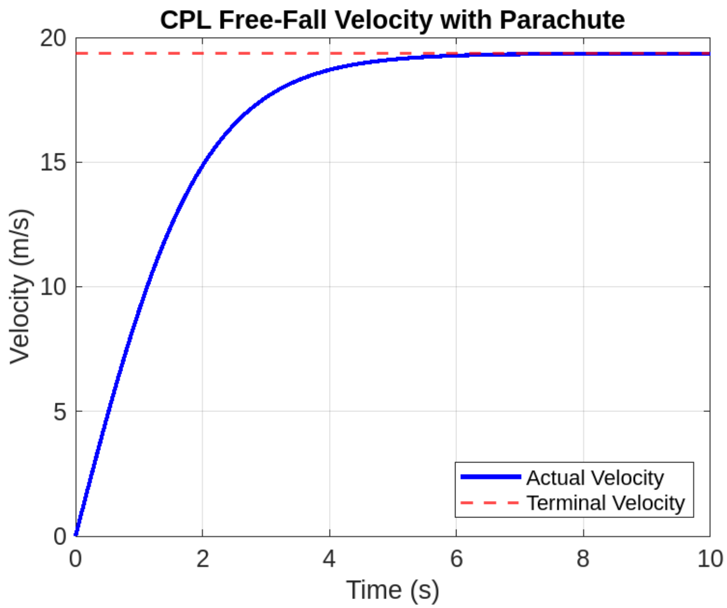


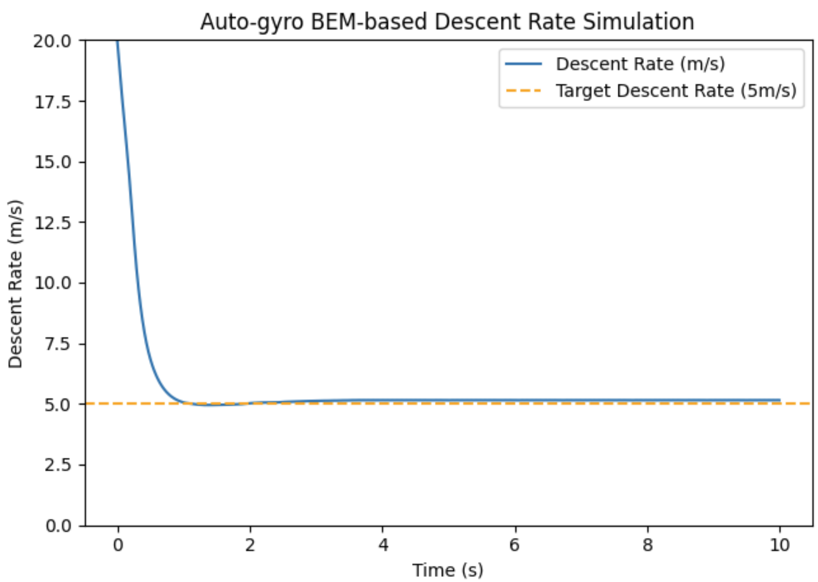
Ansys Fluent pathlines for the dual-rotor simulations, showcasing the flow through both rotors at the target



Descent Rate Estimates (Summary)

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

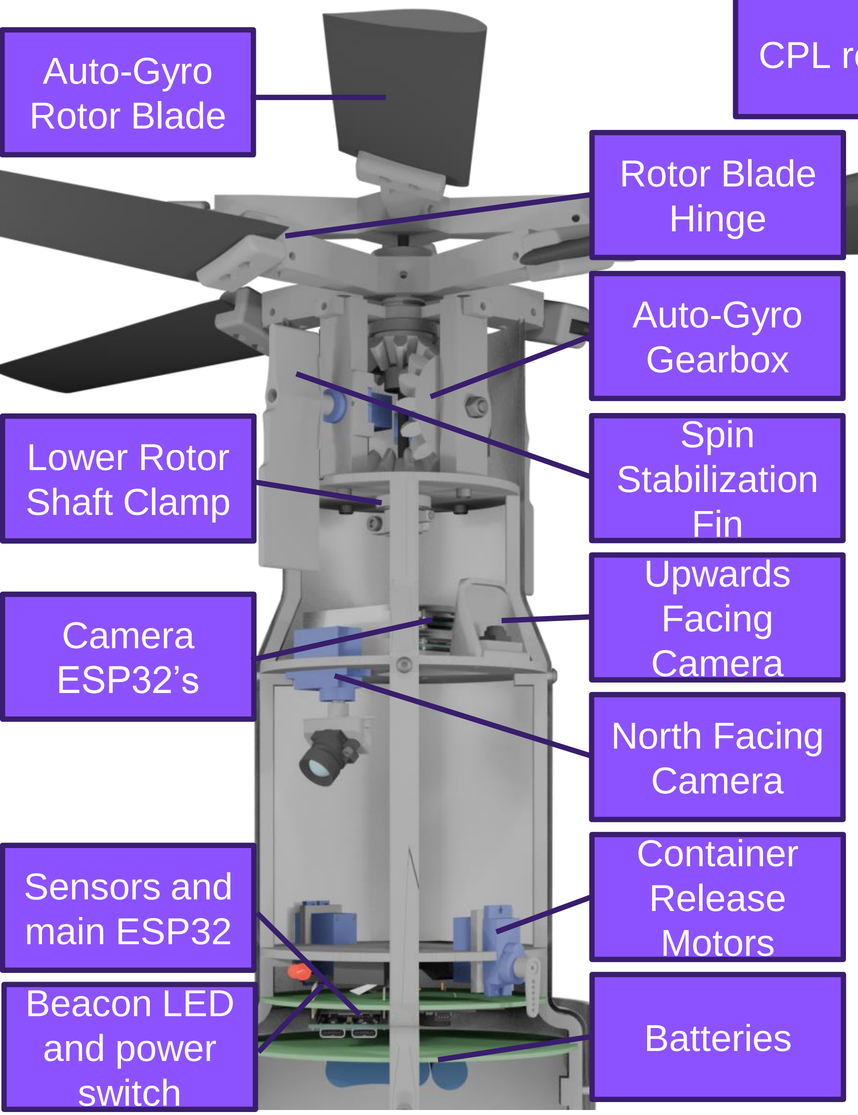


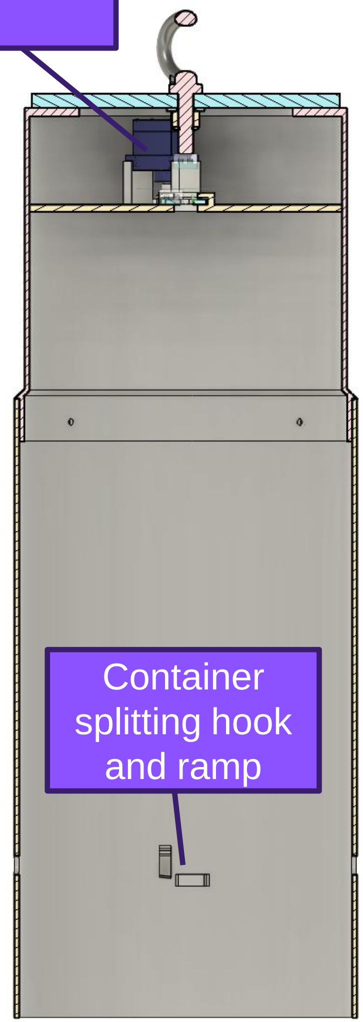


Mechanical Subsystem Design

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.

CanSat Mechanical Layout of Components Trade & Selection

General Structure Material	PLA	ABS	LW-ASA
Tensile Strength (XZ direction) (MPa)	57	34	24
Tensile Strength (Y direction) (MPa)	43	18	12
Density (g/cm^3)	1.27	1.07	0.43
Cost (USD/kg)	20.29	18.9	34.99
Heat Deflection Temperature (C)	55	90	96

Reasons for Choosing:

We chose LW-ASA as our structural material as it offers the best strength-to-weight ratio while having a sufficiently high heat deflection temperature to pass the environmental tests.

CanSat Mechanical Layout and Trade Selection

	Configuration A	Configuration B
Main Structure Material/Frame Design	LW-ASA	Carbon rods as a frame holding LW-ASA parts
Electronics Placement	Bottom of CPL	Middle of CPL due to spin wheel
North Facing Camera Placement	Bottom of CPL	Middle of CPL due to nose cone
Connections between parts	M3 bolts and heat-set inserts with threadlocker	M3 bolts and captive locknuts

Reasons for Choosing:

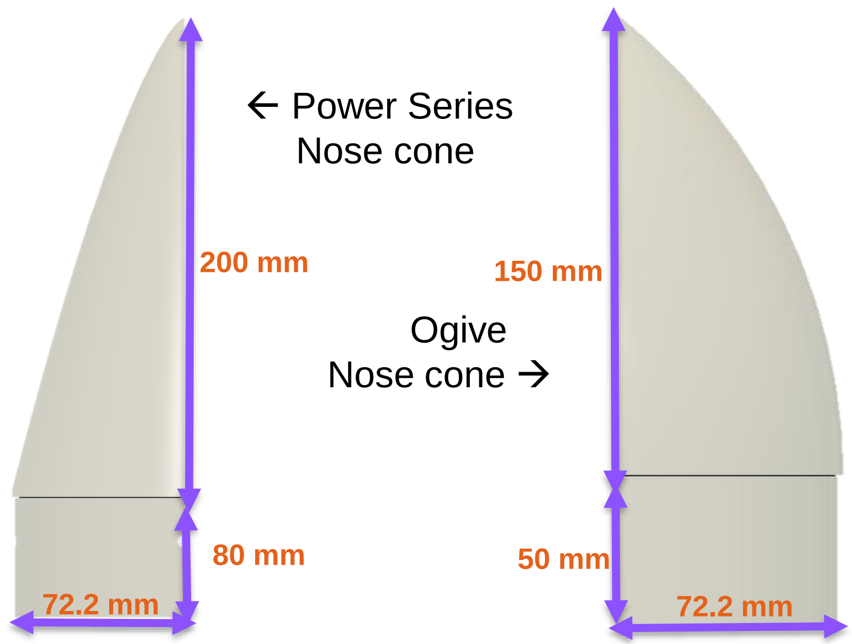
We chose the frame design of configuration A as it allows us to 3D print all the parts, reducing cost. We then also chose to place the electronics at the bottom of the CPL, as this lowers the center of mass. This wasn't possible in configuration B because of the spin wheel, which occupied the bottom of the CanSat. Finally, as we chose to not eject the nose cone, the north facing camera is placed in the middle of the CanSat. We chose to use heat-set inserts with threadlocker instead of captive locknuts, because of the tight tolerances required to use captive nuts. The threadlocker is necessary to help pass the 15 G vibration test.

Nose Cone Design Trade & Selection

	Configuration A	Configuration B
Nose Cone Aerodynamic Design	200 mm tall power series nose cone	150 mm tall ogive nose cone
Nose Cone Shoulder Design	80 mm shoulder	50 mm shoulder
Material	PLA	LW-ASA
Coefficient of Drag (@ 20 m/s)	0.4286	0.4269
Mass [g]	164	55

Reasons for Choosing:

The 150 mm tall ogive nose cone was chosen as it provides a lower drag coefficient of 0.4286 vs 0.4386 for configuration B's nose cone, enabling a 40 m higher apogee. The shorter length also allows the ogive nose cone to be 1.25% lighter than the power series nose cone. The shoulder was chosen to be as short as possible, as this enables the CanSat payload to have longer auto-gyro rotor blades. Finally, we chose to 3D print the nose cone out of LW-ASA as it allows us to make a nose cone weighing only 33% of equivalent.



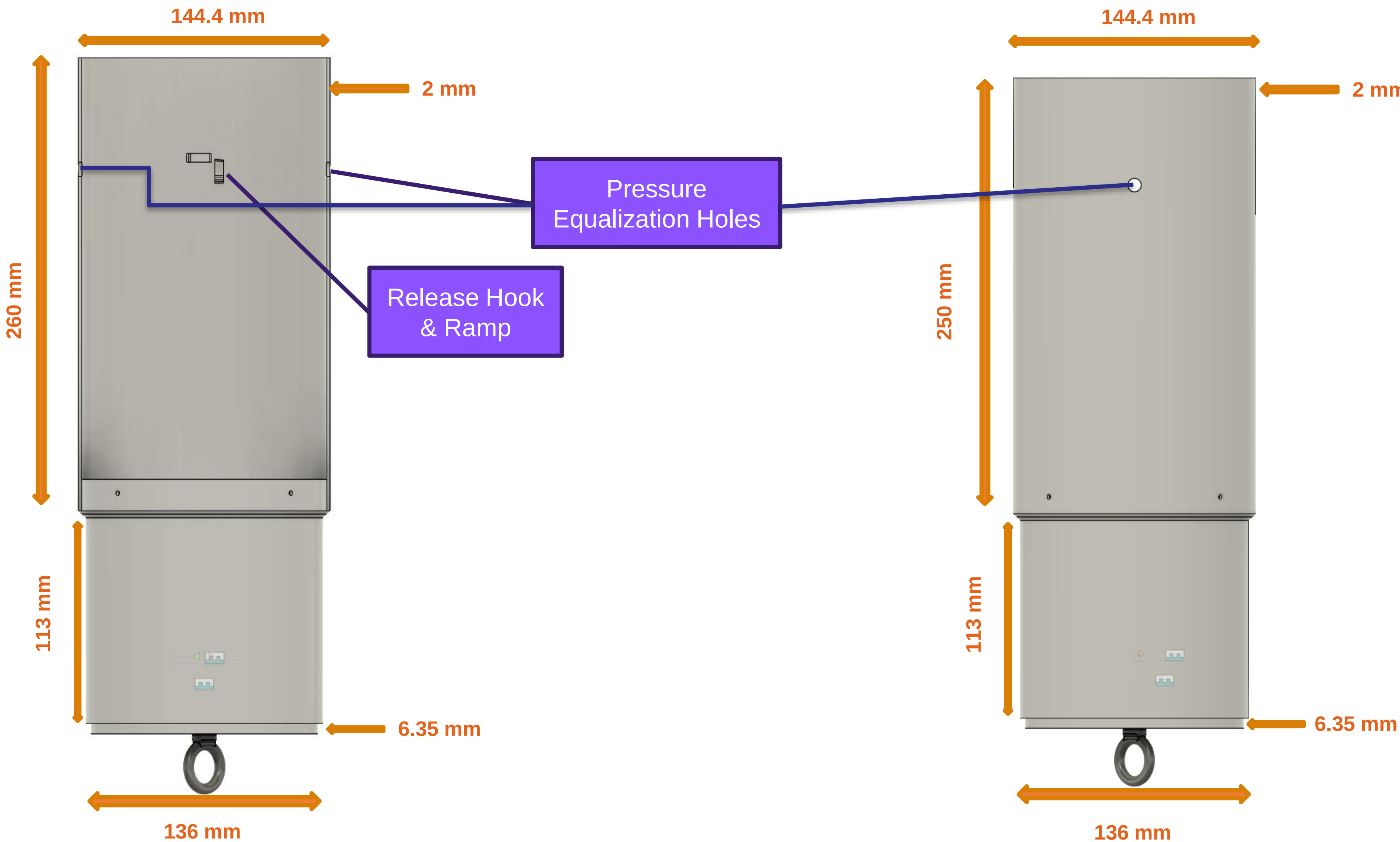
* Note: The graph of the nose cone is shown as a half-side view for comparison, as it is symmetric about the thrust axis.

Container Design and Configuration Trade & Selection 1/2

	Configuration A	Configuration B
Container Design	Passive single piece container from which the payload and nose cone slide out	Active servo-released split container design
Container Length	260 mm	250 mm
Container Design	Passive single piece container from which the payload and nose cone slide out	Active servo-released split container design

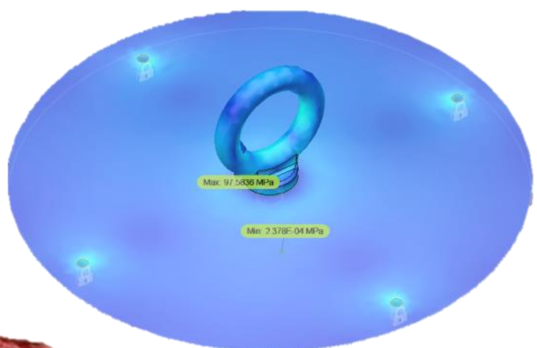
Reasons for Choosing:
For the container design, configuration B was chosen as using a single piece container from which the payload slides out could result in the payload becoming stuck, while in configuration B, the container will split into 2 parts, guaranteeing payload separation. The container's servo release also helps keep the payload in the stored configuration as it holds the container walls fixed, stopping the blades from deploying. We also chose a longer container (within allowed dimensions), as it allows us to use longer auto-gyro blades, increasing the lift generated by the auto-gyro.

Container Design and Configuration Trade & Selection 2/2



Parachute Attachment

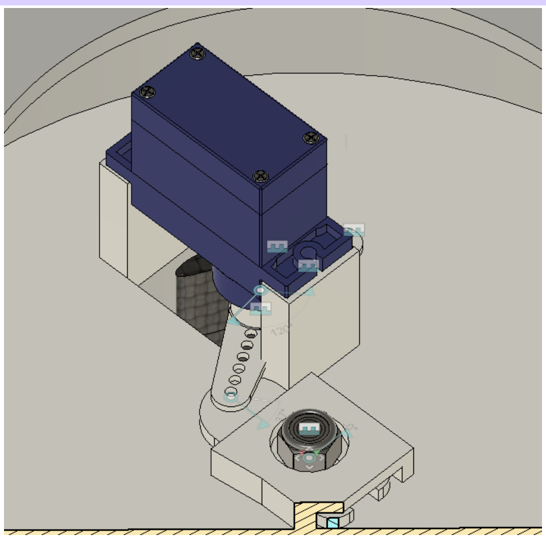
Component	Description
3/8" Tubular Nylon 20' with Loops Sewn	This nylon cord is rated to withstand 1020 pounds of force. The CanSat is required to withstand a 30 G shock, meaning it is expected to withstand a force 30 times it's weight. Based on the maximal mass of the CanSat, the cord will exert a maximal force of 93 lbs. The cord is certainly capable of withstanding this shock.
Eye-Bolt and 6 mm Plywood	Testing of the 6 mm plywood attachment point with the eye-bolt. The Autodesk Fusion test implies that the steel eye-bolt and 6 mm thick plywood are fully capable of withstanding the forces of deployment.



Payload Release Trade & Selection (1/3)

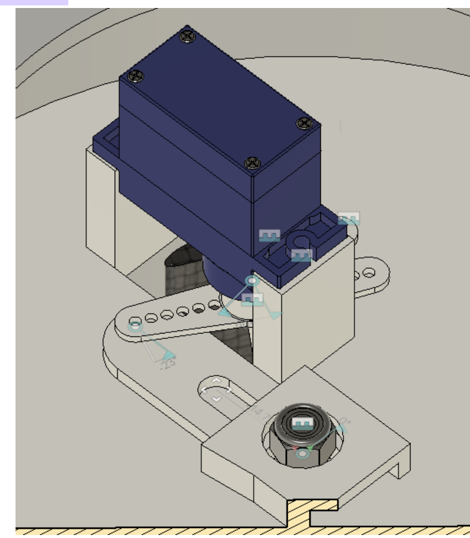
	Configuration A	Configuration B
Release Mechanism	Servo-actuated sliding latch using gravity to pull the payload away	Hot wire cutting a nylon rope held under tension by a spring

Reasons for Choosing:
We chose configuration A's servo-actuated sliding latch release mechanism as it is reusable, allowing us to test the exact flight configuration multiple times before flight, while a hot wire setup is destructive, and variance in how the mechanism is set up on launch day could affect the release. Additionally, not using a hot wire means we are compliant with requirement M2.



← Payload release latch stored position

Payload release latch deployment position →

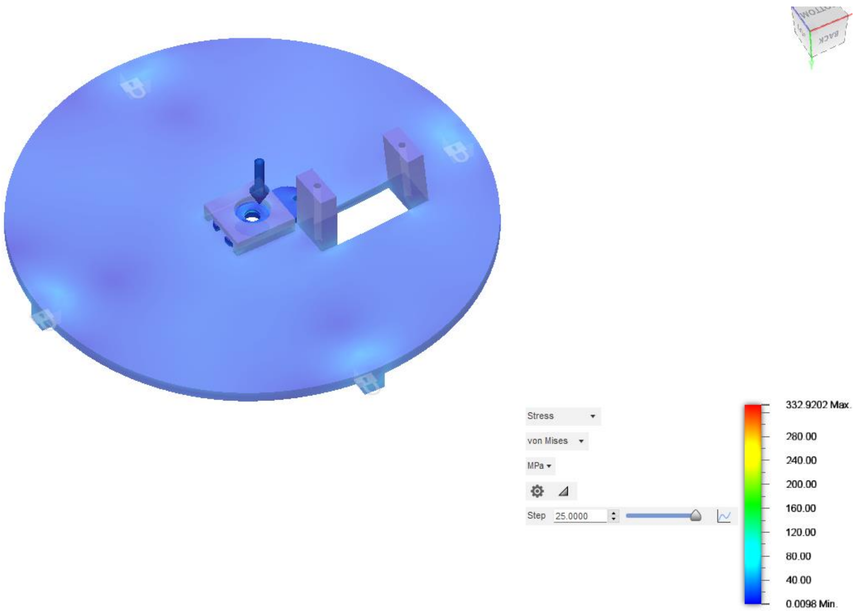


Payload Release Trade & Selection (2/3)

	Configuration A	Configuration B
Release Latch Material	¼ inch steel plate	ASA
Payload Attachment Structure	3D printed hook	M4 threaded rod & locknut

Reasons for Choosing:

We chose a ¼ inch steel plate for the release latch since it can hold the entire CanSat payload as the container parachute is deployed and can retain the payload under the 30 G shock environmental test. When simulated in Fusion 360, a latch made of ASA failed under the shock load, so the steel plate was chosen. We then use the top rotor's shaft to hang the CanSat from the payload. As the M4 shaft has a maximum tensile load of 7.02 kN, it can support the entire payload under the 30 G shock (maximum of ~300 N).

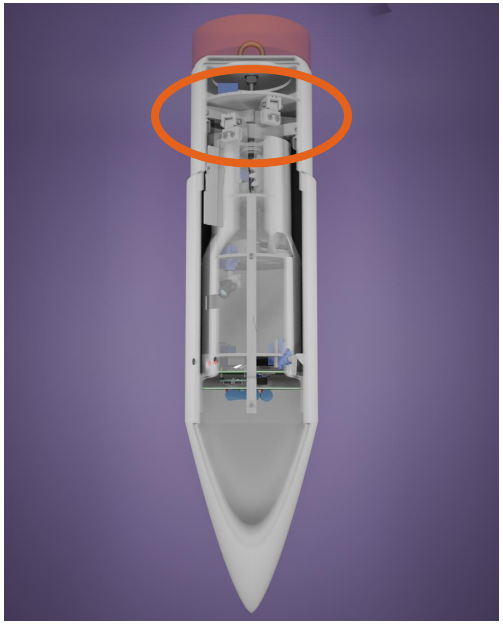


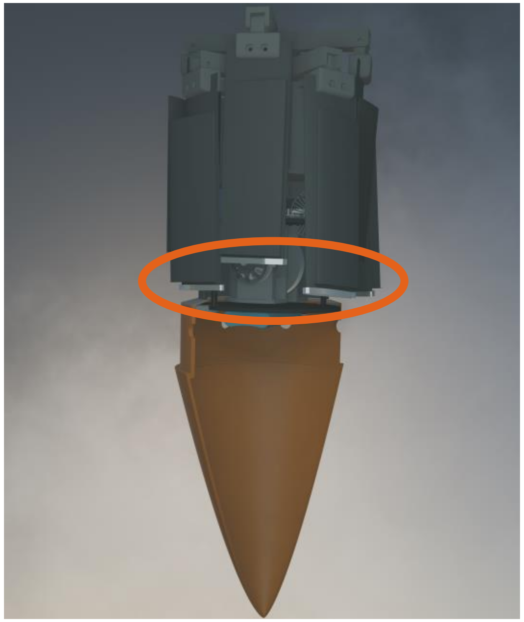
Auto-Gyro Stow Configuration Trade & Selection

	Configuration A	Configuration B
Stowing Mechanism	Hinges at the base of the rotor blades	Hinges at the base of the rotor blades, and a split rotor blade with additional hinges

Reasons for Choosing:

To stow the auto-gyro, we chose configuration A's single hinge at the rotor base, as it is much simpler, lighter, and less failure-prone during deployment when compared to the double hinge in configuration B. Additionally, while configuration B allows us to use longer blades, this is not necessary as sufficient lift is already produced with blades that fit in configuration A.





Auto-Gyro Deployment Configuration Trade & Selection

	Configuration A	Configuration B
Deployment Mechanism	Rubber bands pulling rotors around the hinge at the rotor blade base	Rubber bands pulling up rotors at the base hinge, and torsion springs unfolding the rotor blades
Nose cone ejection	Nosecone ejected from CPL	Nosecone not ejected - used by the CPL to achieve the 5 m/s decent rate

Reasons for Choosing:

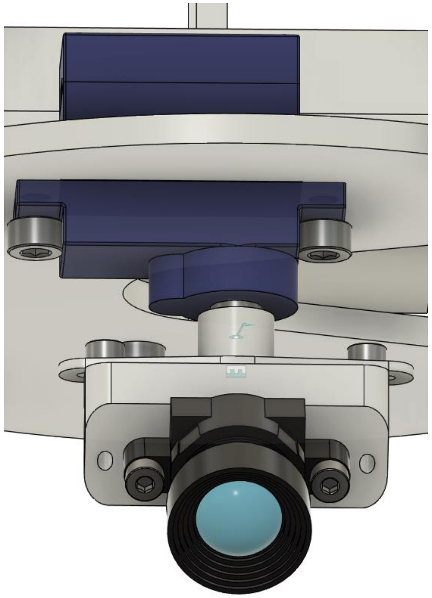
To deploy the auto-gyro, we chose to use configuration A's rubber-band driven single hinge at the rotor base, as it is simpler, lighter, and less failure-prone during deployment when compared to the double hinge in configuration B. We however chose to not eject the nosecone from the CPL, as this reduces complexity and helps achieve the target descent rate.

Ground Pointing and Orientation Trade & Selection

	Configuration A	Configuration B
Camera Mount	Solid mount to the CanSat structure	Servo horn adapter (45 deg from horizontal)
Pointing Mechanism	Active aerodynamic spin control of the entire CanSat payload	Servo-mounted camera

Reasons for Choosing:

We chose configuration B for the camera mount, as it allows us to use a servo for fine control of the camera direction. We then chose both configuration A and B for the pointing mechanism, where we will use the aerodynamic spin control for major direction adjustments, then use the servo for fine corrections to the camera direction. We chose both because 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.

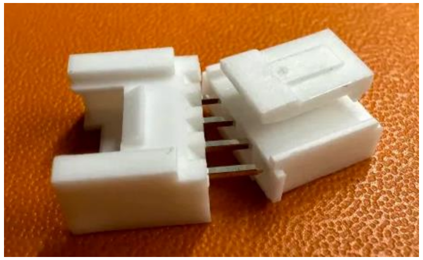


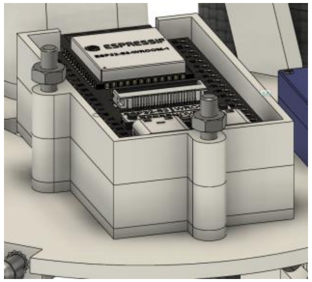
Electronics Structural Integrity

	Option 1	Option 2	Option 3
Electronics Mounting Method	M3 bolt hard-mount	Glue	Press-fit
Electronics Enclosure	None	LW-ASA 3D printed box	PLA 3D printed box
Electronical Connections	SMD components	THT components	Tamiya connector

Reasons for Choosing:

We chose to hard-mount all electronic components and PCB's to the CanSat payload structure using M3 bolts. This ensures a secure, vibration and shock-proof connection. All components are held with multiple mounting points across the board to minimize the structural load on the electrical components. If the components do not have mounting holes, they are enclosed in a LW-ASA 3D printed enclosure with mounting holes. Electrical connections are primarily composed of soldered connections on the main PCB, using either SMD or THT soldering. For connections between boards, batteries and motors, plastic latching connectors since they are vibration-proof, helping to pass the 15G vibration test.





Mass Budget (1/4)

Subsystem	Component	Quantity	Mass per Piece [g]	Total [g]	Source
CanSat Payload 3D-printed Only	Top Rotor Holder	1	25.46	25.46	Estimate
	CanSat Slice Holder	4	3.61	14.44	Estimate
	Northcam Slice	1	21.07	21.07	Estimate
	Nose Cone	1	51.7	51.7	Estimate
	Blade Assembly	8	1.2	9.6	Estimate
	Bottom Rotor Holder	1	28.78	28.78	Estimate
	Fins	2	3.01	6.02	Estimate
	Bottom Rotor Shaft Holder	1	13.17	13.17	Estimate
	Top Rotor Shaft Holder	1	40.93	40.93	Estimate
	Shaft Clamp (Upper)	1	5.24	5.24	Estimate
	Bottom Clamp	1	3.44	3.44	Estimate
	Small Shaft Clamp	1	2.43	2.43	Estimate
	Top & Bottom Rotor Shaft + Ball Bearing	1	5	5	Estimate
	Shroud	1	86	86	Estimate
	TOTAL			**313.28**	

Mass Budget (2/4)

Subsystem	Component	Quantity	Mass per Piece [g]	Total [g]	Source
CanSat Container	Release Latch Release Slice	1	20.21	20.21	Estimate
	Release Latch	1	0.43	0.43	Estimate
	Release Assembly	1	12.04	12.04	Estimate
	Shoulder	1	55.9	55.9	Estimate
	Side Walls	1	105.35	105.35	Estimate
	Eye Bolt Mount	1	45.2	45.2	Estimate
	Steel Parts	1	37.1	37.1	Estimate
	TOTAL			**276.23**	

Subsystem	Component	Quantity	Mass per Piece [g]	Total [g]	Source
Other Mechanical	Power PCB	1	40	40	Estimate
	Main PCB	1	40	40	Estimate
	Parachute Cord	18 inches	12.04	12.04	Estimate
	Parachute	1	6.9	6.9	Measured
	Carbon Fibre Layup	8	2.77	22.12	Estimate
	Steel Parts	-	23.0	23.0	Estimate
	Coin Cell Battery Holder	1	1	1	Estimate
	TOTAL			**145.06**	

Mass Budget (3/4)

Subsystem	Component	Material / Part Number	Quantity	Mass Piece [g]	Total [g]	Source
Electrical System	Buzzer	MATEK 5V Loud Buzzer	1	2.2	2.2	Measured
	Timer	NE555P	1	0.4	0.4	Measured
	Boost converter	TPS610333	2	1	2.0	Estimate
	XBee	XBP9B-XCWT-001	1	4.0	4.0	Measured
	Barometer	BME280	1	2.4	2.4	Measured
	GPS	BN-220	1	5.6	5.6	Measured
	Hall Sensor	A3144EU	1	0.1	0.1	Measured
	ESP32	ESP32 S3 WROOM	2	11.8	23.6	Measured
	ESP32	ESP32 S3 WROOM 32D	1	8.3	8.3	Measured
	Camera (Ground)	OV5640 Camera Module	1	6.4	6.4	Measured
	Camera (Release)	OV5640AF Camera Module	1	0.7	0.7	Measured
	Release Mechanism	SG90	6	10.6	63.6	Datasheet
	IMU	BNO085	1	2.1	2.1	Measured
	Voltage Regulator	LM2596	1	1.0	1.0	Estimate
	Voltage Divider	Resistors	8	0.1	0.8	Estimate
	Power Indicator	C566D-RFF	1	1.0	1.0	Estimate
	TOTAL	**-**	-	-	**124.2**	

Mass Budget (4/4)

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	96.0	Datasheet
	Buzzer Battery	3.7 V 2000 mAh Li-Ion	1	51.2	51.2	Datasheet
	Timer Buzzer	Uline Ultra 2032 Coin Cell Batteries	1	3	3	Datasheet
	TOTAL	**-**	-	-	**150.2**	-

The total mass is 1008.97g. Since we are currently 391.3 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

Payload Command Data Handler (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
Sensors	See Sensor Selection Table (Slide 19)	• Sensors will measure external environmental data and battery voltage • Data is written to processor through various interfaces
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

Payload Processor & Memory Trade & Selection (1/2)

Model	Boot Time [s]	Speed [MHz]	Cores	Communication 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 I²C • 2x UART • 2x SPI, 3 slaves each	• 520 KB SRAM • 4MB Flash memory	3.0 to 3.6	80	25 x 48
Raspberry Pi Zero W	~8 to 16	1000	1	• 27x GPIO • 1x I²C • 1x UART • 1x SPI	• 512 MB RAM • Relies on external SD card	5	~120	30 x 65

Reasons for Choosing: ESP32 ESP-WROOM-32D

We selected the ESP32 with a NodeMCU-32S Dev module. This choice is due to its dual-cores, low power consumption, high speed, sizable SRAM, and interface selection. In addition, it uses a real-time OS supporting tasks like interrupts. There is also a great amount of available documentation and support.

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

Model	Size [mm]	Storage [MB]	Write Speed [MB/s]	Power [V]	Communication Interface
ESP32 Integrated SPI Flash Memory	N/A	4*	~10 to 20	3.3	Internal SPI bus
DAOKAI MicroSD Card Module + SanDisk Industrial MLC MicroSD	17.9 x 17.9	8000	80	3.3 or 5	SPI

Reasons for Choosing: ESP32 Integrated Flash Memory

The internal memory on the ESP32 has much less storage than the SD card, but it is still of decent size for storing data in simple text files that can be parsed on the ground. The flash memory is non-volatile and will remain after a processor reset.

*Note: Not all 4 MB is available due to reservations for bootloader, NVS, etc. By default, the partition table allocates 1.4 MB to SPIFF. However, we can also partition it ourselves if more space is needed, reducing the size of OTA configuration for example (over-the-air updates, which is unneeded).

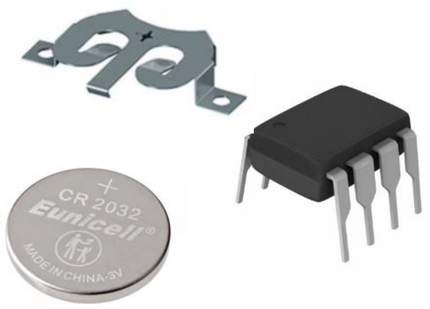
Payload Real-Time Clock

Model	Size [mm]	Communication Interface	Operating Power [V]	Clock Crystal [kHz]	Mass [g]
DS1307 Module	25.8 x 21.7 x 5	I²C	5	32	2.3
ESP32 Internal RTC	N/A	N/A	N/A	32	N/A

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 can be easily connected to the ESP32 with its I²C interface.

Note that the DS1307 will be powered using its own 3.3v (stepped up to 5v) coin cell battery as shown in slide 84. In addition, it will be using Keystone's low-profile coin cell battery holders that are designed for high shock and vibration applications



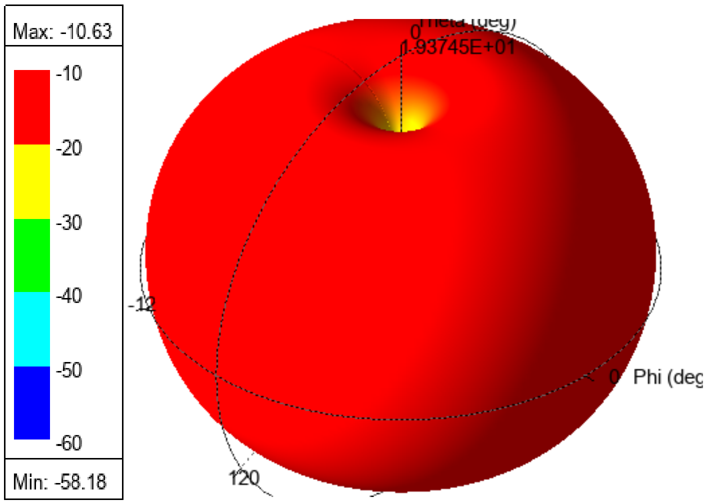
Payload Antenna Trade & Selection (1/2)

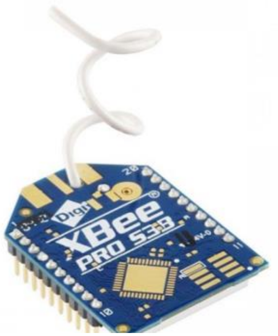
Model	Type	Radiation Pattern	Frequency Range [MHz]	Size [mm]	Gain [dBi]	Outdoor Range [m]	Mounting
XBee Integrated Wire (XBP9B-XCWT-001)	¼ Wave Wire (Monopole)	Omnidirectional	900	82.6	1.9	1300[1]	Pre-soldered onto PCB
Pulse Electronics W5012	Straight Whip (Monopole)	Omnidirectional	868 to 928	179	2	Not specified	RP-SMA

Reasons for Choosing: XBP9B-XCWT-001

We chose an XBee that comes with an integrated wire as it meets the requirements for range and eliminates the need for an external component. This antenna is pre-installed by Digi so it is compact and reliably compatible with the XBee.

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





Simulation of Antenna Gain (dB)

[1] Estimated based on Digi Whip antenna measurements.

Payload Antenna Trade & 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.

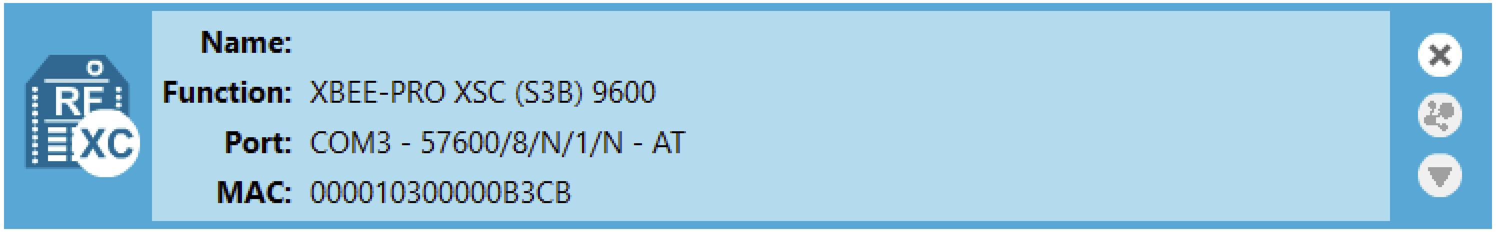
Payload Radio Configuration (2/2)

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, which meets the mission requirements.

"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 altitude to 0 meters
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

Electrical Power Subsystem (EPS) Design

Adam Kabbara

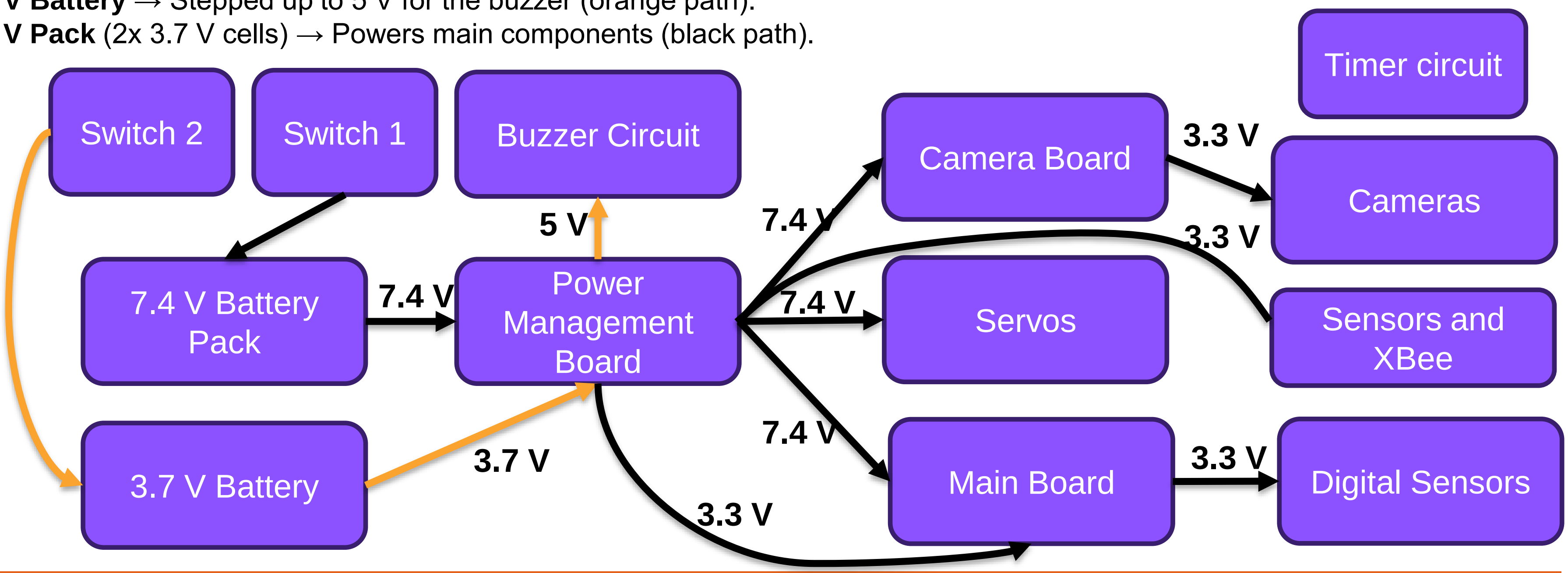
EPS Overview

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.

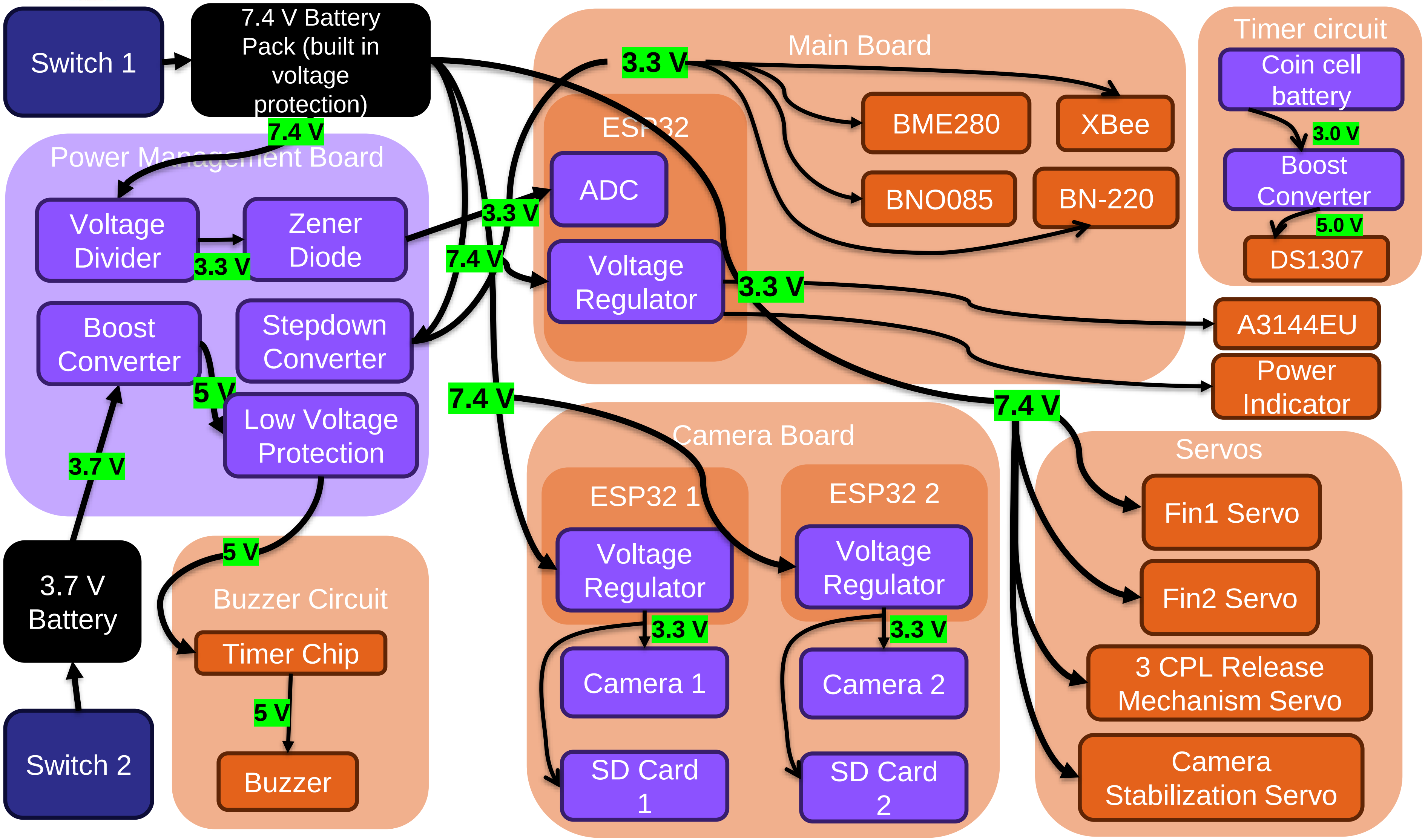
- **Main Board**: The main board houses an ESP32, which uses its onboard buck converter to regulate 7.4 V down to 3.3 V and supply power to the digital sensors. This ensures that the digital sensors receive a more stable and less noisy signal compared to a direct voltage step-down.
- **Camera Board**: 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).



Payload Electrical Block Diagram

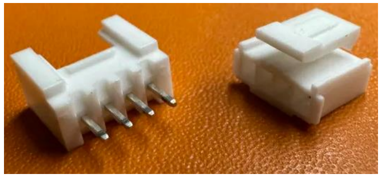


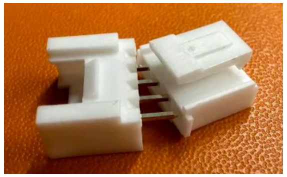
Payload Power Trade & Selection

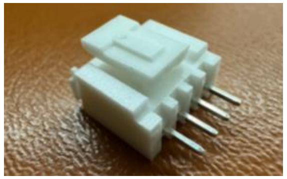
Battery	Units Needed	Total Mass [g]	Total Energy [Wh]	Total Capacity Estimate [mAh]	Total Supplied Voltage [V]	Cost [USD]	C rating
Lithium-Ion Battery Pack	1	96	19.24	2600	7.4	16.00	1.5
9V Duracell	3 or more	138	13.5	1500	9	8.75	0.05

Reasons for Choosing: Lithium-Ion Battery Pack

At peak consumption, the circuit draws over 2 A, making a **three 9V Duracell setup impractical**. A single 9V battery lasts **just under 2 hours at 250 mA** (~500 mAh capacity), but at higher currents, its capacity drops significantly. Supplying 2 A by limiting the max current supply per battery to 250 mA would require ~9 batteries, adding **excess weight while also being non-rechargeable**. In contrast, the **2600 mAh Lithium-Ion Battery Pack** provides **longer runtime, lower weight (30.4% less than three 9V setup), built-in protection circuits**, and **rechargeability**, reducing costs during testing.







We are using **Tamiya connectors** instead of spring connectors to connect the batteries to the power board (and sensors to the main board). Tamiya connectors provide a **secure, vibration-resistant connection**, preventing power interruptions during launch and descent when compared to spring contacts.

Buzzer Power Trade & Selection

Battery	Units Needed	Total Mass [g]	Total Energy [Wh]	Capacity Estimate [mAh]	Supplied Voltage [V]	Cost [USD]
Lithium-Ion Battery	1	51.2	7.4	2000	3.7	7.70
9V Duracell	1	46	4.5	500	9	2.92
Lithium Coin Cell Battery Duracell (CR2032)	2 or more	6.2	0.735	245	6.0	6.66

Reasons for Choosing: Lithium-Ion Battery

The MATEK 5V buzzer has a current consumption of 200 mA so step-up 9V Duracell can only last a little over 2 hours of operation, while also being not rechargeable. The CR2032 Duracell needs two in series to get to 6 V, enough to power the buzzer but not enough for 2 hours. Therefore, the Lithium-Ion Battery is chosen for its capacity and its ability to recharge to cut back on testing costs. Note that a step-up voltage converter is needed to bring the battery's 3.7 V to 5 V.

Uses same mounting system as the 7.4 V battery pack, ensuring no spring contacts are in use

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	200	75	50	0.15	Measured
Buzzer Timer	NE555P	1	5	15	75	100	0.15	Measured
Communication	XBP9B-XCWT-001	1	3.3	290	957	100	1.914	Measured
Temperature & Pressure	BME280	1	3.3	0.18	0.594	100	0.001188	Measured
GPS Location and Time	BN-220	1	3.3	47	155.1	100	0.3102	Measured
Rotor Spin Count	A3144EU	1	3.3	6.12	20.196	100	0.040392	Measured
Camera CPU	ESP32 S3 WROOM	1	5	51	255	100	4.46	Measured
Main CPU	ESP32 S3 WROOM 32D	1	5	48	240	100	0.6	Measured
Boost Converter	TPS610333	2	3.7	0.023	0.088	100	0.0002	Estimated
Camera 2	OV5640 Camera Module	1	3.3	45	148.5	100	0.297	Measured
Camera 1	OV5640AF Camera Module	1	3.3	45	148.5	100	0.297	Measured
Servos	SG90 (Release Mechanism)	3	7.4	250	1850	0.1	0.46	Measured

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
Magnetic Field, 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	**6.725**	**13.45**

Flight Software (FSW) Design

Luke Watson

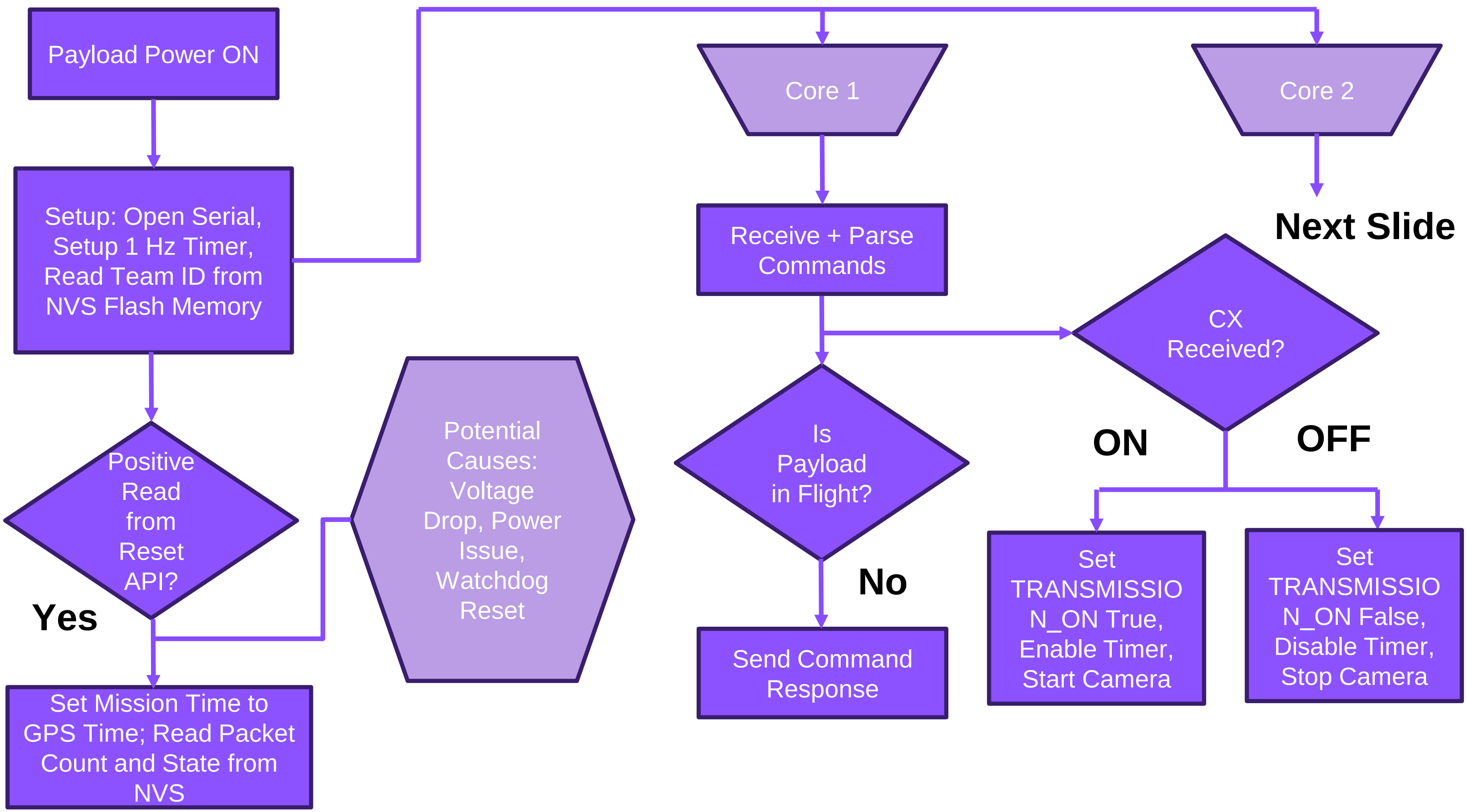
FSW Overview

Language	Libraries	Dev Environment	FSW Tasks
All logic in C, C++ for Serial Functions	Arduino Library, Adafruit_Sensor.h, Adafruit_BME280.h, Wire.h, TinyGPS++.h, HardwareSerial.h, Adafruit_BNO08x.h, Servo.h	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

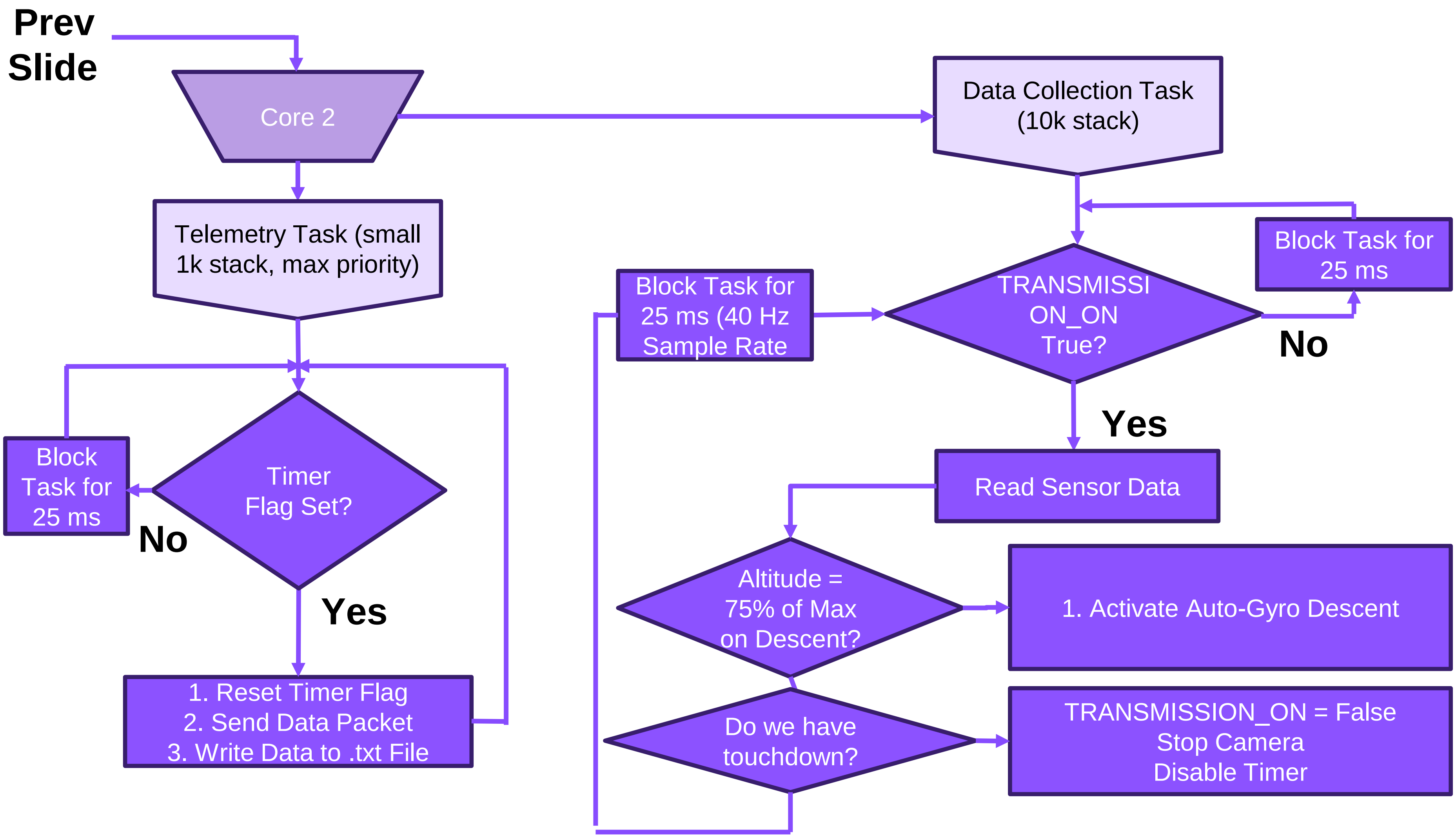
FSW Flow

Power ON	Receive Commands	Telemetry Activation	Mission	Landing
Connection to Ground Station begins	Receive, parse, and respond to commands From Ground Station	Receive CX,ON command from Ground Station Begin mission tasks on 2nd core	Collect measurement data from sensors Trigger video recording Send data packets to Ground Station Save data to memory	End telemetry Stop video and data collection

Payload FSW State Diagram (1/2)



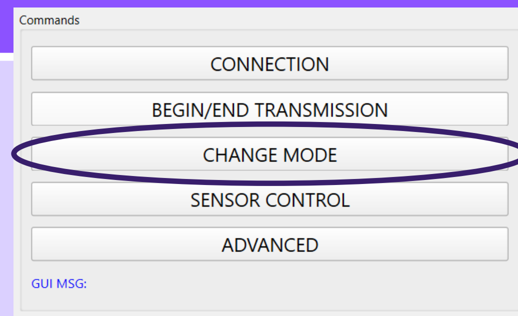
Payload FSW State Diagram (2/2)

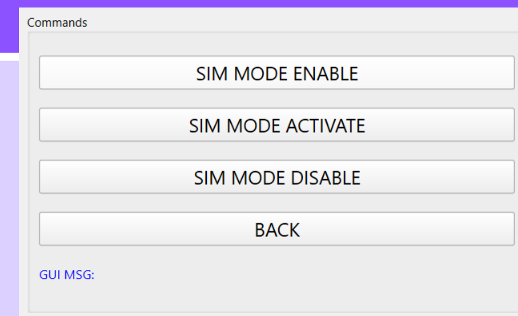


Simulation Mode Software

Start Simulation Mode

Can control simulation mode by pressing these buttons in the GUI.
Each will send “CMD,3114,SIM,<ENABLE/ACTIVATE/DISABLE>” to the payload. Upon sending CX,ON command pressure values will be sent with “CMD,3114,SIMP,<VALUE>” at 1 Hz.





Payload

The payload checks for reception of ENABLE and then ACTIVATE in succession before starting simulation mode. DISABLE will reset this. In simulation mode the previous logic is the same, the only difference being the packet pressure data is collected from the last received value from the ground station instead of reading from the sensor.

Software Development Plan

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 – 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 / GCS Development → Test Individual Prototype Functionality → Test Functionality Together → Update Complete; Verify all Features Bug-Free → Merge into Main Development Branch / Update Release of Compiled GCS App

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

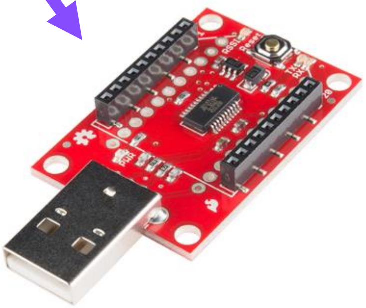
Ground Control System (GCS) Design

Luke Watson, Robert Saab

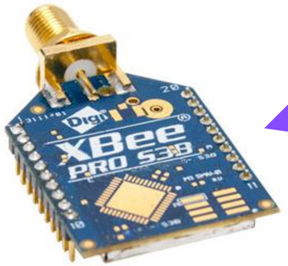
GCS Overview

Laptop

USB to USB-C Adapter



SparkFun XBee Explorer Dongle



XBee Pro S3B

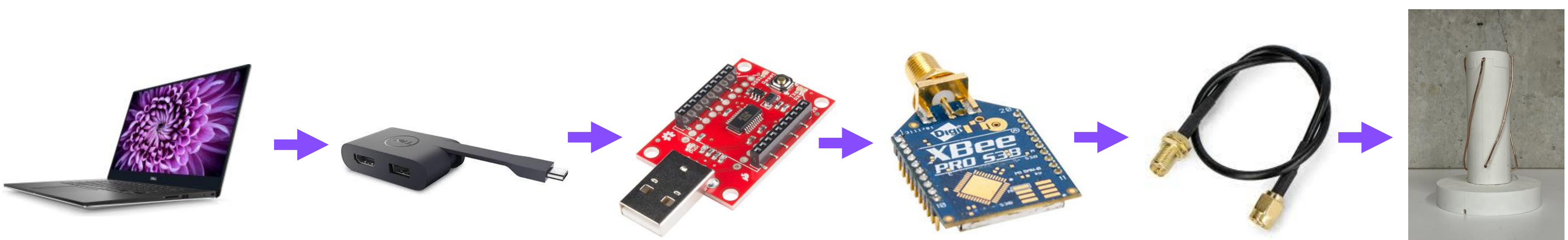
RP-SMA Connector

Antenna

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 Trade & Selection (1/3)

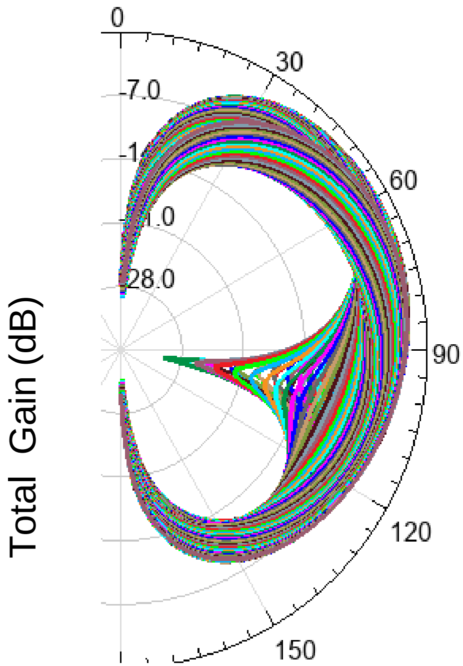
Antenna Type	Design Description	Gain [dBi]	Beamwidth
Handheld - Helical Antenna (QHA - Quadrifilar Helical)	A circularly polarized antenna made of a helical wire wound around a core.	Moderate, typically around 3-5 dBi.	Moderate, providing coverage in a circular pattern.
Tabletop - Yagi Antenna	Directional antenna with a reflector, driven element, and directors.	Typically high, around 8-12 dBi (depending on design).	Narrow, thus focuses the signal on a specific direction.
Tabletop - Omni-directional Antenna	Radiates signal in all directions, usually a simple monopole or dipole antenna.	Low, around 2-3 dBi.	360-degree coverage, providing consistent signal in all directions.

Reasons for Choosing: Handheld (QHA - Quadrifilar Helical)

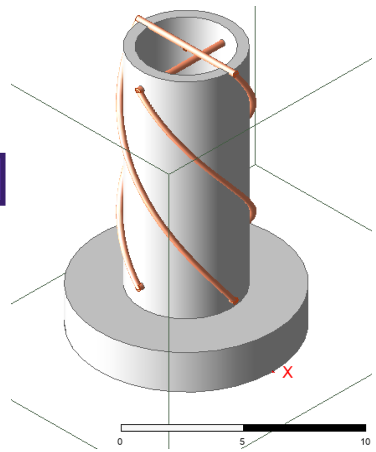
For a **handheld ground station** that must **track the CanSat** during **ascent** and **descent**, the **Helical Antenna** is the best choice due to:

- **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.

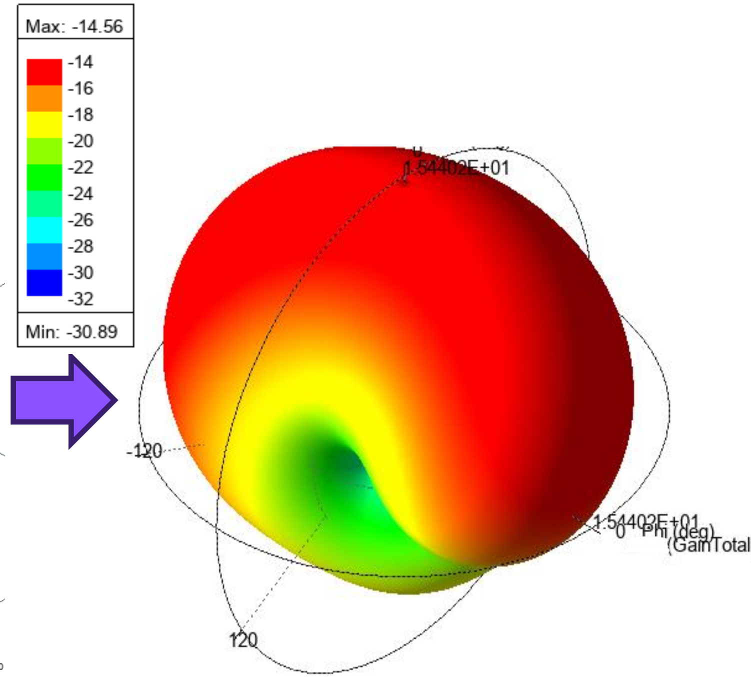
GCS Antenna Trade & Selection (2/3)



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.

GCS Antenna Trade & Selection (3/3)

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

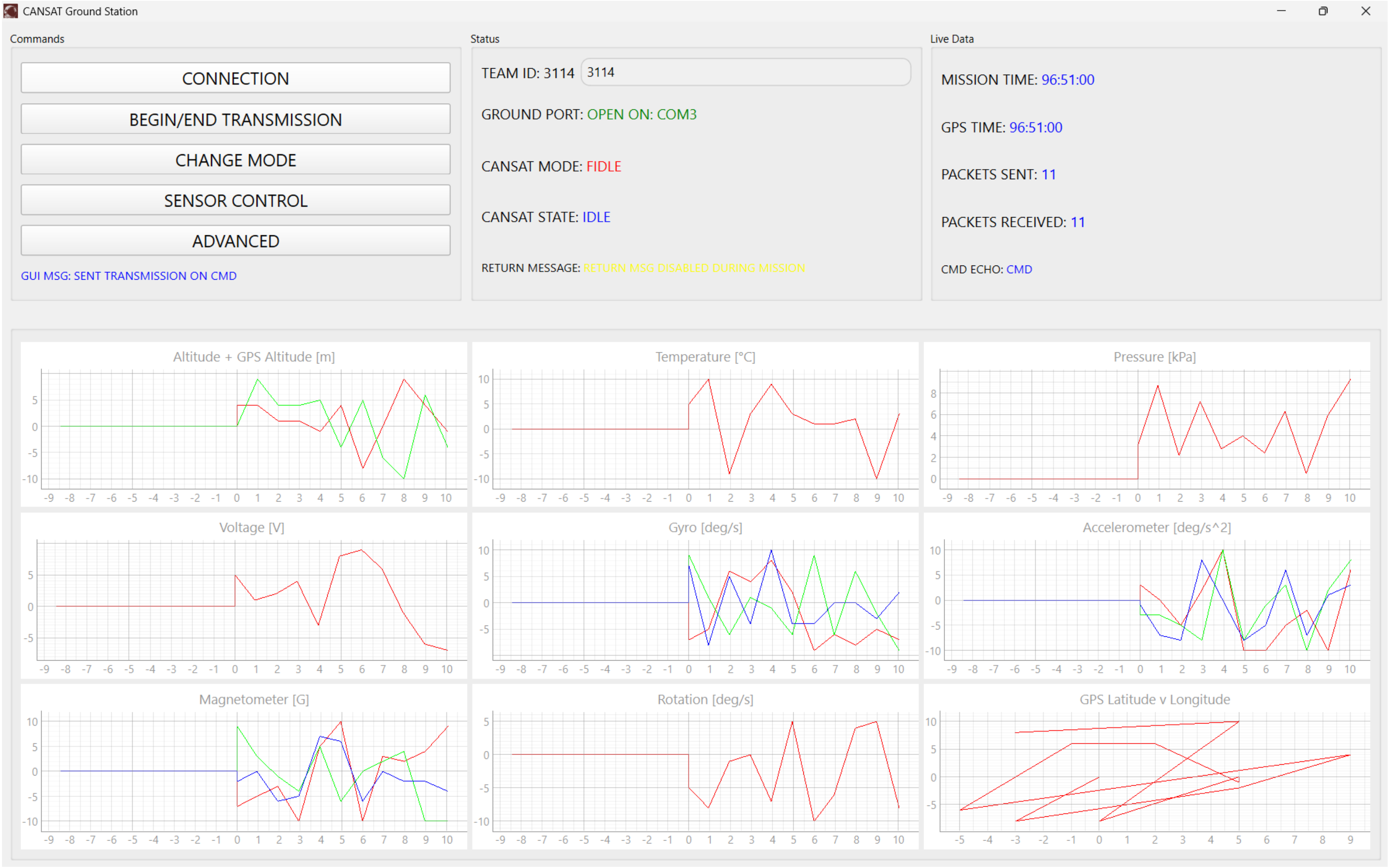
Applying the Formula to our Antennas

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

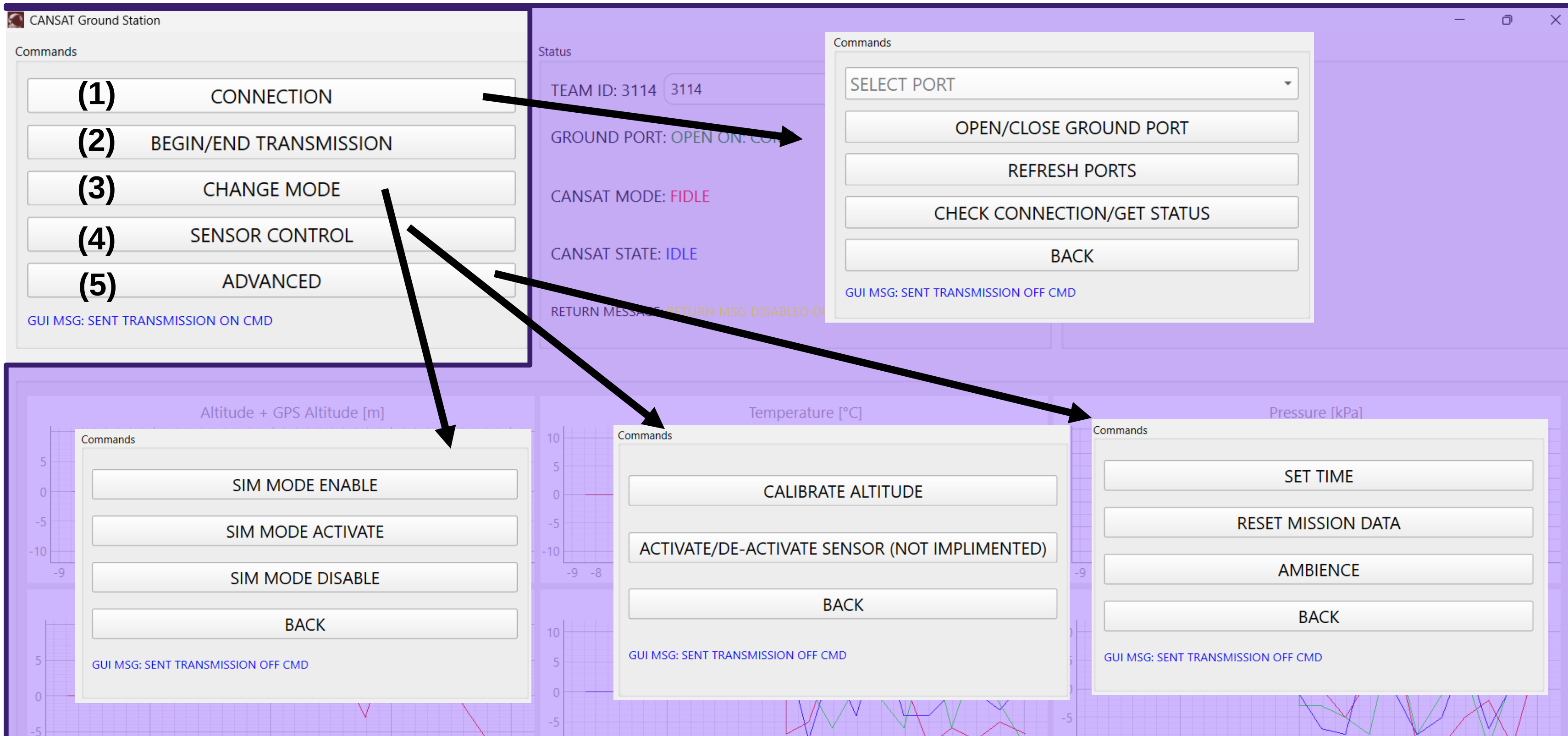
GCS Software (1/5)

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 (created on first transmission) • Send all required commands to the payload • Track number of received packets • Be user-friendly and easy to figure out
Compiling	• Using cx-freeze & bdist-msi to create a downloadable .msi file that can be ran on any Windows computer with no pre-requisites • Compiling to msi instead of .exe is done to prevent virus detection

GCS Software (2/5)

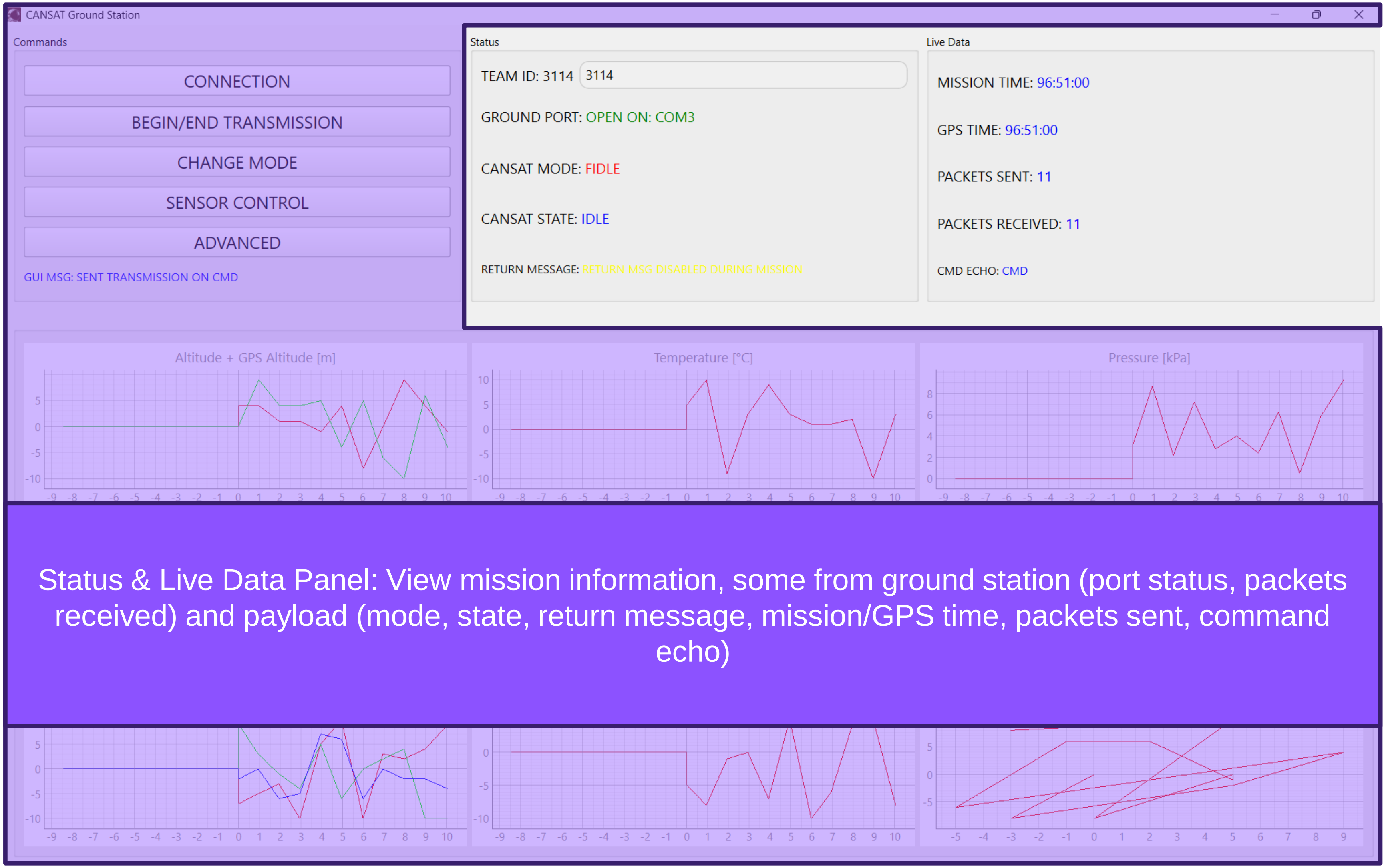


GCS Software (3/5)



Commands Panel: (1) Connect to Payload (2) Toggle Transmission of Mission Data (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

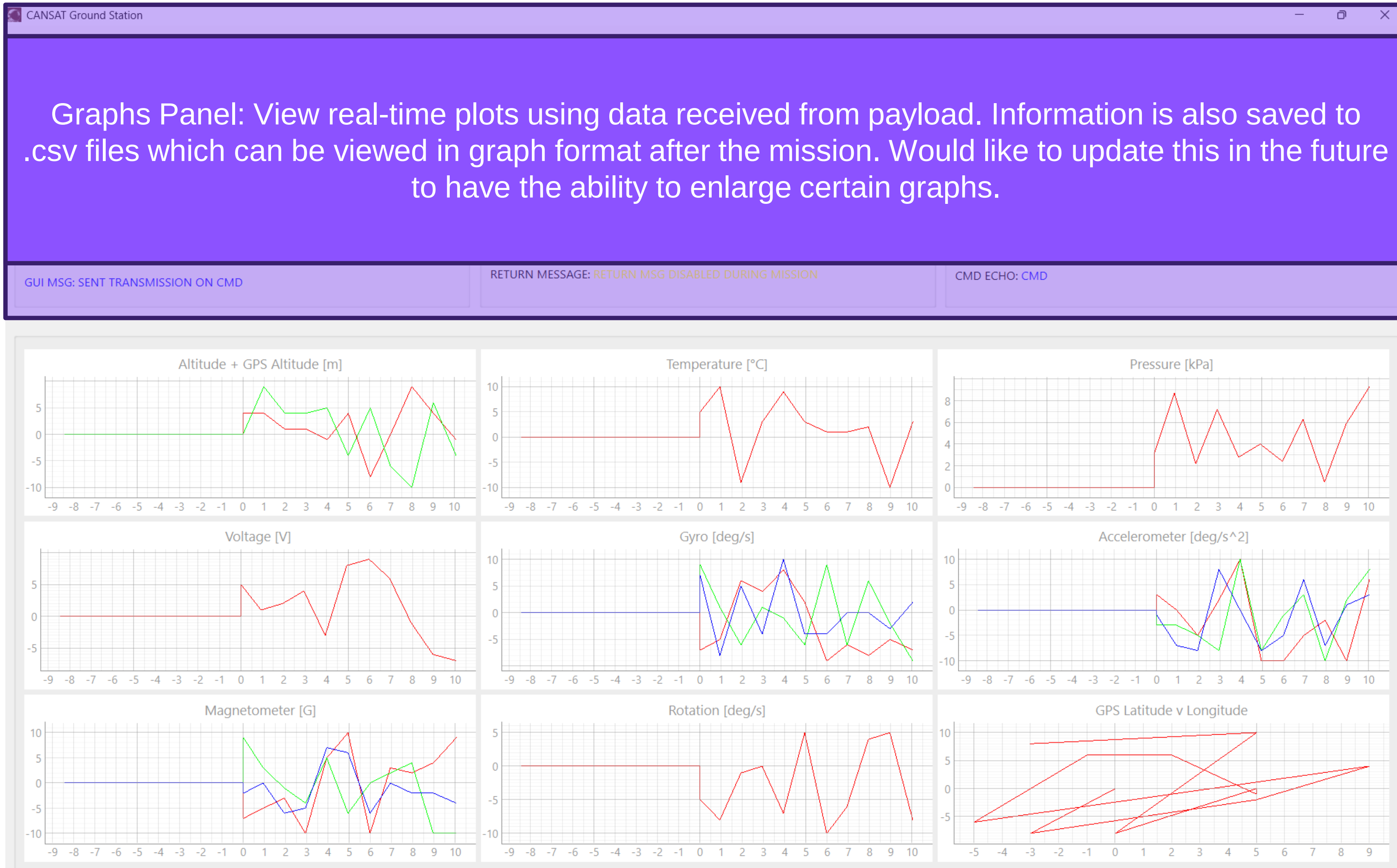
GCS Software (4/5)



Status & Live Data Panel: View mission information, some from ground station (port status, packets received) and payload (mode, state, return message, mission/GPS time, packets sent, command echo)

GCS Software (5/5)

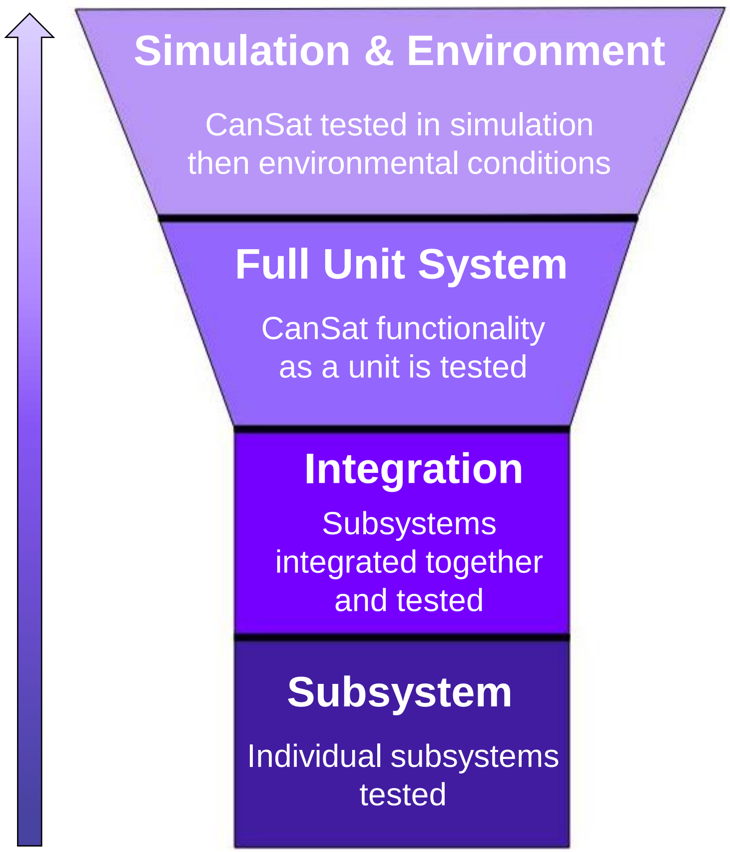
Graphs Panel: View real-time plots using data received from payload. Information is also saved to .csv files which can be viewed in graph format after the mission. Would like to update this in the future to have the ability to enlarge certain graphs.



CanSat Integration and Test

Nour Barsoum

CanSat Integration and Test Overview



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 Plan (1/4)

Subsystem	Test Case	Acceptance Criteria	Test Status
Mechanical	Payload remains structurally sound after undergoing shock, vibrations, and simulated landing	No damages to structure (including cracks or lose bolts) after undergoing the tests	Open
	Parachute successfully slows down CPL to desired speed	Payload slowed to desired speed	Verified
	Successful rotor deployment from the container	All rotors have successfully deployed 90 degrees from their initial position	Verified
	Electronics board is isolated from shock and vibrations	Electronics do not reset, and all communications interfaces are working	Open
	Stabilizing fins can move unobstructed	Fins can freely rotate 90 degrees	Active
Flight Software (FSW + GCS)	Software is capable sending and receving commands	All commands tested and working	Active
	Accurate progression through FSM mission states	FSM states represent flight state accurately (initialized, start, ascent, descent phase 1 & 2, landed)	Open
	Data can be properly visualized on graphs/text	Random data is properly displayed	Verified
	System can survive power cuts	Large capacitor sustains power for 1 to 2 seconds. Logs data alerts of backup power usage	Open

Subsystem Level Testing Plan (2/4)

Subsystem	Test Case	Acceptance Criteria	Test Status
Sensors	IMU, magnetometer, hall effect sensors are successfully initialized – communications enabled	Sensor readings are accurate and successfully sent to their respective output interfaces	Active
	Temperature, Pressure and Voltage readings	All values are correctly measured and accurate	Active
	Buzzer sounds	Buzzer beeps intermittently when connected to the circuit and power	Verified
	Both cameras can successfully record and save video	Camera video are taken and stored in the MicroSD card	Verified
	Camera pointing due North	Servo attached to camera moves such that the camera is pointing in the due north direction with a tolerance of ±10 degrees	Open
	GPS data decoded from NMEA frame and readable	Longitude latitude, number of satellites, altitude, UTC time data is outputted and readable by the FSW	Verified
	Altitude is properly calculated from barometer	Altitude measurements are within ±2 (propagated from barometer tolerance) and are relative to ground level (zero'd accordingly)	Active
	GPS altitude data is correct	GPS altitude output is respective to sea level and within range of the barometer	Verified
	High altitude GPS testing	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 Plan (3/4)

Subsystem	Test Case	Acceptance Criteria	Test Status
CDH	Format of data sent by FSW is correct and can be accurately parsed by GCS	Commands and telemetry tested	Verified
	Data is sent at 1 Hz	GCS graphs show data points every second	Verified
	Sensor data can be properly read by FSW	All sensors can be read	Active
EPS	Servo torque is sufficient for the fins to move	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	From fully charged batteries, electrical systems stay operational for 2 hours (high currents concidered)	Open
	PCB circuit is closed with proper soldering	Multimeter on continuity setting beeps when probes are touching soldered points.	Open
	Voltage regulators powered correctly	Voltage measured at relevant pins is accurate	Verified
	Pressure, temperature, voltage sensors powered	Voltage measured at relevant pins is accurate	Verified
	Camera, processor, MicroSD card are powered	Voltage measured at relevant pins is accurate	Verified
	IMU and XBee powered	Voltage measured at relevant pins is accurate and expected output is seen from the device	Verified

Subsystem Level Testing Plan (4/4)

Subsystem	Test Case	Acceptance Criteria	Test Status
Radio Communications	XBee radio can transmit data	Both XBees capable of sending data that can be received on computer using XCTU software	Verified
	XBee radio can receive data	Both XBees capable of receiving data send through computer using XCTU software	Verified
	Antenna signal range	XBees can communicate at a range of at least 1 km	Active
Descent Control	FSM detects flight phase changes between descent and landing	State output changes appropriately with the CanSat's states	Open
	FSW controls deployment mechanisms using FSM	Parachute is released properly at appropriate time	Open
	Parachute maintains appropriate descent velocity for the CanSat	Parachute allows the CanSat to descend at ~20 m/s	Active
	Auto-gyro system is functional	CanSat maintains controlled descent with stable rotation	Open

Integrated Level Functional Test Plan

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	Checking that the CanSat components are powered, the sensors are reading and outputting data, and the wireless communications modules are functional. 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.
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.
Deployment	Ensuring the CanSat can easily slide in and out of the container for smooth deployment. Checking that the rotor deployment with the spring system works. Parachute deployment testing will also be done simultaneously with the descent testing to ensure the parachute decreases the CanSat's velocity appropriately.

Environmental Test Plan

CanSat Environmental Tests	
Drop Test	Show if CanSat can survive a sudden shock of 30 G. Using a 61 cm 1/8 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, turn the heaters on – for 2 hours, whenever 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. A random orbital sander is secured upside down and the CanSat is placed where the sandpaper would be. The CanSat is powered on, ensuring accelerometer data is being collected. Power on the sander and when it reaches full speed, wait 5 seconds then power off the sander (wait until it fully stops) – repeat this process 4 more times. 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. Chamber is created using a vacuum, 5-gallon bucket with a lid. Power on the CanSat and suspend it in the chamber, turn on the vacuum to start pulling a vacuum. Stop the vacuum when the telemetry reaches max altitude. Let air enter the chamber slowly and monitor the operation of the CanSat. Collect and saved telemetry and take a video that 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.

Simulation Test Plan

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.

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, Alexy 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.

Mission Operations Manual Development Plan (1/2)

- The Mission Guide's insights, members' prior experiences, and the upcoming test results will all be used to create the Mission Operations Manual. After the Critical Design Review, the Mission Operations Manual will be finalized.
- 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.

Mission Operations Manual Development Plan (2/2)

GS Configuration

- Ground Control System Assembly & Antenna Assembly
- Ground Control System and Communication System Initialization

CanSat Preparation

- Communication and Sensor Test, Battery Check
- Container and Parachute Separation Test
- Probe Assembly

CanSat Integration

- Heatshield Stowage, Probe Parachute Folding and Securing, and CanSat Mounting inside the Rocket
- Communication Verification and Sensor Calibration

CanSat Recovery

- Ground Station Data backup
- CanSat Retrieval, Damage Assessment, and MicroSD Card Acquisition

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

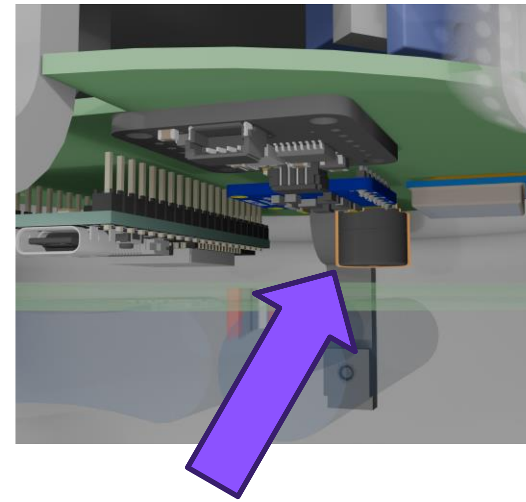
- The probe will be orange in color so that it can be easily observed
- The parachute will be in white to help distinguishment

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

CanSat Beacon Design

Sensor	Sound Output [dB]	Operating Voltage [V]	Power Consumption [W]	Cost [USD]	Dimension [mm]	Mass [g]
5V Loud Buzzer	90	4.5 to 5.2	1	3.06	18 x 13 x 8	2.2
CLT1026 Speaker Stereo Woofer	90	12	3	10.99	40 x 40 x 20	24



As mentioned by requirement E6, the audio beacon must be powered by a separate battery. The short trade selection table above shows that using a 5V buzzer would be much more feasible as it is cheaper, consumes less power, is smaller and weighs much while maintaining similar output sound.

The battery selection for was made in the **Buzzer Power Trade & Selection** section. In summary, the 5V buzzer drains 200 mA, two CR2032 batteries can power it but not for long. A rechargeable Lithium-Ion battery is chosen for longer use and cost-saving, requiring a step-up converter to boost its 3.7 V to 5 V.

Requirements Compliance

Angelique Liao

Requirements Compliance Overview

- Majority of requirements is already fulfilled (approx. 94%).
- All Mechanism, Electrical, Communication, Ground Station, and Flight Software requirements are reached.
- Management requirements are also met.

- Several requirements to be tested include real descent rates, survivability under shock, vibration, and acceleration, and orientation stability.
- These will be tested and confirmed their fulfillments in the following weeks.

- There are no serious issues, since all requirements were considered and have been applied during design process.
- Further tests to ensure fulfillment will be conducted in the upcoming weeks.

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	12, 13, 14, 15, 19, 53	
C2	The CanSat container shall be mounted on top of the rocket with the shoulder section inserted into the airframe.	Comply	12, 13, 19, 55	
C3	The CanSat payload and container shall be deployed from the rocket when the rocket motor ejection charge fires.	Comply	13, 14, 50, 55	
C4	After deployment, the CanSat payload and container shall descend at 20 m/s using a parachute that automatically deploys.	Partial Comply	33, 48	Simulation meets. Real test needed.
C5	At 75% flight peak altitude, the payload shall be released from the container.	Comply	32, 57, 58	
C6	At 75% peak altitude, the payload shall deploy an auto-gyro descent control system.	Comply	32, 60	
C7	The payload shall descend at 5 m/s with the auto-gyro descent control system.	Partial Comply	12, 32, 45, 48	Simulation meets. Real test needed.

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	75, 88, 89, 90, 108, 112	
C9	The payload shall record video of the release of the parachute and the operation of the auto-gyro descent control system.	Comply	18, 29, 30, 50	
C10	The second video camera shall point in the north direction during descent.	Comply	18, 50, 61	
C11	The second camera shall be pointed 45 degrees from the CanSat nadir direction during descent.	Comply	61	
C12	The second video camera shall be spin stabilized so the ground view is not rotating in the video.	Comply	36, 50, 61, 107	
C13	The CanSat payload shall include an audible beacon that is turned on separately and is independent of the CanSat electronics.	Comply	80, 81, 83, 85, 119	
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	140	

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	66	
S2	The nose cone shall be symmetrical along the thrust axis.	Comply	53	
S3	The nose cone radius shall be exactly 72.2 mm.	Comply	19, 53	
S4	The nose cone shoulder length shall be a minimum of 50 mm.	Comply	53	
S5	The nose cone shall be made as a single piece. Segments are not allowed.	Comply	19, 53	
S6	The nose cone shall not have any openings allowing air flow to enter.	Comply	19, 53	
S7	The nose cone height shall be a minimum of 76 mm.	Comply	53	
S8	CanSat structure must survive 15 G vibration.	Partial Comply	52, 62	Design to do so, will be tested
S9	CanSat shall survive 30 G shock.	Partial Comply	56, 58, 111	Design to do so, will be tested
S10	The container shoulder length shall be 90 to 120 mm.	Comply	19, 55	

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	15, 19, 55	
S12	Above the shoulder, the container diameter shall be 144 mm.	Comply	15, 19, 55	
S13	The container wall thickness shall be at least 2 mm.	Comply	55	
S14	The container length above the shoulder shall be 250 mm +/- 5%.	Comply	5, 19, 55	
S15	The CanSat shall perform the function of the nose cone during rocket ascent.	Comply	15, 53, 59	
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	55, 57, 58, 59, 60	
S17	All electronics and mechanical components shall be hard-mounted using proper mounts such as standoffs, screws, or high-performance adhesives.	Comply	62	
S18	The CanSat container shall meet all dimensions in section F.	Comply	55	
S19	The CanSat container materials shall meet all requirements in section F.	Comply	56	

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	15, 16	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	15, 16, 59	CanSat not use any heat-based mechanism
M3	All mechanisms shall be capable of maintaining their configuration or states under all forces.	Comply	50, 56, 58, 61, 62	
M4	Spring contacts shall not be used for making electrical connections to batteries. Shock forces can cause momentary disconnects.	Comply	82, 83	

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	82, 83	
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	82, 83	
E3	An easily accessible power switch is required.	Comply	50, 80, 81	
E4	A power indicator is required.	Comply	50, 81	
E5	The CanSat shall operate for a minimum of two hours when integrated into the rocket.	Comply	82, 83	
E6	The audio beacon shall operate on a separate battery.	Comply	81, 83, 119	
E7	The audio beacon shall have an easily accessible power switch.	Comply	80, 81	

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	74, 75	
X2	XBee radios shall have their NETID/PANID set to their team number.	Comply	75	
X3	XBee radios shall not use broadcast mode.	Comply	75	
X4	The CanSat shall transmit telemetry once per second.	Comply	75, 88, 89, 90, 108, 112	
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	76	

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	22	
SN2	CanSat payload shall measure its internal temperature.	Comply	23	
SN3	CanSat payload shall measure its battery voltage.	Comply	24	
SN4	CanSat payload shall track its position using GPS.	Comply	25	
SN5	CanSat payload shall measure its acceleration and rotation rates.	Comply	26, 27	
SN6	CanSat payload shall measure auto-gyro rotation rate.	Comply	26	
SN7	CanSat payload shall video record the release of the parachute and deployment of the auto-gyro at 75% peak altitude.	Comply	18, 29, 30, 50	
SN8	CanSat payload shall video record the ground at 45 degrees from nadir direction during descent.	Comply	61	

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.	**Partial Comply**	**36, 50, 61, 107**	Mechanism is designed to do so, will be tested
SN10	The video cameras shall record video in color and with a minimum resolution of 640 x 480.	**Comply**	**29, 30**	
SN11	The CanSat shall measure the magnetic field.	**Comply**	**28**	Our current sensor is able to measure the magnetic, yet not as accurately as we hope. More iteration is required.

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	103	
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	88, 89	
G5	Each team shall develop their own ground station.	Comply	94, 95	
G6	All telemetry shall be displayed in real-time during ascent and descent on the ground station.	Comply	100, 102, 103	
G7	All telemetry shall be displayed in the International System of Units (SI), and the units shall be indicated on the displays.	Comply	76, 100	
G8	Teams shall plot each telemetry data field in real-time during flight.	Comply	100, 103	

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	93, 94, 95	
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	93, 94, 95	
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	76, 77, 78, 110	
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	100, 101, 103, 112	
G13	The ground station shall use a tabletop or handheld antenna.	Comply	96	

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.	Partial Comply	95, 100, 101, 102, 103	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	100, 102	
G16	The ground station shall be able to activate all mechanisms on command.	Comply	101	

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	101, 102, 103	
F2	The CanSat shall maintain mission time throughout the entire mission even in the event of processor resets or momentary power loss.	Comply	88, 89	
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	76, 77, 78, 90, 112	
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	9	
F6	The flight software shall only enter simulation mode after it receives the **SIMULATION ENABLE** and **SIMULATION ACTIVATE** commands.	Comply	76, 77, 78, 90, 112	
F7	The flight shall include commands to activate all mechanisms. These commands shall be documented in the mission manual.	Comply	77, 78	

Management

Adam Kabbara

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:	$77.985

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	0.015	0.015	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	Estimated
Cansat Release Sliding Latch	Steel	1	5.5	5.5	Estimated
Eyebolt Mount	6.35 mm Plywood	1	11.20	11.20	Estimated

CanSat Budget – Hardware (3/4)

Slide Total:	$45.80

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	Estimated
Coin cell Battery Holder	Time chip battery	1	0.96	0.96	Actual
PCBs	Power and Main PCB	2	-	13.24	Estimated

CanSat Budget – Hardware (4/4)

Slide Total:	$186.60

Component	Description	Quantity	Price per Unit [USD]	Total	Source	Status
Electrical Subsystem Continued						
MATEK 5V Loud Buzzer	Buzzer	1	2.9	2.9	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	0.062	0.062	Estimated	New
Freenove ESP32 S3 WROOM	Camera ESP32	2	5.55	11.1	Actual	New
ESP32 S3 WROOM 32D	ESP32	1	7.7	7.7	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	0.2	0.2	Estimated	New
C566D-RFF	Power indicator	1	0.129	0.129	Estimated	New
Lithium-ion Battery Pack	Main battery	1	16.0	16.0	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

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	-	-	-

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

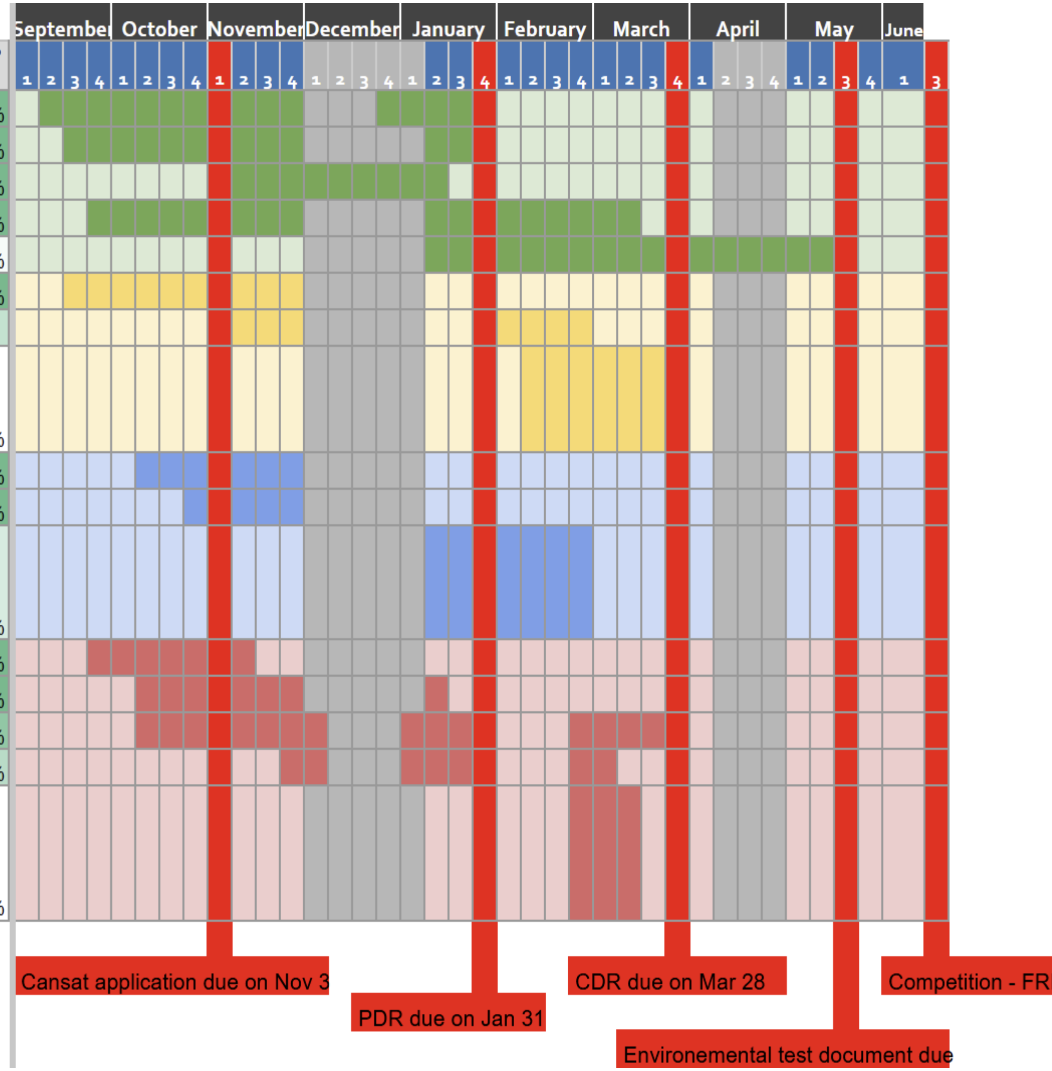
Component	Description	Total Cost [USD]
Other Expenses		
Prototyping	3D Prints and Failed Electronics	50.00
Testing Facilities	Environmental Testing	100.0
GCS Total	GCS Total	92.45
Competition Fee	Registration	200.00
Transportation (Van + Gas)	Faculty Van	567.30
Accommodation	4 Days	600.00
Food	12 Meals	800.00

Budget Summary [USD]	
Credit	17,149.94
CanSat	-321.345
GCS	-92.45
Other	-2,409.75
Balance	**14,326.395**

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	100%
	5	Final Assembly and Testing	AR - NO	6%
ELECTRICAL	1	Research on Required Sensors	DA - NO	100%
	2	PCB Design	AD	42%
	3	Final Assembly and Validaiton	AD - DA	0%
SOFTWARE	1	Code Research and Exploration	AN	100%
	2	Refinement Phase	LK	100%
	3	Simulation	LK	28%
COMMUNICATIONS	1	Preliminary Design Phase	RO - LK	100%
	2	Validation Phase	LK	100%
	3	Simulation Mode	LK	80%
	4	Antenna Design	RO - AL	50%
	5	Final Design and Integration	LK	0%

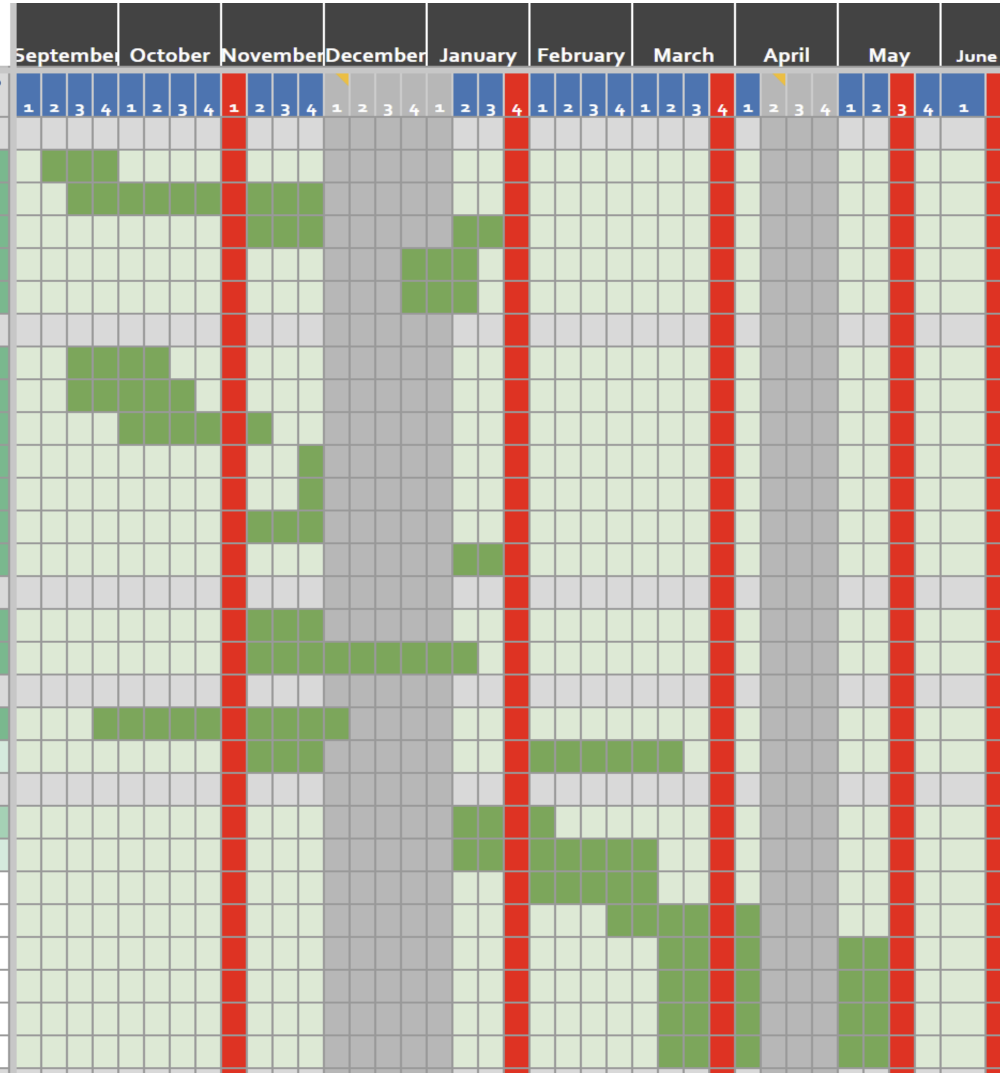


Detailed Program Schedule (1/3)

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	30%
5	Final Assembly and Testing		
5.1	Order parts	AD	66%
5.2	Print final parts	AR - NO	30%
5.3	Assemble final design	AR	0%
5.4	Design environemental tests	NR - AN	0%
5.5	Drop test	GI - NO	0%
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%



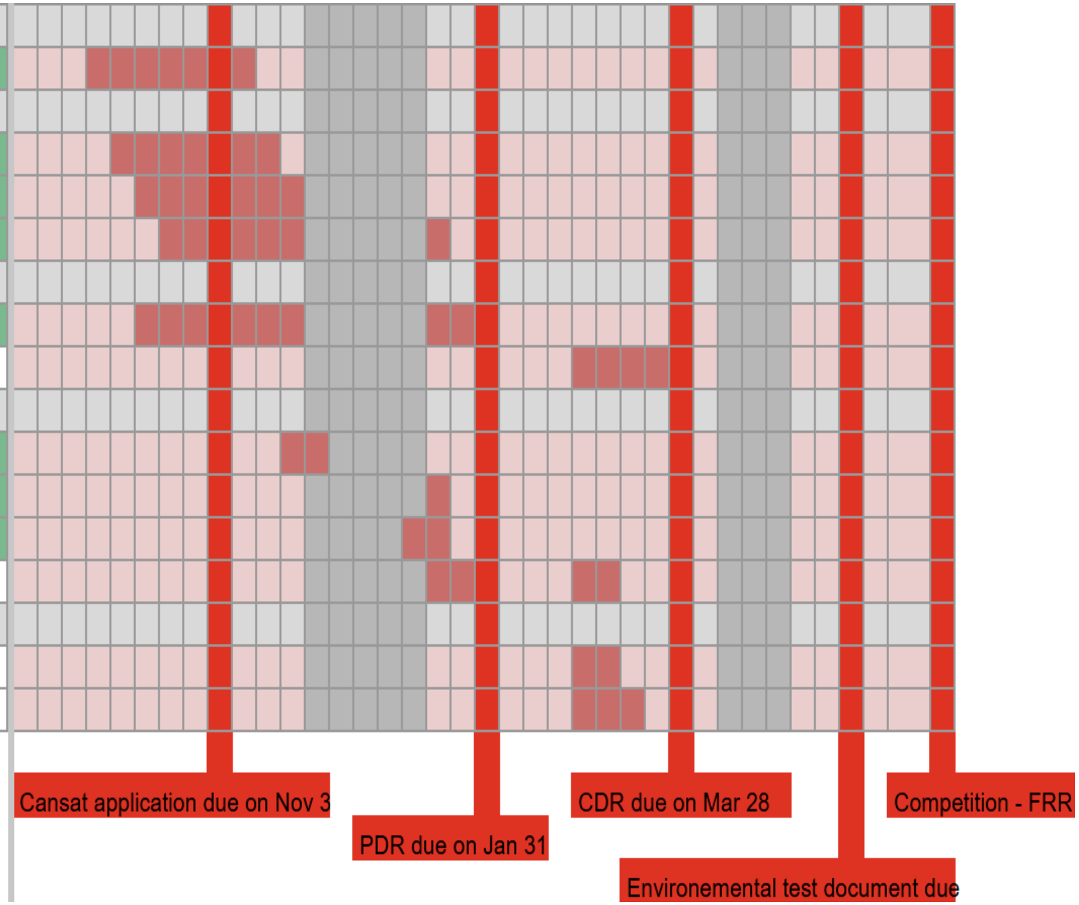
Detailed Program Schedule (2/3)

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 and integration	AD - GI	20%
	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	20%

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	0%
5	Final Design and Integration		
5.1	Integrate with PCB	LK	0%
5.2	Ensure it can withstand testing	LK	0%



Conclusions

Accomplishments
• Mechanical/structural and electrical systems have been designed • Ground station GUI and antenna have been designed • CDH system has been tested with FSW and GUI • Teamwork has been organized and a structured meeting schedule of once a week is in place
Unfinished Work
• Work on implementing the in-house forged carbon fibre air foils • Mechanical systems need to be assembled with possible iteration • GUI needs a few visual updates to match requirements • Integration, simulation, and environmental testing must be refined and conducted • Further trade and selection testing needs to be completed for the magnetometer
Readiness for the Design Stage
• We are currently ahead of schedule in development with no delays • Our ground station GUI is functional • We have tested the individual electrical components and ensured functionality and integration on the subsystem level • We have clear testing goals to help us achieve mission objectives • Good team morale and preparation enhances our excitement for the design stage