CanSat 2024
Critical Design Review (CDR)
Version 2.0

Team #2078

Shockwave

Presentation Outline

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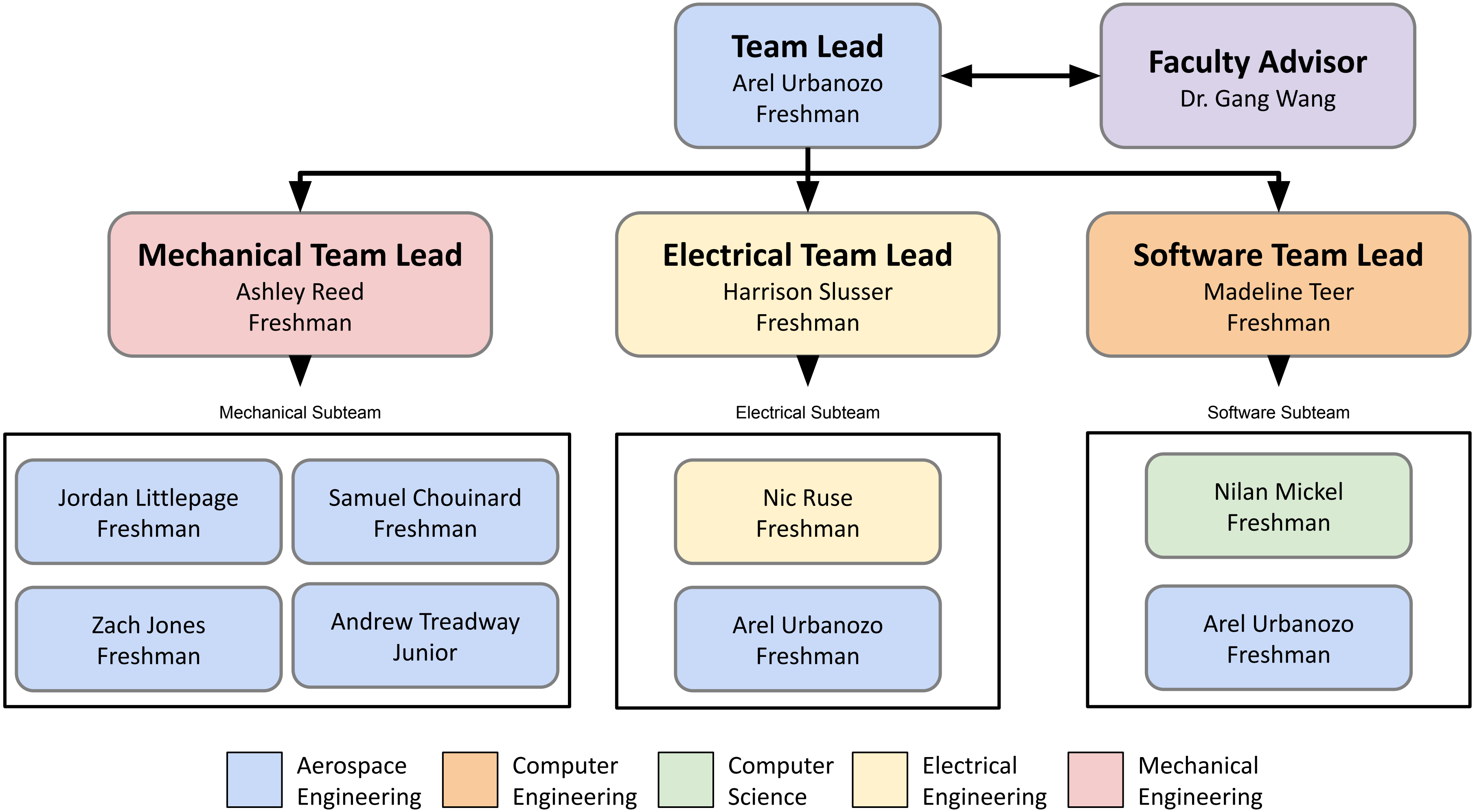
Team Organization



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Faculty Advisor
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Mechanical Team Lead
Ashley Reed
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Electrical Team Lead
Harrison Slusser
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Software Team Lead
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Mechanical Subteam

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Samuel Chouinard
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Andrew Treadway
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Electrical Subteam

Nic Ruse
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Arel Urbanozo
Freshman

Software Subteam

Nilan Mickel
Freshman

Arel Urbanozo
Freshman

🟦	Aerospace Engineering	🟧	Computer Engineering	🟩	Computer Science	🟨	Electrical Engineering	🟥	Mechanical Engineering

Acronyms (1 of 2)

Acronym	Definition	Acronym	Definition
ADC	Analog to Digital Converter	Kb	Kilobit
C	Celsius	LED	Light Emitting Diode
CSV	Comma Separated Value	MECH	Mechanical Subteam
COTS	Commercial-Off-The-Shelf	MCU	Microcontroller Unit
ELEC	Electrical Subteam	MHz	Megahertz
FSW	Flight Software	MISC	Miscellaneous
FOV	Field of View	MOM	Mission Operation Manual
GCS	Ground Control System	PETG	Polyethylene Terephthalate Glycol
Gs	Force of Gravity	PCB	Printed Circuit Board
Hz	Hertz	PID	Proportional-Integral-Derivative
I2C	Inter-Integrated Circuit	PFR	Post Flight Review
IMU	Inertial Measurement Unit	PWM	Pulse Width Modulation

Acronyms (2 of 2)

Acronym	Definition
SD	Secure Digital
RSO	Range Safety Officer
RTC	Real Time Clock
UART	Universal Asynchronous Receiver/Transmitter
UAH	University of Alabama in Huntsville
ODR	Output Data Rate
GPS	Global Positioning System
SPI	Serial Peripheral Interface
SHC	Space Hardware Club
USB	Universal Serial Bus
UTC	Universal Time Coordinated

System Overview

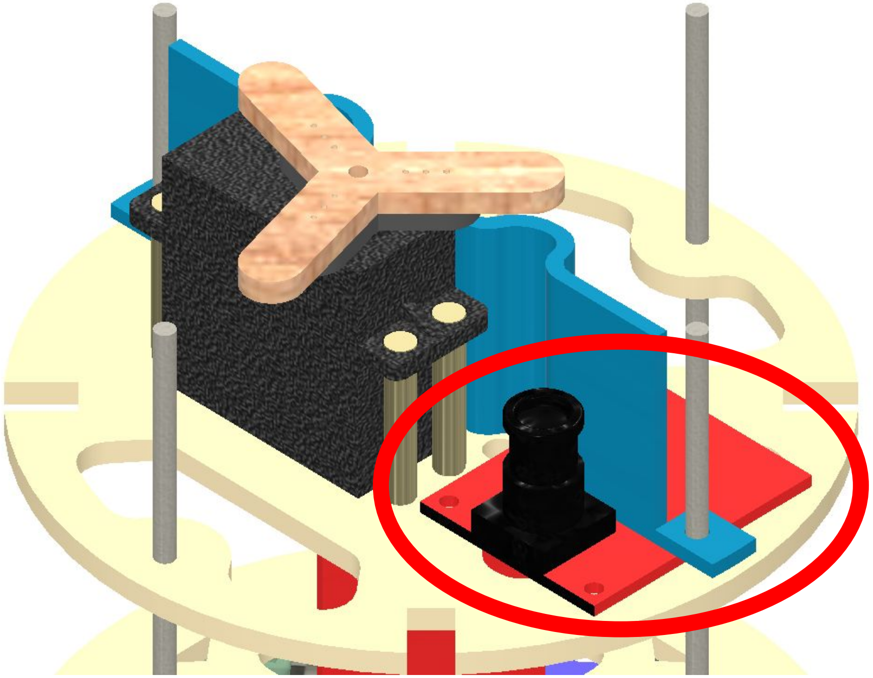
Arel Urbanozo, Ashley Reed

Mission Summary (1 of 2)

Mission Objectives	
1	Design a CanSat containing electronics, a hens egg, and a detachable heat shield that simulates a space probe entering a planetary atmosphere.
2	The CanSat shall function as the nose cone of the rocket during ascent.
3	The CanSat will be launched to a maximum of 725 meters before ejecting from the rocket and immediately deploying an aerobraking mechanism.
4	At 100 meters, the CanSat shall release the aerobrake and simultaneously deploy a parachute to descend at a rate less than 5 m/s.
5	The CanSat shall land with the egg intact.
6	A silver or gold mylar streamer shall be used to identify the CanSat.
7	The CanSat shall transmit telemetry to a ground station during flight and stop transmitting once landed.
8	The CanSat shall activate an audio beacon once landed.
9	A video camera will capture the horizontal view during ascent and landing and must be pointed in one direction during descent.

Mission Summary (2 of 2)

Bonus Objective
A video camera shall be integrated into the Cansat and point aft of the Cansat. The camera shall capture the Cansat being deployed from the rocket and the release of the parachute. Video shall be in color with a minimum resolution of 640x480 pixels and a minimum of 30 frames per second. The video shall be recorded and retrieved when the Cansat is retrieved.



Summary of Changes Since PDR (1 of 3)

Section	Part	PDR	CDR	Rationale
Mechanical	Egg Container	3D printed out of PETG	Fiberglass and plywood composite plates	Saves mass and survived a test launch.
	Egg Container and Rotating Camera	Egg container was above the rotating camera	Rotating camera is above the egg container	Brings center of mass lower for better stabilization.
	Aerobrake Release Servo	The motor was in the center of the plate	The motor has been moved to one side	A slip ring was added and needed to be centered.
	Aerobrake Fabric	Aerobrake nylon fabric had spill holes in it	Spill holes have been removed and now has a 3D printed rubber band and fabric mount	Cansat was tested without holes and protected the egg and the pitot tube.
	Rotating Camera	There was no mount for the rotating camera	There is now a PETG mount for the brushed motor	Makes the camera and motor more secure during flight

Summary of Changes Since PDR (2 of 3)

Section	Part	PDR	CDR	Rationale
Mechanical	Rotating Camera Slip Ring	Nonexistent	A slip ring has been added	Required so electrical wires don’t get tangled.
	Parachute Layer	A layer that the parachute sits on	The layer replaced with a divider between the parachute and the motor	There was not enough space for the parachute to release and we needed more room.
	Bonus Camera and Aerobrake Release Layer	Components were centered around the servo	Mylar mount has been added	Several components like the mylar and slip ring were added.

Summary of Changes Since PDR (3 of 3)

Section	Part	PDR	CDR	Rationale
Electrical	Motor Encoder	Two Accelerometers	Hall Effect Motor Encoder	More accurate data for PID loops and all around better power efficiency.
	Camera Motor	14,400 RPM Brushed Motor	650 RPM Brushed Motor	Test flight data showed allowance for a slower, more power efficient motor.
	Batteries	Surefire CR123As	Panasonic CR123As	Lower cost for the same kind of battery.
Software	Graphing Library	HighCharts	CanvasJS	Better Documentation and more effective live plotting.

System Requirement Summary (1 of 2)

System Requirement Summary	
Requirement	**Description**
S1	The Cansat mass shall be 900 grams +/- 10 grams without the egg being installed.
C1, S2	The Cansat shall perform the function of the nose cone during rocket ascent and shall be symmetrical along the thrust axis.
S6, S7	Cansat structure must survive 15 Gs vibration and 30 Gs shock.
X1	XBEE radios shall be used for telemetry. 2.4 GHz Series radios are allowed. 900 MHz XBEE radios are also allowed.
M3	All mechanisms shall be capable of maintaining their configuration or states under all forces.
M5	The Cansat shall deploy a heat shield after deploying from the rocket at 725m.
X4	The Cansat shall transmit telemetry once per second.
G8	Teams shall plot each telemetry data field in real time during flight.

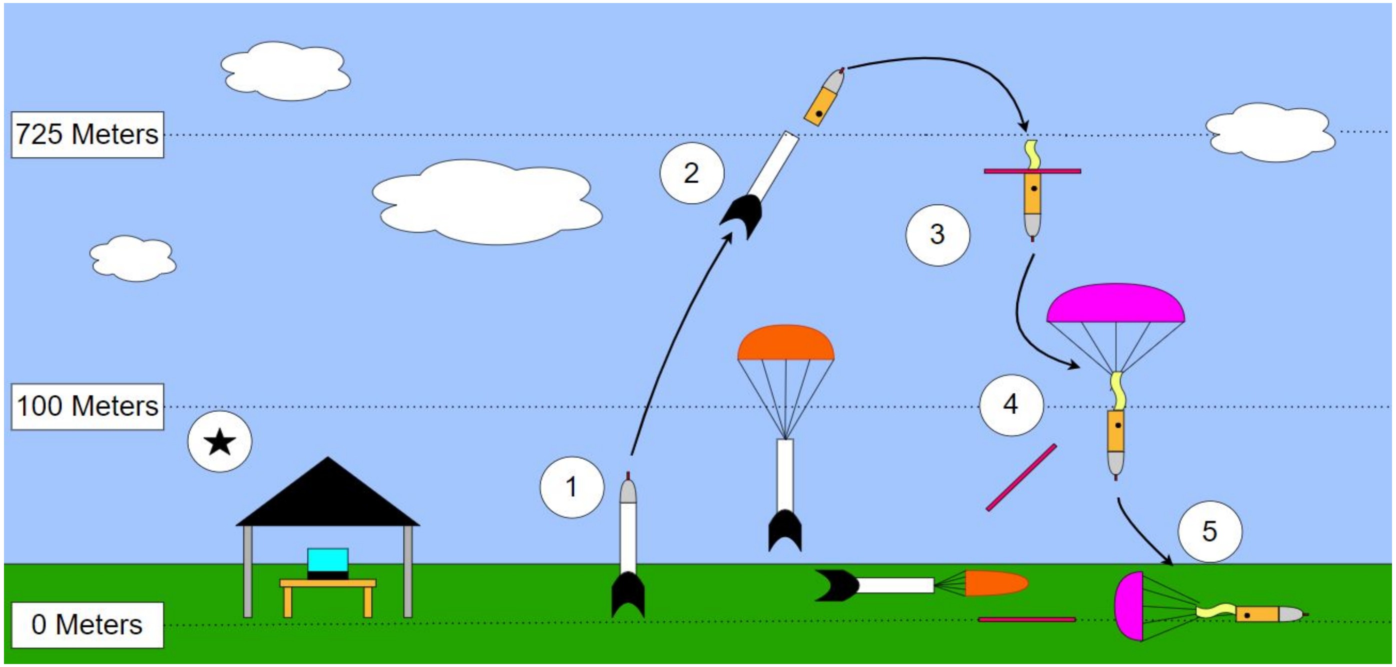
System Requirement Summary (2 of 2)

System Requirement Summary	
Requirement	**Description**
M6	The heat shield shall be used as an aerobrake and limit the descent rate to 10 to 30 m/s.
M7	At 100 meters, the Cansat shall release a parachute to reduce the descent rate to less than 5 m/s.
M8	The Cansat shall protect a hens egg from damage during all portions of the flight.
SN1-6	Cansat shall measure its air pressure, internal temperature, angle stability, rotation rate, and voltage.
SN7	The Cansat shall include a video camera pointing horizontally.
SN8	The video camera shall record the flight of the Cansat from launch to landing.
SN9	The video camera shall record video in color and with a minimum resolution of 640x480.
G5	Each team shall develop their own ground station.
G6	All telemetry shall be displayed in real time during descent on the ground station.

System Concept of Operations (CONOPS) (1 of 4)

Pre-Launch	Launch	Post Launch
● Arrive at the launch site ● Complete flight readiness review ● Ground Station and antenna setup ● Final mechanical Cansat checks ● Turn in Cansat at the check-in table by noon ● Collect Cansat and load it into rocket ● Verify the Cansat is communicating with the ground station ● Take the rocket with the ground station to the assigned launch pad and have it installed	● CanSat is loaded into rocket and zeroed before flight ● CanSat deploys from the rocket (725 m) immediately deploying the aerobrake ● CanSat releases aerobrake and deploys parachute (100 m) ● CanSat lands on the ground with egg intact and mylar visible ● Cansat stops transmitting telemetry to the ground station	● CanSat body is recovered based on last known GPS location, buzzer, LED, mylar, and chosen neon pink nylon parachute fabric ● Aerobrake is recovered using the chosen neon pink nylon fabric ● Inspect Cansat for damage ● On board video footage recovered from the bonus and required cameras SD cards ● Analyze telemetry received ● Post Flight Review preparation ● Post Flight Review presentation

System Concept of Operations (CONOPS) (2 of 4)



★	1	2	3	4	5
Ground Station receives telemetry during flight.	CanSat is loaded into rocket and zeroed before flight.	CanSat deploys at 725 meters above ground level.	After ejection, CanSat deploys aerobrake and mylar.	At 100 meters, the CanSat releases aerobrake and deploys parachute.	CanSat lands on the ground with egg intact and mylar visible.

System Concept of Operations (CONOPS) (3 of 4)

Role	Team Member(s)	Responsibilities
Mission Control Officer	● Arel Urbanozo	● Manages the team at the time of the launch ● Verifies with the ground station crew everything is ready ● Informs flight coordinator when the Cansat is ready for launch
Ground Station Team	● Madeline Teer ● Nilan Mickel ● Nic Ruse	● Monitors the ground station for telemetry reception and issuing commands to the Cansat
Recovery Team	● Andrew Treadway ● Zach Jones ● Harrison Slusser	● Track the Cansat and going out into the field for recovery ● Returning the Cansat to the judges at check-in
Cansat Team	● Ashley Reed ● Samuel Chouinard ● Jordan Littlepaige	● Preparing the Cansat, integrating it into the rocket, and verifying its status

System Concept of Operations (CONOPS) (4 of 4)

Note:
Aerobrake and parachute will be neon pink for competition

Test Flight

Mechanical Successes:

- Deployed from payload section
- Validated egg survivability
- On board electronics survived
- No major structural damage

Software Successes:

- Received and verified flight altitude data

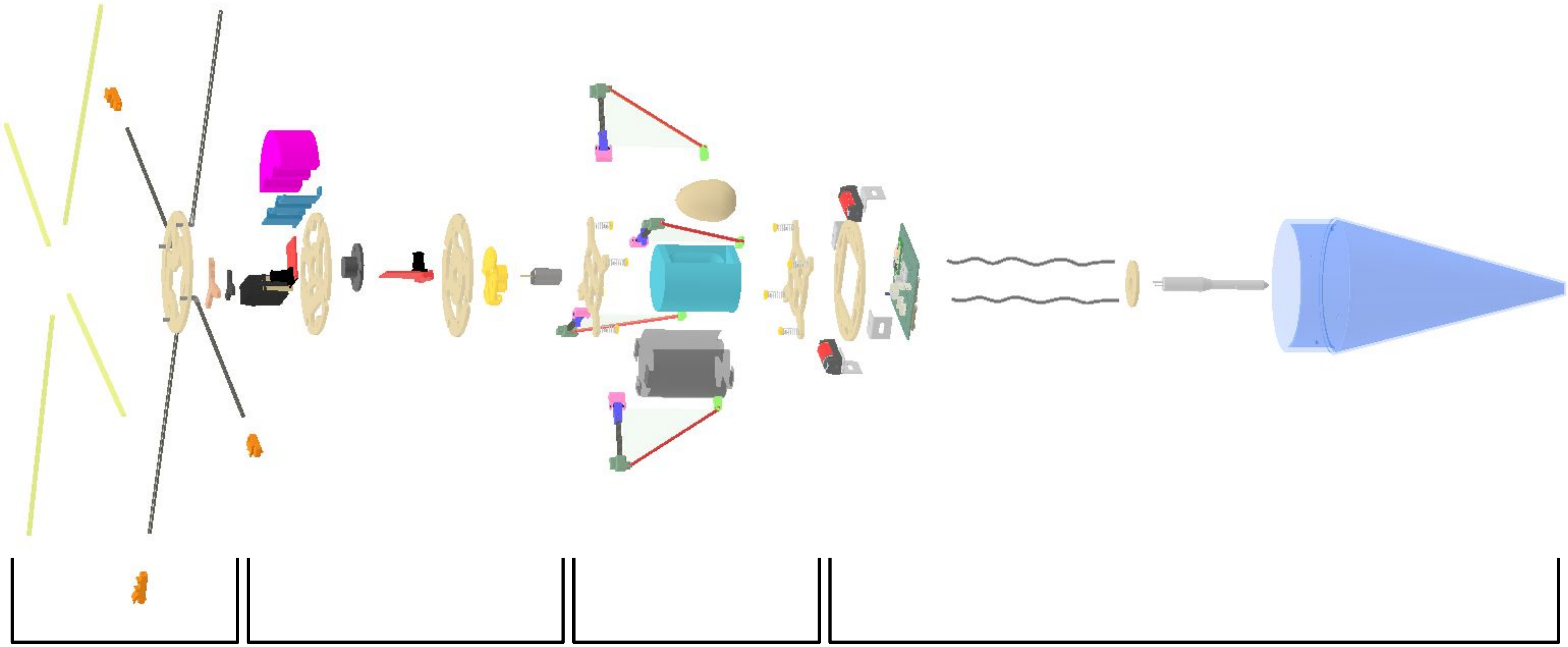
Electrical Successes:

- No damaged components
- Batteries remained in place
- Power maintained through duration of flight

CanSat Physical Layout (1 of 8)

Note:
Aerobrake nylon fabric hidden for better viewing

Full Exploded View



View 1

View 2

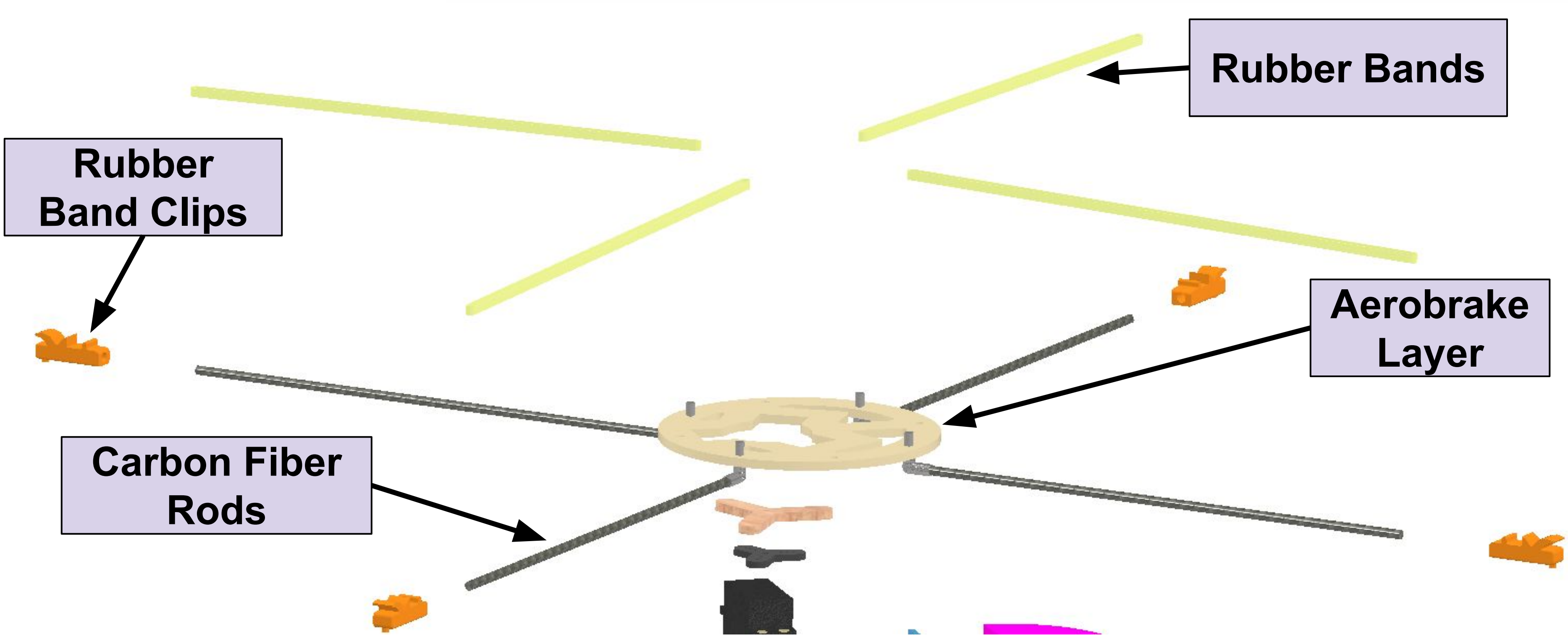
View 3

View 4

CanSat Physical Layout (2 of 8)

Note:
Aerobrake nylon fabric hidden for better viewing

Exploded View 1

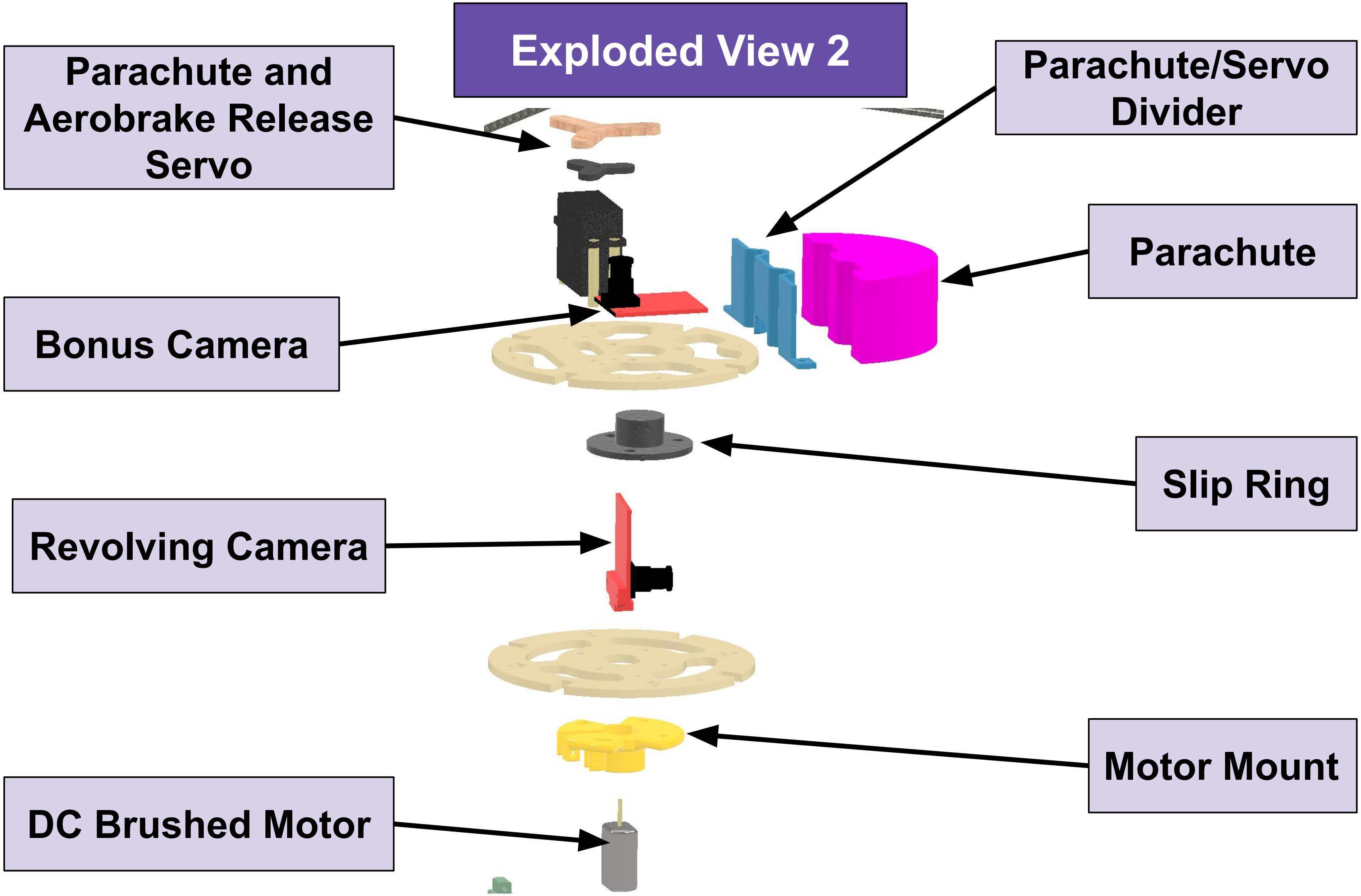

Rubber Bands

Rubber Band Clips

Aerobrake Layer

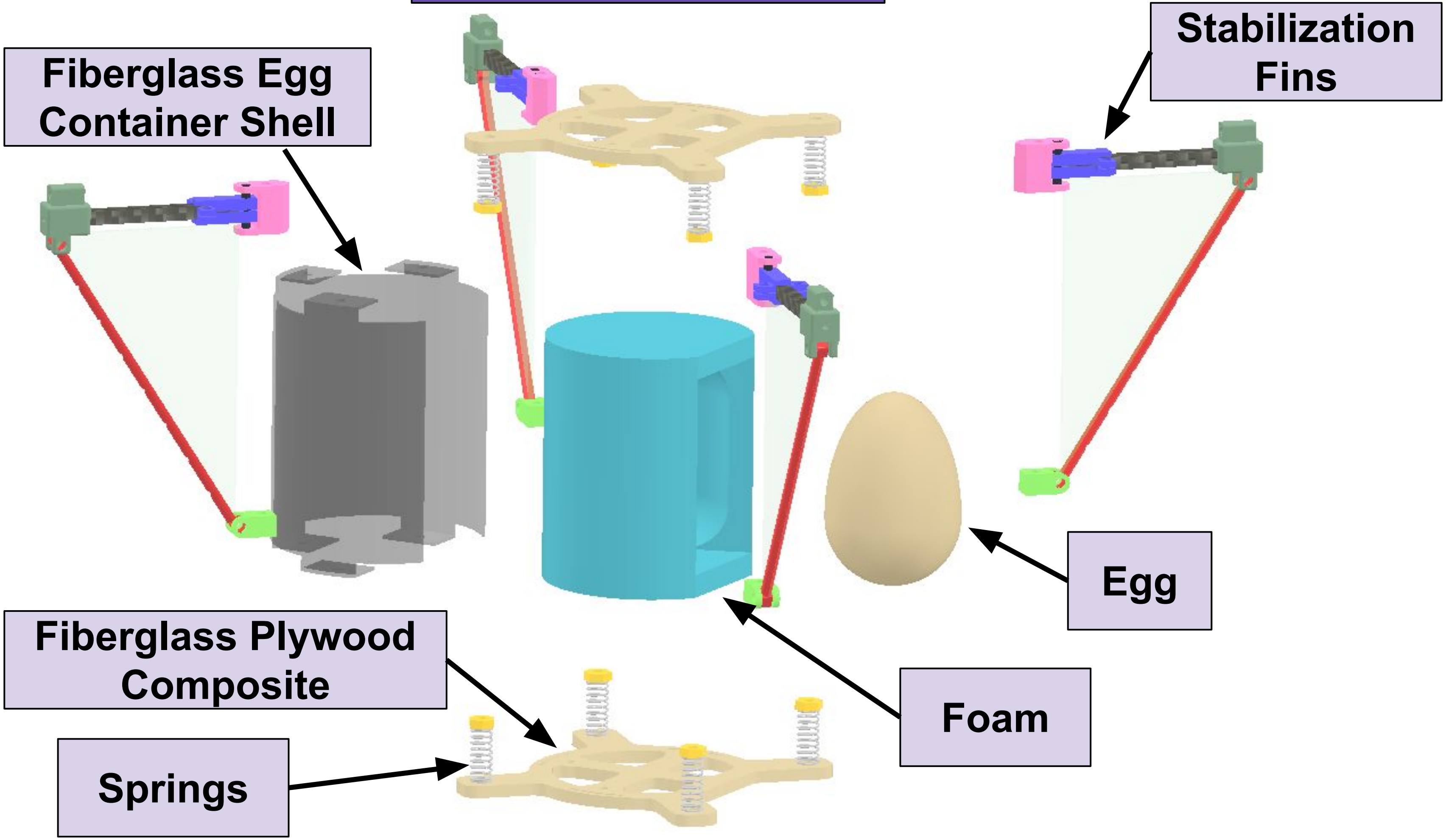
Carbon Fiber Rods

CanSat Physical Layout (3 of 8)



CanSat Physical Layout (4 of 8)

Exploded View 3



Fiberglass Egg Container Shell

Stabilization Fins

Egg

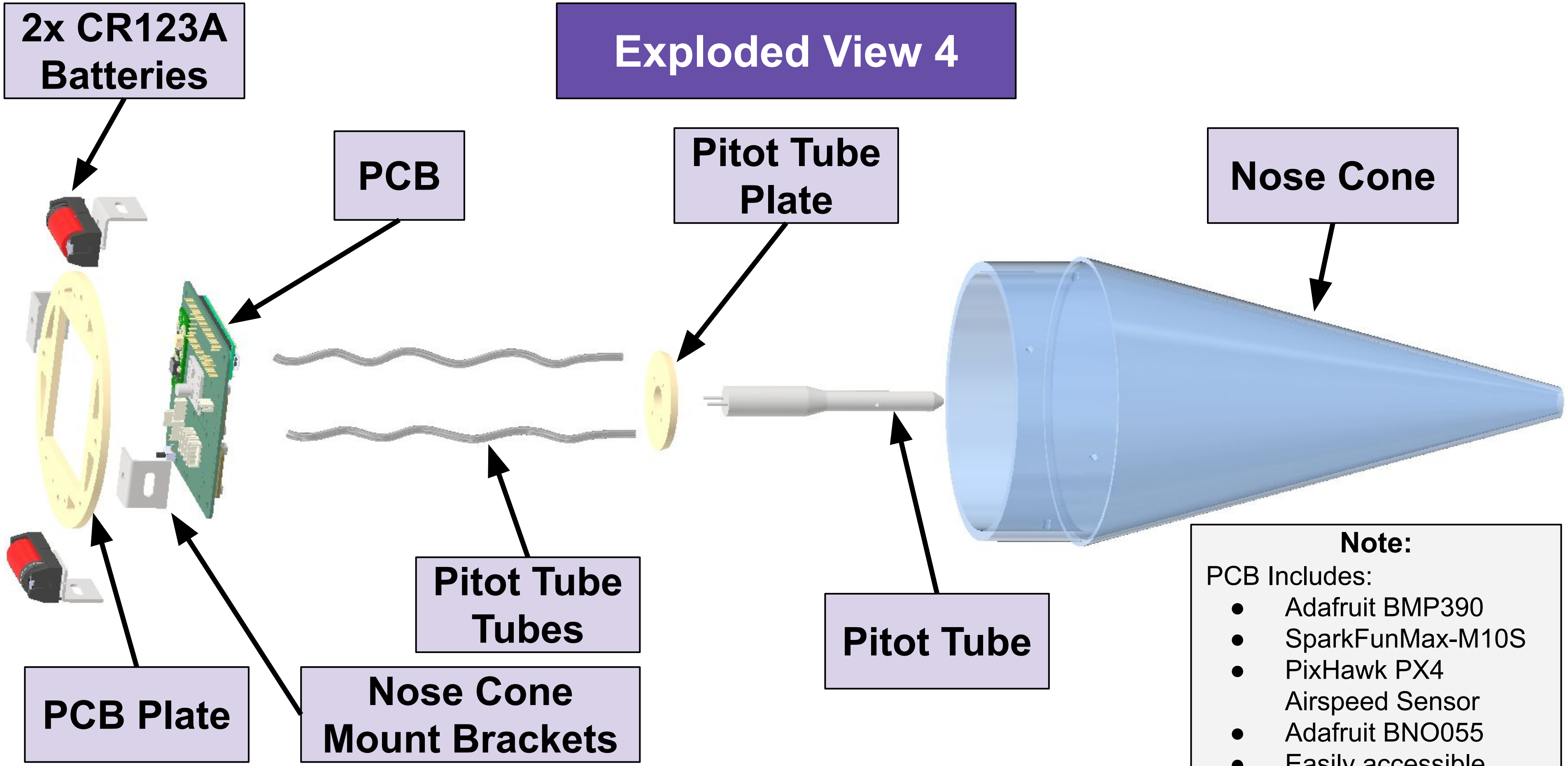
Foam

Fiberglass Plywood Composite

Springs

CanSat Physical Layout (5 of 8)

Exploded View 4

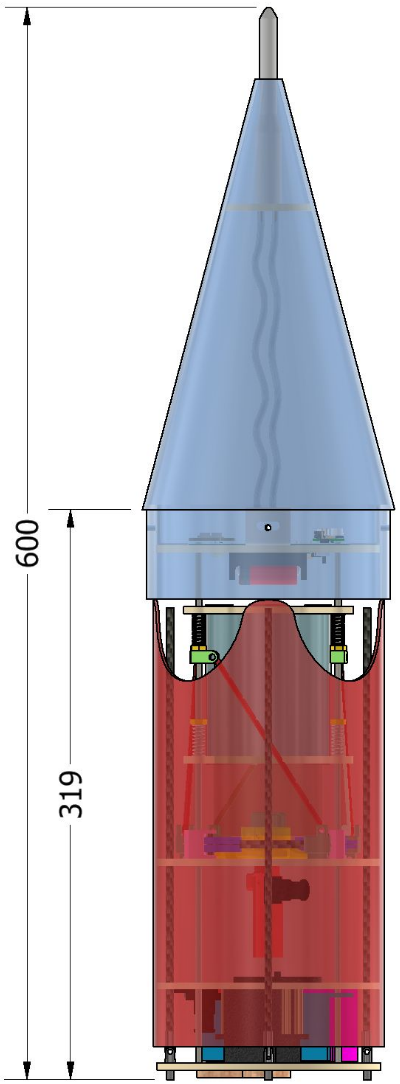


Note:
PCB Includes:

- Adafruit BMP390
- SparkFunMax-M10S
- PixHawk PX4 Airspeed Sensor
- Adafruit BNO055
- Easily accessible on/off switch
- LED and buzzer
- Teensy (CDH)
- Radio and Antenna

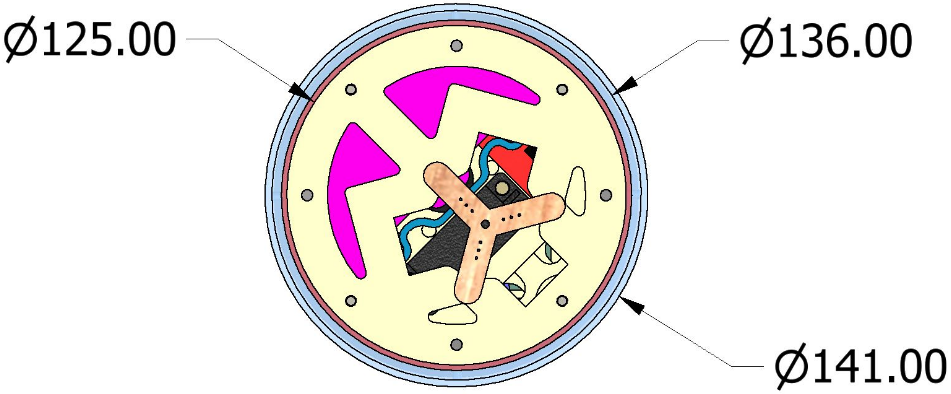
CanSat Physical Layout (6 of 8)

Stowed Configuration



Note:
All dimensions are in mm.

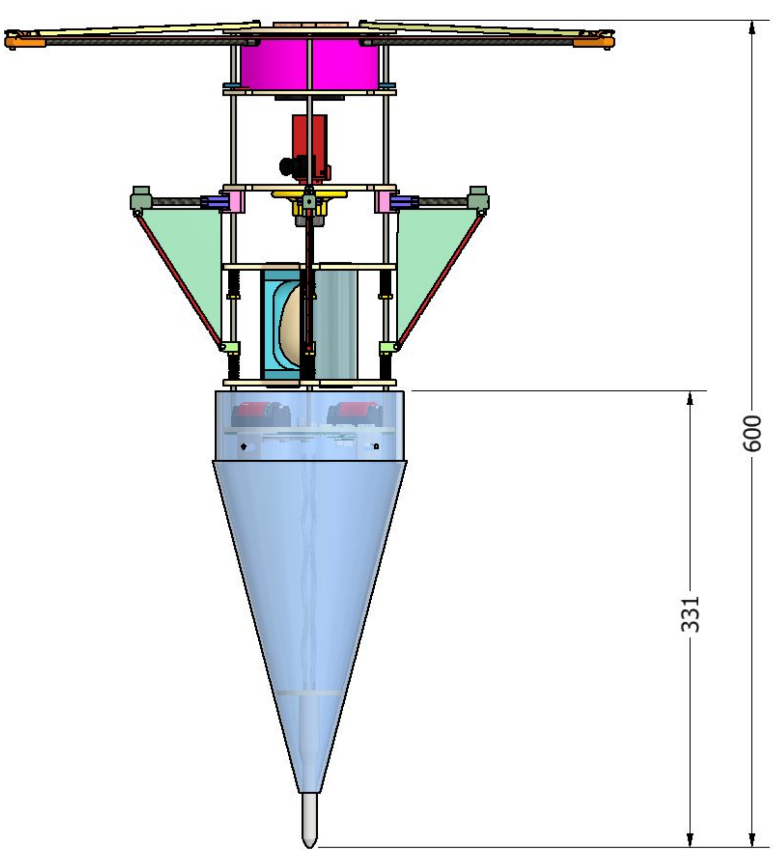
Note:
Aerobrake and parachute will be neon pink for competition (we have this material in our lab).

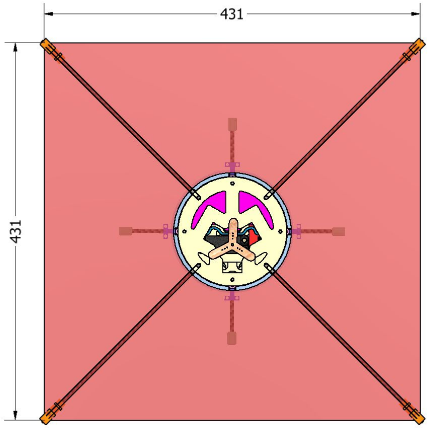


CanSat Physical Layout (7 of 8)

Note:
All dimensions are in mm.

Aerobrake Descent Configuration

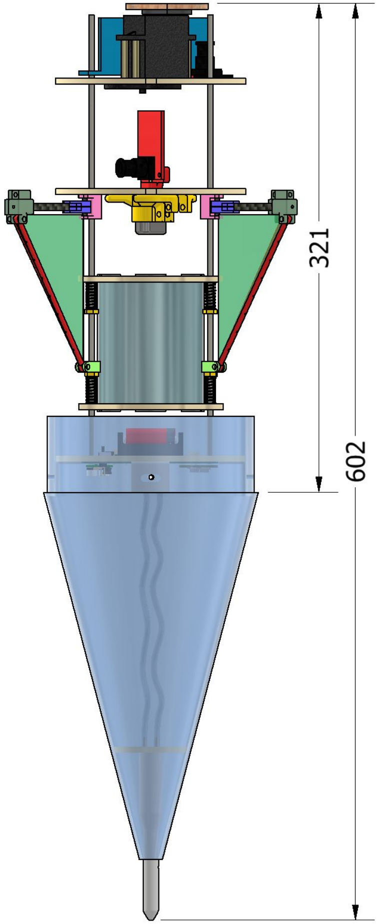




CanSat Physical Layout (8 of 8)

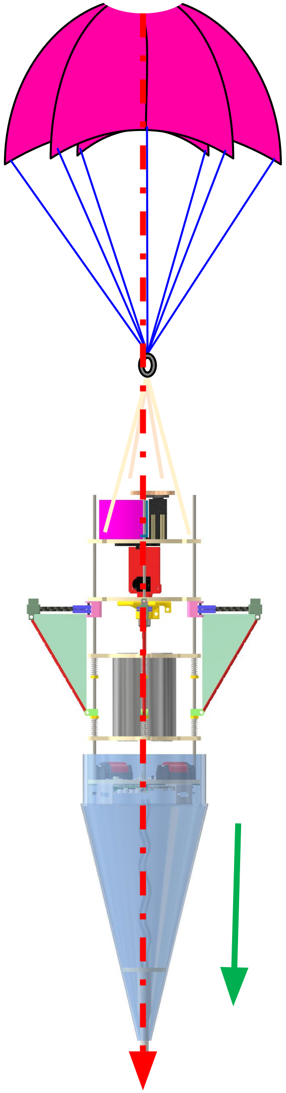
Note:
All dimensions are in mm.

Released Aerobrake Configuration



🟩 Direction of Travel

🟥 Nadir



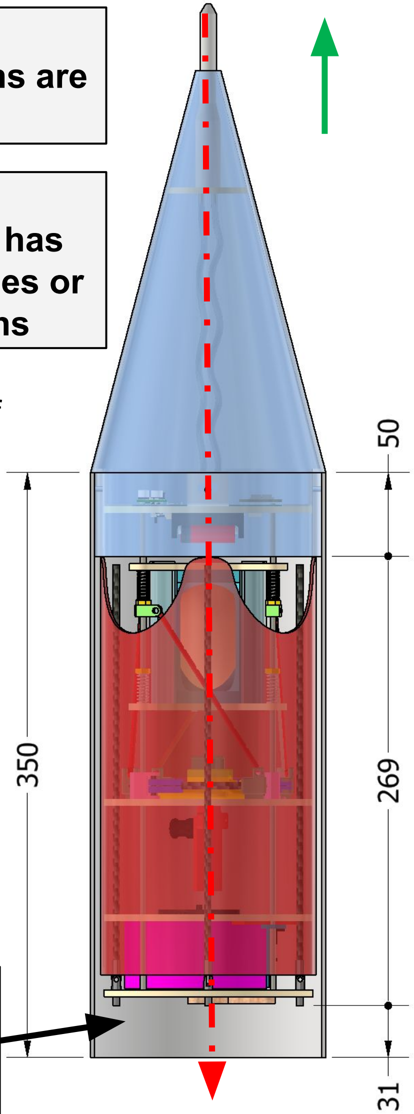
Launch Vehicle Compatibility

Note:
All dimensions are in mm.

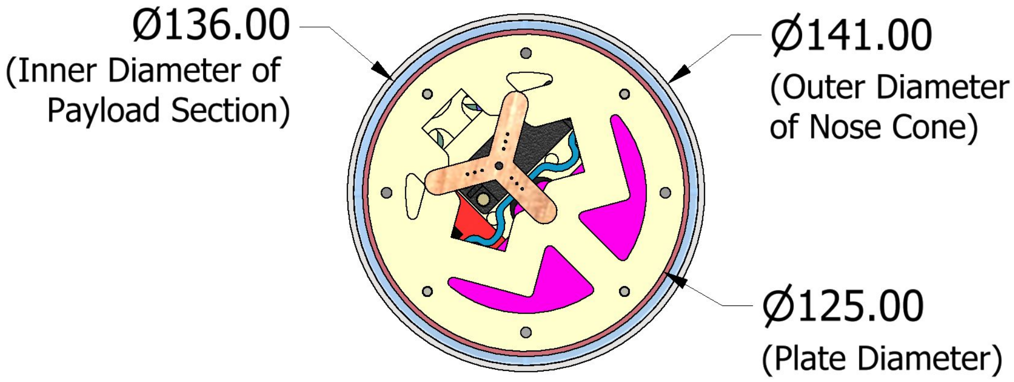
Note:
The CanSat has no sharp edges or protrusions

🟩 Direction of Travel

🟥 Nadir



Payload Section of Rocket



Dimensions	Cansat	Payload Section	Clearance
Diameter (mm)	125	136	5.5
Height (mm)	319	350	31

Sensor Subsystem Design

Nic Ruse

Sensor Subsystem Overview

System	Sensor	Description
Air Pressure	Adafruit BMP390	Measures Air Pressure
Air Temperature	Adafruit BMP390	Monitors Air Temperature
Battery Voltage	Voltage Divider Circuit	Measures Battery Voltage
Air Speed Sensor	PixHawk PX4	Measures Air Speed
Orientation	Adafruit BNO055	Measures CanSat Orientation
GPS	SparkFun MAX-M10S	Tracks Longitude and Latitude of the CanSat
Camera	OpenMV Cam H7 R1	Records Single View From the CanSat
Bonus Camera	OpenMV Cam H7 R1	Records Parachute Release

Sensor Changes Since PDR

Part	PDR	CDR	Rationale
Pololu Hall Effect Motor Encoder	Used two accelerometers, the BNO055, for PID loop data point.	Switched to a pololu hall effect motor encoder for the PID loop data point.	This solution provides more accurate, driftless data for the PID loop while being more power efficient.
50:1 Micro Metal Brushed Gearmotor	Used a 14,400 RPM brushed motor for camera stabilization.	Switched to a 650 RPM 50:1 micro metal brushed gearmotor.	Post test flight data gave us a better understanding of the CanSat's rotational speed which allowed for a slower, more power efficient motor.

Payload Air Pressure Sensor Summary

Sensor	Sampling Rate (Hz)	Range (hPa)	Comm. Bus	Voltage (V)	Current (mA)	Mass (g)	Cost
Adafruit BMP 390	100	300 - 1250	I2C	3.3	0.03	3	$10.95

Accuracy
±3 Pa
±0.25 m
Image Credit:
adafruit.com

Air Pressure Sensor Example Code

```
#include "Adafruit_BMP3XX.h"
Adafruit_BMP3XX bmp;
padPressure is the pressure taken right before launch to set a
standard point.
press = (bmp.pressure/1000.0);
alti = (bmp.readAltitude(padPressure));
```

Data Format

Pressure: x.x kPa
Altitude: xxx.x m

Payload Air Temperature Sensor Summary

Sensor	Sampling Rate (Hz)	Range (°C)	Comm. Bus	Voltage (V)	Current (mA)	Mass (g)	Cost
Adafruit BMP 390	100	0 - 65	I2C	3.3	0.03	3	$10.95

Accuracy
±0.5 °C
Image Credit:
adafruit.com

Air Temperature Sensor Example Code

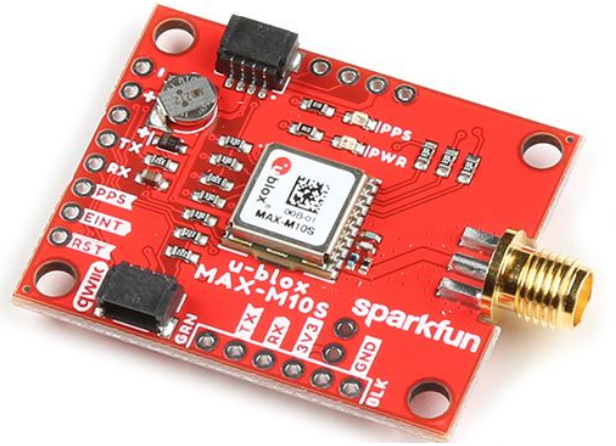
```
#include "Adafruit_BMP3XX.h"
Adafruit_BMP3XX bmp;
tem = (bmp.temperature);
```

Data Format

Temperature: xx.x °C

Payload GPS Sensor Summary

Sensor	Hot Boot Time (s)	Cold Boot Time (s)	Range (m)	Comm. Bus	Voltage (V)	Current (mA)	Mass (g)	Cost
SparkFun MAX-M10 S	1	24	2	I2C	3.3	100	12	$44.95



Accuracy
±1.5 m
Image Credit:
adafruit.com

GPS Sensor Example Code

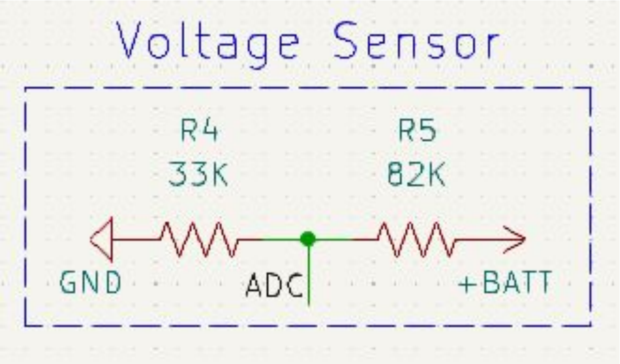
```
#include <SparkFun_u-blox_GNSS_v3.h>
#include "Adafruit_BMP3XX.h"
SFE_UBLOX_GNSS myGNSS;
latitude = myGNSS.getLatitude();
longitude = myGNSS.getLongitude();
altitude = myGNSS.getAltitude();
```

Data Format

GPS Time: xx:xx:xx s
GPS Latitude: xx.xxxx°
GPS Longitude: xx.xxxx°
GPS Satellites: x satellites

Payload Voltage Sensor Summary

Sensor	Total Resistance (kOhm)	Raange (V)	Comm. Bus	Voltage (V)	Current (mA)	Mass (g)	Cost
Voltage Divider Circuit	95	0-25	ADC	6	0.03	2	$0.15



Accuracy
±0.012 V

Voltage Sensor Sensor Example Code

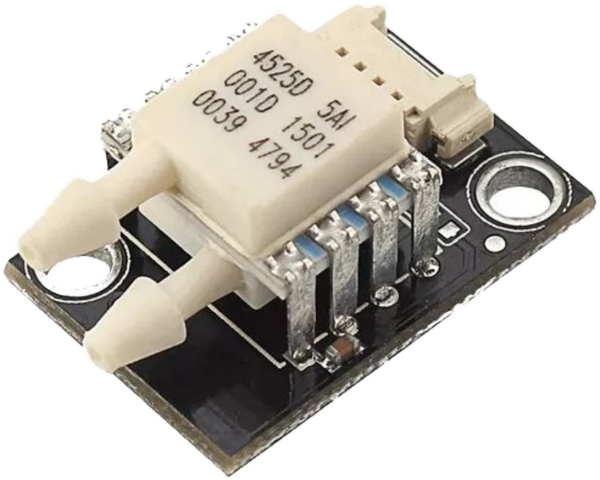
```
#define ANALOG_IN_PIN A14
float r1 = 33000.0; // update
float r2 = 82000.0;
adc_value = analogRead(ANALOG_IN_PIN);
adc_voltage = (adc_value * ref_voltage) / 1024.0;
in_voltage = adc_voltage*(r1+r2)/r2;
```

Data Format

x.x V

Speed Sensor Summary

Sensor	Sampling Rate (m/s)	Range (m/s)	Comm. Bus	Voltage (V)	Current (mA)	Mass (g)	Cost
PixHawk PX4 Airspeed Sensor	100	0 - 100	I2C	5	3	22	$49.99



Accuracy
±0.25 kPA
Image Credit:
robotics.org

Sensor Example Code

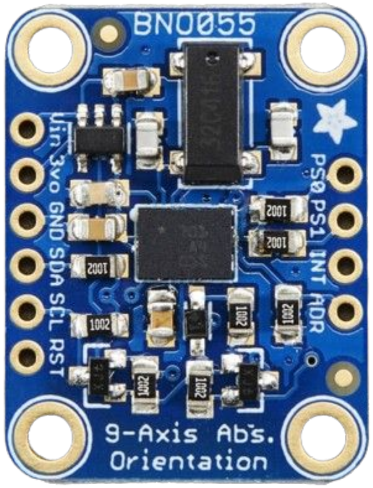
```
#include "ms4525do.h"
bfs::Ms4525do pres;
PX_pressure = pres.pres_pa();
PX_temperature = pres.die_temp_c();
int airSpeed =sqrt((2*(PX_pressure/1.293)))
```

Data Format

xx.xx m/s

Payload Tilt Sensor Summary

Sensor	Sampling Rate (Hz)	Range (deg/sec)	Comm. Bus	Voltage (V)	Current (mA)	Mass (g)	Cost
Adafruit BNO055	100	125 - 2000	I2C	3.3	12.3	3	$34.95



Accuracy
2.5 deg/sec
Image Credit:
adafruit.com

Sensor Example Code

```
#include <Adafruit_BNO055.h>
Adafruit_BNO055 bno = Adafruit_BNO055(55, 0x29)
roll = event.orientation.x;
pitch = event.orientation.y;
```

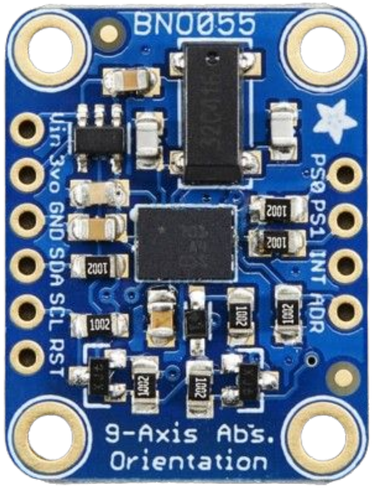
The BNO055's ADC pin will be powered with its 3.3vo pin to switch its I2C address to stop interference between the BNO055 and the Pixhawk airspeed sensor.

Data Format

x.x°/sec

Payload Rotation Sensor Summary

Sensor	Sampling Rate (Hz)	Range (deg/sec)	Comm. Bus	Voltage (V)	Current (mA)	Mass (g)	Cost
Adafruit BNO055	100	125 - 2000	I2C	3.3	12.3	3	$34.95



Accuracy
2.5 deg/sec
Image Credit:
adafruit.com

Sensor Example Code

```
#include <Adafruit_BNO055.h>
#define BNO055_SAMPLERATE_DELAY_MS (100)
Adafruit_BNO055 bno = Adafruit_BNO055(55, 0x29)
yaw = event.orientation.z;
```

The BNO055's ADC pin will be powered with its 3.3vo pin to switch its I2C address to stop interference between the BNO055 and the Pixhawk airspeed sensor.

Data Format

x.x°/sec

Camera Summary

Sensor	Sampling Rate (MB/s)	Range (FPS)	Comm. Bus	Voltage (V)	Current (mA)	Mass (g)	Cost
OpenMV Cam H7 R1	100	75-150	UART	3.3	170	16	$101.94

Camera

Video Format: RGB565 MJPEG
Resolution: 640x480 (Color)
Framerate: 75 FPS
Live Compile: Yes
Onboard Storage: microSD
Maximum Storage Capacity: 32 GB
Maximum Data Rate: 100 MB/s

Image Credit:
adafruit.com

Bonus Camera Summary

Sensor	Sampling Rate (MB/s)	Range (FPS)	Comm. Bus	Voltage (V)	Current (mA)	Mass (g)	Cost
OpenMV Cam H7 R1	100	75-150	UART	3.3	170	16	$101.94

Bonus Camera

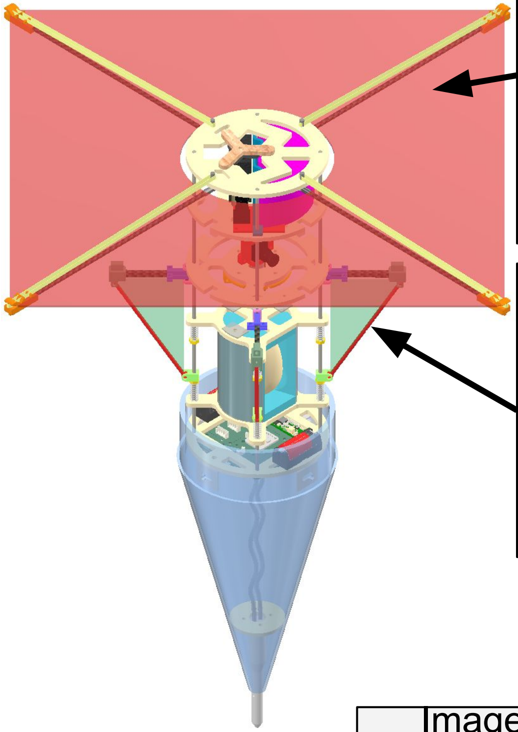
Video Format: RGB565 MJPEG
Resolution: 640x480 (Color)
Framerate: 75 FPS
Live Compile: Yes
Onboard Storage: microSD
Maximum Storage Capacity: 32 GB
Maximum Data Rate: 100 MB/s

Image Credit:
adafruit.com

Descent Control Design

Zach Jones, Jordan Littlepage

Descent Control Overview



Square Aerobrake

- **Components:**
  - Servo
  - Rubber Bands
  - Nylon
  - Carbon Fiber
  - PETG Clips

Parachute

- Components:
  - Metal O Ring
  - Paracord
  - Fishing Wire
  - Nylon

Stabilization Fins

- Components:
  - Fiberglass
  - 3D Print
  - Carbon Fiber
  - Rubber band

Active Rotating Camera about Z-Axis

- Components:
  - DC Brushed Motor
  - Camera
  - Composite Wood

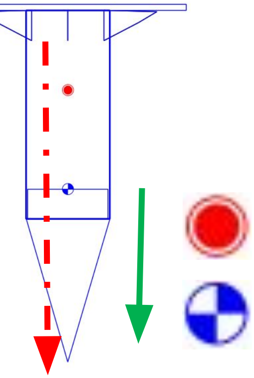
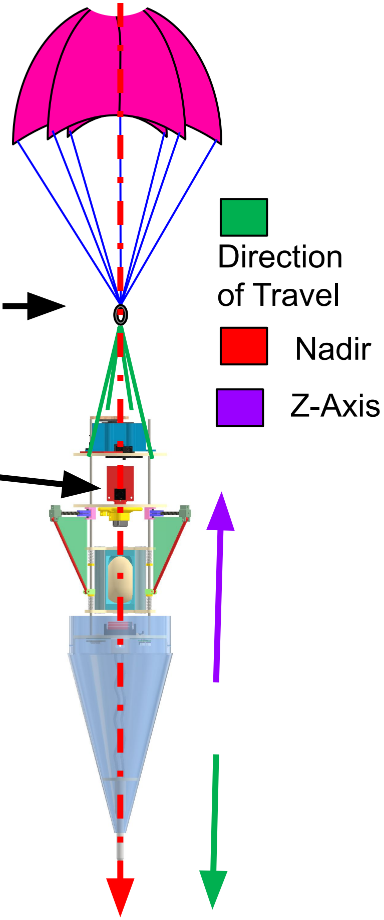


Image from OpenRocket (0.415cal stability)

● Center of Pressure

◐ Center of Mass



725m-100m

100m-0m

Descent Control Changes Since PDR (1 of 5)

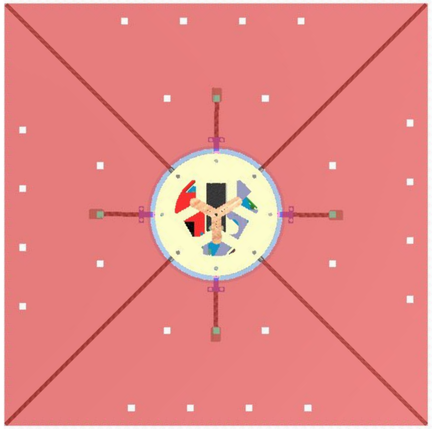
Part	PDR	CDR	Rationale
Aerobrake	Nylon fabric had spill holes and end corners were attached with zip ties.	Spill holes have been removed and it now has a 3D printed rubber band and fabric mount.	Stabilization fins work enough and 3D print results in a more secure and definite location.
Parachute	Single string riser.	Multiple string riser.	The parachute was oscillating too much.
Stabilization Fins	Located near the aerobrake.	Lower on CanSat around the egg.	Camera and egg container switched locations so the fins did as well.
Aerobrake Layer	Servo was located in the center of the layer.	Servo has been moved to the side. Mylar attachment added.	Allows for more parachute storage space. Mylar attachment did not exist beforehand.

Descent Control Changes Since PDR (2 of 5)

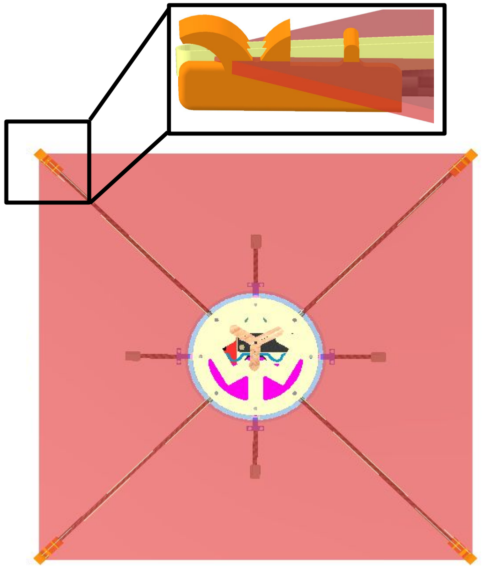
Aerobrake

Note:
Aerobrake will be neon pink for competition.

Old design



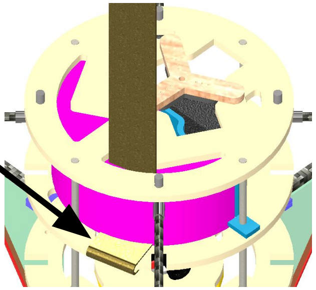
New design



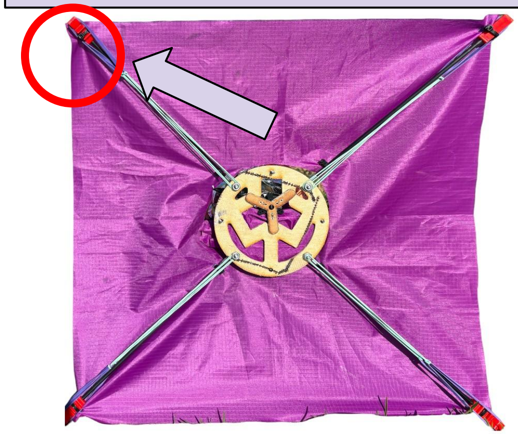
Changes

- Fabric, mylar, and rubber band mounts were added.
- Grommeted spill holes were removed.

Mylar Attachment Point



Test Launch Prototype



Rationale

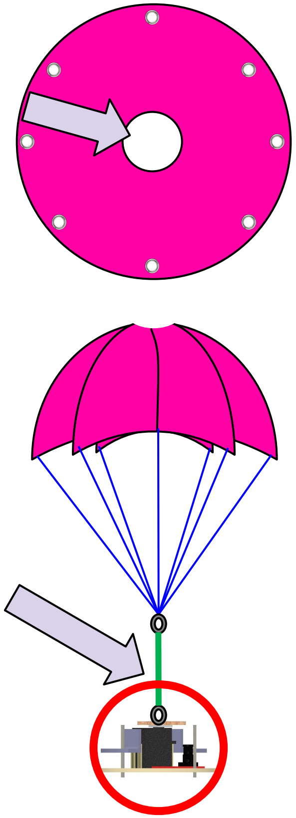
- Printed mounts were added to better secure both the nylon fabric and rubber bands.
- While grommet holes may have possibly helped with stabilization, they also added extra weight.
- We were previously missing a mount for the mylar.

Descent Control Changes Since PDR (3 of 5)

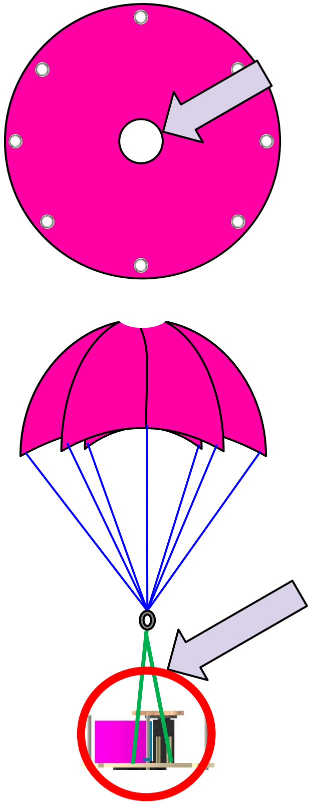
Parachute

Note:
Parachute will be neon pink for competition.

Old design



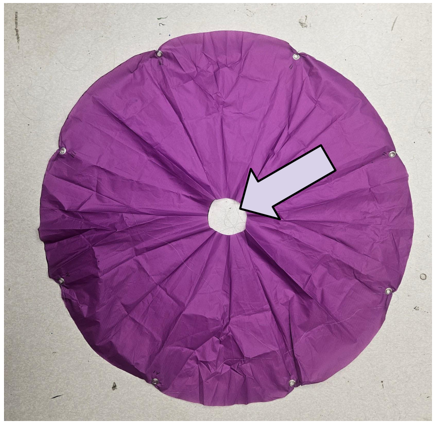
New design



Changes

- Decreased spill hole diameter
- 4 braided paracords attached under the parachute plate.

Test Launch Prototype



Rationale

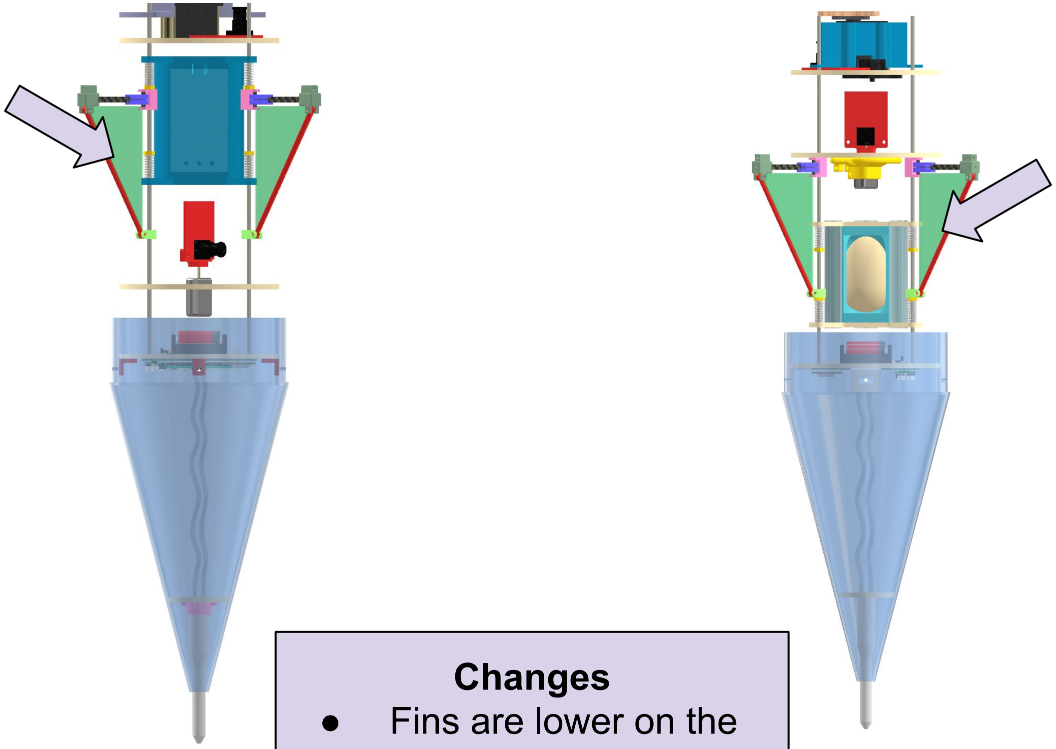
- The nylon paracord was replaced by 2 smaller paracords looped around the center of the payload for space efficacy and stability.
- The spill hole is decreased to increase drag while still maintaining stability.

Descent Control Changes Since PDR (4 of 5)

Stabilization Fins

Old Design

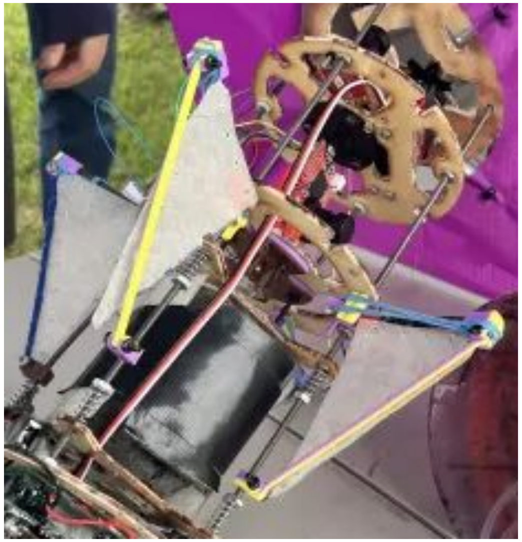
New Design



Changes

- Fins are lower on the CanSat.

Test Launch Prototype



Rationale

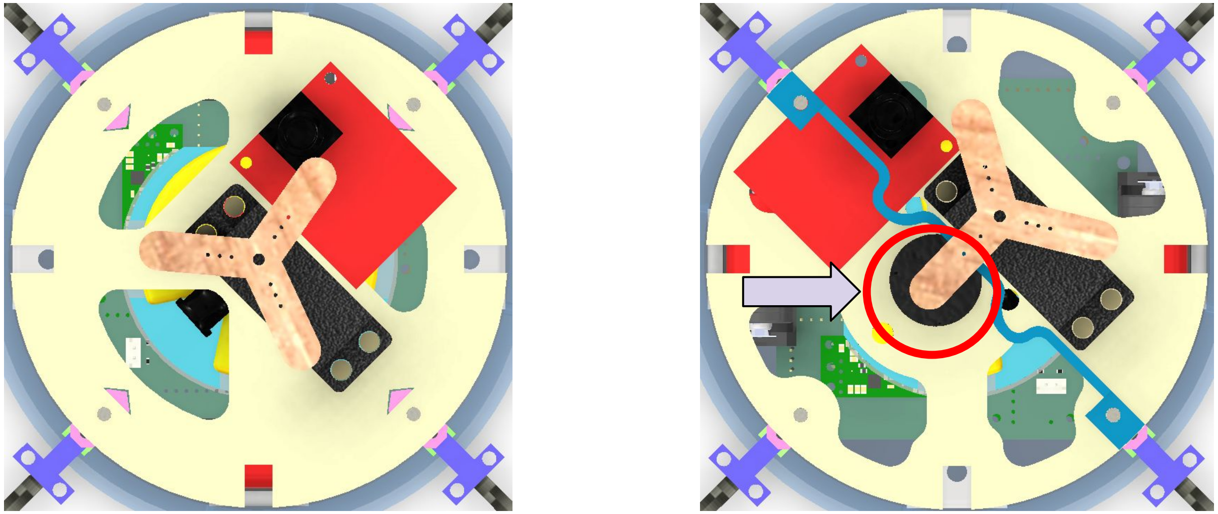
- The placement of the fins was more convenient.
- OpenRocket calculated out stability as 0.415cal.

Descent Control Changes Since PDR (5 of 5)

Aerobrake Layer

Old Design

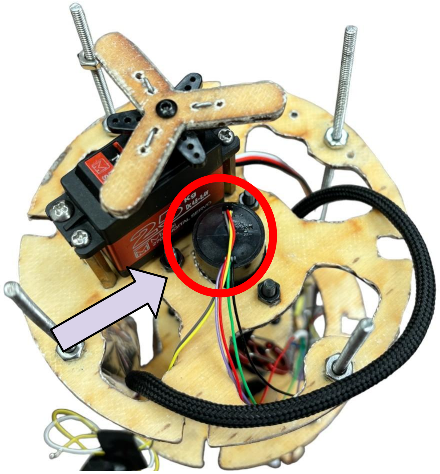
New Design



Changes

- A slip ring was added (black circle in center).
- Fins are not mounted on this platform.
- Servo moved off center.
- Divider added (blue across center).

Test Launch Prototype

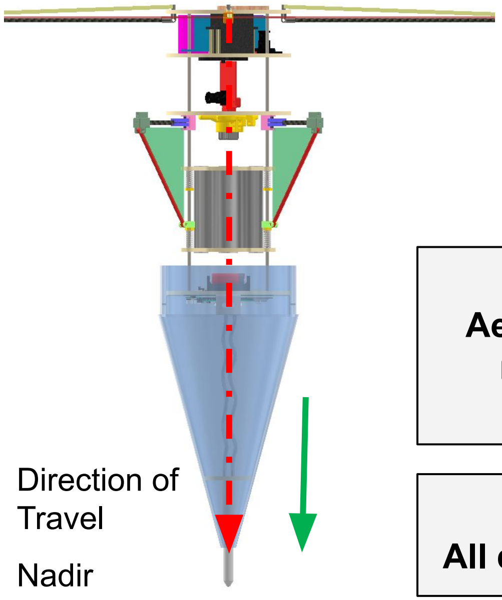


Rationale

- Slip ring needed to prevent tangling wires for rotating camera beneath.
- The fins no longer fit.
- Servo moved because of slip ring.
- Divider changed to be lighter.

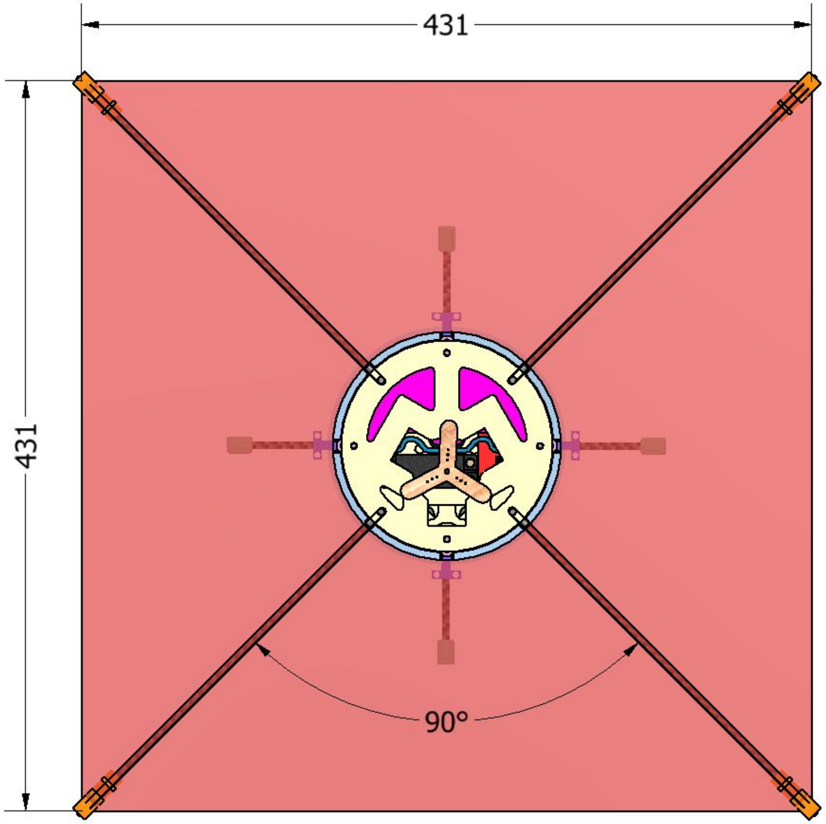
Payload Aerobraking Descent Control Hardware Summary (1 of 2)

Aerobrake Hardware Legend:
- 🟥 Nylon fabric
- 🟧 PETG fabric mounts
- 🟨 Rubber band
- 🟩 Fiberglass sheets
- ⬛ Carbon fiber arms
- ⬜ Aerobrake arm hinges



🟩 Direction of Travel

🟥 Nadir



Note:
Aerobrake will be neon pink for competition

Note:
All dimensions are in mm.

Aerobrake Design

- 431mm square decided from descent calculations.
- 90 degree angles from arm to arm.

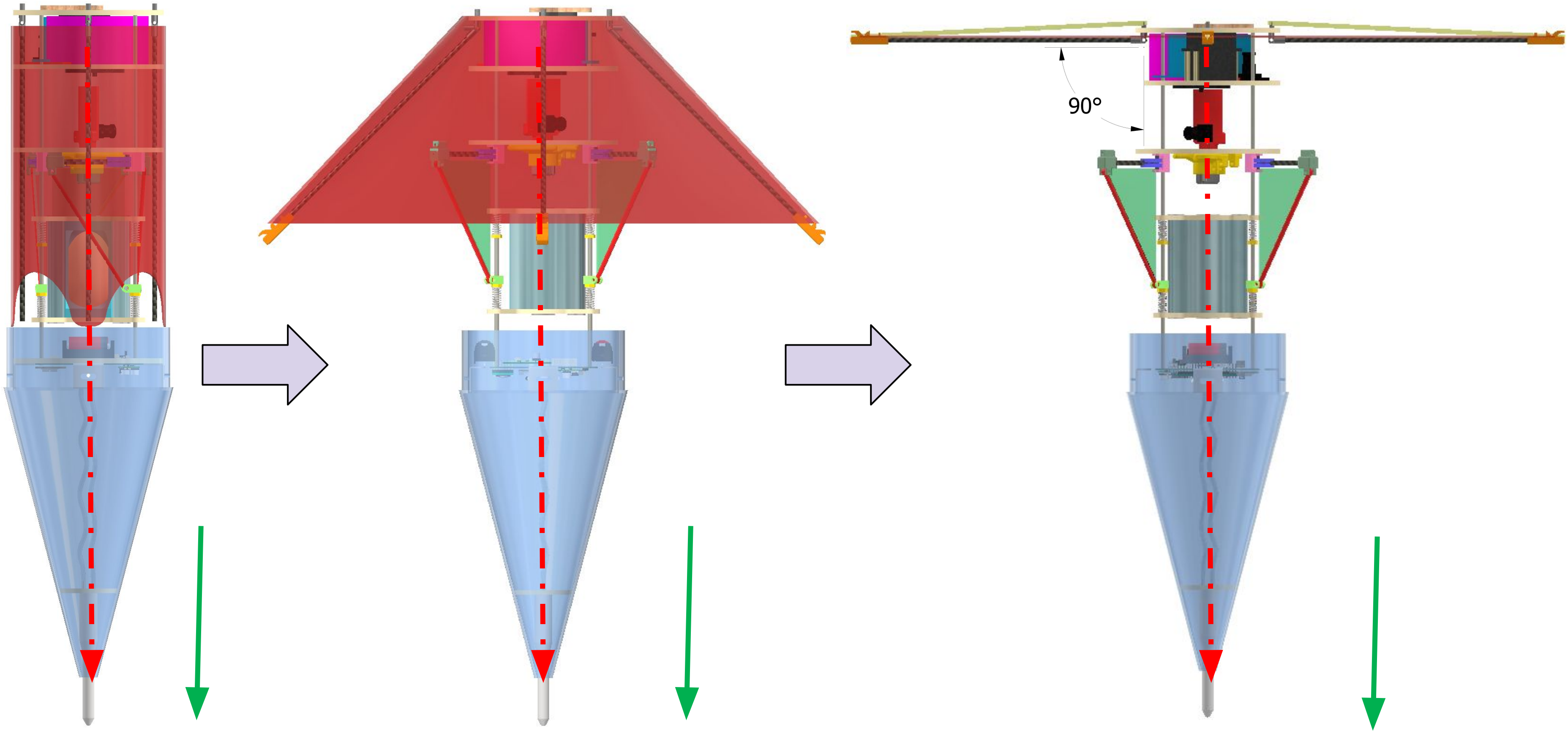
Payload Aerobraking Descent Control Hardware Summary (2 of 2)

🟩 Direction of Travel

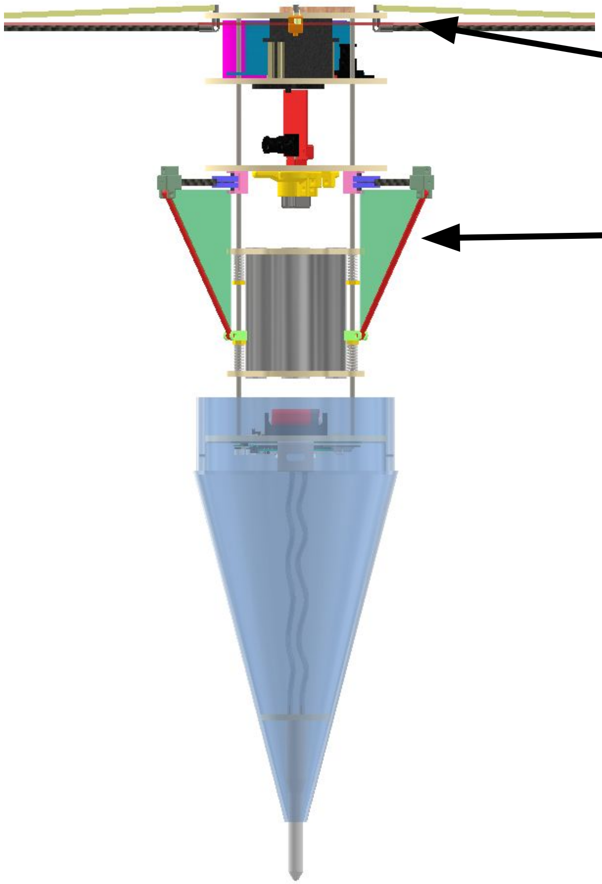
🟥 Nadir

Aerobrake Order of Operations

Note:
Aerobrake will be neon pink for competition



Payload Descent Stability Control Design

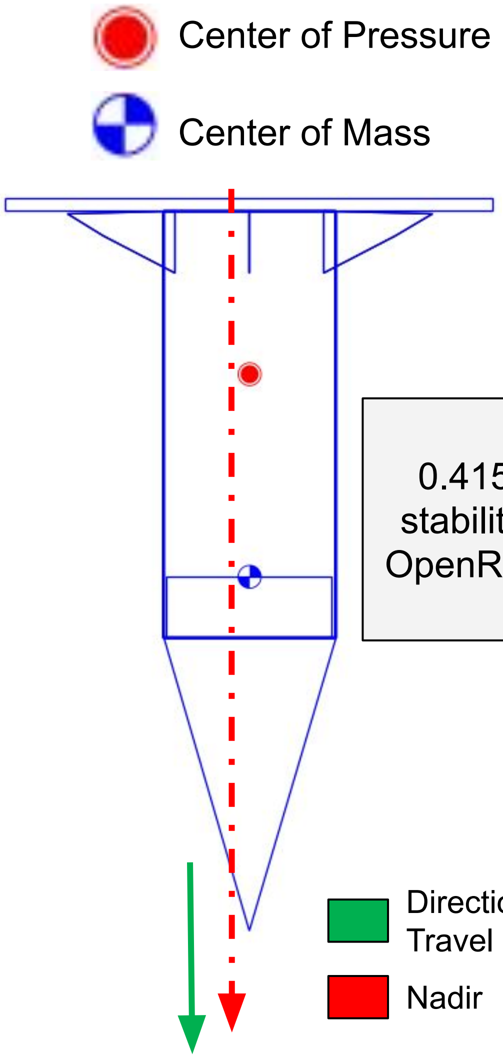


Aerobrake Arm Locking Mechanism

Stabilization Fins

Passive Stability

- Nadir is maintained via aerodynamic shape of the CanSat and stabilization fins.
- Using OpenRocket we determined the center of mass to be in front of the center of pressure.



0.415cal stability on OpenRocket

🟩 Direction of Travel

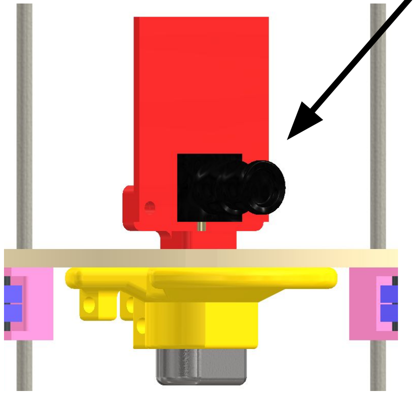
🟥 Nadir

Payload Rotation Control Strategy

Legend:
- 🟥 Nylon fabric
- 🟧 PETG fabric mounts
- 🟪 PETG attachments
- ⬜ Fiberglass sheets
- ⬛ Carbon fiber
- 🟥 PETG camera mount

Active Horizontal Rotating Camera

- PETG Camera Mount
- Composite Wood Layer

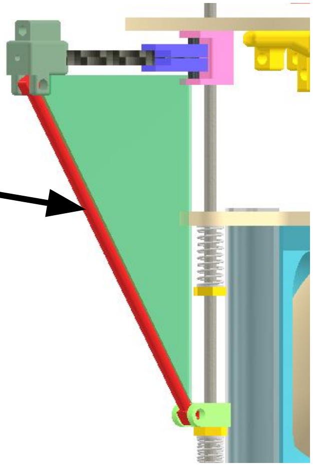


Descent Stability

During aerobraking, the stabilization fins will keep the payload from tumbling and the camera will actively rotate to a fixed point on the horizon.

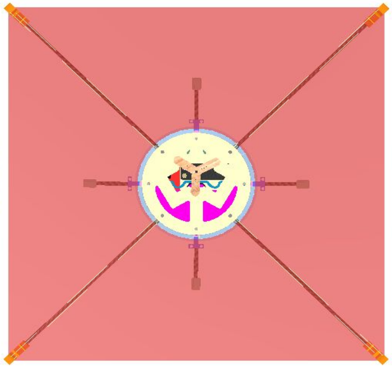
Passive Stabilization Fins

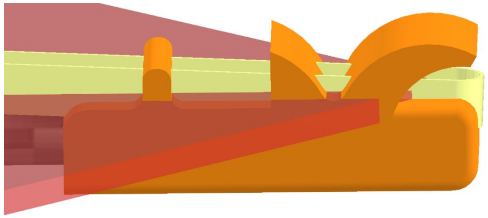
- PETG Attachments
- Fiberglass
- Carbon Fiber



Square Nylon Aerobrake

- Carbon Fiber Arms
- Metallic Hinges
- Nylon Fabric
- PETG mounts



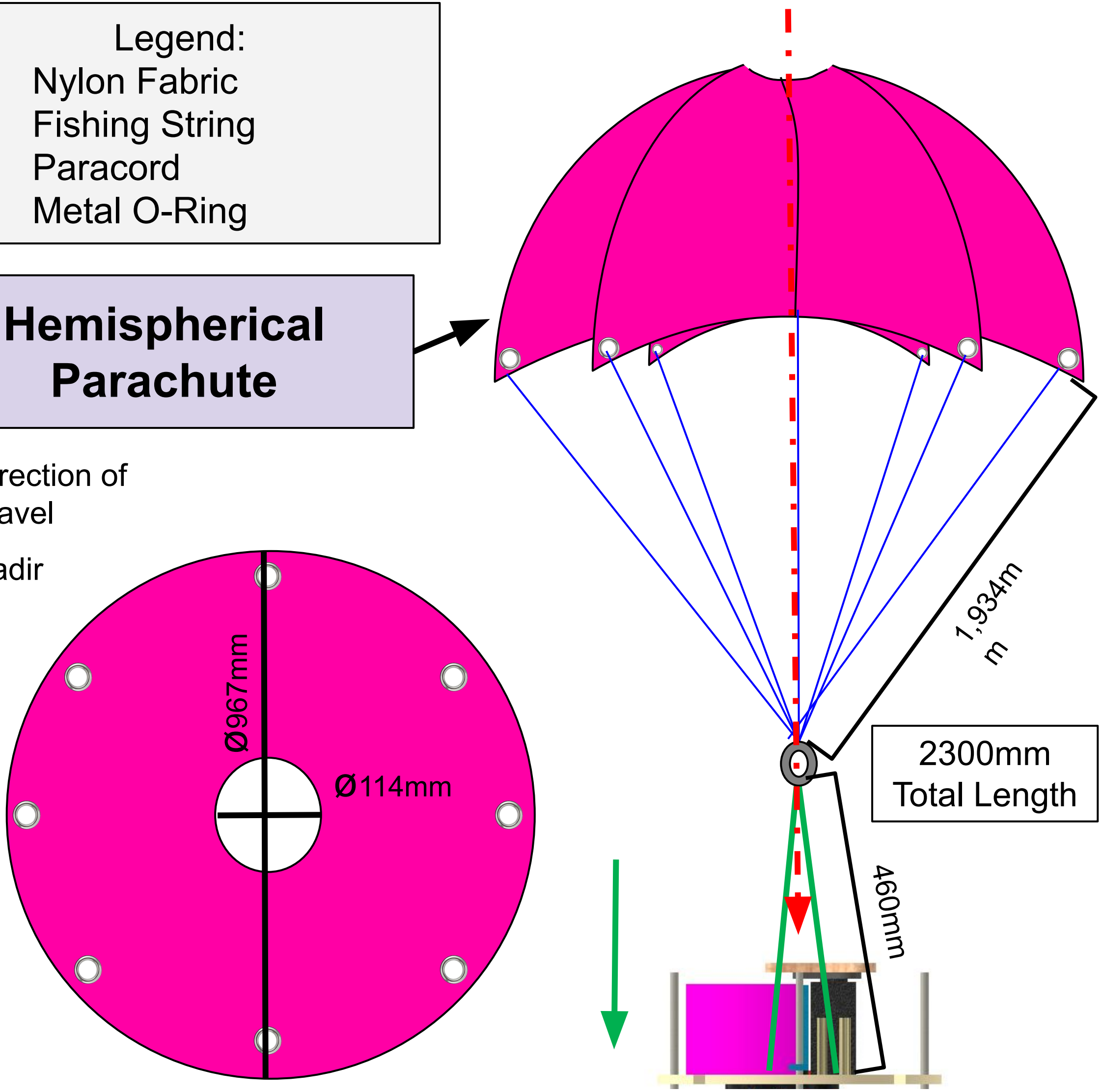


Payload Parachute Descent Control Hardware Summary

Legend:
- 🟪 Nylon Fabric
- 🟦 Fishing String
- 🟩 Paracord
- ⬜ Metal O-Ring

Hemispherical Parachute

- 🟩 Direction of Travel
- 🟥 Nadir



Dimensions

- Parachute Flat Diameter: 967mm
- Spill Hole Diameter: 114mm
- Parachute Deployed Diameter: 800mm
- Fishing String: 1,934mm (2x Deployed Diameter)
- Paracord: 80mm
    - The above dimensions were chosen to achieve less than 5m/s.

Hardware

The paracord is used to make a strong connection to the payload and reduce tangling.The o-ring makes a single point of connection (riser) and the riser is used to help stabilize descent. Pink nylon was chosen to be easily visible.

Descent Rate Estimates (1 of 4)

Aerobrake and Parachute Diameter

Equation Variables

- mg = Force from Gravity
- m = Mass
- g = Gravitational Acceleration
- v = Velocity
- cd = Drag coefficient
- a = Air density
- kg= kilograms

Note:
These equations are used under ideal conditions.

Equation for Force from Gravity

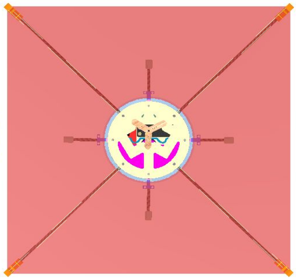
$$mg = kg(9.8)$$

Equation for Velocity

$$v = \sqrt{\frac{8mg}{\pi \cdot cd \cdot a \cdot d^2}}$$

Descent Rate Estimates (2 of 4)

Aerobrake



Aerobrake $mg = .9(9.8) = 8.82$

Assumptions & Variables

- Aerobrake ø =0.431m
- Aerobrake cd= 0.75
- Air density= 1.229
- Performed under ideal conditions.

Equation Variables

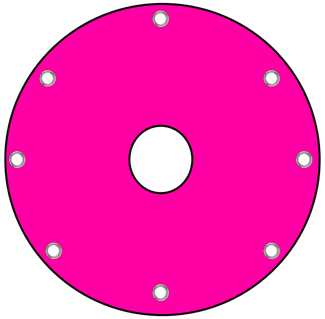
- mg = Force of Gravity
- m = Meters
- mm = Millimeters
- v = Velocity
- C_d = Drag coefficient
- a = Air density

Estimated Constant Velocity from Diameter

Aerobrake $v = \sqrt{\frac{8mg}{\pi \cdot cd \cdot a \cdot d^2}}$ $v = \sqrt{\frac{8(8.2)}{\pi(0.75)(1.229)(0.431)^2}} = 11.043\frac{m}{s}$

Descent Rate Estimates (3 of 4)

Parachute



Parachute $mg = .816(9.8) = 7.99$

Assumptions & Variables

- Parachute ø 967mm-15%=0.782 m
- Aerobrake ø =0.44m
- Parachute cd= 1.5
- Air density= 1.229
- Performed under ideal conditions.

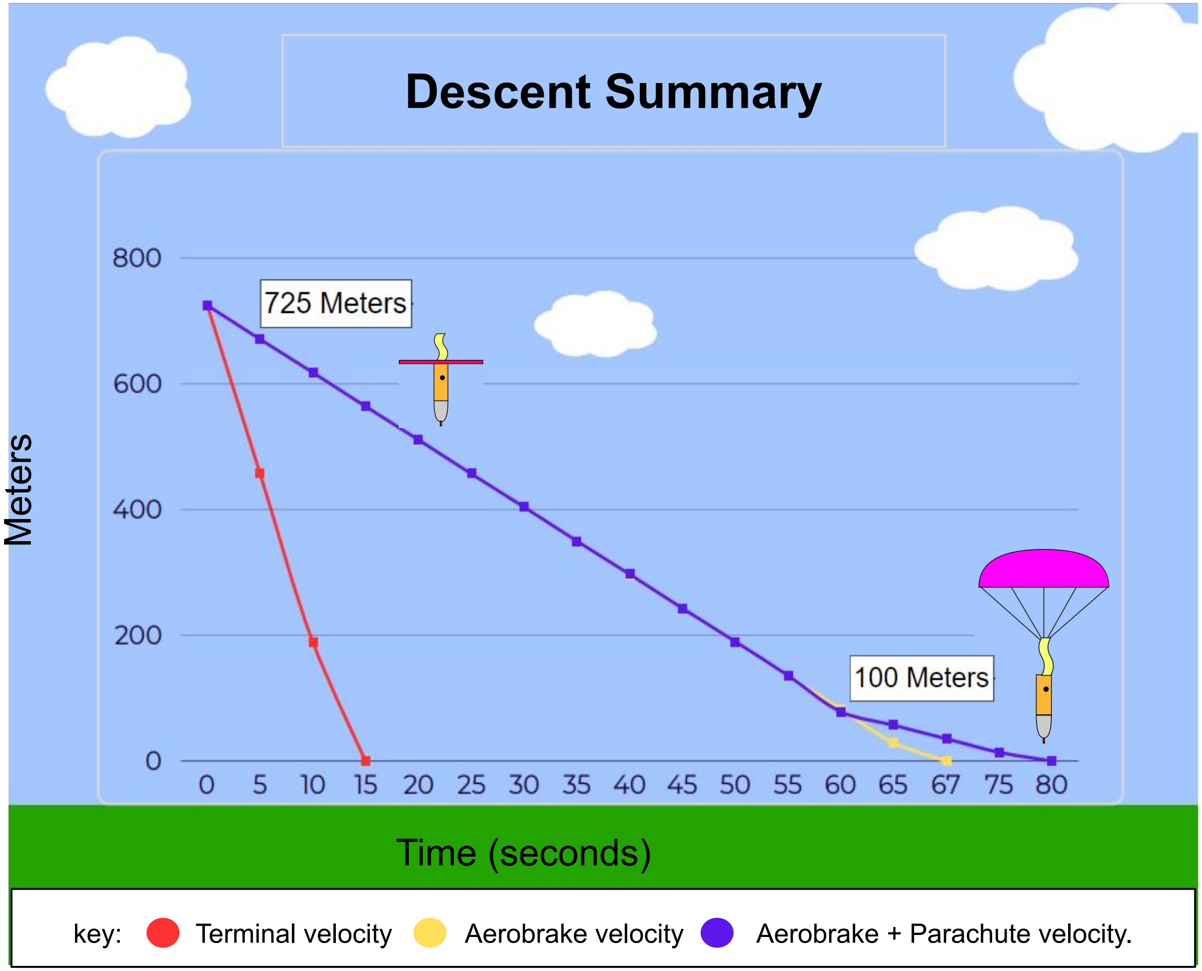
Equation Variables

- mg = Force of Gravity
- m = Meters
- mm = Millimeters
- v = Velocity
- C_d = Drag coefficient
- a = Air density

Estimated Constant Velocity from Diameter

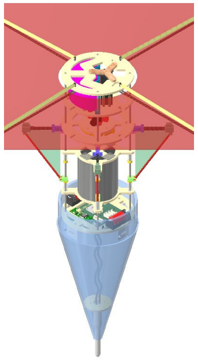
Parachute $v = \sqrt{\frac{8mg}{\pi \cdot cd \cdot a \cdot d^2}}$ $v = \sqrt{\frac{8(7.99)}{\pi(1.5)(1.229)(0.782)^2}} = 4.248\,\frac{m}{s}$

Descent Rate Estimates (4 of 4)



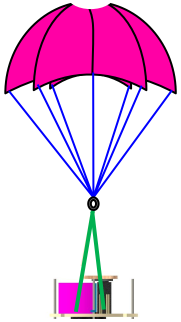
Note:
This graph is made under assumed ideal conditions.

Aerobrake



$$v=\sqrt{\frac{8(8.2)}{\pi(0.75)(1.229)(0.431)^2}}=11.043\,\frac{m}{s}$$

Parachute

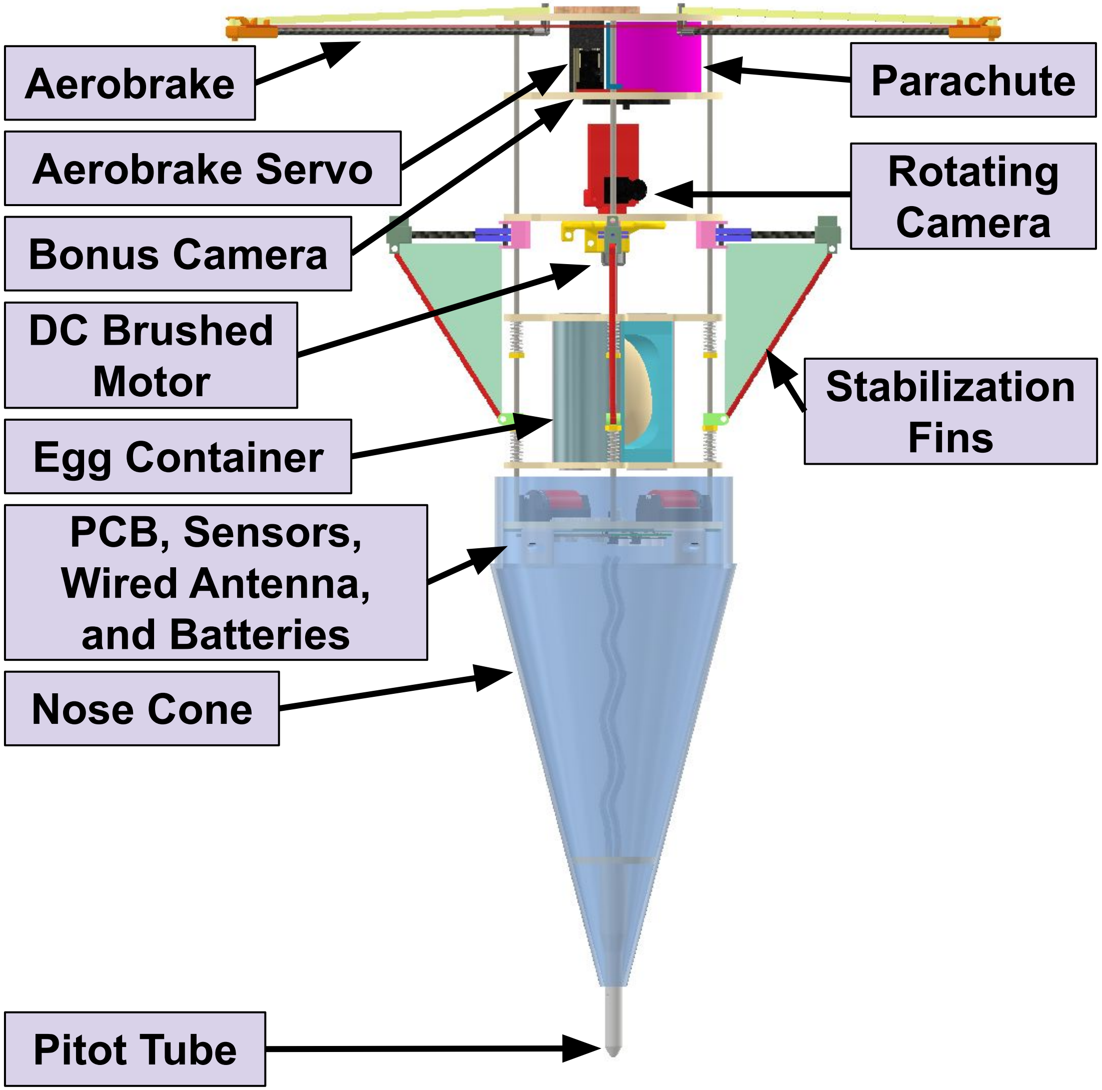


$$v=\sqrt{\frac{8(7.99)}{\pi(1.5)(1.229)(0.782)^2}}=4.248\,\frac{m}{s}$$

Mechanical Subsystem Design

Samuel Chouinard, Andrew Treadway

Mechanical Subsystem Overview



Part	Material
Aerobrake	Nylon Fabric, Zinc-Plated Brass Hinged Standoffs, Circular Carbon Fiber Rods, 3D printed PETG, Rubber Bands
Rotating Camera Mount	3D printed PETG
Stabilization Fins	Fiberglass Sheet, Square Carbon Fiber Rods, 3D printed PETG
Egg Container	Fiberglass Composite Plywood, Memory Foam, Fiberglass Sheet
Nose Cone	Fiberglass
Payload Structure	Fiberglass Composite Plywood, Threaded Steel Rods

Mechanical Subsystem Changes Since PDR (1 of 8)

Section	Part	PDR	CDR	Rationale
Mechanical	Egg Container	3D printed out of PETG	Fiberglass and plywood composite plates	Saves mass and survived a test launch.
	Egg Container and Rotating Camera	Egg container was above the rotating camera	Rotating camera is above the egg container	Brings center of mass lower for better stabilization.
	Aerobrake Release Servo	The motor was in the center of the plate	The motor has been moved to one side	A slip ring was added and needed to be centered.
	Rotating Camera	There was no mount for the rotating camera	There is now a PETG mount for the brushed motor	Makes the camera and motor more secure during flight

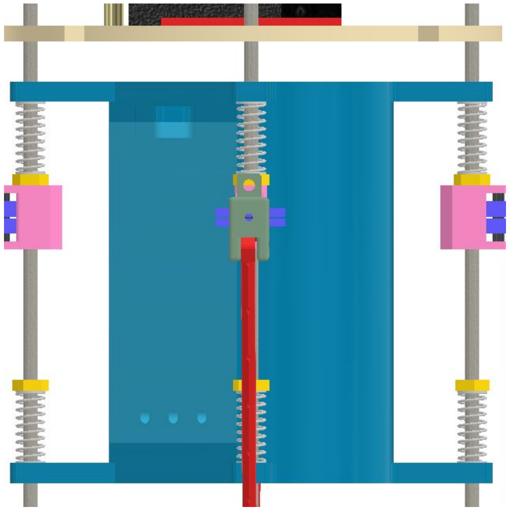
Mechanical Subsystem Changes Since PDR (2 of 8)

Section	Part	PDR	CDR	Rationale
Mechanical	Rotating Camera Slip Ring	Nonexistent	A slip ring has been added	Required so electrical wires don’t get tangled.
	Parachute Layer	A layer that the parachute sits on	The layer replaced with a divider between the parachute and the motor	There was not enough space for the parachute to release and we needed more room.
	Bonus Camera and Aerobrake Release Layer	There was no mylar mount	Mylar mount has been added	The mylar is required for the competition and needed a mount on the cansat.

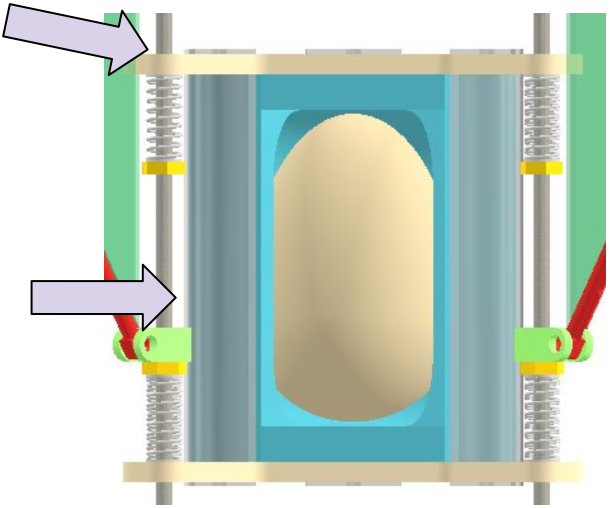
Mechanical Subsystem Changes Since PDR (3 of 8)

Egg Container

Old Design



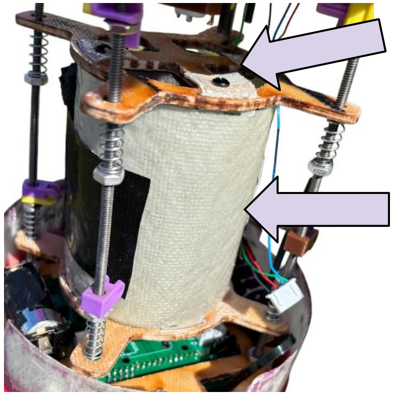
New Design



Changes

- Is no longer made out of PETG(dark blue) and is now made out of fiberglass(silver) and fiberglassed composites (tan) and the door is duct taped on.
- Consists of 3 total parts opposed to 2.
- The new design has survived a test flight.

Test Launch Prototype



Rationale

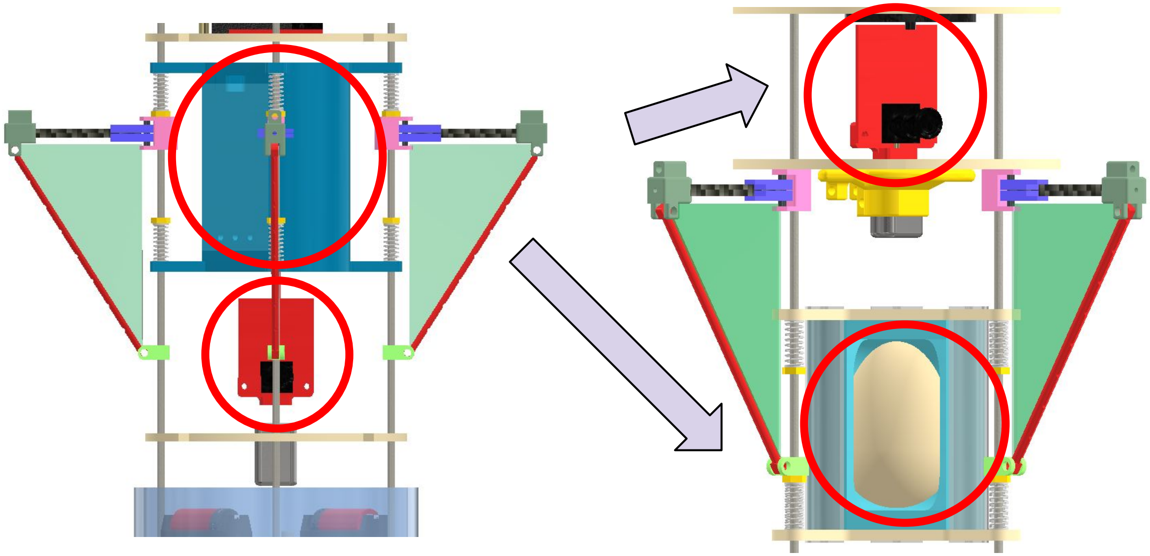
- Due to the original design being over mass the middle portion of the canister was changed to fiberglass sheets.
- The top and bottom plates of the container were changed to plywood fiberglass composites because it is stronger than PETG.

Mechanical Subsystem Changes Since PDR (4 of 8)

Egg Container and Rotating Camera

Old Design

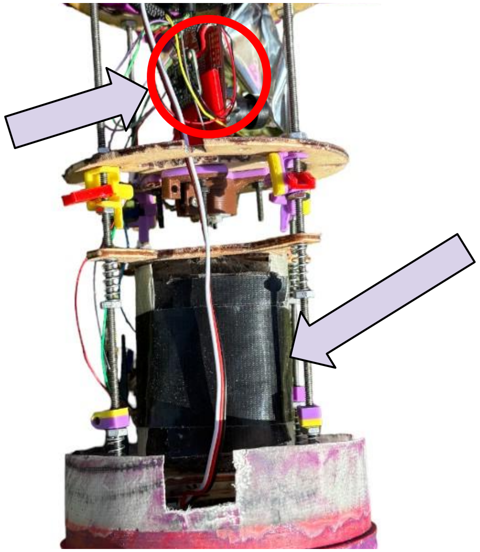
New Design



Changes

- The egg container and rotating camera have switched positions.
- The egg container is now under the rotating camera.

Test Launch Prototype



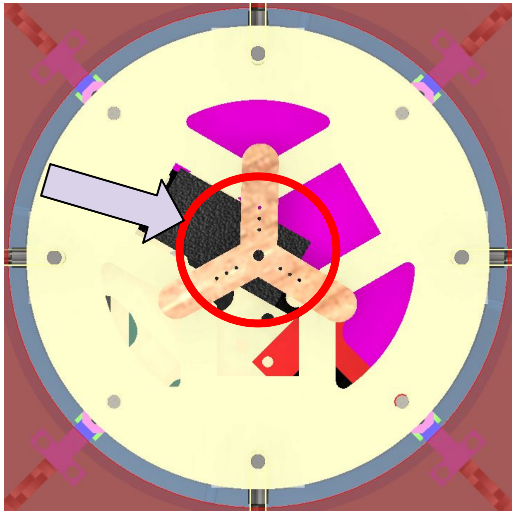
Rationale

- Changing where the egg container and rotating camera were located brought our center of mass lower and gave us a greater stability from 0.212cal to 0.415cal (numbers from OpenRocket).

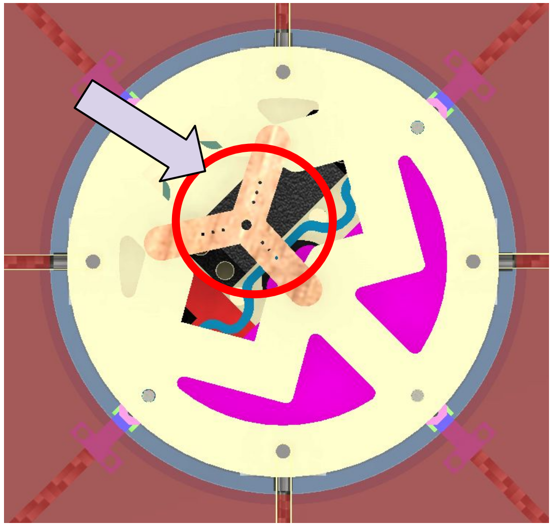
Mechanical Subsystem Changes Since PDR (5 of 8)

Aerobrake Release Servo

Old Design



New Design



Changes
- The servo has been off-set.
- The cut out in the aerobrake layer has been moved to fit the new location.

Test Launch Prototype

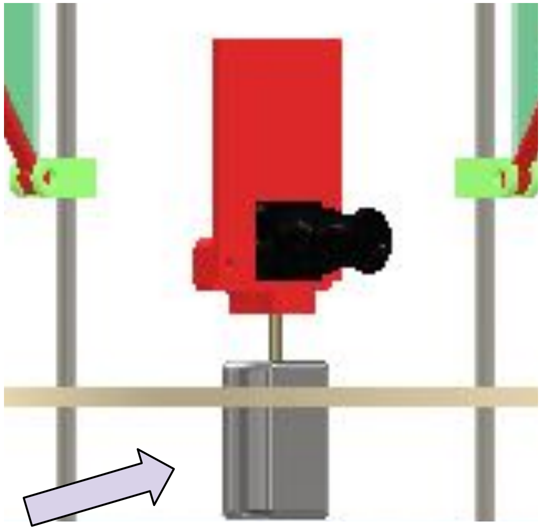
Rationale

- The movement of the servo allows for more parachute storage space.
- The parachute can release without a chance of getting stuck.

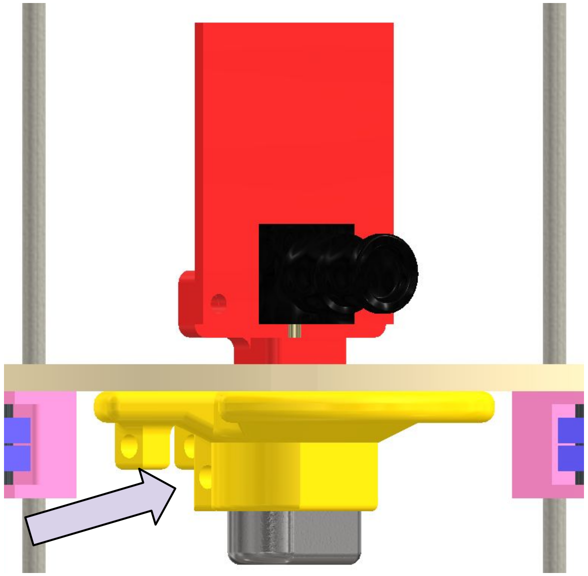
Mechanical Subsystem Changes Since PDR (6 of 8)

Rotating Camera

Old Design



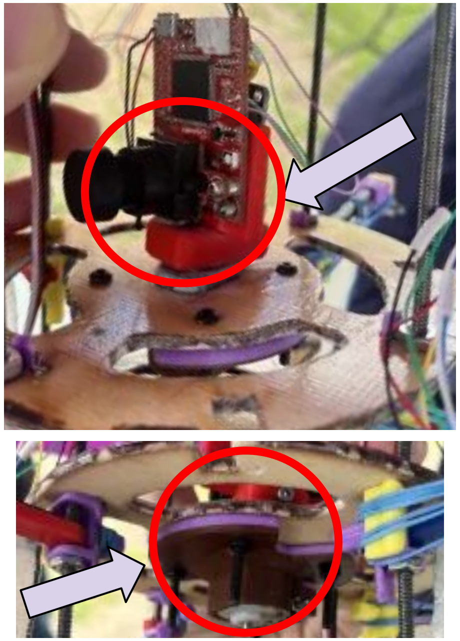
New Design



Changes

- There is now a PETG mount for the brushed motor.

Test Launch Prototype



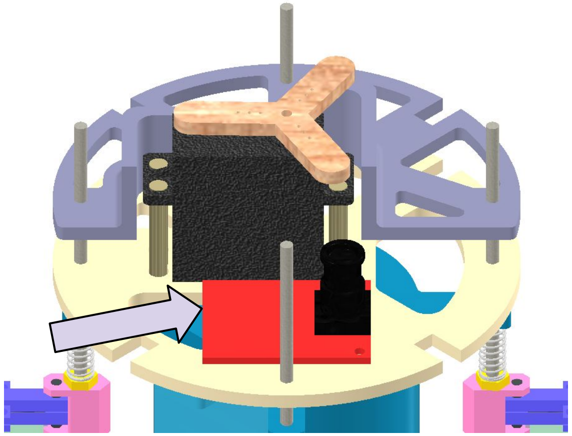
Rationale

- With the addition of the motor mount, the rotating camera is now secure and stable.

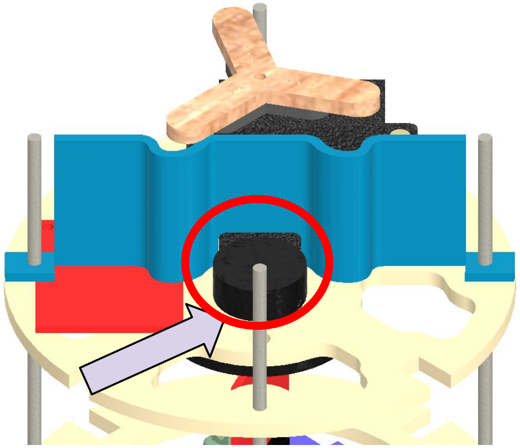
Mechanical Subsystem Changes Since PDR (7 of 8)

Rotating Camera Slip Ring

Old Design



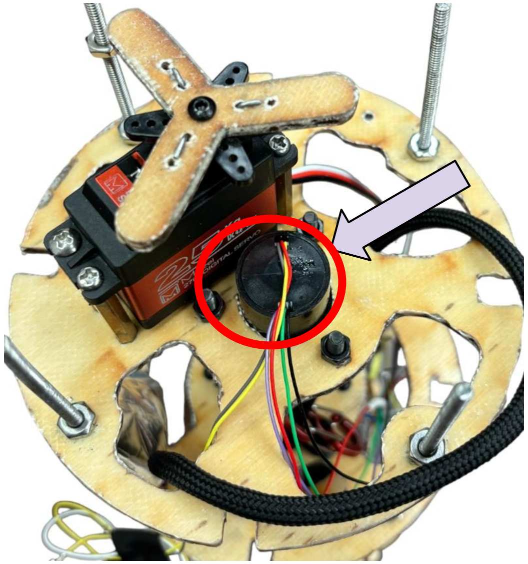
New Design



Changes

- A slip ring was added to the parachute layer and is connected to the rotating camera.

Test Launch Prototype



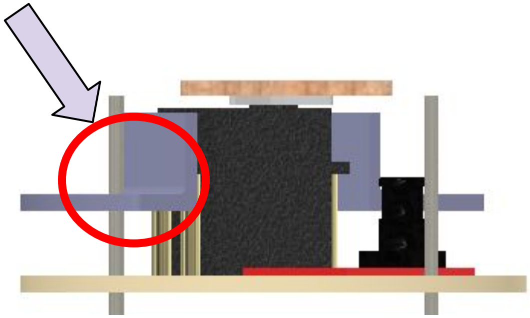
Rationale

- Helps prevent the camera wires from tangling while its rotating.
- Increased stability of camera motor mount to reduce oscillation during flight.

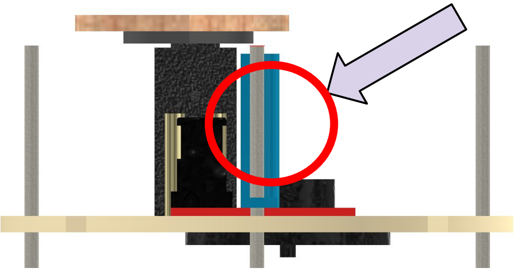
Mechanical Subsystem Changes Since PDR (8 of 8)

Parachute Layer

Old Design



New Design



Changes

- PETG 3D printed parachute layer(purple) has been removed and does not exist on our current design.
- A PETG 3D printed divider(blue) has been added to separate the motor and the parachute.

Test Launch Prototype

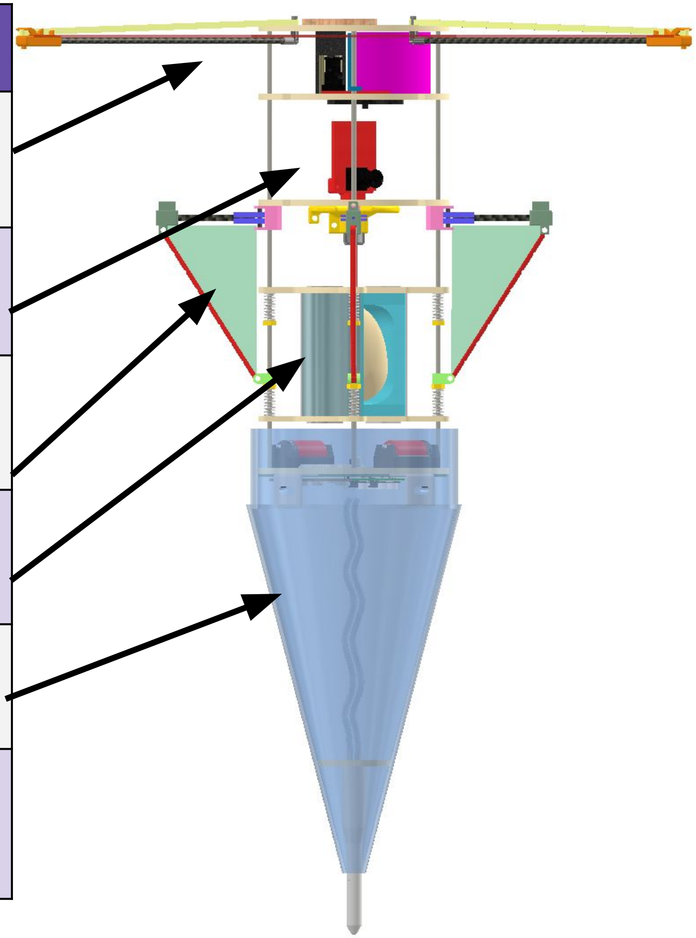
Rationale

- Removing the layer reduces mass and allows more room for the parachute to be stored.
- Adding in the divider ensures that the parachute won't get caught on the aerobrake release mechanism.

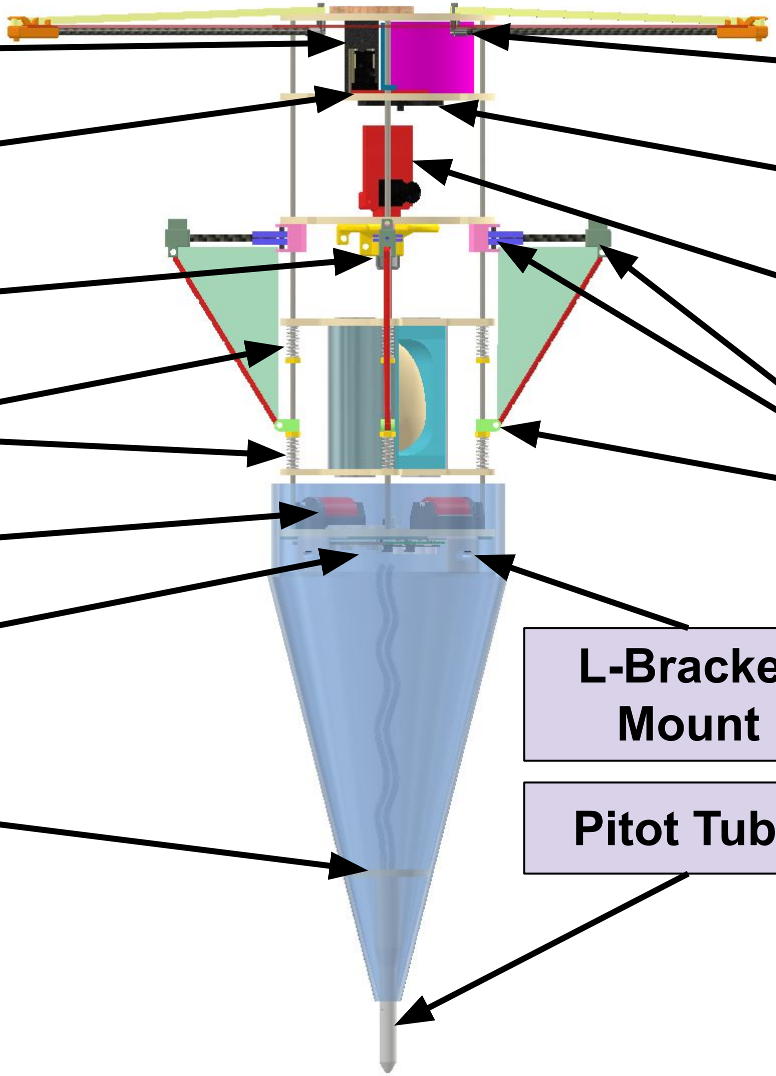
Payload Mechanical Layout of Components (1 of 9)

Key Features and Structural Materials

Key Feature	Structural Material
Aerobrake	Zinc-Plated Brass Hinged Standoffs, Circular Carbon Fiber Rods, 3D printed PETG
Rotating Camera Mount	3D printed PETG
Stabilization Fins	Fiberglass Sheet, Square Carbon Fiber Rods, 3D printed PETG
Egg Container	Fiberglass Composite Plywood, Fiberglass Sheet, Springs
Nose Cone	Fiberglass
Payload Structure	Fiberglass Composite Plywood, Threaded Steel Rods, Aluminum Nuts, Steel Screws



Payload Mechanical Layout of Components (2 of 9)



Servo

Bonus Camera

Brushed Motor

Springs

Batteries

PCB

Pitot Tube Mounting Plate

Aerobrake Hinge

Slip Ring

Rotating Camera

PETG Stabilization Fin Hinges

L-Bracket Mount

Pitot Tube

Note:

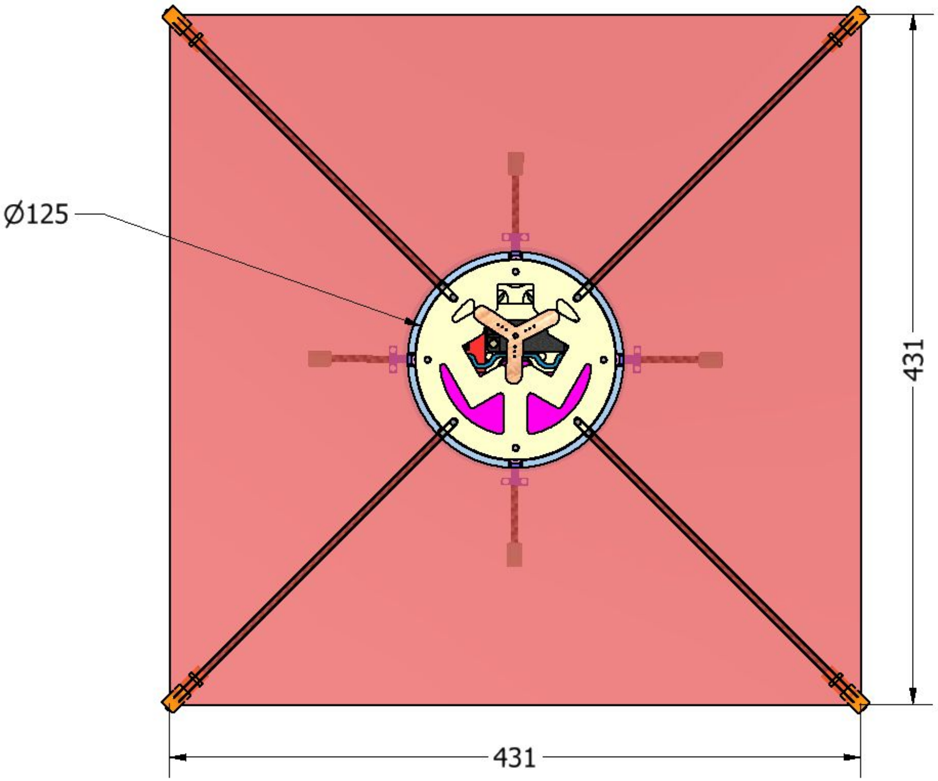
PCB Includes:

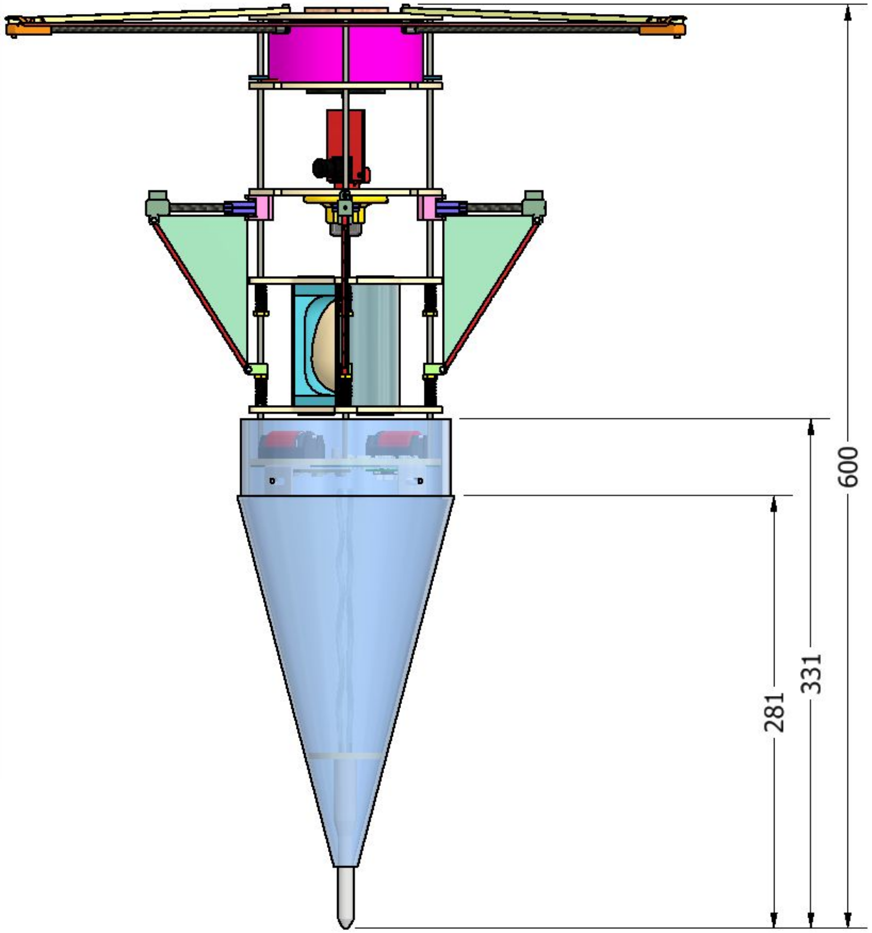
- **Teensy (CDH)**
- **Radio and Antenna**
- Adafruit BMP390
- SparkFunMax-M10S
- PixHawk PX4 Airspeed Sensor
- Adafruit BNO055
- Easily accessible on/off switch
- LED and buzzer

Payload Mechanical Layout of Components (3 of 9)

Note:
All dimensions are in mm.

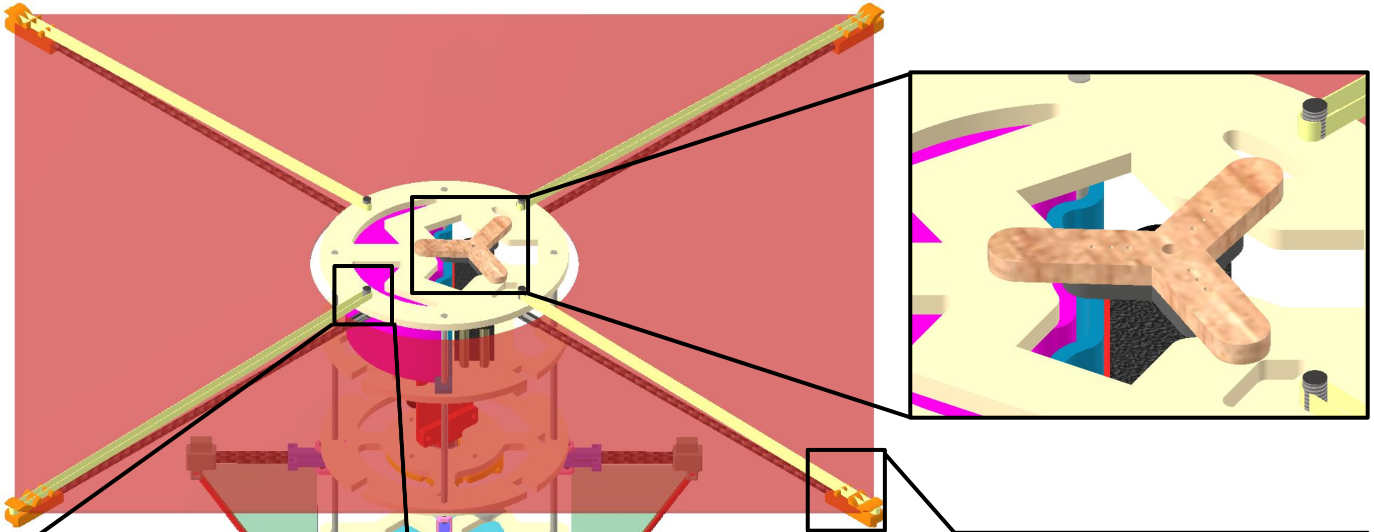
Overall Dimensions

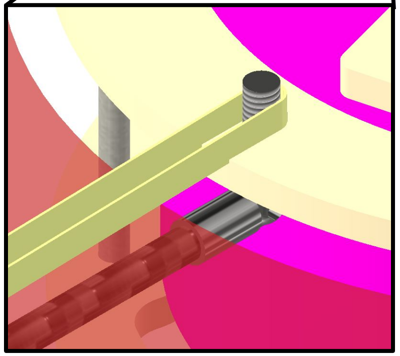


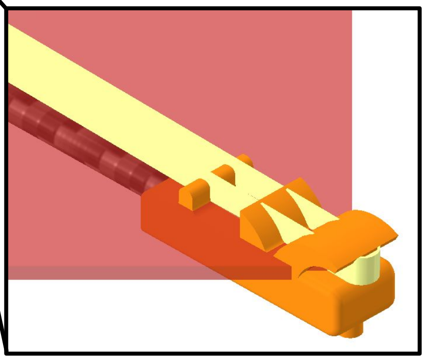


Payload Mechanical Layout of Components (4 of 9)

Aerobrake Component Locations







Aerobrake Release Mechanism

- Composite wood ‘star’ mounted to servo.
- Rotates 60 Degrees.
- Rotates twice to ensure aerobrake detachment.

Aerobrake Arm Mechanism

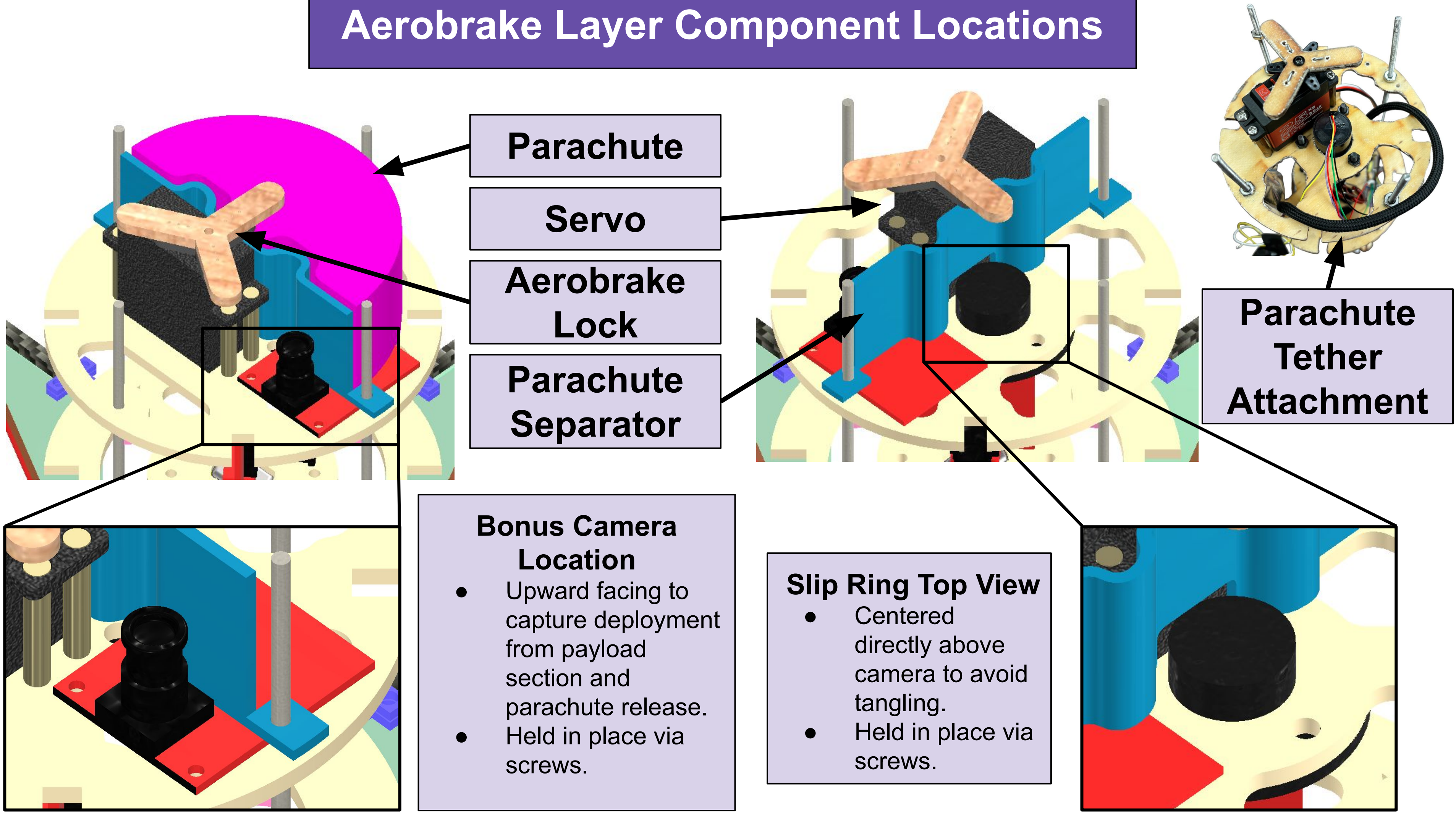
- Hinged standoff mounted to payload.
- Deployed by tension from rubber band and wind from descent.

Aerobrake Arm Attachment

- PETG 3D printed attachment to cylindrical carbon fiber arm.
- Rubber band attached to add tension for automatic deployment.

Payload Mechanical Layout of Components (5 of 9)

Aerobrake Layer Component Locations



Bonus Camera Location

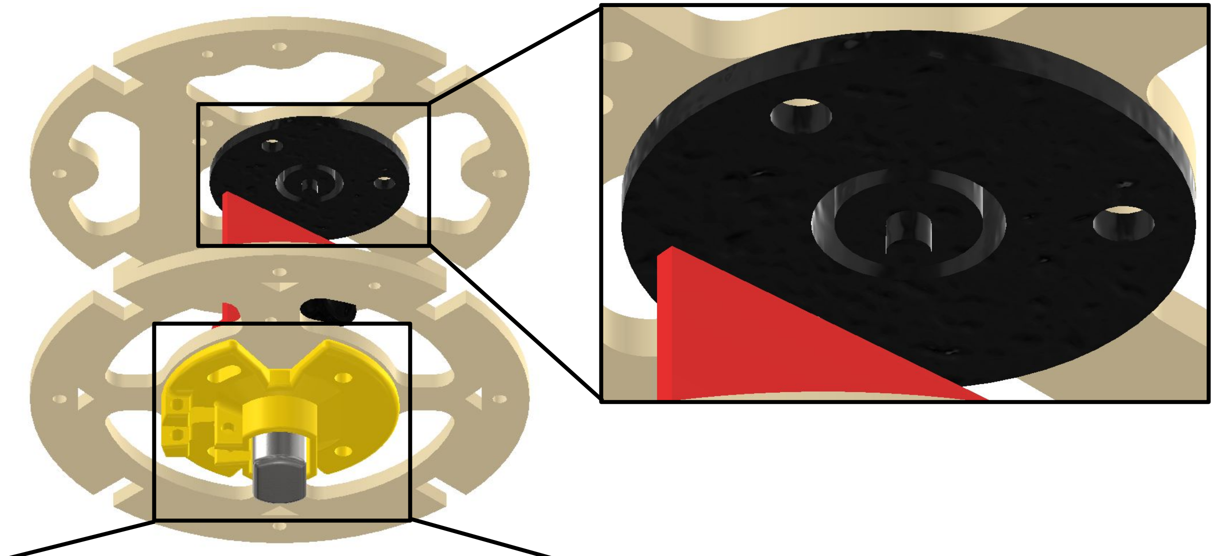
- Upward facing to capture deployment from payload section and parachute release.
- Held in place via screws.

Slip Ring Top View

- Centered directly above camera to avoid tangling.
- Held in place via screws.

Payload Mechanical Layout of Components (6 of 9)

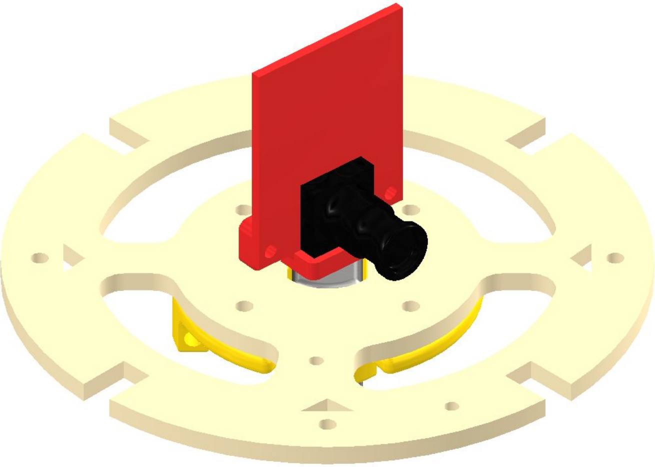
Rotating Camera Mount

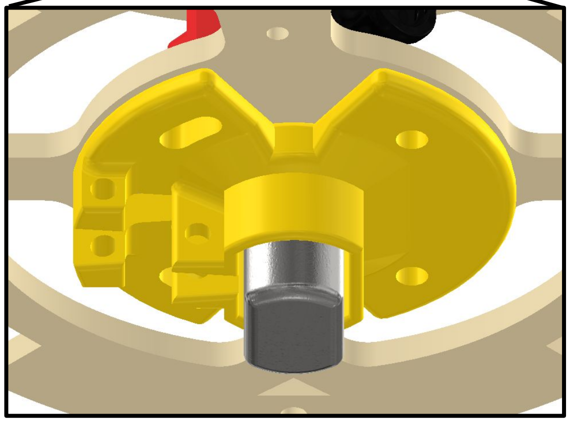


Slip Ring Bottom View

- Wires run from slip ring onto the mounted rotating Camera for seamless integration and rotation.

Rotating Camera Top View





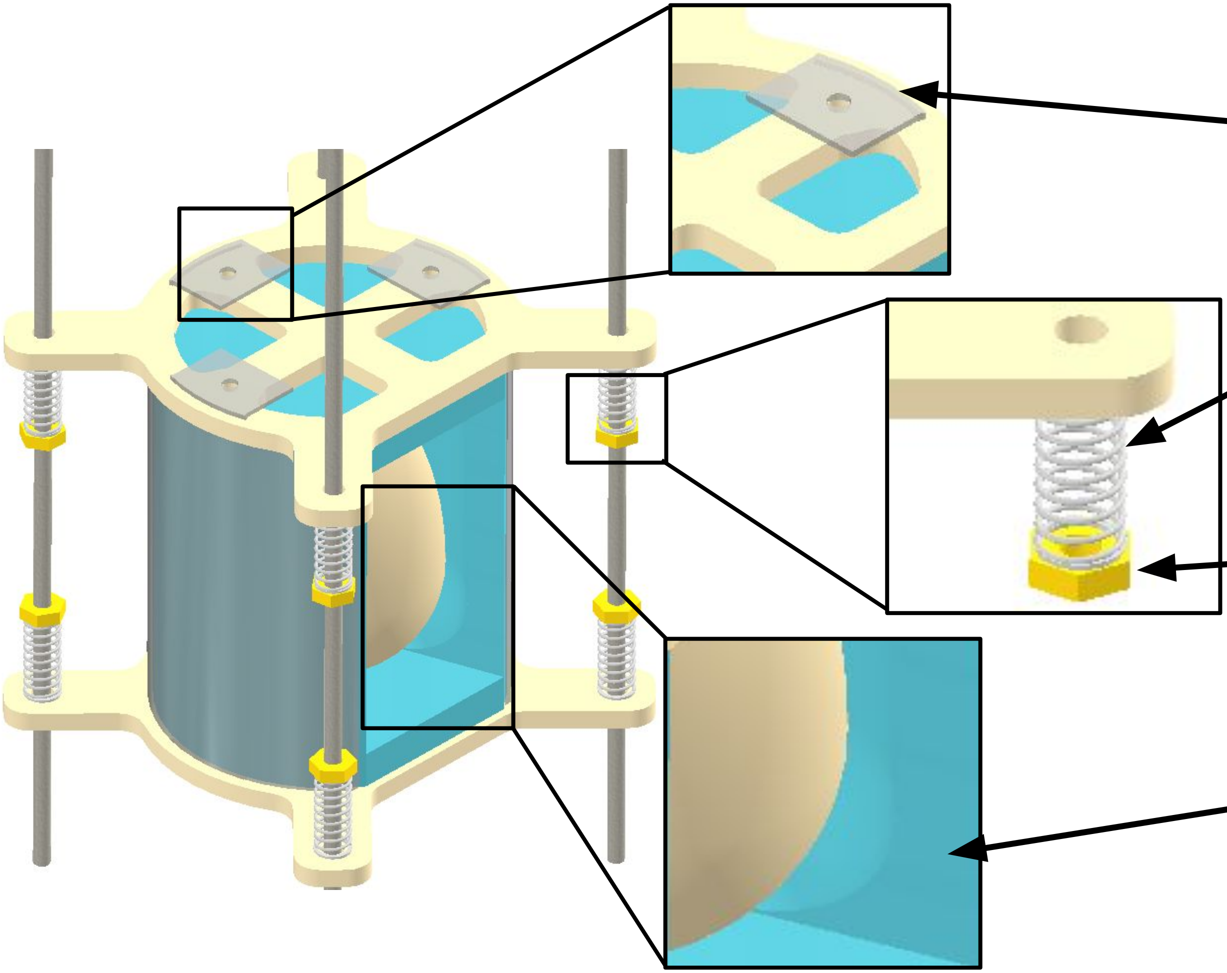
Brush Motor Mount

- PETG 3D printed to precisely fit the dimensions of our motor.
- Attached via screws for seamless and stealth like integration.

Payload Mechanical Layout of Components (7 of 9)

Egg container

Egg Container



Fiberglass Sheets

- Held in by nuts and bolts.

Aluminum Springs

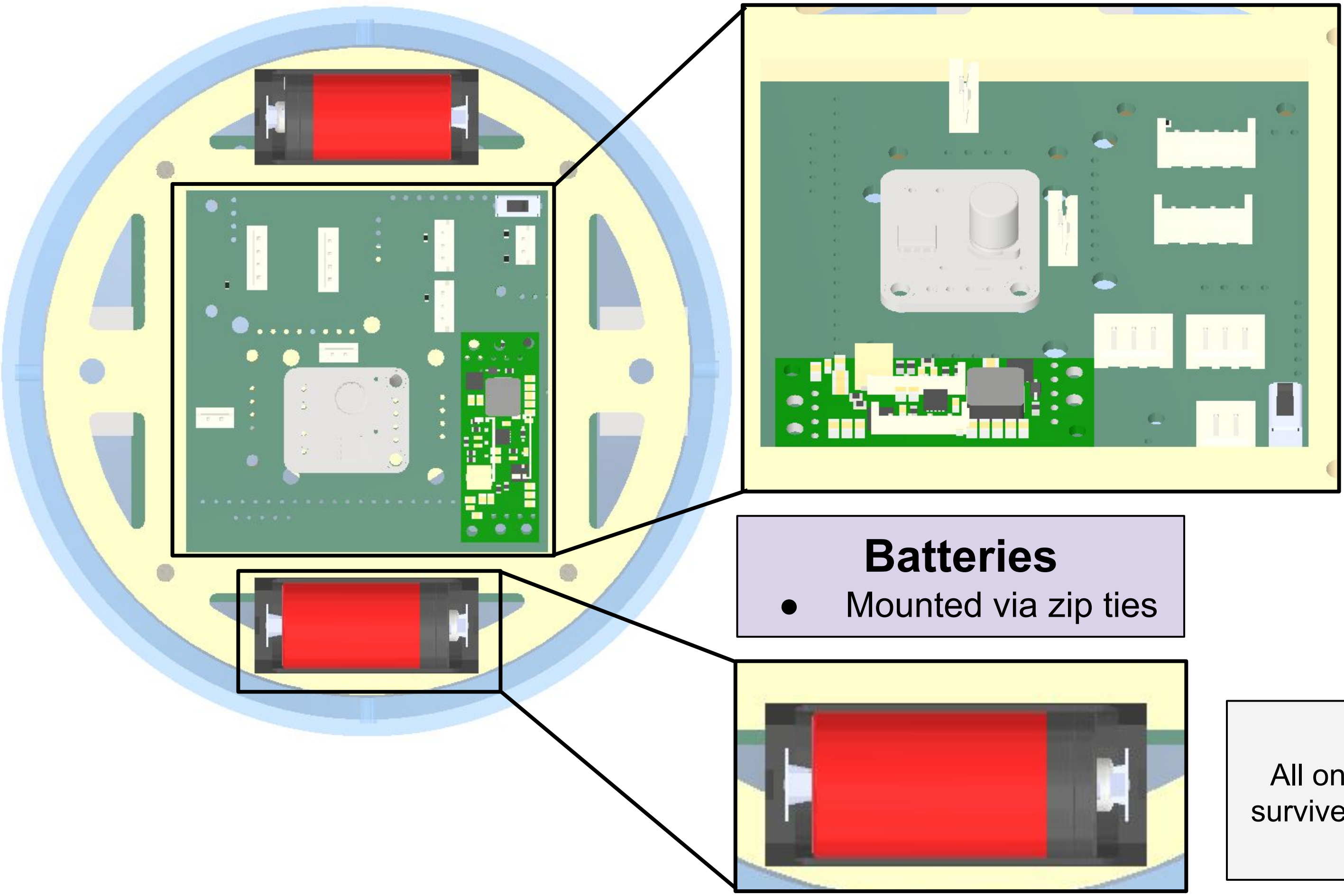
Aluminum Nuts

- Nuts are used to both secure the spring and canister into place.

Memory Foam

Payload Mechanical Layout of Components (8 of 9)

PCB Location and Components



PCB

- Mounted via threaded rod frame and nuts.
- All sensors are mounted to the PCB.

Note:

PCB Includes:

- Adafruit BMP390
- SparkFunMax-M10S
- PixHawk PX4 Airspeed Sensor
- Adafruit BNO055
- Easily accessible on/off switch
- LED and buzzer
- Teensy (CDH)
- Radio and Antenna

Batteries

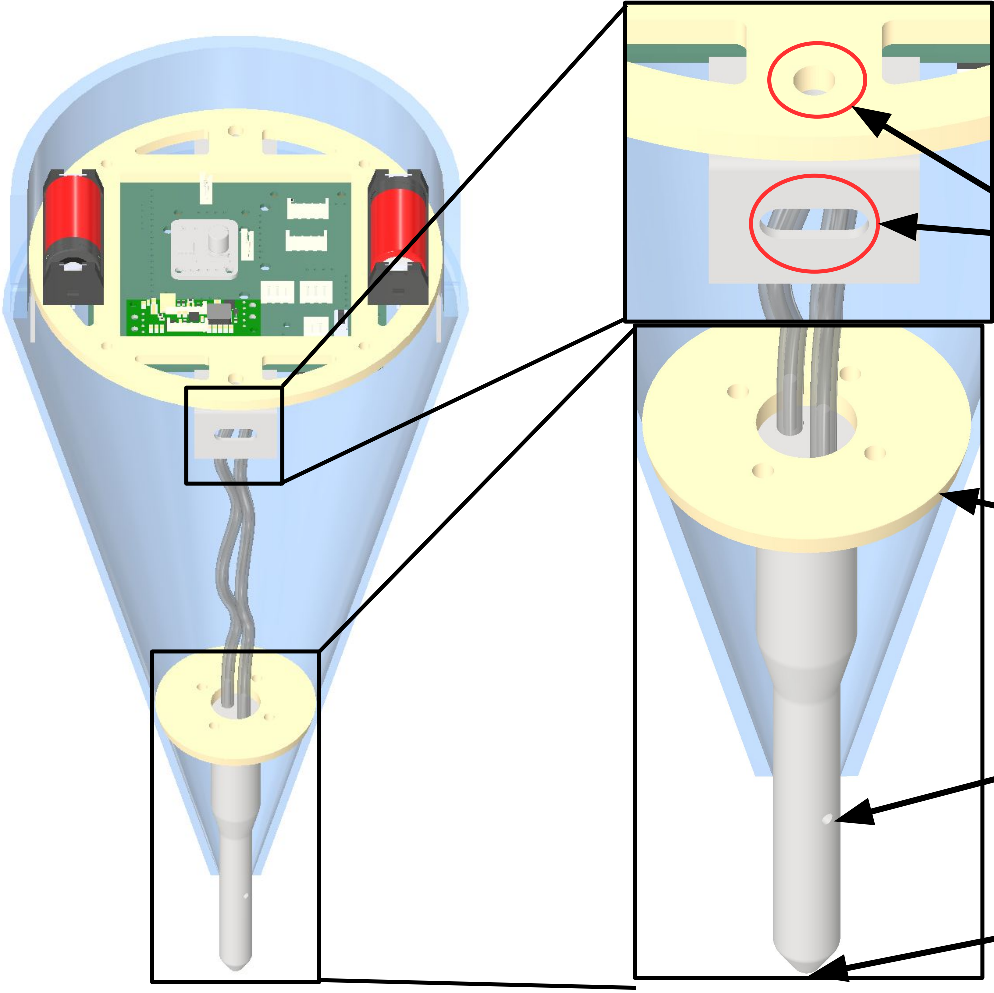
- Mounted via zip ties

Note:

All on board electrical components survived and remained mounted after a test flight

Payload Mechanical Layout of Components (9 of 9)

Nose Cone and Pitot Tube Component Locations



L-Bracket Nose Cone Attachment to Payload

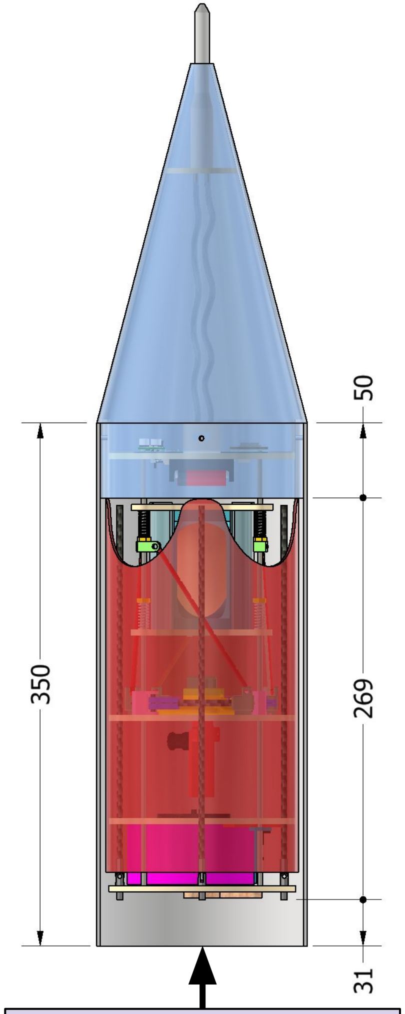
- PETG 3D printed L-bracket attached to nose cone via screws through the horizontal hole on y-axis.
- Nose cone attached to payload via screws through hole on z-axis.

Pitot Tube Mounting Plate

Static Pressure Hole

Stagnation Pressure Hole

Payload Aerobraking Pre Deployment Configuration



Rocket Body

Note:
All dimensions are in mm.

Frictionally Stowed

- Friction between the shoulder and the payload section will keep our CanSat in the stowed configuration during ascent.
- Verified frictional storage during a test flight.
- No changes since PDR.

Stowed Components

- Aerobrake: The walls of the payload section will keep the aerobrake arms from deploying.
- Internal Components: These are stored rigidly using screws and bolts while not possessing any sharp protrusions.
- No Changes from PDR.

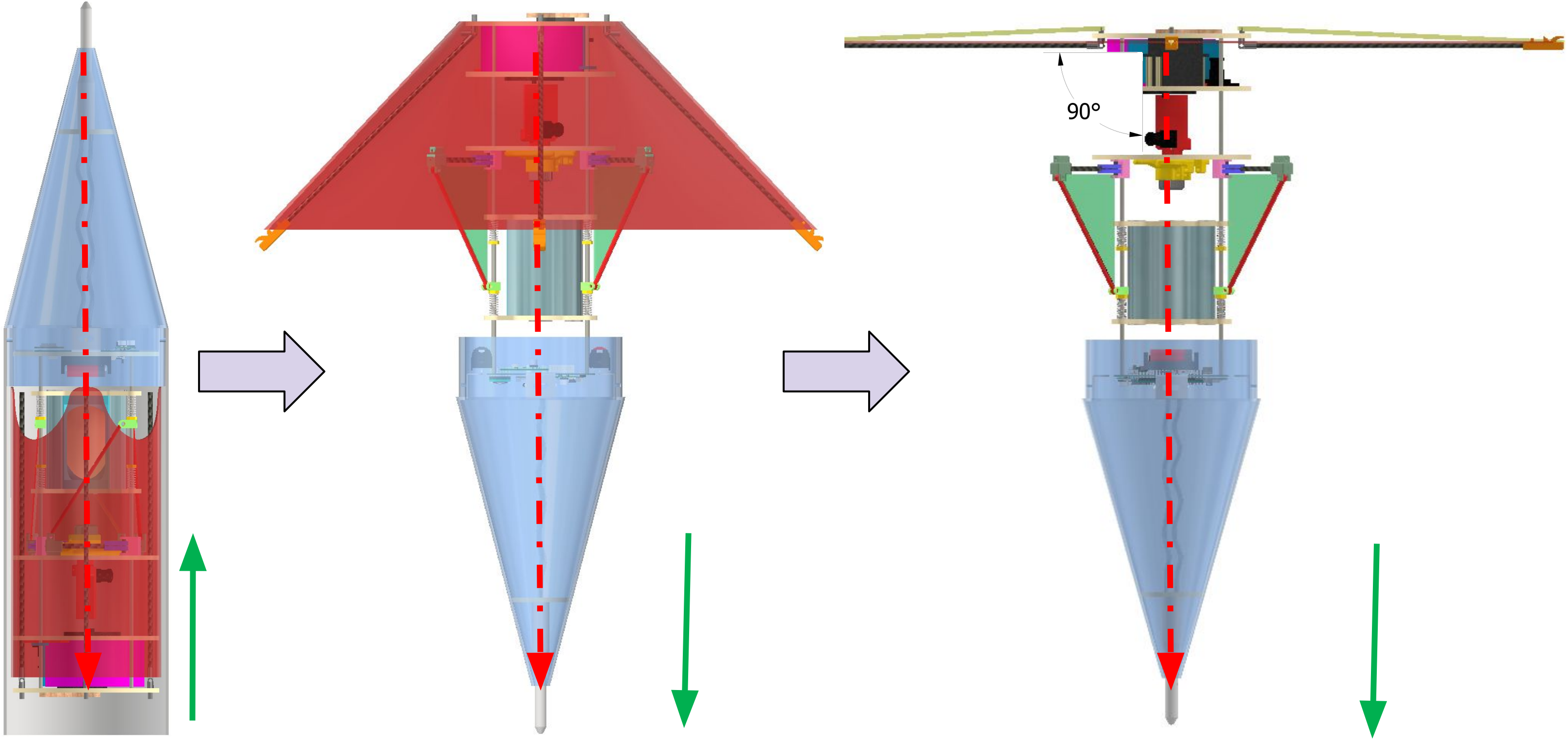
Payload Aerobraking Deployment Configuration (1 of 2)

🟩 Direction of Travel

🟥 Nadir

Aerobrake Order of Operations

Note:
Aerobrake is passively deployed using rubber bands



Pre-Deployment
(in rocket airframe)

Transitional Phase

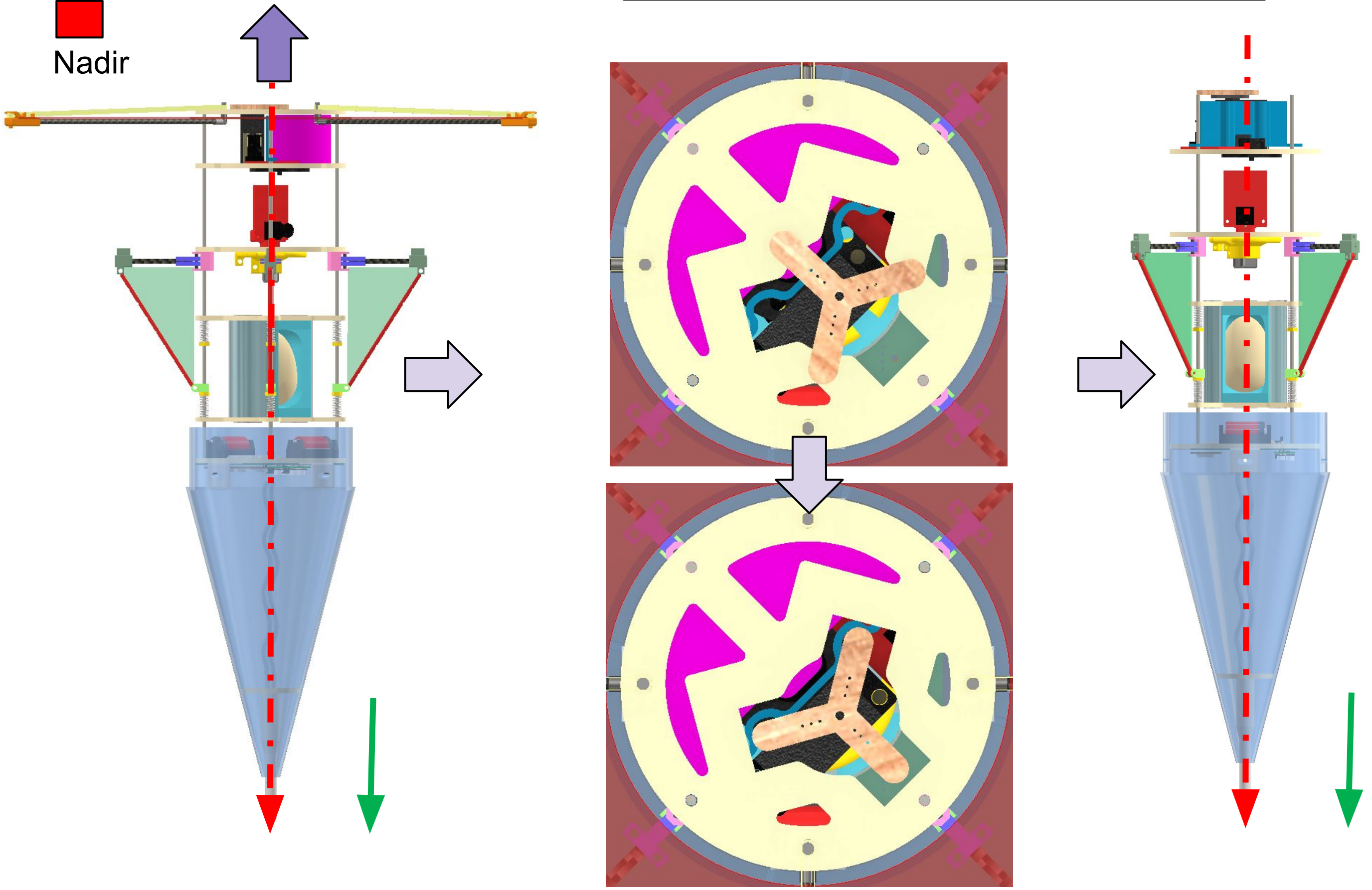
Deployed

Payload Aerobraking Deployment Configuration (2 of 2)

🟩 Direction of Travel

🟥 Nadir

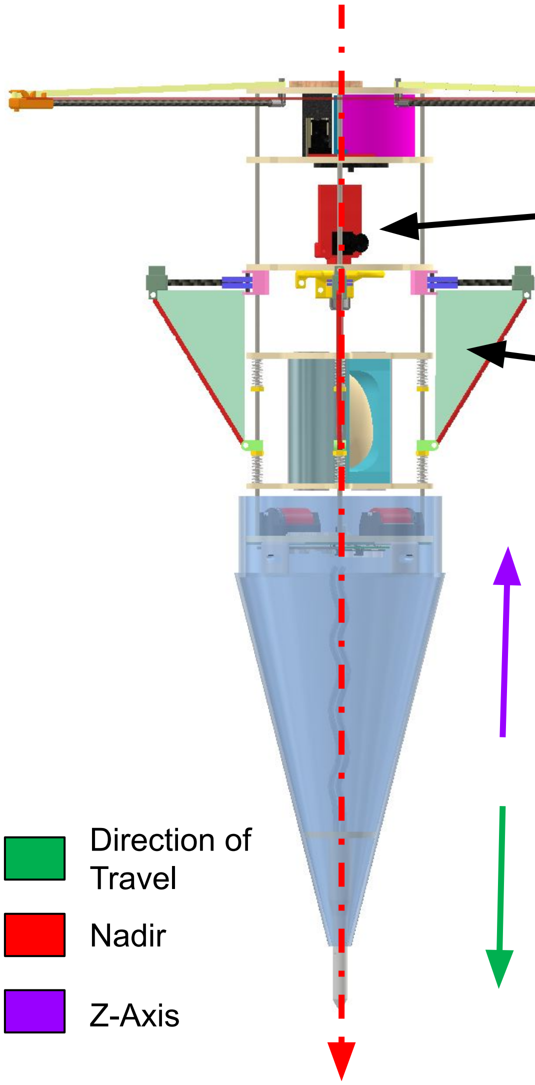
Aerobrake Release Order of Operations

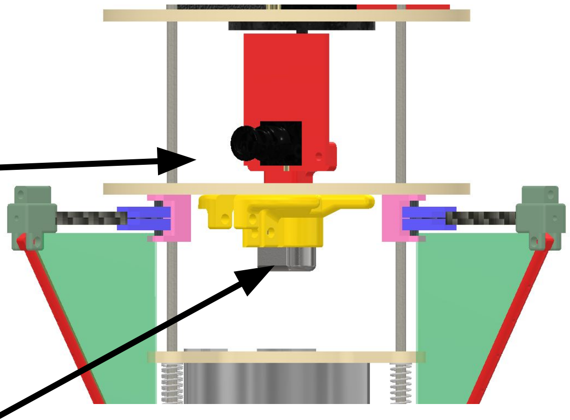


Release Mechanism

The aerobrake plate is held in by a servo with an attachment on the end of it. During its release, the servo will turn until it falls through the aerobrake plate. This causes the aerobrake plate to be forced off by air pressure.

Camera Pointing Control



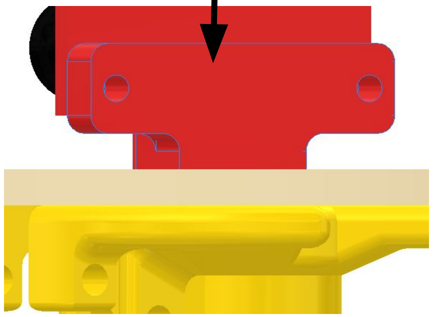


Active Z-Axis to Horizon Rotating Camera

Stabilization Fins

Brushed Motor

3D Printed Camera Mount



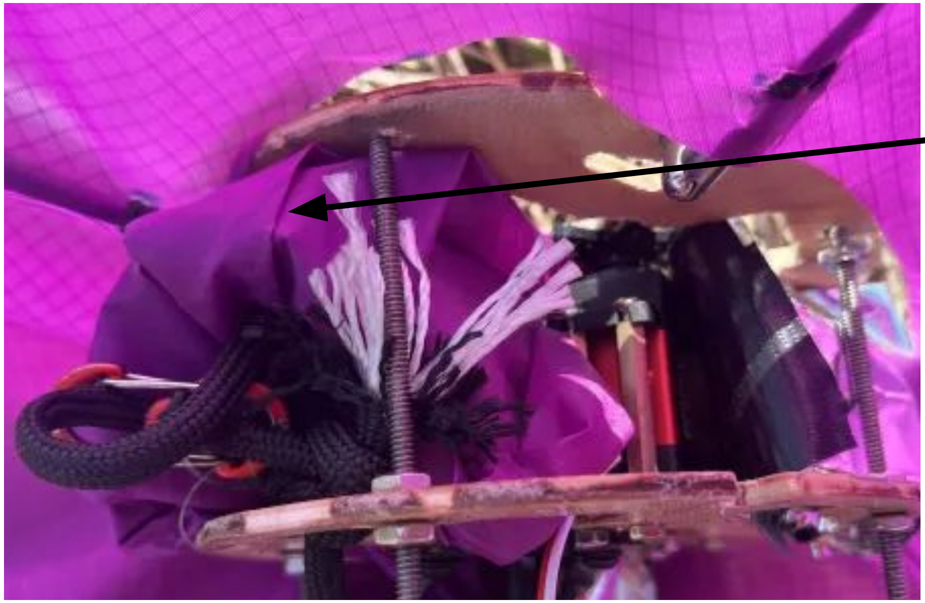
🟩 Direction of Travel

🟥 Nadir

🟪 Z-Axis

Payload Parachute Deployment Configuration (1 of 2)

Stowed and Attached

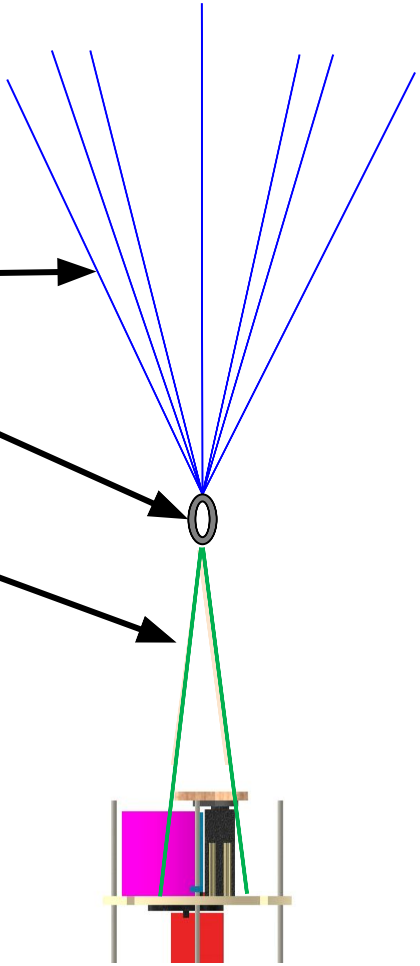


Nylon Fabric

Fishing Line

Metal O-Ring

Paracord



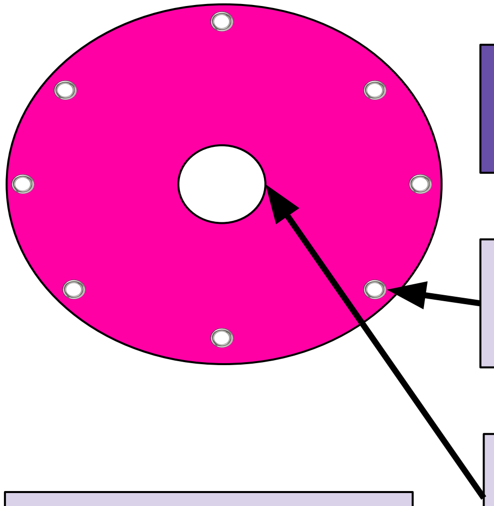
Storage

- Frictionally stored under released layer and on layer with servo and slip ring. Uses a divider to avoid tangling with servo head.
- Folded into a pizza shape with all rope and string inside the fold.

Attachment

- Paracord tied under parachute layer to threaded rod.
- Metal o-ring links four strings of paracord to fishing line.
- Fishing line attaches to grommets.

Payload Parachute Deployment Configuration (2 of 2)



Release and Deployed

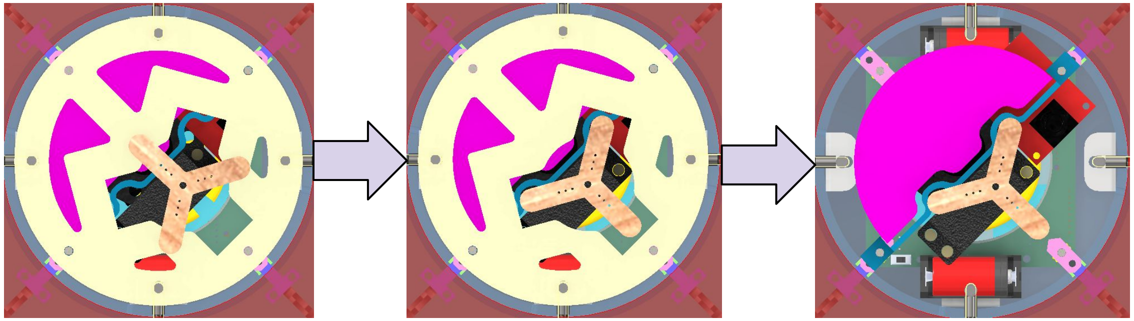
Grommets
- 8 total

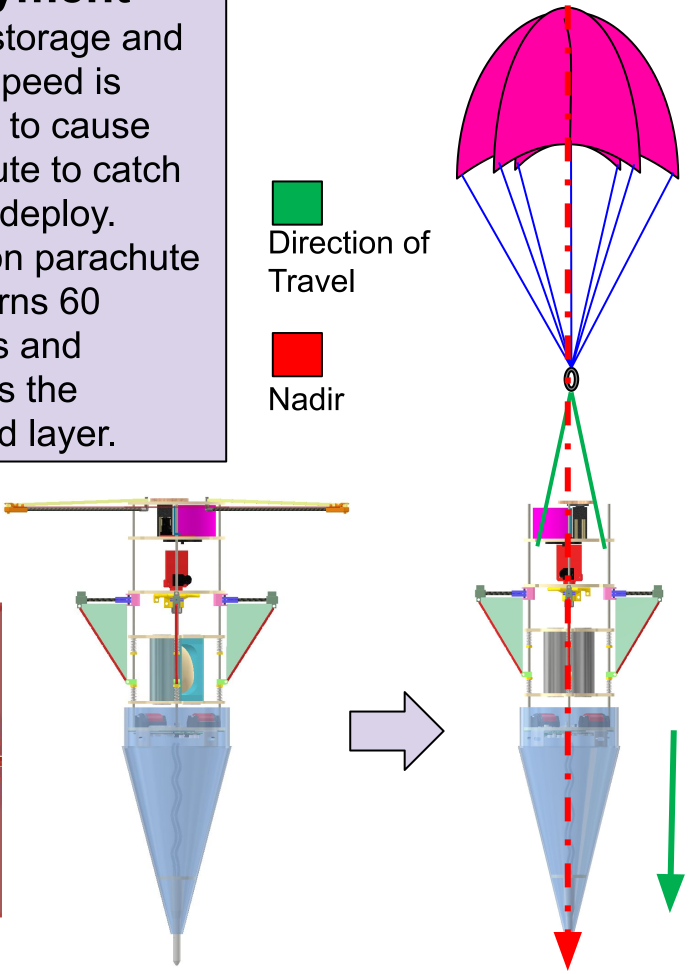
Spill Hole
- 114mm diameter

Deployment

- Loose storage and falling speed is enough to cause parachute to catch air and deploy.
- Servo on parachute layer turns 60 degrees and releases the released layer.

Aerobrake Release Order of Operations

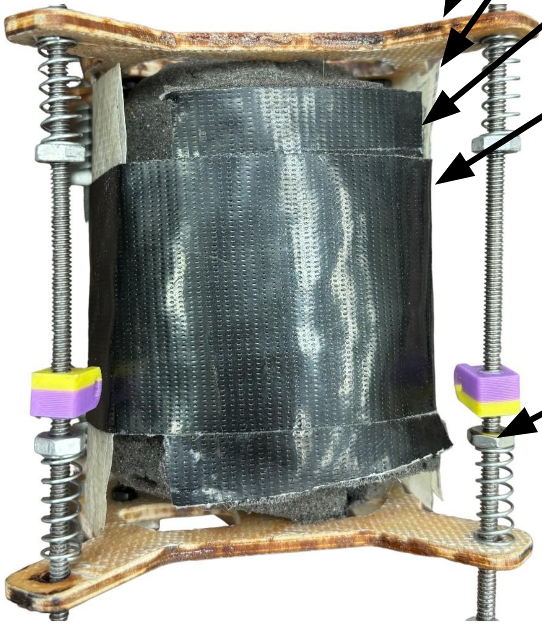




🟩 Direction of Travel

🟥 Nadir

Payload Egg Containment Configuration



Fiberglass Plates (2 total)

Fiberglass Sheets (2x layers)

- The door is duct-taped on.

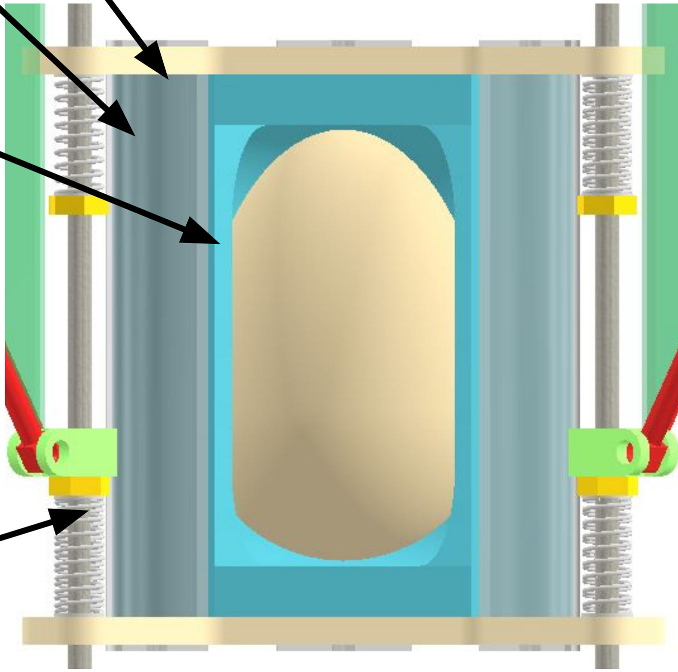
Foam (dark grey or blue)

Tape (black)

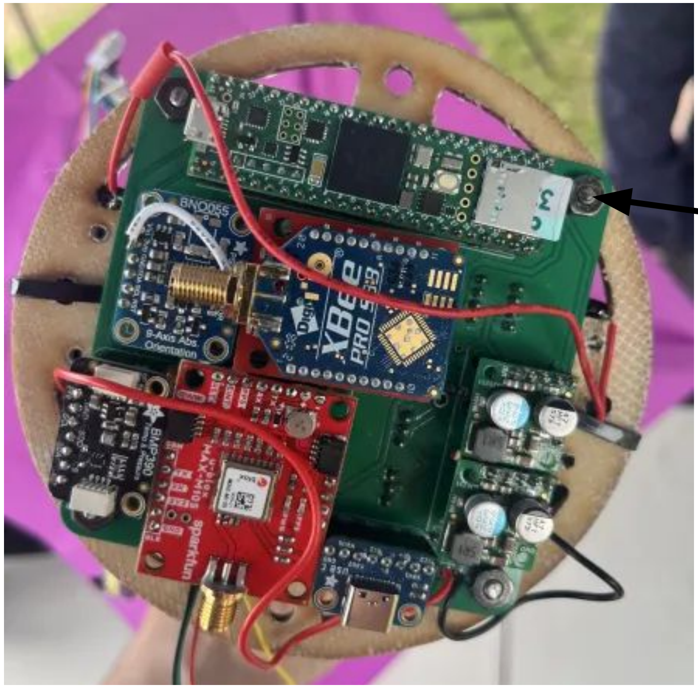
Springs and Nuts

- Springs(silver) are used as an extra shock absorbent for the entire canister.
- Nuts(gold) are used to both secure the spring and canister into place.

Note:
Not depicted: an extra layer of foam acting as a door. This is secured with duct tape

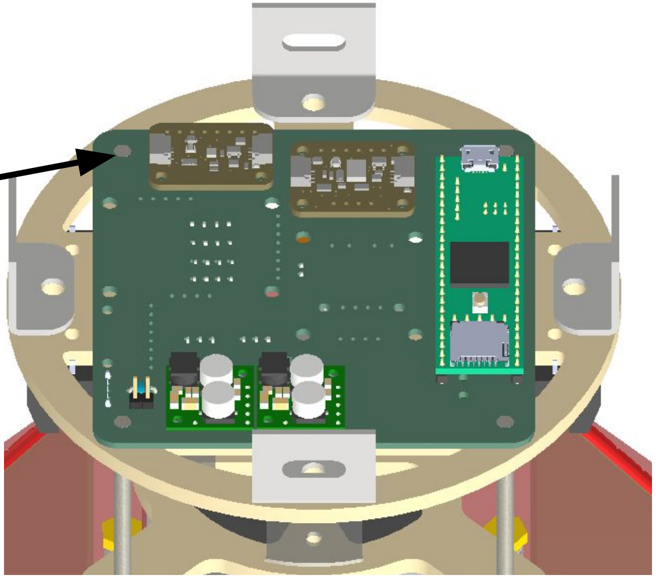


Structure Survivability (1 of 3)

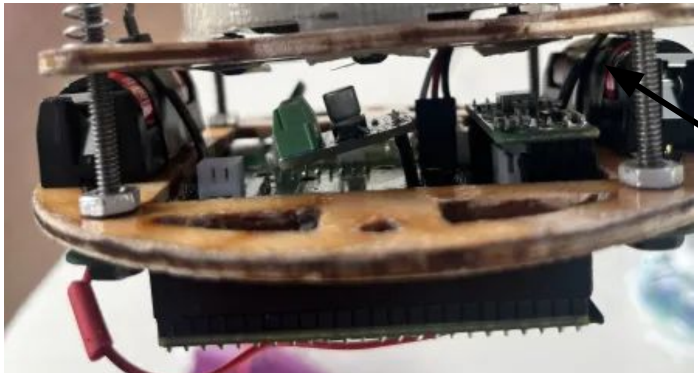


PCB Mount

- Mounted directly to composite wood via threaded rod frame. Locked in place with Loctite.
- Stored inside nose cone.

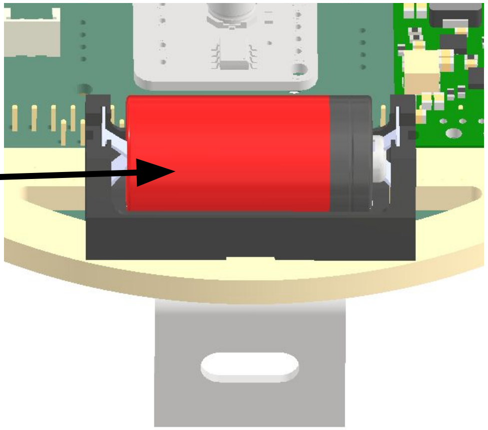


Note: All electronics survived a test flight and were not dislodged

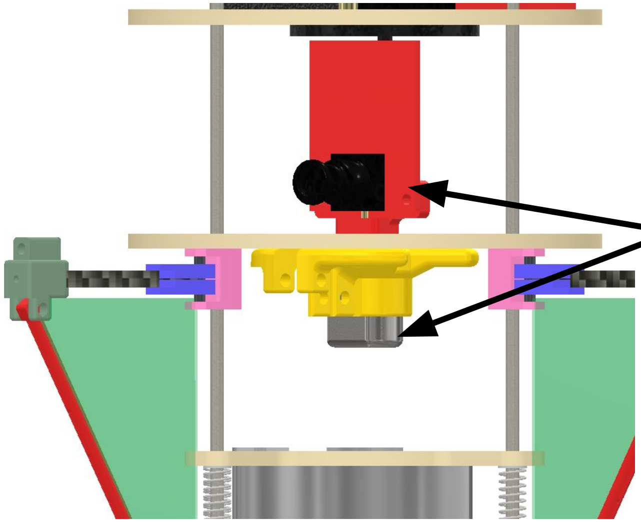


Battery Mount

- Mounted using zip ties around composite wood and electrical tape.
- Stored inside nose cone.

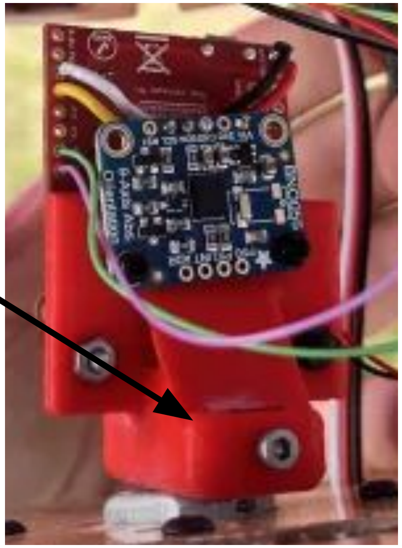


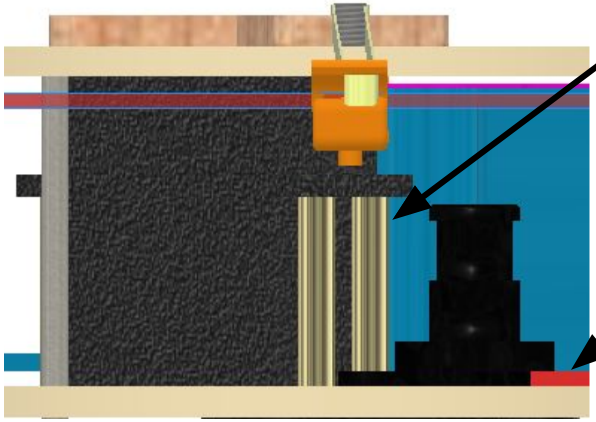
Structure Survivability (2 of 3)



Camera and Motor Mount

- Mounted via nuts and bolts.
- Tightened via screw (single screw in the back).
- Motor is clamped in place.





Servo Mount

- Mounted via standoffs and Loctite.

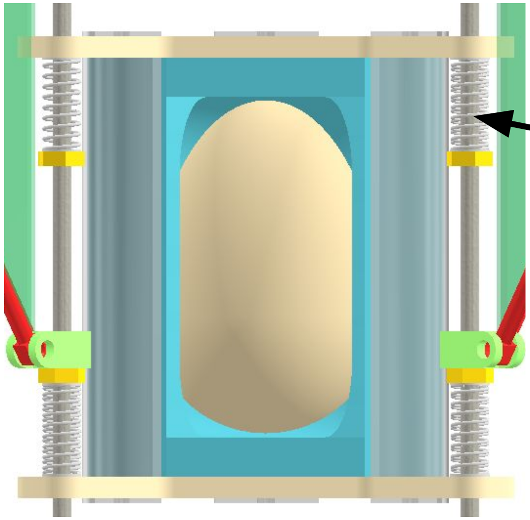
Bonus Camera Mount

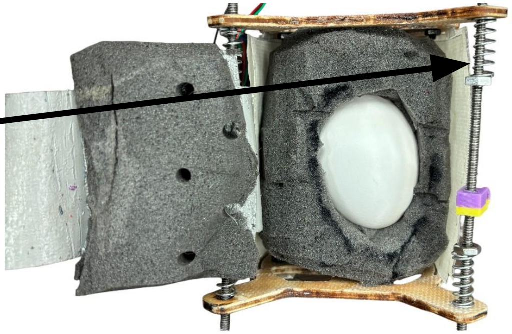
- Mounted via nuts and bolts.

Testing

- Drop Test: CanSat survived a 61cm drop and full test flight verifying we meet requirement S7
- Vibration Test: CanSat survived 5 intervals of 5 seconds at ~14,000opm and test flight verifying we meet requirement S6

Structure Survivability (3 of 3)

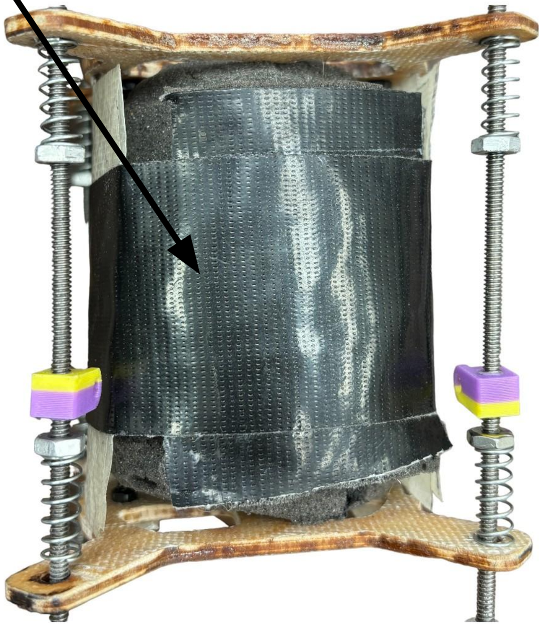




Egg Container

- Spring suspension gives a restricted oscillation range
- Door attached via duct tape

Note:
The egg and nose cone survived test flight



Nose Cone

- Mounted via threaded rod and l-brackets (threaded rod extruded through nose cone)

Mass Budget (1 of 3)

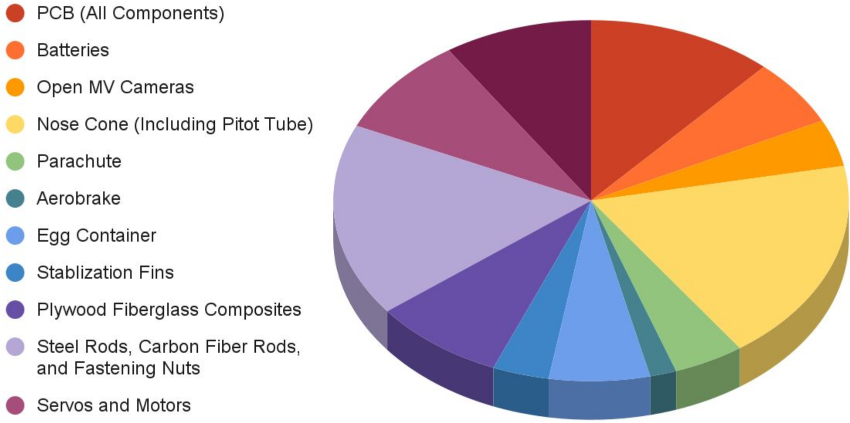
Part	Quantity	Mass (g)	Total Mass (g)	Uncertainty (g)	Source
Teensy 4.1	1	32.1	32.1	-	Datasheet
BNO055	1	3	3	-	Datasheet
MAX-M10S and Antenna	1	30	30	± 0.5	Estimate
BMP 390	1	3	3	-	Datasheet
PixHawk Airspeed Sensor	1	3.5	3.5	-	Datasheet
Open MV Camera	2	19	38	-	Datasheet
PCB	1	30	30	-	Datasheet
Battery	2	27	54	-	Datasheet
XBee Explorer Board	1	5	5	-	Datasheet
3.3V Regulator	1	2.3	2.3	-	Datasheet
5V Regulator	1	2.3	2.3	-	Datasheet
Switch	1	1.8	1.8	-	Datasheet
USB C Umbilical	1	1.3	1.3	-	Datasheet
LED	1	7.4	7.4	-	Datasheet
Buzzer	1	8	8	-	Datasheet
12V Regulator	1	3.6	3.6	-	Datasheet
Motor Driver	1	2.2	2.2	-	Datasheet
Pitot Tube	1	25	25	-	Datasheet
270° Servo	1	60	60	-	Datasheet
Brushed Motor	1	20	20	-	Datasheet
Total Electrical Basic Mass			**332.5**	**0.5**	**Estimate**

Mass Budget (2 of 3)

Part	Quantity	Mass (g)	Total Mass (g)	Uncertainty (g)	Source
Nosecone	1	140	140	± 0.5	Measured
Parachute	1	40	40	± 0.5	Estimate
Aerobrake	1	15	15	± 0.5	Estimate
Rubber Bands	4	1	4	± 0.5	Estimate
Rubber Band Clips	4	1	4	± 0.5	Estimate
Parachute Divider	1	11	11	± 0.5	Estimate
Slip Ring	1	7	7	-	Datasheet
Motor Mount	1	12	12	± 0.5	Estimate
Stabilization Fins	4	8	32	± 0.5	Estimate
Plywood Fiberglass Composites	5	15	75	± 0.5	Estimate
Steel Rod	4	16	64	± 0.5	Estimate
Carbon Fiber Rods	4	13	52	± 0.5	Estimate
Fastening Nuts	40	1	40	-	Datasheet
Egg Container	1	57	57	-	Datasheet
Springs	8	1	8	± 0.5	Estimate
Nose Cone Mounting Brackets	4	2	8	± 0.5	Estimate
Total Structural/Aerodynamic Basic Mass			**569**	**6.5**	**Estimate**

Mass Budget (3 of 3)

Category	Mass (g)
Total Electrical Basic Mass	332.5
Total Structural/Aerodynamic Basic Mass	569
CanSat Basic Mass	901.5
Total Uncertainty	7
Total Estimated CanSat Mass	**908.5**
Margin	-8.5



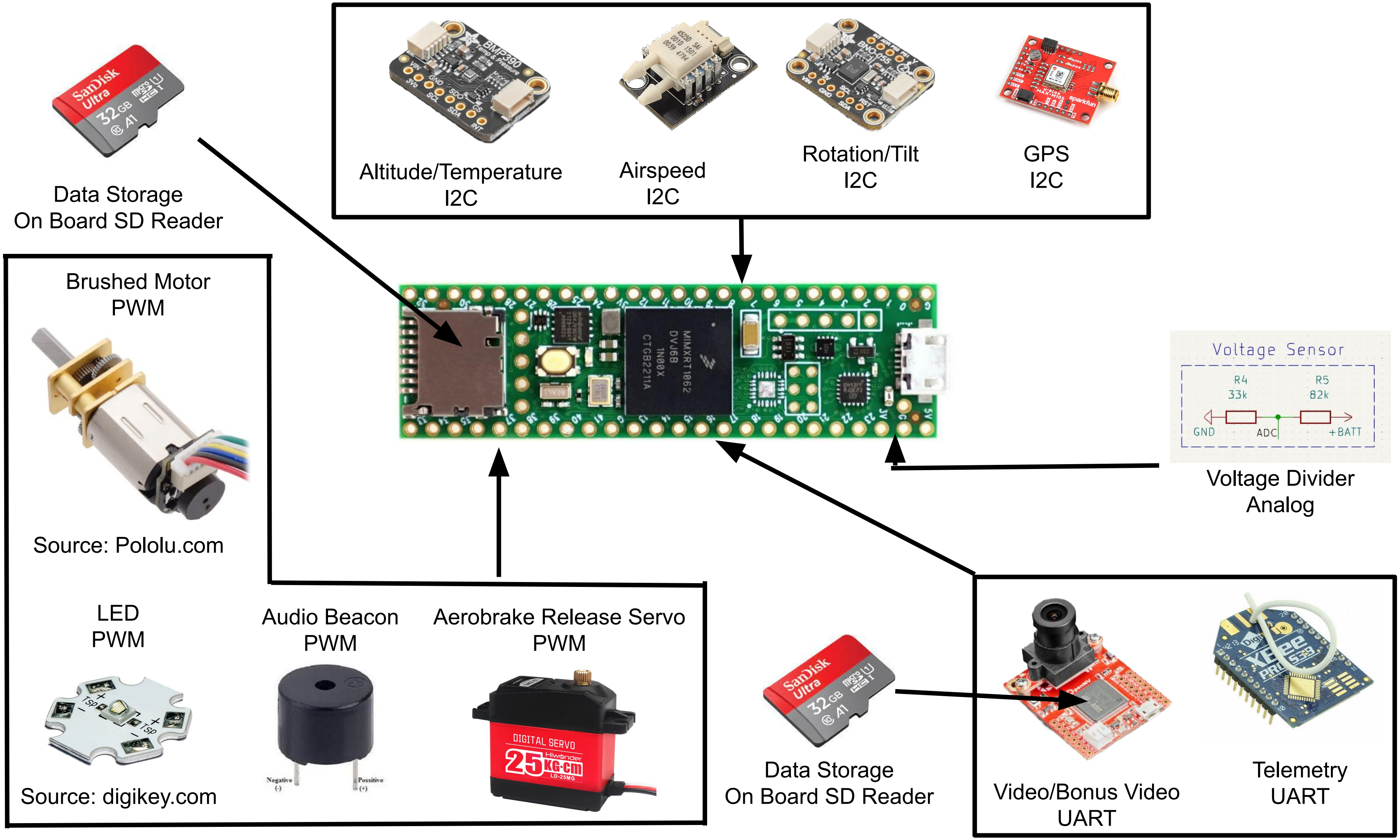
At this time, the payload **is within** the the mass tolerance of 900 grams ±10 grams.

- In the event that the payload is overweight, we will save weight through the composite manufacturing process of the nose cone, composite sandwich layers, and egg canister. The aerobrake release servo can be swapped with a lighter one if necessary.
- In the event that the payload is underweight, additional mass can be added with 3D printed weight brackets that will attach to the composite sandwich layers.

Communication and Data Handling (CDH) Subsystem Design

Arel Urbanozo, Madeline Teer

CDH Overview



Altitude/Temperature
I2C

Airspeed
I2C

Rotation/Tilt
I2C

GPS
I2C

Data Storage
On Board SD Reader

Brushed Motor
PWM

Source: Pololu.com

Voltage Divider
Analog

LED
PWM

Source: digikey.com

Audio Beacon
PWM

Aerobrake Release Servo
PWM

Data Storage
On Board SD Reader

Video/Bonus Video
UART

Telemetry
UART

CDH Changes Since PDR

Part	PDR	CDR	Rationale
Telemetry	No Self Reported Telemetry Data	Adding PID controller state	To help test and properly track the accuracy of the PID controller for the camera
Test Reports	● Successful telemetry communication ● Successful sending of packets		

Payload Processor & Memory Selection (1 of 2)

Processor	Boot Time (ms)	Power Consumption (mW)	Data Bus Width	Processor Speed (MHz)	Comm. Types	RAM (kB)	Decision Matrix Weight	Cost
Teensy 4.1	20	330	64 Bit	600	8 UART 3 SPI 3 I2C	1024	124	$31.50

Image Credit: pjrc.com

Teensy:
- **Boot Time**
- **Processor Speed**

Image Credit: pjrc.com

Payload Processor & Memory Selection (2 of 2)

Memory Unit	Interface	µSD Card	Flash (MB)	RAM (MB)	Cost
OpenMV Cam H7 R1	On Board SD Slot	64GB	2	1	$84.95
Teensy 4.1	On Board SD Slot	1TB	8	1	$31.50

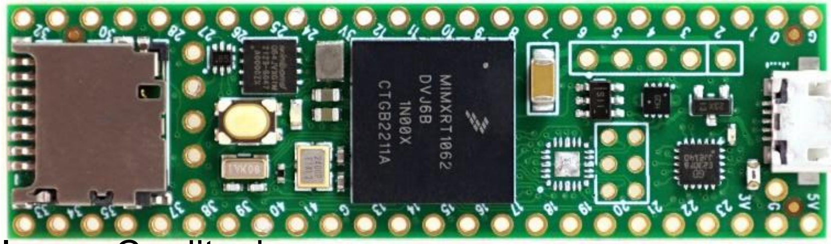


Image Credit: pjrc.com

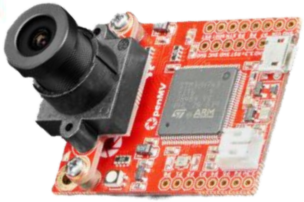


Image Credit: openmv.com

OpenMV and Teensy:

- **Integration**
- **µSD Size**
- **Real time**

Image Credit: adafruit.com & pjrc.com

Payload Real-Time Clock

Unit	Accuracy (ns)	Battery	Battery Capacity (mWh)	Mass (g)	Cost
Teensy 4.1	±1.2	CR2032	705	2.8	$23.80

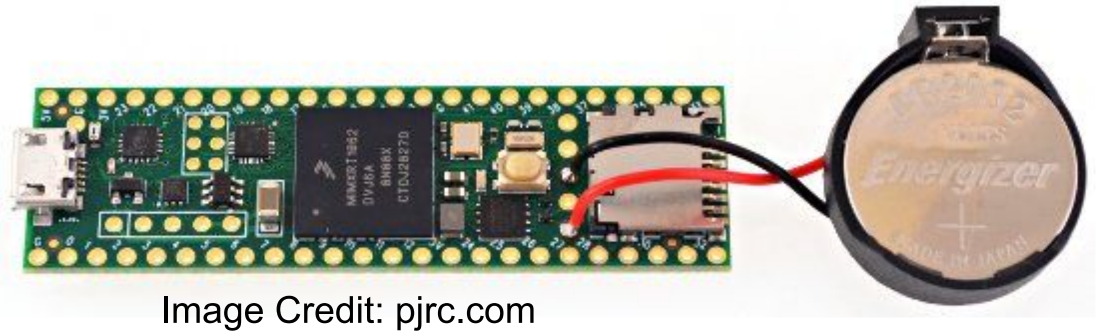


Image Credit: pjrc.com

Teensy:
- **Accuracy**
- **Battery Capacity**

Reset

Payload Antenna Selection

Antenna	Range (GHz)	Gain (dBi)	Mount	Mass (g)	Cost (USD)
Integrated Wire	0.87	1.9	Integrated	Negligible	Integrated

Radiation Pattern

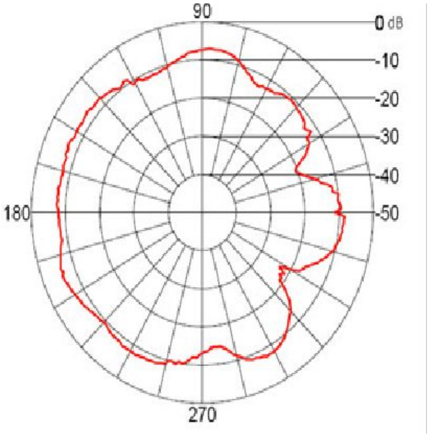


Image Credit: researchgate

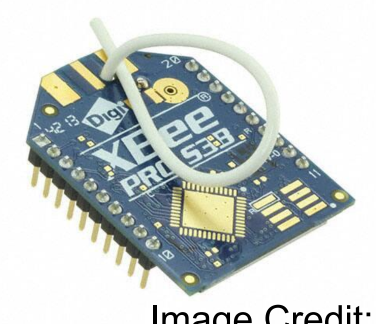


Image Credit: Digikey.com

Integrated Wire:
- Weight
- Cost
- Appropriate Range

Payload Radio Configuration

- **XBEE radio selection:** XBee-Pro 900HP
- **NETID:** 2078
- **Transmission control:**
  - Transmission begins once the payload has received the command cx_on and will transmit telemetry at a rate of 1Hz
  - Transmission will end one the payload has received the command cx_off or the payload has landed
  - The XBee will not be in broadcast mode

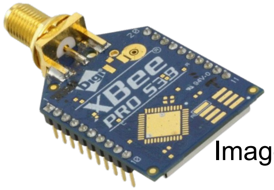


Image Credit: Digikey.com

Testing Methodology	Progress
Short Range (100m)	Completed
Medium Range (400m)	Completed
High Range (700m)	Needs More Testing
Test Launch	Needs More Testing
Integrated In Nose Cone	Completed
GCS Integration	Needs More Testing

XBee	Mode	Destination High	Destination Low
Shockwave	API	13A200	Cybertron Low
Cybertron	API	13A200	Shockwave Low

Payload Telemetry Format (1 of 4)

Telemetry 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>,, <PID_STATE>

Packet Example
“2078,08:13:24.54,814,F,ASCENSION,4,N,N,34,6.7,1013.25,08:13:23,401.56,14.0056,3.6457,1,14.74,96.25,45.01,BCN_ON,, FORWARD”

NOTE:
All packets are sent at a rate of 1Hz over the XBees.

Payload Telemetry Format (2 of 4)

Data Field	Description	Units
<Team_ID>	Identification number	N/A
<MISSION_TIME>	Time since the mission began in UTC	hh:mm:ss.ms ±1s
<PACKET_COUNT>	Packet count since mission began (Data)	N/A
<MODE>	Payload and Ground Station Mode (Flight and Simulation)	N/A
<STATE>	State of the software (Ascension, descension, landing, etc.)	N/A
<ALTITUDE>	Height above launch site	Meters
<AIR_SPEED>	The air speed measured from the pilot tube in m/s	m/s
<HS_DEPLOYED>	“P” Indicates probe has deployed heat shield, “N” indicates otherwise	N/A
<PC_DEPLOYED>	“P” Indicates the probe has deployed the parachute, “N” indicates otherwise	N/A

Payload Telemetry Format (3 of 4)

Data Field	Description	Units
<TEMPERATURE>	The temperature of the CanSat in Celsius	°C
<VOLTAGE>	Voltage of the cansat with resolution of Volts	V
<PRESSURE>	Our air pressure, has a resolution of 0.1 kPa	kPa
<GPS_TIME>	Time from the GPS receiver in UTC	hh:mm:ss.ms
<GPS_ALTITUDE>	Altitude from our GPS receiver in meters above mean sea level. Has a resolution of 0.1 Meters	m
<GPS_LATITUDE>	Latitude from the GPS receiver in decimal degrees. Has a resolution of 0.0001 degrees North	°North/°South
<GPS_LONGITUDE>	Longitude from the GPS receiver in decimal degrees. Has a resolution of 0.0001 degrees West	°East/°West
<GPS_SATS>	Total number of GPS satellites being tracked by our GPS receiver.	N/A
<TILT_X>	Angle of cansat on the X axis. Has a resolution of 0.01 degrees	° (Degrees)

Payload Telemetry Format (4 of 4)

Data Field	Description	Units
<TILT_Y>	Angle of cansat on the Y axis. Has a resolution of 0.01 degrees	° (Degrees)
<ROT_Z>	Rotation rate of Cansat in degrees per second. Has resolution of 0.1 degrees per second	°/s
<CMD_ECHO>	Text of last command sent and received by the CanSat	N/A
<PID_STATE>	A string describing the direction in which the brushed motor is moving, and the rate at which its moving	N/A

Payload Command Formats (1 of 2)

Team ID	Command	Argument	Example Format	Command Description
2078	CX	ON	CMD,2078,CX,ON	Turning on telemetry
2078	CX	OFF	CMD,2078,CX,OFF	Turning off telemetry
2078	SIM	ENABLE	CMD,2078,SIM,ENABLE	Enabling the simulation mode
2078	SIM	ACTIVATE	CMD,2078,SIM,ACTIVATE	Activating the simulation mode
2078	SIM	DISABLE	CMD,2078,SIM,DISABLE	Disabling the simulation mode
2078	SIMP	[Float Input]	2078,SIMP,[Input]	Sending a random pressure input
2078	ST	UTC	2078,ST,UTC	Setting the time on probe to UTC
2078	ST	GPS	2078,ST,GPS	Setting the time on probe to UTC from the GPS

Payload Command Formats (2 of 2)

Team ID	Command	Argument	Example Format	Command Description
2078	BCN	ON	CMD,2078,BCN,ON	Turn on audio beacon
2078	BCN	OFF	CMD,2078,BCN,OFF	Turn off audio beacon
2078	CAL	-	CMD,2078,CAL	Calibrate Altitude to Zero
The Following Commands Are Team Designed				
2078	MECH	PAR	CMD,2078,MECH,PAR	Activate parachute release in case of emergency
2078	MECH	AERO	CMD,2078,MECH,AERO	Activate aerobrake release in case of emergency

Electrical Power Subsystem Design

Harrison Slusser

EPS Overview

Batteries:
Two Panasonic 123A’s in series to take the voltage from 3V to 6V.

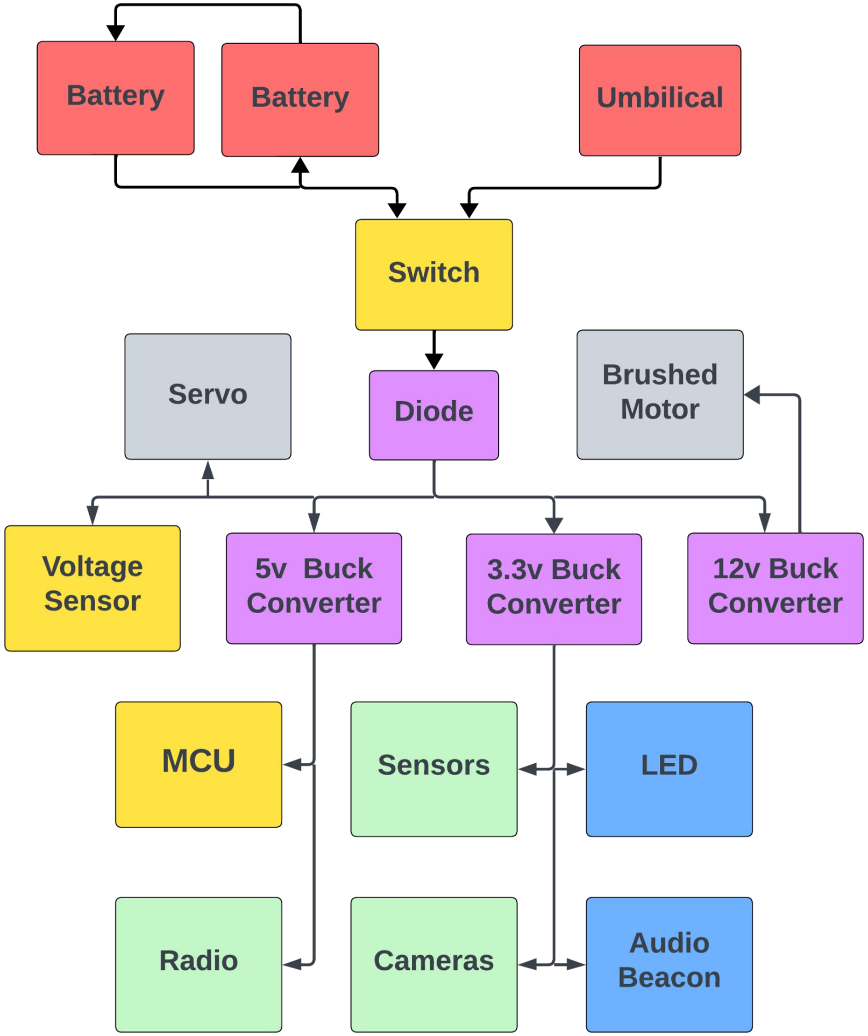
Umbilical:
USB C Power Delivery to provide 5V at 3 amps of wall power.

Switch:
Switches between battery power and umbilical power.

Diode:
Prevents the flow of power backwards up the stack.

Voltage Sensor:
Monitors the voltage of batteries to determine the energy remaining.

Voltage Regulators:
Steps up/down the input voltage to 3.3V, 5V, 12V.



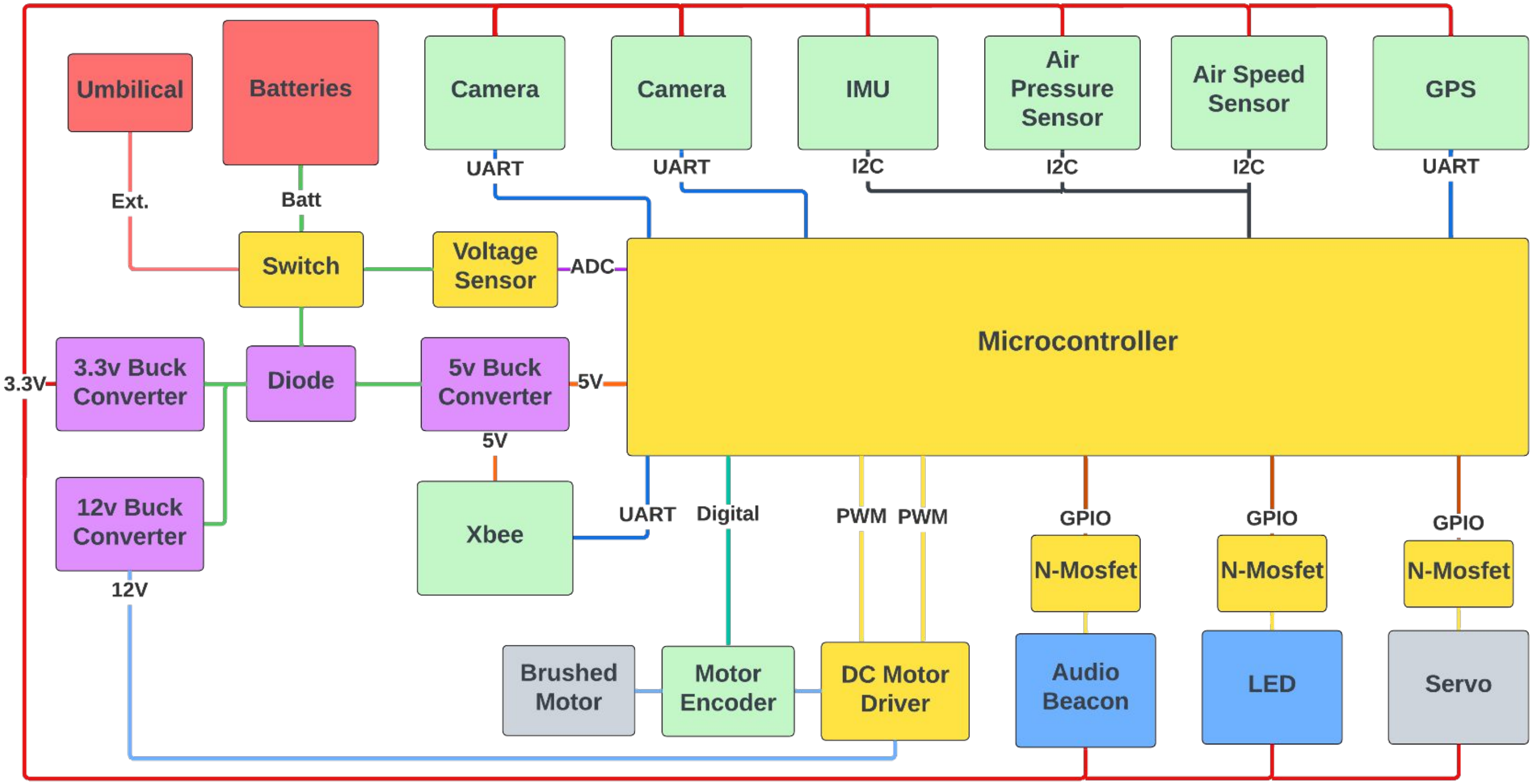
EPS Changes Since PDR

Part	PDR	CDR	Rationale
Panasonic Two CR123A Batteries	Used two Surefire CR123A batteries in series.	Switched to two panasonic CR123A batteries in series.	Panasonic CR123As are cheaper than the Surefire's when bought in bulk.
Pololu Hall Effect Motor Encoder	Used two accelerometers, the BNO055, for PID loop data point.	Switched to a pololu hall effect motor encoder for the PID loop data point.	This solution provides more accurate, driftless data for the PID loop while being more power efficient.
50:1 Micro Metal Brushed Gearmotor	Used a 14,400 RPM brushed motor for camera stabilization.	Switched to a 650 RPM 50:1 micro metal brushed gearmotor.	Post test flight data gave us a better understanding of the CanSat's rotational speed which allowed for a slower, more power efficient motor.

Payload Electrical Block Diagram

***Switch is Mounted Externally; *Power Verified by LED Flash**

Motor Encoder was Added to the Diagram



Umbilical
Batteries
Camera
Camera
IMU
Air Pressure Sensor
Air Speed Sensor
GPS
UART
UART
I2C
I2C
I2C
UART
Ext.
Batt
Switch
Voltage Sensor
ADC
Microcontroller
3.3V
3.3v Buck Converter
Diode
5v Buck Converter
5V
5V
Xbee
12v Buck Converter
12V
UART
Digital
PWM
PWM
GPIO
GPIO
GPIO
N-Mosfet
N-Mosfet
N-Mosfet
Brushed Motor
Motor Encoder
DC Motor Driver
Audio Beacon
LED
Servo

Team Name: Shockwave
Team: #2078

Component Key

- 🟨 Control
- 🟪 Regulation
- 🟥 Batteries
- 🟩 Sensors
- ⬜ Electro-Mechanical
- 🟦 Beacon

Lines Key

- ● 3.3V Circuit
- ● 5V Circuit
- ● 12V Circuit
- ● External Voltage
- ● Batt Voltage
- ● I2C
- ● UART
- ● PWM
- ● GPIO
- ● Analog to Digital
- ● Digital

Payload Power Source

Model	Total Capacity (mA)	Total Voltage (V)	Instant Current (mA)	Composition	Gravimetric Energy Density (Wh/kg)	Series or Parallel	Quantity Required	Total Mass(g)
Panasonic CR123A	1,550	6	0.5	Alkaline Manganese Dioxide	273.53	Series	2	34

Image Credit: digikey.copm

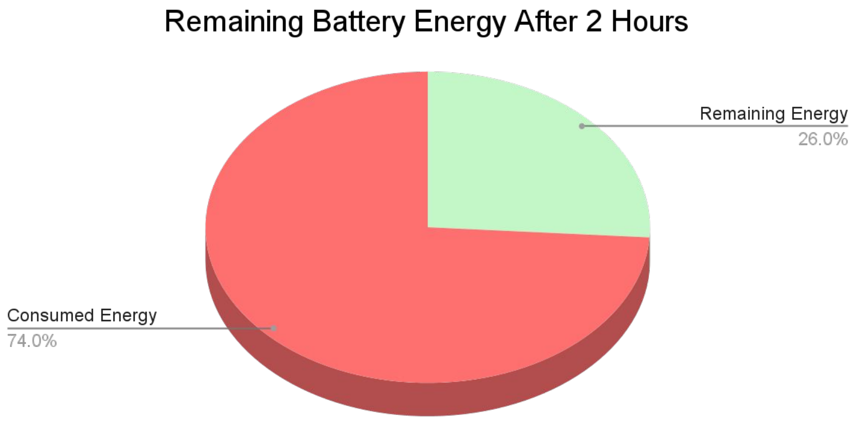
***Not Lithium Polymer Battery (LiPO)**

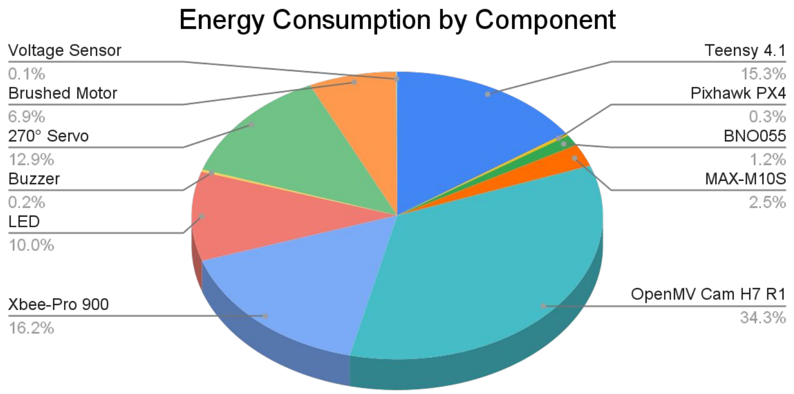
Payload Power Budget (1 of 2)

Components:	Quantity:	Voltage (V):	Active Current (mA):	Active Duration (h):	Idle Current (mA):	Idle Duration (h):	Energy (Wh):	Source:
Teensy 4.1	1	5.0	100.00	2.00	0.00	0.00	1.00	Datasheet
BMP390	1	3.3	0.003	2.00	0.001	0.00	0.00	Datasheet
Pixhawk PX4	1	3.3	3.00	2.00	0.01	0.00	0.02	Datasheet
BNO055	1	3.3	12.30	2.00	0.04	0.00	0.08	Datasheet
MAX-M10S	1	3.3	25.00	2.00	2.20	0.00	0.17	Datasheet
OpenMV Cam H7 R1	2	3.3	170.00	2.00	0.00	0.00	2.24	Datasheet
Xbee-Pro 900 Radio	1	3.3	160.00	2.00	2.80	0.00	1.06	Datasheet
LED	1	5.0	525.21	0.25	0.00	1.75	0.66	Datasheet
Buzzer	1	5.0	12.44	0.25	0.00	1.75	0.02	Datasheet
270° Servo	1	6.0	2800.00	0.05	0.00	1.95	0.84	Datasheet
Brushed Motor	1	12.0	750.00	0.05	80.00	0.00	0.45	Datasheet
Voltage Sensor	1	6.0	0.50	2.00	0.00	0.00	0.01	Calculated
Energy Subtotal (Wh):							**6.53**	Calculated

Payload Power Budget (2 of 2)

Energy Consumption (Wh)	6.53
Power Supply Efficiency (%)	95.00%
Total Energy Consumption	6.88
Available Battery Energy (Wh)	9.30
Energy Margin	2.42
Remaining Battery Percent	26.04%





Flight Software (FSW) Design

Madeline Teer

FSW Overview

Source:
arduino.com

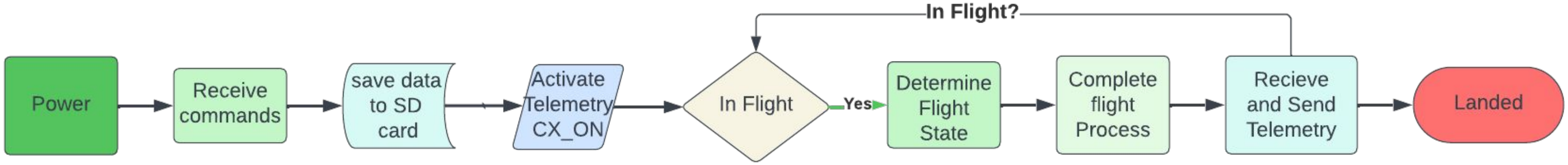
Source:
openmv.com

Start Up	Flight	Landing
- Power all systems - Boot and calibrate all sensors - Read last saved packet	- Determine Flight state - Record all flight - Release the mechanisms at desired point - Save data	- Turn on buzzer and LED - End all recordings - Save all data

Source:
adafruit.com

Languages and Environments
FSW: C++ using ArduinoIDE Cameras: MicroPython using OpenMV IDE XBee’s: XTCU

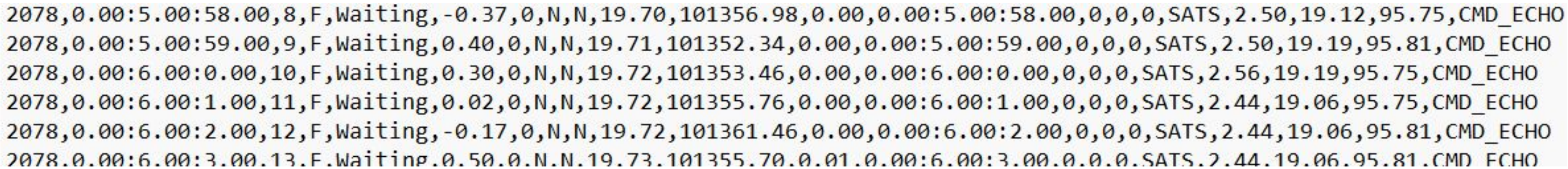
Organization
GitHub Google Drive Header Files



FSW Changes Since PDR

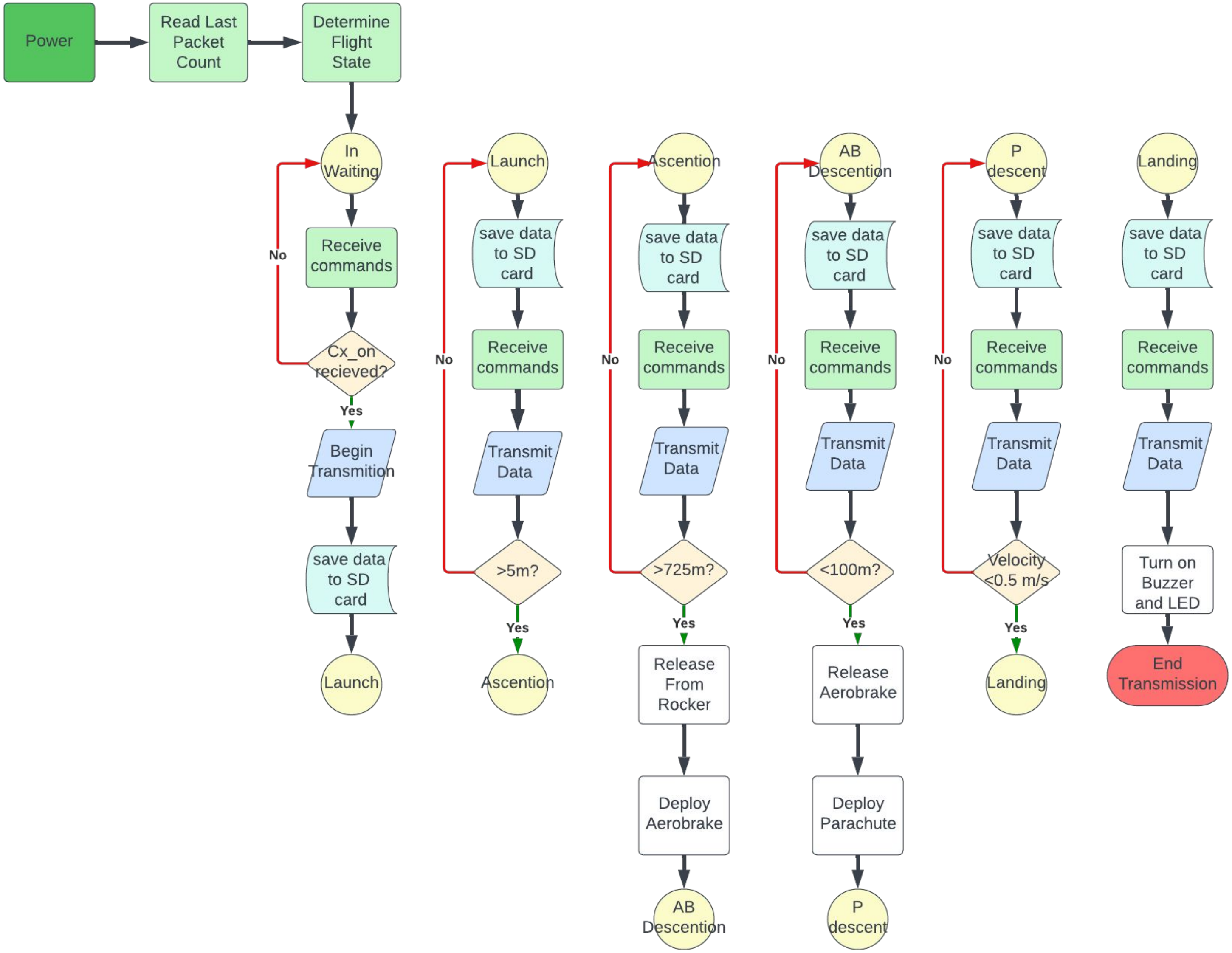
Changes	Test Reports
There have been no significant changes since PDR to the FSW	● We have tested and received communication with all sensors. XBee communication is still in testing phases. All servo controls are working. Brushed motor controls still in testing phases.

Test Launch SD Card Data



```
2078,0.00:5.00:58.00,8,F,Waiting,-0.37,0,N,N,19.70,101356.98,0.00,0.00:5.00:58.00,0,0,0,SATS,2.50,19.12,95.75,CMD_ECHO
2078,0.00:5.00:59.00,9,F,Waiting,0.40,0,N,N,19.71,101352.34,0.00,0.00:5.00:59.00,0,0,0,SATS,2.50,19.19,95.81,CMD_ECHO
2078,0.00:6.00:0.00,10,F,Waiting,0.30,0,N,N,19.72,101353.46,0.00,0.00:6.00:0.00,0,0,0,SATS,2.56,19.19,95.75,CMD_ECHO
2078,0.00:6.00:1.00,11,F,Waiting,0.02,0,N,N,19.72,101355.76,0.00,0.00:6.00:1.00,0,0,0,SATS,2.44,19.06,95.75,CMD_ECHO
2078,0.00:6.00:2.00,12,F,Waiting,-0.17,0,N,N,19.72,101361.46,0.00,0.00:6.00:2.00,0,0,0,SATS,2.44,19.06,95.81,CMD_ECHO
2078,0.00:6.00:3.00,13,F,Waiting,0.50,0,N,N,19.73,101355.70,0.01,0.00:6.00:3.00,0,0,0,SATS,2.44,19.06,95.81,CMD_ECHO
```

Payload CanSat FSW State Diagram (1 of 4)



Payload CanSat FSW State Diagram (2 of 4)

Sampling	Data Storage	Communications
All Sensors will start up once receiving power, calibrate, and then be sampled at a rate of 3 Hz.	The telemetry will be stored on the on board SD card for the Teensy. All camera footage will be stored on the on board SD card for both cameras.	All telemetry will be sent at a rate of 1 Hz over XBee to the ground station. The ground station will send all commands and the payload will parse process and execute all commands.

Power Management
● Mosfets will be used to stop current draw from the LED, buzzers, and servo. ● The XBee will be in low power mode while

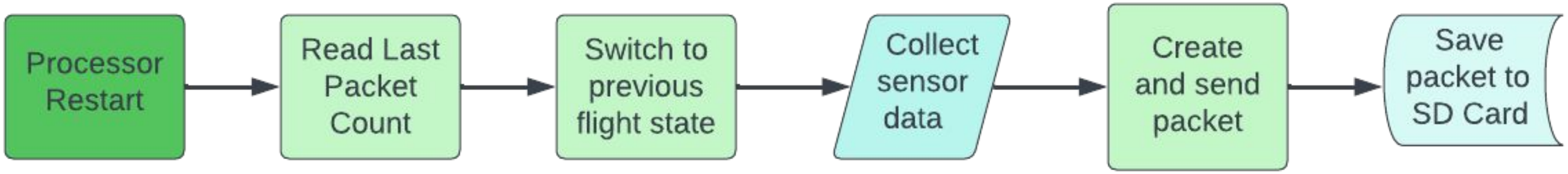
Payload CanSat FSW State Diagram (3 of 4)

Mechanism Activations
At 700m the brushed motor will activate: ● The BNO055 will take a reading and a PID controlled motor shall rotate accordingly to keep a camera at the same point on the horizon. At 100m the servo will activate: ● The servo will rotate an initial 60 degrees to release the aerobrake and deploy the parachute. ● The servo will then rotate an additional 60 degrees incase the aerobrake did not deploy the first time.
Major Decision Factors
Decision points in logic are determined by altitude and state to release mechanisms and determine the state we are in.

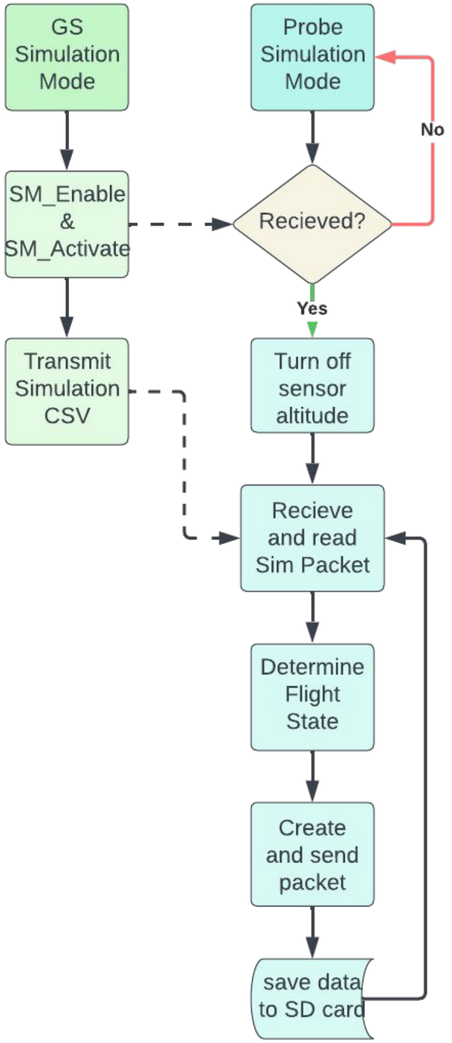
Payload CanSat FSW State Diagram (4 of 4)

Data Stored	Reasons for restart
● Reference Altitude ● Mission Time ● Packet Count ● Last State ● Command Echo	● High temperatures/overheating ● Loss of power ● Watchdog timer timeout ● Electromagnetic interference

Recovery Method
● The last packet will be read from the SD card. ● Assign the previous flight state and restore sensor data. ● Create packet and send to Ground Station. ● Continue Flight.



Simulation Mode Software



Simulation Mode:

- Probe must receive both SIM_ENABLE and SIM_ACTIVATE from the GCS to activate Sim Mode.
- SIM Mode will transmit pressure data at a rate of 1Hz to the probe. Transmitted pressure data is used to determine altitude
- The probe will read all other sensor data except pressure data.
- The probe will determine the flight state and send telemetry packets throughout Sim Mode.

Commands:

SIM_ENABLE: turns on the ability to activate the Sim Mode

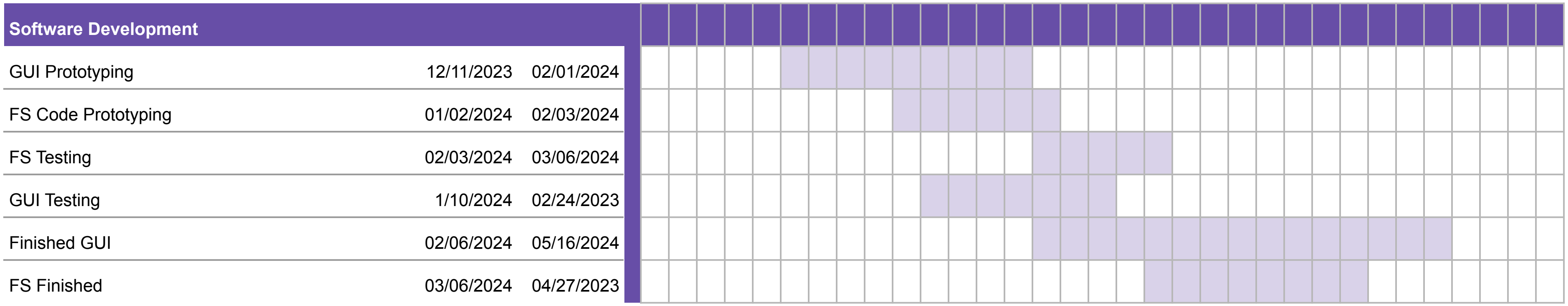
SIM_ACTIVATE: turns on Sim Mode

SIM_DISABLE: turns off Sim Mode

Software Development Plan (1 of 2)

Team Member	Responsibilities
Madeline Teer	Embedded Software - development of embedded software with sensors, servos, cameras, motors, and the state machines. Also in charge of integration with electrical systems.
Nilan Mickel	GCS Software- development of both frontend and backend software for receiving, parsing, saving and graphing all telemetry

Embedded Prototyping	GCS Prototyping
• C++ in Arduino IDE • Cameras in OpenMV IDE • XBees in XCTU	• GOLang for backend • Javascript & HTML for frontend • CanvasJS for plotting



Software Development		
GUI Prototyping	12/11/2023	02/01/2024
FS Code Prototyping	01/02/2024	02/03/2024
FS Testing	02/03/2024	03/06/2024
GUI Testing	1/10/2024	02/24/2023
Finished GUI	02/06/2024	05/16/2024
FS Finished	03/06/2024	04/27/2023

Software Development Plan (2 of 2)

Embedded Software	Progress
Sensor Communication	Completed
State Machine	Completed
Telemetry	Completed
Servo Connections	Completed
PID Controller	In Progress
XBee Communication	Needs More Testing
Command Parser/Handler	Needs More Testing

GCS Software	Progress
Telemetry Parser	Completed
CSV Writer	Completed
Data Generator	Completed
Backend-Frontend Connection	Completed
Graphs	Completed
Labels	Completed
Command Buttons	In Progress

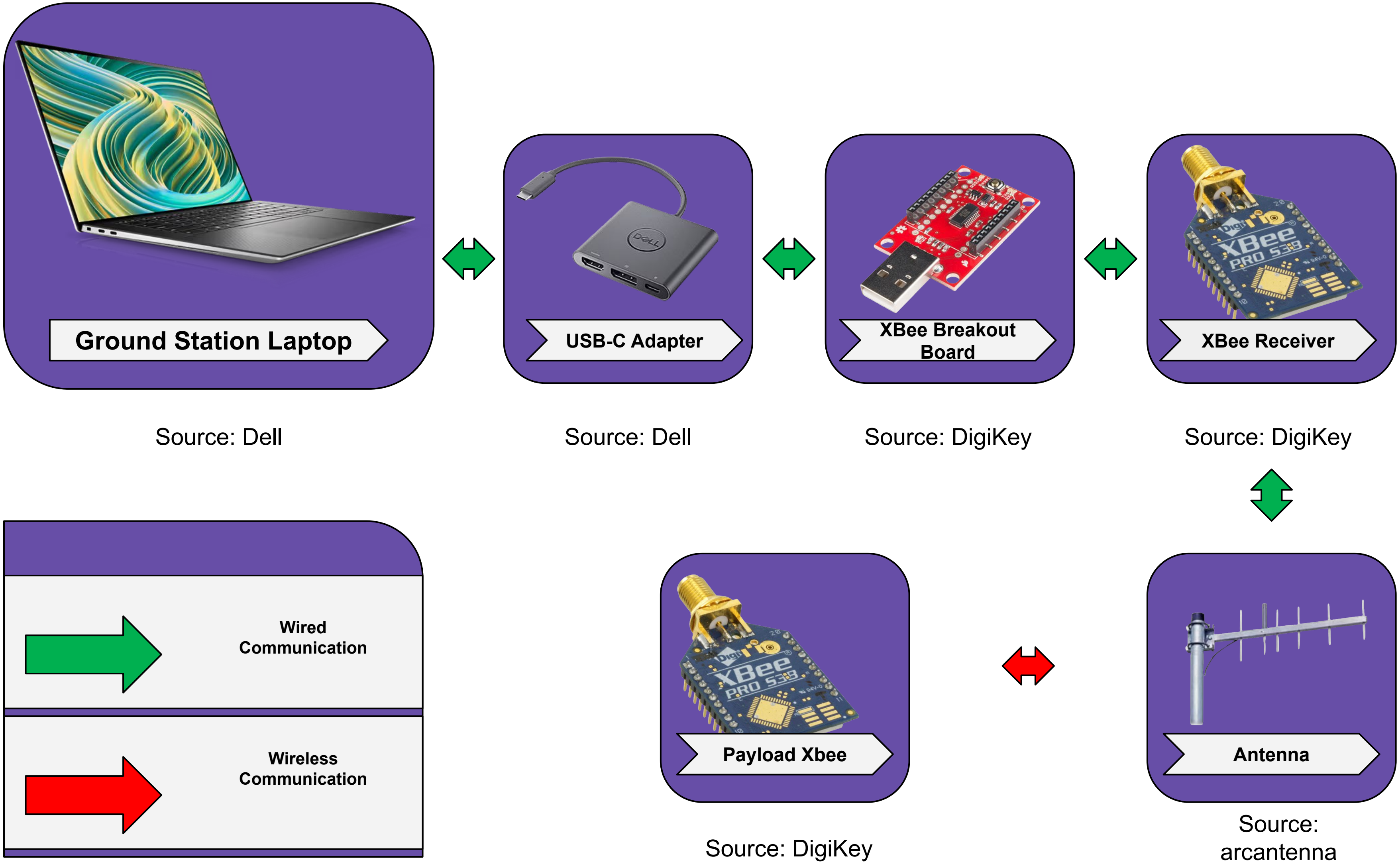
Test Methodology

- Continuous integration with Electrical to catch bugs early on
- Data Generator and continuous telemetry testing to test GCS
- 2 test launches to determine accurate functionality and to test restarts

Ground Control System (GCS) Design

Nilan Mickel

GCS Overview



Ground Station Laptop

Source: Dell

USB-C Adapter

Source: Dell

XBee Breakout Board

Source: DigiKey

XBee Receiver

Source: DigiKey

Antenna

Source: arcantenna

Payload Xbee

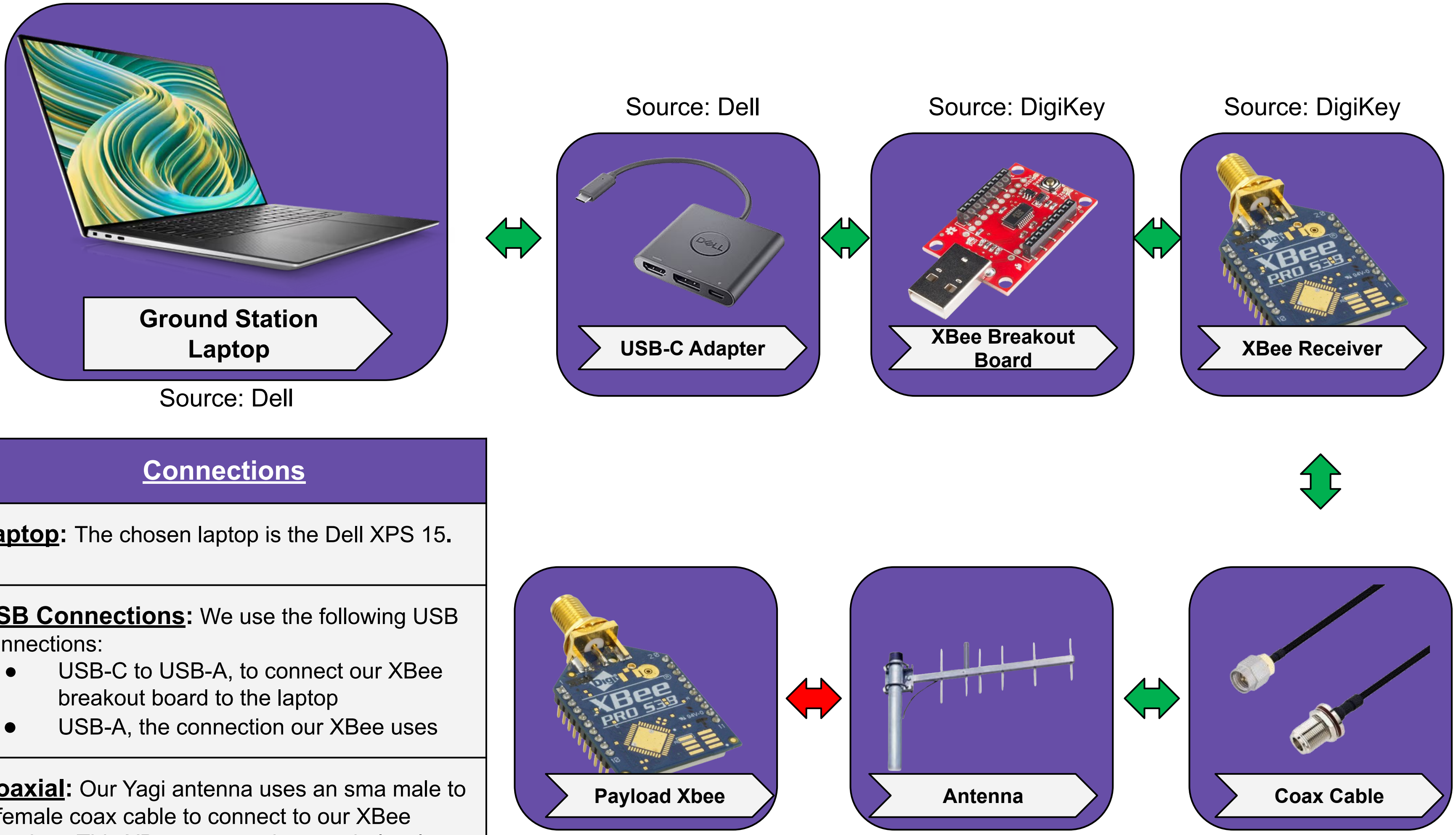
Source: DigiKey

🟩	**Wired Communication**
🟥	**Wireless Communication**

GCS Changes Since PDR

Part	PDR	CDR	Rationale
Graphing Libraries	HighCharts	CanvasJS	More efficient live graphing and better documentation.
Test Reports	• Successful frontend to backend communication • Successful CSV file creation • Successful data plotting		

GCS Design (1 of 2)



Ground Station Laptop

Source: Dell

USB-C Adapter

Source: Dell

XBee Breakout Board

Source: DigiKey

XBee Receiver

Source: DigiKey

Coax Cable

Source: L-Com

Antenna

Source: arcantenna

Payload Xbee

Source: DigiKey

Connections

Laptop: The chosen laptop is the Dell XPS 15.

USB Connections: We use the following USB connections:

- USB-C to USB-A, to connect our XBee breakout board to the laptop
- USB-A, the connection our XBee uses

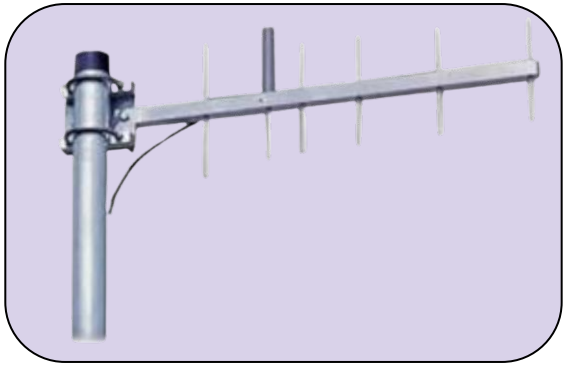
Coaxial: Our Yagi antenna uses an sma male to n female coax cable to connect to our XBee Receiver. This XBee communicates wirelessly to the payload XBee.

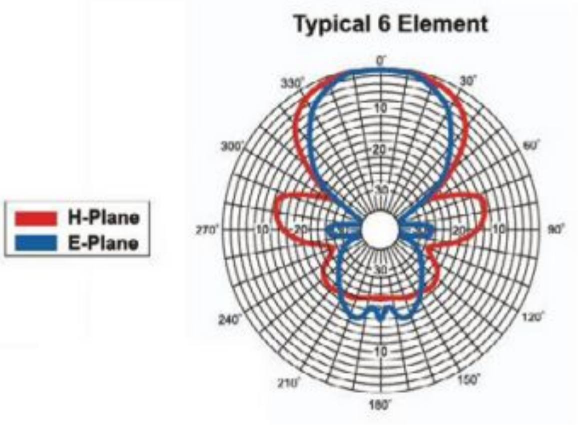
GCS Design (2 of 2)

Specifications
Battery Life: The XPS 15 Laptop has over 11 hours of battery life over a single charge.
Overheating Mitigation: We plan on using an umbrella to keep the laptop out of direct heat and laptop stands to increase airflow. If an overheat does occur, we will have a backup laptop on standby.
Auto-Update Mitigation: Auto Update for our laptop will be turned off the week of flight day.

GCS Antenna (1 of 2)

Antenna	Gain (dBi)	Frequency Range (MHz)	Polarity	Horizontal/ Azimuth Bandwidth (degrees)	Vertical/Elevation Bandwidth (degrees)	Cost (USD)
PC906N-handheld	8.5	896-940	Linear	65	55	$65.68





<u>Selection:</u> PC906N-Handheld

- **Gain**
- **Cost effective**

Image Credit: arcantenna.com

TE Connectivity

GCS Antenna (2 of 2)

Antenna Information

Construction:

- All parts needed to assemble the antenna come in the package.

Portability:

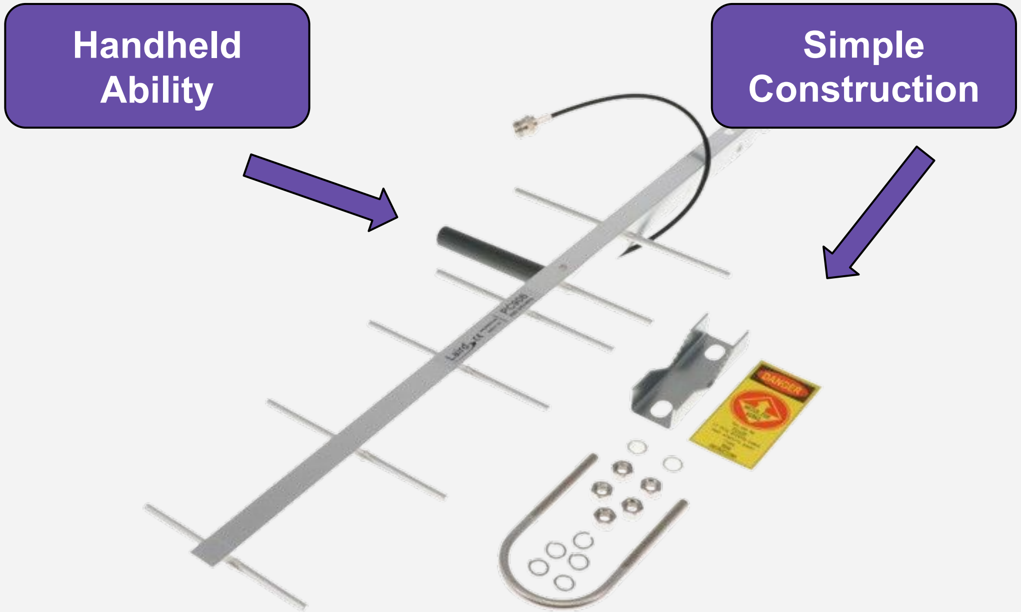
- The antenna is 24.75” (2 feet).
- The handle can be removed from the antenna if needed to increase portability.

Coverage:

- **Link Margin:** approx 7.33 dB
- **Distance:** approx 8km

Source: “https://www.bannerengineering.com/us/en.html ”

Construction Diagram



Source:
DigiKey.com

GCS Software (1 of 2)

GCS Software Decisions

Software

- Javascript and HTML as the frontend.
- GOLang as the backend.
- GCS will utilize Websocket communication.

COTS software

Graphs and Plotting

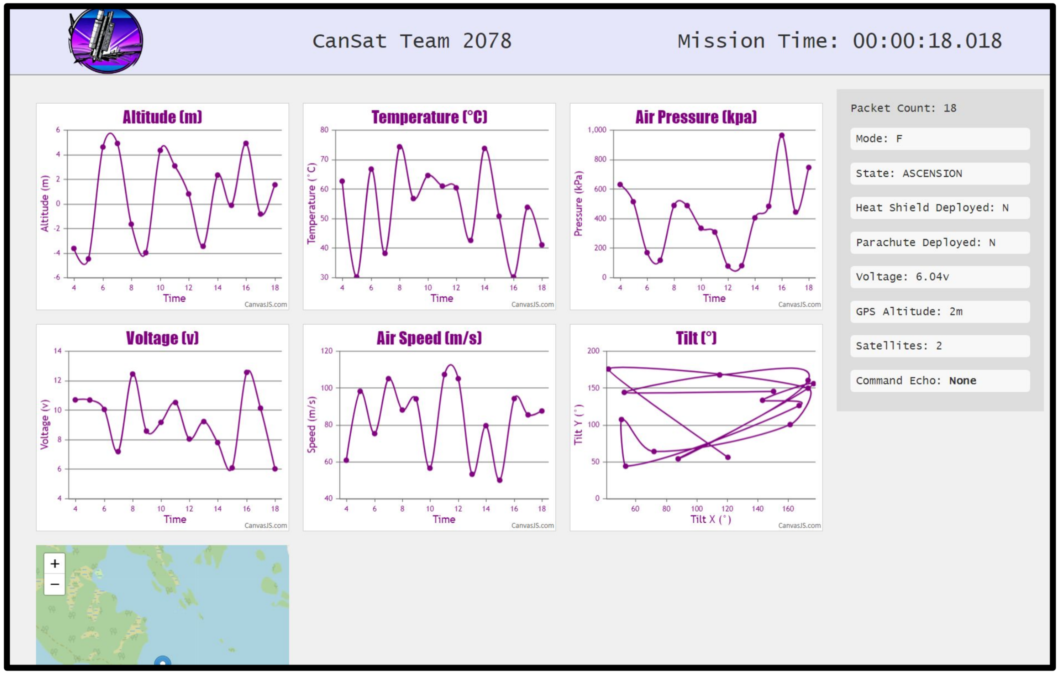
- CanvasJS

CSS Framework

- Bootstrap

Telemetry Data and CSV

- Receive packet, sort it by the packet number, each field is separated by delimiter. This information is then saved to a csv file.
- Seperated in GOLang and then plotted in the frontend.
- The ground station will also count the number of packets received.



CanSat Team 2078

Mission Time: 00:00:18.018

Packet Count: 18

Mode: F

State: ASCENSION

Heat Shield Deployed: N

Parachute Deployed: N

Voltage: 6.04v

GPS Altitude: 2m

Satellites: 2

Command Echo: None

GCS progress since PDR
(Number of graphs subject to change)

GCS Software (2 of 2)

GCS Sim Mode and Command Explanation

Command software

- Our mission commands will be activated via button press.
- When pressed, it sends a string over the xbee radio to our flight software.
- When our flight software receives this string, it will perform the specified command.

Simulation Mode

- The GCS will send both SIM_ENABLE and SIM_ACTIVATE by a button press to start the simulation mode.
- Once both have been pressed the GCS will send the competition given CSV packet line by line at a rate of 1hz.
- The FSW will then parse the data, convert pressure to altitude and send down telemetry packets.
- The GCS will then receive packets and graph the real time data like normal.
- Sim Mode will stop once the command SIM_DISABLE has been sent by button command.

Additional Commands

- The GCS will also calibrate the altitude to 0 prior to launch via a button command.

CanSat Integration and Test

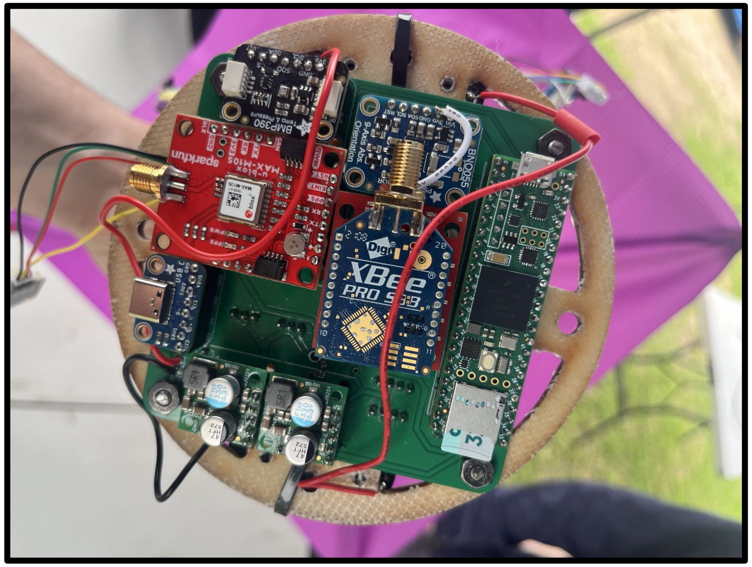
Arel Urbanozo

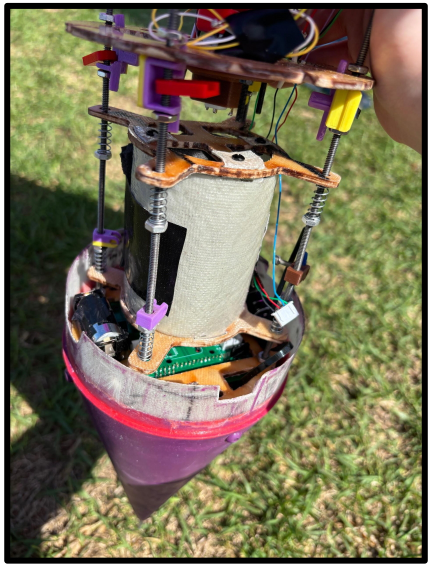
CanSat Integration and Test Overview (1 of 2)

Integration and Test Overview	
Individual Subsystem	Each individual subsystem will be tested to make sure are requirements are met.
Integration	Each system will be integrated and tested to determine fit and function of all parts together.
Environmental	After complete integration the Cansat will be run through environmental testing as described in mission guide.
Simulation	Cansat will be put into simulation testing mode with two step commands to receive simulated CSV data.
Test Launches	Test launch the Cansat in launch day replica rocket and environments twice to determine any launch day complications and fix them.

CanSat Integration and Test Overview (2 of 2)

March 17 Test Launch	
Test	**Pass/Fail**
CanSat Integration Test	Pass
Payload Fit Check	Pass
Aerobraking and Parachute Deployment	Fail
Egg Survivability	Pass





Subsystem Level Testing Plan (1 of 2)

Subsystem	Components	Test Description	Requirements to pass
Sensors	BMP390 BNO055 MAX-M10S Voltage Divider Camera PixHawk PX4	Test all sensors using areas of known values to check the accuracy of the sensors.	All sensor data matches the accuracy of the data sheets.
CDH	Command Input	Send commands from GCS to the container.	The Cansat and GCS will communicate effectively and parse sent data/packets.
EPS	PCB Sensors MCU Batteries	2 hour battery life of the batteries and electrical continuity of proper voltage among all components.	The system has the proper operating voltage for the duration of 2 hours.
Radio Communication	GCS XBees	Testing long distance two way communication between GCS and XBees.	Packets must be sent between GCS and Cansat and the Cansat must receive commands from GCS.

Subsystem Level Testing Plan (2 of 2)

Subsystem	Components	Test Description	Requirements to pass
FSW	MCU	Test all command implementation, real time clock, and transition of flight states.	All flight states switch at the proper moment, all command implementation is successful and RTC is working correctly.
Mechanical	Aerobrake Parachute Release	Test deployment mechanisms for the aerobrake and parachute. Verify aerobrake release mechanism.	Aerobrake fully deploys. Parachute deploys on command. Aerobrake releases from rest of payload on command.
Descent Control	Aerobrake Servo	Test payload stability during descent, verifying the position of COM and effect of turbulent flow due to aerobrake.	Payload does not flip. Maintains stable orientation during descent.

Integrated Level Functional Test Plan

Subsystem	Testing Plan	Pass Requirements
Descent	● Throwing CanSat simulated weight with aerobrake and parachute off a high place. ● Rocket tests 1 and 2	The CanSat shall fall at a rate of 10-30m/s for aerobrake descent and less than 5m/s for the parachute descent.
Communications	● Long distance communication ● Two-way communication ● Optimal Antenna Position ● All tested during test launches	Communication is stable at 1000m and still sends and receives packets throughout the flight and 2 hour battery test.
Mechanisms	● Simulated tests using ground station commands ● Altitude tests with vacuum chamber	All release mechanisms work at the correct altitude.
Deployment	● Ejection from the rocket ● Test Flights 1 and 2	Clean ejection from the rocket without losing power, control, or mechanical function.

Environmental Test Plan (1 of 2)

Test	Method	Test Description	Requirements to Pass
Drop Test	Fixed Point Drop	Using a 61cm non stretch cord, The CanSat will be attached on one end and a fixed object will be attached to the other end. The Cansat will be raised to the attachment points are at the same height and will be released.	The structure must not flex during the drop test. Telemetry is still received. Power is still on.
Thermal Test	Thermal Chamber	Assembled using an insulated cooler, a hairdryer, and a thermometer. The hairdryer will circulate heated air inside the cooler at 60°C for 2 hours.	Structures and mechanisms have no damage and all epoxy joints and composites maintain strength.
Vibration Test	Random Orbital Sander	The CanSat will be attached to a random orbital sander that exposes it to vibrations of 0Hz-233Hz and generates 20-30Gs for one minute.	No damage and maintains functionality, and accelerometer data is still collected.

Environmental Test Plan (2 of 2)

Test	Method	Test Description	Requirements to Pass
Fit Check	Mock Rocket Test	The CanSat will be slid into a tube that has the same dimensions as the rocket used during the competition.	The CanSat slides in and out of the rocket easily with no impediments.
Vacuum Test	Vacuum Chamber	The fully configured and powered CanSat will be placed into a vacuum chamber, and will be pulled to a vacuum. Throughout the process telemetry will be monitored and when max altitude is reached the vacuum will be stopped.	The CanSat must transmit and save telemetry and be provided to judges.

Test Procedures Descriptions (1 of 8)

Subsystem Level Testing			
Test Procedure	**Test Description**	**Rqmts**	**Pass Fail Criteria**
1	Connect BMP 390 to a microcontroller that is hooked up to Arduino IDE. Run the example code from the Adafruit_BMP3xx library and verify the pressure and temperature are correct.	X5, SN2, SN3	Measures ambient pressure with a resolution of 0.1 kPa. Measures temperature with a resolution of 0.1 C. Measures altitude with a resolution of 0.1 m.
2	Connect BNO 055 to a microcontroller that is hooked up to Arduino IDE. Run the example code from the Adafruit_BNO055 library and verify that the sensor measures the correct orientation.	X5, SN4, SN5, G4	Measures tilt in X and Y and rotation about the Z to 0.1 degrees.
3	Connect MAX-M10S to a microcontroller that is hooked up to Arduino IDE. Run the example code from the Sparkfun U-Block library. Verify the number of satellites connected and get the position of the sensor.	X5, F3	Measures time within 1 second of UTC, altitude to a resolution of 0,1 m, latitude and longitude to a resolution of 0.0001 degrees, and reports the number of acquired satellites.
4	Connect voltage divider circuit to a microcontroller that is hooked up to Arduino IDE. Provide voltage to the microcontroller through this port and verify the measures voltage is similar to the multimeter reading	X5, SN6,	Measures battery voltage to a resolution of 0.1 V.

Test Procedures Descriptions (2 of 8)

Subsystem Level Testing			
Test Procedure	**Test Description**	**Rqmts**	**Pass Fail Criteria**
5	Connect camera to a microcontroller. With an SD card inside the camera, send a signal from the microcontroller to the camera to begin recording and stop recording after five minutes. Verify the camera records video for the correct amount of time.	SN7, SN8, SN9	Records uncorrupted 680x480 resolution color video at 30 frames per second.
6	Connect PixHawk PX4 to a microcontroller. Run the MS4525DO example code and verify the dynamic and static pressure values are correct. Verify the calculated airspeed.	SN1	Measures pressure to an accuracy of 0.1 kPa and speed to an accuracy of 0.1 m/s.
7	Connect a coin cell battery to the Teensy 4.1 and verify that with main power off, the clock runs for 30 minutes.	F2, F3	Records time within 1 second of UTC after main power is off for 30 minutes.
8	Insert a microSD into the slot on the Teensy 4.1 and push code from Arduino IDE that activates the data logging code on the microcontroller. Verify data is being written in the correct formal after 30 minutes.	G2	Records telemetry packets for 30 minutes in the correct csv format.
9	Send a command from the ground station to the microcontroller.	G1	Correct parsing of command and logging of command in flight software.

Test Procedures Descriptions (3 of 8)

Subsystem Level Testing			
Test Procedure	**Test Description**	**Rqmts**	**Pass Fail Criteria**
10	With batteries attached to the team design PCB logic board via wires, measure the voltage from the positive and negative terminals on the board.	M4, E1, E2, E5	Input voltage is greater than 6 V, wires are not used for battery connections, using non-lithium polymer Battery CR123As.
11	With the PCB logic board fully assembled on on, measure the voltage across the buck-converters, ensuring the correct voltage is being output by the regulators.		3.3 V, 5 V, and 12 V regulators output 3.3 V, 5 V, and 12 V respectively, with a 0.1 V tolerance.
12	Connect LED and buzzer to respective terminals on the PCB. Verify visual of the LED and audio output of the buzzer.	E4	LED must be visible in daylight and the buzzer have a volume > 92 dB.
13	Connect all components to the PCB and boot Teensy 4.1 with FSW. Verify the system runs for two continuous hours, measuring the voltage of the batteries with a multimeter.	E5	Payload logs data for two continuous hours with no power outages. Battery maintains total system power during entire duration.
14	Inspect electrical systems by tugging connections and verifying integrity of components.	S11	No banned materials used and sound electrical connections.
15	Set up XBEE radios operating frequency, NETID, PANID, and transmission protocol, ensuring it is not in broadcast mode.	X1, X2, X3	Radios set up according to requirements in mission guide.

Test Procedures Descriptions (4 of 8)

Subsystem Level Testing			
Test Procedure	**Test Description**	**Rqmts**	**Pass Fail Criteria**
16	Verify connection between the GCS and payload by sending the CX,ON command to the CanSat from a distance of 500m. Telemetry is sent at a rate of 1 Hz and there is no packet loss.	X5, G3, G5, G6, G7, G8	Payload receives the command and begins transmitting telemetry. Telemetry is in competition format with time resolution of 1 second. Telemetry on ground station is displayed with engineering units.
17	Connect the ground station consisting of laptop computer and handheld antenna to the payload and move 50m away.	G9, G10, G13, G14	Ensure the ground station is receiving data and is legible under sunlight with big font, bolded title and axes, and a light background.
18	Connect the GCS on battery power to the CanSat in simulation mode. Send example pressure data to the CanSat for two hours, verifying telemetry transmission for the entire duration.	G9, G15	Ground station runs off battery power for entire two hour duration and keeps count of received packets throughout entire test.
19	With the probe in the initial flight state, power cycle the electrical system and verify the probe boots up into the correct flight state and mission time. Confirm the altitude has not changed and packet count is maintained.	F1, F2, G4	Maintains packet count, mission time, altitude AGL and MSL, and boots into correct flight state.

Test Procedures Descriptions (5 of 8)

Subsystem Level Testing			
Test Procedure	**Test Description**	**Rqmts**	**Pass Fail Criteria**
20	With ground link established, send the commands: SIM,ENABLE and SIM,ACTIVATE to the probe. Begin sending pressure data from the provided CSV file at a rate of 1 Hz to the CanSat. Confirm payload continues taking readings from other sensors and continues through flight states as the pressure changes.	F4, F5, F6, X4, G11, G12	Payload receives commands and enters simulation mode. Payload receives telemetry data and correctly interprets altitude while collecting all other sensor data. Payload enters different flight states as expected.
21	With CanSat stowed in a rocket, hold the nose cone portion and shake it free from the rocket. Verify the aerobrake opens.	C3, M5	Aerobrake opens when released from rocket.
22	Attach the aerobrake layer to the CanSat and lock it into place with the servo motor. With the CanSat on and linked with the ground station, activate the aerobrake release mechanism. Verify that the servo turns, releasing the aerobrake from the CanSat.	C5, M9	CanSat receives command and activates servo motor. Aerobrake layer separates from the CanSat.

Test Procedures Descriptions (6 of 8)

Subsystem Level Testing			
Test Procedure	**Test Description**	**Rqmts**	**Pass Fail Criteria**
23	With aerobrake layer attached to the CanSat, hold the CanSat head height above a foam pad. Activate the aerobrake release mechanism and verify that the parachute deploys as the aerobrake layer is jettisoned with the mylar streamer visibly attached.	C4, C5	Parachute deploys on aerobrake release
24	With CanSat in simulation mode, send pressure data from the CSV file to the CanSat. When the CanSat hits 100 m on descent the CanSat should release its heat shield and deploy the parachute.	C5	Aerobrake layer is released and parachute deploys within 5 seconds of reaching 100 meters.
25	With CanSat in the parachute descent state and parachute configuration, drop the CanSat from a distance such that it impacts at 5m/s	C11	The CanSat survives a drop at 5 m/s. No parts are broken and the payload can fly again.
26	With CanSat in simulation mode, once the CanSat reaches the "landed" state, verify the buzzer and LED beacon activate.	C7	Beacon turns on when the payload lands. LED must be visible in daylight and the buzzer have a volume > 92 dB.
27	Payload is inspected to be in compliance with color, banned mechanisms, and material requirements as outlined in the mission guide.	M1, M2, E3	Aerobrake and parachute fabric are bright orange or pink; no pyrotechnic, chemical, or heat activated mechanisms; labeled with team information; switch is easily accessible.

Test Procedures Descriptions (7 of 8)

Integration Level Testing			
Test Procedure	**Test Description**	**Rqmts**	**Pass Fail Criteria**
28	The aerobrake layer attached to a simulated 1 kg weight with altimeter package to measure descent rate will be thrown off a high place and fall 20 m. Repeat with the parachute deployed.	C10, M6, M7, M10	The CanSat shall fall at a rate of 10-30m/s for aerobrake descent and less than 5m/s for the parachute descent.
29	The CanSat will complete two test launches acting as the nose cone with replica rockets from competition and a large hens egg to simulate the real flight conditions.	C1, C2, C8, S8, M8	Clean ejection from the rocket without losing power, control, and mechanical function, along with survival of the egg.
30	The CanSat will test long distance two-way communication and optimal antenna position during two real test launches to determine the accuracy and optimization of telemetry.		Communication is stable at 1000m and still sends and receives packets throughout the flight and 2 hour battery test.
31	Simulated tests using ground station commands sent over XBee to command the payload to test the activation mechanisms and zeroing altitude.	C9	All release mechanisms work at the correct altitude.
32	Measure the fully assembled CanSat and verify the shoulder fits snug into the rocket. Inspect placement and integrity of components. Weigh the full CanSat using a scale and verify the components used total under $1000.	S1, S2, S3, S4, S5, C12, E3	71mm nose cone radius, nose cone shoulder 68mm radius, 50 mm length. Mass between 890 and 910 g. Payload less than $1000. Switch is accessible.

Test Procedures Descriptions (8 of 8)

Environmental Testing			
Test Procedure	**Test Description**	**Rqmts**	**Pass Fail Criteria**
33	Using a 61cm non stretch cord, The CanSat will be attached on one end and a fixed object will be attached to the other end. The Cansat will be raised to the attachment points are at the same height and will be released.		The structure must not flex during the drop test. Telemetry is still received. Power is still on.
34	Assembled using an insulated cooler, a hairdryer, and a thermometer. The hairdryer will circulate heated air inside the cooler at 60°C for 2 hours.		Structures and mechanisms have no damage and all epoxy joints and composites maintain strength.
35	The CanSat will be attached to a random orbital sander that exposes it to vibrations of 0Hz-233Hz and generates 20-30Gs for one minute.	S6, S7, M3	No damage and maintains functionality, and accelerometer data is still collected.
36	The CanSat will be slid into a tube that has the same dimensions as the rocket used during the competition.	S9, S10	The CanSat slides in and out of the rocket easily with no impediments. Rocket body used to stow payload.
37	The fully configured and powered CanSat will be placed into a vacuum chamber, and will be pulled to a vacuum. Throughout the process telemetry will be monitored and when max altitude is reached the vacuum will be stopped.	C6	The CanSat must transmit and save telemetry and be provided to judges. It must also stop data transmitting when in landed state.

Simulation Test Plan

Component	Description	Requirement
Ground Station	Testing two way communication sending CSV data to the CanSat using the SIM and SIMP commands.	The GCS should provide data to the CanSat with the simulated CSV file pressure at a rate of 1Hz.
Cansat	When activate and enable commands are received, the CanSat should record all data as normal except altitude which shall be received by CSV over XBee.	The Cansat enters simulation mode from the GCS. The CanSat should receive the CSV telemetry and respond according the the altitude with the proper flight protocols.

Mission Operations & Analysis

Arel Urbanozo

Overview of Mission Sequence of Events (1 of 2)

Event	Task	Team
Arrival	**Arrive at launch site**	**All**
Prelaunch	Cansat Check In	CanSat
	GCS Setup and Antenna Construction	Ground Station
Launch	Cansat Integration	CanSat
	Monitor GCS	Ground Station
	Execute Launch Procedures	CanSat
Flight	Monitor GCS	Ground Station
Recovery	Recover Cansat	Recovery
Data Analysis	Analyze Data and Turn in Thumb Drive to Judge	All
	Post Flight Review	All

Overview of Mission Sequence of Events (2 of 2)

Role	Team Member(s)	Responsibilities
Mission Control Officer	Arel Urbanozo	Manages the team at the time of the launch. Verifies with the ground station crew everything is ready. Informs flight coordinator when the Cansat is ready for launch.
Ground Station Team	Madeline Teer Nilan Mickel Nic Ruse	Monitors the ground station for telemetry reception and issuing commands to the Cansat.
Recovery Team	Andrew Treadway Zach Jones Harrison Slusser	Track the Cansat and going out into the field for recovery. Returning the Cansat to the judges at check-in.
Cansat Team	Ashley Reed Samuel Chouinard Jordan Littlepaige	Preparing the Cansat, integrating it into the rocket, and verifying its status.

Field Safety Rules Compliance

Missions Operation Manual (MOM) Overview	
Section	**Description**
Ground Station Configuration	Procedures for setting up the ground station hardware and initializing the software.
Cansat Preparation	Checklists of all Cansat components and system procedures prior to launch.
Cansat Integration	Procedures outlining the pre-flight steps to load the Cansat into the rocket and check functionality once integrated.
Launch Preparation	Outlines the responsibilities for each team member from the time the Cansat is sitting on the pad and rocket ignition.
Launch Procedure	Procedure for all team members immediately before, during, and immediately after launch into recovery.

Development Status

Currently the MOM template has been downloaded from the website and is under development. Our team is using the knowledge we gained from our first test launch on March 17 to develop a comprehensive Mission Operations Manual by competition.

CanSat Location and Recovery

Component	Visibility
Nose Cone, Aerobrake and Parachute	Brightly Colored filaments and pink or orange fabric to identify Cansat and nose cone.
Visible Beacon	Bright Flashing LED.
Audio Beacon	100dB Beeping Buzzer.
GPS	Real Time Position within 3m.
Team Contact	Phone Number of both team lead and recovery lead, return label address, and email address of team lead. Both on the Cansat and Nose Cone.

Team Contact Info:
Arel Urbanozo (314) 800-5382 au0020@uah.edu; Ashley Reed (423) 509-2726 ar0253@uah.edu;
601 John Wright Dr Huntsville AL 35805

Mission Rehearsal Activities (1 of 2)

Section	Procedures
Ground Station Radio Link	● Put XBee Board into COM port and attach antenna. ● Verify power on CanSat. ● Point antenna on CanSat and monitor CanSat for a good connection. ● Send CX,ON command. ● If GCS receives telemetry, ground link is established.
Powering On/Off the CanSat	● Put batteries into CanSat and switch the CanSat from umbilical power. supply to internal battery power. ● Unplug the umbilical and verify power indicators and lights are on. ● Switch internal power off and verify power indicators are off.
Launch Configuration Preparations	● Assemble CanSat and ensure all layers are securely fastened to the frame. ● Fold and pack the parachute into the top layer of the CanSat. ● Attach the aerobrake layer to the CanSat and turn the servo motor to lock the layer into place. ● Turn on internal power to the CanSat.

Mission Rehearsal Activities (2 of 2)

Section	Procedures
Loading the CanSat into the launch vehicle	● With internal power on the CanSat, verify launch configuration on all systems. ● Load the payload into the rocket and ensure the nose cone fit is correct.
Telemetry processing, archiving, and analysis	● Turn power on CanSat and ground station on. ● Send the CX,ON command. ● Send SIM,ENABLE and SIM,ACTIVATE commands. ● Send pressure data from a csv file. ● Verify telemetry and graphs on the ground station. ● Power off CanSat and remove SD cards. ● Check cards for video and telemetry data files.
Recovery	● Visually track CanSat and rocket during ascent. ● Recovery team track CanSat during descent and maintain visual of aerobrake layer once it jettisons. ● Once payload is on the ground, recovery team uses GPS data and visual and audio indicators to locate CanSat.

All mission rehearsal activities were practiced during our first test launch on March 17, 2024.

Requirements Compliance

Arel Urbanozo

Requirements Compliance Overview

Full Compliance
73/73 (100% Compliance)
Partial Compliance
N/A
No Compliance
N/A

CanSat systems comply with all mission requirements as of the first test launch.

Requirement Compliance (OR I)

Rqmt. 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	15, 22, 23, 26	
C2	The Cansat shall be deployed from the rocket when the rocket motor ejection charge fires.	Comply	15, 24	
C3	After deployment from the rocket, the Cansat shall deploy its heat shield/aerobraking mechanism.	Comply	15, 24	
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	15	
C5	At 100 meters, the Cansat shall deploy a parachute and release the heat shield.	Comply	15, 25	
C6	Upon landing, the Cansat shall stop transmitting data.	Comply	15, 111	

Requirement Compliance (OR II)

Rqmt. Num.	Requirement	Comply / No Comply / Partial	X-Ref Slide(s) Demonstrating Compliance	Team Comments or Notes
C7	Upon landing, the Cansat shall activate an audio beacon.	Comply	15, 111, 148	
C8	The Cansat shall carry a provided large hens egg with a mass range of 51 to 65 grams.	Comply	7, 15, 21, 80	
C9	0 altitude reference shall be at the launch pad.	Comply	15, 111	
C10	During descent with the heat shield deployed, the descent rate shall be between 10 to 30 m/s.	Comply	15, 52, 54	
C11	At 100 meters, the Cansat shall have a descent rate of less than 5 m/s.	Comply	15, 53, 54	
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	172-174	

Requirement Compliance (SR I)

Rqmt. Num.	Requirement	Comply / No Comply / Partial	X-Ref Slide(s) Demonstrating Compliance	Team Comments or Notes
S1	The Cansat mass shall be 900 grams +/- 10 grams without the egg being installed.	Comply	84-86	
S2	Nose cone shall be symmetrical along the thrust axis.	Comply	18-26	
S3	Nose cone radius shall be exactly 71 mm.	Comply	26	
S4	Nose cone shoulder radius shall be exactly 68 mm.	Comply	26	
S5	Nose cone shoulder length shall be a minimum of 50 mm.	Comply	26	
S6	Cansat structure must survive 15 Gs vibration.	Comply	17, 132, 142, 184	
S7	Cansat shall survive 30 G shock.	Comply	17, 142, 184	
S8	The Cansat shall perform the function of the nose cone during rocket ascent.	Comply	15, 18, 22, 26	

Requirement Compliance (SR II)

Rqmt. Num.	Requirement	Comply / No Comply / Partial	X-Ref Slide(s) Demonstrating Compliance	Team Comments or Notes
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	
S10	The rocket airframe can be used as part of the Cansat operations.	Comply	26	
S11	All electronics and mechanical components shall be hard mounted using proper mounts such as standoffs, screws, or high performance adhesives.	Comply	65-73	

Requirement Compliance (MR I)

Rqmt. Num.	Requirement	Comply / No Comply / Partial	X-Ref Slide(s) Demonstrating Compliance	Team Comments or Notes
M1	No pyrotechnical or chemical actuators are allowed.	Comply	56	
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	56	
M3	All mechanisms shall be capable of maintaining their configuration or states under all forces.	Comply	17, 26, 81-83	
M4	Spring contacts shall not be used for making electrical connections to batteries. Shock forces can cause momentary disconnects.	Comply	72	
M5	The Cansat shall deploy a heat shield after deploying from the rocket.	Comply	15, 24, 46, 47	
M6	The heat shield shall be used as an aerobrake and limit the descent rate to 10 to 30 m/s.	Comply	15, 24, 46, 47, 52, 54	

Requirement Compliance (MR II)

Rqmt. Num.	Requirement	Comply / No Comply / Partial	X-Ref Slide(s) Demonstrating Compliance	Team Comments or Notes
M7	At 100 meters, the Cansat shall release a parachute to reduce the descent rate to less than 5 m/s.	Comply	25, 40, 50, 53, 54	
M8	The Cansat shall protect a hens egg from damage during all portions of the flight.	Comply	15, 83	
M9	If the nose cone is to be considered as part of the heat shield, the documentation shall identify the configuration.	Comply	24, 25, 40,	
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	15, 25, 52	

Requirement Compliance (E I)

Rqmt. Num.	Requirement	Comply / No Comply / Partial	X-Ref Slide(s) Demonstrating Compliance	Team Comments or Notes
E1	Lithium polymer batteries are not allowed.	Comply	105	
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	105	
E3	Easily accessible power switch is required.	Comply	104	
E4	Power indicator is required.	Comply	104	
E5	The Cansat shall operate for a minimum of two hours when integrated into the rocket.	Comply	106	

Requirement Compliance (X I)

Rqmt. Num.	Requirement	Comply / No Comply / Partial	X-Ref Slide(s) Demonstrating Compliance	Team Comments or Notes
X1	XBEE radios shall be used for telemetry. 2.4 GHz Series radios are allowed. 900 MHz XBEE radios are also allowed.	Comply	94	
X2	XBEE radios shall have their NETID/PANID set to their team number.	Comply	94	
X3	XBEE radios shall not use broadcast mode.	Comply	94	
X4	The Cansat shall transmit telemetry once per second.	Comply	94, 95, 112	
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	95-98	

Requirement Compliance (SN I)

Rqmt. Num.	Requirement	Comply / No Comply / Partial	X-Ref Slide(s) Demonstrating Compliance	Team Comments or Notes
SN1	Cansat shall measure its speed with a pitot tube during ascent and descent.	Comply	36, 73, 96	
SN2	Cansat shall measure its altitude using air pressure.	Comply	32	
SN3	Cansat shall measure its internal temperature.	Comply	33	
SN4	Cansat shall measure its angle stability with the aerobraking mechanism deployed.	Comply	37	
SN5	Cansat shall measure its rotation rate during descent.	Comply	38	
SN6	Cansat shall measure its battery voltage.	Comply	35	
SN7	The Cansat shall include a video camera pointing horizontally.	Comply	39	
SN8	The video camera shall record the flight of the Cansat from launch to landing.	Comply	106, 112	
SN9	The video camera shall record video in color and with a minimum resolution of 640x480.	Comply	39	

Requirement Compliance (G I)

Rqmt. Num.	Requirement	Comply / No Comply / Partial	X-Ref Slide(s) Demonstrating Compliance	Team Comments or Notes
G1	The ground station shall command the Cansat to calibrate the altitude to zero when the Cansat is on the launch pad prior to launch.	Comply	126	
G2	The ground station shall generate csv files of all sensor data as specified in the Telemetry Requirements section.	Comply	125	
G3	Telemetry shall include mission time with 1 second or better resolution.	Comply	96	
G4	Cansat shall measure its angle stability with the aerobraking mechanism deployed.	Comply	97, 98	
G5	Each team shall develop their own ground station.	Comply	125	
G6	All telemetry shall be displayed in real time during descent on the ground station.	Comply	125	
G7	All telemetry shall be displayed in engineering units (meters, meters/sec, Celsius, etc.) and the units shall be indicated on the displays.	Comply	125	

Requirement Compliance (G II)

Rqmt. Num.	Requirement	Comply / No Comply / Partial	X-Ref Slide(s) Demonstrating Compliance	Team Comments or Notes
G8	Teams shall plot each telemetry data field in real time during flight.	Comply	125	
G9	The ground station shall include one laptop computer with a minimum of two hours of battery operation, XBEE radio and an antenna.	Comply	121, 122	
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	123-125	
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	126	
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	126	
G13	The ground station shall use a table top or handheld antenna.	Comply	123	

Requirement Compliance (G III)

Rqmt. Num.	Requirement	Comply / No Comply / Partial	X-Ref Slide(s) Demonstrating Compliance	Team Comments or Notes
G14	Because the ground station must be viewed in bright sunlight, the displays shall be designed with that in mind, including using larger fonts (14 point minimum), bold plot traces and axes, and a dark text on light background theme.	Comply	125	
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	125	

Requirement Compliance (F I)

Rqmt. Num.	Requirement	Comply / No Comply / Partial	X-Ref Slide(s) Demonstrating Compliance	Team Comments or Notes
F1	The flight software shall maintain a count of packets transmitted which shall increment with each packet transmission throughout the mission. The value shall be maintained through processor resets.	Comply	96, 114	
F2	The Cansat shall maintain mission time throughout the whole mission even with processor resets or momentary power loss.	Comply	92, 114	
F3	The Cansat shall have its time set to within one second UTC time prior to launch.	Comply	99	
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	115, 126	
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	115, 126	
F6	The payload flight software shall only enter simulation mode after it receives the SIMULATION ENABLE and SIMULATION ACTIVATE commands.	Comply	115, 126	

Management

Arel Urbanozo

Status of Procurements (1 of 5)

Hardware

Component	Date Ordered	Date Received
Air Pressure and Temp Sensor - **BMP390**	1/12/24	2/26/24
Microcontroller - **Teensy 4.1**	1/12/24	3/4/24
Orientation and Tilt Sensor - **BNO055**	1/12/24	2/26/24
GPS - **MAX-M10S**	1/12/24	3/4/24
Camera - **OpenMV Cam H7 R1**	1/12/24	2/26/24
Battery Voltage Sensor - **Resistor Module**	1/12/24	2/28/24
Radio Module - **XBee Pro 900 HP**	1/12/24	2/28/24
XBee Explorer Breakout Board	Reused	Reused
Visual Beacon - **New Energy LED**	1/12/24	2/28/24
Audio Beacon - **PUI Audio Buzzer**	1/12/24	2/28/24
Power - **Panasonic CR 123A**	1/12/24	2/22/24

Status of Procurements (2 of 5)

Hardware

Component	Date Ordered	Date Received
Umbilical - **USB C Breakout**	1/12/24	2/26/24
Power Regulation - **Diode**	1/12/24	2/28/24
Resistors	1/12/24	2/28/24
Power Regulation - **N-Channel MOSFET**	1/12/24	2/28/24
Power Switch - **OS102011MS2QN1C**	1/12/24	2/28/24
Antenna- **W1902**	1/12/24	2/28/24
Motor Driver **DRV8871**	1/12/24	2/26/24
3.3v Regulator	1/12/24	2/21/24
5v Regulator	1/12/24	2/21/24
12v Regulator	1/12/24	2/21/24
50:1 Micro Gearmotor	2/23/24	In Progress

Status of Procurements (3 of 5)

Hardware

Component	Date Ordered	Date Received
Fabric - Nylon Sheet	1/12/24	2/21/24
Cylinder Carbon Fiber Rods- 5 pack	1/12/24	2/20/24
Steel Rods	1/12/24	2/20/24
3MM 1/8" x 12" x 20" Baltic Birch Plywood	1/12/24	2/21/24
Fastening nuts kit	1/12/24	2/21/24
PETG Roll	1/12/24	2/21/24
Epoxy- 25Fl oz	1/12/24	2/21/24
Fiberglass	Reused	Reused
Pitot Tube	1/12/24	2/21/24
Aerobrake 25kg Servo	1/12/24	2/20/24
Hinged Threaded Round Standoffs	1/12/24	2/20/24

Status of Procurements (4 of 5)

Hardware

Component	Date Ordered	Date Received
NF123G-305	1/12/24	2/26/24
Gromets	1/12/24	2/21/24
Fishing Line	1/12/24	2/21/24
Mylar	1/12/24	2/21/24
Loctite	1/12/24	2/21/24
Screws	1/12/24	2/20/24
Standoffs	1/12/24	2/21/24

Status of Procurements (5 of 5)

Ground Station

Component	Date Ordered	Date Received
Ground Station Laptop - Dell XPS 15	Reused	Reused
Antenna - Laird Technologies PC906N	Reused	Reused
GCS Cable - Coaxial Cable	Reused	Reused
Radio Board - Sparkfun XBee USB Board	Reused	Reused
Radio Module - XBee Pro 900HP	1/12/24	2/28/24
USB Mini to USB A Cable	Reused	Reused

CanSat Budget – Hardware (1 of 2)

Name	Designation	Quantity	Unit Price	Total Price	Source	Reuse
Air Pressure and Temperature Sensor - **BMP390**	ELEC	1	$10.95	$10.95	Digikey	
Microcontroller - **Teensy 4.1**	ELEC	1	$33.08	$33.08	Digikey	
Orientation and Tilt Sensor - **BNO055**	ELEC	1	$34.95	$34.95	Digikey	
GPS - **MAX-M10S**	ELEC	1	$44.95	$44.95	Digikey	
Camera - **OpenMV Cam H7 R1**	ELEC	2	$101.94	$203.88	Digikey	
Battery Voltage Sensor - **Resistor Module**	ELEC	1	$0.20	$0.20	Digikey	
Radio Module - **XBee Pro 900 HP**	ELEC	1	$55.66	$55.66	Digikey	X
Radio Board - **XBee Explorer Breakout Board**	ELEC	1	$3.50	$3.50	Digikey	X
Visual Beacon - **New Energy LED**	ELEC	1	$7.26	$7.26	Digieky	X
Audio Beacon - **PUI Audio Buzzer**	ELEC	1	$1.00	$1.00	Digikey	X
Power - **Surefire CR 123A**	ELEC	2	$2.33	$4.66	Digikey	X
Umbilical - **USB C Breakout**	ELEC	1	$2.95	$2.95	Digikey	
Power Regulation - **Diode**	ELEC	1	$0.08	$0.08	Digikey	X
Resistors	ELEC	6	$0.10	$0.60	Digikey	
Power Regulation - **N-Channel MOSFET**	ELEC	4	$0.44	$1.76	Digikey	X
Power Switch - **OS102011MS2QN1C**	ELEC	1	$0.68	$0.68	Digikey	X
Antenna- **W1902**	ELEC	1	$6.16	$6.16	Digikey	
Motor Driver **DRV8871**	ELEC	1	$7.50	$7.50	Digikey	
3.3v Regulator	ELEC	1	11.95	$11.95	Pololu	
5v Regulator	ELEC	1	11.95	$11.95	Pololu	
12v Regulator	ELEC	1	29.95	$29.95	Pololu	
50:1 Micro Gearmotor	ELEC	1	23.45	$23.45	Pololu	

CanSat Budget – Hardware (2 of 2)

Name	Designation	Quantity	Unit Price	Total Price	Source	Reuse
Fabric - Nylon Sheet	MECH	1	$8.75	$8.75	Amazon	X
Cylinder Carbon Fiber Rods- 5 pack	MECH	1	$11.99	$11.99	Amazon	
Steel Rods	MECH	4	$0.92	$3.67	amazon	X
3MM 1/8" x 12" x 20" Baltic Birch Plywood	MECH	3	$10.65	$31.95	amazon	
Fastening nuts kit	MECH	1	$17.99	$17.99	amazon	X
PETG Roll	MECH	1	$23.99	$23.99	Amazon	X
Epoxy- 25Fl oz	MECH	1	$16.35	$16.35	Amazon	X
Fiberglass	MECH	1	$8.95	$8.95	Amazon	
Pitot Tube	MECH	1	$14.99	$14.99	Amazon	
Aerobrake 25kg Servo	MECH	1	$16.99	$16.99	Amazon	
Hinged Threaded Round Standoffs - 98010A460	MECH	6	$3.14	$18.84	McMaster Carr	
NF123G-305	MECH	1	$5.64	$5.64	Adafruit	
Gromets	MECH	1	$6.59	$6.59	Amazon	
Fishing Line	MECH	1	$4.99	$4.99	Amazon	
Mylar	MECH	1	$5.99	$5.99	Amazon	
Loctite	MECH	1	$8.99	$8.99	Amazon	
Screws	MECH	1	$15.99	$15.99	Amazon	
Standoffs	MECH	1	$22.96	$22.96	Amazon	

Electrical Subtotal: $497.12	**Mechanical Subtotal: $239.97**
Hardware Total: $737.09	

CanSat Budget – Other Costs

Name	Designation	Quantity	Unit Price	Total Price	Source	Reuse
Ground Station Laptop - **Dell XPS 15**	GCS	1	$2,350	$2,350	Dell	X
GCS Antennae - **Laird Technologies PC906N**	GCS	1	$47.39	$47	Digikey	X
GCS Cable - **Coaxial Cable**	GCS	1	$11.99	$12	Digikey	X
Radio Board - **Sparkfun XBee USB Board**	GCS	1	$27.95	$28	Digikey	X
Radio Module - **XBee Pro 900 HP**	GCS	1	$56.00	$56	Digikey	X
USB Mini to USB A Cable	FSW	1	$6.99	$7	Digikey	X
Travel (Per Person)	MISC	10	$132.23	$1,322	Estimate	
Lodging (Per Person)	MISC	10	$283.33	$2,833	Estimate	
Food (Per Person)	MISC	10	$100.00	$1,000	Estimate	

Other Costs: $7,656

Graciously funded by the Alabama Space Grant Consortium.

Program Schedule Overview

Basic Program Schedule

TASK	Start	End	November					December				January					February				March				April				May					June	
			1	8	15	22	29	6	13	20	27	3	10	17	24	31	7	14	21	28	6	13	20	27	3	10	17	24	1	8	15	22	29	5	12
Shockwave																																			
Team Application	11/1/23	11/3/23	▨																																
PDR Phase	11/4/23	2/5/24	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨																			
CDR Phase	2/6/24	4/8/24															▨	▨	▨	▨	▨	▨	▨	▨	▨	▨									
Prototyping and Test Launch Phase	3/18/24	6/2/24																					▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨		
Competition Phase	6/3/24	6/9/24																																▨	▨

Detailed Program Schedule (1 of 4)

TASK	Start	End	November					December				January					February				March				April				May					June	
			1	8	15	22	29	6	13	20	27	3	10	17	24	31	7	14	21	28	6	13	20	27	3	10	17	24	1	8	15	22	29	5	12
Detailed Schedule																																			
Team Application	11/1/23	11/3/23	▨																																
MCR	11/2/23	11/29/23	▨	▨	▨	▨	▨																												
Parts Ordering	12/1/23	1/1/24					▨	▨	▨	▨	▨																								
PDR Preparation	12/2/23	1/23/24						▨	▨	▨	▨	▨	▨	▨	▨																				
Fall Term Finals	12/4/23	12/8/23						■	■																										
Winter Break	12/9/23	1/8/23							▨	▨	▨	▨	▨																						
PDR Presentation	2/2/24	2/23/24														▨	▨	▨	▨																
E-Week	2/19/24	2/25/24																	▨	▨															
CDR Preparation	2/26/24	4/1/24																		▨	▨	▨	▨	▨	▨										
Initial Prototyping	1/10/24	3/14/24											▨	▨	▨	▨	▨	▨	▨	▨	▨	▨													
Test Launch 1	3/14/24	3/15/24																				▨													
CDR Presentation	4/8/24	4/26/24																							▨	▨	▨	▨							
Environmental Test Review	4/16/24	5/24/24																									▨	▨	▨	▨	▨	▨			
Spring Term Finals	4/29/24	5/3/24																										■	■						
Test Launch 2	5/6/24	5/10/24																												▨					
Competition Weekend																																		▨	▨

Approximately 70% done with the competition at time of CDR

Detailed Program Schedule (2 of 4)

TASK	Start	End	November					December				January					February				March				April				May					June	
			1	8	15	22	29	6	13	20	27	3	10	17	24	31	7	14	21	28	6	13	20	27	3	10	17	24	1	8	15	22	29	5	12
Shockwave																																			
Team Application	11/1/23	11/3/23	▨																																
PDR Phase	11/4/23	2/5/24	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨																			
CDR Phase	2/6/24	4/8/24															▨	▨	▨	▨	▨	▨	▨	▨	▨	▨									
Prototyping and Test Launch Phase	3/18/24	6/2/24																					▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨		
Competition Phase	6/3/24	6/9/24																																▨	▨
Mechanical Development																																			
Finish Initial CAD design (both sub teams)	11/9/2023	11/16/2023			▨																														
Integrated Designs	11/9/2023	11/26/2023			▨	▨	▨																												
Updated CAD Designs for PDR	11/26/2023	1/29/2024					▨	▨	▨	▨	▨																								
Full CanSat Assembly for Test Launch	1/8/2024	3/7/2024										▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨													
Updated Design for CDR	3/7/2024	3/21/2024																				▨	▨	▨											
Fully Updated CanSat for Test Launch 2	3/7/2024	4/28/2024																				▨	▨	▨	▨	▨	▨	▨							
Final Designs	4/28/2024	5/24/2024																									▨	▨	▨	▨	▨	▨	▨	▨	▨

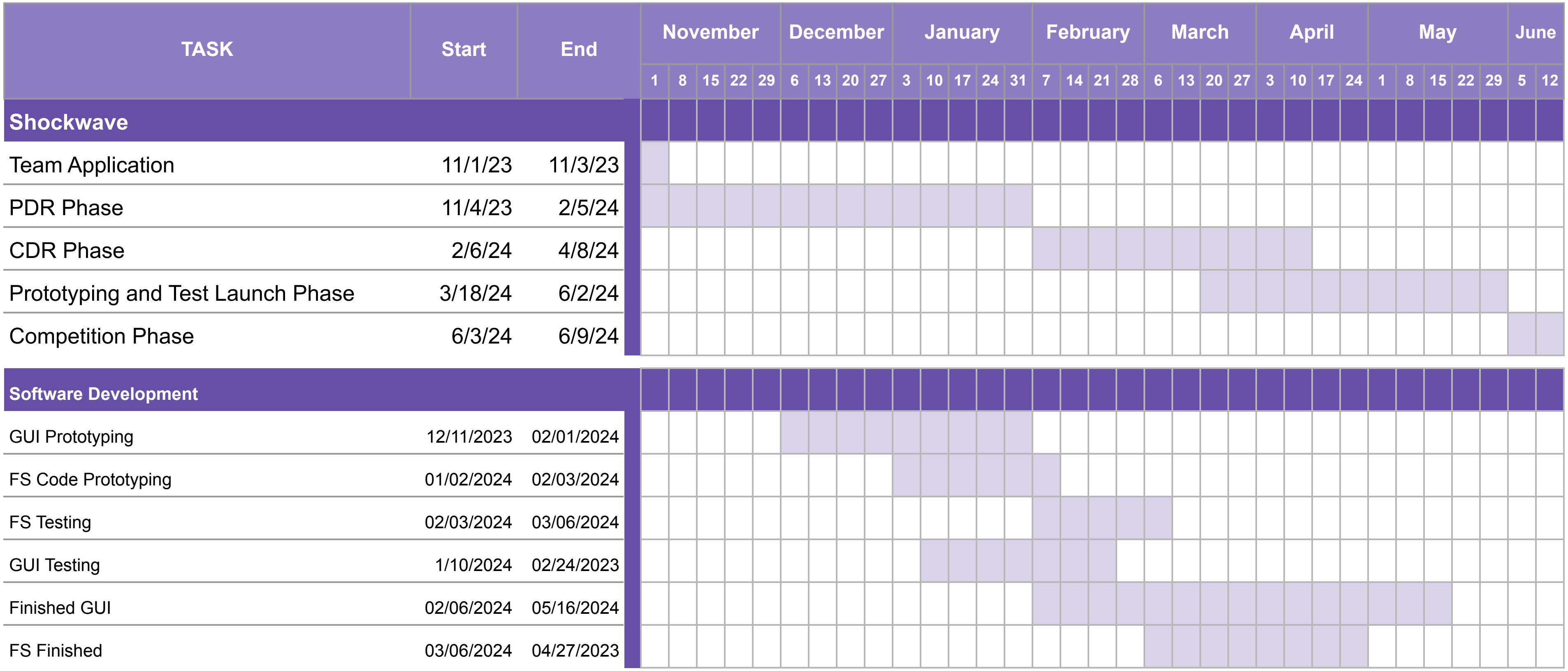
Mechanical Schedule

Detailed Program Schedule (3 of 4)

TASK	Start	End	November					December				January					February				March				April				May					June	
			1	8	15	22	29	6	13	20	27	3	10	17	24	31	7	14	21	28	6	13	20	27	3	10	17	24	1	8	15	22	29	5	12
Shockwave																																			
Team Application	11/1/23	11/3/23	▨																																
PDR Phase	11/4/23	2/5/24	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨																			
CDR Phase	2/6/24	4/8/24															▨	▨	▨	▨	▨	▨	▨	▨	▨	▨									
Prototyping and Test Launch Phase	3/18/24	6/2/24																					▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨		
Competition Phase	6/3/24	6/9/24																																▨	▨
Electrical Development																																			
Trade Studies	11/6/2023	11/10/2023		▨	▨																														
Schematic	11/20/2023	11/24/2023			▨	▨																													
PCB Design #1	12/8/2023	12/15/2023					▨	▨	▨	▨																									
PCB Order #1	12/17/2023	12/17/2023								▨																									
PCB Assembly	1/13/2024	1/20/2024									▨	▨																							
Prototyping	2/20/2024	6/12/2024									▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨
PCB Design #2	2/21/2024	2/28/2024																	▨	▨															
PCB Order #2	2/27/2024	2/28/2024																		▨															
PCB Design #3	3/20/2024	3/27/2024																					▨	▨											

Electrical Schedule

Detailed Program Schedule (4 of 4)



TASK	Start	End	November					December				January					February				March				April				May					June	
			1	8	15	22	29	6	13	20	27	3	10	17	24	31	7	14	21	28	6	13	20	27	3	10	17	24	1	8	15	22	29	5	12
Shockwave																																			
Team Application	11/1/23	11/3/23	▨																																
PDR Phase	11/4/23	2/5/24	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨																			
CDR Phase	2/6/24	4/8/24															▨	▨	▨	▨	▨	▨	▨	▨	▨	▨									
Prototyping and Test Launch Phase	3/18/24	6/2/24																					▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨		
Competition Phase	6/3/24	6/9/24																																▨	▨
Software Development																																			
GUI Prototyping	12/11/2023	02/01/2024						▨	▨	▨	▨	▨	▨	▨	▨	▨																			
FS Code Prototyping	01/02/2024	02/03/2024										▨	▨	▨	▨	▨	▨																		
FS Testing	02/03/2024	03/06/2024															▨	▨	▨	▨	▨														
GUI Testing	1/10/2024	02/24/2023											▨	▨	▨	▨	▨	▨	▨																
Finished GUI	02/06/2024	05/16/2024															▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨			
FS Finished	03/06/2024	04/27/2023																			▨	▨	▨	▨	▨	▨	▨	▨							

Software Schedule

Shipping and Transportation

Transportation Plan

Our team will drive vans provided by The University of Alabama in Huntsville to transport personnel and hardware to the competition site from Huntsville, AL. Equipment to be brought to the competition will include two identical CanSats, spare parts, tools, and ground station equipment. Since all equipment will be with the team during the commute to the competition, no tools or equipment will be checked with airlines or shipped separately to the site.

Image Credit: ford.com

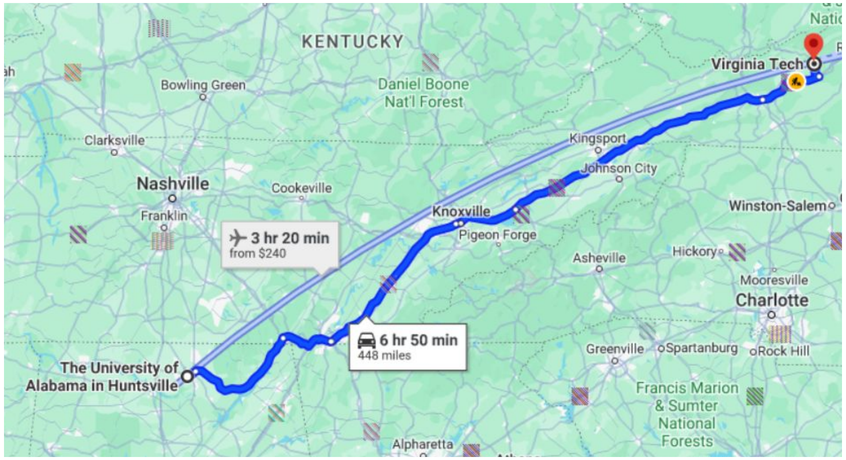
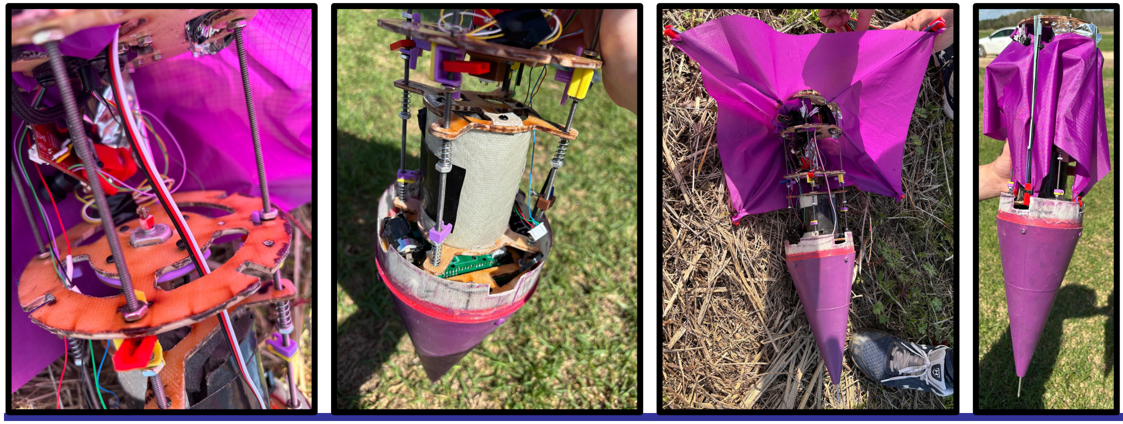


Image Credit: google.com

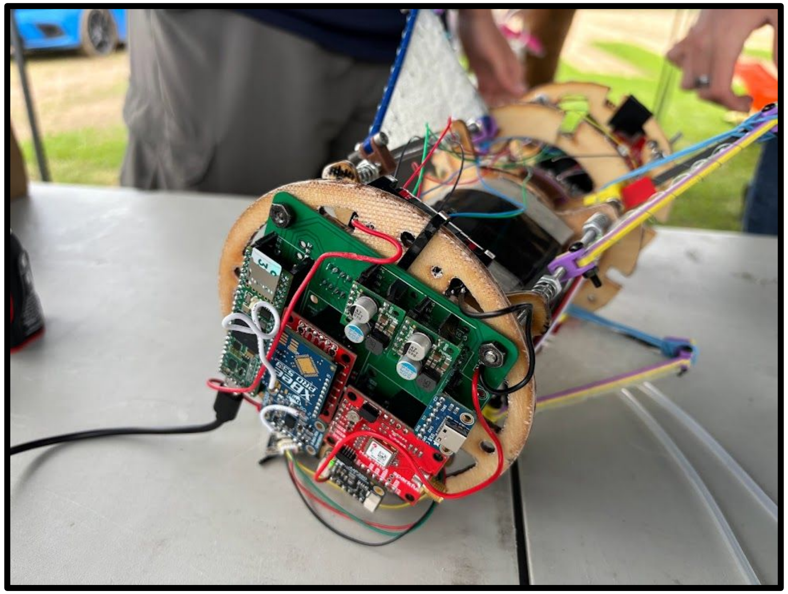
Conclusions (1 of 4)

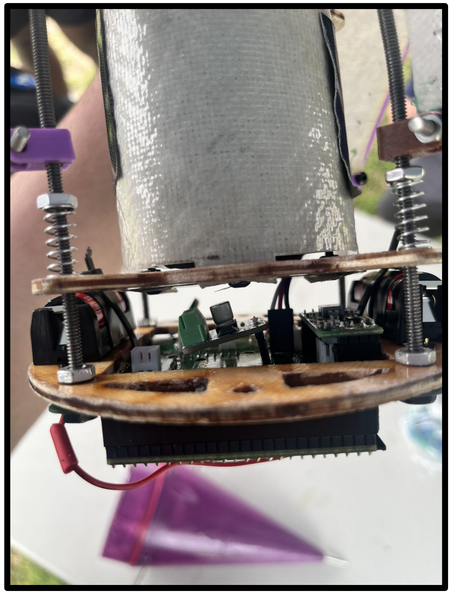
Mechanical Conclusions	
Accomplishments	- Built and launched a prototype payload. - Had a surviving egg during test launch.
Major To-Do's	- Design a mechanism to hold the aerobrake open. - Redesign nose cone-payload attachment. - Redesign rotating camera mount. - Continue testing existing designs and new designs.

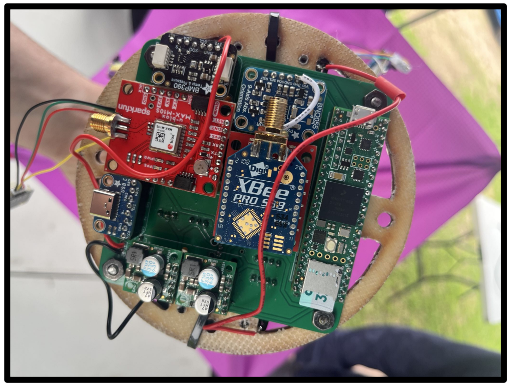


Conclusions (2 of 4)

Electrical Conclusions	
Accomplishments	PCB Integration, Survived Test Flight.
Major To-Do's	PCB Post Flight Redesign, Further Servo and Motor Testing.

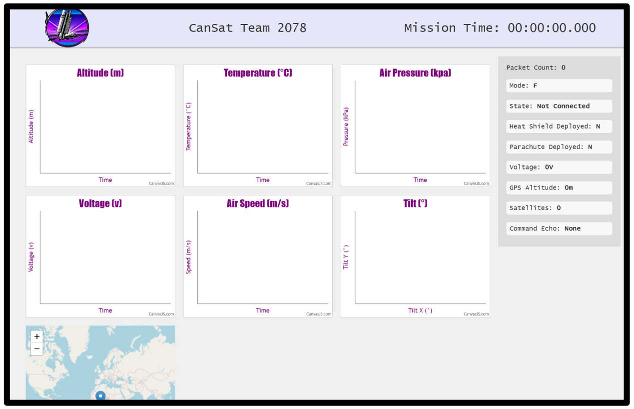






Conclusions (3 of 4)

Software Conclusions	
Accomplishments	FSW ● State Machine ● Sensor Communication ● Release Mechanisms GCS ● CSV Creation ● WebSocket Communication ● GCS Prototype ● Real Time Plotting
Major To-Do's	FSW ● PID Controller ● Button Communication GCS ● Button Communication Overall ● Finalized Testings ● 2nd Flight Test ● Further Telemetry Testing



CanSat Team 2078

Mission Time: 00:00:00.000

Packet Count: 0

Mode: F

State: Not Connected

Heat Shield Deployed: N

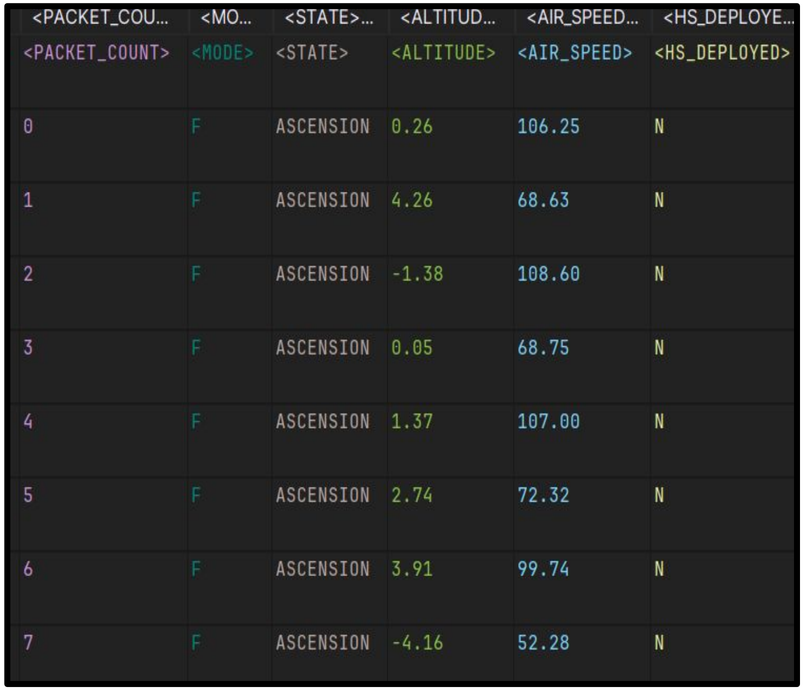
Parachute Deployed: N

Voltage: 0V

GPS Altitude: 0m

Satellites: 0

Command Echo: None



<PACKET_COU...	<MO...	<STATE>...	<ALTITUD...	<AIR_SPEED...	<HS_DEPLOYE...
<PACKET_COUNT>	<MODE>	<STATE>	<ALTITUDE>	<AIR_SPEED>	<HS_DEPLOYED>
0	F	ASCENSION	0.26	106.25	N
1	F	ASCENSION	4.26	68.63	N
2	F	ASCENSION	-1.38	108.60	N
3	F	ASCENSION	0.05	68.75	N
4	F	ASCENSION	1.37	107.00	N
5	F	ASCENSION	2.74	72.32	N
6	F	ASCENSION	3.91	99.74	N
7	F	ASCENSION	-4.16	52.28	N

Conclusions (4 of 4)

Rationale for Further Development
Our team is ready to begin prototyping and testing our final CanSat, building off the successes and failures of our first design. We will continue to iterate our design in order to fulfill the mission requirements by competition. With the majority of our hardware having survived the first test flight, our team is looking ahead to environmental testing and finishing our competition payload.