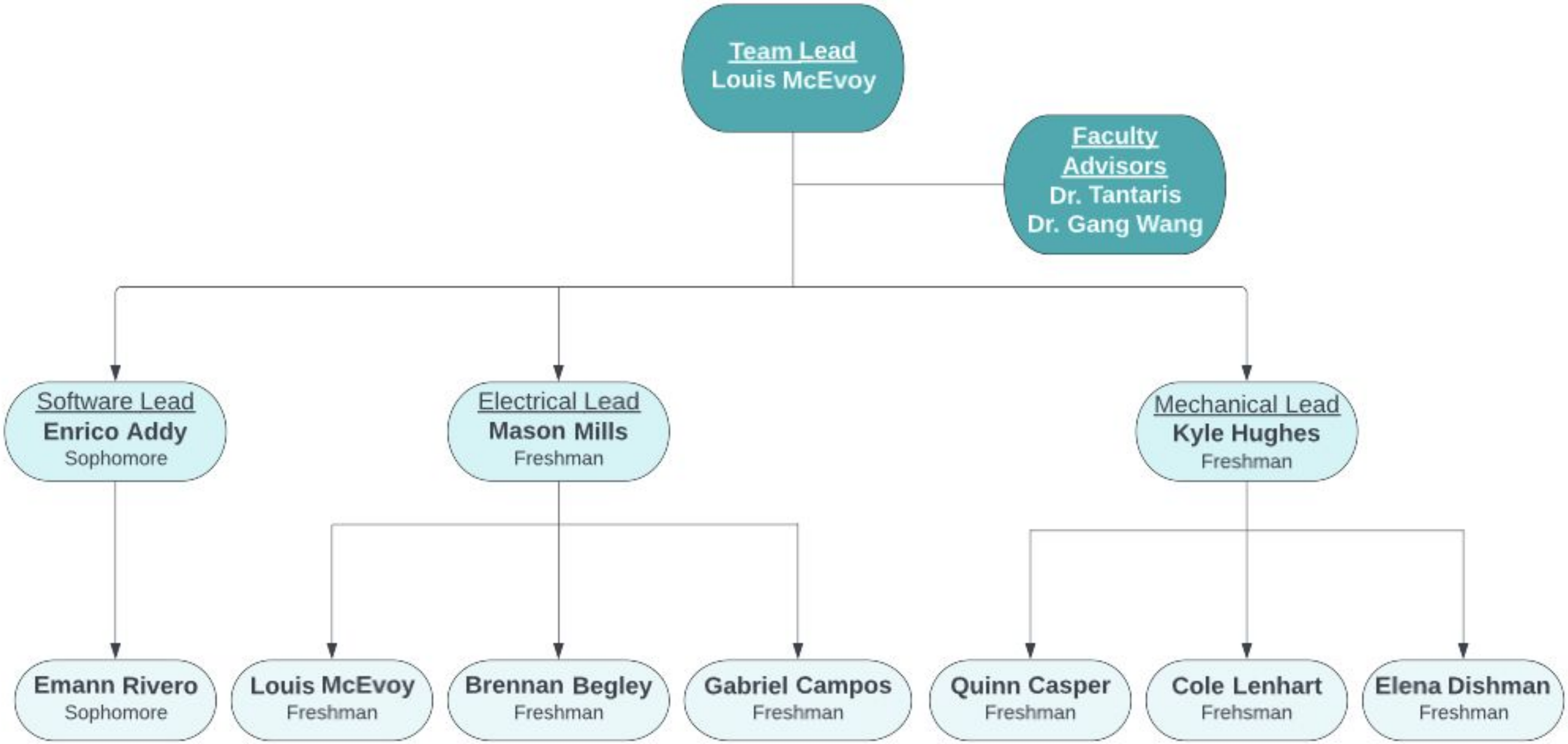
CanSat 2023
Preliminary Design Review (PDR)
Version 2.0

Team 1079

Team Afterburner

Presentation Outline

Team Organization



Acronyms (1 of 5)

Acronym	Explanation
ADC	Analog to Digital Converter
µA	Microamps
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
CSV	Comma Separated Values
dBi	Decibel Relative to Isotrope
EPS	Electrical Power Subsystem

Acronyms (2 of 5)

Acronym	Explanation
EPS	Electrical Power Subsystem
FPS	Frames per Second
FSW	Flight Software
G	Gravitational Shock
g	Grams
GHz	Gigahertz
GND	Ground
GPIO	General Purpose Input/Output
GPS	Global Positioning System
GS	Ground Station
Hz	Hertz
I2C	Inter-Integrated Circuit
IDE	Integrated Development Environment

Acronyms (3 of 5)

Acronym	Explanation
KB	Kilobytes
kg	Kilograms
KHz	Kilohertz
Kohms	Kiloohms
LED	Light Emitting Diode
m	Meter
m/s	Meters per Second
mA	Milliamps
mAh	Milliamp Hours
MCU	Microcontroller Unit
MG	Megapixel
MHz	Megahertz

Acronym	Explanation
mm	Millimeter
MOSFET	Metal Oxide Semiconductor Field Effect Transistor
mWh	Milliwatt Hours
N	Newton
ns	Nanosecond
Pa	Pascals
PCB	Printed Circuit Board
PETG	Polyethylene Terephthalate Glycol
ppm	Parts Per Million
PSI	Pound per Square Inch
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
TTL	Transistor-Transistor Logic
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)

Systems Overview

Presented by 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.

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

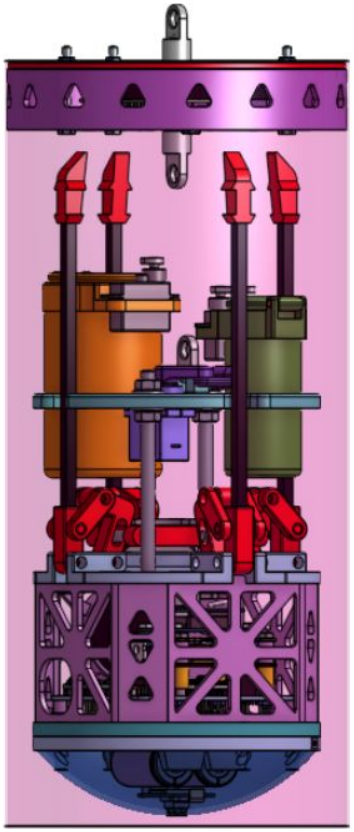
System Requirement Summary (3 of 4)

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

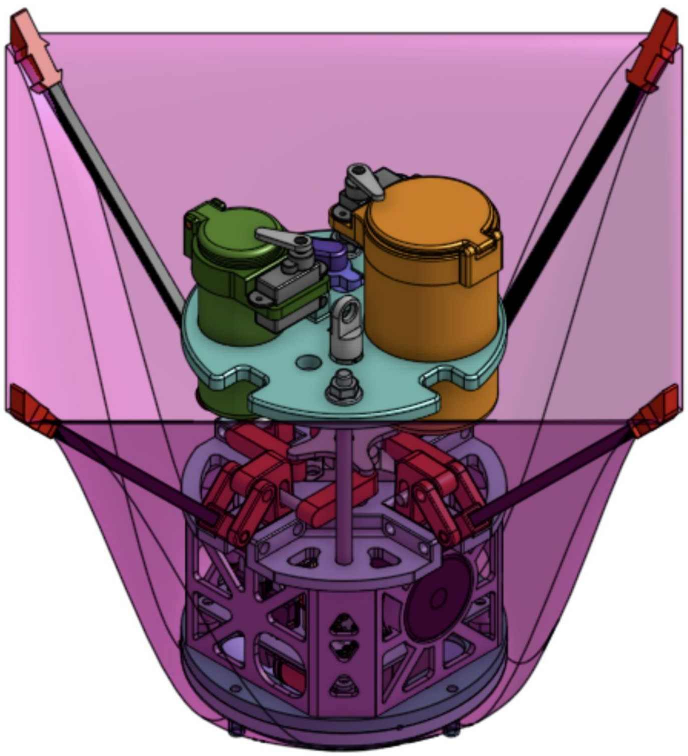
System Requirement Summary (4 of 4)

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

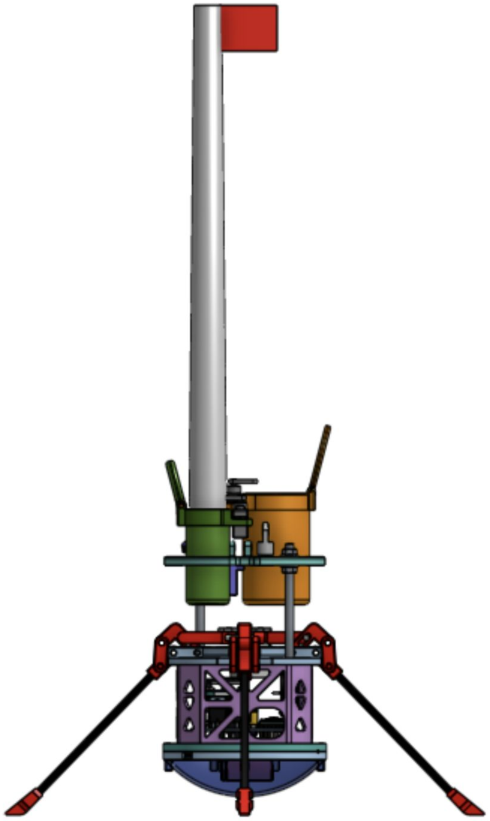
4 Arm 1 Servo System



Stowed Configuration



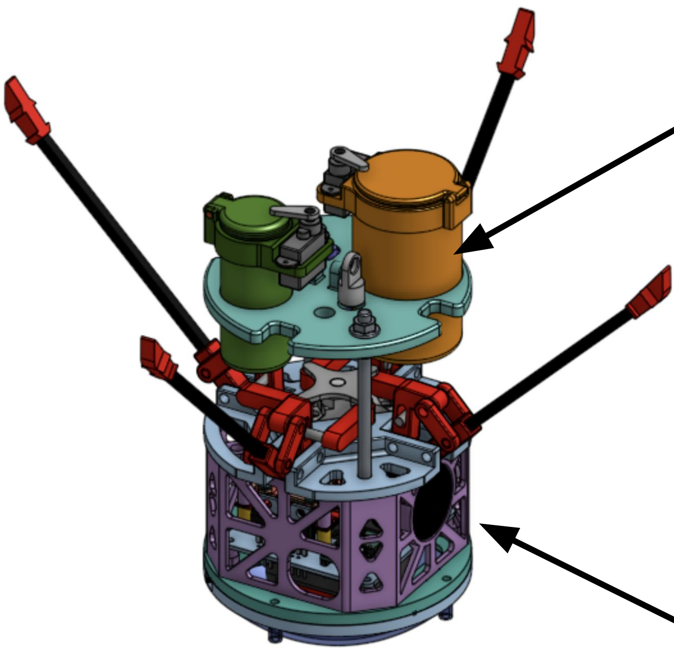
Descent Configuration



Upright Configuration

System Level CanSat Configuration Trade & Selection (2 of 5)

4 Arm 1 Servo System



Parachute Container

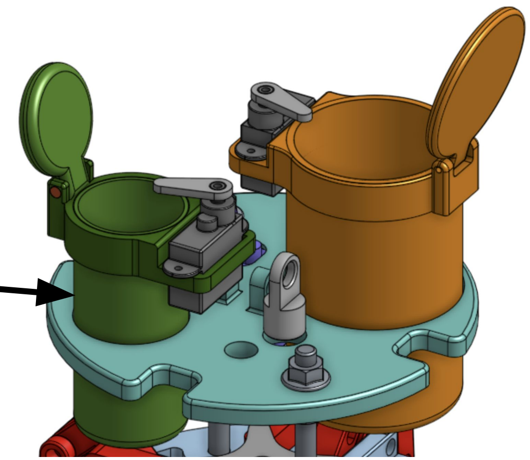
Flag Mechanism

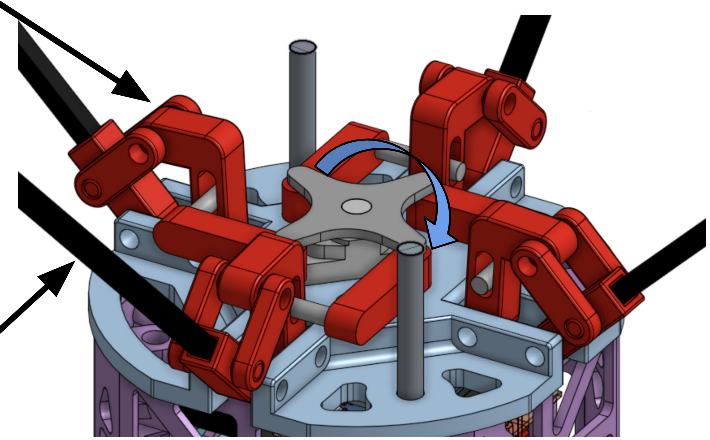
Heat Shield Deployment Linkages

Electronics Housing

Carbon Composite Heat Shield Arms

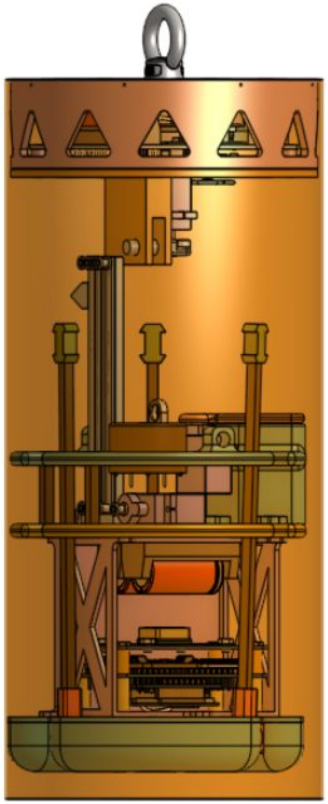
Descent Configuration with Ripstop Nylon Hidden



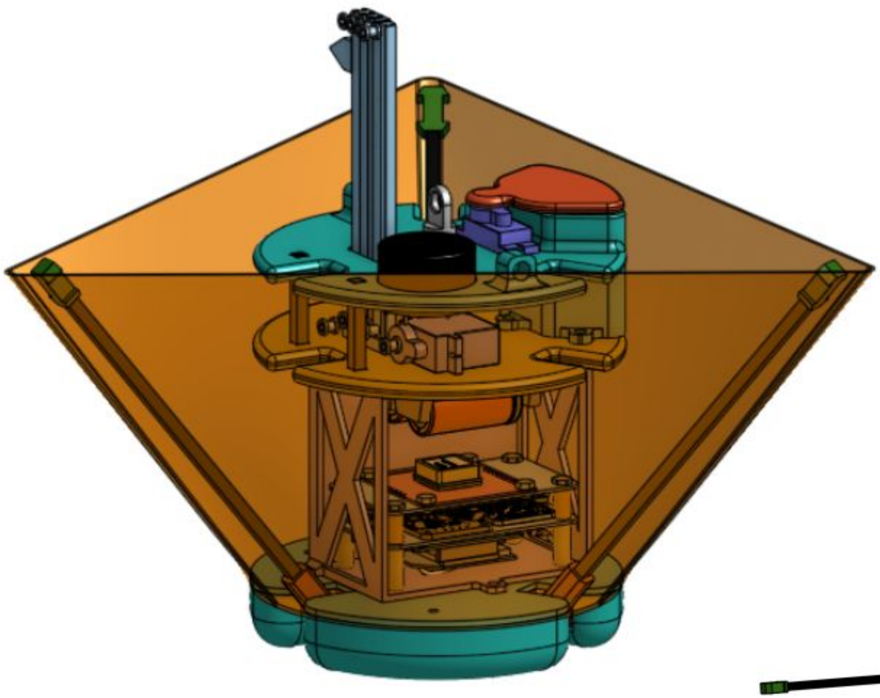


System Level CanSat Configuration Trade & Selection (3 of 5)

3 Arm 3 Servo System



Stowed Configuration

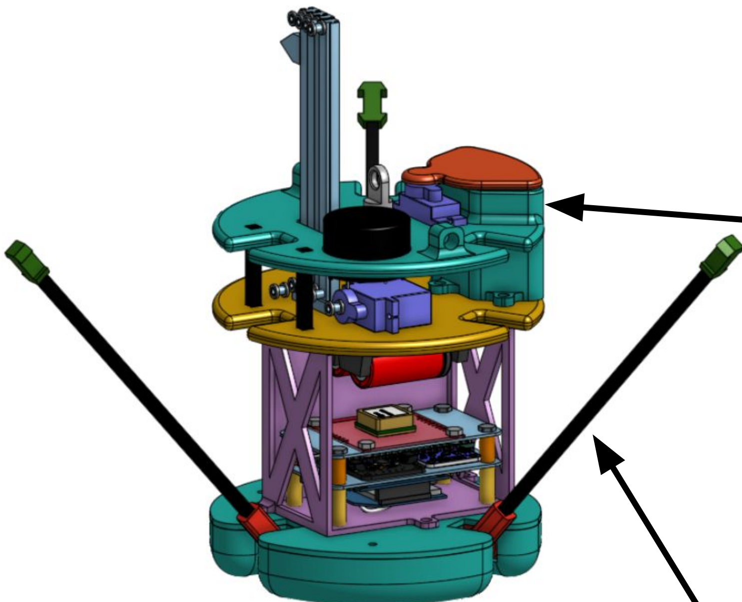


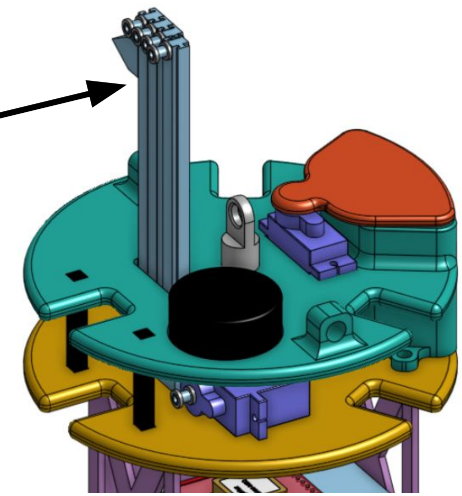
Descent Configuration

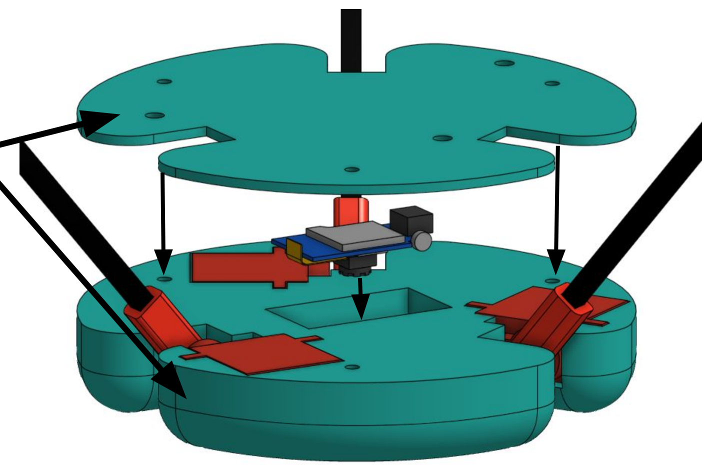
Upright Configuration

System Level CanSat Configuration Trade & Selection (4 of 5)

3 Arm 3 Servo System







Cascading Rail Flag Mechanism

Parachute Deployment

3 Servo Mounting Plates

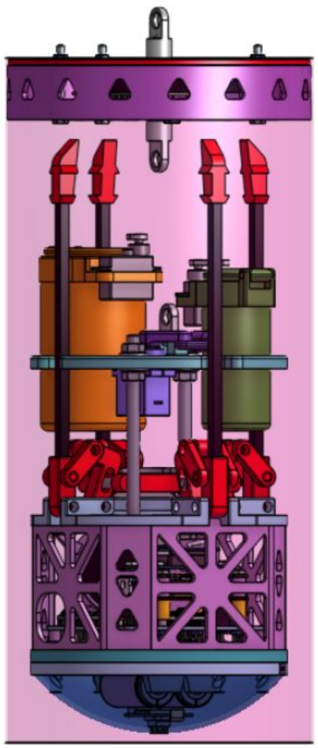
Carbon Composite Heat Shield Arms

Descent Configuration with Ripstop Nylon Hidden

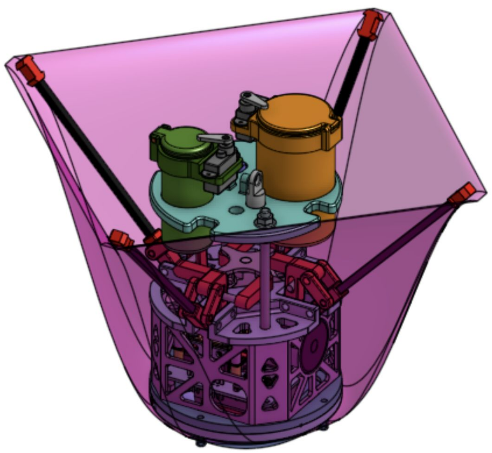
System Level CanSat Configuration Trade & Selection (5 of 5)

Selection: 4 Arm 1 Servo System

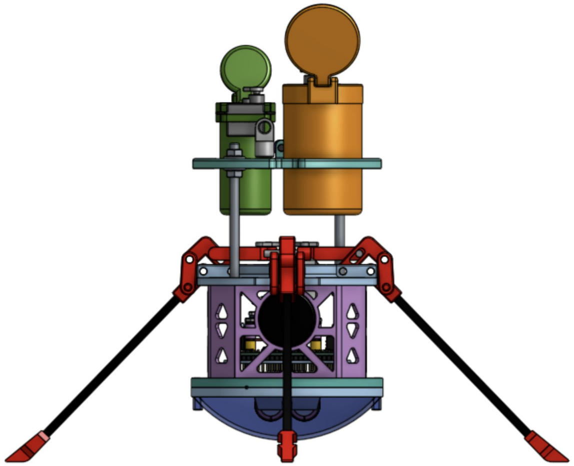
Design	Heat Shield Arm Count	Container Mass (g)	Descent Stabilization Method	Total Servo Count
4 Arm 1 Servo	4	195.7	Passive	4
3 Arm 3 Servo	3	269.8	Active	6



Stowed Configuration



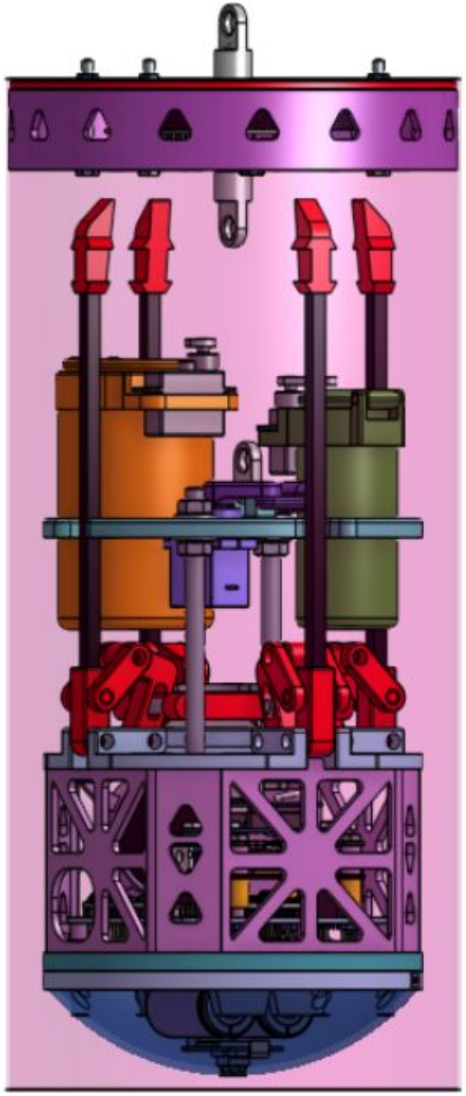
Descent Configuration



Upright Configuration

System Level Configuration Selection

Selection: 4 Arm 1 Servo System
Rationale: ● Heat shield arms support CanSat during launch ● Parachute deploys substantially quicker ● Rounded nose cone eases uprighting ● 4 heat shield arms creates larger cross-sectional area ● Easy camera and battery access ● Minimal container and bonus objective mass
Drawbacks: ● Greater moment on the payload arms ● Greater complexity of the deployment mechanism ● Inefficient flag mechanism



Physical Layout (1 of 5)

Container Electronics

Fiberglass Shell

Heat Shield Arms

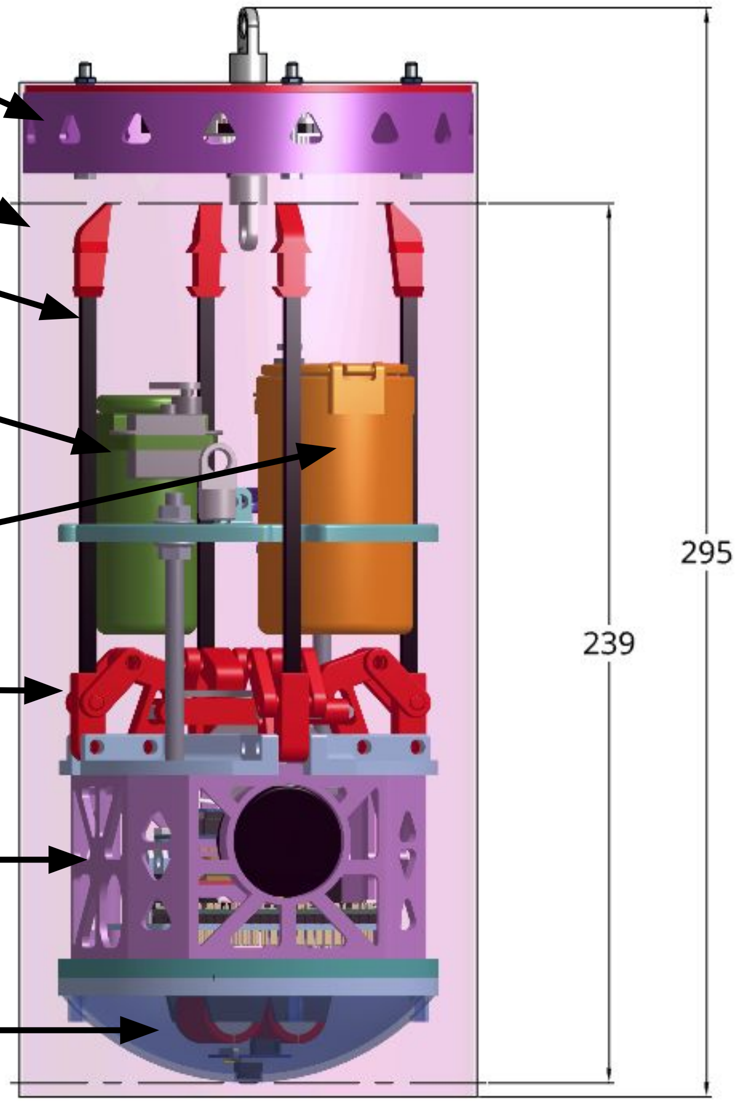
Servo-Actuated Flag Mechanism

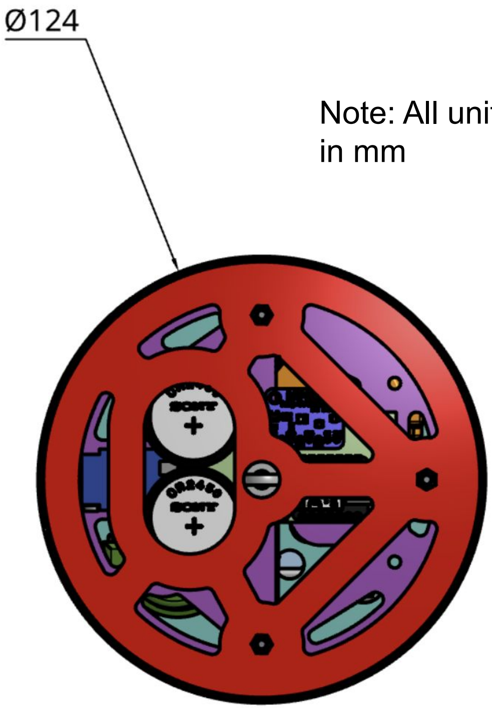
Servo-Actuated Parachute Deployment

Servo-Actuated Heat Shield System

Electronics Housing (PCB, Radio Antenna, GPS Antenna)

Nose Cone with Batteries and Camera

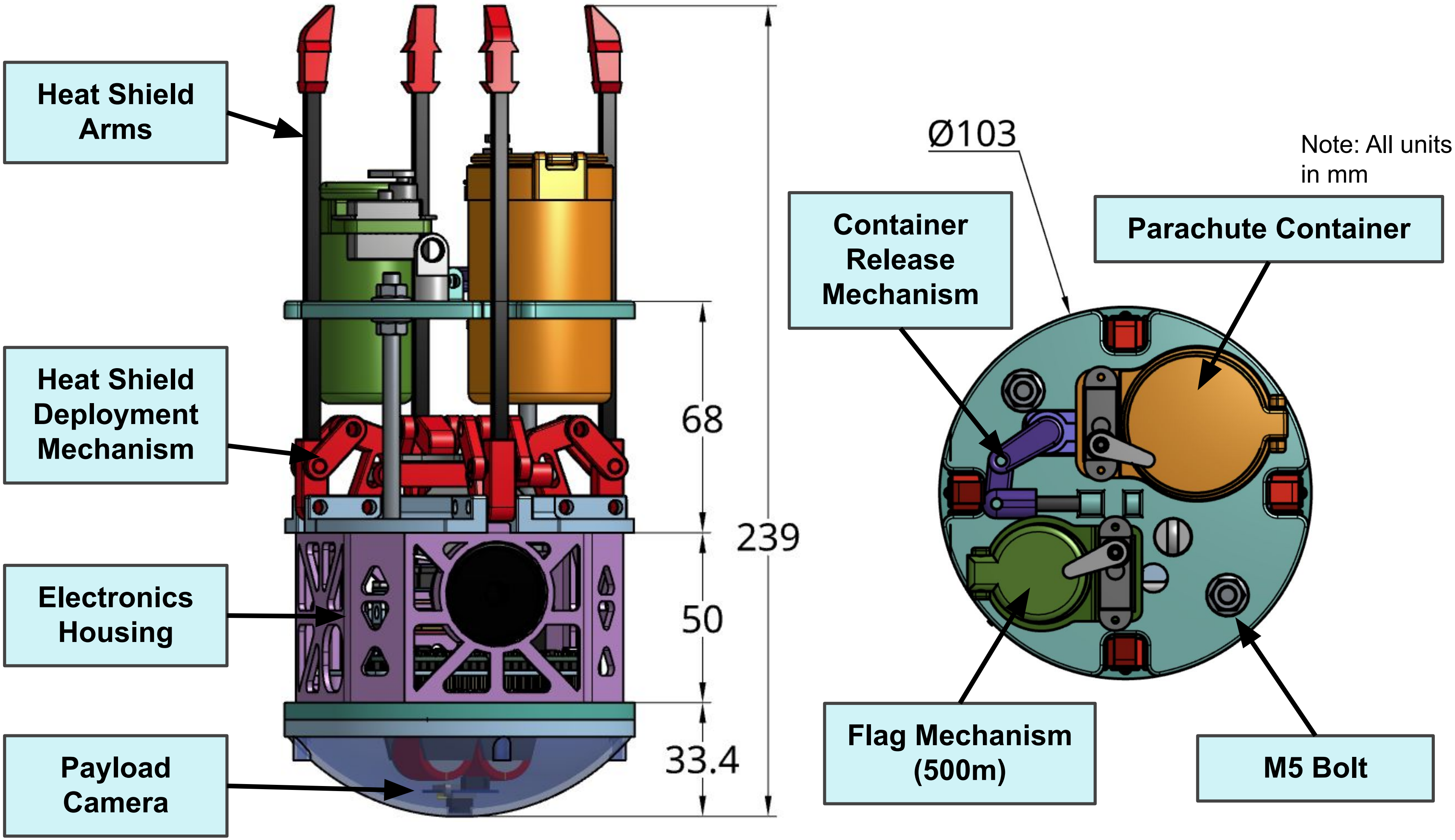




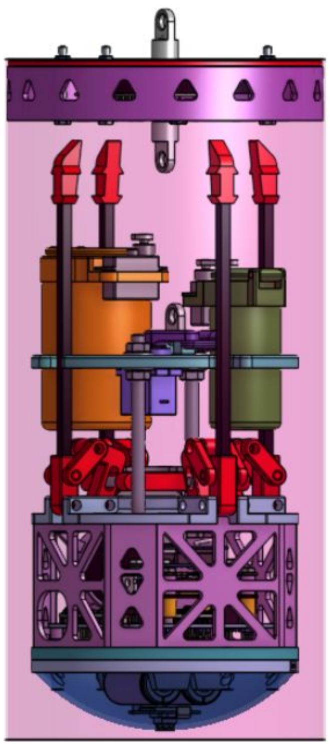
Note: All units in mm

Container houses electrical components needed for bonus objective camera

Physical Layout (2 of 5)

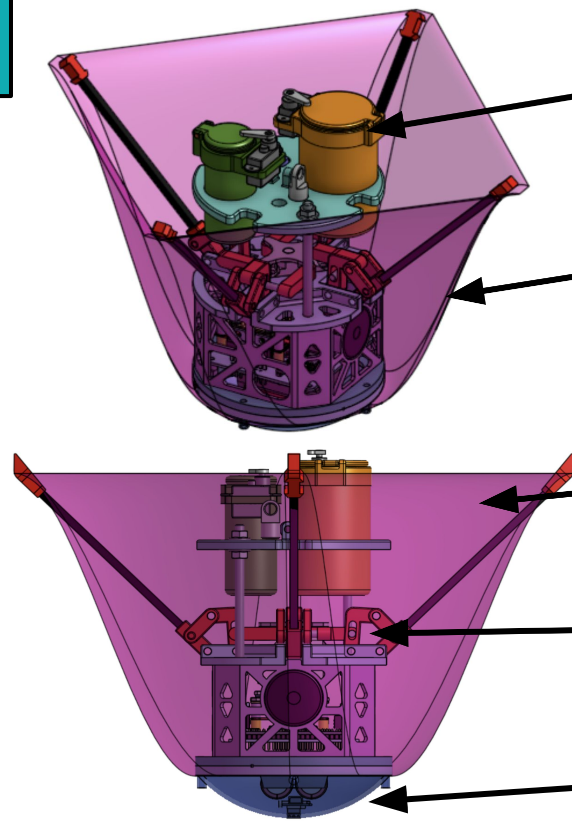


Stowed and Deployed Configuration



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

Stowed Configuration



Parachute Container

Deployed Ripstop Nylon Heat Shield

Deployed Heat Shield Arms

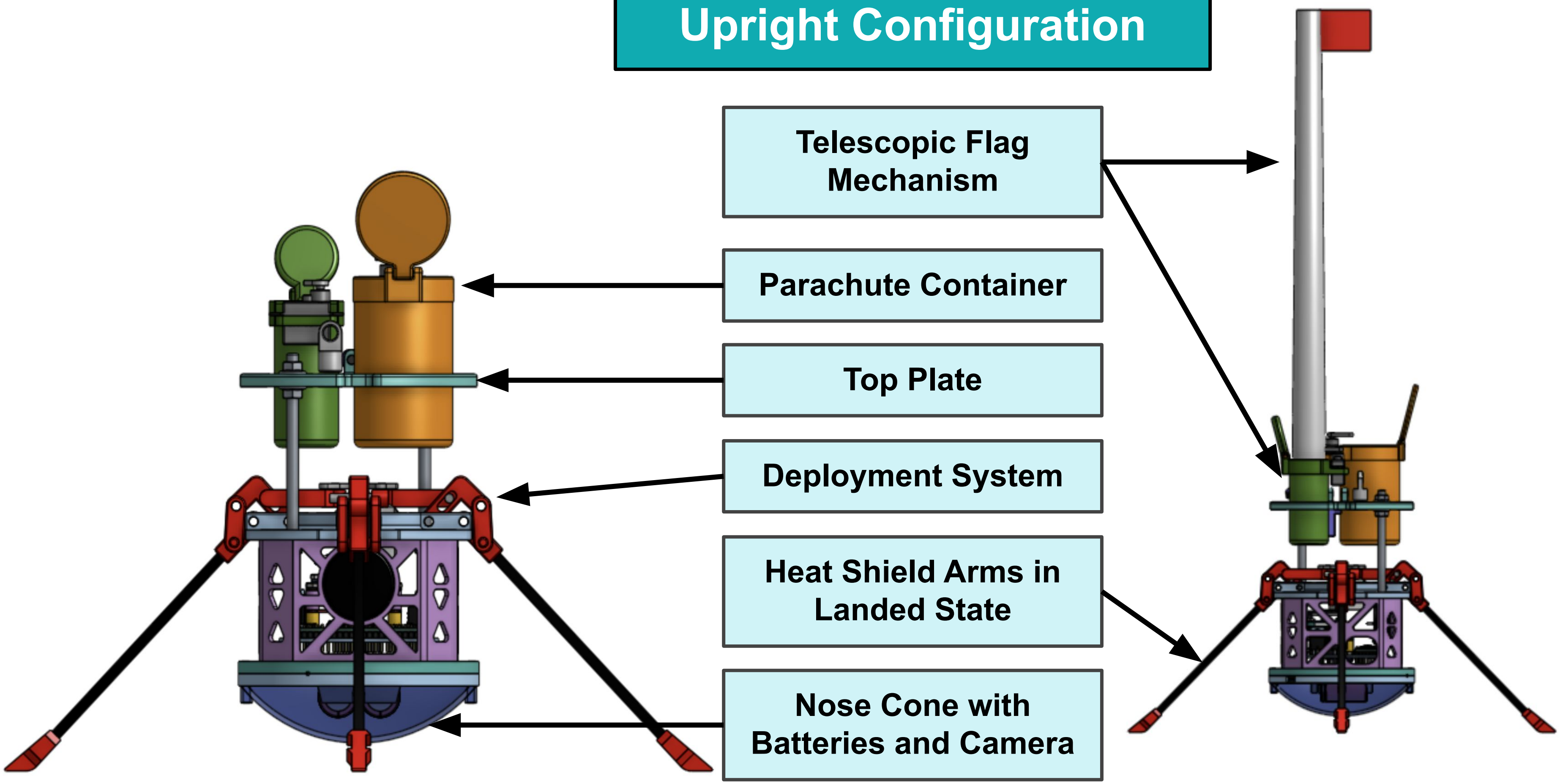
Deployment System

Nose Cone with Batteries and Camera

Heat Shield Deployed Configuration

Physical Layout (4 of 5)

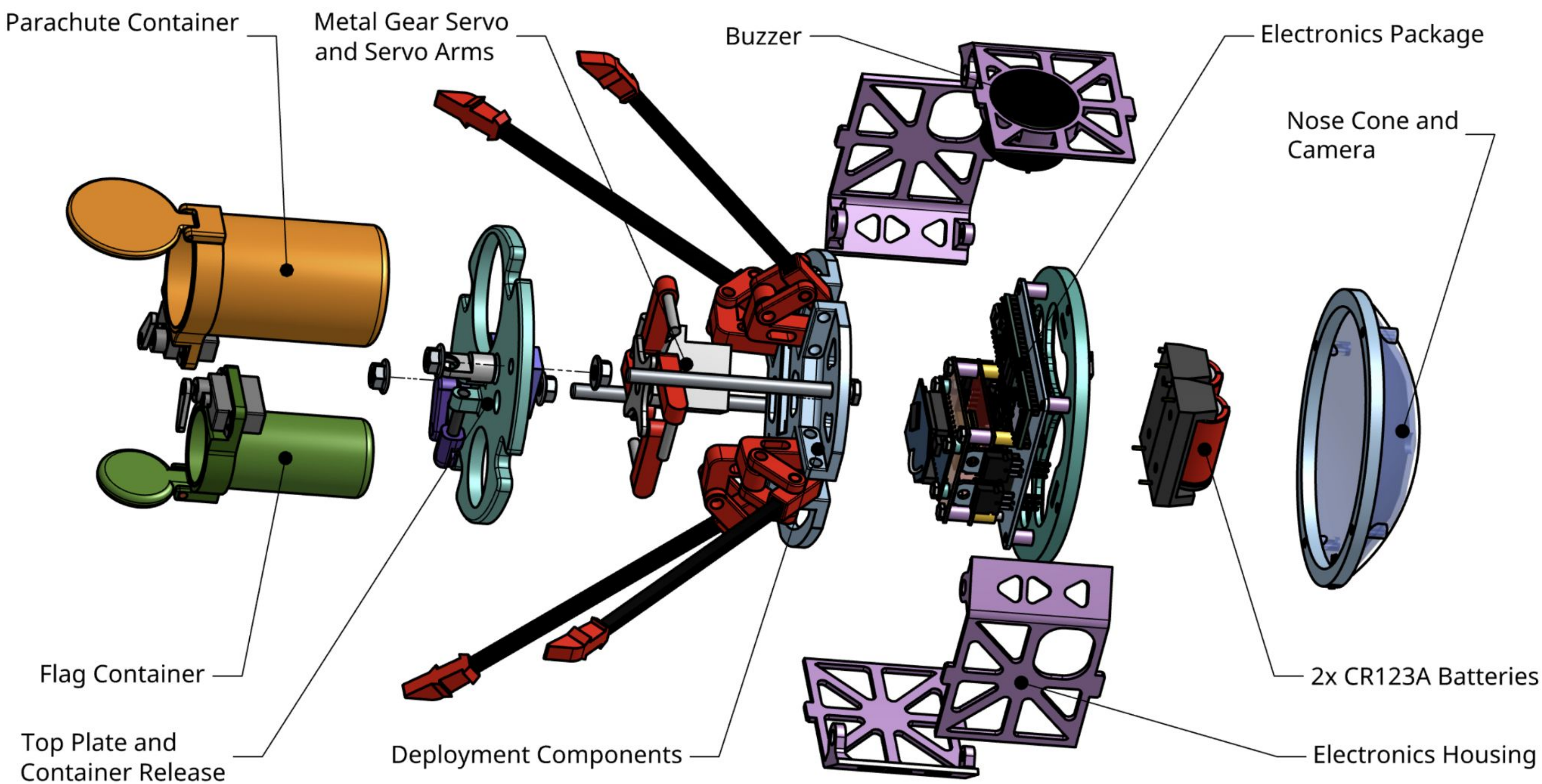
Upright Configuration



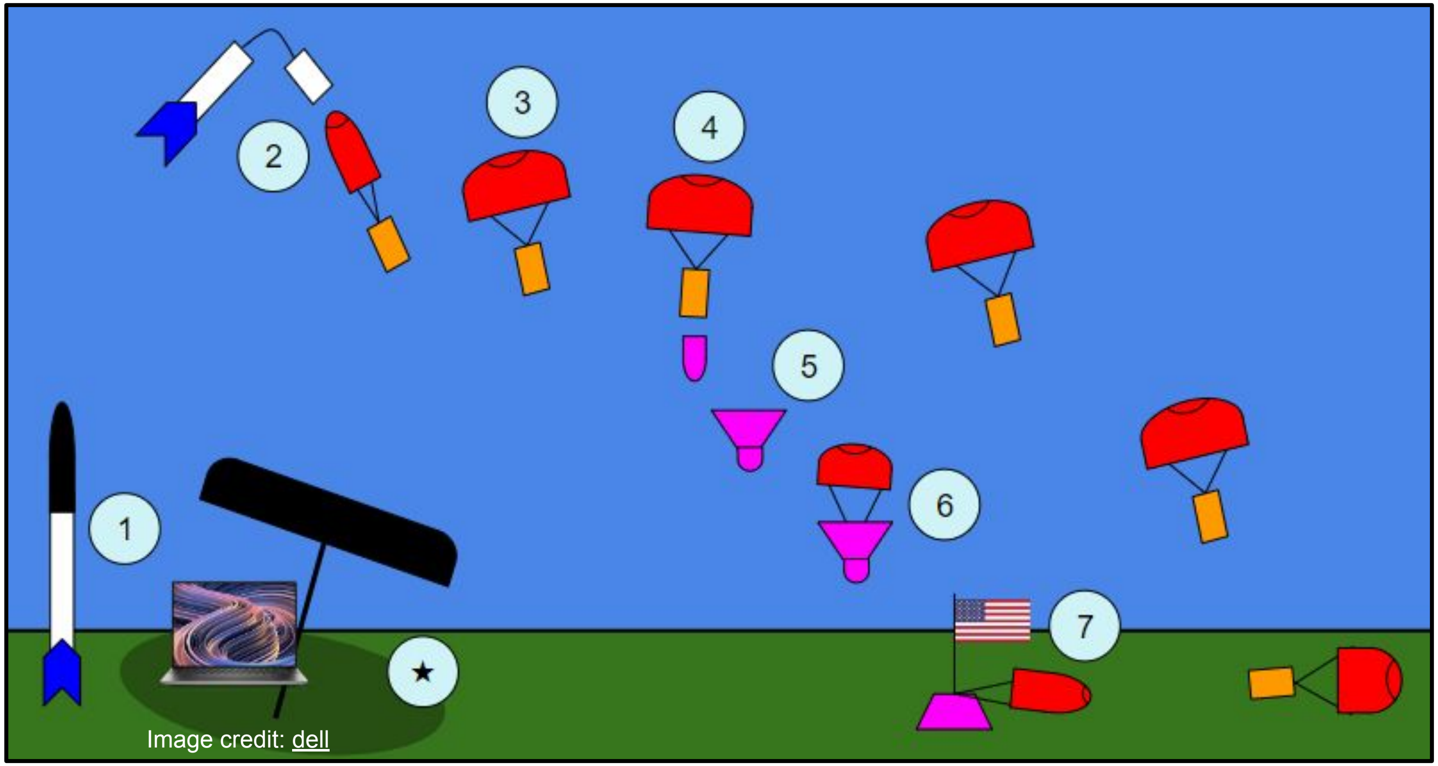
Upright Configuration Closeup

Upright Configuration

Exploded View



System Concept of Operations



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

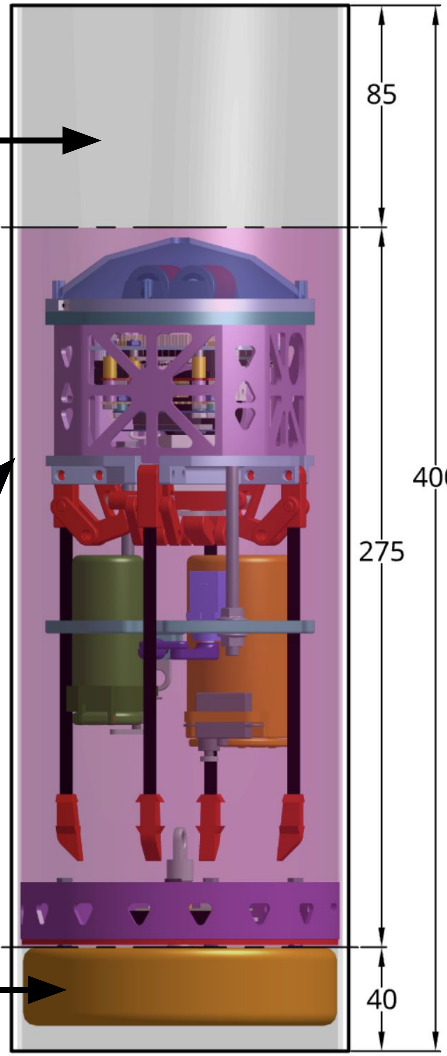
1	2	3	4	5	6	7
CanSat is loaded into launch vehicle	CanSat deploys at an altitude of 670m to 725m	Descent is slowed via parachute to a rate of 15 m/s	Probe is released at 500m	Probe opens a heat shield and descends at 20 m/s	Probe deploys parachute at 200m, slows descent to 5 m/s	Probe lands, uprights,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

Key Dimensions

85 mm of unused payload space

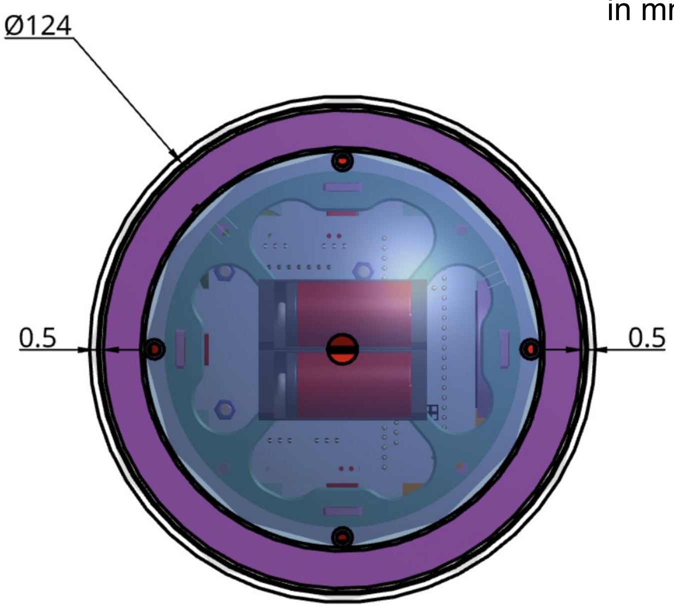
0.5 mm of radial clearance

40 mm allocated for parachute



Note: The CanSat has no sharp edges or protrusions

Note: All units in mm



Maximum Dimensions
Height: 400 mm Diameter: 125 mm

Sensor Subsystem Design

Presented by Gabriel Campos

Sensor Subsystem Overview

Required	Sensor	Purpose
Air Pressure	BMP390	Provide altitude data that is used to trigger the different flight states of the payload, as well as providing pressure telemetry
Air Temperature	BMP390	Provide temperature data inside the CanSat, which is used for telemetry
Battery Voltage	Analog Digital Converter of MCU	Provide status of the batteries' voltage, aiding in troubleshooting of electronics
Orientation	BNO055	Provide the orientation of the payload used to self right, and provide telemetry of the payload acceleration in 3D space
GPS	SAM - M8Q	Provide location of CanSat, aiding in payload recovery
Video	Adafruit Spycamera	Record for the duration of the mission which is to be viewed afterwards to aid in data analysis

Payload Air Pressure Sensor Trade & Selection

Module	Accuracy	Max Current Draw (mA)	Area (mm^2)	Price ($)	Software Resources
BMP390	± 3 Pascals/ ±0.25 meters	0.730	359	10.95	Adafruit_BMP3XX Coding Library
MPL3115A2	± 4 Pascals/ ±0.30 meters	2.0	342	9.95	Built in pressure to altitude conversion
Parallax 29124	± 2.5 Pascals/ ±0.20 meter	1.74	438	29.99	Comes with example code

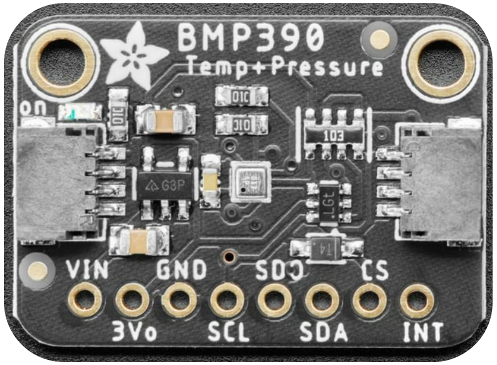


Image credit: adafruit.com

Selection: BMP390
- **Low power draw**
- **Comes with coding library**
- **Built in temperature sensor**

Payload Air Temperature Sensor Trade & Selection

Module	Typical Accuracy (℃)	Max Current Draw (µA)	Area (mm^2)	Price ($)
BMP390	± 0.50	320	359	10.95
TMP117	± 0.10	220	220	11.50
MCP9808	± 0.25	200	273	4.95

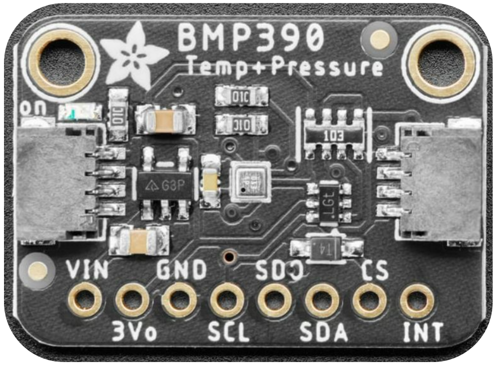
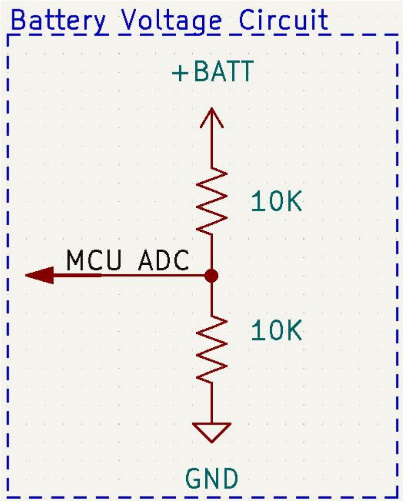


Image credit: adafruit.com

Selection: BMP390
- Integrated into pressure sensor
- Less total area and mass
- Adequate accuracy

Payload Battery Voltage Sensor Trade & Selection

Module	Dimension (mm)	Weight (g)	Accuracy (%)	Max Voltage Read (V)	Price ($)
Analog Digital Converter of MCU	5.0 x 5.0 x 2.0	0.5	±3	6.6	0.50
Adafruit INA260	22.9 x 22.8 x 2.7	2.0	±1	36	9.95



<u>Selection:</u> **Analog Digital Converter of MCU**

- **Integrated in MCU, only requires two resistors**
- **Small and lightweight**
- **Low additional cost**

Payload Tilt Sensor Trade & Selection

Module	Max Current Draw (mA)	Gyroscope Accuracy (degrees)	Magnetometer Accuracy (degrees)	Accelerometer Accuracy (mm/s)	Price ($)
Absolute Orientation IMU BNO055	29	± 0.97	± 2.50	19.16	29.95
SparkFun 9DoF IMU ICM-20948	3.11	± 1.00	Not Listed	15.63	18.50

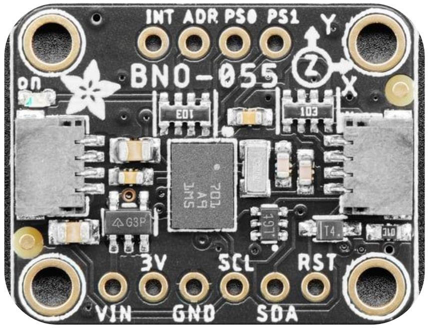


Image credit: Adafruit.com

Selection: IMU BNO055
- **Well documented libraries**
- **Easy to integrate with other Adafruit sensors**
- **Four point quaternion angles**

Payload GPS Sensor Trade & Selection

Module	Accuracy (m)	Max Current Draw (mA)	Hot Start Acquisition (s)	Antenna Type	RTC Battery	Price ($)
SparkFun SAM-M8Q Chip Antenna	2.5	29	~1	Internal	Included on board	42.95
SparkFun - ZOE-M8Q	2.5	25	~1	External	Included on board	49.95
Adafruit PA1616S	3.3	30	34	Internal, External	Not included	29.95

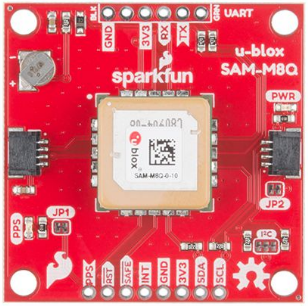


Image credit: Sparkfun.com

Selection: SparkFun SAM-M8Q Chip Antenna
- **Quick satellite acquisition**
- **Internal antenna**

Payload Camera Trade & Selection

Module	Resolution/ Frame Rate	Max Current Draw (mA)	Voltage (V)	Connection Type	Price ($)
Adafruit Spycamera	640 x 480 Video / 30 fps	110	3.7 - 5.0	Digital	12.50
TTL Serial JPEG Camera	640 x 480 Video / 30 fps	75	5.0	Digital | TTL	39.95
Arducam 5MP Plus OV5642	2592 x 1944 Video / 15 fps	Not Listed	5.0	SPI	42.95

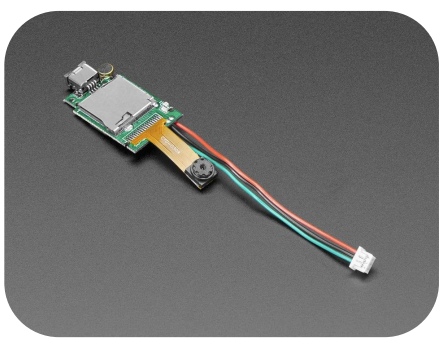


Image credit: Adafruit.com

Selection: Adafruit Spycamera
- **Embedded SD card reader**
- **Resolution fulfills requirements**
- **Prior experience using sensor**

Bonus Camera Trade & Selection

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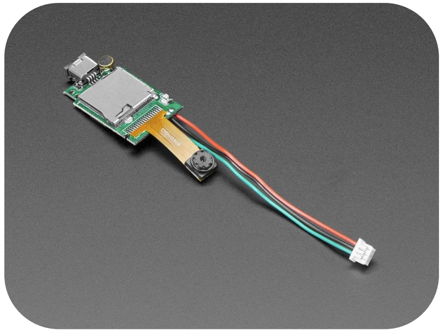


Image credit: Adafruit.com

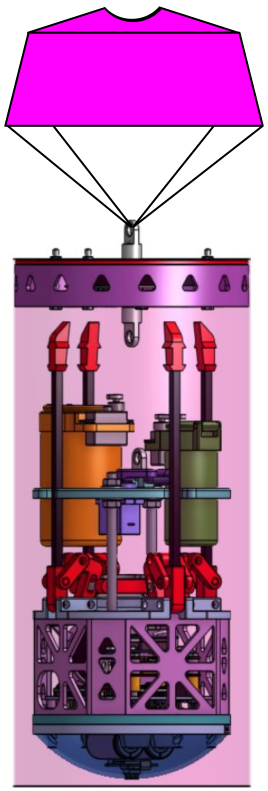
Selection: Adafruit Spycamera
- **Embedded SD card reader**
- **Resolution fulfills requirements**
- **Prior experience using sensor**

Descent Control Design

Presented by Quinn Casper

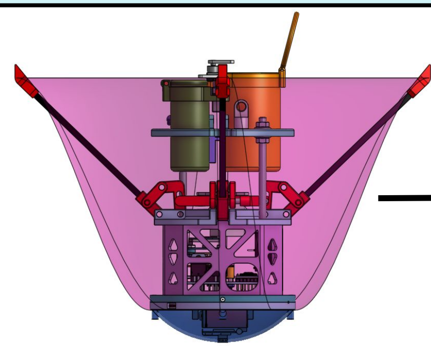
Descent Control Overview

- Passive stabilization
- Utilizes single, hexagonal-shaped nylon parachutes with spill holes

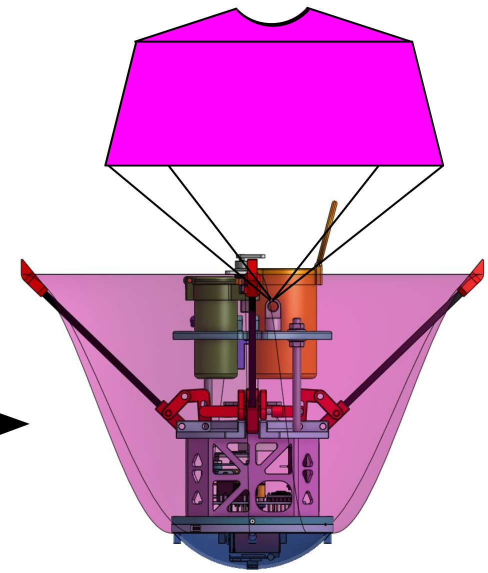


Container and Probe:
Parachute
725m-500m at 15m/s

Container: Parachute
500m to Ground

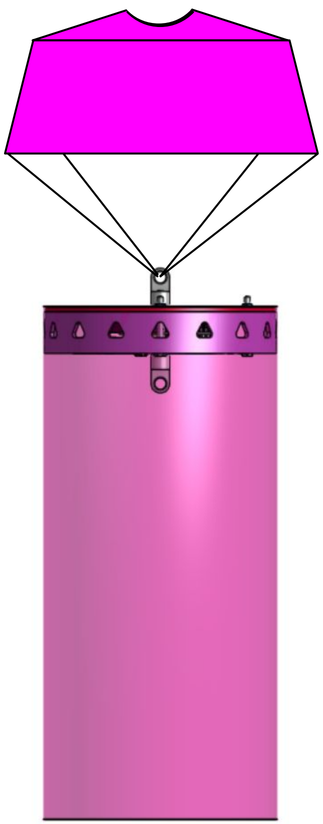


Probe: Heat Shield
500m-200m at 20m/s



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

Container Descent Control Strategy Selection and Trade



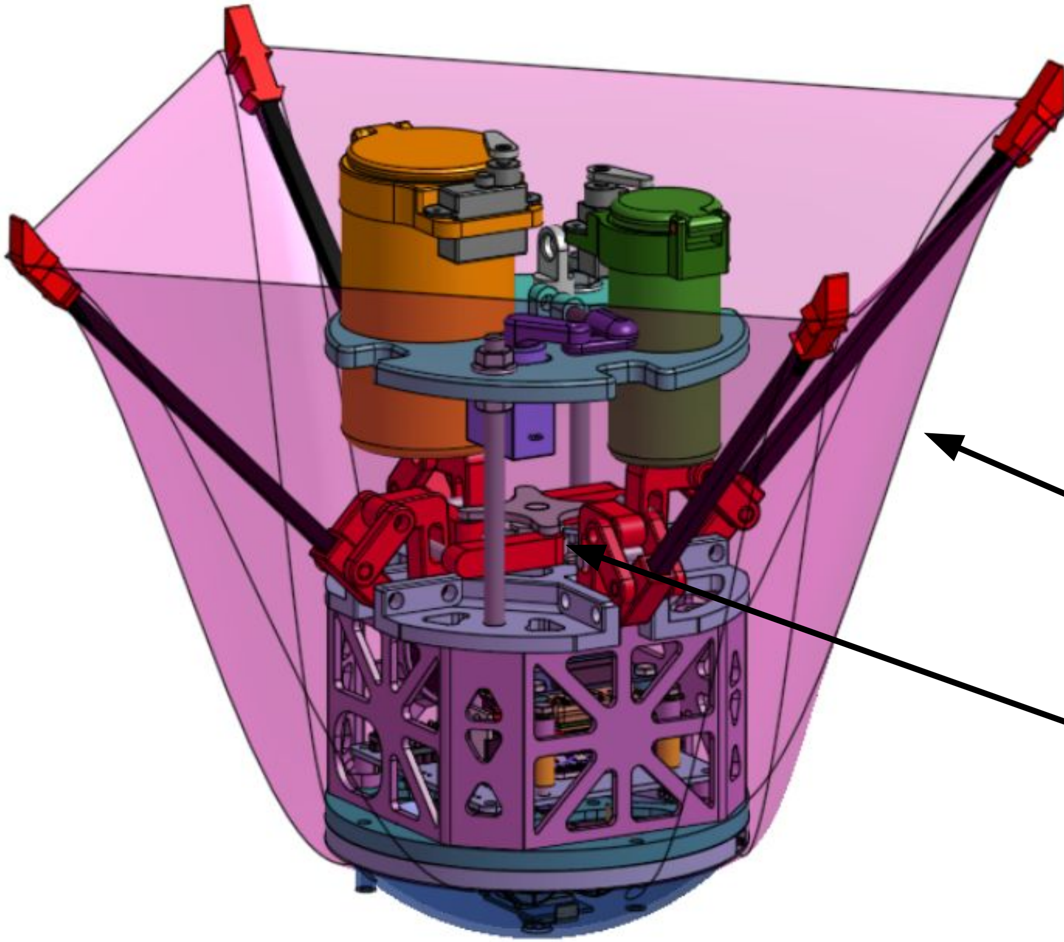
Shape	Mass (g)	Average Angle of Oscillation (Degrees)	Paracord Lines
Hexagonal	20	±10 to ±15	6
Round	23	±10 to ±40	4

Material	Tensile Strength (psi)	Porosity (%)	Price ($/yd^2)	Density (g/m^3)
Ripstop Nylon	72,519	25.8	9	48
Silk	87,023	35.0	22	35

<u>Shape Selection</u>: Hexagonal
- Less oscillation during freefall
- Easy to manufacture
- Lighter

<u>Material Selection:</u> Nylon
- Lower porosity produces more drag
- High tensile strength
- Cost effective

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



4 Arm 1 Servo Design

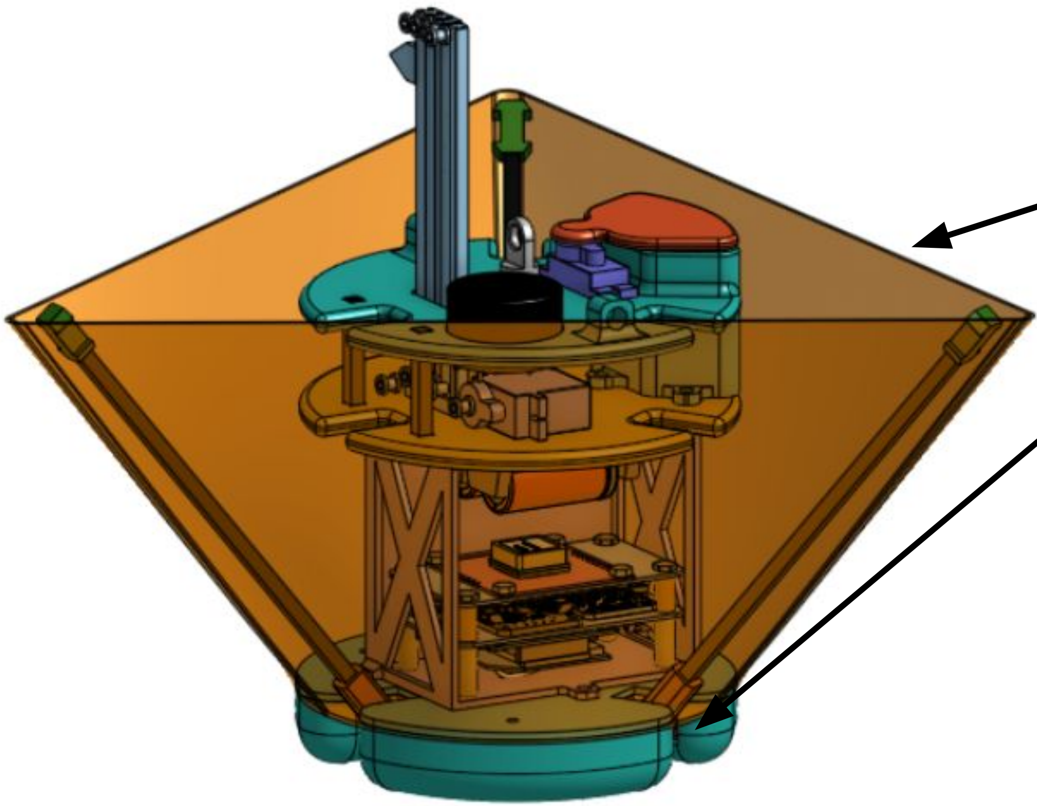
Mechanism is actuated to change heat shield surface area from stowed to deployed

Ripstop Nylon Aerobraking Heat shield

Single servo deployment mechanism

Passive stabilization

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



3 Arm 3 Servo Design

Ripstop Nylon Aerobraking Heat Shield

3 Servo Deployment Mechanism

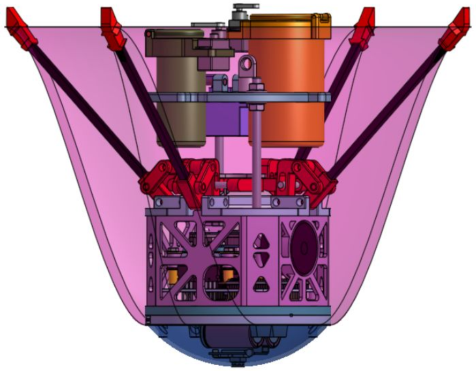
Independent control of arms allows manipulation of size and shape of the heat shield for uprighting

Active stabilization

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

Design	Stabilization	Heat Shield Area (cm^2)	Deployment Power Consumption (mWh)	Heat Shield Arm Count
Design 1: 4 Arm 1 Servo System	• **Passive** • Reliant on center of mass staying below center of drag	425	46	4
Design 2: 3 Arm 3 Servo System	• **Active** • Independent control of arms to combat swaying	325	108	3

Selection: Design 1 (4 Arm 1 Servo)
- Reduced power consumption
- Stronger rod attachment
- Fourth arm gives more attachment points for the heat shield, increasing its surface area and stability



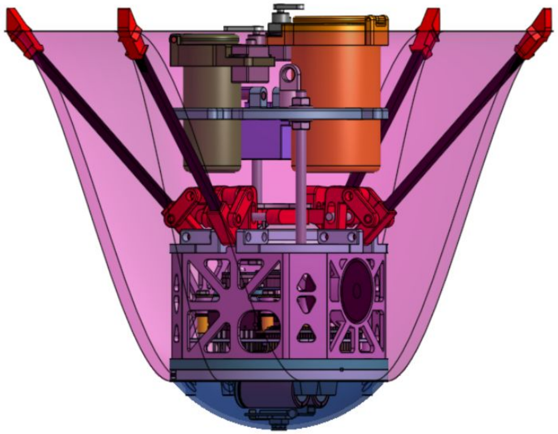
Payload Aerobraking Descent Stability Control Strategy Selection and Trade

Design	Stabilization	Heat Shield Control Actuation	Heat Shield Servo Count	Cross-sectional Area
Design 1: 4 Arm 1 Servo System	• **Passive** • Reliant on center of mass staying below center of drag	Diameter	1	Square
Design 2: 3 Arm 3 Servo System	• **Active** • Independent control of arms to combat swaying	Diameter and Shape	3	Triangle

<u>Selection</u>: Passive Control

- Decreased stability, design, and programming time
- Reduced power consumption due to lower servo motor count
- Square cross section increases stability

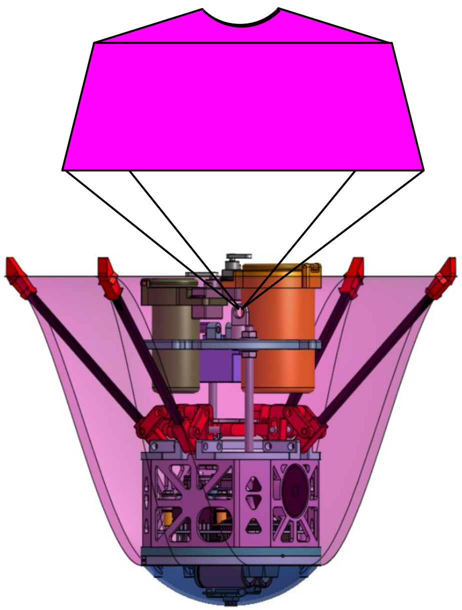
Design 1 (4 Arm 1 Servo) utilizes passive control



Payload Parachute Descent Control Strategy Selection and Trade

Shape	Mass (g)	Average Angle of Oscillation (Degrees)	Paracord Lines
Hexagonal	20	±10 to ±15	6
Round	23	±10 to ±40	4

Material	Tensile Strength (psi)	Porosity (%)	Price ($/yd^2)	Density (g/m^2)
Ripstop Nylon	72,519	0	9	48
Silk	87,023	35	22	35



<u>Shape Selection</u>: Hexagonal
- Reduced oscillation during freefall
- Easy to manufacture
- 3 grams lighter

<u>Material Selection:</u> Nylon
- Zero porosity produces more drag
- High tensile strength
- Cost effective

Both payloads utilize hexagonal shape, ripstop nylon, and spill hole design for their parachute

Descent Rate Estimates (1 of 3)

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 3)

Assumptions & Variables

- CanSat is 700g
- Probe is 500g
- Heat shield is a tetrahedron
- Heat shield area is smaller due to having only three attachment points

- **m** = mass
- **g** = gravitational acceleration = 9.8 m/s^2
- **D** = parachute diameter
- **ρ** = air density = 1.3 kg/m^3
- **C_D**= coefficient of drag (estimated)
- **v** = velocity

Competing Configuration Calculations

Container and Probe Parachute

$$v = \sqrt{\frac{8(.7kg)(9.8\frac{m}{s^2})}{(1.3\frac{kg}{m^3})\pi(.21m)^2(1.5)}} = 14.3\ \frac{m}{s}$$

Probe Aerobraking Heatshield

$$v = \sqrt{\frac{2(.5kg)(9.8\frac{m}{s^2})}{(1.3\frac{kg}{m^3})(3.25x10^{-2}\ m^2)(.666)}} = 18.7\ \frac{m}{s}$$

Probe Parachute

$$v = \sqrt{\frac{8(.5kg)(9.8\frac{m}{s^2})}{(1.3\frac{kg}{m^3})\pi(.55m)^2(1.5)}} = 4.60\ \frac{m}{s}$$

Assumptions & Variables

- CanSat is 700g
- Probe is 500g
- Heat shield is a square truncated pyramid
- Heat shield area is larger due to having four attachment points

- **m** = mass
- **g** = gravitational acceleration = 9.8 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 and Probe Parachute

$$v = \sqrt{\frac{8(.7kg)(9.8\frac{m}{s^2})}{(1.3\frac{kg}{m^3})\pi(.21m)^2(1.5)}} = 14.3\ \frac{m}{s}$$

Probe Aerobraking Heatshield

$$v = \sqrt{\frac{8(.5kg)(9.8\frac{m}{s^2})}{(1.3\frac{kg}{m^3})(4.25x10^{-2}\ m^2)(1.5)}} = 16.3\ \frac{m}{s}$$

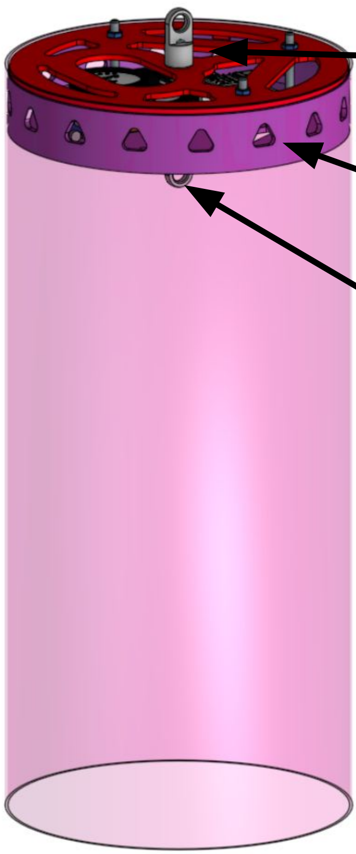
Probe Parachute

$$v = \sqrt{\frac{8(.5kg)(9.8\frac{m}{s^2})}{(1.3\frac{kg}{m^3})\pi(.55m)^2(1.5)}} = 4.60\ \frac{m}{s}$$

Mechanical Subsystem Design

Presented by Elena Dishman, Kyle Hughes, & Cole Lenhart

Selected Container: Container A



Parachute Attachment

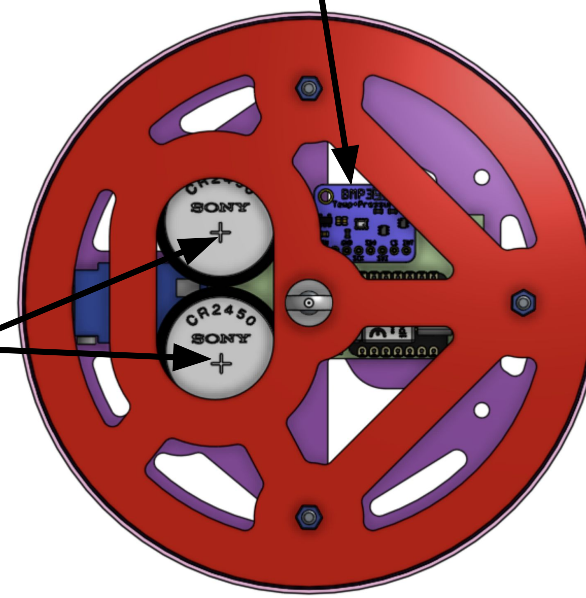
Container Electronics Housing with Bonus Camera

Payload Attachment

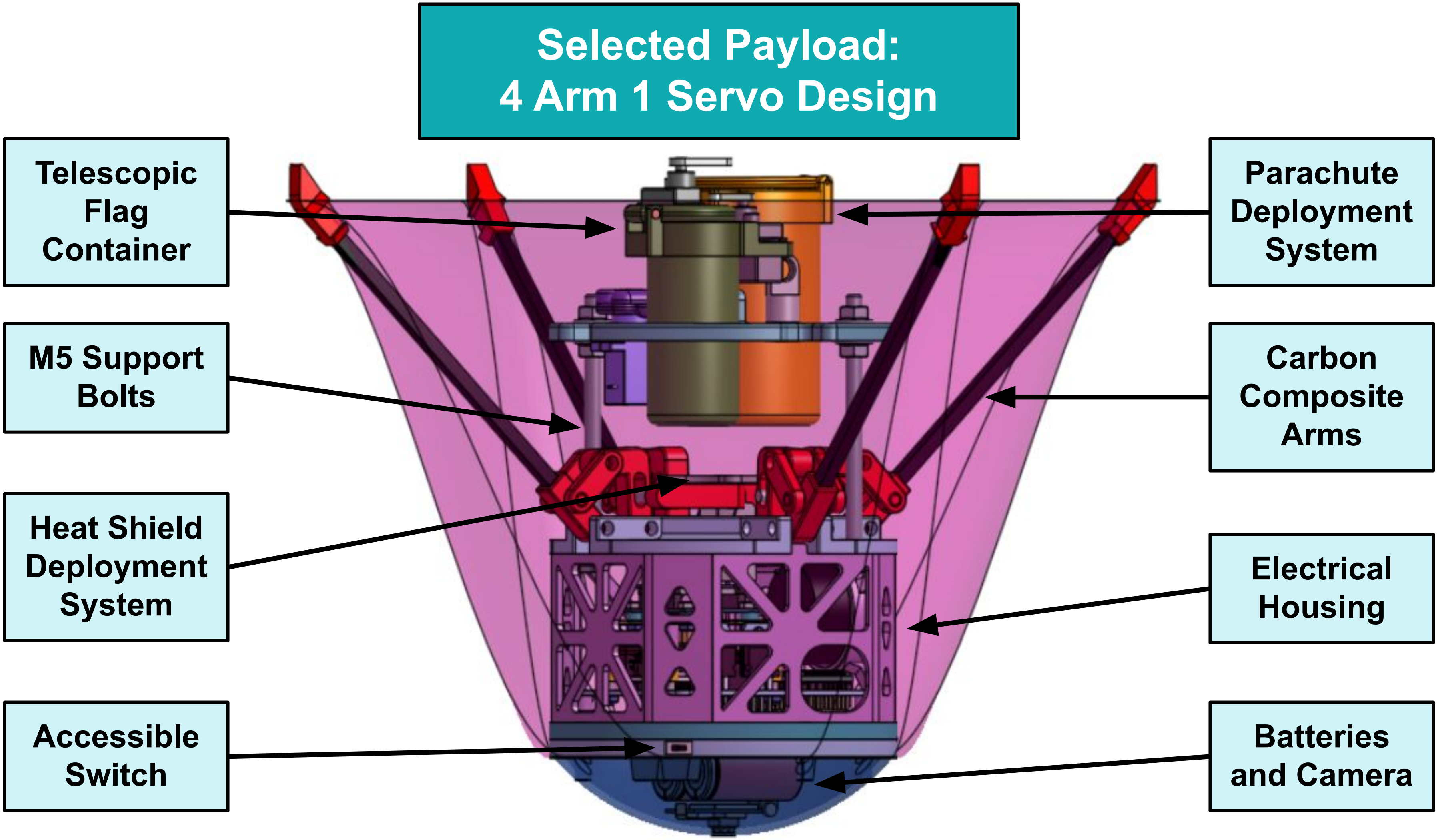
Removable Container Batteries

Fiberglass Shell

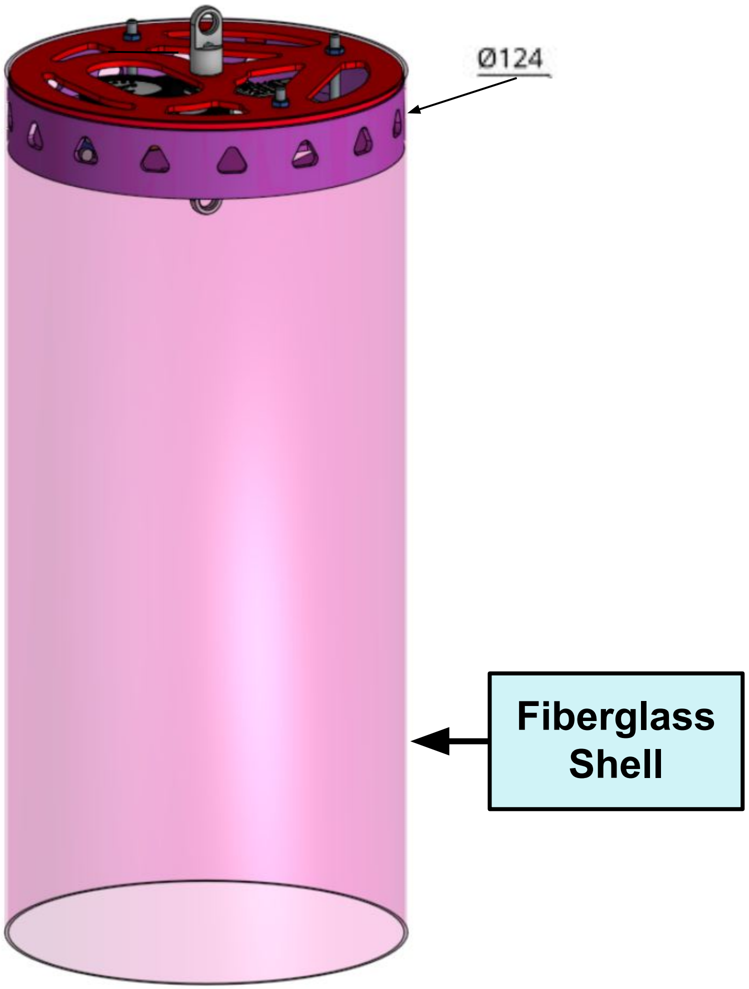
Electrical Subsystem for Bonus Camera



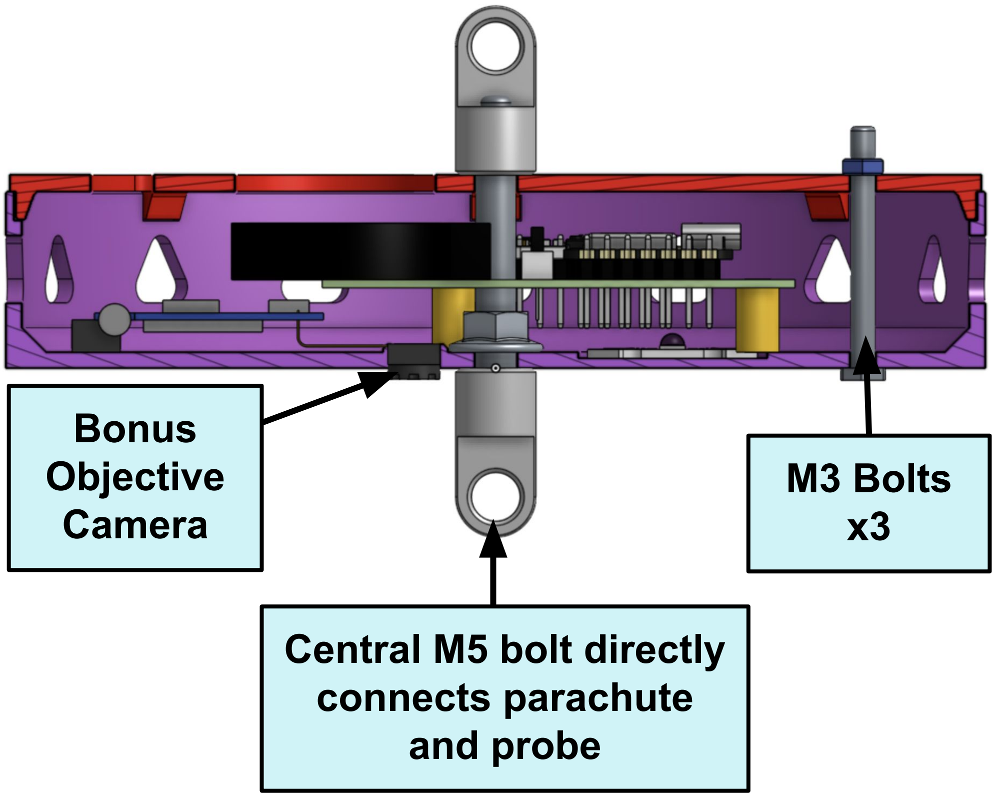
Mechanical Subsystem Overview (2 of 2)



Container A

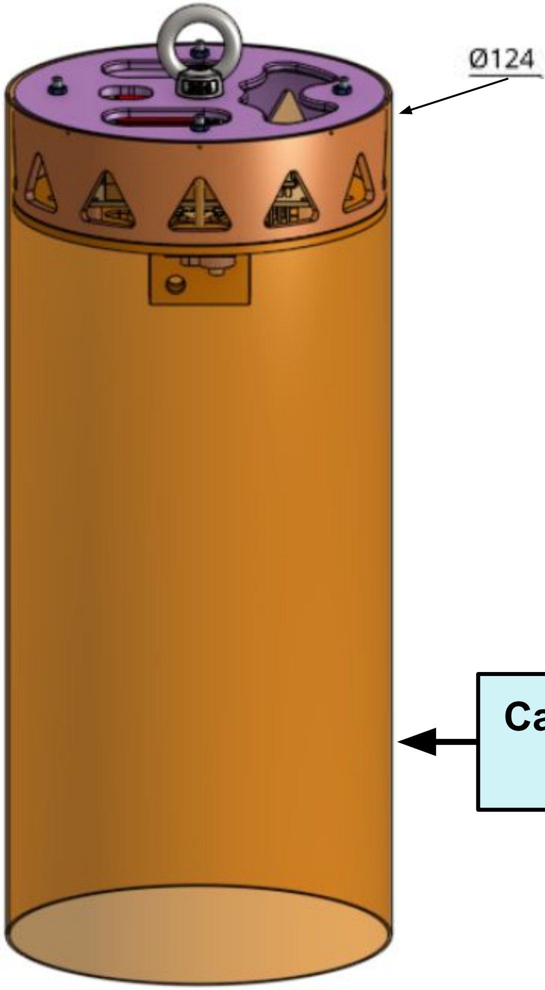


Section View

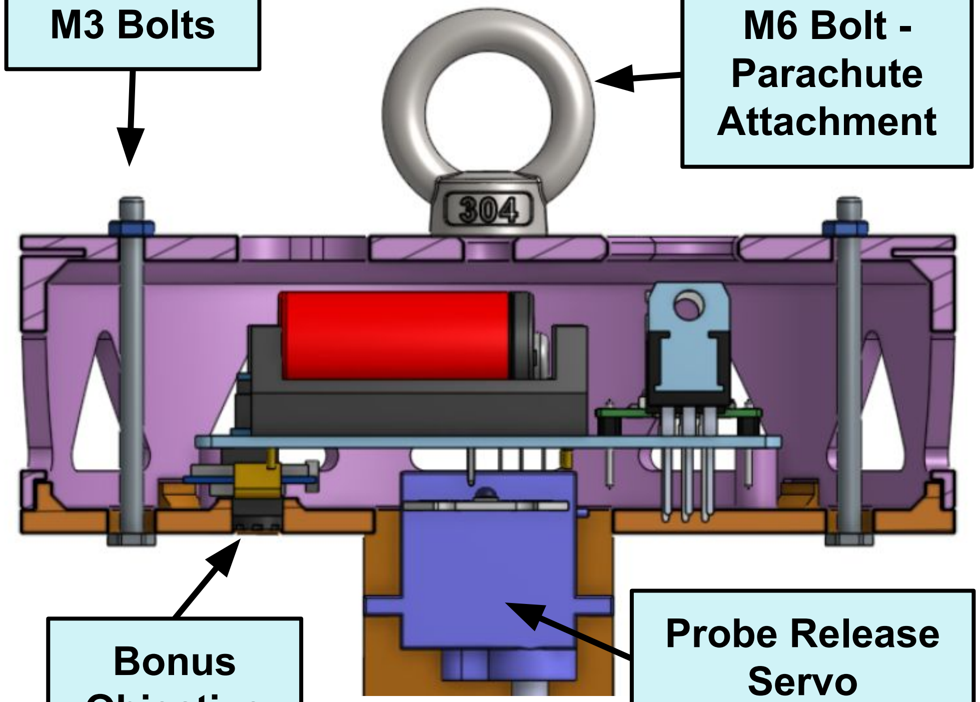


Note: Loctite used on all bolted connections

Container B



Section View

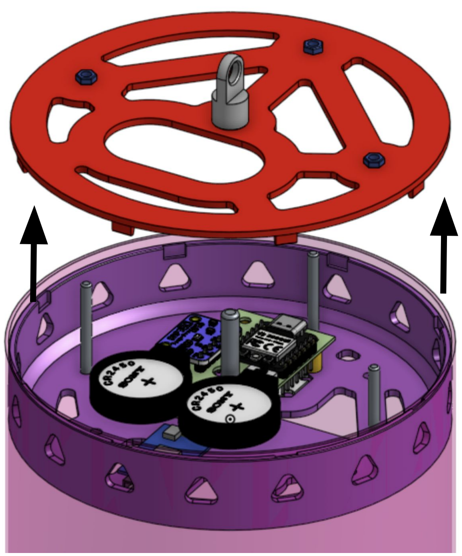


Note: Loctite used on all bolted connections

Container Mechanical Layout of Components Trade & Selection (3 of 3)

Container	Mass (g)	Length (mm)	Shell Material	Total Energy Consumption (Wh)
A	195.7	296	Fiberglass	1.5
B	269.8	309.5	Cardboard	4.9

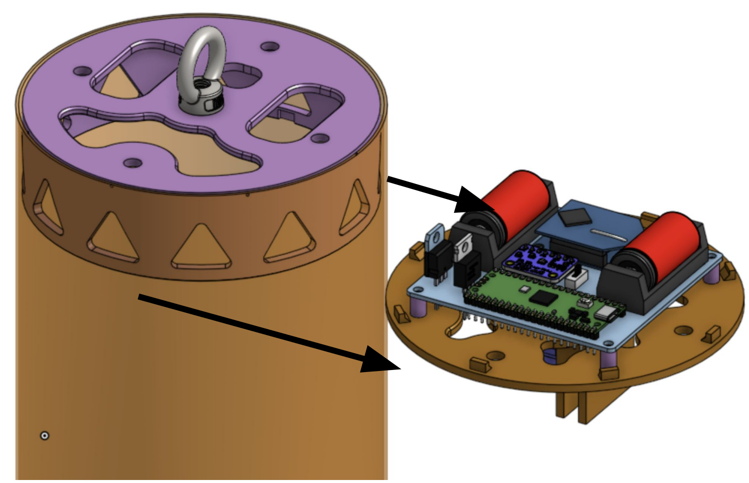
Container A



<u>Selection</u>: Container A
- Low power consumption
- Lightweight
- Durable fiberglass shell
- Reduced container length

The filament for all 3D prints will be PETG because:
- High tensile strength (7700 PSI)
- Low density (1.25g/cm^3)
- Easy manufacturing

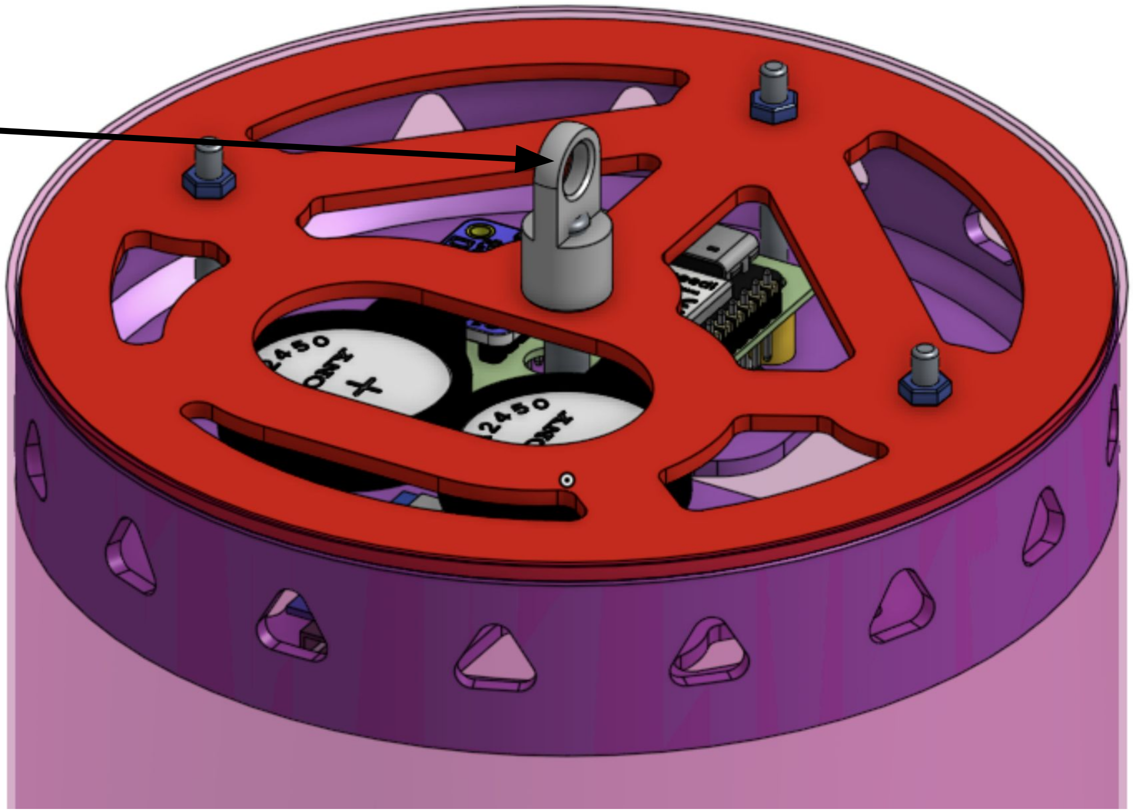
Container B



Container Parachute Attachment Mechanism

- Container parachute is attached via an M5 swiveling eye nut and bolt in the center of the container

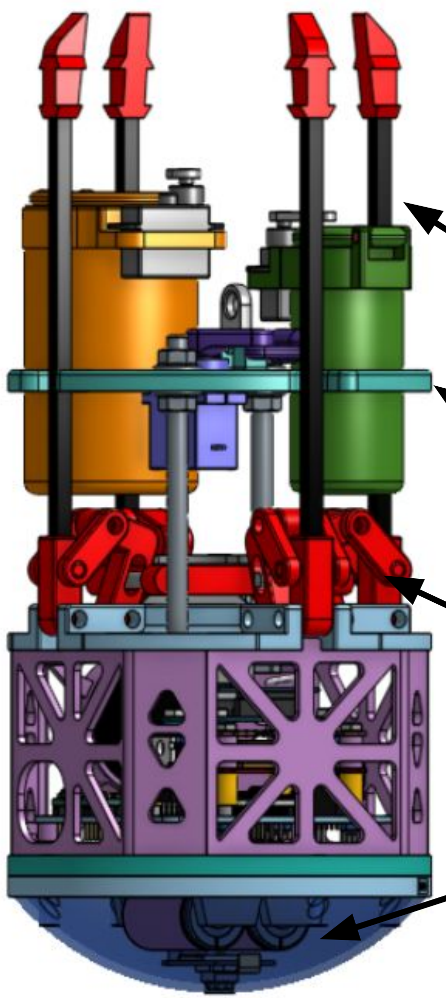
- Central bolt passes through PCB and directly connects to probe attachment point



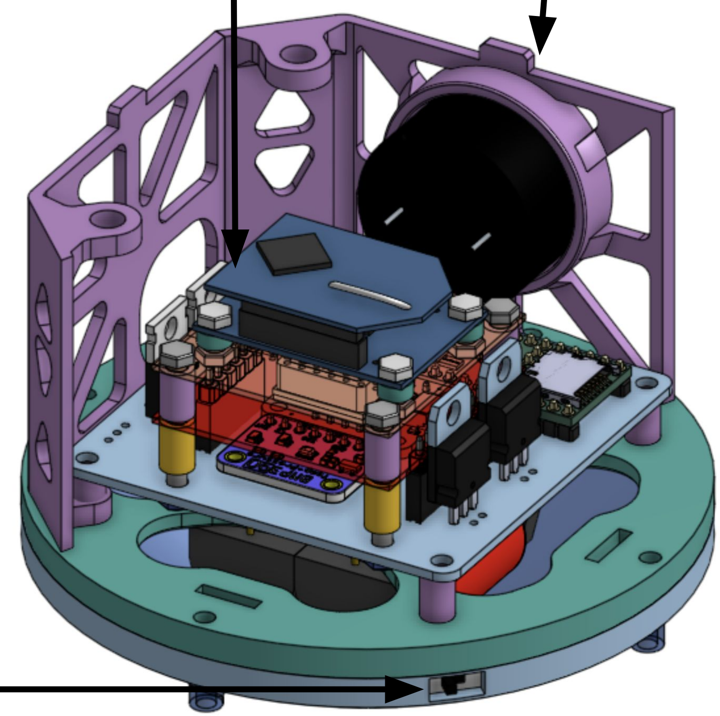
Note: The parachute will be folded in such a way that it can release passively after rocket separation

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

4 Arm 1 Servo Design



Stowed Configuration

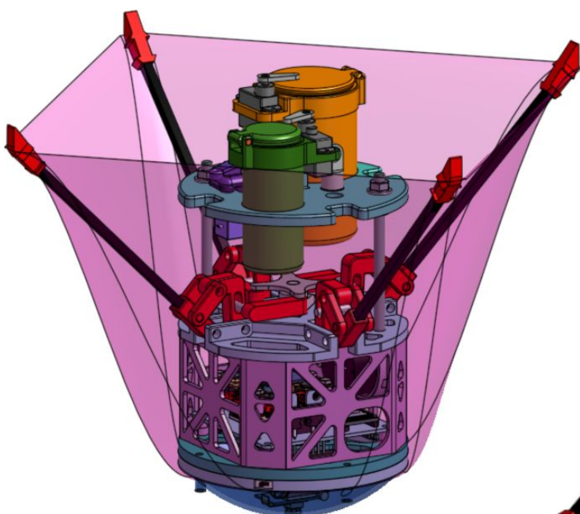


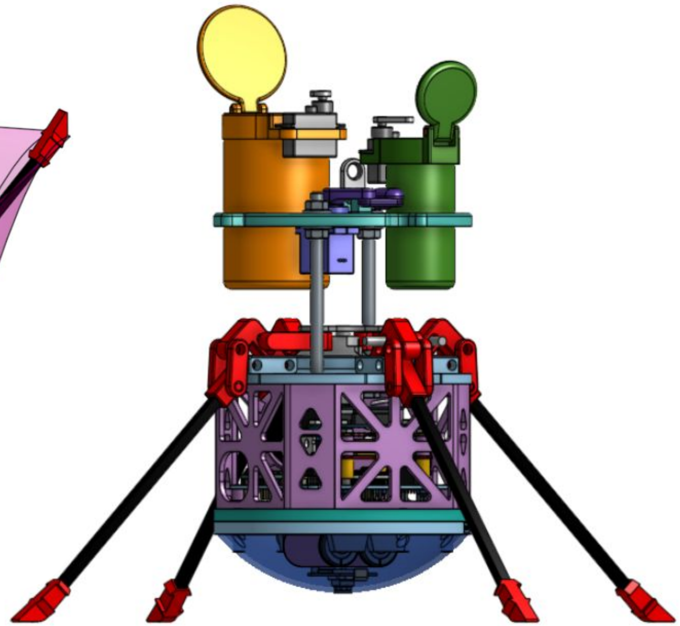
Payload Mechanical Layout of Components Trade & Selection (2 of 5)

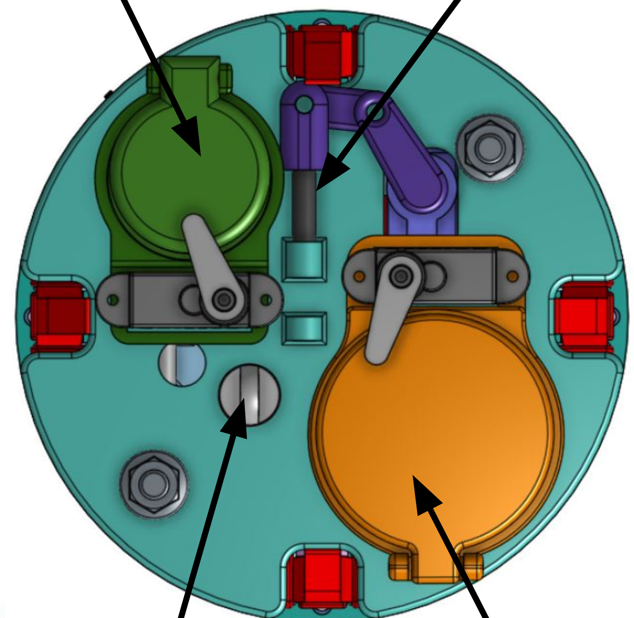
Heat shield is made of ripstop nylon

Spring-Loaded Telescopic Flag Release (500 mm)

Container Release Mechanism







Heat Shield Configuration

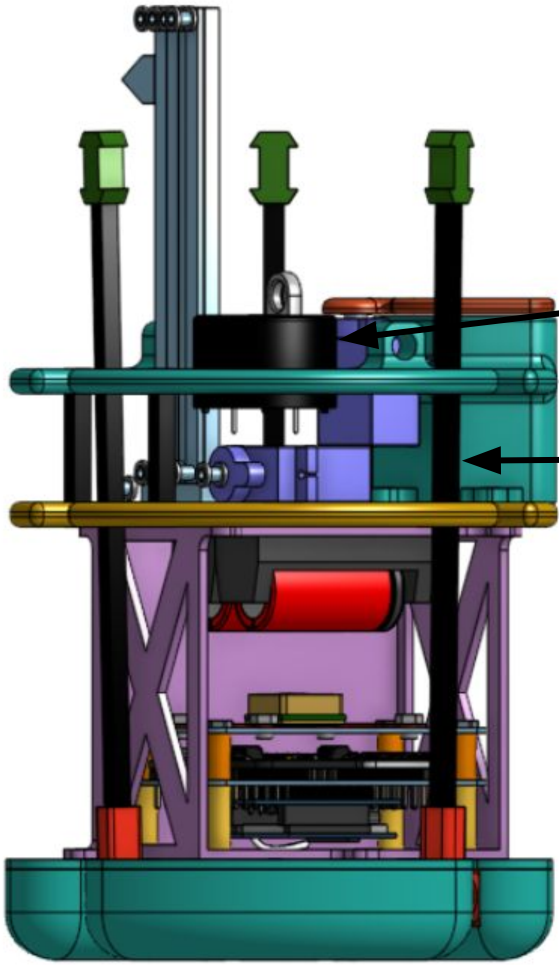
Uprighting Configuration

M5 Parachute Attachment

Parachute-Release Mechanism

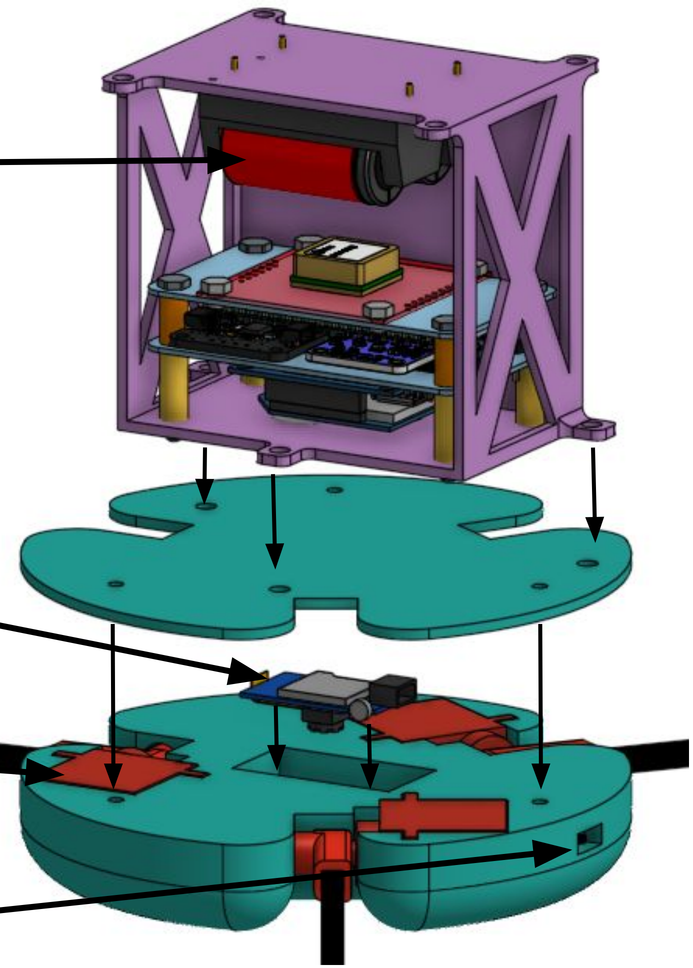
Payload Mechanical Layout of Components Trade & Selection (3 of 5)

Stowed Configuration



3 Arm 3 Servo Design

PCB & Electronics Housing



Batteries

Buzzer

Carbon Composite Heat Shield Arm

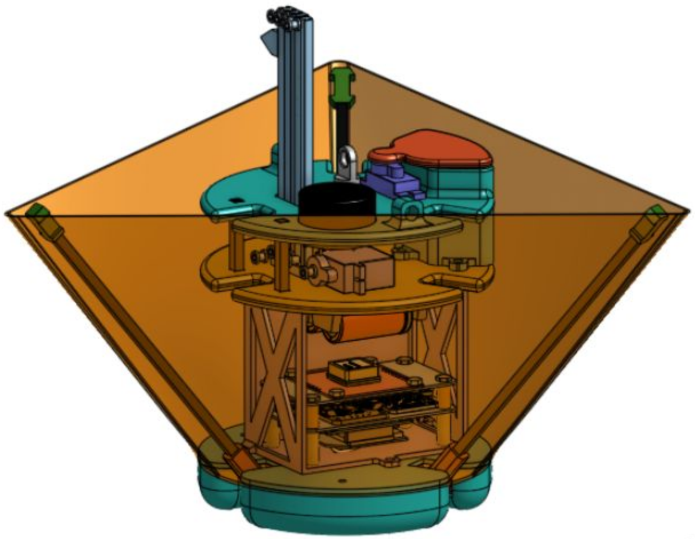
Camera

3 Servo Deployment System

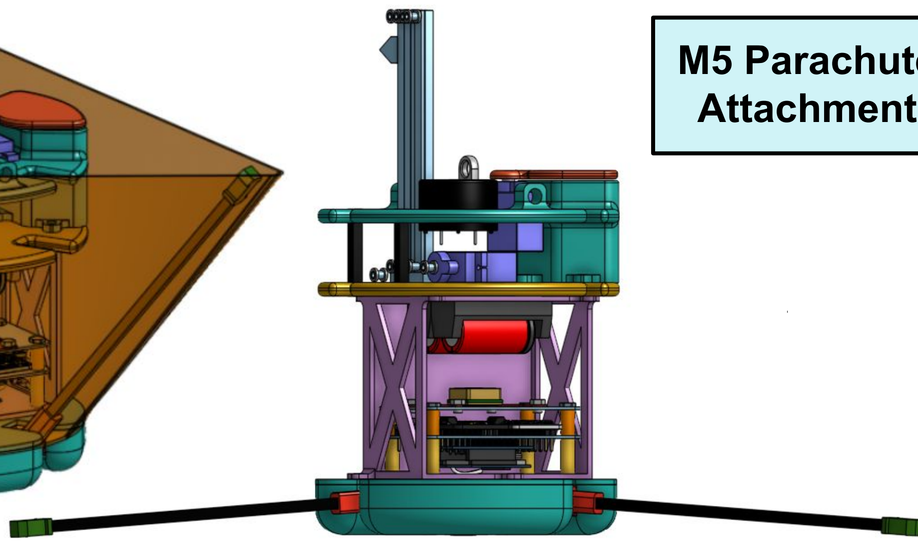
Switch

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

Heat shield is made of ripstop nylon



Heat Shield Configuration

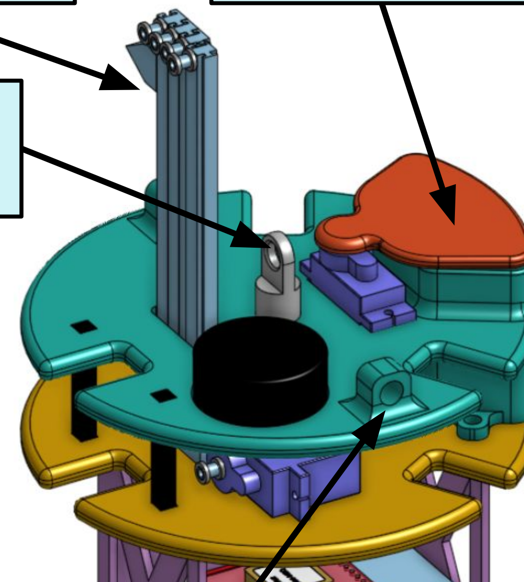


Uprighting Configuration

Servo-Actuated Cascading Rail Flag Mechanism

Servo-Actuated Plate Parachute Deployment

M5 Parachute Attachment



Probe Release Mechanism - Paracord attached to the probe and looped through a release system on container B

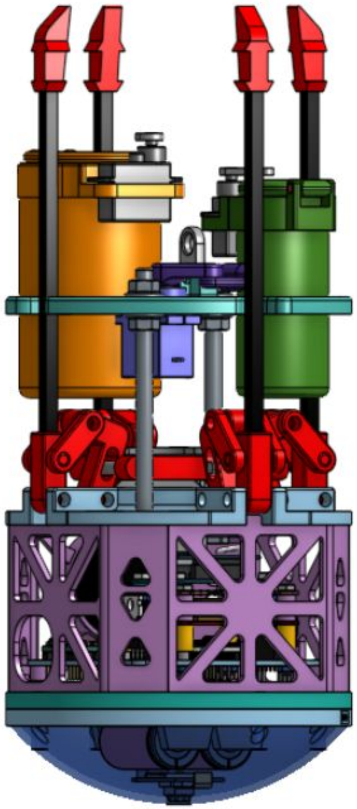
Payload Mechanical Layout of Components Trade & Selection (5 of 5)

Selection: 4 Arm 1 Servo Design

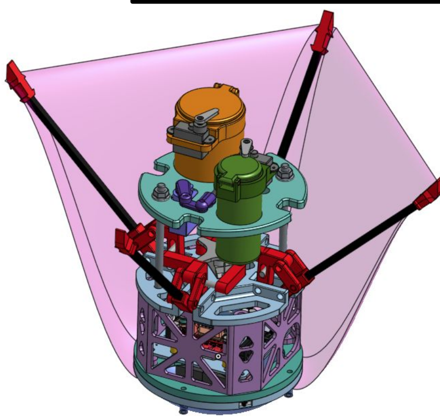
Design	Total Servos	Heart Shield Arms	Battery Access
4 Arm 1 Servo	4	4	Easy
3 Arm 3 Servo	6	3	Difficult

Selection: 4 Arm 1 Servo:

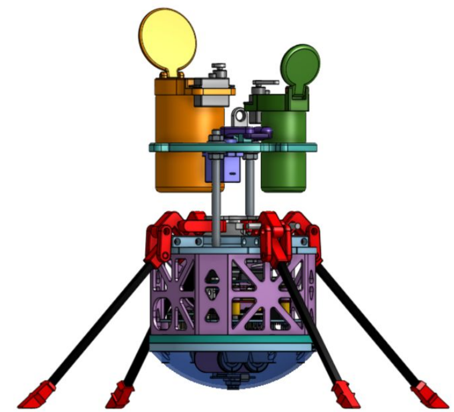
- Battery access time meets mission requirements
- Reduced power draw due to lower servo count
- Additional heat shield arms supports CanSat during launch and landing



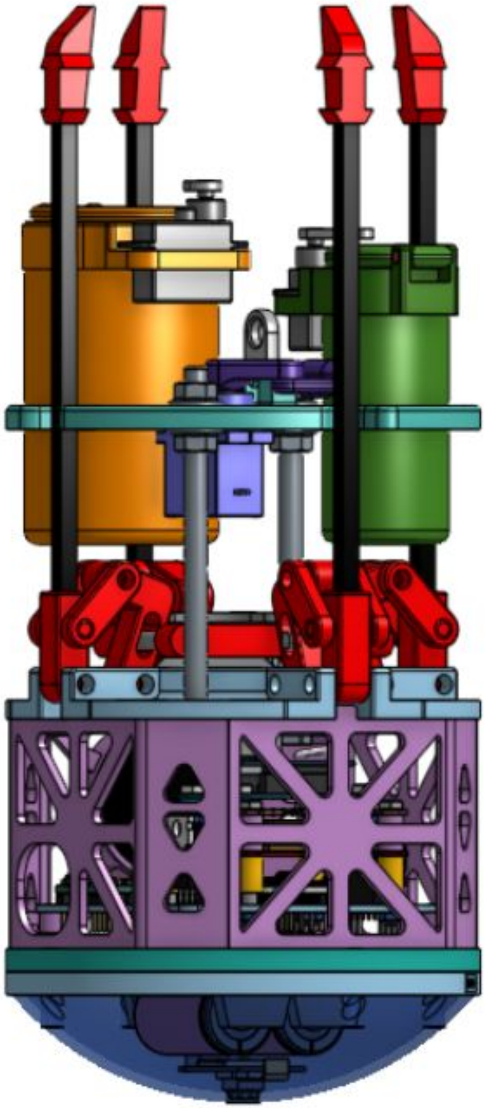
Stowed Configuration



Heat Shield Configuration



Uprighting Configuration



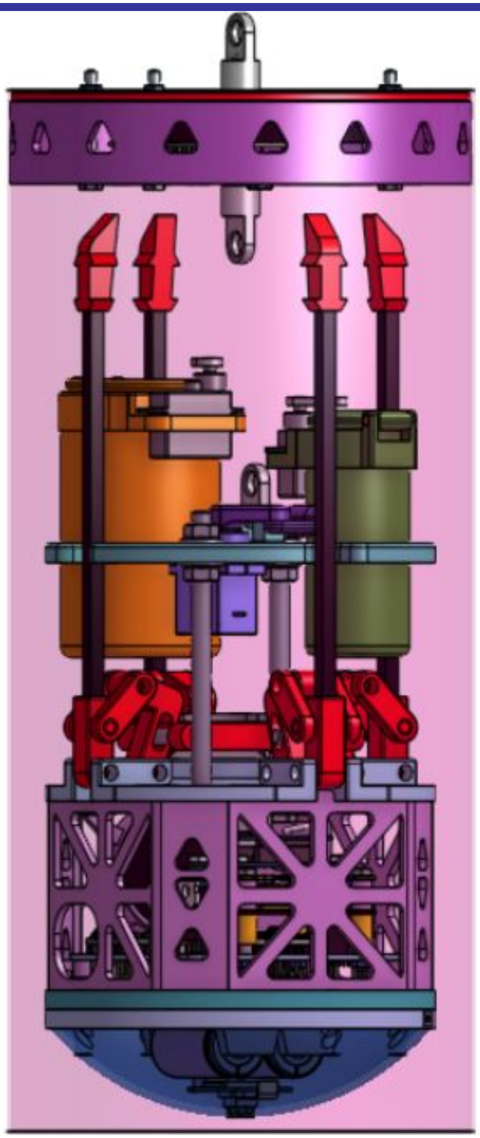
4 Arm 1 Servo System

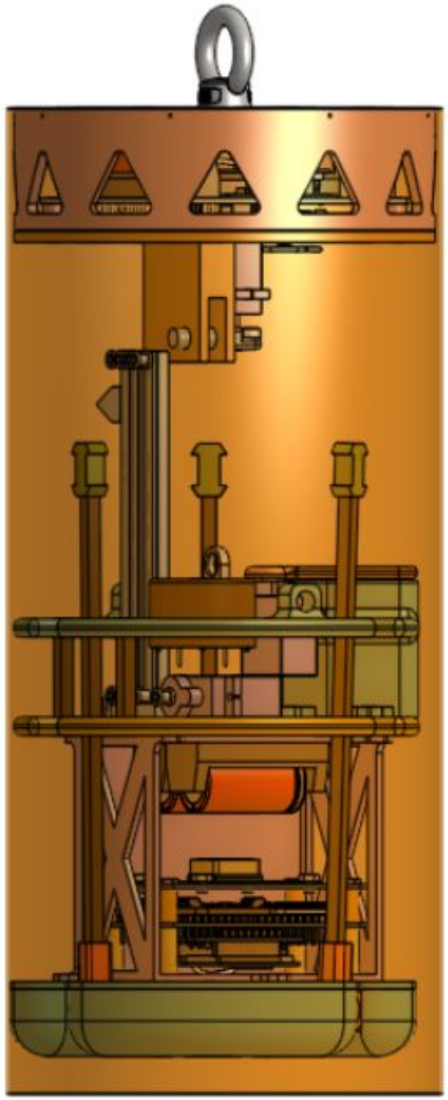
Pros

- Greater radial clearance for deployment from container
- Low chance of nylon interfering with probe components

Cons

- Possibility of heat shield arms sliding on container walls
- Deployment mechanism supports mass of CanSat during launch





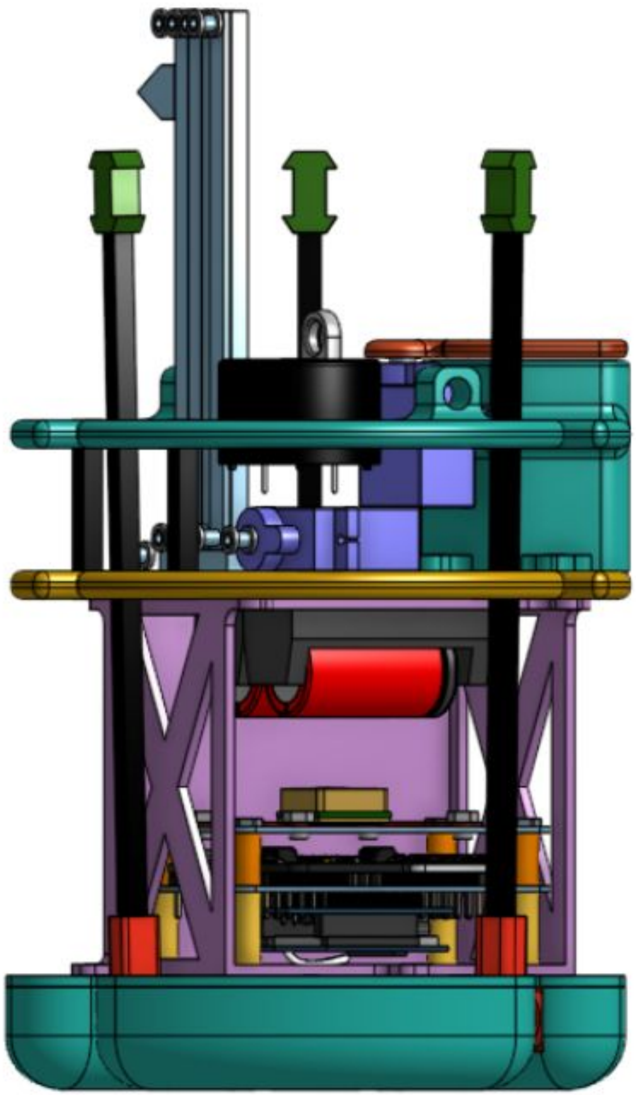
3 Arm 3 Servo System

Pros

- Plates act as sliding surface
- Heat shield arms are completely vertical and protected by plates

Cons

- Increased probability of heat shield material getting caught on plates
- Flag raising mechanism potentially interferes with container during launch

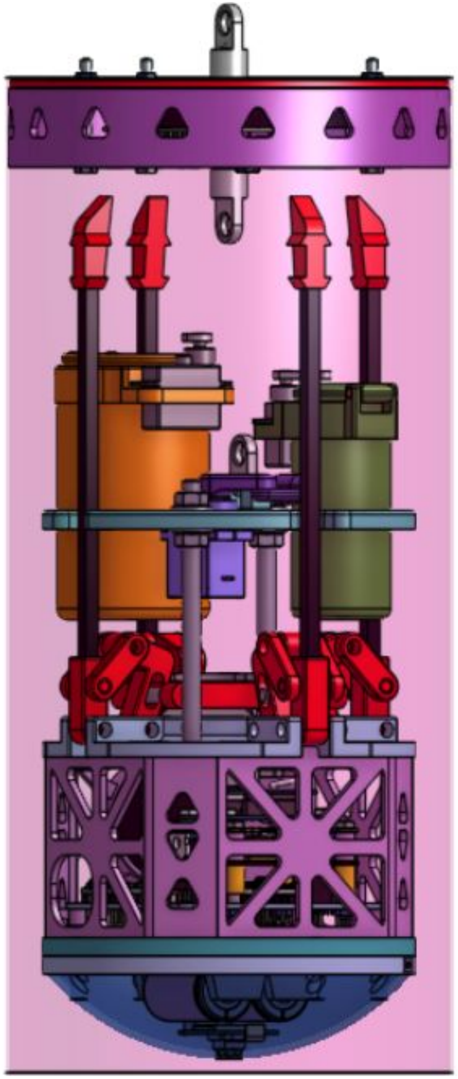


Payload Aerobraking Pre Deployment Configuration Trade & Selection (3 of 3)

Selection: 4 Arm 1 Servo System

Design	Probe Diameter (mm)	Nylon Pinch Points	Launch Force per Contact Point (N)
4 Arm 1 Servo	103	No	36.8
3 Arm 3 Servo	115	Yes	147

Rationale:
- Greater radial clearance for deployment from container
- Low chance of nylon interfering with probe components
- Four points of contact of deployment system supports CanSat while upside down instead of flag mechanism

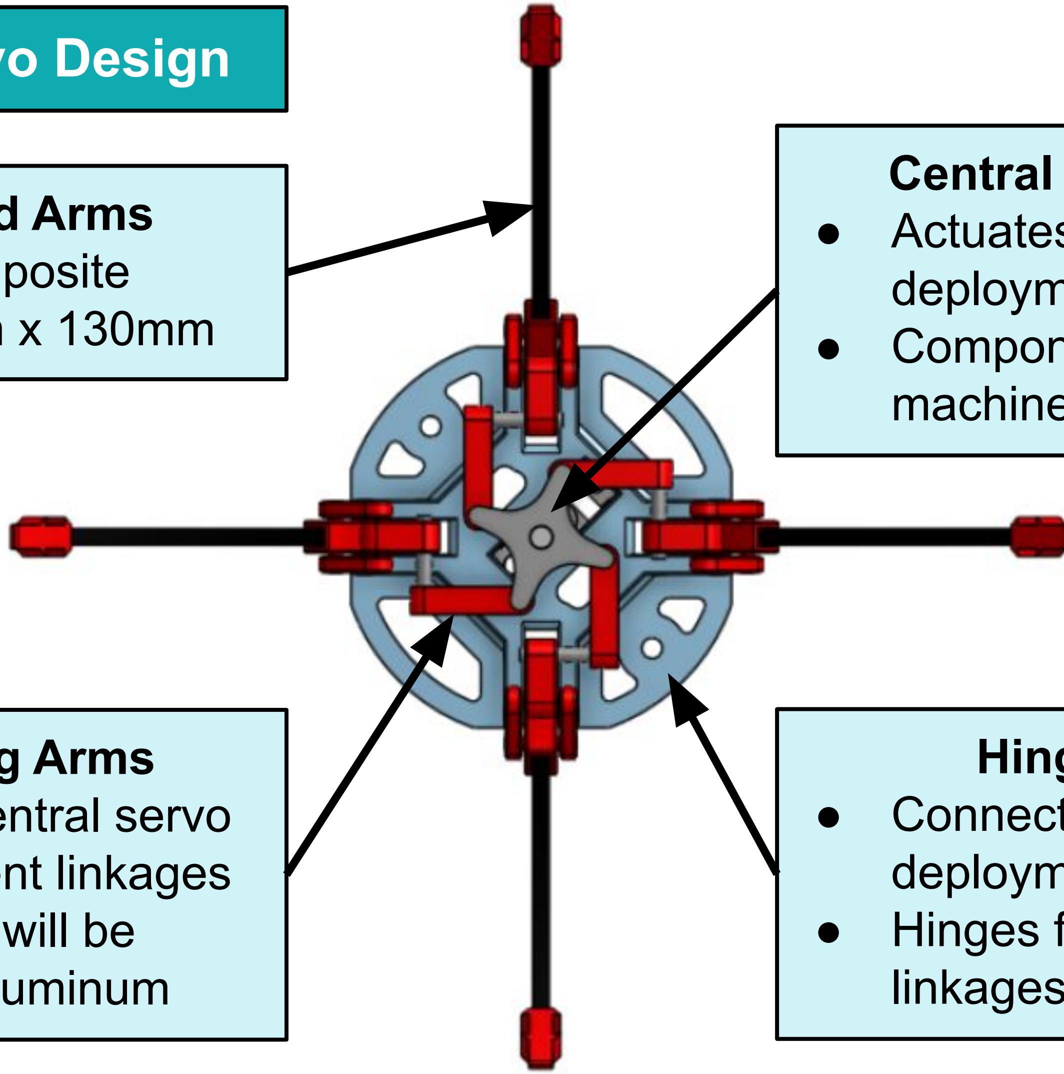


Payload Aerobraking Deployment Configuration Trade & Selection (1 of 3)

4 Arm 1 Servo Design

Heat Shield Arms
- Carbon composite
- 4mm x 4mm x 130mm

Central Servo Horn
- Actuates heatshield deployment mechanism
- Component will be machined aluminum



Connecting Arms
- Connects central servo to deployment linkages
- Component will be machined aluminum

Hinge Plate
- Connects heat shield deployment to CanSat
- Hinges for deployment linkages

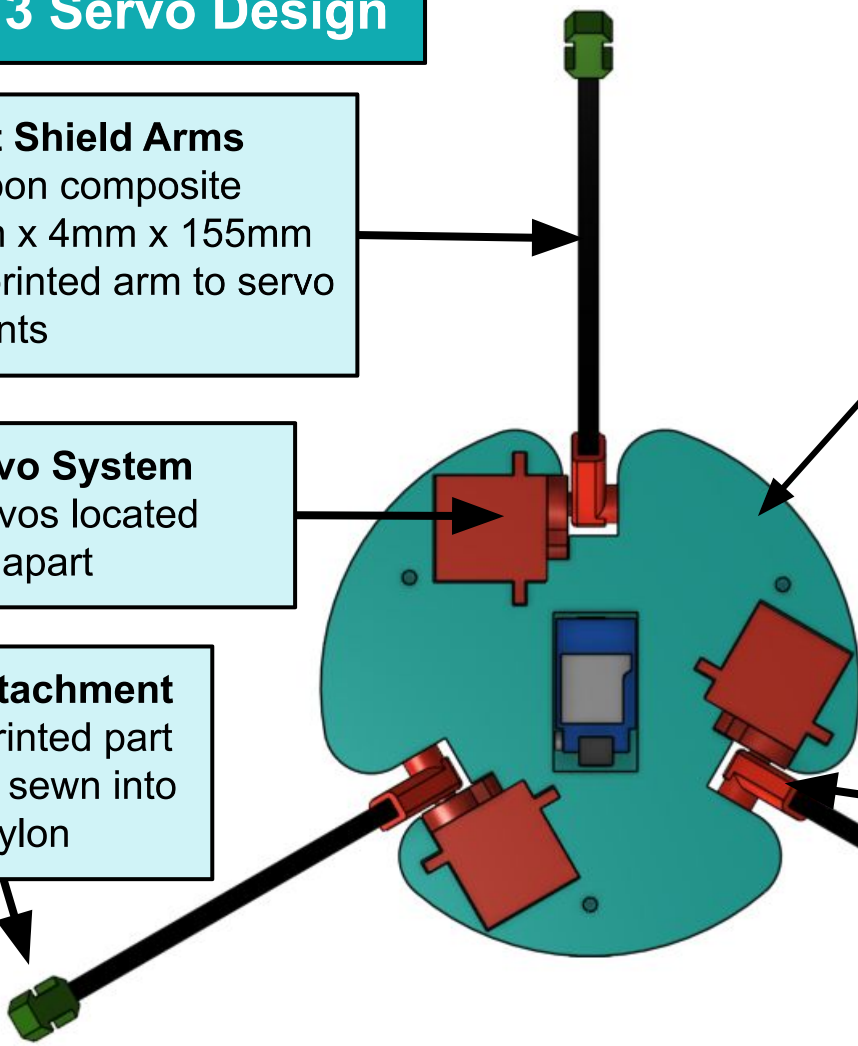
Payload Aerobraking Deployment Configuration Trade & Selection (2 of 3)

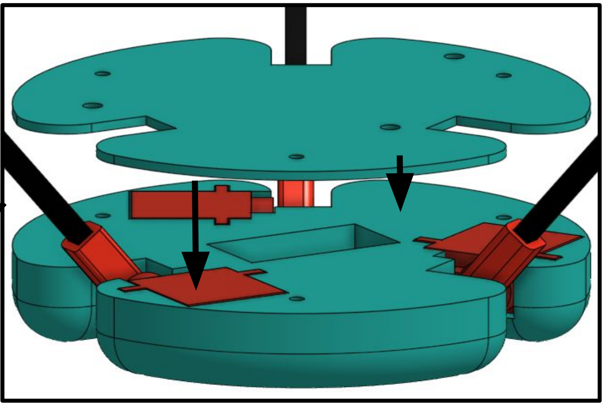
3 Arm 3 Servo Design

Heat Shield Arms
- Carbon composite
- 4mm x 4mm x 155mm
- 3D printed arm to servo mounts

3 Servo System
- 3 servos located 120° apart

Nylon Attachment
- 3D printed part to be sewn into the nylon



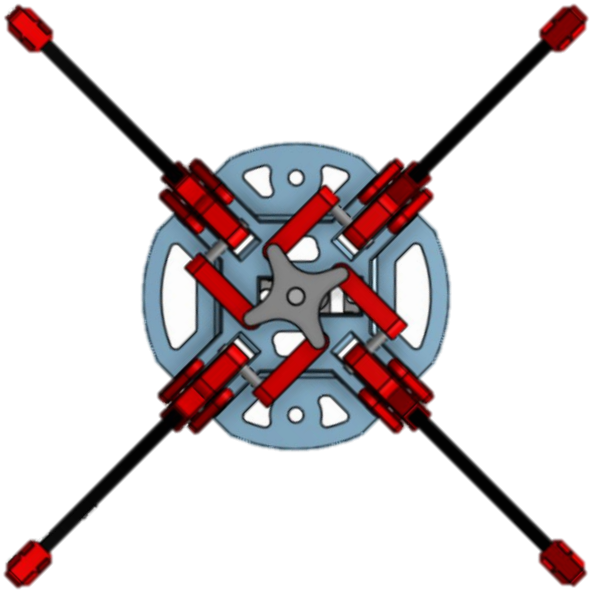


Base Plates 1 & 2
- Provides mounting for servos to the rest of the CanSat

Servo Hinges
- Runs through the opening in the base plate
- Supports servo and heat shield arm

Selection: 4 Arm 1 Servo Design

Design	Number of Servos	Area When Deployed (mm^2)	Application of Force
4 Arm 1 Servo	1	42,500	Arms and Hinges
3 Arm 3 Servo	3	32,500	Servo

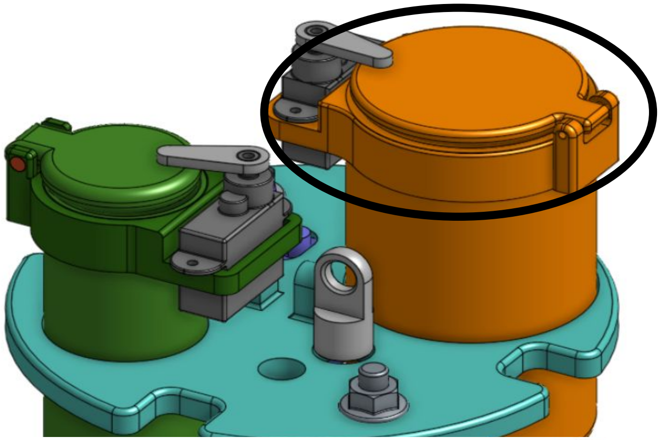


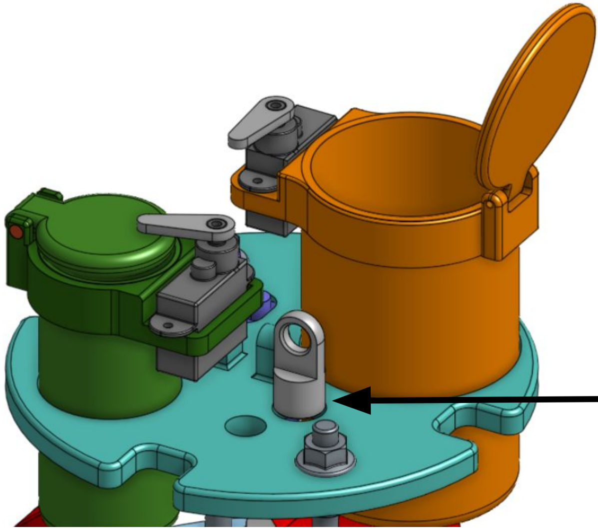
- Single servo reduces mass and failure points
- Strong points of attachment for arms
- Additional arm increases support and surface area of heat shield

Option 1

Mortar Release

- Servo holds container lid closed
- Servo turns and allows parachute to be ejected by a spring and piston





Mortar Deployment
- Fast Parachute Deployment
- Reliable spring mechanism
- Large footprint on top plate

M5 Eye Nut Probe Parachute Attachment

Option 2

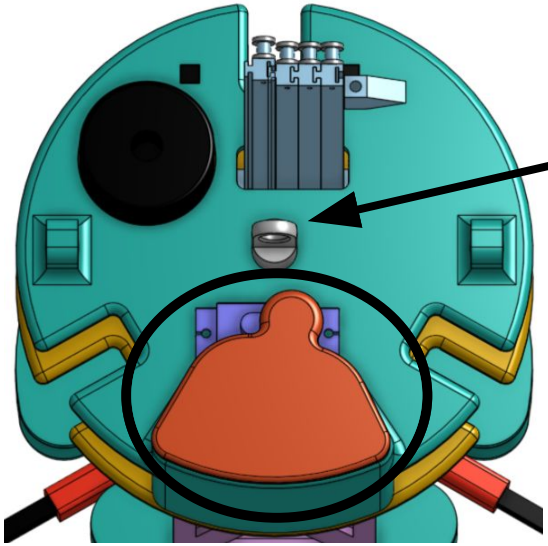
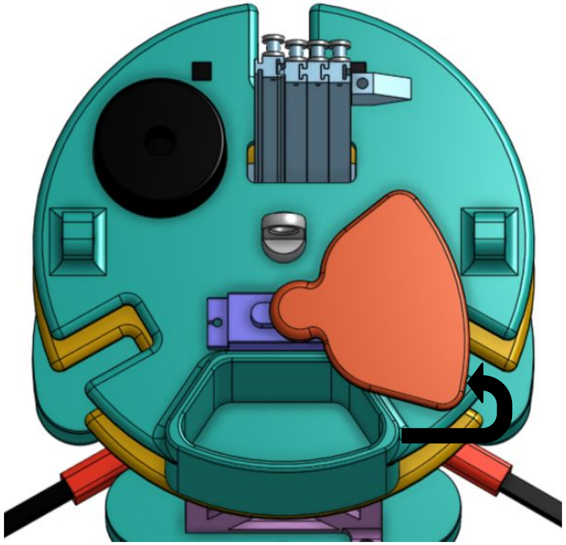


Plate & Servo Parachute Release

- Servo is connected to a plate that holds the parachute in a storage compartment
- Servo turns and allows the parachute to catch air and unfold



Servo Plate Release

- Higher chance of entanglement
- Moving plate could collide with CanSat components
- Chance of unfolding while stowed

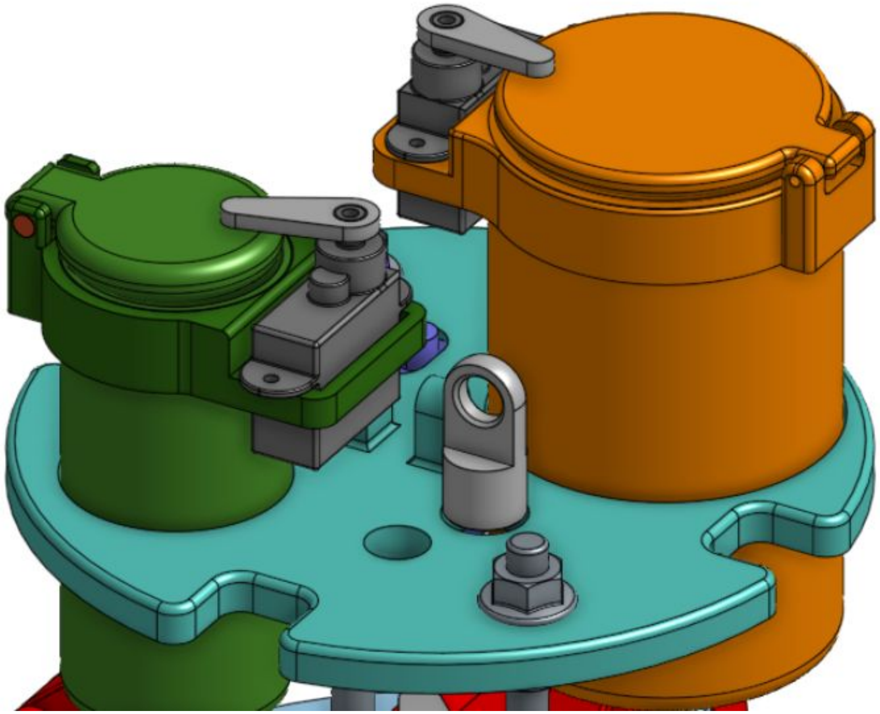
Payload Parachute Deployment Configuration Trade & Selection (3 of 3)

Design	Deployment Style	Area When Deployed (mm^2)	Volume (mm^3)
Mortar Release	Spring actuated	1392.05	67,512
Plate and Servo Release	Relies on wind	2631.07	32,485

Selection: Mortar Release

- Low chance of entanglement
- Parachute is firmly held in compartment
- More consistent releases due to spring release

4 Arm 1 Servo System utilizes mortar release

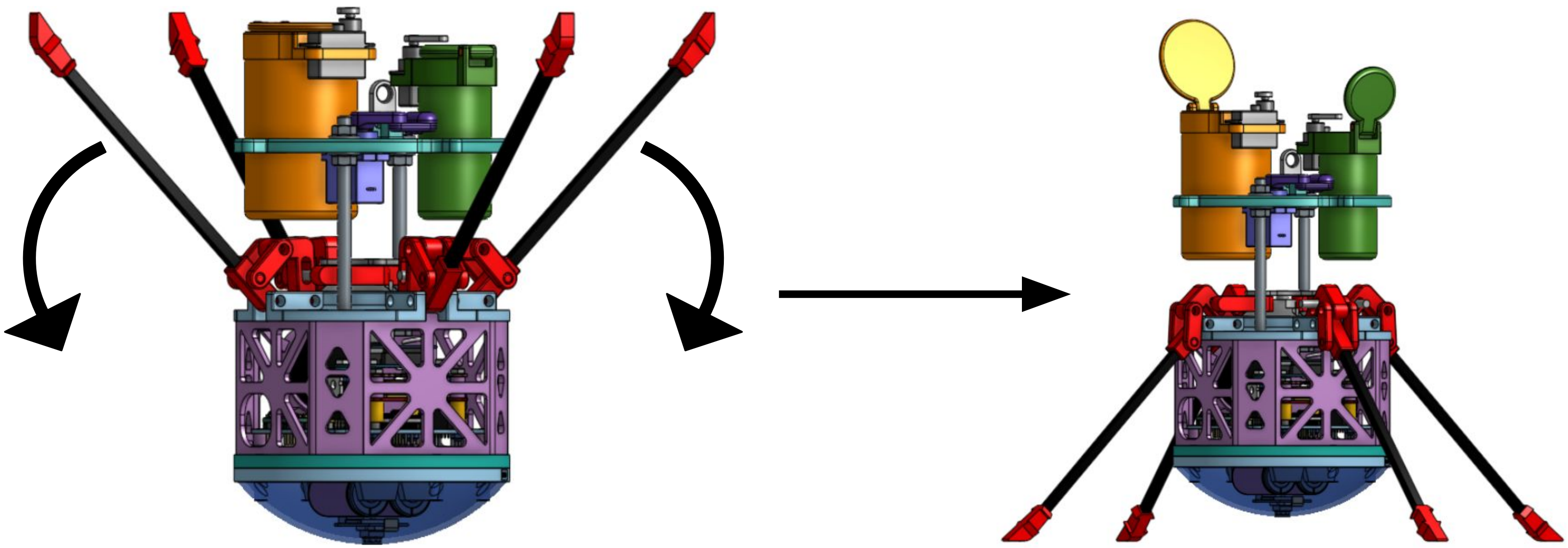


Payload Uprighting
Configuration Trade & Selection (1 of 3)

4 Arm 1 Servo Design

Pros
- Deployment mechanism linkages bear the landed weight instead of the servo
- Low center of mass eases uprighting action

Cons
- Narrow base when landed
- Extra heat shield material is folded back
- Only 2 threaded rods securing top plate and base during force of landing



Heat Shield Orientation

Upright Orientation

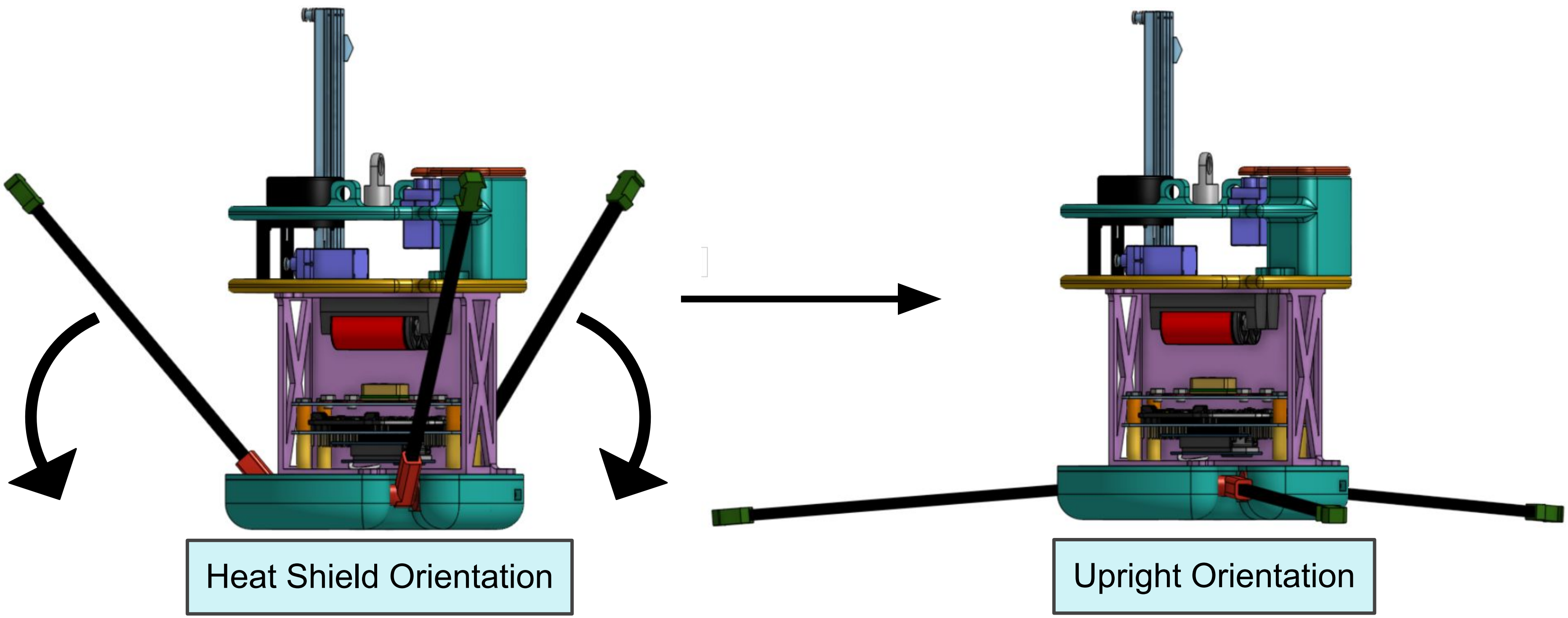
3 Arm 3 Servo Design

Pros

- Wide base when upright
- Servos can actuate independently of each other in case of failure

Cons

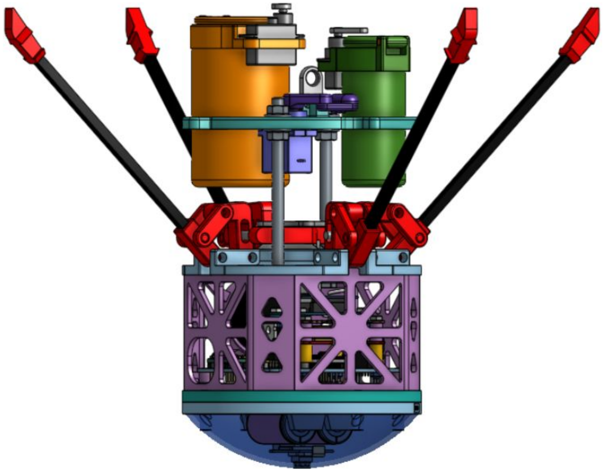
- Servo motor horns are stress points when when uprighting
- Only 3 uprighting arms

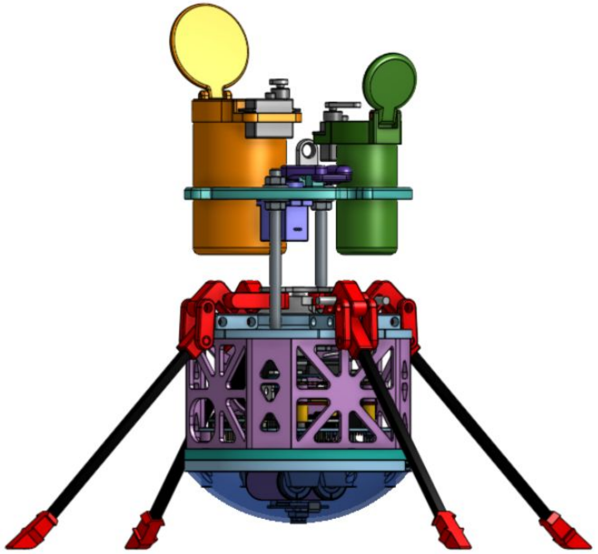


Selection: 4 Arm 1 Servo Design

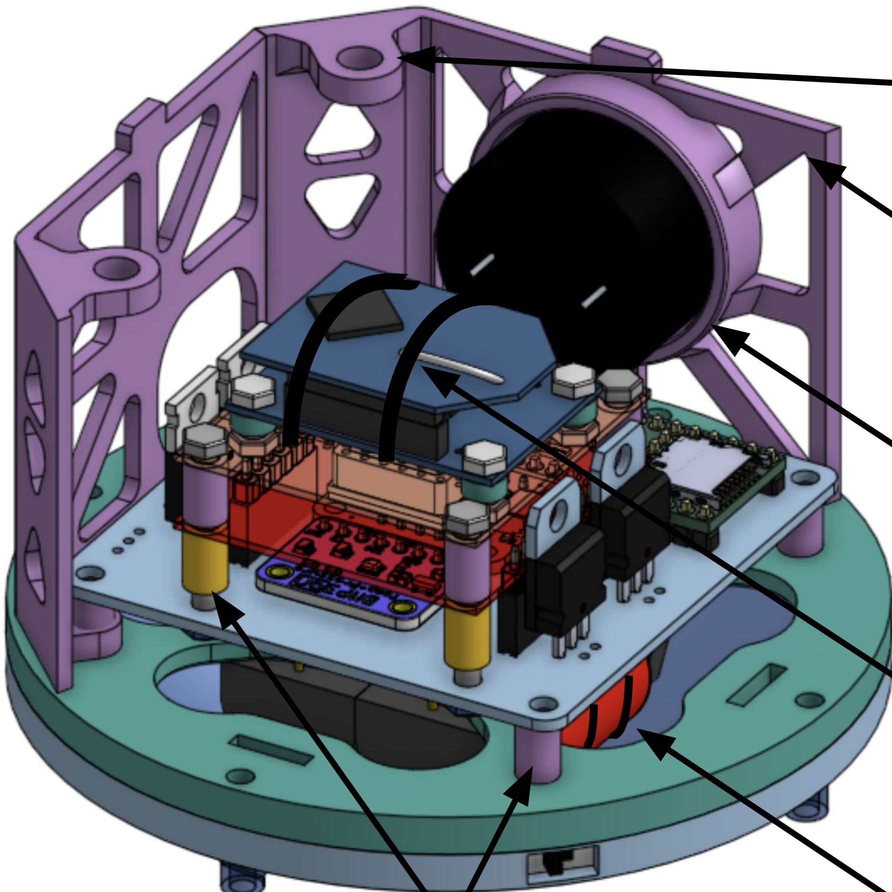
Servo Count	Footprint (mm^2)	Heat Shield Arms	Landing Shape
1	45,800	4	Square
3	50,600	3	Triangle

Rationale:
- Distribution of landing force throughout deployment mechanism linkages rather than servo horns
- 4 heat shield arms provides additional uprighting capability and points of contact with ground





Electronics Structural Integrity



Mounting holes that attach electronics housing to the decent mechanism above

Housing surrounds each side of the PCB and major electrical systems

>100 dB Buzzer superglued and press fit to electronics housing

Two zip ties used to secure XBee to its board

Two zip ties around batteries 3D printed camera mount (Not Pictured)

All primary electronic components and the PCB use screws and standoffs to secure to the probe

Mass Budget (1 of 7)

Container (1 of 2)

Component	Quantity	Mass (g)	Mass Summary (g)	Source
Seeed RP 2040	1	0.8	0.8	Datasheet
Adafruit Spycamera	1	2.8	2.8	Datasheet
BMP390	1	3.0	3.0	Measured
P-Channel MOSFET	1	2.0	2.0	Measured
CR2450 Battery	2	6.2	12.4	Datasheet
Switch	1	2.0	2.0	Measured
Small PCB	1	6.0	6.0	Measured
Battery Holders	2	2.0	4.0	Measured
(Wires, Solder, Misc)	1	10.0	10.0	Estimate
Electrical Total	**-**	**-**	**41.0**	**-**

Mass Budget (2 of 7)

Container (2 of 2)

Component	Quantity	Mass (g)	Mass Summary (g)	Source
Fiberglass Shell	1	60.0	60.0	Measured
M5 40mm Threaded Rod	1	4.4	4.4	Manufacturer
M5 Eye Nuts	2	7.0	14.0	Manufacturer
M5 Nuts	1	1.7	1.7	Manufacturer
Nylon Parachute	1	15	15	Estimate
Container Wafer Top	1	43.2	43.2	Estimate
Container Wafer Bottom	1	16.4	16.4	Estimate
Mechanical Total	**-**	**-**	**154.7**	**-**
Electrical Total	**-**	**-**	**41.0**	**-**
Container Total	**-**	**-**	**195.7**	**-**

Mass Budget (3 of 7)

Probe (1 of 4)

Component	Quantity	Mass (g)	Mass Summary (g)	Source
Teensy 4.1	1	2.8	2.8	Datasheet
Adafruit Spycamera	1	2.8	2.8	Datasheet
BMP390	1	3.0	3.0	Measured
SAM-M8Q (GPS)	1	6.0	6.0	Datasheet
BNO055 (IMU/Tilt Sensor)	1	3.0	3.0	Datasheet
XBee Pro 900 HP	1	6.0	6.0	Datasheet
XBee Explorer Breakout Board	1	5.0	5.0	Datasheet
Linear 5.0V Regulator	1	2.0	2.0	Measured
LED	1	2.0	2.0	Datasheet
Buzzer Piezo 3V 30MM	1	8.0	8.0	Datasheet
Slide Total	**-**	**-**	**42.1**	**-**

Mass Budget (4 of 7)

Probe (2 of 4)

Component	Quantity	Mass (g)	Mass Summary (g)	Source
Previous Slide	**-**	**-**	**42.1**	**-**
Switch	1	2.0	2.0	Measured
CR2032	1	3.0	3.0	Datasheet
P-Channel MOSFET	2	2.0	4.0	Measured
CR123A Battery	2	16.0	32.0	Datasheet
Battery Holder	2	4.0	8.0	Measured
PCB	1	15.0	15.0	Measured
Analog Feedback Micro Servo	1	15.8	15.8	Datasheet
Micro Servo	3	8.4	25.2	Datasheet
(Wires, Capacitors, Resistors, Solder)	-	40.0	40.0	Estimate
Electrical Total	**-**	**-**	**187.1**	**-**

Mass Budget (5 of 7)

Probe (3 of 4)

Component	Quantity	Mass (g)	Mass Summary (g)	Source
Carbon Fiber Rods	4	4.0	16.0	Measured
M4 Bolts 80mm	2	6.8	13.6	Manufacturer
M4 Nuts	6	0.7	4.2	Manufacturer
Rigid PETG Tube 25mm	1	20.3	20.3	Estimate
Cardboard tube 229mm	1	41.4	41.4	Manufacturer
M5 Eye Nut	1	7.0	7.0	Manufacturer
M3 Bolts 20mm	4	3.85	15.4	Estimate
M3 Bolts 14mm	4	2.4	9.7	Manufacturer
Nylon Parachute	1	20.0	20.0	Estimate
Nylon Heat Shield	1	15.0	15.0	Estimate
Deployment Hinge Plate	1	28.7	28.7	Measured
Slide Total	**-**	**-**	**191.3**	**-**

Mass Budget (6 of 7)

Probe (4 of 4)

Component	Quantity	Mass (g)	Mass Summary (g)	Source
Previous Slide	**-**	**-**	**191.3**	**-**
Electrical enclosure	1	20.0	20.0	Measured
Top Plate	1	19.1	19.1	Estimate
Nose Cone	1	28.7	28.7	Estimate
Base Plate	1	17.0	17.0	Estimate
Flag Servo Mount	1	3.5	3.5	Estimate
Parachute Servo Mount	1	4.7	4.7	Estimate
3D Printed Deployment Components	1	25.7	25.7	Estimate
Metal Deployment Components	1	9.0	9.0	Estimate
Mechanical Total	**-**	**-**	**319.0**	**-**
Electrical Total	**-**	**-**	**187.1**	**-**
Probe Total	**-**	**-**	**506.1**	**-**

Mass Budget (7 of 7)

Probe Mass Total	506.1g
Container Mass Total	195.7g
CanSat Mass Total	**701.8g**

701.8 - 700.00 = +1.8
Above Ideal Mass of 700g
Within Mass limit of 690g-710g

Methods to reduce CanSat mass:

- Re-design container electronics housing
- Remove probe electronics housing and design a new buzzer mount
- Research alternative flag raising mechanisms

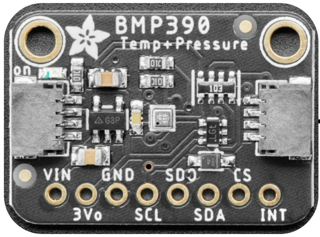
Methods to increase CanSat mass:

- Increase infill on 3D printed parts to increase structural integrity
- Add mass (washers) to nose cone to lower center of mass

Communication and Data Handling (CDH) Subsystem Design

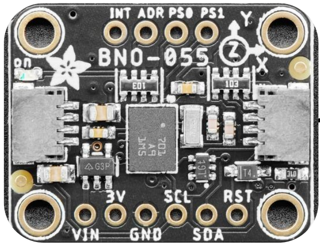
Presented by Brennan Begley and Emann Rivero

Payload Command Data Handler (CDH) Overview



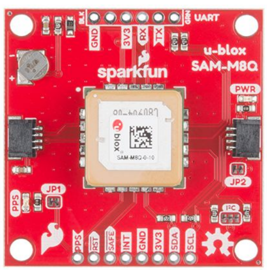
BMP390 (I²C)
Temperature
Pressure/Altitude

Image credit: Adafruit.com



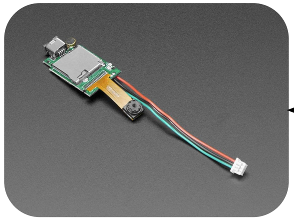
BNO055 (I²C)
Quaternion Angles
Acceleration XYZ

Image credit: Adafruit.com



SAM-M8Q (UART)
GPS Position
UTC Acquisition

Image credit: Sparkfun.com



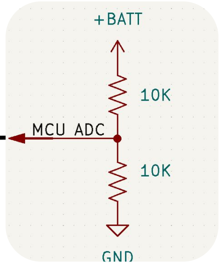
Spycamera (Digital)
Local Video Recording

Image credit: Adafruit.com

Image credit: pjrc.com

Teensy 4.1 (ARM Cortex-M7)
Compiles Data into Packets
Stores packets onto SD Card
Interprets Commands
Maintains mission time with RTC

Battery Voltage (Analog - ADC)
Battery Voltage



XBee Pro 900HP (UART)
Sends Packets
Relays Commands

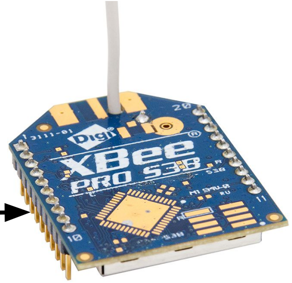


Image credit: Digi.com

To Ground Station (Wireless)

Payload Processor & Memory Trade & Selection

Module	Boot Time (ms)	Processor Speed (MHz)	RAM (KB)	Data Storage	Comm. Languages	Ports	Price ($)
Teensy 4.1 (ARM Cortex-M7)	5	600	1024	Yes	8 UART 3 SPI 3 I2C	55 digital input/output 35 PWM outputs 18 analog inputs	31.50
Raspberry Pi Pico (RP2040)	20	400	264	No	2 UART 2 SPI 2 I2C	26 digital input/output PWM output pins 3 analog inputs	4.00
Teensy 4.0 (ARM Cortex-M7)	5	600	1024	No	7 UART 3 SPI 3 I2C	40 digital input/output 31 PWM outputs 14 analog inputs	23.80

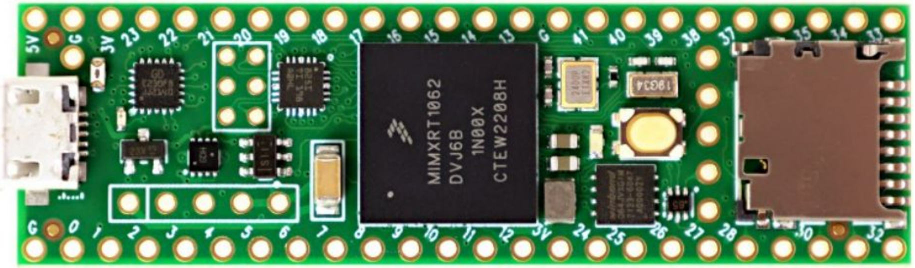


Image credit: www.pjrc.com

Selection: Teesy 4.1

- **Low start-up time**
- **Most useable ports**
- **Integrated SD card reader/writer**
- **Fast processing speed**

Payload Real-Time Clock

Module	Time Accuracy (ns)	Battery	Lifetime (hours)	Price
Teensy 4.1	± 1.2	CR2032	24	Included with Teensy 4.1
SAM-M8Q	± 60	LR44	4	Included with SAM-M8Q

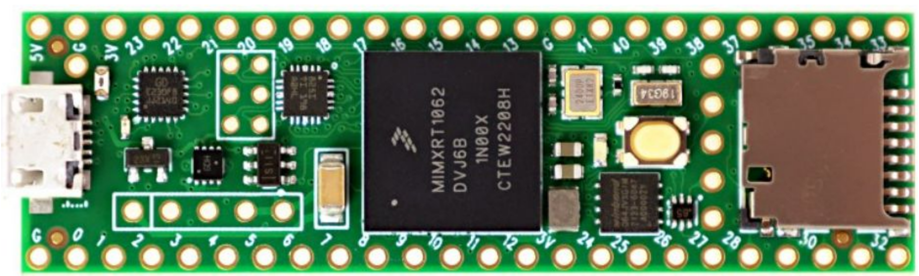


Image credit: www.pjrc.com

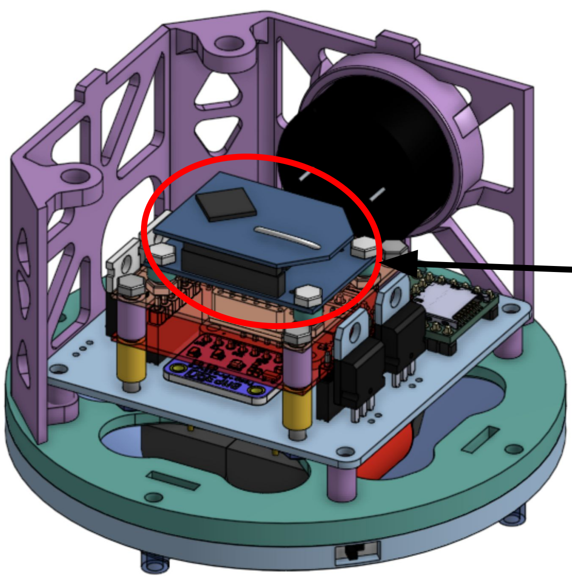
Selection: Teensy 4.1

- **Integrated with Teensy module**
- **High accuracy**
- **Use with any 3.3V cell**
- **Long lifetime**

Note: External CR2032 coin cell battery will be used to independently power the RTC

Payload Antenna Trade & Selection

Module	Range (km)	Gain (dBi)	Pattern	Mass (g)	Price
Integrated Wire Antenna	3.2	1.9	Omnidirectional	<1	Integrated
A24-HASM-450	4.0	2.1	Omnidirectional	5	$6.60



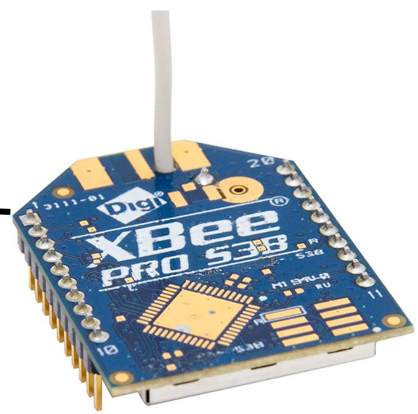


Image credit: Digi.com

Selection: Integrated Wire Antenna
- **Sufficient range**
- **Included with XBee**
- **Negligible mass**

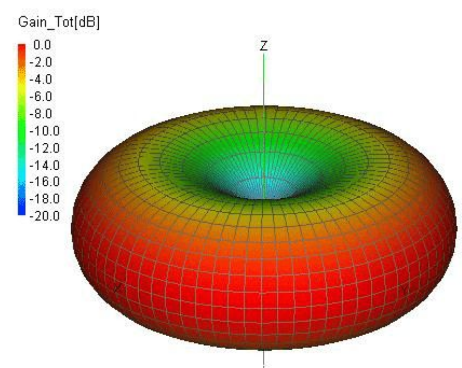


Image credit: researchgate.net

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.

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

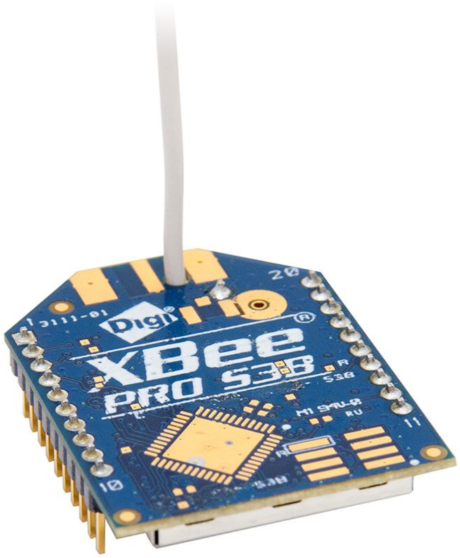


Image credit: digi.com

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”

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:ms
<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.
CMD	1079	CX	OFF	“CMD.1079,CX,OFF”	Deactivates receiving telemetry.
CMD	1079	ST	UTC	“CMD,1079,ST,UTC”	Sets time on the probe to UTC Time
CMD	1079	ST	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.
CMD	1079	SIM	ACTIVATE	“CMD,1079,SIM,ACTIVATE”	Activates Simulation Mode.
CMD	1079	SIM	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 (EPS) Design

Presented by 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

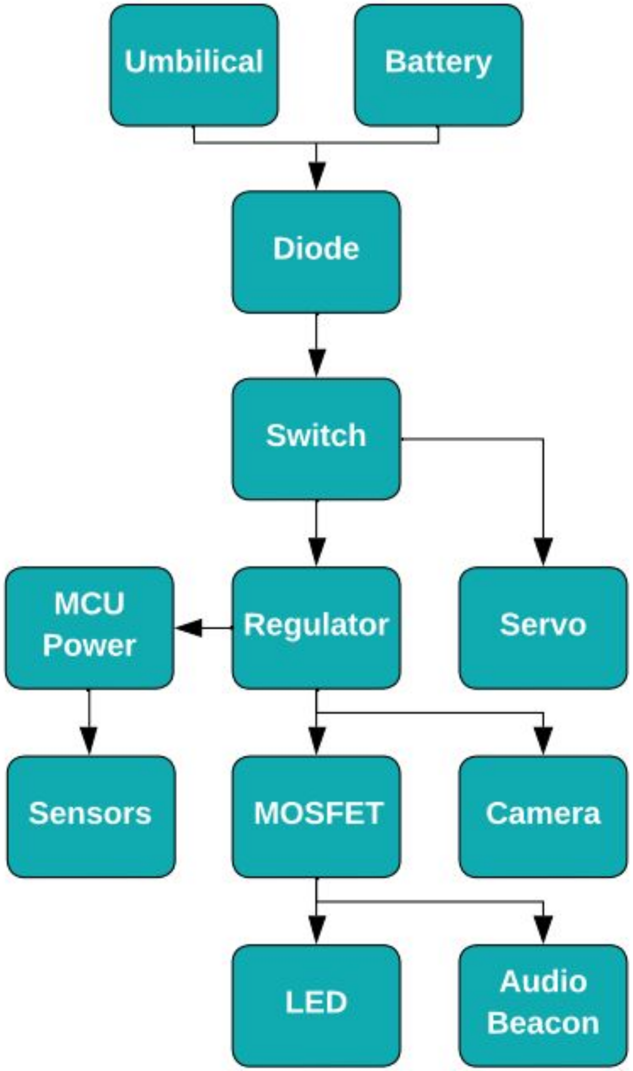
Diode:
Prevents the reverse flow of electricity

Switch:
Gate that turns on and off the electrical system

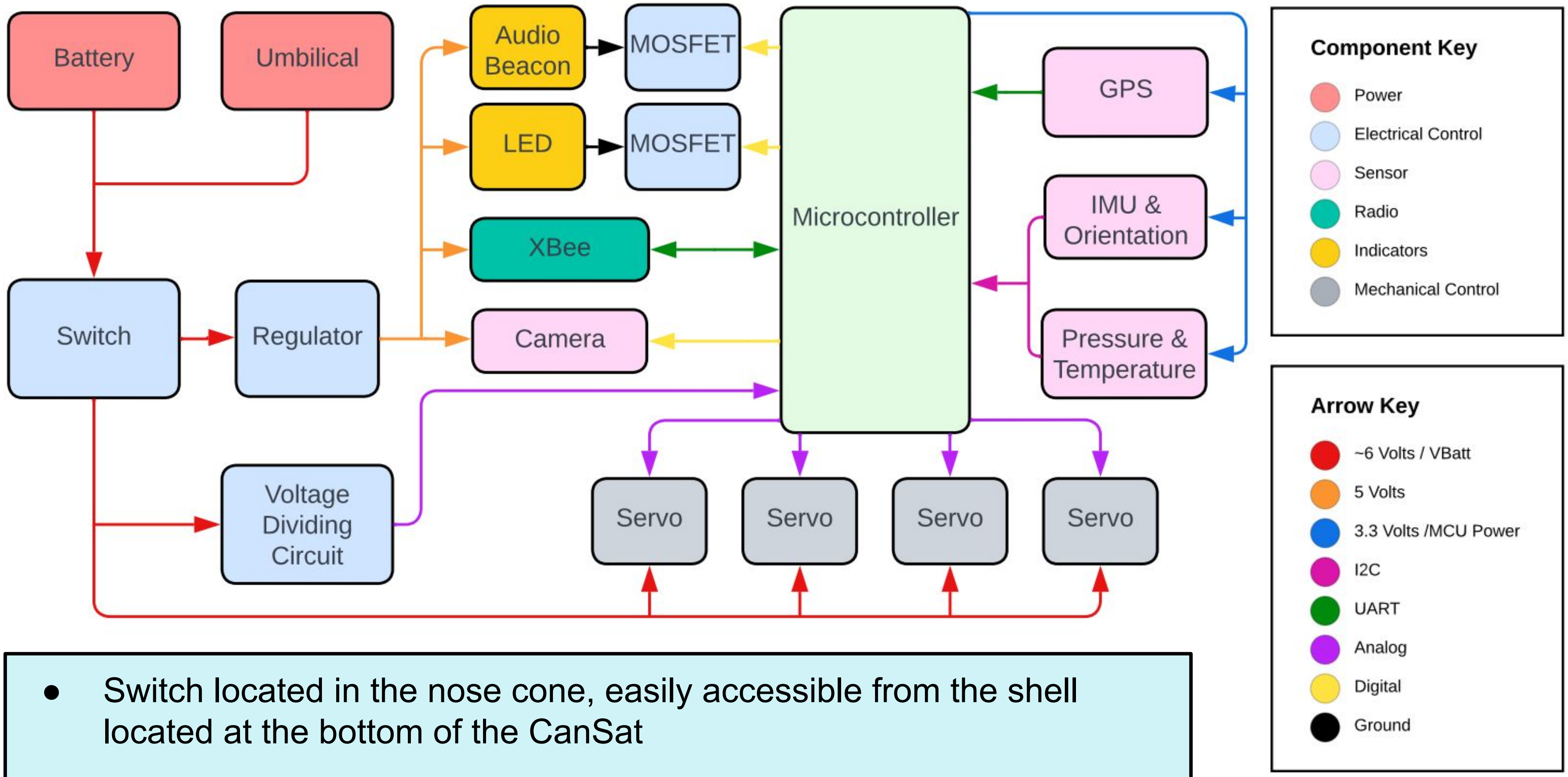
Regulator:
Reduce voltage from batteries to 5.0V providing required voltage to components

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



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 Trade & Selection

Battery	Voltage (V)	Capacity (mAh)	Quantity Needed	Layout	Power Density (mWh/g)	Voltage Drop After Two Hours (V)	Unit Weight (g)	Unit Price ($)
Surefire CR123A	3.0	1550	2	Series	273.5	< 0.5 per cell < 1.0 Total	17	1.80
Exell EB-CR123A	3.0	1700	2	Series	283.3	Not Listed	18	2.00
Duracell Ultra 223	6.0	1400	1	Series	221.1	1.0 - 2.0	38	11.75

Image credit: surefire.com

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

Selection: 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
BMP390	3.3	1.05	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	25.0	0.50	0.000	1.50	1	0.063	Datasheet
LED	5.0	100.00	0.16	0.000	1.84	1	0.080	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
Metal Gear Micro Servo	6.0	154.00	0.05	0.025	1.95	1	0.046	Measured
Plastic Gear Servo	6.0	120.00	0.01	0.000	1.99	3	0.022	Datasheet

Payload Power Budget (2 of 2)

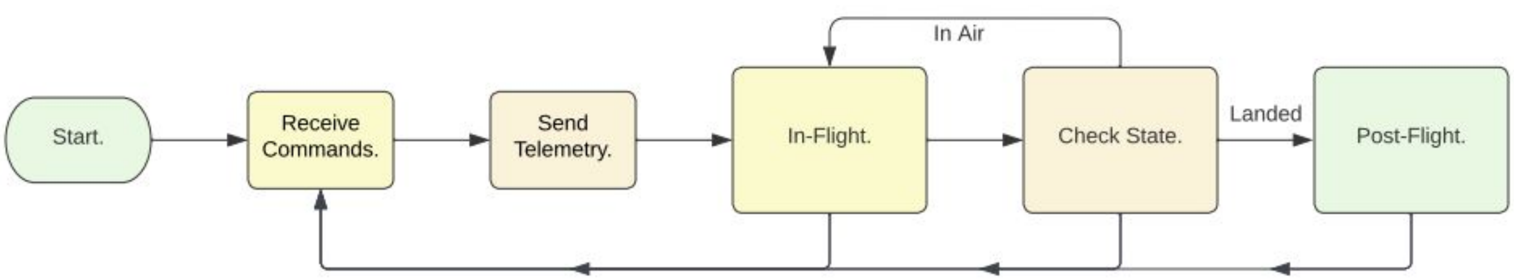
Energy Consumption Subtotal (Wh):	4.9
Power Supply Efficiency :	81.7 %
Total Energy Consumption (Wh):	6.0
Available Battery Capacity (Wh):	9.3
Percent of Battery Used:	64.5 %
Energy Margin (Wh):	3.3
Remaining Battery Percentage:	35.5 %

Flight Software (FSW) Design

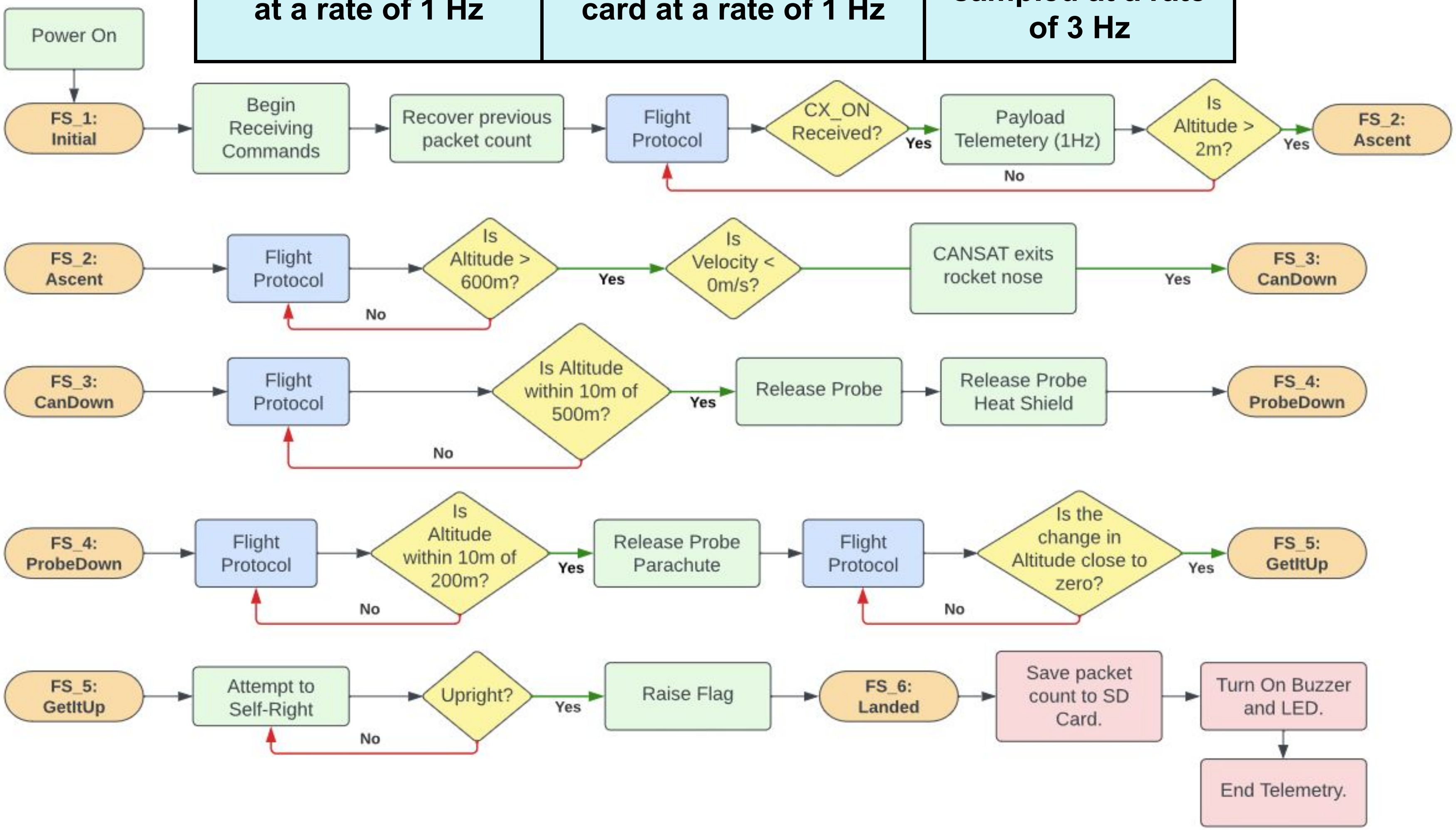
Presented by Emann Rivero

FSW Overview

Start:	In-Flight:	Post-Flight:
• Boot all sensors • Power all devices • 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		



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)

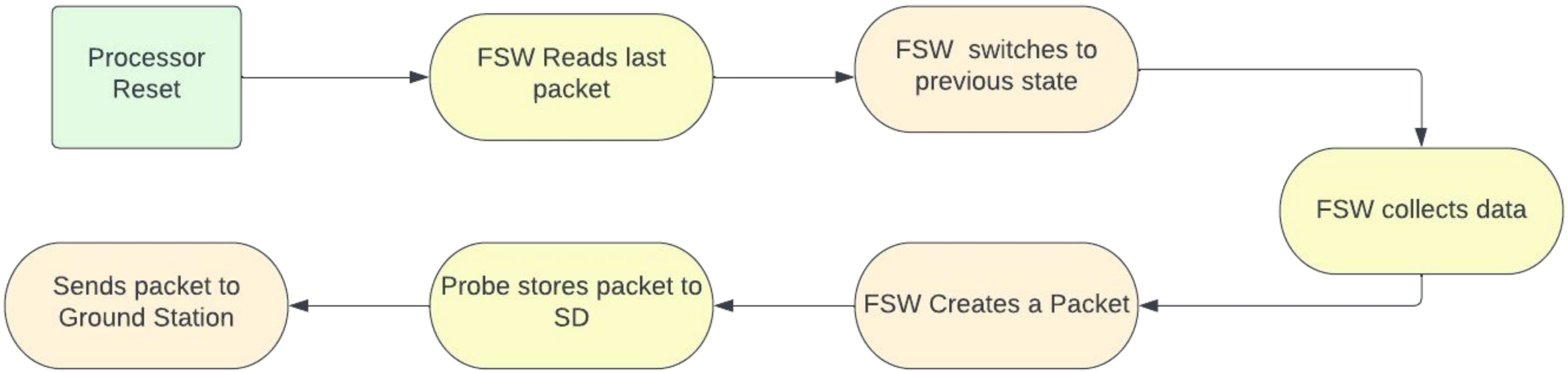
<u>After Processor Restart:</u>

- 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

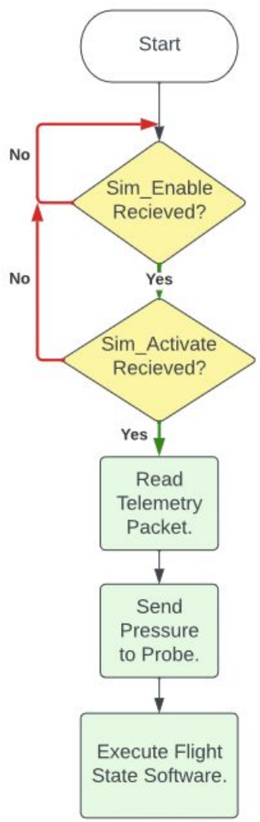
<u>Power Failure:</u>

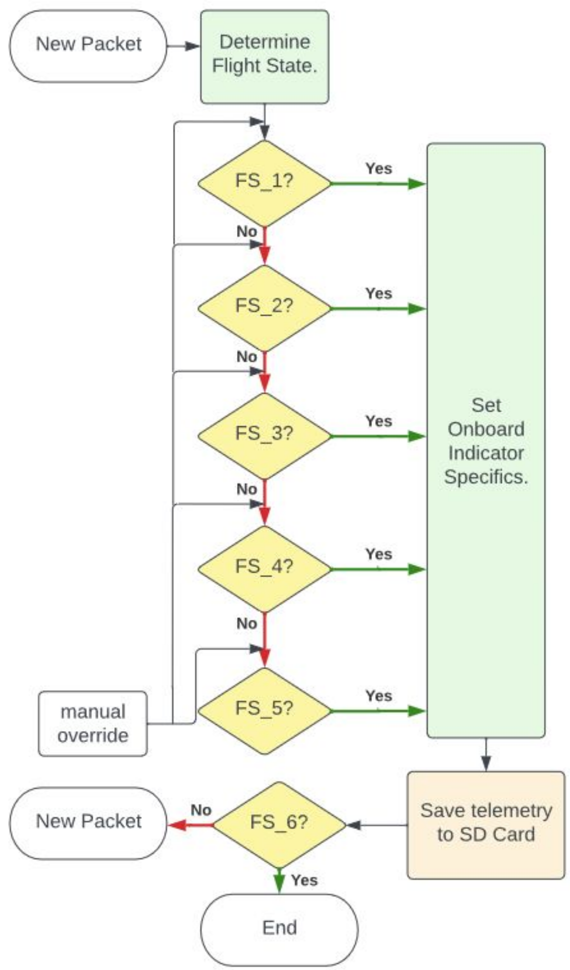
Packet count and Flight state will be stored to the Teensy 4.1's internal EEPROM, to act as a backup in case of power failure during processor restart operations.

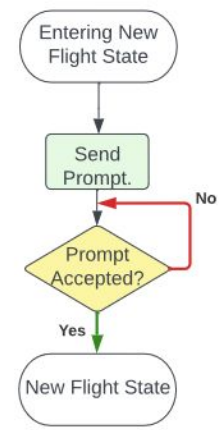


Simulation Mode Software

Simulation Mode	Flight State	Prompt Logic







Onboard indicators include:
- LED
- Buzzer
- Camera

<u>Simulation Commands:</u>
- “SIM,ENABLE” and “SIM,ACTIVATE” are both required to implement Simulation Mode, while “SIM,DISABLE” will return the system to Flight Mode.

<u>Power Consumption:</u>
- To reduce power consumption during flight, the LED has a 1Hz 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	2/6/2023																																			
CDR Phase	2/6/2023	4/14/2023																																			
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																																			

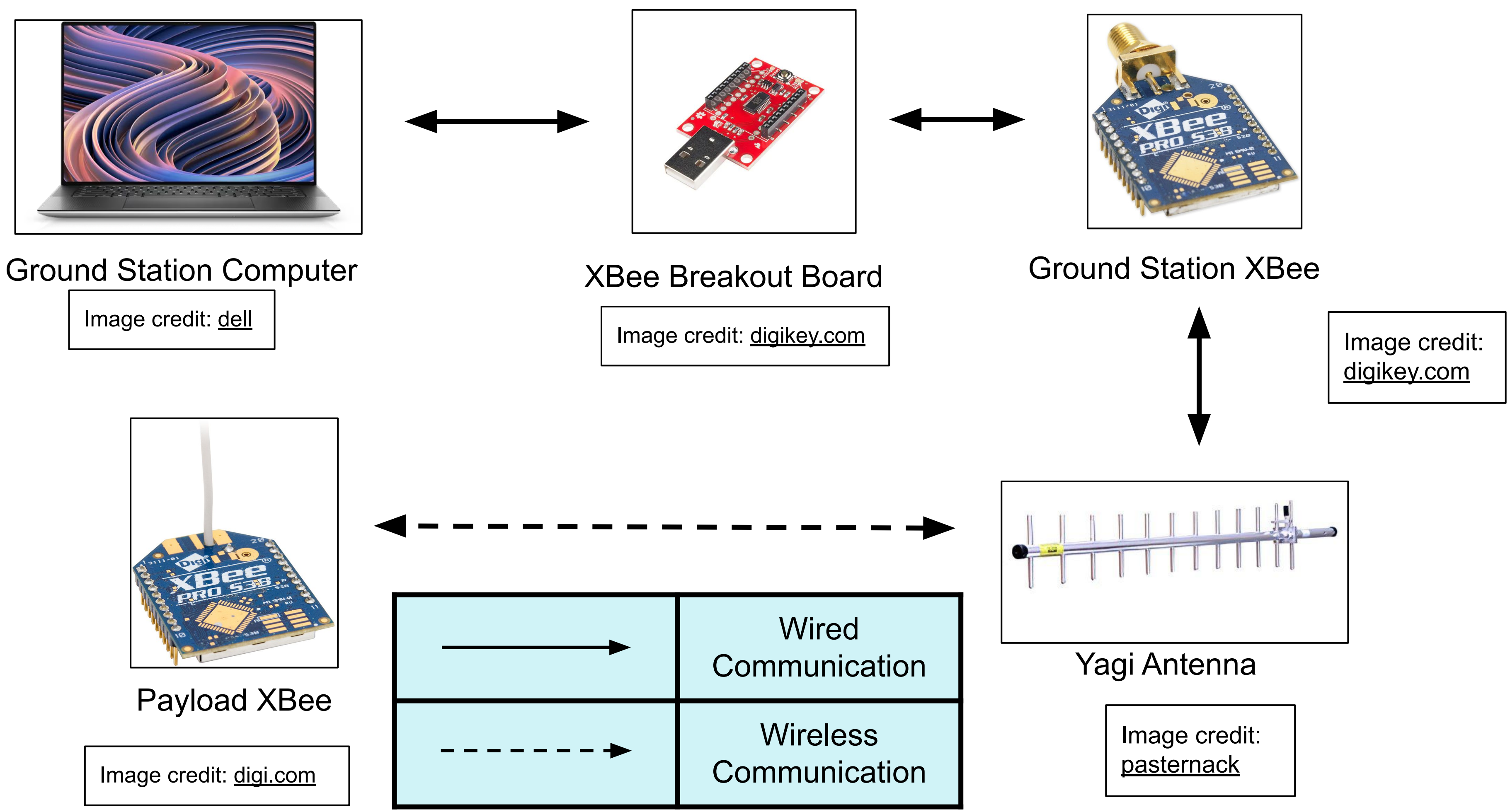
Software Development Progress (Enrico Addy and Emann Rivero)

- Large portions of software development will be aligned with electrical development to prototype and test as quickly as possible.
- Testing will largely involve flight simulation with the given simulation profile, sensor initialization, and sensor calibration.

Ground Control System (GCS) Design

Presented by Enrico Addy

GCS Overview



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 connectors 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

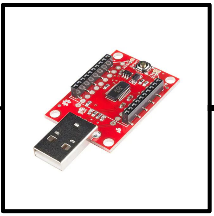


Image credit: digikey.com

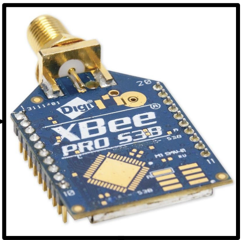


Image credit: digikey.com

Image credit: pasternack.com

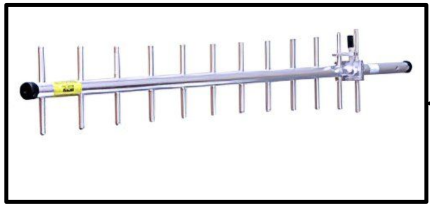


Image credit: pasternack

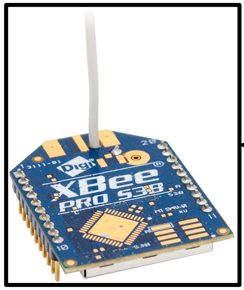


Image credit: digi.com

GCS Design (2 of 2)

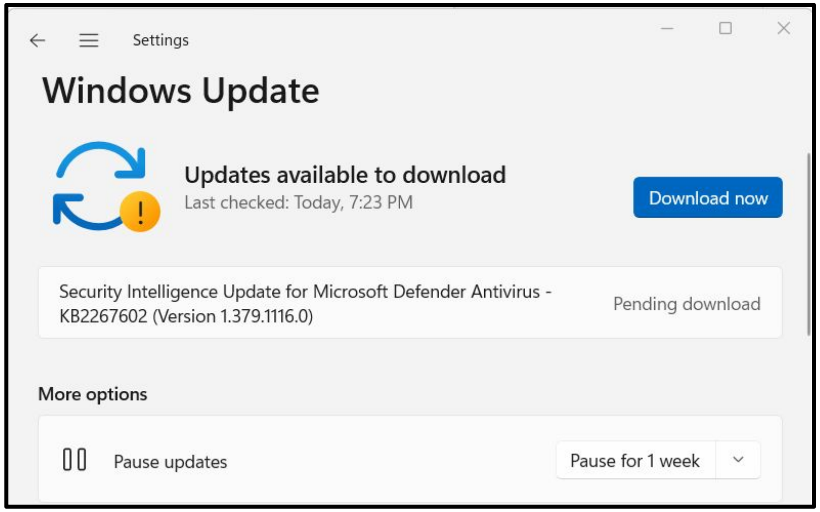
GCS Specifications

- 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

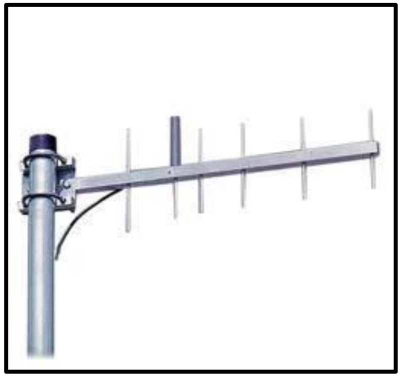
Image credit: amazon.com

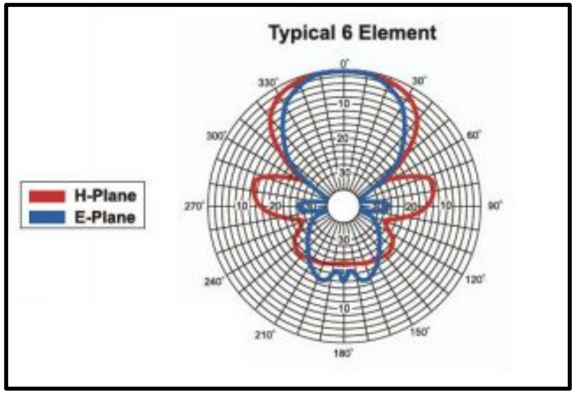
Image credit: microsoft.com



GCS Antenna Trade & Selection

Model	Mount	Gain (dBi)	VSWR	Cost ($)
Laird PC906N Yagi	Handheld	8.5	1.5:1	65.68
Pasternack PE51012 Yagi	Handheld	11.0	1.5:1	66.99
Digi A24-HASM-525	Tabletop	2.1	2:1	31.88





Selection: Laird PC906N Yagi

- Availability without purchase
- Sufficient gain and VSWR

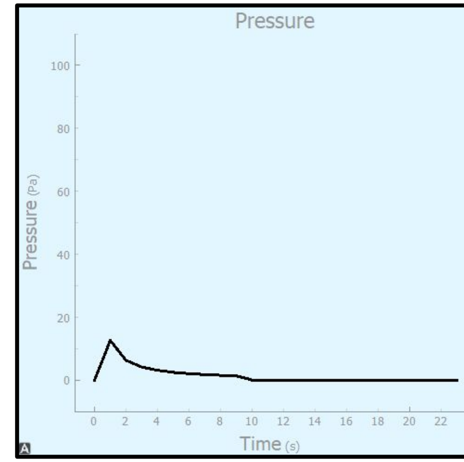
Image credit: arcantenna.com

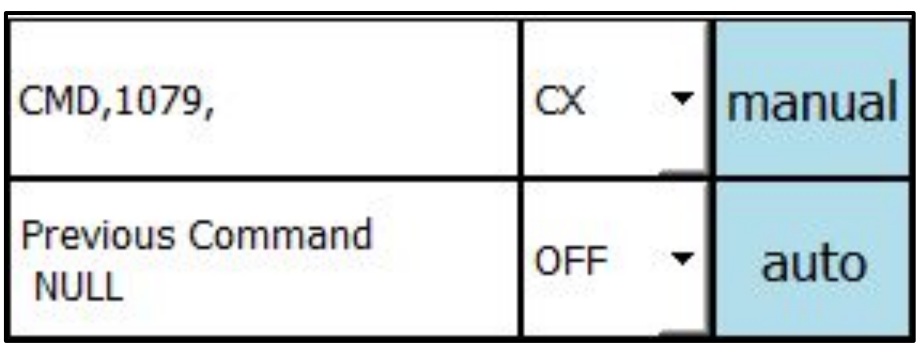
Image credit: laird connectivity

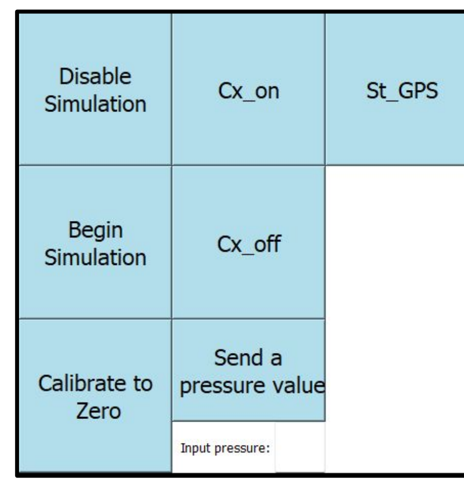
GCS Software (1 of 3)

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

Command Software and Interface	• Using the PyQtGraph module of PyQt5, graph items will be updated as information is read from the CanSat XBee
Real-Time Plotting	• 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
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



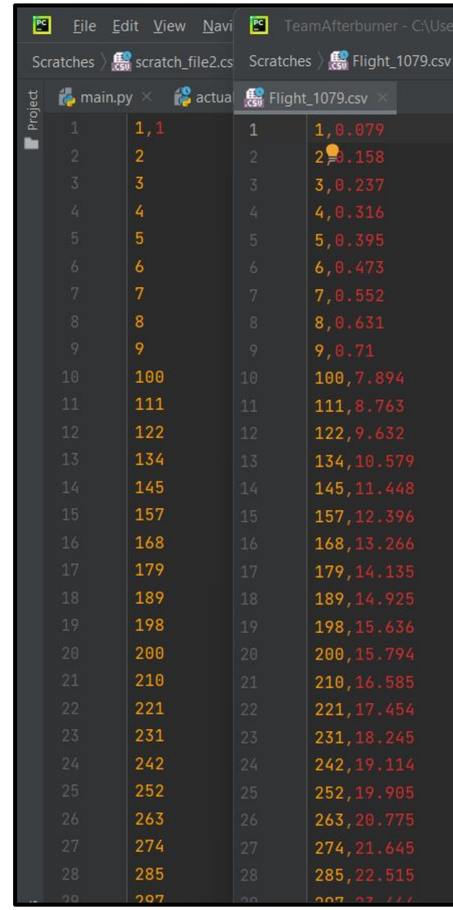




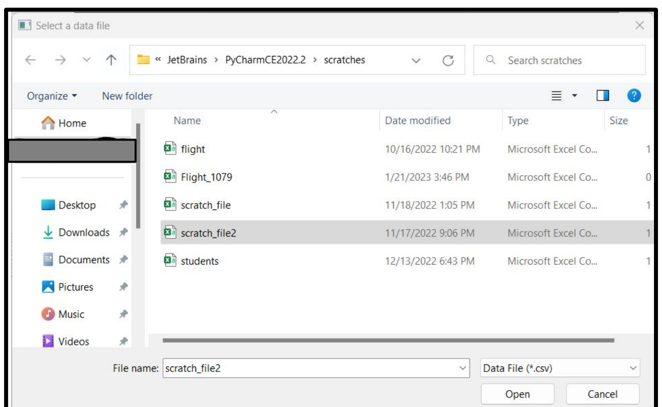
GCS Software (2 of 3)

CSV File Creation

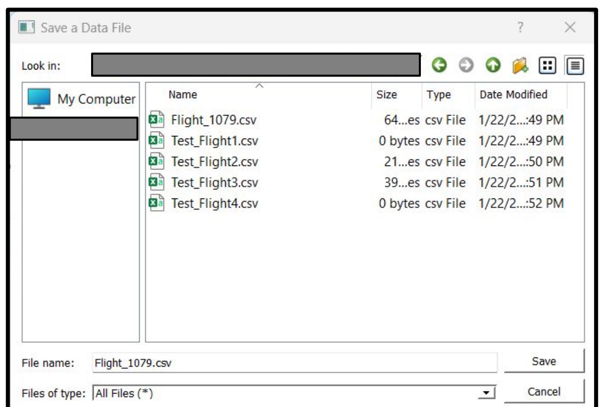
- After deciding to enter Simulation Mode a file dialog box will open, allowing selection of read-only CSV file.
- Information in this file is read to the Probe once per second, and return telemetry is saved to a Flight_1079.csv file.
- On GS termination another file dialog will open, copying above file 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

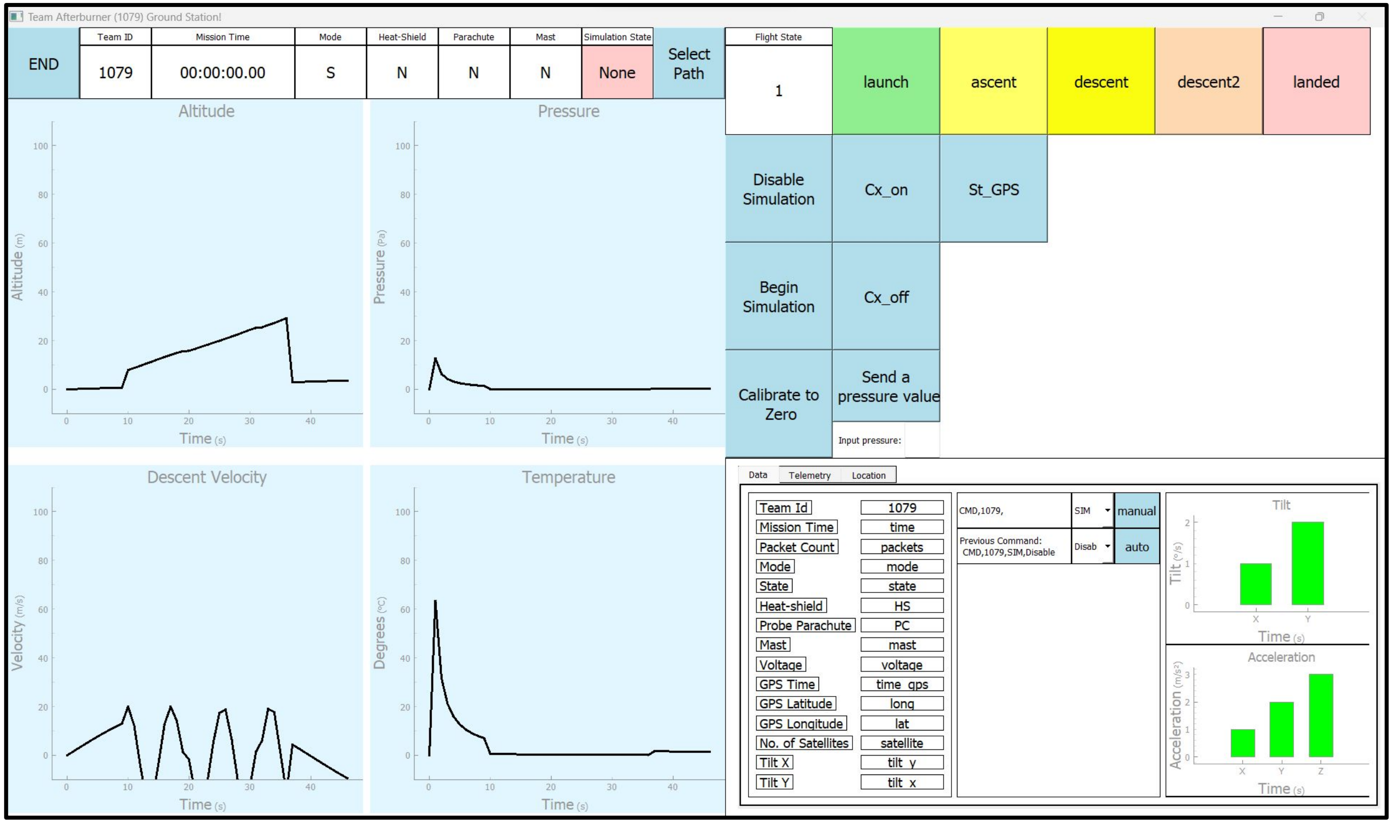


Data Saving



GCS Software (3 of 3)

Calibration Processing
To verify correct communication, sensors will be calibrated prior to displaying telemetry. If there are no shifts in sensor data greater than 5% without probe movement, sensors are considered to be calibrated.



CanSat Integration and Test

Presented by Cole Lenhart

CanSat Integration and Test Overview

Test	Testing plan
Individual Subsystem Testing	• Test each individual subsystem, such as the CDH, electrical, mechanical, and software systems to identify problems that need to be solved before integration
Integration Testing	• As we integrate each of the subsystems with each other, we will test the fit and the function of each of the subsystems to identify any issues and fix them as we test them
Environmental Testing	• After the full integration of the CanSat, we will test the entire assembly to the environmental testing standards defined by the mission guide
Simulation Testing	• The CanSat will be put into testing mode with the two step commands to receive simulated launch data from the ground station instead of the sensors to demonstrate functionality
Test Launch	• We will construct an L1 rocket similar to the launch day rockets to test the CanSat in its entirety to identify any unaccounted for issues before competition

Subsystem Level Testing Plan (1 of 2)

Sub System	Components	Testing plan	Pass Requirement
Sensors	BNO055 BMP390 SAM-M8Q	• Test sensors individually • Calibrate sensors • Test sensor accuracy	• Sensors calibrate correctly • Accurate readings compared to data sheet
CDH	BNO055 BMP390 SAM-M8Q 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 below operation voltage
Radio Comms.	MCU XBees Ground Station	• Test long distance radio communication between XBees • Test two-way communication • Test for optimal antenna position	• Packets sent between probe and ground station • Probe receives commands from ground station

Subsystem Level Testing Plan (2 of 2)

Sub System	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	• Test parachute and heat shield mechanisms' functionality and reliability • Test probe release mechanism strength and reliability • Test flag release mechanism functionality and reliability • Test CanSat structural integrity via environmental testing	• Parachute deploys when commanded by MCU • Probe deploys while on battery power • Flag raised to 500mm after commanded by MCU • The structure passes all environmental testing

Integrated Level Functional Test Plan (1 of 2)

Subsystem	Testing plan	Pass Requirement(s)
Descent	• Drop 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) • Drop 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	• 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 function correctly 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 • 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

Integrated Level Functional Test Plan (2 of 2)

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 ● 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 will be tested before competition via test launch	● The parachute deploys when the release servo is activated ● The parachute cords and mounts are able to withstand the shock forces that they are exposed to ● The parachute cords and mounts are able to withstand the forces of the test launch

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
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	• CanSat remains fully functioning after being left in the thermal chamber for two hours

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 • We will construct a rocket payload section and test tolerances between the payload wall and CanSat	• CanSat comfortably fits 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 Check	• 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 functions correctly and passes all flight states as the pressure simulates different altitudes • The cameras record the deployment and raising of the flag

Simulation Test Plan (1 of 2)

Test	Testing plan	Pass Requirements(s)
Accuracy test	• The goal is to ensure that each of the CanSat's sensors are functioning correctly and recording correct data • We will test this by attempting to start each sensor and examining transmitted data against a control set of data	• Data is within 1% of the control values
Command Test	• The goal of this test is to ensure that the CanSat is correctly receiving and implementing commands • We will send each of the mission requirement commands to the CanSat, along with select custom commands	• The CanSat passes this test if all commands are interpreted correctly

Simulation Test Plan (2 of 2)

Test	Tested Components	Testing plan	Pass Requirement(s)
Simulation test	BMP390 Teensy4.1 XBee Ground Station	• The goal of this test is to complete a successful run of the Simulation Mode • We will test this by running Simulation Mode with a given set of pressure values	• Values returned though Simulation Mode are consistent with a sample solution • CanSat performs actions expected at certain altitudes

Mission Operations & Analysis

Presented by Brennan Begley

Overview of Mission Sequence of Events

Event	Objective	Team
Arrival	Arrive at Launch Location	All
Pre-Launch	Assemble CanSat and Ground Station	CanSat
Launch	Turn CanSat On	CanSat
	Rocket - CanSat Integration	CanSat
	Validate Signal Acquisition	Ground Station
Flight	Monitor CanSat	Ground Station
Recovery	Recover CanSat	Recovery
Data Analysis	Verify Data and Recording Integrity	Ground Station

Mission Control Officer	Recovery Team	Groundstation Team	CanSat Team
Louis McEvoy	Brennan Begley, Mason Mills	Enrico Addy, Emann Rivero	Gabriel Campos, Quinn Casper, Elena Dishman, Kyle Hughes, Cole Lenhart

Mission Operations Manual Development Plan

Section Name	Description
Team Roster	List of each member of the team, what their role is, when, and what they each will be doing.
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.

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); wlm0021@uah.edu;
901 John Wright Dr NW, Huntsville, AL 35805

Requirements Compliance

Presented by Louis McEvoy

Requirements Compliance Overview

We comply with 54 of the 60 requirements listed in the mission guide.

Partial Compliance:
#12, 13, 15, 30, 37, 53

- Partially-compliant items are awaiting verification through testing.
  - Requirement #43 was omitted because it was skipped in the mission guide.
- Our goal is to complete a prototype that we can use to verify the partially-compliant requirements
- We are currently on track to comply with all requirements by CDR

#	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	27		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	27		X	X		
4	The container shall be a fluorescent color; pink, red or orange.	Comply	124			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	27			X		
7	The rocket airframe shall not be used as part of the CanSat operations	Comply	27			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	27		X	X		X
9	The Parachute shall be fluorescent Pink or Orange	Comply	124			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	97		X		X	
12	All structures shall be built to survive 15 Gs of launch acceleration.	Partial	111	Awaiting Testing	X			X
13	All structures shall be built to survive 30 Gs of shock.	Partial	111	Awaiting Testing	X			X
14	All electronics and mechanical components shall be hard mounted using proper mounts such as standoffs, screws, or high performance adhesives.	Comply	51, 72		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.	Partial	111	Awaiting Testing	X			X
16	Mechanisms shall not use pyrotechnics or chemicals.	Comply	40-42, 63-71			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	40-42, 63-71			X		
18	Both the container and probe shall be labeled with team contact information including email address.	Comply	124			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	142		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	85			X		
21	XBee radios shall have their NETID/PANID set to their team number.	Comply	85			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	85			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	54, 55			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	55			X	X	
25	An audio beacon is required for the probe. It shall be powered after landing.	Comply	55			X	X	X
26	The audio beacon shall have a minimum sound pressure level of 92 dB, unobstructed.	Comply	72				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	93			X		

#	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	25, 54, 55			X	X	
29	Spring contacts shall not be used for making electrical connections to batteries. Shock forces can cause momentary disconnects.	Comply	54, 55, 72			X		
30	The CanSat shall operate during the environmental tests laid out in Section 3.5.	Partial	111-113	Awaiting Testing			X	
31	The CanSat shall operate for a minimum of two hours when integrated into the rocket.	Comply	95				X	X
32	The probe shall be released from the container when the CanSat reaches 500 meters.	Comply	98				X	X
33	The probe shall deploy a heat shield after leaving the container.	Comply	32, 98				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, 98				X	X
36	Once landed, the probe shall upright itself.	Comply	69, 71, 98				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.	Partial	15, 22	Awaiting Testing			X	X
38	The probe shall transmit telemetry once per second.	Comply	85		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	86-88		X		X	
40	The probe shall include a video camera pointing down to the ground.	Comply	55			X		
41	The video camera shall record the flight of the probe from release to landing.	Comply	29, 94			X	X	X
42	The video camera shall record video in color and with a minimum resolution of 640x480.	Comply	35-36			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	97-99			X	X	
45	The probe shall maintain mission time throughout the whole mission even with processor resets or momentary power loss.	Comply	97-99			X	X	
46	The probe shall have its time set to within one second UTC time prior to launch.	Partial	97-99			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	100			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	100		X		X	
49	The container flight software shall only enter simulation mode after it receives the SIMULATION ENABLE and SIMULATION ACTIVATE commands.	Comply	100				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	97				X	
51	The ground station shall generate csv files of all sensor data as specified in the Telemetry Requirements section.	Comply	108				X	X
52	Telemetry shall include mission time with 1 second or better resolution.	Comply	87		X			X
53	Configuration states such as zero altitude calibration shall be maintained in the event of a processor reset during launch and mission.	Partial	99	Awaiting Testing	X		X	X
54	Each team shall develop their own ground station.	Comply	104			X		X
55	All telemetry shall be displayed in real time during descent on the ground station.	Comply	107			X		X
56	All telemetry shall be displayed in engineering units (meters, meters/sec, Celsius, etc.)	Comply	86-88			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	107			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	103-104			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	105			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	100			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	98			X		X

Management

Presented by Louis McEvoy

CanSat Budget – Hardware (1 of 6)

Component	Quantity	Unit Price ($)	Total Cost ($)	Source	Reuse
BMP390	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	
Nylon parachute	296.9cm^2	0.001 per cm^2	0.30	Estimate	
Paracord	128.3cm	0.004 per cm	0.51	Estimate	
Container wafer top (3D printed PETG)	39.2g	0.034 per gram	1.33	Estimate	
Container wafer bottom (3D printed PETG)	16.4g	0.034 per gram	0.56	Estimate	
Carbon fiber rods	4	2.66	10.63	Actual	
Slide total	**-**	**-**	**394.84**	**-**	**-**

CanSat Budget – Hardware (4 of 6)

Component	Quantity	Unit Price ($)	Total Cost ($)	Source	Reuse
Previous Slide total	-	-	394.84	-	-
M4 bolts 80mm	2	2	4.0	Actual	
M4 nuts	6	0.26	1.56	Actual	
Rigid PETG tube 25mm	1	1.90	1.9	Actual	
Cardboard tube	1	2.59	2.59	Actual	
M5 eye nut	1	6.16	6.16	Actual	
M3 bolts 20mm	4	1.48	5.92	Actual	
M3 bolts 14mm	4	1.48	5.92	Actual	
M3 24mm pins	4	2.21	8.84	Actual	
Nylon Parachute	1945cm^2	0.001 per cm^2	1.95	Estimate	
Paracord	328.32cm	0.004 per cm	1.31	Estimate	
Slide total	**-**	**-**	**434.99**	**-**	**-**

CanSat Budget – Hardware (5 of 6)

Component	Quantity	Unit Price ($)	Total Cost ($)	Source	Reuse
Previous Slide total	-	-	434.99	-	-
Nylon heat shield	356.0cm^2	0.001 per cm^2	0.36	Estimate	
Deployment hinge plate	28.74g	0.034 per gram	0.98	Estimate	
Electrical enclosure (3D printed PETG)	20g	0.034 per gram	0.68	Estimate	
Top plate (3D printed PETG)	19.05g	0.034 per gram	0.65	Estimate	
Nose cone (3D printed PETG)	28.71g	0.034 per gram	0.98	Estimate	
Base plate (3D printed PETG)	16.97g	0.034 per gram	0.58	Estimate	
Flag servo mount (3D printed PETG)	3.52g	0.034 per gram	0.12	Estimate	
Slide total	**-**	**-**	**436.34**	**-**	**-**

CanSat Budget – Hardware (6 of 6)

Component	Quantity	Unit Price ($)	Total Cost ($)	Source	Reuse
Previous Slide total	-	-	436.34	-	-
Flag raising mechanism (baton)	1	10.78	10.78	Actual	
Parachute servo mount (3D printed PETG)	4.67g	0.034 per gram	0.16	Estimate	
Misc. 3D printed deployment components	25.67g	0.034 per gram	0.87	Budgeted	
Misc. aluminum deployment components (6063 Bar Stock)	2	7.50	15.00	Budgeted	

CanSat Total = $466.15

CanSat Budget – Other Costs

Component	Cost ($)	Quantity	Total Cost ($)	Source	Reuse
Ground Station Laptop (Vivobook Asus Laptop)	$395.75	1	$395.75	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 = $5,885.49

Funding is Provided by the Alabama Space Grant Consortium

Program Schedule Overview

General Detailed Timeline

Name	Start Date	End Date	October				November				December				January					February				March				April				May					June			
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	12	19	26
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	4/14/2023																																						
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																																						

Mechanical Detailed Timeline

Name	Start Date	End Date	October				November				December				January					February				March				April				May					June			
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	12	19	26
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	4/14/2023																																						
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																																						

Electrical Detailed Timeline

Name	Start Date	End Date	October				November				December				January					February				March				April				May					June			
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	12	19	26
Team Formation	10/10/2022	10/30/2022																																						
MCR Phase	10/24/2022	12/2/2022																																						
PDR Phase	12/2/2022	2/6/2023																																						
CDR Phase	2/6/2023	4/14/2023																																						
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																																						

Detailed Program Schedule (3 of 3)

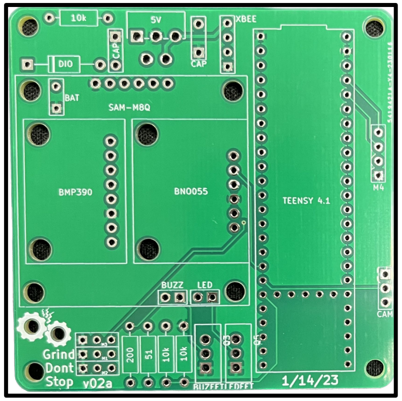
Software Detailed Timeline

Name	Start Date	End Date	October				November				December				January					February				March				April				May					June			
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	12	19	26
Team Formation	10/10/2022	10/30/2022																																						
MCR Phase	10/24/2022	12/2/2022																																						
PDR Phase	12/2/2022	2/6/2023																																						
CDR Phase	2/6/2023	4/14/2023																																						
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																																						

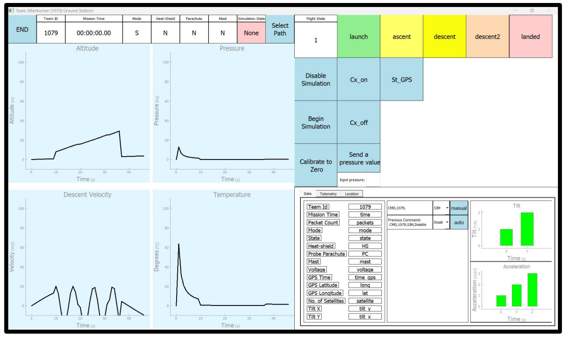
Conclusions (1 of 2)

Accomplishments

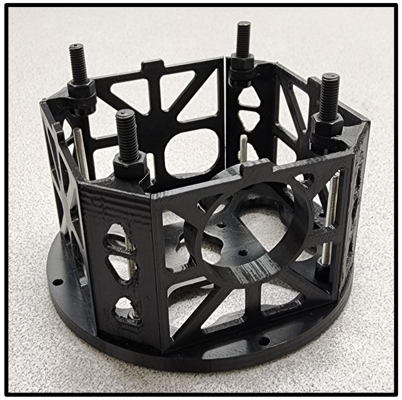
Electrical	Software	Mechanical
• Component selection • Block diagram • Full schematic design • Container and probe electrical CAD • PCB prototypes	• State diagram • GS mock • Sensor test code • State transition code • Container and payload flight software prototypes	• Two fully functional CAD models • Parachute design • Trade studies • Material selection • First test parts



PCB Prototype



Ground Station GUI



Electrical Housing

Conclusions (2 of 2)

	Electrical	Software	Mechanical
In Progress	• Refine PCB design • Test CDH system • Assembly • Integration and testing with software	• Commands • Sensor testing • Communication testing and integration • Ground station final GUI	• Manufacturing and prototyping • Test systems • Deployment and uprighting test • Refine flag deployment system

What's Next?

Team Afterburner has completed all the necessary preliminary steps to move into the prototyping and manufacturing phase of development. We are on track with the timeline set both by the team and the competition. We are eager to continue work on our hardware and move towards integration within the coming months.