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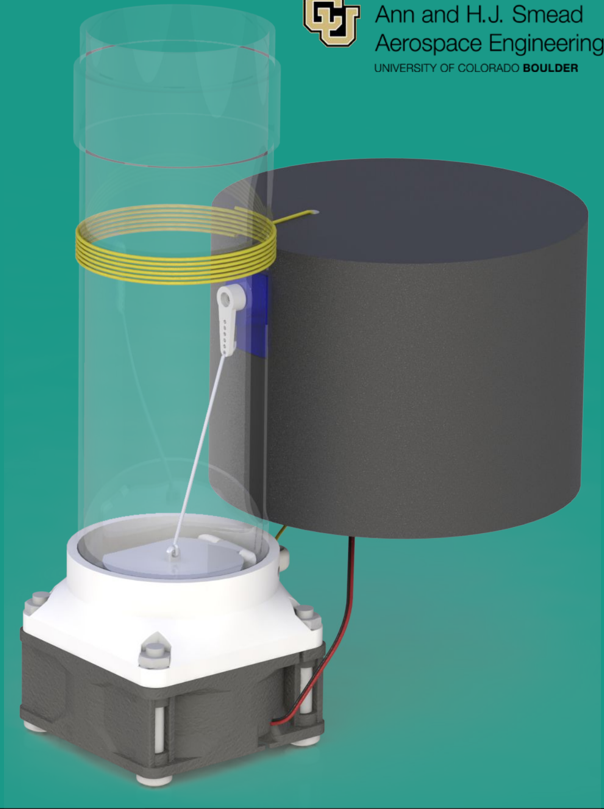
UNIVERSITY OF COLORADO **BOULDER**

ODDITY Test Readiness Review

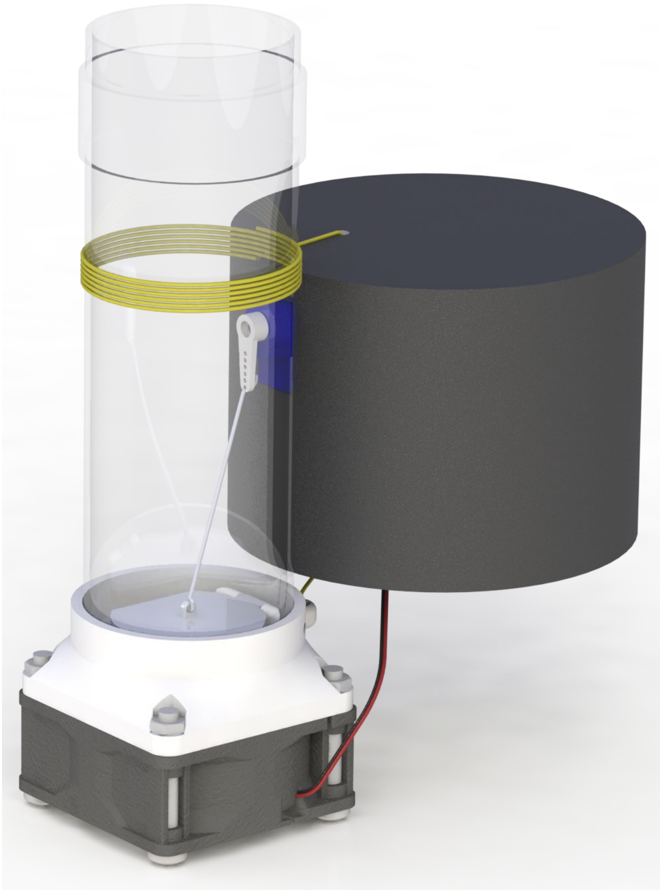
Members:
Alexander Larson, Anders Olsen, Emily Riley, Corey LePine, Thania Ruiz, Marcus Bonilla, Stephen Chamot, Elliott McKee, Michael McCuen, Steven Priddy

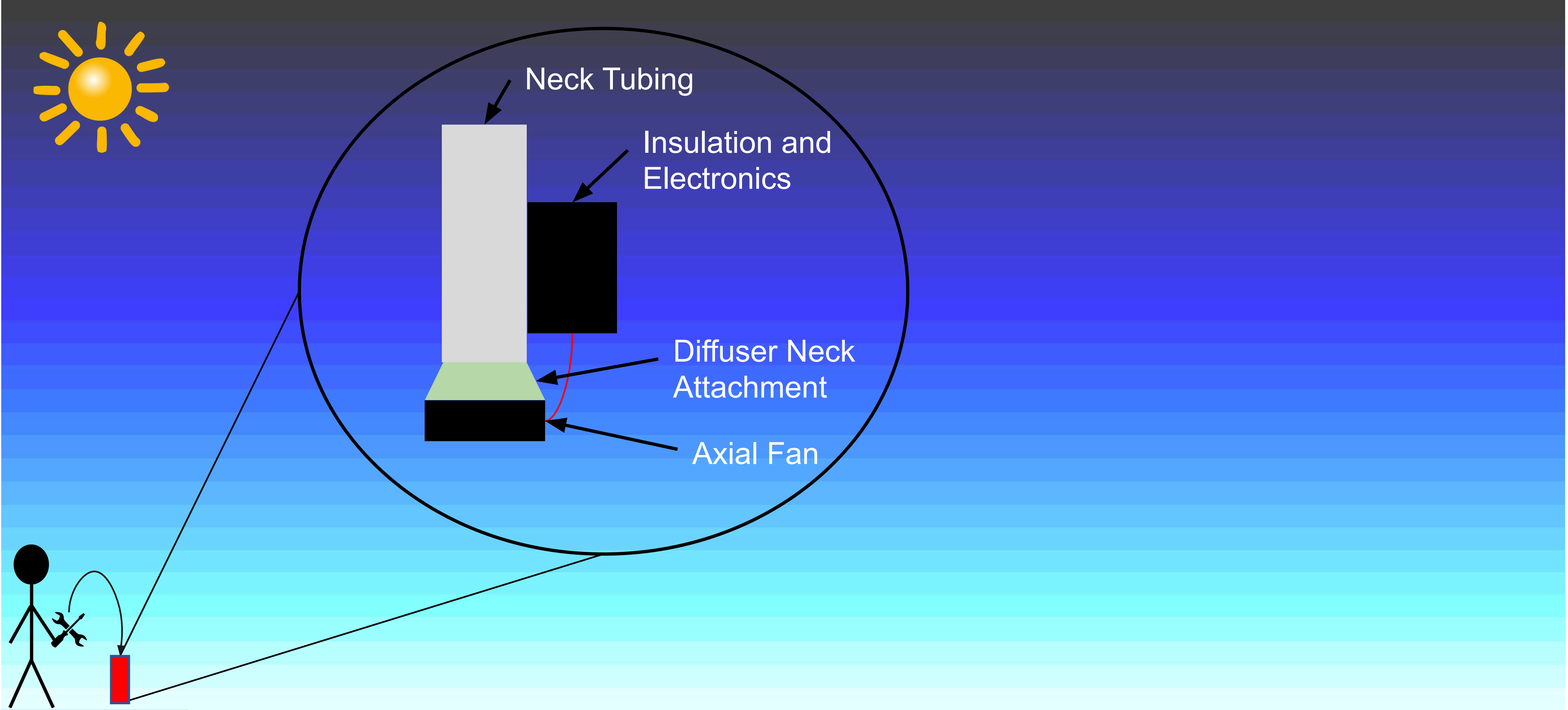
Overview



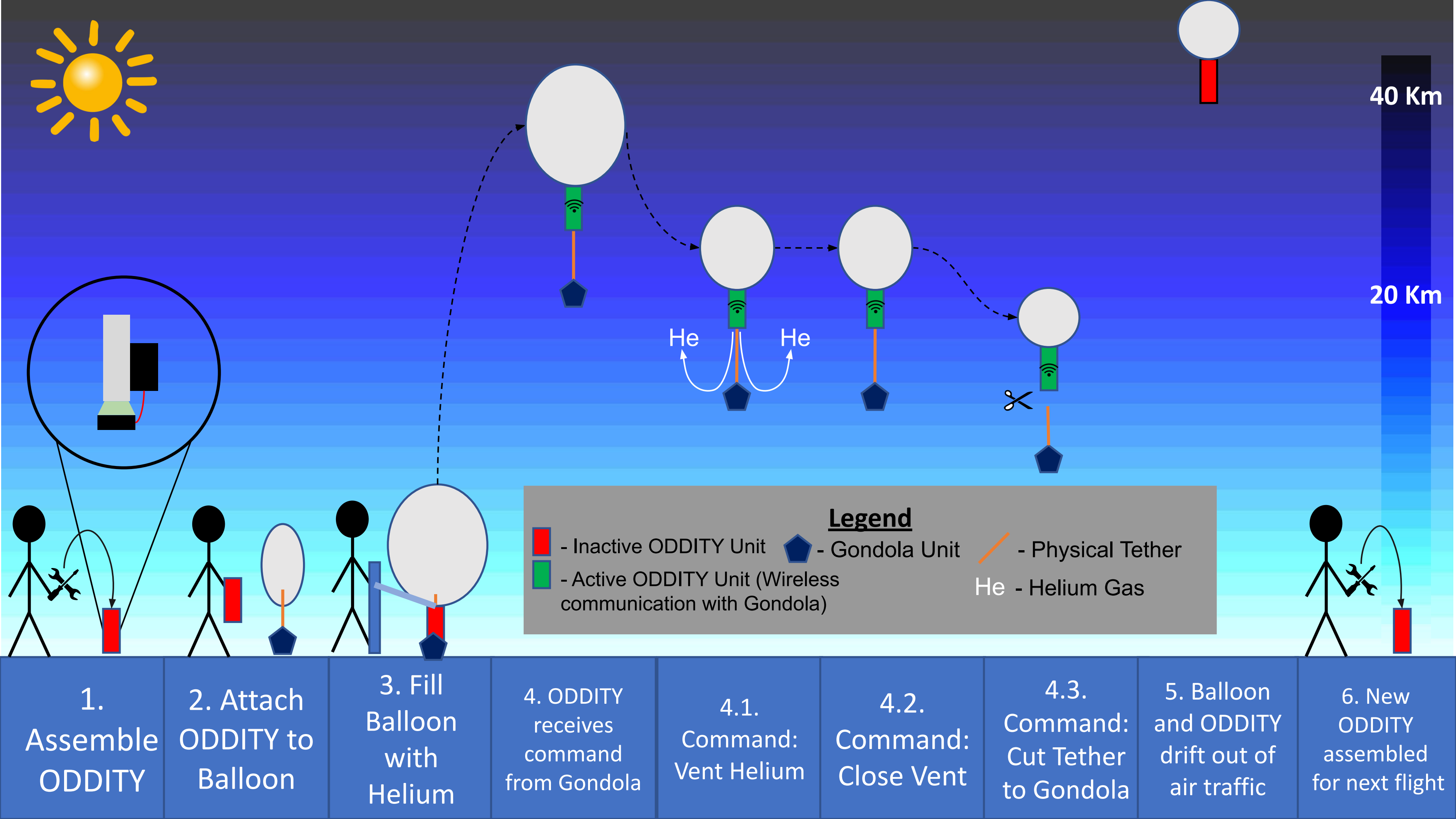
Mission Summary

- Turbulence data is required for high altitude hypersonic aircraft design
- Helium vent aids in proper high altitude turbulence data collection
- Altitude conditions deform balloon canopy which forms an effectively trapped "helium bubble"
- Active helium withdrawal is required due to this plastic deformation of the balloon





1. Assemble ODDITY



40 Km
20 Km
He
He
Legend
- Inactive ODDITY Unit
- Gondola Unit
- Physical Tether
- Active ODDITY Unit (Wireless communication with Gondola)
He - Helium Gas
1. Assemble ODDITY
2. Attach ODDITY to Balloon
3. Fill Balloon with Helium
4. ODDITY receives command from Gondola
4.1. Command: Vent Helium
4.2. Command: Close Vent
4.3. Command: Cut Tether to Gondola
5. Balloon and ODDITY drift out of air traffic
6. New ODDITY assembled for next flight

Levels Of Success

	Descent Control	*Balloon Attachment*	*Communications*	*Survivability*
Level 1	System is able to extract helium from balloon in conditions similar to those at 35km	ODDITY is able to attach to a 5cm neck diameter Kaymont balloon prior to being filled	ODDITY shares communication link with the Gondola via XBee radio	ODDITY is able to withstand pressures and temperatures similar to those seen at 35km
Level 2	ODDITY and Gondola will match legacy system performance in flight testing (35km altitude)	ODDITY is able to be installed on 8cm neck diameter Hwoyee balloons prior to being filled	ODDITY is able to receive data and commands from the Gondola	ODDITY is able to abort the mission if conditions become undesirable
Level 3	ODDITY and Gondola are able to reach a target apogee of 40km		ODDITY is able to transmit data to the Gondola	ODDITY is able to withstand pressures and temperatures similar to those seen at 40km

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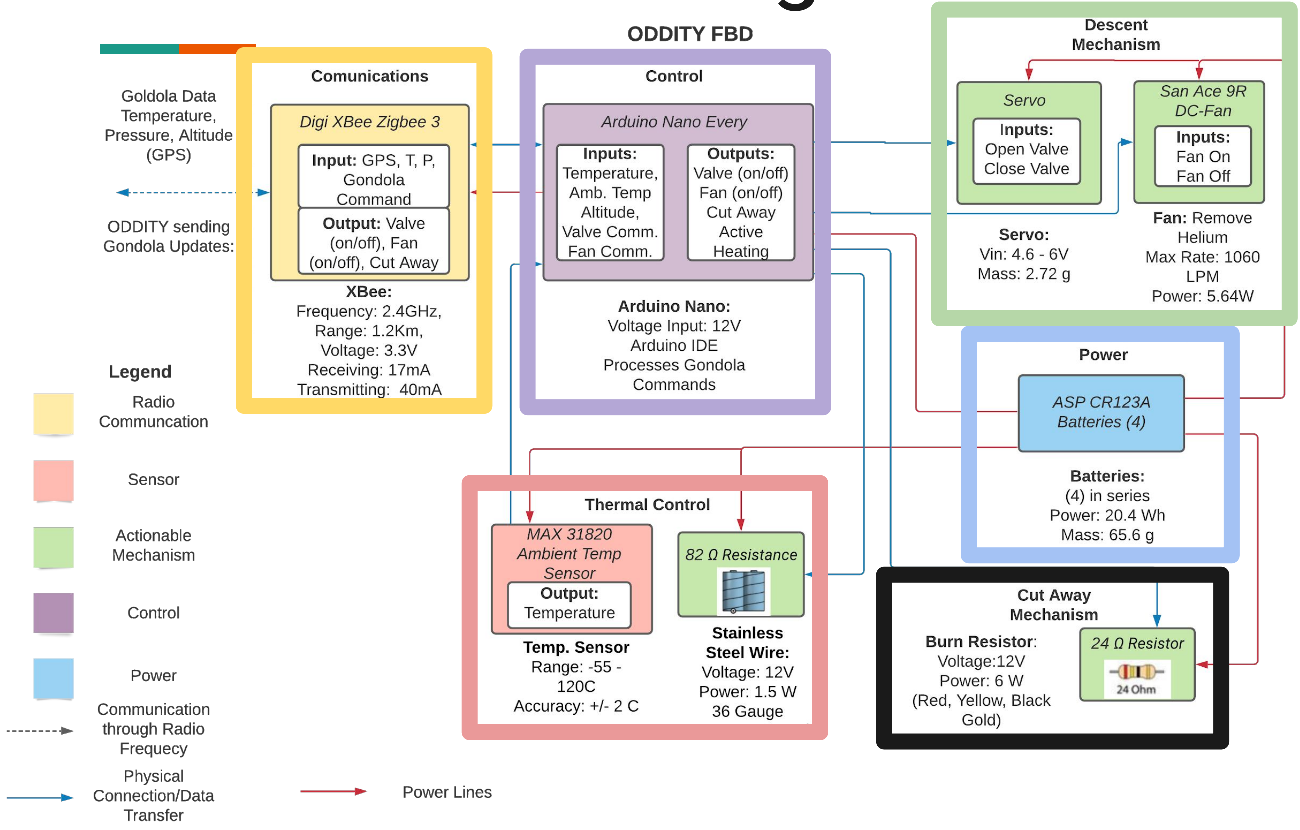
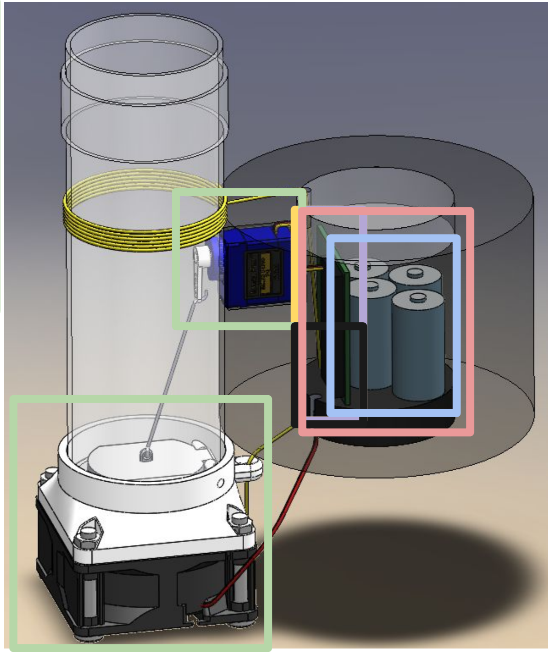
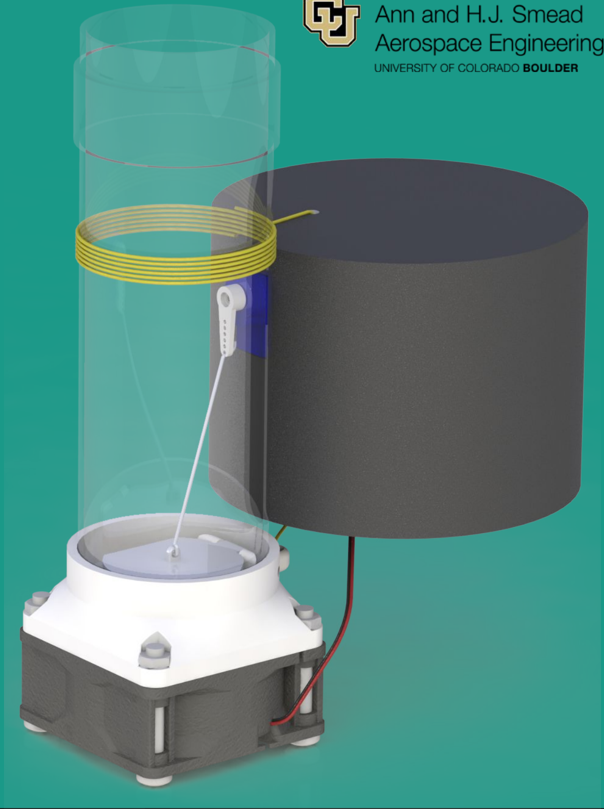
Functional Block Diagrams

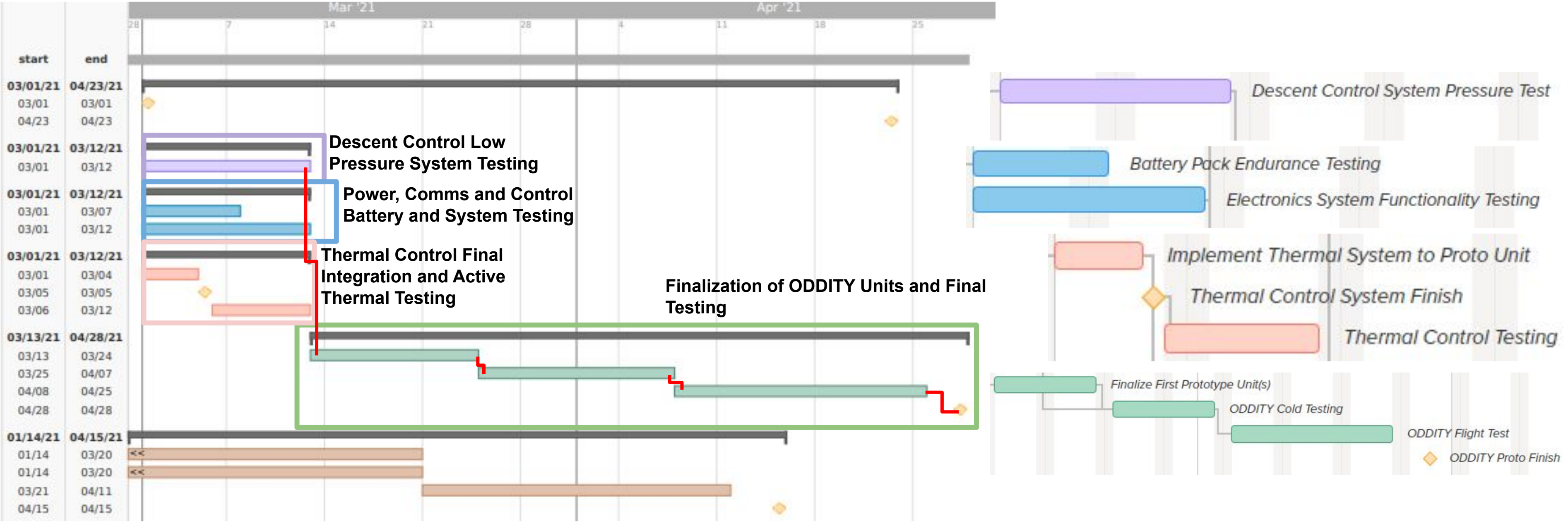




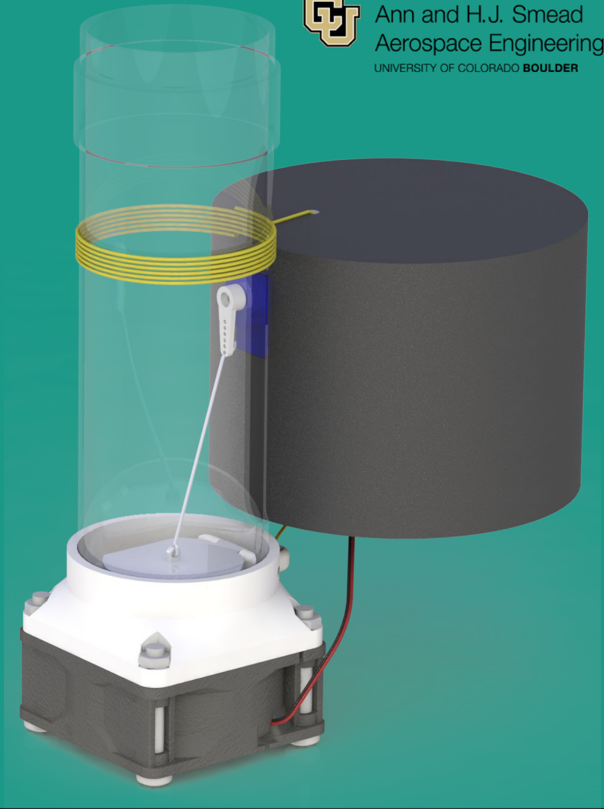
Schedule



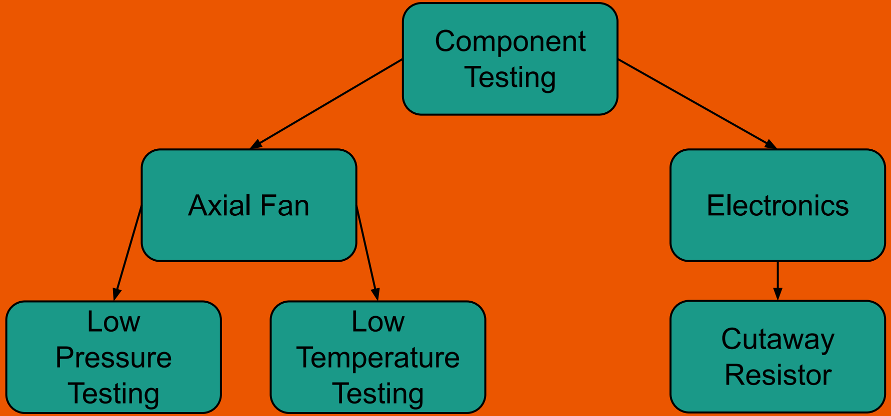
Gantt Chart - Spring Semester

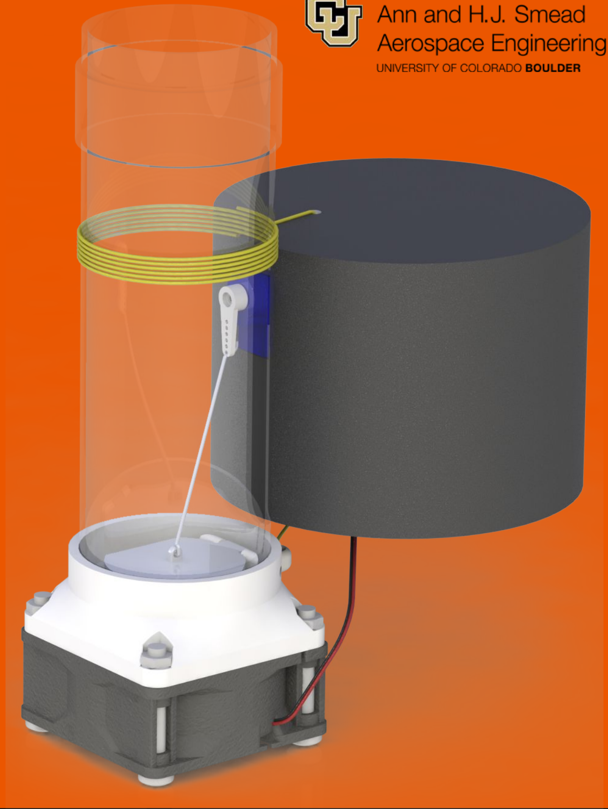


Test Readiness



Completed Tests





Low Pressure Flowrate Testing - Goals + Status

Goals:

How it will reduce risk:

- Verifying fan flowrate in a representative environment

Expected Results:

- Flowrates comparable to those given by CFD

What Models will be Validated

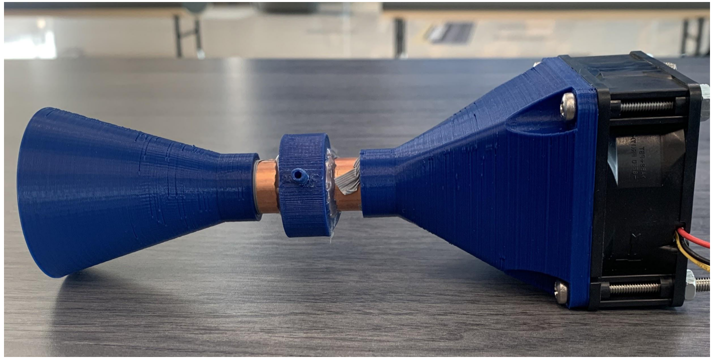
- CFD Simulations

Allows confidence going forward with full-system pressure testing

Status:

Multiple rounds of testing have been completed as of right now

- Multiple datasets to characterize Flowrate vs. Pressure
- 5+ Test datasets across 2 separate testing dates

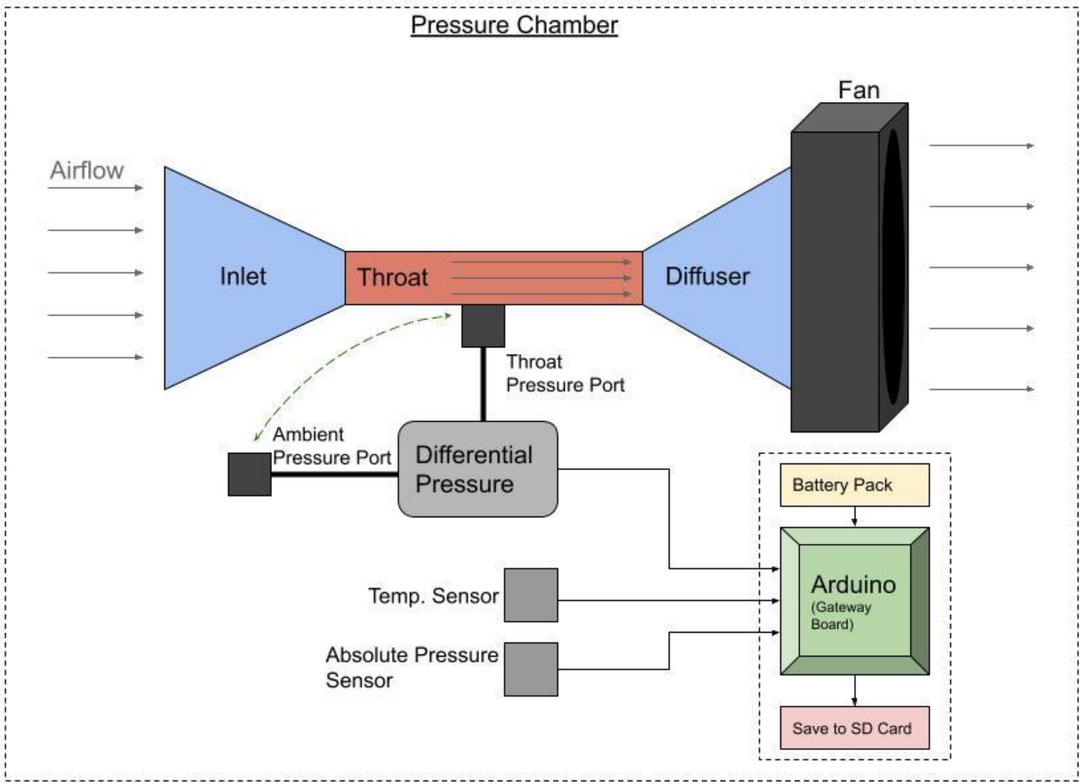


Low Pressure Fan Testing - Rationale + Concept

- Need to verify the fan flowrate at the high altitudes expected

- Utilizes Bernoulli Equation, and assumes incompressible flow, constant total pressure throughout the Inlet+Throat (Ideal)

- Due to the low densities expected, this Venturi Tube apparatus is required in order to accelerate the flow s.t. The dynamic pressure is *measurable.*



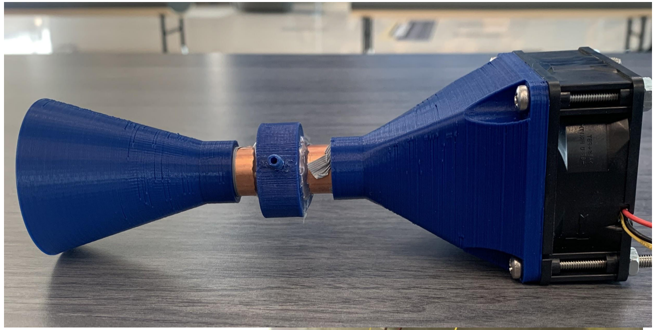
Low Pressure Fan Testing - Setup

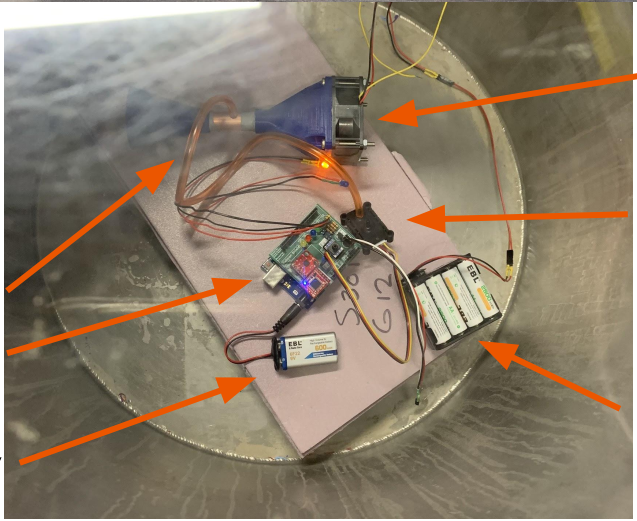
Facilities Required:

- Low-Pressure Chamber
  - Available in AERO via Matt R.

Test Equipment:

- Arduino & Gateway to Space Cape
  - Also provided by Matt R.
- 9V Arduino Battery
- Fan with Venturi assembly
  - 3D Printed Inlet/Diffuser
  - Press Fit Copper Tube w/ drilled holes
- High-Res Differential Pressure Sensor
  - Tubing
- 12V Fan Battery Pack





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Low Pressure Fan Testing - Results

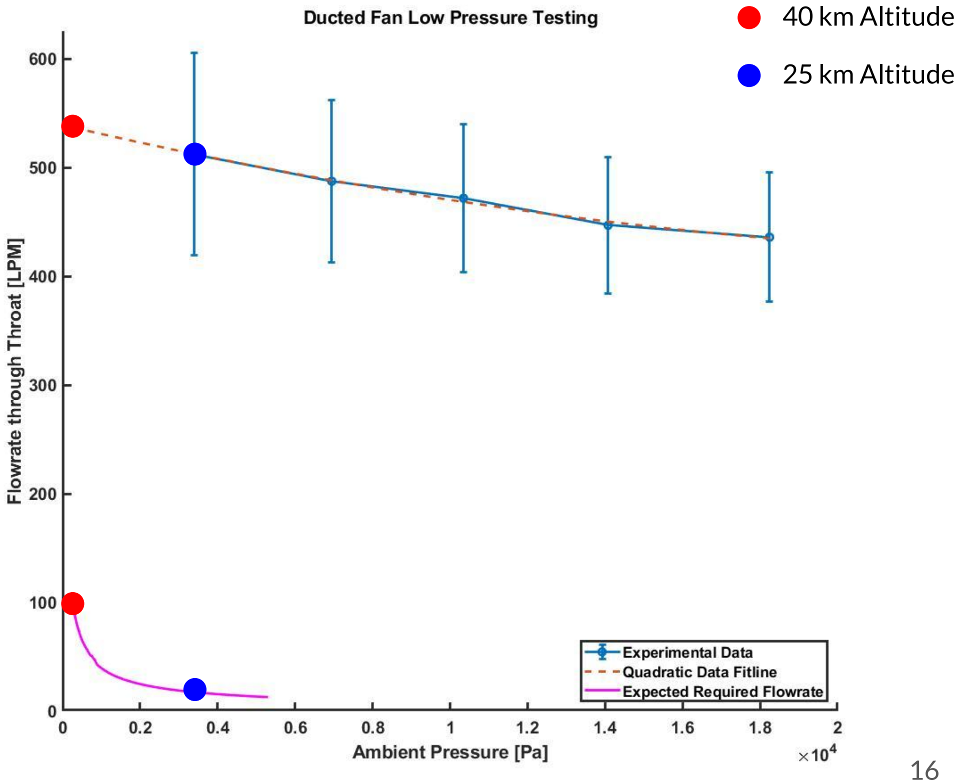
We are seeing higher flow rates than expected

- Good, as more flow rate is desirable
- However, does not match our CFD Modelling predictions

Likely un-modelled behavior occurring

- CFD assumes nominal, data sheet (assuming S.L.) RPM
- Due to thinner air, actual fan could be rotating much faster
- Fan w/ Tach or external Tachometer to be implemented on next tests

Results are showing acceptable flow rates



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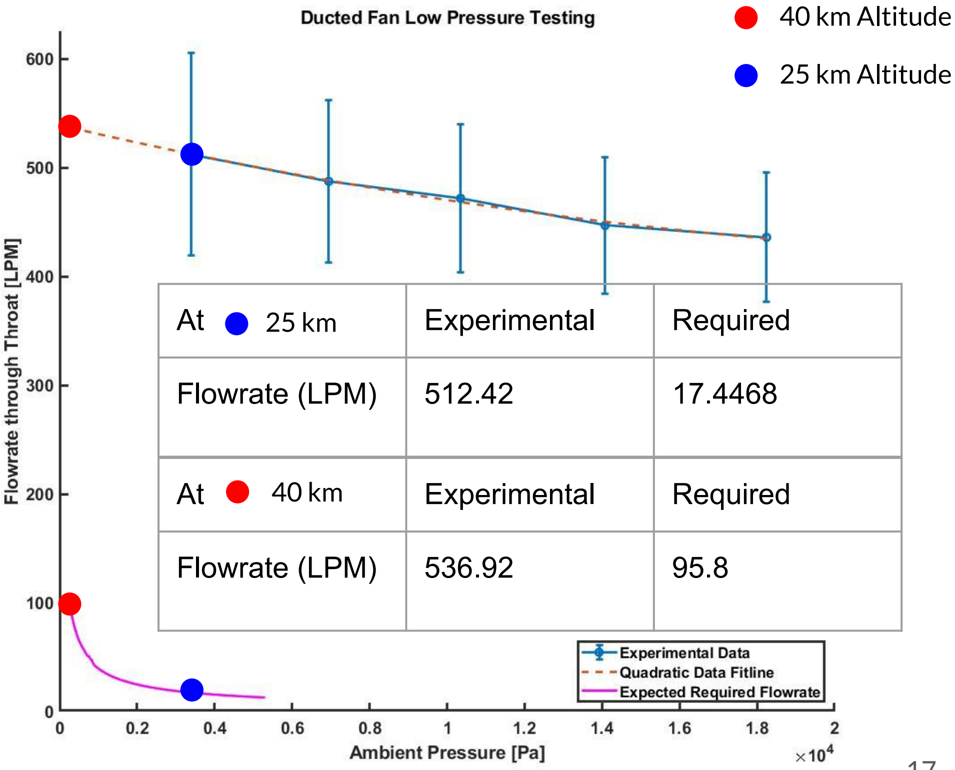


At ● 25 km	Experimental	Required
Flowrate (LPM)	512.42	17.4468
At ● 40 km	Experimental	Required
Flowrate (LPM)	536.92	95.8

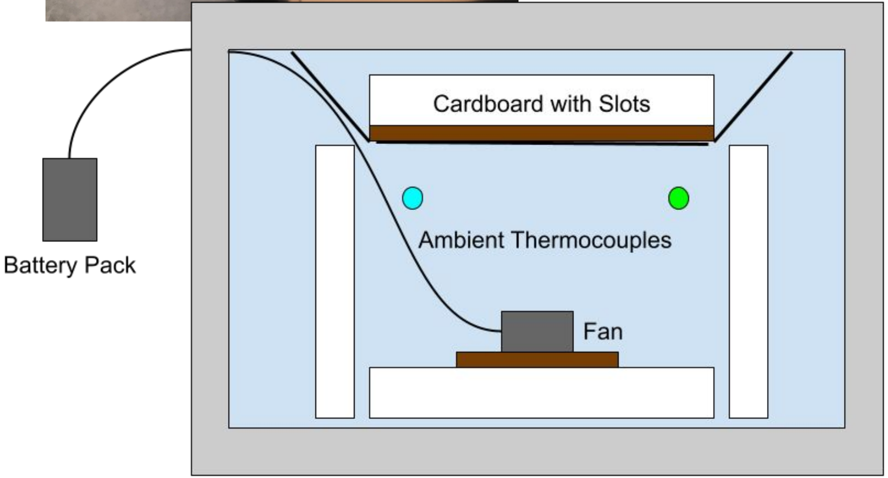
Fan Risk - After Mitigation

Risk:	Fan flow rate is lower than expected
Effect:	ODDITY is unable to achieve desired descent rates
Mitigation:	Experiments are run in low pressure chambers and reflect reasonable flow rates

Low Temperature Fan Testing

Test Setup:
- Place dry-ice in Yeti cooler
- Place 4 thermocouples on fan
- Place 2 thermocouples as ambient

Procedure:
1. Cold soak fan for 25 minutes (or until temperatures are around -56.5 C)
2. Turn on fan
3. Verify fan turns on by listening for noise



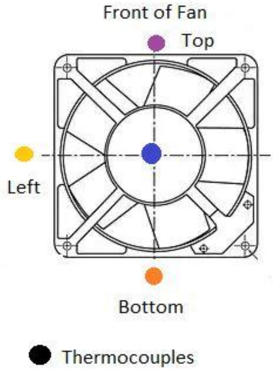
Low Temperature Fan Testing

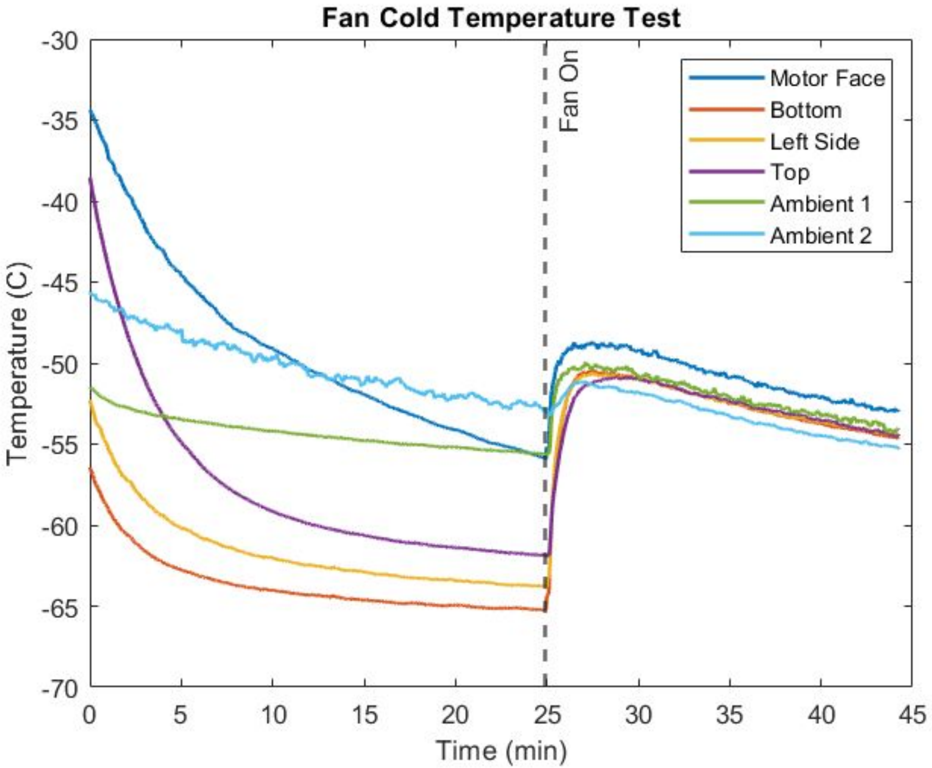
Results:

- Fan turned on
- Temperatures in the cooler ranged from -53 to -60 C

Takeaway:

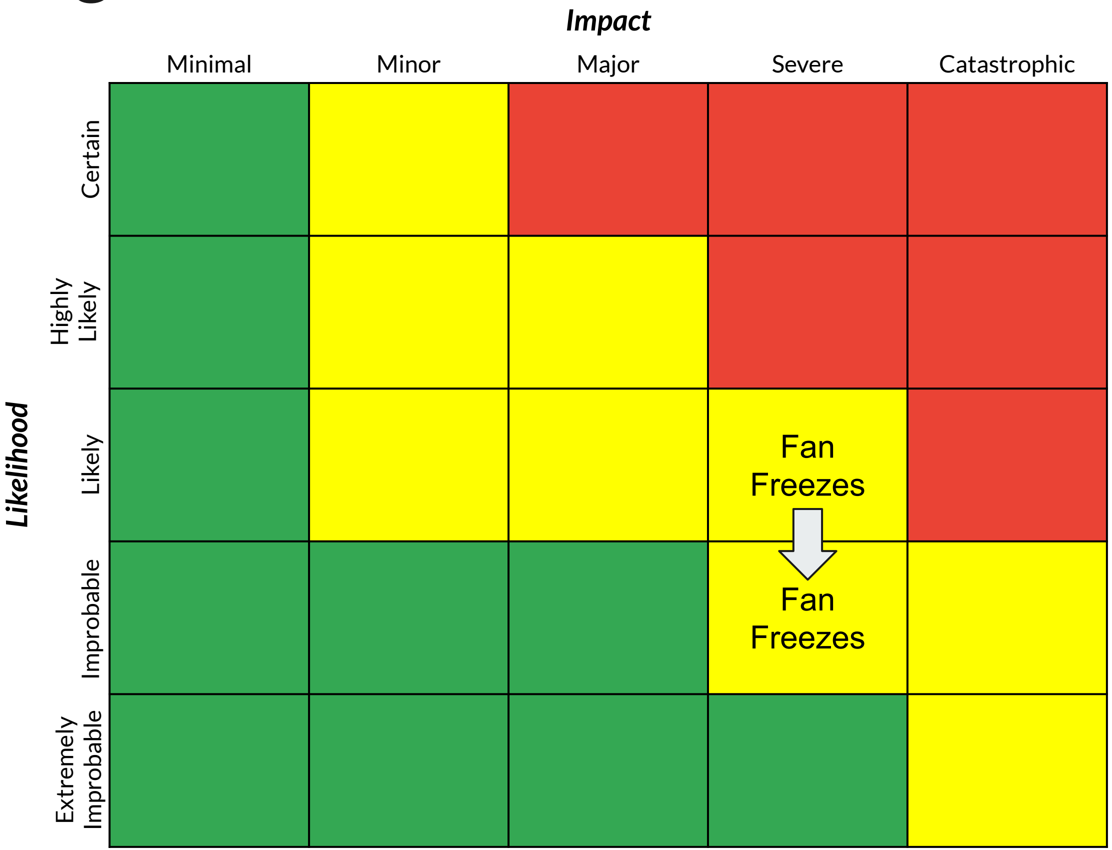
- Fan should operate without additional thermal protection





Fan Risk - After Mitigation

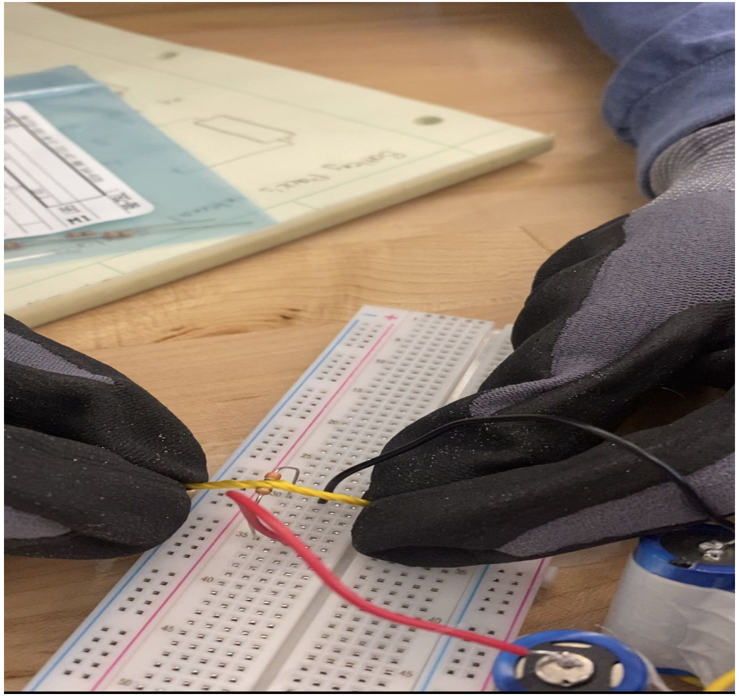
Risk:	Fan Freezes
Effect:	Helium is unable to be actively removed from the balloon
Mitigation:	Testing shows that fan shouldn't require additional thermal control. Additional testing will be performed to better characterize performance of the fan.



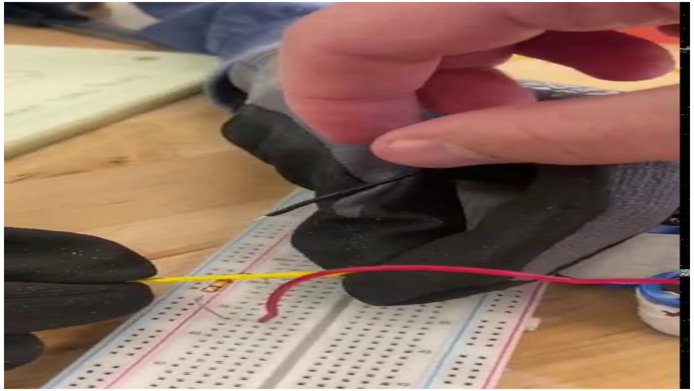
Cutaway Resistor Testing

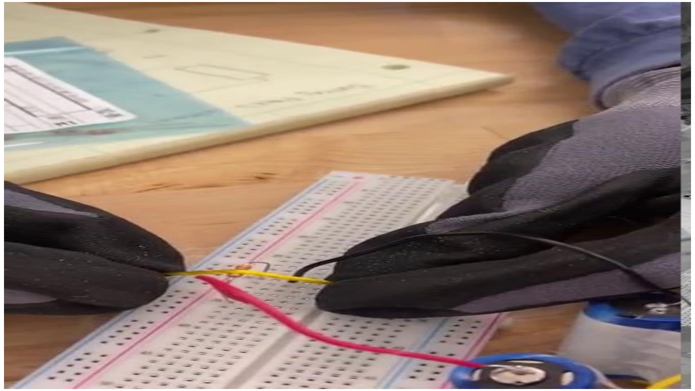
Test Setup:
- Put resistor on a breadboard
- Hold tether against resistor
- Have battery pack or a 12V power supply ready with positive and negative leads

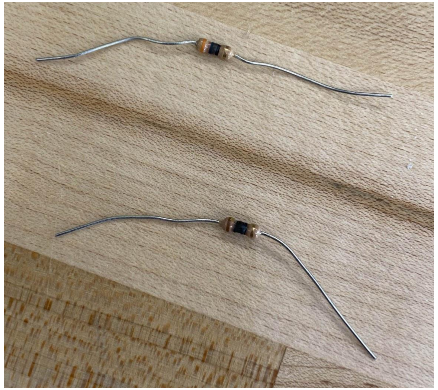
Procedure:
1. Verify the resistor is on the breadboard
2. Connect positive lead of battery pack or power supply to one lead of resistor on breadboard
3. Have someone hold tether against resistor
4. Connect negative lead to open lead on the resistor



Cutaway Resistor Testing







Results:
- Resistors did not explode
- Cut cleanly through tether
- Battery pack was able to supply power to resistor
- No tether globbing

Takeaway:
- Chosen resistor(s) will work for the cutaway of the gondola tether
- Resistors are not usable after cutaway
- Tether will be cut cleanly with no foreseen issues

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Cutaway Risk - After Mitigation

Risk:	Resistor Blows Up
Effect:	Tether may not be fully cut leading to gondola staying with balloon
Mitigation:	After testing, verified the chosen resistors will not blow up and burns cleanly through the tether

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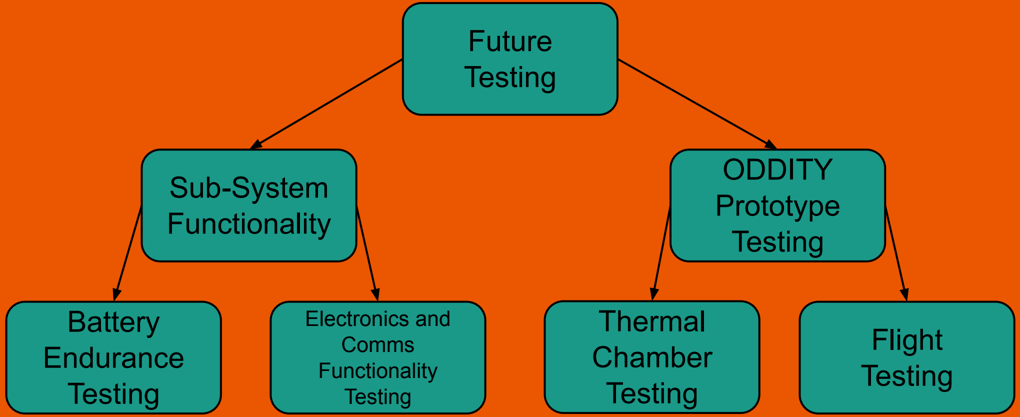
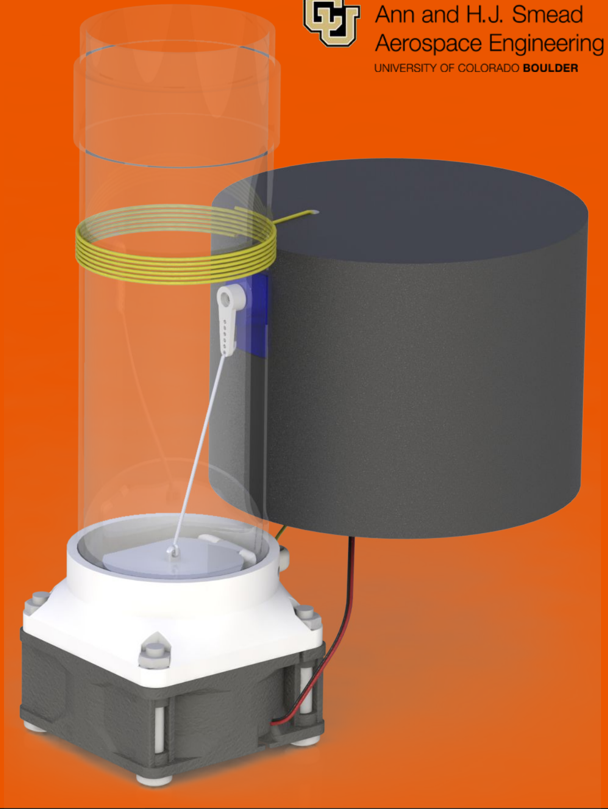
Tests to be Done





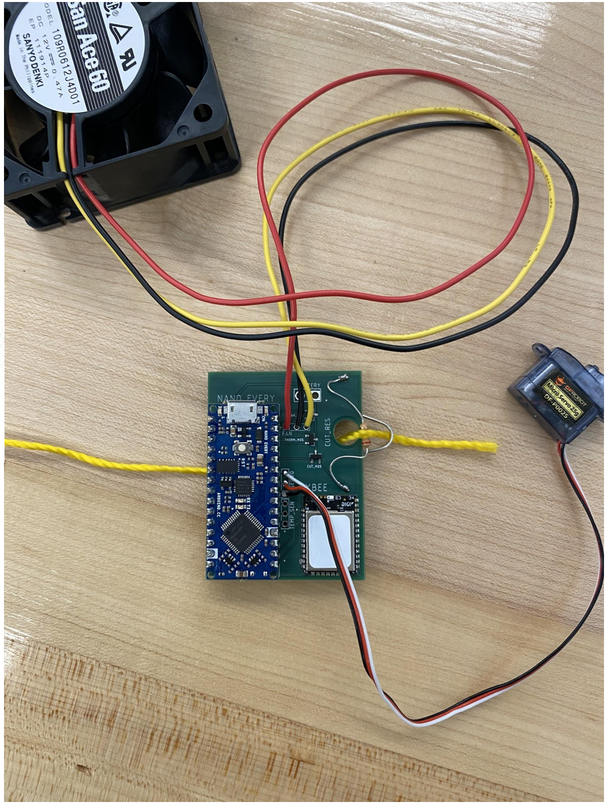
Electronics Testing - Battery Endurance

Test Setup:

- Have a fully integrated PCB with all external components wired correctly
- Have an external Xbee ready to receive status updates from ODDITY's Xbee
- Have a fresh (unused) battery pack

Procedure:

1. Verify ODDITY's Xbee and external Xbee can communicate with each other
2. Verify ODDITY's Arduino Nano Every has code to send time stamps through its Xbee at consistent intervals
3. Connect fresh battery pack to power ports on ODDITY
4. Time how long it takes for the battery to drain to zero capacity, during nominal conditions (activating various components to simulate flight)



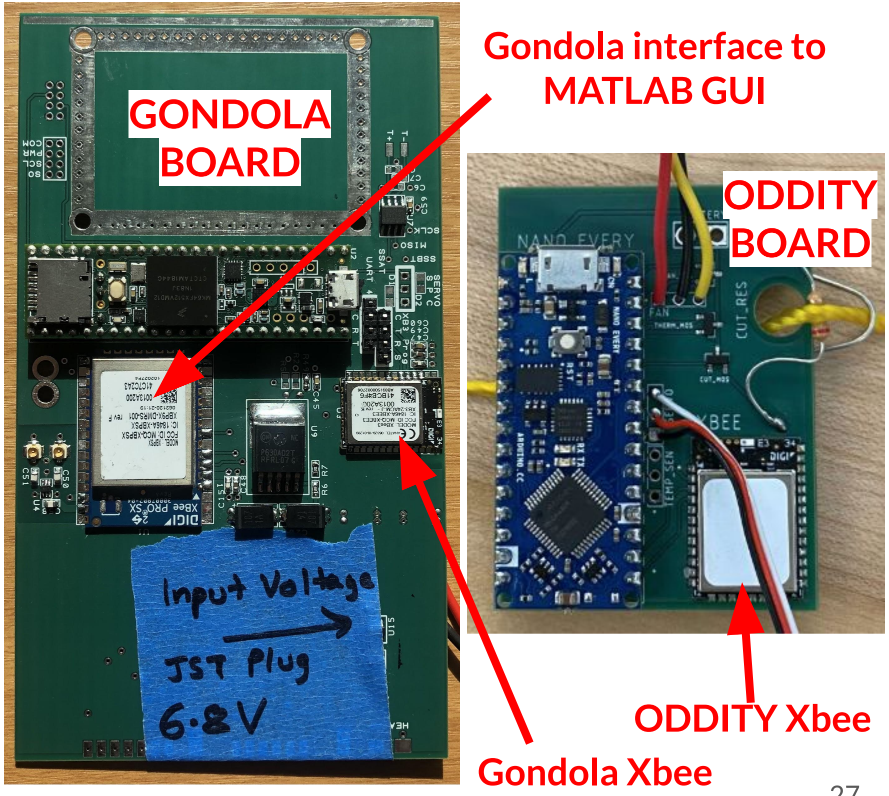
Communications Testing (Gondola to Xbee)

Test Setup:

- Have a fully integrated ODDITY PCB with all external components wired correctly
- Have a fully functional Gondola board to send commands to ODDITY
- Utilize a functional MATLAB GUI to confirm data packets are received by gondola

Procedure:

1. Connect Gondola board to PC and open MATLAB GUI
2. Send commands from Gondola to ODDITY followed by ODDITY sending data packets back to the Gondola
3. Inspect the MATLAB GUI to verify data packets are being received by the Gondola
4. Verify ODDITY turns on appropriate components based on the command packet received



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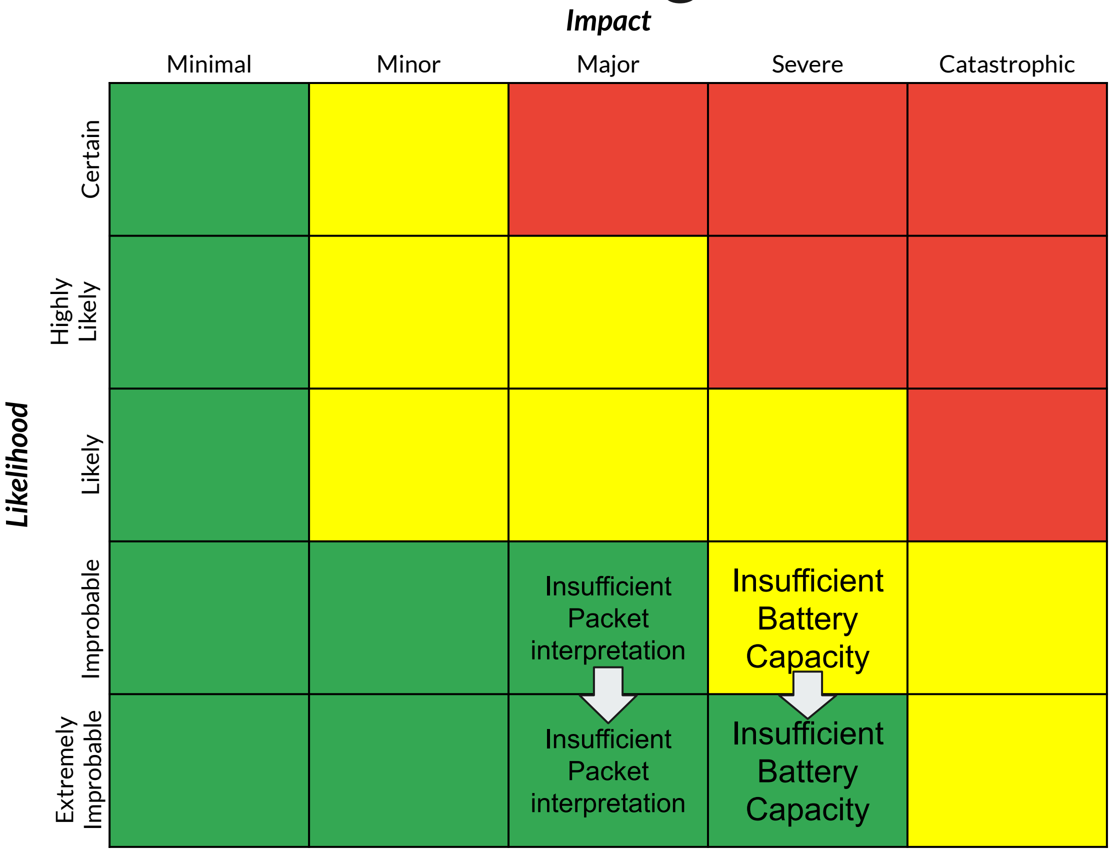
Electronics & Comms Risk - After Mitigation

Risk:	Insufficient Battery Capacity
Effect:	ODDITY's power fails during flight resulting in: mission failure, loss of gondola, and safety hazards
Mitigation:	After testing, verify selected batteries will last for full mission duration

Risk:	ODDITY is not able to interpret the packets transmitted from the Gondola
Effect:	ODDITY will not be able receive commands to turn on/off components
Mitigation:	Verify communication interpretation through testing



Cold Testing (Thermal Chamber)

Test Set-Up:

- Use Professor Palo's temperature chamber
- Insulation cylinder with electronics and batteries mounted inside
- Resistive wire + temperature sensor heating system

Test Goals:

- Verify thermal modeling and characterize performance of the active heating system
- Prove that batteries will not get too cold and lose voltage

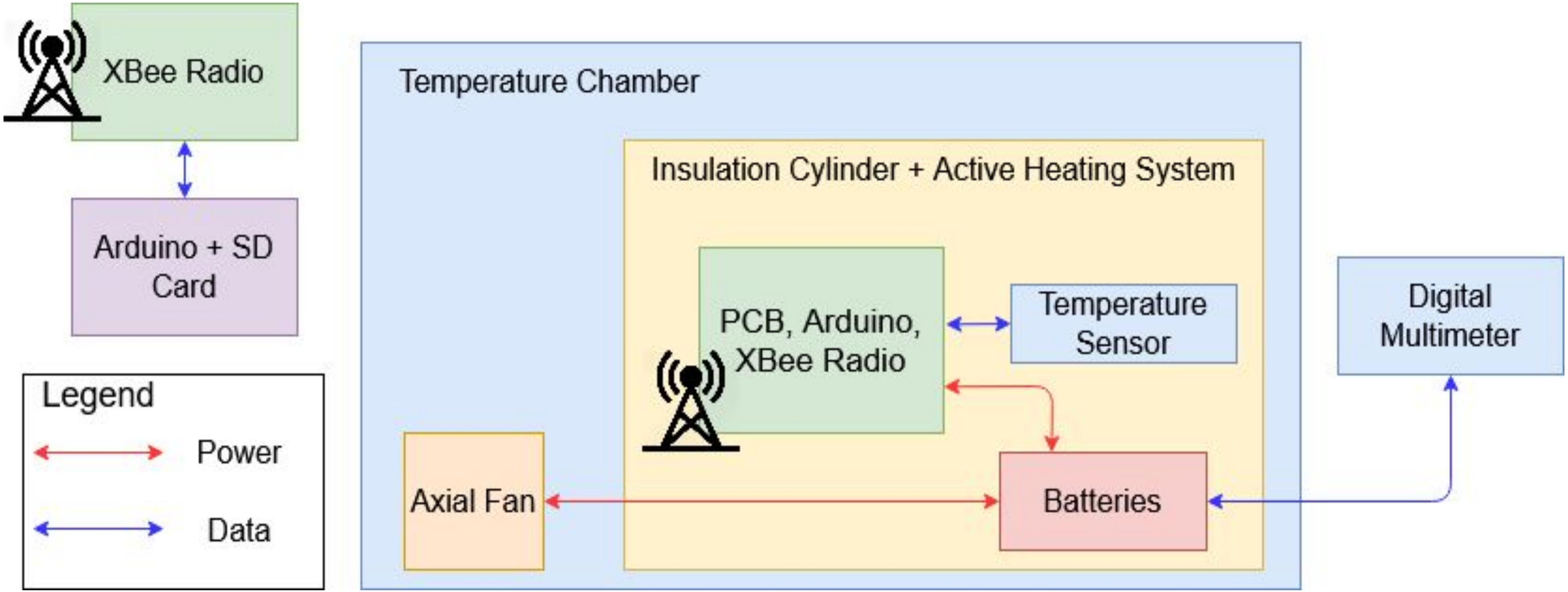
Procedure:

1. Bring chamber down to -60 C, maintain this temperature for ~20 minutes
2. Raise temperature to -50 C, maintain for ~ 40 minutes
3. Allow chamber to warm back to room temperature, continually recording data

TestEquity 115A-F Temperature Chamber

Min. Temperature: -73 C

Thermal Chamber Testing Diagram



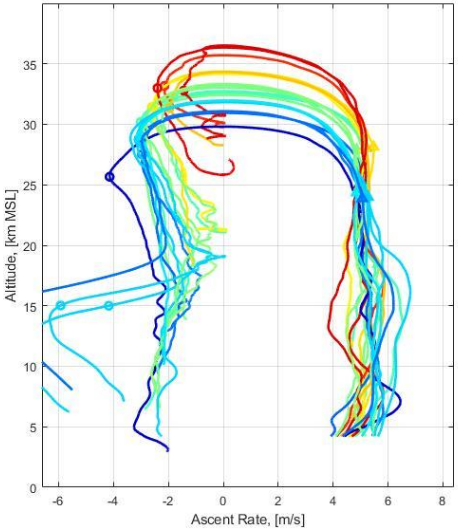
Flight Test

Test Set-Up and equipment:

- Balloon and Helium
- Complete and Functioning ODDITY System
- HYFLITS' Gondola, ground stations and general launch support

Procedure:

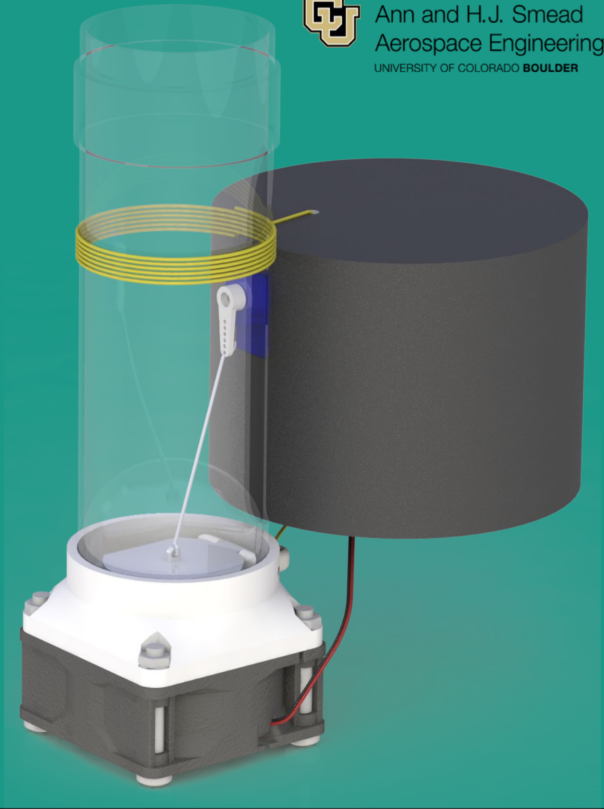
1. Attach ODDITY System to Weather Balloon and weight balloon down with 1325g tare weight
2. Fill Balloon with Helium until the Balloon is able to lift tare weight, ODDITY and Gondola off the ground
3. Launch
4. Actuate valve and fan at the same time
5. Monitor data with particular attention to the descent velocities and general profile



Results:

- Compare with Legacy descent velocities and flight trajectories
- Determine Buoyancy Control level of success by categorizing descent performance to Legacy system

Budget

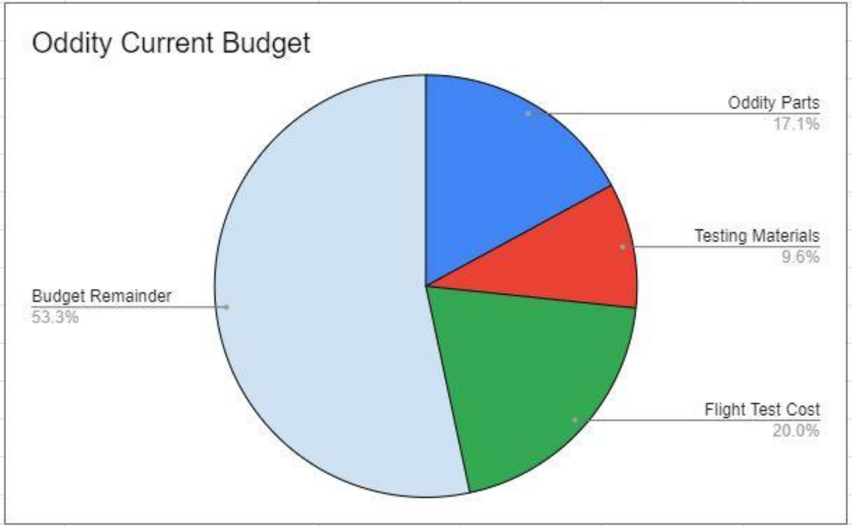


Budget

ODDITY Parts	Quantity	Cost	Total	Uncertainties
Electronics			$604.58	$20.34
Arduino Nano	5	$12.90	$64.50	$7.35
Xbee Zigbee 3	8	$16.21	$129.68	$7.99
ASP CR123A Batteries	24	$1.90	$45.60	$5.00
Transistors	4	$0.45	$1.80	$0.00
Printed Circuit Board	***11***	***$33.00***	***$363.00***	***$0.00***
Thermal Control Parts			$75.47	$15.76
Insulation (6ft)	3	$20.09	$60.27	$7.99
Active Heating Resistor	10	$0.50	$5.00	$0.00
Mounting tape (3ft)	1	$4.35	$4.35	$0.00
Temperature Sensor	3	$1.95	$5.85	$7.77
Descent Control Parts			$108.48	$9.49
Servo	6	$7.98	$47.88	$0.50
Sealing Valve	2	$2.00	$4.00	$1.00
Axial Fan	5	$11.32	$56.60	$7.99
Cut Away Mechanism Parts			$5.00	$0.10
Burning Resistor	10	$0.50	$5.00	$0.10
Balloon Attachment			$10.32	$4.10
Diffuser Neck Attatchment	1	$0.32	$0.32	$0.10
Balloon Neck Plastic Tube (5 cm)	**1**	**$4.00**	**$4.00**	**$2.00**
Balloon Neck Plastic Tube (8 cm)	**1**	**$6.00**	**$6.00**	**$2.00**
		Total	$803.85	$49.79

Flight Test Cost: $2000.00 (cover half)

Total Budget Used: 26%



Questions?

Resources

- Team ATOMIC 2019-2020 for presentation formatting
- Prof. Argrow's Customer Presentation Fall 2020
- Star CCM
- MATLAB
- SolidWorks
- Google Drive, Sheets, Drawing, Slides
- TeamGantt
- PAB Members
- Advisor, Prof. Akos
- Prof. Lawrence
- Prof. Argrow

Appendix

- Valve Testing
- Balloon Neck Attachment Testing
- Low Pressure Fan Testing - Procedure
- Thermal Control of Fan
- Communications Risk - After Mitigation
- Cold Risk - After Mitigation
- Flight Test - After Mitigation
- Communications Testing (Gondola to Xbee)
- Communications Testing (Dev. Board to ODDITY)
- Communications Testing (Dev. Board to ODDITY)

Valve Testing

Test Setup:

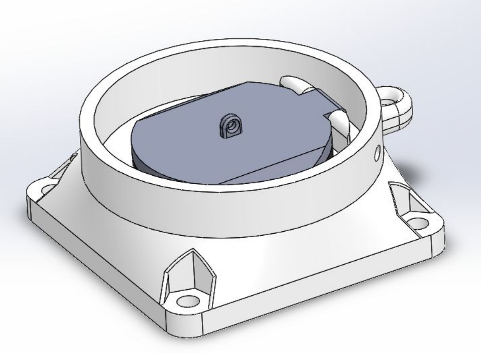
- Complete Valve, Diffuser, servo and tube
- Filling diffuser

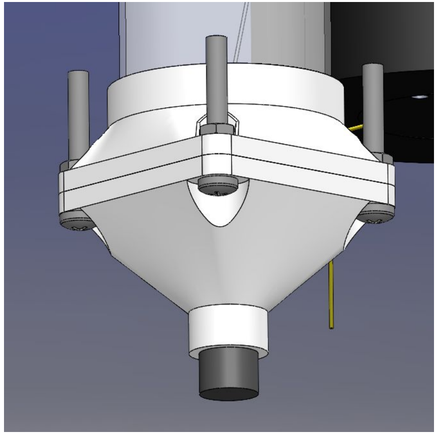
Procedure:

1. Make a whole valve assembly with the servo, wire and tube
2. Connect the two diffusers with bolts
3. Close the valve shut and begin filling with valve closed
4. Put maximum pressure of air though the opposite end of the diffuser
5. See if there are leakages thought he pressure gage on the tank that "FIlls" the balloon

Results:

- Ensures a proper seal so no helium leaks





Balloon Neck Attachment Testing

Test Setup:

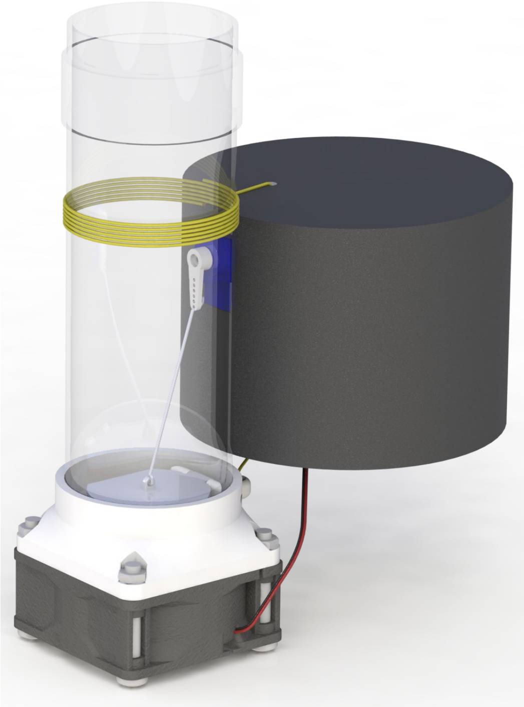
- Complete ODDITY (8cm & 5cm)
- Gondola Weight
- Weather Balloon (8cm & 5cm)
- Fiber tape

Procedure:

1. Connect ODDITY and the Gondola to the neck of the balloon
2. Secure overlapped section with fiber tape
3. Suspend the complete system from the balloon neck for 6 hours

Results:

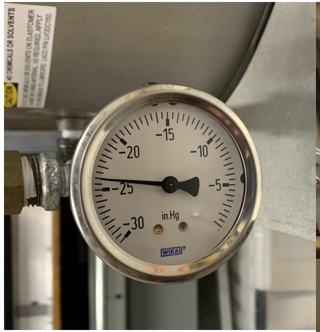
-Confidence that it will not fall



Low Pressure Fan Testing - Procedure

Procedure:

1. Powers Arduino, cape, and sensor on
2. Let sit in closed chamber for 1 min
3. Power fan on
4. Depressurize chamber to -15 inHg
5. Let sit for 1 min
6. Depressurize chamber by -1 inHg
7. Let sit for 1 min
8. Repeat steps 5 - 7 until chamber cannot depressurize any more
9. Repressurize chamber
10. Power off fan and Arduino
11. Take data from SD card



Thermal Control of Fan

Possible Solutions:

- Twitch Fan Motor On and Off
- Insulation
  - Attached to face of fan motor and sides of fan
  - Foam and Foil Insulation Tape
    - Thickness: 3.18 mm
  - Aerogel Blankets
    - Thermal Conductivity: ~ 15 mW/mK
    - Thickness 3.5 mm to 8 mm
- Heating:
  - Nichrome or Stainless Steel wire coiled on face of motor
    - Power available: ~1.49 Wh

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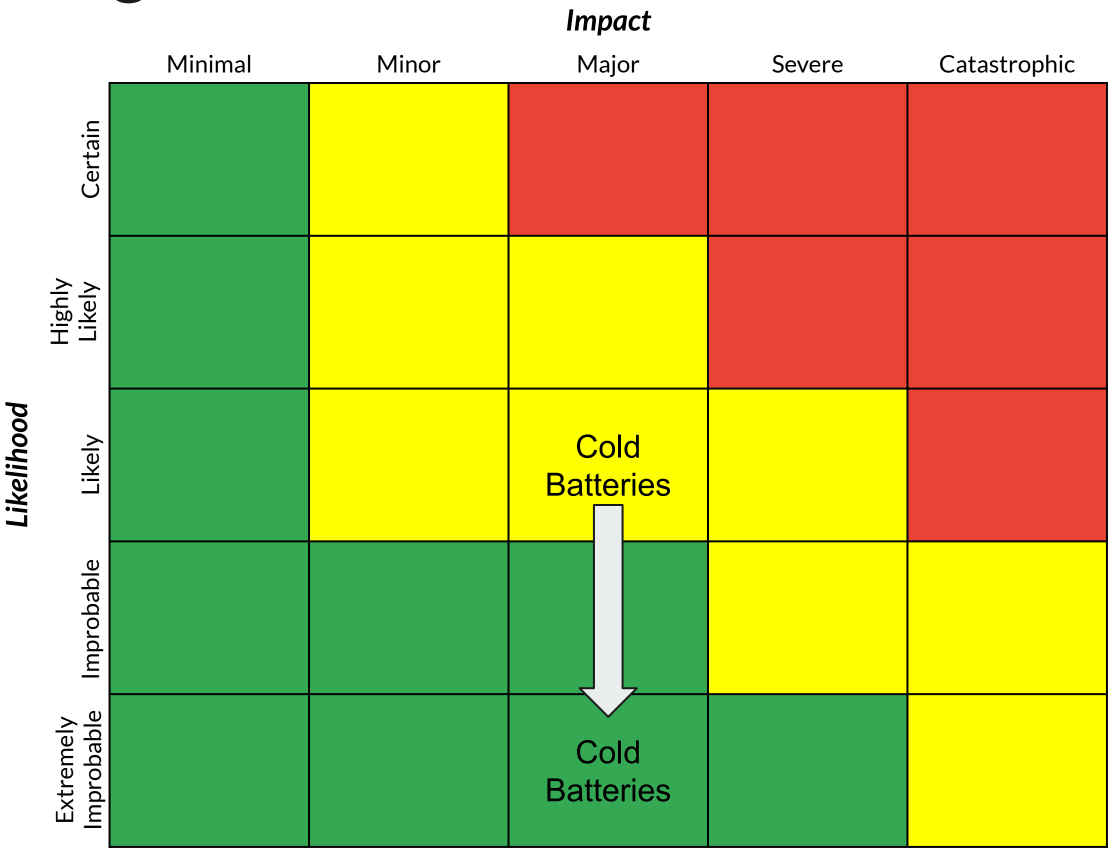
Communications Risk - After Mitigation

Risk:	ODDITY cannot communicate with the Gondola
Effect:	ODDITY will not be able to vent helium or cutaway the tether

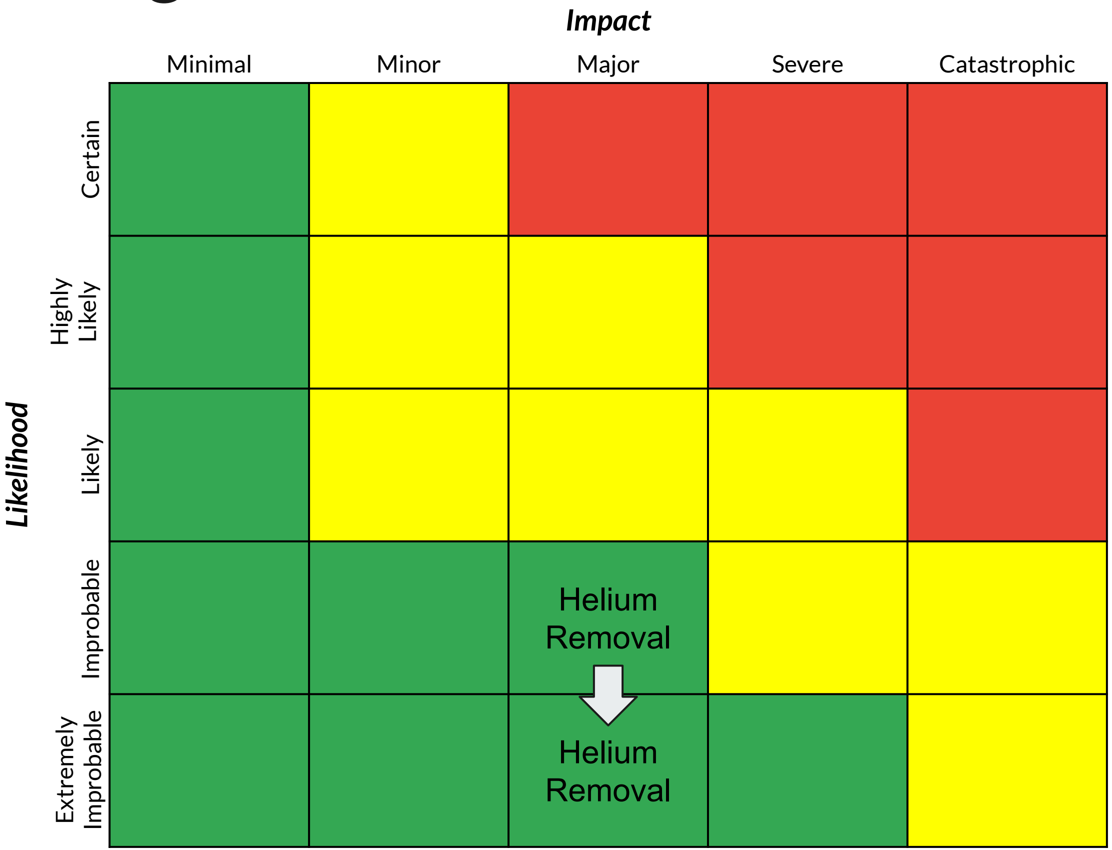
Cold Risk - After Mitigation

Risk:	Batteries get too cold
Effect:	Batteries are not able to deliver the current that is required to power the subsystems
Mitigation:	Testing will ideally show that the ODDITY heating system is capable of providing sufficient heat to electronics

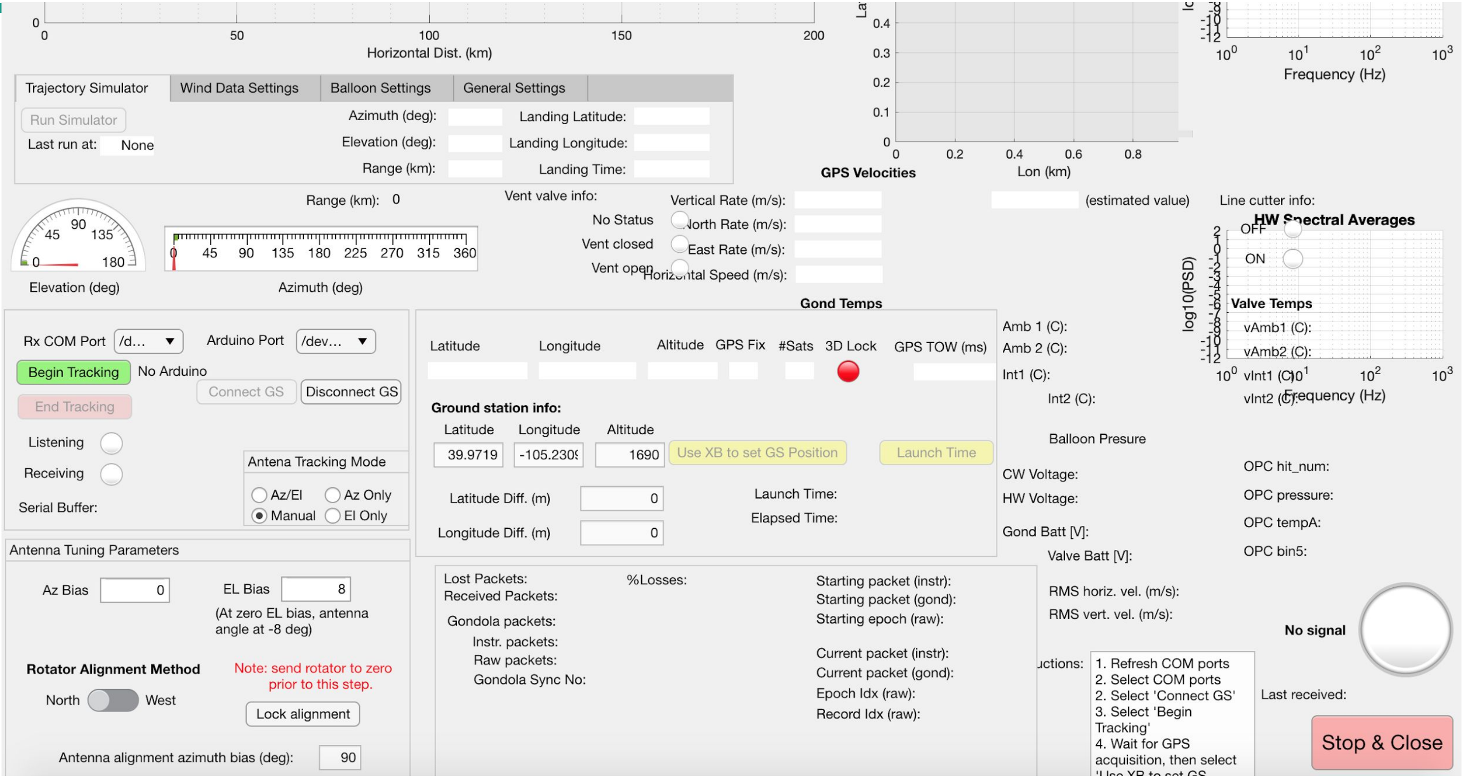


Flight Test - After Mitigation

Risk:	Fan is unable to remove helium fast enough at altitude
Effect:	ODDITY is unable to achieve desired descent rates for data collection
Mitigation:	Test flight profile should show that the ODDITY system is removing helium fast enough



Communications Testing (Gondola to Xbee)



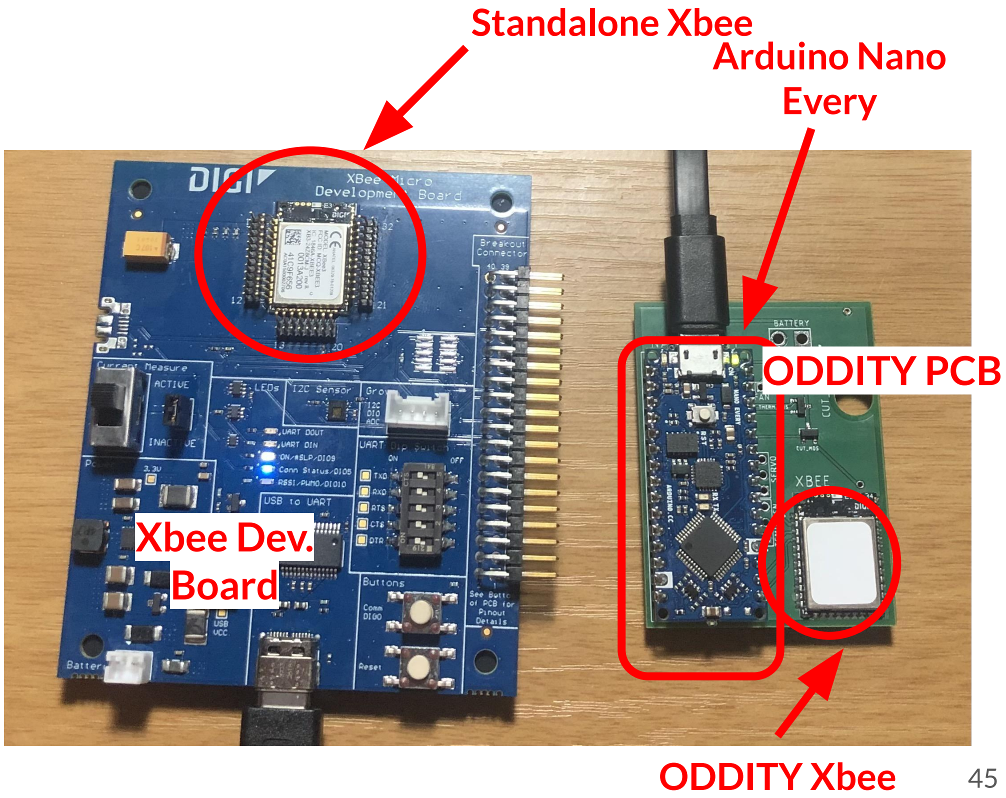
Communications Testing (Dev. Board to ODDITY)

Test Setup:

- Xbee Development Board connected to PC
- ODDITY connected through Arduino to PC
- XBee XCTU Software
  - GUI for sending Xbee Packets

Procedure:

1. Mount standalone Xbee to Dev Board and connect Dev Board and Arduino to PC
2. Verify PC can discover Xbee Dev Board and Arduino
3. Upload Arduino code to read serial packets
4. Send API Frame through XCTU from Dev Board to ODDITY
5. Verify Arduino receives commands through Serial Monitor



Communications Testing (Dev. Board to ODDITY)

Results:

- Successful Xbee/PCB/Arduino connection
- Arduino Code can read incoming serial information
- Xbee Packet string was successfully communicated to ODDITY

Takeaway:

- Current PCB successfully connects the Xbee and Arduino
- Basic Xbee communication established
- Need to implement data extraction