ASTRO CATS

Critical Design Review Presentation

Team

Nicholas Fagan – Team Lead

Brandon Horne – Payload Lead

Kevin Eliason – Rocket Lead

Aaron Deutsch – Safety Lead

Andrew Auffenberg

Caleb Wasmund

Justin Mulloney

Cameron Crippa

Gabriel Punte-Lay

Jake Chesley

Presentation Outline

- Final launch vehicle and payload dimensions
- Discuss key design features
- Final motor choice
- Rocket flight stability in static margin diagram
- Thrust-to-weight ratio and exit rail velocity
- Drift
- Mass statement and mass margin
- Parachute sizes, recovery harness type, size, length, and descent rates
- Kinetic Energy at key phases of the mission, especially landing
- Test Plans and Procedures
- Scale model flight test
- Tests of staged recovery systems
- Final payload design overview
- Payload integration
- Interfaces
- Status of requirements verification

Project Statement

The Astro Cats will win the NASA University Student Launch by developing a vehicle capable of carrying a planetary probe to approximately 1 mile above ground level. The probe will be deployed via a custom fairing system and will capture atmospheric data. The data will then be transmitted via radio to a ground station. This system will be developed for under $7,500.

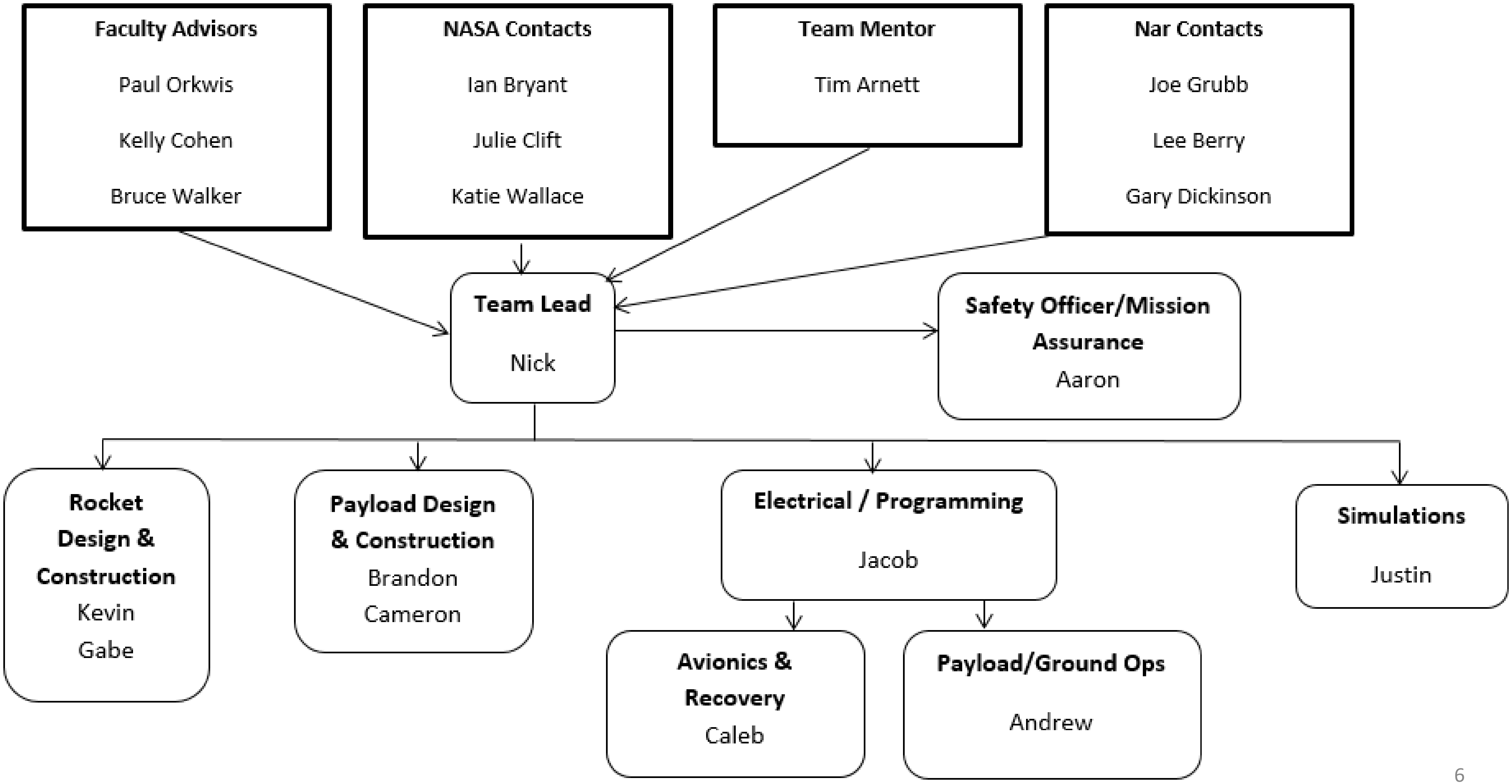
Level 1 Safety Analysis

- Please be aware of any hazards that exist in the room
  - Tripping hazards – cords, chair legs, and backpacks
  - Pinch points – hands with doors and hands in between chairs and desks

- In the event that we need to evacuate please exit the building out the main entrance and meet in quad.

- In the event that we need to shelter in place please make your way to the 400 level of Baldwin and shelter in the hallway.

Work Breakdown Structure



Project Budget

- Current budget of $7550

- Purchasing final components now

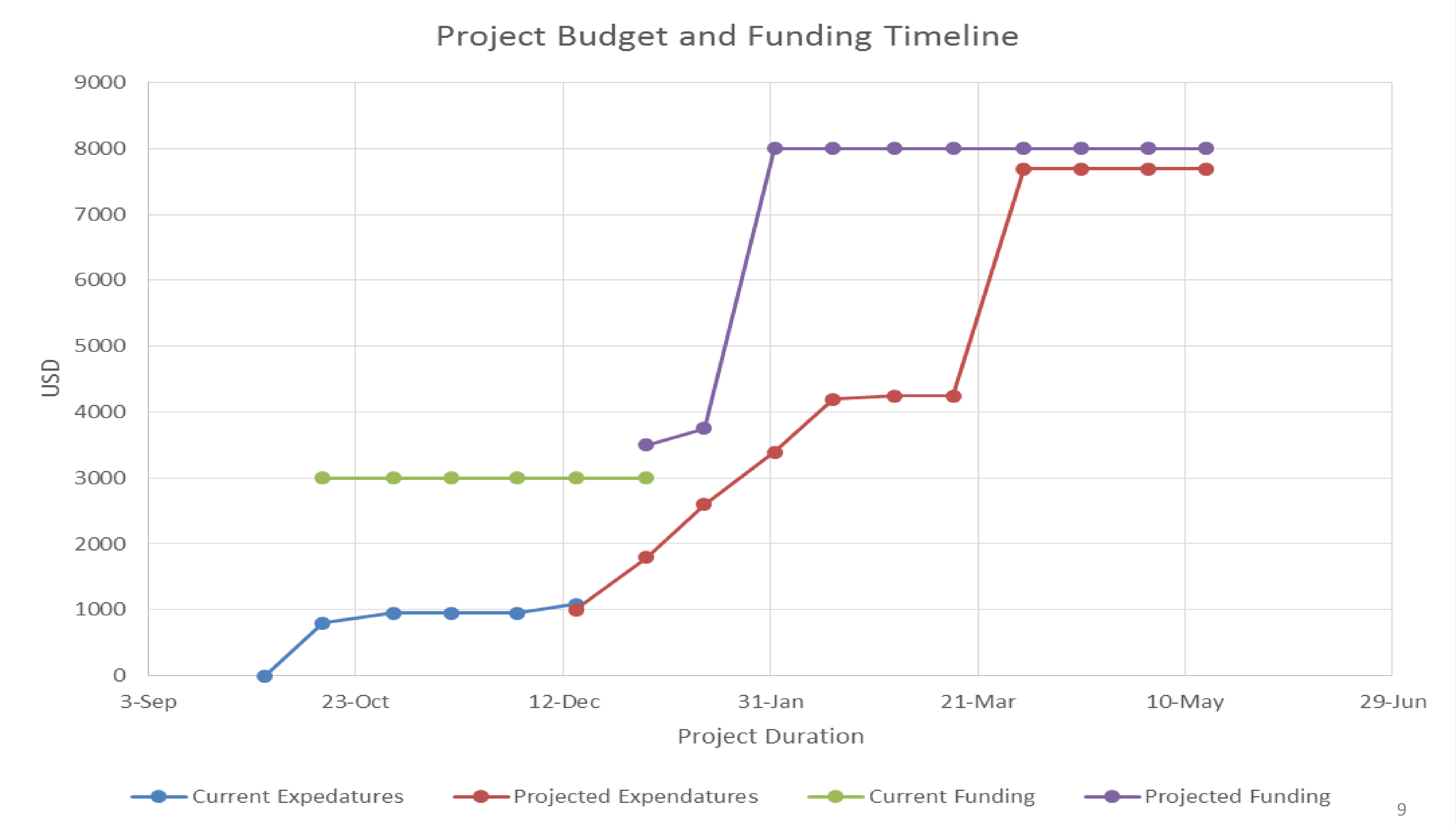
- Travel arrangements soon

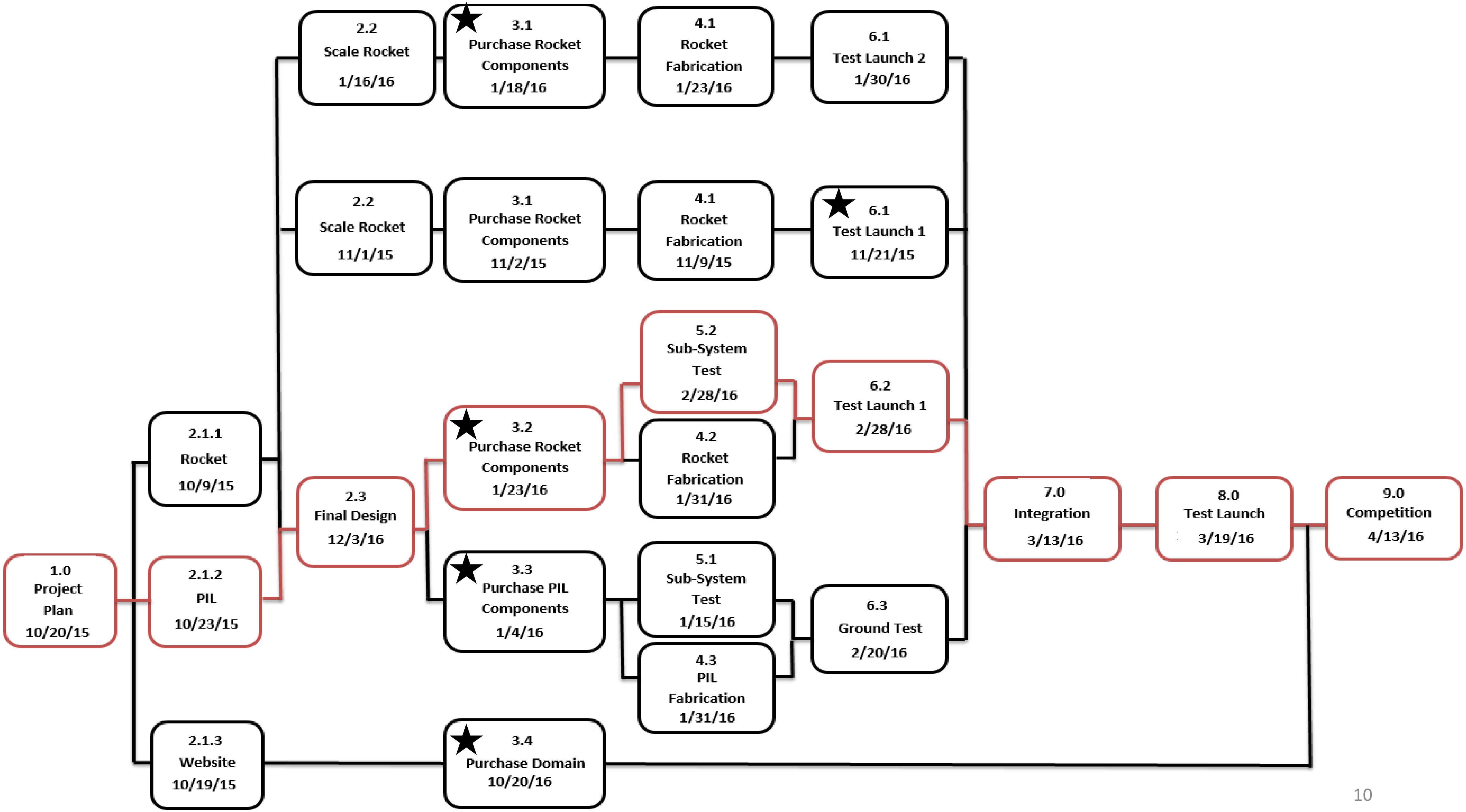
Expense Summary	
Travel	$ 3,442.00
Rocket	$ 1,750.62
Payload	$ 2,288.65
Educational	$ 70.00
Total	$ 7,551.27

Project Funding

- Expect OSGC funds available at the start of February
- Working on corporate sponsors

Funding Summary	
Item	Amount
UC SEDS	$ 2,333.00
Past Years Senior Design	$ 667.00
Outside Sponsers	$ 500.00
OSGC	$ 5,000.00
TOTAL	$ 8,500.00


Project Budget and Funding Timeline
9000
8000
7000
6000
5000
4000
3000
2000
1000
0
USD
3-Sep
23-Oct
12-Dec
31-Jan
21-Mar
10-May
29-Jun
Project Duration
Current Expedatures
Projected Expendatures
Current Funding
Projected Funding


2.2
Scale Rocket
1/16/16
3.1
Purchase Rocket
Components
1/18/16
4.1
Rocket
Fabrication
1/23/16
6.1
Test Launch 2
1/30/16
2.2
Scale Rocket
11/1/15
3.1
Purchase Rocket
Components
11/2/15
4.1
Rocket
Fabrication
11/9/15
6.1
Test Launch 1
11/21/15
5.2
Sub-System
Test
2/28/16
6.2
Test Launch 1
2/28/16
2.1.1
Rocket
10/9/15
3.2
Purchase Rocket
Components
1/23/16
4.2
Rocket
Fabrication
1/31/16
2.3
Final Design
12/3/16
7.0
Integration
3/13/16
8.0
Test Launch
3/19/16
9.0
Competition
4/13/16
1.0
Project
Plan
10/20/15
2.1.2
PIL
10/23/15
3.3
Purchase PIL
Components
1/4/16
5.1
Sub-System
Test
1/15/16
6.3
Ground Test
2/20/16
4.3
PIL
Fabrication
1/31/16
2.1.3
Website
10/19/15
3.4
Purchase Domain
10/20/16

Launch Vehicle Objectives

- Vehicle shall reach as close to 5,280 ft (AGL) as possible.
- Vehicle shall be reusable after recovery.
- Tracking bay shall transmit position data back to ground station.
- At landing, each independent section of the launch vehicle shall have a maximum kinetic energy of 75 ft-lbf.
- Vehicle will deploy parachutes via stratologger altimeters.

Payload Objectives

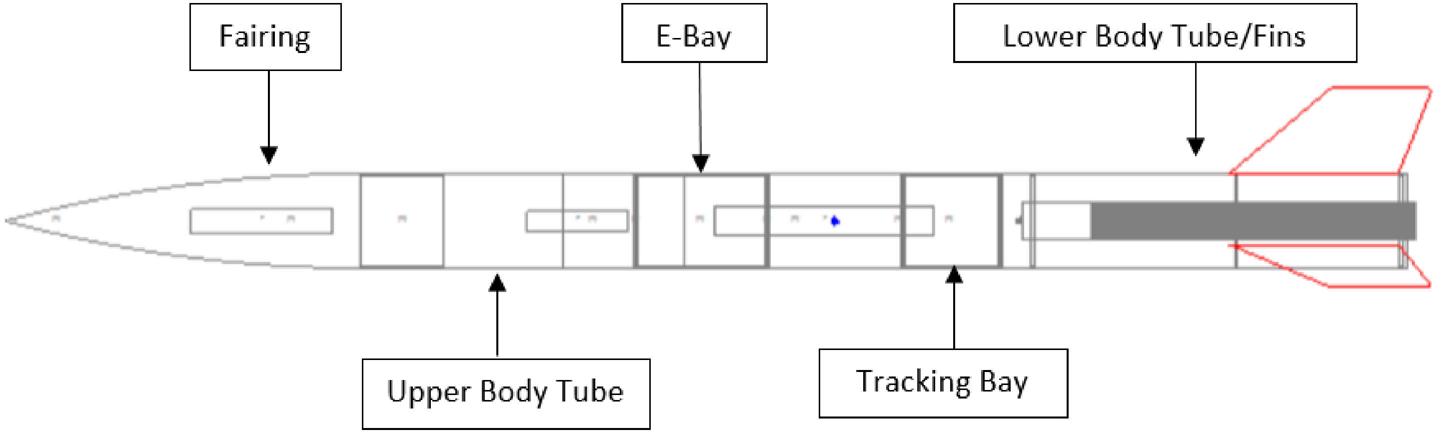
- Payload shall measure and record atmospheric data both during descent and after landing.
- Payload shall record and transmit 2 pictures upon descent, and 3 after landing.
- Payload shall remain in orientation during descent, and after landing.
- Payload shall record all data and images and wirelessly transmit them to a ground station.
- A Fairing shall be utilized to house, protect, and deploy the payload when target altitude is achieved.

Launch Vehicle Overview

- Design Overview
- Fairing Design
- Fin Design
- Integration
- Motor Selection
- Mass Breakdown
- Static Stability Margin

Launch Vehicle Design

- Total length: 87.14 inches
- Airframe Diameter: 5.54”
- Fin count: 3
- Empty weight: ~15 lbs
- Loaded weight: ~23.5 lbs
- Center of Gravity: 51.72”
- Center of Pressure: 61.9”
- Stability Margin: 1.85
- Number of Subsections: 4

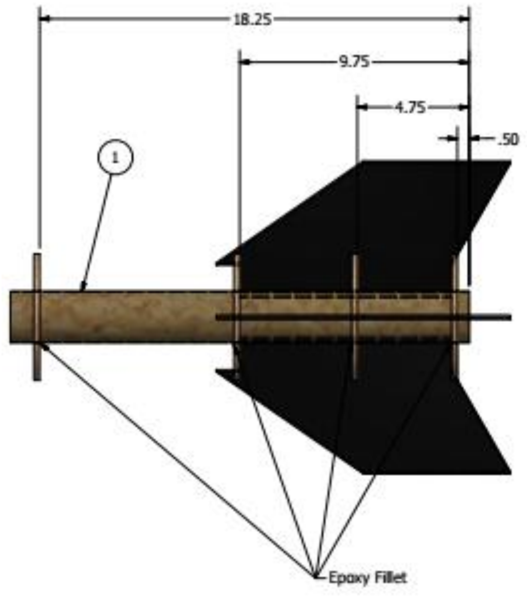


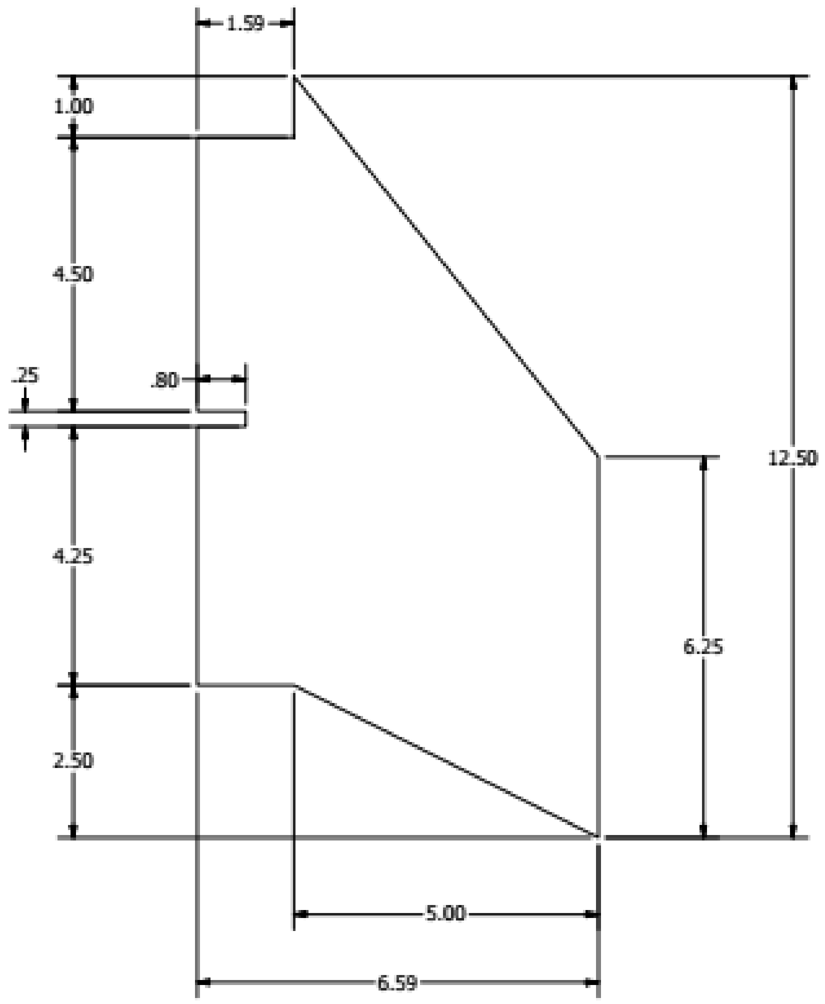
Fairing Design

- Mold made from standard 5.54” plastic nosecone
- Layers of 4 oz. and 6 oz. fiberglass and epoxy resin
- Sealed with RTV silicone sealant
- Nylon shear screws to join pieces
- Tethered to P.I.L. parachute

Fin Design

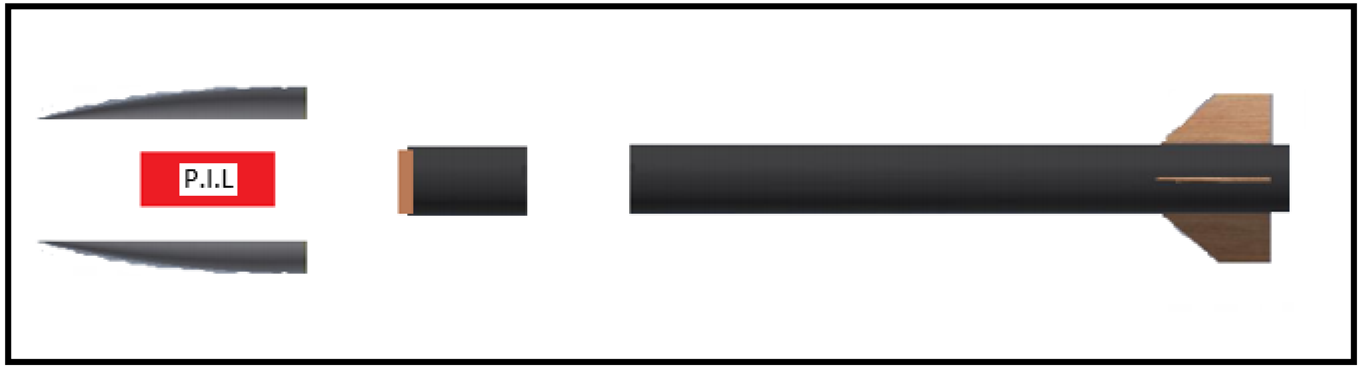
- Fin Count: 3
- 3/16” G-10 Fiberglass
- Permanently attached to lower body tube





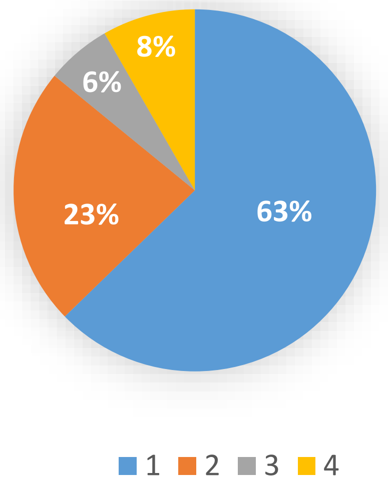
Integration

- 2 separation points – above and below recovery bay
- P.I.L. housed in fairing
- Drogue chute in lower section between Recovery and Tracking bay
- Main chute in upper section below the PIL



Launch Vehicle Mass Breakdown

- The current estimated mass is 18.8 lbs
    - Lower Section = 11.8 lbs.
    - Upper Section = 4.36 lbs.
    - Electronics Bay = 1.09 lbs.
    - Tracking Bay = 1.56 lbs.



- 10 lbs. can be added before a thrust-to-weight ratio below 5:1 occurs and cannot launch on the current motor selection

Motor Selection

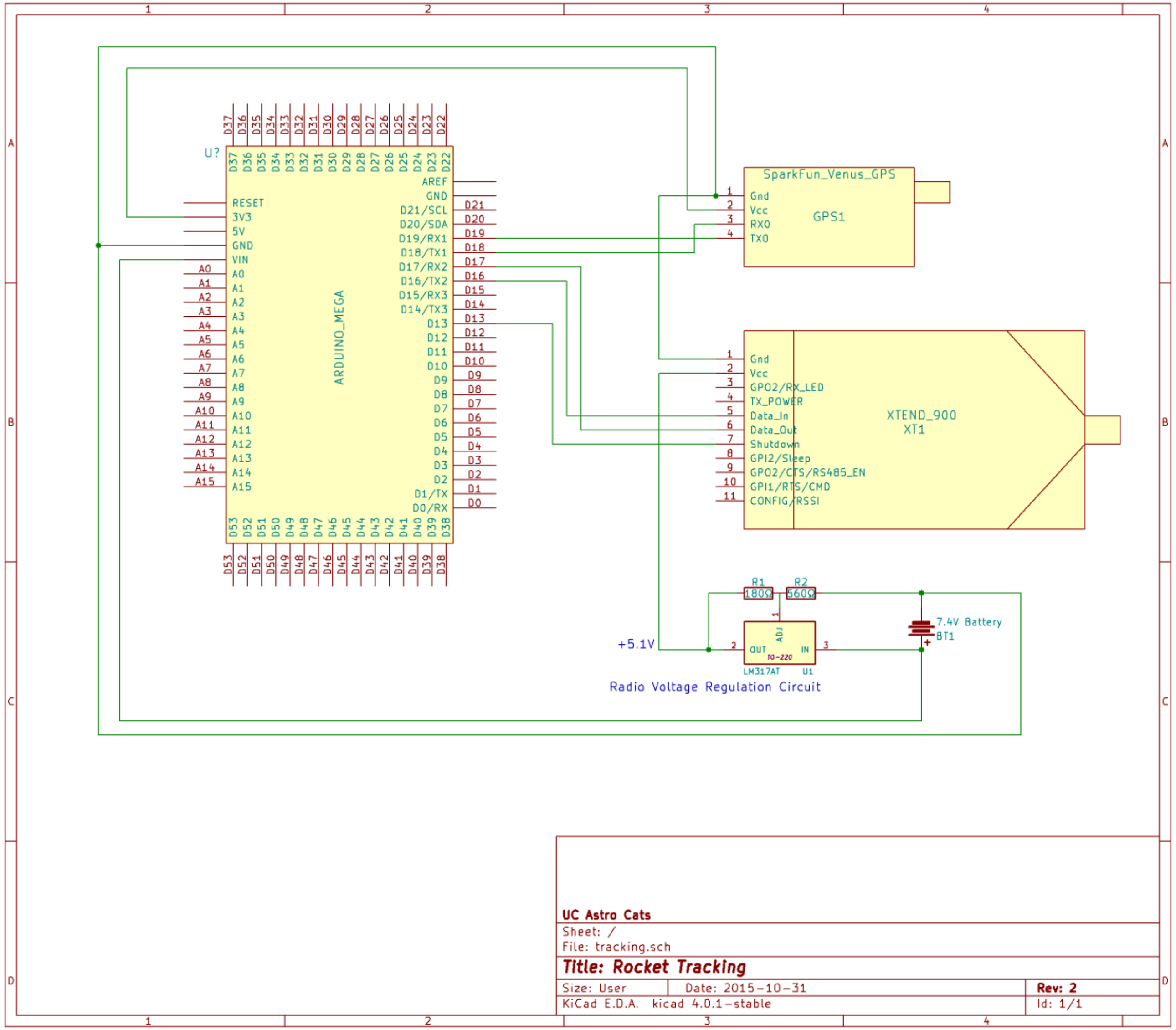
- Motor: Cesaroni-Pro54-6G (750-RL)
- Size: 54 mm
- Burn time: 3.1 seconds
- Total Impulse: 2352.5 Newton-Seconds
- Max Thrust: 946.3 Newtons
- Mass: 2057 grams
- Delay Charged will be removed

Tracking Bay

- Components:
  - Arduino Mega
  - XTEND-900 radio transceiver
  - Venus GPS Module
  - Radio and GPS Antenna
  - Battery

- Communicates vehicle position data back to ground station in real time.

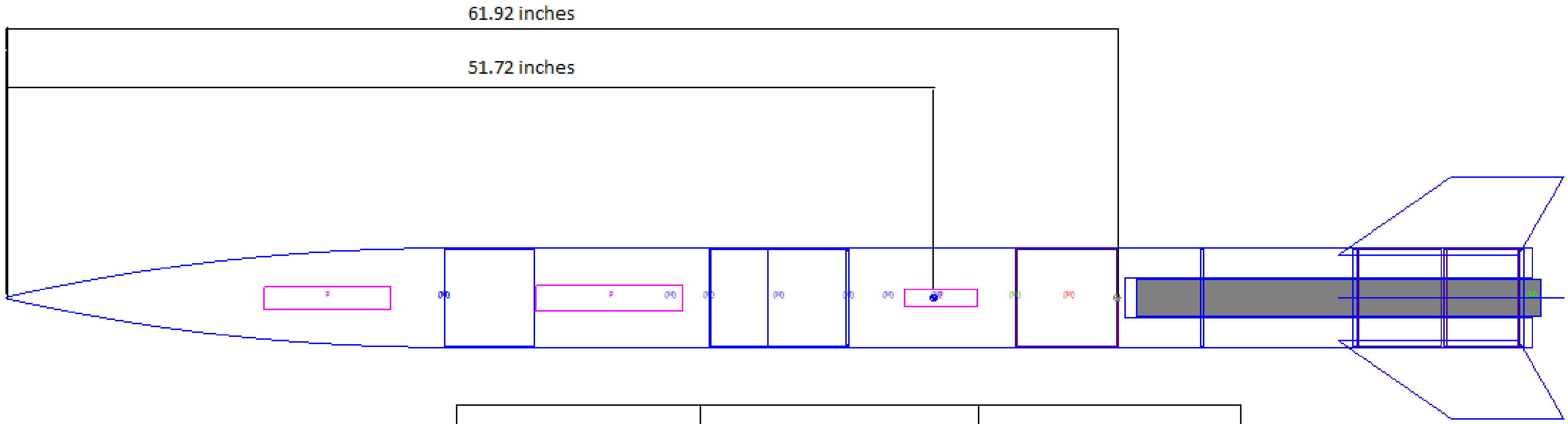
Tracking Bay Electronic Schematic



Thrust-to-weight ratio, exit rail velocity

- Cesaroni K750-RL has a total impulse of 2352.5 Newton-Seconds and a 3.1 second burn time
- Thrust-to-weight ratio of 7.03
- Max Velocity of 621 feet/second
- Exit rail velocity: 62.07 feet/second

Static Stability Margin

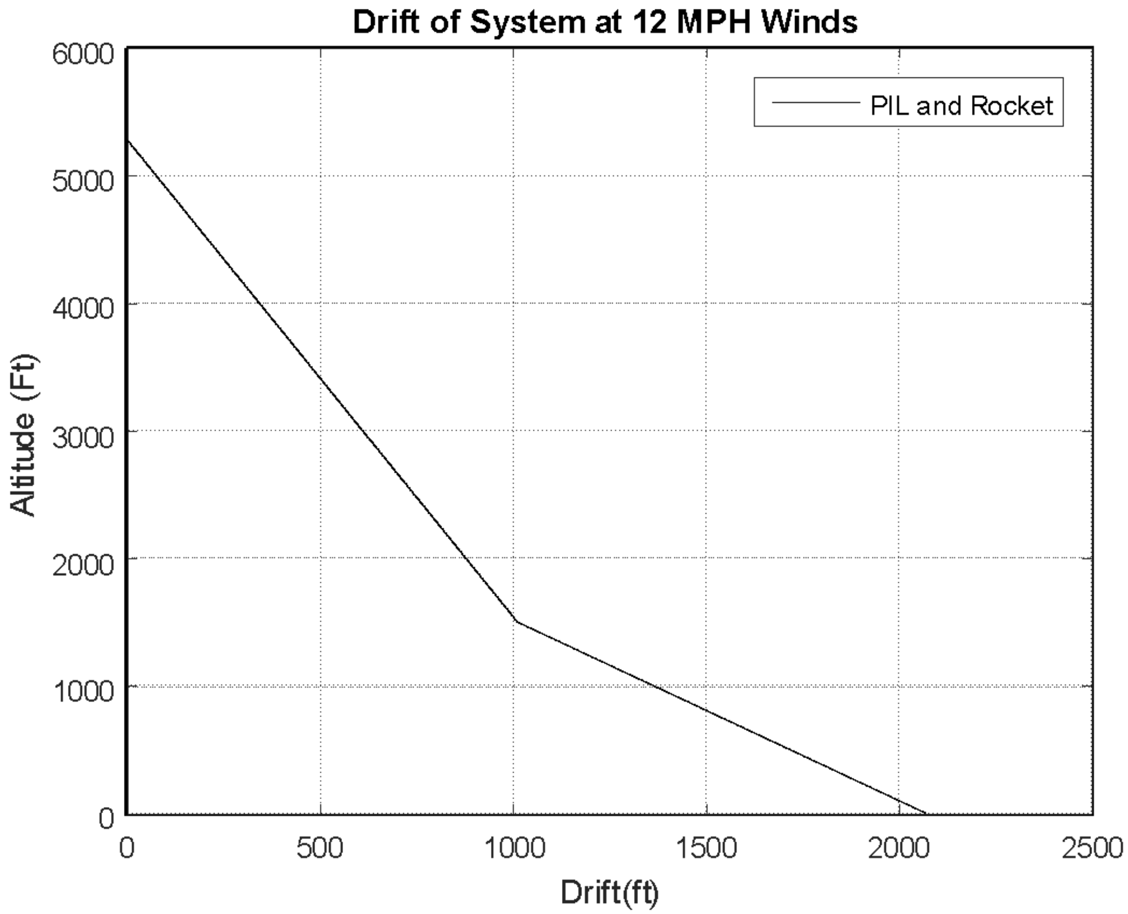


	On Launch Pad	After Burnout
CP (from tip)	61.92 in.	---
CG (from tip)	51.72 in.	48.6 in.
Static Margin	1.85	2.40

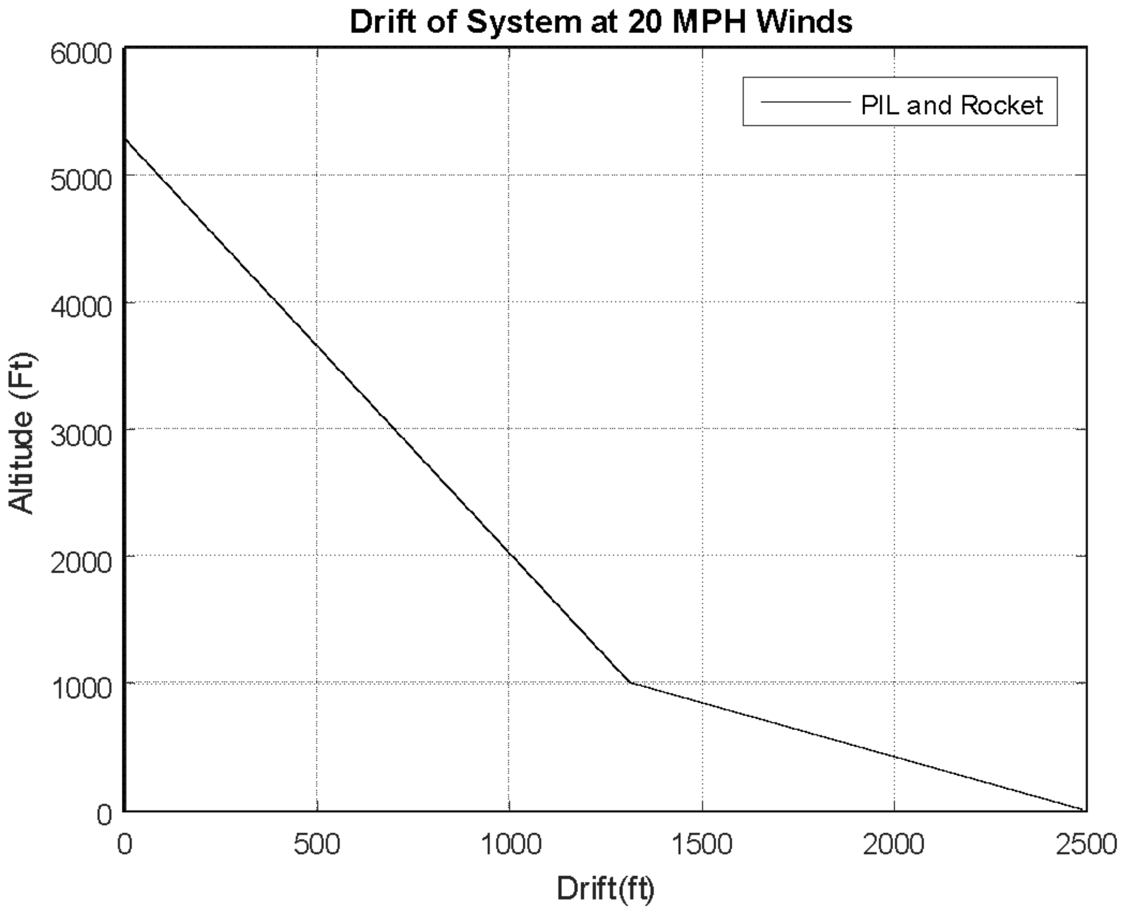
Drift

- Drift was completed for two different scenarios, 0-12 MPH and 13- 20 MPH
  - 20 MPH was analyzed because it is a requirement for the worst case scenario
  - 12 MPH was analyzed based on data from the National Weather Service.
  - Each scenario has a specific drogue parachute and altitude that the main is deployed
- Drift at 5 MPH was 918.45 feet and 10 MPH was 1836.9 feet
- Drift at 15 MPH was 1874.4 feet and 20 MPH was 2498.2 feet
- Graphs of drift at 12 MPH and 20 MPH can be seen on the next slide

Drift



Drift of System at 12 MPH Winds
PIL and Rocket
Altitude (Ft)
Drift(ft)
0
500
1000
1500
2000
2500
1000
2000
3000
4000
5000
6000



Drift of System at 20 MPH Winds
PIL and Rocket
Altitude (Ft)
Drift(ft)
0
500
1000
1500
2000
2500
1000
2000
3000
4000
5000
6000

Launch Vehicle Testing Plan

- Launch Vehicle
  - Subscale launch
  - Wind tunnel
  - Parachute drop tests
  - Full scale launch- simulated payload
  - Full scale launch – full integration
- Fairing
  - Pop Tests
  - Impact and vibration testing
- Electronics
  - Radio communication tests
  - Altimeter vacuum test

Sub Scale Launch

- 0.57 Scale Size
- 7.25 lbs. loaded weight
- Motor – Cesaroni J335
- T to W of 10.4
- Predicted altitude ~4400 ft. (AGL)
- Parachute deployed but drifted into trees

Subscale Fairing Test

- Subscale Fairing pop test conducted on 1/14/2016
- Successfully separated at 0.75 grams ejection charge
- Verified fairing design

Parachute Summary

Deployment	Parachute	Decent Rate (ft/sec)	Cd	Surface Area (sq. ft)	Ke at Landing (lbf)
Case 1: Drogue	SkyAngle Classic 28”	63.2	0.93	8.6	Upper: 564 Lower: 595
Case 2: Drogue	SkyAngle Classic 20”	103	0.8	4.4	Upper: 1193 Lower: 1259
Main	SkyAngle Classic 52”	22.9	1.46	29.5	Upper: 21 Lower: 71
PIL	SkyAngle Classic 36”	24.9	1.34	14.2	34
Faring	SkyAngle Classic 36”	24.9	1.34	14.2	12

Recovery Systems

- Parachute Summary
- PIL Recovery System
- Rocket Recovery System
- Ejection Charges
- Attachment Method & Durability

PIL Recovery System

- The PIL recovery will be a single parachute.

- The PIL will deploy its parachute when the fairing separates.
  - Two cases
    - 1. Deploys at 1500 feet if wind conditions are less than 13 mph.
    - 2. Deploys at 1000 feet if wind conditions are greater than 13 mph.
  - Parachute: Skyangle Classic 36”
    - Descent Rate: 24.9 ft/s

Rocket Recovery System

- The rocket shall be a two stage deployment, at the second stage releasing the PIL.

- A drogue parachute will deploy at apogee. Two parachute slections.
  - Case 1: SkyAngle Classic 28”
    - Descent Rate: 63.2 ft/s
  - Case 2: SkyAngle Classic 20”
    - Descent Rate: 103 ft/s

- Main parachute will deploy at either 1500 feet or 1000 feet AGL. Pre determined.
  - Two cases
    - 1. Deploys at 1500 feet if wind conditions are less than 13 mph.
    - 2. Deploys at 1000 feet if wind conditions are greater than 13 mph.

Ejection Charges

- Two black powder charges will be used for both the drogue and main parachute.
- A 2.0-3.0 gram charge will separate the fairing.
- Each parachute deployment will have a 1.5 gram main charge and a 2 gram redundant charge.
    - Pop-tests will refine these values.
- The Recovery Bay Sled will have three StratoLogger altimeters.
    - Strat 1 – Deploys main charge.
    - Strat 2 – Deploys main charge for the drogue and back-up for main parachute
    - Strat 3 – Deploys the fairing charge and the back-up drogue charge

Attachment Method & Durability

- Attachment method for all parachutes will be ½” Tubular Kevlar shock cords.
  - Lengths of shock cords will be three times that of rocket, or PIL accordingly.

- The shock cords will be connected to Quicklinks for easy interchange of parachutes.

- Quicklinks will be secured to Bulkheads via ½” U-bolts.

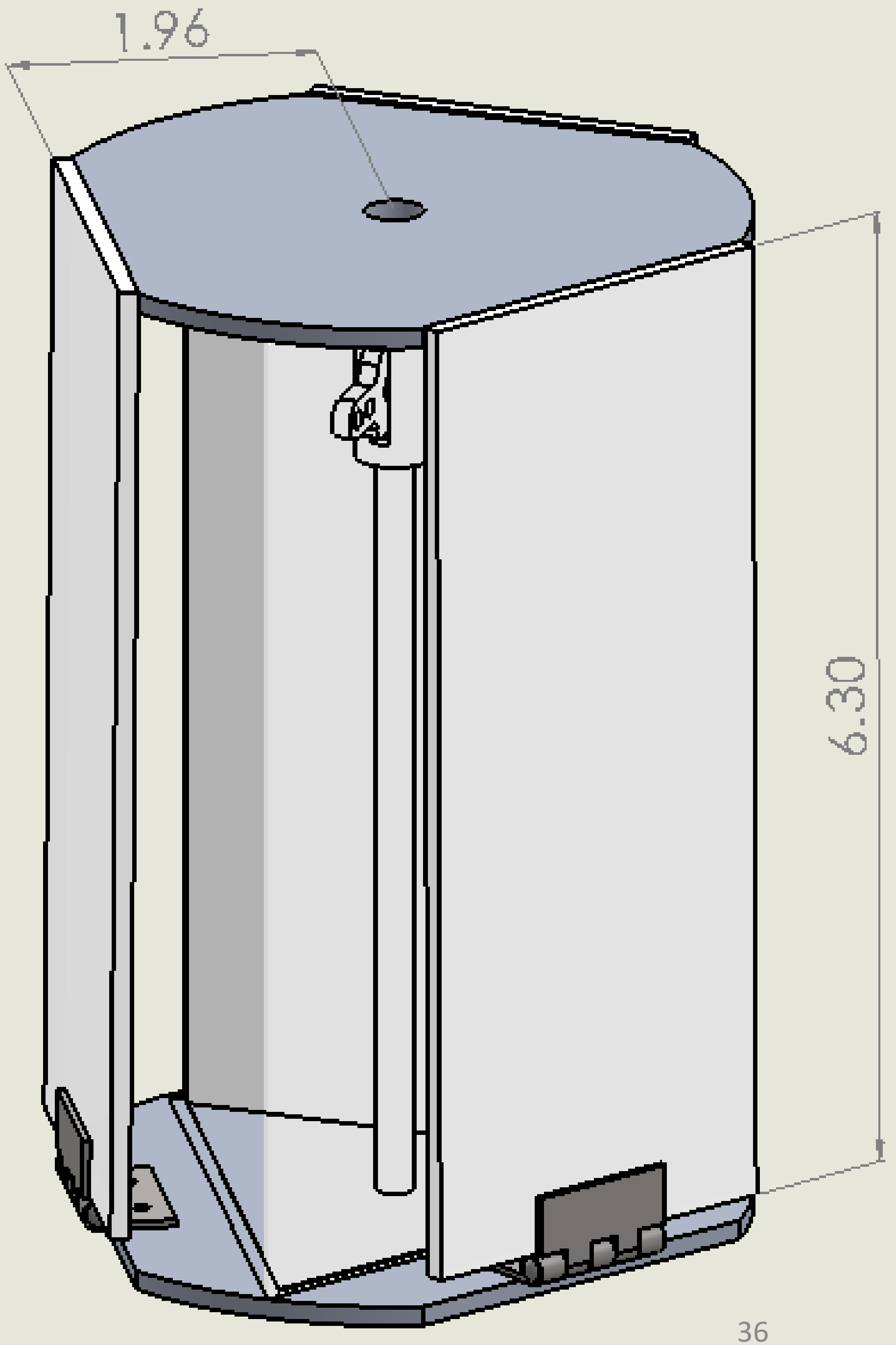
- Load capacity of each parachute and shock cords is not exceeded. Sturdy U-bolts shall be used to avoid load bending.

Science Value

- Data from PIL will be compared to atmospheric models and weather station data
  - Enhance and reinforce scientific knowledge base
- Landing site will be predicted pre-launch and compared to actual landing site
  - Test prediction software for drift
- Team will learn how to communicate with an atmospheric probe

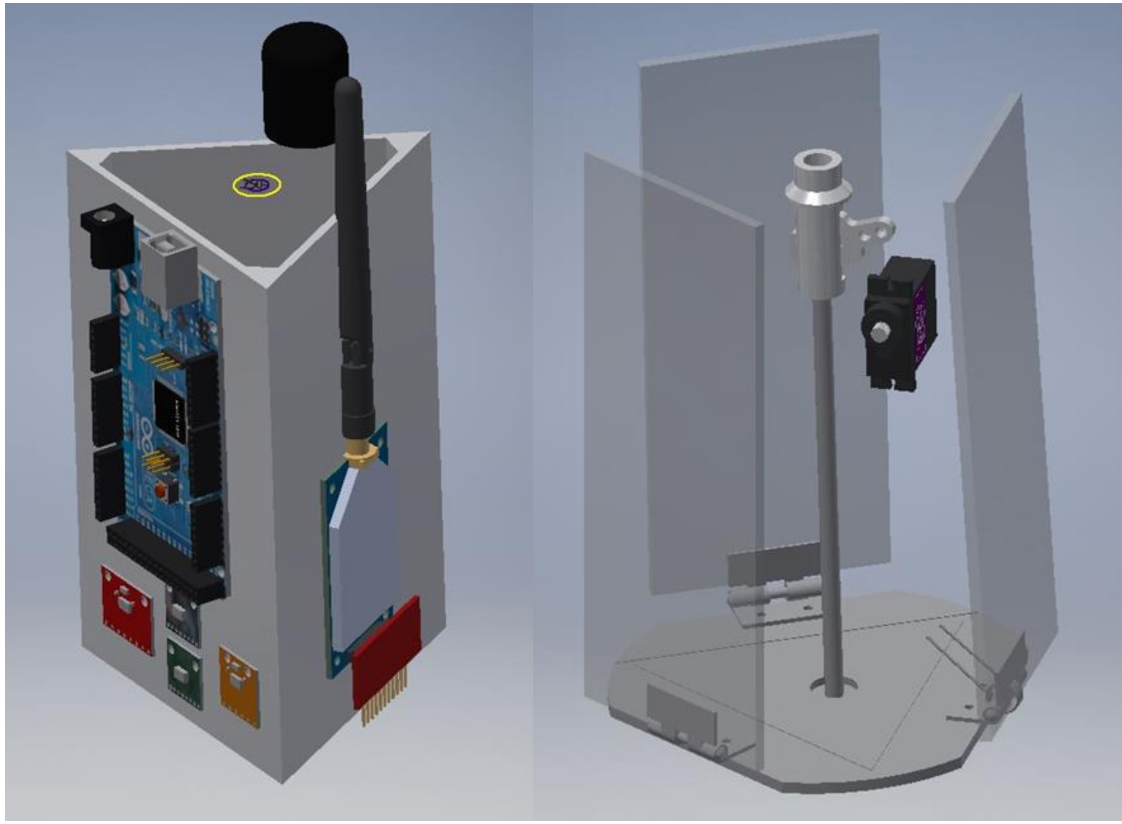
Payload Design

- System Overview
- PIL Structure
- Deployment System
- Structural Analysis
- PIL and Rocket Integration
- PIL and Ground Station Integration
- Testing and Prototyping
- PIL Manufacture
- Future Plans and Testing
- Mass Breakdown



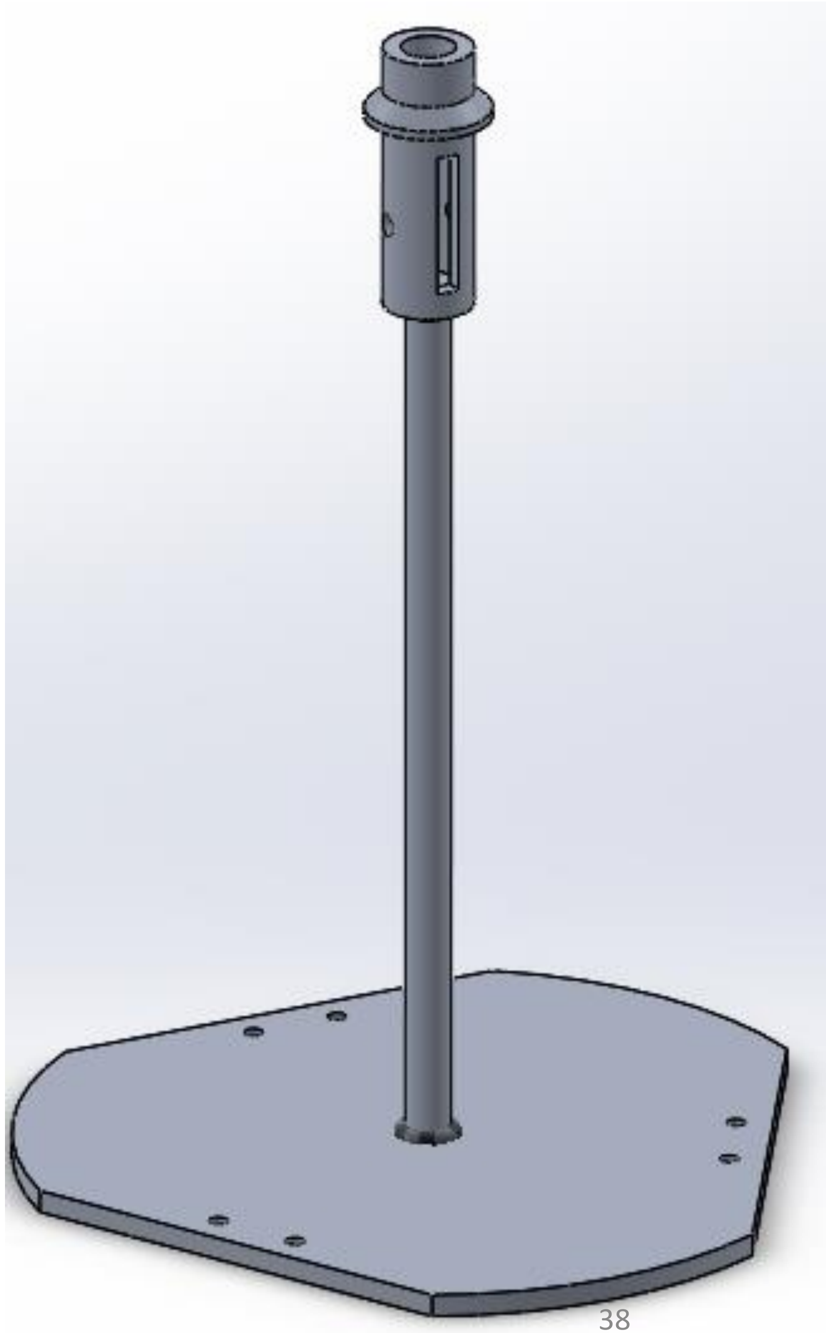
System Overview

- The main systems of the PIL are the :
  - Structural
  - Deployment
  - Electrical
- These systems must work together to achieve the PIL's overall mission



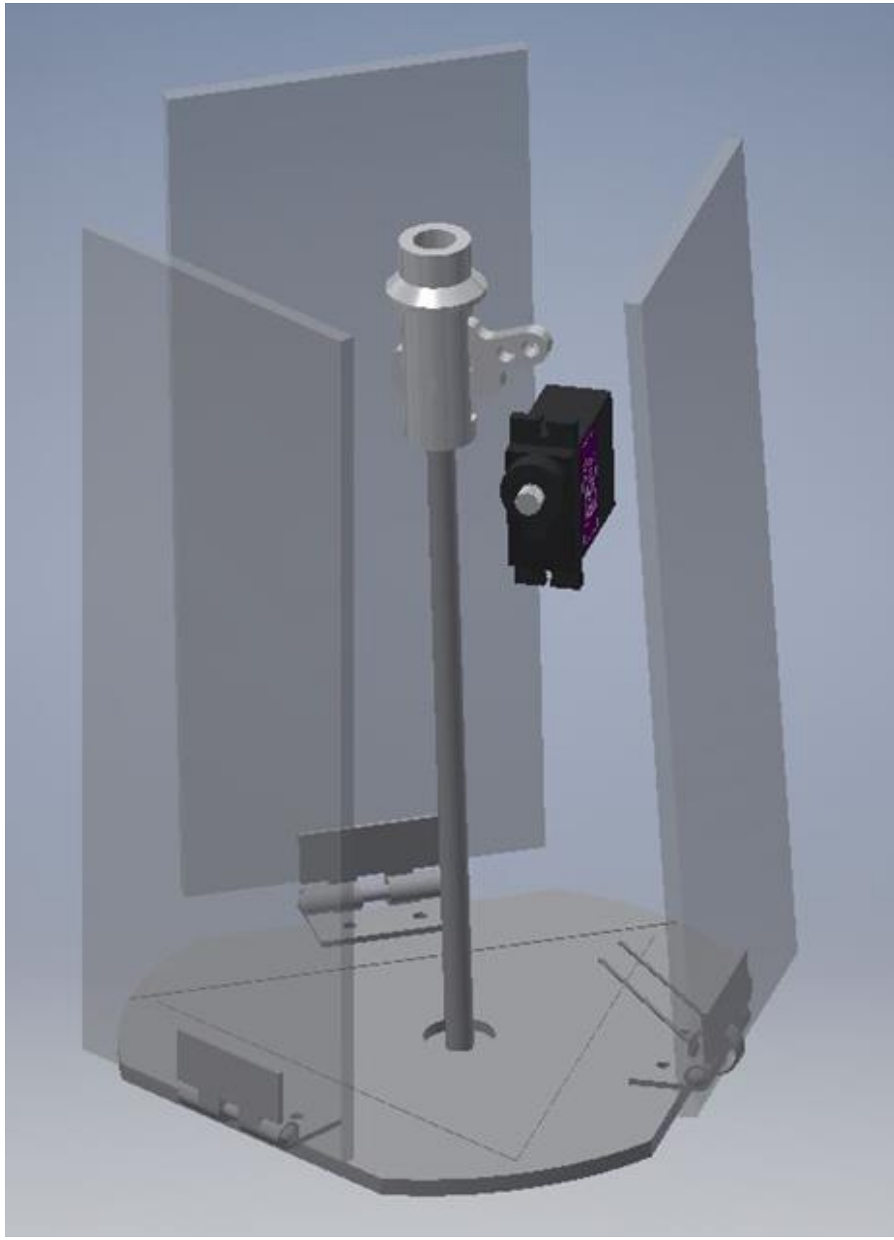
PIL Structure

- Components:
  - Aluminum base plate
  - Aluminum center support
  - Parachute release mechanism
- Components are welded together



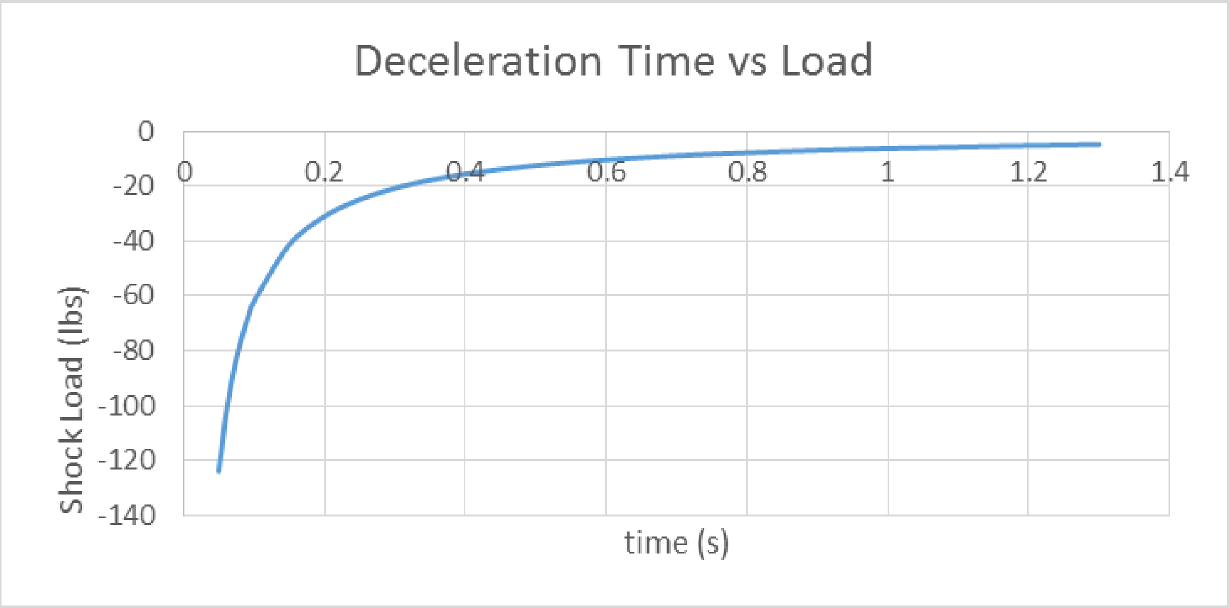
Deployment System

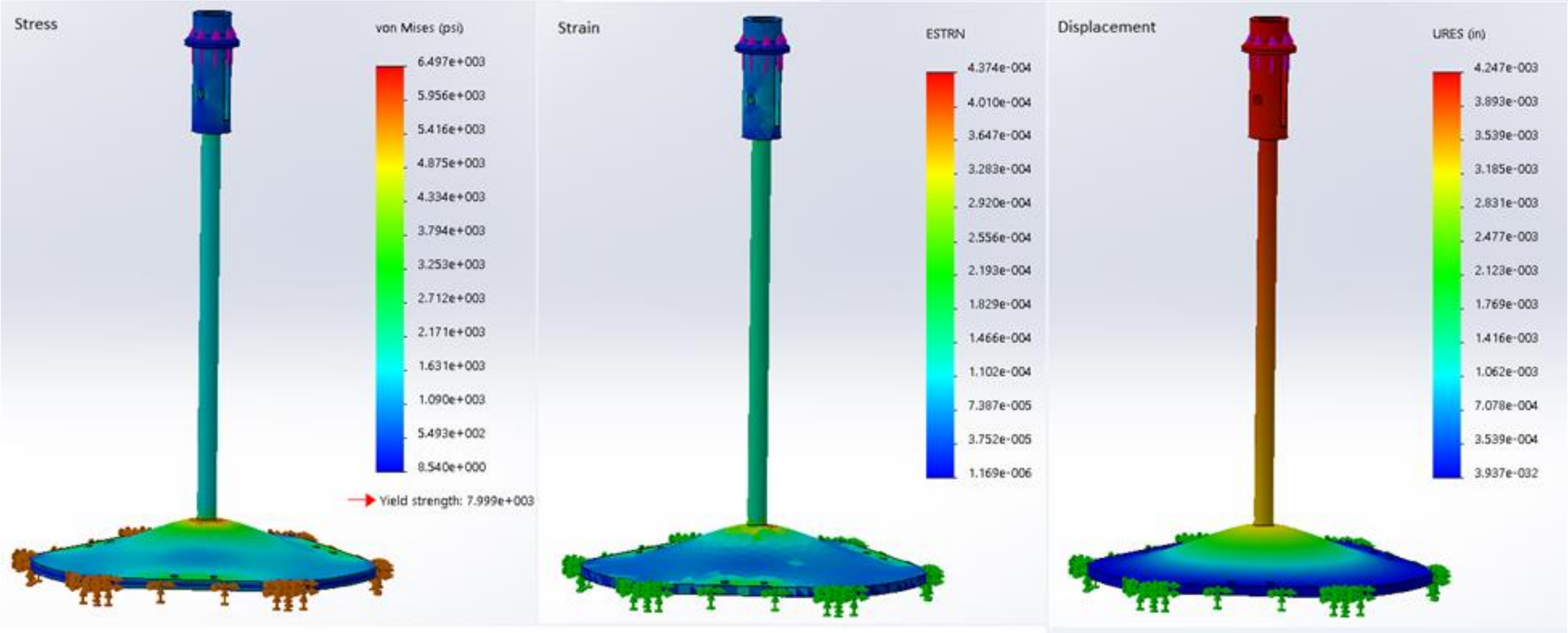
- This system will stand the PIL in an upright position upon detection of landing
- Parachute release mechanism is used to drop the parachute and deploy the legs to lift the payload
- Uses 28 in-lb torsion springs
- Vertical upright position allows the pyranometer and camera to capture good data



Structural Analysis

- It was found the PIL structure will fail under a 100 lb static load
- Shock loads are expected to be no greater than 60 lbs



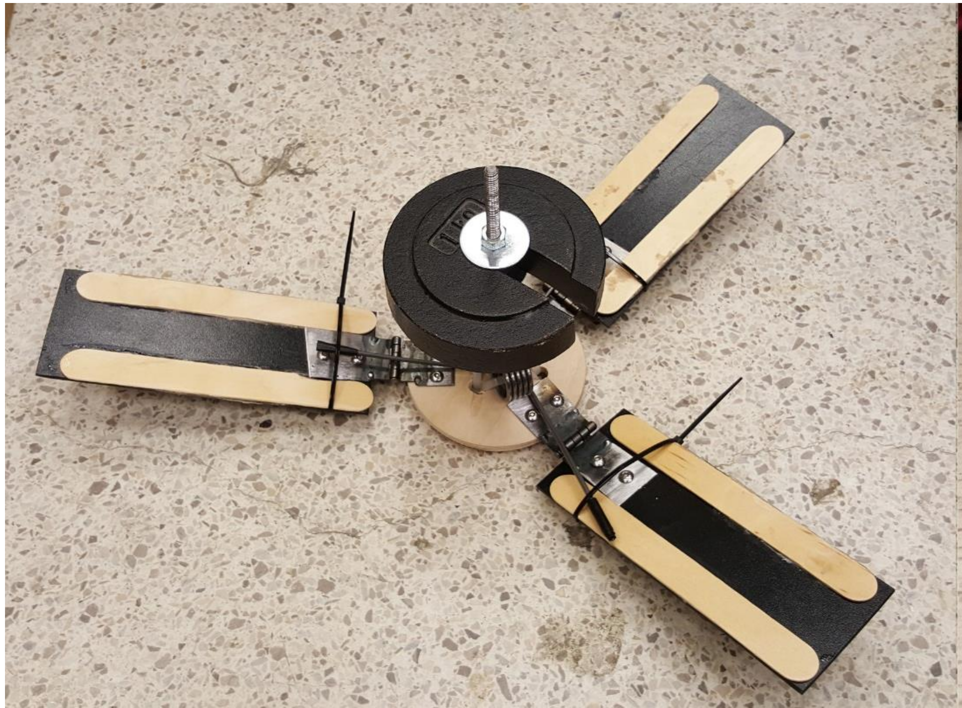


PIL and Rocket Integration

- A custom sleeve is used to mate the PIL, fairing, and rocket
- This sleeve acts as a coupler between the fairing and rocket body
- This sleeve keeps the PIL from sliding further into the rocket

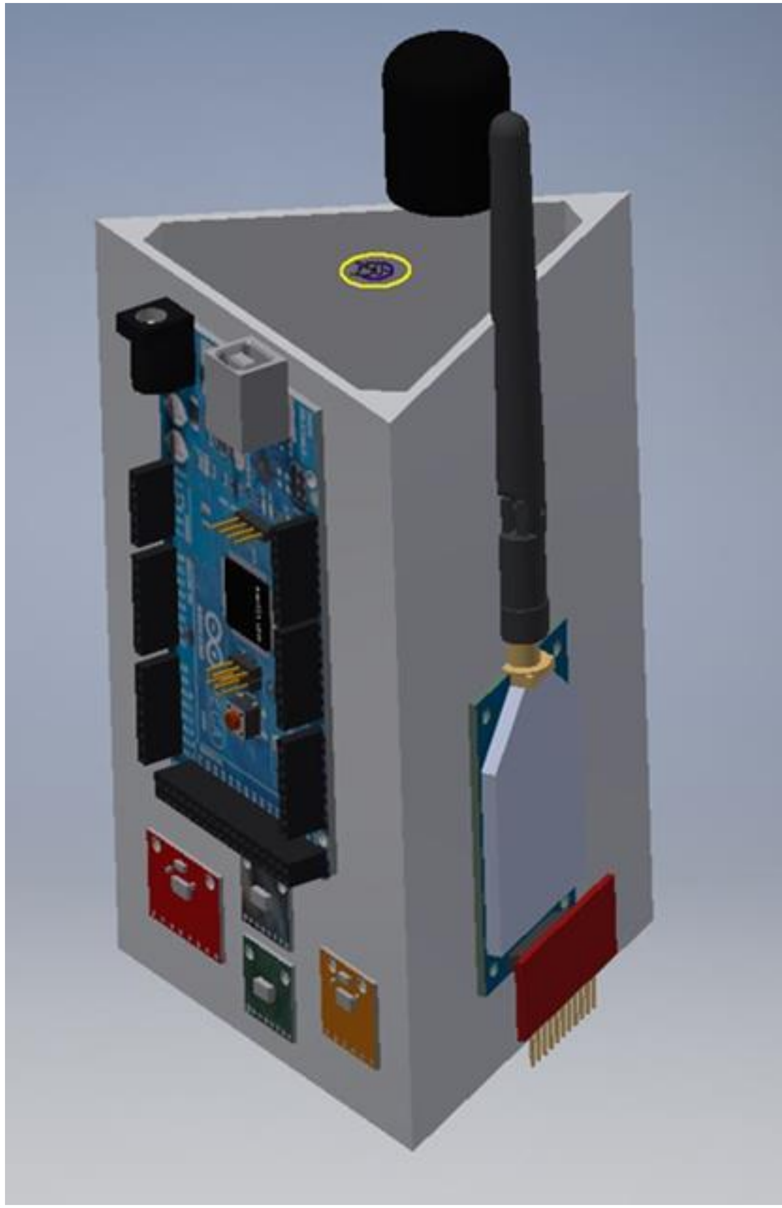
Testing and Prototyping

- The design of the payload structure was verified by prototype testing
- The center of mass can be no more than 4 in above the base plate
- 28 in-lb torsion springs are needed



PIL Manufacturing

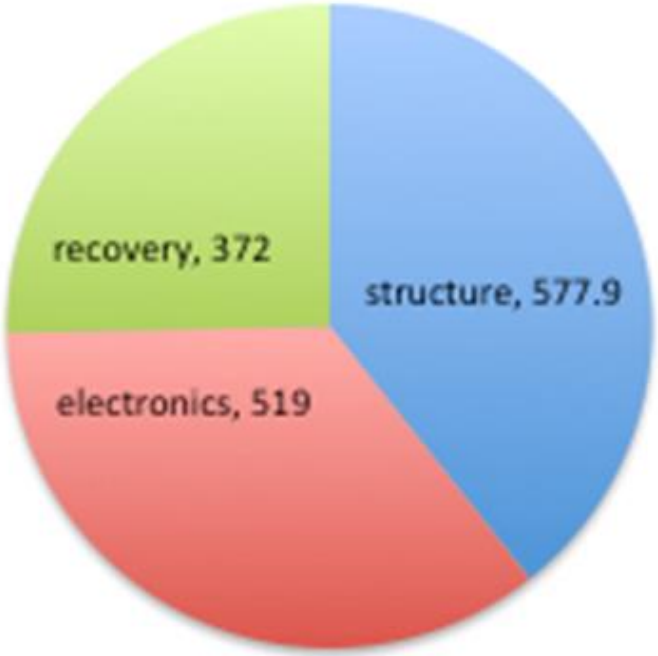
- Base plate and top plate
  - Machined from 1/8 in aluminum 6061 plate stock
  - Using a CNC mill
- Outer shell
  - Cut from 1/8 in high impact acrylic
  - Using band saw and mill
- Tri-Structure
  - Cut from 1/8 in ABS plastic
  - Using band saw and mill
- Center Support
  - Turned from 3/8 in aluminum 6061 round stock
  - Using a lathe
- All other components are attached using hardware and or epoxy



Future Plans and Testing

- Start manufacture on final PIL design
- Test PIL structure using real shock loads
- Add deployment and electronic mounting structures
- Add test weight to simulate electronics
- Test deployment system
- Use PIL (without electronics) in full scale rocket test

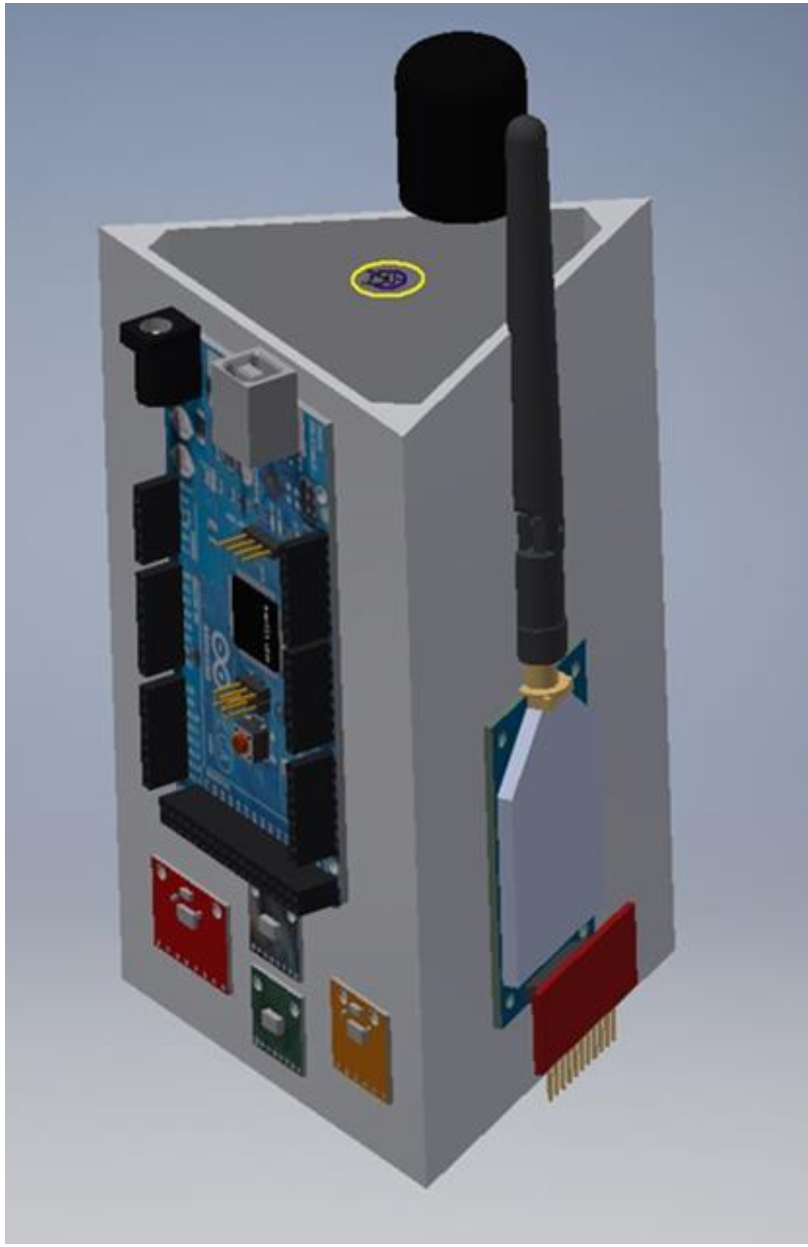
PIL Mass Breakdown



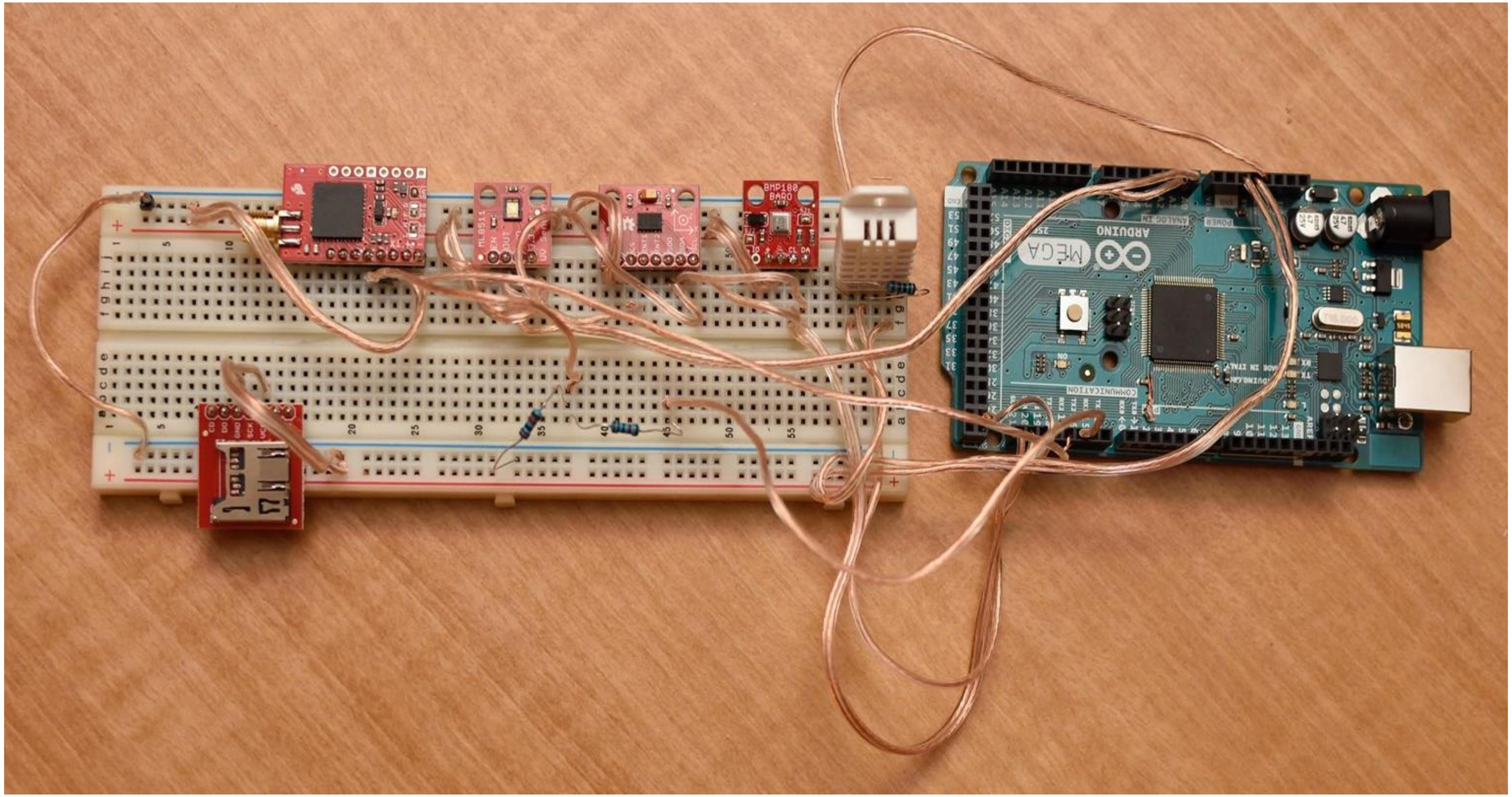
	component	weight (grams)	category
	Pil Housing	117	structure
	tri-structure	117	structure
	Humidity and Temperature Sensor	3	electronics
	Barometer	5	electronics
	UV Sensor	5	electronics
	Accelerometer	5	electronics
	Camera (x3)	90	electronics
	Radio - XTEND 900	18	electronics
	Radio Antenna	100	electronics
	GPS - SparkFun Venus GPS	10	electronics
	GPS Antenna	18	electronics
	Micro SD	7	electronics
	Arduino	37	electronics
PIL	battery	161	electronics
	parachute (60 in)	223	recovery
	parachute connection hardware	100	recovery
	torsion springs	80	structure
	hinges	30	structure
	hardware	12	structure
	bottom plate	75.7	structure
	top plate	75.7	structure
	center support	4	structure
	epoxy resin	35	structure
	parachute release	5	recovery
	power distribution circuit board	60	electronics
	landing module servo	44	recovery
	c-channels	31.5	structure
	total	1468.9	1505.6 (+2.5%) 1432.2 (-2.5%)
		3.23158	lbs

Electrical System

Parameter	Sensor
Temperature	RHT03 Temp. & Humidity sensor
Relative Humidity	RHT03 Temp. & Humidity sensor
Pressure	BMP180 Barometer
Solar Irradiance	Apogee Instruments SP-215
UV Radiation	ML8511 UV sensor
Images	LinkSprite JPEG Color Camera
Accelerometer	ADXL345
Data Transmission	XTend 900 1W RPSMA radio
GPS	Spark Fun Venus GPS
Micro Controller	Arduino Mega 2650
Ground and PIL Antenna	Digi International A09-HSM-7
Micro SD Card Board	SparkFun microSD Transflash Breakout



PIL Hardware Prototype



Ground Control Hardware

- Arduino Mega 2650
  - Microcontroller that interfaces the radio transceiver with the PC
  - Sends incoming radio data from the PIL and Tracking Bay to the PC
  - Sends outgoing commands to the radio, to transmit to the PIL
- XTEND-900 - Radio transceiver
- PC - A laptop used to interface with the Arduino
  - Collect and display gathered data using custom software

Ground Control Software

- Arduino will collect data from radio that has been received from PIL and Rocket Tracking Bay, and send it to the PC over serial connection.

- PC will utilize custom software that retrieves serial data sent from the Arduino.

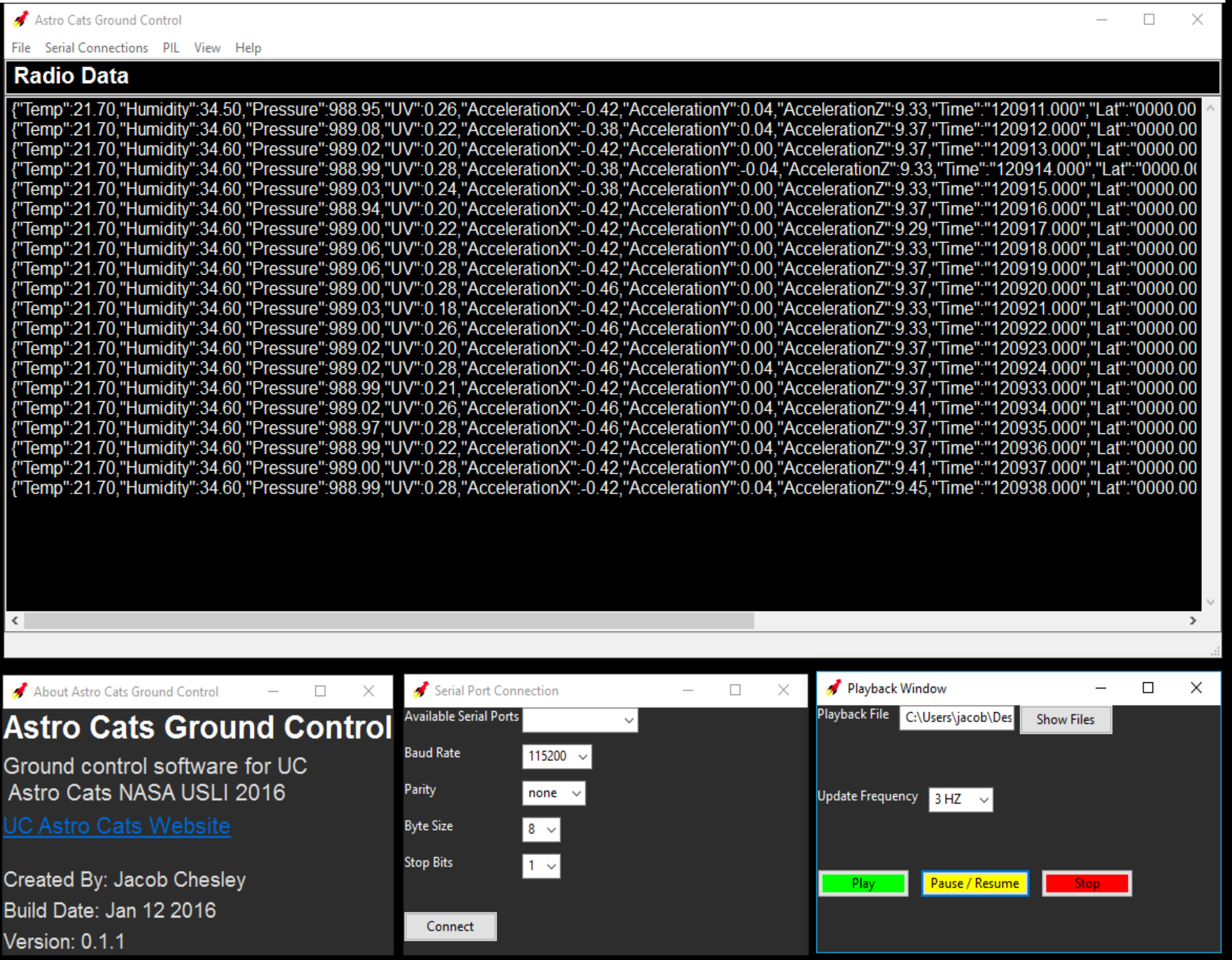
- Data will be parsed and the user interface display will be updated in real time with new data. Data will be stored on machine running the software.

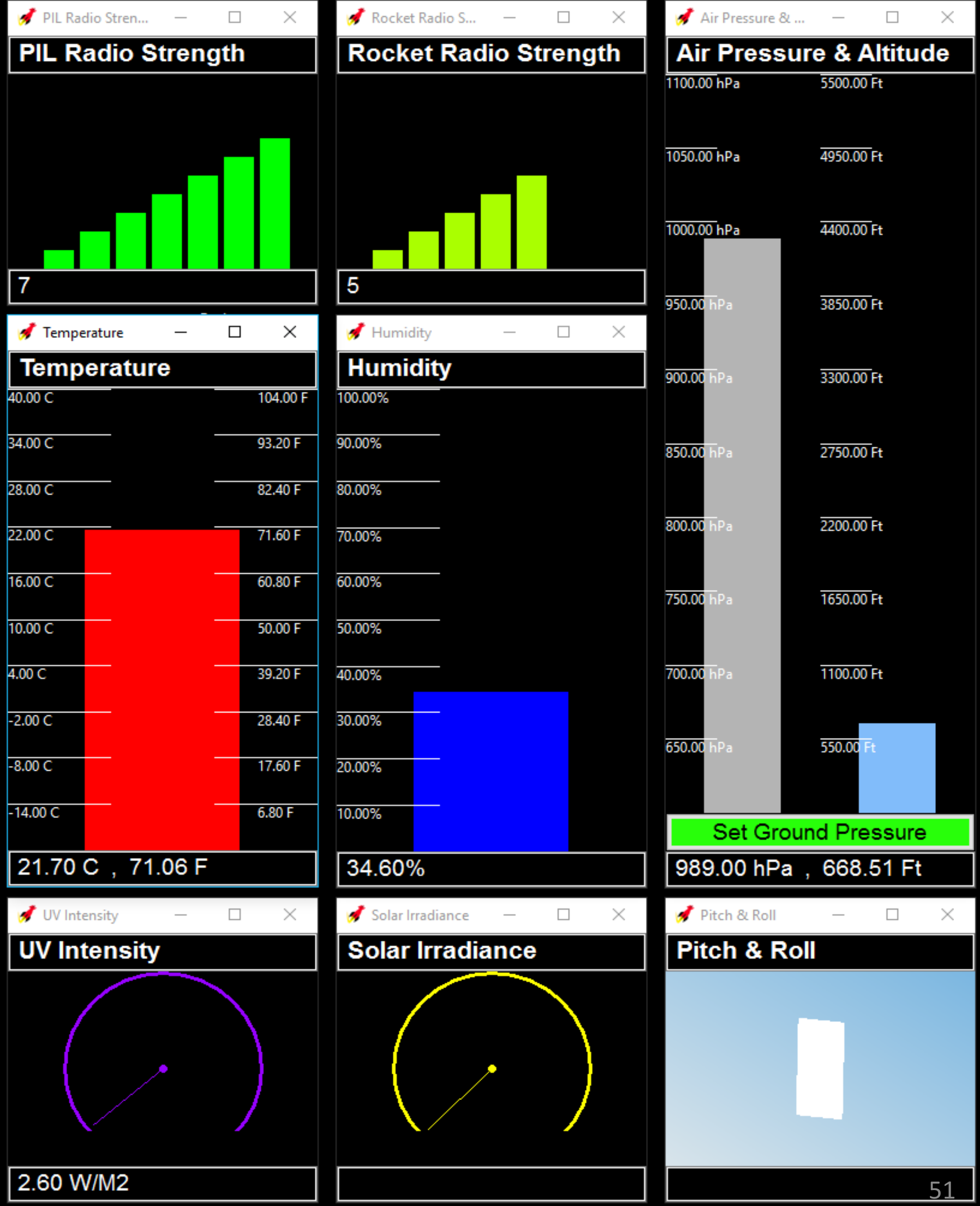
- wxWidgets C++ GUI Library being used for GUI.

Ground Control Software Development

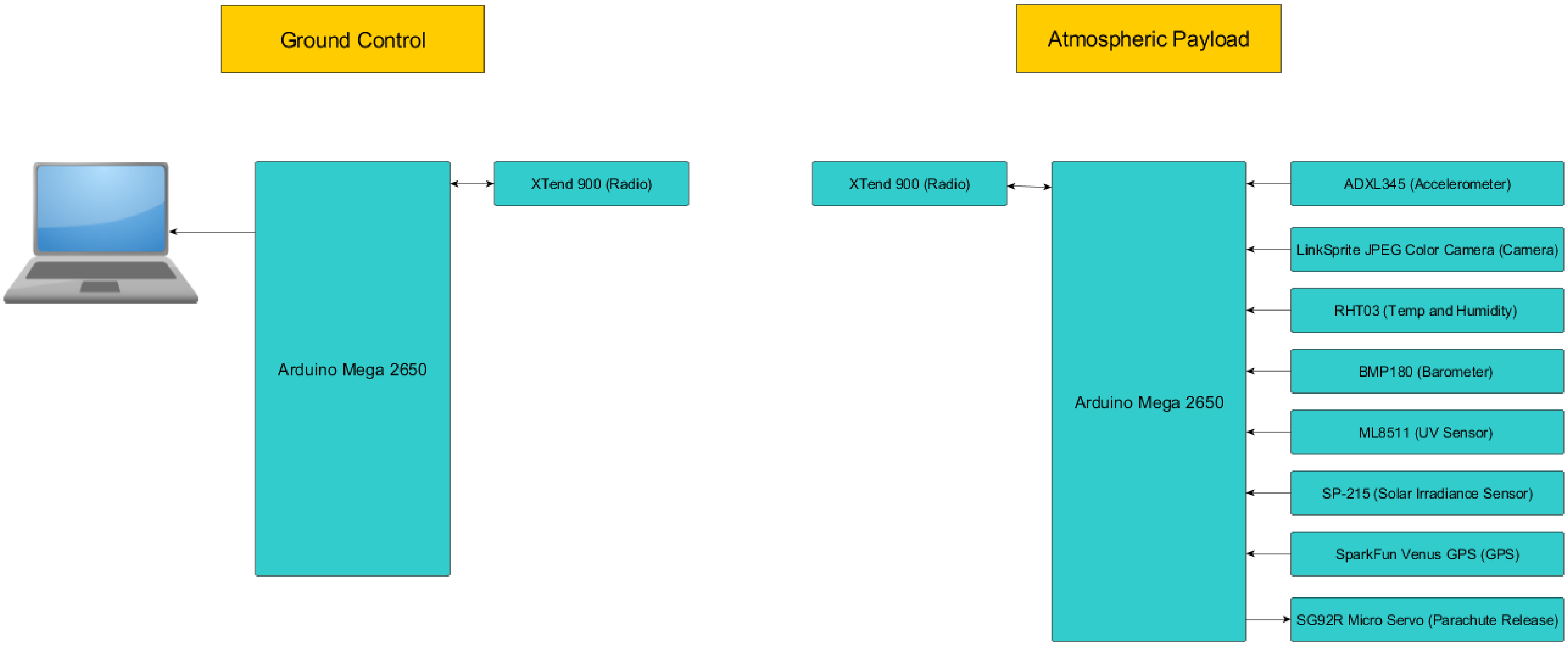
- Able to connect to Arduino using Serial Port.
- User Interface development started.
- Data recording system is implemented.
- Data playback system is implemented.

Ground Control Software GUI





System Integration - PIL & Ground Ops



Educational Engagement

- Completed on November 4 at Winton Woods High School
  - 200 high school students
- Water Bottle Rocketry
- Taught about thrust, stability, drag, and fin design
- Looking to do an engagement on UC’s campus