CanSat 2024
Preliminary Design Review (PDR)
Outline
Version 1.0

Team 2083

Apollo Two-Dozen

Presentation Outline

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Systems Overview

Aarav Parikh

Mission Summary

Mission Objectives

Design a CanSat that consists of a probe that can perform these tasks:

- Survives launch and deployment forces.
- Release from the rocket that deploys an a parachute at 725 meters to achieve a target descent rate between 10 and 30 meters/second.
- Perform the function of the nose cone during the rocket ascent.
- At an altitude of 100 meters deploys an aero-braking (heatshield) to reduce the descent rater to less than 5 meters/second.
- The Egg shall remain intact
- The CanSat must include sensors for tracking altitude by using air pressure, internal temperature, battery voltage, GPS position, and tilt sensor.
- A pitot tube has to be included to measure both ascent and descent speed.

External Objectives

- Get close to real-world engineering.
- Learn how to work efficiently and effectively in a group setting.
- Have fun!

Bonus Objective

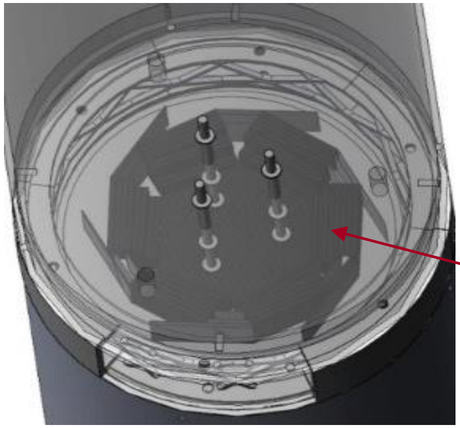
- Given that the bonus objective is relatively simple in terms of onboard resources and, design, the team decided to maximize the opportunity to score by attempting to do the bonus objective.

System Level Configuration Trade & Selection (1/4)

Nose-Up System

System Summary

- Nose cone face up during ascent and descent
- Two Pitot tubes (One for ascent and one for descent)
- Motor based deployment
- Nose cone ejected during parachute deployment
- Survival cell uses honeycomb-based shock-absorbent packaging



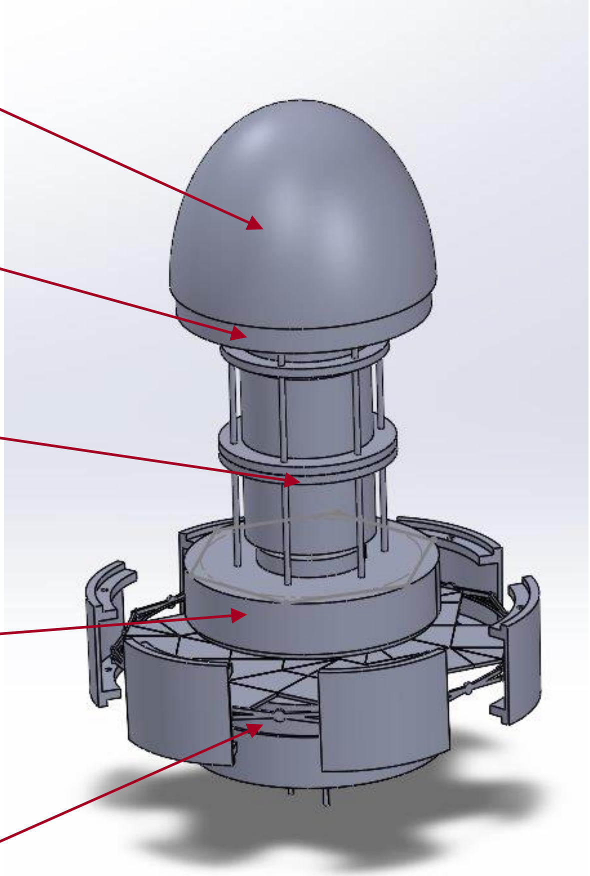
Empty Nose Cone
Decoupled by motor pulling a pin

Parachute
Deployed using drag

Egg Survival Cell
Honeycomb paper mesh

Electronics
Completely enclosed in tube

“Origami” Aerobrake
Unfolded by motor using scissor mechanism



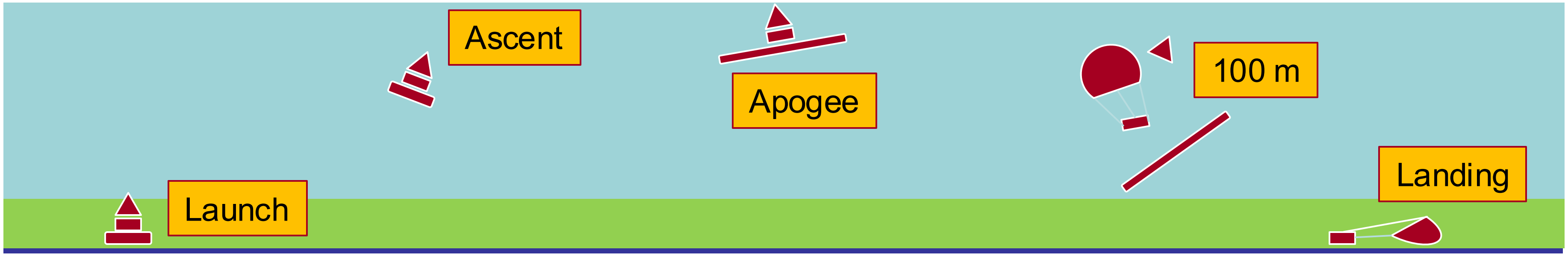
System Level Configuration Trade & Selection (2/4)

Nose-Up System

Advantages
- Folding mechanism for aerobrake is more compact
- COTS Nose cone easier to acquire
- No attitude change so lower chance of uncontrollable roll during heat-shield descent
- Motor based deployment has simpler electronics and is more reliable

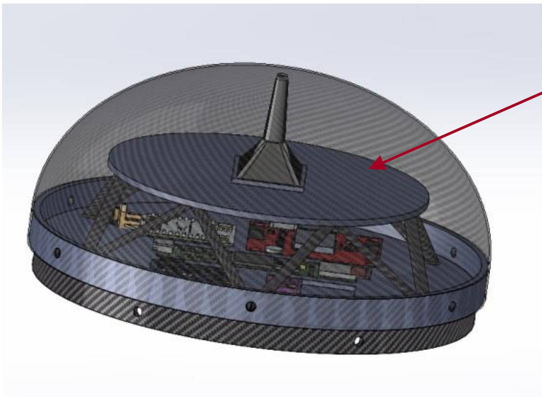
Drawbacks
- Aerobrake mechanism is complex, tough to manufacture
- Two pitot tubes required as one faces up for ascent and one faces down for descent
- Aerobrake and parachute will not deploy in case of power failure

Summary of ConOps
- At apogee, IMU detects nose up and aerobrake motor begins unfolding heat shield
- At 100 m, motor pulls pins from the nosecone and aerobrake. Nosecone is pushed out by the parachute. Parachute drag causes separation from aerobrake
- Landing shock is absorbed by the egg-cell damping mechanism



System Level Configuration Trade & Selection (3/4)

Nose-Down System



Custom Nose Cone

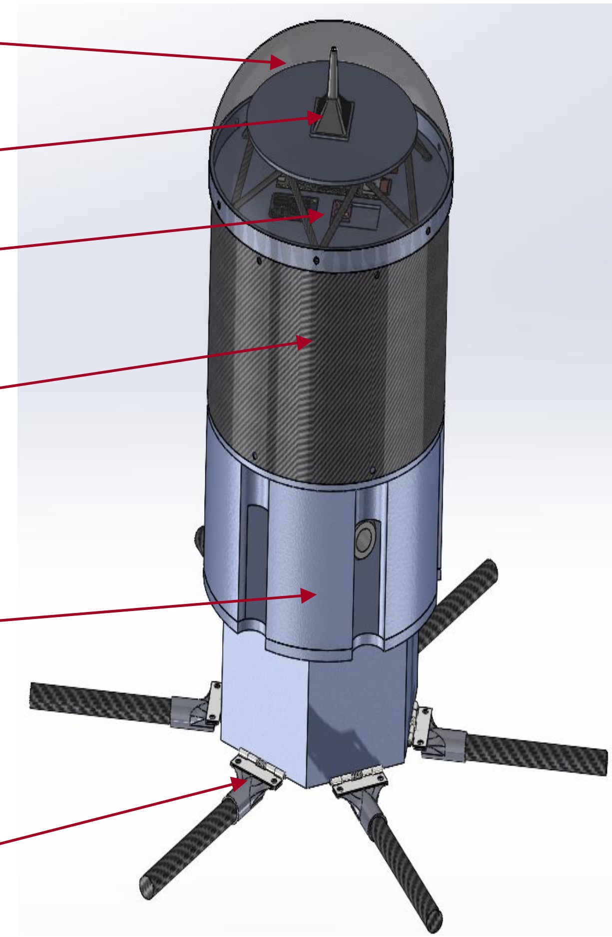
Pitot Tube

Electronics Bay

Egg Protection Cell
Contains high density foam

Burn Wire Bay
Contains deployment and separation mechanism for heatshield

Hinged Aerobrake
Unfolded by spring loaded hinge



System Summary

- Nose facing up during ascent and down during descent
- Burn Wire based deployment
- Aerobrake uses nylon material connected between arms to increase area
- Aerobrake assembly detaches from burn wire bay
- Parachute contained in burn wire bay

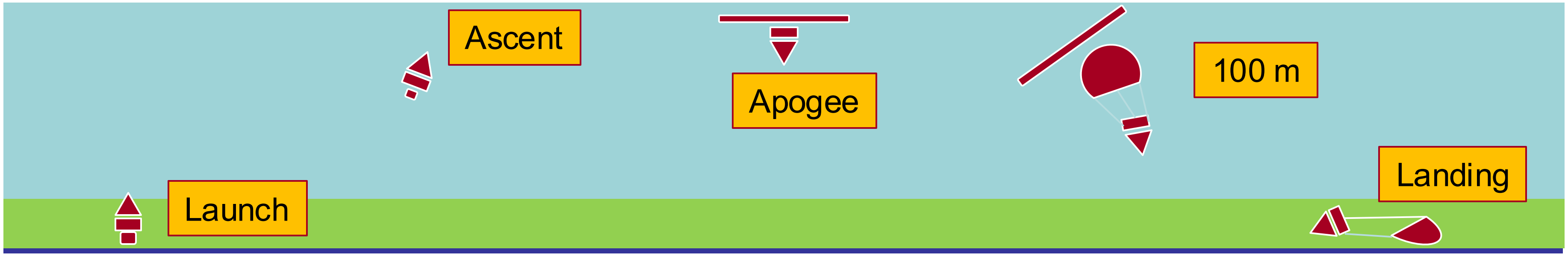
System Level Configuration Trade & Selection (4/4)

Nose-Down System

Advantages
- Lower manufacturing complexity
- Only one pitot tube needed
- Efficient use of space inside nosecone
- Aerobrake deploys despite power failure
- Aerobrake can deploy at any attitude
- Large volume for egg-protection material
- Lower battery consumption as no motors

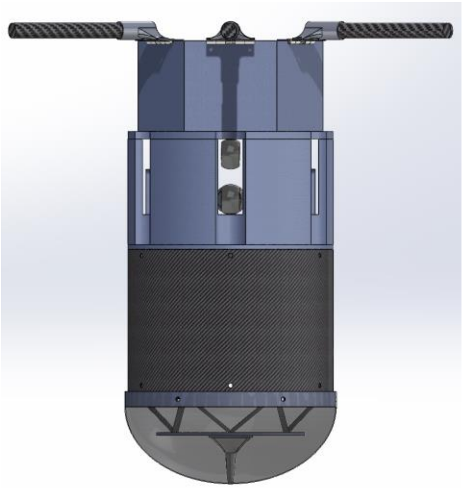
Drawbacks
- Burn wire-based deployment is complex
- Parachute deployment is reliant on aerobrake separation
- Custom nose-cone is tough to manufacture
- Use of carbon fiber increases machining complexity

Summary of ConOps
- At apogee burn wire releases aerobrake mechanism, nose flips to face Earth.
- At 100 m, burn wire releases aerobrake. Aerobrake pulls parachute along.
- Landing shock is passed by the carbon fiber nosecone and body into the PLA rather than by the egg



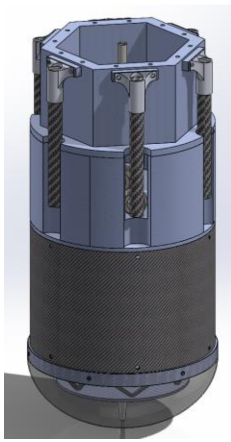
System Level Configuration Selection

Criteria	Explanation	Weightage	Configuration	
			Nose Up	Nose Down
Manufacturing Complexity	Designs that are tough to manufacture (smaller parts, more tightly packed etc.) are ranked lower	20%	3	8
Reliability	Designs that are operational when other systems fail or, designs whose nomal state is deployed are ranked higher	35%	6	9
Mass	Lower mass ranked higher	35%	6	4
Space Efficiency	More Space efficient designs ranked higher	10%	8	3
			5.6	6.45

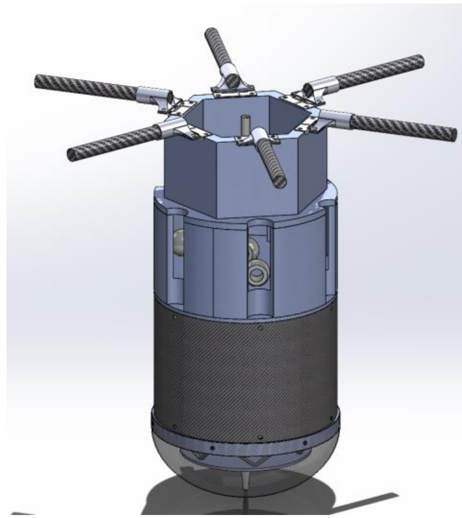


Additional Considerations
Other factors were also deliberated, like the separation mechanisms, availability of materials and team member's experience working with certain components. Based on these considerations, the team decided to chose the 'nose down' configuration

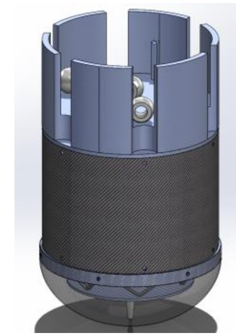
Physical Layout (1/2)



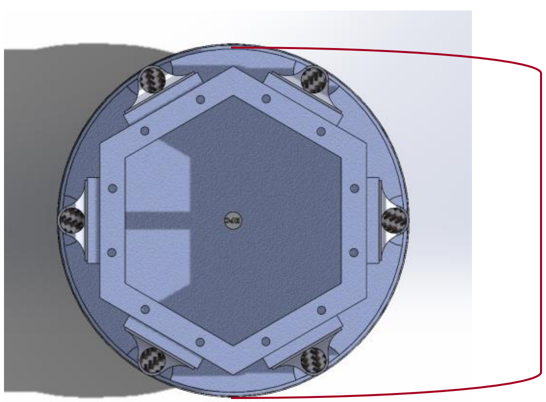
Stowed



Aerobrake Deployed

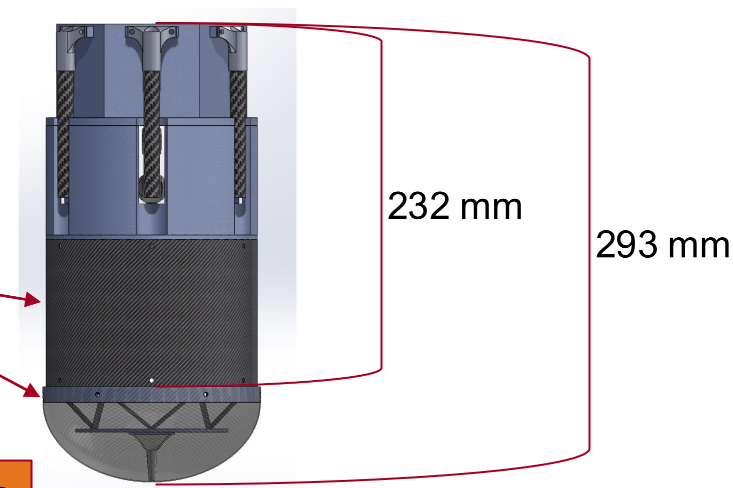


Aerobrake Separated Parachute deployed Landing



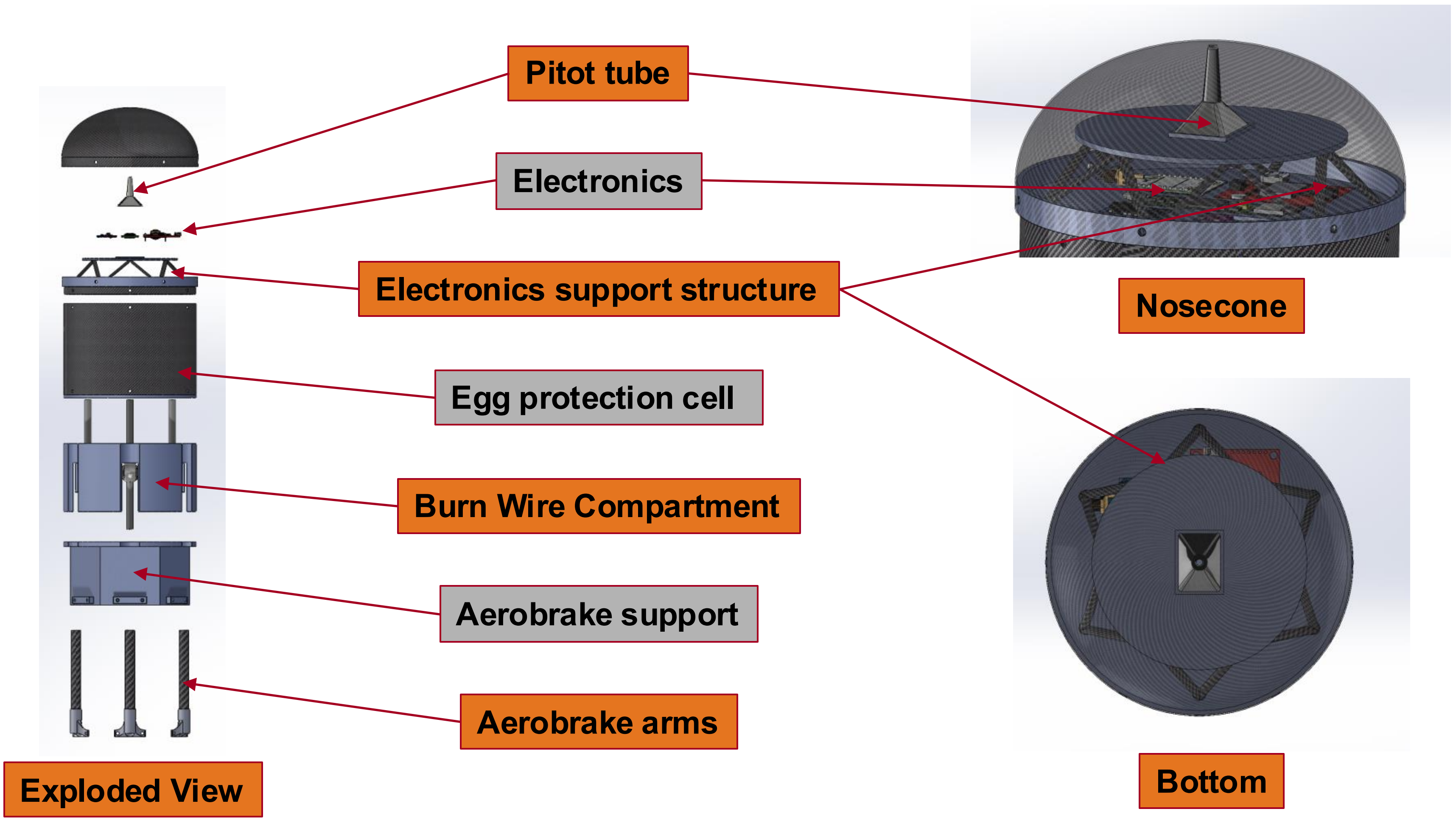
Top

⌀ 136 mm (Shoulder)
⌀ 140 mm (Nose Cone)

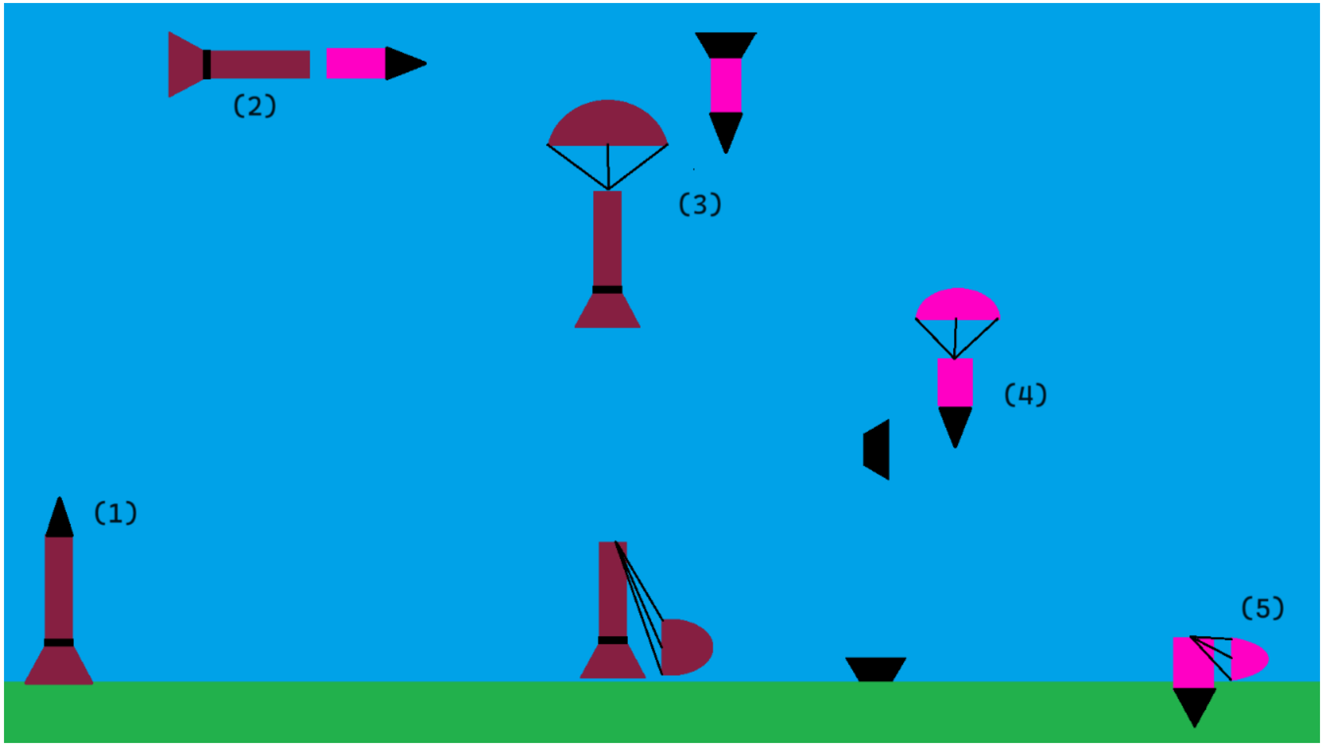


Side

Physical Layout (2/2)



System Concept of Operations (1/2)



Stage 1
- Undergo pre-launch operations
- CanSat is loaded into the rocket
- Rocket is launched
- Altitude: 0 meters

Stage 2
- CanSat is released from rocket
- Altitude: 725 meters

Stage 3
- Rocket parachute deploys
- CanSat aerobrake deploys
- Altitude: 725 meters

Stage 4
- CanSat aerobrake releases
- CanSat parachute deploys
- Altitude: 100 meters

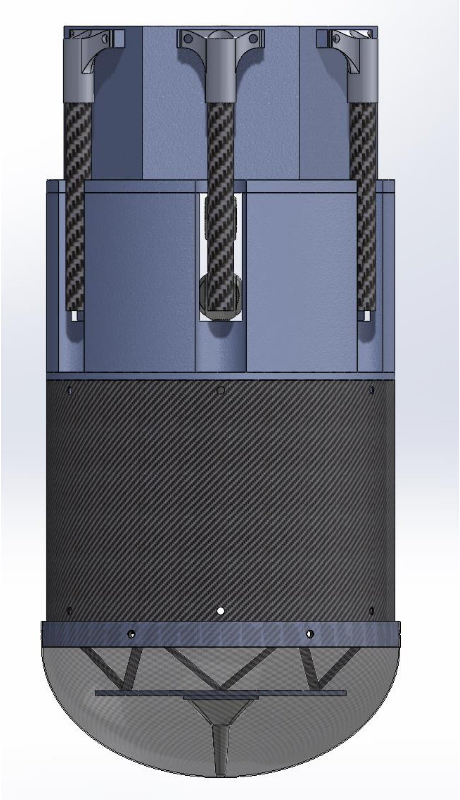
Stage 5
- CanSat lands on the ground
- Undergo post-launch operations to retrieve CanSat
- Altitude: 0 meters

System Concept of Operations (2/2)

Pre-Launch Operations	In-Flight Payload Operations	Post-Launch Operations
• CanSat is powered on • Ensure CanSat has stable connection with GCS • CanSat is fully assembled • CanSat is inserted into the rocket	• CanSat is launched at 0 meters • CanSat detaches from rocket and deploys aerobrake at 750 meters • CanSat's descent rate is 10-30 m/s once aerobrake is released • CanSat detaches aerobrake and deploys parachute at 100 meters • CanSat's descent rate is <5 m/s once aerobrake is detached • CanSat lands on ground at 0 meters • CanSat transmits telemetry through in-flight operations and stops once landed	• Ensure audio and visual beacon are turned on • Review GCS for approximate location of CanSat • Recovery crew will depart to collect aerobrake, CanSat, and rocket • CanSat will be inspected for damages • GCS crew will ensure necessary telemetry is saved

Launch Vehicle Compatibility

- Launch configuration has no protrusions
- Dimensions are exact as per the mission requirements
  - 140 mm dia. For nosecone and 136 mm dia. For shoulder
  - Shoulder length is at least 5 mm
- No clearance as mission requirements are exact.



Sensor Subsystem Design

Shriya Vishwanathan

Sensor Subsystem Overview (1/2)

Serial	Sensor Type	Model	Function	Payload	Container
1	Air Pressure	BME280	Measure air pressure for altitude calculation	Y	N
2	Air Temperature	BME280	Measure air temperature; provide temperature correction for RTC	Y	N
3	Camera	Adafruit Mini Spycam 3202	Record Probe Flight	Y	N
4	Bonus Camera	Adafruit Mini Spycam 3202	Record Probe Flight	N	Y

Sensor Subsystem Overview (2/2)

Serial	Sensor Type	Model	Function	Payload	Container
5	Inertial Measurement Unit	Adafruit BNO055 Absolute Orientation Sensor	Generate an Inertial Map of probe position; Measure X and Y axis tilt values for telemetry reporting	Y	N
6	GPS	SparkFun Neo M9N	Track Payload Location; Redundant time keeping	Y	N
7	Battery Voltage	Microcontroller Analog Pin	Measure Battery Voltage; Brownout Protection	Y	N

Payload Air Pressure Sensor Trade & Selection

Name	Interface	Resolution (Pa)	Size (mm)	Weight (g)	Cost ($)	Operating Range (kPa)	Range Accuracy (kPa)
BME280	I2C SPI	1	15.5 x 11.5 x 0.93	1.0	21.50	30 to 110	± 0.1
BMP388	I2C SPI	0.6	21.6 x 16.6 x 3.0	1.2	9.95	30 to 125	± 0.05

Selected Processor	Rationale
BME280	• Smallest size • Low weight • Relatively high accuracy • Sufficient for mission objective

Payload Air Temperature Sensor Trade & Selection

Name	Interface	Resolution (Pa)	Size (mm)	Weight (g)	Cost ($)	Operating Range (°Celsius)	Range Accuracy (°Celsius)
BME280	I2C SPI	0.18	15.5 x 11.5 x 0.93	1.0	21.50	-40 to 85	± 1
BMP388	I2C SPI Serial	0.0016	21.6 x 16.6 x 3.0	1.2	9.95	-40 to 85	± 1

Selected Processor	Rationale
BME280	• Smallest size • Low weight • Relatively high accuracy • Sufficient for mission objective

Payload Battery Voltage Sensor Trade & Selection (1/2)

Name	Interface	Resolution (bits)	Size (mm)	Weight (g)	Cost ($)
Teensy 4.1 Analog Pin	Analog	10	60.96 x 17.78	Embedded	Embedded
INA-260	I2C	16	22.9 x 22.8 x 2.7	2.0	2

Selected Processor	Rationale
Teensy 4.1 Analog Pin	• Size and Cost both embedded/included with microcontroller • Requires low operating current

Payload Tilt Sensor Trade & Selection

Name	Interface	Max Power	Size (mm)	Weight (g)	Cost ($)	Resolution (bit)	Accuracy
BNO055	HID-I2C I2C UART	3.6V x 12.3 mA	5.2 x 3.8	0.15	34.95	14 (Accelerometer) 16 (Gyroscope) 13 (Magnetometer)	± 0.5
BMI160	I2C SPI	3.6V x 0.925 mA	12.6 x 12.6	0.09	14.95	16 (Accelerometer) 16 (Gyroscope)	± 2.5

Selected Processor	Rationale
BNO055	• Contains 3 sensors • Fused sensor output • Greater number of measurement axis • Smaller size • Higher accuracy

Payload Rotation Sensor Trade & Selection

Name	Interface	Max Power	Size (mm)	Weight (g)	Cost ($)	Resolution (bit)	Accuracy
BNO055	HID-I2C I2C UART	3.6V x 12.3 mA	5.2 x 3.8	0.15	34.95	14 (Accelerometer) 16 (Gyroscope) 13 (Magnetometer)	± 0.5
BMI160	I2C SPI	3.6V x 0.925 mA	12.6 x 12.6	0.09	14.95	16 (Accelerometer) 16 (Gyroscope)	± 2.5

Selected Processor	Rationale
BNO055	• Contains 3 sensors • Fused sensor output • Greater number of measurement axis • Smaller size • Higher accuracy

Payload GPS Sensor Trade & Selection

Name	Interfaces	Accuracy	Sampling Rate (Hz)	Size (mm)	Max Power	Cost ($)
NEO-M9N	I2C UART SPI	1.5 m (Horizontal) 0.05 m/s (Velocity) 0.3 Degrees	25	12.2 x 16.0 x 2.4	3.3V x 31mA	69.95
ZOE-M8	I2C UART SPI	2.5 m (Horizontal) 0.05 m/s (Velocity) 0.3 Degrees	18	4.5 x 4.5 x 1.0	3.3V x 29mA	49.95

Selected Processor	Rationale
NEO-M9N	• Highest accuracy • Highest sampling rate • Own RTC
Minimum Requirement: • Includes latitude, longitude, altitude measurements	

Payload Camera Trade & Selection

Name	Interfaces	Resolution (Pixels)	Angle View	Operating Current (mA)	Size (mm)	Weight (g)	Cost ($)
Adafruit Mini Spy Cam 3202	GPIO	680 x 480	120 Degrees	110	28.5 x 17.0 x 4.2	2.8	12.50
Raspberry Pi Camera v2.1	GPIO	1980 x 1080	111 Degrees	250	25.0 x 24.0 x 9.0	3.0	25.00

Selected Processor	Rationale
Adafruit Mini Spy Cam 3202	• Lowest weight • Lowest cost • Smallest size • Largest angle view
Minimum Requirement: • Colored video • 680 x 480 Resolution	

Descent Control Design

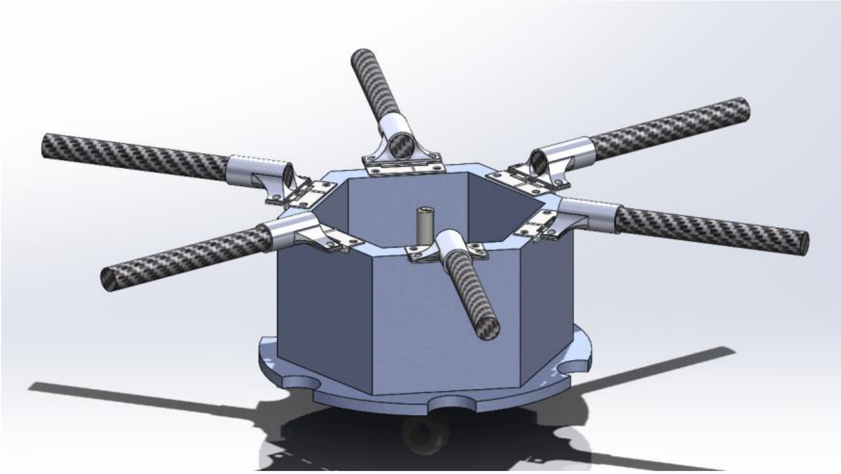
Ethan Klepper

Descent Control Overview

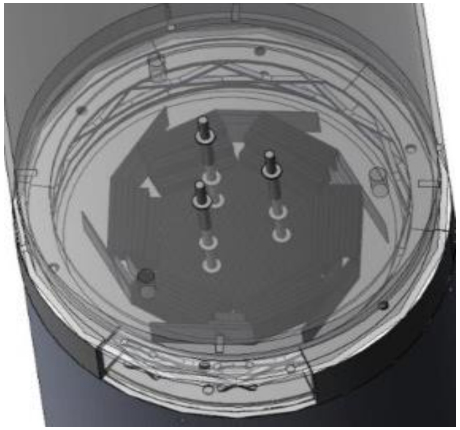
- **Two Stages**
  - Aerobrake
    - Deployed at apogee
    - Target Velocity of 17m/s
  - Parachute
    - Deployed at 100m
    - Target Velocity of 2.5m/s

Main Components

- Round Parachute
- Heatshield Arms
- Webbing Fabric
- Burn Wire Release

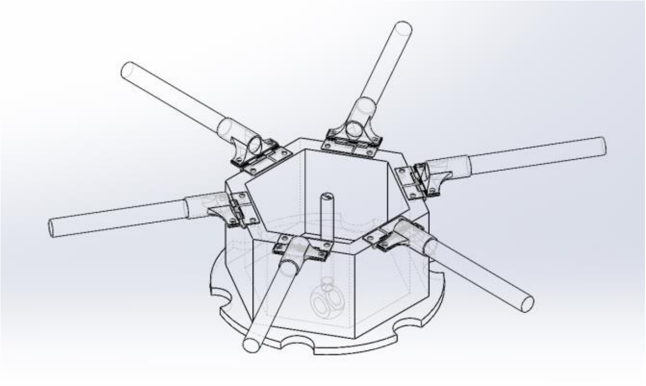


Payload Aerobraking Descent Control Strategy Selection and Trade



Origami
- An expanding origami mesh with carbon-fiber panels to increase air resistance.
- Will be circular in shape and a size of approximately .6m^2

Webbing
- Carbon fiber rods placed around the body that will lower upon deployment with webbing placed between each rod to increase air resistance
- Will be circular in shape and a size of approximately .6m^2



Payload Parachute Descent Control Strategy Selection and Trade

- **Aerobrake type trade studies and selection**

Aerobrake Selection				
Criteria	Explanation (Graded 1-10)	Weight	Webbing	Origami
Stability	How stable is it in adverse/turbulent air	40%	7	6
Manufacturing	Difficulty to manufacture	25%	8	2
Weight	How heavy would it be	10%	9	6
Reliability	Can it consistently deploy safely with no problems	25%	7	4
	Totals	100%	7.45	4.5

Webbing
- Easy and simple to deploy should allow for a reliability
- Much easier to manufacture and build
- Webbing will allow for light weight
- Webbing would be more open to tares

Origami
- Complex structure could be difficult to manufacture and build, and would lead to a decreased reliability
- Material would be stronger and more rigid than the webbing

Payload Rotation Control Strategy Selection and Trade

- **Rotation control**
  - To prevent any rotation, we will have the Cansat weight equally distributed along each axis.
  - This should prevent and forces that would cause the Cansat to rotate

Parachute Choices

- Ram-Air Parachute

- Round Parachute

Payload Parachute Descent Control Strategy Selection and Trade

- **Parachute type trade studies and selection**

Parachute Selection				
Criteria	Explanation (Graded 1-10)	Weight	Round	Ram-Air
Stability	How stable is it in adverse/turbulent air	30%	10	6
Cost	Price of each	25%	9	6
Drag	How large it's drag coefficient is	20%	8	10
Reliability	Can it consistently deploy and land safely with no problems	25%	9	7
	Totals	100%	9.1	7.05

- Round Parachute
  - Better for uncontrolled decent
  - Cheaper and more readily available
  - Less complex
- Ram-Air Parachute
  - Better for controlled decent
  - More maneuverable
  - Higher drag coefficient

Descent Rate Estimates

Summary

Aerobrake

- After being released at apogee, the aerobrake will maintain a speed of 17m/s
- To do this we will need an area of .0496m^2

Parachute

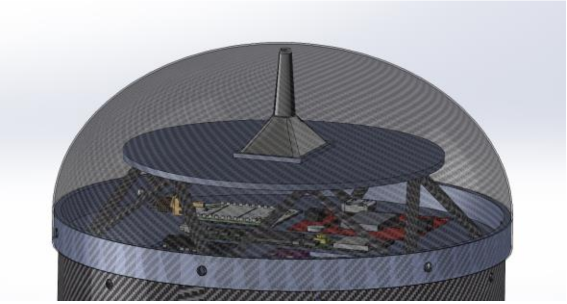
- After being released at 100m, the parachute will maintain a speed of 2.5m/s
- To do this we will need an area of .476m^2

Mechanical Subsystem Design

John Santosuosso

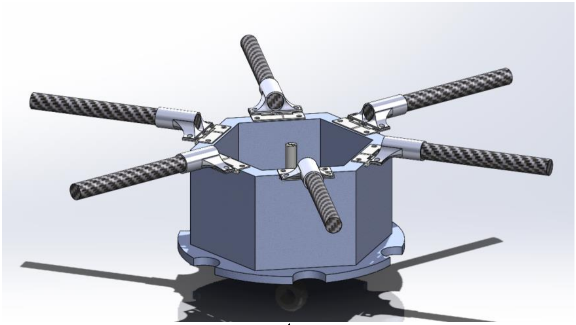
Payload Mechanical Layout of Components Trade & Selection

- Electrical components are stored near the nose
- Egg is protected below the electronics
- Electronics near the nose to allow close proximity to the pitot tube and minimize empty space
- Egg is directly below the electronics, so that the center of mass is easily lower than the center of pressure

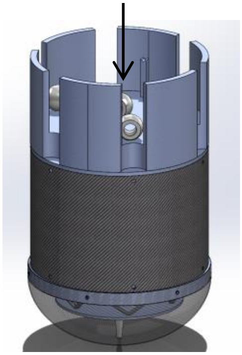


Payload Aerobraking Pre Deployment Configuration Trade & Selection

- **Aerobrake secured by line**
  - The eye bolts, shown in the CAD on the right, are connected by fishing line, as it is lightweight yet strong
  - The tension of the string keeps the two bodies together
  - A burn wire, wrapped around the line, will sever the line to deploy

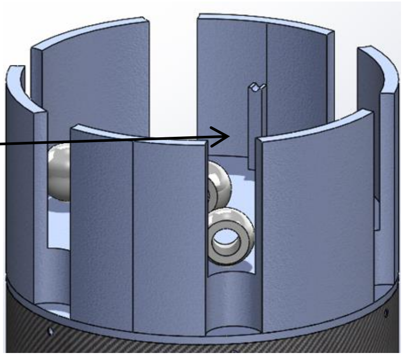


Line connected here

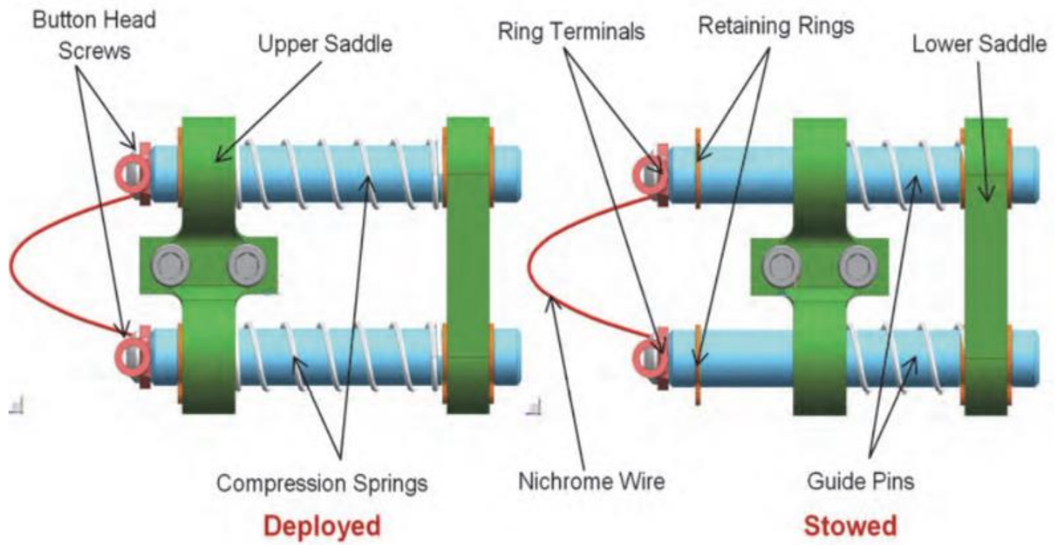


Aerobrake Separated Parachute deployed Landing

Burn wire will be guided by supports like this one

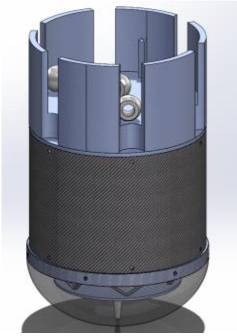


- **Spring loaded hinge**
  - To extend the arms of the aerobrake we will use a spring-loaded hinge in each of the arms.
  - To prevent them from deploying early, each arm be attached with a thin wire.
  - We will then burn though the wire with burn wire to deploy the arms



Payload Parachute Deployment Configuration Trade & Selection

- **Parachute is deployed when the aerobrake is separated**
- **The aerobrake falls at a slower rate than the parachute, and it pulls the parachute out to deploy it**



Aerobrake Separated
Parachute deployed
Landing

Payload Egg Containment Configuration Trade & Selection

- Egg would be placed in the Cansat and the rest of the Cansat would be attached around the egg
- **Foam**
  - Used to surround the egg and provide cushion to any force
- **Springs**
  - Used to hold the egg in an Oobleck filled container to cushion any force

Payload Egg Containment Configuration Trade & Selection

- **The Egg will be placed into the Cansat and then the remaining part of the Cansat will be attached.**

Parachute Selection				
Criteria	Explanation (Graded 1-10)	Weight	foam	spring
Ease	How easy is it to manufacture and build	30%	10	6
Cost	Price of each	10%	9	8
Size	How large and heavy will it be	20%	8	8
Reliability	How reliably will it protect the egg	40%	9	7
	Totals	100%	9.1	7.00

- Foam
  - More consistent and reliable
  - Easier to manufacture and build
  - Less complex
- Spring
  - More adjustable (change to ideal spring)
  - Harder to predict and less reliable

Mass Budget (1/2)

Part	Volume (mm^3)	Material	Density (g/mm^3)	Mass (g)	Source
Nose Cone	14757.63	Carbon Fiber	0.0018	26.56373	CAD
Pitot Tube	468.68	Aluminum	0.0027	1.265436	CAD
Nose Cone Adapter	56304.01	PLA (20% infill)	0.00125	14.076	CAD
Egg Tube	77220.2	Carbon Fiber	0.0018	138.9964	CAD
Burn Wire Section	345643.57	PLA (20% infill)	0.00125	86.41089	CAD
Aerobrake adapter	273743	PLA (20% infill)	0.00125	68.43575	CAD
Rod Connector (6)	1462	PLA (20% infill)	0.00125	2.193	CAD
Aerobrake Arm (6)	8325	Carbon Fiber	0.0018	89.91	CAD
Subtotal				**427.8512**	

These are the mass values for the mechanical and structural elements that the team will build. The volume has been taken from the CAD model and multiplied by the density of the material as given in the datasheet provided by the supplier.

Mass Budget (2/2)

Component	Mass (g)	Source
Mini Spycam (2)	2.8	Datasheet
BME 280	1	Datasheet
Teensy 4.1	2.8	Datasheet
BNO055	3	Datasheet
NEO M9N	1.6	Datasheet
Adafruit PCF8523 RTC	3.2	Datasheet
DigXBee Pro RF Module	5	Datasheet
LG MJ1-18650 Battery	48.71	Datasheet
SD card	0.5	Approximation
Burn Wire (2)	2	Approximation
High Density Foam	50	Approximation
Parachute	85	Datasheet
Total	**633.4612**	

Datasheet values have been taken from the datasheet of the manufacturer. Approximation values are based on a volume estimation (for foam and burn wire)

Total Mass
The total mass of the CanSat therefore, is expected to be ~635 grams without the egg

Margin
This leaves a ~30% for mass increase considering a mass limit of 900g. Which is sufficient to cover any uncertainties in mass used for calculations

Corrective Steps
Based on the margin, no corrective steps are necessary at this time. However, if the need arises for mass reduction, the team can decrease the infill % on non-load bearing 3d printed components. The size of the egg cell and burn wire bay can also be reduced.

Communication and Data Handling (CDH) Subsystem Design

Hannah Lexer

Payload Command Data Handler (CDH) Overview

Item	Selected Product Model	Functions
Processor	iMXRT1062 on Teensy V4.1	• Controls all other components
Data Storage	Micro Center 16GB Micro SD	• Stores telemetry data
Real Time Clock	Adafruit PCF8523 RTC	• Keeps time • Ensures 1 Hz broadcast of telemetry data to ground station
Antenna	915Mhz ISM Band Antenna	• Amplifies signal range
Radio	Digi XBee Pro RF Module 900 MHz	• Transmits telemetry data to ground station

Payload Processor & Memory Trade & Selection (1/2)

Name	Boot Time (ms)	Processor Speed (MHz)	Data Interfaces	Flash Memory (kB)	RAM (kB)
iMXRT1062 on Teensy V4.1	~5	500	2x SPI 8x UART 3x I2C	7936	1024
STM32F103C8T6 on Blue Pill	~5	72	2x SPI 3x UART 2x I2C	64	20

Selected Processor	Rationale
iMXRT1062 on Teensy V4.1	• Higher processor speed • More data interfaces • Works with Arduino IDE • Adequate flash memory and RAM

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

Name	Memory	Interface	Read	Write	Cost
Micro Center 16GB Micro SDHC	16 GB	SPI and SD	80 MB/s	15 MB/s	$2.80
Sandisk Ultra Micro SDHC	16 GB	SPI and SD	160 MB/s	60 MB/s	$5.33

Selected Memory Chip	Rationale
Micro Center 16GB Micro SDHC	• Sufficient write speed • Lower cost • Compatible with Teensy 4.1 • Adequate storage space

Payload Antenna Trade & Selection (1/2)

Name	Connection Type	Frequency	Type	Gain	Length	Cost
915Mhz ISM Band Antenna	RP-SMA	902~928 MHz	Linear	1.5 dBi	75mm	$13.61
915MHz Embedded Patch Antenna with Cable and Connector	RP-SMA	902 – 928 MHz	RHCP	5.21 dBi	49.5 mm	$22.13

Selected Antenna	Rationale
915 Mhz ISM Band Antenna	• Smaller size and lighter in weight • Lower cost • Known to work well with 900 MHz Xbee • Sufficient gain

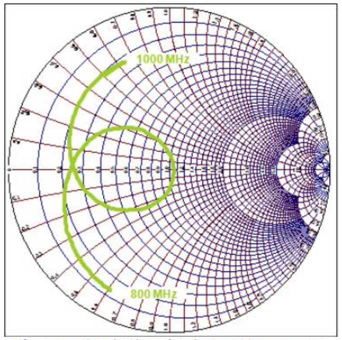


Figure 5. Smith Chart for the FXP290 Antenna.

Payload Antenna Trade & Selection (2/2)

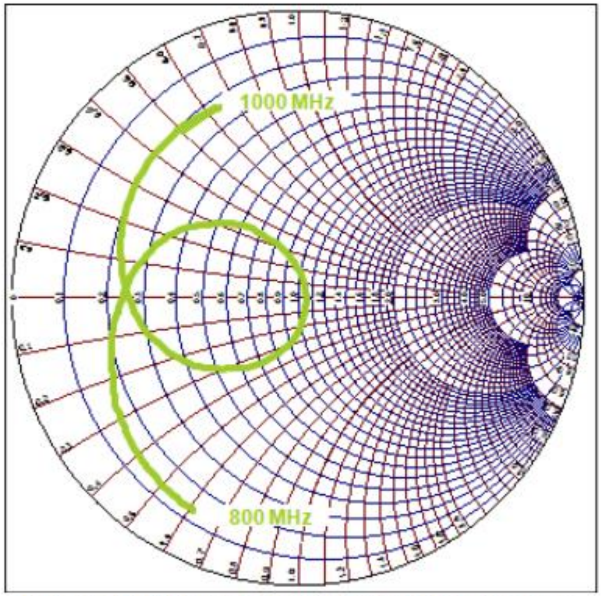
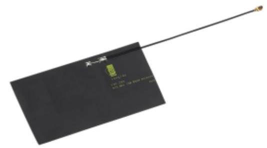
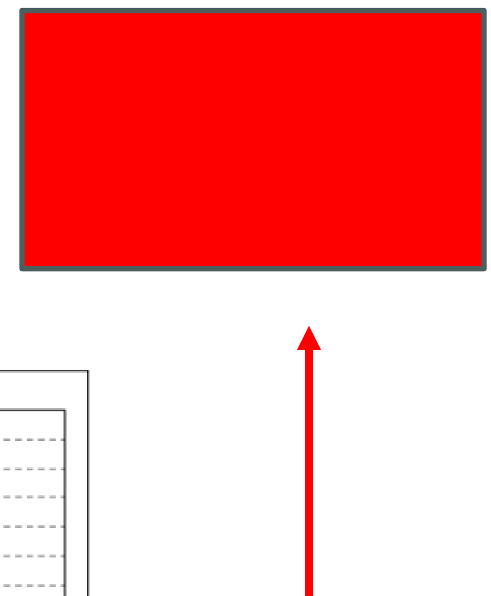
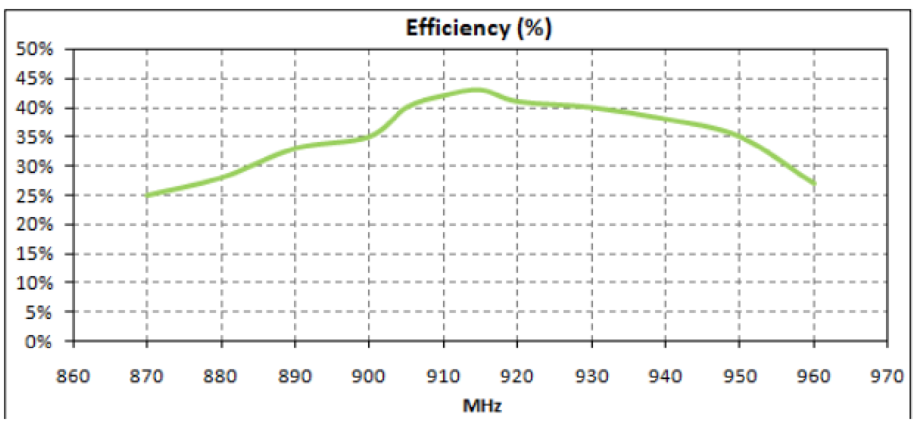


Figure 5. Smith Chart for the FXP290 Antenna.





Antenna Location



Payload Radio Configuration (1/2)

Name	Frequency	Connection Type	Data Rate	Reported Range	Cost
Digi XBee Pro RF Module 900 MHz	902-928 MHz	RP-SMA	200 Kbps	6500m	$62.08
Digi XBee 3 DigiMesh 2.4 RF Module	2.4 GHz	RP-SMA	250 Kbps	3200m	$98.99

Selected Radio	Rationale
Digi XBee Pro RF Module 900 MHz	• Adequate frequency • Larger range • Lower cost • Compatible with chosen antenna • High data rate

Payload Radio Configuration (2/2)

NETID of XBee	• ID: 2083
Transmission Control	• Software on Teensy 4.1 will prepare and transmit the telemetry at 1Hz for the duration of the mission • Most data will simply be packaged and streamed to ground station (e.g. TeamID, Temperature) • Mission phase data will change based on altitude and other internally stored information (e.g. PC_DEPLOYED, MAST_RAISED) • We will not use broadcast mode in XBee receivers.

Payload Telemetry Format (1/3)

Field	Description	Resolution
TEAM_ID	The assigned four digit team identification number	N/A
MISSION_TIME	UTC time in format hh:mm:ss, where hh is hours, mm is minutes, and ss.ss is seconds, calibrated within one second of UTC	0.01s
PACKET_COUNT	The total count of transmitted packets since turn on	N/A (discrete)
MODE	‘F’ for flight mode and ‘S’ for simulation mode	N/A
STATE	The operating state of the software (e.g., LAUNCH_WAIT, ASCENT, ROCKET_SEPARATION, DESCENT, HS_RELEASE, LANDED, etc.)	N/A
ALTITUDE	The altitude in units of meters and must be relative to ground level at the launch site.	0.1m
AIR_SPEED	The air speed measured in meters per second with the pilot tube during both ascent and descent	N/A
HS_DEPLOYED	‘P’ for probe (and heat shield) deployed. ‘N’ otherwise	N/A
PC_DEPLOYED	‘C’ for probe parachute deployed. ‘N’ otherwise	N/A

Payload Telemetry Format (2/3)

Field	Description	Resolution
TEMPERATURE	The temperature in degrees Celsius	0.1 degrees
VOLTAGE	The voltage of the CanSat power bus	0.1V
GPS_TIME	The time from the GPS receiver. Must be reported in UTC	1s
GPS_ALTITUDE	The altitude from the GPS receiver in meters above mean sea level	0.1m
GPS_LATITUDE	The latitude generated by the GPS receiver in decimal degrees	0.0001 N
GPS_LONGITUDE	The longitude generated by the GPS receiver in decimal degrees	0.0001 W
GPS_SATS	The number of GPS satellites being tracked by the GPS receiver.	N/A (discrete)
TILT_X, TILT_Y	Angles of the CanSat X and Y axes from a Z axis pointing to the center of the earth with a reference of zero when perpendicular to Z-axis.	0.01 degrees
ROT_Z	Rotation Rate of the CanSat in degrees per second	0.1 degrees per second
CMD_ECHO	The text of the last command received and processed by the CanSat	N/A
PRESSURE	The air pressure of the sensor used in kPa	0.1 kPa

Payload Telemetry Format (3/3)

The telemetry data is transmitted in the ASCII comma separated fields followed by a carriage return.
The data will be sent at **1Hz** frequency.

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

Telemetry frame example:
2083,12:32:15.65,13253,F,ROCKET_SEPARATION,321.5,23,P,N,30.2,5.1,20,12:32:15,300.8,45.3231,15.2311, 10,20.1,CXON

The telemetry data will be named: Flight_2083.csv

Payload Command Formats (1/2)

Command	Format	Description	Example
CX - Container Telemetry On/Off Command	CMD,<TEAM_ID>, CX,<ON_OFF>	1. CMD and CX are static text 2. <TEAM ID> is the team ID (e.g. 1100) 3. <ON_OFF> is the string ‘ON’ to activate the Container telemetry transmissions and ‘OFF’ to turn off the transmissions.	CMD,1100,CX,ON
ST: Set Time	CMD,<TEAM_ID>, ST,<UTC_TIME>|GPS	1. CMD and ST are static text. 2. <TEAM ID> is the team ID (e.g. 1100) 3. <UTC_TIME>|GPS is either (A) UTC time (hh:mm:ss) or (B) ‘GPS’ which sets the flight software time to the GPS time.	CMD,1100, ST, 11:22:45 CMD, 1100,ST,GPS
SIM - Simulation Mode Control Command	CMD,<TEAM_ID>, SIM,<MODE>	1. CMD and SIM are static text. 2. <TEAM_ID> is the team ID (e.g. 1100) 3. <MODE> is the string ‘ENABLE’ to enable the simulation mode, ‘ACTIVATE’ to activate the simulation mode, or ‘DISABLE’ which deactivates and disables the simulation mode.	CMD,1100, SIM, ENABLE
SIMP - Simulated Pressure Data (used only in Simulation Mode)	CMD,<TEAM ID>,SIMP, <PRESSURE>	1. CMD and SIMP are static text. 2. <TEAM ID> is the assigned team identification. 3. <PRESSURE> is the simulated atmospheric pressure data in units of pascals with a resolution of one Pascal.	CMD,1100, SIMP,120142

Payload Command Formats (2/2)

Command	Format	Description	Example
CS – Calibration Altitude to Zero	CMD,<TEAM_ID>, CAL	1. CAL command is to be sent when the CanSat is installed on the launch pad and causes the flight software to calibrate the telemetered altitude to 0 meters.	CMD,<1100>,CAL
BCN – Control Audio Beacon	CMD, <TEAM ID>, BCN, ON|OFF	1. CMD and BCN are static text. 2. <TEAM ID> is the assigned team identification. 3. <ON|OFF> are static strings "ON" or "OFF" that control the audio beacon	CMD,<1100>,BCN,ON

Electrical Power Subsystem (EPS) Design

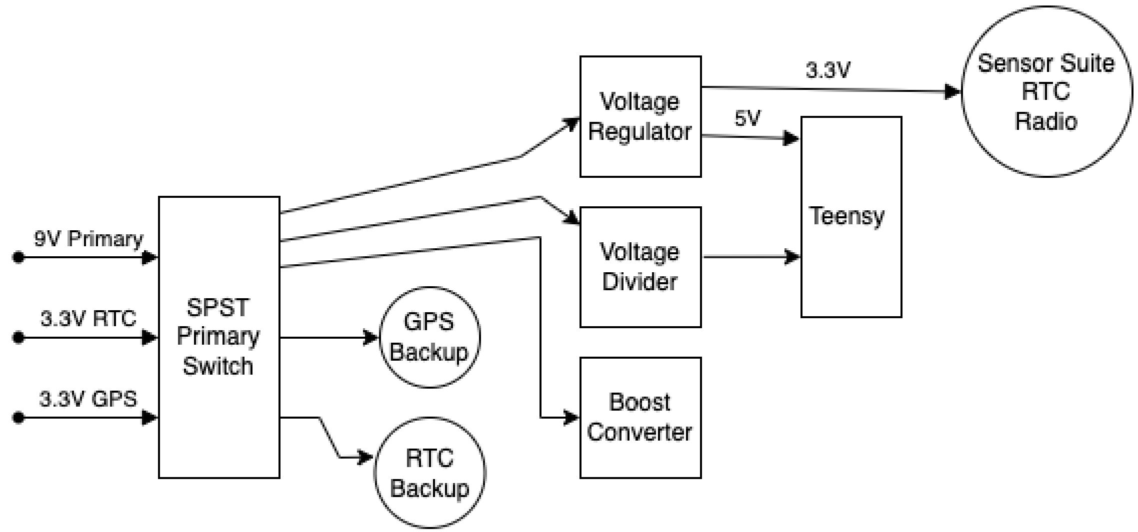
Shriya Vishwanathan

EPS Overview (1/2)

Component	Purpose
3.7V Main Battery	Primary Power Source
3.3V Backup Battery (RTC)	Backup power source for external clock. Backup Power Source for clock on Teensy Microcontroller
3.3V Backup Battery (GPS)	Backup Power source for GPS module
Single-Pole Single-Throw (SPST) Primary Switch	Switch to isolate circuit from main power supply
Triple-Pole Single-Throw (TPST) Kill Switch	Switch to isolate circuit from all power supplies
LED	Power Indicator
Diodes	Reverse Current protection
Voltage Regulator	Provides stable 3.3V and 5V voltage to components
Voltage Divider	Monitoring battery voltage

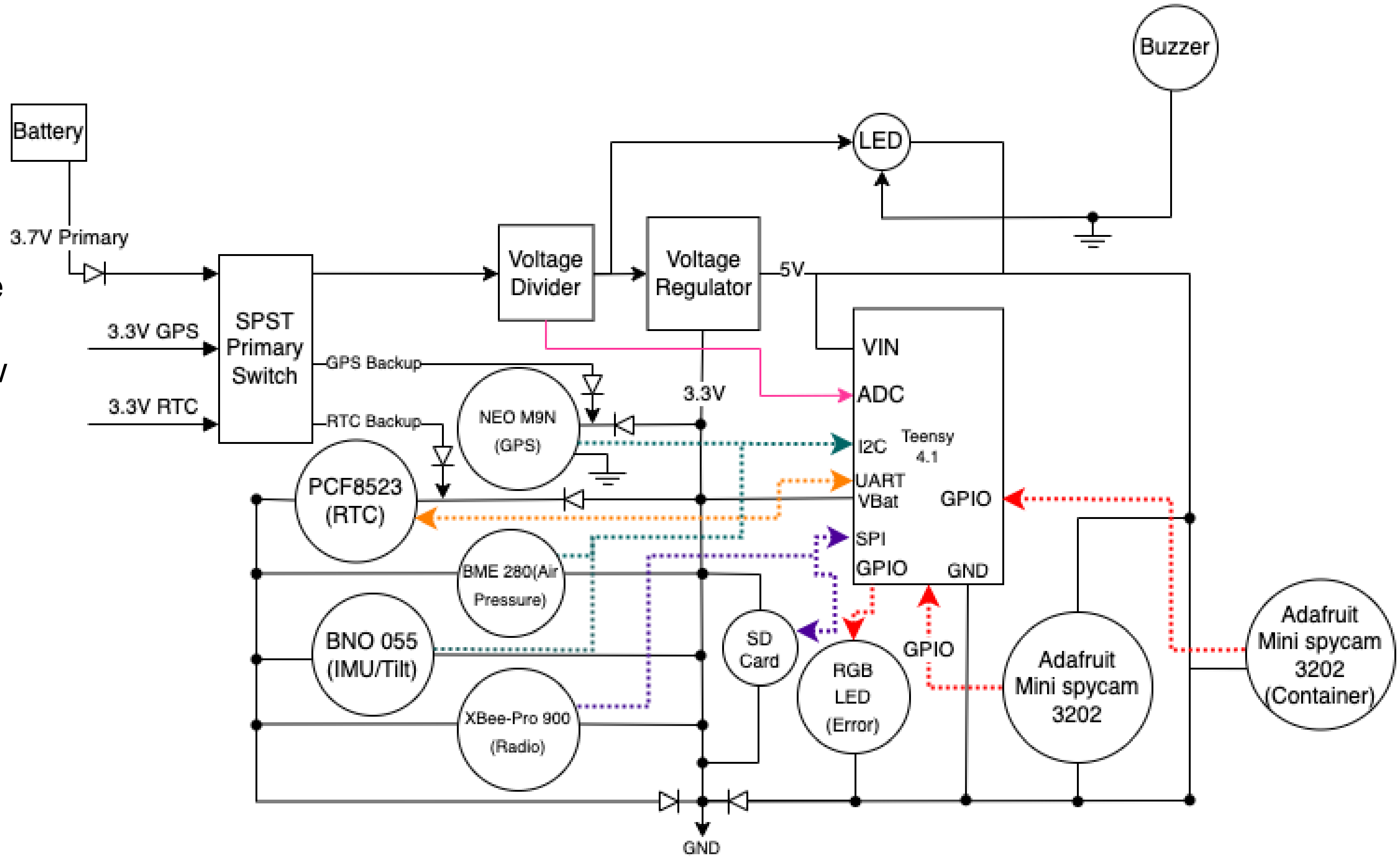
EPS Overview (2/2)

Component	Purpose
POGO Magnetic Pin Connector	For umbilical power supply and bonus camera
Fuse	Overcurrent protection
3 color LED	Error Indication



Payload Electrical Block Diagram

*Arrows indicate direction of current/data flow



Power

UART

I2C

SPI

GPIO

ADC

Payload Power Trade & Selection (1/2)

Name	Size (mm)	Weight (g)	Voltage (V)	Capacity (mAh)	Type	Cost ($)
LG MJ1-18650	65.0 x 18.0 x 117.0	48.71	3.7	3500	Li-ion	$5.99
Energizer L522	46.5 x 26.5 x 17.50	33.9	9	~750	Lithium	8.8

Selected Component	Rationale
LG MJ1-18650	• High capacity • Cheaper • Rechargeable • Easy connection to circuit

Payload Power Trade & Selection (2/2)

Battery Connection	
Solder battery to leads with a connector which will connect to the primary circuit board	

Payload Power Budget

Component	Source	Voltage (V)	Current (mA)	Duty Cycle (%)	Power Consumption (wH)
Voltage Divider	Estimate	9	0.2	100	0.0018
Boost Converter	Datasheet	9	100	100	0.90
Voltage Regulator	Datasheet	9	50	100	0.45
Parachute Servo	Estimate	12	150	25	0.45
Deployment Servo	Estimate	12	150	25	0.45
Power LED	Estimate	12	10	100	0.12
Indicator LED	Estimate	3.3	20	100	[Powered By Teensy]
Buzzer	Datasheet	12	80	50	0.48
GPS	Datasheet	3.3	36	100	0.12
RTC	Datasheet	3.3	50	100	0.17
Air Pressure/ Temperature	Datasheet	3.3	2.80E-06	100	9.24E-09
IMU/ Tilt	Datasheet	3.3	12.3	100	0.04

Payload Power Budget

Component	Source	Voltage (V)	Current (mA)	Duty Cycle (%)	Power Consumption (wH)
Radio Rx	Datasheet	3.3	44	20	0.03
Radio Tx	Datasheet	3.3	229	100	0.76
SD Card Reader	Datasheet	3.3	100	100	0.33
Adafruit Mini Spycam (Probe)	Datasheet	3.3	110	90	0.33
Adafruit Mini Spycam (Container)	Datasheet	3.3	110	20	0.07
Teensy 4.1	Datasheet	3.3	100	100	0.33
Burn Wire	Datasheet	3.7	1500	0.14	0.90
Total Consumption					**5.92**
Primary Power Source	**Datasheet**	**3.7V**	**5000mAh**	**-**	**12.95**
Margin					**7.93**

Flight Software (FSW) Design

Aarav Parikh

FSW Overview (1/2)

Overview of the CanSat FSW Design

- FSW runs 1 central ‘struct’ that stores the probe’s current state
  - All functions can access the current state
  - Only some functions can update the state
- State_estimator also keeps track of current flags and flight time
  - Data pushed to XBEE every second
- Updates to only critical timing and flag information to EEPROM, updates to SD card every second
  - To protect in case of power reset
- Based on the RC_pilot library

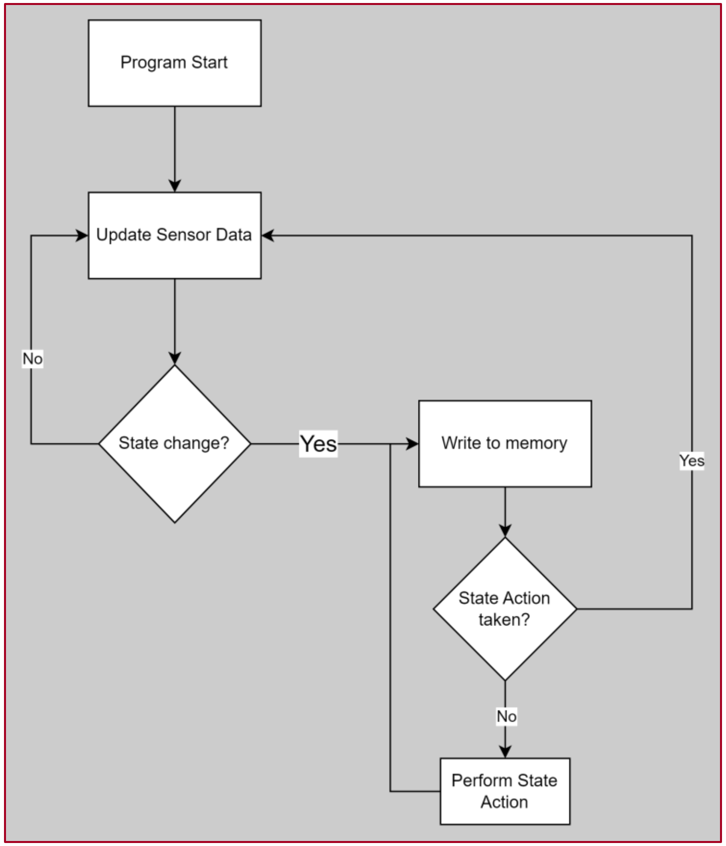
Programming Language

- C for CanSat payload
- Python for ground station

Development Environment

- Visual Studio Code as an IDE
- PlatformIO as an environment
- GitLabs for version control

FSW Overview (2/2)



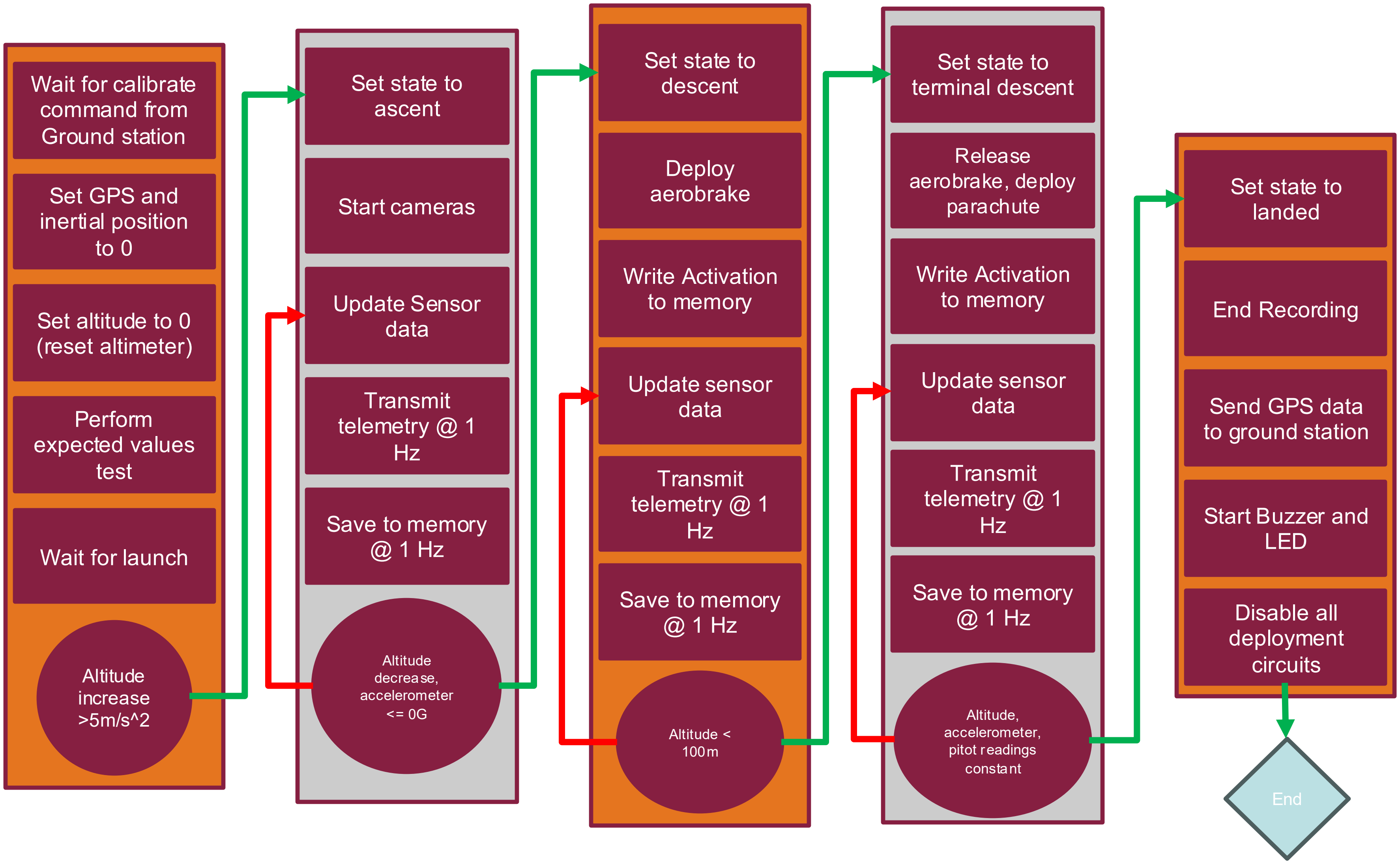
FSW Flowchart

- This simplified flowchart shows the normal operation of the FSW.
- State Change occurs when certain sensor conditions are met (Launch, apogee, 100m and landing)
- State action refers to the appropriate action that needs to be taken by the control system during state change (deploying the heatshield, parachute, activating the buzzer etc.)

Summary of FSW Tasks

- Update Sensor Data
- Control mechanical deployment systems
- Receive and Process ground station commands
- Record and store video feed
- Transmit telemetry data

Payload FSW State Diagram (1/2)



FSW State Diagram (2/2)

State Diagram

- Green arrows indicate condition met
- Red arrows indicate condition not met
- All state changes are written to memory
- Sensors are sampled at 20 Hz

Data Storage

- State changes are stored to EEPROM along with time of state change
- Mechanism activations and telemetry are stored to SD card

FSW recovery

- Upon initialization, software jumps to last known state based on EEPROM
- Then checks for mechanism activation
- Then checks time since the state was set
- Combines these to determine if it should
  - Continue as normal (normal FSW flow resumes)
  - Activate skyfall protection
    - Parachute deployed and buzzer started to prevent CanSat hitting bystanders on the ground

Simulation Mode Software

Implementation

- Simulation mode is used for testing and demonstrating the CanSat's softwares and mechanics over a full mission span.
- The GCS will send the container two command, SIM ENABLE and SIM ACTIVATE, to ensure simulation mode is initialized correctly.
- The GCS will then send barometric pressure sensor values from a data file to the FSW.
- The FSW will receive the sensor values and use software logic to calculate the simulated altitude.
- All other sensors and data values, excluding the pressure, will be taken from the expected range (used for comparison in flight mode).

SIM - Simulation Mode Control Commands

- CMD, XXXX, SIM, ENABLE - Used to enable simulation mode
- CMD, XXXX, SIM, ACTIVATE - Used to activate simulation mode
- CMD, XXXX, SIM, DISABLE - Used to disable and deactivate simulation mode

SIMP - Simulated Pressure Data

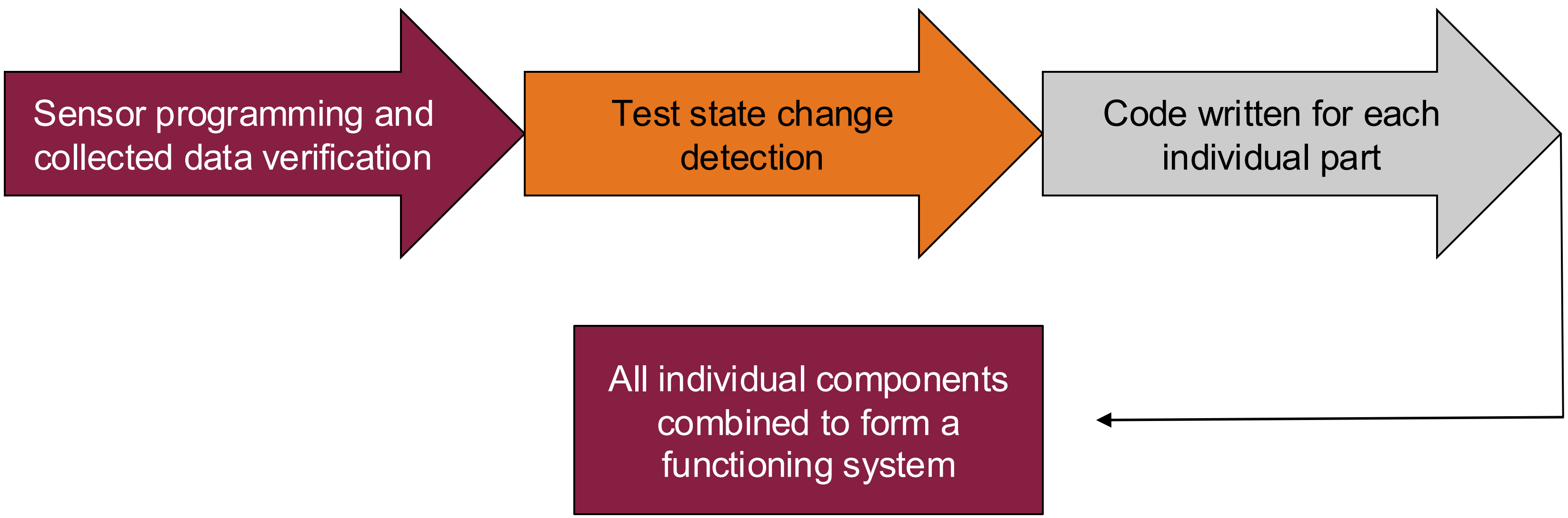
- CMD, XXXX, SIMP, <PRESSURE> - simulated pressure data received by FSW (Pa)

Software Development Plan (1/2)

Prototyping and Prototyping Environments

- Individual sensor testing
- Testing of prototype with all included components
- Uploading and testing of software
- Data output inspected for possible errors

Software Subteam Development Testing



Software Development Plan (2/2)

Test Methodology

- A device containing the CanSat's electrical parts and connections with the PCB will be created digitally and physically to ensure potential risks and mission failures are mitigated and/or prevented.
- All sensors and electrical parts will be tested independently from the CanSat to ensure the components are functional and compatible with the software utilized.
- FSW is reviewed by all team members and advisors to ensure mission success.

Development Team

Aarav Parikh	FSW diagram FSW overview FSW design
Shreeya Rambhad	EPS Overview Sensor subsystem design Testing

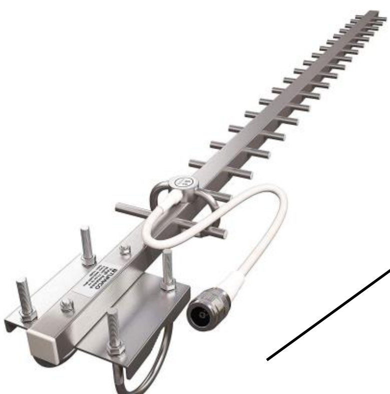
Ground Control System (GCS) Design

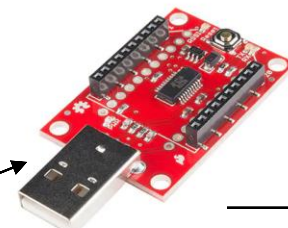
Hannah Lexer

GCS Overview

XBee will act as a receiver to collect data from the CanSat. In the use of simulation mode, will act as a transmitter to CanSat.

The laptop will run a continuous data collection software from a direct connection to CanSat.





Thread wire connection

Pin I/O connection

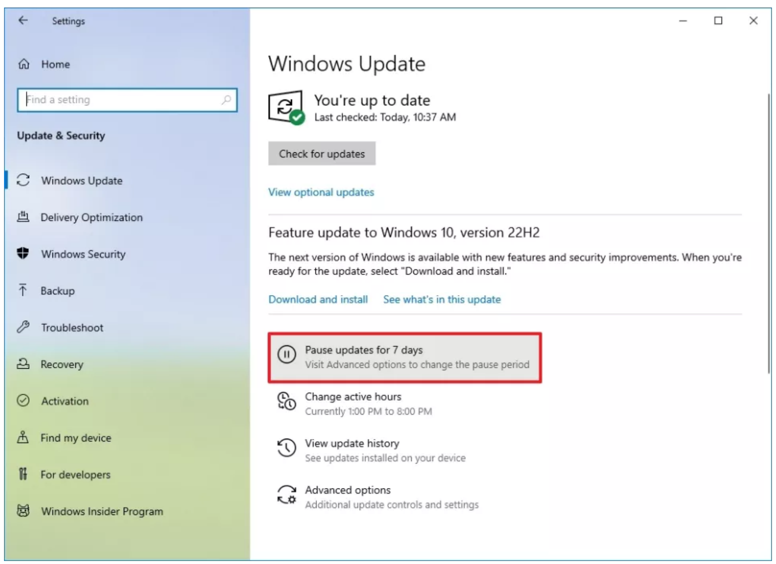
USB Connection

Yagi antenna will allow for an appropriate connection between CanSat and Ground Station.

XBee adaptor is necessary to make a connection between our receiver and laptop. This is necessary for data collection.

GCS Design

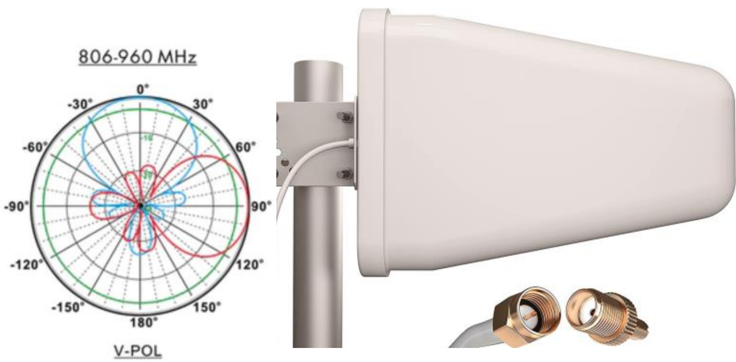
- The laptop can operate for more than 2 hours
- Canopy will prevent overheating
- Windows auto-update will be turned off



GCS Antenna Trade & Selection

Name	Connection Type	Frequency	Type	Gain	Mount	Cost
Tupavco TP514 Yagi Antenna	RP-SMA	806-960 MHz	Directional	9 dBi	Tabletop	$29.99
WeBoost Directional Yagi Antenna	N-Female	700~800~900 MHz	Directional	10.8 dBi	Handheld	$50.88

Selected Antenna	Rationale
Tupavco TP514 Yagi Antenna	• Tabletop mount included • Lower cost • Connection type compatible with XBee • More than adequate gain



Our antenna will be handheld to aid adjustment to track the position of CanSat.

GCS Software

- **Software packages: PySerial, PyQt6, and the Digi Xbee Python Library**

- We will use PySerial to get data from the XBee connected via USB in real-time. On the front end, PyQt6 will be used to immediately update real-time line graphs for the sensor data, as well as the stand-alone count and status values.

- A Python library will be imported to aid in GUI creation. Our interface will present a number of graphs displaying our variables in a meaningful and concise manner. Data will be recorded in mutable data structures that will update new information as packages are received. Xbee will need to connect to Python software methods to receive data.

- A built-in Python method *write()* will update a .csv file every second. There will be a column for each data type recorded.

- In simulation mode, the ground station software will read rows of data from a CSV file with the built-in Python *read() method*, package the data, and then transmit it with the aid of the imported Python libraries.

CanSat Integration and Test

Shreeya Rambhad

CanSat Integration and Test Overview

Subsystem Testing
Each individual subsystem will be tested independently to detect problems, including the mechanical, electrical, FSW, and CDH systems.

Integration Testing
All subsystems will be integrated to become one unit, detecting issues such as part clearances, proper telemetry detection, and circuit reliance.

Simulation Testing
The assembled CanSat will be put into SIMULATION mode to verify that an existing data file can be recieved and flight actions can be taken automatically.

Environmental Testing
The assembled CanSat will be confirmed of its compliance by completing the drop, thermal, vibration, and vacuum test as defined in the mission guidelines.

Environmental Test Plan

Testing Category	Testing Methodology
Drop Test	• Probe will be attached to an eyebolt and raised 61 cm with a paracord • Probe will be dropped to ensure 30 g's of shock is generated • All subsystems will be checked to be in working condition • The structural integral should not be compromised
Thermal Test	• Probe will be placed into a thermal-vacuum chamber • Probe will undergo temperatures ranging 55 to 60 degrees C • All subsystems will be checked to be in working condition • The structural integral should not be compromised
Vibration Test	• Probe will be placed on a random orbital sander • Probe will be vibrated at 0 to 233 Hz to ensure launch conditions are generated • All subsystems will be checked during the test to be in working condition • The structural integral should not be compromised through the test
Fit Check	• Probe will be placed into a test rocket to mirror the competition rocket • Proper tolerances between the probe and rocket will be verified • Deployment from the rocket will be ensured
Vacuum Test	• Probe will be placed into a thermal-vacuum chamber • Probe will undergo varying pressures ranging to peak altitude conditions • All subsystems will be checked during the test to be in working condition • The structural integral should not be compromised through the test

Requirements Compliance

Shreeya Rambhad

Requirements Compliance Overview

Requirement Compliance: 70 / 73
The requirements that we are partially compliant with are due to needed testing. We are on track to be fully compliant by the CDR.

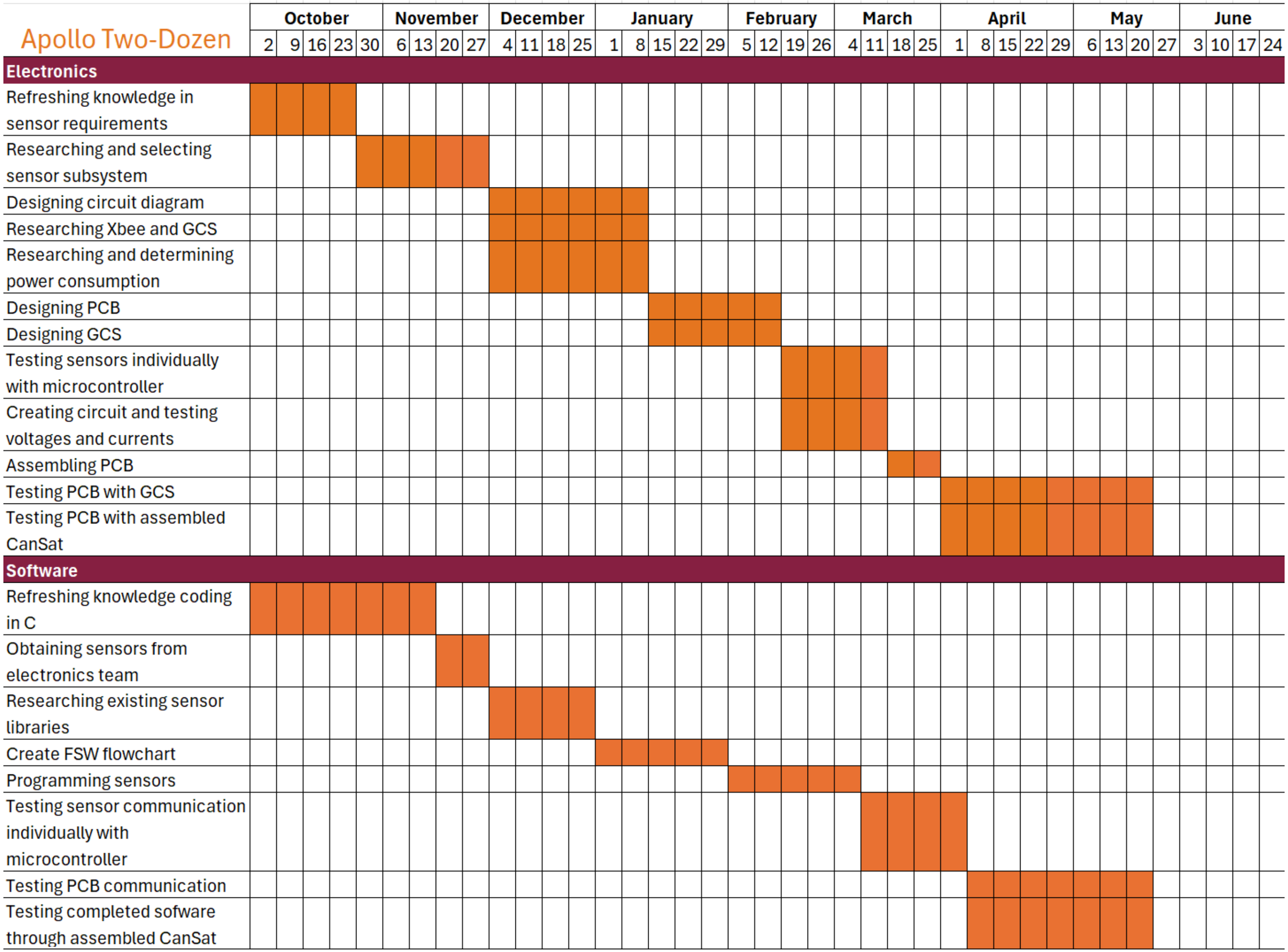
Management

Aarav Parikh

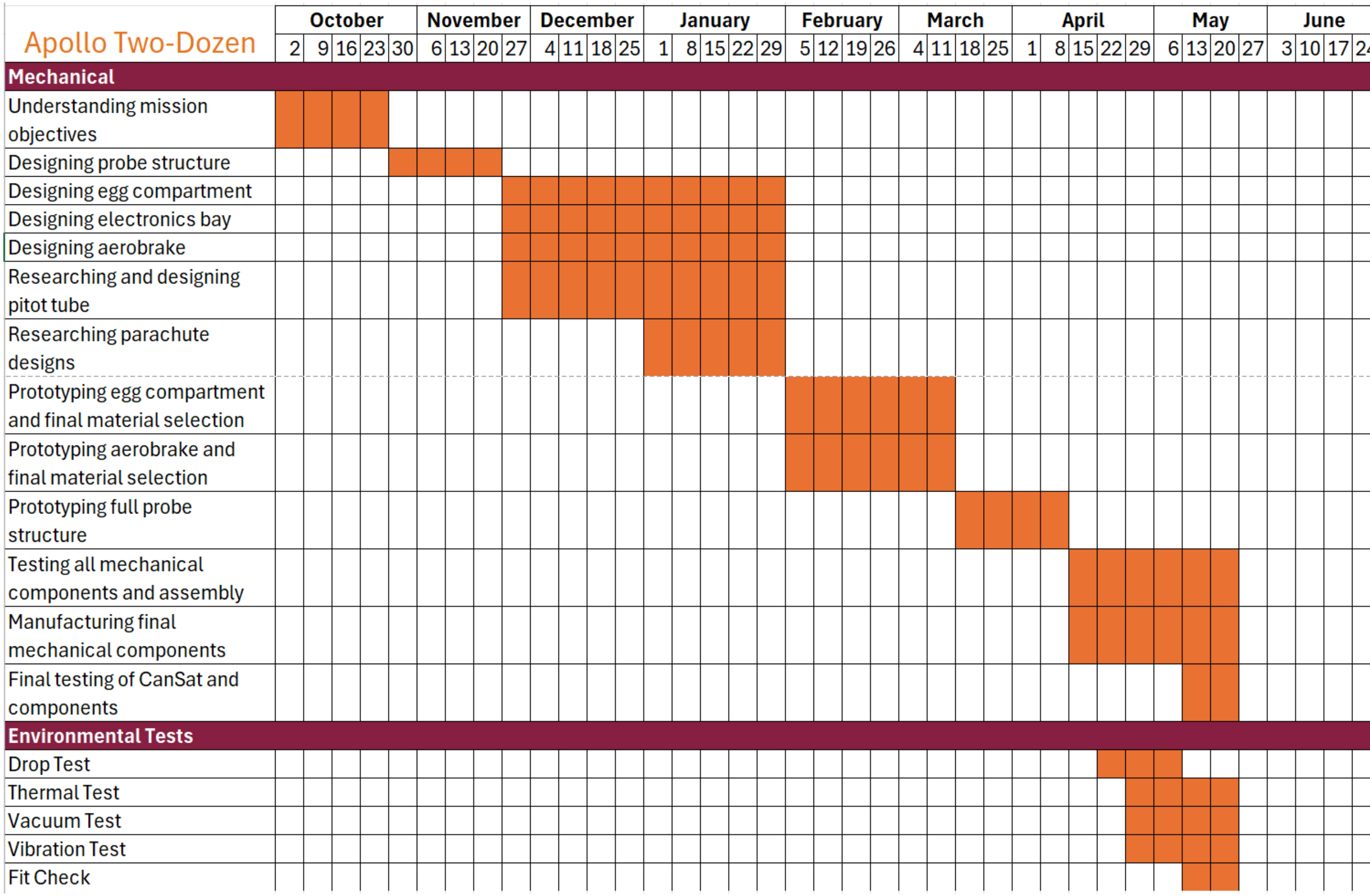
Program Schedule Overview

Apollo Two-Dozen	October					November				December				January					February				March				April					May				June			
	2	9	16	23	30	6	13	20	27	4	11	18	25	1	8	15	22	29	5	12	19	26	4	11	18	25	1	8	15	22	29	6	13	20	27	3	10	17	24
Phases																																							
Team Formalized	■	■																																					
PDR			■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■																					
CDR																			■	■	■	■	■	■	■	■													
Testing																											■	■	■	■	■	■	■	■					
Competition																																			■	■			
General Design																																							
Competition Brainstorming	■	■	■	■	■																																		
Design						■	■	■	■	■	■	■	■	■	■	■																							
Prototyping																	■	■	■	■	■	■	■	■	■	■													
Testing																											■	■	■	■	■	■	■	■					
Final Competition Planning																																			■	■			
School Events																																							
Thanksgiving Break								■																															
Fall Classes End										■																													
Final Finals										■	■																												
Winter Break												■	■	■	■																								
Spring Classes Start																■																							
Spring Break																							■																
Spring Classes End																															■								
Spring Finals																															■	■							

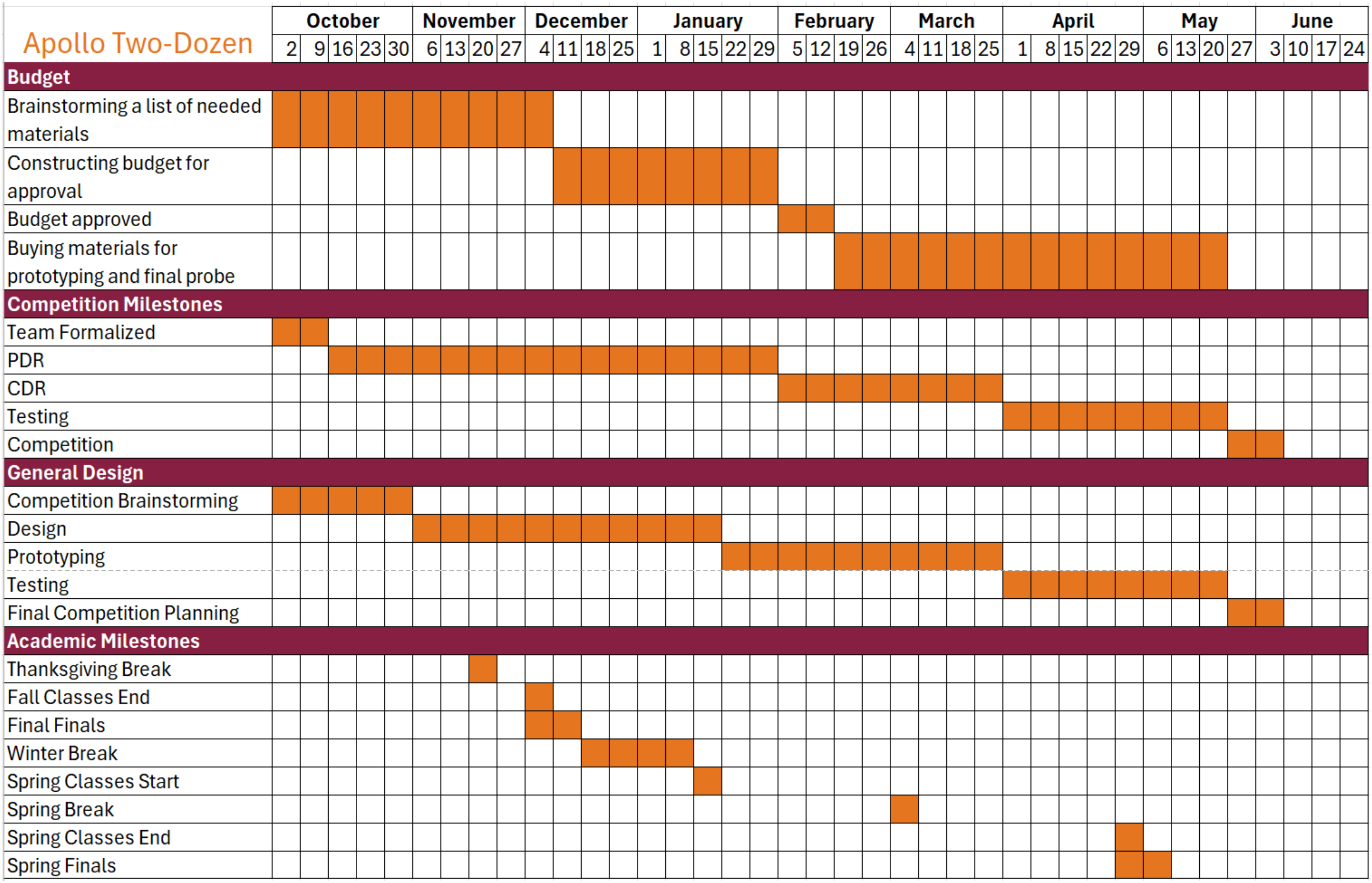
Detailed Program Schedule (1/3)



Detailed Program Schedule (2/3)



Detailed Program Schedule (3/3)



Conclusions

Conclusions

- The team has created a viable, comprehensive design which meets all budget and design restrictions
- Thorough research and multiple iterations have gone into the design of each part

Next steps

- Next, the team must purchase the required components and begin manufacturing preparation
- We will follow a process of testing, iterating and redesigning until we arrive at a satisfactory CDR-worthy CanSat

Why we are ready to proceed

- We have worked hard to secure the required funding for the competition
- We have also made sure that our manufacturing and testing facilities are ready to use
- We have created a comprehensive, attainable and practical design

To summarize, we are ready to proceed because we have a functional, compliant design, a strong, specific plan moving forward, and the financial and information resources to fulfill the plan.