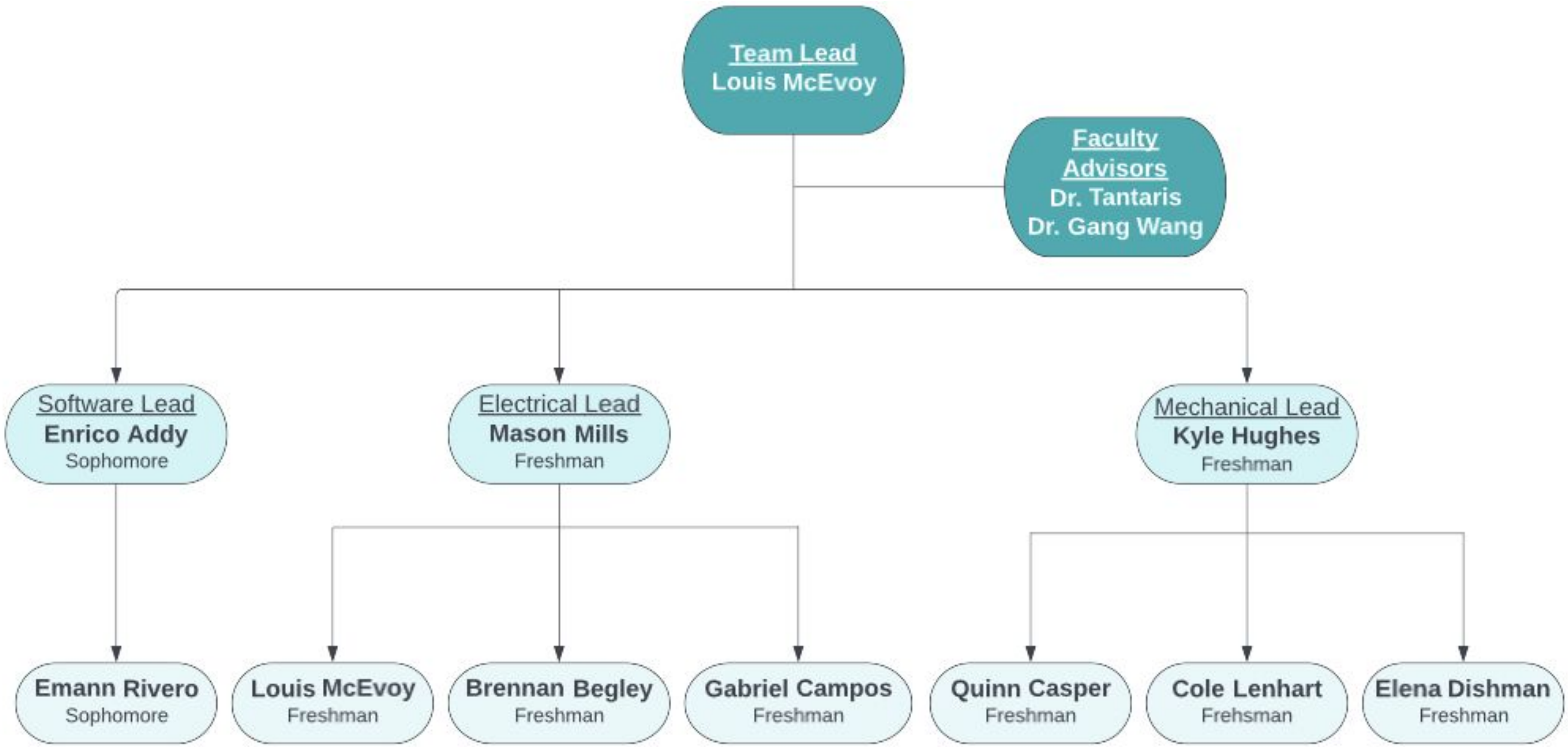
CanSat 2023
Critical Design Review (CDR)
Outline
Version 1.0

1079

Afterburner

Presentation Outline

Team Organization



Acronyms (1 of 5)

Acronym	Explanation
ADC	Analog to Digital Converter
API	Application Programming Interface
ARM	Advanced RISC (Reduced Instruction Set Computer) Machine
°C	Degree Celsius
C_D	Coefficient of Drag
CDH	Command Data Handler
CDR	Critical Design Review
cm	Centimeter
CMD	Command
CSV	Comma Separated Values
dBi	Decibel Relative to Isotrope
dBm	Decibel Milliwatts

Acronyms (2 of 5)

Acronym	Explanation
EPS	Electrical Power Subsystem
EEPROM	Electrically Erasable Programmable Read-Only Memory
FPS	Frames per Second
FSW	Flight Software
G	Gravitational Shock
g	Grams
GHz	Gigahertz
GND	Ground
GPS	Global Positioning System
GS	Ground Station
hPa	Hectopascals
Hz	Hertz

Acronyms (3 of 5)

Acronym	Explanation
I2C	Inter-Integrated Circuit
IDE	Integrated Development Environment
KB	Kilobytes
kg	Kilograms
kPa	Kilopascals
L1	Level One
LED	Light Emitting Diode
m	Meter
m/s	Meters per Second
mA	Milliamps
mAh	Milliamp Hours
MCU	Microcontroller Unit

Acronyms (4 of 5)

Acronym	Explanation
MHz	Megahertz
mm	Millimeter
MOSFET	Metal Oxide Semiconductor Field Effect Transistor
N/A	Not Available
ns	Nanosecond
Pa	Pascals
PCB	Printed Circuit Board
PETG	Polyethylene Terephthalate Glycol
PWM	Pulse Width Modulation
RAM	Random Access Memory
RP	Raspberry Pi

Acronyms (5 of 5)

Acronym	Explanation
RTC	Real-Time Clock
SD	Secure Digital
SPI	Serial Peripheral Interface
UART	Universal Asynchronous Receiver-Transmitter
UTC	Coordinated Universal Time
V	Volts
v	Velocity
VDC	Voltage Dividing Circuit
VSWR	Voltage Standing Wave Ratio
Wh	Watt Hours
yd	Yard
ρ	Density (kg/m^3)

System Overview

Louis McEvoy

Mission Summary

Main Objectives	
Design a CanSat that will consist of a container and probe and simulate the landing sequence of a planetary probe.	
1	The CanSat will separate from the rocket between 670 and 725 meters and descend under a parachute at 15 meters per second.
2	At 500 meters the CanSat will release a probe that will deploy an aerobraking heat shield.
3	Once the probe reaches 200 meters, the probe will deploy a parachute and descend at a rate of 5 meters per second.
4	Upon landing, the probe will upright itself and raise a flag 500 millimeters above the base of the probe.
5	A video camera on the probe will point toward the ground to record the descent.
6	The probe will transmit all required telemetry and relay sensor data to the ground station.

Bonus Objective	
The container shall contain a camera that will record the probe deployment and its descent.	**Rationale:** Team Afterburner has experience working with small onboard cameras aboard CanSats and are interested in using the video for evaluation and outreach.

Summary of Changes Since PDR (1 of 2)

Sub-Team	System	PDR	CDR	Reasoning
Mechanical	Heat Shield Deployment System	Single servo driven linkage assembly	Dual servo driven heat shield for deployment and uprighting	• Reduced mass over previous system • Lowers center of mass to improve stability • Reduced backlash
	Parachute Container	Spring loaded parachute container	Increased parachute container volume	• Increases parachute reliability • Decreases parachute opening time
	Flag Raising Mechanism	Spring loaded baton	Tape measure flag raising design	• Flag now resistant to wind shear • Easier actuation
	Electronics Package Location	Inside electronics housing	Electronics package inside of deployment system	• Lower center of mass • Easy access to connectors

Summary of Changes Since PDR (2 of 2)

Sub-Team	System	PDR	CDR	Reasoning
Electrical	Sensor Subsystem	BMP390	BMP388	• BMP390 was not available for purchase
	Electrical Power Subsystem	1 Analog Feedback Servo	2 MG90 360° Servos	• Revised heat shield design requires two 360° servos
Software	Ground Control System (GCS)	Location Tracking implemented using QPixMap	Location Tracking implemented using Folium	• Interactive map of GPS coordinates • Live updating of map elements
	Flight Software (FSW)	Progressive command interpretation	Simultaneous command interpretation	• Reduced probability of late commands
	Flight Software (FSW)	Unified Functions	Modularized Functions	• Reduced the code's complexity and improved readability

System Requirement Summary (1 of 4)

Req. #	Description	Subsystem	Verification Method			
			A	I	T	D
1	Total mass of the CanSat (science probe and container) shall be 700 grams ± 10 grams.	MECH	X	X		
2	CanSat shall fit in a cylindrical envelope of 125 mm diameter x 400 mm length. Tolerances are to be included to facilitate container deployment from the rocket fairing.	MECH	X		X	
3	The container shall not have any sharp edges to cause it to get stuck in the rocket payload section which is made of cardboard.	MECH	X		X	
4	The parachutes and container shall be fluorescent pink or orange.	MECH		X		
5	Rocket airframe shall not be used in CanSat operations or to restrain any deployable systems.	MECH	X	X		
6	The descent rate of the CanSat (container and science probe) shall be 15 meters/second +/- 5 m/s.	MECH	X		X	X
7	0 altitude reference shall be at the launch pad.	FSW	X		X	
8	All structures shall withstand 15 Gs of launch acceleration as well as 30 Gs of Shock.	MECH			X	X
9	All electrical and mechanical components shall be hard mounted.	MECH,EPS	X	X		

System Requirement Summary (2 of 4)

Req. #	Description	Subsystem	Verification Method			
			A	I	T	D
10	Cost of CanSat shall be under 1000 dollars.	MANAGEMENT	X	X		
11	2.4 GHz or 900 MHz XBee Radios shall be used for telemetry and set to not to broadcast mode.	CDH		X		
12	Probe and container must contain power switches that can be accessed in the stowed configuration.	MECH	X	X		
13	Probe shall include a power indicator such as an LED or sound generating device that can be easily seen or heard without disassembling the CanSat and in the stowed state. The probe requires an audio beacon to be activated after landing.	EPS	X	X		X
14	An easily accessible battery compartment shall be included allowing batteries to be installed or removed in less than a minute and not require a total disassembly of the CanSat.	EPS, MECH	X			X
15	CanSat shall survive all required environmental tests as established in the mission guide.	EPS, MECH			X	X
16	The CanSat shall operate for a minimum of two hours when integrated into the rocket.	EPS	X		X	X

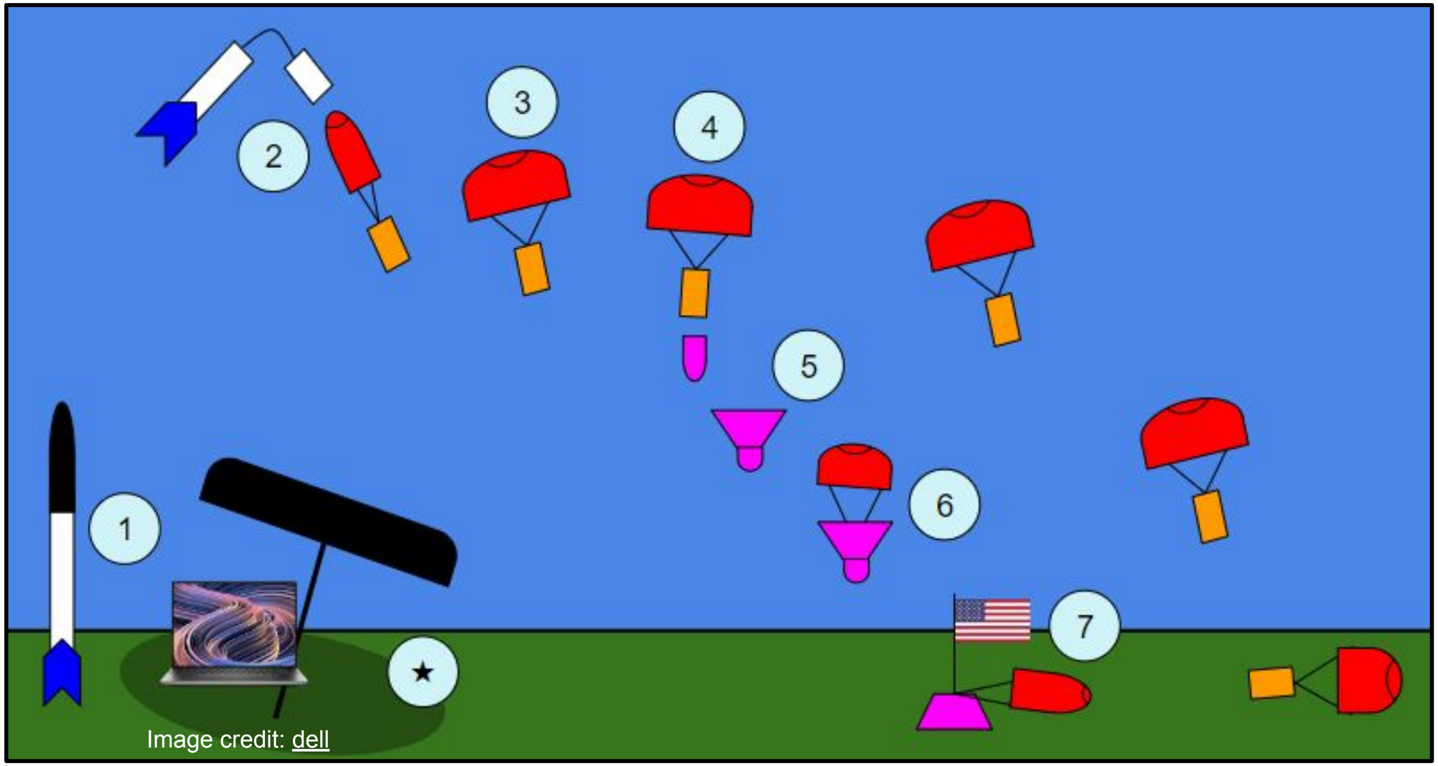
System Requirement Summary (3 of 4)

Req. #	Description	Subsystem	Verification Method			
			A	I	T	D
17	The probe shall be released from the container when the CanSat reaches 500 meters and deploy a heat shield.	EPS, MECH, FSW			X	X
18	Heat shield will limit probe descent rate to 20 m/s or less.	EPS, MECH, FSW			X	X
19	At 200 meters, the probe shall release a parachute to reduce the descent rate to 5 m/s ±1 m/s.	EPS, MECH, FSW			X	X
20	Once landed, the probe shall upright itself.	EPS, MECH, FSW			X	X
21	After uprighting, the probe shall deploy a flag 500 mm above the base of the probe.	EPS, MECH, FSW			X	X
22	The probe telemetry shall include altitude, air pressure, temperature, battery voltage, probe tilt angles, command echo, and GPS coordinates that include latitude, longitude, altitude and number of satellites tracked.	CDH, FSW	X			X
23	The probe shall include a downward facing video camera to record the flight of the probe from release to landing.	EPS	X		X	
24	Probe will maintain packet count, mission time, and configuration state through processor resets.	FSW	X			X

System Requirement Summary (4 of 4)

Req. #	Description	Subsystem	Verification Method			
			A	I	T	D
25	The probe 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.	FSW	X			X
26	In simulation mode, the flight software shall use the radio uplink pressure values in place of the pressure sensor for determining the container altitude.	FSW	X			X
27	The container flight software shall only enter simulation mode after it receives the SIMULATION ENABLE and SIMULATION ACTIVATE commands.	FSW	X			X
28	The ground station shall generate CSV files of all sensor data as specified in the Telemetry Requirements section.	CDH, GCS	X			X
29	Each team shall develop their own ground station.	GCS		X		X
30	All telemetry shall be displayed in real time during descent to the ground and plot each data field in real time.	GCS		X		X
31	All telemetry shall be displayed in engineering units (meters, meters/sec, Celsius, etc.).	GCS		X	X	
32	Container shall include a camera to satisfy the bonus objective.	EPS	X			X

System Concept of Operations (1 of 2)



★
CanSat will communicate with the ground station for the duration of the mission

1	2	3	4	5	6	7
CanSat is loaded into launch vehicle	CanSat deploys at an altitude of 670 m - 725 m	Descent is slowed via parachute to a rate of 15 m/s	Probe is released at 500 m	Probe opens a heat shield and descends at 20 m/s	Probe deploys parachute at 200 m, slows descent to 5 m/s	Probe lands, uprights, and raises a flag 500 mm above the probe

System Concept of Operations (2 of 2)

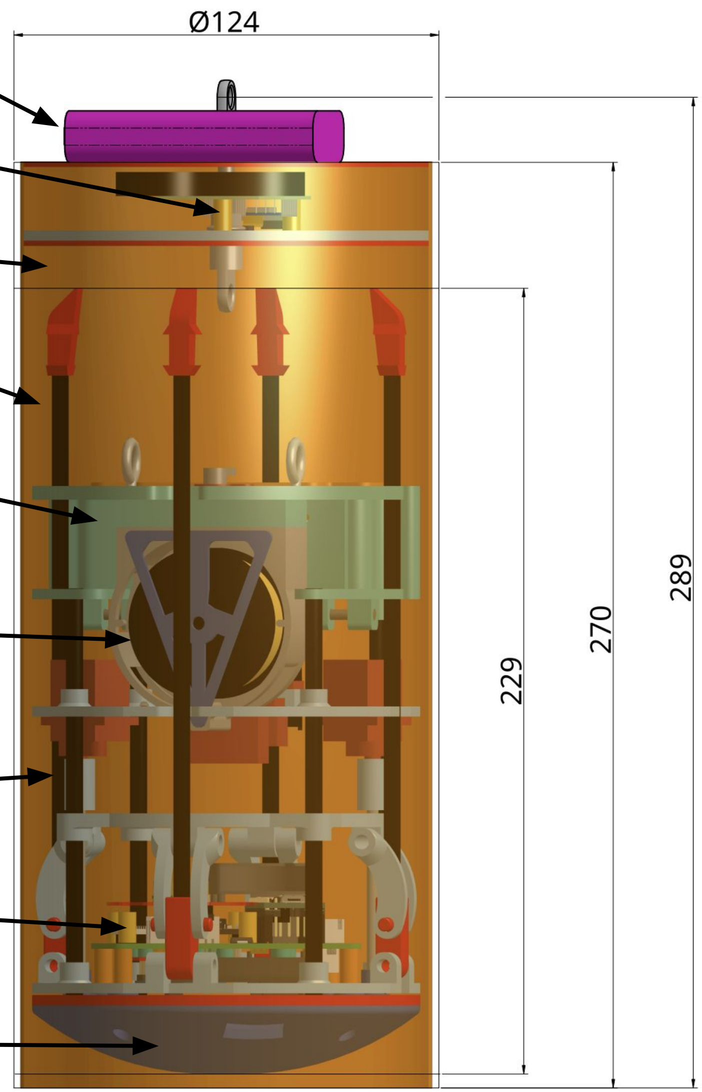
Team Roles and Responsibilities:

- Everyone on the team will be contributing to the events of launch day
- The Mission Operation Manual lays out the events that the team will follow

Team	Description	Personnel
Mission Control Officer	Responsible for informing flight coordinator when their team and CanSat is ready to be launched.	Louis McEvoy
Ground Station Team	Responsible for monitoring the ground station for telemetry reception and issuing commands to the CanSat.	Enrico Addy, Emann Rivero
Recovery Team	Responsible for tracking the CanSat and going out into the field for recovery and interacting with the field judges. This team is responsible for making sure all field scores are filled in.	Brennan Begley, Mason Mills
CanSat Team	Responsible for preparing the CanSat, integrating it into the rocket, and verifying its status.	Gabriel Campos, Quinn Casper, Elena Dishman, Kyle Hughes, Cole Lenhart

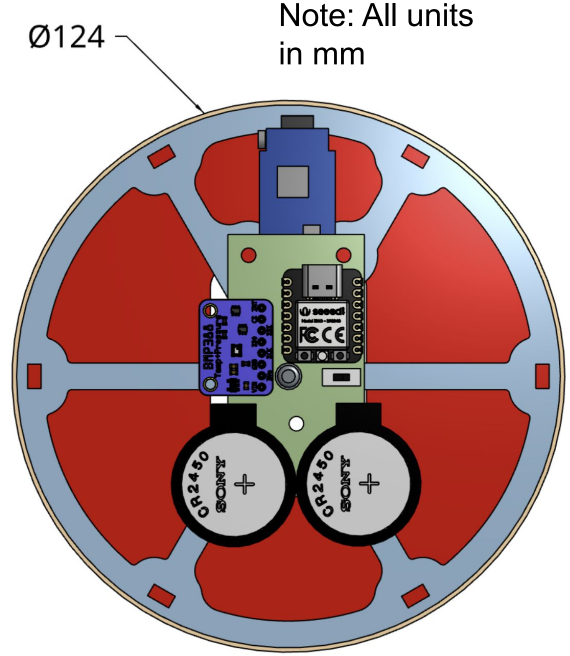
Physical Layout (1 of 5)

- Container Parachute
- Container Electronics
- Fiberglass Shell
- Heat Shield Arms
- Servo-Actuated Parachute Deployment
- Servo-Actuated Flag Mechanism
- Continuous Servo Heat Shield Deployment
- Electronics Package
- Nose Cone with Batteries and Camera

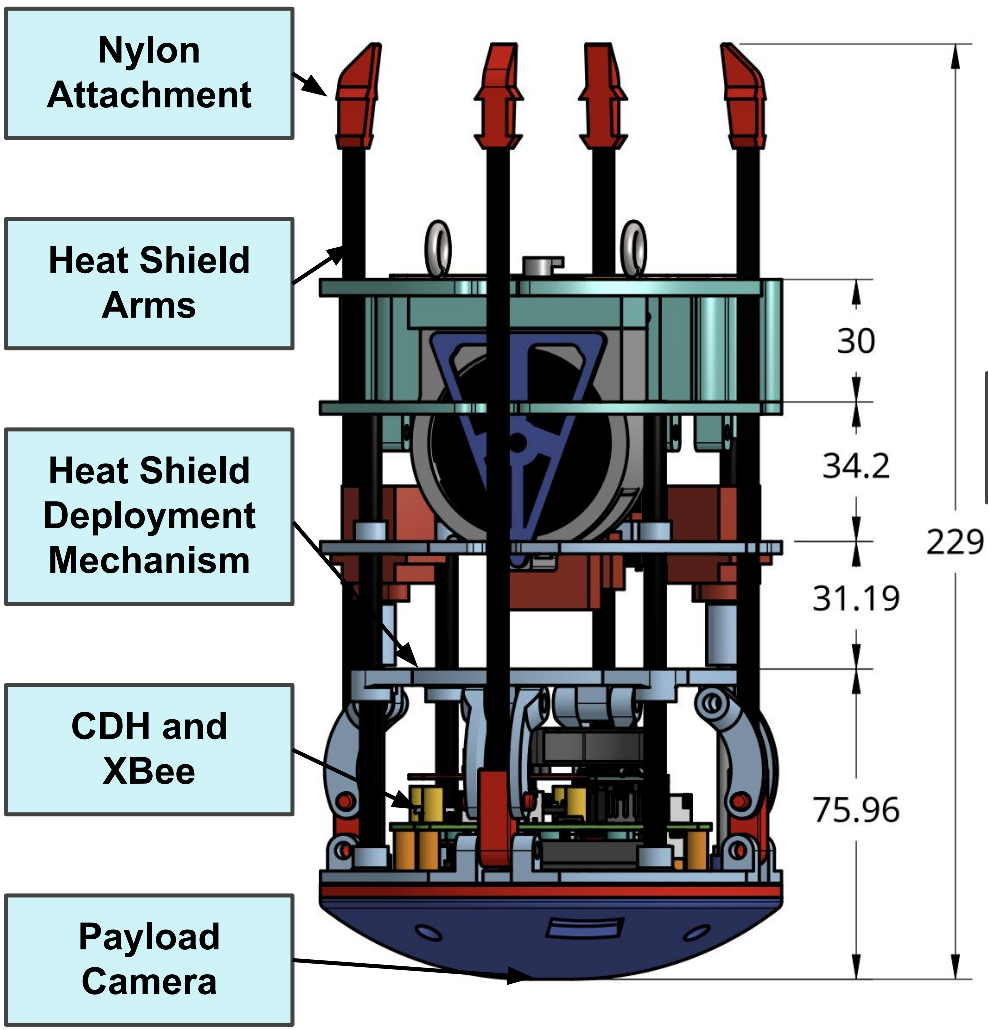


Launch Configuration

Note: All units in mm

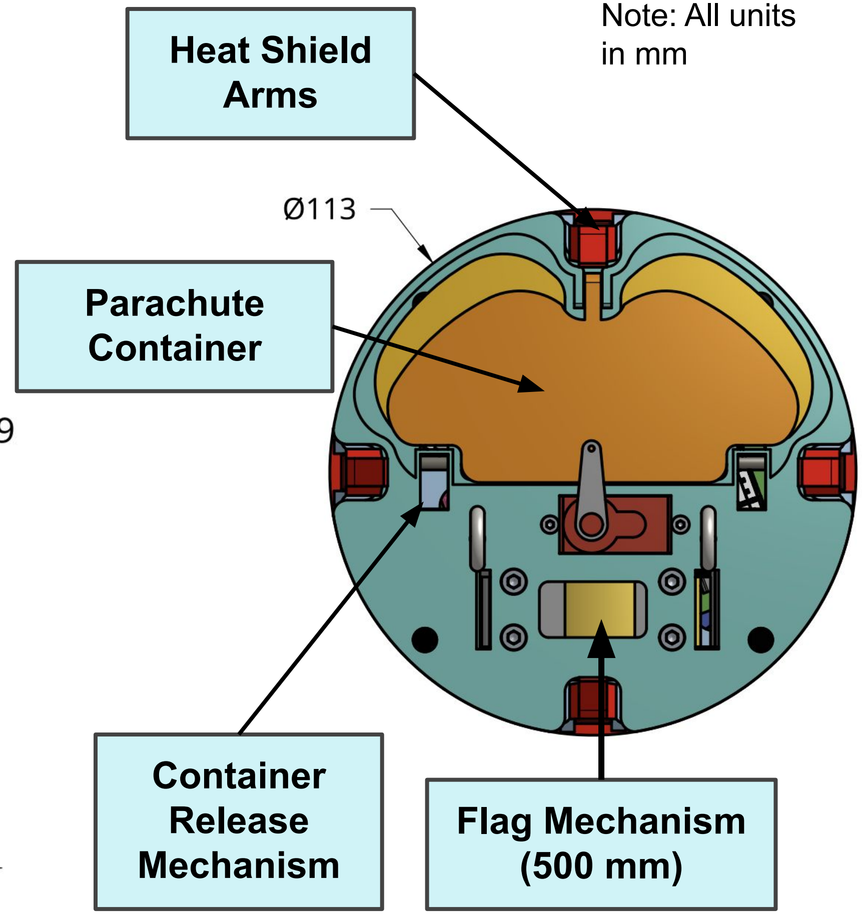


Container houses electrical components needed for bonus objective camera



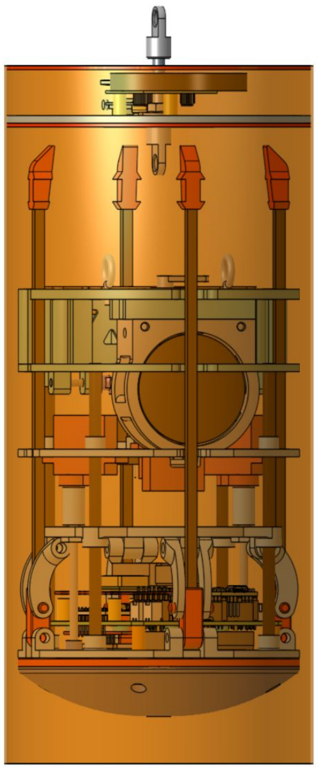
Payload

Note: All units in mm



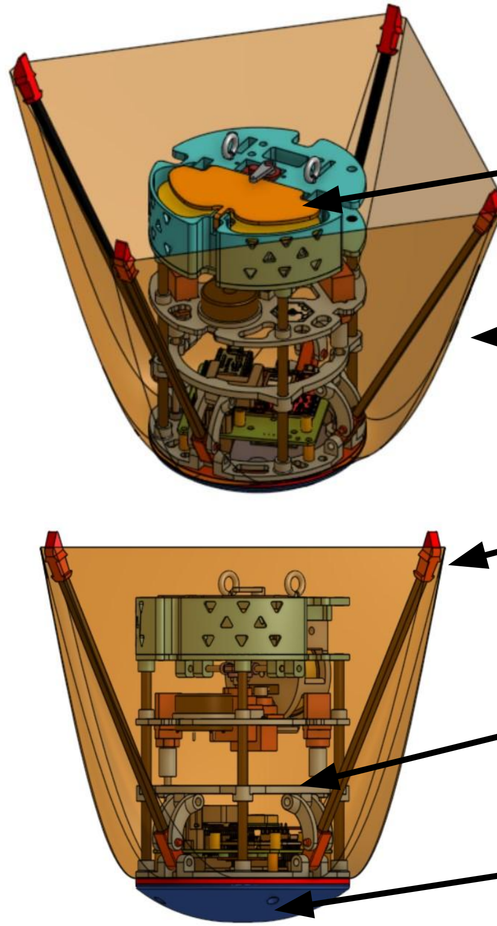
Physical Layout (3 of 5)

Stowed and Deployed Configuration



Stowed Configuration

Note: CanSat will be upside down when integrated into the rocket



Parachute Container

Deployed Ripstop Nylon Heat Shield

Deployed Heat Shield Arms

Deployment System

Nose Cone with Batteries and Camera

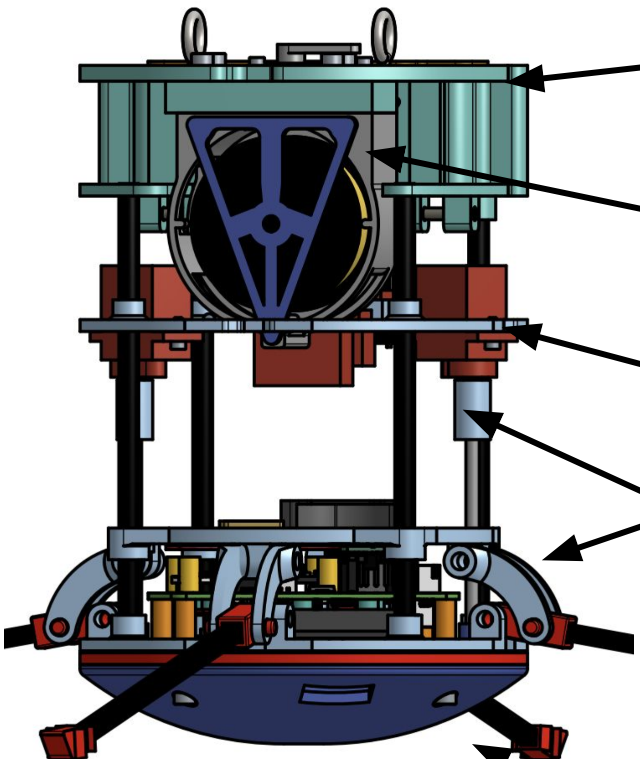
Heat Shield Deployed Configuration

Physical Layout (4 of 5)

Flag Undeployed

Upright Configuration

Flag Deployed



Parachute Container

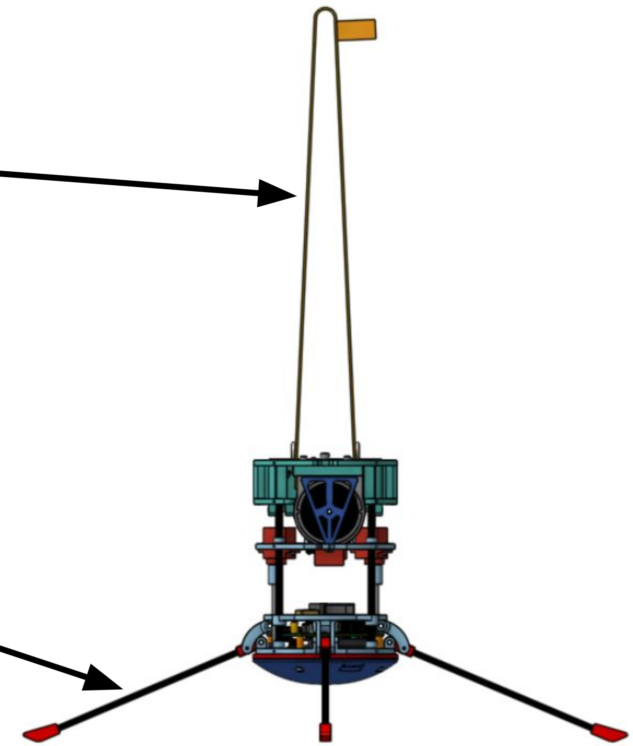
Flag Raising Mechanism (500 mm)

Servo Plate

Deployment System

Heat Shield Arms in Landed State

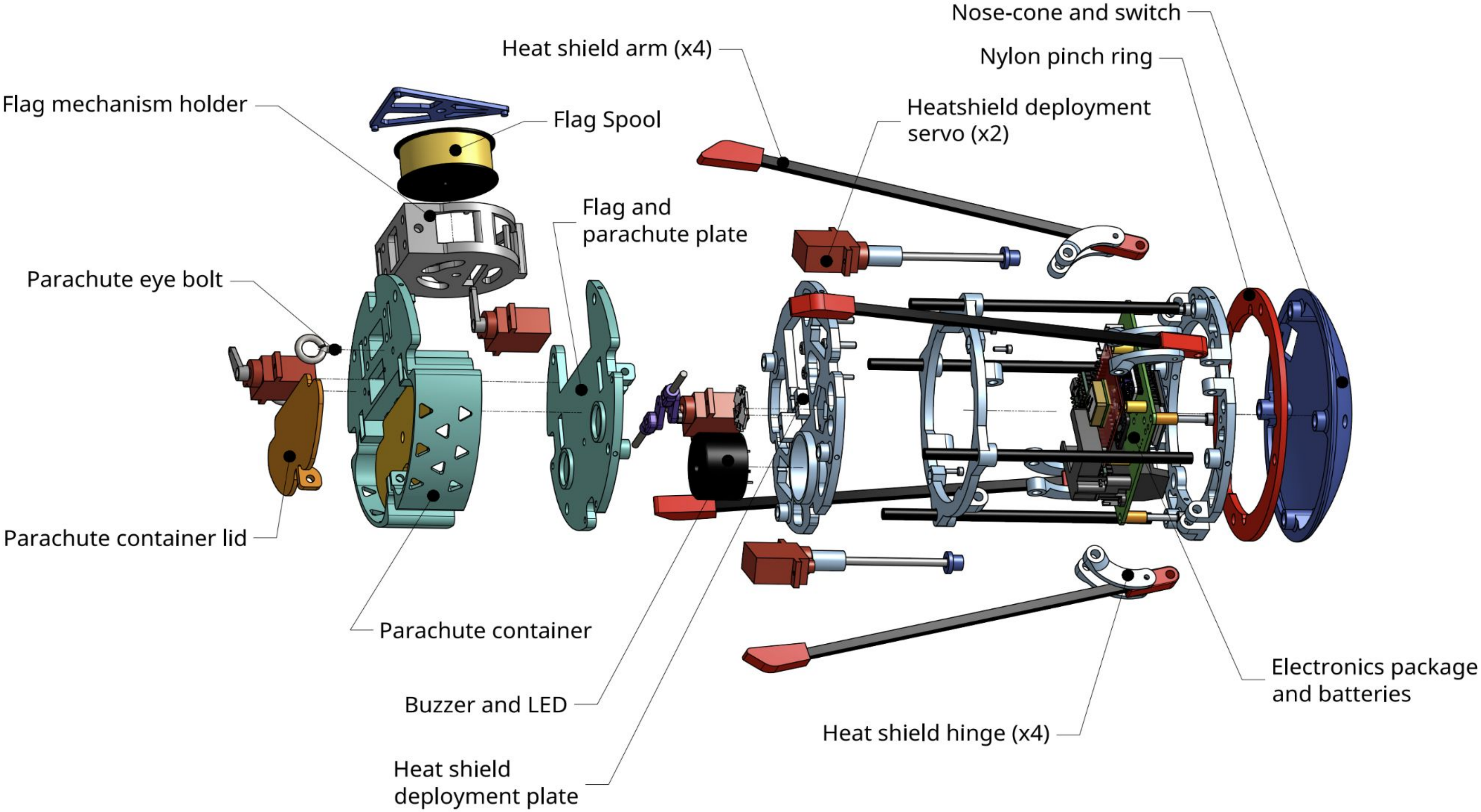
Nose Cone with Batteries and Camera



Upright Configuration Closeup

Upright Configuration

Exploded View



Launch Vehicle Compatibility

Maximum Dimensions

Height: 400 mm
Diameter: 125 mm

CanSat Dimensions

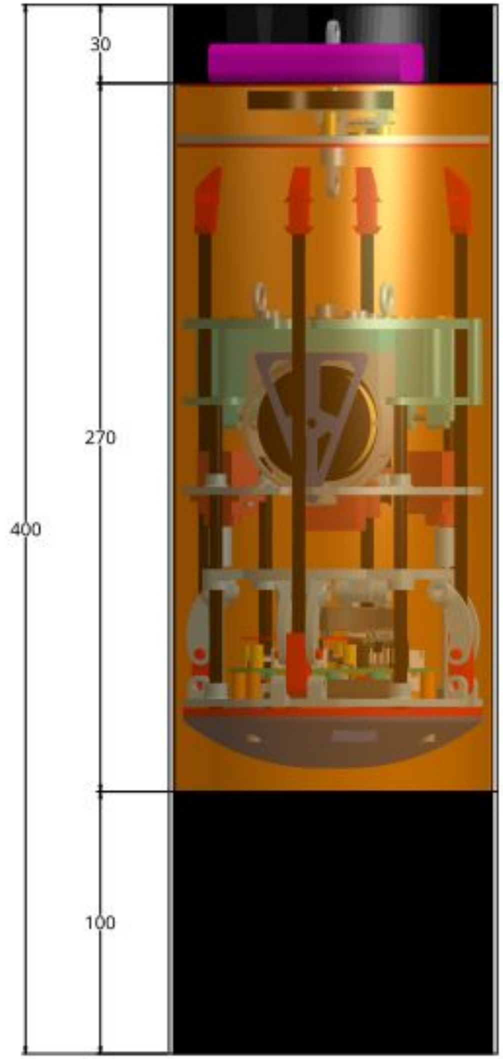
Height: 270 mm
Diameter: 124 mm

CanSat Clearance

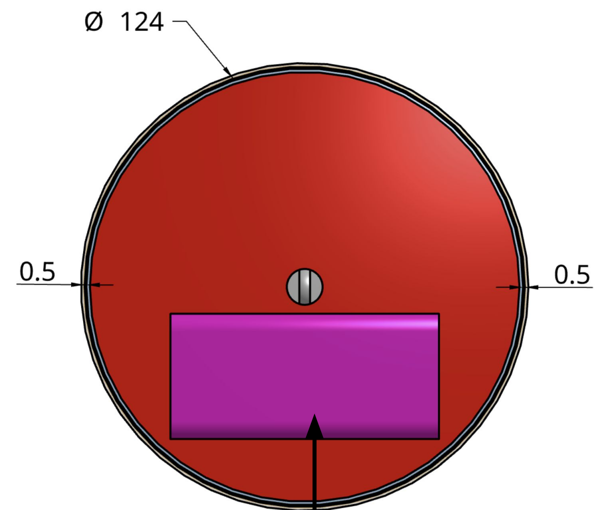
Vertical Clearance: 100 mm
Radial Clearance: 0.5 mm

30 mm allocated for parachute to avoid pinching

Note: The CanSat has no sharp edges or protrusions



Note: All units in mm



Container Parachute

Rocket Body

Sensor Subsystem Design

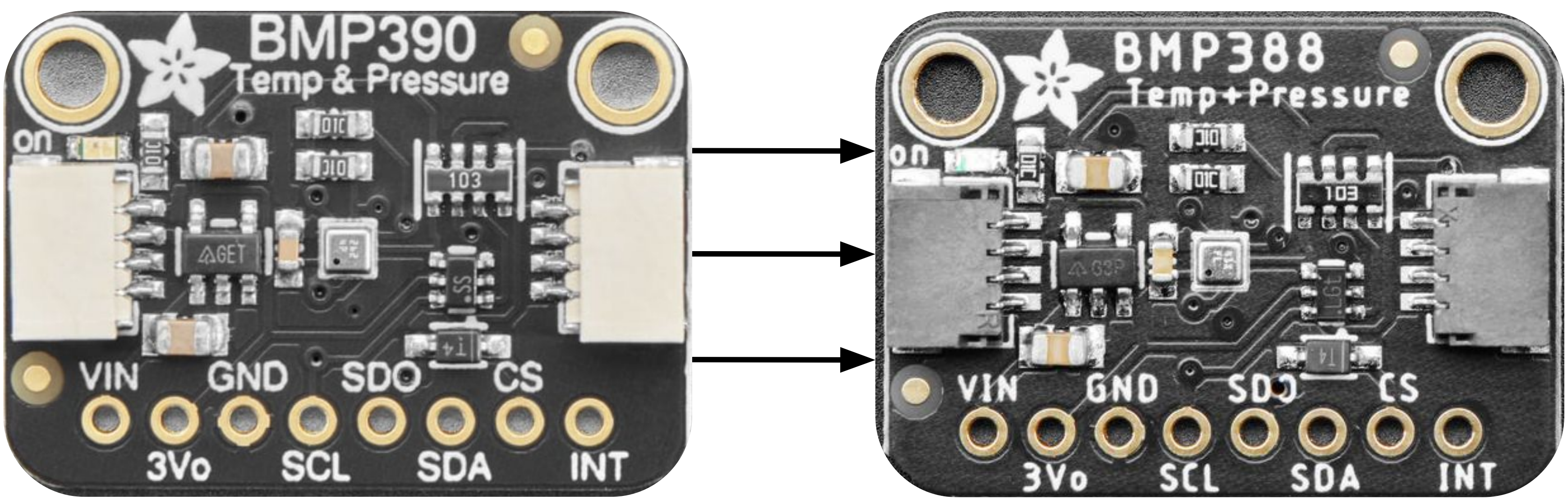
Gabriel Campos

Sensor Subsystem Overview

Required	Sensor	Purpose
Air Pressure	BMP388	Provide altitude data that is used to trigger the different flight states of the payload, as well as provide pressure data
Air Temperature	BMP388	Provide temperature data
GPS	SAM - M8Q	Provide location of CanSat, aiding in payload recovery
Battery Voltage	Analog Digital Converter of MCU	Provide status of the batteries' voltage, aiding in troubleshooting of electrical systems
Orientation	BNO055	Provide the orientation of the payload used to self right, and provide telemetry of the payload acceleration in 3D space
Video	Adafruit Spycamera	Record video for the duration of the mission which is to be viewed afterwards to aid in data analysis

Sensor Changes Since PDR

Data Collected	PDR Sensor	CDR Sensor	Reason for Change	Rationale
Pressure	BMP390	BMP388	BMP390 was not available for purchase	• Comparable accuracy to BMP390 (±0.5 m vs. ±0.25 m) • Identical size and pinout of BMP390
Temperature	BMP390	BMP388	BMP390 was not available for purchase	• Equivalent accuracy to BMP390



Payload Air Pressure Sensor Summary

Module	Accuracy	Measurement Range (hPa)	Max Current Draw (mA)	Voltage (V)	Mass (g)	Interface	Price ($)
BMP388	± 8 pascals/ ±0.50 meters	300-1250	0.700	3.3	1.0	I2C	9.95

Example Code

```
Adafruit_BMP3XX bmp;
#define SEALEVELPRESSURE_HPA (1013.25)
float a = bmp.readAltitude(SEALEVELPRESSURE_HPA);
Altitude = float(a - padAlt);
Pressure = bmp.pressure/1000;
```

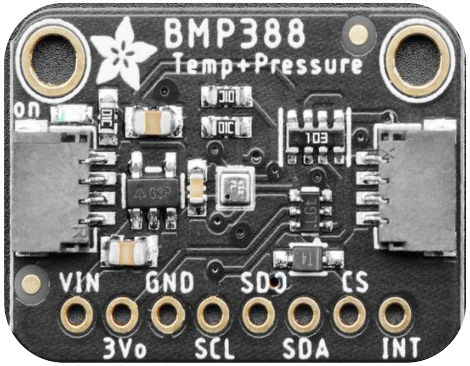


Image credit: adafruit.com

Output

Altitude = X.X m
Pressure = X.X kPa

Rationale:
- **<1 mA max current draw**
- **±0.50 m accuracy**
- **Built in temperature sensor**

Payload Air Temperature Sensor Summary

Module	Typical Accuracy (℃)	Measurement Range (℃)	Max Current Draw (mA)	Voltage (V)	Mass (g)	Interface	Price ($)
BMP388	± 0.50	0-65	0.300	3.3	1.0	I2C	9.95

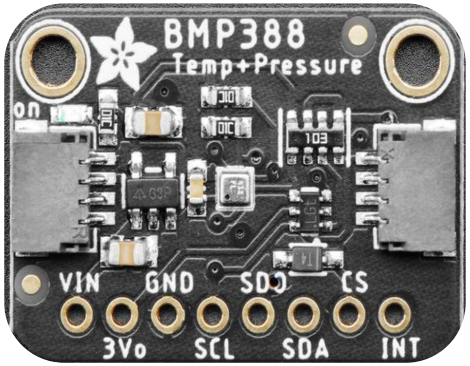


Image credit: adafruit.com

Example Code
Adafruit_BMP3XX bmp; Temperature = bmp.temperature;

Output
Temperature = X.X C

Rationale:

- **Integrated into pressure sensor**
- **Low total area and mass**
- **± 0.50 ℃ accuracy**

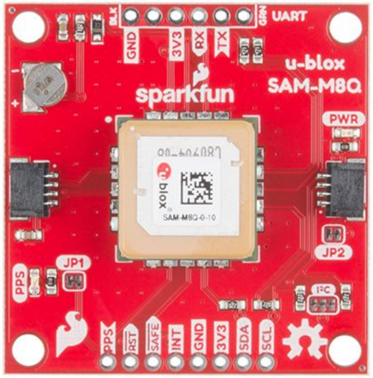
Payload GPS Sensor Summary

Module	Accuracy (m)	Max Current Draw (mA)	Hot Start Acquisition (s)	Mass (g)	Voltage (V)	Interface	Price ($)
SAM-M8Q	2.5	29	~1	12	3.3	UART	42.95

Example Code

```
#include <SparkFun_u-blox_GNSS_Arduino_Library.h>
SFE_UBLOX_GNSS myGNSS;
GPS_Time = (myGNSS.getHour() : myGNSS.getMinute() : myGNSS.getSecond());
GPS_Altitude = myGNSS.getAltitude();
GPS_Latitude = myGNSS.getLatitude();
GPS_Longitude = myGNSS.getLongitude();
GPS_Sat = myGNSS.getSIV();
```

Image credit: Sparkfun.com



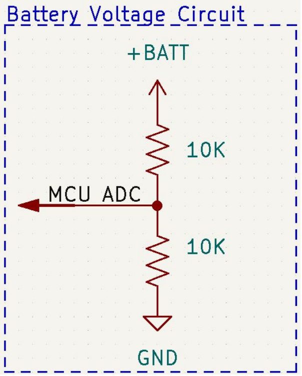
Output

Time= hh:mm:ss
Altitude= X.X m
Latitude= X.XXXX °
Longitude= X.XXXX°
Satellites= X

Rationale:
- **Quick satellite acquisition**
- **Internal antenna**
- **2.5 m precision**

Payload Voltage Sensor Summary

Module	Dimension (mm)	Mass (g)	Accuracy (V)	Measurement Range (V)	Interface	Max Current Draw (mA)	Price ($)
Analog Digital Converter of MCU	5.0 x 5.0 x 2.0	<0.5	±0.2	0-6.6	Analog	<1	0.50



Example Code
int sensorValue = analogRead(A0); float voltage = sensorValue * (3.3 / 1023.0);

Output
Voltage = X.X V

Rationale:
- **Integrated into the MCU**
- **Only requires two resistors**
- **Small and lightweight**
- **Low additional cost**

Payload Tilt Sensor Summary

Module	Max Current Draw (mA)	Gyroscope Accuracy (°)	Magnetometer Accuracy (°)	Accelerometer Accuracy (m/s)
BNO055	29	± 0.97	± 2.50	± 0.02

Mass (g)	Voltage (V)	Interface	Price ($)
1.0	3.3	I2C	34.95

Example Code

```
#include <Adafruit_BNO055.h>
Adafruit_BNO055 bno = Adafruit_BNO055(55, 0x28, &Wire);
bno.getEvent(&orientationData, Adafruit_BNO055::VECTOR_EULER);
event->type == SENSOR_TYPE_ORIENTATION);
x = event->orientation.x;
y = event->orientation.y;
```

Output

X Tilt = X.X °
Y Tilt = X.X °

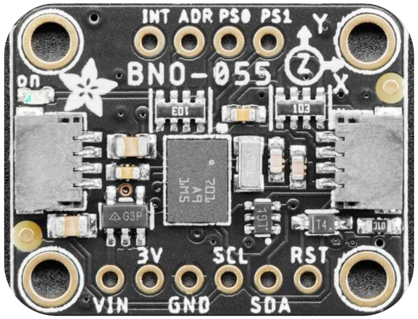


Image credit: Adafruit.com

Rationale:

- **Well documented libraries**
- **Easy to integrate with other Adafruit sensors**
- **Four point quaternion angles**

Camera Summary

Module	Resolution/ Frame Rate	Max Current Draw (mA)	Voltage (V)	Mass (g)	Interface	Price ($)
Adafruit Spycamera	640 x 480 / 30 fps	110	3.7 - 5.0	2.8	Digital	12.50

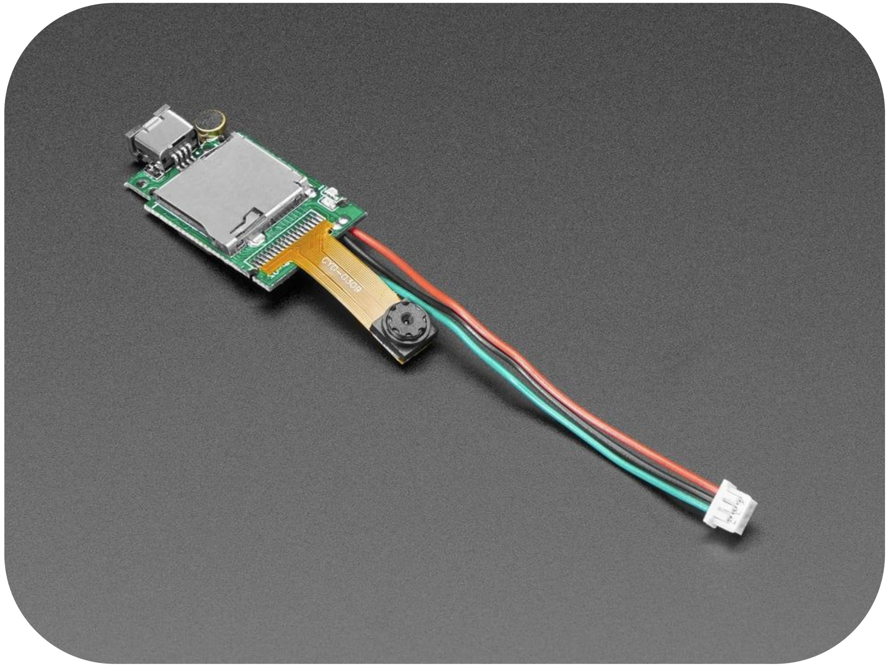


Image credit: Adafruit.com

Rationale:
- **Embedded SD card reader**
- **Resolution fulfills requirements**
- **Prior experience using sensor**

Bonus Camera Summary

Module	Resolution/ Frame Rate	Max Current Draw (mA)	Voltage (V)	Mass (g)	Interface	Price ($)
Adafruit Spycamera	640 x 480 / 30 fps	110	3.7 - 5.0	2.8	Digital	12.50

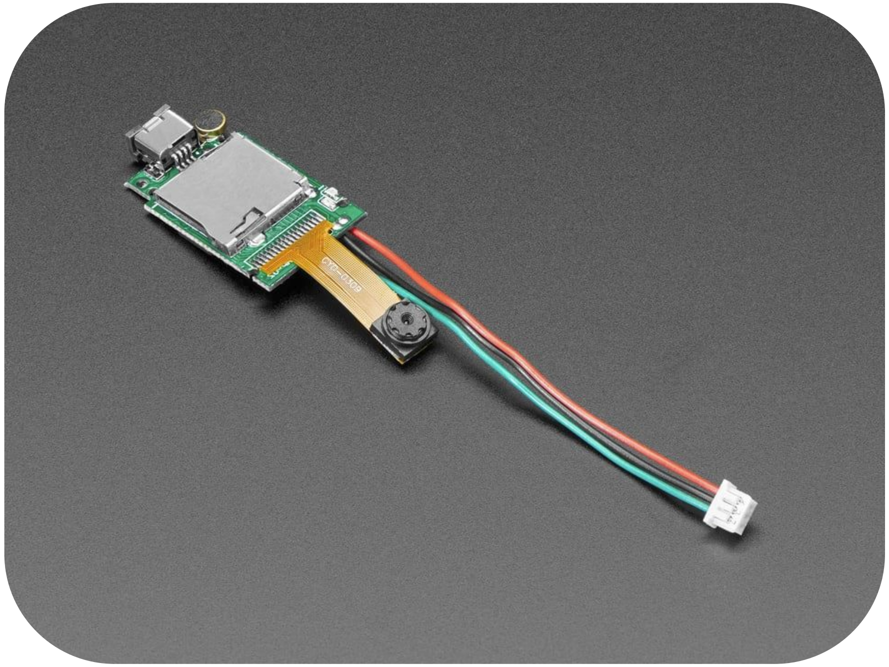


Image credit: Adafruit.com

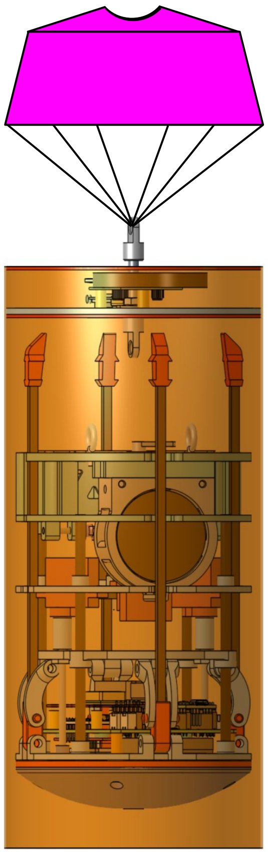
Rationale:
- **Embedded SD card reader**
- **Resolution fulfills requirements**
- **Prior experience using sensor**

Descent Control Design

Quinn Casper

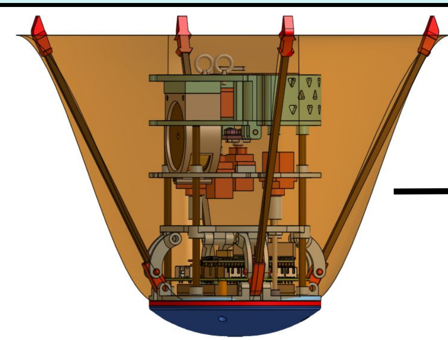
Descent Control Overview

- Passive stabilization
- Utilizes two single, hexagonal-shaped nylon parachutes both with a spill hole to reduce mass and oscillation rate

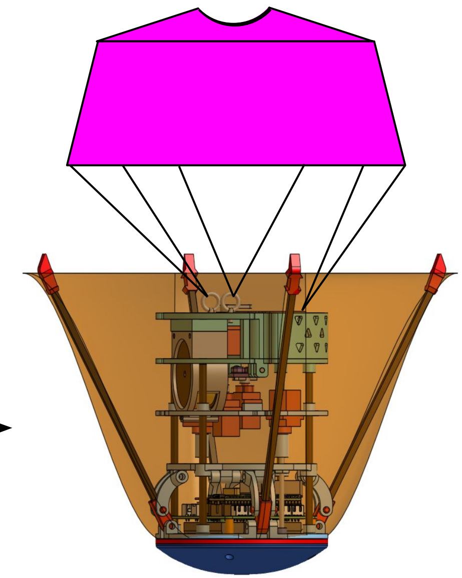


Container and Probe:
Parachute
725 m - 500 m at 15 m/s

Container: Parachute
500 m to Ground



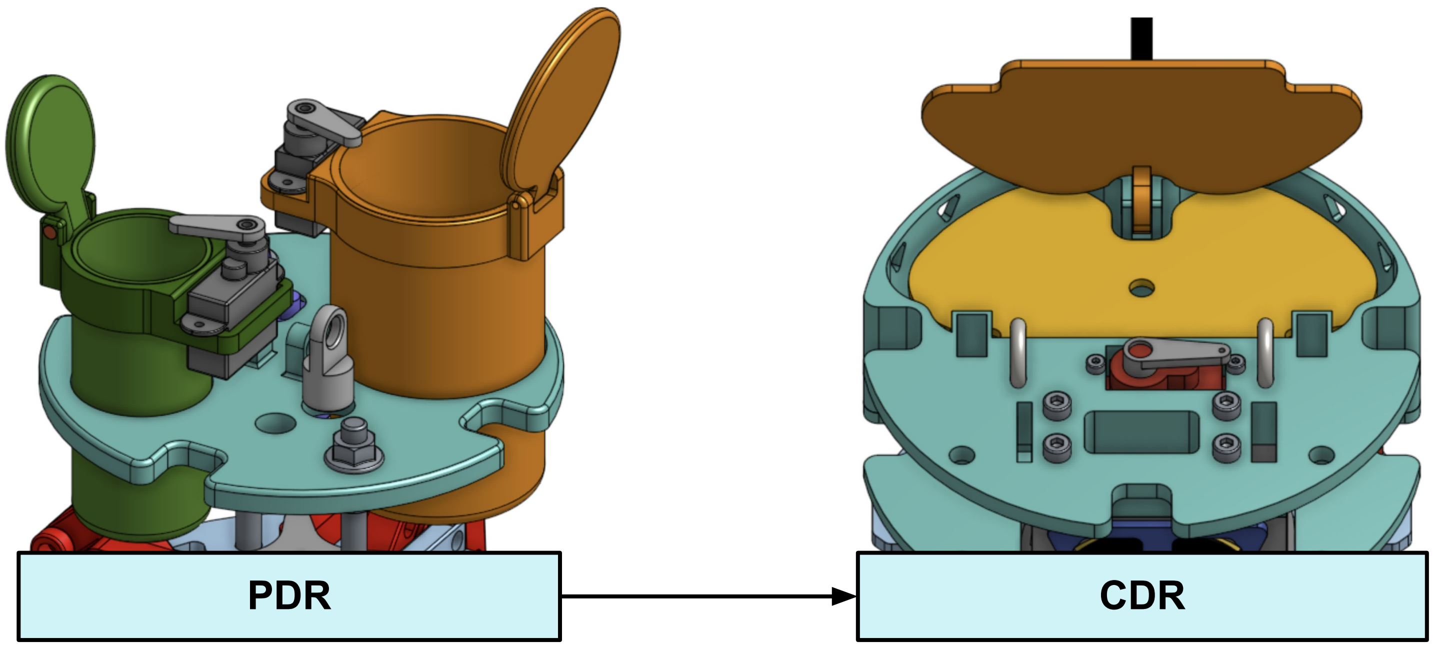
Probe: Heat Shield
500 m - 200 m at 20 m/s



Probe: Parachute
200 m - Ground at 5 m/s

Descent Control Changes Since PDR (1 of 2)

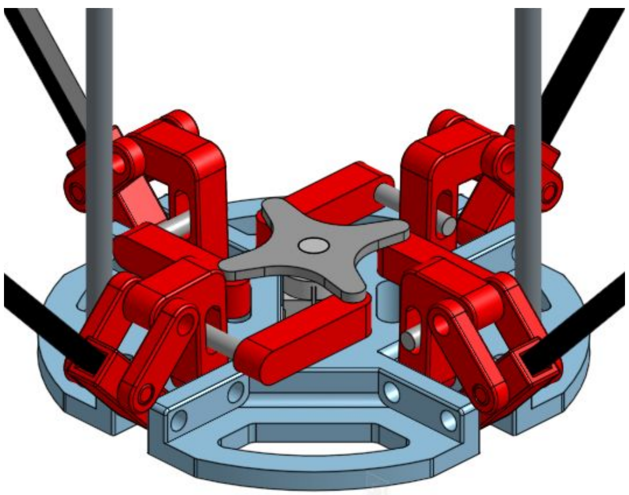
Parachute Descent
Changes: • Increased parachute container volume by 31,020 mm^3 after drop testing results • Payload parachute deployment area increased by 2,586 mm^2
Rationale: • Increased parachute storage • Decreases parachute deployment time

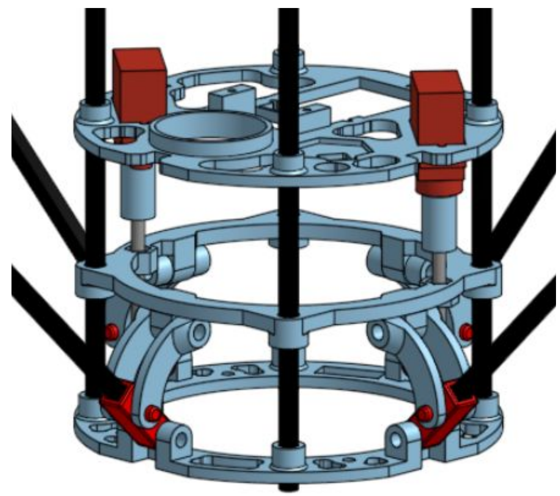


Aerobrake Deployment

Changes:
- Aerobraking and uprighting heatshield arms now powered by two servos with two linkages per arm as opposed to one servo with four linkages per arm

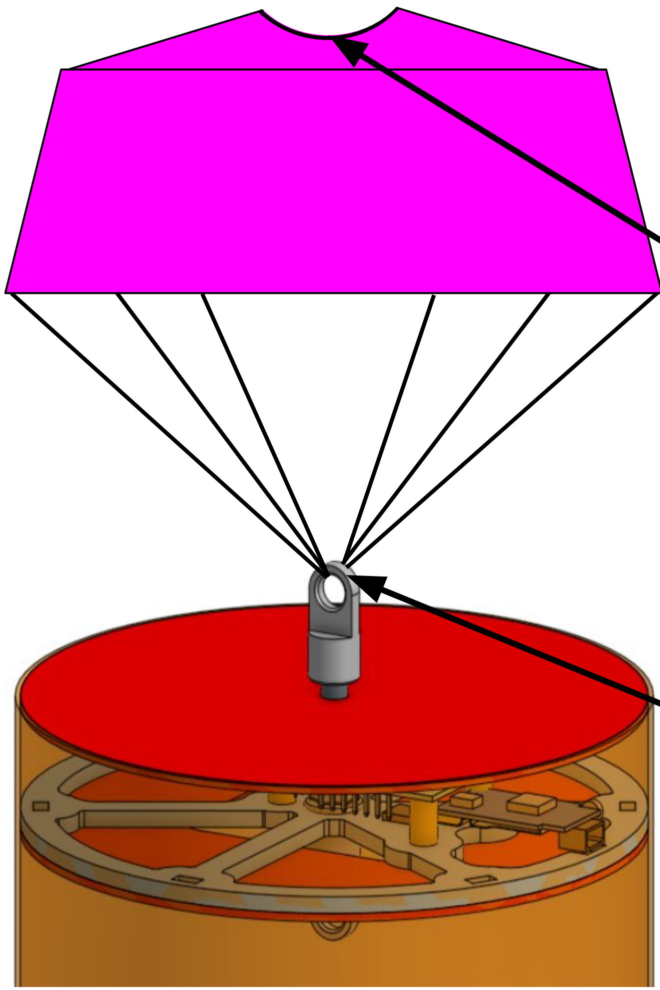
Rationale:
- Increased system torque for heat shield deployment
- Lowered center of mass
- Reduced backlash





PDR → CDR

Container Descent Control Hardware Summary (1 of 2)



The container will descend via a parachute that is deployed passively immediately after rocket separation.

Includes a spill hole for stability

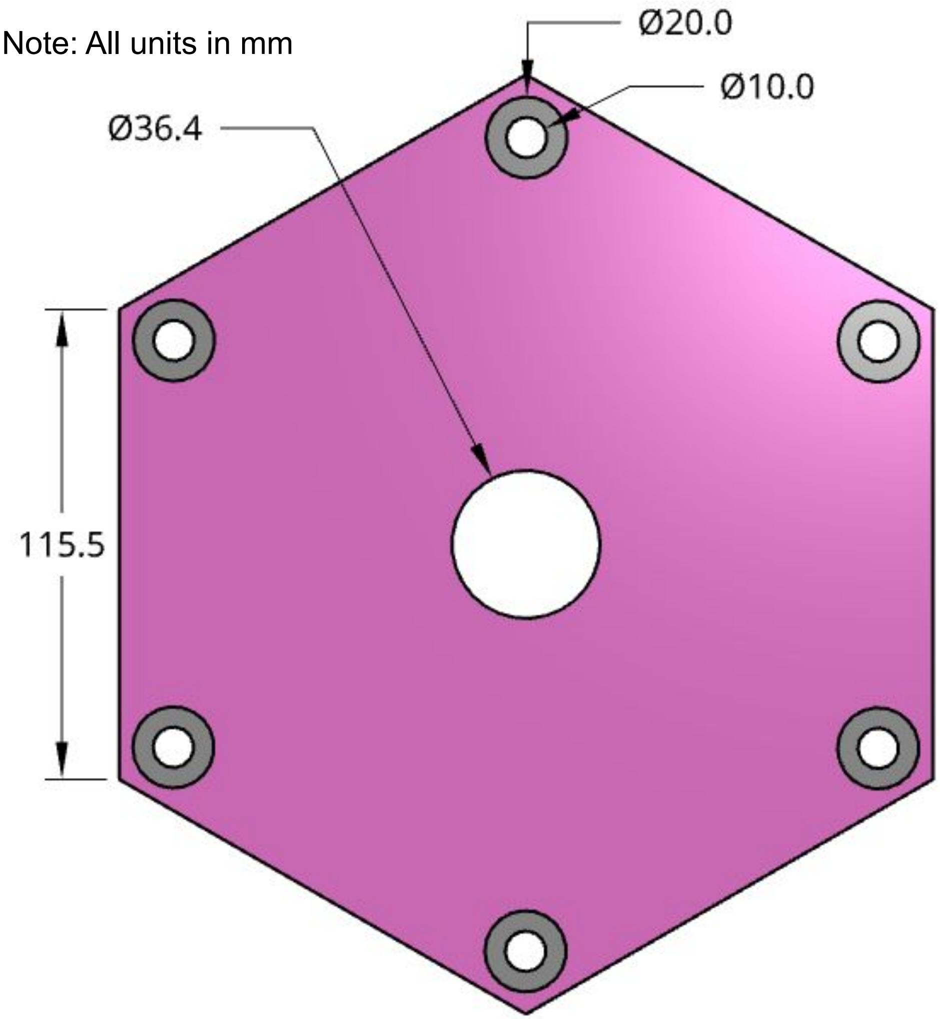
Bright pink ripstop nylon parachute is hexagonally shaped to reduce mass and oscillation rate

Container parachute paracord is attached to a steel M5 eye nut and bolt

Note: Loctite used on all bolted connections

Container Descent Control Hardware Summary (2 of 2)

Note: All units in mm



Container Parachute

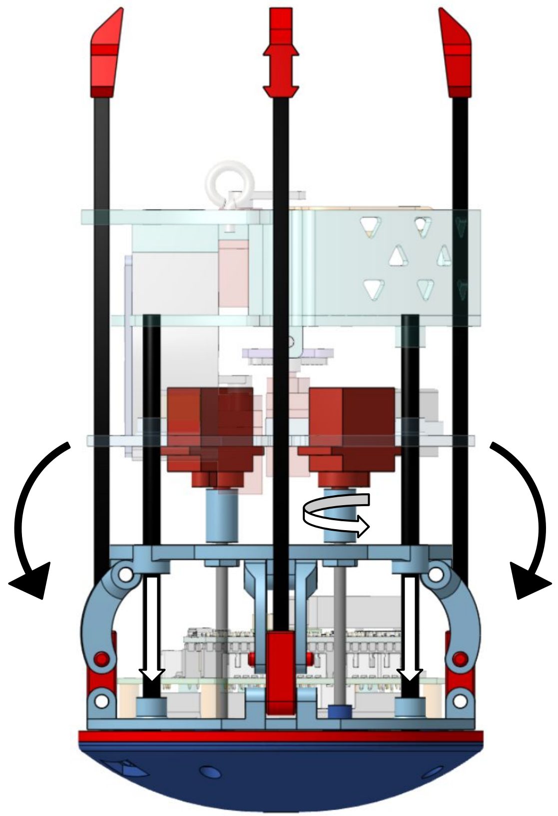
Pink container parachute is attached by 2 mm paracord

Spill hole is the standard 3% of parachute area

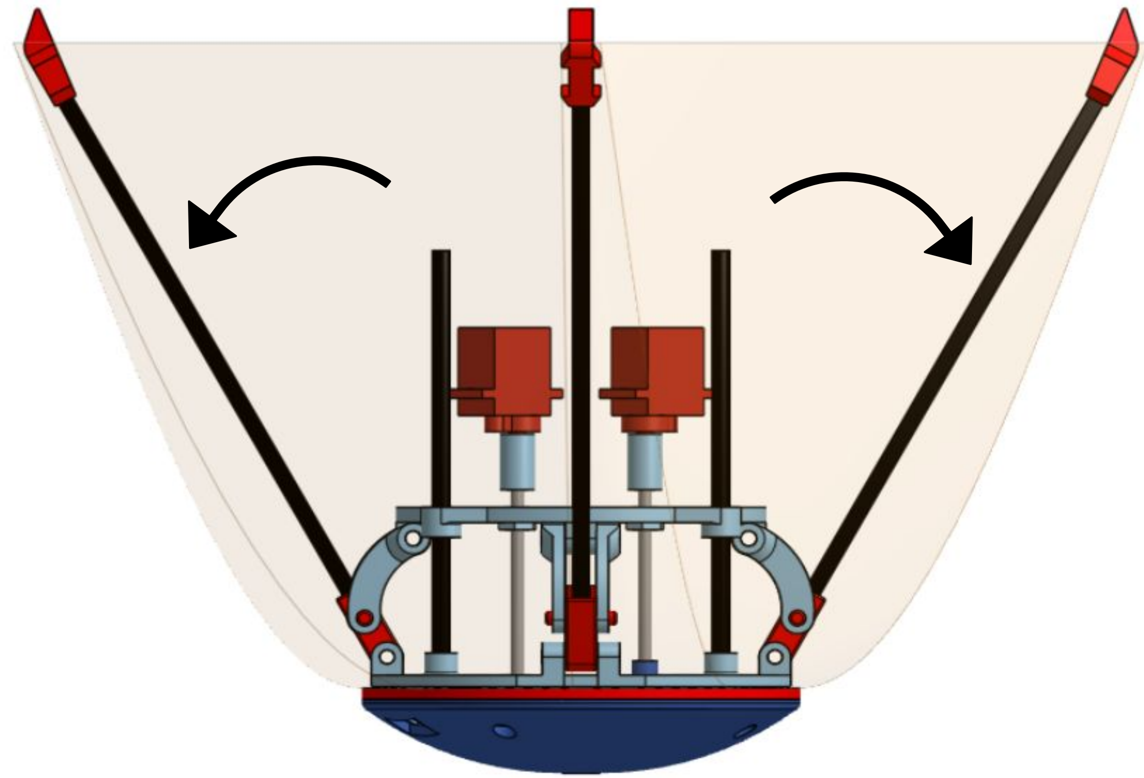
6 steel grommets will be used to attach paracord to parachute

Payload Aerobraking Descent Control Hardware Summary (1 of 2)

Dual-servo deployment mechanism actuates 180 mm carbon composite arms to a 30° heat shield angle to increase surface area while providing passive stabilization



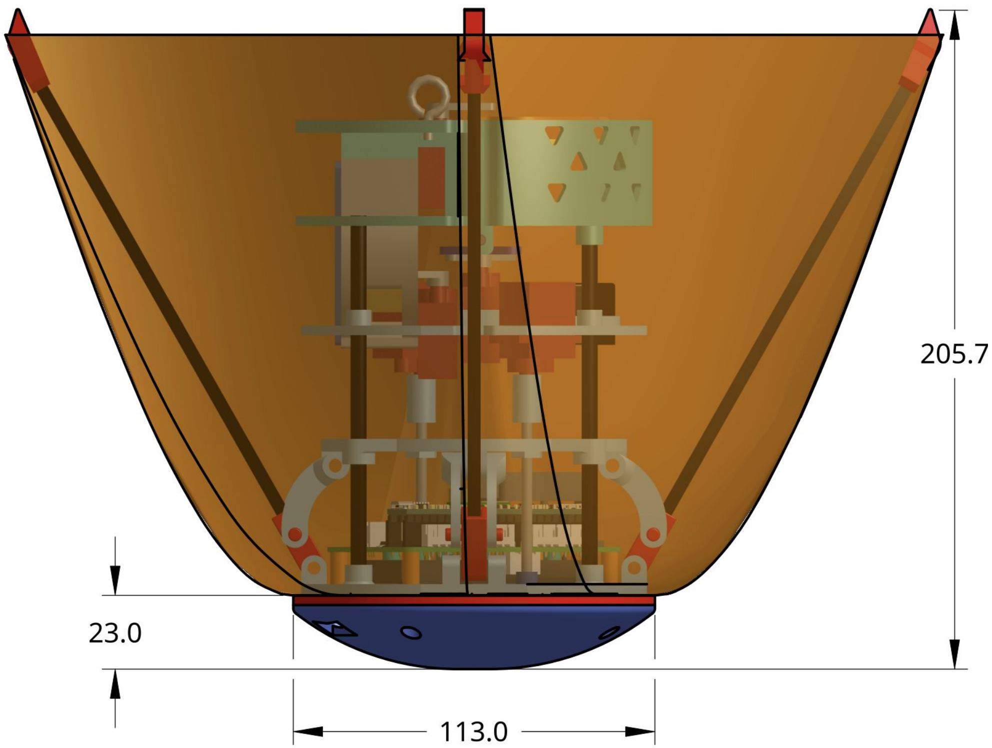
Pre-Aerobrake Deployment

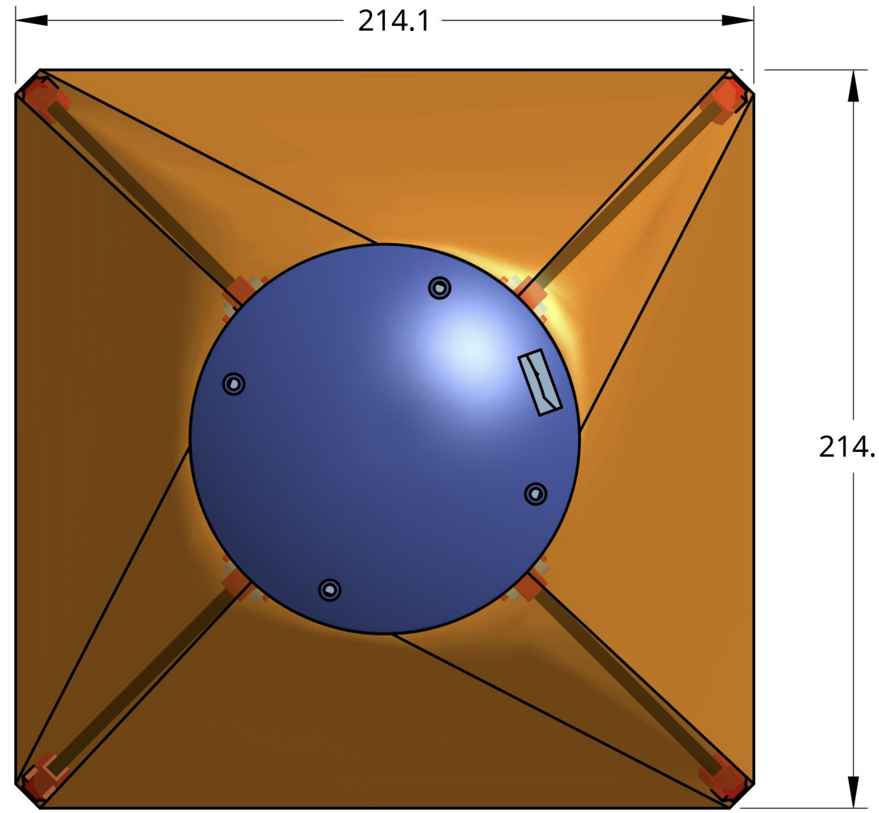


Post-Aerobrake Deployment

Payload Aerobraking Descent Control Hardware Summary (2 of 2)

Note: All units in mm

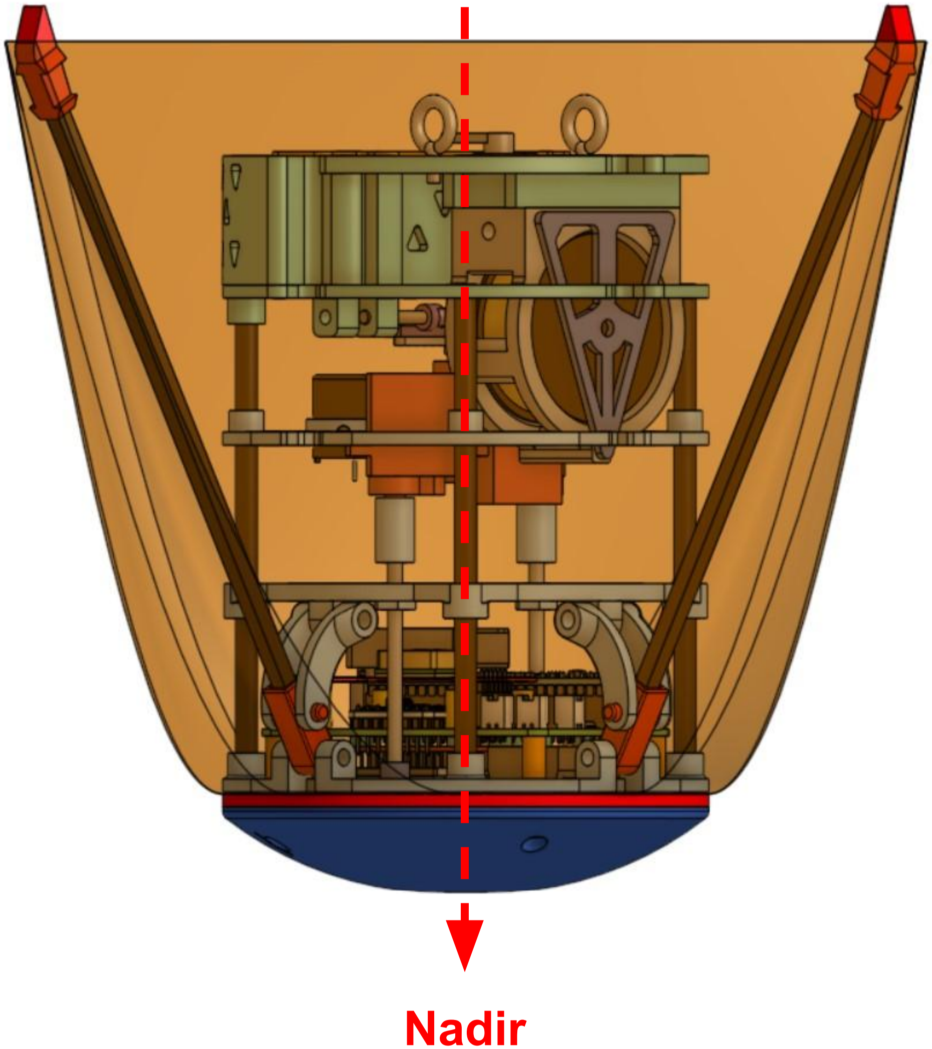




Heat shield utilizes bright orange ripstop nylon aerobraking heat shield

Aerobraking Area of 45,839 mm^2

Payload Descent Stability Control Design

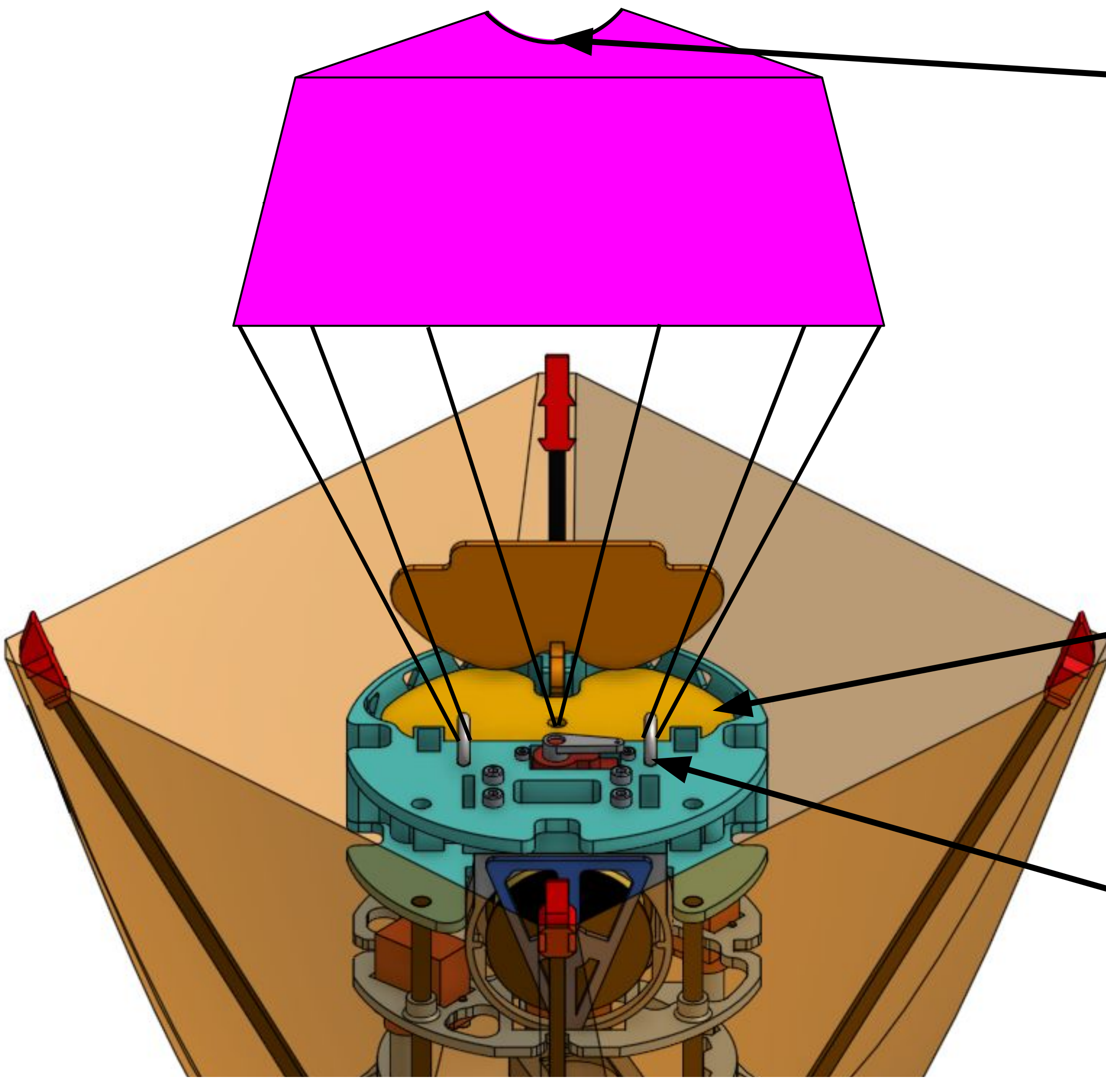


Passive stability control

Low center of mass keeps probe facing nadir direction and prevents tumbling

Sliding plate actuated by servos via threaded rods, which move aerobraking arms downward, thus increasing the heat shield surface area

Payload Parachute Descent Control Hardware Summary (1 of 2)



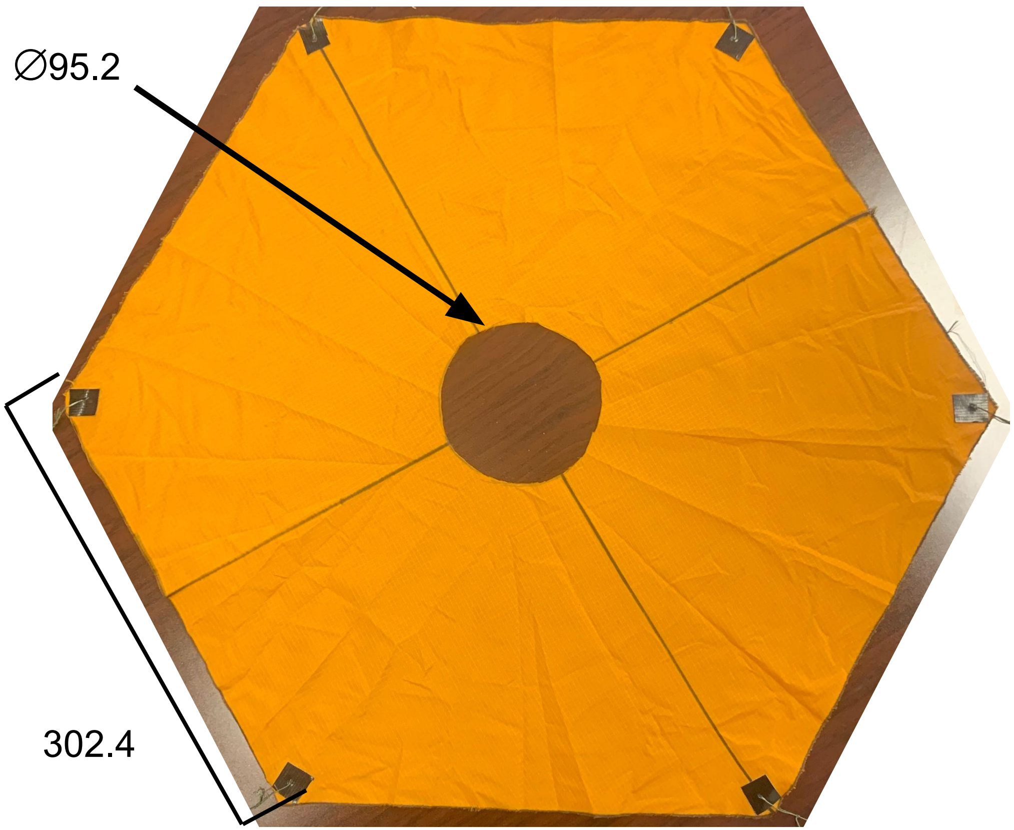
Includes a spill hole for stability

Hexagonal bright pink ripstop nylon parachute reduces mass and oscillation rate

Parachute is deployed using a spring-loaded piston with servo-actuated lid

Parachute attached via paracord to 3 steel screw eye hooks

Note: All units in mm



Probe parachute is attached by 2 mm paracord

Spill hole is the standard 3% of parachute area

6 steel grommets will be used to attach paracord to parachute

Note: Due to availability when manufactured, the prototype does not use correct grommets or ripstop nylon color

Descent Rate Estimates (1 of 2)

Variables

- **m** = mass
- **g** = gravitational acceleration
- **D** = parachute diameter
- **r** = parachute radius
- **ρ** = air density
- C_D= coefficient of drag
- **v** = velocity
- **A** = area

Drag Equation Manipulations

Velocity of Parachutes

$$F_{drag} = F_{gravity} = \frac{1}{2}\rho v^2 A C_d$$

$$mg = \frac{1}{2}\rho v^2 A C_d$$

$$v^2 = \frac{2mg}{\rho A C_d}$$

$$v = \sqrt{\frac{2mg}{\rho A C_d}}$$

$$A_{parachute} = \pi r^2 = \frac{\pi D^2}{4}$$

$$v = \sqrt{\frac{8mg}{\pi D^2 \rho C_d}}$$

Velocity of Heat Shield

$$F_{drag} = F_{gravity} = \frac{1}{2}\rho v^2 A C_d$$

$$mg = \frac{1}{2}\rho v^2 A C_d$$

$$v^2 = \frac{2mg}{\rho A C_d}$$

$$v = \sqrt{\frac{2mg}{\rho A C_d}}$$

Descent Rate Estimates (2 of 2)

Assumptions & Variables

- CanSat is 700 g
- Probe is 540 g
- Heat shield is a square truncated pyramid
- Heat shield area is larger due to having four attachment points

- **m** = mass
- **g** = gravitational acceleration = 9.81 m/s^2
- **D** = parachute diameter
- **ρ** = air density = 1.3 kg/m^3
- **C_D**= coefficient of drag (estimated)
- **v** = velocity

Selected Configuration Calculations and Summary

Container Parachute

$$v = \sqrt{\frac{8(0.7kg)(9.81\frac{m}{s^2})}{\pi(0.21m)^2(1.3\frac{kg}{m^3})(1.5)}} \approx 14.3\frac{m}{s}$$

Probe Aerobraking Heatshield

$$v = \sqrt{\frac{2(0.54kg)(9.81\frac{m}{s^2})}{(1.3\frac{kg}{m^3})(4.25 * 10^{-2}m^2)(0.667)}} \approx 17.0\frac{m}{s}$$

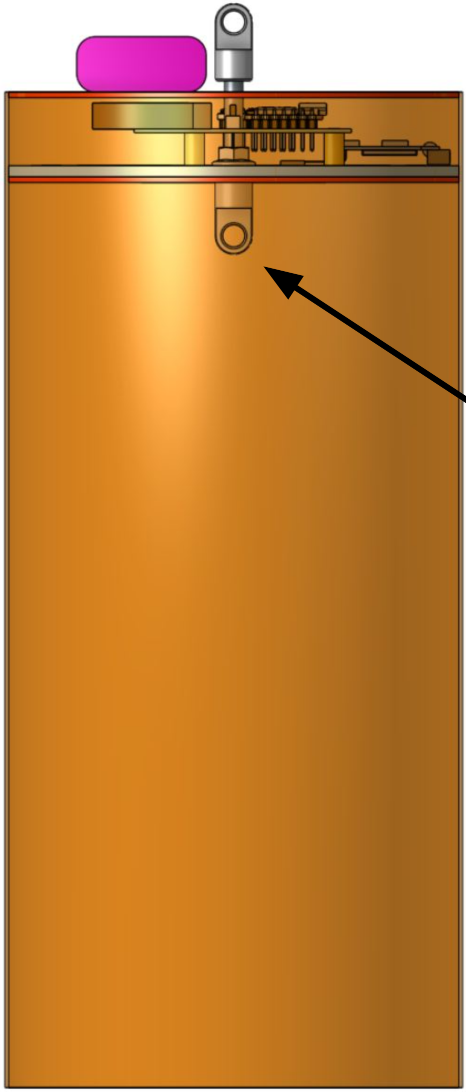
Probe Parachute

$$v = \sqrt{\frac{8(0.54kg)(9.81\frac{m}{s^2})}{\pi(0.55m)^2(1.3\frac{kg}{m^3})(1.5)}} \approx 4.78\frac{m}{s}$$

Mechanical Subsystem Design

Elena Dishman, Kyle Hughes and Cole Lenhart

Mechanical Subsystem Overview (1 of 3)



Container Overview

Steel M5 Parachute Attachment

Fiberglass Reinforced Cardboard Lid

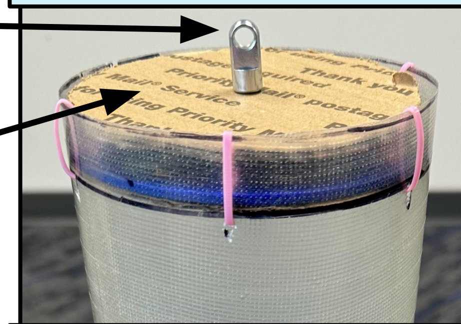
Paracord Payload Attachment

Fiberglass Shell

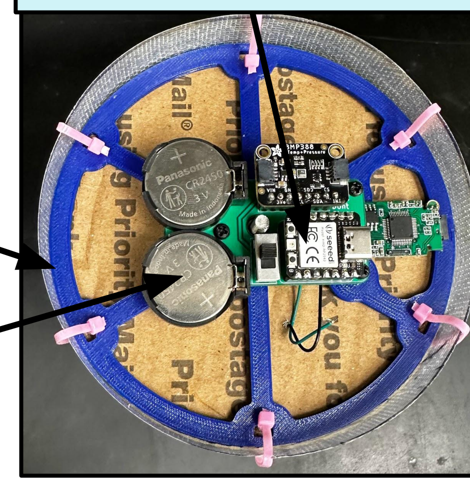
PETG Electronics Housing Support with Bonus Camera

Removable Container Batteries

*Note: Prototype does not include fiberglass reinforcement

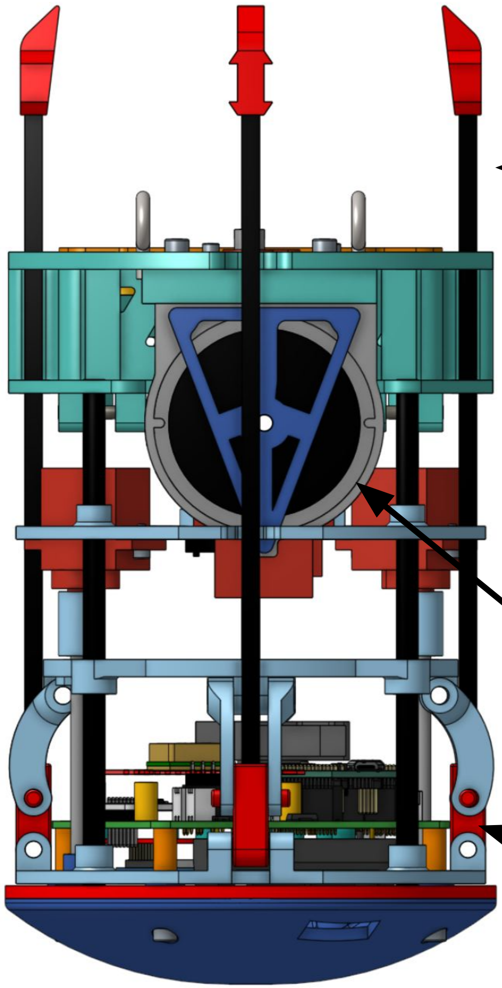


Electrical Subsystem for Bonus Camera



Mechanical Subsystem Overview (2 of 3)

Payload Overview



Front View

Carbon Composite Arms

PETG Parachute Deployment

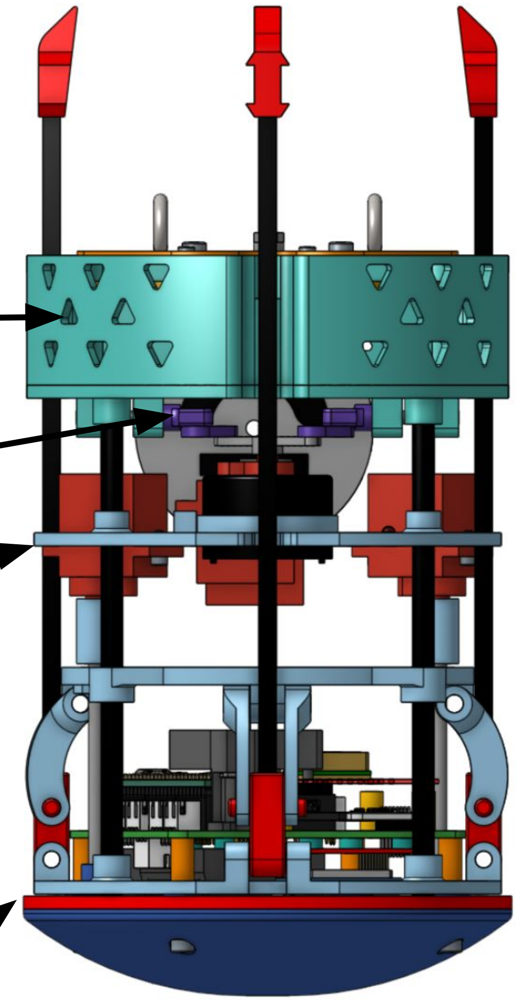
Container Release

Servo Mounting Plate

Modified Tape-Measure Flag Raising

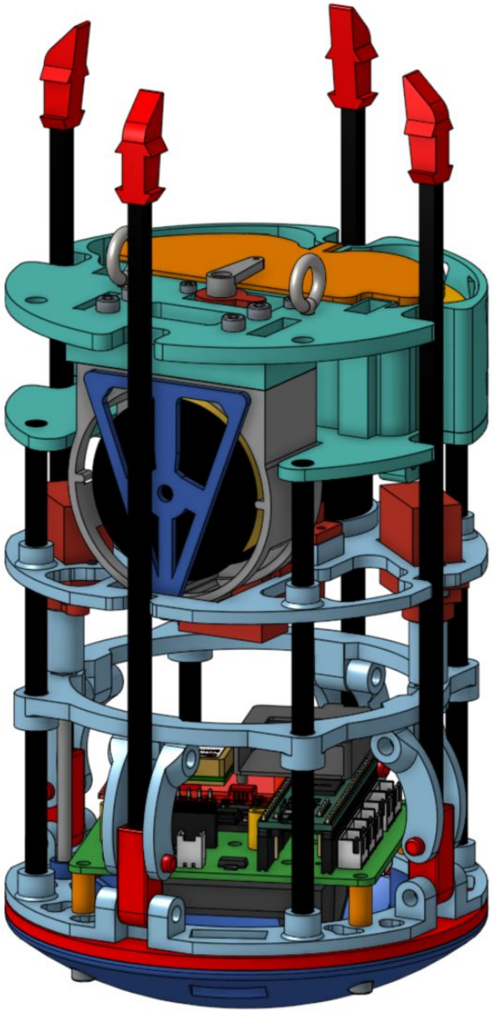
Heat Shield Deployment

Nylon Pinch Plate

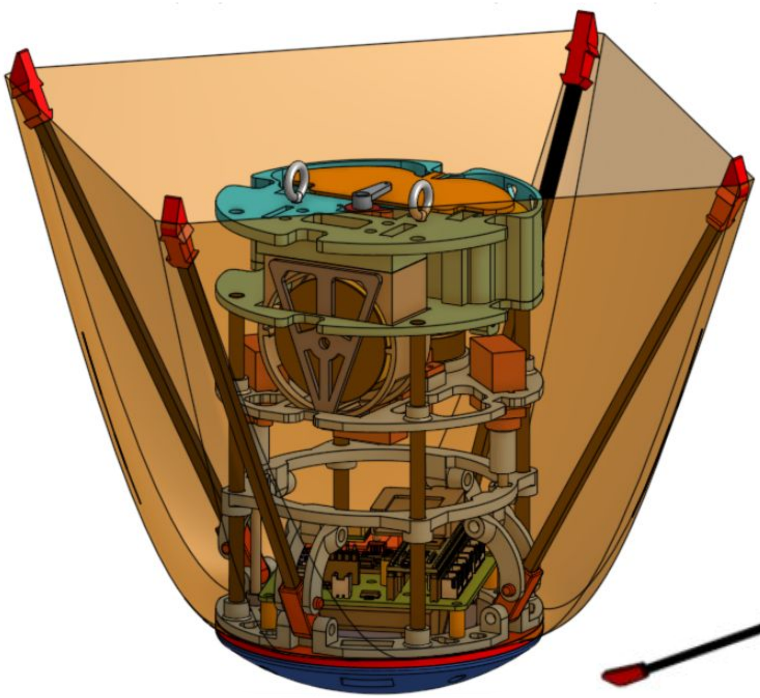


Back View

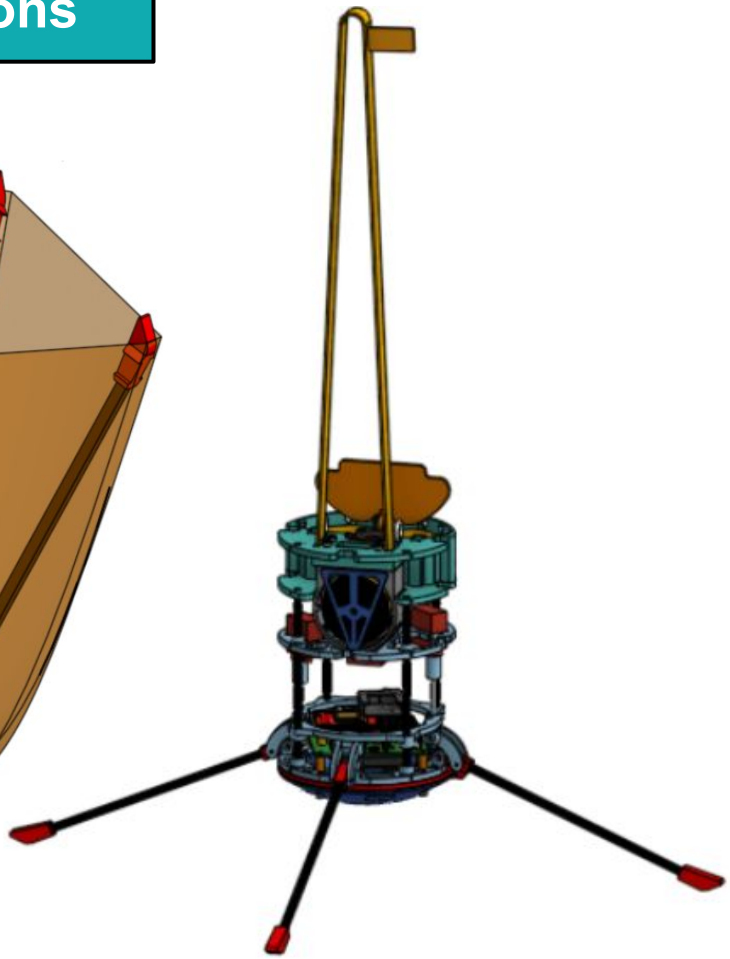
Payload Configurations



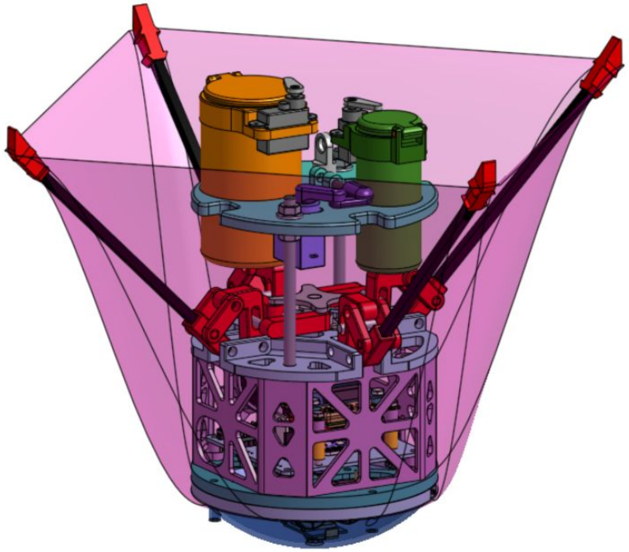
Stowed



Heat Shield

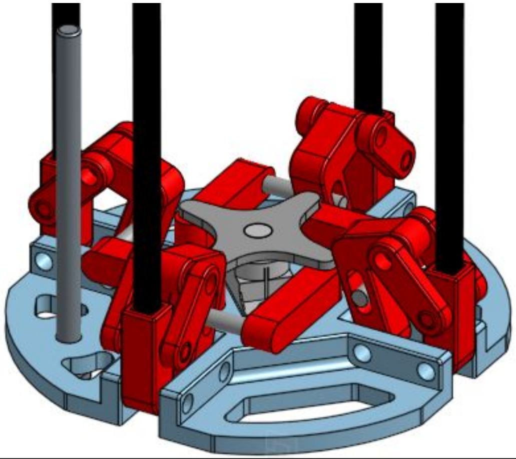


Uprighted

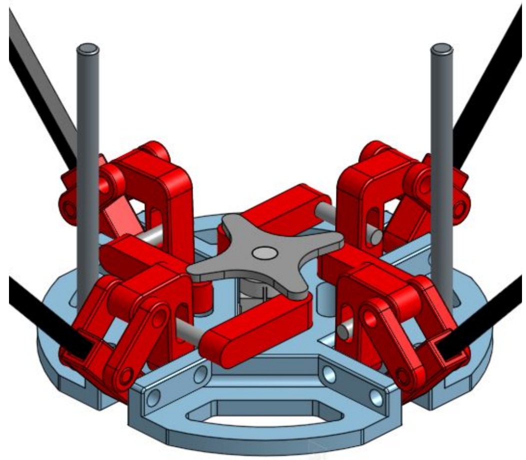


PDR Aerobrake Design

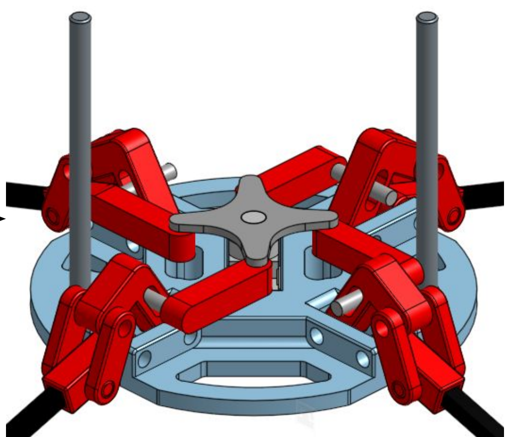
System Summary:
• A single, central servo actuated the heat shield with a system of linkages
Drawbacks:
• Small linkages created manufacturing complexity and backlash



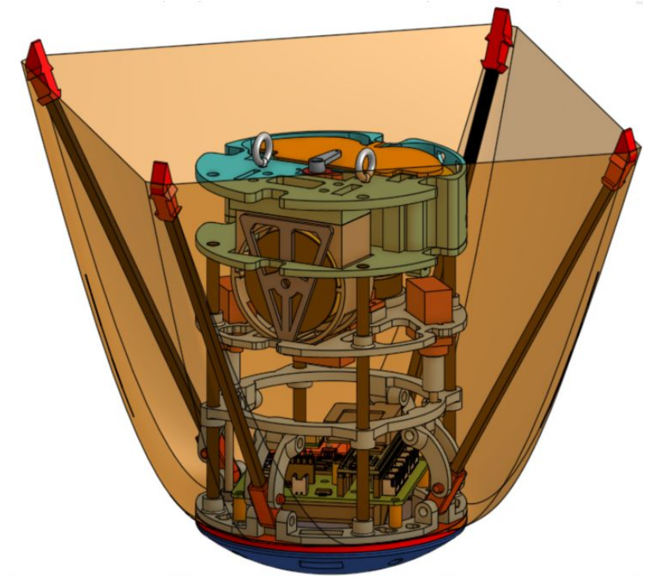
Stowed Configuration



Heat Shield Configuration



Uprighting Configuration



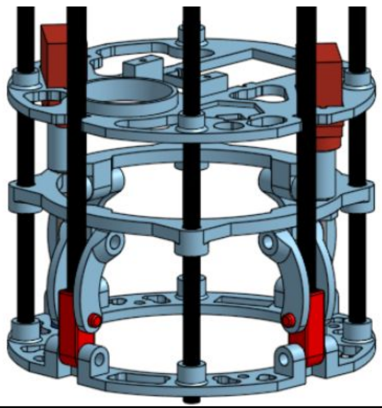
CDR Aerobrake Design

Changes:

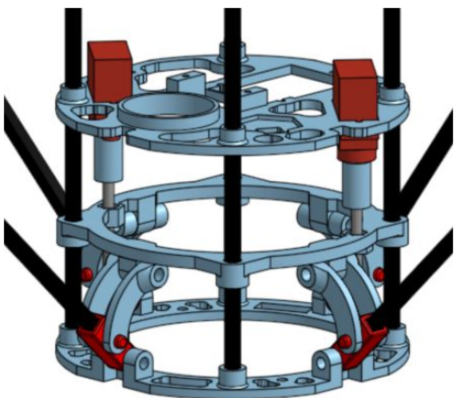
- Dual servo system with sliding plate attached to cylindrical threaded rods
- Low arm connection point

Rationale:

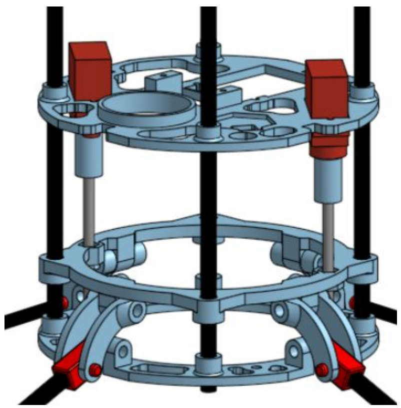
- Decreased complexity
- Increased mechanical advantage for heat shield deployment and uprighting
- Low center of gravity



Stowed Configuration



Heat Shield Configuration



Uprighting Configuration

Mechanical Subsystem Changes Since PDR (3 of 7)

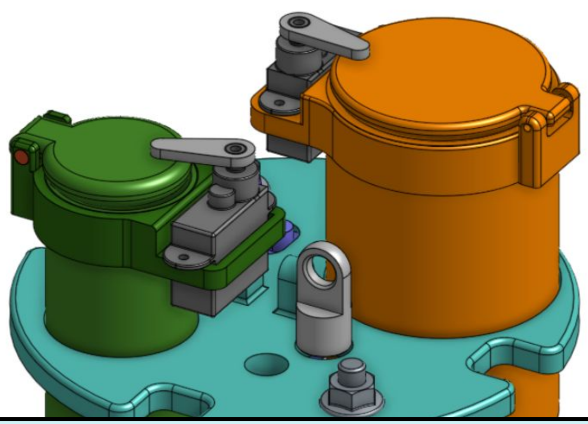
PDR Parachute Container Design

System Summary:

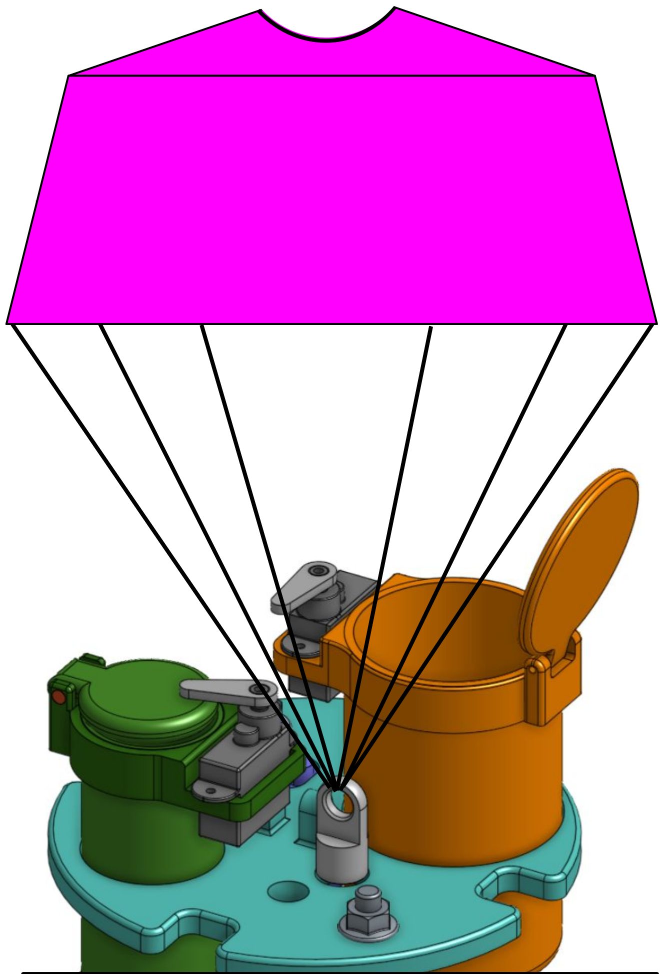
- Paracord attached to one M5 nut
- Cardboard tube used as parachute storage and mounted to top plate
- Utilizes servo-actuated spring-loaded piston deployment

Drawbacks:

- Small area of deployment
- Compact volume for storage



Stowed Configuration



Deployed Configuration

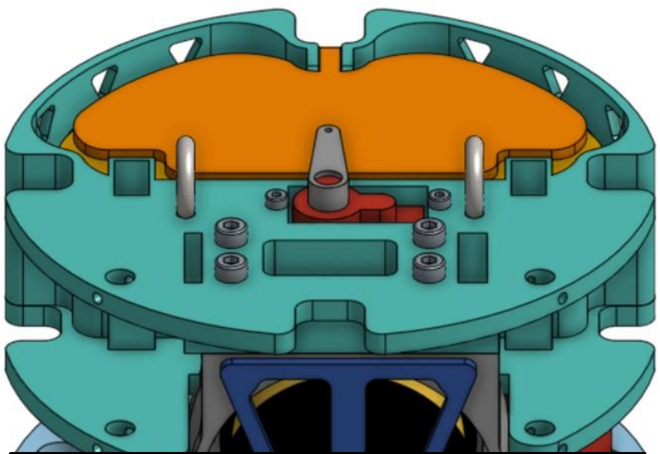
CDR Parachute Container Design

Changes:

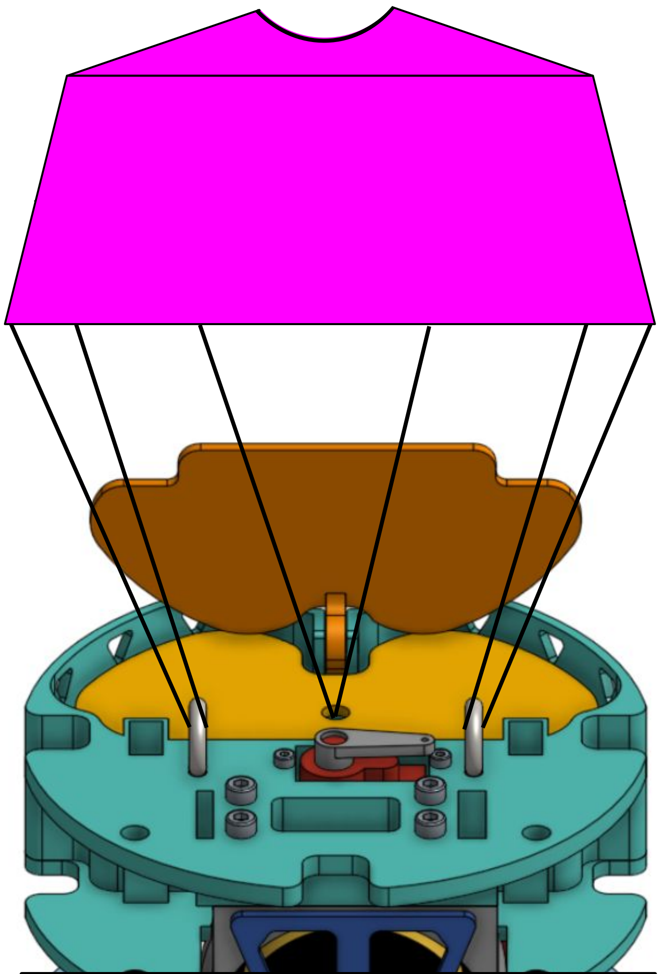
- Parachute container is integrated into the top plate
- Paracord is attached to 3 steel screw eye hooks
- Increases area of deployment by 2,586 mm^2
- Increase storage volume by 31,020 mm^3

Rationale:

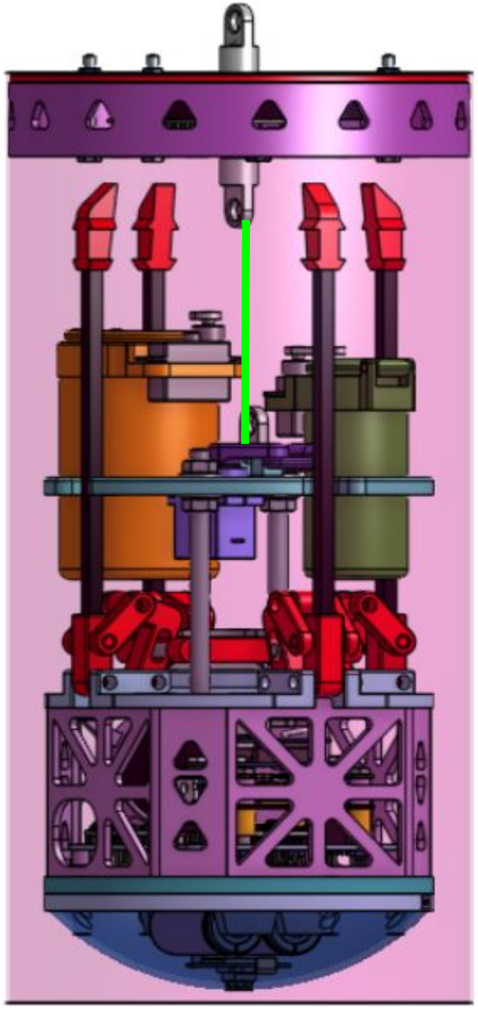
- Increased reliability for deployment
- Decreases deployment time



Stowed Configuration



Deployed Configuration



Stowed Configuration

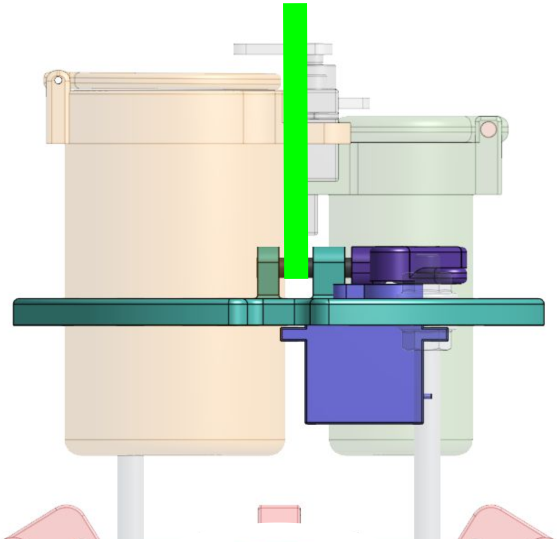
PDR Container Release Design

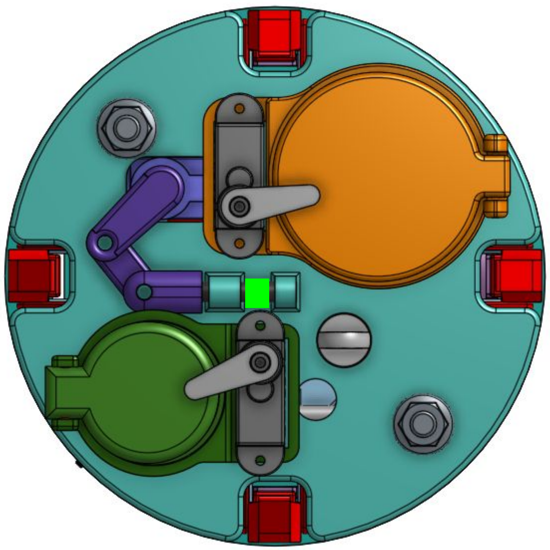
System Summary:

- One-pin system located on the top plate
- 2 mm paracord passes through top plate

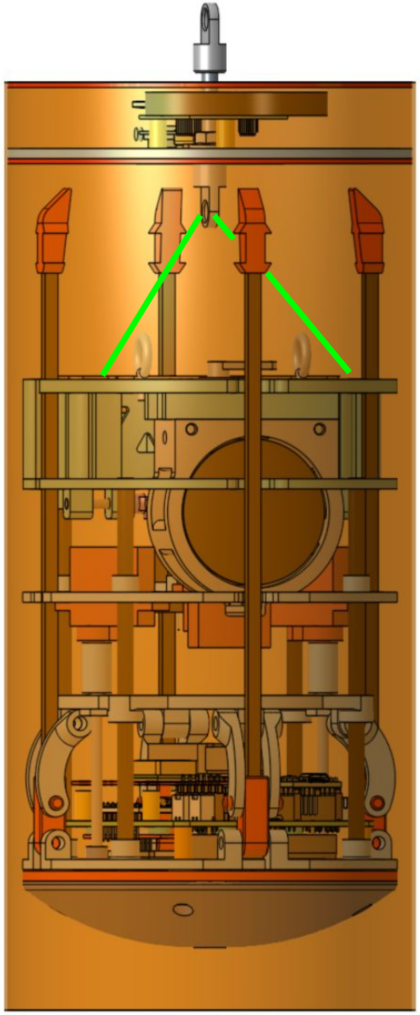
Drawbacks:

- Single point of attachment between container and probe
- Possibility of twisting during flight





Mechanical Subsystem Changes Since PDR (6 of 7)



Stowed Configuration

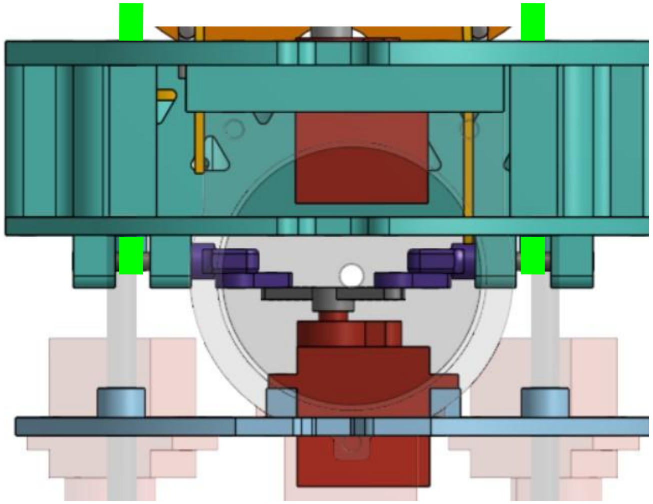
CDR Container Release Design

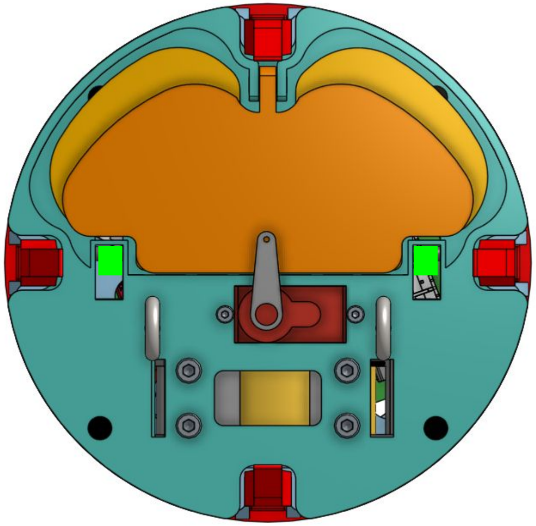
Changes:

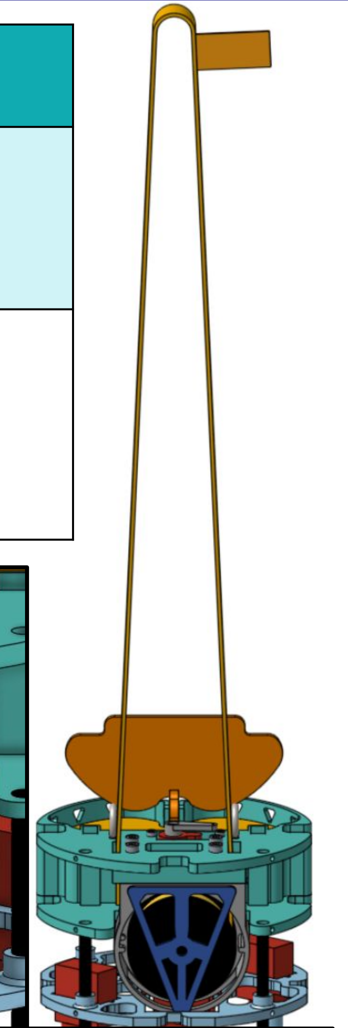
- Two-pin system located under the top plate
- 2 mm paracord passes through top plate

Rationale:

- Due to increased parachute container size, the release mechanism no longer fits on the top plate
- Provides attachment for the paracord in two places versus just one







PDR Flag Design

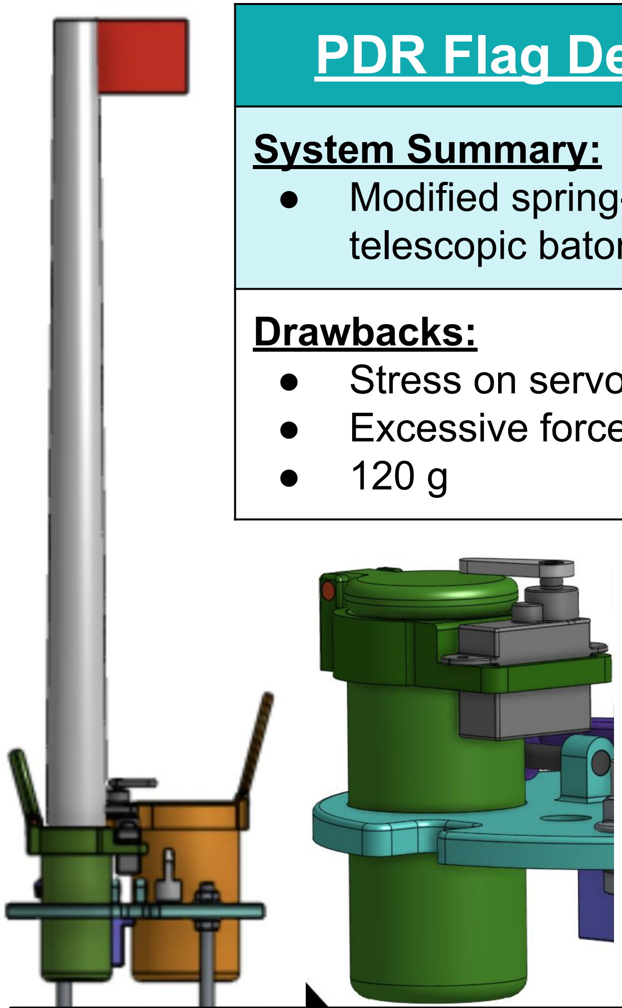
System Summary:
- Modified spring-loaded telescopic baton

Drawbacks:
- Stress on servo horn
- Excessive force
- 120 g

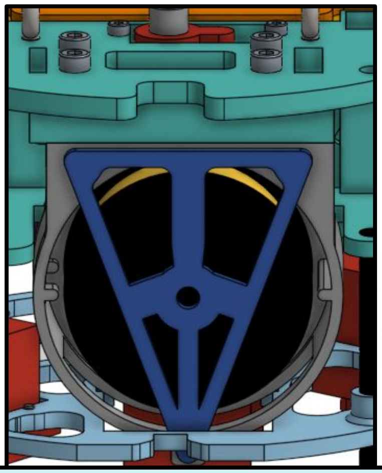
CDR Flag Design

Changes:
- Modified tape measure deploys flag

Rationale:
- Increased Reliability
- Ease of Manufacturing
- 66 g



PDR

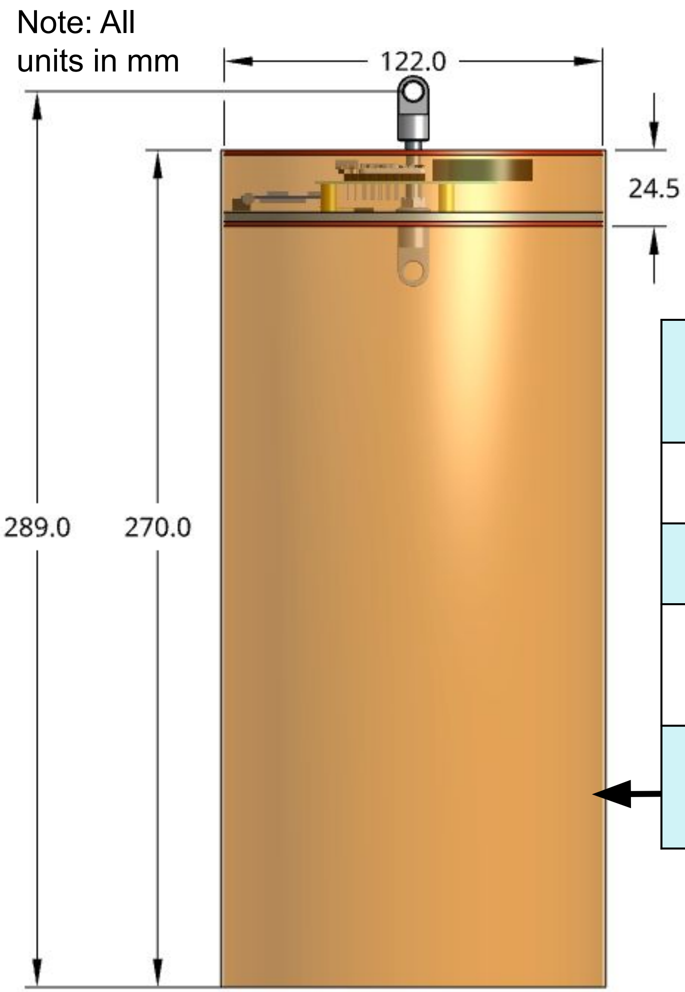


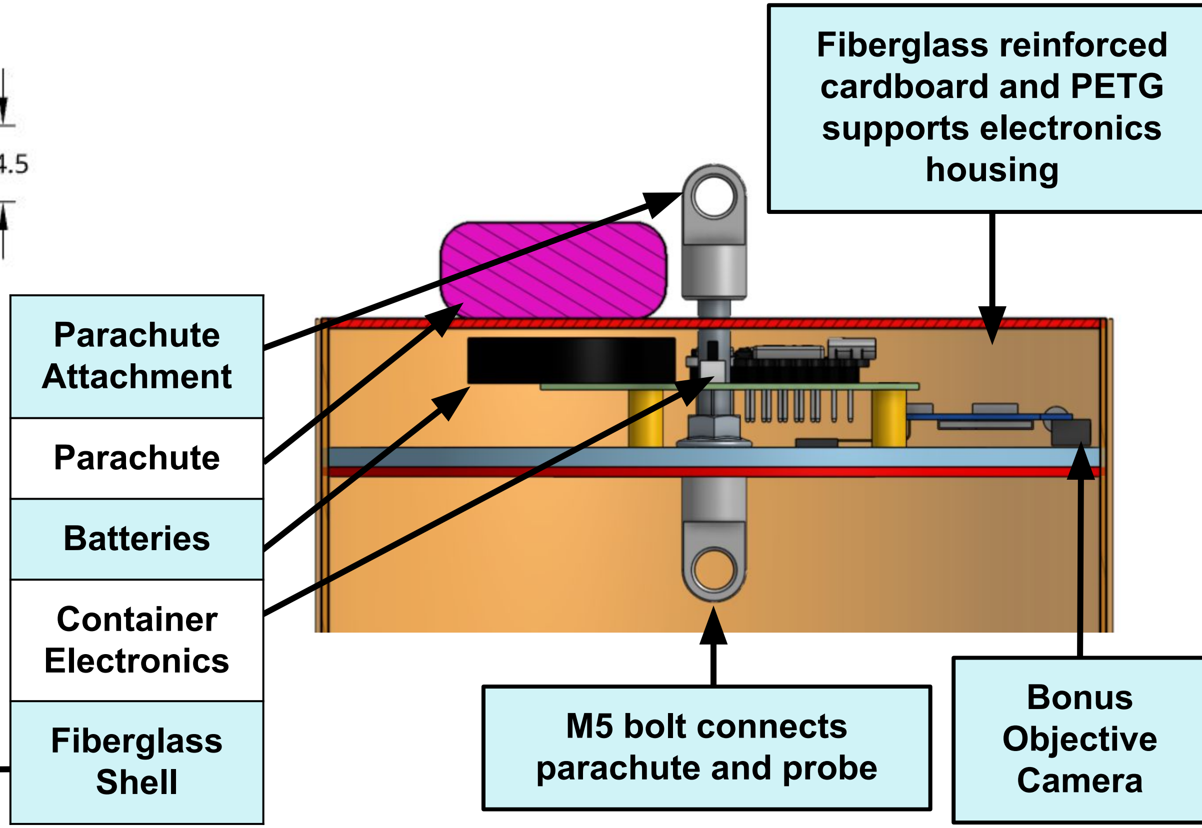
CDR

Container Mechanical Layout of Components

Side View

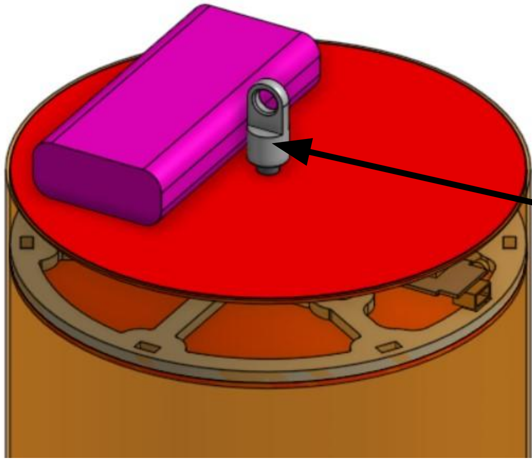
Section View



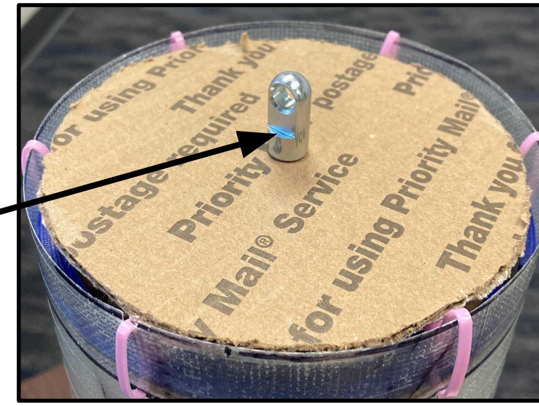


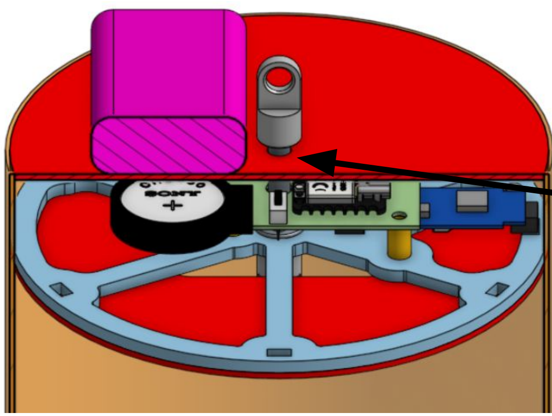
Note: Loctite used on all bolted connections

Container Parachute Attachment Mechanism

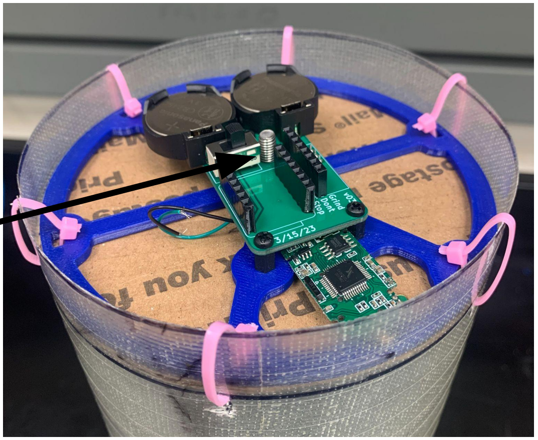


Container parachute is attached via a steel M5 eye nut, swivel, and bolt in the center of the container





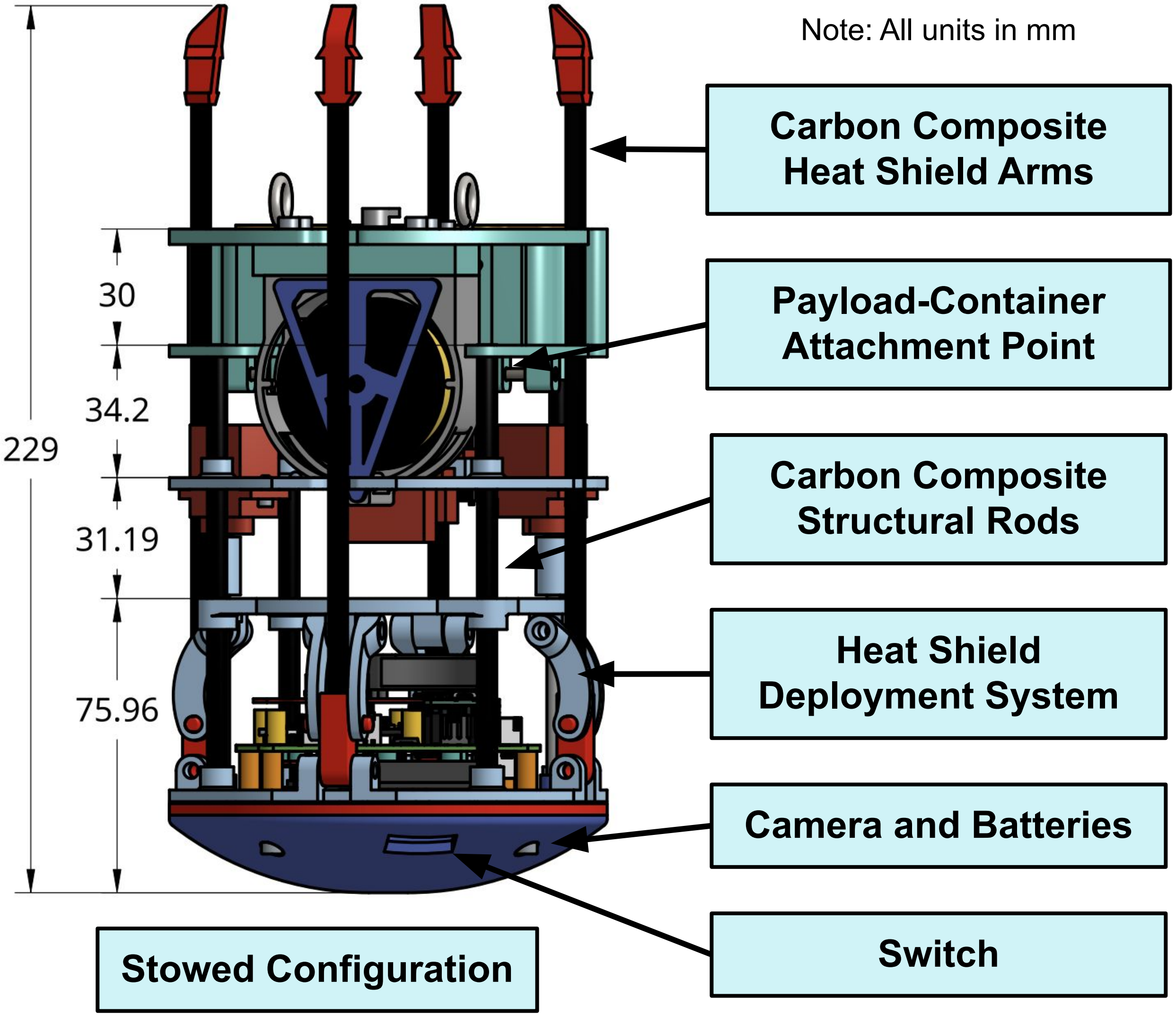
Central bolt passes through PCB and directly connects to probe attachment point



Note: The parachute will be folded in such a way that it can release passively after rocket separation

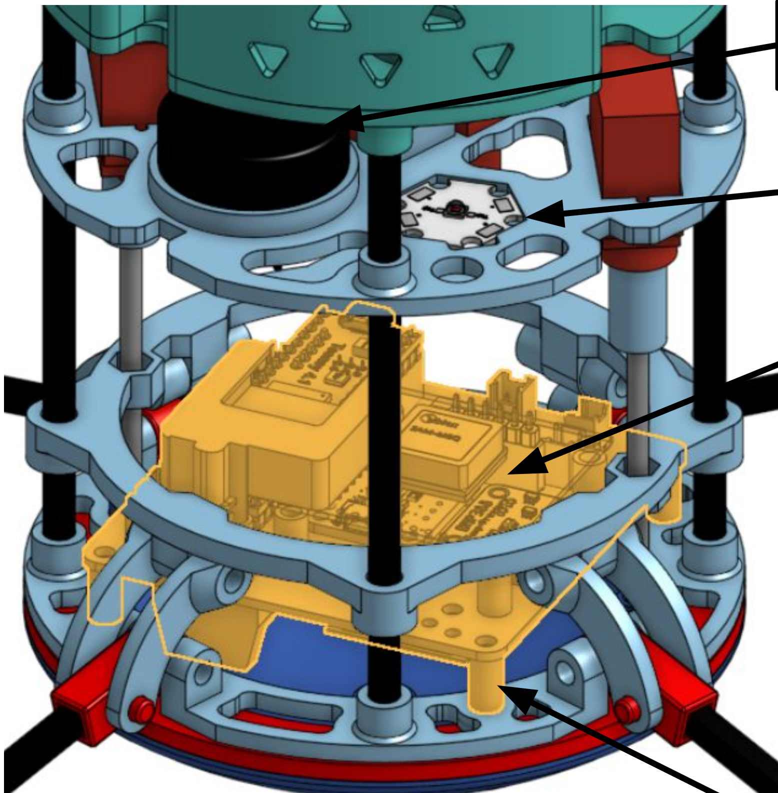
Payload Mechanical Layout of Components (1 of 2)

Note: All units in mm

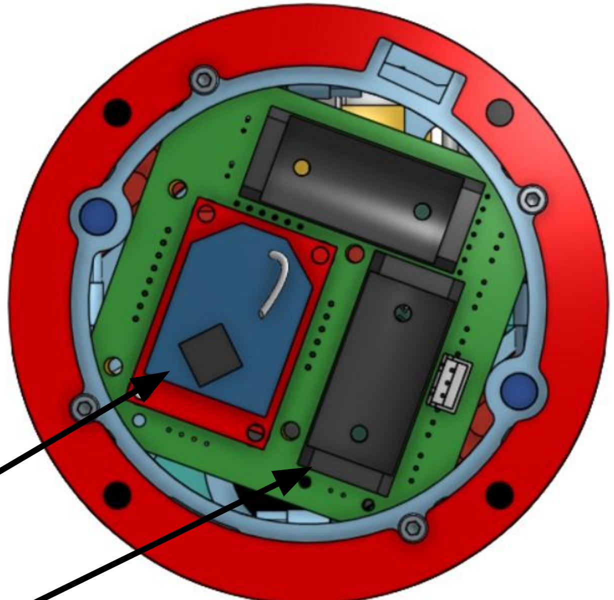


Payload Mechanical Layout of Components (2 of 2)

Electrical Layout



Bottom View with Nose Cone Removed



Buzzer

LED

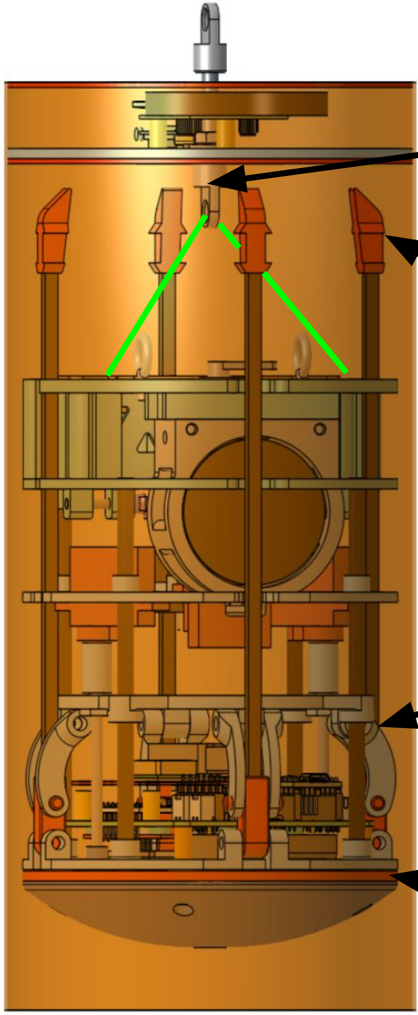
Electronics Package (CDH)

XBee Radio

Battery Holder

Metal Standoffs

Payload Pre Deployment Configuration



M5 paracord attachment on container

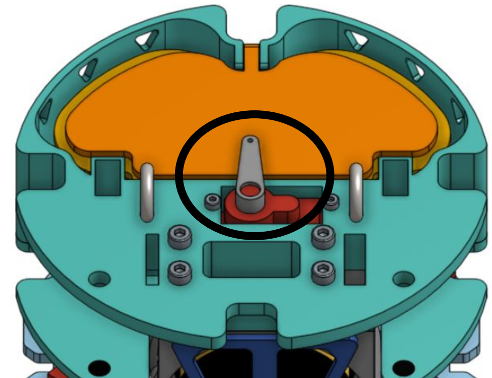
Nylon attachment pieces of landing legs will be sewn into ripstop nylon

Sliding plate is locked in place by threaded rods and deployment servos

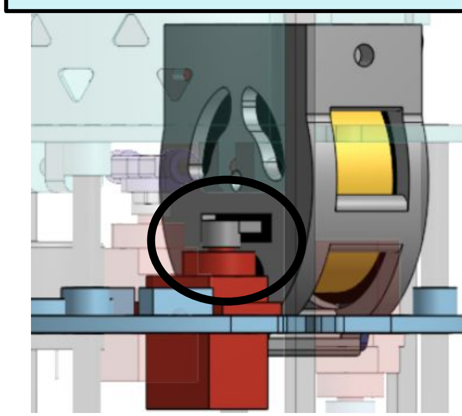
Ripstop nylon attached to a pinch plate and ends of landing legs

Stowed Configuration

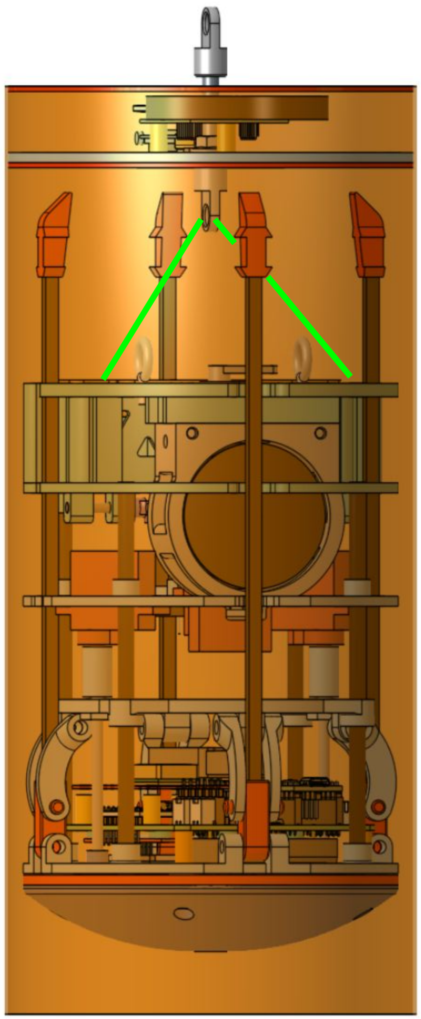
Parachute secured in spring-loaded piston compartment by servo



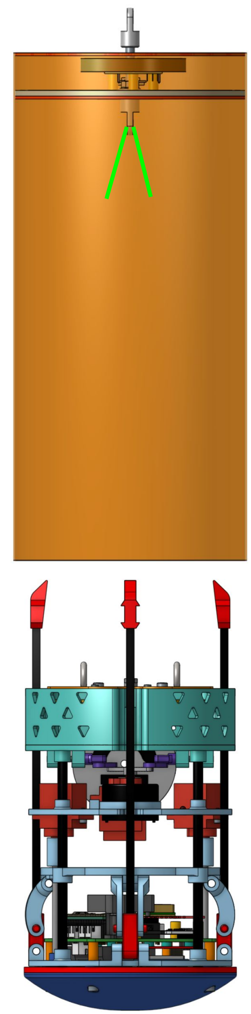
Flag deployment held closed by servo



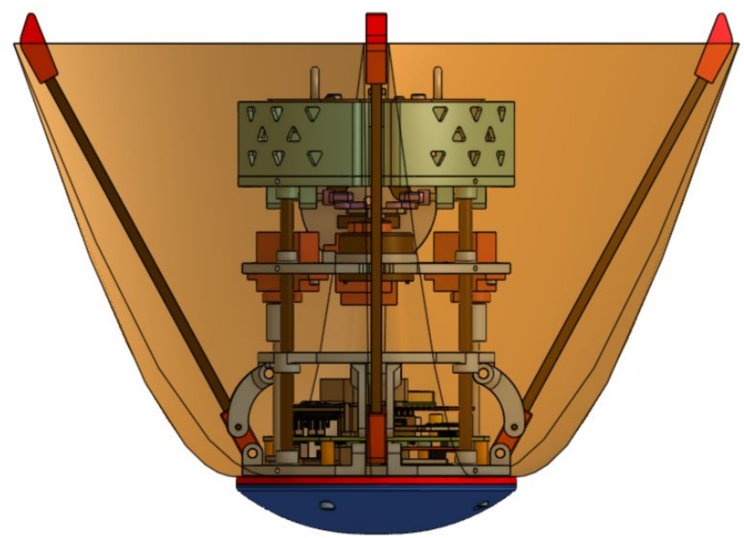
Payload Aerobraking Deployment Configuration (1 of 2)



Servo actuated container release pulls pins to separate probe and container



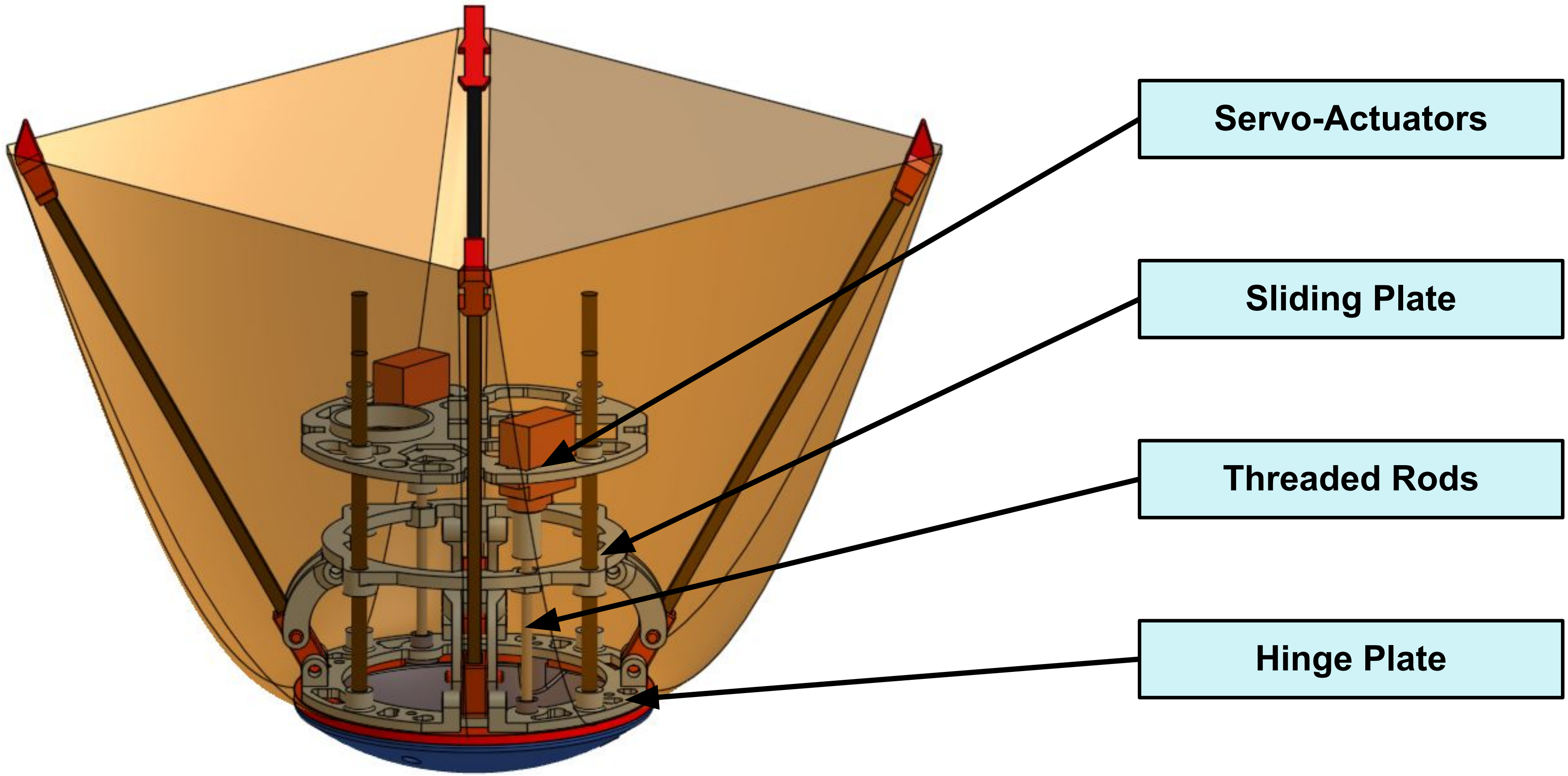
Following probe separation from the container the heat shield will begin deployment until arms reach a 30° aerobraking angle



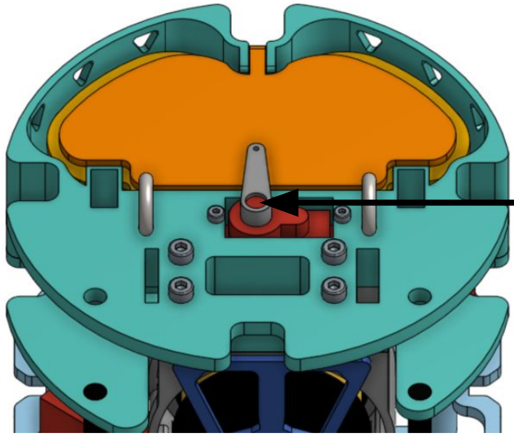
Probe when Stowed → **Post Container Release** → **Fully Deployed Heat Shield**

Payload Aerobraking Deployment Configuration (2 of 2)

The heat shield arms will deploy when two servos rotate threaded rods. A PETG sliding plate will have two captive nuts that move the plate down, extending the arms out and pulling the nylon tight

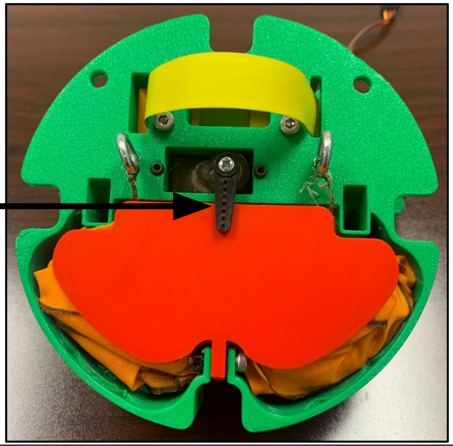


Payload Parachute Deployment Configuration



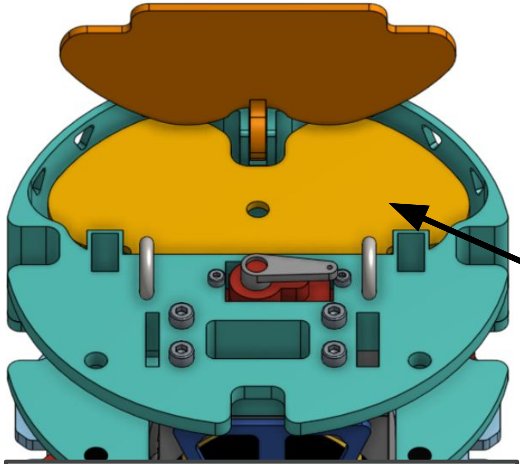
Stowed Configuration

Secured by a servo and lid fastened to the top plate



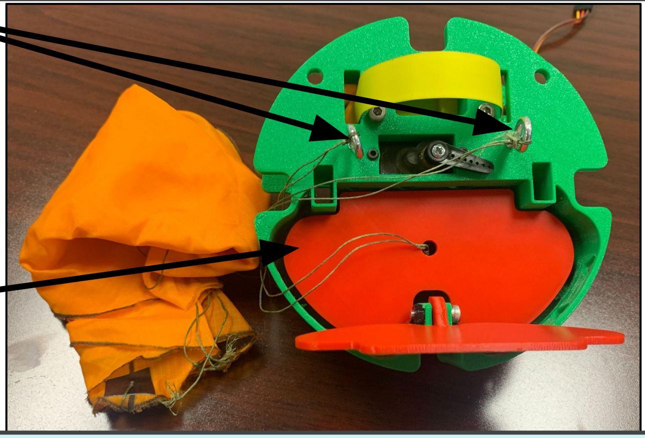
Prototype Stowed Configuration

Parachute is fastened to 3 steel screw eye hooks with 2mm paracord



Released Configuration

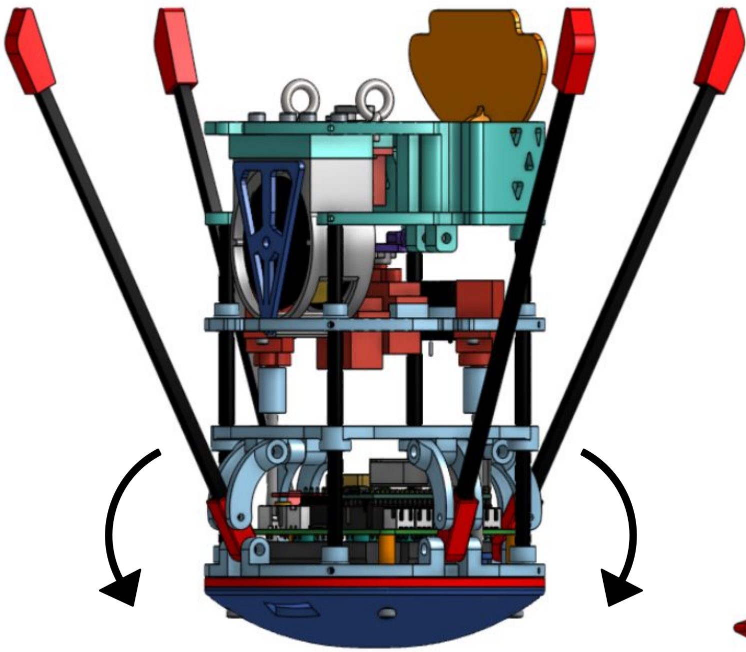
Spring-loaded piston ejects parachute during release



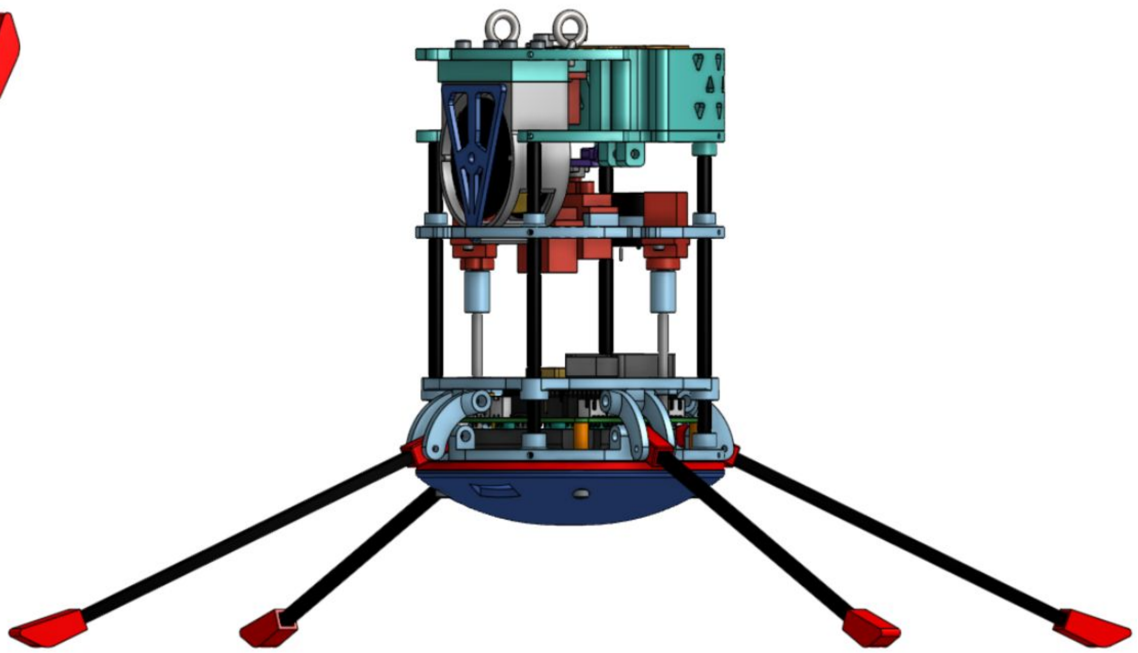
Prototype Released Configuration (with piston removed)

Payload Uprighting Description

Heat Shield Configuration



Uprighted Configuration



To upright, the 360° servos will continue rotating once the probe has landed. The carbon composite heat shield arms also serve as uprighting legs. The ends of the nylon attachment points are rounded to ease the uprighting process.

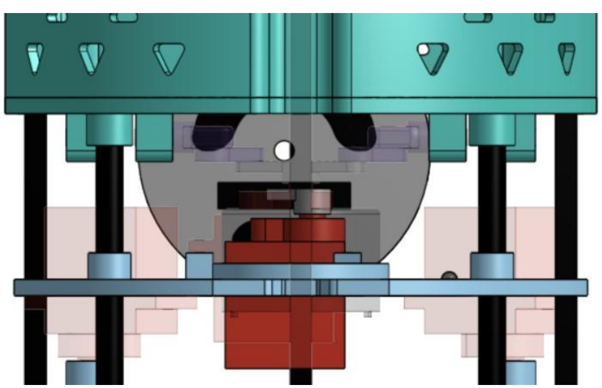
Payload Flag Deployment Configuration

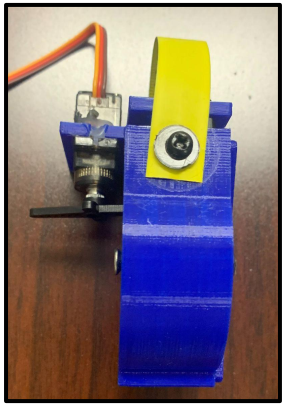
Flag Raising

Deployment:
- Servo actuated spool rotation
- Tape rises as the spool rotates

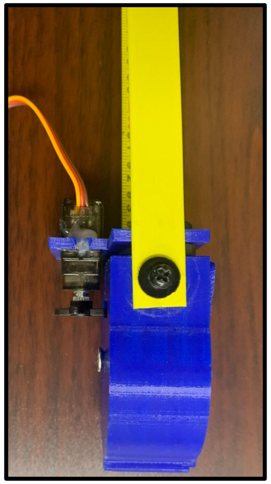
Material:
- Modified off-the-shelf tape measure
- Steel Tape
- Ripstop nylon flag

Attachment:
- Ripstop nylon flag super glued onto the tape and stored within coiled tape
- Tape attached to center of spool



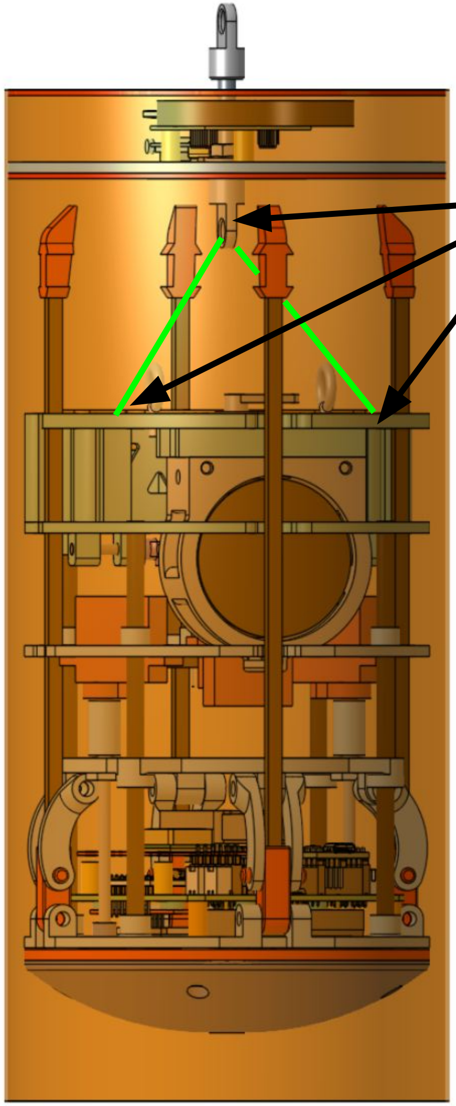


Pre-Deployment



Post-Deployment

Container Payload Mount

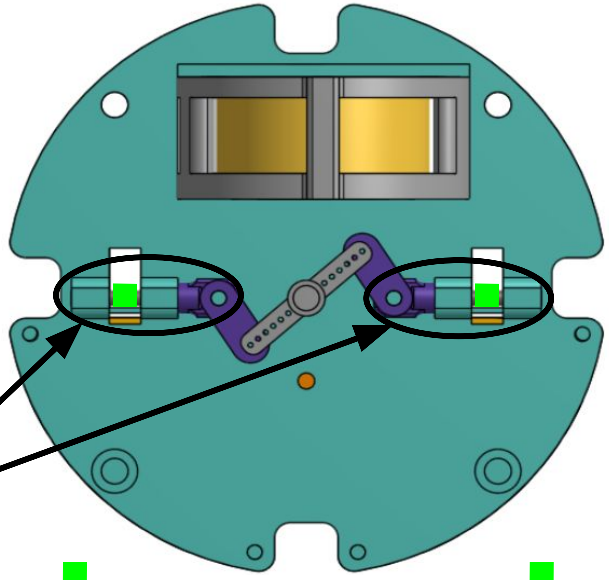


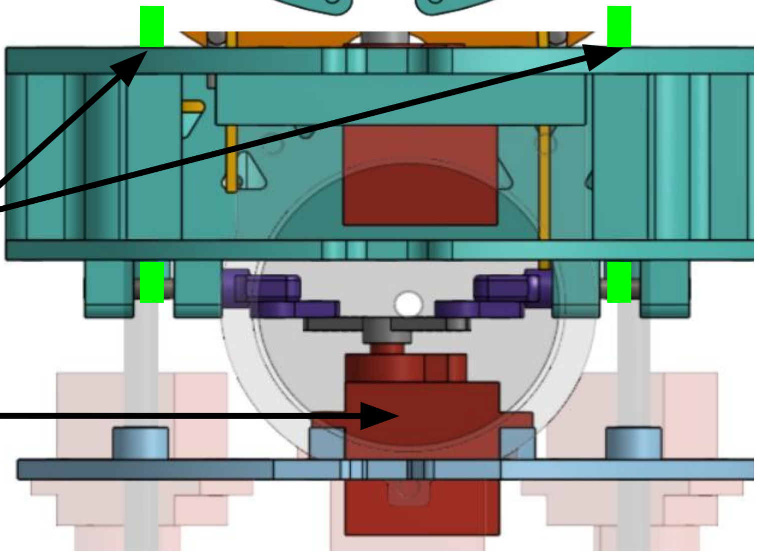
M5 eye bolt directly attaches paracord on the container to release pins on the payload

Paracord loops through pins controlled by a servo and linkages that pull the pins out of their slots

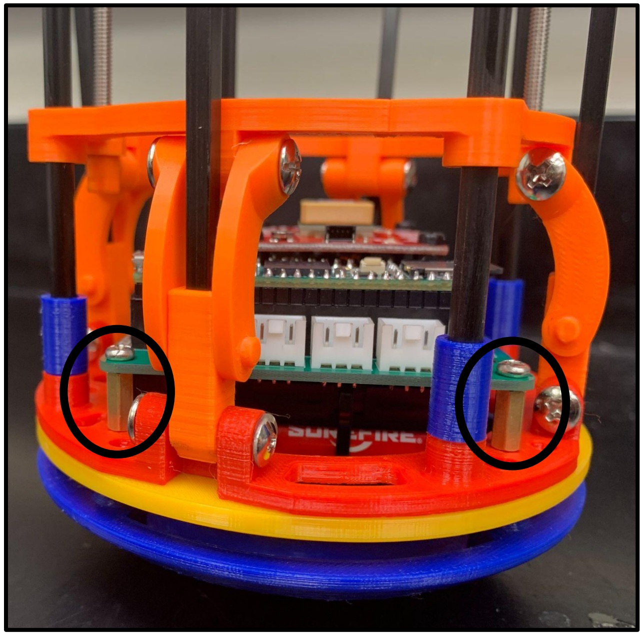
Paracord fed through the top plate

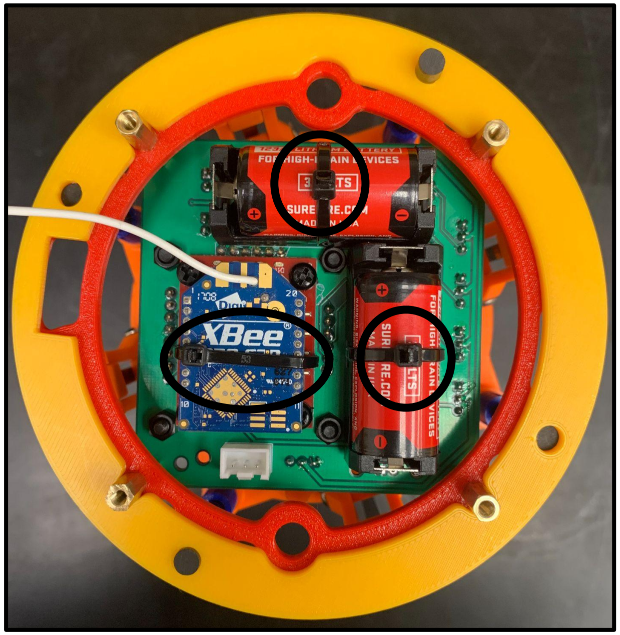
Central servo is secured to a plate below

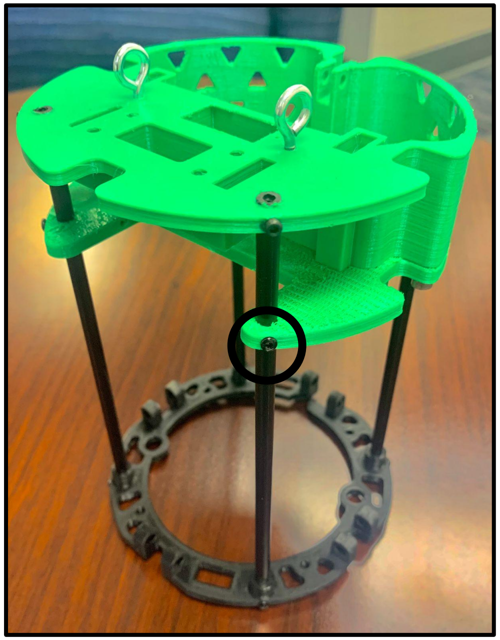




Structure Survivability (1 of 2)







Electronics:

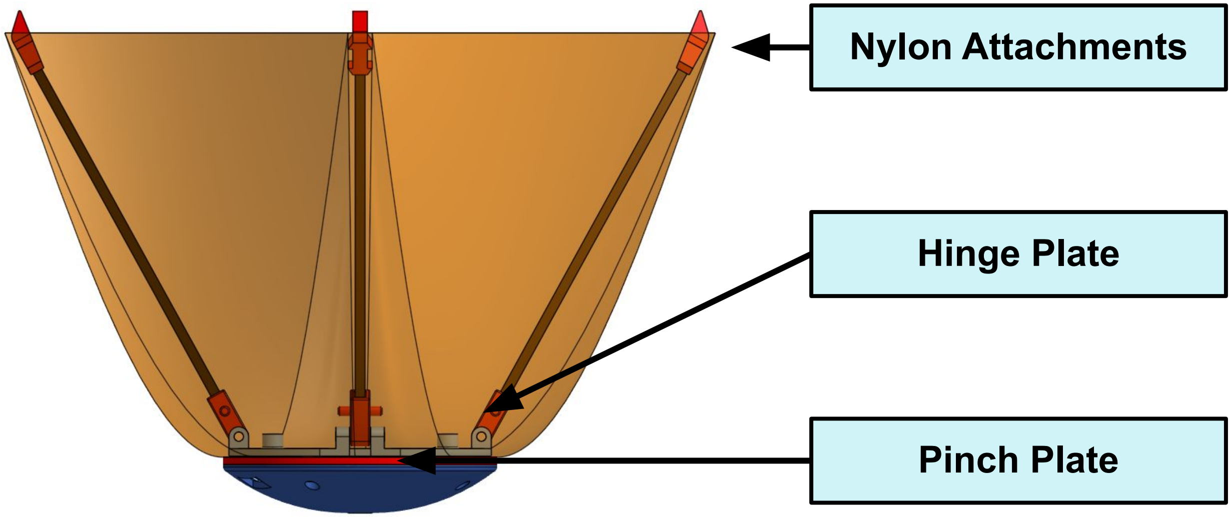
- PCB and breakout boards attached with metal standoffs
- XBee module attached with a zip-tie
- Actuator, buzzer, and LED wires in cable bundles

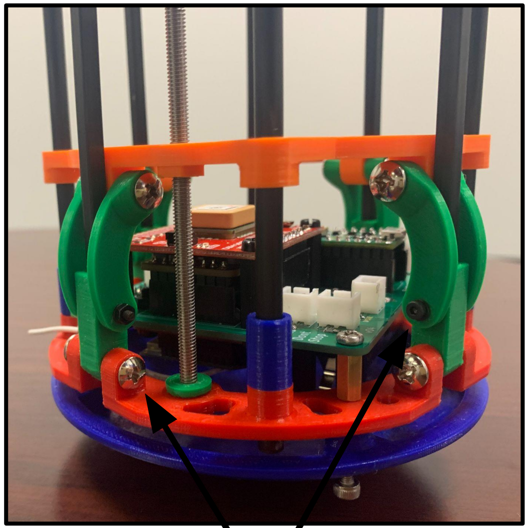
Structural

- Mounting through four carbon composite rod
- Bolt hole into each plate through rod

Decent Control Attachment:

- Ripstop nylon sandwiched between deployment system hinge and pinch plates that are held together with superglue and fasteners
- Ripstop nylon on each deployable arm is sewed into 3D printed nylon attachment piece which is press fit and super glued onto each carbon fiber arm





Heat shield deployment hinges are steel with locking nuts and loctite

G-Shock Testing:

To test all structures to the G forces experienced during launch, we will be recreating our own launch day with an L1 rocket to examine the results and improve future performance.

Mass Budget (1 of 8)

Container (1 of 2)

Component	Quantity	Mass (g)	Mass Summary (g)	Uncertainty (g)	Source
Seeed RP 2040	1	2.0	2.0	–	Datasheet
Adafruit Spycamera	1	2.8	2.8	–	Datasheet
BMP388	1	1.0	1.0	± 0.5	Measured
P-Channel MOSFET	1	1.0	1.0	± 0.5	Measured
CR2450 Battery	2	6.2	12.4	–	Datasheet
Switch	1	2.0	2.0	± 0.5	Measured
Small PCB	1	6.0	6.0	± 0.5	Measured
Battery Holders	2	2.0	4.0	± 0.5	Measured
(Wires, Solder, Misc.)	1	10.0	10.0	–	Estimate
Electrical Total	**-**	**-**	**41.2**		**-**

Mass Budget (2 of 8)

Container (2 of 2)

Component	Quantity	Mass (g)	Mass Summary (g)	Uncertainty (g)	Source
Fiberglass Shell	1	60.0	60.0	± 0.5	Measured
Nylon Parachute	1	14.0	14.0	± 0.5	Measured
Zip Ties	6	0.17	1.0	± 0.5	Measured
Container Plate	1	10.0	10.0	± 0.5	Measured
M5 Bolt	1	6.0	6.0	± 0.5	Measured
Cardboard Plate	1	4.0	4.0	± 0.5	Measured
M5 Eye Nuts	2	6.0	12.0	± 0.5	Measured
Mechanical Total	**-**	**-**	**107.0**	**-**	**-**
Electrical Total	**-**	**-**	**41.2**	**-**	**-**
Container Total	**-**	**-**	**148.2**	**-**	**-**

Mass Budget (3 of 8)

Probe (1 of 5)

Component	Quantity	Mass (g)	Mass Summary (g)	Uncertainty (g)	Source
Teensy 4.1	1	6.0	6.0	± 0.5	Measured
Adafruit Spycamera	1	2.8	2.8	–	Datasheet
BMP388	1	1.0	1.0	± 0.5	Measured
SAM-M8Q (GPS)	1	12.0	12.0	± 0.5	Measured
BNO055 (IMU/Tilt Sensor)	1	1.0	1.0	± 0.5	Measured
XBee Pro 900 HP	1	6.0	6.0	–	Datasheet
XBee Explorer Breakout Board	1	3.0	3.0	± 0.5	Measured
Linear 5.0V Regulator	1	1.0	1.0	± 0.5	Measured
LED	1	1.0	1.0	–	Datasheet
Buzzer Piezo 3V 30MM	1	8.0	8.0	–	Datasheet
Slide Total	**-**	**-**	**41.8**		**-**

Mass Budget (4 of 8)

Probe (2 of 5)

Component	Quantity	Mass (g)	Mass Summary (g)	Uncertainty (g)	Source
Previous Slide Total	**-**	**-**	**41.8**	**-**	**-**
Switch	1	2.0	2.0	± 0.5	Measured
CR2032	1	3.0	3.0	–	Datasheet
P-Channel MOSFET	2	1.0	2.0	± 0.5	Measured
CR123A Battery	2	16.0	32.0	–	Datasheet
Battery Holder	2	3.0	6.0	± 0.5	Measured
PCB	1	18.0	18.0	± 0.5	Measured
360 MG90 Servo	2	12.0	24.0	± 0.5	Measured
180 SG90 Servo	3	12.0	36.0	± 0.5	Measured
(Wires, Capacitors, Resistors, Solder)	-	25.0	25.0	–	Estimate
Electrical Total	**-**	**-**	**189.8**		**-**

Mass Budget (5 of 8)

Probe (3 of 5)

Component	Quantity	Mass (g)	Mass Summary (g)	Uncertainty (g)	Source
Carbon Fiber Arms	4	2.0	8.0	± 0.5	Measured
Carbon Fiber Support Rods	4	4.0	16.0	± 0.5	Measured
Nylon Parachute	1	14.0	14.0	± 0.5	Measured
Nylon Heat Shield	1	10.0	10.0	± 0.5	Measured
Nylon Attachment Points	4	1.0	4.0	± 0.5	Measured
Nose Cone	1	34.0	34.0	± 0.5	Measured
Pinch Plate	1	9.0	9.0	± 0.5	Measured
Slider Plate	1	12.0	12.0	± 0.5	Measured
Hinge Plate	1	13.0	13.0	± 0.5	Measured
Servo Plate	1	15.0	15.0	± 0.5	Measured
Threaded Rods	2	6.0	12.0	± 0.5	Measured
Slide Total	**-**	**-**	**147.0**	**-**	**-**

Mass Budget (6 of 8)

Probe (4 of 5)

Component	Quantity	Mass (g)	Mass Summary (g)	Uncertainty (g)	Source
Previous Slide Total	**-**	**-**	**147.0**	**-**	**-**
Rod Shoes	2	0.3	0.7	± 0.5	Measured
360 Servo Attachment	2	1.0	2.0	± 0.5	Measured
Arm Deployment Linkages	4	3.0	12.0	± 0.5	Measured
Chicago Screws	8	2.0	16.0	± 0.5	Measured
Parachute Deployment Plate	1	38.0	38.0	± 0.5	Measured
Parachute Eye Nuts	3	1.0	3.0	± 0.5	Measured
Parachute Spring Plate	1	8.0	8.0	± 0.5	Measured
Parachute Springs	2	1.0	2.0	± 0.5	Measured
Parachute Container Lid	1	6.0	6.0	± 0.5	Measured
Parachute Plate Base	1	21.0	21.0	± 0.5	Measured
Flag Raising Mechanism	1	52.0	52.0	± 0.5	Measured
Slide Total	**-**	**-**	**307.7**	**-**	**-**

Mass Budget (7 of 8)

Probe (5 of 5)

Component	Quantity	Mass (g)	Mass Summary (g)	Uncertainty (g)	Source
Previous Slide Total	**-**	**-**	**307.7**	**-**	**-**
PCB Standoffs	4	3.0	12.0	± 0.5	Measured
General Fasteners/Adhesive	1	20.0	20.0	-	Estimated
Mechanical Total	**-**	**-**	**339.7**	**-**	**-**
Electrical Total	**-**	**-**	**189.8**	**-**	**-**
Probe Total	**-**	**-**	**529.5**	**-**	**-**

Mass Budget (8 of 8)

Container Mass Total	148.2 ± 6.0 g
Probe Mass Total	529.5 ± 17.5 g
CanSat Mass Total	**677.7 ± 23.5 g**

677.7 g - 700.00 g = -22.3 g
Below Ideal Mass of 700 g
Outside Mass limit of 690 g - 710 g

Methods to increase CanSat mass:

- Increase infill on 3D printed parts to increase structural integrity
- Put ballast in the nose cone to lower center of mass

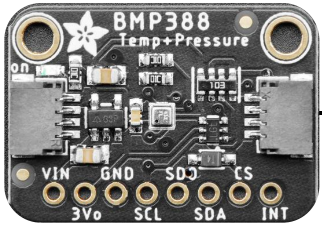
Methods to decrease CanSat mass:

- Remove extra material on top plate and parachute container

Note: The scale used for measurements reads to the gram. Our uncertainty is the standard half of the smallest increment.

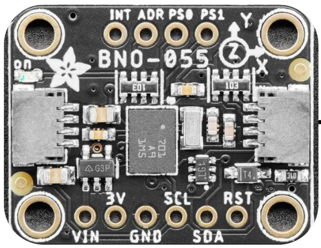
Communication and Data Handling (CDH) Subsystem Design

Brennan Begley and Emann Rivero



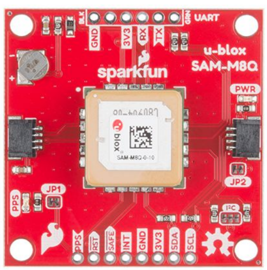
BMP388 (I²C)
Temperature
Pressure/Altitude

Image credit: Adafruit.com



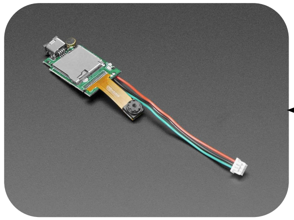
BNO055 (I²C)
Quaternion Angles
Acceleration XYZ

Image credit: Adafruit.com



SAM-M8Q (UART)
GPS Position
UTC Acquisition

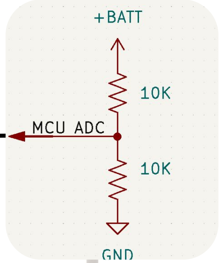
Image credit: Sparkfun.com



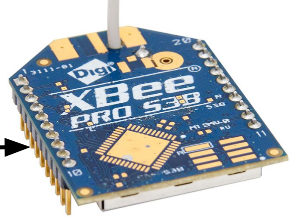
Spycamera (Digital)
Local Video Recording
Video Storage

Image credit: Adafruit.com

Image credit: pjrc.com



Battery Voltage (Analog - ADC)
Battery Voltage



XBee Pro 900HP (UART)
Sends Packets
Relays Commands

Image credit: Digi.com

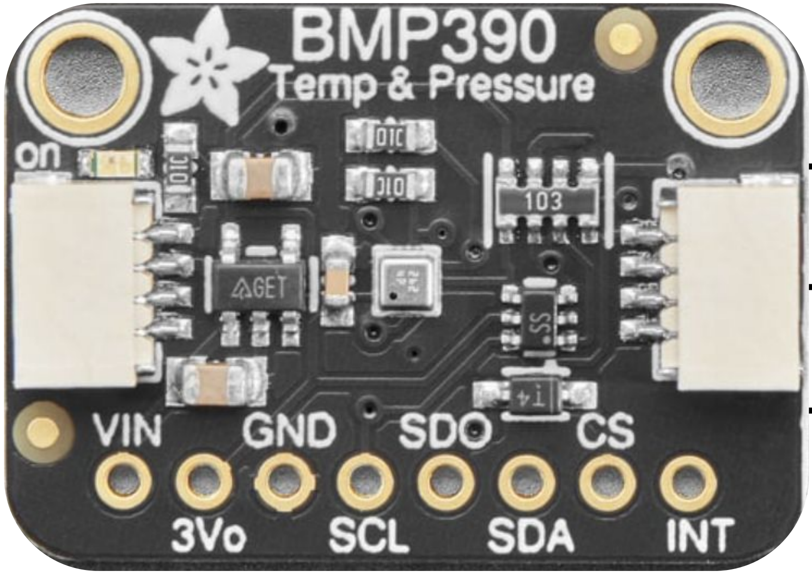
Teensy 4.1 (Data Storage)
Packet storage to
Micro SD Card

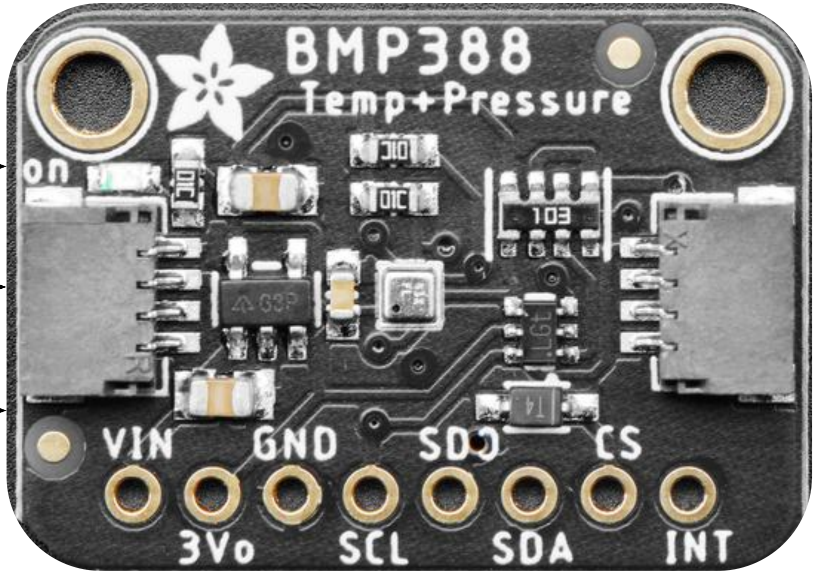
Teensy 4.1 (ARM Cortex-M7)
Compiles Data into Packets
Interprets Commands
Maintains Mission Time with RTC

To Ground Station (Wireless)

CDH Changes Since PDR

Data Collected	PDR Sensor	CDR Sensor	Reason for Change
Pressure	BMP390	BMP388	BMP390 was not available for purchase
Temperature	BMP390	BMP388	BMP390 was not available for purchase





Payload Processor & Memory Selection

Module	Boot Time (ms)	Processor Speed (MHz)	Data Bus Width (bits)	Data Interfaces	Power Consumption (mA)
Teensy 4.1 (ARM Cortex-M7)	5	600	32	8 UART 3 SPI 3 I2C	100

RAM (KB)	Voltage (V)	Ports	Mass (g)	Price ($)
1024	5.0	55 digital input/output 35 PWM outputs 18 analog inputs	6.0	31.50

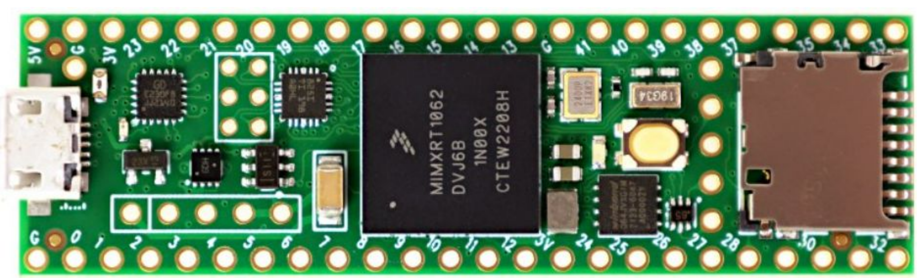


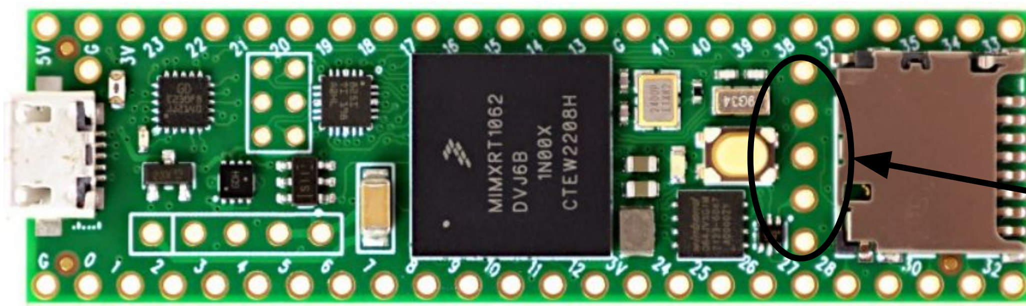
Image credit: www.pjrc.com

Teesy 4.1

- **5 ms start-up time**
- **Many useable ports**
- **Integrated SD card reader/writer**
- **600 MHz processing speed**

Payload Real-Time Clock

Module	Time Accuracy (ns)	Battery	Reset Tolerance	Lifetime (hours)
Teensy 4.1	± 1.2	CR2032	Oscillator runs independently of MCU power	24



Teensy 4.1

- **Integrated with Teensy module**
- **± 1.2 ns accuracy**
- **Use with any 3.3V cell**
- **Long lifetime**

Image credit: www.pjrc.com

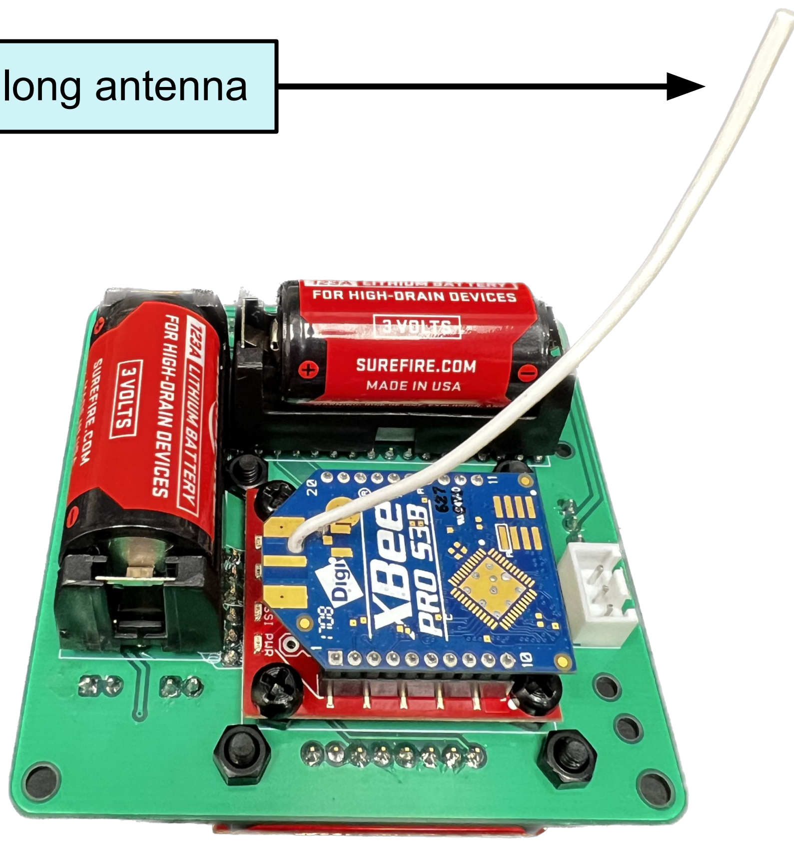
Image credit: adafruit.com

External CR2032 coin cell battery

Payload Antenna Selection

Module	Range (km)	Gain (dBi)	Pattern	Mass (g)
Integrated Wire Antenna	3.2	1.9	Omnidirectional	<1

60 mm long antenna



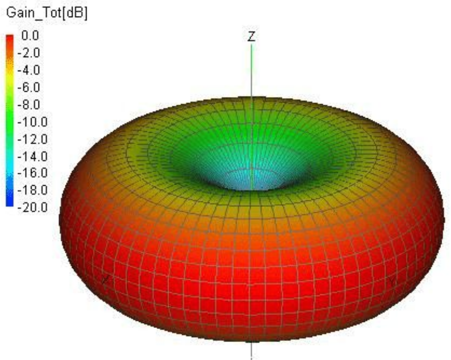


Image credit: researchgate.net

Integrated Wire Antenna
- **3.2 km range**
- **Included with XBee**
- **Negligible mass**

Payload Radio Configuration

XBee Radio Selection : XBee-Pro 900HP

NETID: 1079

Transmission Method: Unicast

Transmission Protocol: XBees will initialize and boot sensors, waiting for CX_ON Command. Once said command is sent, Probe XBee will transmit telemetry at a rate of 1 Hz to Ground XBee regardless of selected flight mode (simulation or flight). On landing, Probe XBee will cease transmission after receiving CX_OFF.

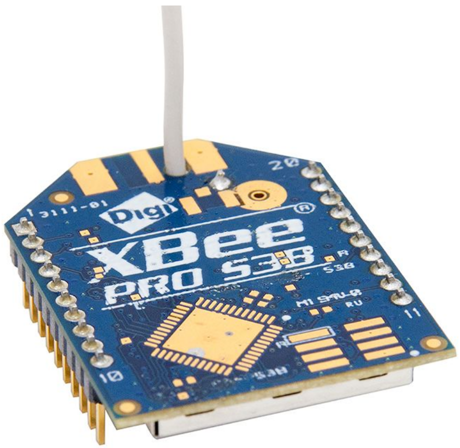


Image credit: digi.com

Configuration			
XBee	Mode	Dest. High	Dest. Low
Probe	API 2	Ground Serial High	Ground Serial Low
Ground	API 2	Probe Serial High	Probe Serial Low

Power	
Transmit Power	Transmit Frequency
250mW	900MHz

Payload Telemetry Format (1 of 3)

Competition Given Telemetry Format
<TEAM_ID>, <MISSION_TIME>, <PACKET_COUNT>, <MODE>, <STATE>, <ALTITUDE>, <HS_DEPLOYED>, <PC_DEPLOYED>, <MAST_RAISED>, <TEMPERATURE>, <PRESSURE>, <VOLTAGE>,<GPS_TIME>, <GPS_ALTITUDE>, <GPS_LATITUDE>, <GPS_LONGITUDE>, <GPS_SATS>, <TILT_X>, <TILT_Y>, <CMD_ECHO>

Example Telemetry Packet
“1079, 01:23:45, 560, S, DESCENT, 30.52, P, C, N, 24.45, 101.3, 5.4, 12:34:55, 329.52, 20.0035, 2.1940, 400, 12.39, 39.12, CMD,1079,SIM,ENABLE”
Note: Spaces added for legibility of telemetry packet; Payload sends packets at a rate of 1 Hz

Example CX_ON Command
“CMD,1079,CX,ON”

Payload Telemetry Format (2 of 3)

Data Field	Description	Units
<TEAM_ID>	Four-digit identification number	N/A
<MISSION_TIME>	UTC time since mission start with resolution of 1 seconds	hh:mm:ss
<PACKET_COUNT>	Number of packets since mission start	N/A
<MODE>	Container and GS mode (flight or simulation)	N/A
<STATE>	Operating state of software i.e 'Launch'	N/A
<ALTITUDE>	Height above launch site with resolution of 0.1 meters	m
<HS_DEPLOYED>	'P' indicates deployed heat shield, else 'N'	N/A
<PC_DEPLOYED>	'C' indicates probe parachute deploy, else 'N'	N/A
<MAST_RAISED>	'M' indicates flag mast has raised, else 'N'	N/A
<TEMPERATURE>	Temperature of CanSat with resolution of 0.1 degrees	°C
<PRESSURE>	Pressure measured from the Probe with resolution of 0.1 kPa	kPa
<VOLTAGE>	Voltage of CanSat power bus with resolution of 0.1 volts	V

Payload Telemetry Format (3 of 3)

Data Field	Description	Units
<TILT_X>	Angle of CanSat X axis with resolution of 0.01 degrees, where Z points towards center of earth	°
<TILT_Y>	Angle of CanSat Y axis with resolution of 0.01 degrees, where Z points towards center of earth	°
<ACCEL_X>	Acceleration of the CanSat towards the X axis with resolution 0.0001	m/s^2
<ACCEL_Y>	Acceleration of the CanSat towards the Y axis with resolution 0.0001	m/s^2
<ACCEL_Z>	Acceleration of the CanSat towards the Z axis with resolution 0.0001	m/s^2
<GPS_ALTITUDE>	Altitude as calculated by the GPS with resolution of 0.1 meters	m
<GPS_LATITUDE>	Latitude as calculated by GPS with resolution of 0.0001 degrees	°North/°South
<GPS_LONGITUDE>	Longitude as calculated by GPS with resolution of 0.0001 degrees	°East/°West
<CMD_ECHO>	Text of last command received and processed	N/A

Payload Command Formats

Command Declaration	Team ID	Command Name	Option Description	Example	Command Description
CMD	1079	CX	ON	“CMD,1079,CX,ON”	Activates receiving telemetry
			OFF	“CMD.1079,CX,OFF”	Deactivates receiving telemetry
CMD	1079	ST	UTC	“CMD,1079,ST,UTC”	Sets time on the probe to UTC time
			GPS	“CMD,1079,ST,GPS”	Sets time on the probe to UTC time given by GPS
CMD	1079	SIM	ENABLE	“CMD,1079,SIM,ENABLE”	Enters Simulation Mode and prevents initiating Flight Mode
			ACTIVATE	“CMD,1079,SIM,ACTIVATE”	Activates Simulation Mode
			DISABLE	“CMD,1079,SIM,DISABLE”	Disables Simulation Mode
CMD	1079	SIMP	Custom	“CMD,1079,SIMP,XYZ”	Sends an input pressure to the probe
CMD	1079	CAL	N/A	“CMD,1079,CAL”	Resets all saved values on the probe to zero

Electrical Power Subsystem Design

Mason Mills

EPS Overview

Umbilical:
Disconnecting plug from the batteries that can be used with an external power source

Battery:
Two CR123A SureFire batteries, each 3V, outputting a combined ~6V

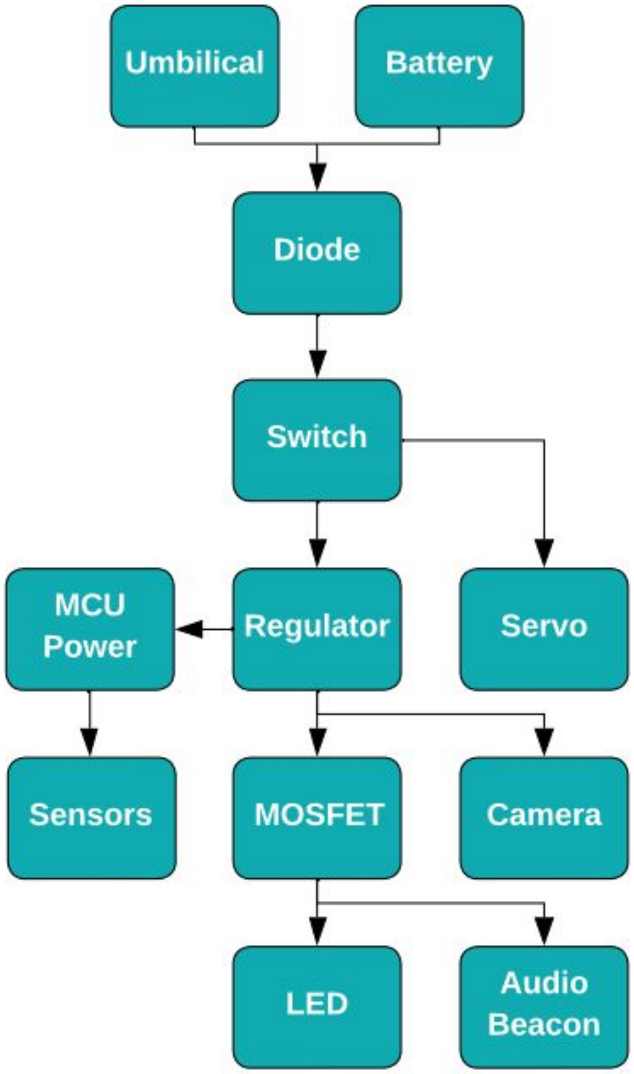
Diode:
Prevents the reverse flow of electricity

Switch:
Gate that turns on and off the electrical system

Regulator:
Reduce voltage from batteries to 5.0V providing required voltage to components

MOSFET:
Programmable switch used to control the supply of power to specific components

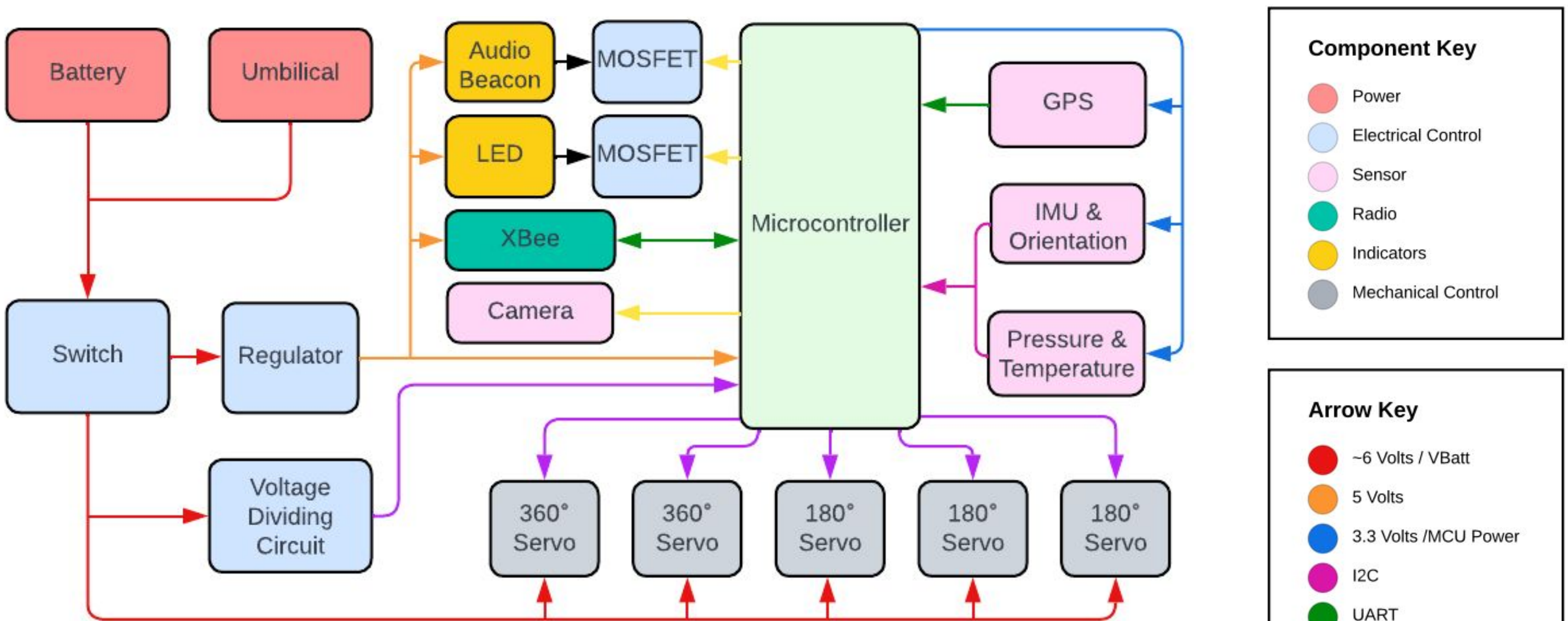
MCU Power:
Internal regulator of MCU reduces 5.0V input to 3.3V output that powers each sensor



EPS Changes Since PDR

Powered Components	PDR	CDR	Reason for Change
Pressure Sensor	BMP390	BMP388	Availability issues with the BMP390
Temperature Sensor	BMP390	BMP388	Availability issues with the BMP390
Heat Shield Motors	1 Analog Feedback Servo	2 MG90 360° Servos	Revised heat shield deployment mechanism requires two 360° servos

Payload Electrical Block Diagram



- **Switch located in the nose cone, easily accessible from the shell located at the bottom of the CanSat**
- **To read voltage, power will pass through a VDC which will then be read by the microcontroller and verified by the ground station**

Payload Power Source

Battery	Voltage (V)	Capacity (mAh)	Quantity Needed	Layout	Power Density (Wh/g)	Instant Current (mA)	Unit Weight (g)	Unit Price ($)
Surefire CR123A	3.0	1,550	2	Series	0.274	1,000	17	1.80

Image credit: surefire.com

Note: **Batteries will be mounted in battery holders and secured with two heavy duty zip ties**

Surefire CR123A

- **High power density**
- **Reliable and predictable**
- **Well documented discharge traits**

Payload Power Budget (1 of 2)

Component	Voltage (V)	Active Draw (mA)	Active Duration (h)	Idle Draw (mA)	Idle Duration (h)	Quantity	Energy (Wh)	Source
BMP388	3.3	1.00	2.00	0.002	0.00	1	0.007	Datasheet
SAM-M8Q	3.3	29.00	2.00	9.500	0.00	1	0.191	Datasheet
XBee	5.0	229.00	2.00	0.003	0.00	1	2.290	Datasheet
BNO055	3.3	12.30	2.00	0.330	0.00	1	0.081	Datasheet
PUI 3V Piezo Buzzer	5.0	22.00	0.50	0.000	1.50	1	0.055	Datasheet
LED	5.0	83.00	0.16	0.000	1.84	1	0.066	Datasheet
Adafruit Spycamera	5.0	110.00	2.00	80.000	0.00	1	1.100	Datasheet
Teensy 4.1	5.0	100.00	2.00	11.730	0.00	1	1.000	Datasheet
360 MG90 Servo	6.0	250.00	0.04	10.0	1.96	2	0.360	Datasheet
180 SG90 Servo	6.0	250.00	0.02	10.0	1.98	3	0.420	Datasheet

Payload Power Budget (2 of 2)

Energy Consumption Subtotal (Wh):	5.57
Power Supply Efficiency :	89.2%
Total Energy Consumption (Wh):	6.24
Available Battery Capacity (Wh):	9.30
Percent of Battery Used:	67.1%
Energy Margin (Wh):	3.06
Remaining Battery Percentage:	32.9%

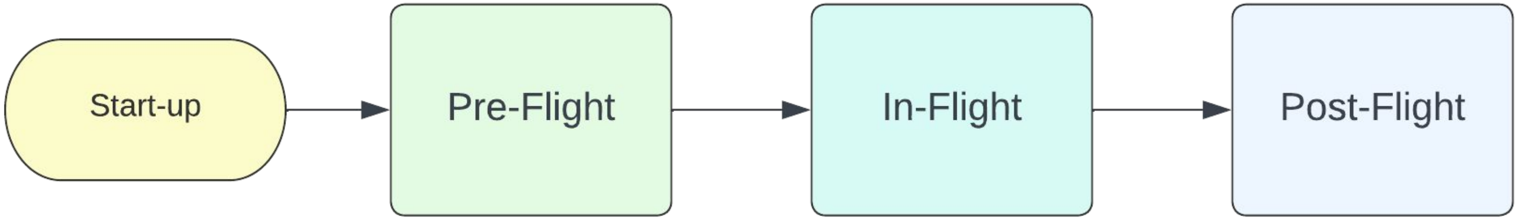
<u>Note:</u> The energy margin will account for any uncertainties in datasheet accuracy

Flight Software (FSW) Design

Emann Rivero

FSW Overview

Pre-Flight:	In-Flight:	Post-Flight:
• Power all devices • Boot all sensors • Read previously saved packet • Calibrate to zero and begin mission time	• Determine flight state • Record video from container and payload cameras • Release descent mechanisms based on flight state • Blink LED	• Set buzzer on, blink LED, raise mast • End recordings • Save telemetry to SD card through processor resets
Note: Flight software is developed in the Arduino IDE using Arduino		

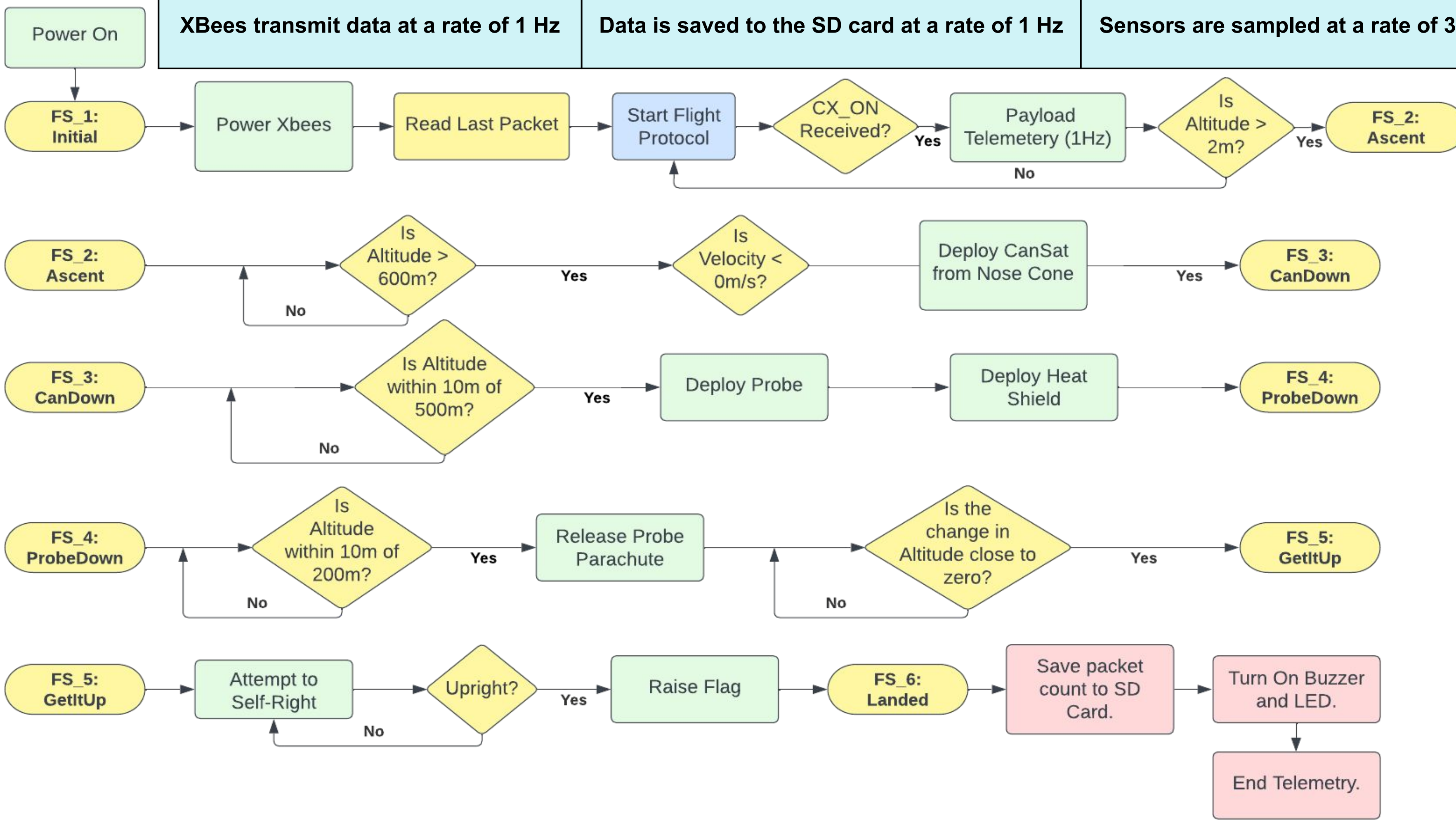


FSW Changes Since PDR

Process	PDR	CDR	Purpose
Restructuring the Backend	Unified Functions	Modularized Functions	Simplifies the code's complexity and enhances readability
Command Detection	Nested if-statements	Switch case	Reduce complexity and increase code efficiency
Code Comment Revision	Comments for Software Development	Explanatory Sections to explain Software Development	Allows for easier testing and integration with electrical team

Payload FSW State Diagram (1 of 2)

Flight Protocol		
XBees transmit data at a rate of 1 Hz	**Data is saved to the SD card at a rate of 1 Hz**	**Sensors are sampled at a rate of 3 Hz**



Payload FSW State Diagram (2 of 2)

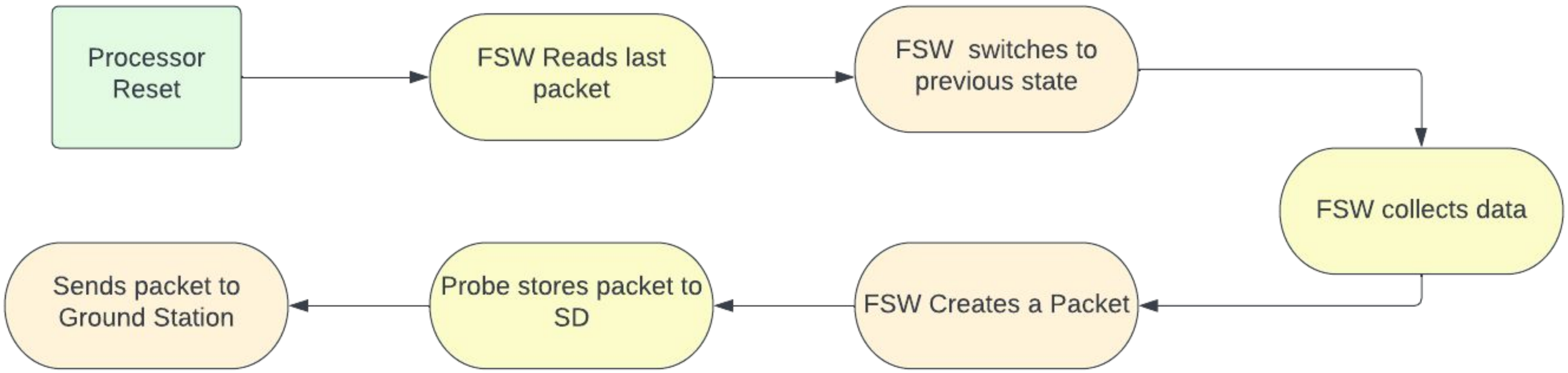
After Processor Restart:

- The payload will read the previous telemetry packet
- Assign a flight state according to previous packet
- Sensors restart data collection
- FSW obtains sensor data and creates a packet
- The packet is then sent to the SD card
- Another copy is sent to the Ground Station for data processing and analysis

Processor resets occur on MCU power loss

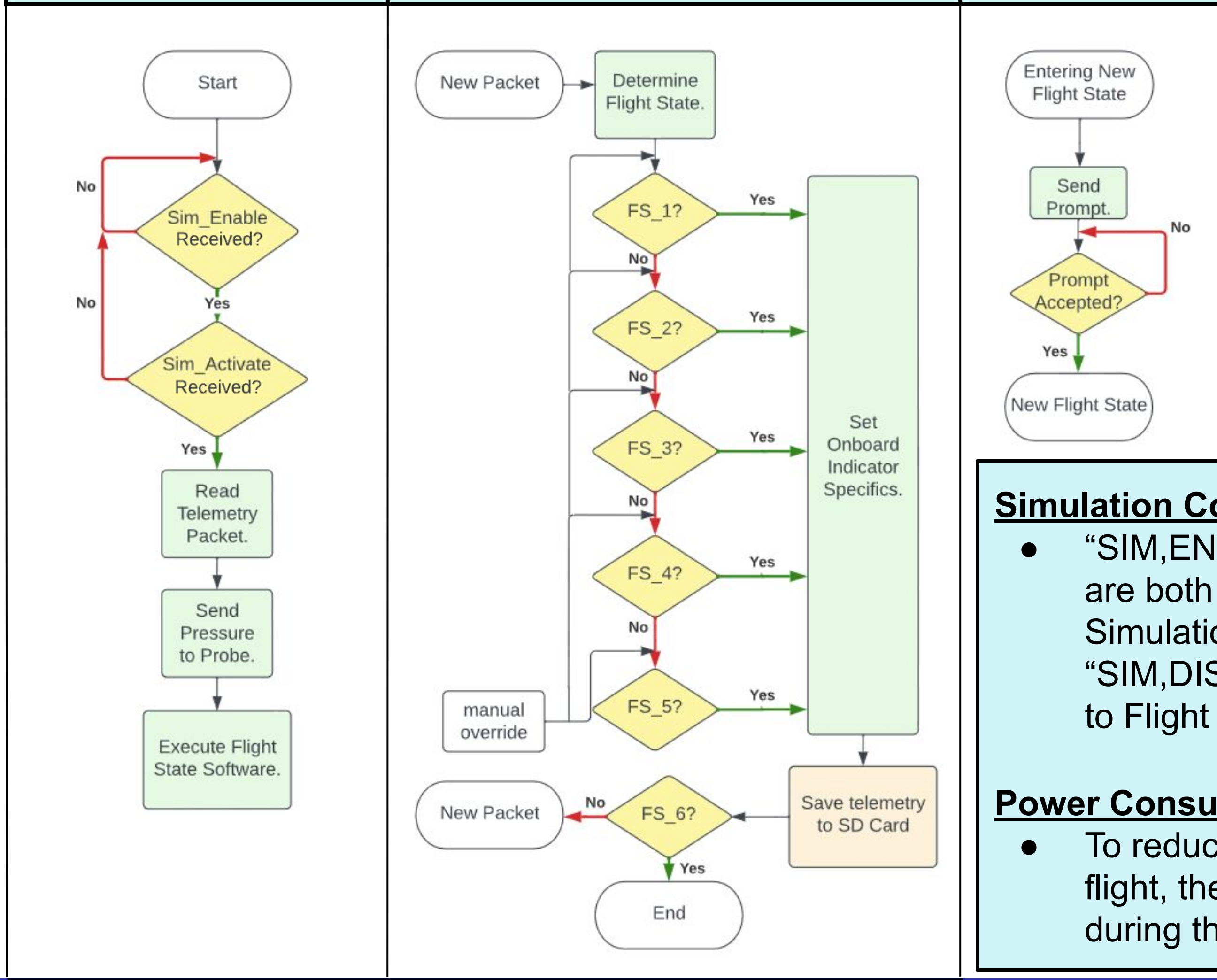
Power Failure:

Packet count and Flight state will be stored to the Teensy 4.1's internal EEPROM, to act as a backup in case of power failure during processor restart operations.



Simulation Mode Software

Simulation Mode	Flight State	Prompt Logic



Onboard indicators include:
- LED
- Buzzer

Simulation Commands:
- "SIM,ENABLE" and "SIM,ACTIVATE" are both required to implement Simulation Mode, while "SIM,DISABLE" will return the system to Flight Mode.

Power Consumption:
- To reduce power consumption during flight, the LED has a 1 Hz blink rate during the majority of flight operations

Software Development Plan

Name	Start Date	End Date	October				November				December				January					February				March				April				May					
General			10	17	24	31	7	14	21	28	5	12	19	26	2	9	16	23	30	6	13	20	27	6	13	20	27	3	10	17	24	1	8	15	22	29	5
Team Formation	10/10/2022	10/30/2022																																			
MCR Phase	10/24/2022	12/2/2022																																			
PDR Phase	12/2/2022	1/27/2023																																			
CDR Phase	1/27/2023	4/10/2023																																			
Parts Ordering	2/6/2023	4/10/2023																																			
Test-Launch Phase	4/14/2023	5/7/2023																																			
Competition Phase	5/7/2023	6/11/2023																																			
Software Team																																					
State Machine	10/10/2022	11/16/2022																																			
Ground Station Development	11/16/2022	1/19/2023																																			
Prototyping	11/16/2022	1/19/2023																																			
Radio Testing	1/20/2023	2/15/2023																																			
Parts Order and Sensor Testing	1/20/2023	2/27/2023																																			
Debugging	2/15/2023	6/10/2023																																			

Software Development Progress (Enrico Addy and Emann Rivero)

- Sensor testing for each sensor has been completed but needs to be maintained throughout sensor integration.
- Sensor integration and simulation testing is still ongoing with electrical team

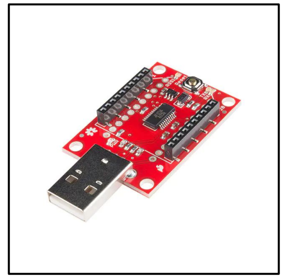
Ground Control System (GCS) Design

Enrico Addy

GCS Overview

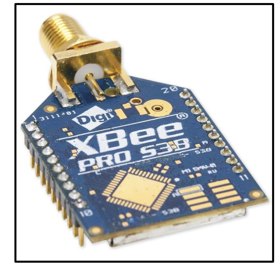
Ground Station Computer

Image credit: dell



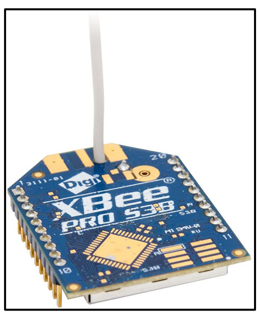
XBee Breakout Board

Image credit: digikey.com



Ground Station XBee

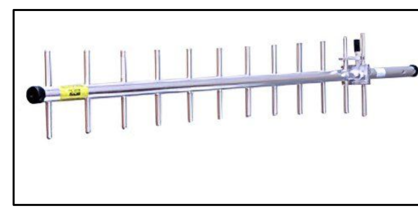
Image credit: digikey.com



Payload XBee

Image credit: digi.com

⟶	Wired Communication
- - - ⟶	Wireless Communication



Yagi Antenna

Image credit: pasternack

GCS Changes Since PDR

System	PDR	CDR	Rationale
Location Tracking	Probe location preserved in CSV file alone	Probe location tracking using Folium package	Recording probe path both in and out of flight is important in post-flight analysis
Ground Station Tab Layout	Incoming data expressed in one component of tab display	Dedicated tab for displaying incoming packets	Greater ease of full packet observation

GCS Design (1 of 2)

GCS Communication Pathway

- The GS is hosted locally on a Dell XPS 15, from which telemetry is communicated through two USB adaptors to the Ground XBee
- The ground XBee communicates via the SMA Male to N Female connector to reach the handheld antenna, which relays telemetry to the Probe XBee

Image credit: dell

Image credit: amazon.com

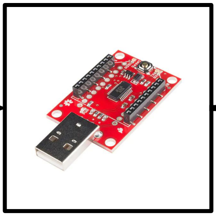


Image credit: digikey.com

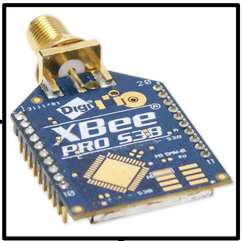


Image credit: digikey.com

Image credit: pasternack.com

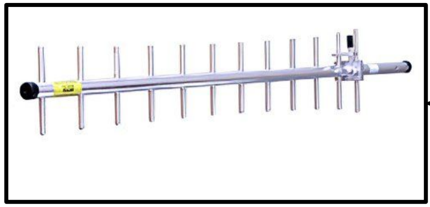


Image credit: pasternack

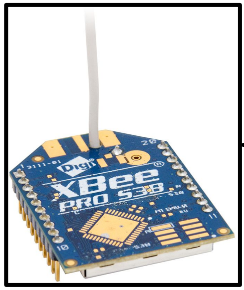


Image credit: digi.com

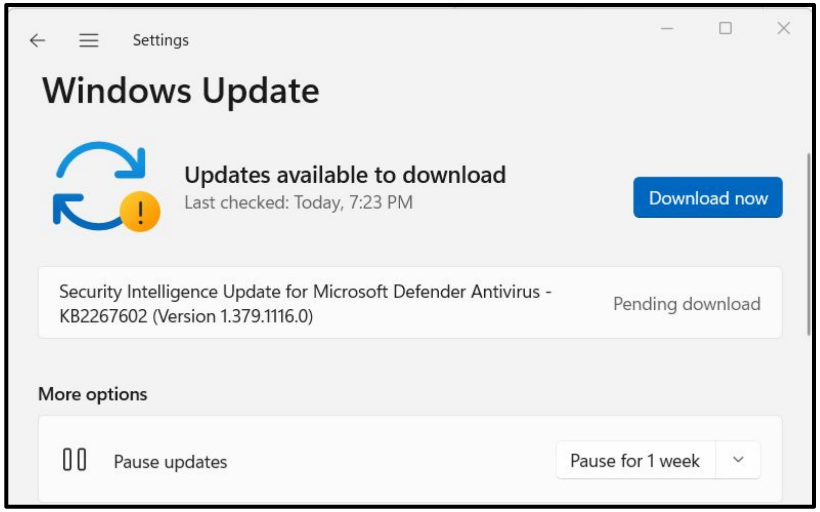
GCS Design (2 of 2)

GCS Specifications
• The GS Computer will be set to pause updates for one month surrounding Flight Day, and the Windows update device will be stopped for the same period. • As seen in the technical diagram, a laptop sunshade will be used to shield the GS computer from the sun. • GS computer has a run time of 3 hours. • A backup mobile power source will be available to extend run time

Image credit: dell

Image credit: amazon.com

Image credit: microsoft.com



Model	Mount	Cable Loss (dBm)	Gain (dBi)	VSWR	Cost ($)
Laird PC906N Yagi	Handheld	0.39	8.5	1.5:1	65.68

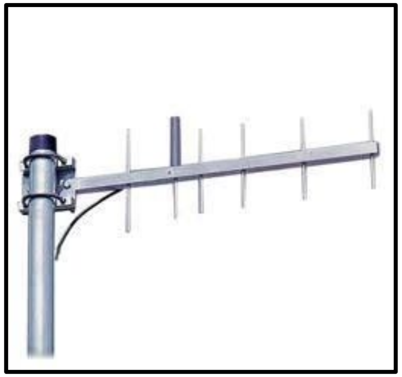


Image credit: arcantenna.com

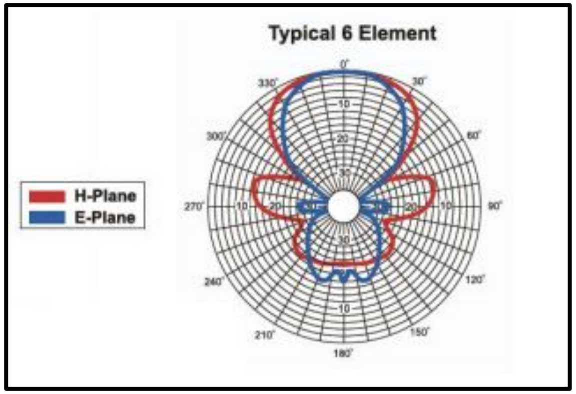


Image credit: laird connectivity

Laird PC906N Yagi

- Available without purchase
- Sufficient gain and VSWR
- Preassembled
- Portable and ready for handheld use

GCS Antenna (2 of 2)

Variables

P_{tx} - Power Transmitted
G_{tx} - Transmitter Gain
L_{tx} - Transmitter Loss
L_{fsp} - Free Space Loss
G_{rx} - Receiver Gain
L_{rx} - Receiver Loss
R_s - Receiver Sensitivity
c - Speed of light
f - Operating frequency
d - max expected distance

Values

P_{tx} = 24 dBm
G_{tx} = 10.65 dBm
L_{tx} = 0.39 dBm
L_{fsp} = 74.89 dBm
G_{rx} = 4.05 dBm
L_{rx} = 0 dBm
R_s = -101 dBm
c = 3 x 10^8 m/s
f = 900 mhz
d = 800 m

Free Space Loss Calculations

$L_{fsp} = 20\log_{10}(d) + 20\log_{10}(f) + 20\log_{10}(4\pi/c) - G_{tx} - G_{rx}$
$L_{fsp} = 20\log_{10}(800) + 20\log_{10}(900) + 20\log_{10}(4\pi/(3\text{x}10\text{^}8))$
$- (10.65) - (4.05)$
L_{fsp} = **74.89 dBm**

Receiver Power Calculations

$P_{rx} = P_{tx} + G_{tx} + G_{rx} - L_{tx} - L_{rx} - L_{fsp}$
$P_{rx} = 24 + 10.65 + 4.05 - 0.39 - 74.89$
P_{rx} = **-36.58 dBm**

Link Budget Calculations

$P_{rx} = P_{Margin} - R_s$
$P_{Margin} = P_{rx} + R_s$
P_{Margin} = 22.163 dBm

With a margin of **22 dBm**, our antenna is suitable for all flight operations.

Link Range Calculations

$$P_{rx} = \frac{P_{tx}G_{tx}G_{rx}(\frac{c}{f})^2}{P_{rx}}$$

$$R = \frac{1}{4\pi}\sqrt{\frac{P_{tx}G_{rx}G_{tx}(\frac{c}{f})^2}{P_{rx}}}$$

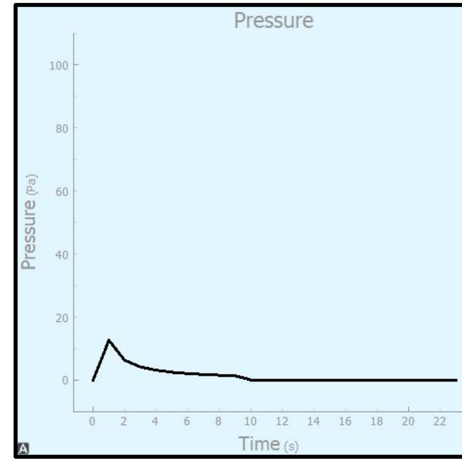
Using an adapted version of the Friis equation, we reached a maximum range of **14.12 kilometers.**

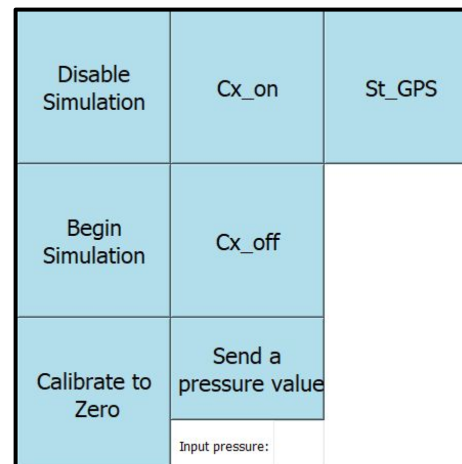
Antenna Calculations

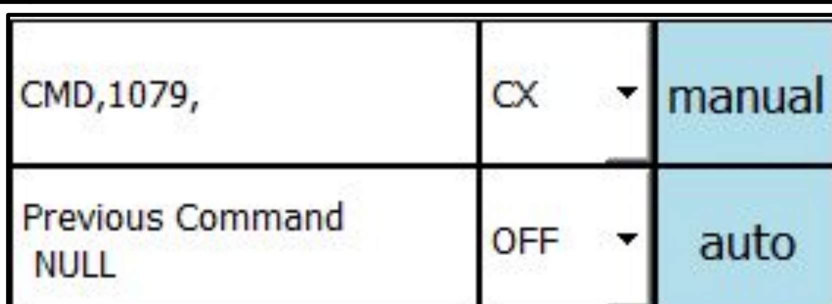
Free Space Loss = 75 dBm
Receiver Power = -37 dBm
Link Budget = 22 dBm
Range: 14 km

Ground Station made in Python 3 with PyQt5, CSV, Folium, and Digi-XBee packages

Command Software and Interface	• All mission requirement commands can be selected through two dropdowns with their names and acceptable options • For quick access, important commands can be sent through a series of buttons • Commands are sent to the serial port, transmitting via UART from ground XBee to CanSat XBee. • Sensors will be calibrated prior to displaying telemetry. Sensors are considered calibrated when data shifts are less than 5%
Real-Time Plotting	• Using the PyQtGraph module of PyQt5, graph items will be updated as information is read from the CanSat XBee.
Simulation Mode	• When the SIM_ENABLE and SIM_ACTIVATE commands are sent, information read from CSV file is sent to CanSat • CanSat uses given information to run through flight protocol, returning sensor values

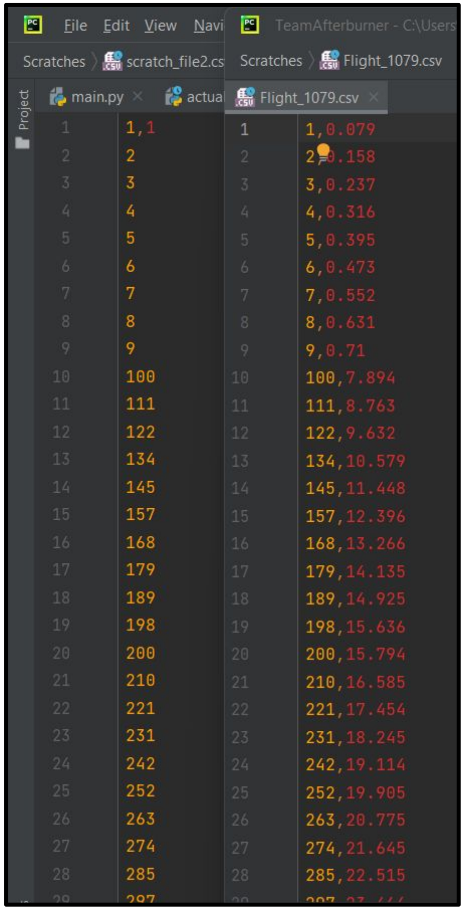




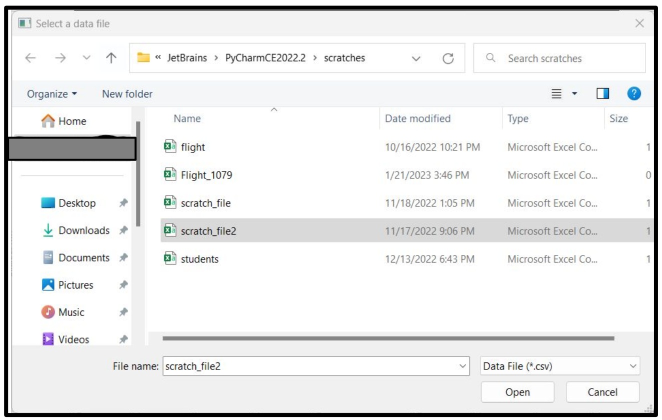


CSV File Creation

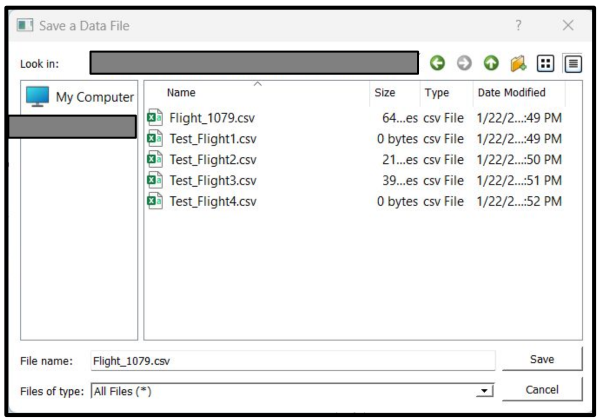
- After deciding to enter Simulation Mode a file dialog box will open, allowing selection of read-only CSV file.
- Information in this file is read to the Probe once per second, and return telemetry is saved to a Flight_1079.csv file.
- On GS termination another file dialog will open, copying above file to a new location as input.
- In Flight Mode, flight telemetry will be saved to our CSV file and GS termination behavior will occur as input.



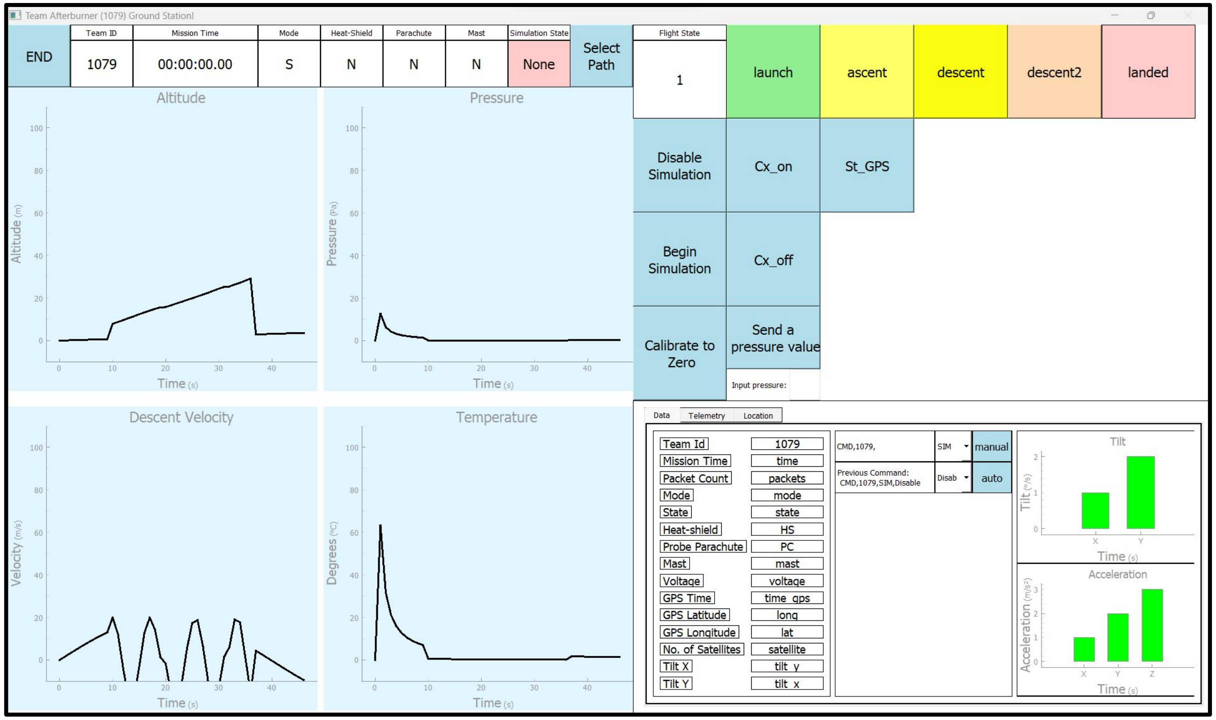
Data Selection



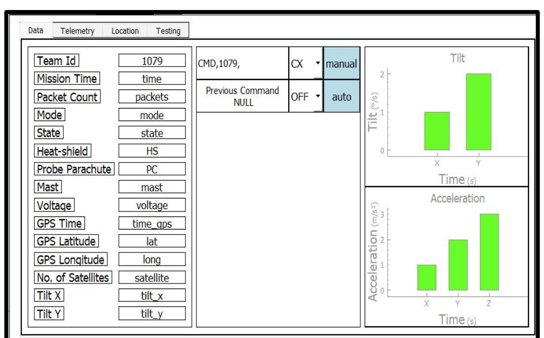
Data Saving

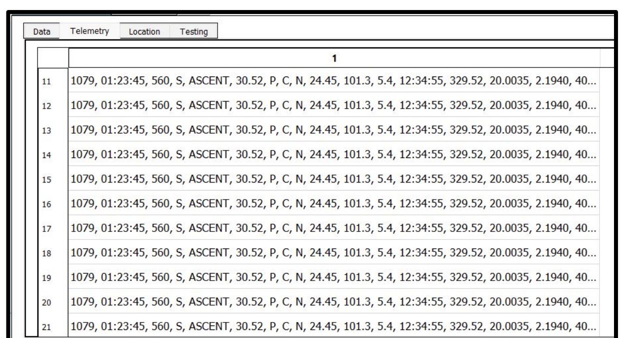


GCS Software (3 of 3)



Changes Since PDR
PDR
Different data fields displayed in sections of tab display
CDR
Graphical displays of data split into tabs of tab display





CanSat Integration and Test

Cole Lenhart

CanSat Integration and Test Overview

Test	Testing plan
Subsystem Testing	Test each individual subsystem such as the Sensors, CDH, EPS, GCS, FSW, and mechanisms to identify and troubleshoot problems before integration
Integration Testing	Integrate systems, electro-mechanical and electro-software, test the fit and function of each, identify any issues and take necessary steps to resolve them
Environmental Testing	With a fully integrated CanSat, test the entire assembly according to the environmental testing standards defined by the mission guide
Simulation Testing	The CanSat is commanded to enter simulation mode, then sent simulated launch data from the ground station to demonstrate FSW, CDH, and mechanical capabilities
Test Launch	Demonstrate CanSat functionality through a mock flight day by conducting flight day activities including pre-flight preparations, flight, post flight recovery and data analysis/ submission. An L1 rocket compliant with the competition requirements will be built and utilized to verify the CanSat's compliance with the mission guide

Subsystem Level Testing Plan (1 of 2)

Subsystem	Components	Testing plan	Pass Requirement
Sensors	BMP388 BNO055 SAM-M8Q VDC Camera	• Test sensors individually • Calibrate sensors • Test sensor accuracy	• Sensors calibrate correctly • Accurate readings compared to data sheet
CDH	BNO055 BMP388 SAM-M8Q VDC Teensy 4.1	• Verify communication between sensors and microcontroller • Verify data logging and mid-flight recovery	• Communication between MCU and sensor suite • MCU internally logs data
EPS	PCB Sensors MCU	• 2 hour battery endurance test • Test voltages for all sensors • Test reverse polarity protection	• System remains powered on after 2 hours • Reverse voltage is significantly below operation voltage
Radio Comms.	MCU XBees Ground Station	• Verify long distance radio communication between XBees • Test two-way communication	• Packets sent between probe and ground station • Probe receives commands from ground station

Subsystem Level Testing Plan (2 of 2)

Subsystem	Testing plan	Pass Requirement(s)
FSW	• Test transitions between simulation and flight states in code • Test flight protocol for start-up and reset • Test calibration with each sensor with commands • Test time set code with GPS sensor	• Flight states switch on time • Sensors show calibrated values • Probe RTC is set by GPS time in UTC • The probe can restore its previous state after processor reset
Mechanical / Descent Control	• Verify parachute and heat shield mechanisms' functionality and reliability through drop tests • Test probe release mechanism strength and reliability • Test flag release mechanism functionality and reliability • Verify CanSat structural integrity via environmental testing	• Probe deploys while on battery power • Parachute deploys when commanded by MCU • Heat shield deploys when commanded by MCU • Flag raised to 500mm after commanded by MCU • The structure passes all environmental testing • Descent rates meet mission requirements

Integrated Level Functional Test Plan (1 of 3)

Subsystem	Testing plan	Pass Requirement(s)
Descent	• Descent tests ensure parachute descent speeds are accurate to 1 m/s of desired speeds (weight will be added to simulate the mass of the electronics) • Descent test to ensure heat shield falls at a speed of <20 m/s (weight will be added to simulate the mass of the electronics) • Heat shield passive stabilization and CanSat center of mass tests • CanSat descent will be tested before competition via test launch	• Container releases probe at 500 m • The descent speed of the probe is 5m/s ± 1 m/s with the parachute deployed • The descent speed of the container and probe is 15m/s ± 5 m/s with the parachute deployed • The descent speed of the probe is 20m/s ± 5 m/s with heat shield deployed • The probe is aerodynamically stable with heat shield deployed • Descent mechanisms including parachute function correctly and survive forces during test launch
Communication	• Test long distance radio communication between XBees • Test communication under probe battery power • Test two-way communication • Test for optimal antenna position • Test ground station GUI display • CanSat communications will be tested before competition via test launch	• Communication is stable at a range of 1000 meters • The probe receives commands and sends packets • Probe sends packets for a minimum of 2 hours under battery power • Communications remain stable during test launch • GUI displays received data correctly

Integrated Level Functional Test Plan (2 of 3)

Subsystem	Testing plan	Pass Requirement(s)
Mechanisms	• Test heat shield deployment mechanism • Test self righting system • Test flag deployment spring and servo • Test servo and pin for probe release mechanism • Test structural integrity of entire structure via environmental tests • CanSat mechanisms will be tested before competition via test launch	• Heat shield deploys to set positions and can maintain its aerobraking shape against wind • Probe is able to upright itself • The probe can successfully release from the container • The CanSat withstands all forces applied to it during environmental tests • Mechanisms survive the forces applied to them during the test launch
Deployment	• Test the parachutes to assure they won't become tangled on release • Test tolerances between parachutes, container/probe, and rocket • Test the tensile strength of parachute chords via environmental drop tests • CanSat deployment at 500m will be tested before competition via test launch	• The parachute deploys when the release servo is actuated • The parachute cords and mounts are able to withstand the shock forces that they are exposed to during drop test and test launch

Integrated Level Functional Test Plan (3 of 3)

Subsystem	Testing plan	Pass Requirement(s)
Simulation	• Test simulation mode software with given competition datasets • Ensure simulation mode commands are transmitted through two way communication • Ensure simulation mode data is received by the ground station	• Simulation test software communicates with ground station and initiates when commanded • Simulation test software triggers flight states at accurate altitude readings

Environmental Test Plan (1 of 3)

Test	Testing plan	Pass Requirement(s)
Drop test	• The goal of this test is to ensure that the CanSat can survive 30Gs of shock • We will attach a 81 cm line to the parachute, and drop it to simulate the shock of the CanSat leaving the rocket body	• The parachute cords and mounts are able to withstand the 30Gs of shock forces without breaking • Batteries and electronics remain firmly attached to the CanSat body • Good communication with the CanSat after the drop
Thermal test	• The goal the thermal test is to ensure that the entire CanSat can operate successfully in a 60 ℃ environment • We will build a thermal chamber to contain the CanSat and place the functioning CanSat into the 60 ℃ chamber for a duration of two hours	• No damage is observed • CanSat remains powered • Good communication with the Cansat

Environmental Test Plan (2 of 3)

Test	Testing plan	Pass Requirement(s)
Vibration test	• The vibration test is to ensure that the structure and internals of the CanSat will survive the rattling of the rocket as it rises • The CanSat will be attached to an orbital sander which will be cycled for five intervals of five seconds	• CanSat remains structurally intact after being placed in the orbital sander • Electrical components and batteries remain attached to the CanSat after being placed in the orbital sander
Fit Check	• The fit check is to ensure that the CanSat will fit in the rocket on flight day and deploy without issues • Construct a rocket payload section and test tolerances between the payload wall and CanSat	• CanSat fits comfortably in the rocket payload section • CanSat deploys from the rocket payload section

Environmental Test Plan (3 of 3)

Test	Testing plan	Pass Requirement(s)
Vacuum Test	• Test the flight software and the integrated CanSat while simulating the ascent and descent of the probe • We will construct a vacuum chamber and then simulate the air pressure changing to ensure that all systems and flight software is working	• The CanSat changes flight states as the pressure simulates different altitudes • The cameras record the deployment and raising of the flag

Test Procedures Descriptions (1 of 10)

Subsystem Level Testing					
Subsystem	**Test Proc**	**Test Description**	**Rqmts**	**Pass Fail Criteria**	**Status**
Sensors / CDH	1	Create a temporary circuit using a breadboard, power supply, and Teensy 4.1. Connect the BMP388 to the I2C communication line of the Teensy 4.1, and push example code with Arduino from the BMP3XX library to the Teensy 4.1. Confirm that the BMP388 has good communication with the Teensy and read the output data.	51, 56	Measures ambient temperature with resolution of 0.1 ℃, pressure with a resolution of 0.1 kPa, and altitude with a resolution of 0.1 m	Pass
	2	Create a temporary circuit using a breadboard, power supply, and Teensy 4.1. Connect the SAM-M8Q to the UART communication line of the Teensy 4.1, and push example code using the Sparkfun U-Block library. Confirm that the SAM-M8Q has good communication with the Teensy 4.1 and read the output data.	46, 51, 56	Measures time within 1 second of UTC, altitude to a resolution to 0.1 m, latitude and longitude with a resolution of 0.0001°, and reports the number of acquired satellites	Pass
	3	Create a temporary circuit using a breadboard, power supply, and Teensy 4.1. Connect the VDC to the ADC pin of the Teensy 4.1, and push example code. Confirm that the VDC has good communication with the Teensy 4.1 and read the output data.	51, 56	Measures voltage accurately to a resolution of 0.1 volt	Pass

Test Procedures Descriptions (2 of 10)

Subsystem Level Testing					
Subsystem	**Test Proc**	**Test Description**	**Rqmts**	**Pass Fail Criteria**	**Status**
Sensors / CDH	4	Create a temporary circuit using a breadboard, power supply, and Teensy 4.1. Connect the BNO055 to the I2C communication line of the Teensy 4.1, and push example code using the Adafruit BNO055 library. Confirm that the BNO055 has good communication with the Teensy 4.1 and read the output data.	51, 56	Measures tilt in the X and Y axis accurately to a resolution of 0.1°	Pass
	5	Create a temporary circuit using a breadboard, power supply, and Teensy 4.1. Connect the external coin cell battery to the RTC of the Teensy 4.1 and push code to set time. Disconnect power from the teensy for 30 minutes. Reconnect power and verify that correct time is kept.	45, 46	Time is maintained for 30 minutes after disconnecting main power with a time drift of < 1s	Ongoing
	6	Create a temporary circuit using a breadboard, power supply, and Teensy 4.1. Connect all flight sensors to the the Teensy 4.1, and push FSW logging code. Confirm that all sensors have good communication with the Teensy 4.1 and read the .csv file that is logged.	56	FSW must write a CSV file with accurate data in the format required by the mission guide	Ongoing
	7	Create a temporary circuit using a breadboard, power supply, and Teensy 4.1. Connect camera to the the Teensy 4.1, and trigger video recording. Wait 20 minutes, trigger camera to stop recording and collect SD card.	40,41,42	Records uncorrupted color video that is 680x480 resolution at 30 frames per second	Pass

Test Procedures Descriptions (3 of 10)

Subsystem Level Testing					
Subsystem	**Test Proc**	**Test Description**	**Rqmts**	**Pass Fail Criteria**	**Status**
EPS	8	Solder diode and battery holders to PCB, install CR123A batteries backwards. Measure the positive terminal of the battery to ground and read voltage.	-	The voltage is less than 0.1 V	Pass
	9	Solder 5 volt linear regulator, and supporting capacitors to PCB and simulate battery voltage with a power supply. Apply simulated load to the 5V rail. Measure all 5V power outputs to ground and read voltage.	-	Power regulation circuit runs at 5 ± 0.1 V	Pass
	10	Connect LED and Buzzer to the PCB and push blink code to the Teensy. Observe luminescence of LED and measure dB of Buzzer.	24, 25, 26	LED is viewable from outside of container and buzzer outputs a volume > 92 dB	Pass
	11	Connect all electrical components and boot Teensy 4.1 with updated FSW. Install two fully charged CR123A batteries into the system. Turn on payload and establish connection with ground station. Monitor voltage level for two hours.	31	Entire electrical system functions with no power outages	Pass
	12	Inspect electrical connections for structural rigidity by tugging connection cables with sufficient force. Inspect electronics used against mission guide requirements.	14, 16, 17, 27, 29	No banned materials used and electrical connectors are secure	Pass

Test Procedures Descriptions (4 of 10)

Subsystem Level Testing					
Subsystem	**Test Proc**	**Test Description**	**Rqmts**	**Pass Fail Criteria**	**Status**
Radio	13	Power on GS computer. Open XCTU application. Connect both XBees to computer. Inspect XBee radios for operating frequency, PANID, and transmission protocol through XCTU.	20, 21, 22	XBees are setup according to mission guide requirements	Pass
	14	Power on payload, power on GS, send CX,ON command (XBee transmission begin). Walk 1 km away from the GS. While in line of sight, transmit telemetry at 1 Hz. Monitor incoming telemetry and flight state on GS. Use GS to send commands to payload and observe changes.	38, 39	The XBees remain connected with no packet loss. XBee on probe receives all sent commands	Ongoing
FSW	15	Put the payload into Flight Mode for a period of two minutes, after which, turn the probe off and on again. Confirm that the FSW has returned to the correct packet count, flight state, mission time, and zero calibration value.	44, 45, 46, 53	Maintains packet count, flight state, mission time, and zero calibration post processor reset.	Ongoing
	16	Power on the payload, and turn on the GS Computer. Use the computer to enter Flight Mode, and send a CX,ON command to the payload to begin telemetry. Confirm that telemetry is sent to the computer with specifications as directed in the Mission Guide.	38, 39, 46, 50, 52,	Calibrates telemetry to zero post CX,ON. Delivers packets with all telemetry fields as specified by the mission guide	Ongoing

Test Procedures Descriptions (5 of 10)

Subsystem Level Testing					
Subsystem	**Test Proc**	**Test Description**	**Rqmts**	**Pass Fail Criteria**	**Status**
FSW	17	Power on the payload and GS computer. Enter Simulation Mode using Simulation Enable and Activate commands, and begin sending simulation pressure commands as directed by provided simulation profile. Confirm that payload reads and acts according to given pressure values.	47, 48, 49	Payload reads simulation commands and enters Simulation Mode. Payload returns telemetry based off input pressure values.	Pass
Mechanical	18	Assemble heat shield sub system on probe. Push and activate the simulation mode software. Once the simulation code reports an altitude of 500 m, verify the probe separates from the container and the aerobrake system begins actuation, then time how long it takes to reach the deployed configuration.	33	Aerobraking Heat shield opens within 10 seconds of container separation	Ongoing
	19	Assemble heat shield sub system on probe. Integrate altimeter package into probe to measure descent rate and add counterweight to achieve fully integrated probe mass. Conduct a drop test with fully deployed heat shield. Verify heat shield descent is less than 20 m/s rate using altitude data from altimeter.	34	Probe heat shield slows probe descent rate to less than 20 m/s.	Ongoing

Test Procedures Descriptions (6 of 10)

Subsystem Level Testing					
Subsystem	**Test Proc**	**Test Description**	**Rqmts**	**Pass Fail Criteria**	**Status**
Mechanical	20	Use simulation mode to test the release mechanism when the CanSat reached 500 m.	35	The probe parachute reliably deploys once the simulation code displays 200 m and the servo rotates	Ongoing
	21	Perform a drop test for probe parachute deployment and descent rate.	35	The parachute slows the probe descent to 5 m/s within the +/- 1 m/s margin	Ongoing
	22	Once the simulation software detects the probe has landed, the self righting mechanism actuates to rotate the probe to the nadir direction relative to the ground within a 15° tolerance. This test will be performed on a variety of different surfaces from different landing orientations.	36	The probe faces the nadir direction relative the the ground within a 15°	Ongoing
	23	Once the simulation software detects probe is upright, the flag will raise to a height of 500 mm from the base of the probe.	37	The flag reliability deploys to 500 mm measured from the base of the probe	Pass

Subsystem Level Testing					
Subsystem	**Test Proc**	**Test Description**	**Rqmts**	**Pass Fail Criteria**	**Status**
Mechanical	24	The entirety of the probe is inspected to ensure compliance with color, banned mechanisms, and material requirements as specified in the mission guide.	9, 16, 17, 18, 23, 40	The external surface of the probe and parachute are fluorescent orange; mechanisms do not use pyrotechnics or chemicals; no heat mechanisms are used nor exposed; probe is labeled with team information; switch is accessible; camera on the probe is pointed down towards the ground	Pass
	25	Electronic and mechanical component connections are inspected for the use of proper standoffs, screws, or high performance adhesives. Battery placement is inspected to ensure that battery installment takes less than one minute	14, 28	Mounts are fastened to their most secure and stable state; batteries can be installed in less than one minute	Pass

Test Procedures Descriptions (8 of 10)

Integration Level Testing					
System	**Test Proc**	**Test Description**	**Rqmts**	**Pass Fail Criteria**	**Status**
CanSat and Launch Vehicle Integration	26	Use simulation mode to perform flight objectives including heatshield deployment, parachute deployment, uprighting, and flag raising without rocket components in use.	6, 7	Cansat does not use any rocket components as a part of CanSat operations or restrain deployable components	Pass
	27	Inspect external surface of the container and verify that there are no sharp edges or protrusions. Container and parachute color is fluorescent orange. Inspect for holes within the container besides small holes for switches and fully encloses probe.	3, 4, 5, 9	Container has no sharp edges or protrusions on its surface that can snag on rocket body. Container and parachute are fluorescent orange. Container is solid and fully encloses probe	Pass
GCS	28	Power on the payload, and turn on the GS computer. Begin sending telemetry to the payload at 1 Hz through the CX,ON command. Calibrate the payload to zero upon placing it on a launch pad.	11, 50	Returned payload values at zero while the payload is on the launch pad, as directed by the GS.	Pass
	29	Inspect GS for mission guide elements including laptop, XBee radio, and hand-held antenna. Power on laptop, and walk 50m while holding laptop.	58, 59	All mission guide elements are present and laptop continues operation despite movement.	Pass

Test Procedures Descriptions (9 of 10)

Environmental Testing					
Test	**Test Proc**	**Test Description**	**Rqmts**	**Pass Fail Criteria**	**Status**
Drop	30	Power the CanSat and GS on. Verify good telemetry between the CanSat and the GS. Hook the top of of the CanSat to a fixed point 1 meter above the ground with 1/8" kevlar cord. Raise the CanSat such that the connection point to the CanSat and the fixed point are at the same height, and drop the CanSat. Verify any changes to the state of the CanSat.	12, 13, 15, 30	Verify no power loss or damaged parts and telemetry packets are still being received	Ongoing
Thermal	31	Place the CanSat, a hair dryer, and a thermometer in an insulated cooler. Power on the CanSat and seal the chamber. Power the heat source, pointing it away from the CanSat. Manage temperature by powering off the heat source when the thermometer reads 60°C and powering it on when the temperature subceeds 55°C. Continue this process for two hours then verify functionality and integrity of all subsystems while hot.	15, 30	Structural, mechanical, and electrical components function and have no visible deformation from thermal warping. All subsystems are able to perform their respective tasks while the CanSat is still hot.	Ongoing
Vibration	32	Securely attach fully assembled Cansat to orbital sander. Power on CanSat and start collecting accelerometer data. Turn on orbital sander for five seconds and then turn if off and wait for it to stop. Repeat four more times. Inspect CanSat and verify accelerometer is still collecting data.	15, 30	Verify no power loss or damaged parts and that accelerometer telemetry was interrupted	Ongoing

Test Procedures Descriptions (10 of 10)

Environmental Testing					
Test	**Test Proc**	**Test Description**	**Rqmts**	**Pass Fail Criteria**	**Status**
Vacuum test	33	Suspend the CanSat in the vacuum chamber and turn CanSat on. Turn on the vacuum pump and then turn it off as peak altitude is reached. Monitor telemetry as the pressure slowly returns. Collect and save the telemetry for review.	15, 30	Telemetry and flight states reflect the simulated altitude and pressure changes	Ongoing
Fit check	34	Measure fully assembled container dimensions including radius and height. Container height will be no greater than 390mm and container diameter will be no greater than 124mm. Integrate the probe and container. Weigh the full assembly using a scale. Verify the full list of components used and tabulate cost.	1, 2, 19	Cansat maximum dimensions will be no greater than 390 mm in height and 124 mm in diameter. The mass of the CanSat must be within 700 ± 10 g. The CanSat is under $1000	Pass
Simulation Test	35	Power on the payload, and turn on the GS computer. Attempt sending Simulation Activate without a prior Enable. Afterwards, enter Simulation Mode through both Simulation Enable and Activate, then begin sending simulation profile commands to the probe at 1 Hz. Confirm received packets contain mission guide telemetry fields with resolution as specified by mission guide. Inspect GS for plots of telemetry and generated CSV files.	38, 39, 46, 54, 55, 57, 60, 61	Payload returns an error upon invalid entrance of Simulation Mode. In Simulation Mode, GCS sends and receives telemetry at 1 Hz with graphics and csv files.	Ongoing

Simulation Test Plan

Test	Testing plan	Pass Requirement(s)
Simulation Test	• Test the function of the fully integrated probe under commands given by the competition command profile. • We will integrate probe components and transmit profile commands at a rate of 1Hz to the probe to clarify that the probe acts identically under profile and real conditions.	• The CanSat functions as if it received real pressure values, passing all flight states and implementing all mechanical actions as necessary. • Onboard components of the probe act according to flight states, such as camera activation.

Mission Operations & Analysis

Brennan Begley

Overview of Mission Sequence of Events (1 of 3)

Team Roles and Responsibilities:
- Everyone on the team will be contributing to the events of launch day
- The Mission Operation Manual lays out the events that the team will follow

Team	Description	Personnel
Mission Control Officer	Responsible for informing flight coordinator when their team and CanSat is ready to be launched.	Louis McEvoy
Ground Station Team	Responsible for monitoring the ground station for telemetry reception and issuing commands to the CanSat.	Enrico Addy, Emann Rivero
Recovery Team	Responsible for tracking the CanSat and going out into the field for recovery and interacting with the field judges. This team is responsible for making sure all field scores are filled in.	Brennan Begley, Mason Mills
CanSat Team	Responsible for preparing the CanSat, integrating it into the rocket, and verifying its status.	Gabriel Campos, Quinn Casper, Elena Dishman, Kyle Hughes, Cole Lenhart

Overview of Mission Sequence of Events (2 of 3)

Event	Description and Objectives	Team
Arrival	Arrive at Launch Location with CanSat and Ground Station Hardware	All
Pre-launch	Assemble CanSat and Test Integrity of Mechanical Systems	CanSat
	Assemble Antenna and Ground Station	Ground Station
	Power CanSat On	CanSat
	Validate Signal Acquisition and Calibrate/Test Electrical Systems	Ground Station
	CanSat Integration into Rocket	CanSat
Launch	Initiate CanSat Launch	Mission Control Officer
	Validate Flight State Changes	Ground Station
	Monitor Data Reception and Integrity	Ground Station
	Prepare Recovery Operations	Recovery

Overview of Mission Sequence of Events (3 of 3)

Event	Description and Objectives	Team
Recovery	Track CanSat Using GPS and Audio-Visual Indicators	Recovery
	Recover Probe and Container	Recovery
	Return CanSat to the Launch Site	Recovery
	Recover SD Cards.	Recovery
Data Analysis	Submit Transmitted Data and SD Cards to Judges for Scoring	Ground Station Recovery

Field Safety Rules Compliance

The Mission Operations Manual (MOM) will contain the following sections:

Section Name	Description
Ground Station Configuration	Process for setting up the ground station as well as initializing communication between the CanSat and the ground station.
CanSat Preparation	Instructions for assembly and pre-flight operation of the CanSat.
CanSat Integration	Instructions for Rocket-CanSat integration and verification of CanSat functionality.
Launch Preparation	Instructions for delivery and installation of rocket on launch pad.
Launch Procedure	Step by step guide for Mission Control Officer and standard operating procedures pertaining to rocket arming and launch.

Development Status

1. MOM template has been downloaded from the CanSat website and development has begun. Will be filled in further as changes are encountered leading up to launch day.
2. Each team member will familiarize themselves with the MOM and appendix A of the mission guide for their and everyone else’s safety at the launch site.
3. Each member of the team will receive a copy of the MOM with the field safety rules on launch day for reference.

CanSat Location and Recovery

Recovery Strategy	Container	Probe
Brightly Colored	• Spray painted neon pink • Parachute will be sown with neon pink fabric	• Final parts will be printed in orange filament • Parachute will be sown with neon pink fabric
Visible Beacon	N/A	Bright flashing LED
Audio Beacon	N/A	100dB beeping buzzer
GPS Position	N/A	Real Time Position within 2.5m
Team Contact	Phone number of team lead, phone number of recovery lead, email address of team lead, and the return address labeled on the container	Phone number of team lead, phone number of recovery lead, email address of team lead, and the return address labeled on the probe in two locations

Team Contact Info:
Louis McEvoy (951-395-4732); Mason Mills (205-520-6471); wlm0013@uah.edu;
901 John Wright Dr NW, Huntsville, AL 35805

Mission Rehearsal Activities (1 of 3)

Activity	Rehearsal Plan	Date Rehearsed
Powering On/Off the Cansat	1. Insert batteries into the electronics package of the CanSat and secure them with zip-ties 2. Power on the CanSat 3. Verify power indicators are activated 4. Power off the CanSat 5. Verify the power indicators are no longer activated.	March 21, 2023
Radio Link Check	1. Attach Yagi antenna to ground station 2. Power on the CanSat 3. Point Yagi antenna towards CanSat 4. Monitor ground station for good probe connection 5. If connection is established, send CX,ON command 6. Monitor GCS for sent telemetry 7. If GCS receives telemetry, radio link is established	March 21, 2023
Launch Configuration Preparations	1. Assemble probe and container and ensure all connection points and linkages are strong 2. Pack probe parachute, spool flag raising mechanism and ensure servos are in their starting positions 3. Integrate probe and container. Ensure the deployment system is zeroed and secure 4. Pack container parachute and temporarily secure.	May 6, 2023

Mission Rehearsal Activities (2 of 3)

Activity	Rehearsal Plan	Date Rehearsed
Loading CanSat into launch vehicle	1. Power on probe and container 2. Verify launch configuration of all subsystems 3. Integrate Cansat with parachute on the coupler 4. Spin CanSat around to ensure free movement out of the payload section	May 6, 2023
Telemetry Processing, Archiving, and Analysis	1. Turn on the CanSat and ground station 2. Send the CX,ON command 3. Send Simulation enable command and Activate command 4. Send flight pressure data test packet 5. Check ground station for graphs 6. If graphs present, processing and analysis have occurred 7. When FSW reaches flight state 6, turn off CanSat 8. Remove and check SD card for archived data as CSV files	April 8, 2023
Recovery	1. Visually track CanSat while in flight 2. At probe separation, recovery lead maintain visual with probe and co-lead maintain visual with container 3. Once probe lands, use GPS coordinates, visual and audio indicators to locate landing site 4. Once container lands, travel in heading of last visual to locate landing site	May 6, 2023

Mission Rehearsal Activities (3 of 3)

Drop Test and Test Launch
• We will be conducting an "at altitude" drop test on April 8th, 2023 and a full scale test launch on May 6th, 2023 to validate launch day procedures, familiarize the team with the MOM, and test the entire CanSat assembly • Using what we learn from the drop test and test launch, we will be able to make the necessary adjustments to our CanSat and the team's procedures so that we are as prepared as possible for competition

T-	Test Launch Description
-2:00:00 to -0:45:00	Team arrives to the launch site and prepares the CanSat for rocket integration.
-0:45:00 to -0:15:00	CanSat team powers on the CanSat and integrates the CanSat and rocket.
-0:15:00 to +0:00:00	Communication is validated and MCO makes launch call. CanSat is launched.
+0:00:00 to +1:00:00	Recovery team keep visual on the CanSat, recovers it, and analyzes the data.

Requirements Compliance

Louis McEvoy

Requirements Compliance Overview

We comply with 60 of the 60 requirements listed in the mission guide.

Requirement #43 was omitted because it was skipped in the mission guide.

Mechanical:	Electrical:	Software:
All of our structural components comply with the strength, size, appearance and descent rate requirements.	Our PCB and electronics package collect the required information and send telemetry to the ground station.	Our FSW and GS comply with the formatting and telemetry presentation requirements.

Requirements Compliance (1 of 9)

#	Requirement	Compliance State	Slide Referencing Compliance	Notes	Verification Method			
					A	**I**	**T**	**D**
1	Total mass of the CanSat (science probe and container) shall be 700 grams +/- 10 grams.	Comply	79		X	X		
2	CanSat shall fit in a cylindrical envelope of 125 mm diameter x 400 mm length. Tolerances are to be included to facilitate container deployment from the rocket fairing.	Comply	24		X			X
3	The container shall not have any sharp edges to cause it to get stuck in the rocket payload section which is made of cardboard.	Comply	24		X	X		
4	The container shall be a fluorescent color; pink, red or orange.	Comply	141			X		
5	The container shall be solid and fully enclose the science probes. Small holes to allow access to turn on the science probes are allowed. The end of the container where the probe deploys may be open.	Comply	49			X		X
6	The rocket airframe shall not be used to restrain any deployable parts of the CanSat.	Comply	24			X		
7	The rocket airframe shall not be used as part of the CanSat operations	Comply	24			X		

Requirements Compliance (2 of 9)

#	Requirement	Compliance State	Slide Referencing Compliance	Notes	Verification Method			
					A	I	T	D
8	The container's parachute shall not be enclosed in the container structure. It shall be external and attached to the container so that it opens immediately when deployed from the rocket	Comply	39		X	X		X
9	The Parachute shall be fluorescent Pink or Orange	Comply	39			X		
10	The descent rate of the CanSat (container and science probe) shall be 15 meters/second +/- 5 m/s.	Comply	47		X		X	X
11	0 altitude reference shall be at the launch pad.	Comply	99		X		X	
12	All structures shall be built to survive 15 Gs of launch acceleration.	Comply	71		X			X
13	All structures shall be built to survive 30 Gs of shock.	Comply	71		X			X
14	All electronics and mechanical components shall be hard mounted using proper mounts such as standoffs, screws, or high performance adhesives.	Comply	70		X	X		

Requirements Compliance (3 of 9)

#	Requirement	Compliance State	Slide Referencing Compliance	Notes	Verification Method			
					A	I	T	D
15	All mechanisms shall be capable of maintaining their configuration or states under all forces.	Comply	70-71		X			X
16	Mechanisms shall not use pyrotechnics or chemicals.	Comply	49-71			X		
17	Mechanisms that use heat (e.g., nichrome wire) shall not be exposed to the outside environment to reduce potential risk of setting vegetation on fire.	Comply	49-71			X		
18	Both the container and probe shall be labeled with team contact information including email address.	Comply	141			X		
19	Cost of the CanSat shall be under $1000. Ground support and analysis tools are not included in the cost. Equipment from previous years shall be included in this cost, based on current market value.	Comply	166		X	X		
20	XBee radios shall be used for telemetry. 2.4 GHz Series radios are allowed. 900 MHz XBee radios are also allowed.	Comply	86			X		
21	XBee radios shall have their NETID/PANID set to their team number.	Comply	86			X		

Requirements Compliance (4 of 9)

#	Requirement	Compliance State	Slide Referencing Compliance	Notes	Verification Method			
					A	I	T	D
22	XBee radios shall not use broadcast mode	Comply	86			X		
23	The container and probe shall include an easily accessible power switch that can be accessed without disassembling the CanSat and science probes and in the stowed configuration.	Comply	61,94			X	X	
24	The probe shall include a power indicator such as an LED or sound generating device that can be easily seen or heard without disassembling the CanSat and in the stowed state.	Comply	62			X	X	
25	An audio beacon is required for the probe. It shall be powered after landing.	Comply	62			X	X	X
26	The audio beacon shall have a minimum sound pressure level of 92 dB, unobstructed.	Comply	62				X	
27	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	95			X		

Requirements Compliance (5 of 9)

#	Requirement	Compliance State	Slide Referencing Compliance	Notes	Verification Method			
					A	I	T	D
28	An easily accessible battery compartment shall be included allowing batteries to be installed or removed in less than a minute and not require a total disassembly of the CanSat.	Comply	62,70			X	X	
29	Spring contacts shall not be used for making electrical connections to batteries. Shock forces can cause momentary disconnects.	Comply	70,71,95			X		
30	The CanSat shall operate during the environmental tests laid out in Section 3.5.	Comply	122-124				X	
31	The CanSat shall operate for a minimum of two hours when integrated into the rocket.	Comply	97				X	X
32	The probe shall be released from the container when the CanSat reaches 500 meters.	Comply	101				X	X
33	The probe shall deploy a heat shield after leaving the container.	Comply	64,65				X	X
34	The heat shield shall be used as an aerobrake and limit the descent rate to 20 m/s or less.	Comply	47				X	X

Requirements Compliance (6 of 9)

#	Requirement	Compliance State	Slide Referencing Compliance	Notes	Verification Method			
					A	I	T	D
35	At 200 meters, the probe shall release a parachute to reduce the descent rate to 5 m/s +/- 1 m/sec.	Comply	47, 101				X	X
36	Once landed, the probe shall upright itself.	Comply	67, 101				X	X
37	After uprighting, the probe shall deploy a flag 500 mm above the base of the probe when the probe is in the upright position.	Comply	68,101				X	X
38	The probe shall transmit telemetry once per second.	Comply	87,101		X	X	X	
39	The probe telemetry shall include altitude, air pressure, temperature, battery voltage, probe tilt angles, command echo, and GPS coordinates that include latitude, longitude, altitude and number of satellites tracked.	Comply	87		X		X	
40	The probe shall include a video camera pointing down to the ground.	Comply	61			X		
41	The video camera shall record the flight of the probe from release to landing.	Comply	20,96,99			X	X	X
42	The video camera shall record video in color and with a minimum resolution of 640x480.	Comply	33,34			X	X	

Requirements Compliance (7 of 9)

#	Requirement	Compliance State	Slide Referencing Compliance	Notes	Verification Method			
					A	I	T	D
44	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	99-103			X	X	
45	The probe shall maintain mission time throughout the whole mission even with processor resets or momentary power loss.	Comply	99-103			X	X	
46	The probe shall have its time set to within one second UTC time prior to launch.	Partial	99-103			X	X	
47	The probe 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	103			X	X	X
48	In simulation mode, the flight software shall use the radio uplink pressure values in place of the pressure sensor for determining the container altitude.	Comply	103		X		X	
49	The container flight software shall only enter simulation mode after it receives the SIMULATION ENABLE and SIMULATION ACTIVATE commands.	Comply	103				X	X

Requirements Compliance (8 of 9)

#	Requirement	Compliance State	Slide Referencing Compliance	Notes	Verification Method			
					A	I	T	D
50	The ground station shall command the CanSat to start calibrating the altitude to zero when the CanSat is on the launch pad prior to launch.	Comply	99-101				X	
51	The ground station shall generate csv files of all sensor data as specified in the Telemetry Requirements section.	Comply	113				X	X
52	Telemetry shall include mission time with 1 second or better resolution.	Comply	30,89		X			X
53	Configuration states such as zero altitude calibration shall be maintained in the event of a processor reset during launch and mission.	Comply	103		X		X	X
54	Each team shall develop their own ground station.	Comply	112-114			X		X
55	All telemetry shall be displayed in real time during descent on the ground station.	Comply	114			X		X
56	All telemetry shall be displayed in engineering units (meters, meters/sec, Celsius, etc.)	Comply	88,89			X		X

Requirements Compliance (9 of 9)

#	Requirement	Compliance State	Slide Referencing Compliance	Notes	Verification Method			
					A	I	T	D
57	Teams shall plot each telemetry data field in real time during flight.	Comply	114			X		X
58	The ground station shall include one laptop computer with a minimum of two hours of battery operation, XBee radio, and a hand-held antenna.	Comply	106-110			X		X
59	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	106-110			X		X
60	The ground station software shall be able to command the container to operate in simulation mode by sending two commands, SIMULATION ENABLE and SIMULATION ACTIVATE.	Comply	103			X		X
61	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	103			X		X

Management

Louis McEvoy

Status of Procurements (1 of 4)

Electrical Components				
Components	**Quantity**	**Status**	**Date Ordered**	**Date Received**
BNO055	1	Received	February 6, 2023	March 10, 2023
BMP388	2	Received	February 6, 2023	March 10, 2023
SAM-M8Q Breakout	1	Received	February 6, 2023	March 10, 2023
Teensy 4.1	1	Received	February 6, 2023	March 10, 2023
XBee Pro 900HP	1	Received	N/A	N/A
XBee Explorer Board	1	Received	February 6, 2023	March 10, 2023
Adafruit Spycamera	2	Received	N/A	N/A
XIAO SEEED	1	Received	February 6, 2023	March 10, 2023
Metal Gear Servo	5	Received	February 6, 2023	March 10, 2023
Custom PCB (V4)	2	Received	March 15, 2023	March 21, 2023
CR123A Surefire	2	Received	February 6, 2023	March 10, 2023
CR2450 Coin Cell	2	Received	February 6, 2023	March 10, 2023
CR2032 Coin Cell	1	Received	February 6, 2023	March 10, 2023

Status of Procurements (2 of 4)

Electrical Components				
Components	**Quantity**	**Status**	**Date Ordered**	**Date Received**
Battery Holders (Surefires and Coin Cells)	5	Received	February 6, 2023	March 10, 2023
Starboard LED	1	Received	February 6, 2023	March 10, 2023
Buzzer	1	Received	February 6, 2023	March 10, 2023
Power Switch	2	Received	February 6, 2023	March 10, 2023
SD Cards	3	Received	February 6, 2023	March 10, 2023
SMD Power Management (Capacitors,Resistors, MOSFETS, Regulators, etc.)	-	Received	February 6, 2023	March 10, 2023

Mechanical Components				
Components	**Quantity**	**Status**	**Date Ordered**	**Date Received**
Fiberglass Shell	1	Received	N/A	N/A
Ripstop Nylon	1	Received	February 6, 2023	March 10, 2023
Zip Ties	6	Received	February 6, 2023	March 10, 2023

Status of Procurements (3 of 4)

Mechanical Components				
Components	**Quantity**	**Status**	**Date Ordered**	**Date Received**
M5 Eye Nut	3	Received	N/A	N/A
M5 40mm Threaded Rod	1	Received	February 6, 2023	March 10, 2023
Carbon Fiber Arm	4	Received	February 6, 2023	March 10, 2023
Carbon Fiber Structural Rod	4	Received	N/A	N/A
M4 80mm Threaded Rod	2	Received	N/A	N/A
Heat Shield Hinge	4	Received	N/A	N/A
Parachute Spring	2	Received	N/A	N/A
Tape Measure	1	Received	February 6, 2023	March 10, 2023
M3 24mm Pin	2	Received	February 6, 2023	March 10, 2023
PETG Filament	1	Received	February 6, 2023	March 10, 2023

Status of Procurements (4 of 4)

Ground Station Components				
Components	**Quantity**	**Status**	**Date Ordered**	**Date Received**
Ground Station Computer	1	Received	N/A	N/A
XBee Breakout Board	1	Received	N/A	N/A
Ground Station XBee	1	Received	N/A	N/A
Yagi Antenna	1	Received	N/A	N/A
Umbrella	1	Received	N/A	N/A

*Note: For date ordered/received, N/A indicates re-used components

CanSat Budget – Hardware (1 of 6)

Component	Quantity	Unit Price ($)	Total Cost ($)	Source	Reuse
BMP388	2	10.95	21.90	Actual	
SAM-M8Q	1	42.95	42.95	Actual	
BNO055	1	34.95	34.95	Actual	
Teensy 4.1	1	31.50	31.50	Actual	
XBee Pro 900HP	1	61.23	61.23	Actual	X
XBee Explorer Breakout Board	1	11.95	11.95	Actual	X
New Energy LED Starboard	1	6.18	6.18	Actual	
BUZZER PIEZO 3V 30MM	1	2.78	2.78	Actual	
SPDT Switch	2	5.39	5.39	Actual	
Linear 5.0V Regulator	1	5.87	5.87	Actual	
Slide Total	**-**	**-**	**224.70**	**-**	**-**

CanSat Budget – Hardware (2 of 6)

Component	Quantity	Unit Price ($)	Total Cost ($)	Source	Reuse
Previous Slide Total	**-**	**-**	**224.70**	**-**	**-**
P-Channel MOSFET TO-220AB	3	1.64	4.92	Actual	
CR123A Battery	2	2.00	4.00	Actual	
Cr123A Battery Holder	2	1.23	2.46	Actual	
Custom PCB	2	20.00	40.00	Budgeted	
Micro Servo Metal Gear	1	14.95	14.95	Actual	X
DC Motor in Micro Servo Body	3	3.50	13.50	Actual	X
Wires, Solder, Resistors, Capacitors	1	30.00	30.00	Budgeted	
Seeed RP 2040	1	5.40	5.40	Actual	
CR2450 Battery	2	3.41	6.82	Actual	
CR2450 Battery Holders	2	0.60	1.20	Actual	
Slide Total	**-**	**-**	**347.95**	**-**	**-**

CanSat Budget – Hardware (3 of 6)

Component	Quantity	Unit Price ($)	Total Cost ($)	Source	Reuse
Previous Slide Total	**-**	**-**	**347.95**	**-**	**-**
Fiberglass shell	1	20	20.00	Estimate	
M5 40mm threaded rod	1	0.5	0.50	Actual	
M5 eye nuts	2	6.16	12.32	Actual	
M5 nuts	1	0.11	0.11	Estimate	
Rip Stop Nylon	420cm^2	0.001 per cm^2	0.42	Estimate	
Paracord	128.3cm	0.004 per cm	0.51	Estimate	
Petg Container Piece	20g	0.034 per gram	0.68	Estimate	
Carbon fiber arms	4	2.66	10.63	Actual	
Carbon fiber structural rods	4	2.66	10.63	Actual	
Slide Total	**-**	**-**	**403.75**	**-**	**-**

CanSat Budget – Hardware (4 of 6)

Component	Quantity	Unit Price ($)	Total Cost ($)	Source	Reuse
Previous Slide Total	**-**	**-**	**403.75**	**-**	**-**
M5 eye nut	3	6.16	18.48	Actual	
Nylon Attachment Points	4	0.034 per gram	0.14	Estimate	
M3 bolts 14mm	8	1.48	11.84	Actual	
M3 24mm pins	2	2.21	4.42	Actual	
Paracord	328 cm	0.004 per cm	1.31	Estimate	
Nose Cone	1	0.034 per gram	1.15	Estimate	
Pinch Plate	1	0.034 per gram	0.31	Estimate	
Slider Plate	1	0.034 per gram	0.41	Estimate	
Slide Total	**-**	**-**	**441.51**	**-**	**-**

CanSat Budget – Hardware (5 of 6)

Component	Quantity	Unit Price ($)	Total Cost ($)	Source	Reuse
Previous Slide Total	**-**	**-**	**441.51**	**-**	**-**
Hinge Plate	1	0.034 per gram	0.44	Estimated	
Servo Plate	1	0.034 per gram	0.68	Estimated	
Rod Shoe	2	0.034 per gram	0.07	Estimated	
Deployment Link	8	0.034 per gram	0.55	Estimated	
Heatshield Hinge	8	0.25	2.00	Estimated	
Parachute Container	1	0.034 per gram	1.23	Estimated	
Parachute Eye Nut	3	0.50	1.50	Actual	
Tape Measure	1	10.00	10.00	Actual	--
Slide Total	**-**	**-**	**457.98**	**-**	**-**

CanSat Budget – Hardware (6 of 6)

Component	Quantity	Unit Price ($)	Total Cost ($)	Source	Reuse
Previous Slide Total	**-**	**-**	**457.98**	**-**	**-**
Parachute Piston	1	0.034 per gram	0.27	Estimated	
Parachute Spring	2	0.30	0.60	Estimated	
Parachute Pate	1	0.034 per gram	0.71	Estimated	
PCB Standoff	8	0.07	0.56	Actual	
Total	**-**	**-**	**460.13**	**-**	**-**

CanSat Total = $460.13

This total is less than the $1000 limit and therefore complies with requirement 19

CanSat Budget – Other Costs

Component	Cost ($)	Quantity	Total Cost ($)	Source	Reuse
Ground Station Laptop (Dell XPS 15 Laptop)	$1,996.00	1	$1,996.00	Actual	X
Laird Technologies PC906N Yagi Antenna	$47.39	1	$47.39	Actual	X
N Male to RP-SMA Male Coaxial Cable	$11.99	1	$11.99	Actual	X
SparkFun XBee Explorer USB	$27.95	2	$27.95	Actual	X
XBee Pro 900HP	$62.08	1	$62.08	Actual	X
USB Mini to USB A Cable	$6.99	1	$6.99	Actual	X
Travel (Per Person)	$116.67	10	$1,166.67	Estimate	
Lodging (Per Person)	$250.00	10	$2,500.00	Estimate	
Food (Per Person)	$166.67	10	$1,666.67	Estimate	

Other Costs Total = $7,485.74

Funding is Provided by the Alabama Space Grant Consortium

Total Mission Cost: $7,945.27

Program Schedule Overview

General Detailed Timeline

Name	Start Date	End Date	October				November				December				January					February				March				April				May					
General			10	17	24	31	7	14	21	28	5	12	19	26	2	9	16	23	30	6	13	20	27	6	13	20	27	3	10	17	24	1	8	15	22	29	5
Team Formation	10/10/2022	10/30/2022																																			
MCR Phase	10/24/2022	12/2/2022																																			
PDR Phase	12/2/2022	1/27/2023																																			
CDR Phase	1/27/2023	4/10/2023																																			
Parts Ordering	2/6/2023	4/10/2023																																			
Test-Launch Phase	4/14/2023	5/7/2023																																			
Competition Phase	5/7/2023	6/11/2023																																			
Important School Dates																																					
Fall Finals	12/5/2022	12/12/2022																																			
Winter Break	12/12/2022	1/6/2023																																			
Spring Break	3/13/2023	3/17/2023																																			
Spring Finals	4/22/2023	4/28/2023																																			
Team Milestones																																					
Initial Design	10/10/2022	2/6/2023																																			
Prototyping	2/6/2023	4/1/2023																																			
Testing	4/1/2023	5/1/2023																																			
Cansat Finalization	5/1/2023	6/1/2023																																			

At the time of CDR, we are approximately 70% complete with work for the competition.

Mechanical Detailed Timeline

Name	Start Date	End Date	October				November				December				January					February				March				April				May					
General			10	17	24	31	7	14	21	28	5	12	19	26	2	9	16	23	30	6	13	20	27	6	13	20	27	3	10	17	24	1	8	15	22	29	5
Team Formation	10/10/2022	10/30/2022																																			
MCR Phase	10/24/2022	12/2/2022																																			
PDR Phase	12/2/2022	1/27/2023																																			
CDR Phase	1/27/2023	4/10/2023																																			
Parts Ordering	2/6/2023	4/10/2023																																			
Test-Launch Phase	4/14/2023	5/7/2023																																			
Competition Phase	5/7/2023	6/11/2023																																			
Mechanical Team																																					
Initial Brainstorming	10/10/2022	11/13/2022																																			
Material Trade Studies	10/24/2022	11/20/2022																																			
Decent Mechanism Models	11/7/2022	12/2/2022																																			
CAD Design and Completion	12/2/2022	1/31/2023																																			
Prototyping	2/1/2023	4/3/2023																																			
Itegration	4/3/2023	5/7/2023																																			
Environmental Testing	5/8/2023	6/10/2023																																			

Detailed Program Schedule (2 of 3)

Electrical Detailed Timeline

Name	Start Date	End Date	October				November				December				January					February				March				April				May					
General			10	17	24	31	7	14	21	28	5	12	19	26	2	9	16	23	30	6	13	20	27	6	13	20	27	3	10	17	24	1	8	15	22	29	5
Team Formation	10/10/2022	10/30/2022																																				
MCR Phase	10/24/2022	12/2/2022																																				
PDR Phase	12/2/2022	1/27/2023																																				
CDR Phase	1/27/2023	4/10/2023																																				
Parts Ordering	2/6/2023	4/10/2023																																				
Test-Launch Phase	4/14/2023	5/7/2023																																				
Competition Phase	5/7/2023	6/11/2023																																				
Electrical Team																																						
Trade Stuides	10/10/2022	11/17/2022																																				
PCB Development	11/18/2022	1/9/2023																																				
Parts Order and Breadboarding	1/9/2023	2/27/2023																																				
Assembly	2/27/2023	3/15/2023																																				
Testing	3/15/2023	4/3/2023																																				
Integration	4/3/2023	5/7/2023																																				
Environmental Testing	5/7/2023	6/10/2023																																				

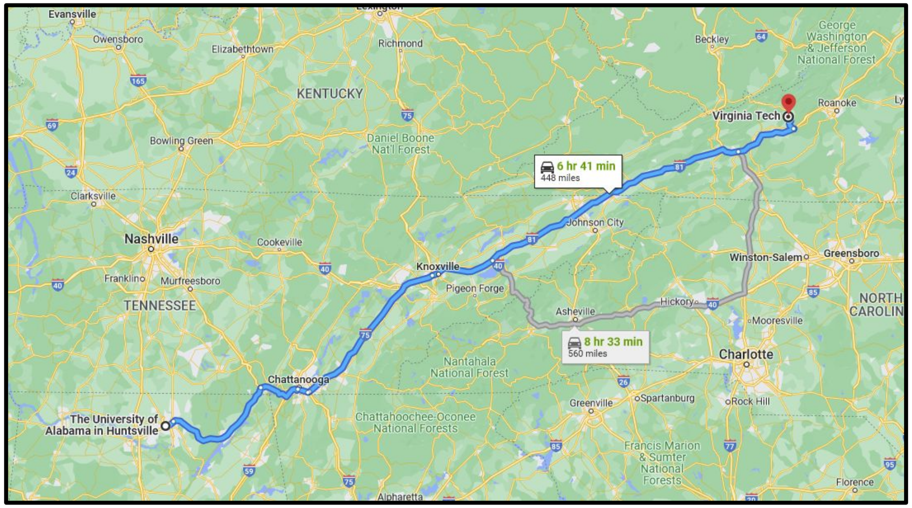
Software Detailed Timeline

Name	Start Date	End Date	October				November				December				January					February				March				April				May					
General			10	17	24	31	7	14	21	28	5	12	19	26	2	9	16	23	30	6	13	20	27	6	13	20	27	3	10	17	24	1	8	15	22	29	5
Team Formation	10/10/2022	10/30/2022																																			
MCR Phase	10/24/2022	12/2/2022																																			
PDR Phase	12/2/2022	1/27/2023																																			
CDR Phase	1/27/2023	4/10/2023																																			
Parts Ordering	2/6/2023	4/10/2023																																			
Test-Launch Phase	4/14/2023	5/7/2023																																			
Competition Phase	5/7/2023	6/11/2023																																			
Software Team																																					
State Machine	10/10/2022	11/16/2022																																			
Ground Station Development	11/16/2022	1/19/2023																																			
Prototyping	11/16/2022	1/19/2023																																			
Radio Testing	1/20/2023	2/15/2023																																			
Parts Order and Sensor Testing	1/20/2023	2/27/2023																																			
Debugging	2/15/2023	6/10/2023																																			

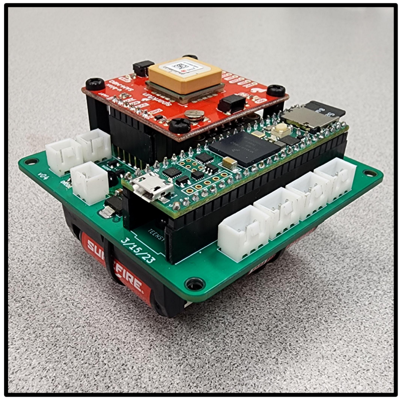
Shipping and Transportation

- Team Afterburner will utilize vans provided by the University of Alabama in Huntsville to transport personnel, CanSat equipment, spare parts, and tools to Virginia Tech from Huntsville, Alabama.
- The drive will take approximately 7 hours
- We will not have to worry about checked bags or shipping equipment since we will be responsible for driving ourselves to the launch site.

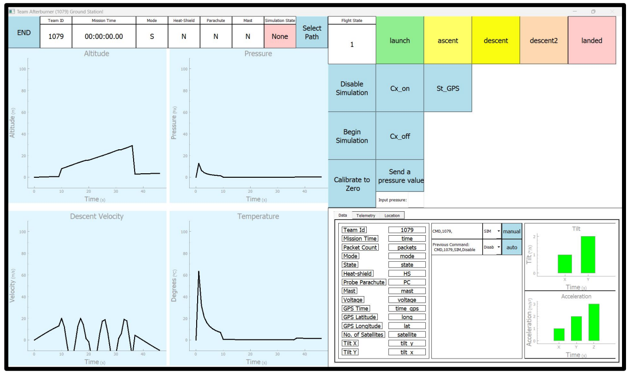
Image credit: Ford.com



	Electrical	Software	Mechanical
Accomplishments	• Working 4th generation PCB • Completed electronics package assembly • Completed sensor testing	• Modularization of functions • Sensor testing and integration • GS updated to V2 with communication and location tracking	• Printed sub system prototypes • Preliminary parachute deployment tests • Begun electrical and software integration



Electronics Package



Ground Station GUI

Prototype Probe Assembly

Conclusions (2 of 2)

In Progress and Future Tests

Electrical	Software	Mechanical
• Finalization of PCB and ordering • Mechanical - electrical integration • Software - electrical testing	• Integrated system testing • Simulation profile testing • Finalizing FSW and GS GUI	• Full mechanical subsystem integration • Full software and electrical integration • Flight Tests • Environmental tests

What's Next?

Team Afterburner has completed many of the steps leading up to and including prototyping and manufacturing. We are on track with the timeline set both by the team and the competition. More vigorous and consistent testing will begin within the coming weeks, and we are eager to compete this coming June.