CanSat 2024
Preliminary Design Review (PDR)
Outline
Version 1.0

#2057

AntSat

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Ryan Liu

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Jacqueline Lai

2 Systems Overview
Jerome Masicat

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Jeremy Rose and Jerome Masicat

5 Mechanical Subsystem Design
Sunny Lin and Jeremy Rose

Presentation Outline (3/4)

Presentation Outline (4/4)

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 Waifie (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

Systems Overview

Ryan Liu and Jerome Masicat

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 (Not Currently 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 will <u>not</u> be attempted at the moment due to design and time constraints

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

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)

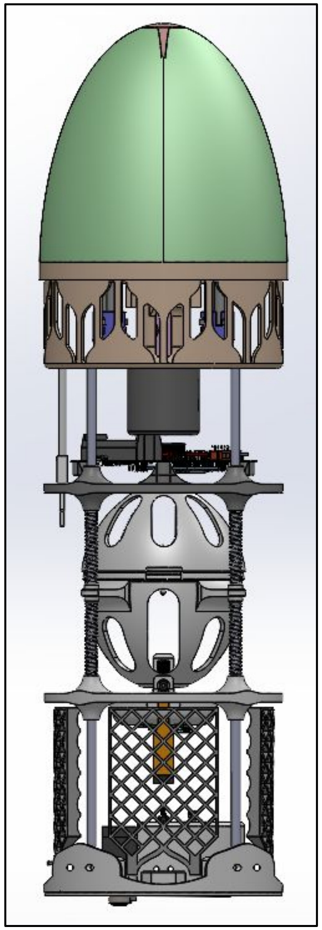
ID	Requirement	Rationale	Category	VM			
				A	I	T	D
SN1	Measures speed with a pitot tube during ascent and descent.	Competition Requirement	Sensor	x		x	
SN2	Measures altitude using air pressure.	Competition Requirement	Sensor	x		x	
SN7	Includes a horizontal video camera.	Competition Requirement	Sensor		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	

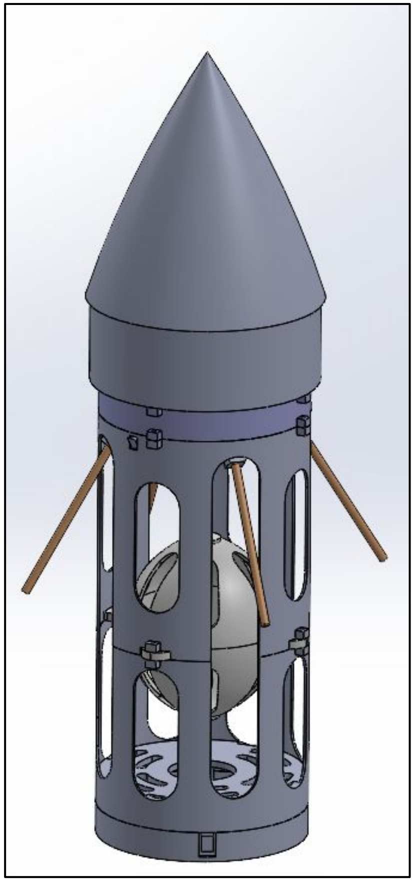
System Level CanSat Configuration Trade & Selection (1/2)

Version 1



- Overall structure made up of carbon fiber rods and circular platforms
- Egg protection device <u>can</u> move freely but is restricted with springs.

Version 2

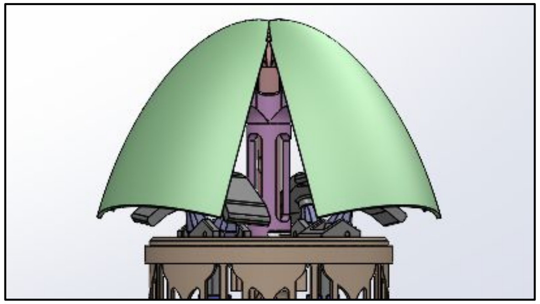


- Overall structure is made entirely by 3-D printing and is assembled using screws.
- Egg protection device <u>cannot</u> move freely and is attached to the main body structure.

System Level CanSat Configuration Trade & Selection (2/2)

Version 1

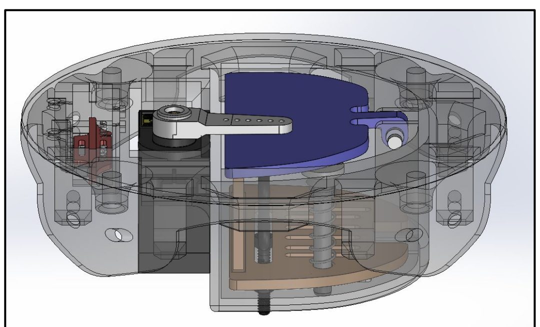
Heat Shield



- Heat Shield doubles as nose cone
- Hides landing gear
- Deployed using springs and servos
- Released using the same servos

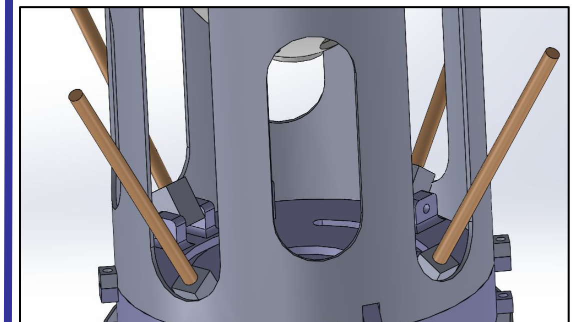
Parachute Release

- Parachute release uses spring loaded platform and a servo locking mechanism



Version 2

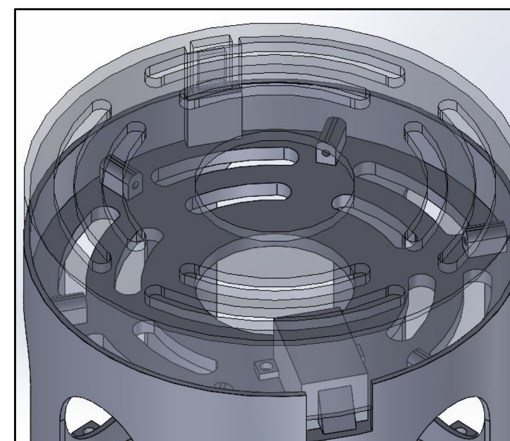
Heat Shield



- Utilizes 4 spring loaded linkages for passive activation
- Released using solenoids

Parachute Release

- Parachute release uses a spring hinged lid and a solenoid to lock the mechanism

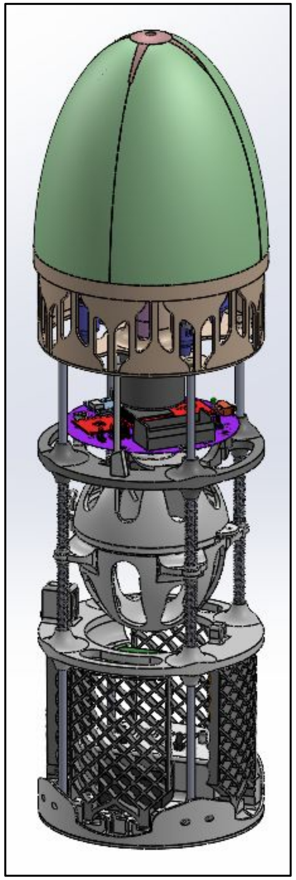


System Level Configuration Selection (1/2)

System Trades (out of 10)	Version 1 (Selected)	Version 2
Use of Space	**7 - The carbon fiber rods coupled with the circular platforms allow for lots of open space for wiring and other parts. Downside is that it's more exposed to the outside environment.**	6 - Less space for wiring and other moving parts but is more protected from the outside environment.
Aerobraking Mechanism	**8 - Nose cone expands after deployment doubling as the aerobraking mechanism. Saves lots of space, but may be weaker in terms of descent rate as the aerobrake area may not be as big.**	8 - Separate mechanism from the nose cone. Wooden dowels make it easy to create and assemble the aerobraking area.
Structure Design	**9 - Uses carbon fiber rods and 3D-printed circles as its main structure. Relatively strong compared to its lower weight. Allows for springs on the egg protection device.**	7 - Everything is 3-D printed. All structural parts are connected with screws. Easier to assemble but structure is overall heavier compared to version 1. No springs on the egg protection device.
Egg Safety	**7- Egg protection device is attached to the carbon fiber rods and placed between springs. This allows for a softer impact but may induce resonance from vibration during launch/ascent**	6 - Egg protection device is attached to the rest of the CanSat using screws. Much more susceptible to force from landing.
TOTAL	**31 (Selected)**	27

System Level Configuration Selection (2/2)

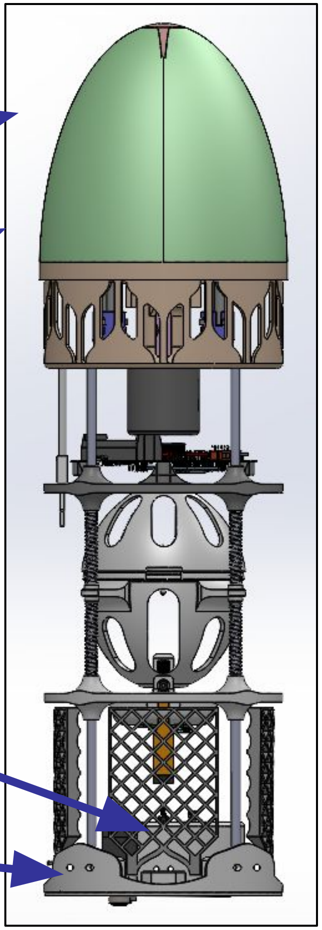
Version 1 was selected due to its superior strength to weight ratio, egg safety, and its combined nose cone/aerobraking mechanism.



*Note: all further mechanical trade studies are with version 1 in mind.

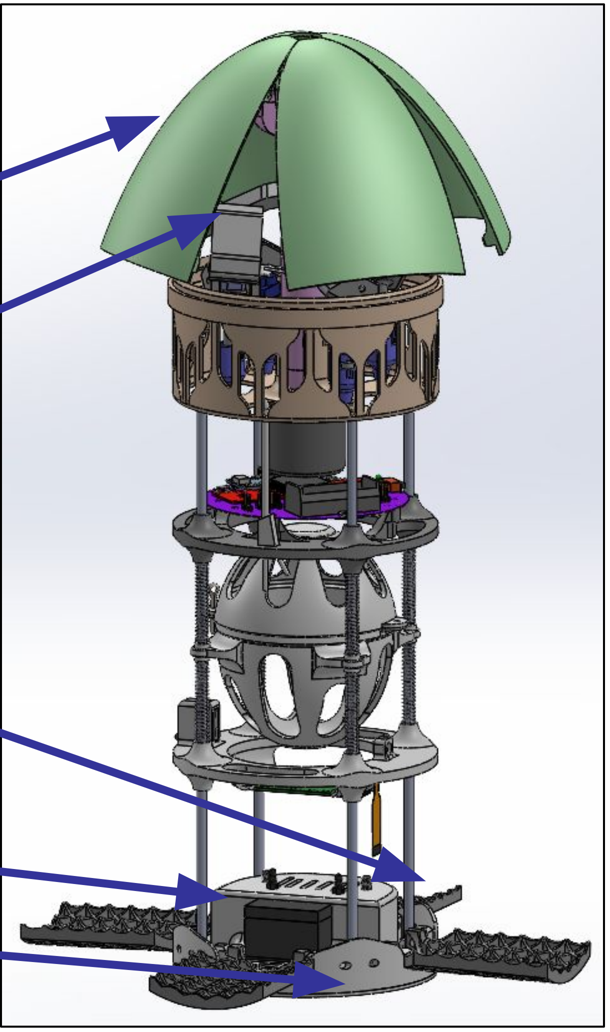
Payload Launch Configuration

- 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



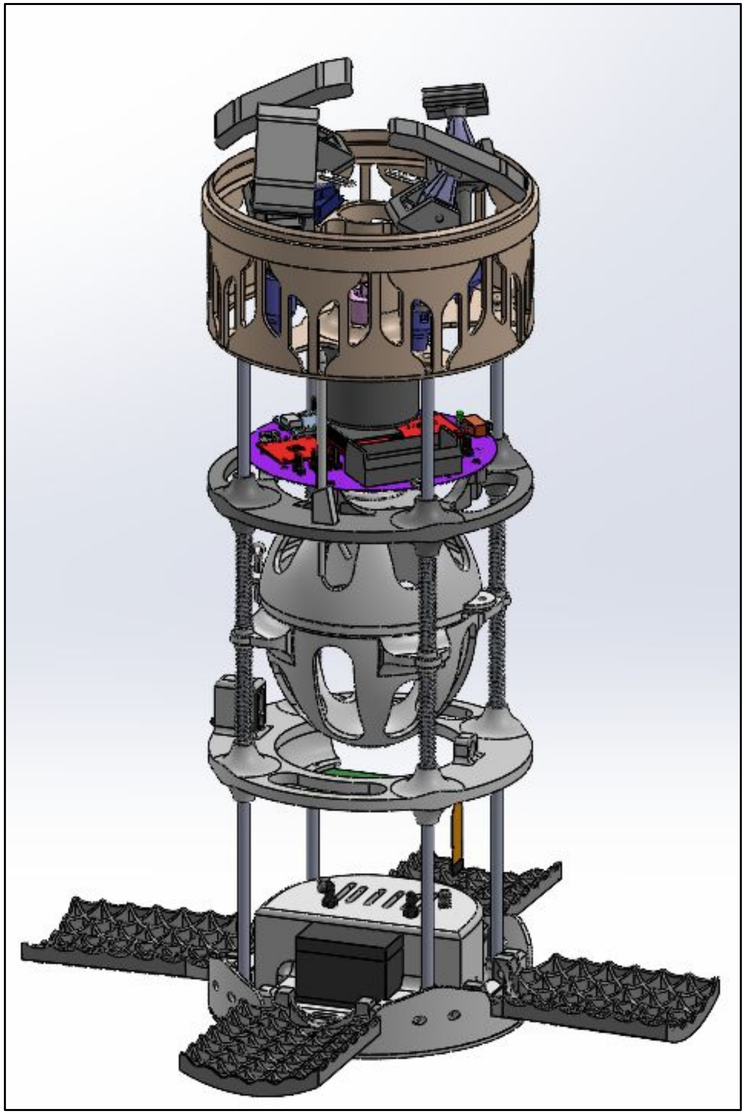
Payload Heat Shield Deployment Configuration

- Nose cone (heat shield) is in open position and locked by servo motors
- Landing gear blocked by open nose cone. Unblocked after heat shield ejects.
- Grid fins deployed
- Parachute stored and locked by servo motor/springs
- Streamer is released as the CanSat exits the rocket



Payload Parachute Deployment

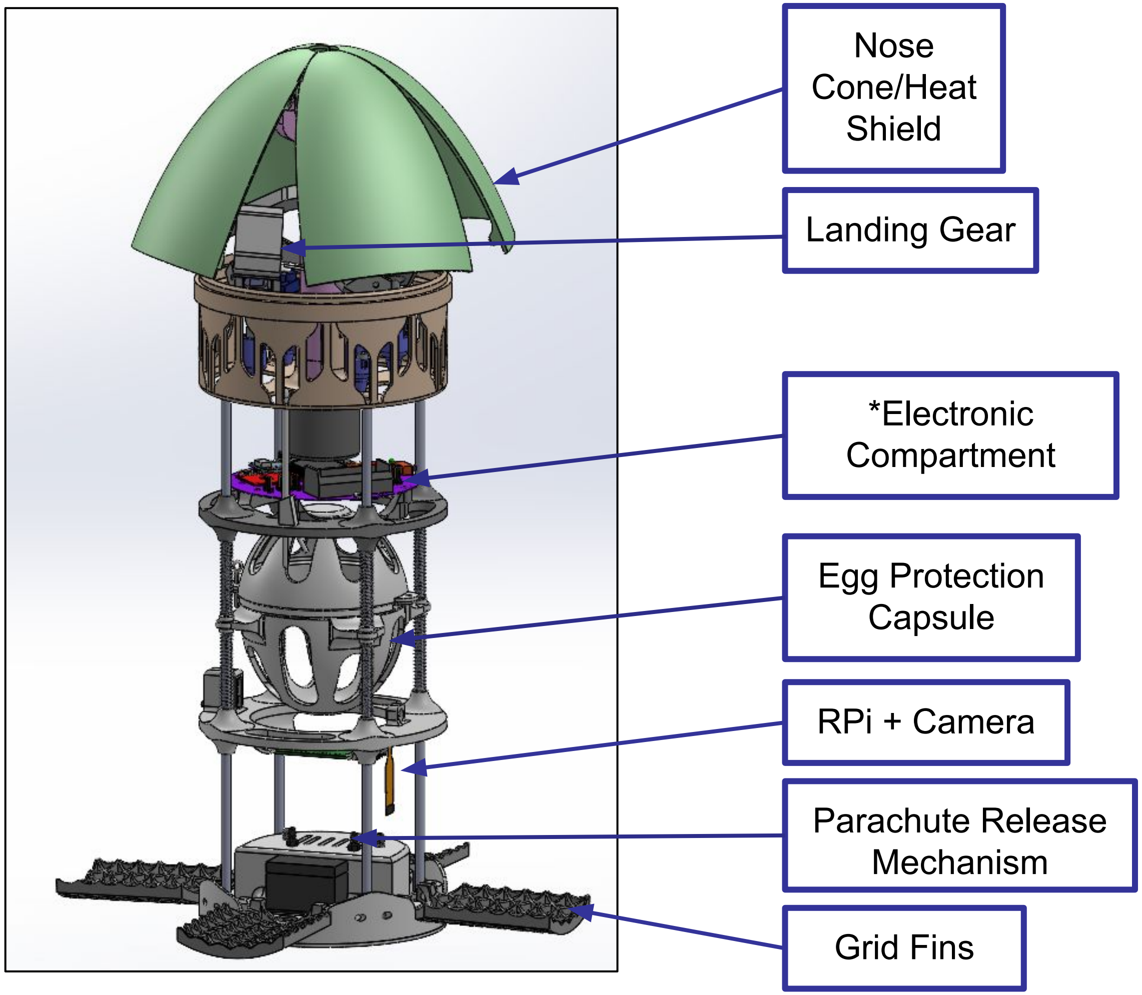
- Nose cone (heat shield) ejected from shoulder
- Landing gear fully exposed to environment
- Grid fins still in deployed state
- Parachute deployed by servo unlocking mechanism



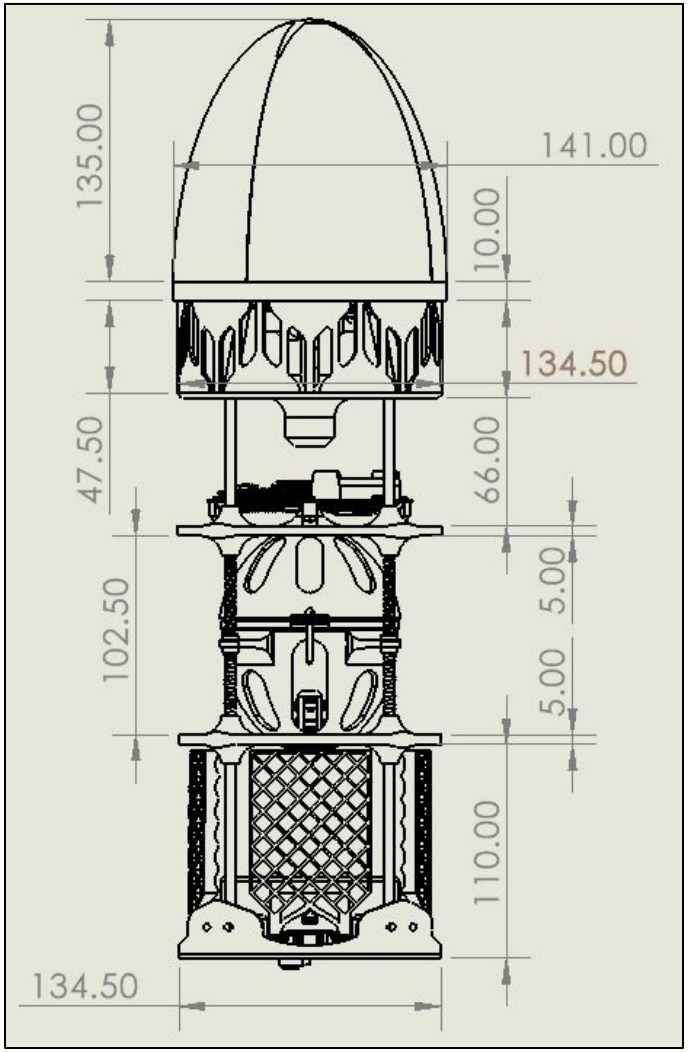
Physical Layout (4/5)

Full Assembly

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

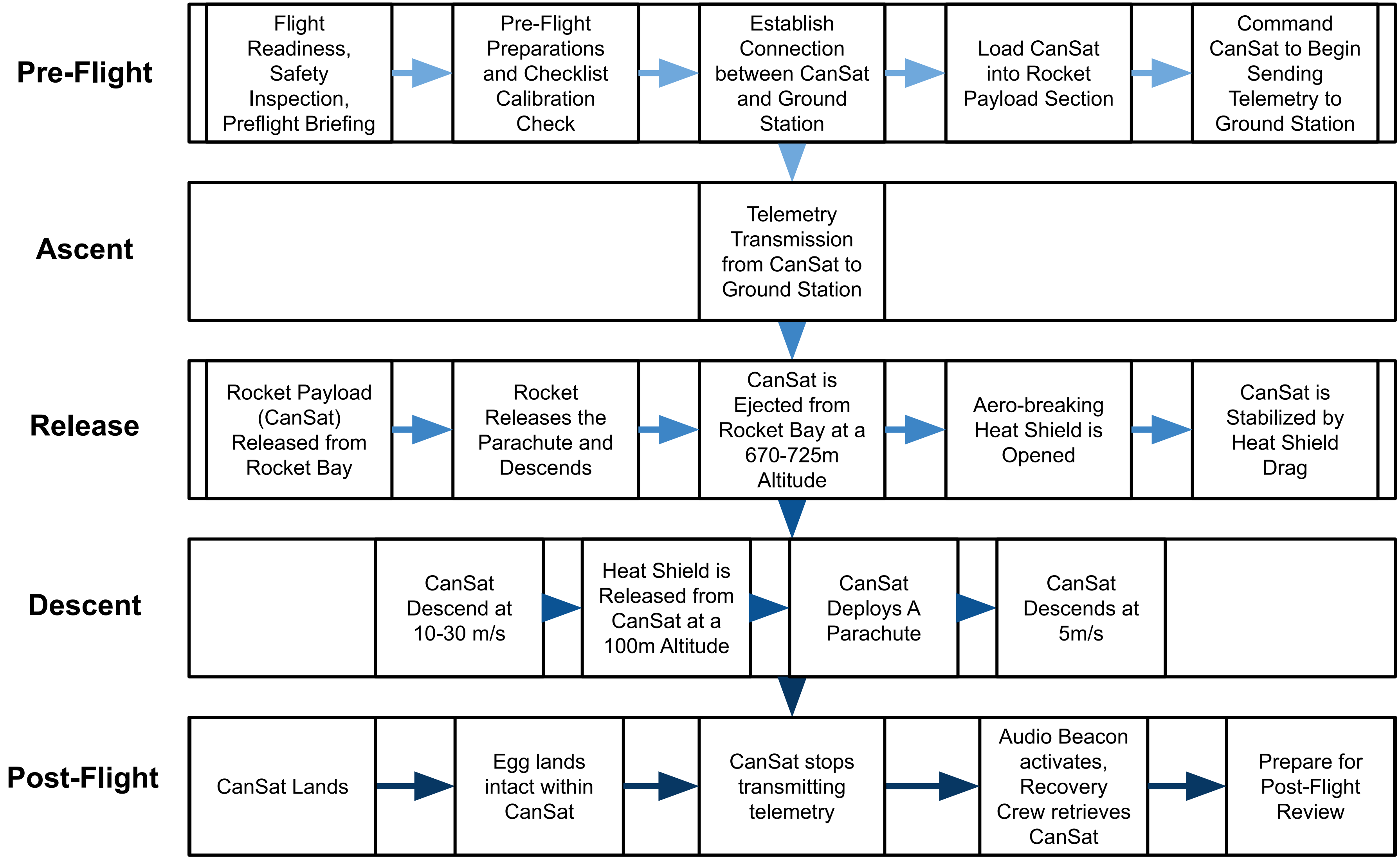


Physical Layout (5/5)

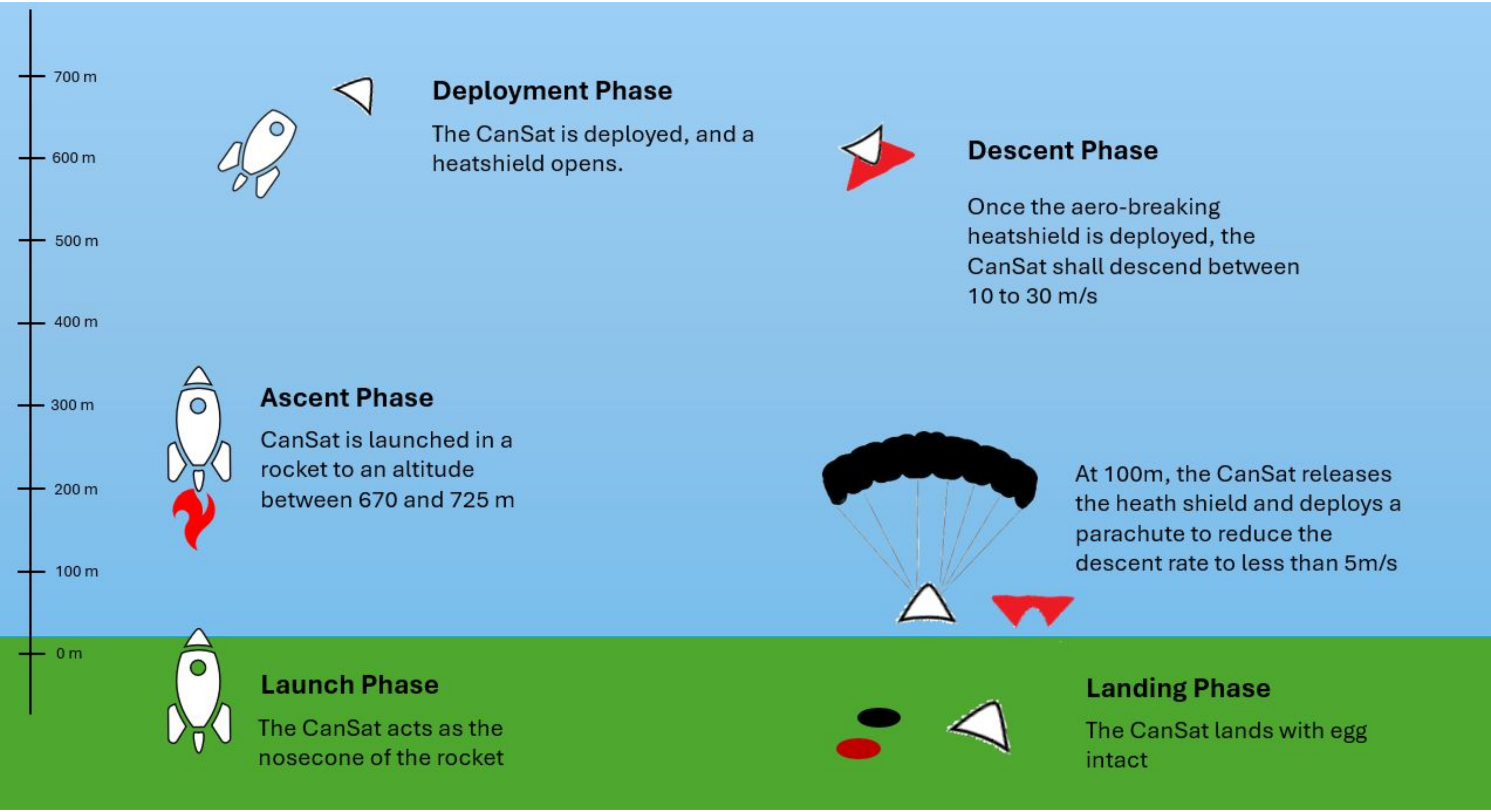


All dimensions in mm

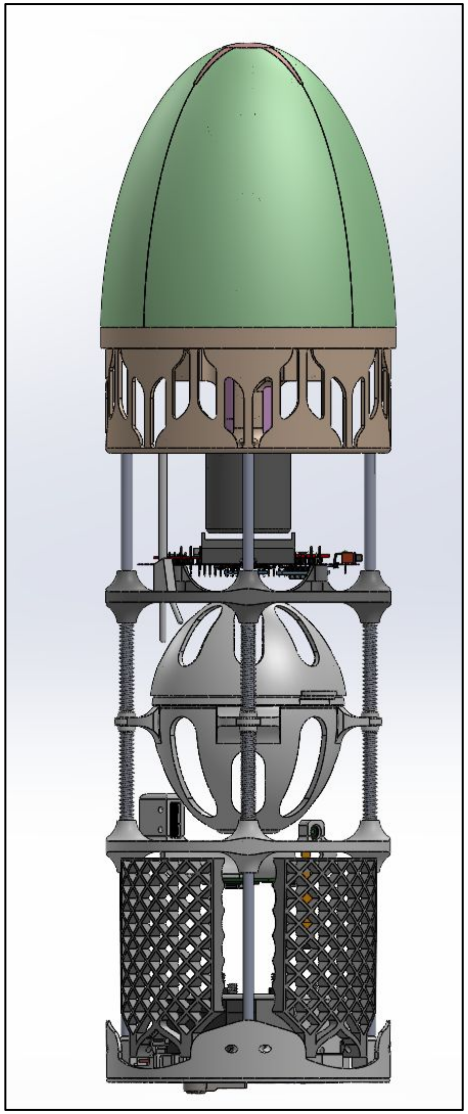
System Concept of Operations (1/2)

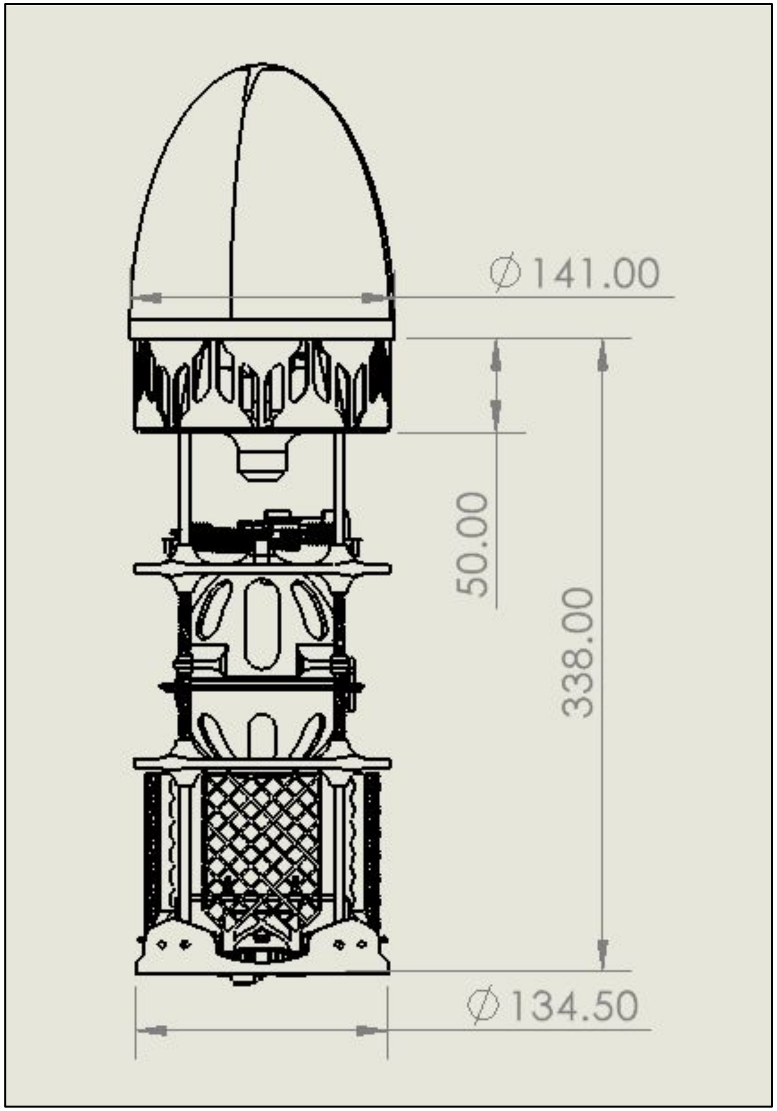


System Concept of Operations (2/2)

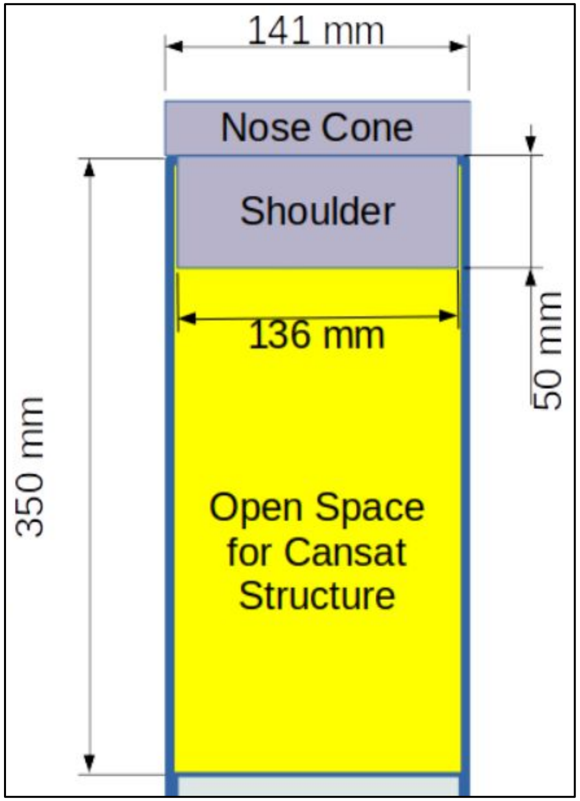


Launch Vehicle Compatibility (1/2)





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	338mm	**12mm**

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

Payload Air Pressure Sensor Trade & Selection

Sensor	Voltage (V)	Current (mA)	Interface	Resolution (Pa)	Cost (USD)	Size (mm)	Weight (g)
BMP581	**1.65 - 3.6**	**0.26**	**I2C/SPI**	**0.0156**	**5.32**	**1.95 x 1.95 x 0.7**	**<1**
BMP390	1.65 - 3.6	0.36	I2C/SPI	0.016	5.36	2.0 x 2.0 x 0.75	<1

Selection	Reasoning
BMP581	• Clear documentation • Fulfills resolution requirement • Less power consumption

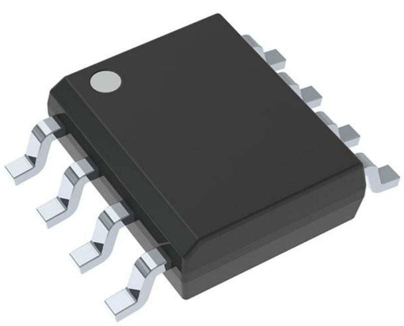
Payload Air Temperature Sensor Trade & Selection

Sensor	Interface	Resolution	Cost	Voltage	Operating Temp. (C)	Size (mm)	Weight (g)
BMP 581	**I2C/ SPI**	**15b**	**$0.00**	**1.65 - 3.6V**	**-40C ~ 85C**	**1.95 x 1.95 x 0.7**	**<1**
TMP117MAIDRVT	I2C	16b	$5.10	1.8 ~ 5.5V	-55C ~ 150C	2.1 x 2.1 x 1	N/A

Selection	Reasoning
BMP 581	● Satisfies resolution requirement ● Size efficient ● Power efficient ● Well documented and wide availability for coding examples

Payload Battery Voltage Sensor Trade & Selection

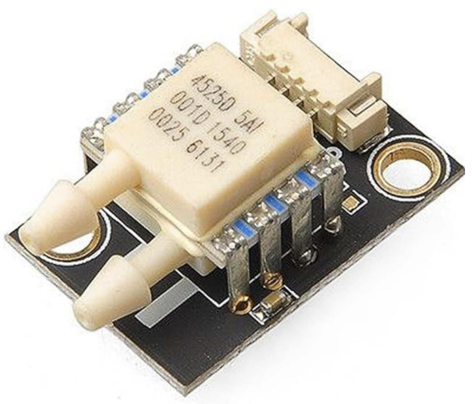
Sensor	Interface	Cost	Voltage	Resolution	Voltage Input Range	Weight
INA219	**I2C**	**$9.95**	**3.3 ~ 5.5V**	**~ 0.005 V**	**0.0 ~ 26V**	**2.57 g**
HiLetGo Voltage Detection Module	I2C	$5.89	3.3 ~ 5.5V	0.00489 V	0.0245 ~ 16.5V	4.95 g



Selection	Reasoning
INA219	• Lightweight by over 2g • Can be integrated into existing power setup • Reliable sourcing

Payload Speed Sensor Trade & Selection

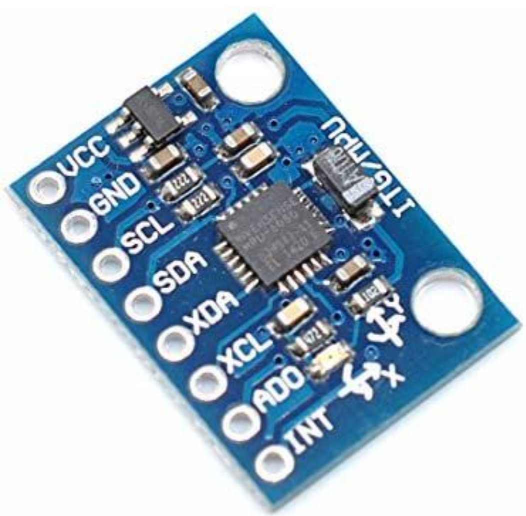
Item	Interface	Voltage	Mass	Accuracy	Cost
MPXV7002DP	I2C	5V	4.5	2.5%	$42.99
MS4525DO	**I2C, SPI**	**3.3V, 5V**	**3.0**	**0.25%**	**$48.89**



Selection	Reasoning
MS4525DO	• Easier to read documentation • **Larger voltage operating range** • Higher accuracy • **Lightweight by 1.5g** • Fulfills requirement for pitot tube

Payload Tilt Sensor Trade & Selection

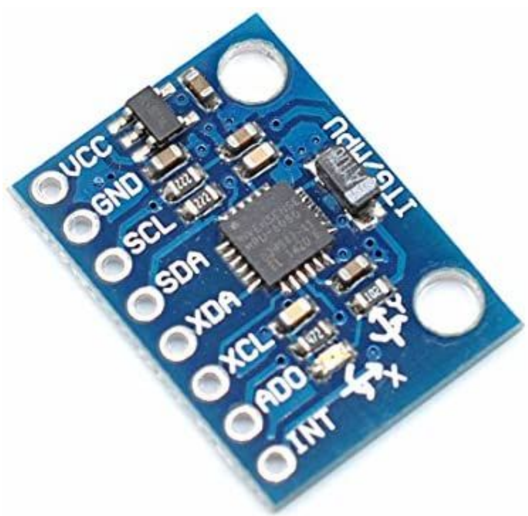
Sensor	Voltage (V)	Current (mA)	Interface	Resolution (m)	Cost (USD)	Size (mm)	Weight (g)
MPU 6050	**3.3**	**35**	**I2C, SPI, UART**	**3**	**3.33**	**21.2 x 16.4 x 3.3**	**11.1**
ADXL377	3.3, 5	30	I2C	3	25.00	3x3x1.45	9.8
ADXL345	3.3	35	I2C, SPI, UART	3	2.99	3 x 5 x 1	11.1



Selection	Reasoning
MPU 6050	● Robust sensor packaging ● Superb documentation ● Legacy; experience from prior year ● Has rotation detection with the onboard gyroscope

Rotation Sensor Trade & Selection

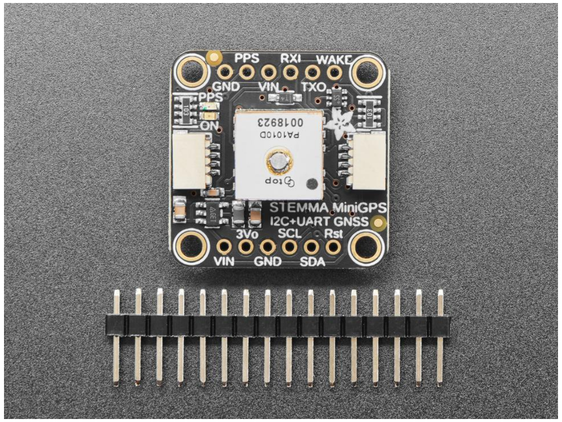
Sensor	Voltage (V)	Current (mA)	Interface	Resolution (m)	Cost (USD)	Size (mm)	Weight (g)
MPU 6050	**3.3**	**35**	**I2C, SPI, UART**	**3**	**3.33**	**21.2 x 16.4 x 3.3**	**11.1**
BNO055	3.3, 5	12.3	I2C, SPI, UART	0.3	35.00	20 x 27 x 11	3



Selection	Reasoning
MPU 6050	• Cheaper than competing options • Superb documentation • Legacy; experience from prior year • Works together with tilt detection, allowing 2 uses with 1 sensor

Payload GPS Sensor Trade & Selection

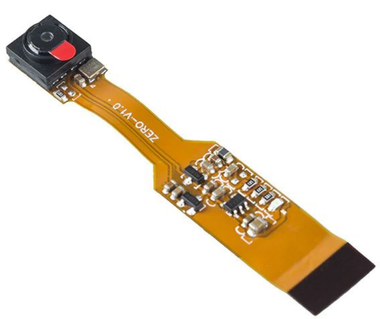
Sensor	Tracking Sensitivity (dBm)	Interface	Voltage (V)	Time-to-First-Fix (s)	Tracking Current (mA)	Weight (g)	Cost (USD)
Adafruit PA1010D Module	**-165**	**I2C or UART**	**3.3 or 5**	**Instant (orbit prediction)**	**28**	**5**	**29.95**
Neo-6M (GT-U7)	-161	UART or USB	5	27	unspecified	6	11.99



Selection	Reasoning
Adafruit PA1010D Module	• Extensive Documentation • Low Power • Excellent time-to-first-fix • Good sensitivity • Uses I2C

Payload Camera Trade & Selection

Sensor	Resolution @30fps	Processor Interface	Voltage* (V)	Current* (mA)	Cost (USD)	Size (mm)	Weight (g)
Zero Spy Camera	**5MP**	**Raspberry Pi Zero**	**5**	250-300	**19.95**	**8.6 x 8.6 x 5.2**	**10**
OV5647	720p	Raspberry Pi Zero	5	300	16.99	30 x 65 x 8.3	9



Selection	Reasoning
Zero Spy Camera	• Dependable Camera • Meets all desired requirements • Lower power draw

Bonus Camera Trade and Selection

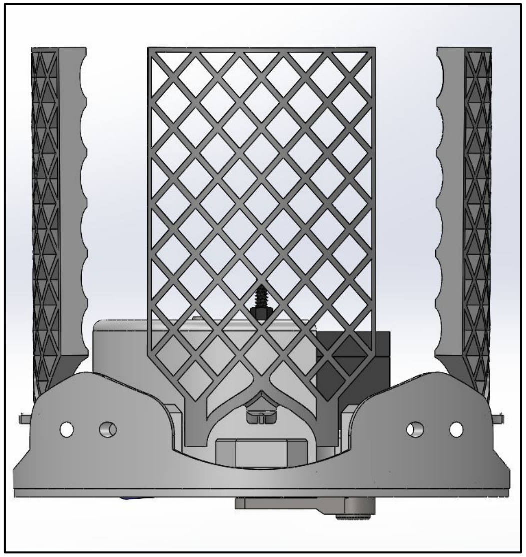
- **Will NOT be attempting due to time constraints**
  - Thus, will be skipped

Descent Control Design

Jeremy Rose, Jerome Masicat

Descent Control Overview

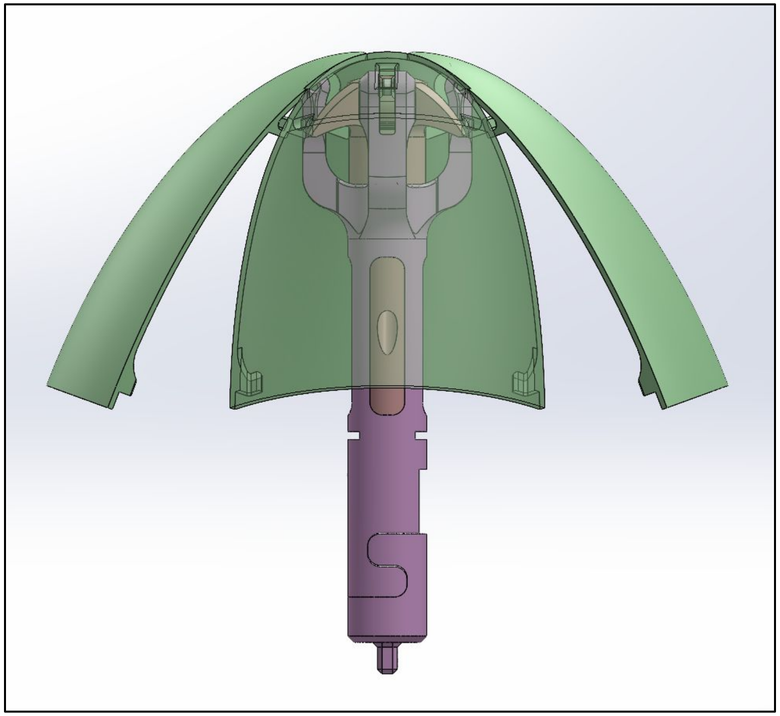
Grid Fins



Descent Stability + Rotational Control

Flight Range: 725m - 0m

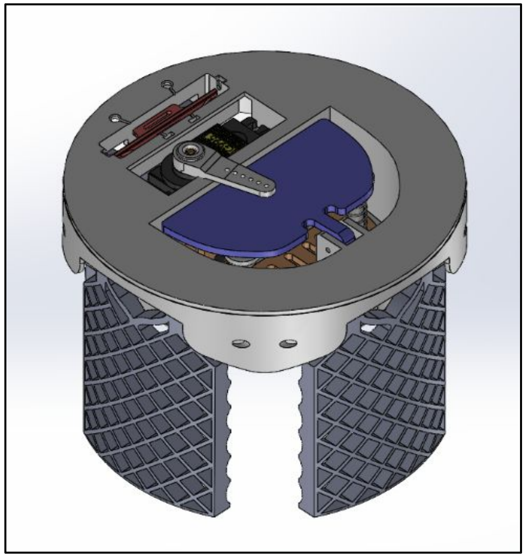
Nose Cone



Aerobraking

Flight Range: 725m - 100m

Parachute



Descent Control

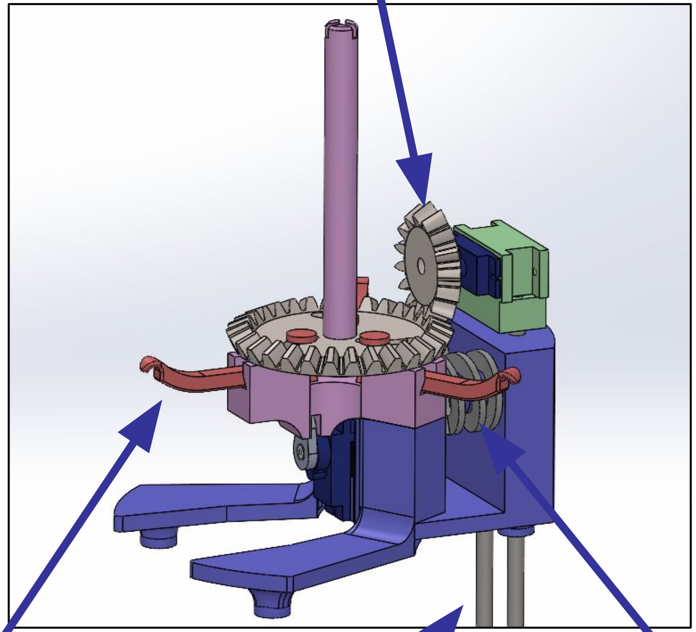
Flight Range: 100m - 0m

Payload Aerobraking Descent Control Strategy Selection and Trade (1/3)

Version 1

- Mechanism opens to an angle of **34 degrees** away from the center axis
- Arms start at the maximum radius of **136 mm and extends to 148 mm**
- **Two servos** and **two springs** required.
- Nylon not shown for mechanism clarity

Structural components made of Nylon

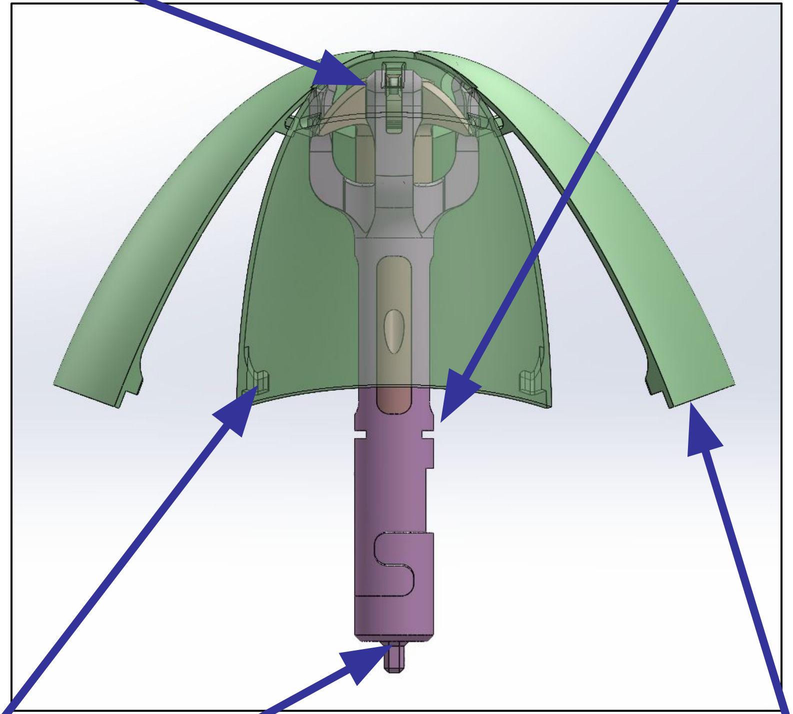


Payload Aerobraking Descent Control Strategy Selection and Trade (2/3)

Version 2

- Mechanism opens to an angle of **38 degrees** (estimate because of curved surface)
- **One spring** and **two servos** required.
- Larger weight savings because this functions as the nose cone on ascent
- Electronics for actuation are installed below the aerobrake

Structural components made of Nylon



Payload Aerobraking Descent Control Strategy Selection and Trade (3/3)

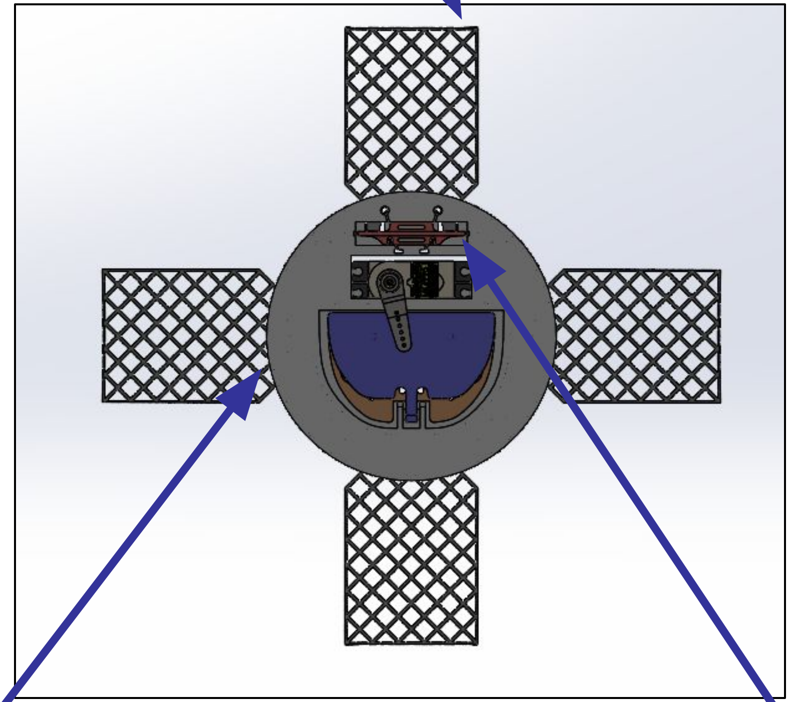
System Trades (out of 10)	Aerobrake Version 1	Aerobrake Version 2
Assembly	6 - Requires multiple springs, intricate servo installation, and press fit carbon fiber rods	**5 - Requires small pins and bearings which are difficult to install, springs and servos are simple**
Manufacturability	6 - All structural components can be 3-D printed, nylon will be purchased, electronics for actuation are COTS	**6 - All structural components can be 3-D printed, nylon will be purchased, electronics for actuation are COTS**
Durability / Drag Produced	4 - With the base having to be placed underneath the nose cone, the drag produced is much lower in comparison to Version 2. Durability is mediocre for the 3-D printed parts.	**9 - Main sections are 3-D printed as opposed to nylon, the assembly is much more rigid, and all joints can be superglued because of the use of bearings. Drag is significantly higher.**
Weight / Volume	6 - System doesn't function as anything else, and uses critical space at top of the CanSat, leaving little room for electronics. Fairly light overall at 150g.	**8 - Takes the place as the nose cone: fantastic weight savings, this also means that the volume taken up is quite minimal and electronics have plenty of room. 220g**
TOTAL	22	**27 (Selected)**

Version 1

- Four fins that weigh 10g each, with 8 torsion springs, no electronics
- Grid fins are restrained by the inner rocket walls, open outwards on ejection
- Grid fins stay open for duration of flight, providing **passive stabilization** by lowering center of pressure farther back on the aerobody to maintain nadir direction

Structural components made of Nylon

Grid fins open outwards



Torsion springs push fins out

Also used to release streamer

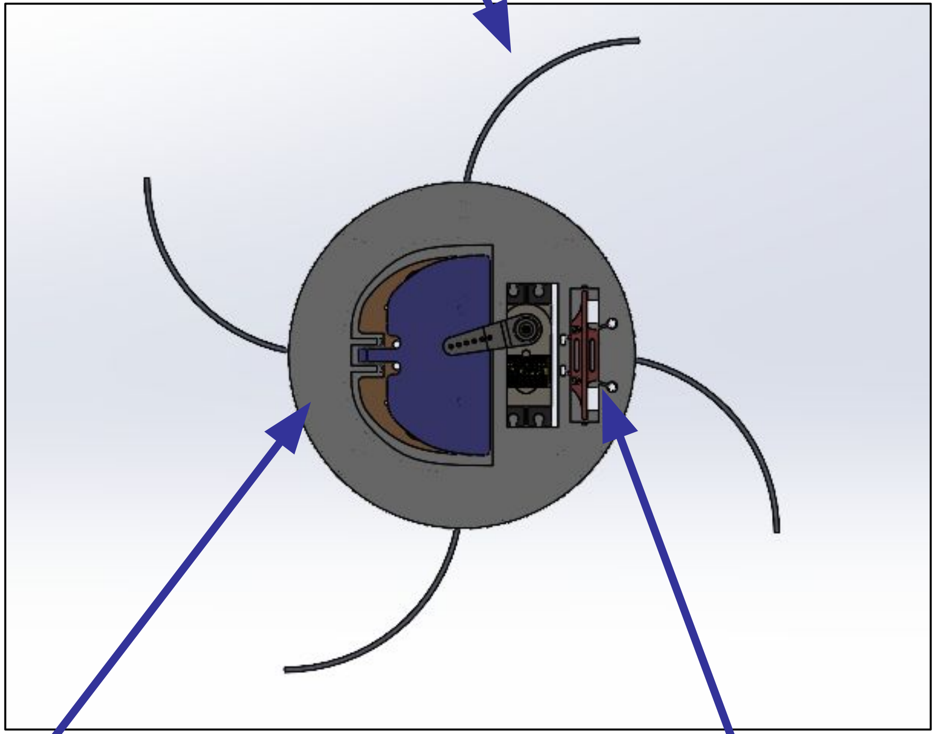
Payload Aerobraking Descent Stability Control Strategy Selection and Trade (2/3)

Version 2

- Four fins that weigh 10g each, with 8 torsion springs, no electronics
- Circular fins are restrained by the inner rocket walls, open outwards on ejection
- Circular fins stay open for duration of flight, providing **passive stabilization** by lowering center of pressure farther back on the aerobody to maintain nadir direction

Structural components made of Nylon

Spiral fins fold into base



Torsion springs push fins out

Alternate mechanism required for streamer release

Payload Aerobraking Descent Stability Control Strategy Selection and Trade (3/3)

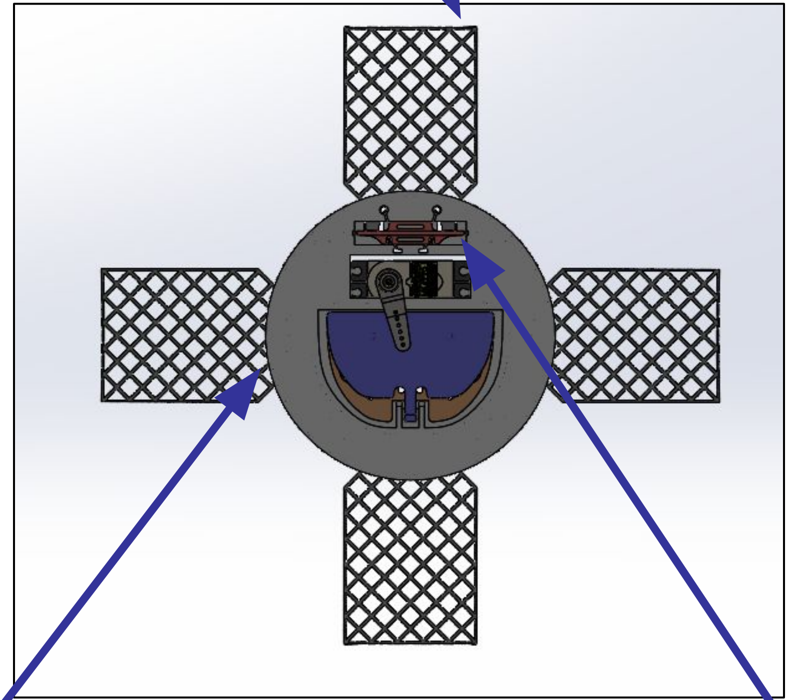
System Trades (out of 10)	Descent Stability Version 1	Descent Stability Version 2
Assembly	**8 - Requires one spring and one metal rod, press fit and glued in with Loctite**	8 - Requires one spring and one metal rod, press fit and glued in with Loctite
Manufacturability	**8 - All structural components can be 3-D printed, metal rod and torsion springs are COTS**	8 - All structural components can be 3-D printed, metal rod and torsion springs are COTS
Durability	**7 - Slightly stronger due to lattice structure, but air passes through the fins perpendicularly which could cause more stress**	7 - Solid nylon, so not as strong, but much less stress due to air passing parallel to fins rather than through them
Weight / Stability	**8 - Slightly lighter due to holes within fins, additionally, doubles as a streamer release to save weight, brings center of pressure back more optimally compared to spiral fins.**	5 - Much less stability due to circular nature, also prone to negative rotational static stability.
TOTAL	**31 (selected)**	28

Payload Rotation Control Strategy Selection and Trade (1/3)

Version 1

- Four fins that weigh 10g each, with 8 torsion springs, no electronics
- Grid fins are restrained by the inner rocket walls, open outwards on ejection
- Grid fins stay open for duration of flight, providing **passive stabilization** by lowering center of pressure farther back on the aerobody to maintain nadir direction

Structural components made of Nylon



Payload Rotation Control Strategy Selection and Trade (2/3)

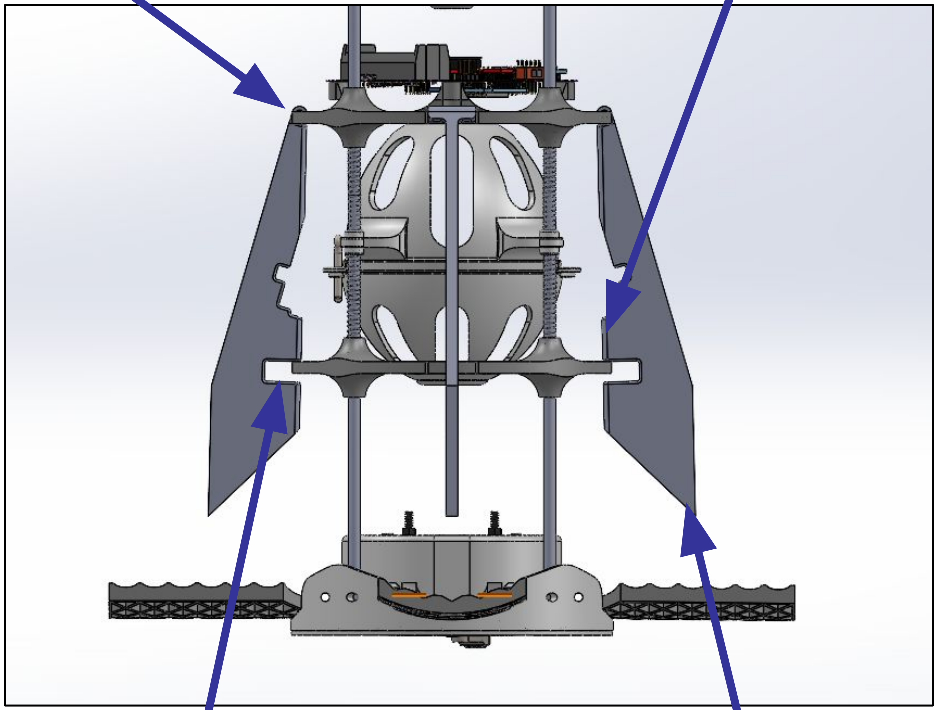
Version 2

- Each fin weighs 12g, **actively stabilized** by servos to maintain nadir direction
- Gyrometer senses rotational motion to adjust servo angle to minimize
- Clipped parallelogram shape in order to bring center of pressure farther back
- Fins would stay open for duration of flight, initially retained by inner rocket wall

Structural components made of Nylon

Servos control angle of fins (not shown)

Springs push fins out upon rocket ejection (not shown)



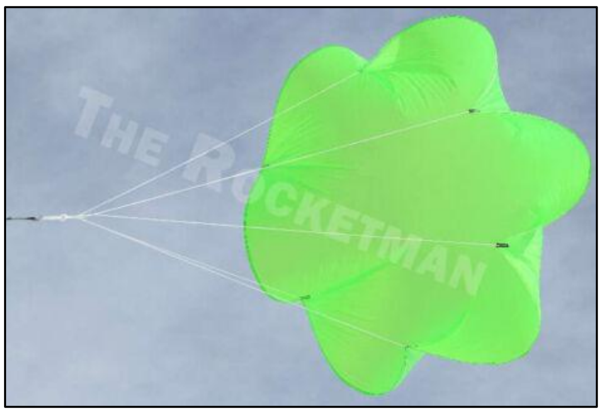
Cutouts allow for taller fins

Fins open outwards

Payload Rotation Control Strategy Selection and Trade (3/3)

System Trades (out of 10)	Rotational Stability Version 1	Rotational Stability Version 2
Assembly	**8 - Requires one spring and one metal rod, press fit and glued in with Loctite**	6 - Requires one spring and one metal rod, press fit and glued in with Loctite, with servo. Servo complicates assembly.
Manufacturability	**8 - All structural components can be 3-D printed, metal rod and torsion springs are COTS**	8 - All structural components can be 3-D printed, metal rod, servo, torsion springs are COTS
Durability	**7 - Slightly stronger due to lattice structure, but air passes through the fins perpendicularly which could cause more stress**	6 - Fairly thin material at 5mm wide, but experiences no stress apart from air flowing by the part.
Weight / Stability	**7 - Slightly lighter due to holes within fins, additionally, this mechanism is also used for the descent stability control. Worse at rotational control, but outweighs the fins in every other way.**	7 - Parts add up to 80 grams of extra weight, but serve as an extra mechanism. Much better rotation control, due to active control, but more complicated mechanism.
TOTAL	**30 (selected)**	27

Payload Parachute Descent Control Strategy Selection and Trade (1/2)

Version 1	Version 2	Version 3
Hemispherical	**Hemispherical w/ Spill Hole**	**Cruciform**
		
Hemispherical includes circular, hexagonal, and octagonal parachute shapes due to their similar descent properties.	All spill holes are assumed to be <20% diameter for the trade study.	Also known as a “cross parachute”. Rarer in air-based applications.

Payload Parachute Descent Control Strategy Selection and Trade (2/2)

System of Trades (out of 10)	Hemispherical	Hemispherical w/ Spill Hole	Cruciform
Drag	9 - Highest drag coefficient	**7 - Spill holes (<20% diameter) only slightly reduce the drag**	8 - Drag coefficients are comparable to hemispherical but fall slightly short
Oscillation	4 - Classic hemispherical parachutes tend to have issues with oscillation	**8 - Main draw for using spill holes. Greatly reduce oscillation at the cost of a little drag**	5 - Greatly reduced oscillations but has an issue with rotational motion
Weight	7 - Medium amount of weight required	**9 - Uses less material at the cost of reduced drag**	6 - Tends to use more material compared to hemispherical
Manufacturability	7 - Easily purchased but can be difficult to manufacture	**6 - Same as hemispherical but slightly harder to make by hand**	8 - Harder to purchase but relatively easy to make by hand
Total (out of 40)	27	**30 (Selected)**	27

Note: Selected parachute material is **1.1oz Mil-Spec Ripstop nylon**

Payload Aerobraking

Assumptions:

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

Given:

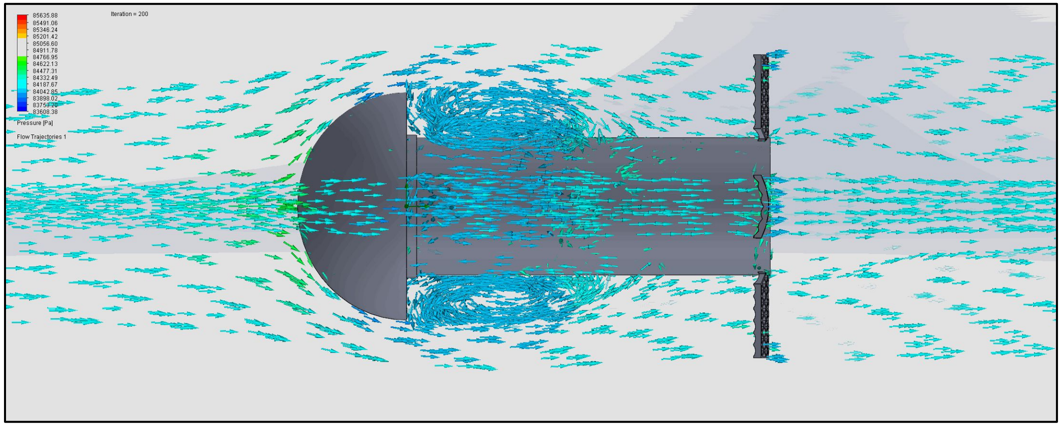
- Target Velocity <30m/s
- Total Drag Area:
  - Deployed Nose Cone Diameter: 0.215 m
  - Grid Fin Area: 0.00583 m^2
- *Drag Coefficient (C_d) = 0.47

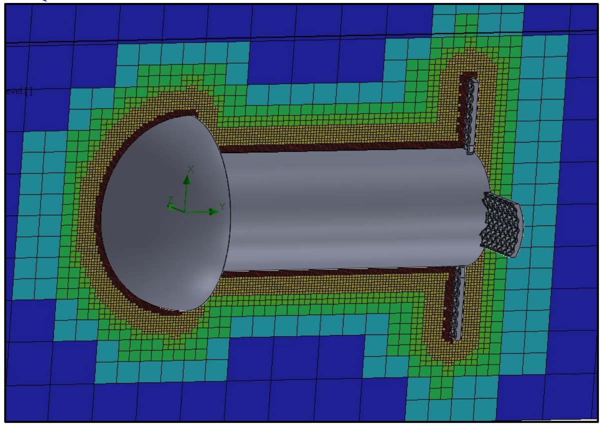
*Note: C_d based on SolidWorks CFD using a simplified model. Expected actual C_d is higher than 0.47 (shown in next slide)

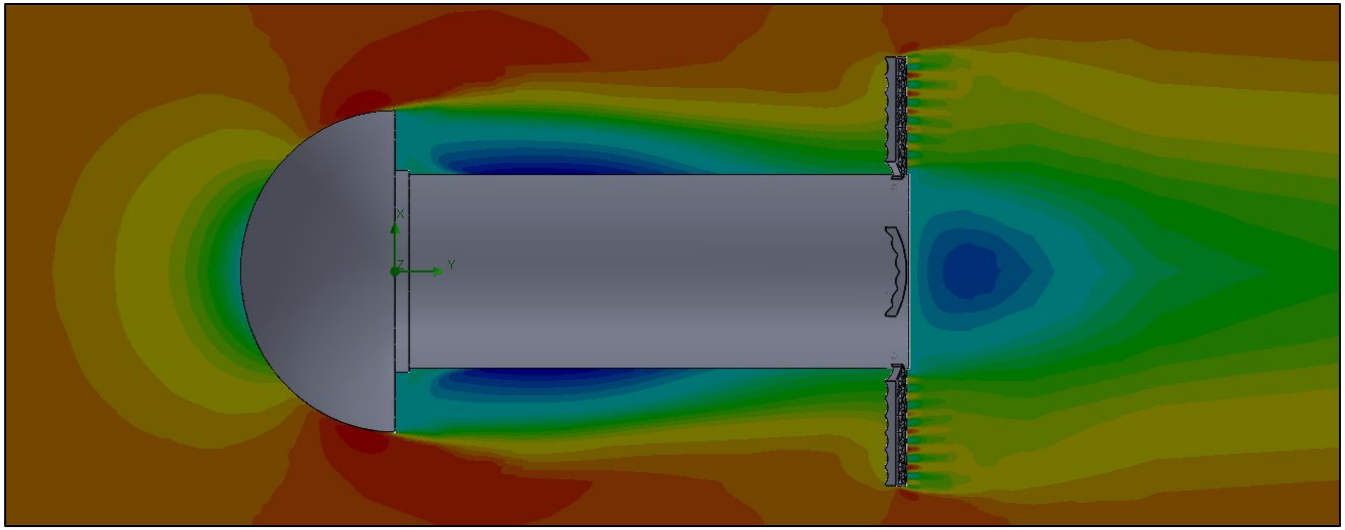
Descent Rate Estimates (2/6)

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 **= 0.47**
- Nose Cone Diameter: **d = 0.215 m**
- Nose Cone Area: A_n
- Grid Fin Area: A_g **= 0.00583 m**^{2}
- Terminal Velocity: V_t

Deployed Aerobraking (Nosecone) Area

$$A_n = \frac{\pi d^2}{4} = \boxed{0.0421\ m^2}$$

Terminal Velocity

$$F_{drag} = m_t g$$

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

$$V_t = \sqrt{\frac{2 m_t g}{\rho (A_g + A_n) C_d}} = \boxed{28.65\ m/s}$$

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)

$$V_t = \sqrt{\frac{2m_t g}{\rho(A_g + A_n)C_d}} = \boxed{28.65\ m/s}$$

- 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

Mechanical Subsystem Design

Sunny Lin and Jeremy Rose

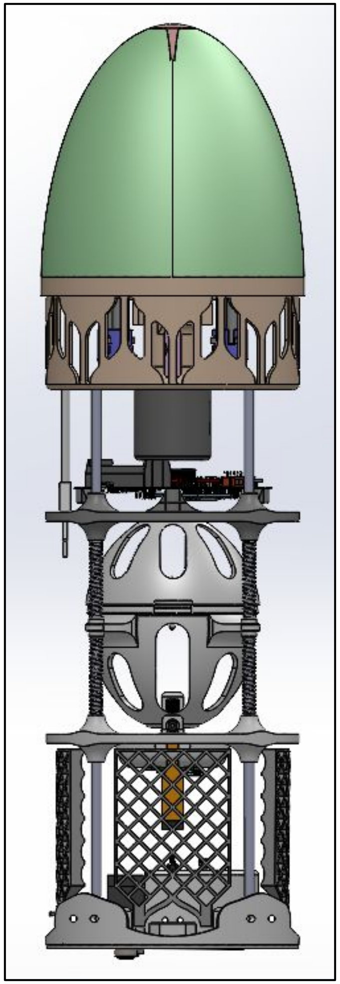
Mechanical Subsystem Overview

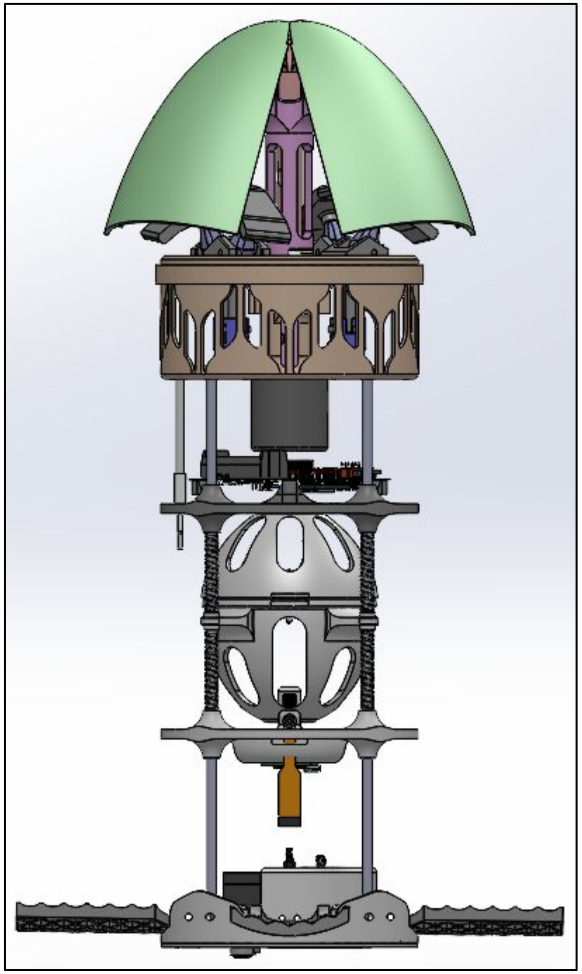
Mechanical Configuration:

1. Servo and spring mechanism to turn nose cone into heat shield.
2. Servo and spring mechanism to release nose cone and reveal landing gears.
3. Electronics compartment housed under shoulder.
4. Springs oscillate egg capsule between two platforms.
5. Grid fins open after sliding out from rocket.
6. Servo and spring mechanism for parachute release.

Material Selection:

Nylon





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

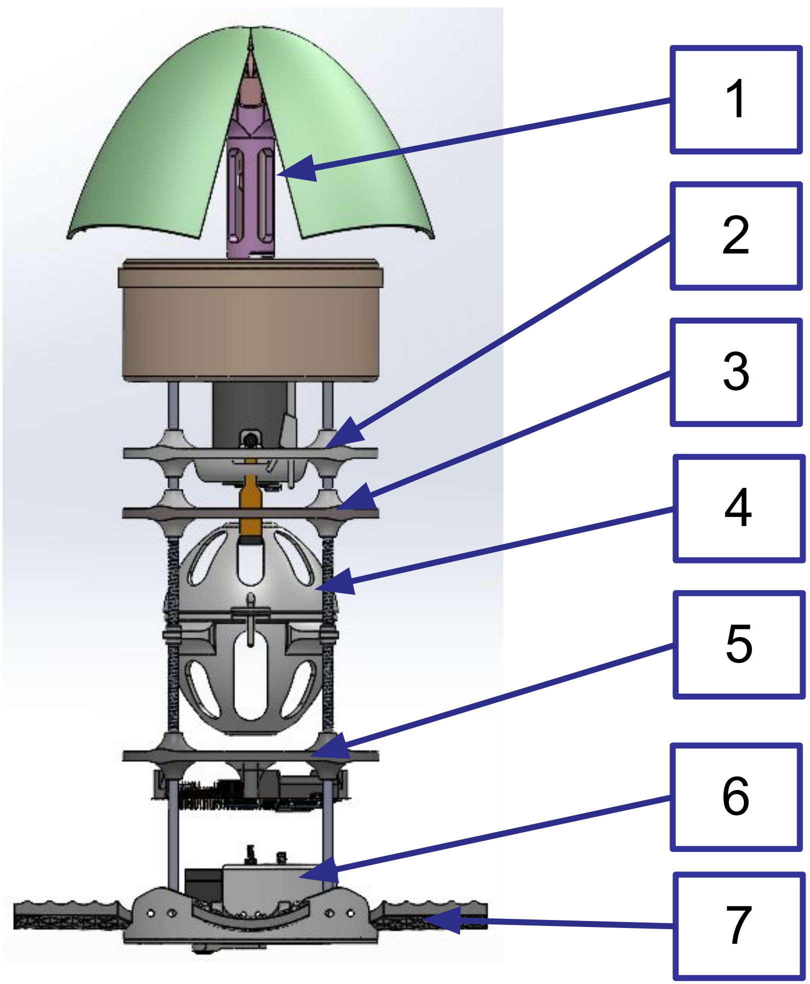


Diagram Number	Component
1	Nose Cone/Heat Shield Mechanism
2	Electronic Mounting Platform
3	Egg Protection Platform
4	Egg Protection Capsule
5	PCB Platform
6	Parachute Mechanism
7	Grid Fins

Version 1

Structural components made of Nylon

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

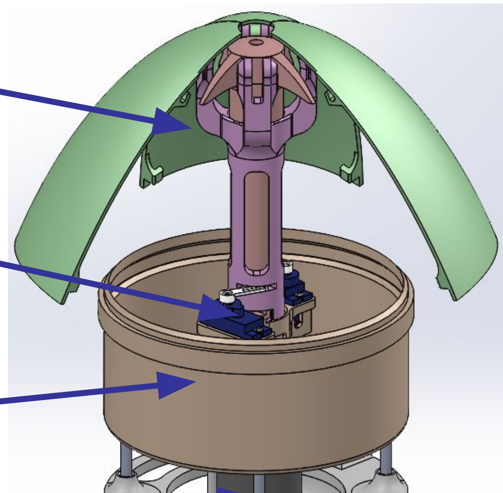
Version 1

Nose Cone / Heat Shield Wings

Servos for Heat Shield/Nose Cone Mechanism

Nose Cone Shoulder

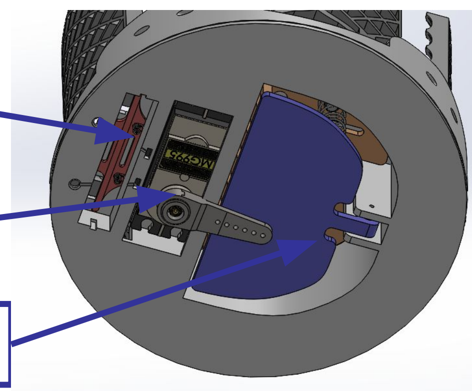
Nose Cone Parachute Compartment



Streamer Mechanism

Servo for Parachute Release

Spring-loaded Parachute Door



Limit Switch

Camera

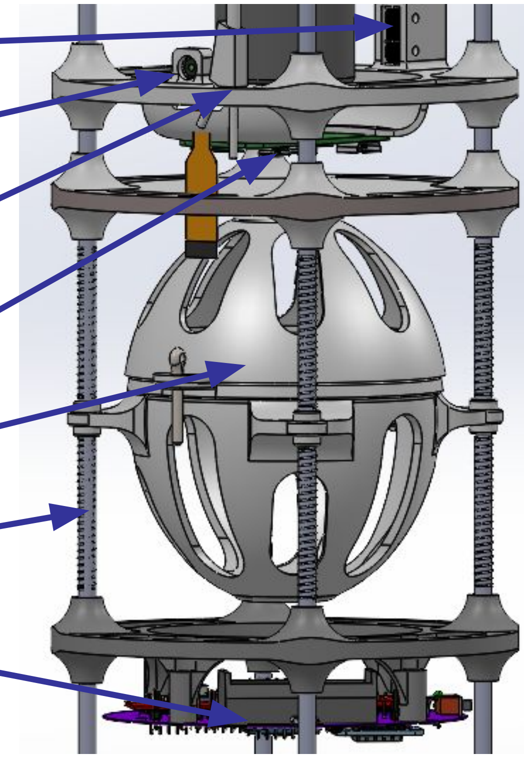
Pitot Tube

Raspberry Pi

Egg Capsule

Springs

PCB/Battery/ Sensors



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

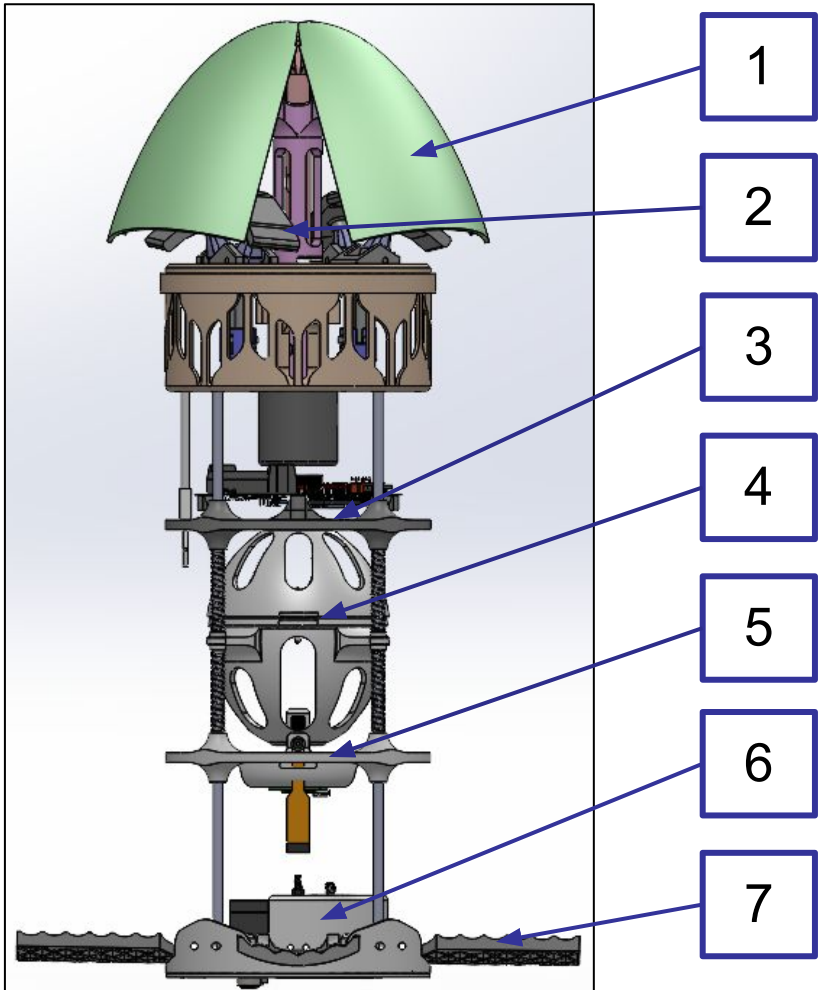


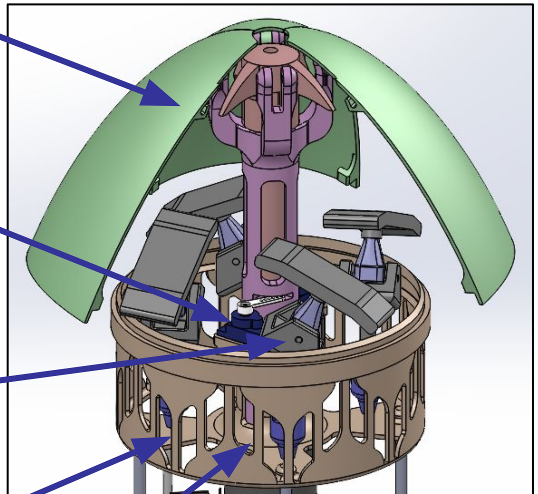
Diagram Number	Component
1	Nose Cone/Heat Shield Mechanism
2	Landing Gears
3	PCB Platform
4	Egg Protection Capsule
5	Camera Platform
6	Parachute Mechanism
7	Grid Fins

Version 2

Structural components made of Nylon

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

Version 2



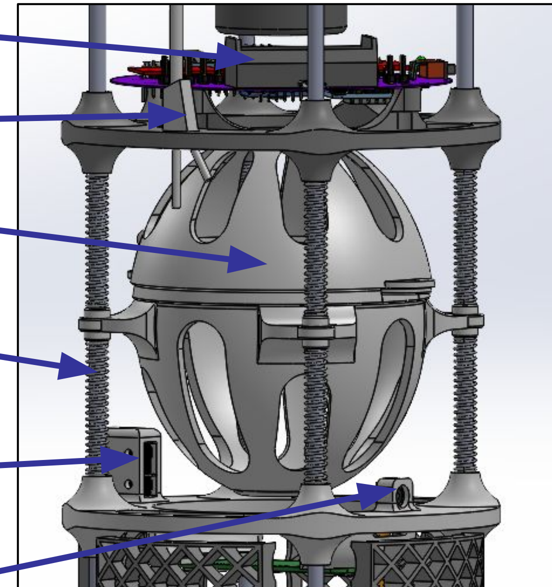
Nose Cone / Heat Shield Wings

Servos for Heat Shield Mechanism and Nose Cone Release

Landing Gears

Nose Cone Shoulder

Nose Cone Parachute Compartment



PCB/Battery/Sensors

Pitot Tube

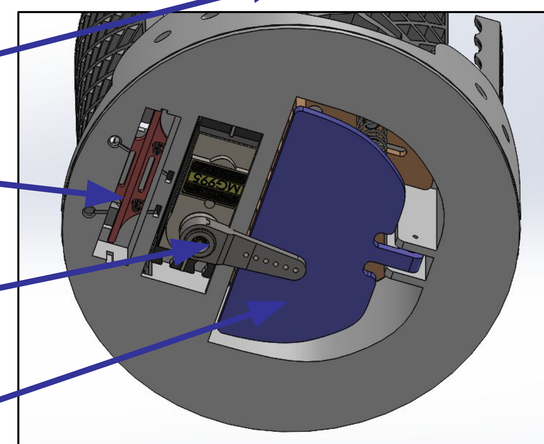
Egg Capsule

Carbon Fiber Rods + Springs

Limit Switch

Camera

Raspberry Pi



Streamer Mechanism

Servo for Parachute Release

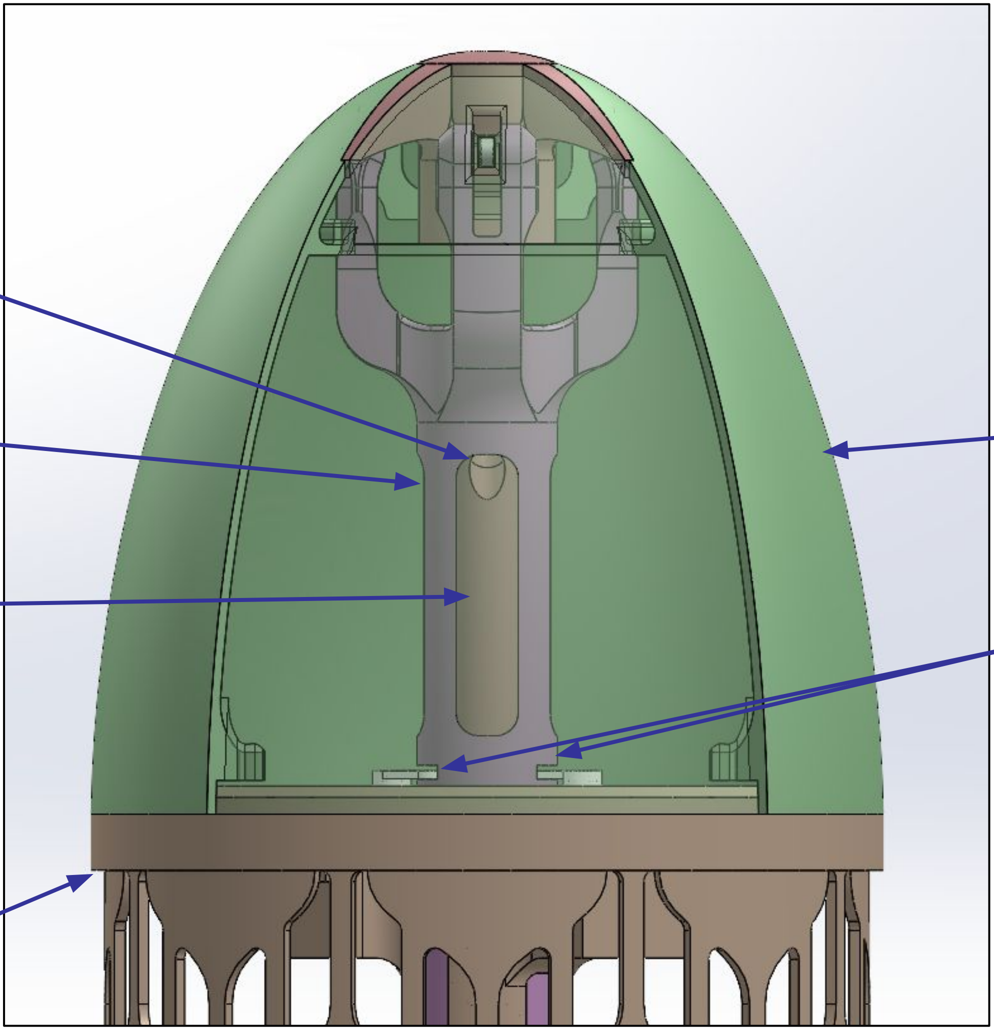
Spring-loaded Parachute Door

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

System Trades (out of 10)	Payload Version 1	Payload Version 2
Use of Space	4 - Electronic placement, such as the PCB and Raspberry Pi are located in spaces not otherwise used by structural components. However, the grid fins are restricted to a size that limits efficiency, and the three platforms take up vertical space. No landing gears.	**7 - Placement of PCB and Raspberry Pi switches and still uses space not otherwise used by structural components. More length is given to grid fins and the egg protection platform is removed. Addition of landing gears takes up unused space in nose cone.**
Electronic Placement	4 - All electronics are generally further apart on the CanSat, increasing length of needed wires. The oscillating egg capsule risks damaging the PCB.	**6 - Electronics are closer, slightly decreasing needed wire length. The oscillating egg capsule risks damages the PCB.**
Manufacturability	7 - Can be 3D printed with minimal supports. Three platforms take more precision to line up and assemble. Components are made of Nylon which is difficult to print with.	**8 - Can be 3D printed with minimal supports. Two platforms are simpler to line up and assemble. Components are made of Nylon which is difficult to print with.**
Weight	7 - Additional egg protection platform and no nose cone cut outs increase weight. Decreased size of grid fins decreases weight.	**7 - Removal of one platform and nose cone cut outs decreases weight. Increased size of grid fins and addition of landing gears increase weight.**
TOTAL	22	**27 (Selected)**

Payload Aerobraking Pre Deployment Configuration Trade & Selection (1/5)

Version 1



Opening for Pitot Tube

Nose Cone Section Hinge

Center Sliding Piece

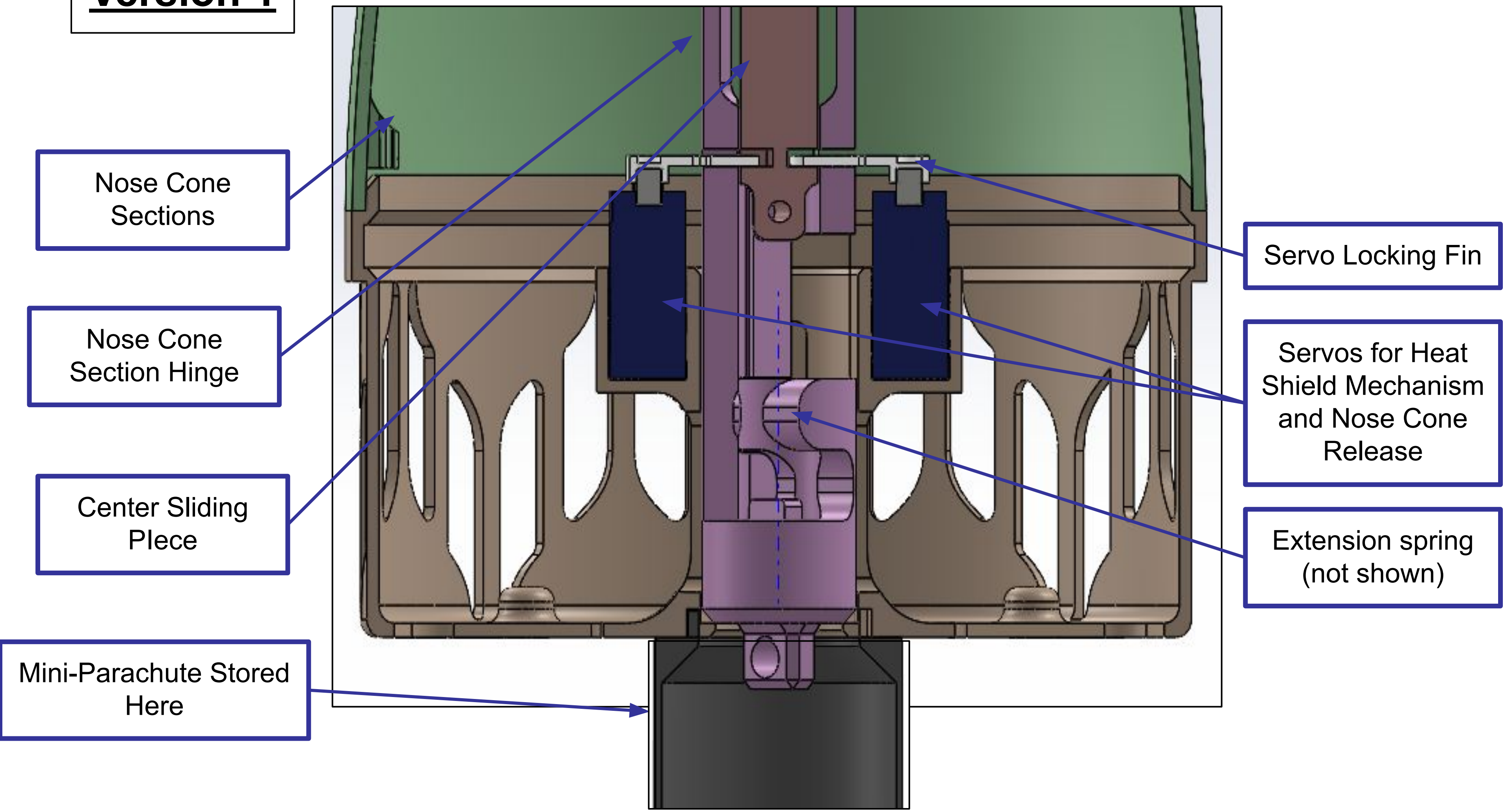
Nose Cone Sections

Servos for Heat Shield Mechanism and Nose Cone Release

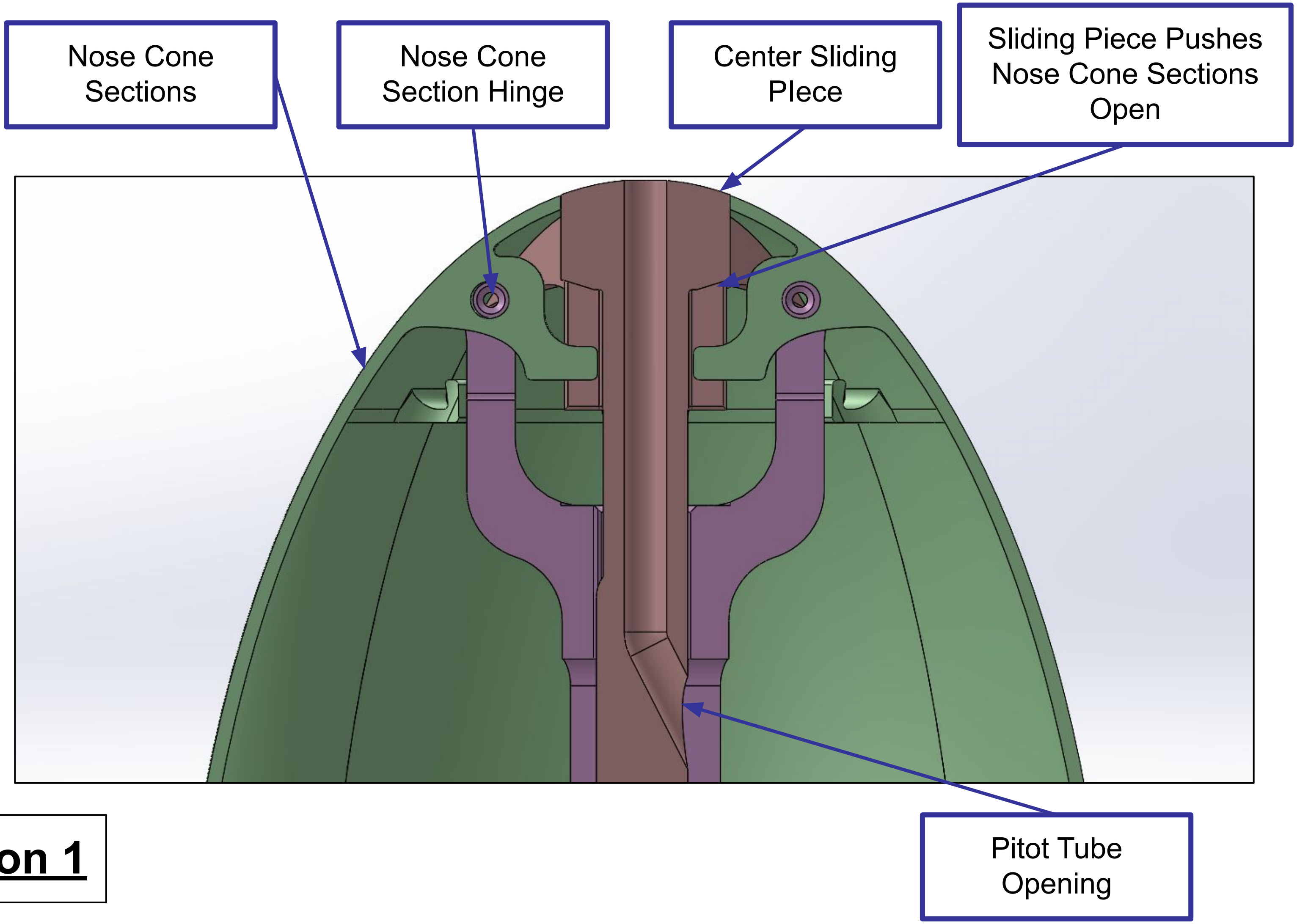
Nose cone shoulder located here. With a 50mm length, slides into rocket and is stowed with nose cone sections closed for the duration of ascent.

Payload Aerobraking Pre Deployment Configuration Trade & Selection (2/5)

Version 1



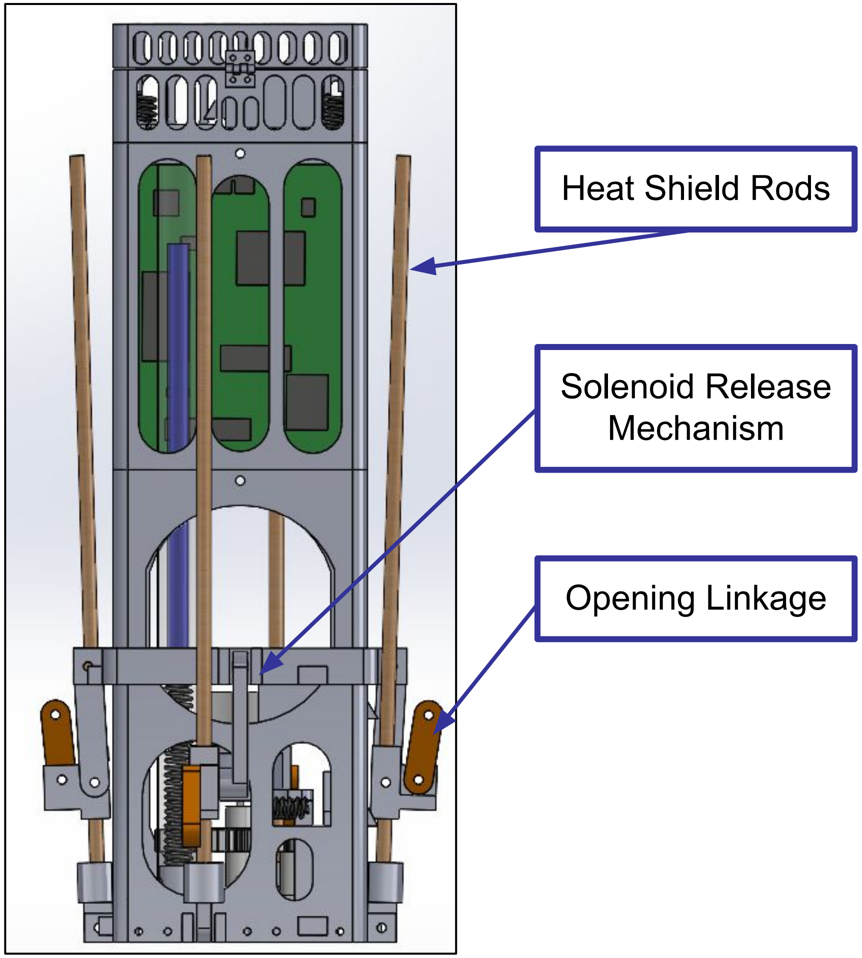
Payload Aerobraking Pre Deployment Configuration Trade & Selection (3/5)



Version 1

Version 2

- Heat shield linkages lay vertically up the cansat
- Rocket inner wall retains the linkages so they cannot fold out
- Solenoid releases linkages by disengaging from a locking mechanism

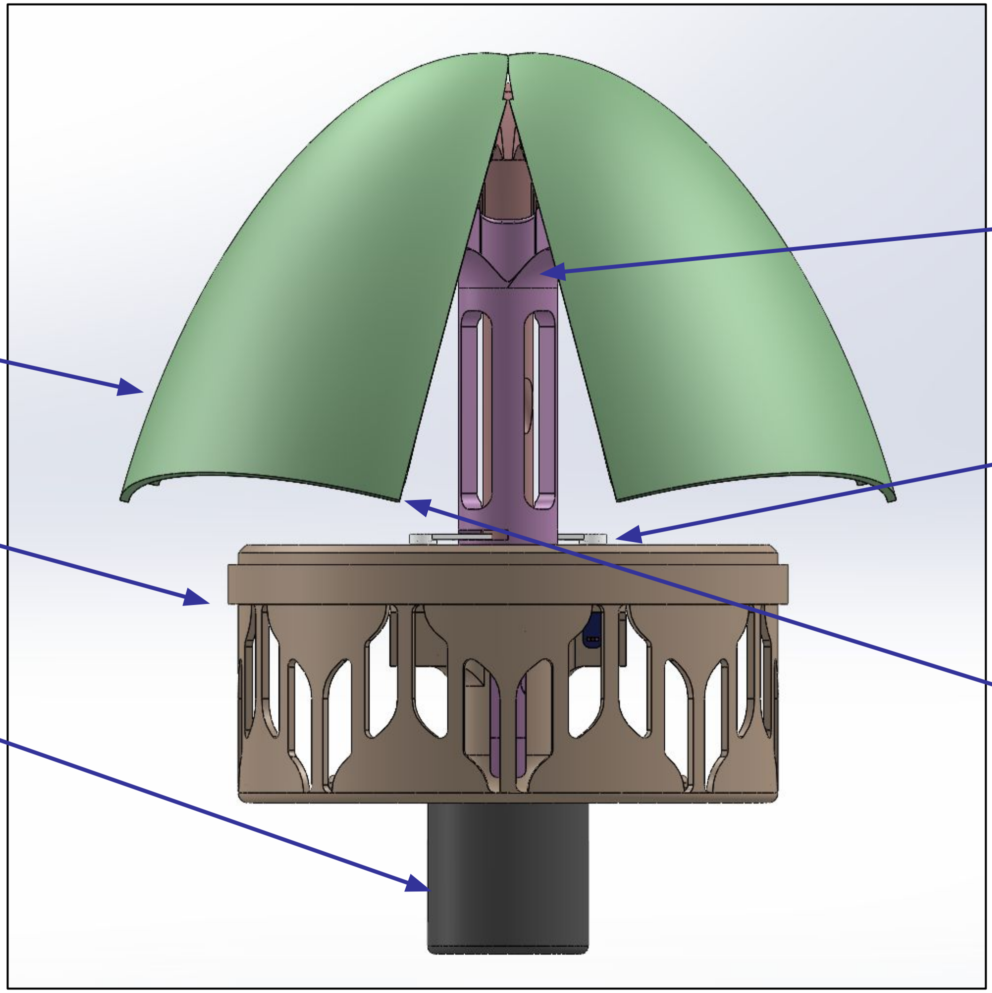


Payload Aerobraking Pre Deployment Configuration Trade & Selection (5/5)

System Trades (out of 10)	Aerobraking Pre Deployment Version 1	Aerobraking Pre Deployment Version 2
Assembly	**5 - Requires small pins and bearings which are difficult to install, springs and servos are simple.**	4 - Complicated linkages mean that assembly, revisions, and fixing parts will be difficult.
Durability	**6 - All structural components can be 3-D printed, nylon will be purchased, electronics for actuation are COTS.**	5 - Some linkages are 3-D printed and quite small, the rods are fairly sturdy.
Weight	**9 - Fairly heavy overall at 220g, however this takes the place as the nose cone, so no extra weight will be needed, therefore very optimal use of space and weight.**	5 - Overall weight is lower than Version 1, but does not replace the nose cone, which when factored in, Version 2 is heavier. Addition of solenoid increases electronic capacity.
Stability	**6 - Extension spring pulling downwards has to overcome drag forces, which is relatively stable. The rest of the mechanism has tight tolerances so nothing can move.**	9 - Locking mechanism is very strong to be able to withstand the drag force that the heat shield experiences as it opens. Mechanically locked.
TOTAL	**27 (Selected)**	23

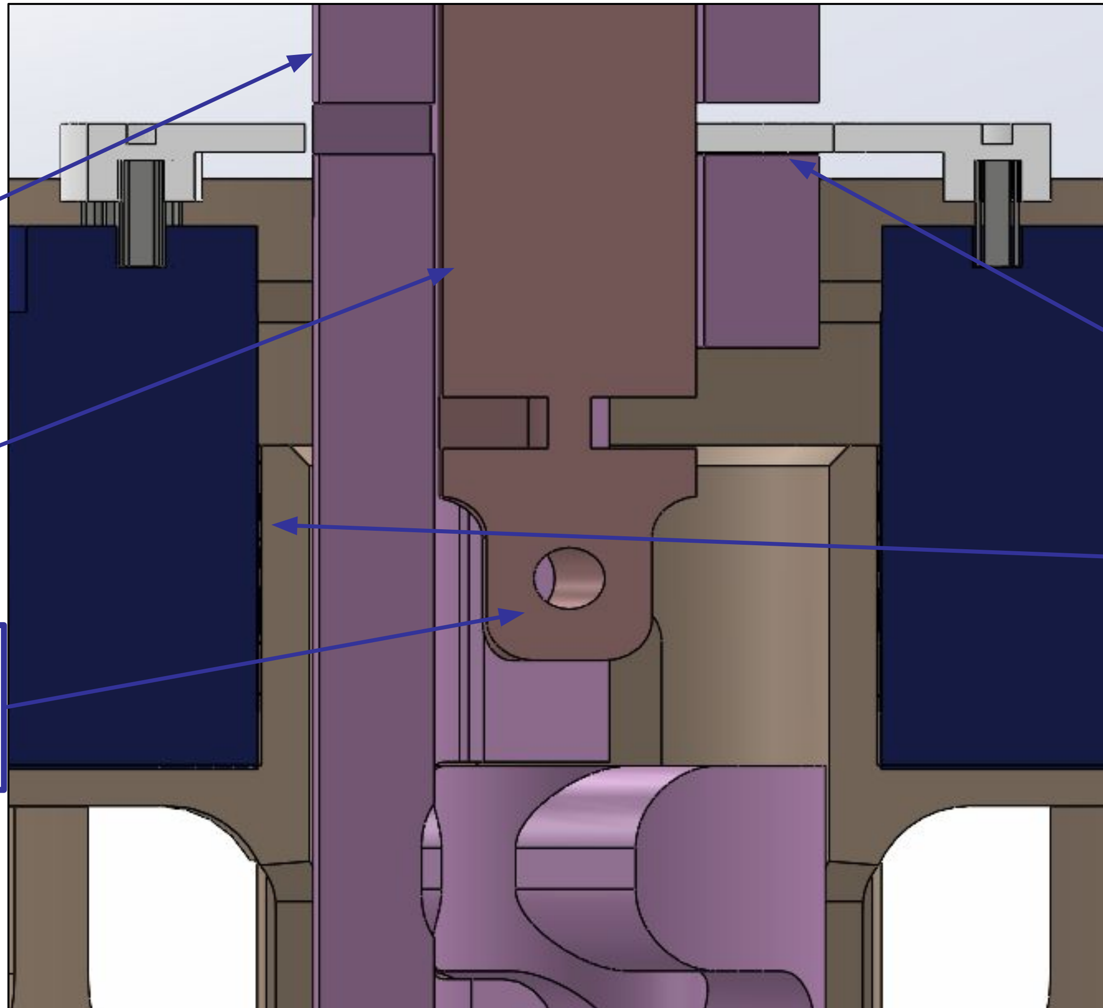
Payload Aerobraking Deployment Configuration Trade & Selection (1/5)

Each section opens up to deploy the heat shield. Nylon fabric fills in between each section.



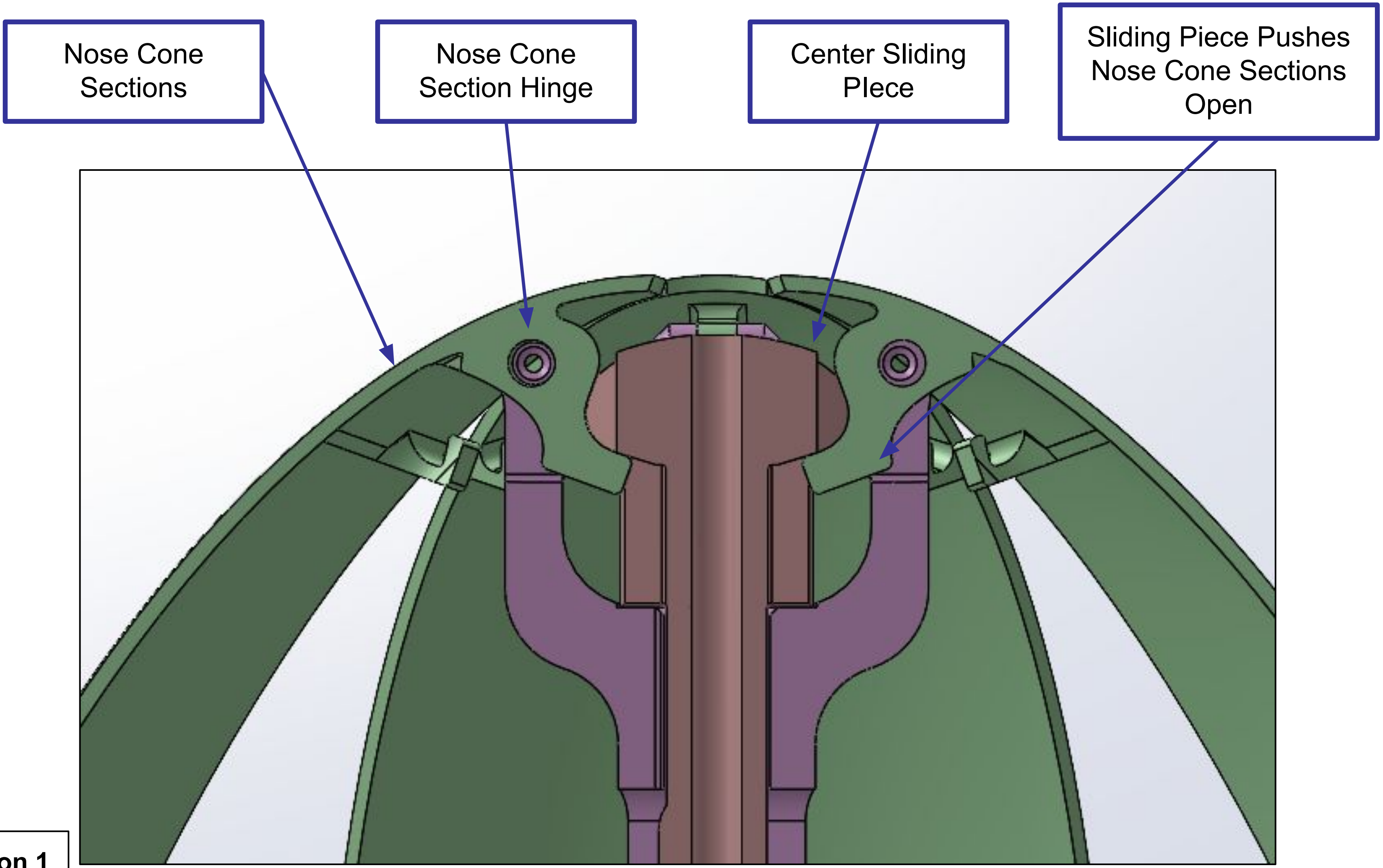
<u>Version 1</u>

Payload Aerobraking Deployment Configuration Trade & Selection (2/5)



Version 1

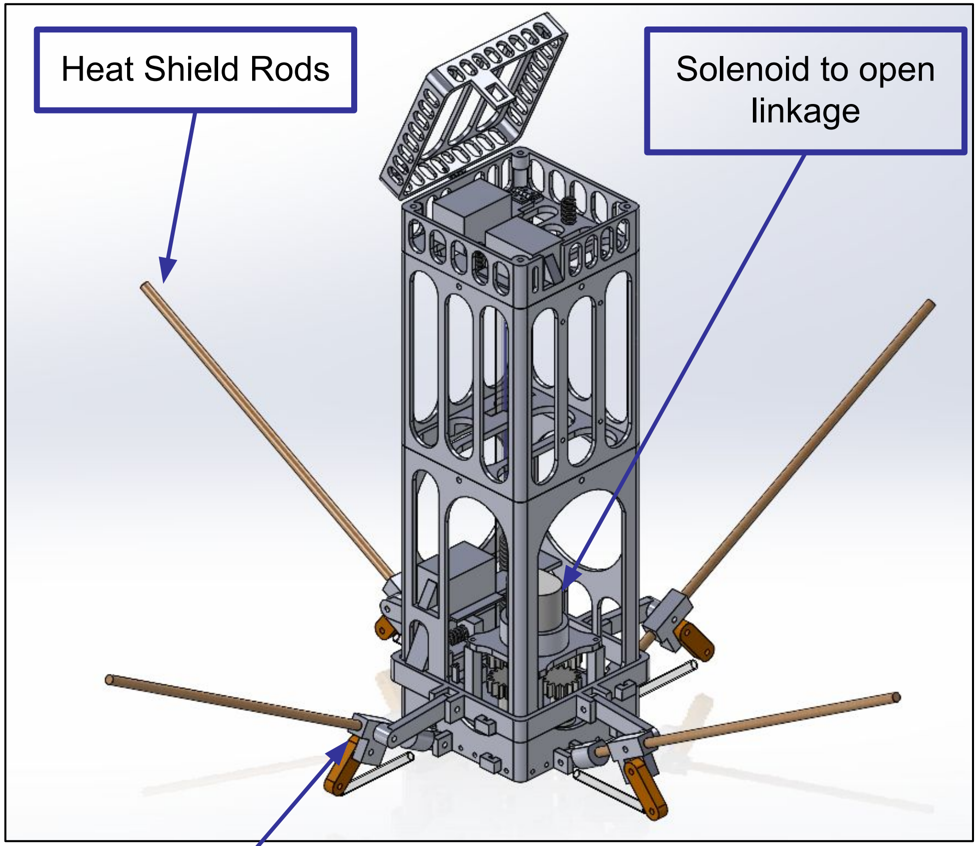
Payload Aerobraking Deployment Configuration Trade & Selection (3/5)



Version 1

Version 2

- Heat shield linkages expand
- Wooden dowel rods have high rigidity, ensuring no rod breakage during flight
- Solenoid unlocks linkages, letting them expand, triangle locking mechanism mechanically locks the rods in place



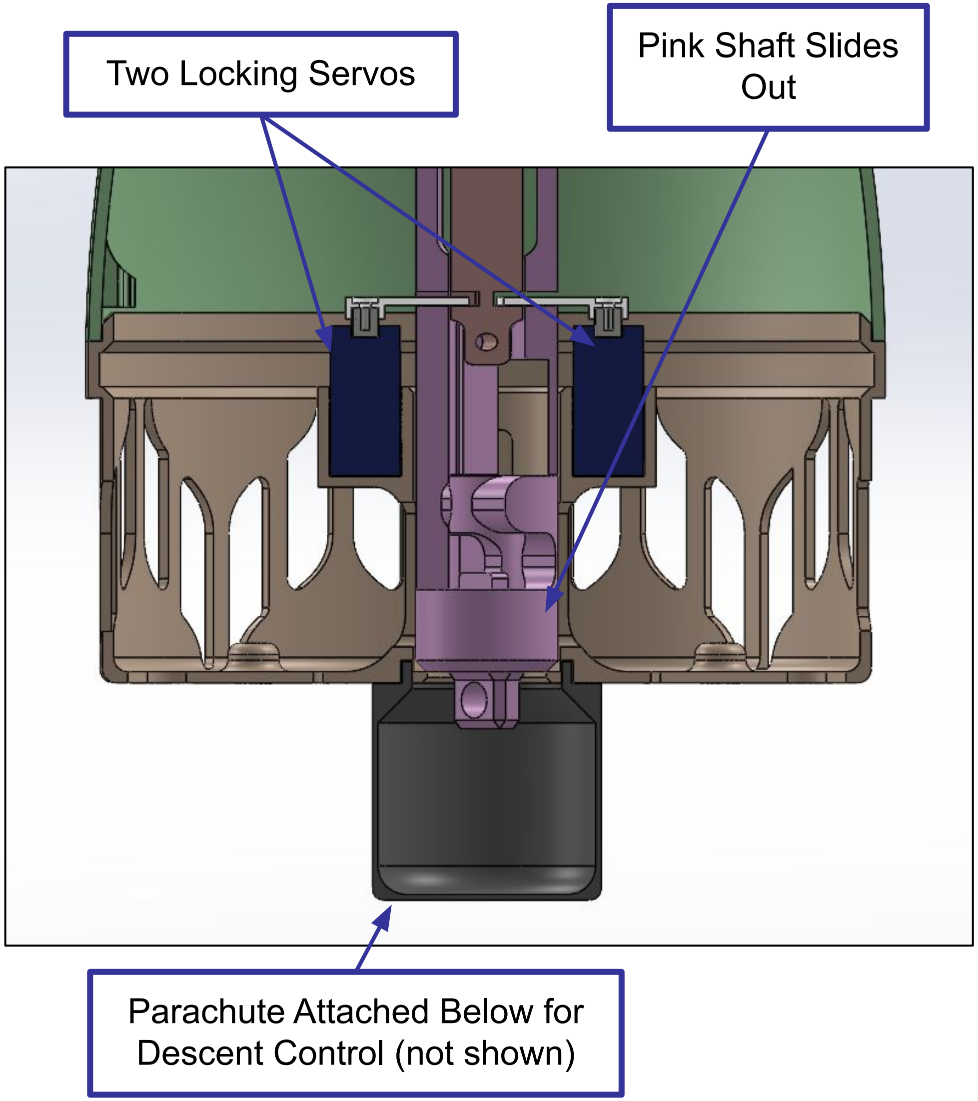
Payload Aerobraking Deployment Configuration Trade & Selection (5/5)

System Trades (out of 10)	Pre Deployment Version 1	Pre Deployment Version 2
Assembly	**6 - Connection points are slightly difficult to get to when closed. When open its easy to work with.**	7 - Connection points are located on the outside of the probe making it easy to assemble.
Efficiency	**8 - Servos sense when limit switch is unpressed, electronically signaling servos to unlock. Utilizes springs.**	4 - Solenoid unlocking mechanism is unnecessary, can be done with springs or servos to reduce weight.
Durability	**5 - Linkages are super glued into place and protected underneath nose cone.**	5 - Heat shield linkages are attached to the outside of the probe. Connection points are not protected.
Weight	**9 - Fairly heavy overall at 220g, however this takes the place as the nose cone, so no extra weight will be needed, therefore very optimal use of space and weight.**	5 - Overall weight is lower than Version 1, but does not replace the nose cone, which when factored in, Version 2 is heavier. Addition of solenoid increases electronic capacity.
Stability	**6 - Spring pulling downwards is relatively stable, grooves in sliding piece and tight hinge tolerances prevent unwanted movement.**	9 - Triangular locking mechanism ensures the heat shield maintains orientation at all time.
TOTAL	**34 (Selected)**	30

Payload Aerobraking Release Trade & Selection (1/3)

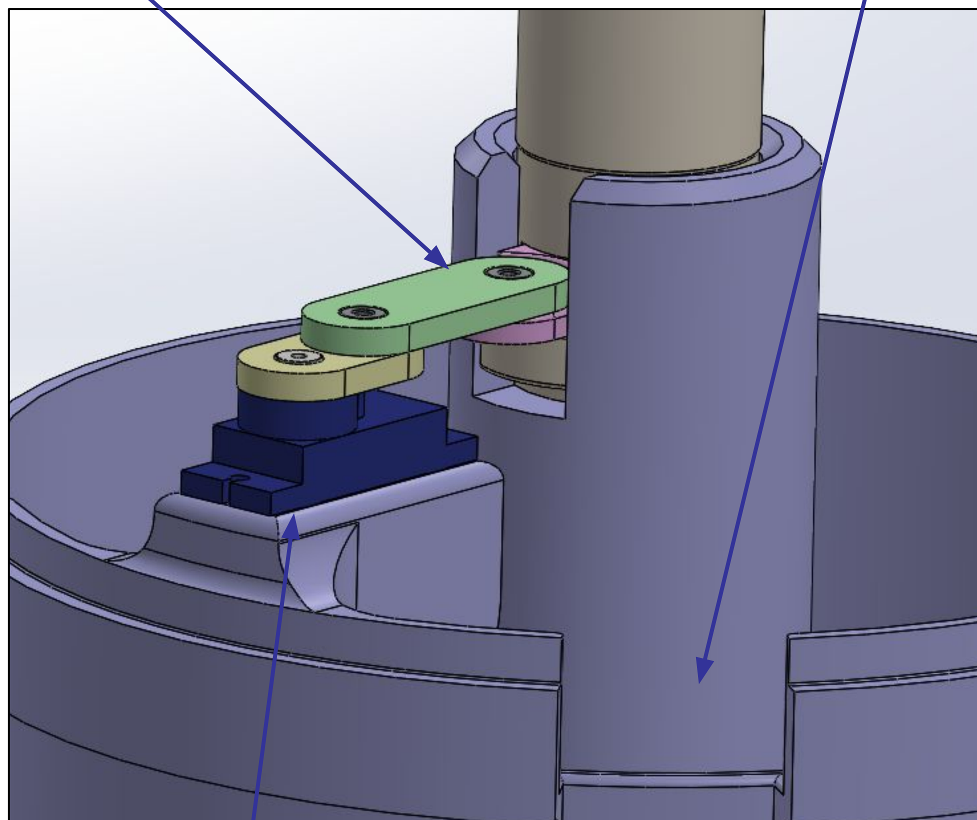
Version 1

- Nose cone is locked in place by 2 servos
- No active release mechanism, nose cone is unlocked just before parachute opens, slides out of base part
- Servos used to unlock mechanism are also used to deploy aerobrake



Version 2

- Nose cone is locked in place by 1 servo
- Active release once servo unlocks mechanism, compressed spring extend to push mechanism out
- Springs are also long enough to be used to soften landing



Payload Aerobraking Release Trade & Selection (3/3)

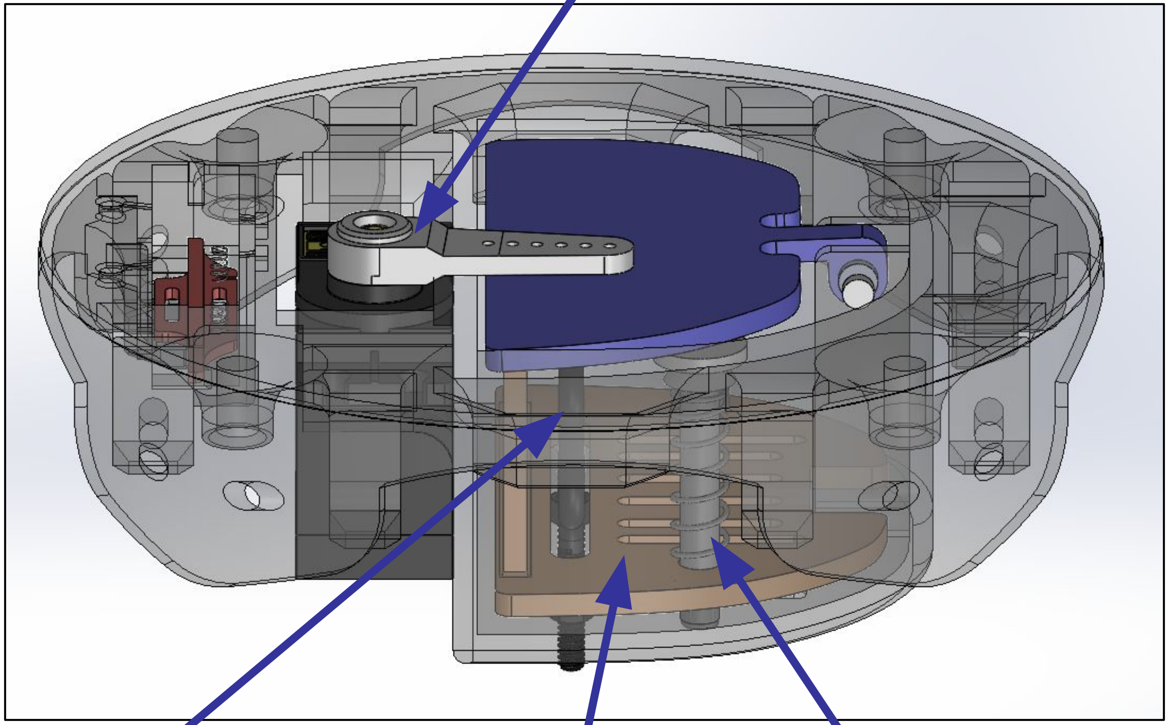
System Trades (out of 10)	Aerobrake Release Version 1	Aerobrake Release Version 2
Assembly	**9 - Servos screw into place. No further assembly required.**	6 - Servo screws into place. Linkage system requires press fit bearings, pins, and spring underneath is slotted in.
Durability	**8 - Two servos means much more even locking of shaft, high durability**	5 - One servo with 3d printed linkages is prone to bending, overall low durability
Weight	**7 - One extra servo adds 9 grams and 2 extra wires, overall much lighter and doubles as the locking mechanism for the aerobrake opening**	7 - Only one servo, which means less electronics, but added spring and 3D printed linkages means roughly the same weight
Stability	**8 - Two servos locking means each servo fin bends less, stronger mechanism overall**	5 - 3D printed linkages are prone to bending and jamming, not as reliable
TOTAL	**32 (Selected)**	23

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

Version 1

- Mechanism uses only one servo and a pair of springs
- Parachute connected to two eye-hooks
- When the servo arm moves, it allows the springs to push the parachute through the door.
- Wires and necessary electronics for the solenoid are installed further down near the egg.

Structural components made of Nylon

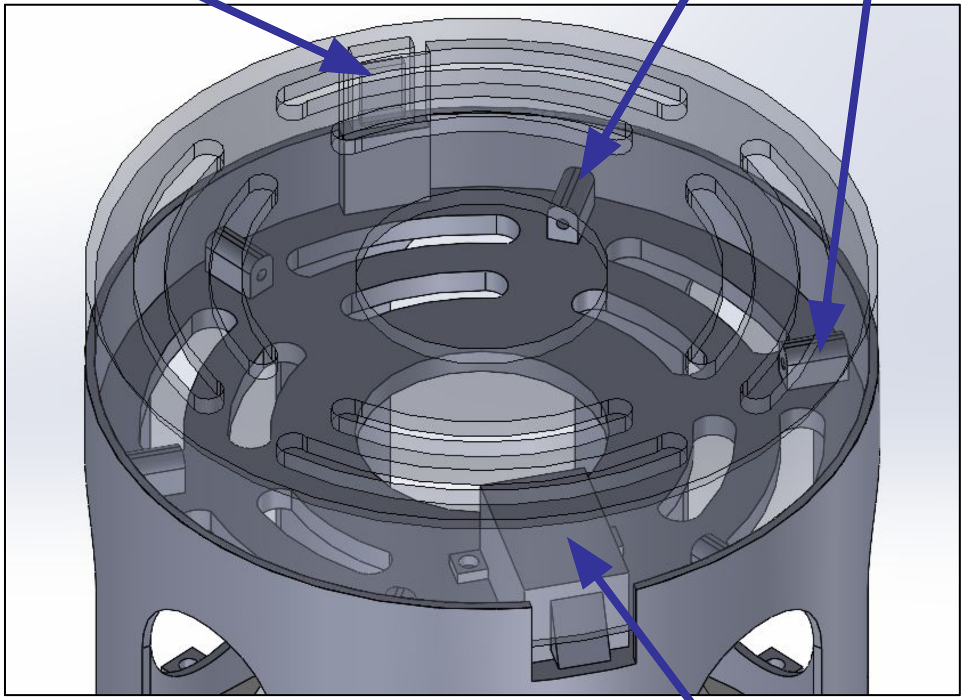


Payload Parachute Deployment Configuration Trade & Selection (2/3)

Version 2

- Features a spring loaded lid held shut by a solenoid.
- Parachute is connected to six extrusions.
- When the solenoid retracts, the lid will shoot open, releasing the parachute.
- Wires and necessary electronics for the solenoid are installed further down near the egg.

Structural components made of Nylon

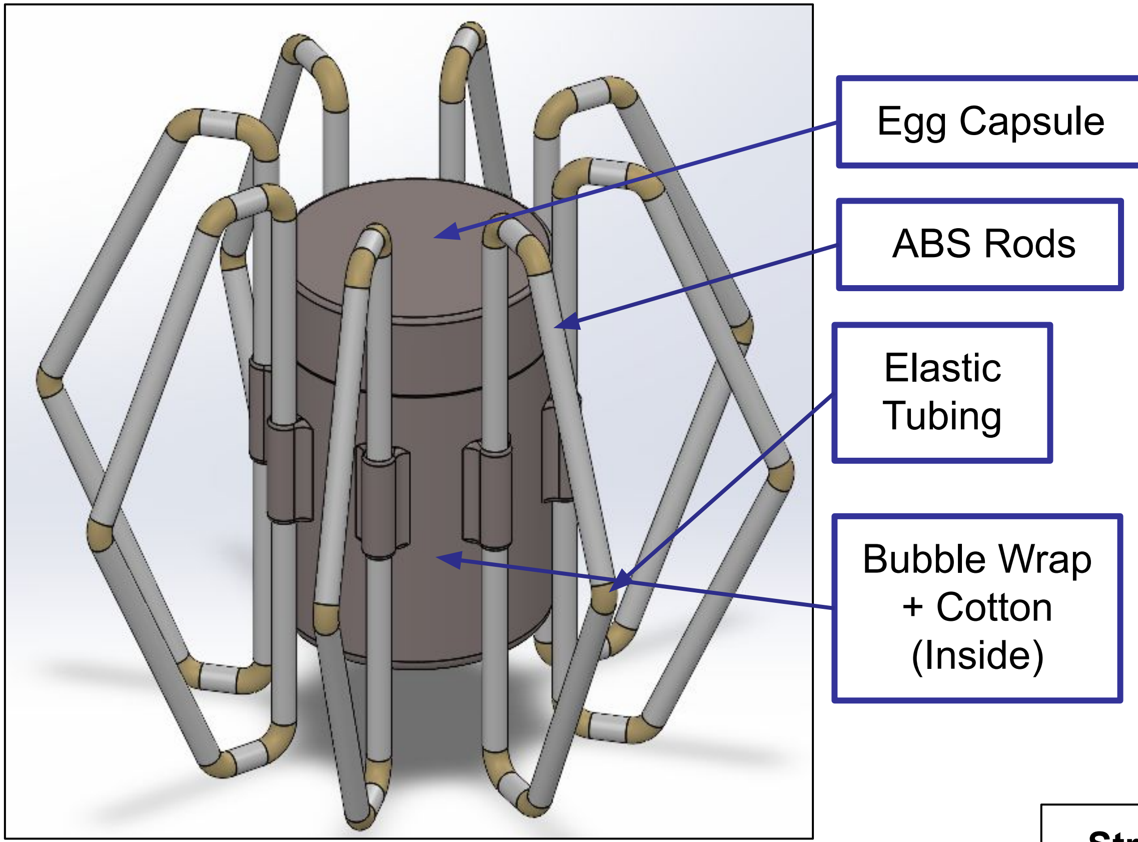


Payload Parachute Deployment Configuration Trade & Selection (3/3)

System Trades (out of 10)	Parachute Deployment Version 1	Parachute Deployment Version 2
Assembly	**7 - Simple assembly using dowel pins, eye-hooks, nuts/screws,**	6 - Assembly requires nuts/screws and zipties.
Manufacturability	**6 - All structural components can be 3-D printed**	6 - All structural components can be 3-D printed
Durability	**7 - Having only two attachment points makes it less stable, but having the attachment points be eye-hooks may help with this. Parts are smaller and can have more infill without adding too much weight making it more durable.**	8 - Six attachment points allow for more stability. Fewer moving parts compared to version one. Parachute attachment points are 3D-printed and may be susceptible to tearing off.
Weight	**8 - Only uses one servo for the lock/unlock mechanism. Can reduce weight even further using cutouts.**	5 - The required solenoid is heavier than the required servo. Already lots of cutouts, can't reduce weight further if needed.
TOTAL	**28 (Selected)**	25

Payload Egg Containment Configuration Trade & Selection (1/3)

Version 1



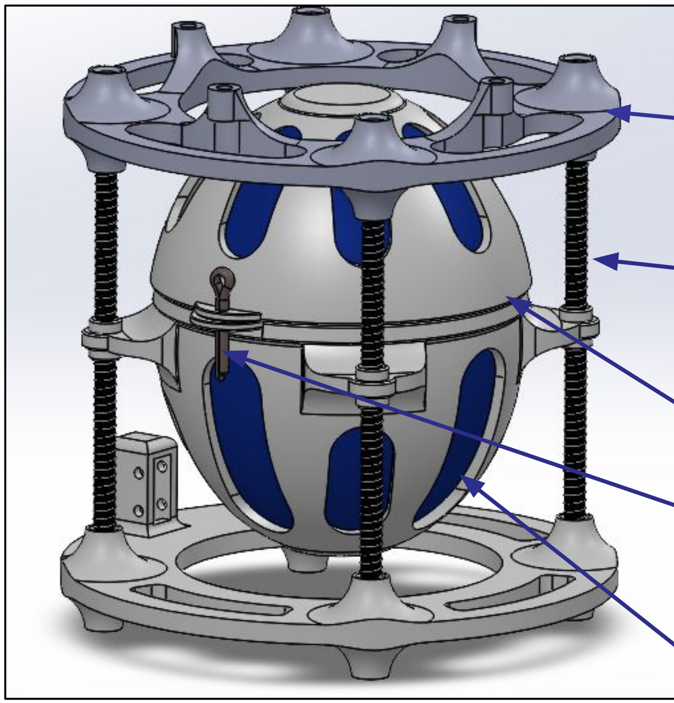
- Top and bottom of the capsule are put together through a set of threads.
- Bubble wrap and cotton prevent egg from moving around in capsule.
- Rods connect to side of the cylinder capsule.
- Elastic tubing connects rods to create a bouncy "cage-like" protection for the egg.

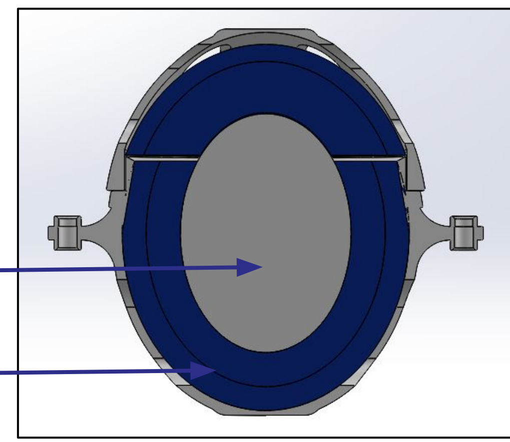
Structural components made of Nylon

Payload Egg Containment Configuration Trade & Selection (2/3)

<u>Version 2</u>

- Top and bottom of spherical capsule is sealed together using cotter pins.
- Polyurethane foam prevents egg from moving around in capsule.
- Capsule attaches to carbon rods with springs to allow oscillation movement.





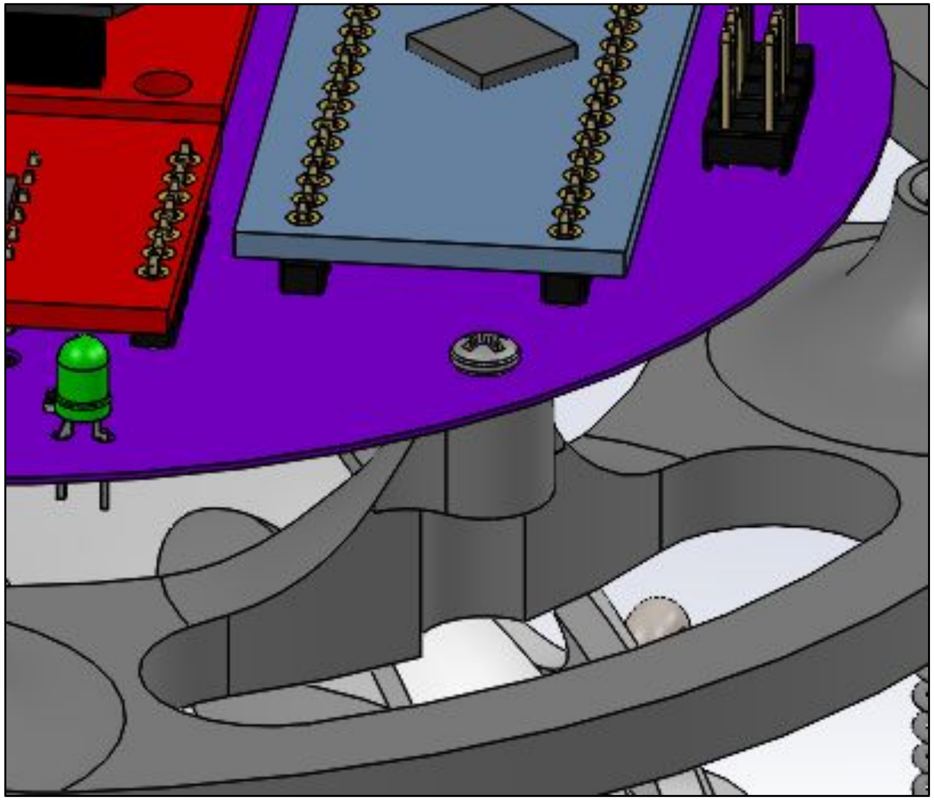
Structural components made of Nylon

Payload Egg Containment Configuration Trade & Selection (3/3)

System Trades (out of 10)	Egg Containment Version 1	Egg Containment Version 2
Integration	3 - "Cage-like" wings are difficult to integrate with a structure connected with carbon fiber rods. Wings use up much vertical space needed for other components.	**8 - Spherical capsule has carbon fiber attachment holes that integrates into overall structure well.**
Manufacturability	4 - Thread in the capsule's top and bottom are difficult to print, especially with nylon. Wings are difficult to assemble with its many components.	**6 - Capsule is easier to 3D-print without threads, but nylon is still difficult to print with. The stacking of springs-capsule-spring between platforms is easy to assemble.**
Protection	4 - Bubble wrap and cotton may flatten after harsh forces are enacted on egg containment. Wings are not stiff and structurally stable with elastic tubing.	**8 - Polyurethane foam is a bouncier material. Springs on the carbon fiber rods provide a structurally sound second layer of protection as capsule can only go up and down.**
Dependability	4 - Wings are able to move in many directions and may collapse with forces during launch and landing. Elastic tubing may decrease in elasticity over time.	**7 - Carbon fiber rods are stiff enough to keep egg capsule in place. Elastic modulus of springs less likely to decrease than rubber/latex tubing.**
TOTAL	17	**29 (Selected)**

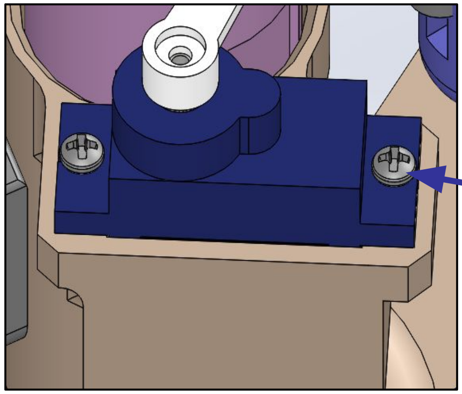
Electronics Structural Integrity (1/2)

Electric Component Enclosure	Electric components are stored on a platform under the nose cone and mounted around the egg protection structure. The PCB is mounted and bolted at four points to a 3-D printed piece.



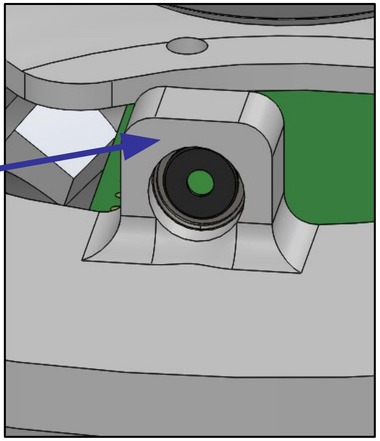
Electronics Structural Integrity (2/2)

Electric Component Securing	Electric components will be attached to mounts with **nuts and bolts** or **press-fit** into mounts to ensure a strong connection.
Electrical Connection Securing	Wires will be held in place using **tape or adhesive** where necessary.
Descent Control Attachments	The parachute is held in the parachute compartment which is locked with a **servo** and attaches to two **I-hooks**. The heat shield is released when two **servos** near the nose cone move and open the nose cone wings.



Servo mounted with bolts and lock nuts.

Camera press-fit into a horizontal 3D-printed mount, with adhesive.



Mass Budget (1/6)

Payload Structural Elements

Element	Quantity	Mass (g)	Source	Uncertainty (g)	Total Mass (g)
Landing Foot	4	2.65	Estimation	1	10.6
Landing Swivel	4	1.63	Estimation	1	6.51
Landing Connector Top	4	0.16	Estimation	0.1	0.62
Egg Top	1	29.3	Estimation	2	29.3
Egg Bottom	1	55.8	Estimation	3	55.8
Electronic Platform	1	21.4	Estimation	2	21.4
Limit Switch Platform	1	21.4	Estimation	2	21.4
Polyurethane Foam (Bottom)	1	8.69	Estimation	2	8.69
Polyurethane Foam (Top)	1	4.35	Estimation	2	4.35
Carbon Fiber Rod (1152 mm)	1	33.41	Estimation	2	33.41
Parachute/Grid Fin Platform	1	124	Estimation	10	124
Parachute Door	1	7.75	Estimation	1	7.75

Mass Budget (2/6)

Payload Structural Elements

Element	Quantity	Mass (g)	Source	Uncertainty (g)	Total Mass (g)
Parachute Pushing Platform	1	10.85	Estimation	1	10.85
Parachute Cap	2	0.62	Estimation	0.1	0.62
Arm Servo	1	1	Estimation	0.5	1
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
Egg Protection Springs	4	0.2	Estimation	0.1	0.8
SS Ball Bearing	2	0.15	Data Sheet	N/A	0.3
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	10.81	Estimation	1	43.25
Nose Cone Slider	1	21.86	Estimation	2	21.86

Mass Budget (3/6)

Payload Structural Elements

Element	Quantity	Mass (g)	Source	Uncertainty (g)	Total Mass (g)
Nose Cone Tip	1	41.7	Estimation	3	41.7
Nose Cone Base	1	144.9	Estimation	5	144.9
Grid Fin	4	21.08	Estimation	2	21.08
Nose Cone Bearing	4	0.01	Estimation	0.01	0.04
Parachute	1	80	Estimation	10	80
Deployment Bag	1	50	Estimation	5	50
				Total:	**752.3**

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	0.5	0.5
STM32	1	8.7	Data Sheet	N/A	8.7
Camera Module	1	4.6	Data Sheet	N/A	4.6
Raspberry Pi	1	5	Data Sheet	N/A	5

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:	**137.9**

Mass Budget (6/6)

Total Mass

Element	Total Mass (g)
Structural Elements	752.3
Electrical Elements	137.9
	890.2

Total Mass: 890.2 g   **Margin Mass: 9.8 g**

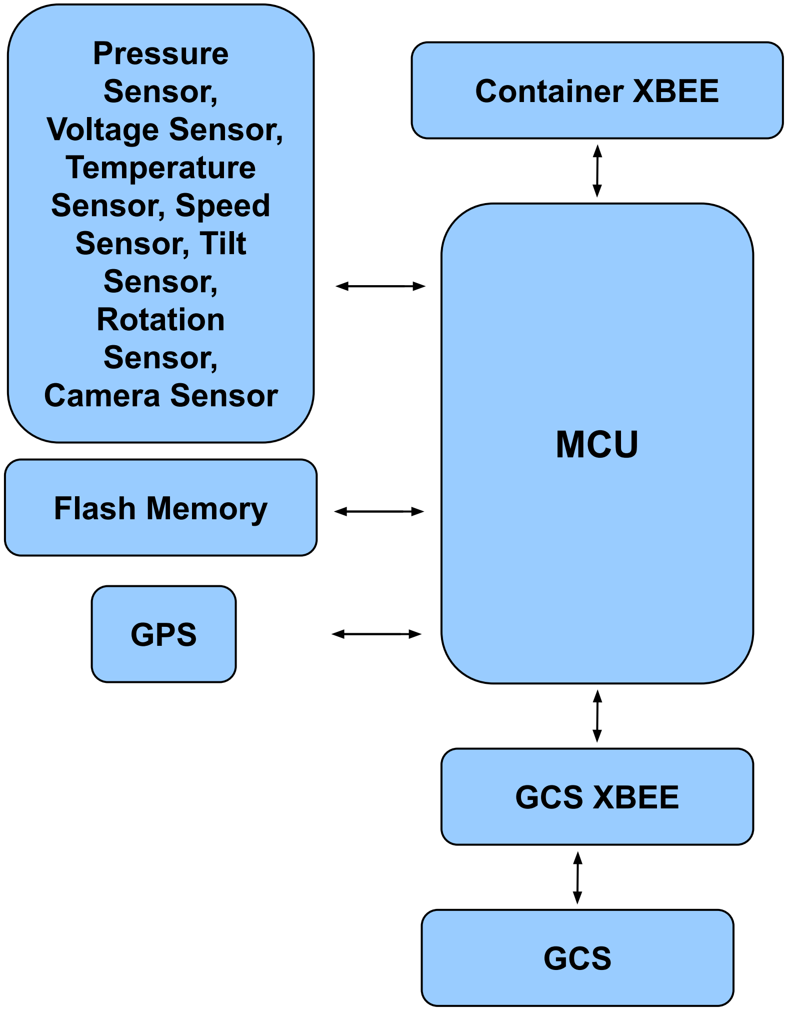
Plans for Extra Mass:

- **Slightly increasing thickness of 3D-printed structures.**
- **Add mass in areas to adjust center of mass and stabilize CanSat.**

Communication and Data Handling (CDH) Subsystem Design

Khushi Gupta

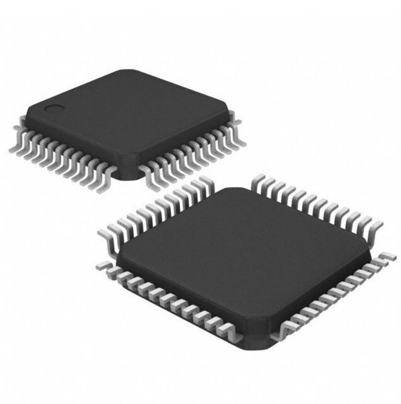
Payload Command Data Handler (CDH) Overview

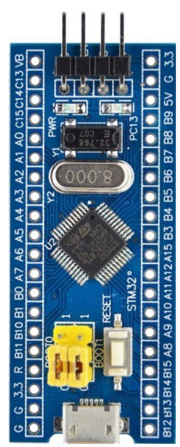


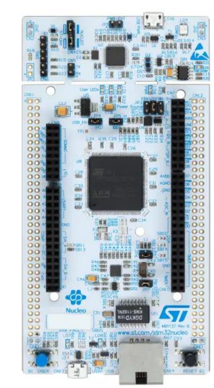
Component	Function
XBEE3 Pro	Radio Transceiver/Receiver
BMP581	Pressure Sensor
INA219	Voltage Sensor
BMP581	Temperature Sensor
MS4525DO	Speed Sensor
MPU-6050	Tilt Sensor
MPU-6050	Rotation Sensor
Zero Spy Cam	Camera Sensor
PA1010D	GPS
Internal Flash memory	Memory
STM32F103C8T6	Microcontroller

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

Processor	Interfaces	# I/O Pins	Speed	Total Pins	Memory	Boot Time	Voltage	Cost
STM32F103C8T6 (Left)	**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)**	**2 ms**	**2.7 - 3.6**	**$6.11**
STM32F765VGT6 (Right)	I2C (4) UART(4) SPI (6) SAI (2) CAN (3) SPDIFRX	Analog (6) Digital (72) PWM (4)	216 MHz	82	Flash (1 MB) SRAM (512 KB)	2 ms	1.7 - 3.6	$28.21

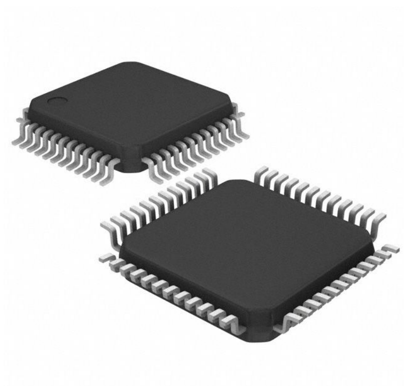


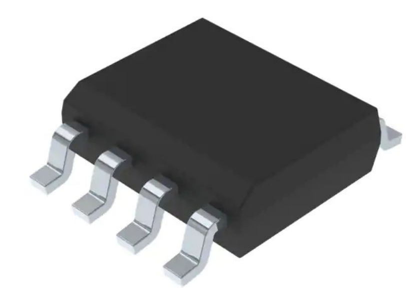




Payload Processor & Memory Trade & Selection (2/4)

Processor	Memory	Size	Interface	Write Time	Cost
STM32 (left)	Flash	64KB	Internal	20-100ms	No extra cost
M95M02 (right)	EEPROM	2MB	I2C	5ms	$5.34

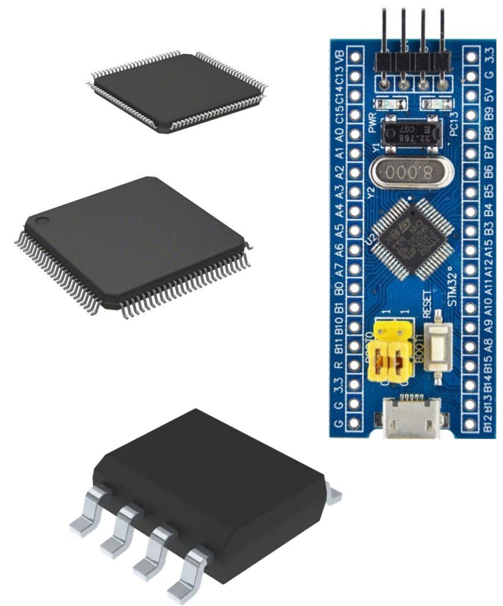




Configuration 1: External EEPROM Memory IC

Processor	STM32F103C8T6
Speed	72 MHz
Pin Count	59
Memory	External Memory
Technology	Flash
Size	2 MB
Write Time	5 ms

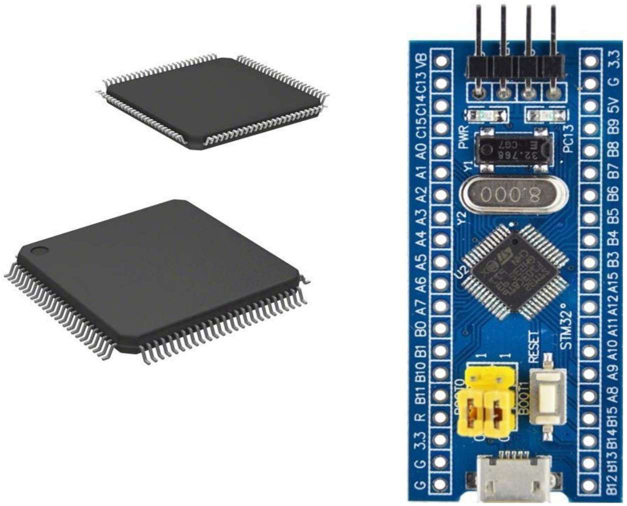
STM32F103C8T6



Configuration 2 (Selected): Select 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**

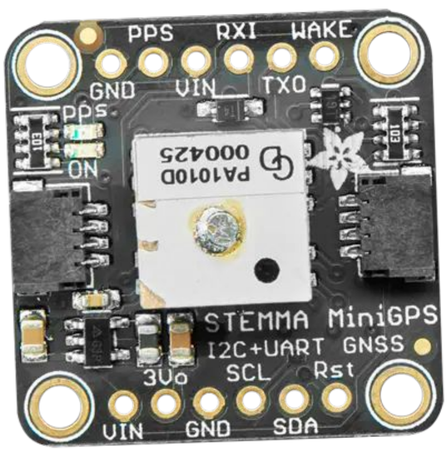
STM32F103C8T6



Selection Reasoning	
• Smaller physical memory size • Cheaper to Implement	• Also reset-tolerant • Faster to access

Payload Real-Time Clock

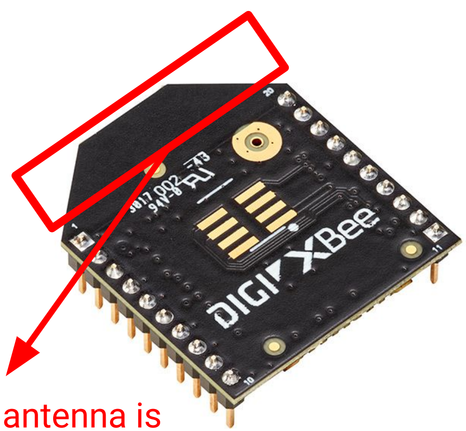
Design	Type	Reset Tolerance	Weight	Cost
Timer on STM32 Processor	Software	Not reset tolerant	No extra weight	No extra cost
RTC on PA1010D GPS	**External Hardware - I2C**	**Reset tolerant, battery backup**	**No extra weight**	**No extra Cost**



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

Payload Antenna Trade & Selection (1/2)

Design	Outdoor Range	Indoor Range	RF TX Power (max)	Cost
Digi XBee S2X Whip (Right)	1200 m (0.75 mi)	60 m (200 ft)	6.3 mW (+8 dBm)	$33.10
XBee3 Pro PCB Antenna (Left)	**3200 m (2 mi)**	**90 m (300 ft)**	**79 mW (+19 dBm)**	**$25.60**

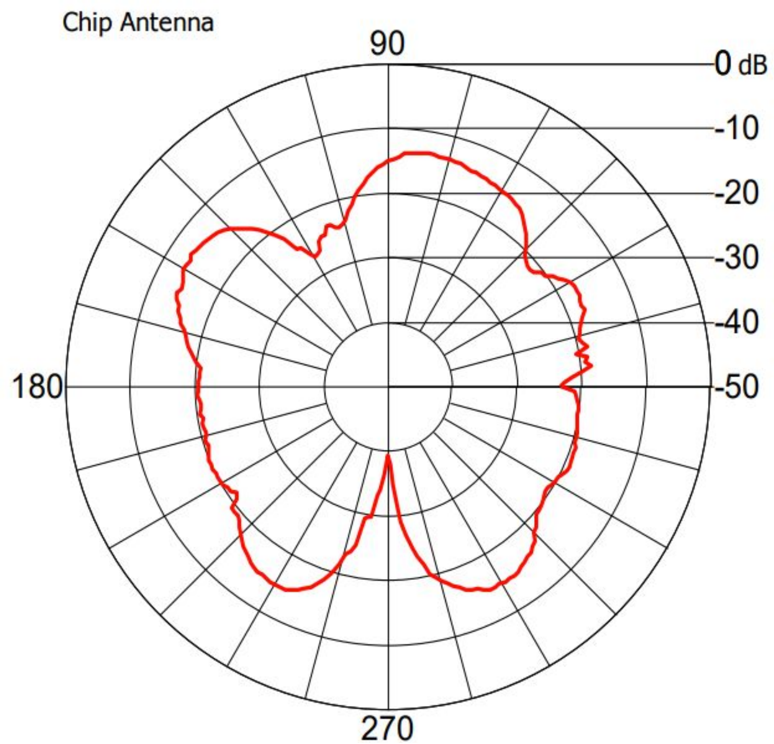


The trace antenna is located at the top of the XBEE.

Payload Antenna Trade & Selection (2/2)

Selection	Reasoning
XBee3 Pro PCB Antenna (Container 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
Digi XBee S2X	$33.10	5g	2.4 GHz	6.3 mW (+8 dBm)	1200 m
XBee3 Pro	**$25.60**	**2.27g**	**2.4 GHz**	**79 mW (+19 dBm)**	**3200 m**
Final Selection: XBee3 Pro					

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 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 -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.
Simulated 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)

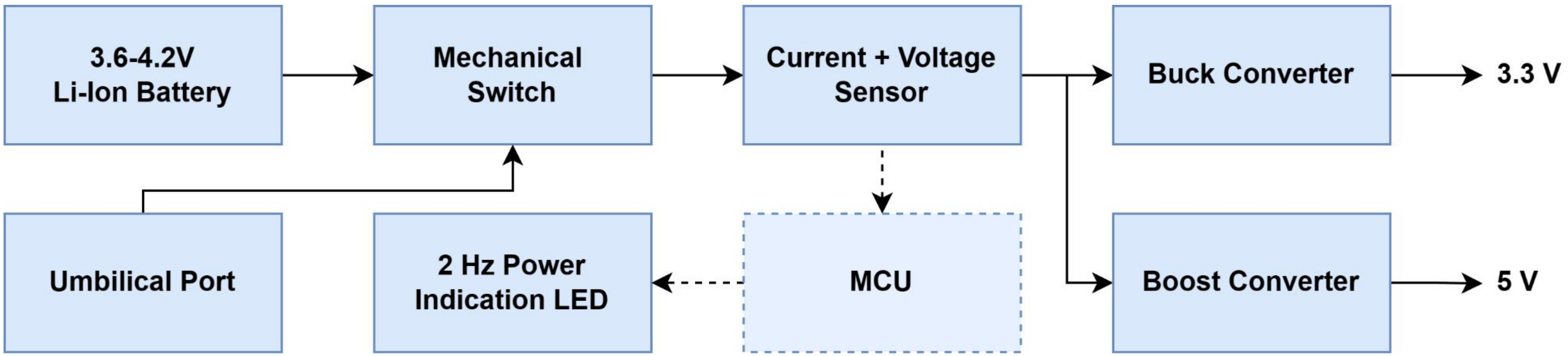
Title	Command	Syntax	Description	Example
Calibrate Altitude to Zero	CAL	**CMD,<TEAM_ID>, CAL**	-CMD and CAL is static text. -<TEAM_ID> is the assigned team id.	**CMD, 2057, CAL** -Altitude is set to zero.
Control Audio Beacon	BCN	**CMD, <TEAM_ID>, BCN,ON|OFF**	-CMD and BCN are static text. -<TEAM_ID> is the assigned team id. -<ON|OFF> are static strings “ON” or “OFF” that control the audio beacon.	**CMD,2057, BCN,ON** -<TEAM_ID> is 2057. -Activates the audio beacon

Team Logo Here

Electrical Power Subsystem (EPS) Design

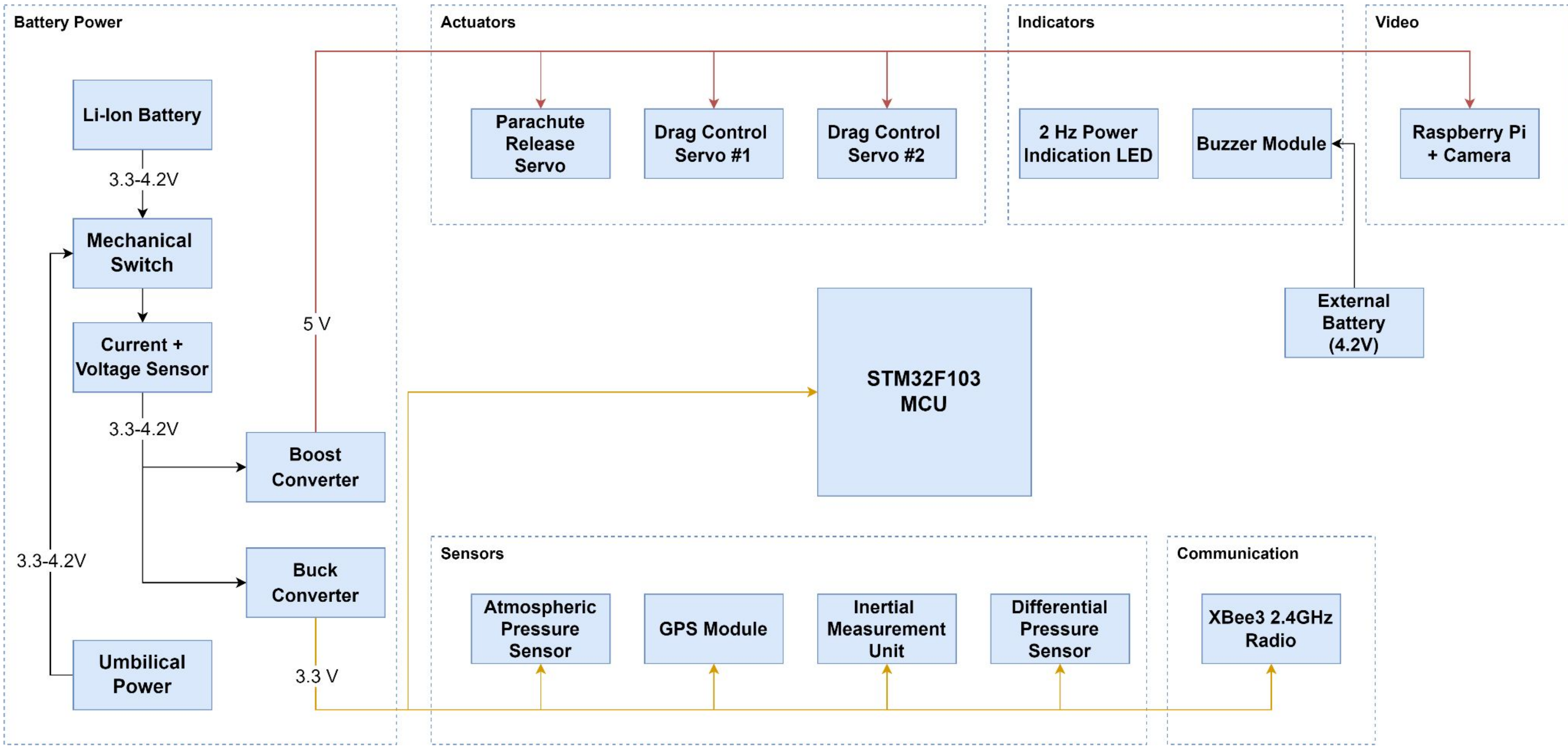
AJ Smyth

EPS Overview



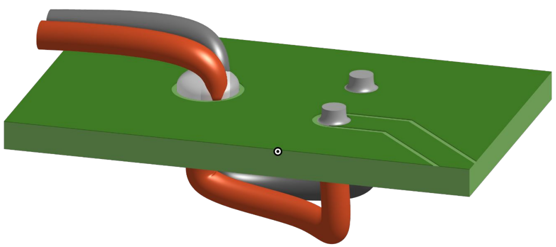
Component	Purpose
Li-Ion Battery	Supplies power to the Cansat
Mechanical Switch	Allows selectable isolation between battery & Cansat
Current + Voltage Sensor	Monitors battery state
Buck Converter	Converts battery voltage to 3.3 V
Boost Converter	Converts battery voltage to 5 V
Power Indication LED	Flashes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

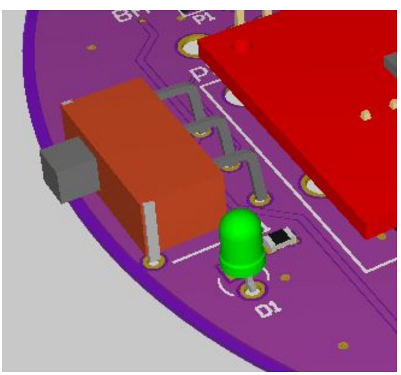
Payload Electrical Block Diagram (1/2)



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

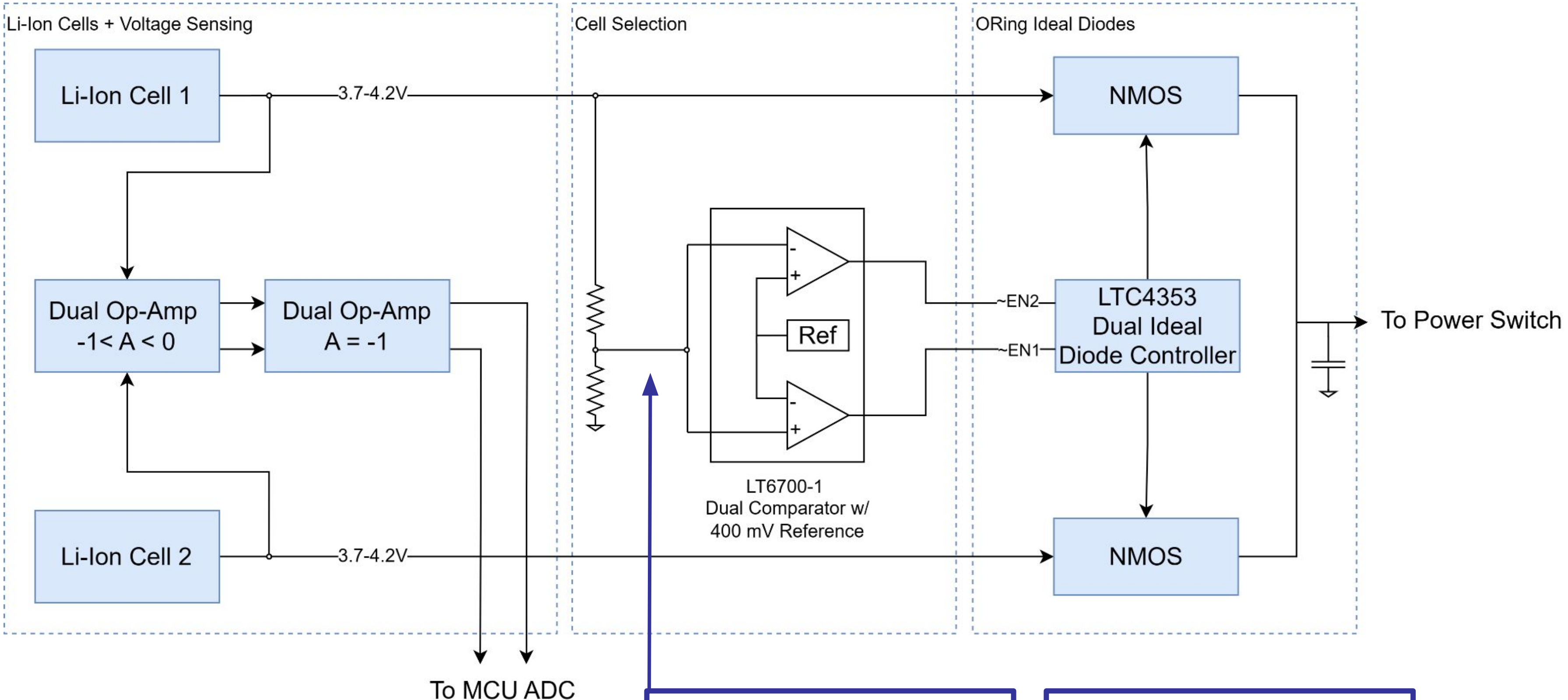
Umbilical Power Supply:

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

CanSat External Power Control:

- Easily accessible power switch and indication LED

Configuration 1: Block Diagram



Reaches V_Ref when Cell 1 @ 3.35V, causing active cell to switch

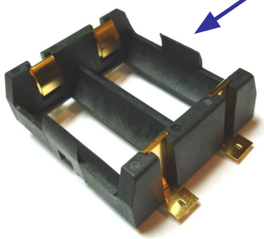
Cell reaches 3.35 V @ approx. 10% capacity

Payload Power Trade & Selection (2/4)

Configuration 1: Trade Study

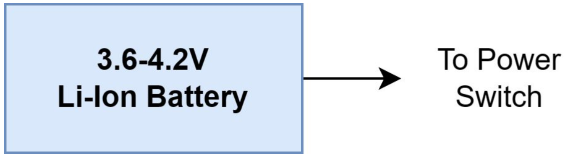
Battery	Chemistry	Voltage (V)	Capacity (mAh)	Weight (g)	Package	Price (USD)
AWT 16340	Li-ion	3.7	550*2 = 1100	17*2 = 34	16340	4.99*2 = 9.98
Efest 16340	**Li-ion**	**3.7**	**700*2 = 1400**	**17*2 = 34**	**16340**	**3.99*2 = 7.98**

Selection	Reasoning
Efest 16340	• Higher capacity • Cheaper



Compliant mechanism for battery security

Configuration 2 (Selected): Block Diagram

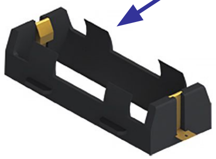


Payload Power Trade & Selection (4/4)

Configuration 2 (Selected): Trade Study

Battery	Chemistry	Voltage (V)	Capacity (mAh)	Weight (g)	Package	Price (USD)
Vapcell M11 INR18350	Li-ion	3.7	1100	26	18350	9.00
Vapcell F14 INR18350	**Li-ion**	**3.7**	**1400**	**26**	**18350**	**11.00**
Keeppower UH1835P	Li-ion	3.7	1200	25	18350	11.00

Selection	Reasoning
Vapcell F14 INR18350	• Similar weight, and cost • Higher capacity



Compliant mechanism for battery security

Payload Power Budget (1/3)

Part	Mode	Voltage (V)	Current (A)	Power (W)	Duty (%)	Active time (s)	Energy (Wh)	Info Source
Temperature Sensor		5			100	7200	**0.000216**	**Datasheet +Estimate**
	Convrsn.		0.0001350	0.000675	14	1008		N/A Uncertainty
	Standby		0.0000031	0.0000155	86	6192		N/A Uncertainty
	Shutdown		0.0000170	0.0000850	0	0		N/A Uncertainty
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	External Battery	5	0.0000000	0.00000000	20	1440	**0.000000**	**N/A**
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	3.10000000	**0.775000**

Totals

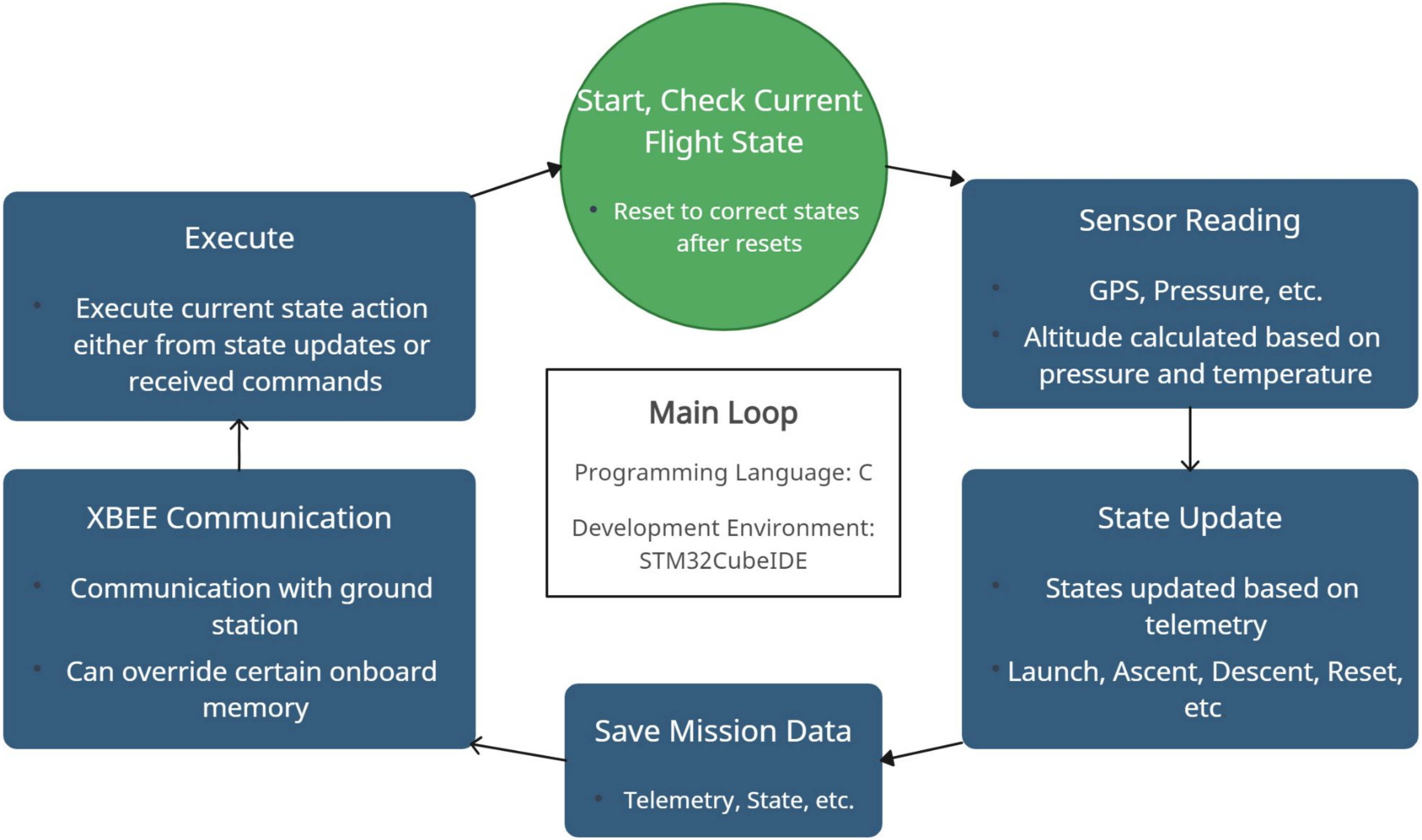
Available (Li-Ion Cell)	Consumption	Margin
5.2 Wh	3.8 Wh	1.4 Wh

Team Logo Here

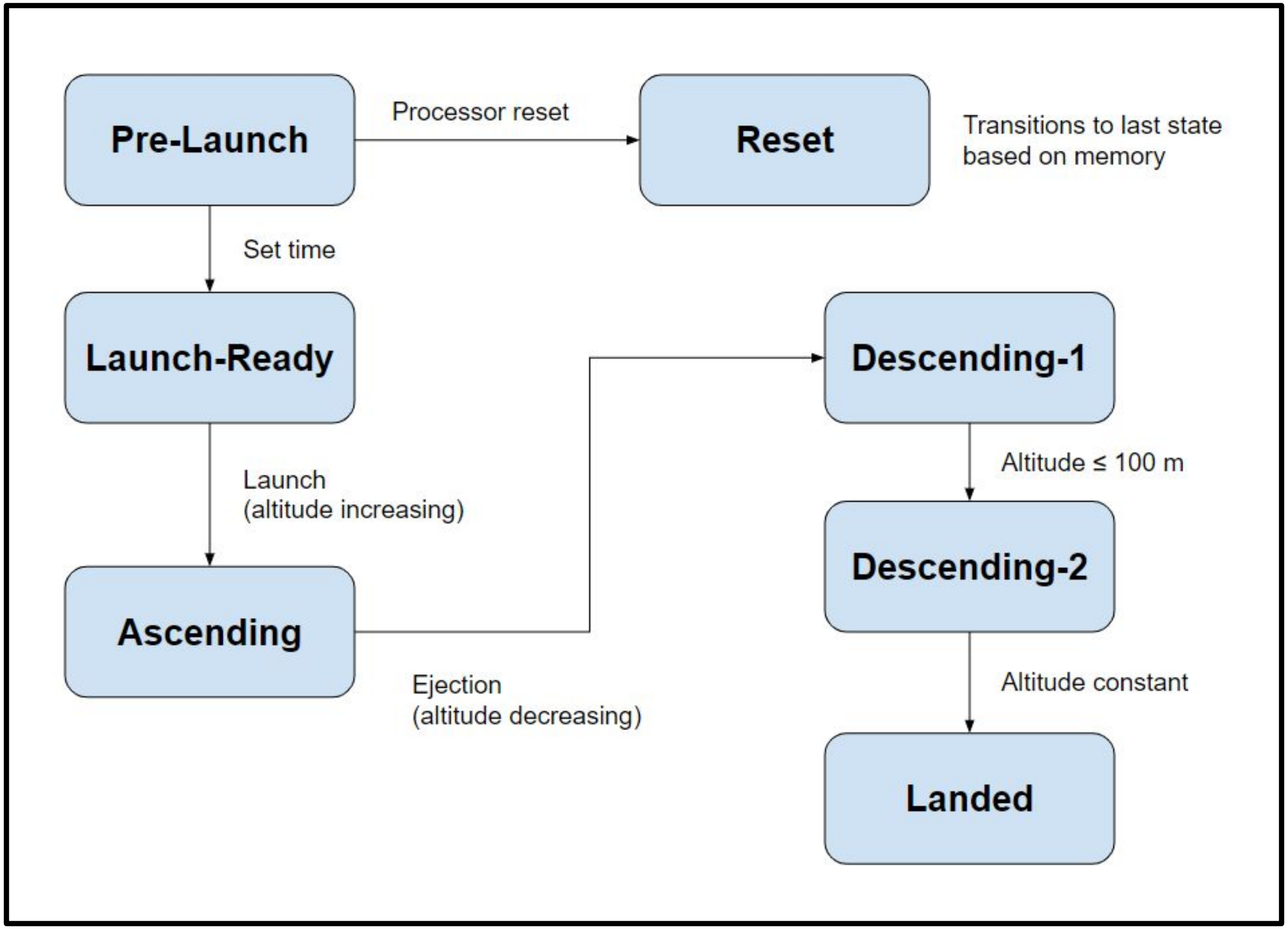
Flight Software (FSW) Design

Husain Wafaie, Kaylee Kim

FSW Overview



Payload FSW State Diagram (1/3)



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
  - Transmit and save telemetry at 1Hz
- **Ascending**
  - Condition: altitude increasing (pressure/temperature sensor)
  - Save and transmit telemetry at 1Hz
  - Wait for ejection (limit switch)

Payload FSW State Diagram (3/3)

- **Descending-1**
  - Condition: Altitude decreasing AND heat shield not deployed (pressure/temperature sensor)
  - ONCE: Deploy heat shield/aerobraking
  - Save and transmit telemetry (including angle stability) at 1 Hz
- **Descending-2**
  - Condition: Altitude decreasing AND altitude is 100 m (pressure/temperature sensor)
  - ONCE: Release heat shield, activate parachute
  - Save and transmit telemetry (including angle stability) at 1 Hz
- **Landed**
  - Condition: Altitude not changing (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. Packet count will be maintained through reset

Simulation Mode Software

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>

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

Software Development Plan

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 below)
    - Full test run will be challenging due to limited space and resources

Test Methodology

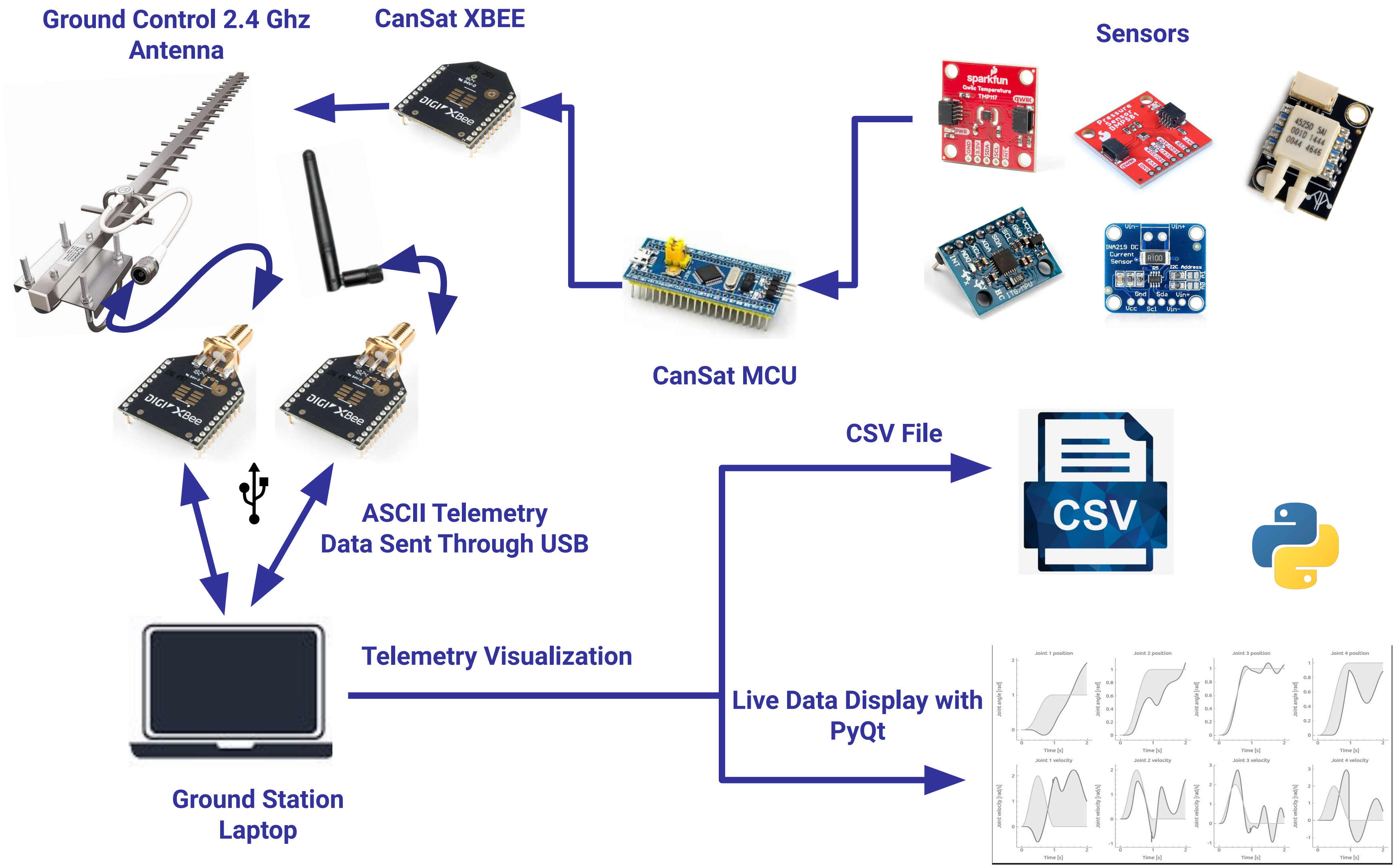
- Individual parts will first be tested with an STM32 module to ensure functionality
- Testing using simulation mode by reading pressure data from designated testing files

Team Logo Here

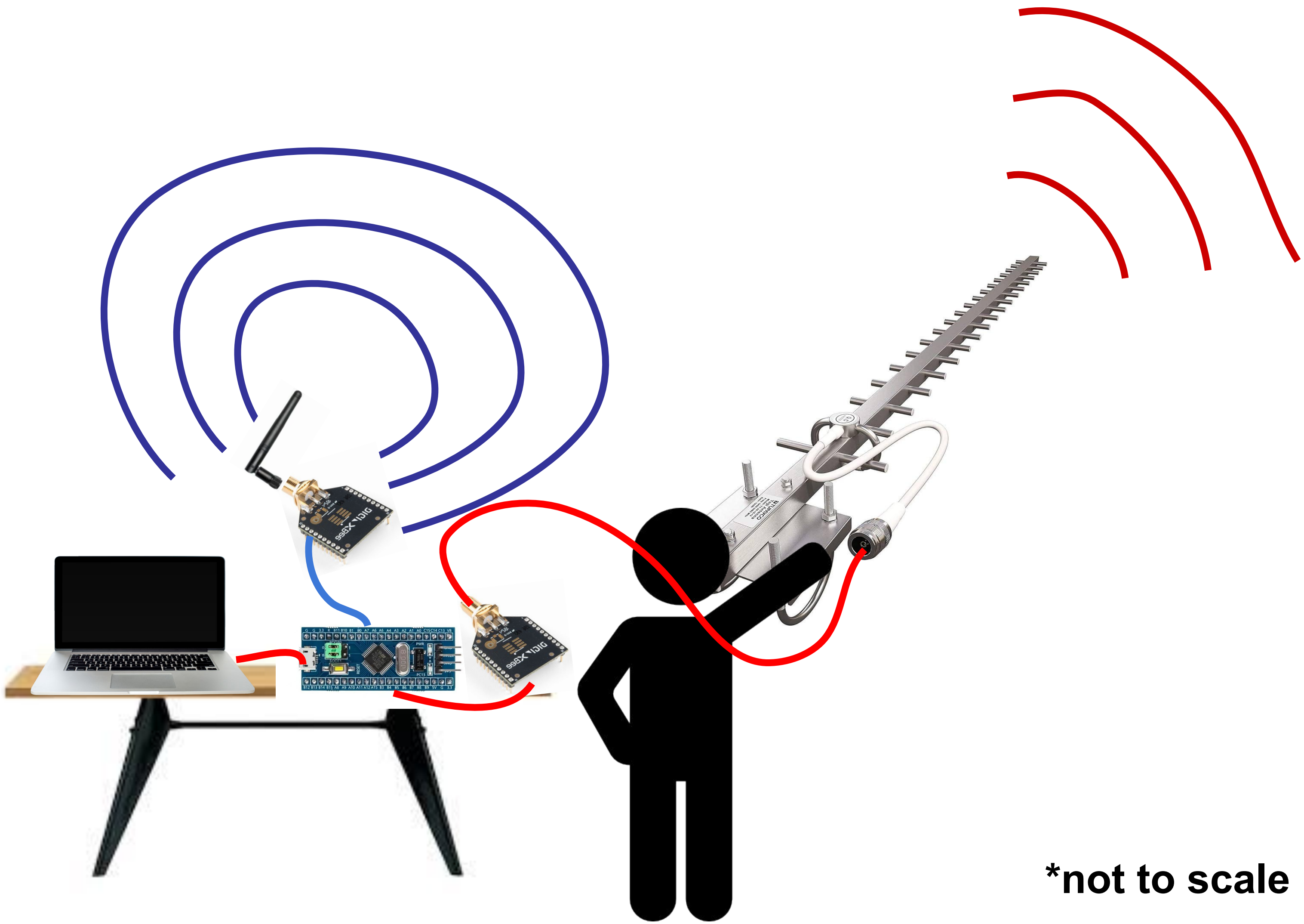
Ground Control System (GCS) Design

Khushi Gupta

GCS Overview



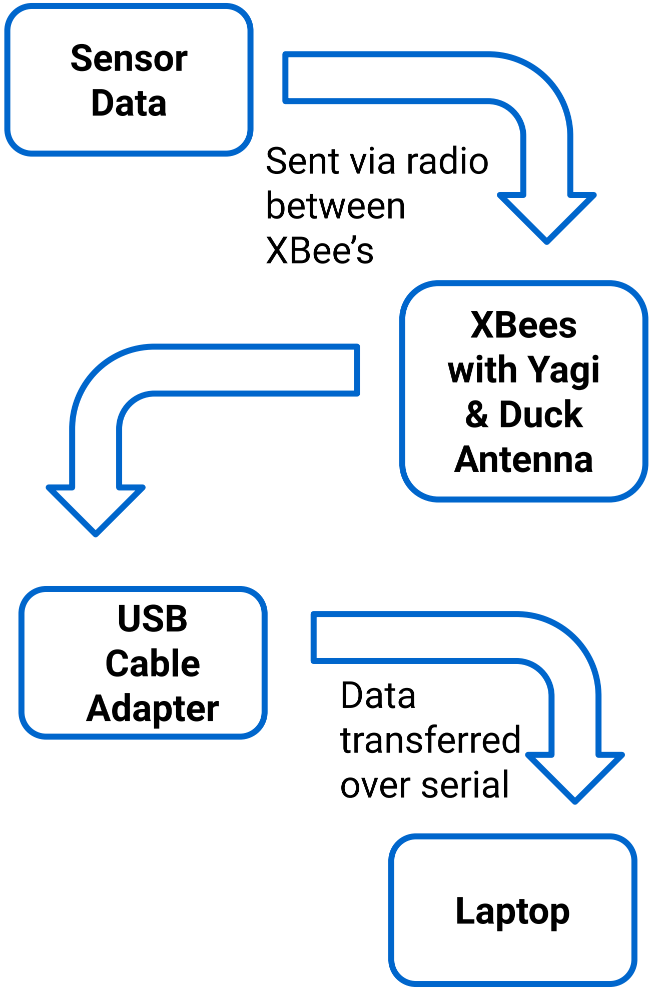
GCS Design (1/2)



*not to scale

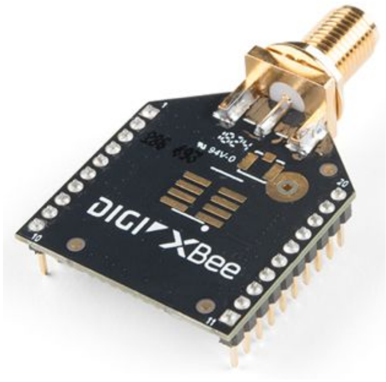
GCS Design (2/2)

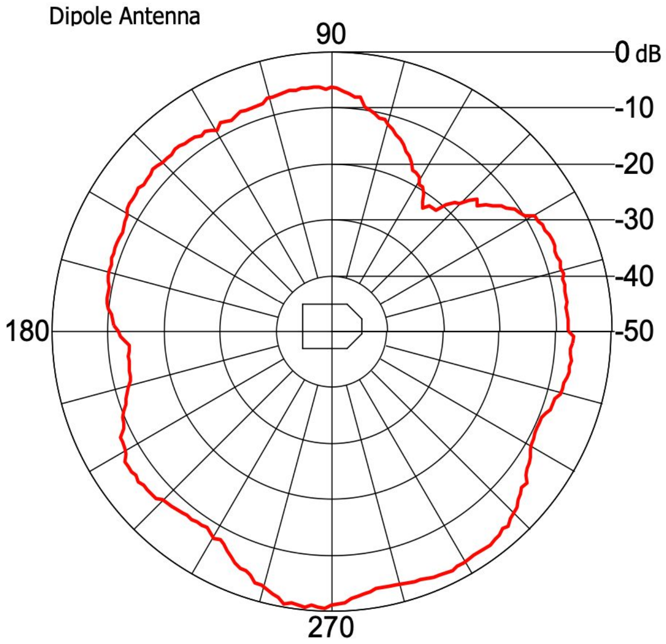
Problem or Specification	Solution
Ground station shall include one laptop computer with a minimum of two hours of battery operation	**Laptop**: Lenovo Yoga 930 **Battery life:** 1. 86 WHr battery 2. 2 hours running multiple applications.
Overheating Mitigation	1. Sunshade 2. Cooling Pad
Auto Update Mitigation	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 Trade & Selection (1/6)

Antenna	Outdoor Range	Indoor Range	RF Tx Power(max)	Cost
XBee3 Pro RP-SMA Antenna	3200 m (2 mi)	90 m (300 ft)	79 mW (+19 dBm)	$28.95

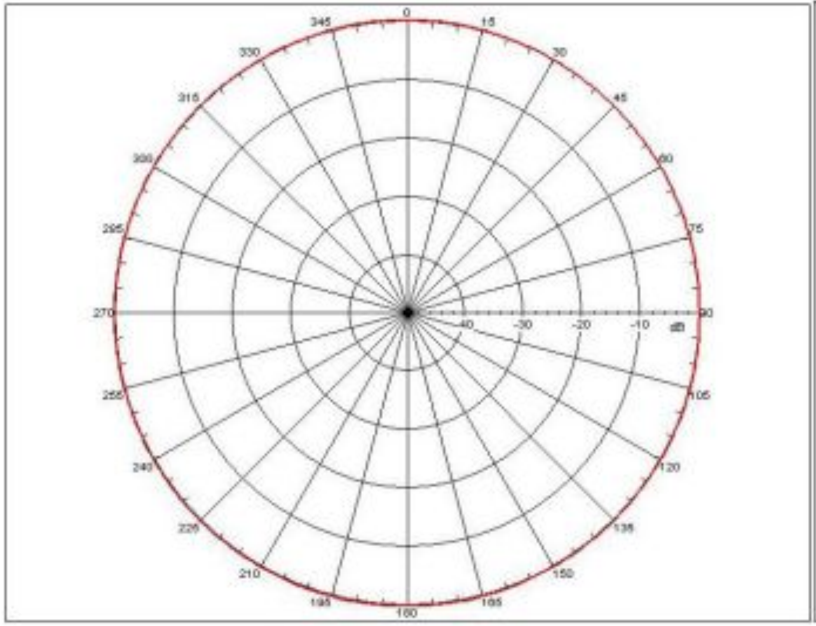




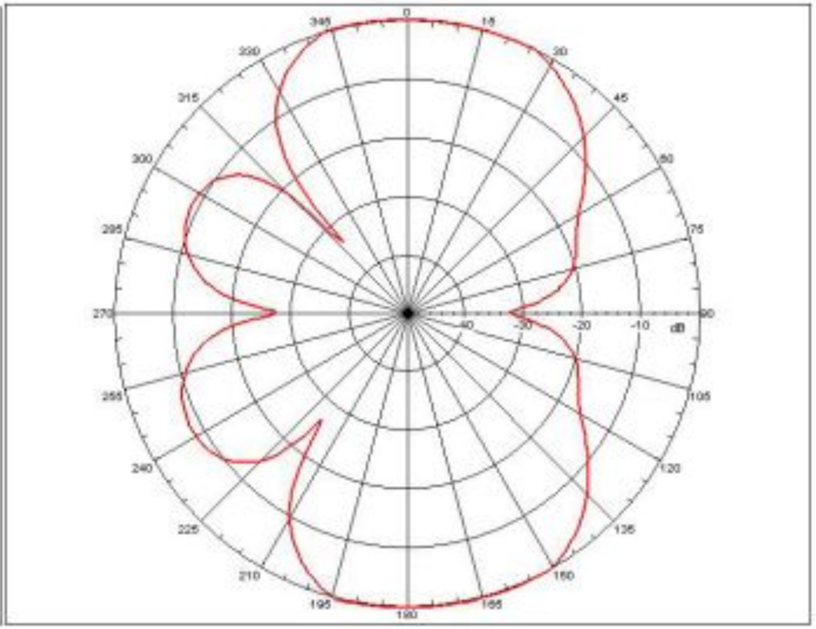
GCS Antenna Trade & Selection (2/6)

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

HORIZONTAL



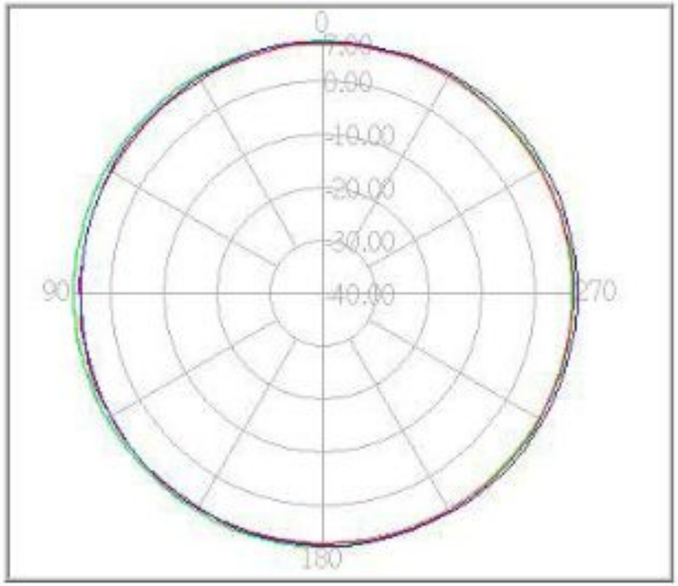
VERTICAL



Antenna	Cost	Impedance	Polarization	Gain	Mount
Alfa ARS-N19M	$15.29	50 Ω	Linear, Vertical	9 dBi	Tabletop

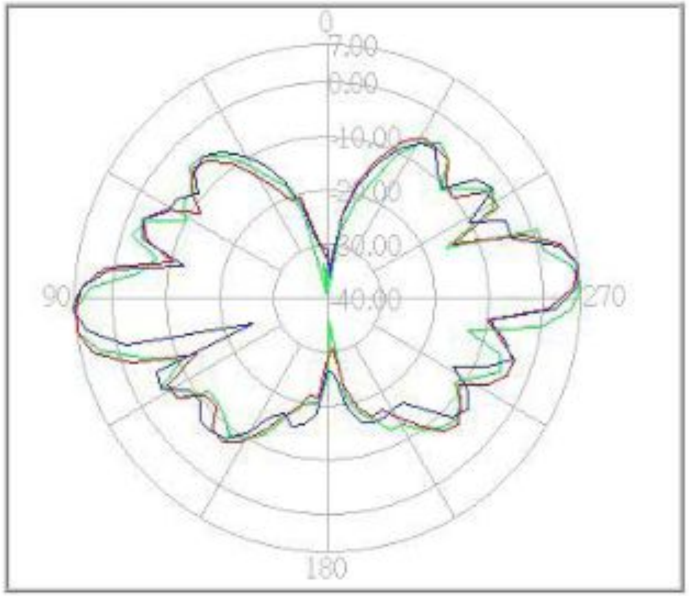
HORIZONTAL

Test Mode: H-PLAN



VERTICAL

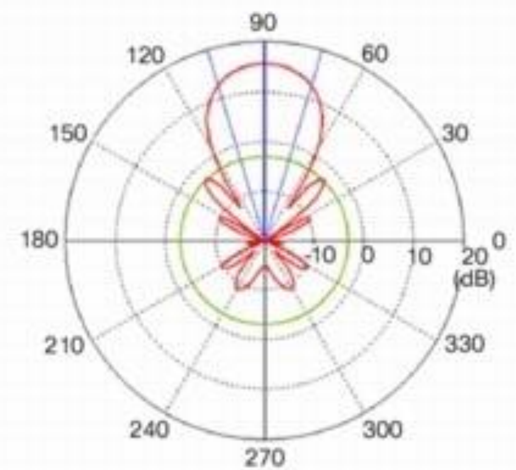
Test Mode: E-PLAN



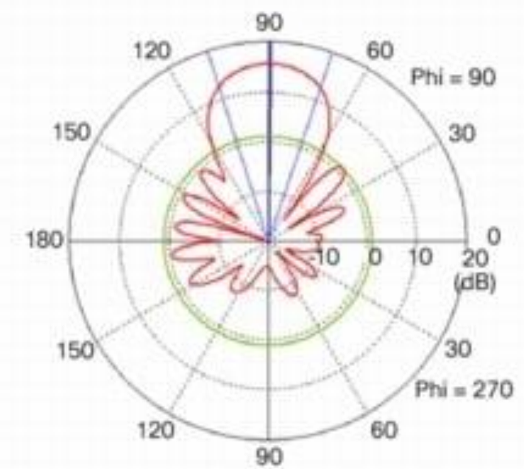
GCS Antenna Trade & Selection (4/6)

Antenna	Cost	Impedance	Polarization	Gain	Mount	Weight
Tupavco TP513 2.4GHz	$34.99	50 Ω	Horizontal or Vertical	17 dBi	Handheld	20oz

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



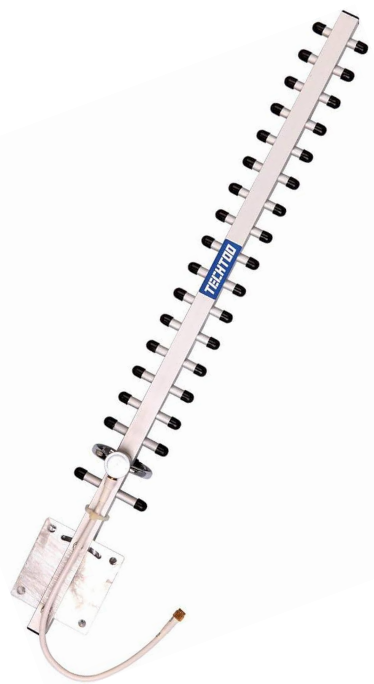
(c) Yagi Antenna Azimuth Plane Pattern



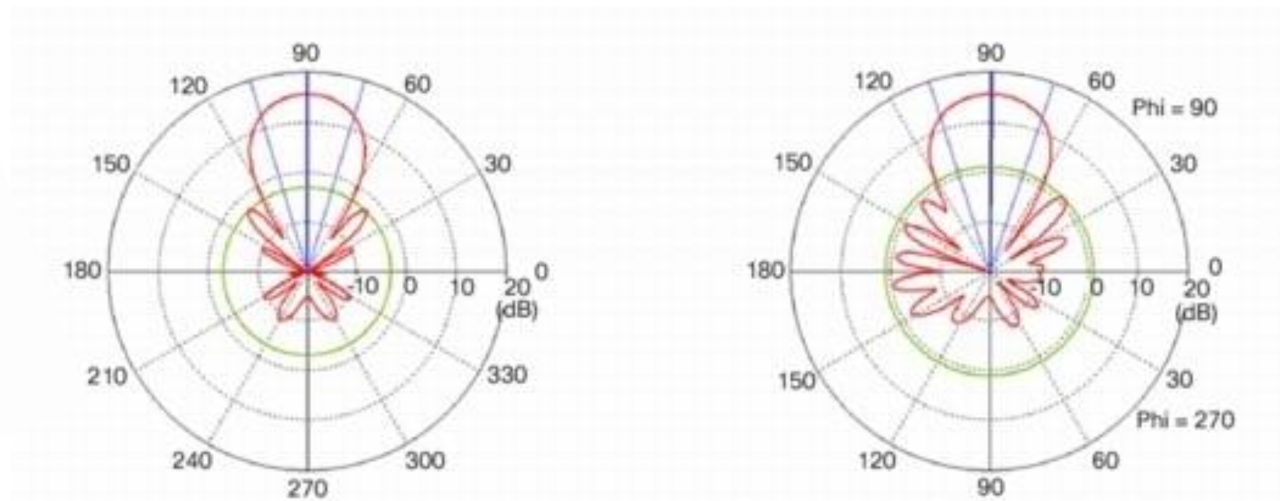
(d) Yagi Antenna Elevation Plane Pattern

GCS Antenna Trade & Selection (5/6)

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.



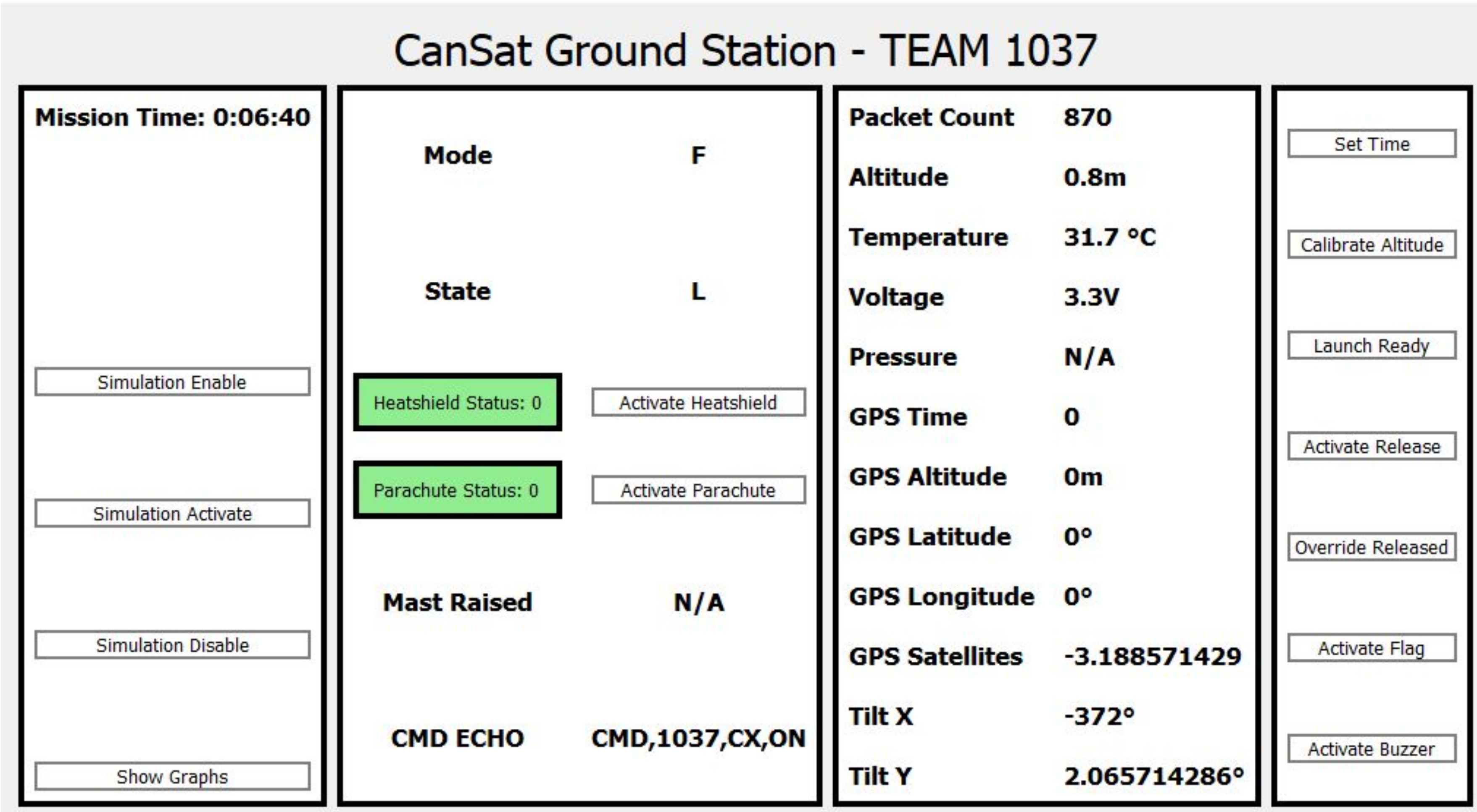
(c) Yagi Antenna Azimuth Plane Pattern

(d) Yagi Antenna Elevation Plane Pattern

GCS Antenna Trade & Selection (6/6)

Selection	Reasoning
ECHTOO High Gain Yagi Directional Antenna Booster (Handheld)	• Higher gain • Lighter weight which is more optimal for a handheld device • Has an RP-SMA connector
2.4GHz Duck Antenna RP-SMA (Tabletop)	• Legacy, more experience so ease of implementation. Will read signals when CanSat is closer to the GCS • Two antennas to ensure signal readings

Main Design


CanSat Ground Station - TEAM 1037
Mission Time: 0:06:40
Simulation Enable
Simulation Activate
Simulation Disable
Show Graphs
Mode
F
State
L
Heatshield Status: 0
Activate Heatshield
Parachute Status: 0
Activate Parachute
Mast Raised
N/A
CMD ECHO
CMD,1037,CX,ON
Packet Count
870
Altitude
0.8m
Temperature
31.7 °C
Voltage
3.3V
Pressure
N/A
GPS Time
0
GPS Altitude
0m
GPS Latitude
0°
GPS Longitude
0°
GPS Satellites
-3.188571429
Tilt X
-372°
Tilt Y
2.065714286°
Set Time
Calibrate Altitude
Launch Ready
Activate Release
Override Released
Activate Flag
Activate Buzzer

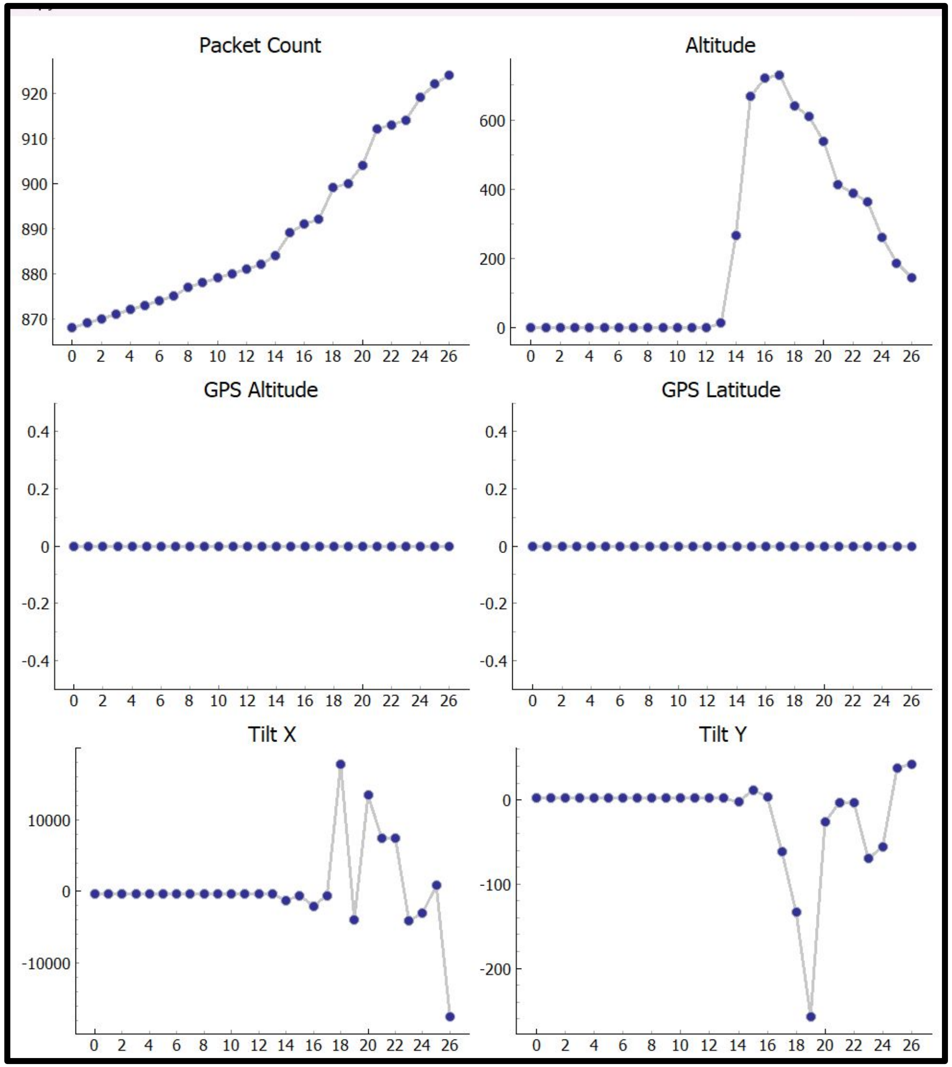
GCS Software (2/5)

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

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

Team Logo
Here

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 container to test GCS parsing
  - Telemetry will then be updated and broadcast at intended rate
  - Processor resets will be done to ensure EEPROM is utilized
  - Repeat for payload-to-container telemetry and commands

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 on board power monitor

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

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

- 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 CanSat structure
- Confirm steady transmission of data from CanSat at long distances
- Confirm the CanSat and ground station operate continuously off battery power for 2 hours while transmitting data
- Confirm the heat shield mechanisms are working properly through deployment tests with controlled drop tests and tests on the ground
- Confirm the parachute 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.

Environmental Test Plan (1/5)

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.

Environmental Test Plan (2/5)

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.

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. Container and payload listen 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

Team Logo Here

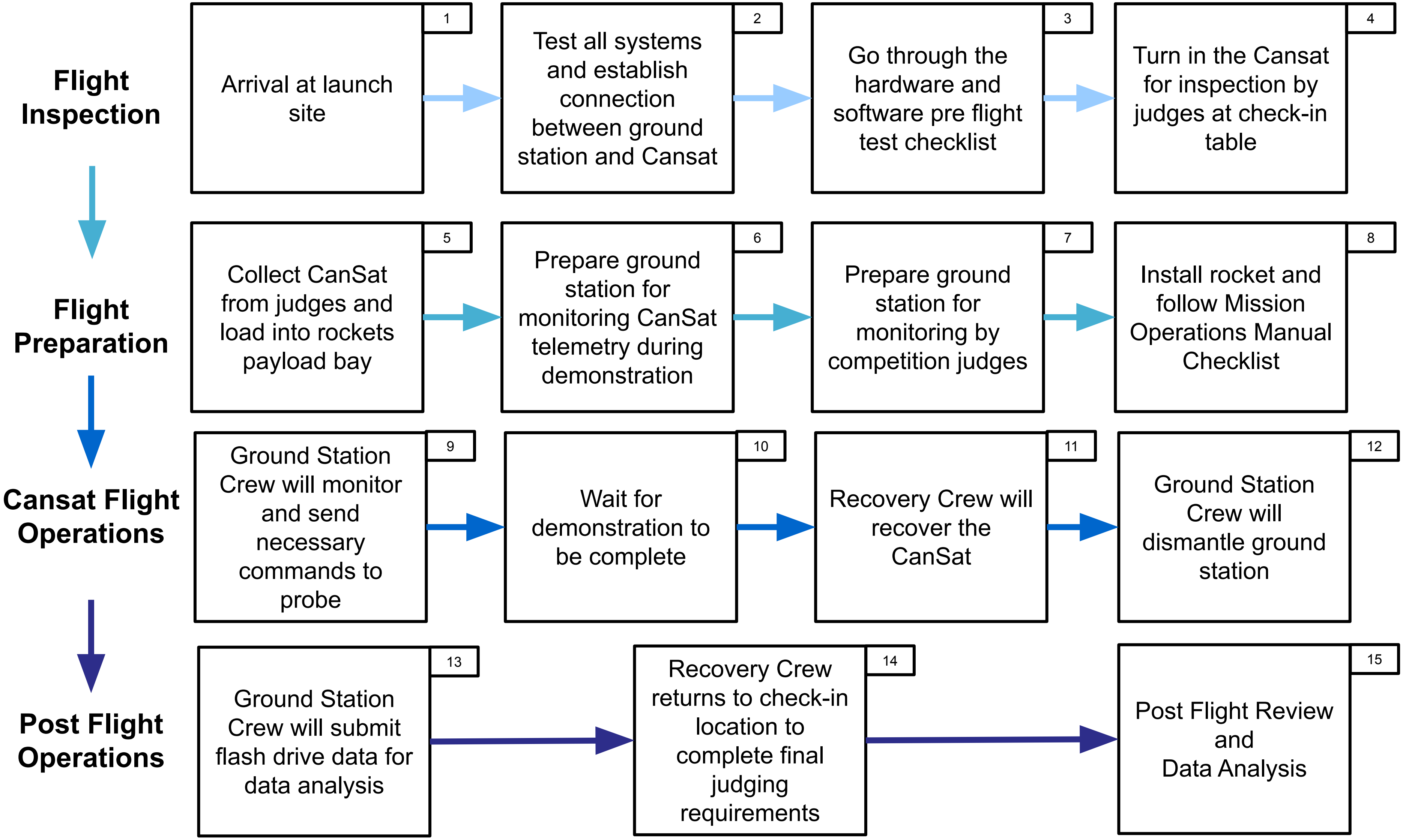
Mission Operations & Analysis

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, Khushi, Sarah
CanSat Crew	AJ, Sunny, Jerome

Overview of Mission Sequence of Events (2/3)



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

Mission Operations Manual Development Plan

Our mission operation manual 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.

Before Launch Day:

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

On Launch Day:

1. Attach 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, Pressure, Orientation, Speed
    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 container and probe separately
3. Data transmission will continue; the container and probe 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 container, probe, 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

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 first edition prototype has been 3D printed, and testing has been completed. The second generation structure is currently in progress
- Prototype PCBs have been made and tested. The second generation PCB is currently being assembled and tested. 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 late February
- Sensor and CDH components have been tested individually to confirm that they operate as expected.

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	19	Completed
C2	C2 The Cansat shall be deployed from the rocket when the rocket motor ejection charge fires.	Comply	25	Completed
C3	After deployment from the rocket, the Cansat shall deploy its heat shield/aerobraking mechanism.	Comply	20	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	20, 63	Completed
C5	At 100 meters, the Cansat shall deploy a parachute and release the heat shield.	Comply	75, 78	Completed
C6	Upon landing, the Cansat shall stop transmitting data.	Comply	123	Completed
C7	Upon landing, the Cansat shall activate an audio beacon.	Comply	24, 123	Completed
C8	The Cansat shall carry a provided large hens egg with a mass range of 51 to 65 grams	Comply	82	Completed
C9	0 altitude reference shall be at the launch pad.	Comply	122	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	52 - 57	Completed
C11	At 100 meters, the Cansat shall have a descent rate of less than 5 m/s.	Comply	52 - 57	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	176	Completed
S1	The Cansat mass shall be 900 grams +/- 10 grams without the egg being installed.	Comply	86-91	Completed
S2	Nose cone shall be symmetrical along the thrust axis.	Comply	18, 145	Completed
S3	Nose cone radius shall be exactly 71 mm	Comply	26-27, 145	Completed
S4	Nose cone shoulder radius shall be exactly 68 mm	Comply	26-2, 145	Completed
S5	Nose cone shoulder length shall be a minimum of 50 mm	Comply	26-27, 145	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**	**18**	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**	**26 - 27**	Completed
S10	The rocket airframe can be used as part of the Cansat operations.	**Comply**	**26 - 27**	Completed
S11	All electronics and mechanical components shall be hard mounted using proper mounts such as standoffs, screws, or high performance adhesives.	**Comply**	**84 - 85**	Completed
M1	No pyrotechnical or chemical actuators are allowed.	**Comply**	61 , 64	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**	61	Completed
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	115	Completed
M5	The Cansat shall deploy a heat shield after deploying from the rocket.	Comply	20	Completed
M6	The heat shield shall be used as an aerobrake and limit the descent rate to 10 to 30 m/s	Comply	52 - 57	Completed
M7	At 100 meters, the Cansat shall release a parachute to reduce the descent rate to less than 5 m/s.	Comply	52 - 57	Completed
M8	The Cansat shall protect a hens egg from damage during all portions of the flight.	Comply	82 , 83	Completed
M9	If the nose cone is to be considered as part of the heat shield, the documentation shall identify the configuration.	Comply	19, 20	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	78	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**	115	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**	115	Completed
E3	Easily accessible power switch is required	**Comply**	22, 111	Completed
E4	Power indicator is required	**Comply**	111	Completed
E5	The Cansat shall operate for a minimum of two hours when integrated into the rocket.	**Comply**	118	Completed
X1	XBEE radios shall be used for telemetry. 2.4 GHz Series radios are allowed. 900 MHz XBEE radios are also allowed.	**Comply**	99, 101	Completed
X2	XBEE radios shall have their NETID/PANID set to their team number.	Comply	101	Completed
X3	XBEE radios shall not use broadcast mode	Comply	101	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	122 - 124	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	104	Completed
SN1	Cansat shall measure its speed with a pitot tube during ascent and descent.	Comply	33	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	34 - 35, 122 - 123	Completed
SN5	Cansat shall measure its rotation rate during descent.	Comply	34 - 35	Completed
SN6	Cansat shall measure its battery voltage.	Comply	32	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	85	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	107, 136	Completed
G2	The ground station shall generate csv files of all sensor data as specified in the Telemetry Requirements section.	Comply	137, 140	Completed
G3	Telemetry shall include mission time with 1 second or better resolution.	Comply	104, 122 - 123	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	127 - 129, 136 - 140	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.	Partial	-	Not tested
G7	All telemetry shall be displayed in engineering units (meters, meters/sec, Celsius, etc.) and the units shall be indicated on the displays.	Comply	136	Completed
G8	Teams shall plot each telemetry data field in real time during flight.	Comply	138	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	129	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	129	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	106, 139	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	139	Completed
G13	The ground station shall use a table top or handheld antenna.	Comply	128	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**	136	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**	140	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**	98, 123	Completed
F2	The Cansat shall maintain mission time throughout the whole mission even with processor resets or momentary power loss.	**Comply**	97, 98	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**	105, 122	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**	124	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**	124	Completed
F6	The payload flight software shall only enter simulation mode after it receives the SIMULATION ENABLE and SIMULATION ACTIVATE commands.	**Comply**	106, 13, 13	Completed

Team Logo Here

Management

Ryan Liu

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
SparkFun Temperature Sensor TMP117	Sensors	2023	1	DigiKey	14.95	14.95
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	**$501.54**

CanSat Budget – Other Costs (1/2)

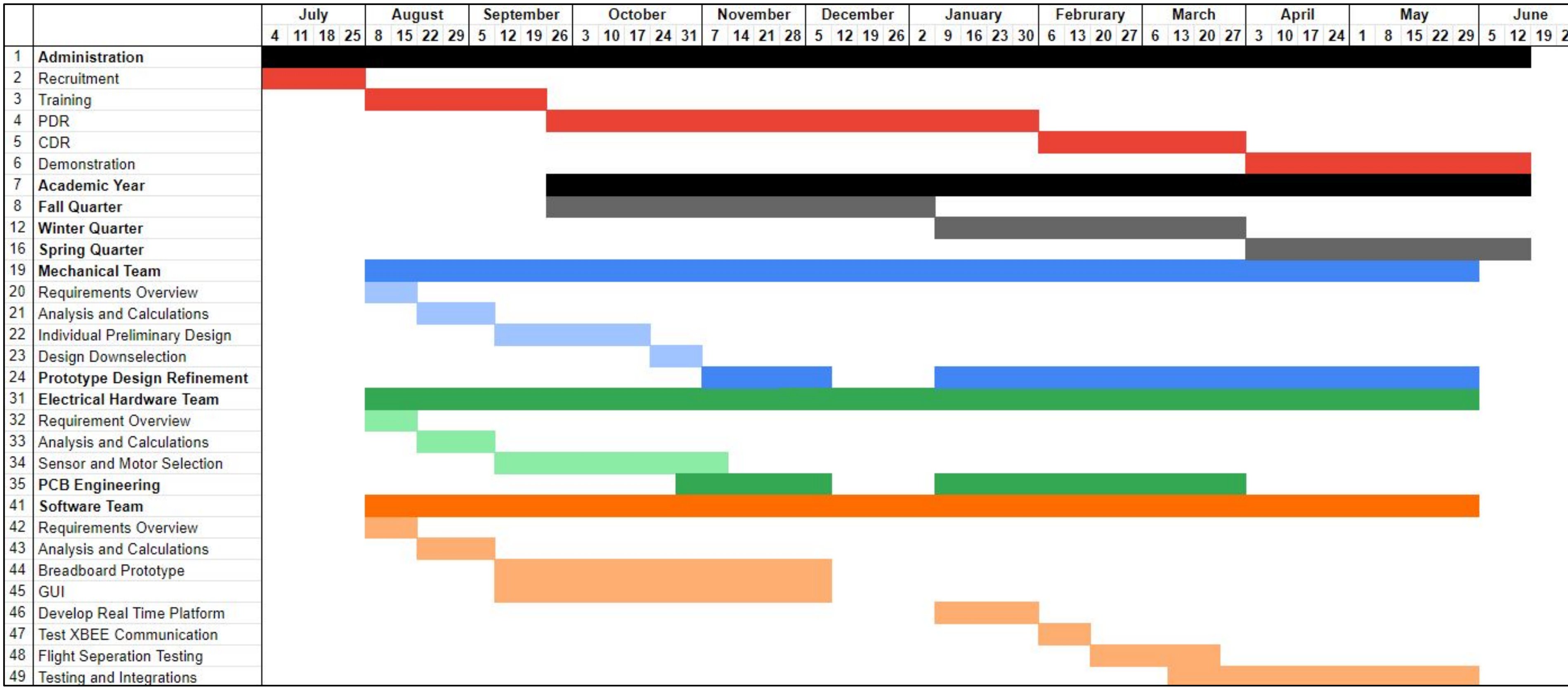
Other Costs

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

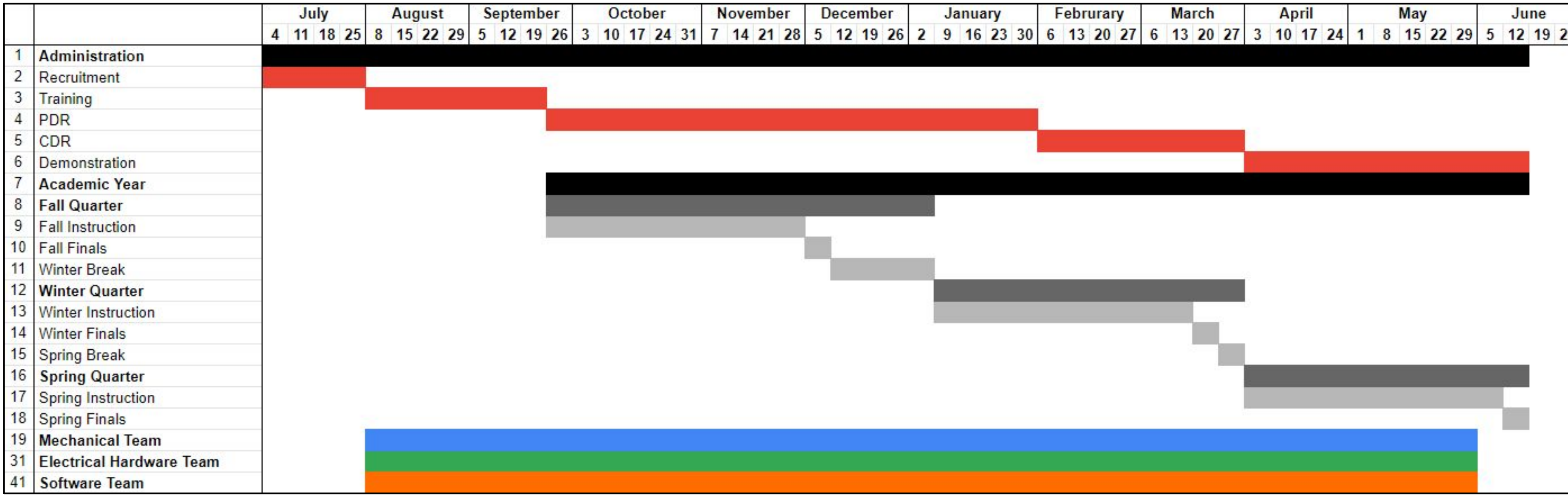
Overall Total	$7024.5

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

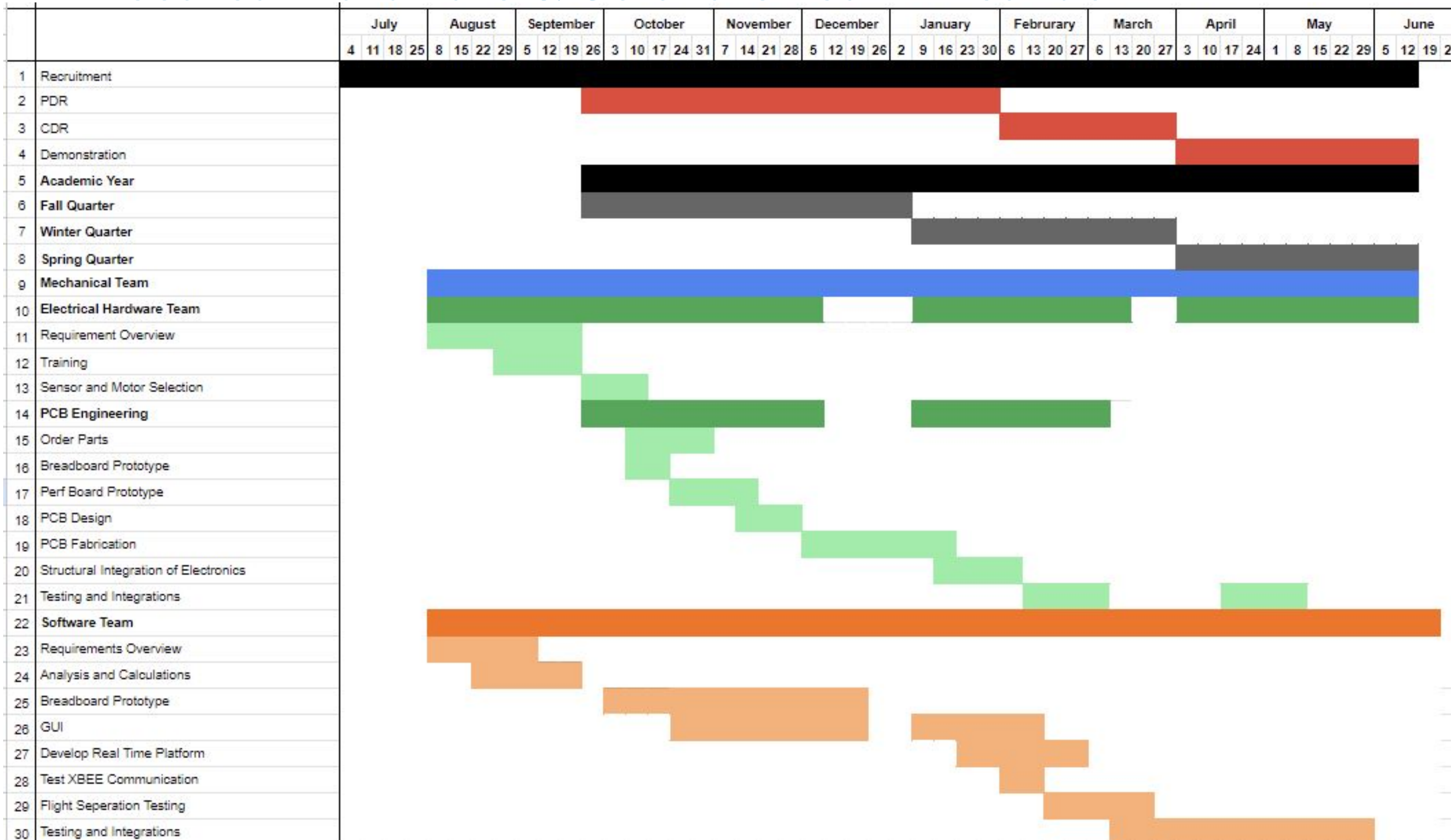


Detailed Program Schedule (2/3)

Mechanical Team Breakdown

Detailed Program Schedule (2/3)

Electrical Hardware & Software Team Breakdown



Conclusions (1/2)

Major Accomplishments:

1. Developed full CAD model of the CanSat. Completed all system, material, and component trades. Selected most appropriate designs utilizing trade studies and combined best components of several proposed designs.
2. Identified backup components and designs in case of issues during testing.
3. Completed the design of the CanSat electrical system including custom prototype PCBs and confirmed all sensors operate accordingly.
4. Began development of the ground station and CanSat software.
5. Purchased components, parts, tools, and materials

Major Unfinished Work:

1. Complete manufacturing and assembly of the prototype design 2 of CanSat (mechanical and electrical)
2. Continue the "CanSat Integration and Test" phase
3. Continue software and ground station development and debug software issues
4. Ensure compliance with all requirements verified via test or demonstration
5. Begin design modification and iteration for the Critical Design Review

Next Steps:

With the initial design complete, fabrication and testing will progress as planned. The focus is on the testing and refining engineering phases.

THANK YOU!