CanSat 2024
Critical Design Review (CDR)
Version 1.2

Team #2057

UCI AntSat

Presentation Outline (1/4)

1 Introduction
Ryan Liu

3 Sensor Subsystem Design
Jacqueline Lai

2 Systems Overview
Ryan Liu and Sarah Ho

Presentation Outline (2/4)

4 Descent Control Design
Jeremy Rose and Jerome Masicat

5 Mechanical Subsystem Design
Sunny Lin and Jerome Masicat

Presentation Outline (3/4)

Presentation Outline (4/4)

10 CanSat Integration and Test
Ryan Liu

11 Mission Operation & Analysis
Ryan Liu

12 Requirements Compliance
Ryan Liu

13 Management
Ryan Liu

Team Organization

- **CanSat** Competition Liaison
  - **Professor Roger Rangel** Primary Faculty Advisor
    - **Professor Sherif Hassaan** Faculty Co-Advisor
      - **Ryan Liu (5)** Project Manager
        - **AJ Smyth (4)** Electrical Lead
          - **Jacqueline Lai (3)** Electrical Engineer
          - **Khushi Gupta (3)** Electrical Engineer
        - **Jeremy Rose (4)** Mechanical Lead
          - **Sunny Lin (2)** Mechanical Engineer
          - **Sarah Ho (3)** Mechanical Engineer
          - **Jerome Masicat (4)** Mechanical Engineer
        - **Husain Wafaie (4)** Software Engineer
          - **Kaylee Kim (2)** Software Engineer

*Note: (#) indicates year of the member

Acronyms

A	Analysis (as verification method)	IDE	Integrated Development Environment (software)
ABS	Acrylonitrile butadiene styrene (type of plastic)	LDPE	Low Density Polyethylene
ADC	Analog-Digital Converter	LED	Light Emitting Diode
CAD	Computer Aided Design	MCU	Microcontroller Unit
CAN	Controller Area Network	MOSFET	Metal–Oxide–Semiconductor Field-Effect Transistor
CanSat	Can-sized Satellite	NETID	Network Identifier
CDH	Communications and Data Handling	PANID	Previous Access Network Identifier
CNC	Computer Numerical Control	PCB	Printed Circuit Board
COG	Center of Gravity	PLA	Polylactic Acid (type of plastic)
COM	Center of Mass	RPM	Revolutions Per Minute
CSV	Comma-Separated Values	SD Card	Secure Digital) cards
D	Demonstration (as verification method)	SPI	Serial Peripheral Interface
EEPROM	Electrically Erasable Programmable Read-Only Memory	T	Test (as verification method)
FEA	Finite Element Analysis	UART	Universal Asynchronous Receiver/Transmitter
GCS	Ground Control Subsystem	USART	Universal Asynchronous Receiver-Transmitter
GPS	Global Positioning System	USB	Universal Serial Bus
I	Inspection (as verification method)	UTC	Coordinated Universal Time
I2C	Inter-Integrated Circuit (I2C)	VM	Verification Method

System Overview

Ryan Liu and Sarah Ho

Mission Summary

Mission Objectives

1. Deploy a Cansat that replaces the rocket's nose cone, launching to **725 meters** and deploying upon rocket parachute charge activation, measuring ascent and descent speeds
2. Opens aero-braking heat shield for stable **10 - 30m/s** descent, controlled by tilt sensor.
3. At 100m, releases heat shield, deploys parachute for **<5m/s** descent.
4. Ensures egg, simulating delicate instrument, lands intact.
5. Equipped with sensors for altitude, temperature, voltage, GPS; pitot tube for speed; camera for ascent and descent recording.

Bonus Objectives (Attempting)

1. Camera: Use a secondary video camera to capture the Cansat being deployed from the rocket and the release of the parachute. Must record in color, have a resolution of **640x480** and a frame rate of **30 frames/sec**
2. Bonus objective <u>will</u> be attempted

External Objectives

1. Provide all team members with practical experience in the engineering design process and allow them to apply skills and knowledge that they have obtained

Summary of Changes Since PDR (1/3)

System	PDR	CDR	Reasoning
Nose Cone	Vertical Length - 135 mm	Vertical Length - 147.7 mm Added 12.7 mm	Aerobraking shield has more surface area to slow down CanSat when nose cone sections open.
Nose Cone Shoulder	Cutouts surround the shoulder.	Cutouts are removed.	Completely covered nose cone shoulder makes CanSat more aerodynamic.
Landing System	Four separate landing gears are located inside nose cone.	Circular landing pad attach at four points inside nose cone.	Separate landing gears were difficult to manufacture due to numerous parts.
Cover/Wall	No Cover	Each platform has an extruded wall up to the next platform.	Covers protect each system and makes CanSat more aerodynamic.
Egg Capsule	Capsule is 90 mm in diameter and 110 mm vertically. The cap is considerably large.	Capsule is 80 mm in diameter and 95 mm vertically. The cap is a smaller portion of the capsule.	Smaller cap makes it easier for egg to be placed and removed from capsule.

Summary of Changes Since PDR (2/3)

System	PDR	CDR	Reasoning
Egg Capsule Springs	Spring Constant - 0.17 lb/mm	Top Spring Constant - 0.09 lb/mm Bottom Spring Constant - 0.05 lb/mm	Previous springs were too stiff to oscillate the egg capsule.
Grid Fins	Located at bottom of CanSat.	Located on the egg capsule platform.	Parachute containment needed to be larger. New grid fin location places center of mass closer to nose cone.
Parachute Containment	Containment takes up less than half of the bottom base.	Containment takes up over half of the bottom base.	The parachute was too large for the previous containment size.
Streamer Release	Mechanism is placed horizontally on parachute base and actuated mechanically with release of grid fins.	Mechanism is placed vertically in parachute base and actuated with the same parachute servo.	Increased size of parachute containment decreased space for streamer release.
Parachute / Streamer Servo Arm	Servo arm only covers parachute door.	Servo arm enlarged to cover parachute door and streamer mechanism.	There is not enough room to create a new mechanism to release streamer.

Summary of Changes Since PDR (3/3)

System	PDR	CDR	Reasoning
Bonus Camera	Not Attempted	Zero Spy Cam	Our video processor had the capability to record another camera

System Requirement Summary (1/5)

ID	Requirement	Rationale	Category	VM			
				A	I	T	D
C1	Functions as a nose cone during ascent	Competition Requirement	Operational	x		x	x
C3	After deployment from the rocket, the Cansat shall deploy its heat shield/aerobraking mechanism.	Competition Requirement	Operational	x		x	x
C5	Deploys parachute and releases heat shield at 100 meters.	Competition Requirement	Operational	x		x	x
C8	Carries a large hen's egg (51-65 grams).	Competition Requirement	Operational		x	x	
C10	Maintains 10-30 m/s descent rate with heat shield.	Competition Requirement	Operational	x		x	

System Requirement Summary (2/5)

ID	Requirement	Rationale	Category	VM			
				A	I	T	D
C11	Achieves <5 m/s descent rate at 100 meters.	Competition Requirement	Operational	x		x	
S1	Mass of 900 grams +/- 10 grams without egg.	Competition Requirement	Structural	x	x		
S6	Survives 15 Gs vibration.	Competition Requirement	Structural	x		x	
S7	Survives 30 G shock.	Competition Requirement	Structural	x		x	
M5	Deploys heat shield after rocket deployment.	Competition Requirement	Mechanism	x		x	

System Requirement Summary (3/5)

ID	Requirement	Rationale	Category	VM			
				A	I	T	D
M6	Heat shield limits descent rate to 10-30 m/s.	Competition Requirement	Mechanism	x		x	
M8	Protects a hen's egg from damage during flight.	Competition Requirement	Mechanism	x		x	x
E3	Easily accessible power switch required	Competition Requirement	Electrical		x		
E4	Power indicator required.	Competition Requirement	Electrical		x		
X4	Transmits telemetry once per second.	Competition Requirement	Communication	x		x	x

System Requirement Summary (4/5)

ID	Requirement	Rationale	Category	VM			
				A	I	T	D
SN1	Measures speed with a pitot tube during ascent and descent.	Competition Requirement	Sensor	x		x	
SN2	Measures altitude using air pressure.	Competition Requirement	Sensor	x		x	
SN7	Includes a horizontal video camera.	Competition Requirement	Sensor		x	x	
G2	Ground station generates CSV files of all sensor data.	Competition Requirement	Ground Station	x		x	x
G4	Maintains configuration states during processor reset.	Competition Requirement	Ground Station	x		x	

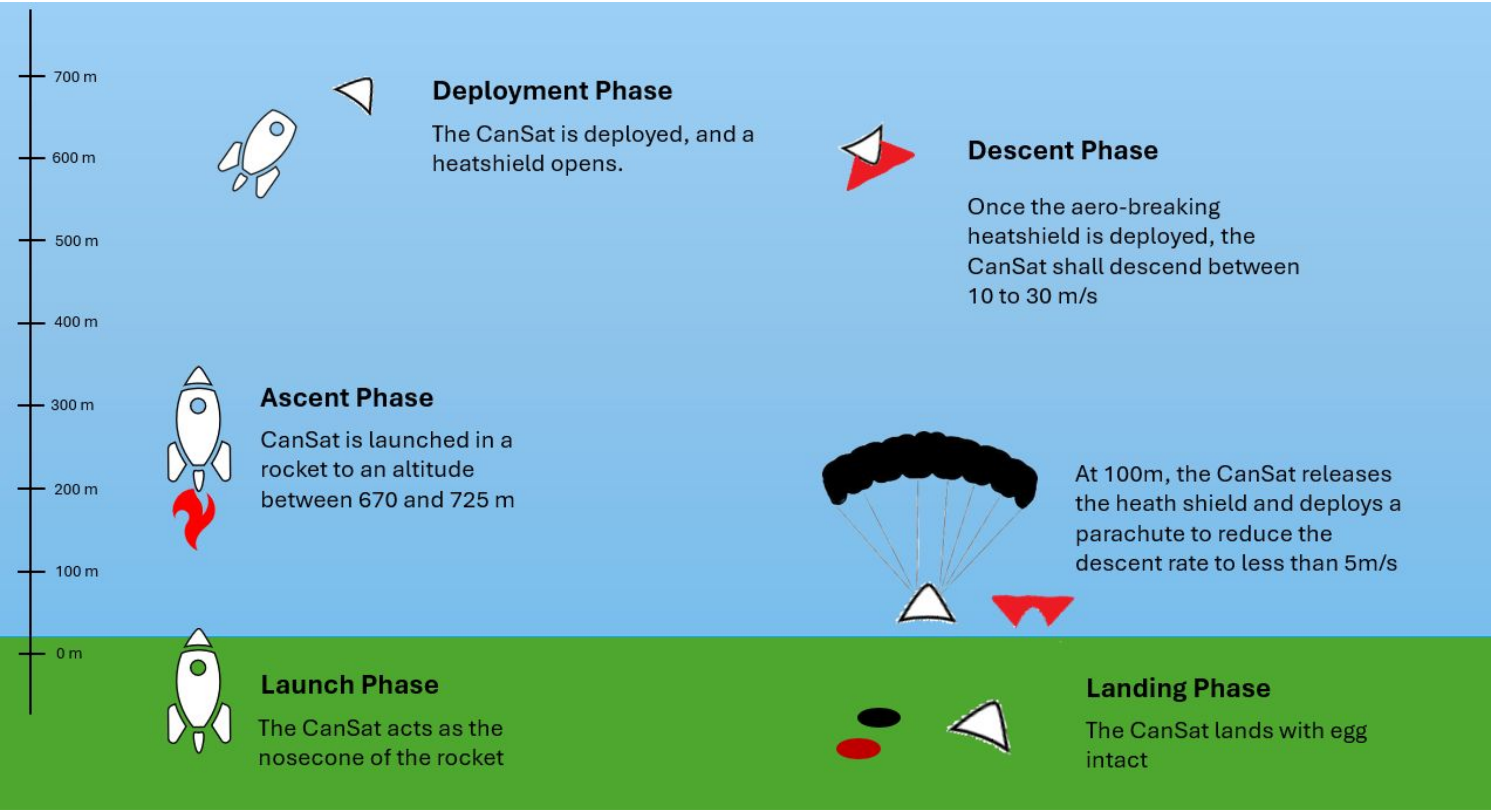
System Requirement Summary (5/5)

ID	Requirement	Rationale	Category	VM			
				A	I	T	D
G5	G5 Each team shall develop their own ground station.	Competition Requirement	Ground Station		x		
F2	Maintains mission time throughout the mission with resets.	Competition Requirement	Flight Software	x		x	

System Concept of Operations (1/2)

Pre-Flight	Flight Readiness, Safety Inspection, Preflight Briefing	Pre-Flight Preparations and Checklist Calibration Check	Establish Connection between CanSat and Ground Station	Load CanSat into Rocket Payload Section	Command CanSat to Begin Sending Telemetry to Ground Station
Ascent			Telemetry Transmission from CanSat to Ground Station		
Release	Rocket Payload (CanSat) Released from Rocket Bay	Rocket Releases the Parachute and Descends	CanSat is Ejected from Rocket Bay at a 670-725m Altitude	Aero-breaking Heat Shield is Opened	CanSat is Stabilized by Heat Shield Drag
Descent	CanSat Descend at 10-30 m/s	Heat Shield is Released from CanSat at a 100m Altitude	CanSat Deploys A Parachute	CanSat Descends at 5m/s	
Post-Flight	CanSat Lands	Egg lands intact within CanSat	CanSat stops transmitting telemetry	Audio Beacon activates, Recovery Crew retrieves CanSat	Prepare for Post-Flight Review

System Concept of Operations (2/2)



Physical Layout (1/5)

Payload Launch Configuration

Nose cone is in closed position and locked by servo motors

Landing gear hidden away inside nose cone

Grid fins upright and tensioned by torsion springs

Parachute stored and locked by servo motor/springs

Payload Heat Shield Deployment Configuration

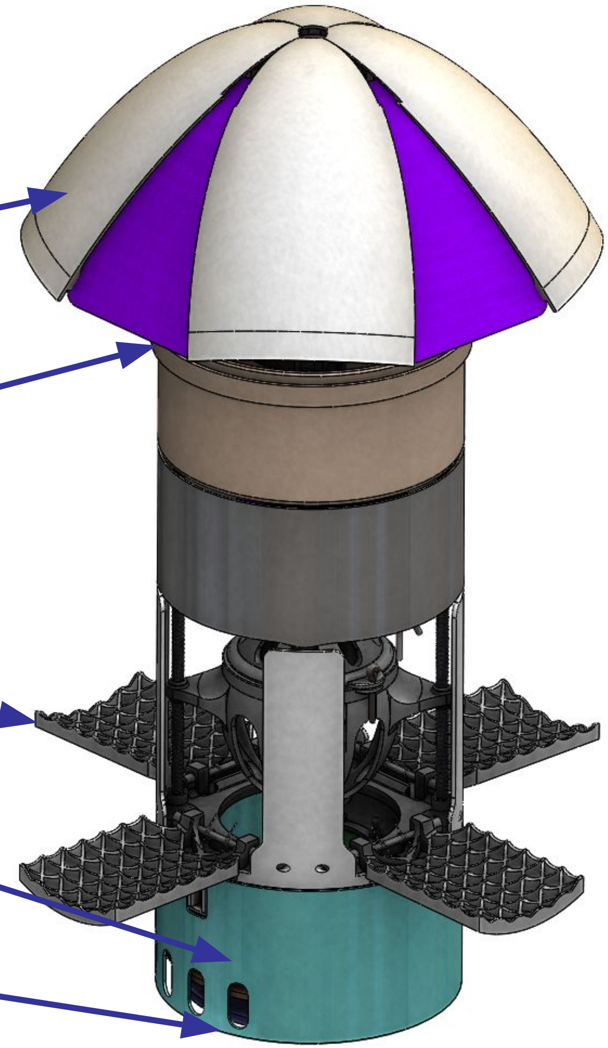
Nose cone (heat shield) is in open position and locked by servo motors

Landing gear covered by open nose cone and becomes exposed after heat shield ejects

Grid fins deployed

Parachute stored and locked by servo motor/springs

Streamer is released by servo motor as the CanSat exits the rocket



Physical Layout (3/5)

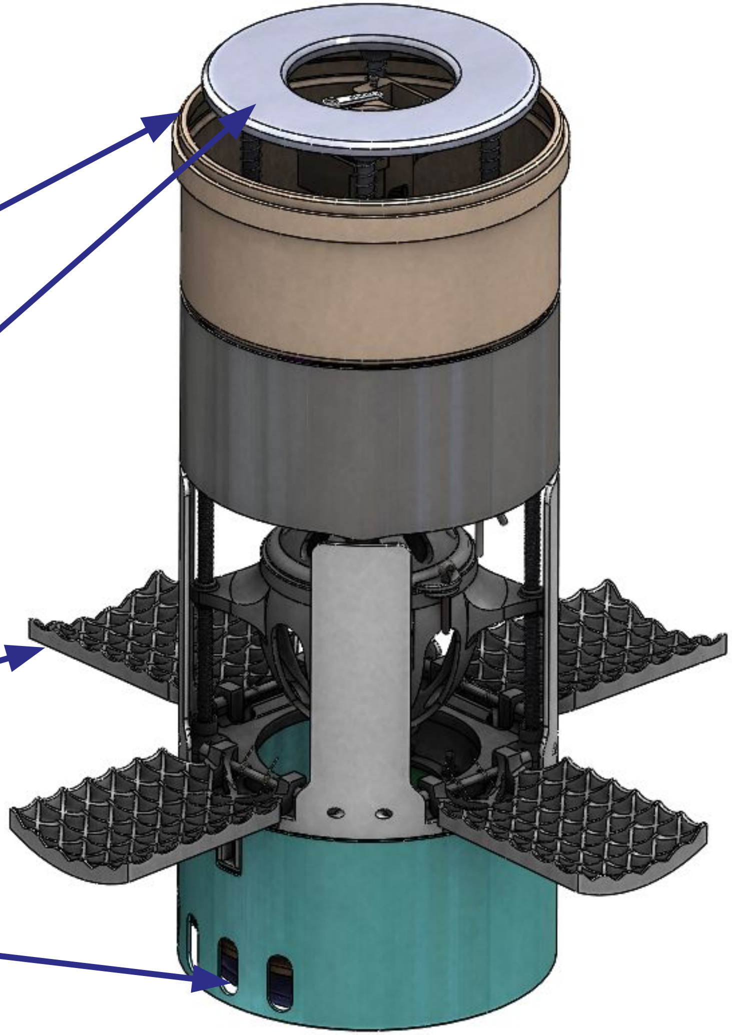
Payload Parachute Deployment

Nose cone (heat shield) ejected from shoulder

Landing gear fully exposed to environment

Grid fins still in deployed state

Parachute deployed by servo unlocking mechanism



Physical Layout (4/5)

Full Assembly

Nose Cone/Heat Shield

Landing Gear

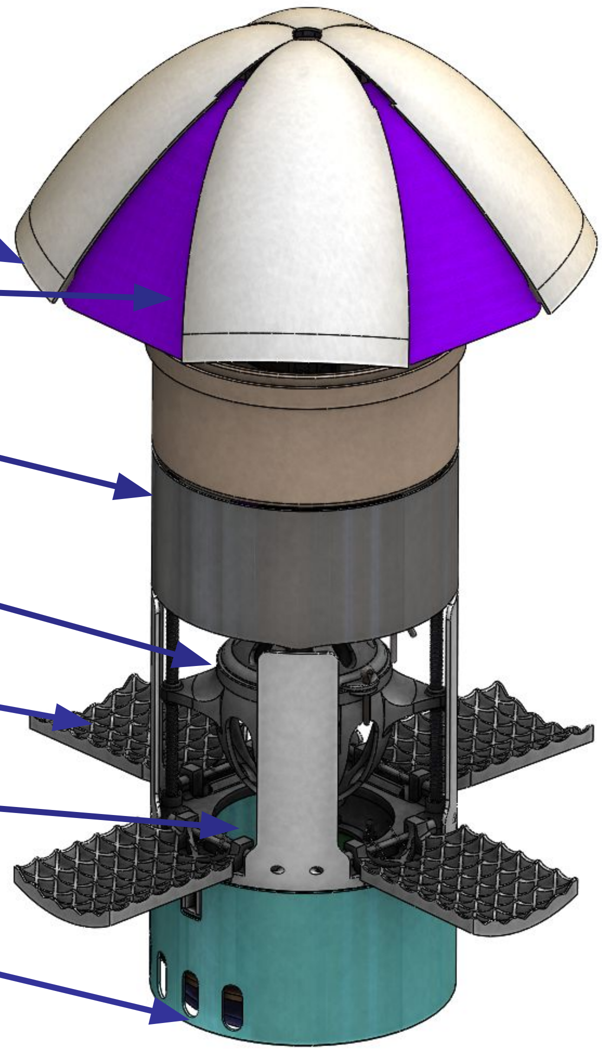
*Electronic Compartment

Egg Protection Capsule

Grid Fins

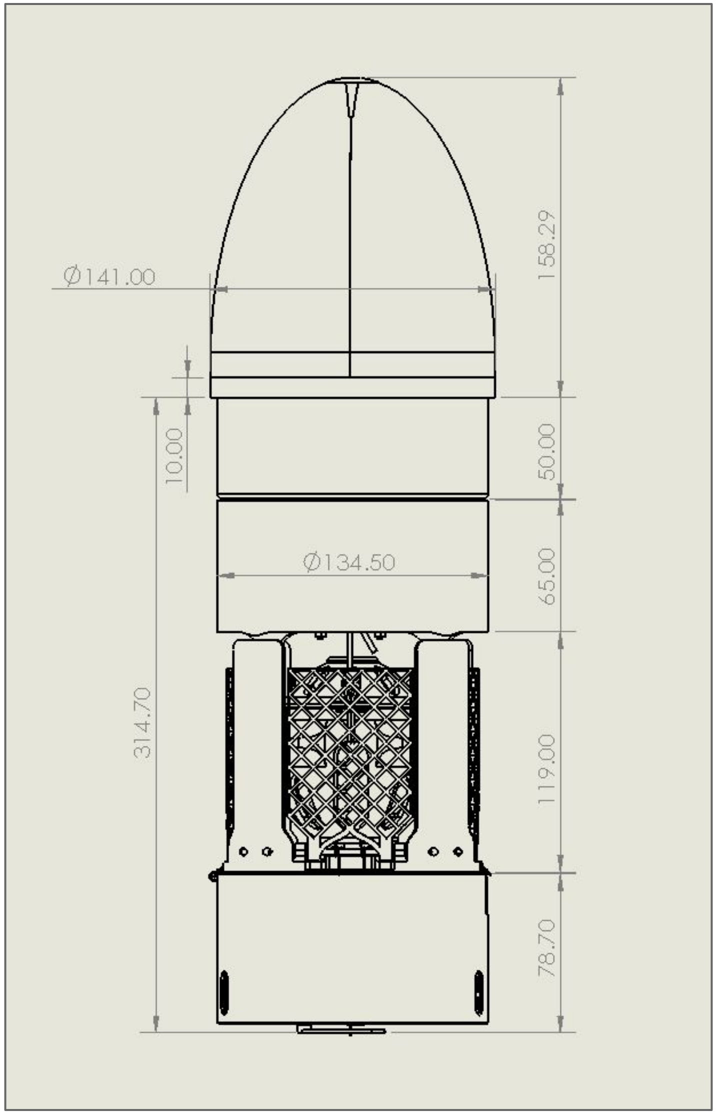
RPi + Camera

Parachute and Streamer Release Mechanism



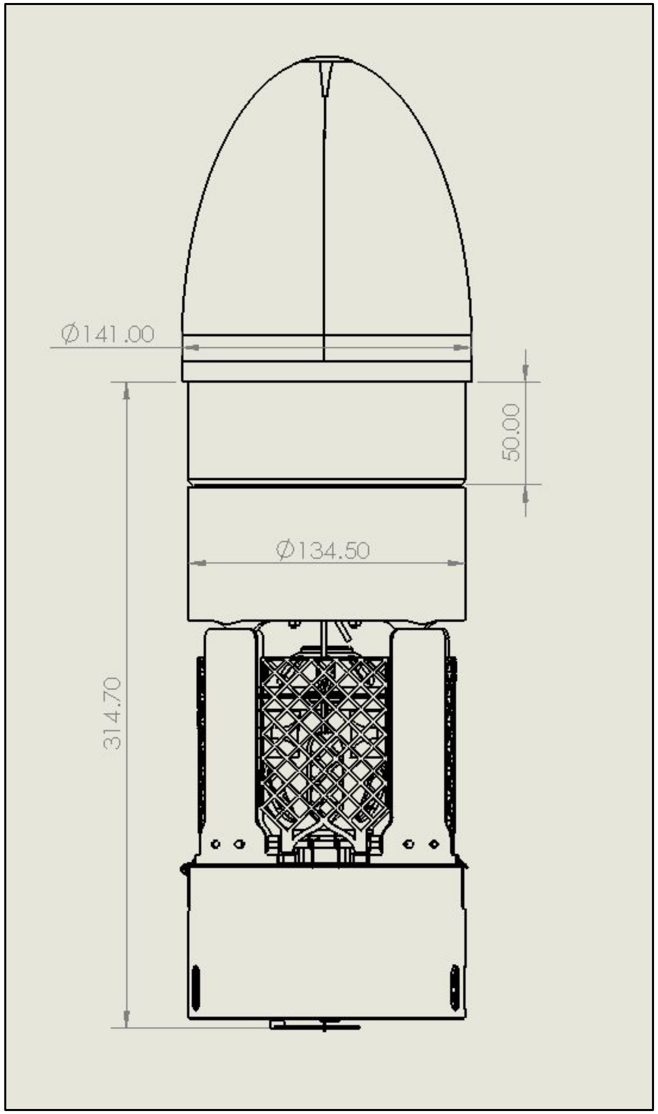
*Electronics compartment includes sensors, battery, pitot tube, and microcontroller mounted on a PCB. Camera, and servos are located outside the compartment, but are connected to the PCB with wires.

Physical Layout (5/5)

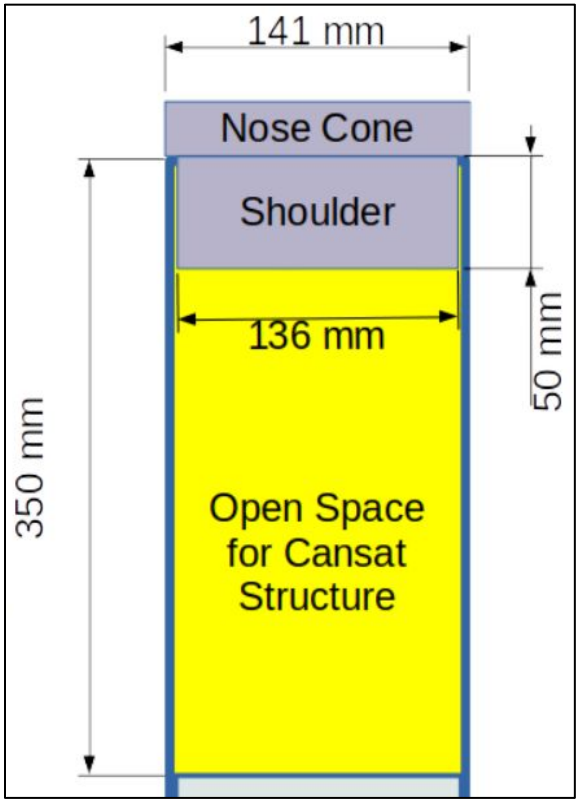


All dimensions in mm

Launch Vehicle Compatibility (1/2)



Launch Vehicle Compatibility (2/2)



Sensor	Maximum	Actual	Clearance
Shoulder Width	141mm	141mm	**0mm (No clearance needed)**
Shoulder Length	50mm	50mm	**0mm (No clearance needed)**
Payload Width	136mm	134.5mm	**1.5mm**
Payload Length	350mm	315mm	**35mm**

Sensor Subsystem Design

Jacqueline Lai

Sensor Subsystem Overview

Sensor	Model	Function
Temperature	BMP581	Measures temperature values inside CanSat
Pressure	BMP581	Measures pressure values throughout descent
Accel/Gyro	MPU-6050	Measures tilt and rotation angles in relation to x-plane
GPS	PA1010D	Measures longitudinal and latitudinal position of CanSat
Voltage	INA219	Measures battery health for electrical systems
Camera	Zero Spy Cam	Records the surrounding environment from the side view
Speed	MS4525DO	Measures static and differential pressures to calculate speed

Sensor Changes Since PDR

Sensor	Model	Function
Bonus Camera	Zero Spy Cam	To complete bonus camera objective

Payload Air Pressure Sensor Summary

Sensor	Voltage (V)	Current (mA)	Interface	Resolution (Pa)	Accuracy (Pa)	Size (mm)	Weight (g)
BMP581	**1.65 - 3.6**	**0.26**	**I2C/SPI**	**6b**	**+/- 6**	**1.95 x 1.95 x 0.7**	**<1**

$$Pascals = \frac{Raw\ Data}{64}$$

Reasoning
• Clear documentation • Fulfills resolution requirement • Less power consumption

Data Format
• Values will be stored in on-board memory as floats in units of kilopascals (kPa)

Payload Air Temperature Sensor Summary

Sensor	Interface	Resolution (C)	Accuracy (K)	Operating Temp. (C)	Size (mm)	Weight (g)
BMP 581	I2C/ SPI	16b	+/- 0.5	-40C ~ 85C	1.95 x 1.95 x 0.7	<1

$$K = \frac{Raw\ Data}{65536}$$

$$C = K - 273.15$$

Reasoning
• Satisfies resolution requirement • Size efficient • Power efficient • Well documented and wide availability for coding examples

Data Format
• Values will be stored in on-board memory as floats in degrees Celsius

Payload GPS Sensor Summary

Sensor	Tracking Sensitivity (dBm)	Interface	Voltage (V)	Time-to-First-Fix (s)	Tracking Current (mA)	Weight (g)	Cost (USD)
Adafruit PA1010D Module	-165	I2C or UART	3.3 or 5	Instant (orbit prediction)	28	5	29.95

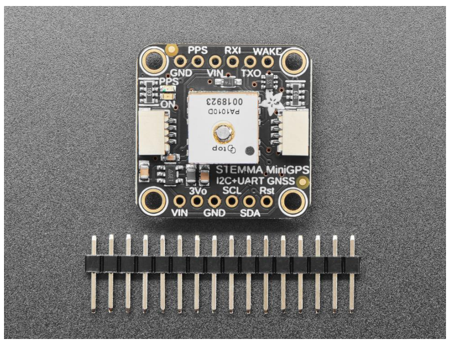


Table-10: RMC Data Format

Name	Example	Units	Description
Message ID	$GNRMC		RMC protocol header
UTC Time	155503.000		hhmmss.sss
Status	A		A → data valid or V → data not valid
Latitude	5606.1725		ddmm.mmmm
N/S Indicator	N		N → North or S → South
Longitude	01404.0622		dddmm.mmmm
E/W Indicator	E		E → East or W → West
Speed over Ground	0.04	knots	
Course over Ground	165.48	degrees	True
Date	260406		ddmmyy
Magnetic Variation	3.05, W	degrees	E → East or W → West
Mode	A		A → Autonomous mode D → Differential mode E → Estimated mode
Checksum	*2C		
<CR> <LF>			End of message termination

Reasoning

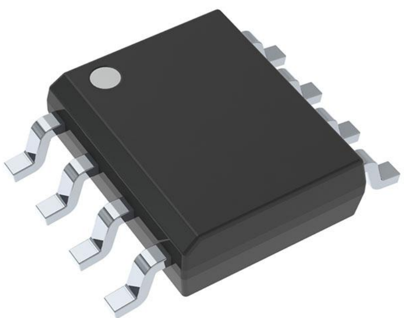
- Extensive Documentation
- Low Power
- Excellent time-to-first-fix
- Good sensitivity
- Uses I2C

Data Format

- Latitude and longitude values will be stored in on-board memory as floats in units of degrees
- Altitude values will be stored in on-board memory as floats in units of meters
- The number of satellites tracked will be stored in on-board memory as an integer.

Payload Voltage Sensor Summary

Sensor	Interface	Resolution (V)	Accuracy	Voltage Input Range	Weight
INA219	I2C	6b	+/- 0.2%	0.0 ~ 26V	2.57 g



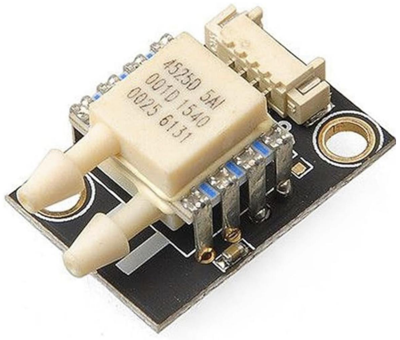
$$V = (Register\ Value >> 3) \times 0.004$$

Reasoning
• Lightweight • Can be integrated into existing power setup • Reliable sourcing

Data Format
• Values will be stored in on-board memory as floats in units of volts (V)

Speed Sensor Summary

Item	Interface	Voltage	Mass	Resolution (psi)	Accuracy
MS4525DO	I2C, SPI	3.3V, 5V	3.0	14b	0.25%



$$kPa = \frac{psi}{6.895}$$

$$v = \sqrt{\frac{2 \times \Delta(p_{tip} - p_{side})}{\rho_{air}}}$$

Reasoning

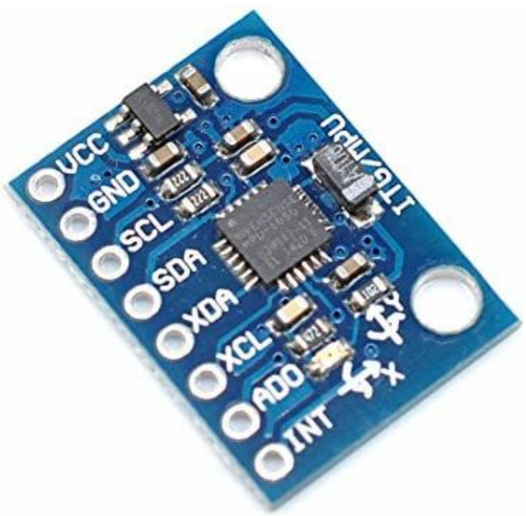
- Easy to read documentation
- Large voltage operating range
- High accuracy
- Lightweight
- Fulfills requirement for pitot tube

Data Format

- Values will be stored in on-board memory as floats in units of meters per second (m/s)

Payload Tilt Sensor Summary

Sensor	Voltage (V)	Current (mA)	Interface	Resolution (°)	Accuracy	Size (mm)	Weight (g)
MPU 6050	3.3	35	I2C, SPI, UART	5b	+/- 2%	21.2 x 16.4 x 3.3	11.1



Reasoning

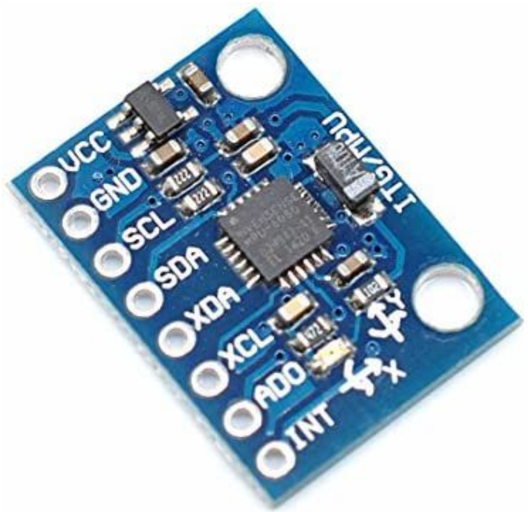
- Robust sensor packaging
- Superb documentation
- Legacy; experience from prior year
- Has rotation detection with the onboard gyroscope

Data Format

- Tilt angle values will be stored in on-board memory as floats in units of degrees.

Payload Rotation Sensor Summary

Sensor	Voltage (V)	Current (mA)	Interface	Resolution (°)	Accuracy	Size (mm)	Weight (g)
MPU 6050	3.3	35	I2C, SPI, UART	5b	+/- 2%	21.2 x 16.4 x 3.3	11.1



$$Rotation = \frac{Raw\ Data}{131}$$

Reasoning

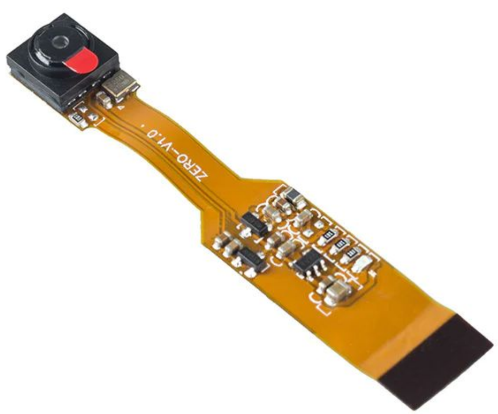
- Cheaper than competing options
- Superb documentation
- Legacy; experience from prior year
- Works together with tilt detection, allowing 2 uses with 1 sensor

Data Format

- Rotation rate values will be stored in on-board memory as floats in units of degrees per second

Camera Summary

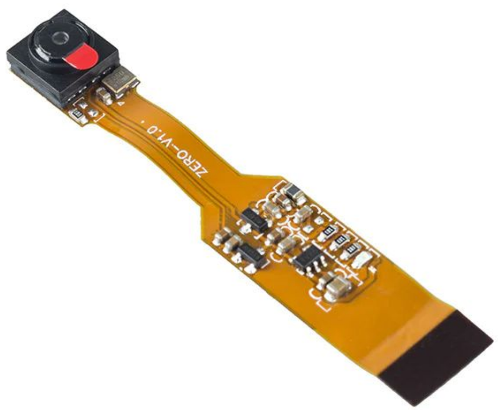
Sensor	Resolution@ 30fps	Processor Interface	Voltage* (V)	Current* (mA)	Size (mm)	Weight (g)
Zero Spy Camera	720p	Raspberry Pi Zero	5	250-300	8.6 x 8.6 x 5.2	10



Reasoning
• Dependable Camera • Meets all desired requirements • Lower power draw

Bonus Camera Summary

Sensor	Resolution@ 30fps	Processor Interface	Voltage* (V)	Current* (mA)	Size (mm)	Weight (g)
Zero Spy Camera	720p	Raspberry Pi Zero	5	250-300	8.6 x 8.6 x 5.2	10



Reasoning
• Dependable Camera • Meets all desired requirements • Lower power draw

Descent Control Design

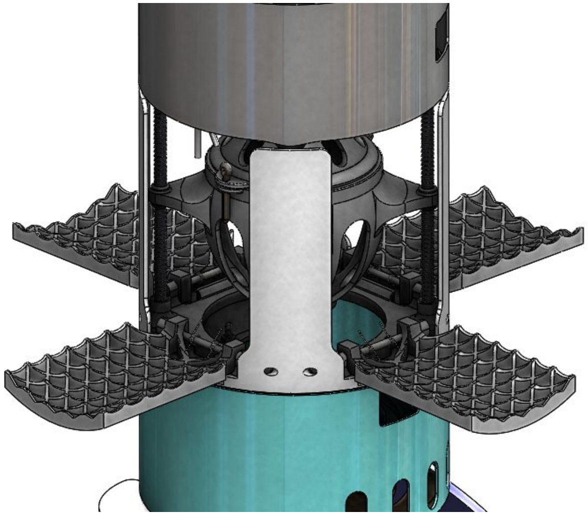
Jeremy Rose and Jerome Masicat

UCI CANSAT

Descent Control Overview

CAN SAT COMPETITION

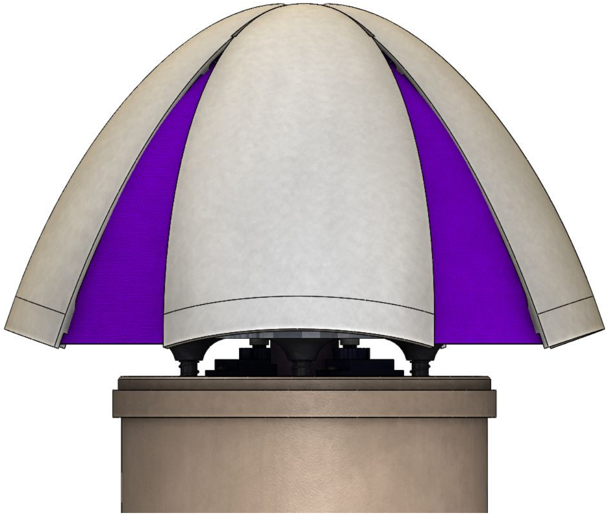
Grid Fins



Descent Stability + Rotational Control

Flight Range: 725m - 0m

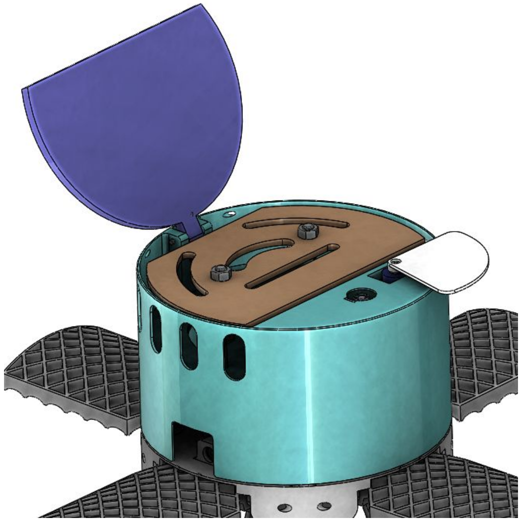
Nose Cone



Aerobraking

Flight Range: 725m - 100m

Parachute



Descent Control

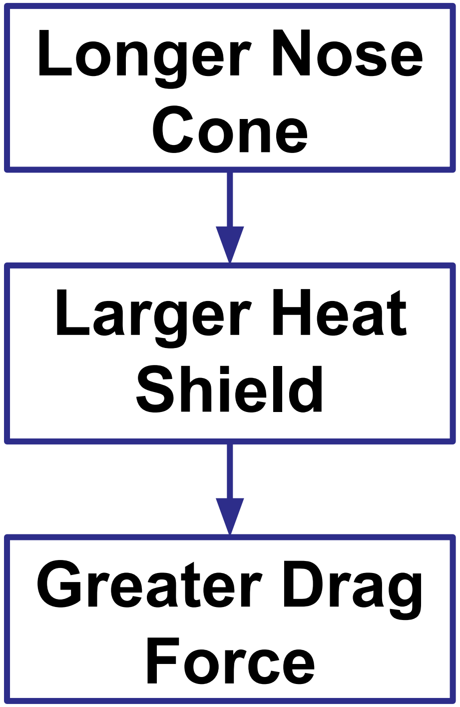
Flight Range: 100m - 0m

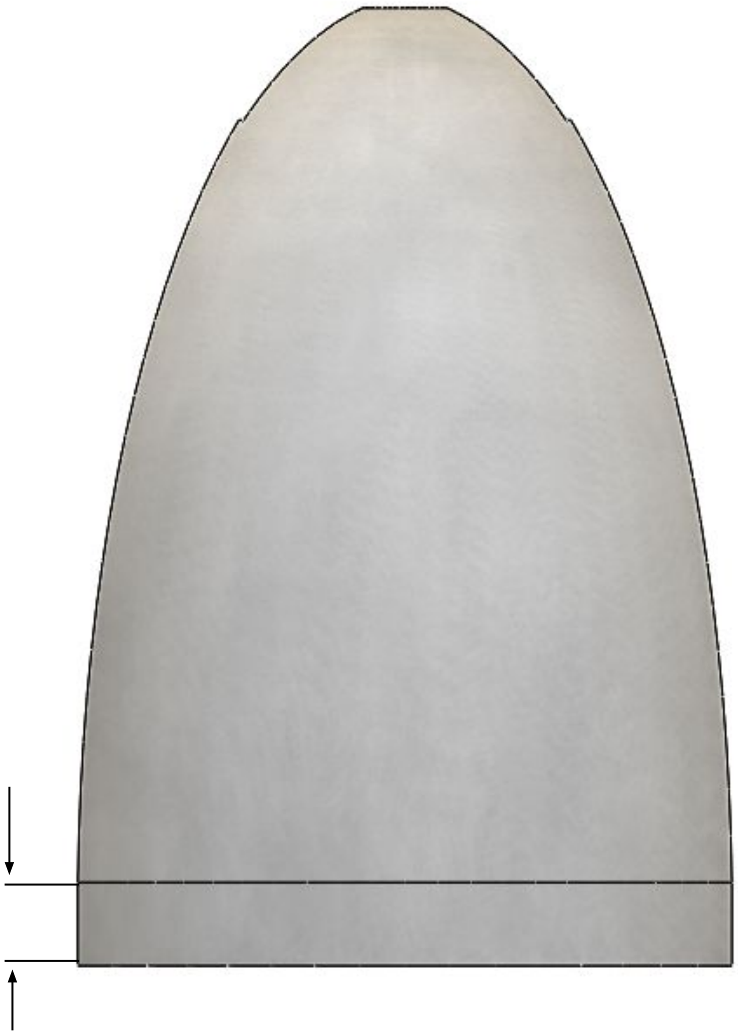
Descent Control Changes Since PDR (1/4)

System	PDR	CDR	Reasoning
Nose Cone	Vertical Length - 135 mm	Vertical Length - 147.7 mm Added 12.7 mm	Aerobraking shield has more surface area to slow down CanSat when nose cone sections open.
Nose Cone Shoulder	Cutouts surround the shoulder.	Cutouts are removed.	Completely covered nose cone shoulder makes CanSat more aerodynamic.
Parachute Containment	Containment takes up less than half of the bottom base.	Containment takes up over half of the bottom base.	The parachute was too large for the previous containment size.

Change #1: Longer Nose Cone

Rationale:





Descent Control Changes Since PDR (3/4)

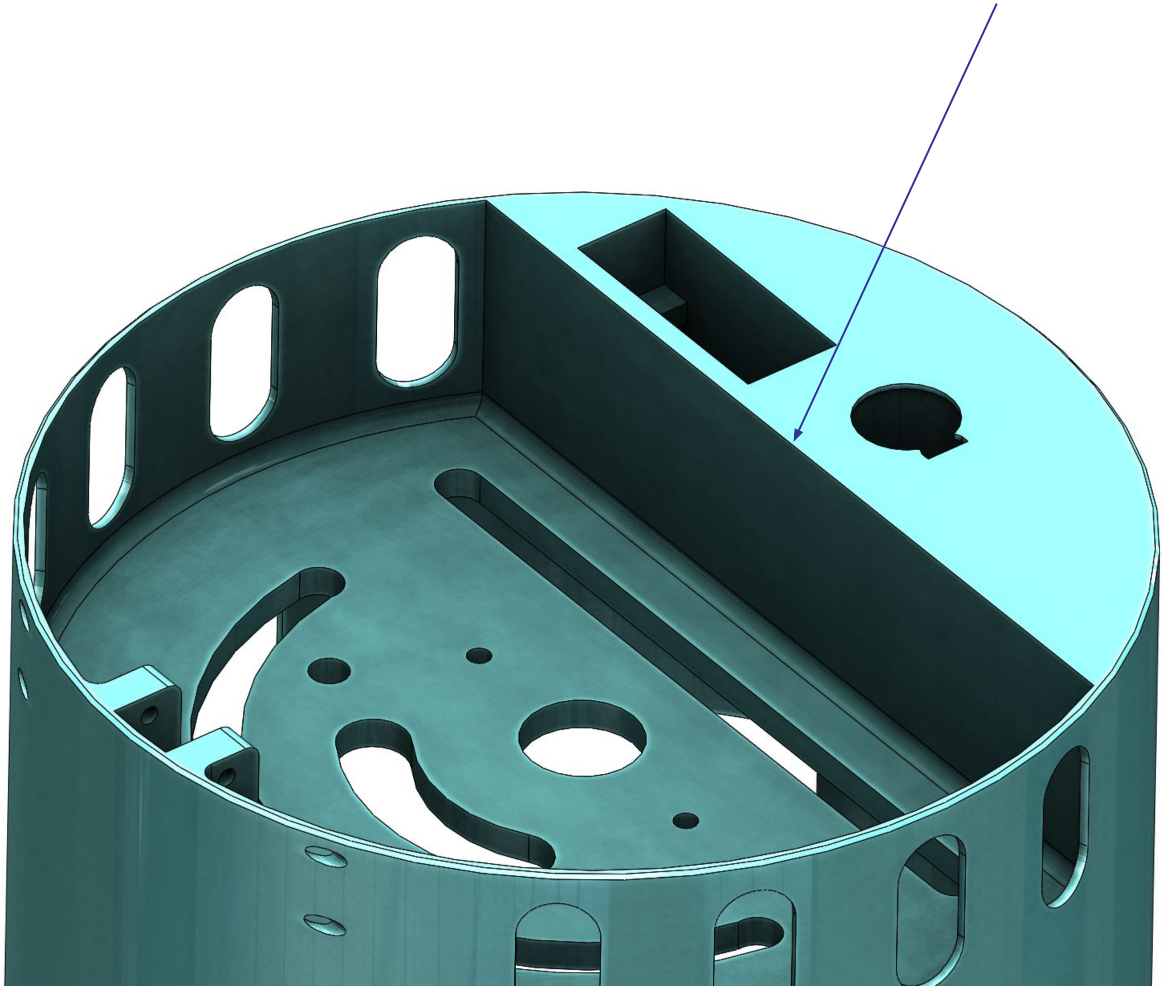
Change #2: Increased Parachute Volume

Rationale:

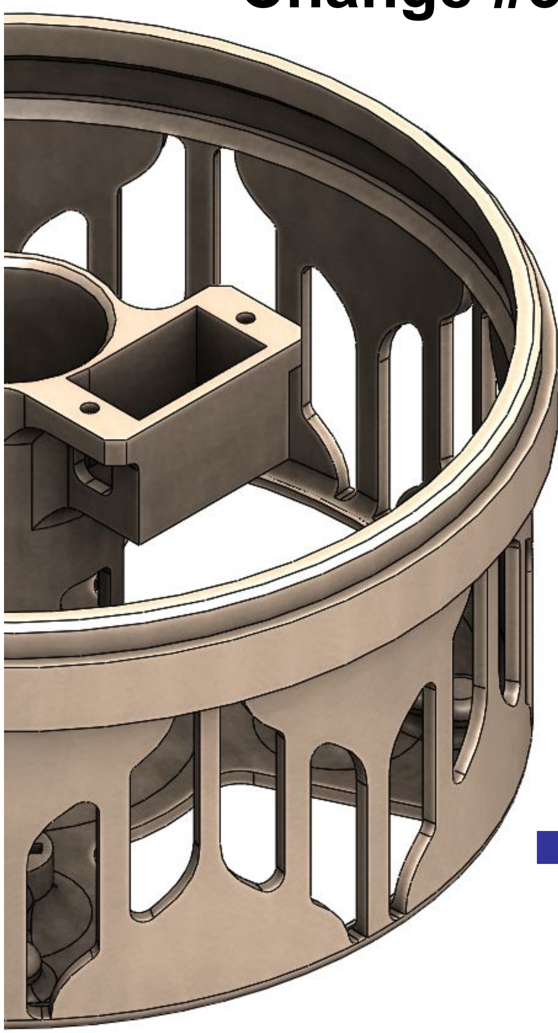
Larger Parachute Volume

↓

More Reliable Parachute Release



Change #3: Removed Nose Cone Base Cutouts

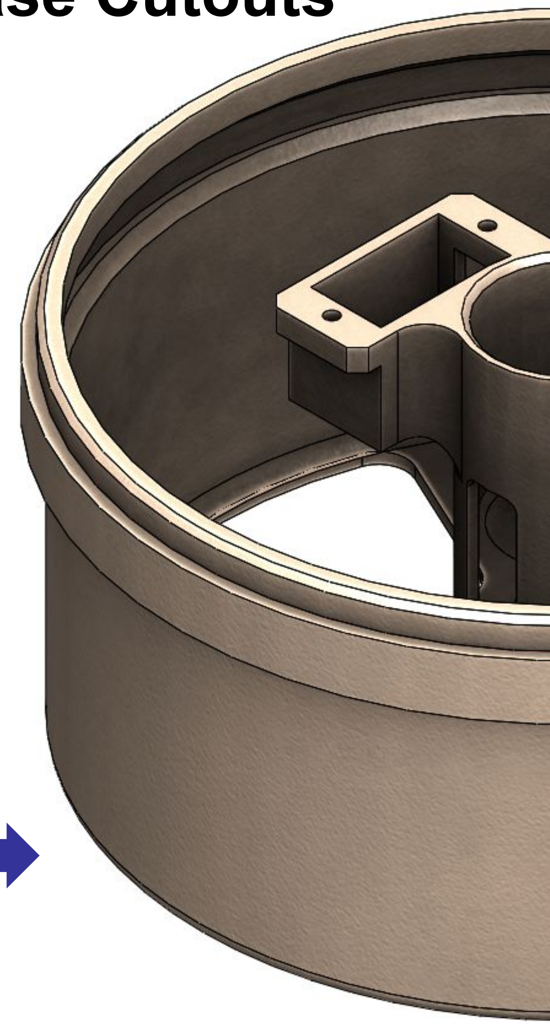


Rationale:

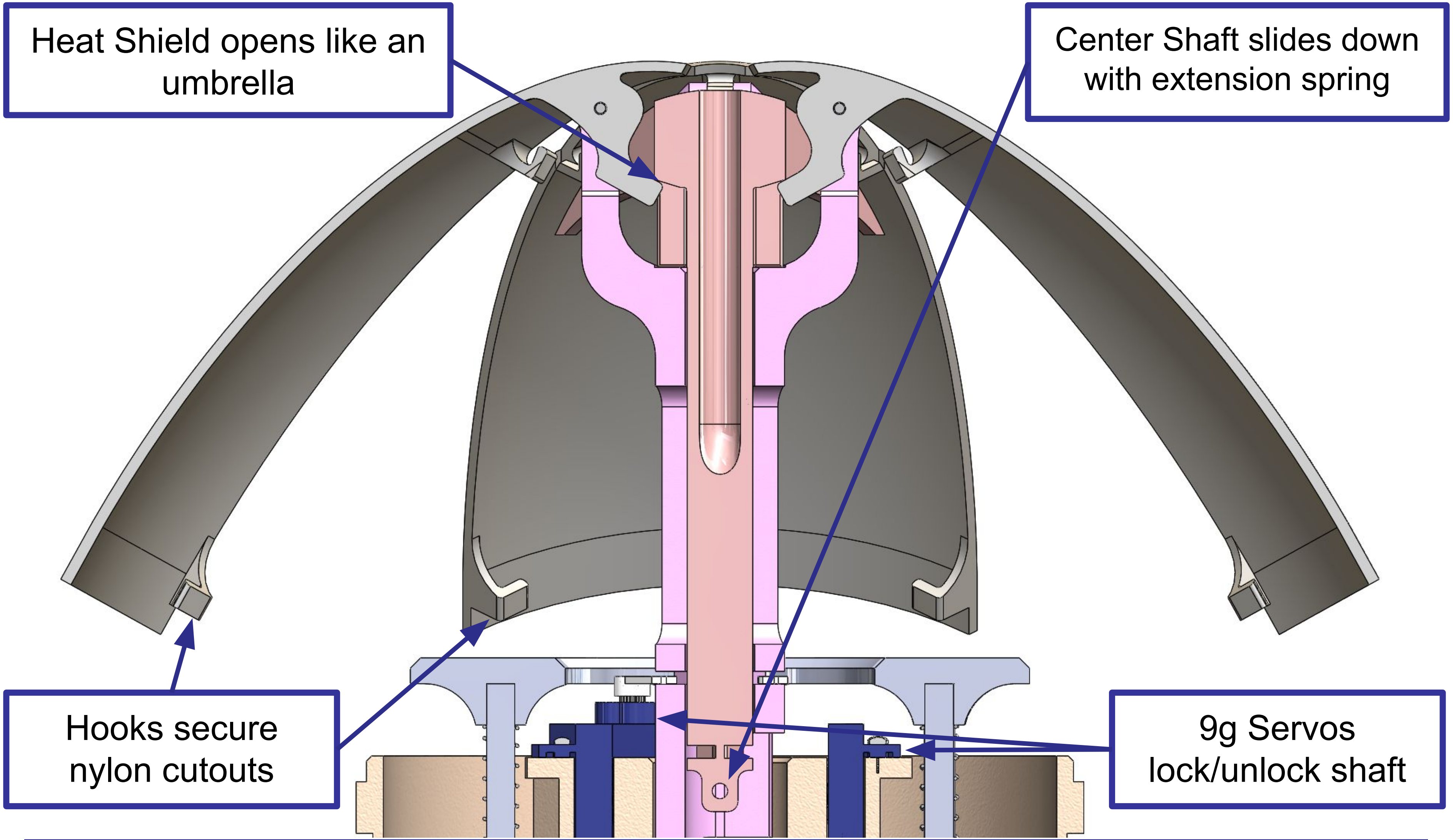
No cutouts

↓

More Aerodynamically Stable

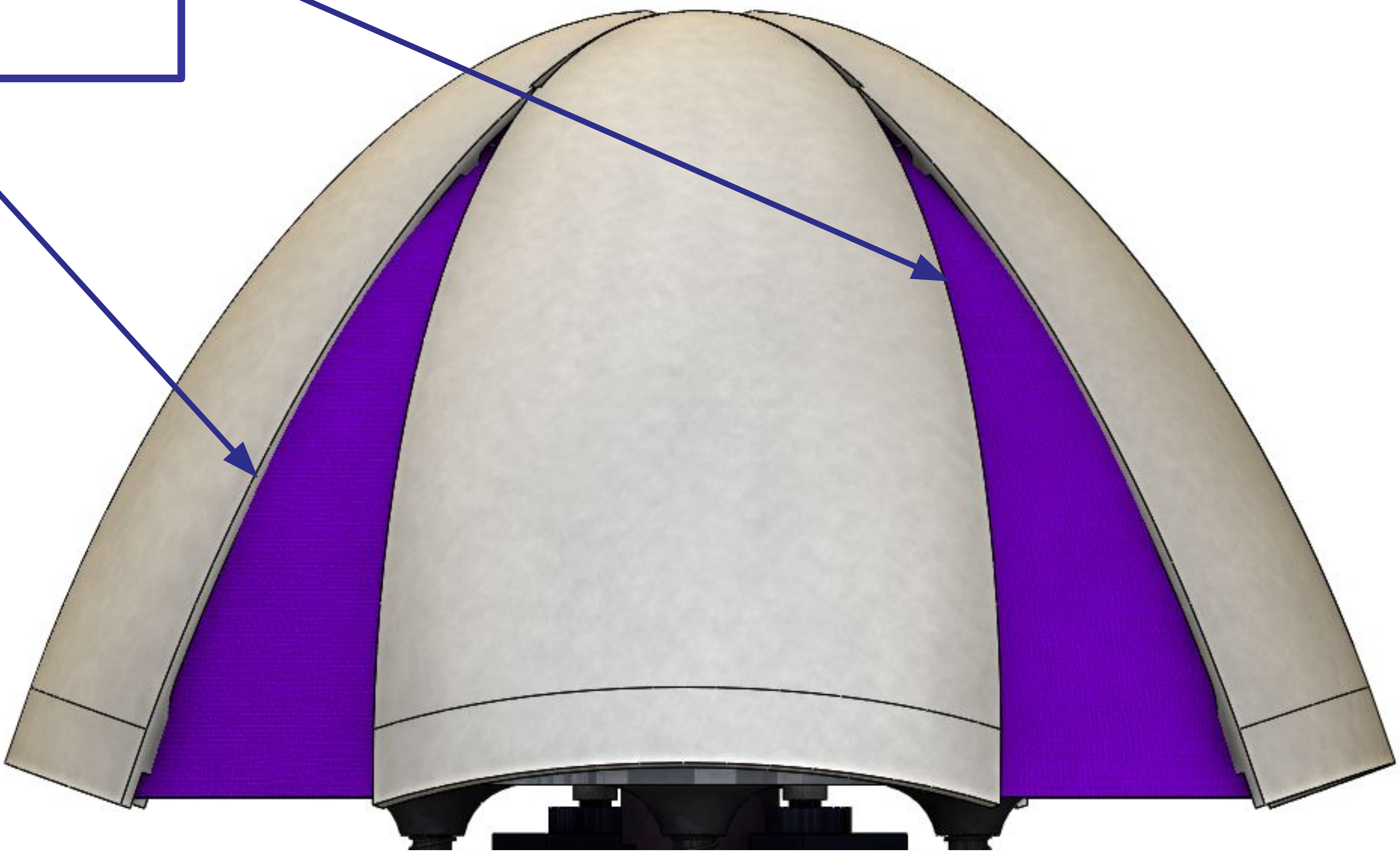


Payload Aerobraking Descent Control Hardware Summary (1/6)

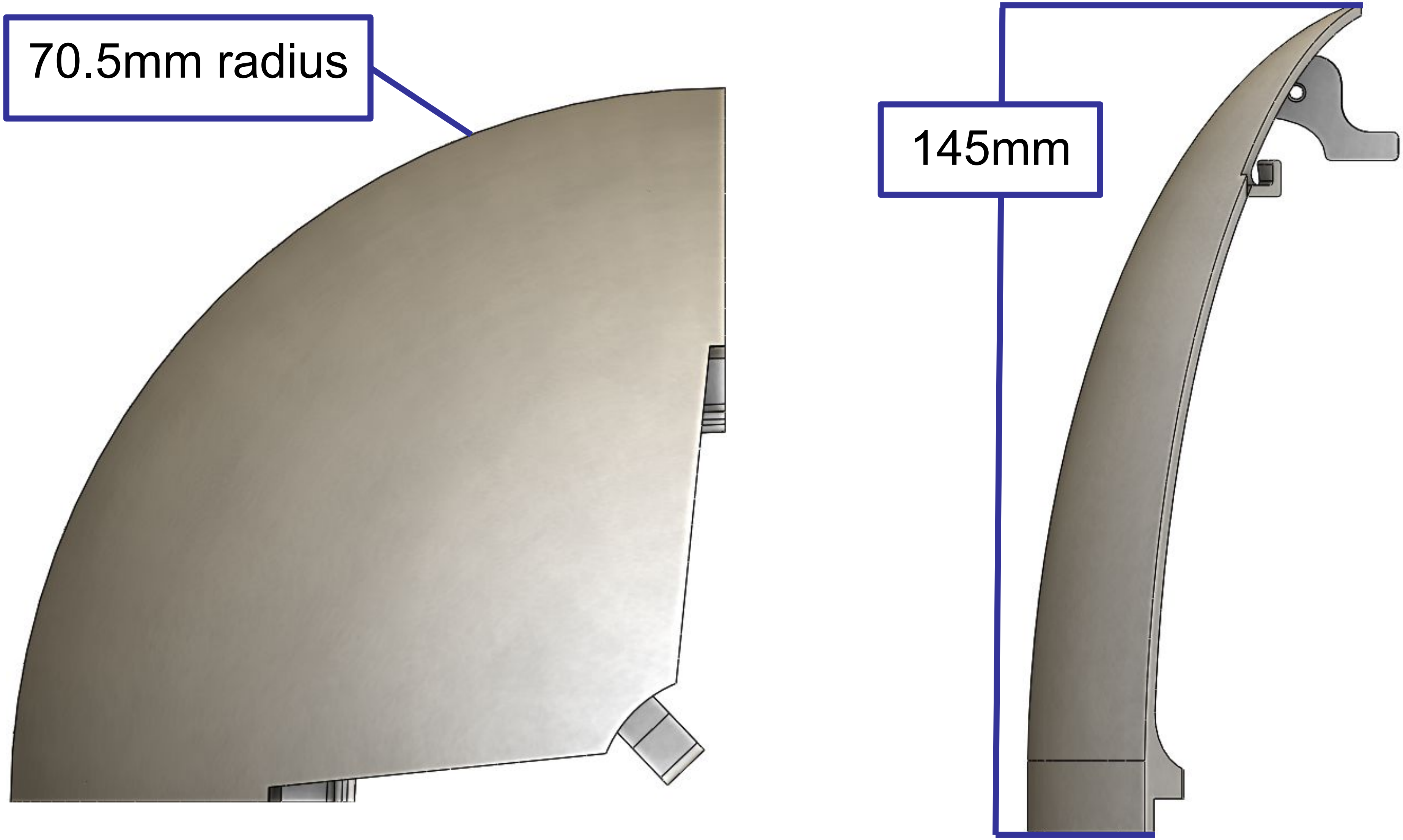


Payload Aerobraking Descent Control Hardware Summary (2/6)

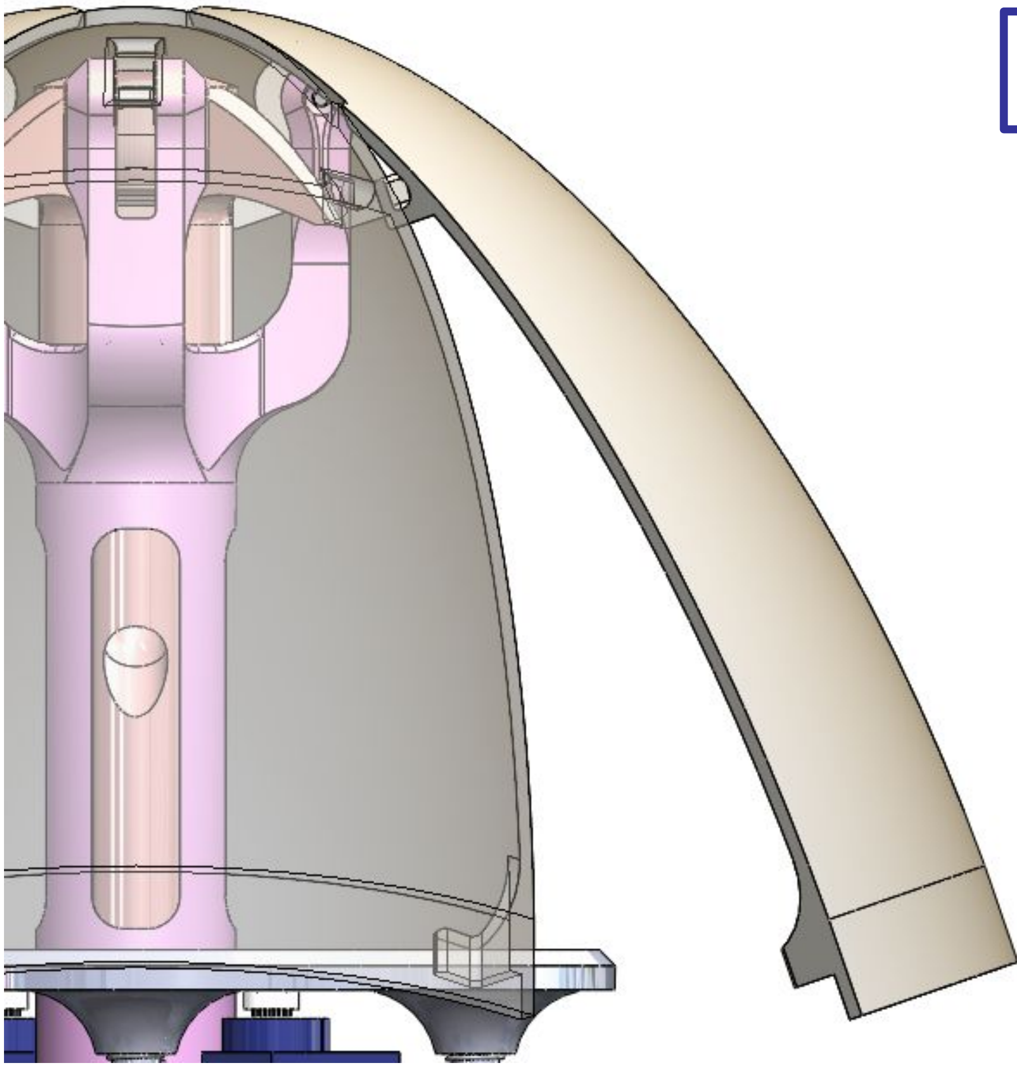
Each section is filled with nylon cutouts, secured to the inside of nose cone



Payload Aerobraking Descent Control Hardware Summary (3/6)



Payload Aerobraking Descent Control Hardware Summary (4/6)



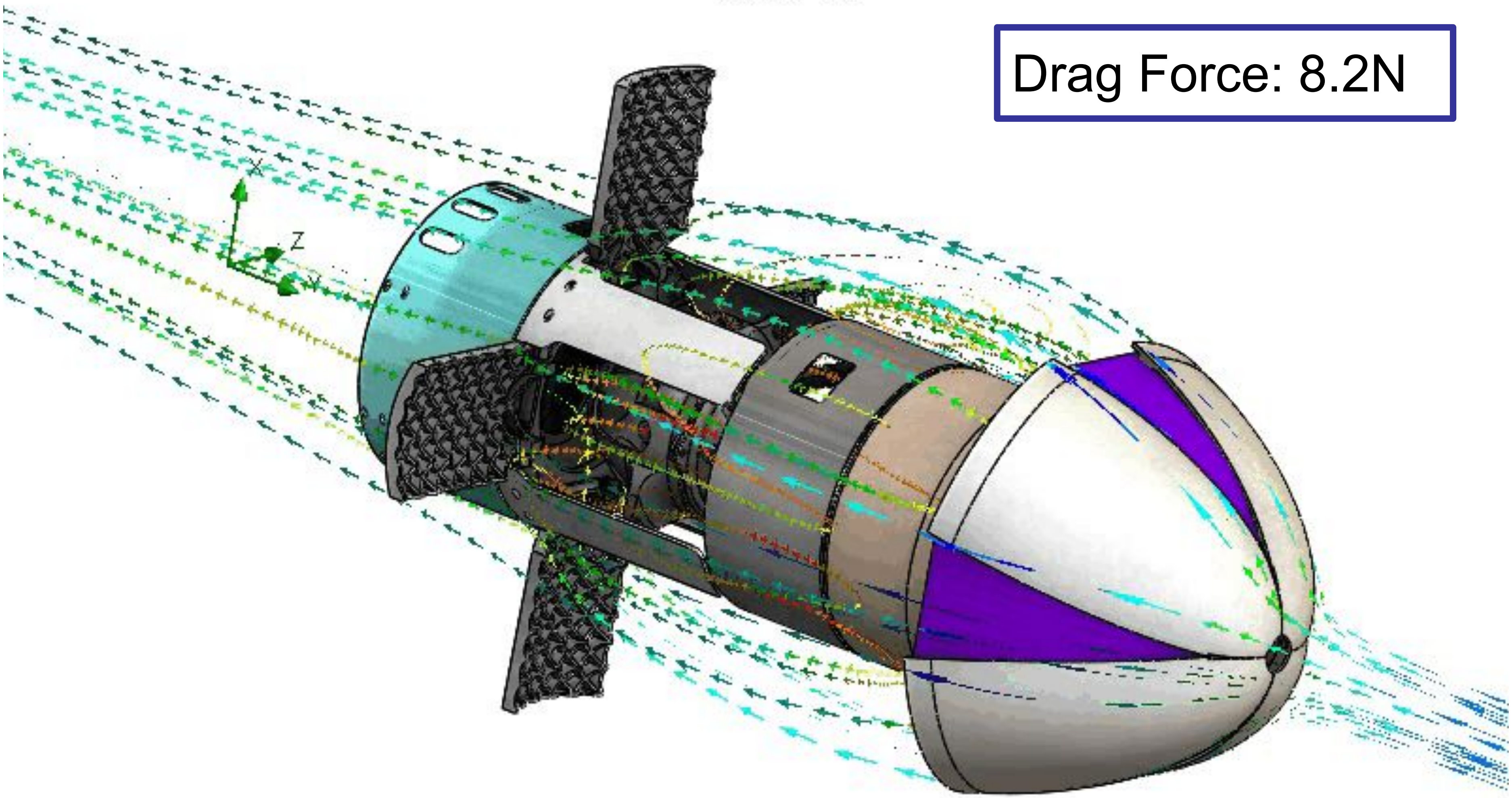
Heat Shield **Area: .518m^2**

Axis Angle from Vertical:
30 degrees

Heat Shield Thickness:
2mm

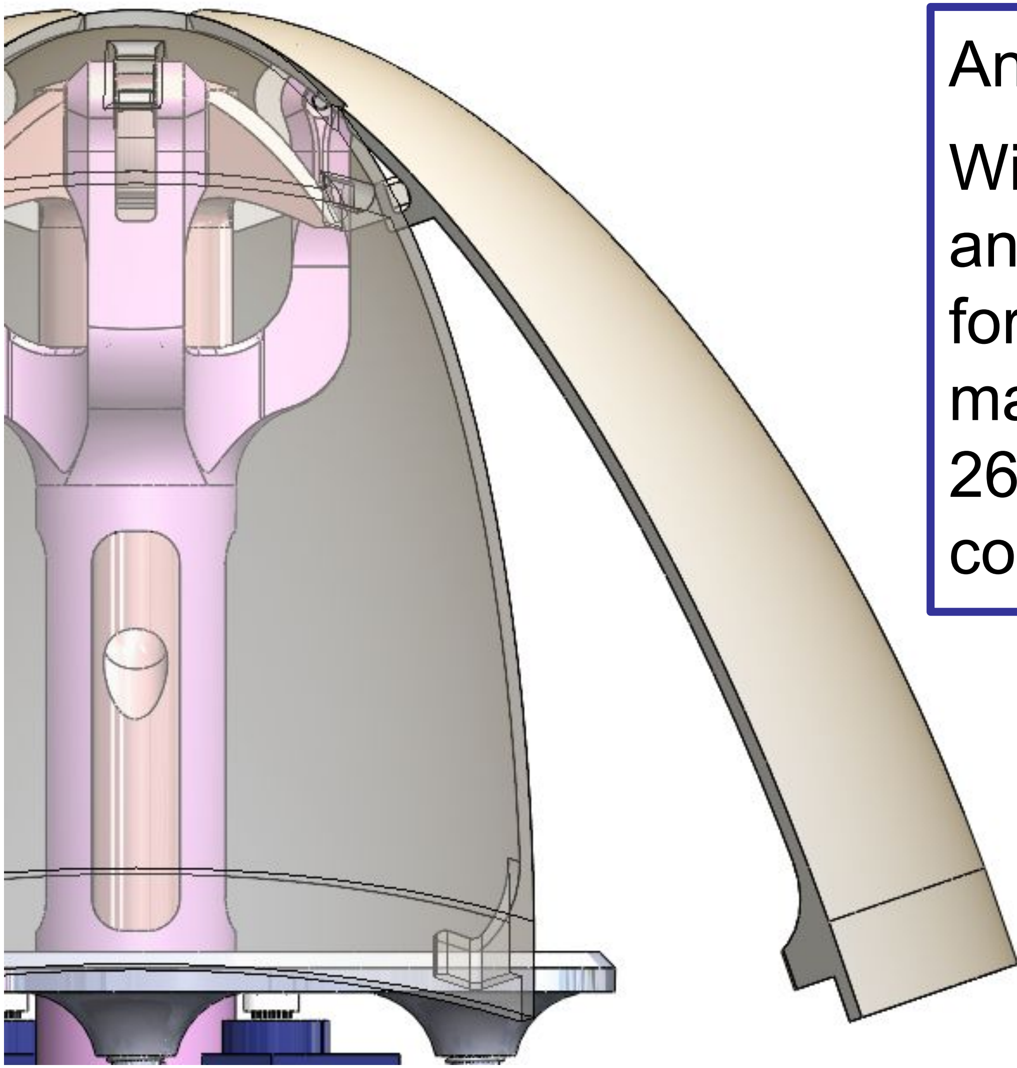
Heat Shield **Color**:
Spray Painted
Neon Orange

Payload Aerobraking Descent Control Hardware Summary (5/6)



Drag Force: 8.2N

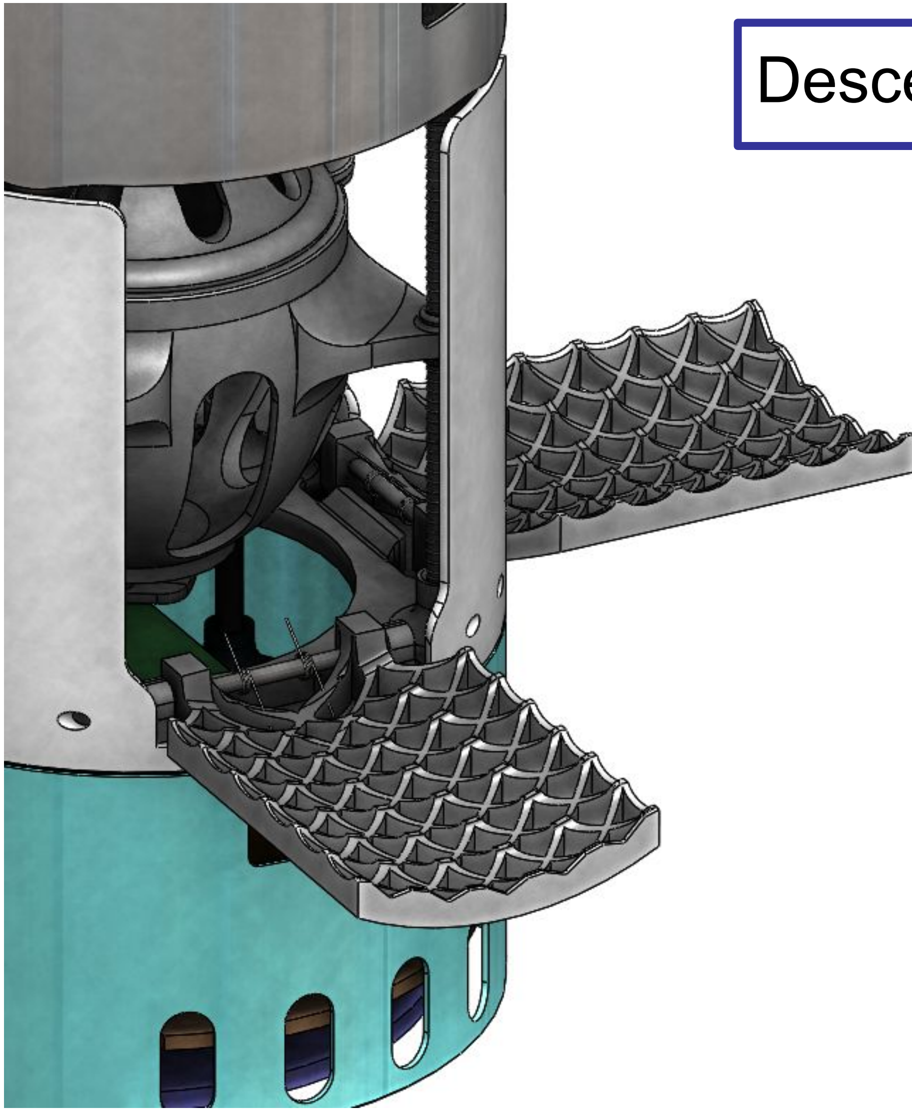
Payload Aerobraking Descent Control Hardware Summary (6/6)



Angle Selection Reasoning:

With a 30 degree Heat Shield angle, this gives us 6.8N of force, which gives us a maximum terminal velocity of 26.1m/s under perfect laminar conditions (unrealistic).

Payload Descent Stability Control Design (1/2)



Descent Stability Control: Grid Fins

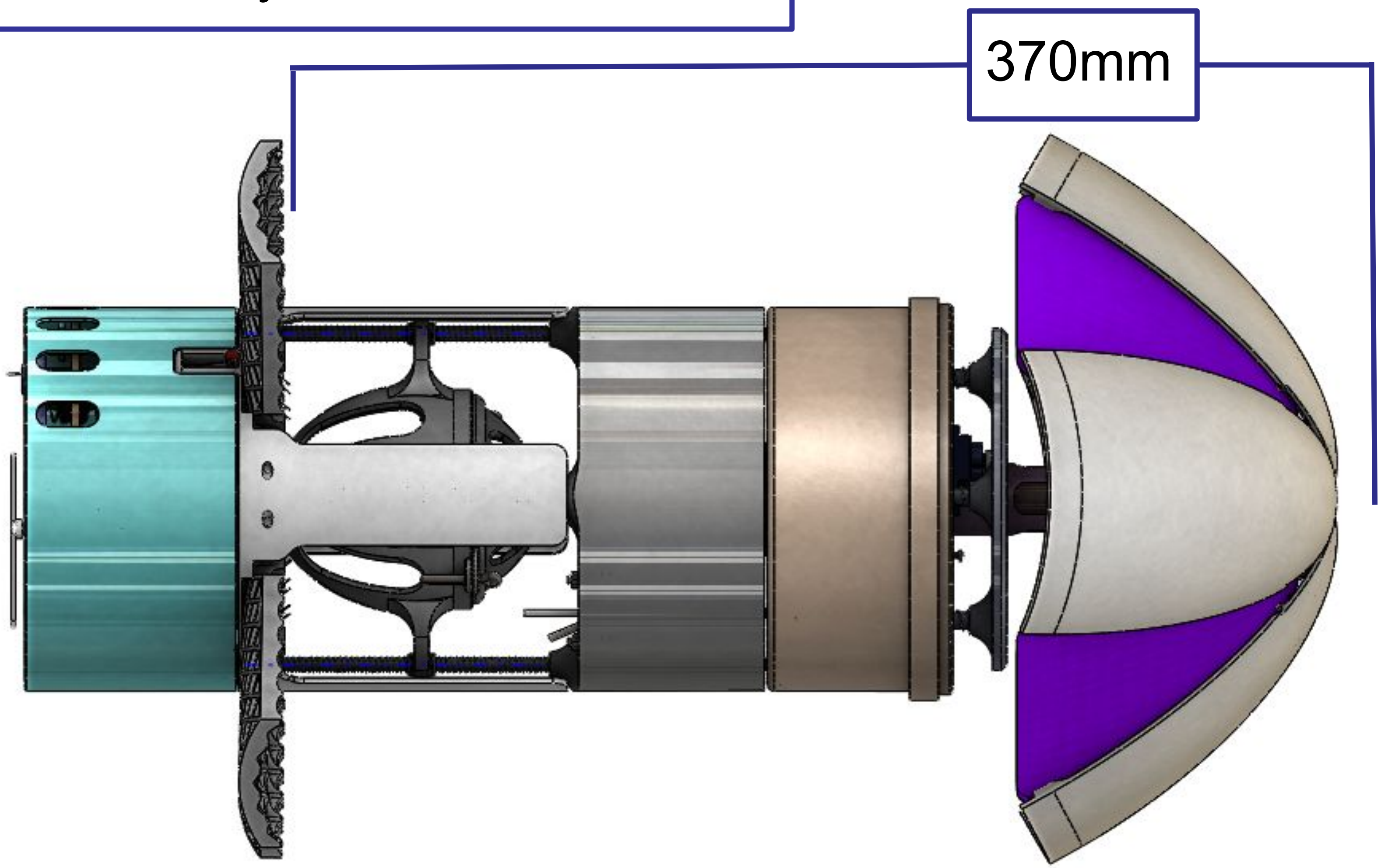
Passive Stability Control

Used to bring center of pressure farther back on the aerobody and keep pointing in nadir direction

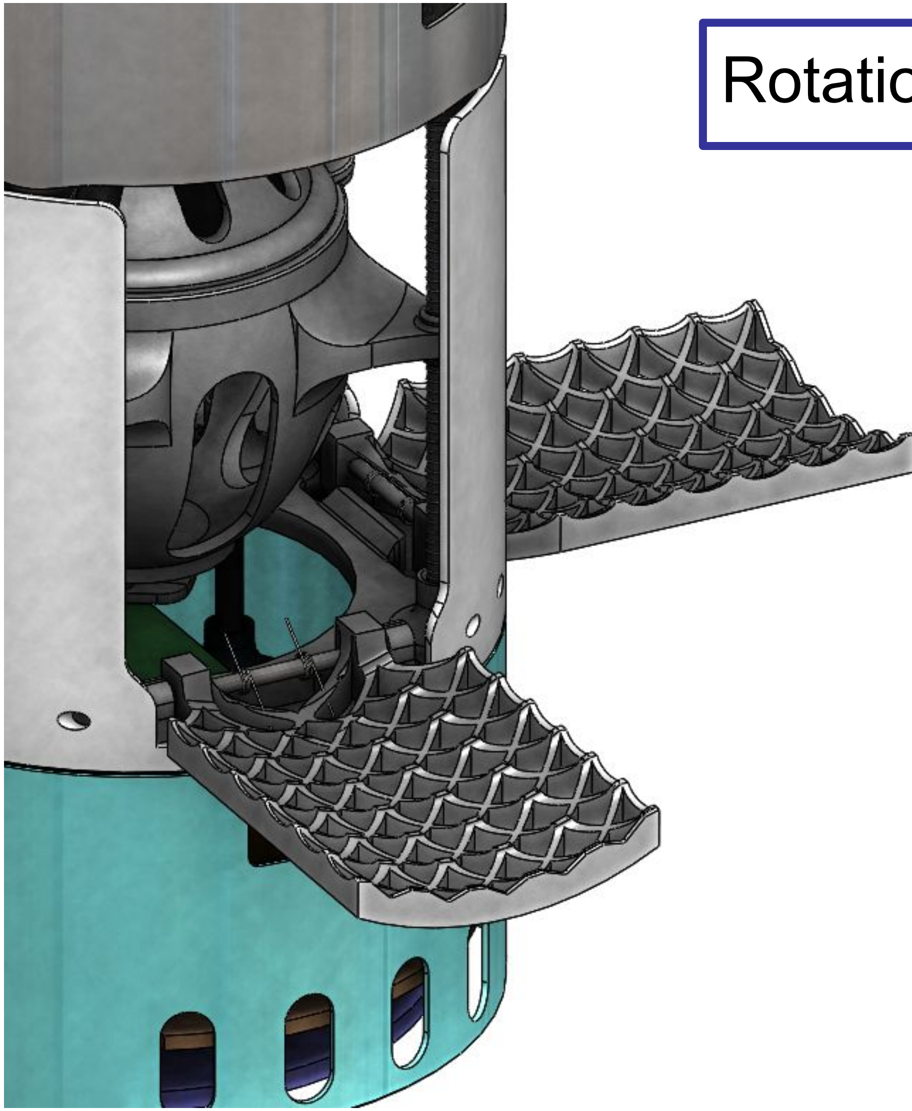
Spring-loaded fins automatically open on rocket exit

Payload Descent Stability Control Design (2/2)

Descent Stability Control: Grid Fins



Payload Rotation Control Strategy



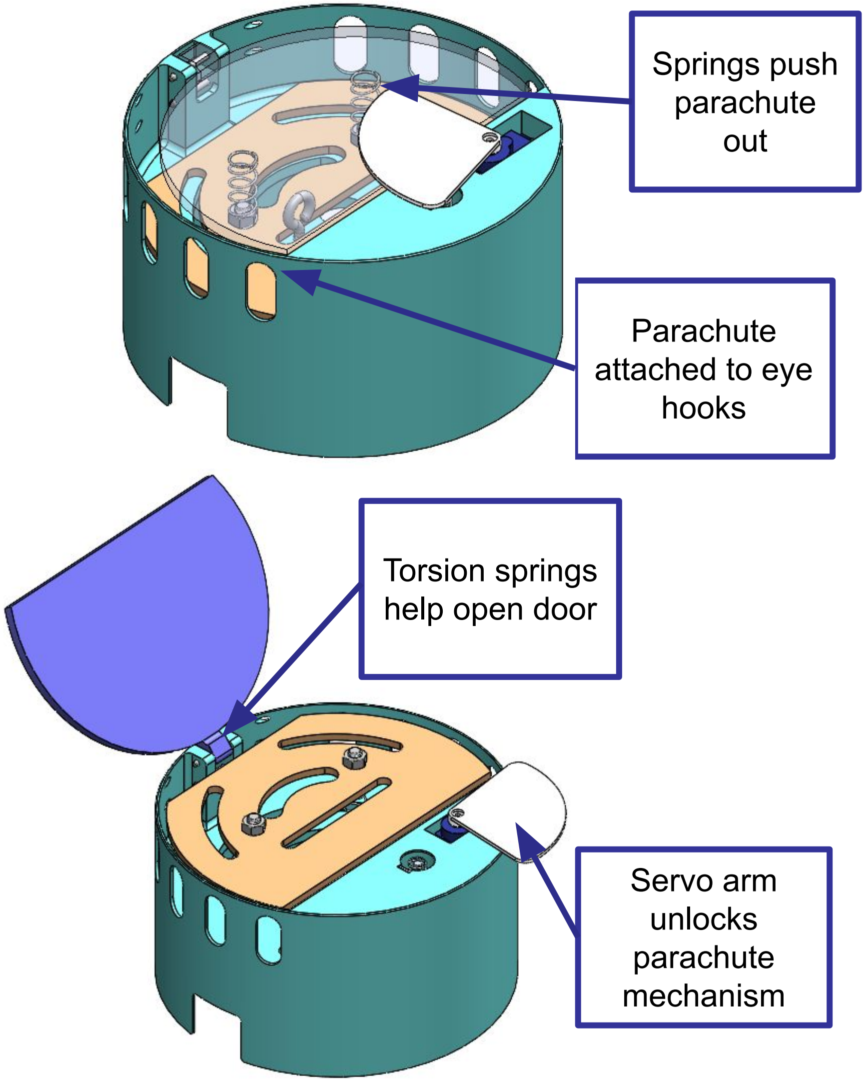
Rotational Stability Control: Grid Fins

Passive Stability Control

Air Flow moves around grid fins, counteracting rotation over the aerobody

Increased thickness would further increase anti-rotation

Payload Parachute Descent Control Hardware Summary (1/2)



Key Design, Sizing and Color

The parachute is an off-the-shelf, 30” elliptical parachute with a center spill hole.

Parachute will be bright yellow and black for visibility.

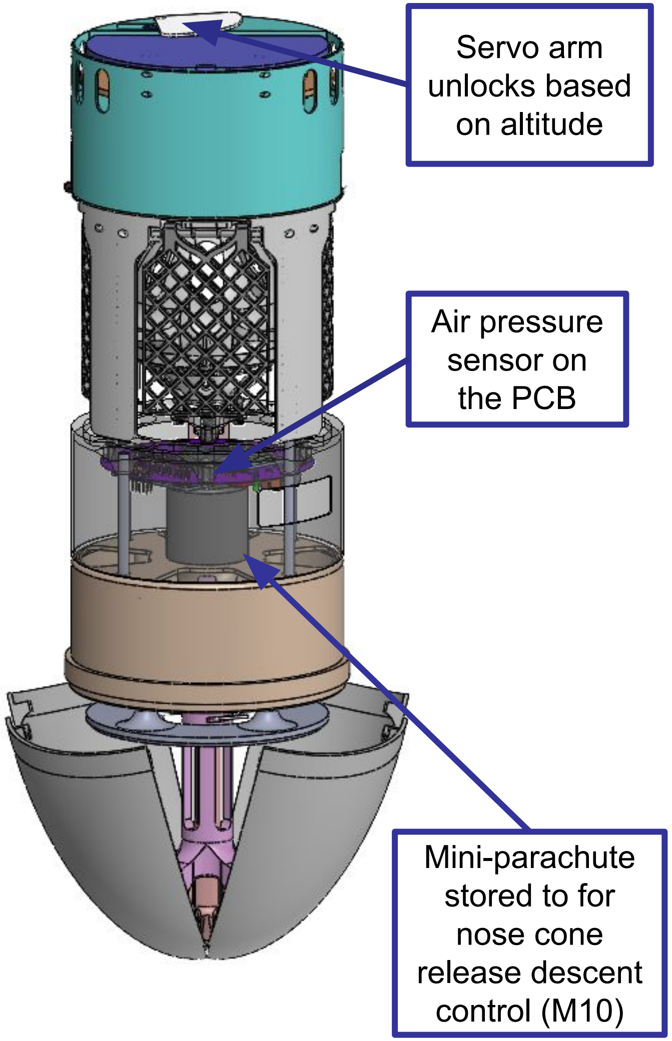
Sizing based off descent rate calculations after aerobrake has released.

How It Works:

The parachute is stored internally and is locked behind a servo arm.

Once the pressure sensor detects the altitude has reached 100m, the servo arm moves and unlocks the parachute deployment mechanism.

Payload Parachute Descent Control Hardware Summary (2/2)



Data Processing Overview:

Step	Description
Initialize sensor	Send I2C ready check to both temperature and pressure sensor
Calibrate zero altitude	Note temperature and pressure on launchpad to calibrate zero altitude
Get data	Communicate with BMP581 over I2C to read temperature and pressure data
Calculate altitude	Calculate altitude using formula: $(T_0/0.0065)*((P/P_0)\text{^}(1/5.257 - 1))$

Descent Rate Estimates (1/6)

Payload Aerobraking

Assumptions:

- 700m above sea level (from US Air Standard Properties)
  - $\rho = 1.1459 \text{ kg/m}^3$
  - $g = 9.805 \text{ m/s}^2$
- Mass (Probe + Egg + Nose Cone): 950g

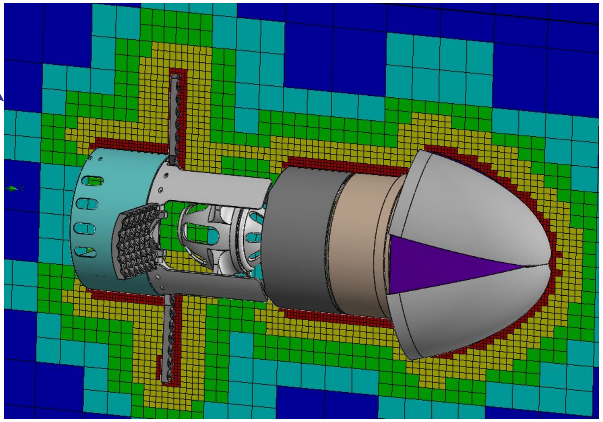
Given:

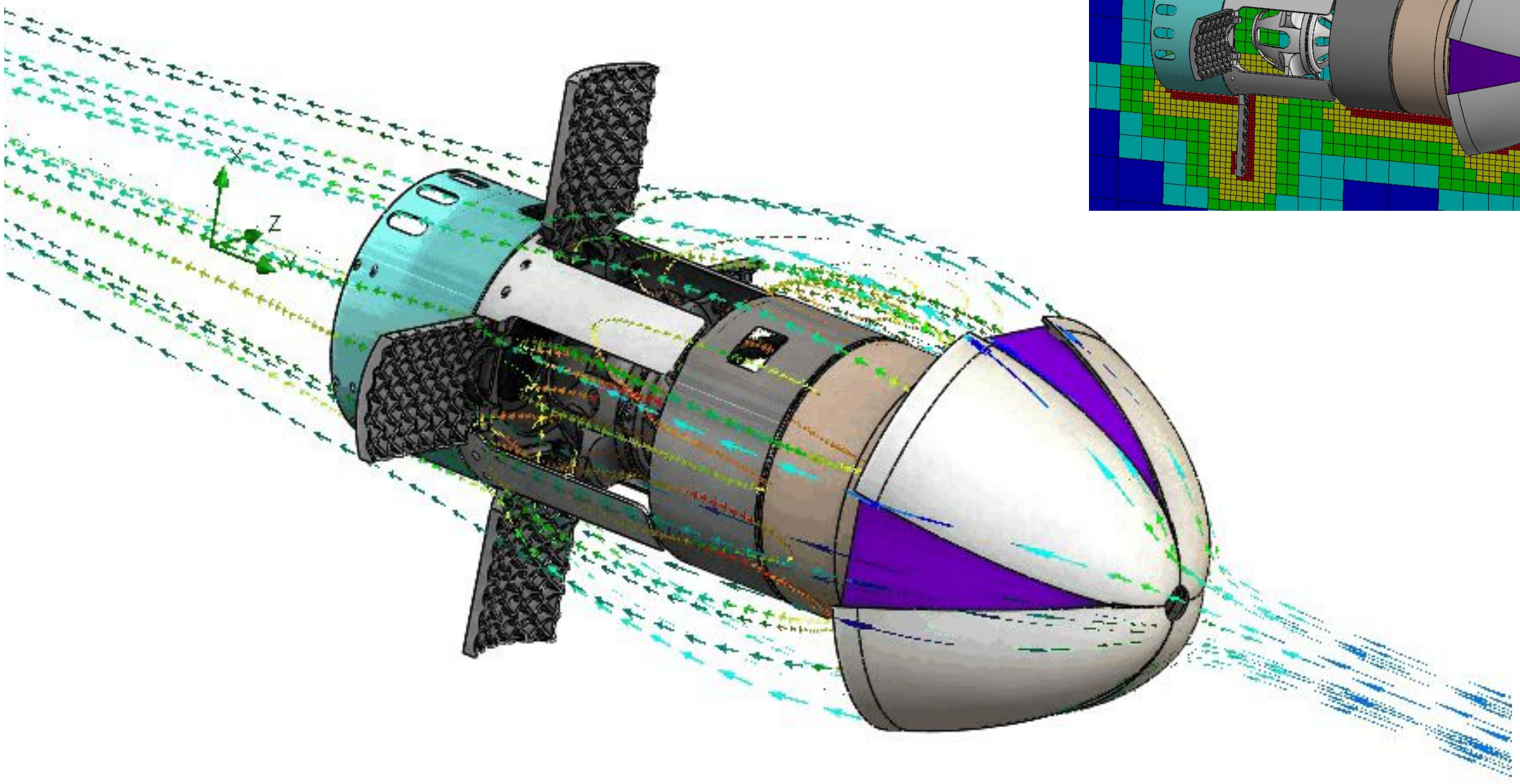
- Target Velocity <30m/s
- Total Drag Area:
  - Deployed Nose Cone Diameter: 0.257 m
  - Grid Fin Area: 0.00583 m^2
- *Drag Coefficient (C_d) = 0.41

*Note: C_d based on SolidWorks CFD using a simplified model. Expected actual C_d is higher than 0.41 (shown in next slide)

Solidworks CFD

Mesh





Descent Rate Estimates (3/6)

Payload Aerobraking

Constants/Variables:

- Mass of probe: **m_t = 0.950kg**
- Air density: **ρ = 1.1459 kg/m^3**
- Gravity: **g = 9.805 m/s^2**
- Drag Coefficient: **C_d = 0.41**
- Nose Cone Diameter: **d = 0.257 m**
- Nose Cone Area: **A_n**
- Grid Fin Area: **A_g= 0.00583 m^2**
- Terminal Velocity: **V_t**

Deployed Aerobraking (Nosecone) Area

$$A_n = \frac{\pi d^2}{4} = \boxed{0.0519\ m^2}$$

Terminal Velocity

$$F_{drag} = m_t g$$

$$0.5\rho V_t^2 C_d(A_g + A_n) = m_t g$$

$$V_t = \sqrt{\frac{2m_t g}{\rho(A_g + A_n)C_d}} = \boxed{26.21\ m/s}$$

Descent Rate Estimates (4/6)

Payload Parachute Released

Assumptions:

- 100m above sea level (from US Air Standard Properties)
  - $\rho = 1.2137\ kg/m^3$
  - $g = 9.807\ m/s^2$
- Mass (Probe + Egg - Nose Cone): 700g

Given:

- Target Velocity <5m/s
- Parachute properties:
  - Diameter = 30 in. (0.762 m)
  - Drag Coefficient (C_d)= 1.6
  - 3.3 lbf @ 20 ft/s
    - 14.68 N @ 6.1 m/s

Note: Parachute used in example from Fruity Chutes: https://shop.fruitychutes.com/products/30-compact-elliptical-parachute-3-3lb-20fps

Descent Rate Estimates (5/6)

Payload Parachute Released

Constants/Variables:

- Mass of probe: **m = 0.700kg**
- Air density: **ρ = 1.2137 kg/m^3**
- Gravity: **g = 9.807 m/s^2**
- Drag Coefficient: **C_d = 1.6**
- Parachute Area: **A_p**
- Given Drag: **F_{drag} = 14.68 N**
- Given Velocity: **V_{ref} = 6.1 m/s**
- Final Velocity: **V_f**

Parachute Area

$$C_d = \frac{2F_{drag}}{\rho V_{ref}^2 A_p}$$

$$A_p = \frac{2F_{drag}}{\rho V_{ref}^2 C_d} = \boxed{0.406\ m^2}$$

Final Velocity

$$F_{drag} = mg$$

$$0.5\rho V_f^2 C_d A_p = mg$$

$$V_f = \sqrt{\frac{2mg}{\rho C_d A_p}} = \boxed{4.17\ m/s}$$

Descent Rate Estimates (6/6)

Summary

Payload Aerobraking(Heatshield)

$$V_t = \sqrt{\frac{2m_t g}{\rho(A_g + A_n)C_d}} = \boxed{26.21\ m/s}$$

8.52% decrease since PDR

- Mass of probe: **m_t = 0.950kg**
- Air density: **ρ = 1.1459 kg/m^3**
- Gravity: **g = 9.805 m/s^2**

*Note: The C_d value used is simulated and is likely higher in real life (V_t will decrease further)

Payload Parachute Released

$$V_f = \sqrt{\frac{2mg}{\rho C_d A_p}} = \boxed{4.17\ m/s}$$

- Mass of probe: **m = 0.700kg**
- Air density: **ρ = 1.2137 kg/m^3**
- Gravity: **g = 9.807 m/s^2**

*Note: Parachute used in example from Fruity Chutes: https://shop.fruitychutes.com/products/30-compact-elliptical-parachute-3-3lb-20fps

Team Logo
Here

Mechanical Subsystem Design

Sunny Lin and Jerome Masicat

Mechanical Subsystem Overview

Mechanical Configuration:

Servo and spring mechanism turns nose cone into the aerobraking shield.

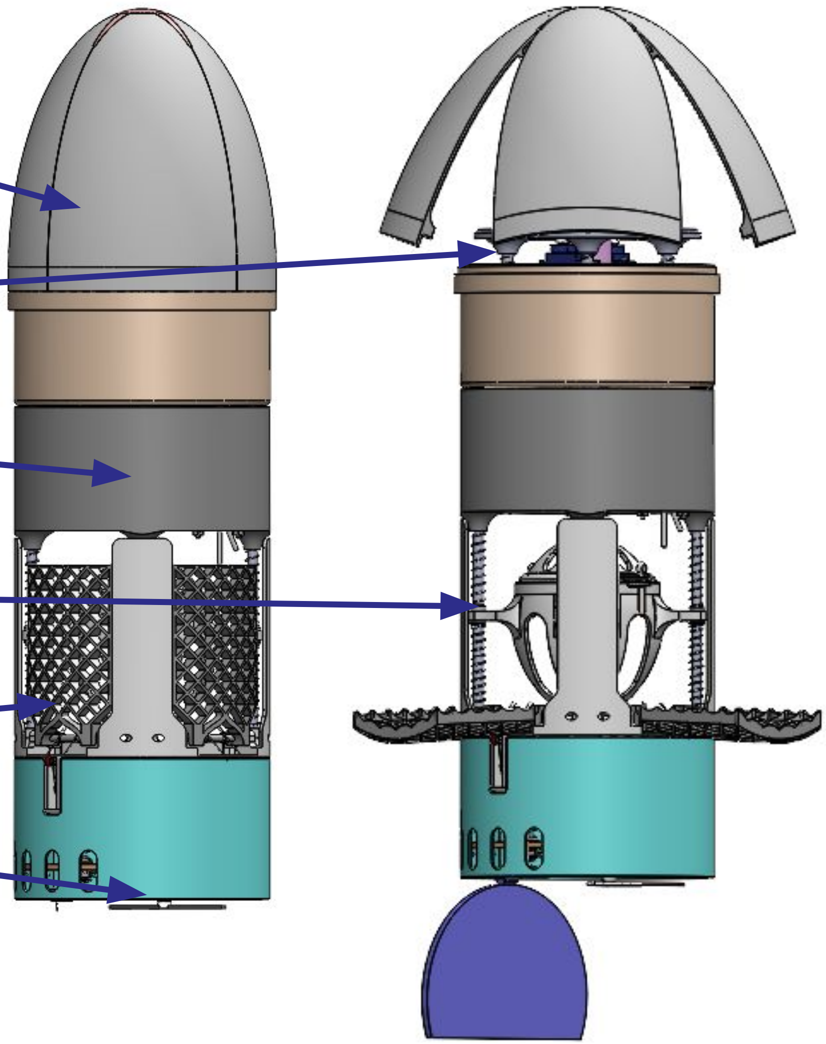
Servo and spring mechanism to release nose cone and reveal landing system.

Electronics compartment housed under shoulder.

Springs oscillate egg capsule between two platforms.

Grid fins open after sliding out from rocket.

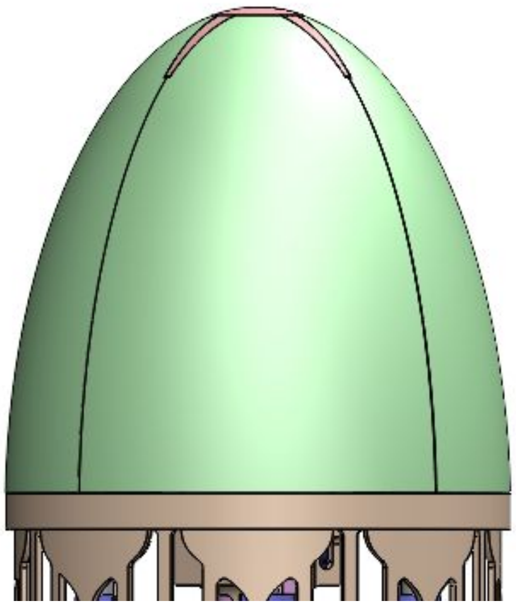
Servo and spring mechanism for parachute release.



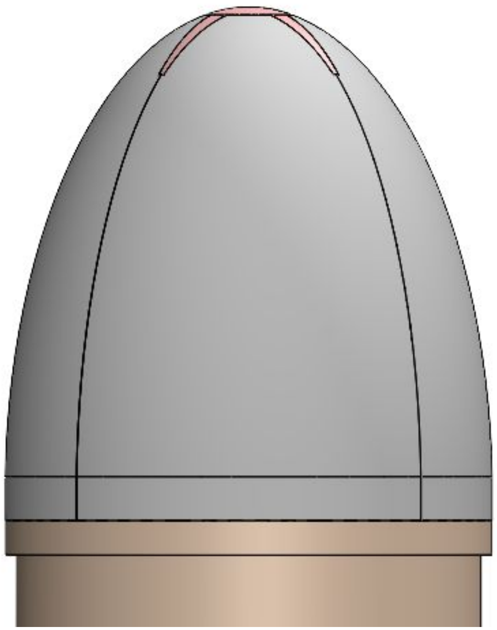
Material Selection: Nylon

Mechanical Subsystem Changes Since PDR (1/10)

Nose Cone



PDR:
Vertical Length - 135 mm

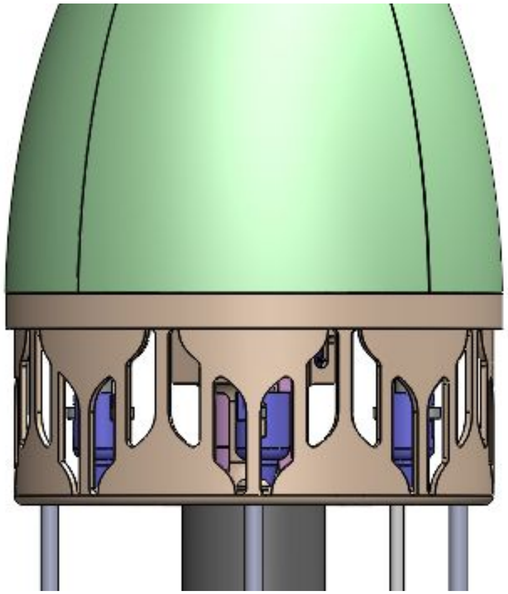


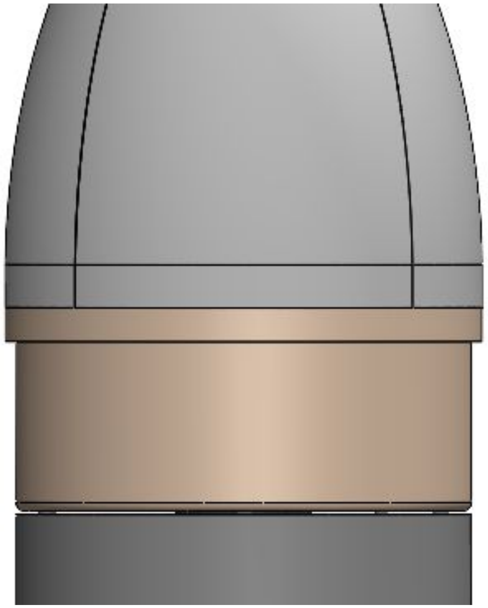
CDR:
Vertical Length - 147.7 mm
Increased by 12.7 mm

Reasoning:

Increases surface area of aerobraking shield.

Nose Cone Shoulder





Reasoning:

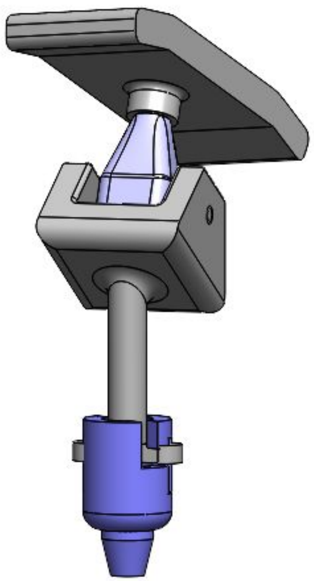
CanSat is more aerodynamic. Center of mass is closer to the nose cone.

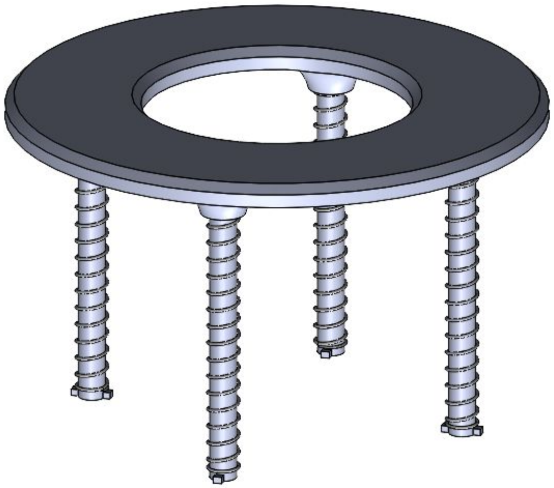
PDR:
Cutouts wrapped around entire shoulder.

CDR:
Cutouts removed.

Mechanical Subsystem Changes Since PDR (3/10)

Landing System





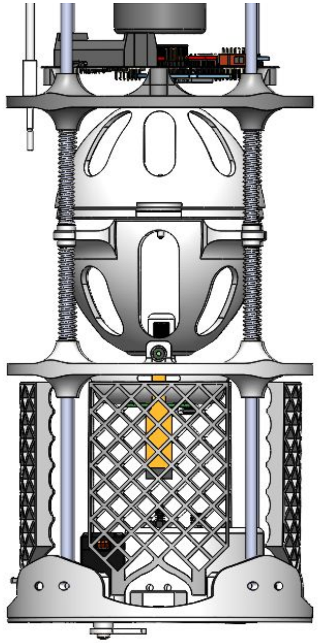
Reasoning:

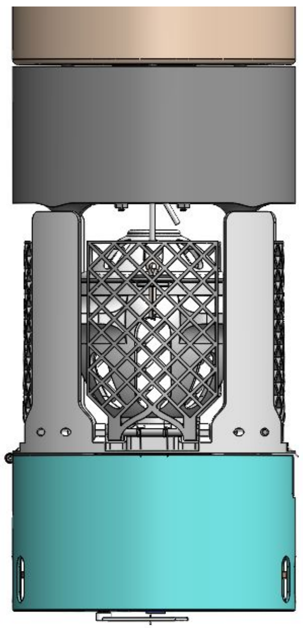
Landing gear is easier to manufacture and has a similar effectiveness.

PDR:
Four separate and complex landing gears attached to the inside of the nose cone

CDR:
One singular landing gear attached at four points to inner nose cone.

Cover/Wall





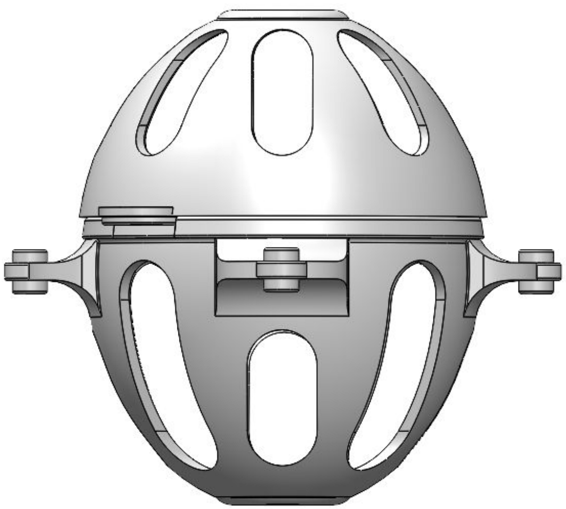
Reasoning:

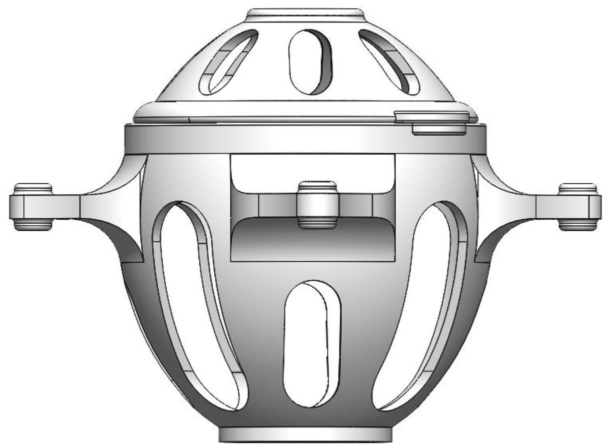
Previous CanSat was below the needed mass, and the walls make the CanSat more aerodynamic.

PDR:
No container or wall surrounding the CanSat.

CDR:
Each platform has an extruded, upward wall up to the next platform.

Egg Capsule





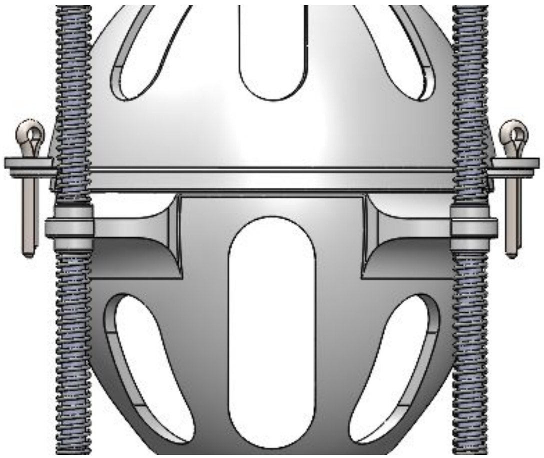
Reasoning:

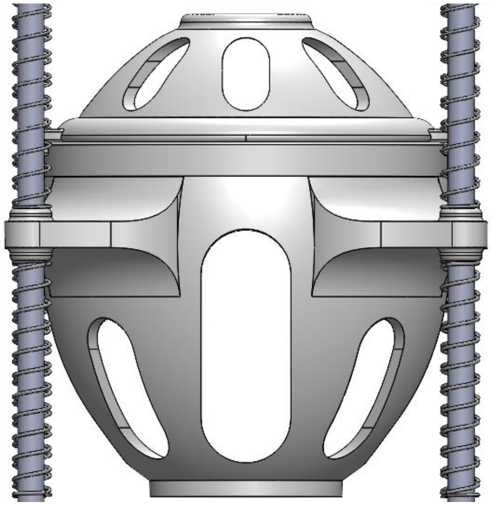
The cap makes it easier to place in and remove the egg from the capsule. The decrease in capsule size saves more vertical space.

PDR:
Diameter: 90 mm
Vertical Length: 110 mm
Cap is considerably large.

CDR:
Diameter: 80 mm
Vertical Length: 95 mm
Cap is smaller.

Egg Capsule Springs





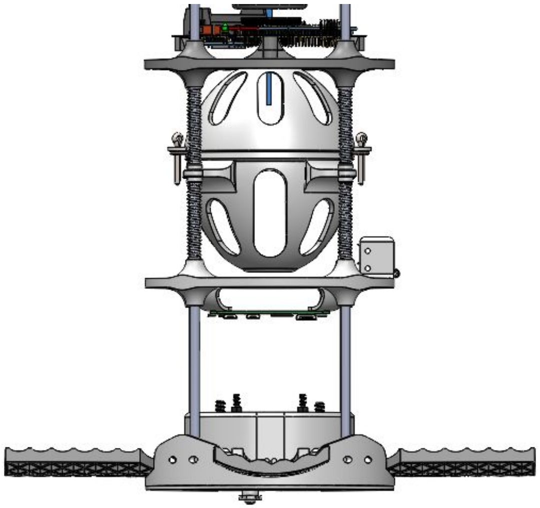
PDR:
Spring Constant:
0.17 lb/mm

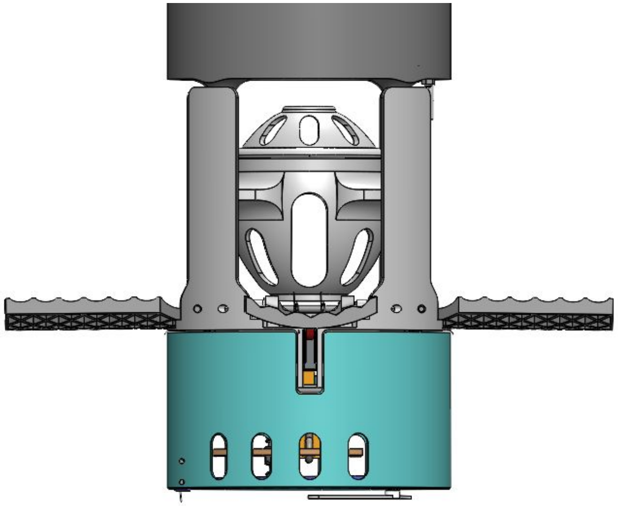
CDR:
Top Springs: 0.05 lb/mm
Bottom Springs: 0.09 lb/mm

Reasoning:

The previous springs were too stiff to effectively oscillate the egg capsule. There is also a considerably larger force during launch, so the bottom springs are stronger.

Grid Fins





Reasoning:

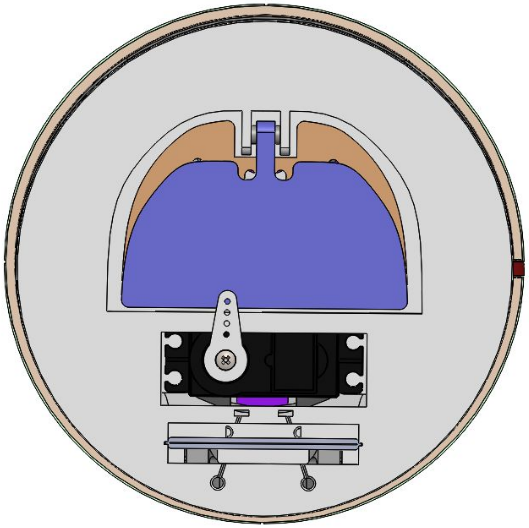
Grid fins are more spatially efficient surrounding the egg capsule. The center of mass is closer to the nose cone.

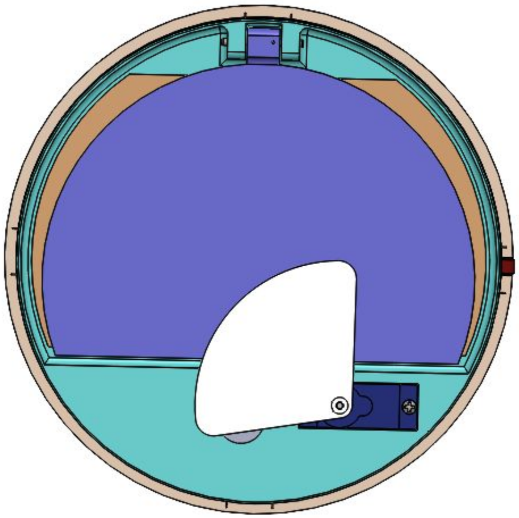
PDR:
Grid fins are placed at the bottom, on the parachute base.

CDR:
Grid fins are placed between the egg protection platforms.

Mechanical Subsystem Changes Since PDR (8/10)

Parachute Containment





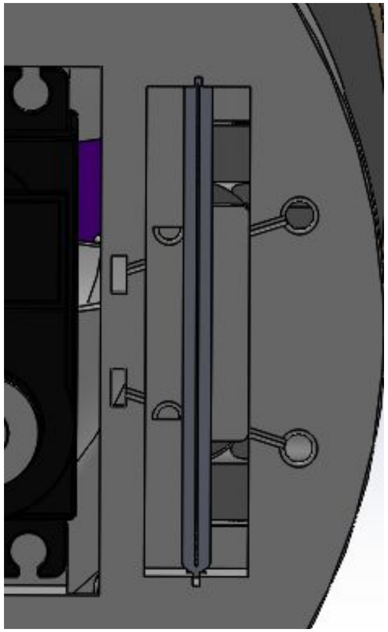
Reasoning:

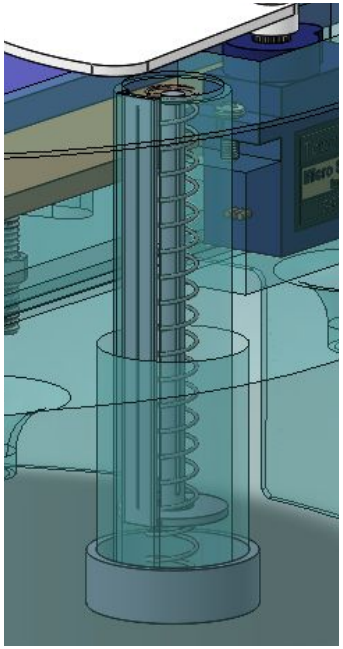
Previous containment was too small for the parachute.

PDR:
Containment is less than half of the parachute base.

CDR:
Containment covers most of the parachute bottom.

Streamer Release





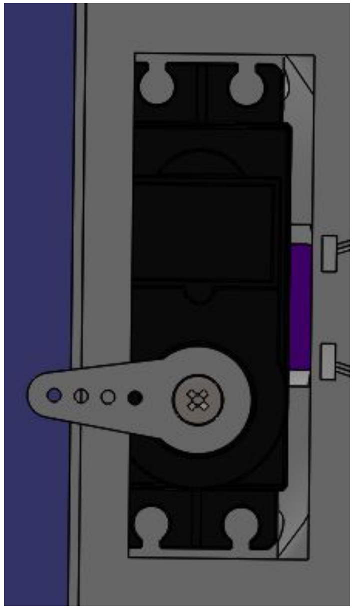
Reasoning:

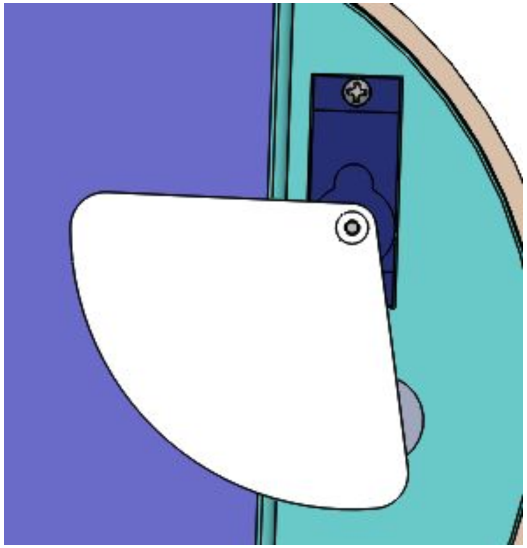
After expansion of the parachute containment, the streamer mechanism needed to take less space in the parachute base.

PDR:
Streamer is mechanically and horizontally released after grid fins open.

CDR:
Streamer is released vertically with a servo mechanism.

Parachute/Streamer Servo Arm





Reasoning:

Grid fins are more spatially efficient surrounding the egg capsule. The center of mass is closer to the nose cone.

PDR:
Servo arm only keeps the parachute door closed.

CDR:
Servo arm is made wider to cover the parachute door and streamer mechanism

Payload Mechanical Layout of Components (1/3)

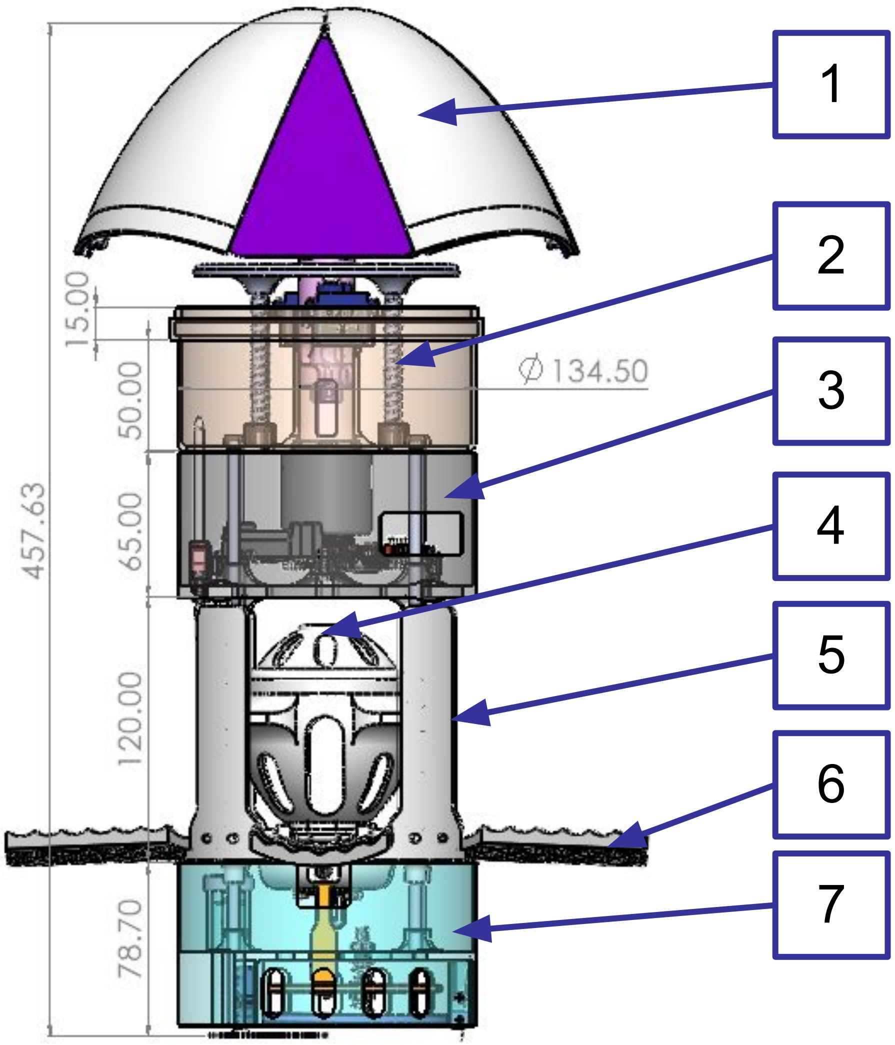
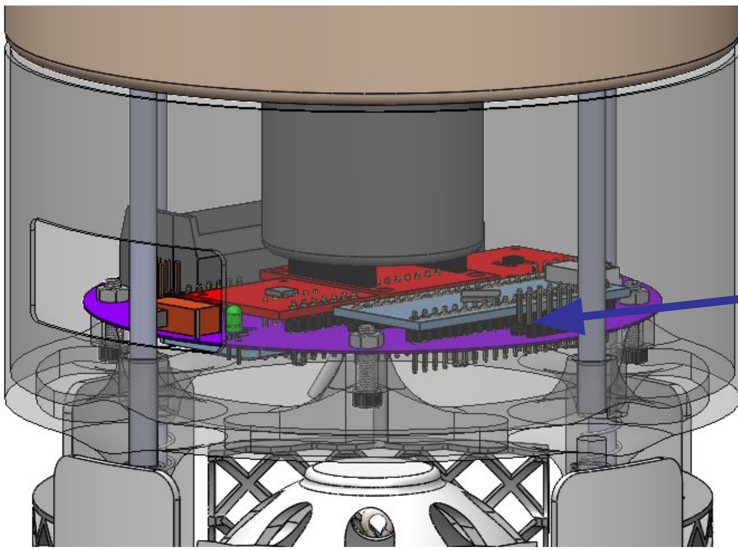


Diagram Number	Component
1	Nose Cone/Heat Shield Mechanism
2	Landing Gear
3	PCB (Electronics) Container
4	Egg Protection Capsule
5	Camera Platform
6	Grid Fins
7	Parachute + Streamer Release

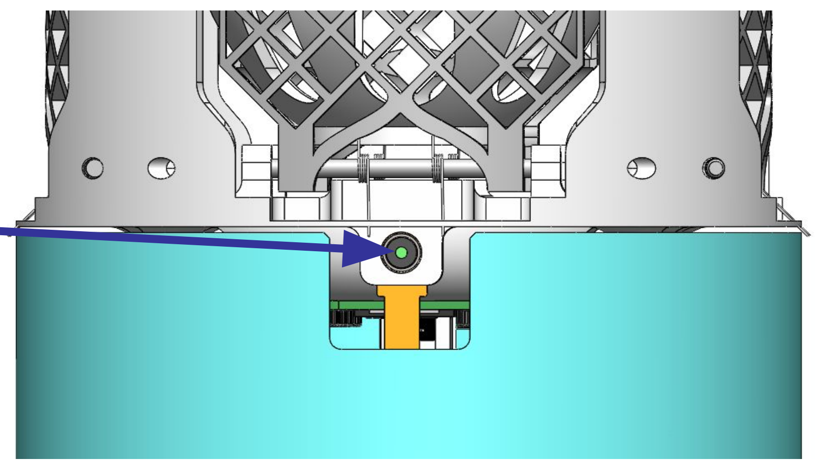
Material Selection: Nylon

Payload Mechanical Layout of Components (2/3)

Sensor and Camera Placement



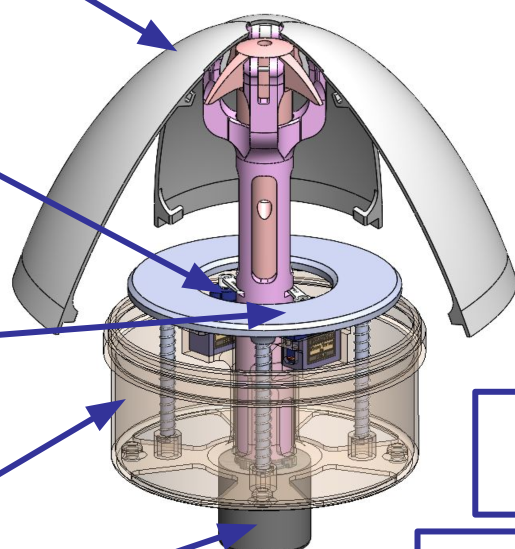
PCB: Contains all sensors required in the container (CDH, radio, antenna, GPS receiver, etc.)

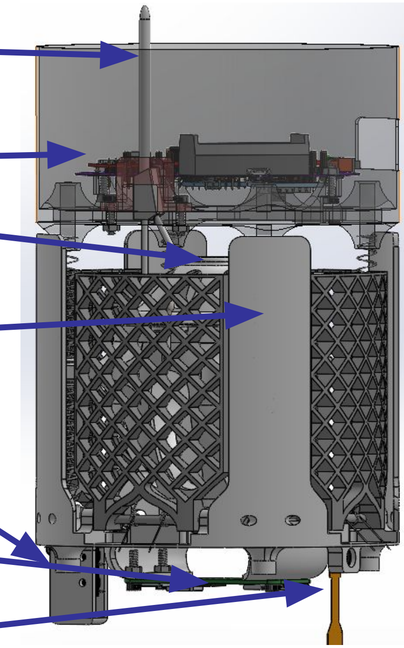


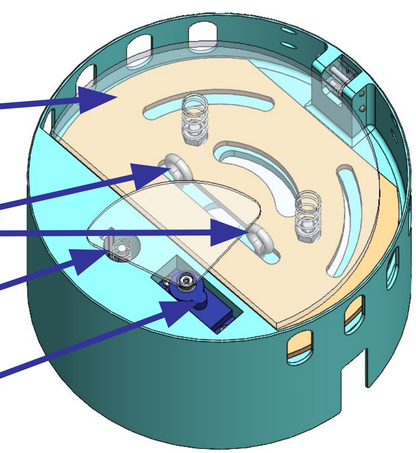
Horizontal camera connected to grid fin platform

Payload Mechanical Layout of Components (3/3)

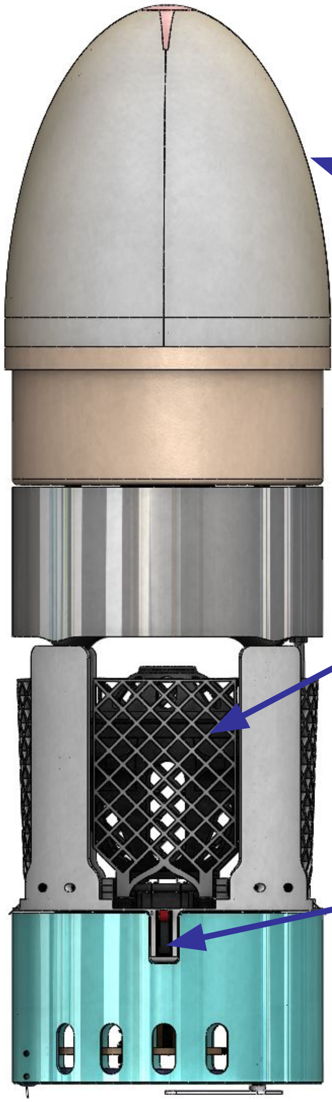
Detailed Breakdown







Payload Aerobraking Pre Deployment Configuration



Nose cone sections are **closed** in the pre-deployment phase

Grid fins folded upward and in tension using torsion springs

Limit switch pushing against wall of rocket, stopping the servos in the nose cone from actuating

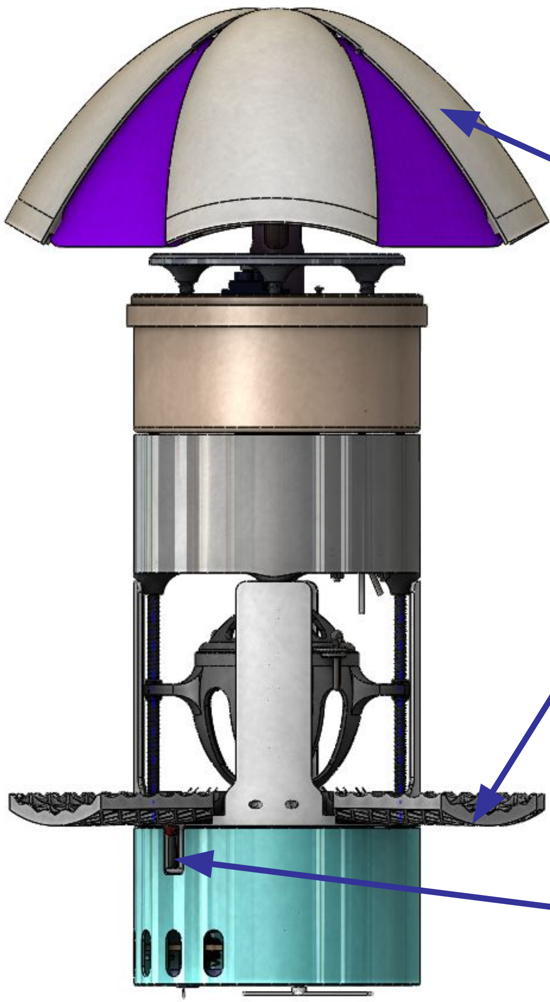
Securing the Payload

The payload is **secured** in the rocket through a **friction/transition fit** between the **shoulder and the rocket**.

There is also friction between the grid fins pushing against the inner rocket wall, helping secure the payload in place during launch

The payload rests in the rocket and the nose cone radius stops the payload from falling further in the rocket.

Payload Aerobraking Deployment Configuration (1/3)

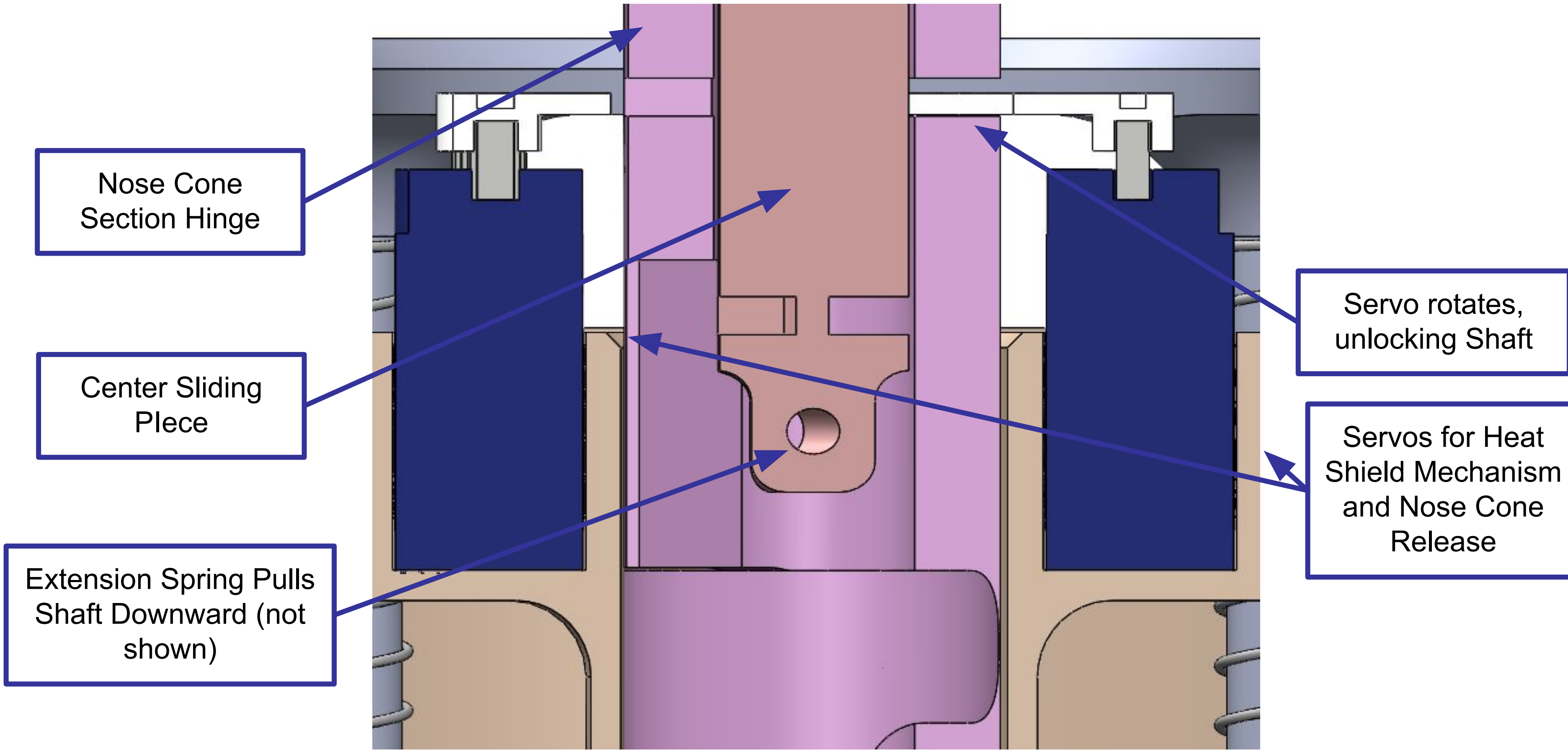


After leaving the rocket, the servos locking mechanism unlocks and the nose cone sections open up, turning into the aerobrake.

The grid fins release their tension from the torsion spring and fold outwards.

The landing gear is exposed and is ready for the landing phase.

Payload Aerobraking Deployment Configuration (2/3)



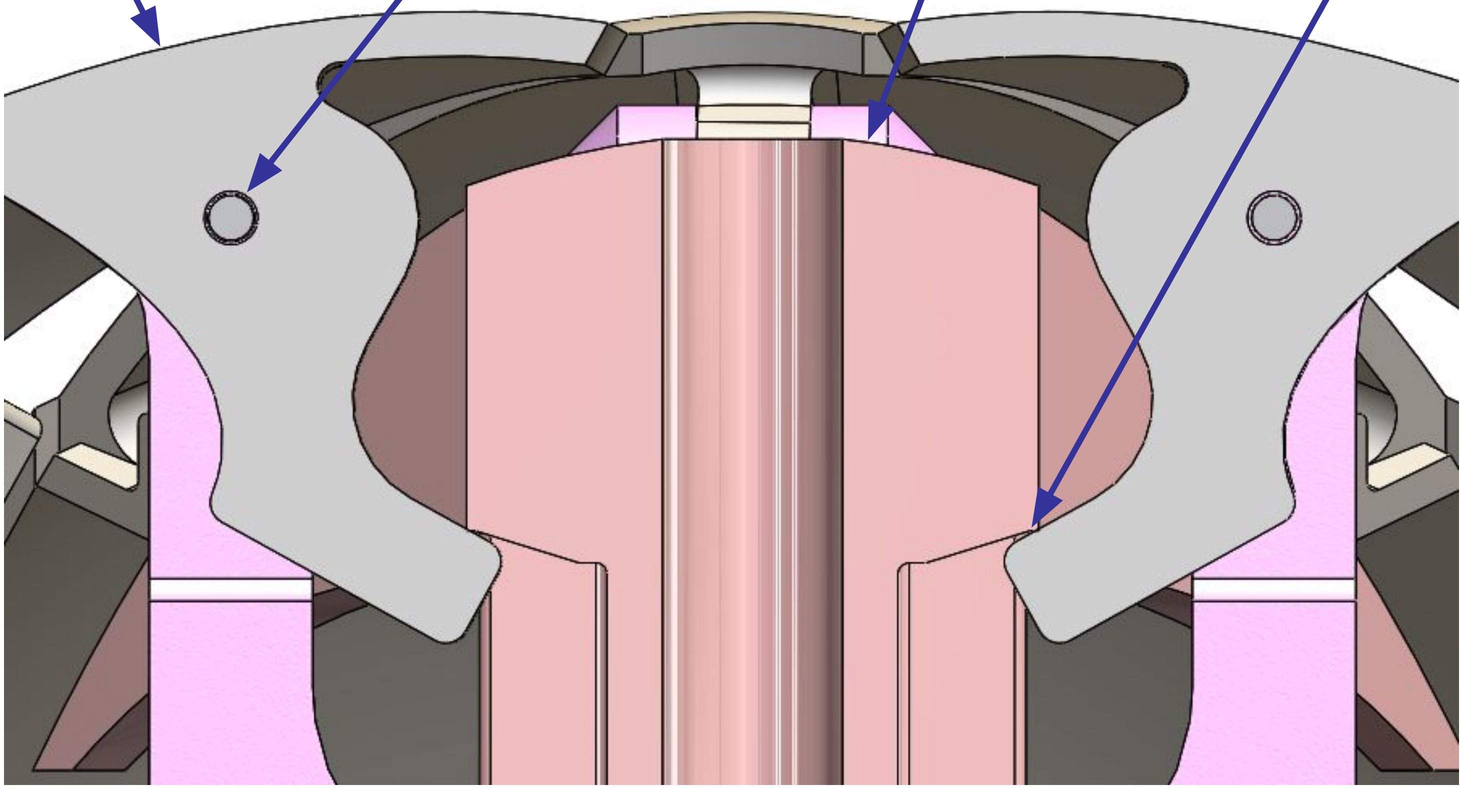
Payload Aerobraking Deployment Configuration (3/3)

Nose Cone Sections

Nose Cone Section Hinge

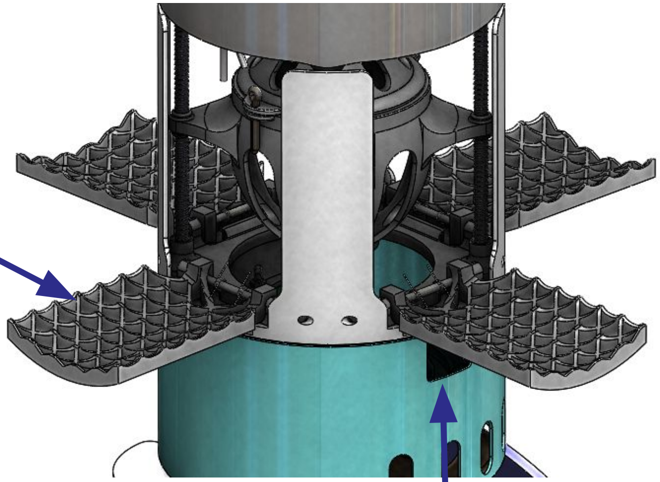
Center Sliding PIece

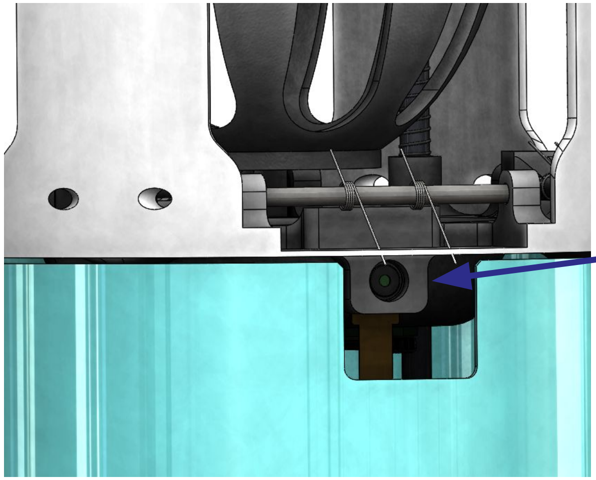
Sliding Piece Pushes Nose Cone Sections Open



Camera Pointing Control

Grid fins deployed for rotation control





Camera

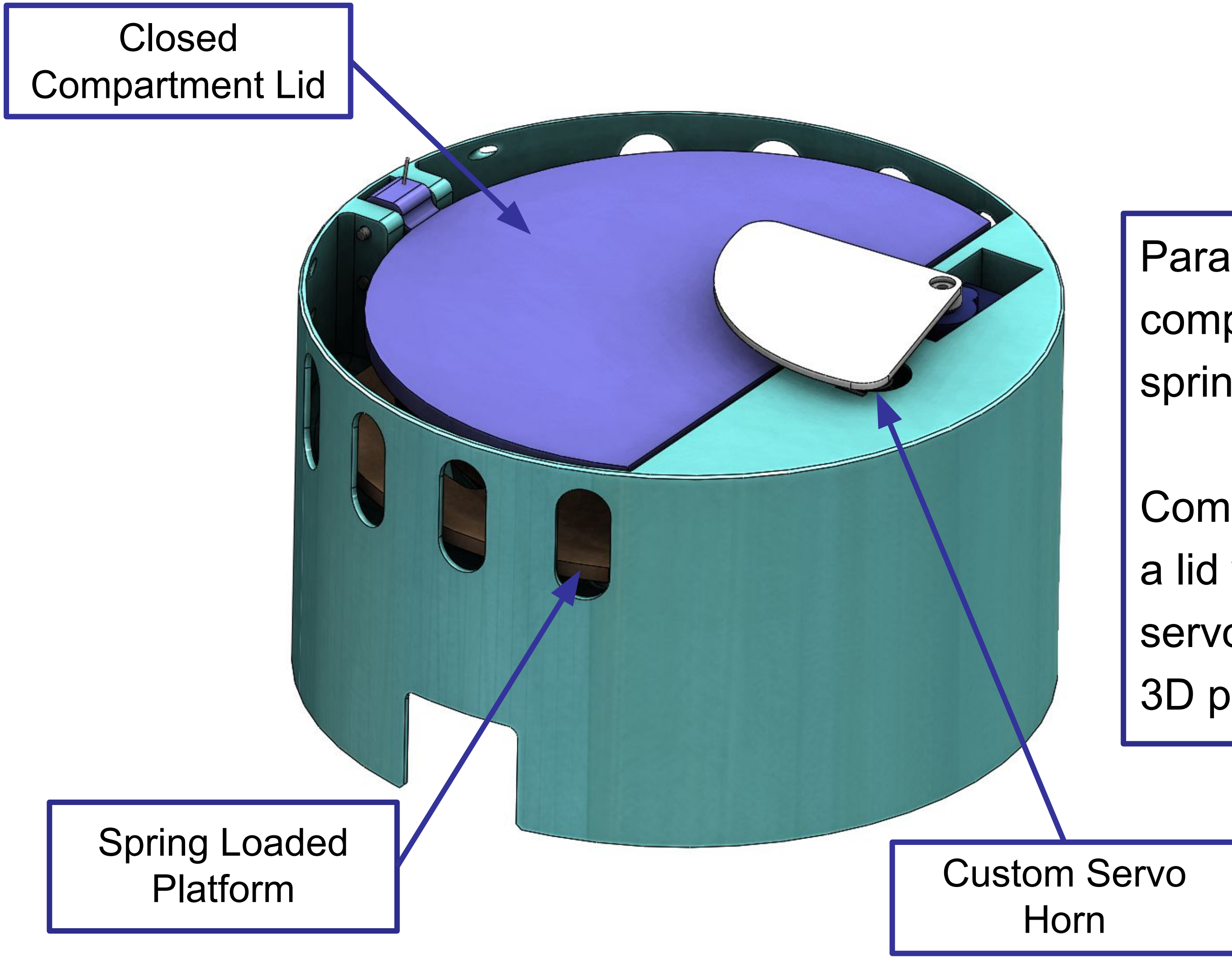
*Grid fin hidden to display camera

Once CanSat is deployed from the rocket, the grid fins are released and able to open

Grid fins provide passive rotation control during descent as air flow is regulated through the inside edges of the fins

Camera's pointing direction is maintained

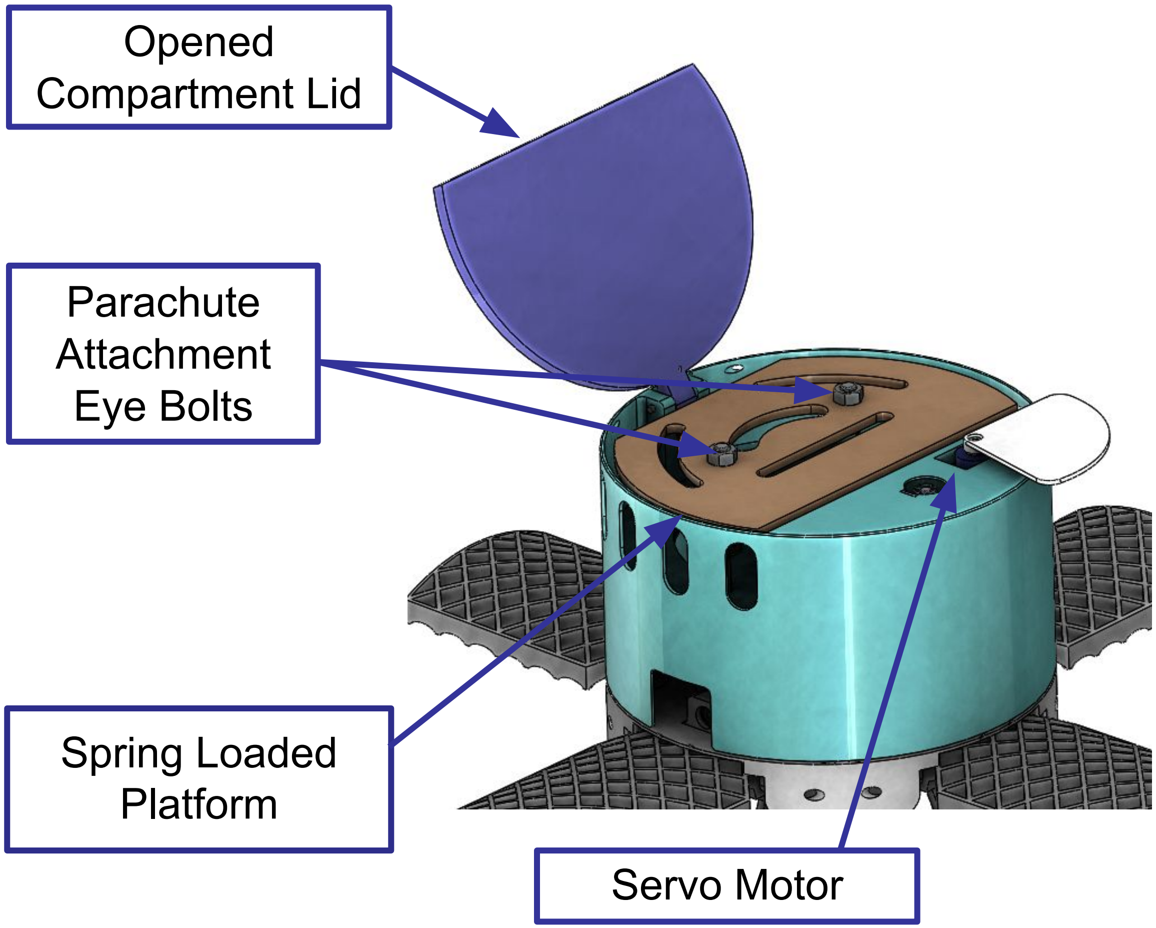
Payload Parachute Deployment Configuration (1/2)



Parachute stowed inside compartment on top of a spring loaded platform.

Compartment is covered by a lid which is held shut by a servo motor with a custom 3D printed horn.

Payload Parachute Deployment Configuration (2/2)

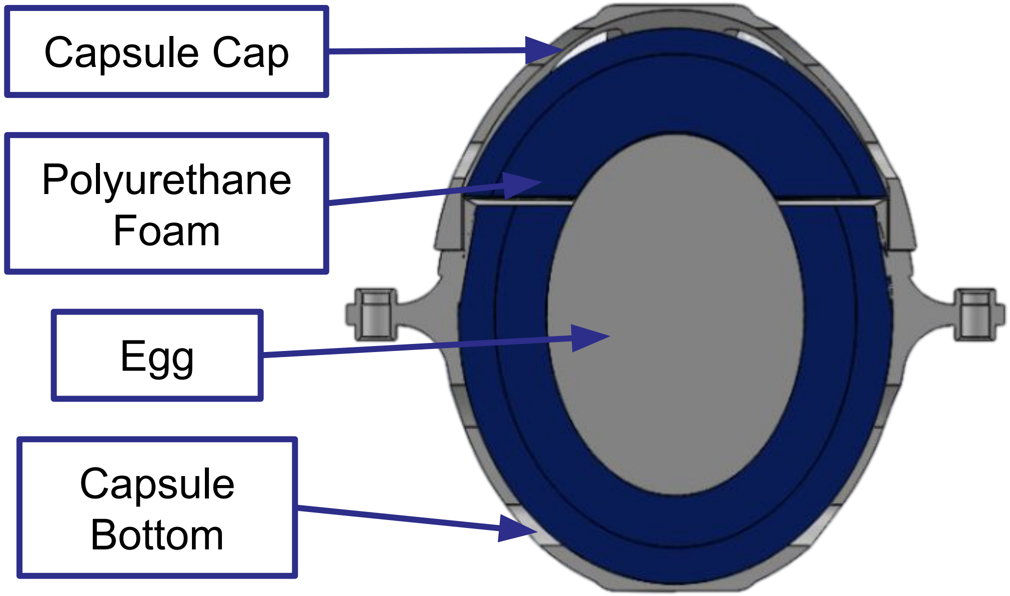


Servo motor rotates at desired altitude, allowing the platform to push the lid open.

Parachute can now exit compartment and open up for descent.

Parachute is attached to two routing eye bolts under the spring loaded pushing platform.

Payload Egg Containment Design (1/2)

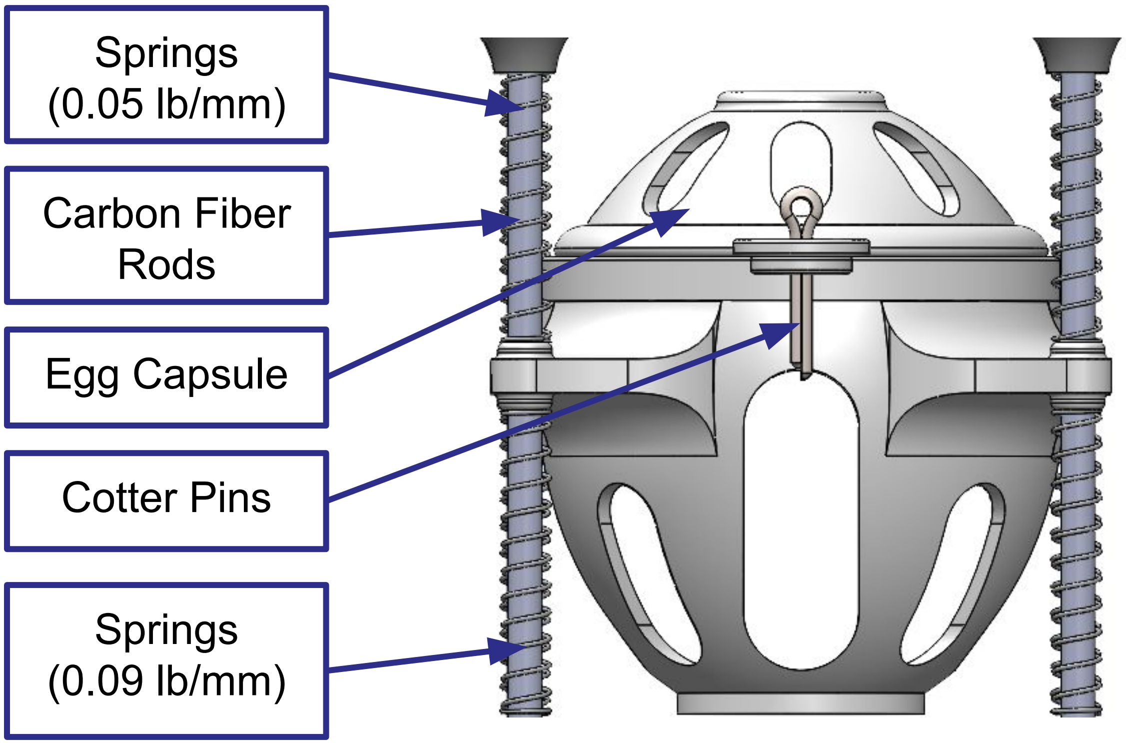


Capsule is filled with foam to conform to egg's shape and act as cushion.

Capsule is closed with two cotter pins on opposite sides.

Capsule extrusions attach to carbon fiber rods.

Payload Egg Containment Design (2/2)



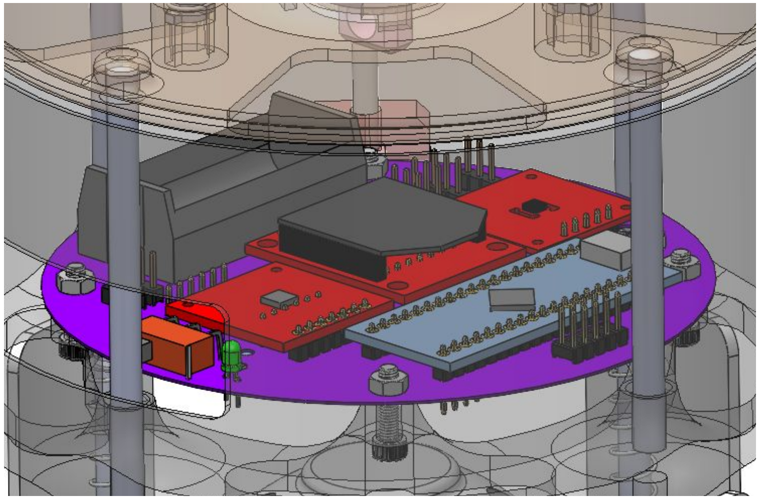
Capsule is suspended and oscillates on springs attached to carbon fiber rods.

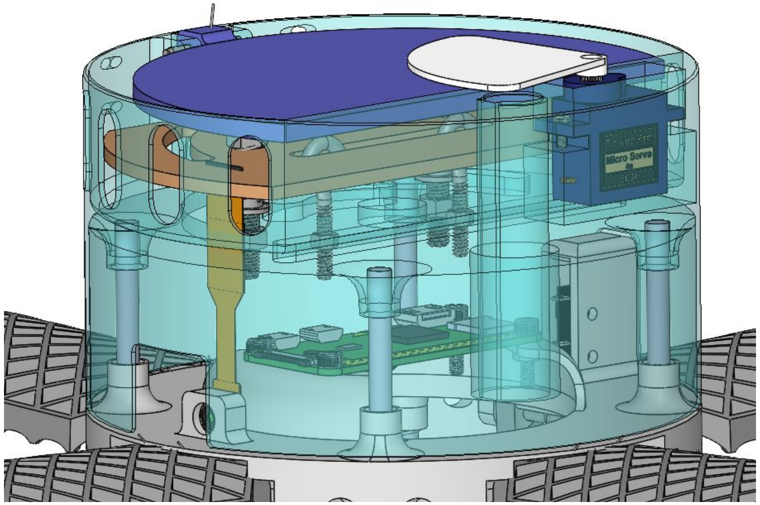
Stronger springs on the bottom due to harder forces experienced during launch.

Egg is removed by taking off cap and pressing down capsule.

Structure Survivability (1/3)

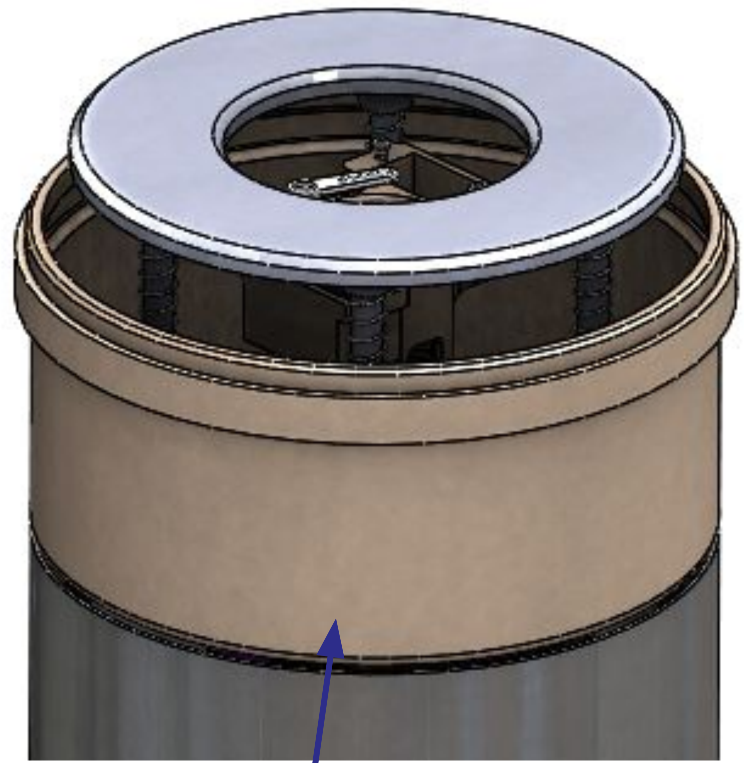
Electric Component Mounting Methods	• **Soldered** onto custom PCBs • PCB and Raspberry Pi attached to mounts with **nuts and bolts** or **press-fit** to ensure a strong connection.
Electrical Connection Securing	• Wires held in place using **friction fit banana connectors** and **soldered** to the PCB
Electronic Component Enclosures	• Components are stored on the PCB on a platform **under the nose cone** • PCB and Raspberry Pi are bolted to **3D printed pieces** • Other components are mounted around the **egg protection structure** • Servos bolted into mounts in the **nose cone** and **parachute base**

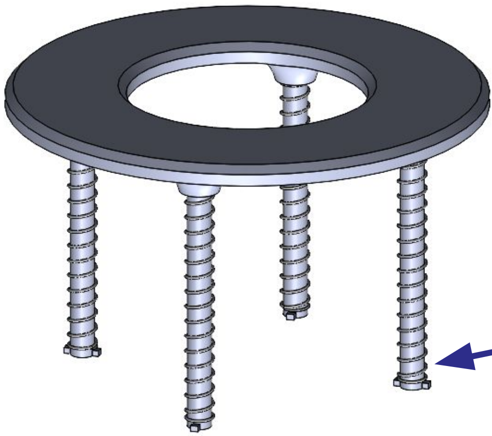




Structure Survivability (2/3)

Acceleration and Shock Force Requirements and Testing	• Built to withstand **30 Gs** of shock • Perform **drop tests** as outlined in the CanSat Mission Guidelines • Landing gear base **reinforced with springs** to absorb shock from landing

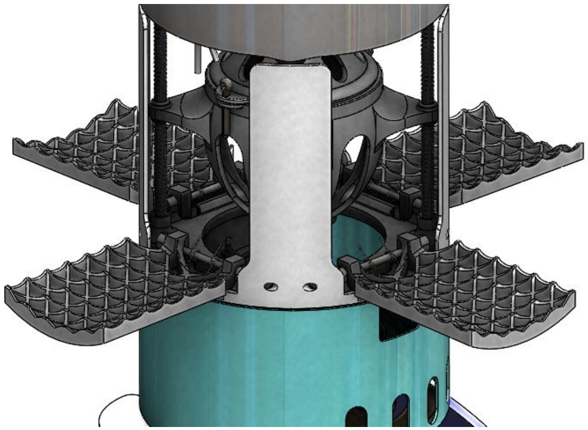


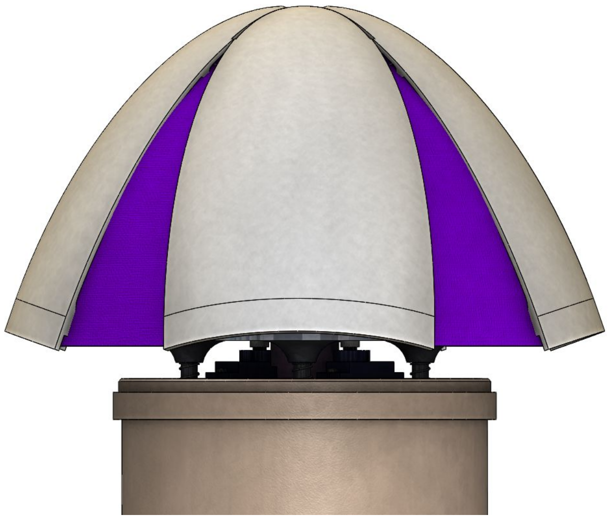


Rods compress into nose cone base as springs absorb shock

Structure Survivability (3/3)

Descent Control Attachments	• Grid fins are attached to the platform with super glued **dowels** and fan out with **torsion springs** once CanSat deploys from the rocket. • Heat shield is opened when two **servos** near the nose cone actuate and open up the nose cone wings. • Parachute is attached to two **routing eye bolts** and held in a compartment locked with a **servo**





Mass Budget (1/6)

Payload Structural Elements

Element	Quantity	Mass (g)	Source	Uncertainty (g)	Total Mass (g)
Landing System	1	12	Estimation	0.6 *	12
Egg Top	1	25	Estimation	1.25 *	25
Egg Bottom	1	60	Estimation	3 *	60
Electronic Platform	1	25	Estimation	1.25 *	25
Limit Switch Platform	1	25	Estimation	1.25 *	25
Polyurethane Foam (Bottom)	1	5	Estimation	1	5
Polyurethane Foam (Top)	1	2	Estimation	0.5	2
Carbon Fiber Rod (1152 mm)	1	33.41	Estimation	2	33.41
Parachute/Grid Fin Platform	1	125	Estimation	6.25 *	125
Parachute Door	1	10	Estimation	0.5 *	10
Parachute Pushing Platform	1	10	Estimation	0.5 *	10

*** structural elements that are 3D-printed have an internally tested uncertainty of 5%**

Mass Budget (2/6)

Payload Structural Elements

Element	Quantity	Mass (g)	Source	Uncertainty (g)	Total Mass (g)
Arm Servo	1	2	Estimation	0.5	2
Shaft (2 mm)	1	0.03	Data Sheet	N/A	0.03
I-Hook	2	3.22	Data Sheet	N/A	6.44
Cotter Pins	2	0.42	Data Sheet	N/A	0.84
Capsule Springs (0.09 lb/mm)	2	0.5	Estimation	0.1	1
Capsule Springs (0.05 lb/mm)	2	0.5	Estimation	0.1	1
Parachute Springs	2	0.438	Data Sheet	N/A	0.438
SS Dowel Pin	2	2.15	Data Sheet	N/A	4.3
Nose Cone Model Section	4	11.5	Estimation	0.58 *	46
Nose Cone Slider	1	22	Estimation	1.1 *	22
Streamer Mount	1	2	Estimation	0.03 *	2

*** structural elements that are 3D-printed have an internally tested uncertainty of 5%**

Mass Budget (3/6)

Payload Structural Elements

Element	Quantity	Mass (g)	Source	Uncertainty (g)	Total Mass (g)
Streamer Weight	1	1	Estimation	0.05 *	1
Streamer Spring	1	0.5	Estimation	0.03 *	0.5
Streamer Cap	1	1	Estimation	0.05 *	1
Landing Gear Springs	4	0.5	Estimation	0.1	2
Nose Cone Tip	1	40	Estimation	2 *	40
Nose Cone Base	1	150	Estimation	7.5 *	150
Grid Fin	4	21	Estimation	1.05 *	21
Parachute	1	80	Estimation	4	80
Deployment Bag	1	50	Estimation	2.5	50
				Total:	**764.96**

*** structural elements that are 3D-printed have an internally tested uncertainty of 5%**

Mass Budget (4/6)

Payload Electrical Elements

Element	Quantity	Mass (g)	Source	Uncertainty (g)	Total Mass (g)
Servo	3	10.3	Data Sheet	N/A	30.9
Accelerometer	1	1.6	Data Sheet	N/A	1.6
Pitot Tube	1	9.8	Data Sheet	N/A	9.8
Pitot Speedometer	1	2.02	Data Sheet	N/A	2.02
Pressure Sensor	1	2.6	Data Sheet	N/A	2.6
GPS	1	6.3	Data Sheet	N/A	6.3
Limit Switch	1	0.5	Estimation	0.1	0.5
STM32	1	8.7	Data Sheet	N/A	8.7
Camera Module	2	4.6	Data Sheet	N/A	9.2
Raspberry Pi	1	5	Data Sheet	N/A	5

Mass Budget (5/6)

Payload Electrical Elements

Element	Quantity	Mass (g)	Source	Uncertainty (g)	Total Mass (g)
XBEE	1	3.6	Data Sheet	N/A	3.6
Voltage Sensor	1	4.54	Estimate	1	4.54
Battery	1	18.6	Data Sheet	N/A	18.6
PCB Wafer	1	34.2	Data Sheet	N/A	34.2
Inductors	2	0.1	Measured	N/A	0.2
Audio Beacon	1	4.7	Measured	N/A	4.7
				Total:	**142.5**

Mass Budget (6/6)

Total Mass

Element	Total Mass (g)
Structural Elements	764.96
Electrical Elements	142.5
	907.46

Total Mass: 907.46 g   Margin Mass: -7.46 g

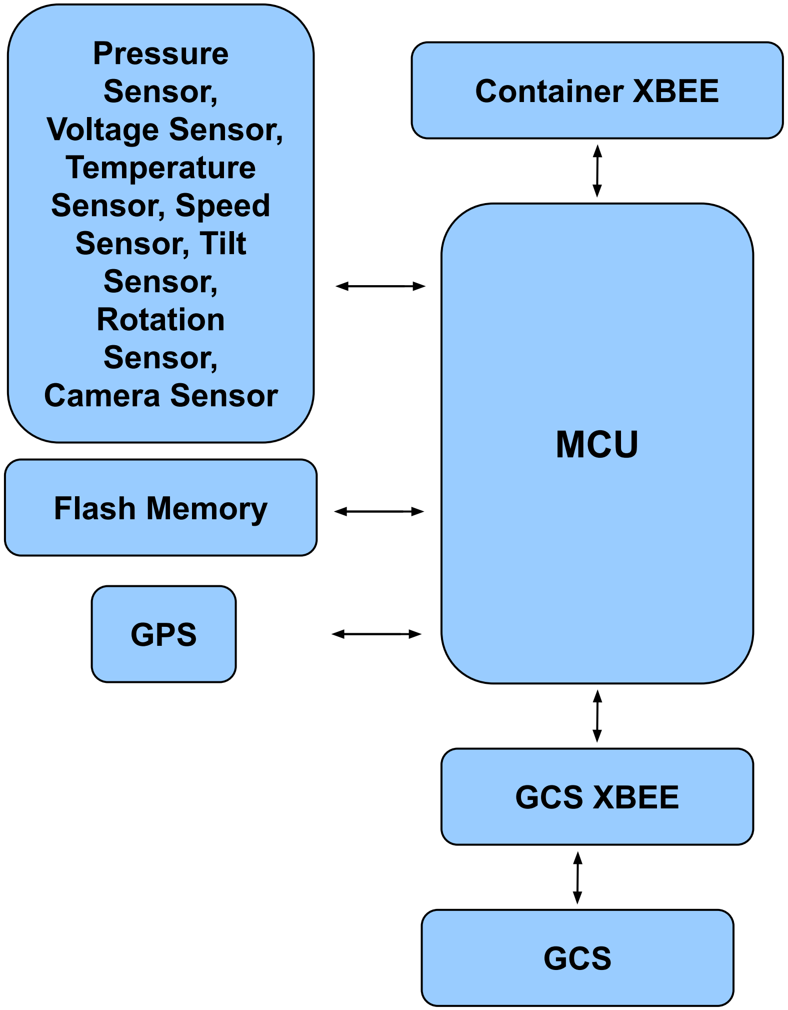
Plans to Cut Mass:

- **Slightly decreasing thickness and adding small cutouts to 3D-printed structures.**

Communication and Data Handling (CDH) Subsystem Design

Khushi Gupta

CDH Overview



Component	Function
XBEE3 Pro	Radio Transceiver/Receiver
BMP581	Pressure Sensor
INA219	Voltage Sensor
BMP581	Temperature Sensor
MS4525DO	Speed Sensor
MPU-6050	Tilt Sensor
MPU-6050	Rotation Sensor
Zero Spy Cam	Camera Sensor
PA1010D	GPS
Internal Flash memory	Memory
STM32F103C8T6	Microcontroller

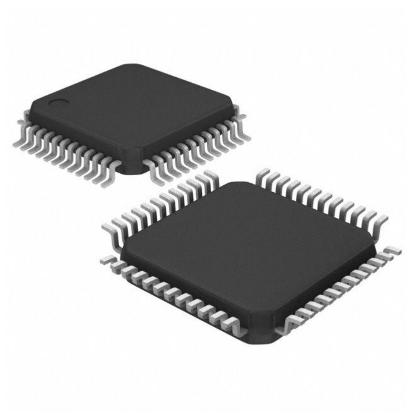
CDH Changes Since PDR

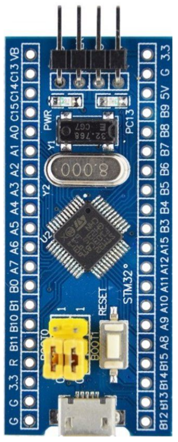
No changes to CDH since PDR.

Payload Processor & Memory Selection (1/3)

Processor	Interfaces	# I/O Pins	Speed	Total Pins	Memory
STM32F103C8T6	I2C (2) USART (3) USB (1) SPI (2) CAN (1)	Analog (10) Digital (37) PWM (12)	72 MHz	59	Flash (64 KB) SRAM (20 KB)

Boot Time	Voltage	Power Consumption [1]	Cost
2 ms	2.7 - 3.6	50 mA	$6.11

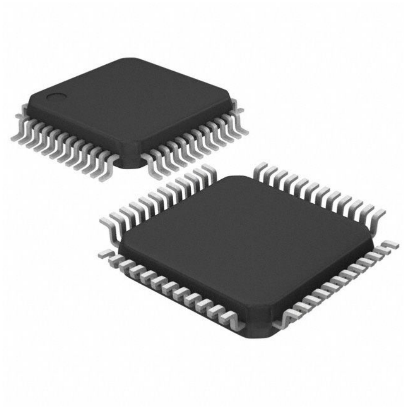




[1] Maximum current consumption in run mode, code with data processing running from flash, 72 MHz, all peripherals enabled (Source: STM32F103 datasheet)

Payload Processor & Memory Selection (2/3)

Processor	Memory	Size	Interface	Write Time	Cost
STM32F103C8T6	Flash	64KB	Internal	20-100ms	No extra cost

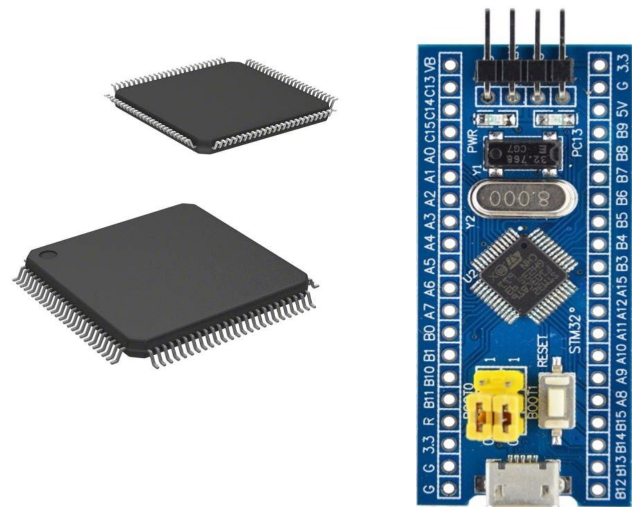


Payload Processor & Memory Selection (3/3)

High Speed Processor and Use Embedded Internal Flash Memory

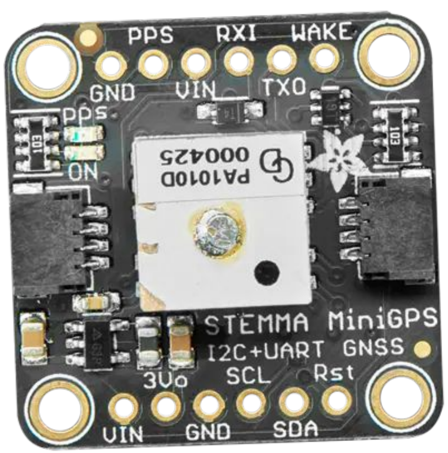
Processor	**STM32F103C8T6**
Speed	**72 MHz**
Pin Count	**59**
Memory	**Internal Memory**
Technology	**Flash**
Size	**64 KB**
Write Time	**20 - 100 ms**

STM32F103C8T6



Payload Real-Time Clock

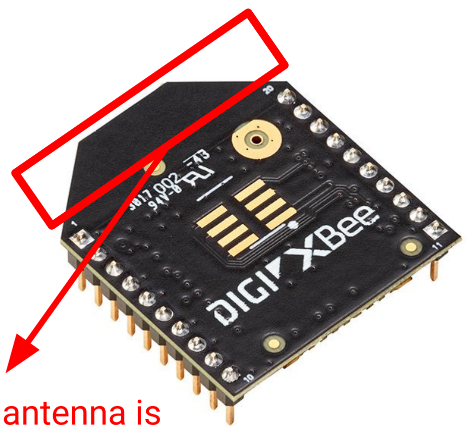
Design	Type	Reset Tolerance	Weight	Cost
RTC on PA1010D GPS	External Hardware - I2C	Reset tolerant, battery backup	No extra weight	No extra Cost



Selection Reasoning	
PA1010D	• Reset Tolerant • Backup coin battery option available in case of processor reset/interruption

Payload Antenna Selection (1/2)

Design	Outdoor Range	Indoor Range	RF TX Power (max)	Mass	Cost
XBee3 Pro PCB Antenna	3200 m (2 mi)	90 m (300 ft)	79 mW (+19 dBm)	3.1g	$25.60

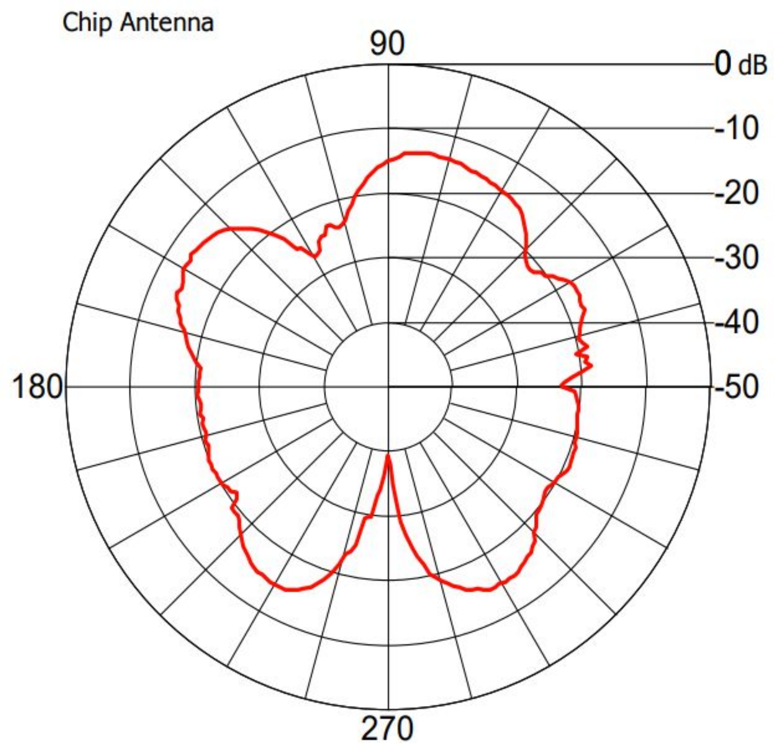


The trace antenna is located at the top of the XBEE.

Payload Antenna Selection (2/2)

Selection	Reasoning
XBee3 Pro PCB Antenna (CanSat to Ground)	• Outdoor Range is far greater • PCB antenna takes up less space than Whip Antenna • Cheaper cost for better specs

~0.6 dB gain
~4.5 dB with larger gain variations
(gives greater range)



Payload Radio Configuration

	Cost	Weight	Frequency	Transmit Power Output	Line of Sight Range
XBee3 Pro	$25.60	2.27g	2.4 GHz	79 mW (+19 dBm)	3200 m

Transmission Control		
Baud Rate	115200	Higher Baud Rate = More bits sent per second
XBee Configuration	“Coordinator” to “End Device”	Common setup for XBee
NETID	**2057**	**Unique ID for XBee to identify each other**

Data Transmission	• **Data packets will be sent four times per second during and after launch** • **After landing, payload will send flag to ground signifying end of mission and cease transmission**

Payload Telemetry Format (1/3)

Data Field	Description
TEAM_ID	4-digit team ID
MISSION_TIME	time since launch (**hh:mm:ss**)
PACKET_COUNT	number of transmitted packets
VOLTAGE, CURRENT*	power bus voltage (**V, 0.1 V**), current (**A**)

Data Field	Description
MODE	current mode (flight/simulation)
STATE	human-readable description of current state
GPS_ALTITUDE, GPS_LATITUDE, GPS_LONGITUDE,	GPS location data (**m, 0.1 m** / **°, 0.001°**)
GPS_TIME, GPS_SATS	GPS time (**hh:mm:ss, 1 s**), number of satellites tracked

*Optional data field

Payload Telemetry Format (2/3)

Data Field	Description
ALTITUDE	altitude relative to launch site (**m, 0.1 m**)
AIR_SPEED	air speed measured by pitot tube (**m/s**)
HS_DEPLOYED, PC_DEPLOYED	deployment status of heatshield, parachute
TEMPERATURE	temperature (**°C, 0.1°**)

Data Field	Description
PRESSURE	air pressure (**kPa, 0.1 kPa**)
TILT_X, TILT_Y	angle of CanSat x/y axes (**°, 0.01°**)
ROT_Z	rotation rate (**°/s, 0.1 °/s**)
CMD_ECHO	last command received by CanSat

Payload Telemetry Format (3/3)

Data Rate:

- Packets will be transmitted at a frequency of 1Hz
- Packet format complies with competition requirements

Data Format:

TEAM_ID, MISSION_TIME, PACKET_COUNT, MODE, STATE, ALTITUDE, AIR_SPEED, HS_DEPLOYED, PC_DEPLOYED, TEMPERATURE, VOLTAGE, PRESSURE, GPS_TIME, GPS_ALTITUDE, GPS_LATITUDE, GPS_LONGITUDE, GPS_SATS, TILT_X, TILT_Y, ROT_Z, CMD_ECHO,, CURRENT

Sample Frame:

2057, 0:07:08, 900, F, NS_UNLOCKED, 421.1, 32, ‘P’, ‘N’, 13.2, 3.3, 96.6, 18:32:40, 402.3, 37.201, -80.343, 5, -33.42, -257.58, 3.4, "CMD, 2057, CX, ON",, 0.2

Payload Command Formats (1/3)

Title	Command	Syntax	Description	Example
Payload Telemetry On/Off Command	CX	**CMD,<TEAM_ID>, CX,<ON_OFF>**	-CMD and CX are static text. -<TEAM_ID> is the assigned team id. -<ON_OFF> is the string 'ON' to activate the payload telemetry transmissions and 'OFF' to turn off the transmissions	**CMD,2057,CX,ON** -<TEAM_ID> is 2057. **-** Activates payload telemetry transmission
Set Time	ST	**CMD,<TEAM_ID>, ST,<UTC_TIME>| GPS**	-CMD and CX are static text. -<TEAM_ID> is the assigned team id. -<UTC_TIME> is the UTC time, formatted as HH:MM:SS (time is within 1 second to UTC TIME) -GPS is text and replaces <UTC_TIME> and uses current GPS time instead.	**CMD,2057,ST,10:45 :57** -<TEAM_ID> is 2057. - Sets mission time to given value -<UTC_TIME> is 10:45:57. **CMD,2057,ST,GPS** -<TEAM_ID> is 2057. -GPS time is used.

Payload Command Formats (2/3)

Title	Command	Syntax	Description	Example
Simulation Mode Control Command	SIM	**CMD,<TEAM_ID>,SIM,<MODE>**	-CMD and CX are static text. -<TEAM_ID> is the assigned team id number. -<MODE> is either 'ENABLE' to enable simulation mode, 'ACTIVATE' to activate simulation mode, or 'DISABLE' to disable and deactivate simulation mode. -'ENABLE' and 'ACTIVATE' are both required to begin simulation mode	**CMD,2057,SIM,ENABLE** -<TEAM_ID> is 2057. -<MODE> is ENABLE. -This command does not begin simulation mode, it only enables it.
Simulate Pressure Data	SIMP	**CMD,<TEAM_ID>,SIMP,<PRESSURE>**	-CMD and SIMP are static text. -<TEAM_ID> is the assigned team id number. -<PRESSURE> is the simulated atmospheric pressure data in pascals, with a resolution of one Pascal.	**CMD,2057,SIMP,101325** -<TEAM_ID> is 2057. -<PRESSURE> is 101325, approximately sea level.

Payload Command Formats (3/3)

<table>
<tr><th>Title</th><th>Command</th><th>Syntax</th><th>Description</th><th>Example</th></tr>
<tr><td>Calibrate Altitude to Zero</td><td>CAL</td><td>CMD,<TEAM_ID>, CAL</td><td>-CMD and CAL is static text.
-<TEAM_ID> is the assigned team id.</td><td>CMD, 2057, CAL

-Altitude is set to zero.</td></tr>
<tr><td>Control Audio Beacon</td><td>BCN</td><td>CMD, <TEAM_ID>, BCN,ON|OFF</td><td>-CMD and BCN are static text.
-<TEAM_ID> is the assigned team id.
-<ON|OFF> are static strings “ON” or “OFF” that control the audio beacon.</td><td>CMD,2057, BCN,ON

-<TEAM_ID> is 2057.
-Activates the audio beacon</td></tr>
</table>

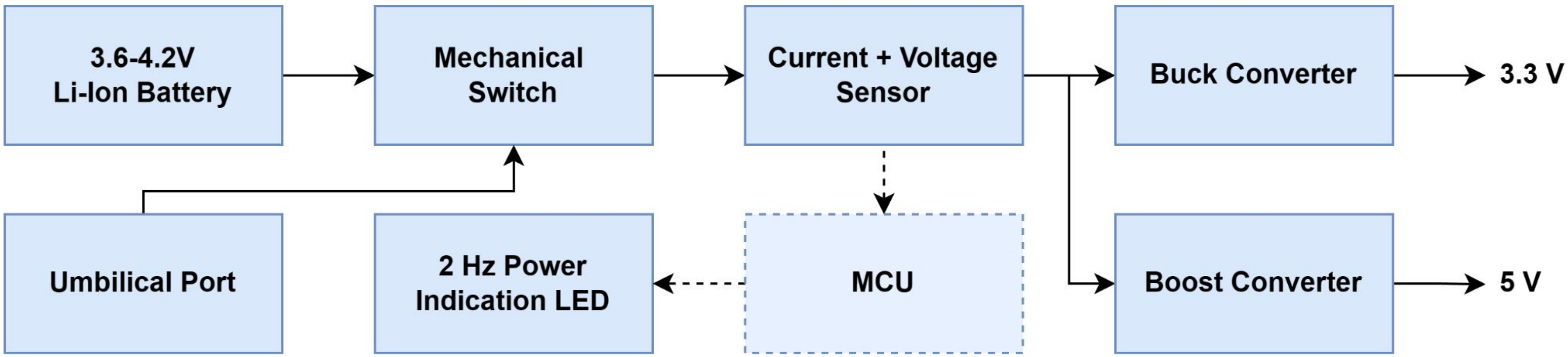
- The presented command formats complies with the competition requirements

Team Logo
Here

Electrical Power Subsystem Design

AJ Smyth

EPS Overview

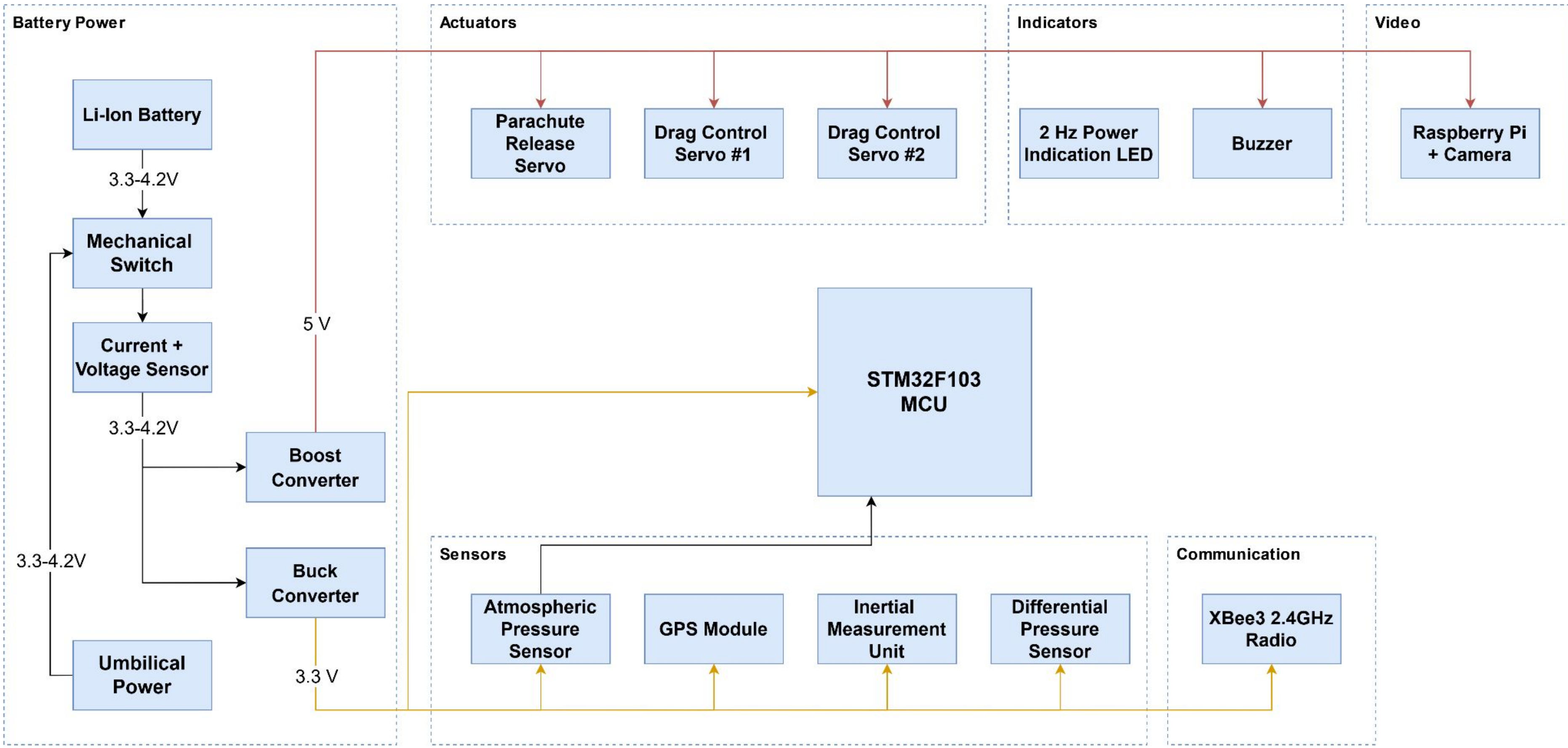


Component	Purpose
Li-Ion Battery	Supplies power to the Cansat
Mechanical Switch	Allows selectable isolation between battery & Cansat
Current + Voltage Sensor	Monitors battery state
Buck Converter	Converts battery voltage to 3.3 V
Boost Converter	Converts battery voltage to 5 V
Power Indication LED	Flashes at 2 Hz to indicate powered on state, possibility to use other patterns for error indication
Umbilical Port	Allows external power source for verification

EPS Changes Since PDR

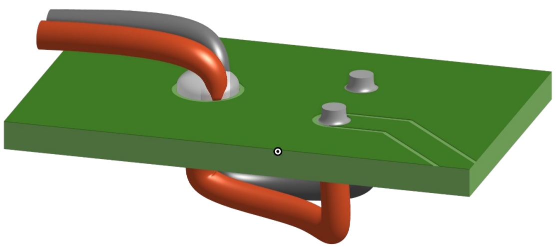
- **No changes have been made since PDR.**

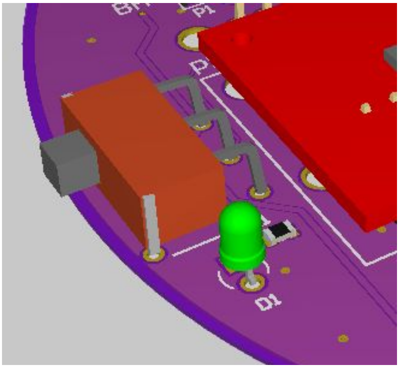
Payload Electrical Block Diagram (1/2)



Payload Electrical Block Diagram (2/2)

External Power Verification & Control





Umbilical Power Cable:

- 18 Gague Stranded,
- Terminated in Male XT-30
- Hot glued board connection

Umbilical Power Supply:

- External battery with Female XT-30 connector, power switch, and indicators

CanSat External Power Control:

- Easily accessible power switch and indication LED

Payload Power Source

Battery	Nominal Voltage (V)	Capacity (mAh)	Max Inst. Disch. (A)	Qty	Price (USD)
Vapcell F14 INR18350	3.7	1400	3	1	11.00

Payload Power Budget (1/3)

Part	Mode	Voltage (V)	Current (A)	Power (W)	Duty (%)	Active time (s)	Energy (Wh)	Info Source
GPS		3.3			100	7200	**0.185680**	**Datasheet +Estimate**
	Acquisition		0.0360000	0.11880000	2	120		N/A Uncertainty
	Tracking		0.0280000	0.09240000	98	7080		N/A Uncertainty
Pressure Sensor		3.3			100	7200	**0.000009**	**Datasheet**
	Low Power (1 Hz)		0.0000014	0.00000462	100	7200		N/A Uncertainty
Diff. Pressure Sensor		5	0.0100000	0.05000000	100	7200	**0.100000**	**Datasheet**

Payload Power Budget (2/3)

Part	Mode	Voltage (V)	Current (A)	Power (W)	Duty (%)	Active time (s)	Energy (Wh)	Info Source
IMU		3.3				7200	**0.025740**	**Datasheet**
	Gyro + Accel + DMP		0.0039000	0.01287000	100	7200		N/A Uncertainty
Power Sensor		3.3	0.0010000	0.00330000	100	7200	**0.006600**	**Datasheet**
Buzzer		5	0.1500000	0.75000000	37.5	5400	**0.562500**	**Datasheet +Estimate**
XBEE		3.3			100	7200	**0.028525**	**Datasheet +Estimate**
	Transmit (19 dBm)		0.1350000	0.44550000	3	230.4		+-0.003 Uncertainty
	Sleep Mode		0.0000020	0.00000660	97	6969.6		N/A Uncertainty

Payload Power Budget (3/3)

Part	Mode	Voltage (V)	Current (A)	Power (W)	Duty (%)	Active time (s)	Energy (Wh)	Info Source
STM32		3.3	0.0500000	0.16500000	100	7200	**0.330000**	**Estimate/ +- 0.0025 Uncertainty**
RPi + Camera	Recording	5	0.3000000	1.50000000	100	7200	**3.000000**	**Estimate/ +- 0.0015 Uncertainty**

Regulators

Part	Voltage (V)	Efficiency (%)	Supplied Energy (Wh)	Added Loss (Wh)
Buck Converter	3.6	85	0.57655402	**0.101745**
Boost Converter	3.6	80	3.66250000	**0.915625**

Totals (2 Hour Mission)

Available (Li-Ion Cell)	Consumption	Margin
5.2 Wh	4.3 Wh	0.9 Wh

Team Logo
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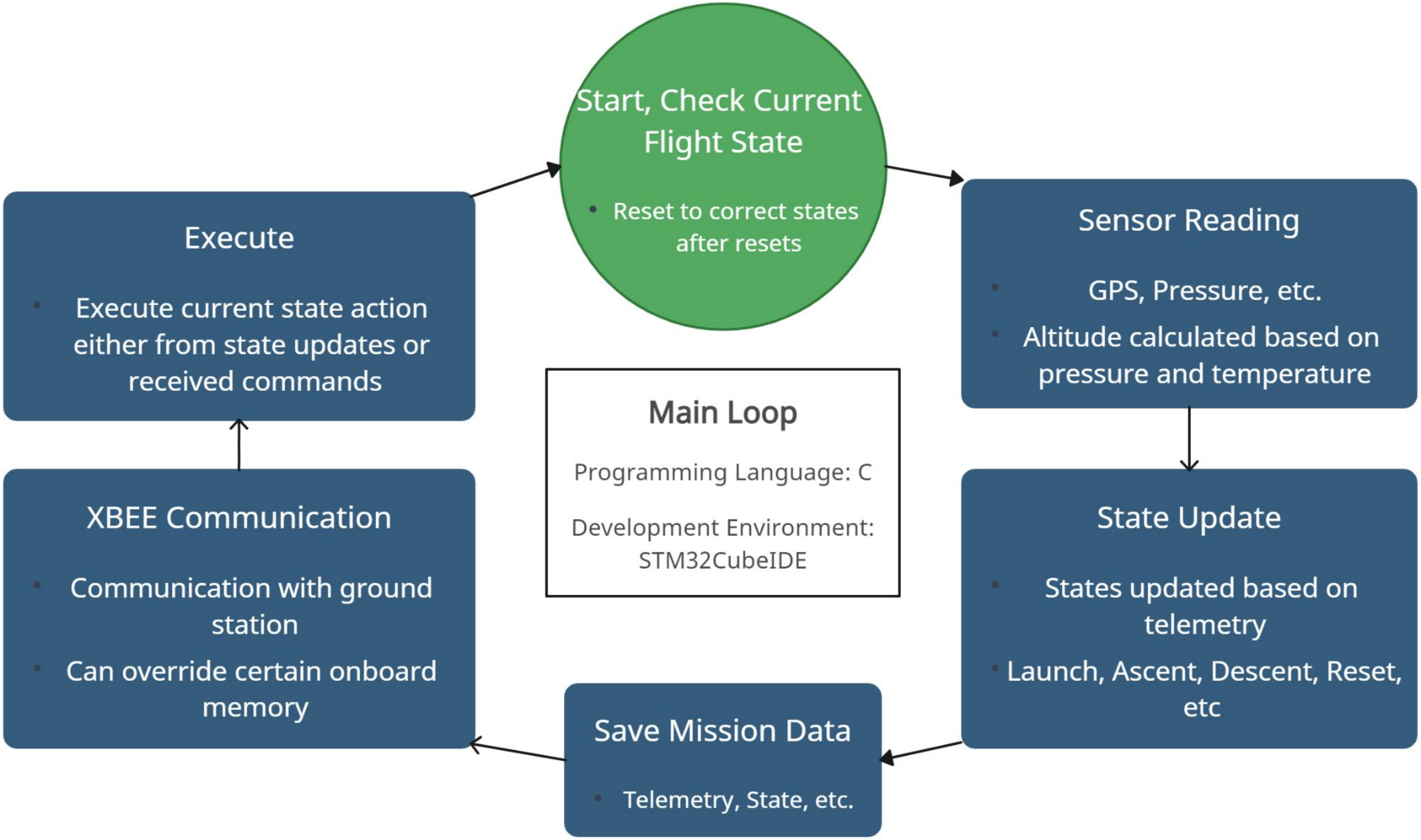
Flight Software (FSW) Design

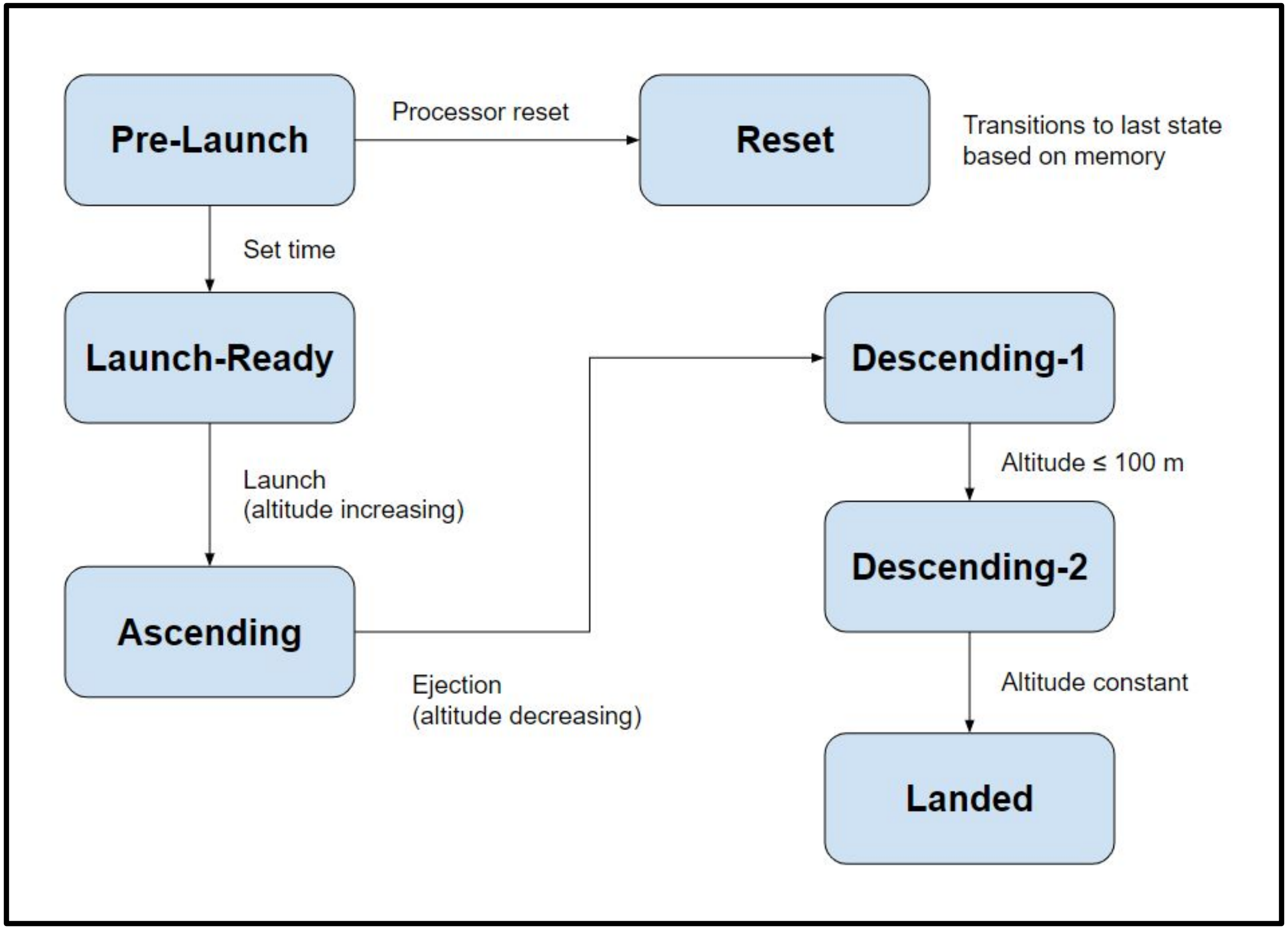
Husain Wafaie and Kaylee Kim


Start, Check Current Flight State
Reset to correct states after resets
Sensor Reading
GPS, Pressure, etc.
Altitude calculated based on pressure and temperature
State Update
States updated based on telemetry
Launch, Ascent, Descent, Reset, etc
Save Mission Data
Telemetry, State, etc.
XBEE Communication
Communication with ground station
Can override certain onboard memory
Execute
Execute current state action either from state updates or received commands
Main Loop
Programming Language: C
Development Environment: STM32CubeIDE

FSW Changes Since PDR

- **There has been no updates to the FSW since the PDR, we are working and developing the flight software to match exactly our proposed overview.**

Payload FSW State Diagram (1/4)



Payload FSW State Diagram (2/4)

States

- **Pre-launch**
  - Condition: initial state
  - Listen for set time/set mode commands
- **Launch-ready**
  - Condition: time set complete
  - ONCE: activate all sensors, reset all servos to starting position, set 0 altitude reference to launchpad
  - Sample all sensors, store and transmit telemetry at 1Hz
- **Ascending**
  - Condition: altitude increasing
    - Altitude: condition checked using pressure/temperature sensor
  - ONCE: turn on cameras
  - Sample all sensors and store and transmit telemetry at 1Hz
  - Wait for ejection (limit switch)

Payload FSW State Diagram (3/4)

- **Descending-1**
  - Condition: CanSat ejected AND altitude decreasing AND heat shield not deployed
    - Eject: Condition checked using limit switch
    - Altitude: Condition checked using pressure/temperature sensor
    - Heat shield: Condition checked from CanSat memory
  - ONCE: Deploy heat shield/aerobraking by activating servos
  - Sample all sensors, store and transmit telemetry (including angle stability) at 1 Hz
- **Descending-2**
  - Condition: Altitude decreasing AND altitude is less than or equal to 100 m
    - Altitude: Condition checked using pressure/temperature sensor
  - ONCE: Release heat shield, activate parachute (both using servos)
  - Sample all sensors, store and transmit telemetry (including angle stability) at 1 Hz

Payload FSW State Diagram (4/4)

- **Landed**
  - Condition: Altitude not changing
    - Altitude condition checked using pressure/temperature sensor
  - ONCE: Stop data transmission, activate audio beacon
- **Reset**
  - Condition: Processor reset (e.g. temporary power loss)
  - ONCE: Check state/packet count from memory, calculate time using GPS time to recover mission time
    - Packet count will be maintained through reset

Simulation Mode Software

Simulated Pressure Data Substitution

- If the CanSat is in simulation mode, data will not be read from the pressure sensor
- The simulated data transmitted by the ground station (1 Hz) will replace the sensor data, used for altitude calculation

Simulation Mode Commands

- Simulation Mode Control
  - Adjusts simulation mode flag depending on <MODE> field
  - Format: CMD, <TEAM_ID>, SIM, <MODE>
- Simulated Pressure Data
  - Sends simulated pressure data (parsed from CSV) to the CanSat
  - Format: CMD, <TEAM_ID>, SIMP, <PRESSURE>

Software Development Plan (1/2)

Development Team

- Husain Wafaie, Kaylee Kim

Prototype

- Development can start prior to acquisition from PCB designs provided
    - Early collaboration with the Electrical subteam would reduce the risk of late software development.
- Port connections will be established as designed and the ground station would be fully developed.

Subsystem Development Sequence

- Skeletal Development
    - Basic blocks indicating different states of payload will be developed first to ease the development process later on and reduce late development risks.
- Sensors and Signals Development
    - Sensor data will be read over I2C and SPI
    - Camera will utilize RX TX communication for control
- XBee Communication Development
    - GATT protocol will be used for radio communication
    - Payload XBee will transmit data at its own rate
- Testing (As shown in the next slide)
    - Full test run will be challenging due to limited space and resources

Software Development Plan (2/2)

Test Methodology

- Individual parts will first be tested with an STM32 module to ensure functionality
- Testing using simulation mode by reading pressure data from designated testing files

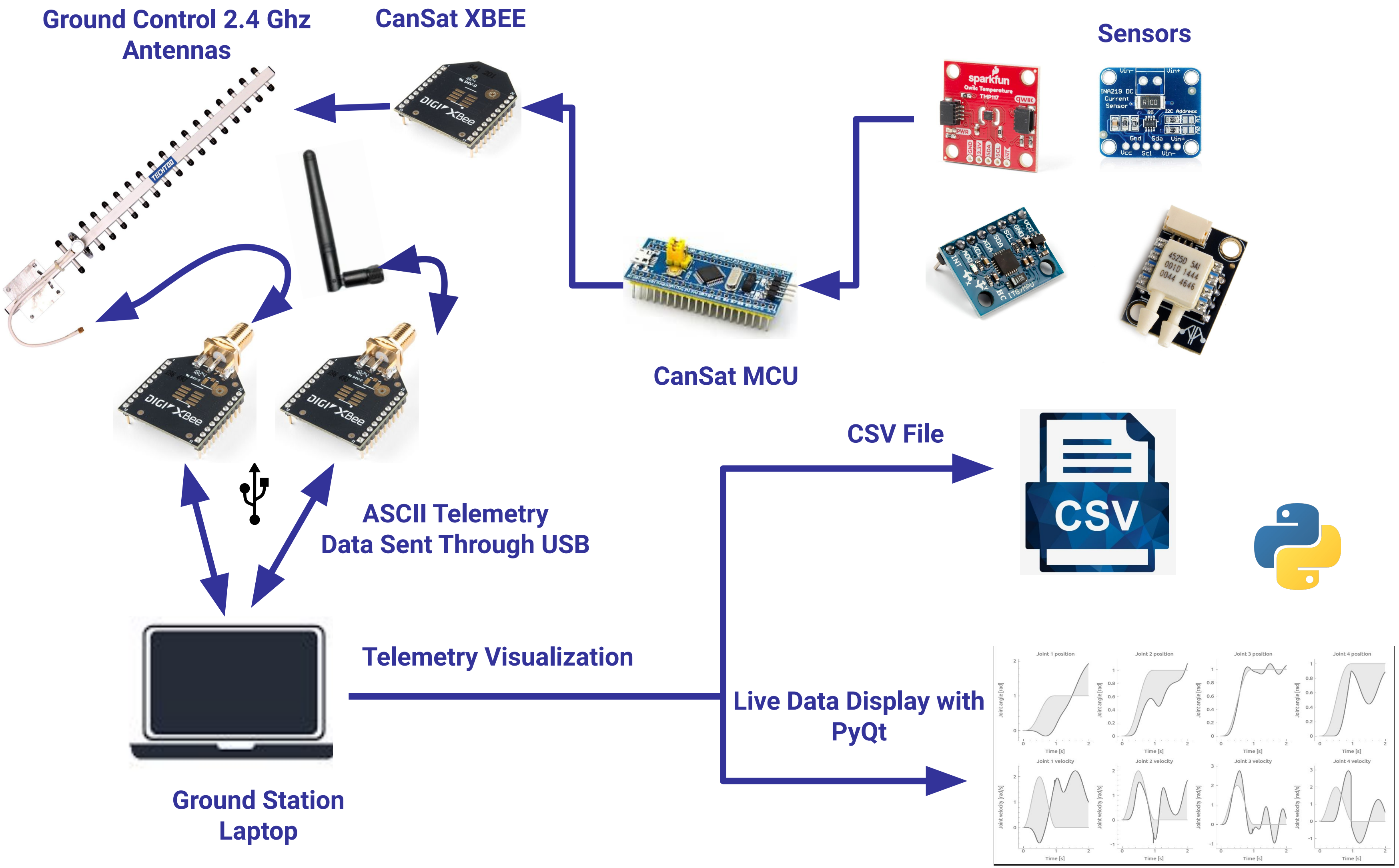
Progress Since PDR

- Since the PDR, were able to accomplish the following tasks:
- Skeletal development was already done before PDR*
- Able to read all sensor data over I2C
- Successful Xbee communication between ground station and payload was established
- Testing will take place in the Spring

Ground Control System (GCS) Design

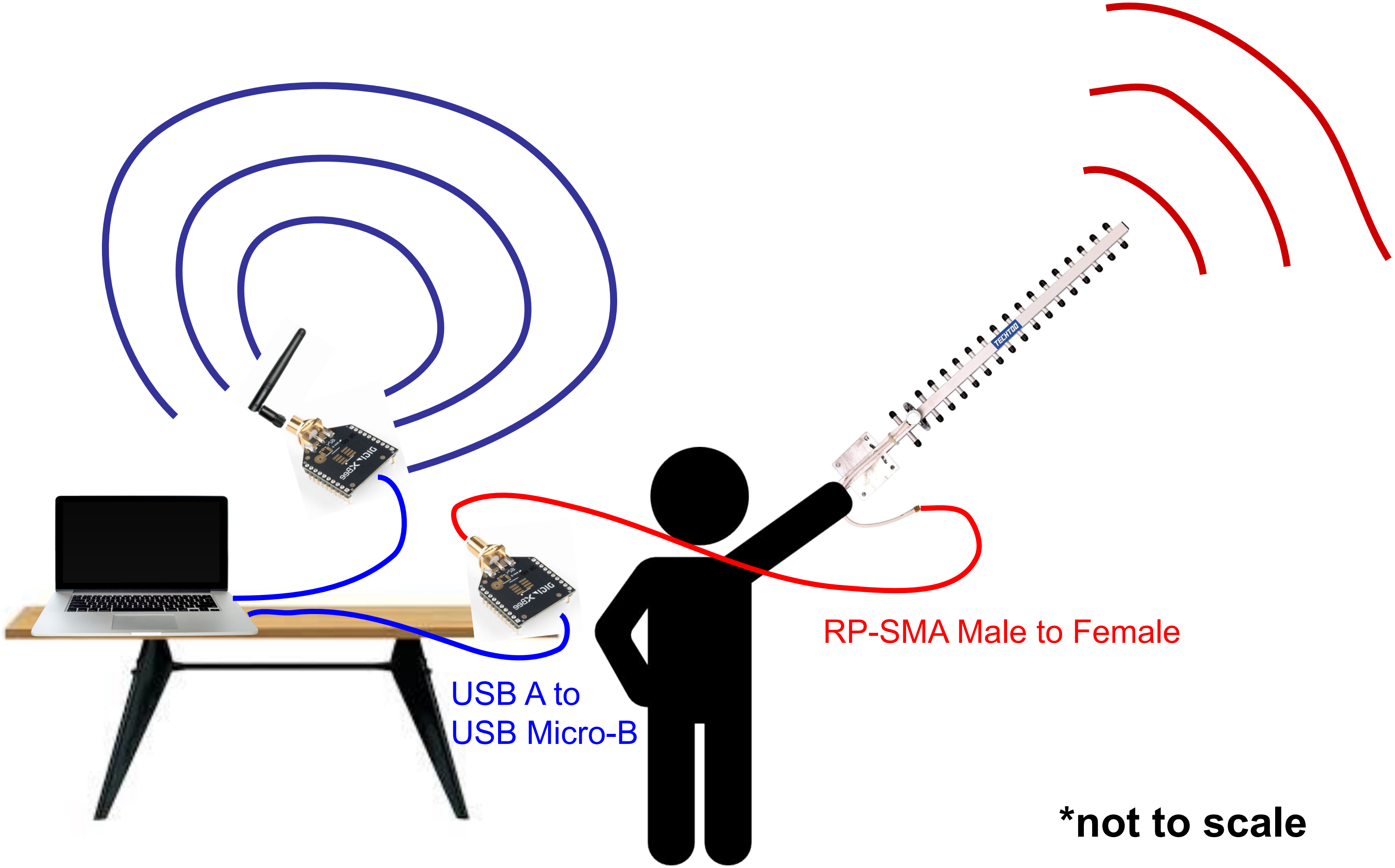
Khushi Gupta

GCS Overview



GCS Changes Since PDR

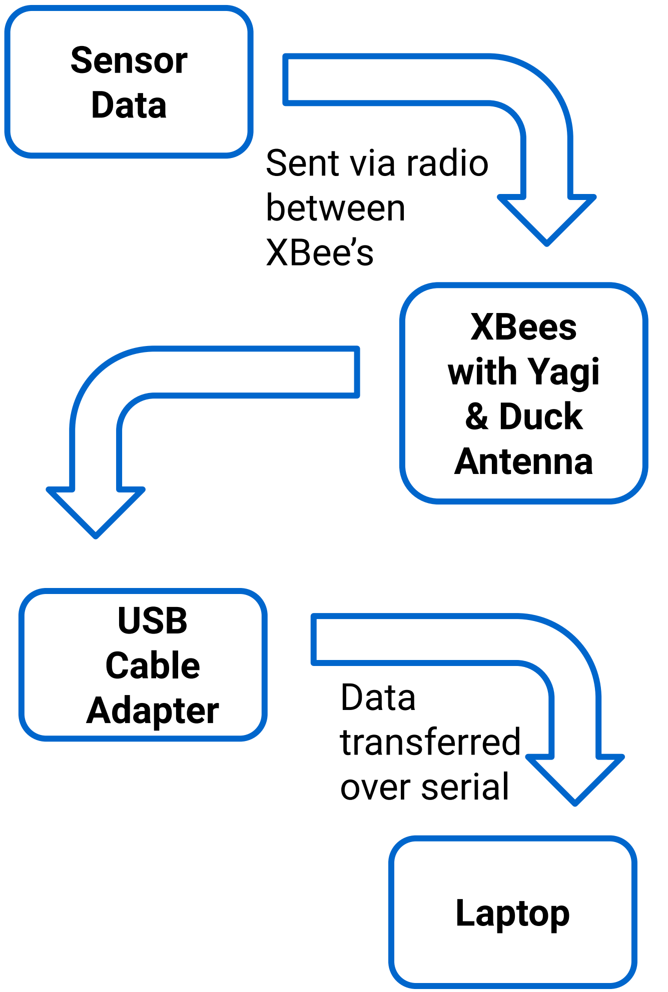
- **No changes since PDR.**



RP-SMA Male to Female
USB A to
USB Micro-B
*not to scale

GCS Design (2/2)

Problem or Specification	Solution
Ground station shall include one laptop computer with a minimum of two hours of battery operation	**Laptop**: Lenovo Yoga 930 **Battery life:** 1. 86 WHr battery 2. 2 hours running multiple applications.
Overheating Mitigation	1. Sunshade 2. Cooling Pad
Auto Update Mitigation	Windows 1. Disable automatic updates 2. Disconnect computer from internet
Power Conservation	1. Run only necessary applications 2. Reduce screen brightness when possible 3. Bring AC battery reserve

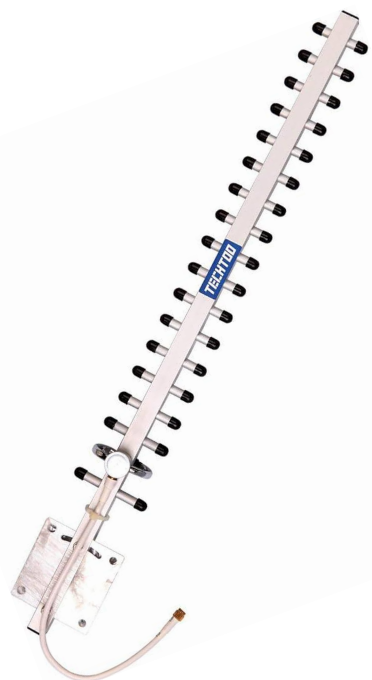


GCS Antenna (1/4)

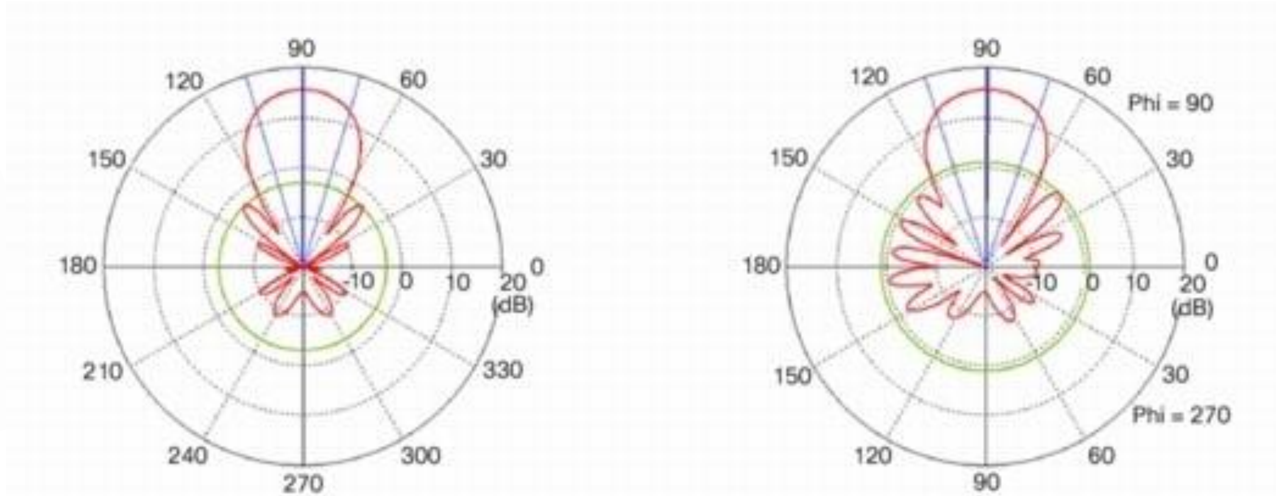
Selection
TECHTOO High Gain Yagi Directional Antenna Booster (Handheld)
2.4GHz Duck Antenna RP-SMA (Tabletop)

GCS Antenna (2/4)

Antenna	Cost	Impedance	Polarization	Gain	Mount	Weight
TECHTOO High Gain Yagi Directional Antenna Booster	$31.99	50 Ω	Horizontal or Vertical	18 dBi	Handheld	12.3oz



No antenna pattern found in documentation.
Generalized Yagi pattern pictured below.



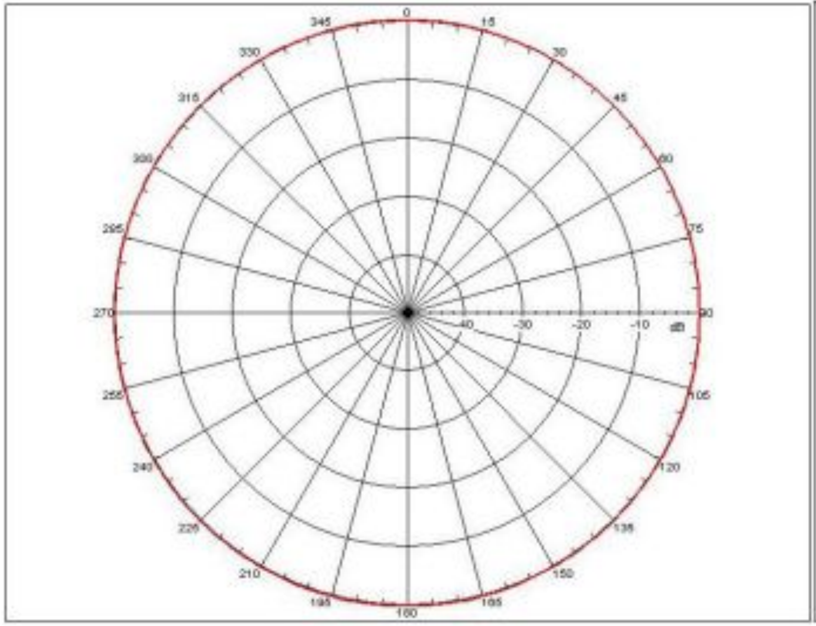
(c) Yagi Antenna Azimuth Plane Pattern

(d) Yagi Antenna Elevation Plane Pattern

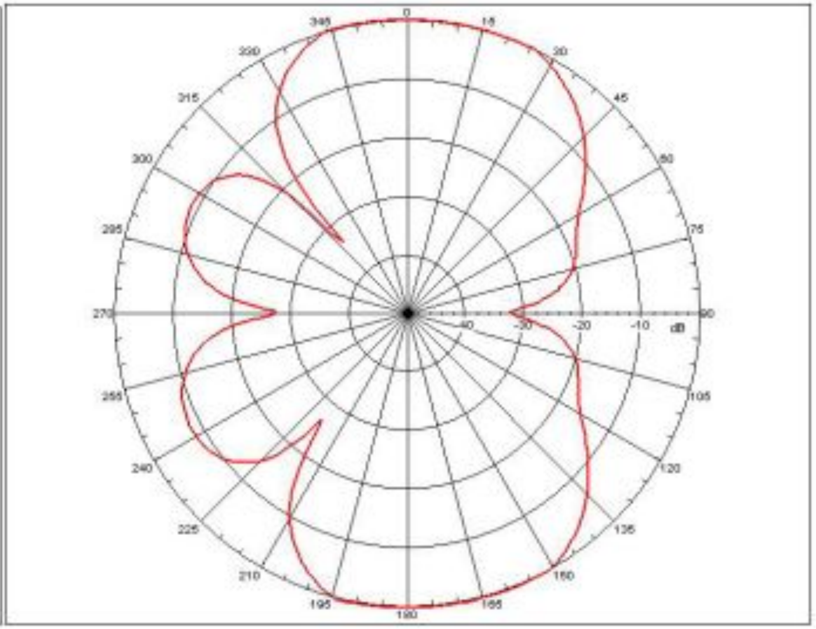
GCS Antenna (3/4)

Antenna	Cost	Impedance	Polarization	Gain	Mount
2.4GHz Duck Antenna RP-SMA	$5.45	50 Ω	Linear, Vertical	5 dBi	Tabletop

HORIZONTAL



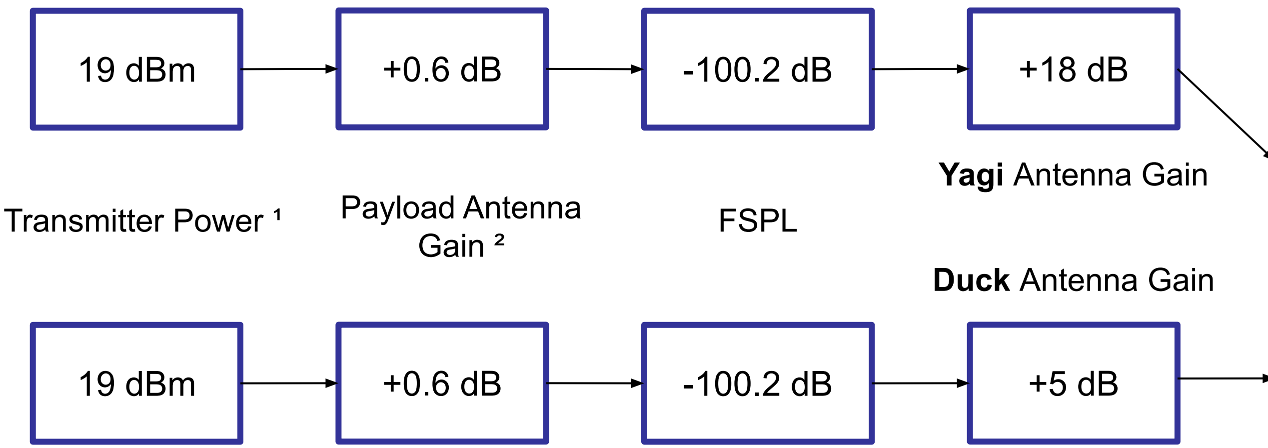
VERTICAL



GCS Antenna (4/4)

Link Budget (Yagi & Duck)

GCS Receiver Sensitivity[1]:
-103 dBm



Received Power	Link Margin
-62.6 dBm	40.4 dBm
-75.6 dBm	27.4 dBm

$$FSPL = 20\log_{10}(d) + 20\log_{10}(f) + 20\log_{10}\left(\frac{4\pi}{c}\right)$$

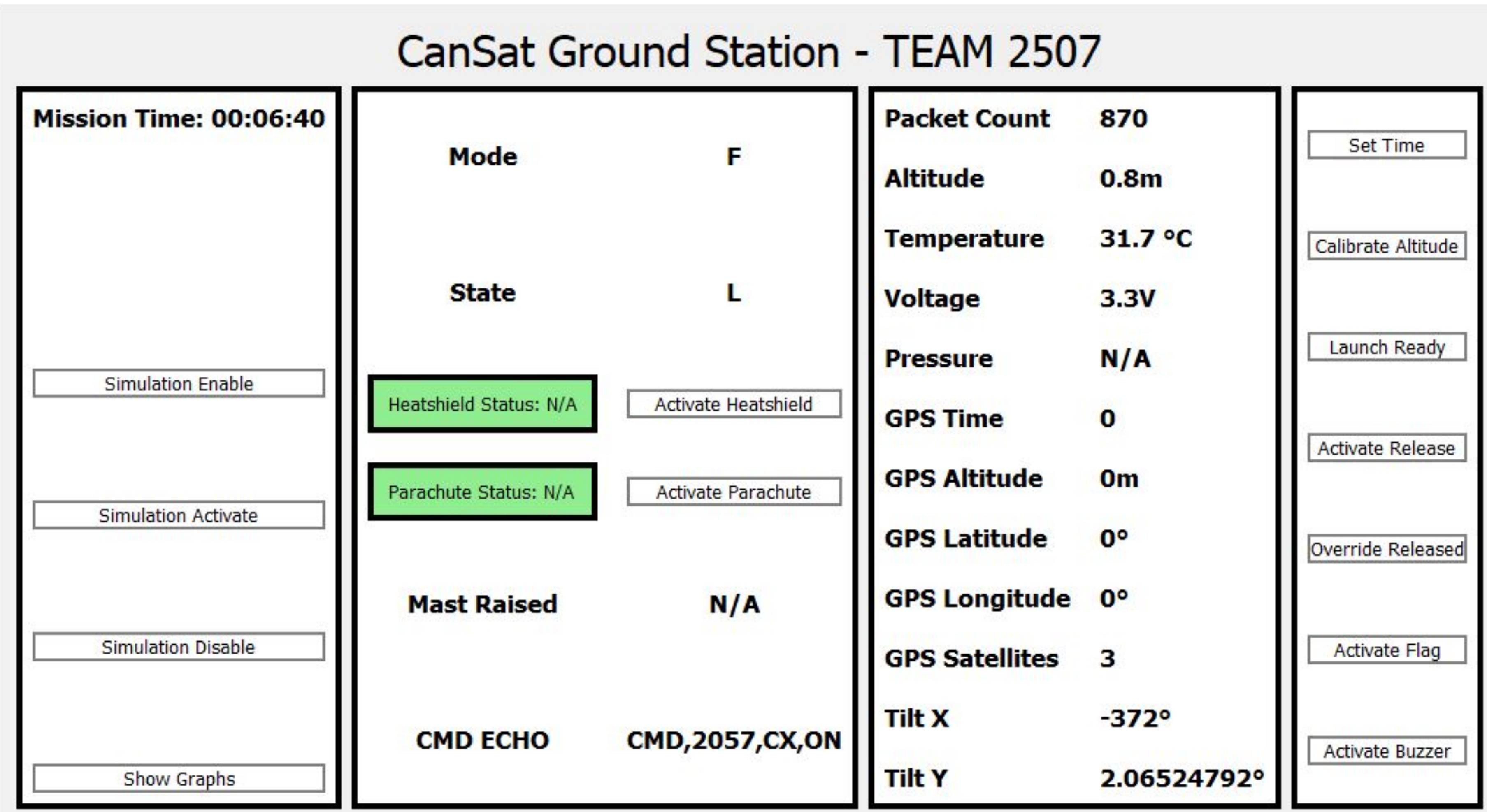
d = distance, f = frequency, c = speed of light

Assumptions:
$d = d_{max} \cong 1000$ m
$f \cong 2.45$ GHz

[1] XBee Pro 3 Datasheet
[2] XBee Pro Application Note XST-AN019a

GCS Software (1/6)

Main Design



GCS Software (2/6)

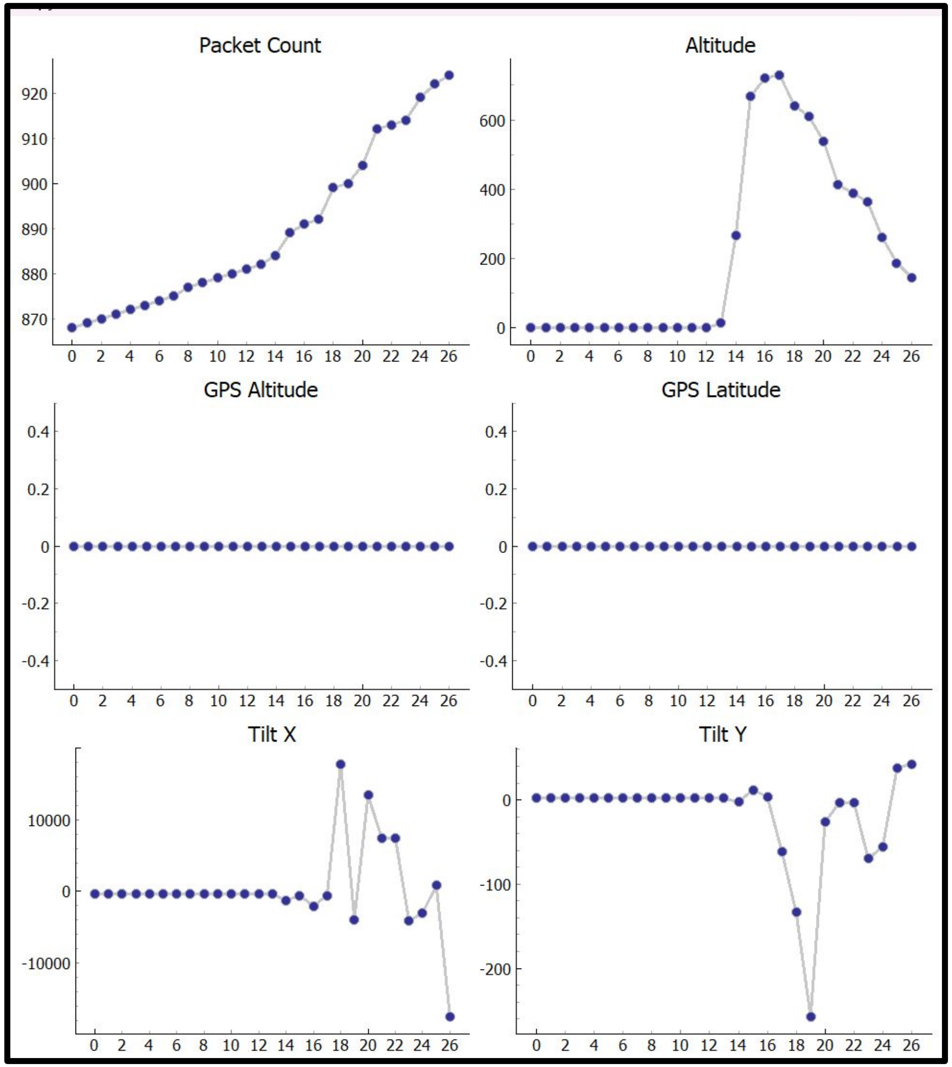
Libraries

- UI elements: **PyQt5, pyqtgraph**
  - Buttons, indicators, and widget arrangement (**PyQt5**)
  - Real-time data display (**PyQt5**)
  - Real-time plotting (**pyqtgraph**)
- Serial Communication : **pyserial**
  - Used to read XBee data from USB port
  - Allows the ground station to display real-time information transmitted by the CanSat
- CSV Files: **csv**
  - Allows ground station to read/write data to/from CSV files

GCS Software (3/6)

Real-time Plotting

- Using the **pyqtgraph** library to generate graphs
- Arranged graphs using **PyQt5**
- As new data is received, each plot resizes to fit all data, updating in real time
- Able to adjust frequency of graph updates



Command Interface

- Commands are grouped on the UI depending on their use (**PyQt5**)
- Each button is linked to its command, using **pyserial** to communicate with the XBee over USB

Simulation Mode

- The simulation data CSV will be placed in a designated directory
- When simulation mode is enabled, the ground station parses the data (**csv**)
- On activation, the ground station sends pressure data at 1Hz

Telemetry Data Recording

- Before the CanSat launches, a CSV file with the correct filename is created
  - Filename: Flight_<TEAM_ID>.csv
- The appropriate header row is then added to the CSV file
- As data is received from the CanSat, the ground station writes each packet to the CSV file using the **csv** library
  - The ground station will store the total number of packets received at the ground station
- After the flight is complete, the CSV file and video recording from the onboard camera will be presented to the judges on a USB drive

Progress Since PDR

- Radio Communications
  - Facilitated serial communication with XBee receiver
  - Successfully received data from CanSat test PCB in competition format
  - Parsed data packets
  - Displayed telemetry on ground station as packets are received
    - Both main dashboard and real-time plotting is functional

CanSat Integration and Test

Ryan Liu

CanSat Integration and Test Overview

Testing Purposes:

- To ensure all systems function separately and while integrated together
- To identify all design flaws and electronics failures are caught and fixed

Prototyping and Testing Plans:

The CanSats structure will be fabricated and assembled and electrical components will be wired and integrated into the system. Test will be performed to verify the structural integrity of the CanSat and the functionality of the descent control devices, all electrical components, and its mechanisms. Subsystems will be tested individually first to ensure no problems occur before moving on to the integrated tests. Integrated tests will be performed to check for compatibility between all subsystems and ensure proper functionality of the combined system.

Environmental tests will be performed according to the procedures outlined in section 3.5 of the Mission Guide

Testing will also be done to ensure the CanSat is operational in both FLIGHT and SIMULATION modes per section 3.3.3 of the Mission Guide

Subsystem Level Testing Plan (1/5)

Sensors

- All sensors will be integrated to a single PCB prototype
- A unit test of each sensor will be conducted to validate data
  - Will be checked against reference sensor to ensure accuracy

CDH

- Verified via XBEE or SW debug
  - Hard-coded telemetry will be broadcast by the Cansat to test GCS parsing
  - Telemetry will then be updated and broadcast at intended rate
  - Processor resets will be done to ensure onboard memory is utilized

EPS

- The entire CanSat electronic system will be assembled
- The circuit will be ran at full load for 2 hour runtime
  - Power characteristics will be captured via a Nordic power profiler kit

Subsystem Level Testing Plan (2/5)

Radio Communications

- XBEE data rate, bandwidth and packet loss will be measured at varying orientations and distances while in line of sight. XBEEs will be tested both with passive antennas and active antennas.

FSW

- CanSat SW behavior will be split into polling interrupt, timed, and looping actions
- SW will gradually incorporate more subsystems (sensors, XBEE communication, motor control)
- Unit tests for sim and flight mode will be created, evaluating features separately

Mechanical Testing Plan (1/2)

1. Weight Verification:
   a. Weigh the assembled CanSat, including all components, to ensure it meets the requirement of **900 grams +/- 10** grams without the egg (S1).
2. Dimensional Accuracy Tests:
   a. Check the nose cone symmetry along the thrust axis (S2).
   b. Measure the nose cone radius to be exactly **71 mm** (S3).
   c. Ensure the nose cone shoulder radius is exactly **68 mm** (S4).
   d. Verify the nose cone shoulder length is a minimum of **50 mm** (S5).
3. Run **Environmental Tests** on the entire assembly
   a. Drop Test
   b. Thermal Test
   c. Vibration Test
   d. Vacuum Test

Mechanical Testing Plan (2/2)

4. Validate the preliminary calculation & CFD results with actual descent testings
   a. CanSat assembly parachute testing
   b. CanSat heat-shield/aerobraking descent testing
5. Test that the egg protection mechanism is viable through physical testing

Mechanism Testing Plan

1. Servo Testing
   a. Verify that servos reach/hold specific positions within acceptable margins
   b. Test under operational loads to ensure no stalling or overheating occurs
   c. Assess functionality under mission temperature ranges and vibrations
2. Mechanism Testing
   a. Conduct tests to confirm the mechanism activates under expected conditions without fail
   b. Ensure the mechanism can withstand operational stresses
   c. Evaluate timing and execution in synchronization with mission parameters

Descent Control Testing Plan

1. Use ANSYS software with approximate CAD models of the probe and heat shield to determine flow patterns around the probe body
2. After finding a fairly stable design, ANSYS simulates the first probe descent rate and we adjust design to yield a descent rate of **10-30 meters per second**
3. Prototypes of this design with the parachute attached to simulate the second descent rate of **5 meters per second**. Measure the actual descent rate.
4. To test for tumbling and stable orientation, simulate the CanSat's descent in ANSYS, focusing on analyzing orientation stability and rotational dynamics under various atmospheric conditions.
5. Assure heat shield will stay connected and will open by sending code to open rapidly. Do this several times in different environmental conditions and repeat while simulating the probe deployment by dropping it from a high height
6. Assure parachute connections are strong by attaching a rope to them and dropping the prototypes from a substantial distance.
7. Simulate the parachute deployment of the CanSat to assure they will open in flight

Integrated Level Functional Test Plan (1/2)

- Complete the Environmental Tests outlined in the competition guidelines
- Perform a fit and weight check to make sure the structure is built within specifications
- Make sure that all moving parts can function regardless of orientation
- Perform controlled drop tests to ensure that the descent control system works properly (attach cable to CanSat and drop from a tall building, then activate descent control mechanisms)
- Perform heat shield and parachute deployment tests to make sure that they work at all orientations or movements
- Use prototype of the CanSat attached to their corresponding parachutes/heat shields and throw them off increasingly tall structures
- Use ANSYS software to determine CanSat velocity with heat shield only and determine parachute size to correlate to the desired descent rate
- Make sure that there are no compatibility issues when the electrical system is installed in the payload structure
- Confirm steady data transmission of data from CanSat at long distances through the antennas
- Confirm the CanSat and ground station operate continuously off battery power for 2 hours while transmitting data
- Utilize Simulation mode within the Ground Station software to test the triggering of the heatshield and payload mechanisms
- Make sure that there are no compatibility issues when the electrical system is installed in the CanSat structure

Integrated Level Functional Test Plan (2/2)

- Confirm the heat shield deployment mechanisms are working properly through deployment tests with controlled drop tests and tests on the ground
- Confirm the parachute deployment mechanism is working properly through deployment drop tests
- Confirm egg will be protected through egg drop test
- Perform at least 3 trials of the full CanSat operation to ensure the reliability of the entire design.
- Test release of heatshield from CanSat through drop tests utilizing the sensors to measure altitude.
- Perform drop tests while sensors are completely integrated to ensure structures can survive shock and other forces during the mission and landing.
- Perform integrated drop tests to ensure all sensors record accurate measurements under all forces and conditions.
  - Telemetry will be verified through cross references with lab sensors
- Performs drop tests starting with the CanSat inside the rocket body to ensure the heatshield deploys and parachute opens as expected. Ensure parachute stays attached and nothing breaks.
- Measure telemetry during drop tests and compare to known conditions to ensure telemetry readings are accurate.
- Verify antennas function properly during testing
- Run ground station software during drop test to test for proper functionality.

Drop Test:

Consists of a 61cm long chord with one side secured to the parachute and the other side secured to an eyebolt attached to a point of the ceiling or a different structure that allows the CanSat to drop without hitting the ground. This will create 30 Gs of shock and the CanSat must not bend.

Procedure:

- Power on the CanSat and check to make sure telemetry readings are being received.
- Raise the CanSat so the parachute attachment points are at the same height as the eyebolt.
- Release the CanSat
- Check to make sure the CanSat did not lose power, there is no damage, no pieces of the system detached, and that telemetry data is still being received.

Thermal Test:

The thermal test verifies that the CanSat can function in a warm environment to ensure the CanSat can handle the hot temperatures experienced on the launch pad. The test heats the CanSat to 60°C for two hours.

Procedure:

- Place the CanSat in the thermal chamber. Turn it on and seal the chamber.
- Turn on the heat source and monitor the temperature. Turn off the heat source when the chamber reaches 60°C and turn it on when it hits 55°C. Maintain this temperature range for two hours.
- After the two hours, turn off the heat source and visually perform visual and functional tests to verify that the CanSat withstanded the heat.
- While the CanSat is still hot, test the mechanisms and structures to make sure they still function correctly.
- Check epoxy joints and composite materials and verify their strength is not compromised.

Environmental Test Plan (3/5)

Vibration Test:

Utilizes an orbital sander to vibrate the Cansat at varying frequencies to try and hit resonance frequencies and test the CanSat's connections. The sander is cycled regularly for a minute to expose the CanSat to frequencies between 200 and 233 Hz which creates between 20 and 29 Gs.

Procedure:

- Power the CanSat on.
- Verify the accelerometer readings are being collected.
- Power up the sander. Wait five seconds after it gets to full speed and power it down to a full stop.
- Repeat this four more times.
- Inspect the CanSat for damage and make sure the system is still functioning.
- check that the accelerometer data is still being recorded.
- Power off the CanSat

Environmental Test Plan (4/5)

Fit Check:

Used to verify the CanSat will fit in the rocket and these specifications:

- Diameter of Nose Cone: The nose cone section must have a diameter of 141 mm to sit effectively on the edge of the airframe.
- Prevention of Cansat Fall: The design should prevent the Cansat from falling into the airframe.
- Diameter of Shoulder: The shoulder of the nose cone must have a diameter of 136 mm for proper fitment.
- Accuracy of Shoulder Dimension: The 136 mm diameter must be precise to ensure the Cansat fits correctly in the airframe.
- Shoulder Length: The shoulder must be at least 50 mm long to maintain the payload's position and orientation within the airframe.
- Maximum Payload Length: From the top of the airframe, the total length of the payload must not exceed 350 mm.

A mock container with these dimensions will be created. The CanSat will be inserted inside it to ensure it fits within the rocket.

Environmental Test Plan (5/5)

Vacuum Test:

A vacuum chamber will be constructed using a 18+ liter bucket, a 6 mm thick sheet of polycarbonate for the lid, and a shop vacuum. This test verifies the deployment operation of the probe.

Procedure:

- Power on the CanSat and suspend it in the vacuum chamber
- Turn on the vacuum to create the vacuum
- Observe the telemetry data and turn off the vacuum when the highest altitude is reached.
- Allow air to slowly enter the chamber and monitor the CanSat
- Record and save the telemetry data.
- Make the data available for the judges.

Test Procedures Descriptions (1/5)

Test Proc	Test Description	Requirements	Pass Fail Criteria
1	Weigh and measure the assembled CanSat. Confirm it slides easily out of the rocket, with all parts acting as expected and containing an egg	C1, C2, C8, S1, S3, S9	CanSat fits within the specified dimensions of the nose cone, weighs 900g +/- 10g without the egg, and slides out freely from the payload section.
2	Perform the tests outlined in the CanSat Environmental Test Guide (drop, vibration, thermal, fit check, vacuum)	S6, S7	CanSat structure, descent control hardware, and internal components survive environmental tests with no damage or change to performance.
3	Perform FEA analysis on mechanical structure of CanSat.	S1, S2, S6	Material doesn’t fail under the applied boundary conditions/loads.
4	Drop the CanSat with parachute from a tall structure and measure its descent rate (use a safety cable) with an egg	C8, M7	The CanSat descends at a rate less than 5 m/s; The parachute stays attached and egg is intact
5	Drop the CanSat with deployed heat shield from a tall structure and measure its descent rate(use a safety cable)	C3, M6	The probe descends at a rate between 10 to 30 m/s; hea tshield stays attached and acts as an aerobrake

Test Procedures Descriptions (2/5)

Test Proc	Test Description	Requirements	Pass Fail Criteria
6	Enter simulation mode when receives SIMULATION ENABLE/SIMULATION ACTIVATE commands. Probe supports simulation mode.	F6, G11, G12	The Cansat flight software enter simulation mode only after receives those commands.
7	Inspect CanSat electrical module for openings, loose components, unsecured wires and other hazards. Subject the electrical module to drop/vibration tests	E3, S6	Electrical module has no loose components which may fall off during the mission. The module survives environmental tests undamaged.
8	Set up ground station without external power supply. Record battery status of computer and operating time of ground station until battery is drained	G9	Ground station laptop and Xbee operates for at least 2 hours on battery power.
9	Test CanSat microprocessor to ensure code executes fast enough, and all sensors can be read accurately with altitude calibration	C9, F4, X4	Probe data is received by ground station at 1 Hz or above.Transmission is not delayed by code execution speed

Test Procedures Descriptions (3/5)

Test Proc	Test Description	Requirements	Pass Fail Criteria
10	After a simulated landing of the CanSat, test the audio beacon's activation and functionality.	C7	The audio beacon activates immediately upon landing and is audible from a minimum distance of 50 meters
11	Inspect XBee radios to ensure NETID/PANID is team number (2057). Ensure they are not in broadcast mode.	X1, X2, X3	XBee NETID is 2057. XBee not in broadcast mode.
12	Test heat shield deployment system + streamer releaseto ensure it can deploy the heat shield.	C4, M5, M9	Heat shield is deployed, and streamer is released
11	Test the CanSat's telemetry data transmission to the ground station and its response to real-time commands during a simulated flight	F4, F6, X4, G6, SN1, SN2, SN3, SN4, SN5, SN6, G3	All telemetry is reliably transmitted at 1Hz, and CanSat responds to commands within 2 seconds, demonstrating effective real-time communication.

Test Procedures Descriptions (4/5)

Test Proc	Test Description	Requirements	Pass Fail Criteria
14	Set an altitude trigger (simulating reaching 500 meters), then confirm the probe releases when this altitude is reached. Do the same with a 100 meter trigger for the probe parachute release.	C5, SN2	The probe deploys less than 3 seconds after detecting correct altitude. Altitude reading is accurate.
15	Reset the CanSat STM32 and observe the packet count and mission time transmitted with the telemetry	F1, F2	Packet count and mission time is retained during a processor reset. The CanSat probe is able to recover from the reset
16	Operate camera and inspect video quality. Verify it has a good view of the ground and can be recorded.	SN7, SN8, SN9	Camera recording is in colors, has resolution of at least 640x480. Has less than 10% obstruction of the view
17	Measure the time to locate and flip the CanSat's power switch	E3	The CanSat can be powered off rapidly without disassembling the CanSat

Test Procedures Descriptions (5/5)

Test Proc	Test Description	Requirements	Pass Fail Criteria
18	Export data as a CSV file and inspect it for accuracy	G2	Data can be saved as a CSV file and opened in other programs such as Microsoft Excel
19	Inspect ground station to measure speed data is received by XBee. Confirm all data is displayed in metric units and all data displays update in real time as data arrives at the Ground Station	X4, G6, G7	Data is received at 1Hz or greater. Data is plotted with little delay once received, and is displayed with correct units
20	Drop the probe with the heat shield and parachute deployed.	M6, M7	The probe slows to less than 5 m/s +/- 1 m/s with both the heat shield and parachute deployed, meeting descent rate requirements at 100 meters.
21	Run CanSat with all sensors active to test battery life	E1, E2, E5	CanSat runs a minimum of 2 hours off of 1 charge

Simulation Test Plans

A functional and powered CanSat will be suspended <15m above the ground. Using a pressure data profile, the CanSat will enter the appropriate flight stages based on calculated altitude, executing all actions (telemetry, deployments, etc.). Multiple test profiles will be used for evaluation.

1. **SIM ENABLE** and **SIM ACTIVATE** must be received from GCS
2. CanSat listens for additional GCS messages containing pressure values used for altitude calculation, sent at 1Hz
3. Received barometric pressure values are used for altitude calculation. Other sensors (temperature, GPS, voltage, etc.) are polled as normal
4. CanSat will go through all states and execute all actions (parachute will not be equipped in simulation mode)
    a. Resets will be tested by removing power from the CanSat
    b. Heat shield deployment and parachute deployment mechanism will be tested through simulated pressure values
5. CanSat telemetry will include altitude based on received pressure values

Mission Operations & Analysis

Ryan Liu

Overview of Mission Sequence of Events (1/3)

Role	Members
Mission Control Officer	Ryan
Ground Station Crew	Husain, Kaylee, Jackie
Recovery Crew	Jeremy, Sarah
CanSat Crew	AJ, Sunny, Jerome, Khushi

Overview of Mission Sequence of Events (2/3)

Flight Inspection

1. Arrival at launch site
2. Test all systems and establish connection between ground station and Cansat
3. Go through the hardware and software pre flight test checklist
4. Turn in the Cansat for inspection by judges at check-in table

Flight Preparation

5. Collect CanSat from judges and load into rockets payload bay
6. Prepare ground station for monitoring CanSat telemetry during demonstration
7. Prepare ground station for monitoring by competition judges
8. Install rocket and follow Mission Operations Manual Checklist

Cansat Flight Operations

9. Ground Station Crew will monitor and send necessary commands to probe
10. Wait for demonstration to be complete
11. Recovery Crew will recover the CanSat
12. Ground Station Crew will dismantle ground station

Post Flight Operations

13. Ground Station Crew will submit flash drive data for data analysis
14. Recovery Crew returns to check-in location to complete final judging requirements
15. Post Flight Review and Data Analysis

Overview of Mission Sequence of Events (3/3)

Antenna Construction and Ground System Setup

1. Establish connection between GCS antennas and CanSat XBee module
2. Confirm that signal remains stable while enclosed in rocket
3. Calibrate orientation and altitude sensors for particular environment
4. Make sure battery is fully charged
5. Prepare console for referee monitoring

CanSat Assembly and Test

1. Make sure all electronics and wiring fit snug within capsule
2. Wrap CanSat parachute and heatshield into a stowed configuration
3. Make sure nothing will get caught during deployment of CanSat during flight
4. Know procedures/equipment in the case of failure during launch
5. Perform any last mechanical tests (vibration/drop) to ensure structure does not fail during real flight demonstration

Data Delivery

1. Telemetry data will be exported as a .CSV file and delivered to a field judge for review in a USB along with camera footage

Field Safety Rules Compliance

Our mission operation manual (MOM) will be based off the template provided by the competition. It will be a thorough manual that will detail checklists and procedures needed to be performed throughout the mission. It is currently under development and will be completed in a 3-ring binder by launch day.

Before Launch Day:

1. Make sure that the software team has stable versions of ground station and is operational
2. Make sure both batteries are fully charged
3. Make sure all hardware and equipment are ready to be moved to competition area

On Launch Day:

1. Attach CanSat parachute to CanSat structure and wrap it into stowed configuration (probe parachute will already be stored)
2. Perform checks on each individual sensor:
   a. GPS, Altitude, Orientation
   b. Temperature, Voltage, Tilt
3. Verify communications between CanSat and ground station
4. Have ready any spare parts or electronic components for replacement

CanSat Location and Recovery

1. CanSat, painted in **red**, will both be attached to their individual **bright orange** parachutes. This will ensure that both the CanSat and Parachutes are visible from a far distance
2. An audio beacon will emit distinct beeps at 1 Hz to assist in finding the CanSat
3. Data transmission will continue; the CanSat should report its GPS coordinates in real time.
4. The team name, address, and contact information will be written in multiple locations on both the CanSat and parachutes. This reduces the risk of the information being obscured

CanSat 2024 Return Address Labeling

Team Name:	AntSat
Team Number:	#2057
Address:	4200 Engineering Gateway, Irvine, CA, 92617
Contact:	cansatuci@gmail.com / 310 - 951 - 2316

Parachutes

CanSat Heatshield

Mission Rehearsal Activities

Our team will be rehearsing the following procedures before the full launch of the CanSat:

1. Storing each parachute in their respective compartments and reloading the servos for the following test
2. Checking the data connection of ground station- correcting issues related to serial data transmission
3. Powering the CanSat on/off and checking electronics bay for any adjustments needed to be made
4. Loading the CanSat into the rocket
5. Completing pre-launch tests of sensors and mechanical components
6. Processing and saving telemetry data
7. Managing telemetry data and ground station operations
8. Recovering the CanSat using the audio beacon and GPS

Written Procedures Development:

All procedures will be updated with the schedule times. The final procedures will be compiled after the final assembly is finished.

Requirements Compliance

Ryan Liu

Requirements Compliance Overview

- All of the base requirements for both the Mechanical and Electrical subsystems are completed at this moment in time.
- The entire CanSat system has been modeled in CAD software. FEA studies and physical tests have been carried out to verify structural integrity of loadings.
- The physical assembly building process is still in progress. The second edition prototype has been 3D printed, and testing has been completed. The final structure is currently in progress
- V1.0 and V2.0 PCBs have been made and tested. V3.0 PCBs are being ordered, and final testing will begin soon. Further progress is being made to integrate the electrical power system with sensors and software.
- Radio testing for data transfer from the ground station to the CanSat has already been done but further testing will need to test the 725 meter plus 10% buffer maximum distance between the probe and ground station during competition
- Drop, pressure, shock, and vibration tests will start in early April
- Sensor and CDH components have been tested individually to confirm that they operate as expected, and GCS basic functionalities have been tested to be compliant

Requirements Compliance (1/10)

Req Num	Requirement	Comply / No Comply / Partial	X-Ref Slide(s) Demonstrating Compliance	Team Comments or Notes
C1	The Cansat shall function as a nose cone during the rocket ascent portion of the flight.	Comply	20	Completed
C2	C2 The Cansat shall be deployed from the rocket when the rocket motor ejection charge fires.	Comply	26	Completed
C3	After deployment from the rocket, the Cansat shall deploy its heat shield/aerobraking mechanism.	Comply	21	Completed
C4	A silver or gold mylar streamer of 50 mm width and 1.5 meters length shall be connected to the Cansat and released at deployment. This will be used to locate and identify the Cansat.	Comply	21	Completed
C5	At 100 meters, the Cansat shall deploy a parachute and release the heat shield.	Comply	40	Completed
C6	Upon landing, the Cansat shall stop transmitting data.	Comply	126	Completed
C7	Upon landing, the Cansat shall activate an audio beacon.	Comply	126	Completed
C8	The Cansat shall carry a provided large hens egg with a mass range of 51 to 65 grams	Comply	68	Completed
C9	0 altitude reference shall be at the launch pad.	Comply	124, 139	Completed

Requirements Compliance (2/10)

Req Num	Requirement	Comply / No Comply / Partial	X-Ref Slide(s) Demonstrating Compliance	Team Comments or Notes
C10	During descent with the heat shield deployed, the descent rate shall be between 10 to 30 m/s.	Comply	61	Completed
C11	At 100 meters, the Cansat shall have a descent rate of less than 5 m/s.	Comply	61	Completed
C12	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	188	Completed
S1	The Cansat mass shall be 900 grams +/- 10 grams without the egg being installed.	Comply	94	Completed
S2	Nose cone shall be symmetrical along the thrust axis.	Comply	20	Completed
S3	Nose cone radius shall be exactly 71 mm	Comply	26	Completed
S4	Nose cone shoulder radius shall be exactly 68 mm	Comply	26	Completed
S5	Nose cone shoulder length shall be a minimum of 50 mm	Comply	26	Completed

Requirements Compliance (3/10)

Req Num	Requirement	Comply / No Comply / Partial	X-Ref Slide(s) Demonstrating Compliance	Team Comments or Notes
S6	Cansat structure must survive 15 Gs vibration	Partial	-	Not tested
S7	Cansat shall survive 30 G shock.	Partial	-	Not tested
S8	The Cansat shall perform the function of the nose cone during rocket ascent.	Comply	20	Completed
S9	The rocket airframe can be used to restrain any deployable parts of the Cansat but shall allow the Cansat to slide out of the payload section freely.	Comply	20	Completed
S10	The rocket airframe can be used as part of the Cansat operations.	Comply	20	Completed
S11	All electronics and mechanical components shall be hard mounted using proper mounts such as standoffs, screws, or high performance adhesives.	Comply	86	Completed
M1	No pyrotechnical or chemical actuators are allowed.	Comply	92-93	Completed
M2	Mechanisms that use heat (e.g., nichrome wire) shall not be exposed to the outside environment to reduce potential risk of setting the vegetation on fire.	Comply	20-25	None Used
M3	All mechanisms shall be capable of maintaining their configuration or states under all forces	Partial	-	Not tested

Requirements Compliance (4/10)

Req Num	Requirement	Comply / No Comply / Partial	X-Ref Slide(s) Demonstrating Compliance	Team Comments or Notes
M4	Spring contacts shall not be used for making electrical connections to batteries. Shock forces can cause momentary disconnects.	Comply	116	Completed
M5	The Cansat shall deploy a heat shield after deploying from the rocket.	Comply	21	Completed
M6	The heat shield shall be used as an aerobrake and limit the descent rate to 10 to 30 m/s	Comply	61	Completed
M7	At 100 meters, the Cansat shall release a parachute to reduce the descent rate to less than 5 m/s.	Comply	61, 83	Completed
M8	The Cansat shall protect a hens egg from damage during all portions of the flight.	Comply	84, 85	Completed
M9	If the nose cone is to be considered as part of the heat shield, the documentation shall identify the configuration.	Comply	20, 21	Completed
M10	After the Cansat has separated from the rocket and if the nose cone portion of the Cansat is to be separated from the rest of the Cansat, the nose cone portion shall descend at less than 10 meters/second using any type of descent control device.	Comply	55	Completed

Requirements Compliance (5/10)

Req Num	Requirement	Comply / No Comply / Partial	X-Ref Slide(s) Demonstrating Compliance	Team Comments or Notes
E1	Lithium polymer batteries are not allowed.	Comply	116	Completed
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	116	Completed
E3	Easily accessible power switch is required	Comply	115	Completed
E4	Power indicator is required	Comply	115	Completed
E5	The Cansat shall operate for a minimum of two hours when integrated into the rocket.	Comply	119	Completed
X1	XBEE radios shall be used for telemetry. 2.4 GHz Series radios are allowed. 900 MHz XBEE radios are also allowed.	Comply	104	Completed
X2	XBEE radios shall have their NETID/PANID set to their team number.	Comply	104	Completed
X3	XBEE radios shall not use broadcast mode	Comply	104	Completed

Requirements Compliance (6/10)

Req Num	Requirement	Comply / No Comply / Partial	X-Ref Slide(s) Demonstrating Compliance	Team Comments or Notes
X4	The Cansat shall transmit telemetry once per second.	Comply	107	Completed
X5	The Cansat telemetry shall include altitude, air pressure, temperature, battery voltage, Cansat tilt angles, air speed, command echo, and GPS coordinates that include latitude, longitude, altitude and number of satellites tracked.	Comply	105-107	Completed
SN1	Cansat shall measure its speed with a pitot tube during ascent and descent.	Comply	34	Completed
SN2	Cansat shall measure its altitude using air pressure.	Comply	30	Completed
SN3	Cansat shall measure its internal temperature.	Comply	31	Completed
SN4	Cansat shall measure its angle stability with the aerobraking mechanism deployed.	Comply	35, 36	Completed
SN5	Cansat shall measure its rotation rate during descent.	Comply	36	Completed
SN6	Cansat shall measure its battery voltage.	Comply	33	Completed

Requirements Compliance (7/10)

Req Num	Requirement	Comply / No Comply / Partial	X-Ref Slide(s) Demonstrating Compliance	Team Comments or Notes
SN7	The Cansat shall include a video camera pointing horizontally	**Comply**	**37**	Completed
SN8	The video camera shall record the flight of the Cansat from launch to landing.	**Comply**	**37**	Completed
SN9	The video camera shall record video in color and with a minimum resolution of 640x480.	**Comply**	**37**	Completed
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**	**124**	Completed
G2	The ground station shall generate csv files of all sensor data as specified in the Telemetry Requirements section.	**Comply**	**131**	Completed
G3	Telemetry shall include mission time with 1 second or better resolution.	**Comply**	**105**	Completed
G4	Configuration states such as zero altitude calibration shall be maintained in the event of a processor reset during launch and mission.	**Partial**	**-**	Not tested
G5	Each team shall develop their own ground station.	**Comply**	**131**	Completed

Requirements Compliance (8/10)

Req Num	Requirement	Comply / No Comply / Partial	X-Ref Slide(s) Demonstrating Compliance	Team Comments or Notes
G6	All telemetry shall be displayed in real time during descent on the ground station.	Comply	139, 141	Completed
G7	All telemetry shall be displayed in engineering units (meters, meters/sec, Celsius, etc.) and the units shall be indicated on the displays.	Comply	139, 141	Completed
G8	Teams shall plot each telemetry data field in real time during flight.	Comply	141	Completed
G9	The ground station shall include one laptop computer with a minimum of two hours of battery operation, XBEE radio and an antenna.	Comply	131, 134	Completed
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	134	Completed
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	109	Completed
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	127	Completed
G13	The ground station shall use a table top or handheld antenna.	Comply	136, 137	Completed

Requirements Compliance (9/10)

Req Num	Requirement	Comply / No Comply / Partial	X-Ref Slide(s) Demonstrating Compliance	Team Comments or Notes
G14	Because the ground station must be viewed in bright sunlight, the displays shall be designed with that in mind, including using larger fonts (14 point minimum), bold plot traces and axes, and a dark text on light background theme.	Comply	139, 141	Completed
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	143	Completed
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	126	Completed
F2	The Cansat shall maintain mission time throughout the whole mission even with processor resets or momentary power loss.	Comply	126	Completed

Requirements Compliance (10/10)

Req Num	Requirement	Comply / No Comply / Partial	X-Ref Slide(s) Demonstrating Compliance	Team Comments or Notes
F3	The Cansat shall have its time set to within one second UTC time prior to launch.	**Comply**	**124, 139**	Completed
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 csv file.	**Comply**	**127**	Completed
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**	**127**	Completed
F6	The payload flight software shall only enter simulation mode after it receives the SIMULATION ENABLE and SIMULATION ACTIVATE commands.	**Comply**	**109, 127**	Completed

Team Logo
Here

Management

Ryan Liu

Status of Procurements

Sensors: All sensors have been ordered and received.

Electrical Hardware: PCBs have been ordered, with the first prototypes already arrived in the past few months. We are currently ordering V3 of the PCBs. All motors, servos, and limit switches have been ordered and are currently being tested.

Mechanical Hardware: Has been purchased and received; minor structural changes can be 3D printed and any other hardware can be quickly ordered.

Ground Station: The communications hardware has been received. Supporting components (sunshade, cooling pad) will be reused from previous years' equipment.

CanSat Budget – Hardware

Structural Components

Component	System	Procurement Year	Quantity	Source	Unit Price	Total Price
Compression Springs (2006N364)	Egg Protection	2024	8	McMaster-Carr	2.84	22.72
Cotter Pins (98355A130)	Egg Protection	2023	2	McMaster-Carr	0.35	0.7
Silver Metallic Streamer	Streamer Deployment	2023	1	Amazon	12.82	12.82
5mm Carbon Fiber Rod (5 pack)	CanSat Structure	2023	1	Amazon	15.99	15.99
9g Micro Servo (4 pack)	Aerobrake	2023	1	Amazon	7.99	7.99
HiLetgo Micro Limit Switch KW12-3 (10 pack)	Aerobrake	2023	1	Amazon	5.99	5.99
Purple Ripstop Nylon Fabric (60" x 36")	Aerobrake	2023	1	Amazon	8.95	8.95
PGXT Parachute Toy (4 pack)	Aerobrake	2023	1	Amazon	8.99	8.99
Mini Ball Bearing (2x5x2.5) (10 pack)	Aerobrake	2023	1	Amazon	5.88	5.88
Dowel Pin, 52100 Alloy Steel, (91595A955) (50 pack)	Landing Gear	2023	1	McMaster-Carr	14.45	14.45
Torsion Spring,180 Degree, (9271K603) (6 pack)	Descent Control	2023	1	McMaster-Carr	5.57	5.57
18-8 Stainless Steel Dowel Pin (90145A480)	Descent Control	2023	1	McMaster-Carr	6.13	6.13
Dowel Pin, 4037, 4140 Alloy Steel, (98381A475)	Parachute Release	2023	1	McMaster-Carr	10.7	10.7
Extensions Springs, Hook Ends, (1942N154) (2 pack)	Aerobrake	2023	1	McMaster-Carr	10.59	10.59
Routing Eyebolt With Nut, 6-32, (9489T111) (10 Pack)	Parachute Release	2023	1	McMaster-Carr	2.89	2.89
Dowel Pin, 4140 Alloy Steel, (98381A015)	Aerobrake / Parachute Release	2023	5	McMaster-Carr	2.03	10.15
3D Printing Filament (1kg)	All	2023	1	Amazon	14.99	14.99
30" Compact Elliptical Parachute (CFC-30-S-ST)	Parachute Release	2024	1	Fruity Chutes	85.14	85.14
					Overall Total	$165.50

* CanSat structures were calculated using an estimation of weight of the structure and the price per weight of the material selected using 3D Printer Slicing Techniques. Since these are 3D printed with variable infill, it is projected that the overall cost of this component to increase as the year progresses.

Electrical Components

Component	System	Procurement Year	Quantity	Source	Unit Price	Total Price
STM32 Bluepill	Microcontroller	2023	1	Amazon	4.75	4.75
Hiletgo MPU6050 Inertial Measurement Unit	Sensors	2023	1	Amazon	6.49	6.49
SparkFun Barometric Pressure Sensor BMP581	Sensors	2023	1	DigiKey	19.95	19.95
Pitot Tube + Differential Pressure Sensor	Sensors	2023	1	Amazon	55.88	55.88
Adafruit Mini GPS	Sensors	2023	1	Adafruit	29.95	29.95
IC Current Monitor	Sensors	2023	1	DigiKey	2.50	2.50
Digi XBee3	Communication	2023	1	Sparkfun	19.5	19.5
SparkFun XBee Breakout Board	Communication	2023	1	Amazon	11.95	11.95
iFlight Buzzer	Input/Output	2023	1	Amazon	9.5	9.5
Slide Switch	Input/Output	2023	1	DigiKey	3.45	3.45
Green LED	Input/Output	2023	1	Amazon	0.02	0.02
SMD Header 4 POS 1.25MM	Connectors	2023	1	DigiKey	0.91	0.91
18350 Battery Holder	Connectors	2023	1	Amazon	1.30	1.30
Buck Converter (TPS563252)	Power Management	2023	1	DigiKey	0.53	0.53
Boost Converter (TPS61022RWUR)	Power Management	2023	1	DigiKey	1.18	1.18
Power Inductor 2.2uH	Passives	2023	1	DigiKey	0.36	0.36
Power Inductor 1uH	Passives	2023	1	DigiKey	0.38	0.38
2W 80mR Current Sense Resistor	Passives	2023	1	DigiKey	0.56	0.56
Other Miscellaneous passives	Pasives	2023	22	Amazon	0.001	0.02
Printed Circuit Board	PCB	2023	1	JLCPCB	1.97	1.97
Vapcell 18350 Li-Ion Battery	Power Supply	2023	1	Amazon	8.5	8.5
Raspberry Pi Zero W	Camera Hardware	2023	1	MicroCenter	14.99	14.99
Zero Spy Camera for Raspberry Pi Zero	Camera Hardware	2023	1	Adafruit	19.95	19.95

Electrical Components

Component	System	Procurement Year	Quantity	Source	Unit Price	Total Price
XBEE	Ground	2021	1	Actual	$41.50	$41.50
Ground Station Antennas	Ground	2019	1	Estimated	$70.00	$70.00
					Overall Total	**$491.59**

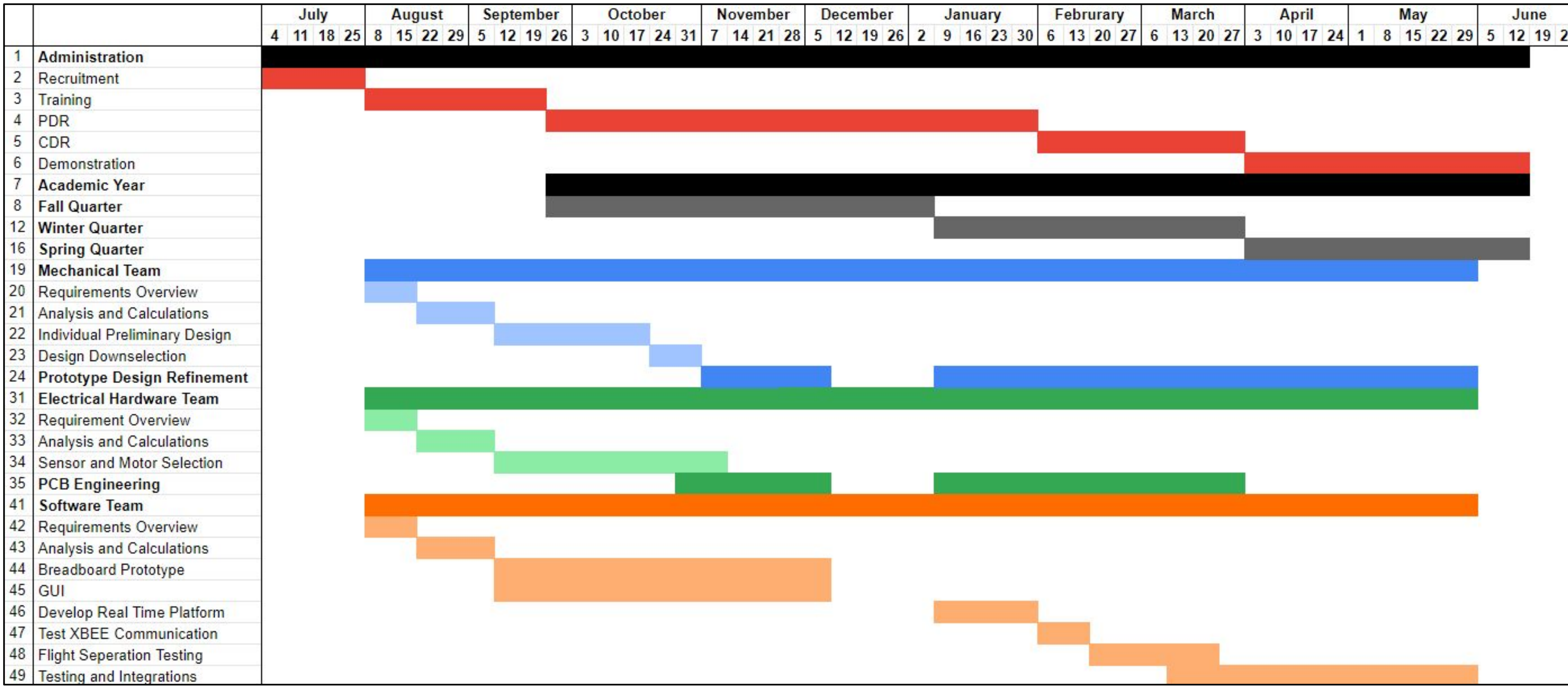
Other Costs

Miscellaneous Costs						
Component	**System**	**Year**	**Quantity**	**Source**	**Unit Price**	**Total Price**
Registration Fee	Team	2023	1	Actual	$200	$200
Cooling Pad	Ground	2020	1	Actual	$17.99	$17.99
Computer	Ground	2020	1	-	-	-
Travel and Lodging	Team	2024	10	Budgeted	$600	$6000
Prototyping	Team	2023	1	Budgeted	$300	$300

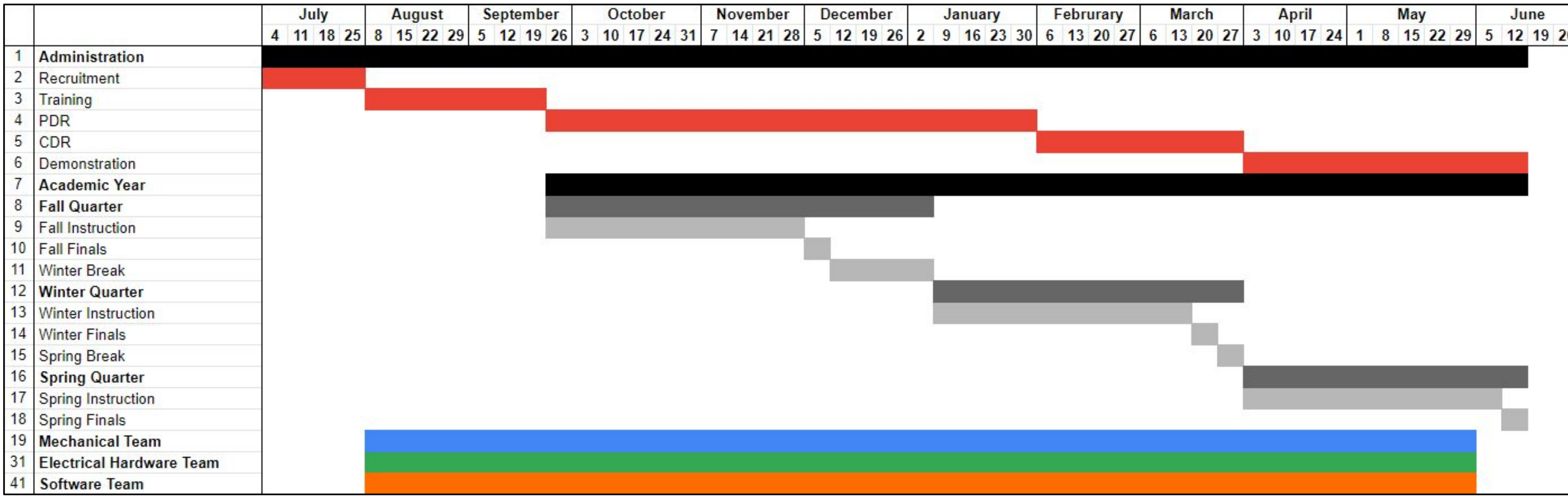
Overall Total	$7024.5

Sources of Income (Estimated)		
Source	**Year**	**Total Amount**
UCI Senior Design Program	2023	$4500
Northrop Grumman Sponsor	2023	$3500
Blue Origin Sponsor	2024	$1000

Program Schedule Overview



Administration and Academic Year Breakdown



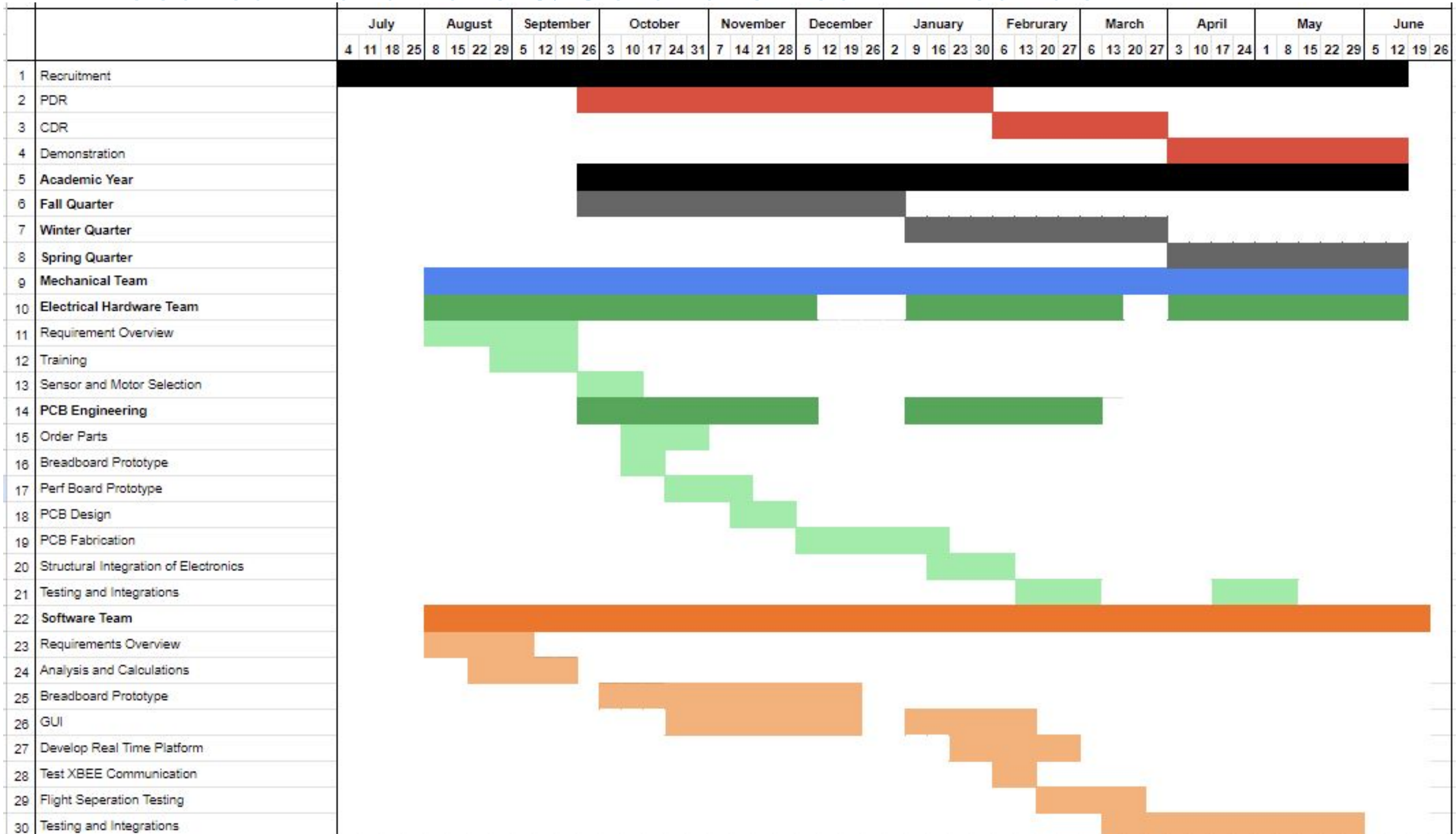
Administration Management of Subteams
Ryan

Detailed Program Schedule (2/4)

Mechanical Team Breakdown

Detailed Program Schedule (3/4)

Electrical Hardware & Software Team Breakdown



Current Percentage Complete Breakdown

8 out of 10 tasks
80%
Mechanical Team
Jeremy, Jerome, Sarah, Sunny

7 out of 9 tasks
77%
Electrical Hardware Team
AJ, Jacqueline, Khushi

6 out of 8 tasks
75%
Software Team
Husain, Kaylee

Transportation of CanSat Hardware

1. The team will attempt to store the CanSat separated in pieces in each of the team member's luggage to bring on-board our flight.
2. Spare flight and CanSat components will be shipped on over.
3. The small Lithium-Ion batteries used by the CanSat are permitted.
4. Airline will be contacted accordingly to preface the storage and transportation of these materials
5. Tools and Equipment will be brought via checked luggage. Each item will have redundant spares separated in multiple luggages to ensure lower probability of insufficient materials required for testing

Additional Options

1. If necessary (due to difficulty with airline representatives or excess hardware) we can ship a package of extra parts and tools to be picked up on arrival.
2. FedEx and UPS both provide next-day shipping; however this option is not preferred due to expenses and unreliability.

Conclusions (1/2)

Accomplishments:

1. Completed the V2.0 prototype of the CanSat structure
2. Completed V2.0 prototype of the PCBs
3. Started preliminary structural, drop, and vibration testing on CanSat
4. Improved upon flight software GUI and functionality
5. Ensure compliance with all requirements verified via test or demonstration

Major Unfinished Work:

1. Integrate PCB V3.0 and Electronics completely into physical CanSat
2. Resolve any issues from the full assembly of the prototype CanSat
3. Continue CanSat Integration and Test phase
4. Iterate further software development and debug issues with integrated software

Testing to Complete:

1. Conduct flight testing and advancement of flight software
2. Drop test, vibration test, thermal test, environmental tests and fit check

Next Steps:

With the design and fabrication complete, integration and assembly will be the main priority for the next following weeks. Testing will follow as planned

Conclusions (2/2)

THANK YOU!