Colorado State University DemoSat-B

Colorado Space Grant Consortium
DemoSat-B
Colorado State University
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Overview

Description

- CO2 spatial mapping system
- High accuracy
- Low cost modular system

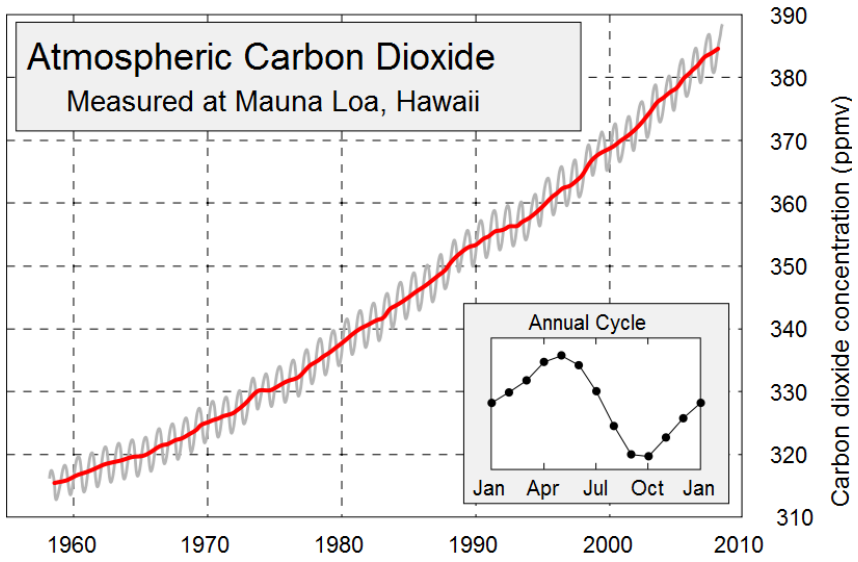
Objectives

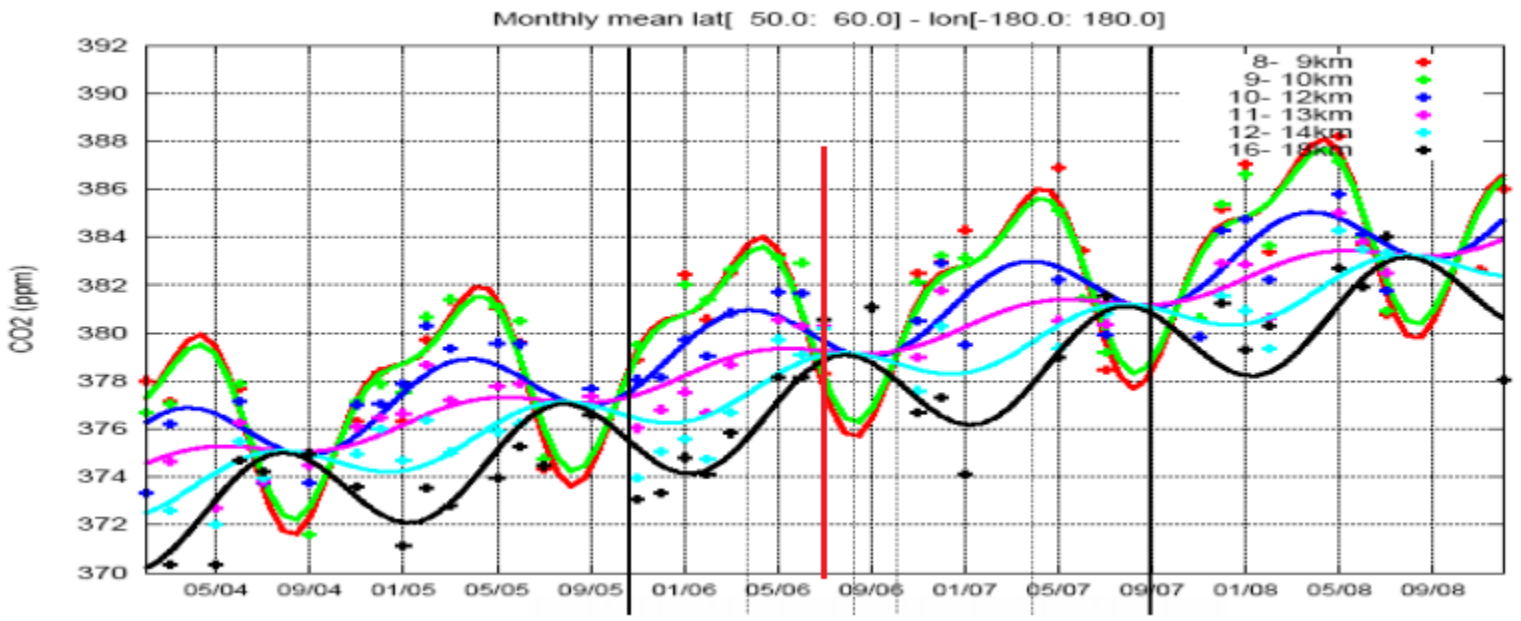
- Measure concentration of CO_2 ,RH, temperature and pressure
- Operate for 200 minutes

Topic Background

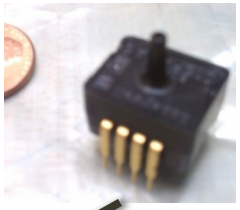
- Multiple organizations have conducted similar research but with different techniques. (sample from aircraft, and Space observation)
- It is important to understand the mechanistic mixings of Carbon Dioxide through the atmosphere to better predict effects of emissions in the future

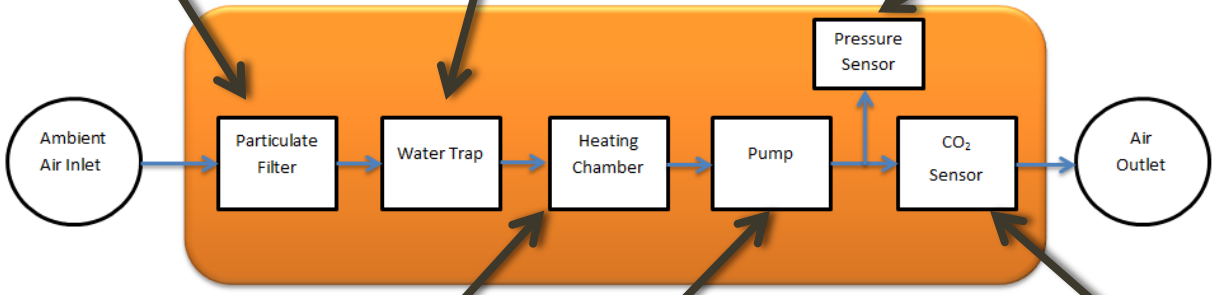
CO_2 concentrations in our atmosphere

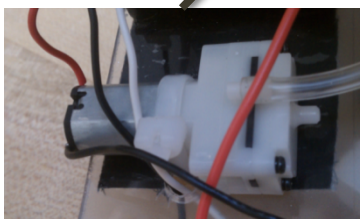


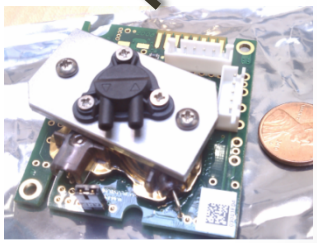


Schematic of major Internal Components









Subsystems Overview

Power Subsystem
- Battery must stay between 0 and 60 C during all operation
- Voltage must be regulated from 9 to 5V depending on the circuit element

Air Flow Subsystem
- Flow rate minimum of .3 liters per minute
- No detectable leaking may occur between inlet and exit
- Air must be maintained above 0 C

Heating Subsystem
- Must maintain both air flow and power subsystem heat requirements

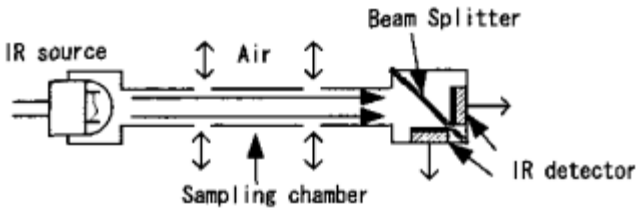
Sensor Subsystem
- Must take accurate measurements of both CO2 concentration and internal pressure

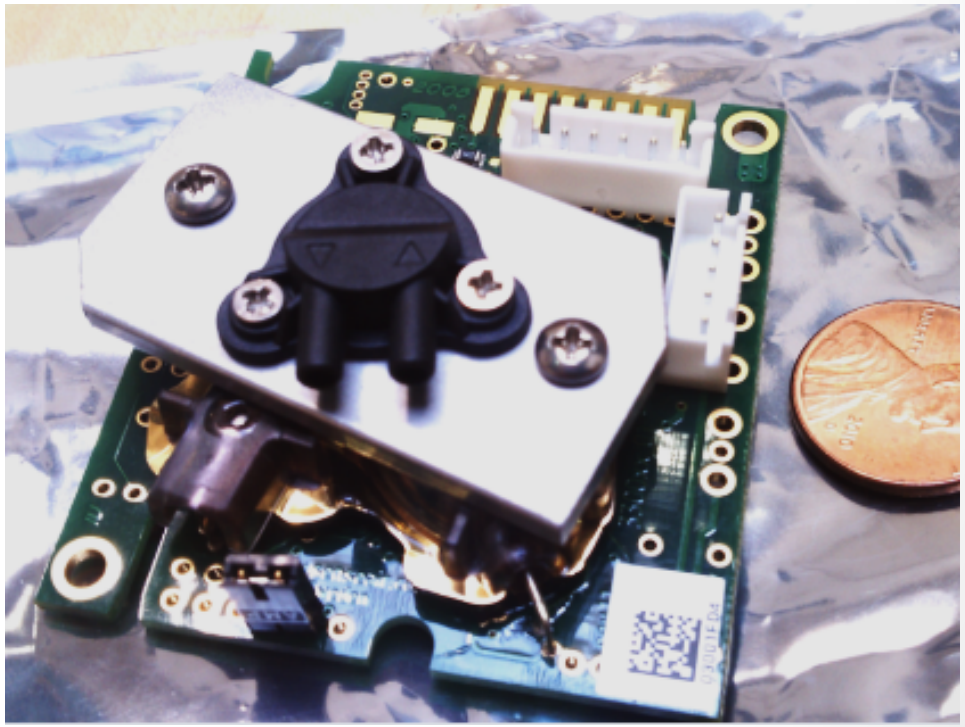
CO_2 Sensor

- K-33 ELG 1% CO2/Temp/RH Data Logging Sensor
- Measure CO_2 up to 10,000ppm
- Also measures Temperature and Relative Humidity of intake air
- dual infrared NDIR sensor technology
- Accuracy: ± 30ppm
- Data logging: 30 seconds to 18 hours sample interval
- Operating temperature between 0C and 50C
- Absolute pressure of intake air must be taken to correct for lack of particle density at high altitudes (low pressure)

Non-dispersive Infrared

The NDIR sensor consists of one IR source, a chamber in which IR beam interacts with CO_2 molecules in air, and a beam splitter terminated by two thermopiles. One thermopile measures the spectrum absorption due to CO_2 molecules, while the other measures the light emission level of the IR source. The ratio of the two outputs from the two thermopiles gives a CO_2 Concentration measurement.





Limitations of CO_2 Sensor

Find all possible sources of error and access each issue:

- Interference with infrared light source

  Main sources of error are water and debris

  Use a 400 micron particulate filter to block out ice crystals and debris.

  Also use a water trap for condensed water particles.

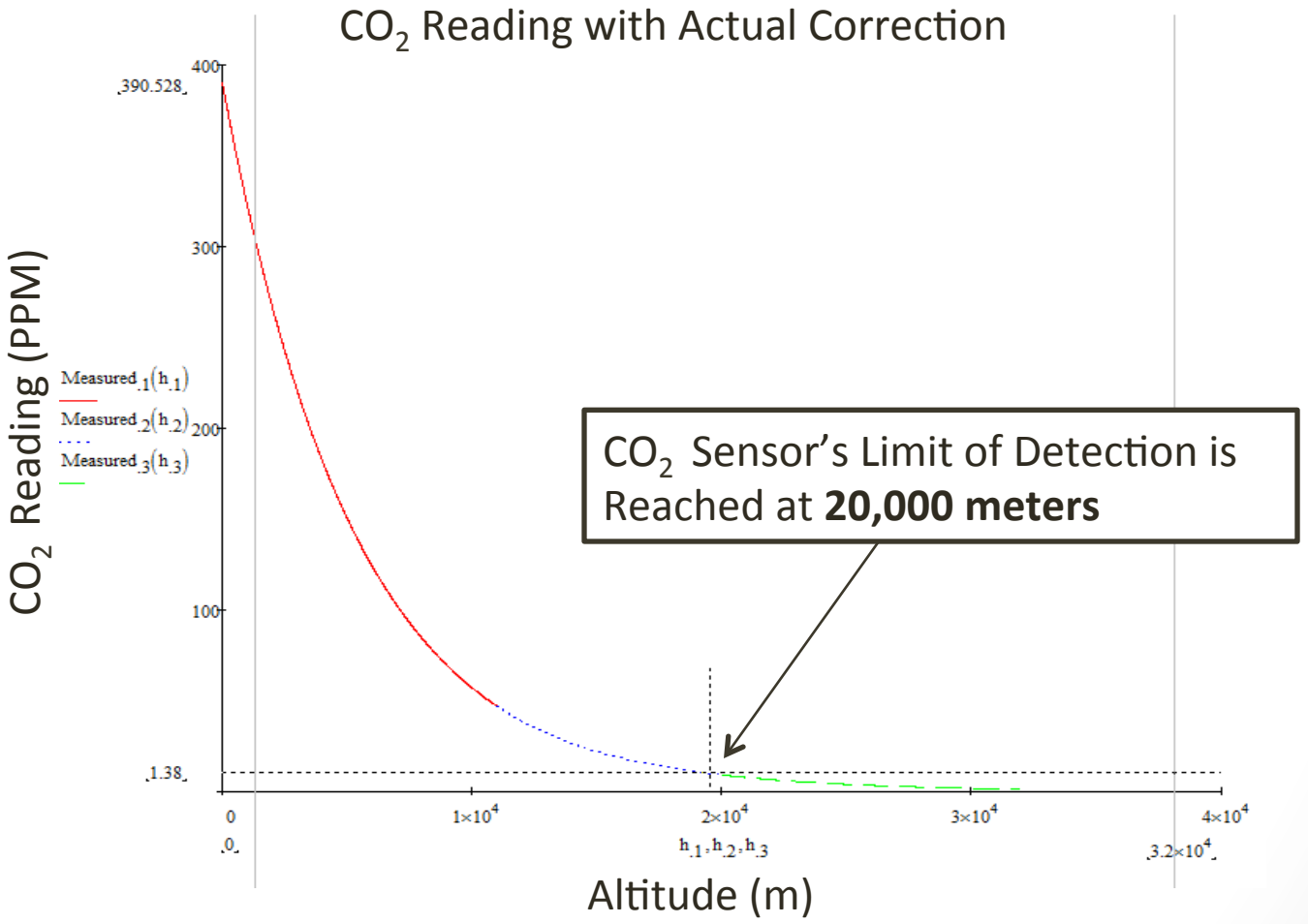
- Limit of detection from density changes of the atmosphere

  Understand changes with atmosphere and correct data after launch

CO2 Measurement's Pressure Dependence

- A drop in air density will alter the CO2 readings

$$\text{TRUE READING ppm (vol.)} = \text{reading} / (4{,}026 * 10^{-4} * P + 5{,}780 * 10^{-7} * P^2);$$



Heating Analysis

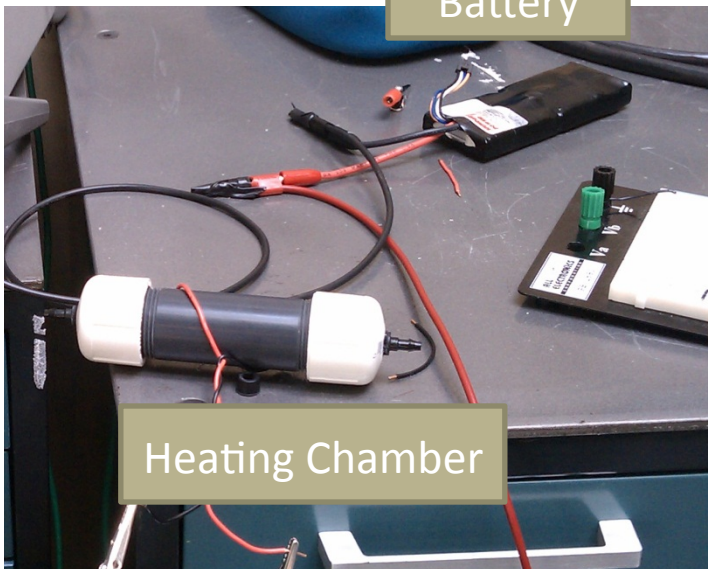
flight time ascent (s)	4500

			Inlet					Outlet		
Altitude (m)	Density (kg/m^3)	P (pa)	T (K)	P (psi)	VF (L/s)	Cp (J/kg*K)	MassFlow (kg/s)	T (K)	Heater Rate (w)	Heat Flux (J)
0	1.225	1.01E+05	288	1.47E+01	6.67E-03	1006	8.17E-06	273	-0.123235	-18.48525
1,000	1.112	8.99E+04	282	1.30E+01	6.67E-03	1006	7.41E-06	273	-0.06712032	-10.068048
2,000	1.007	7.95E+04	275	1.15E+01	6.67E-03	1006	6.71E-06	273	-0.013507227	-2.026084
3,000	9.09E-01	7.01E+04	269	1.02E+01	6.67E-03	1006	6.06E-06	273	0.024393488	3.6590232
4,000	8.19E-01	6.17E+04	262	8.94E+00	6.67E-03	1006	5.46E-06	273	0.060449869	9.0674804
5,000	7.36E-01	5.41E+04	256	7.84E+00	6.67E-03	1006	4.91E-06	273	0.083959419	12.5939128
6,000	6.60E-01	4.72E+04	249	6.85E+00	6.67E-03	1006	4.40E-06	273	0.106249696	15.9374544
7,000	5.90E-01	4.11E+04	242	5.96E+00	6.67E-03	1006	3.93E-06	273	0.122664933	18.39974
8,000	5.26E-01	3.57E+04	235	5.17E+00	6.67E-03	1006	3.51E-06	273	0.134001883	20.1002824
9,000	4.67E-01	3.08E+04	230	4.47E+00	6.67E-03	1006	3.11E-06	273	0.134705412	20.2058118
10,000	4.14E-01	2.65E+04	223	3.84E+00	6.67E-03	1006	2.76E-06	273	0.138660333	20.79905
15,000	1.95E-01	1.21E+04	216	1.76E+00	6.67E-03	1006	1.30E-06	273	0.074468144	55.851108
20,000	8.89E-02	5.53E+03	216	8.02E-01	6.67E-03	1006	5.93E-07	273	0.033988515	25.4913861
30,000	1.84E-02	1.20E+03	231	1.74E-01	6.67E-03	1006	1.23E-07	273	0.005185729	7.7785932

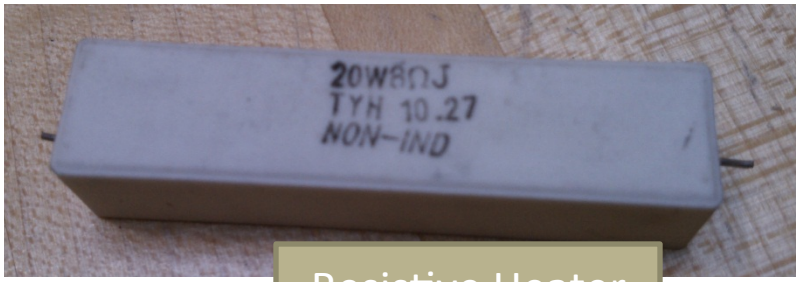
Heater Input (J)	209.8838423

- Sample air must be heated to a temperature within the components operating temps.
- Using Atmospheric tables, an approximation of required heating can be calculated.

Heating System



- Two 8 ohm power resistors in series
- 9 V power supply
- Providing roughly 5 W

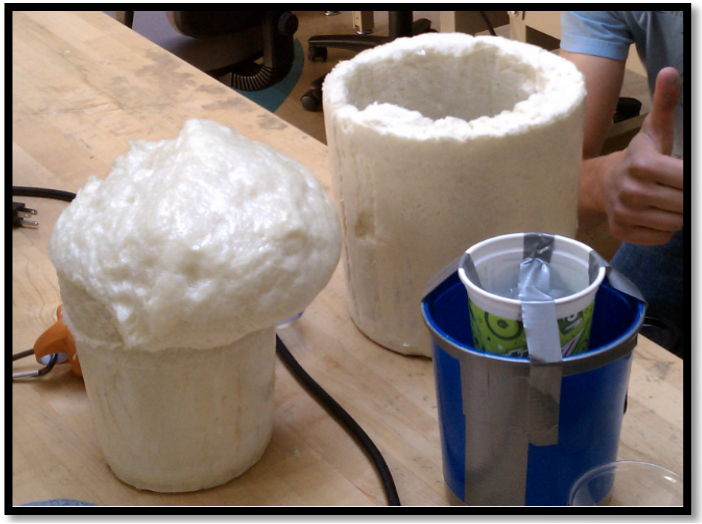


3lb density Urethane foam

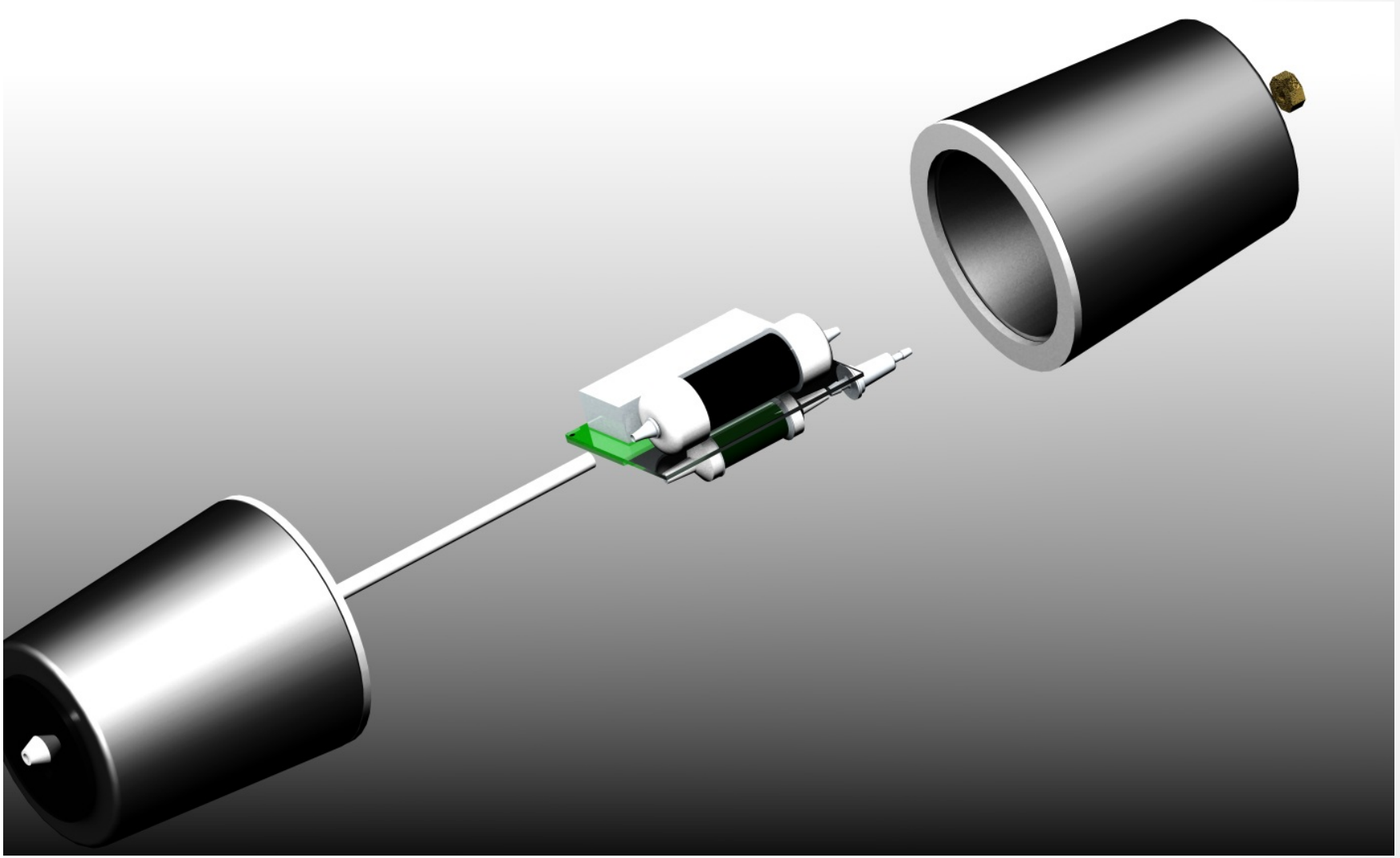
- Lightweight
- Thermal insulator
- Electrical insulator
- Inexpensive
- Preforms well upon impact
- Appropriate for molding applications

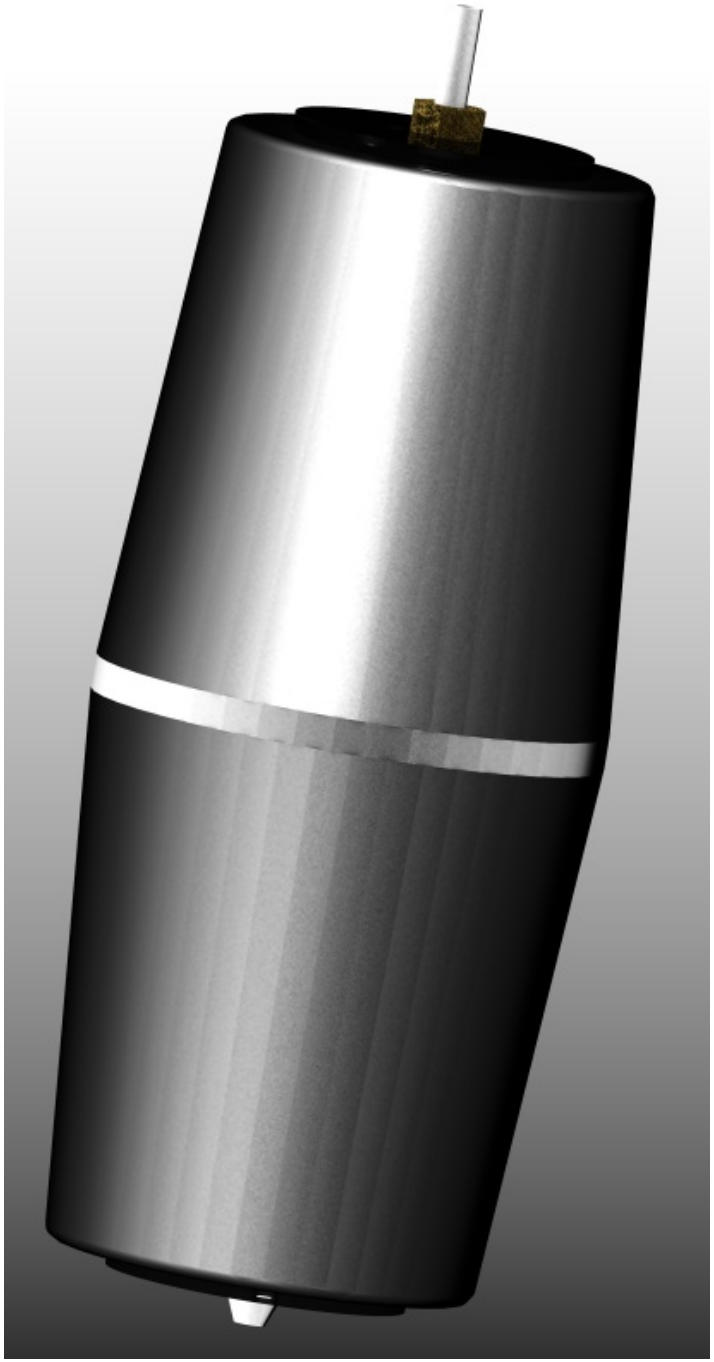
CAD

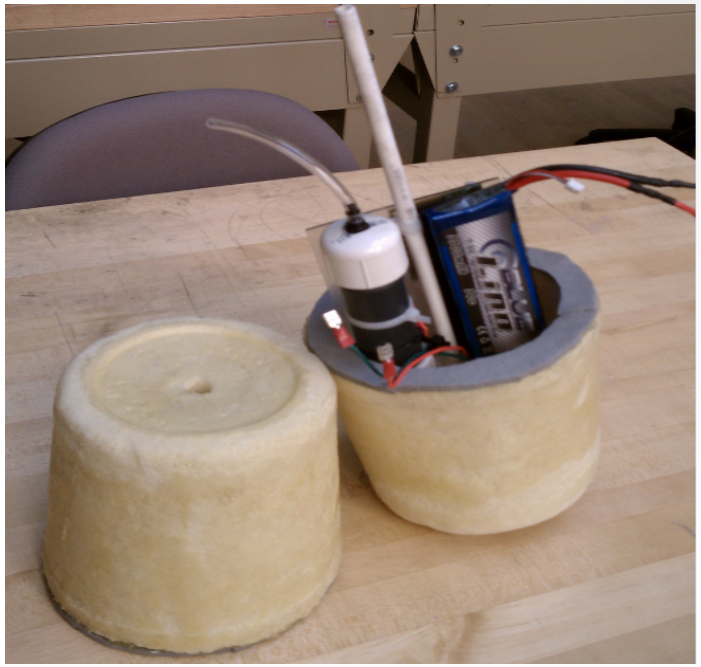
Prototype

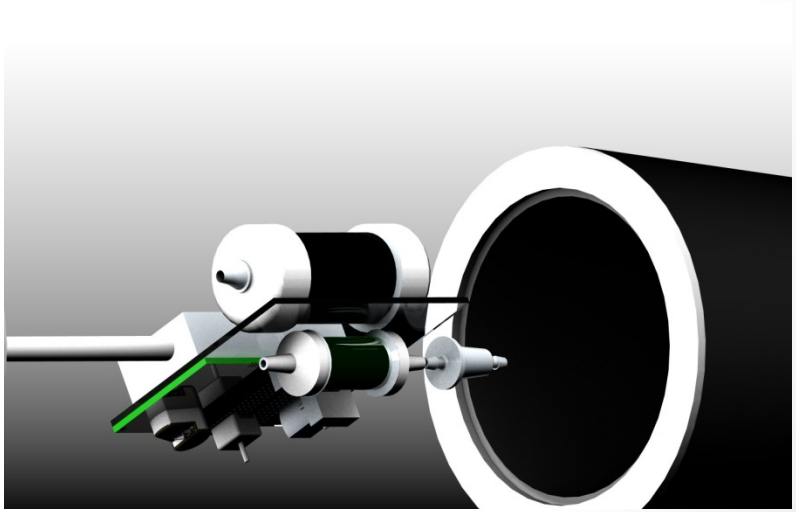


Final CAD Model









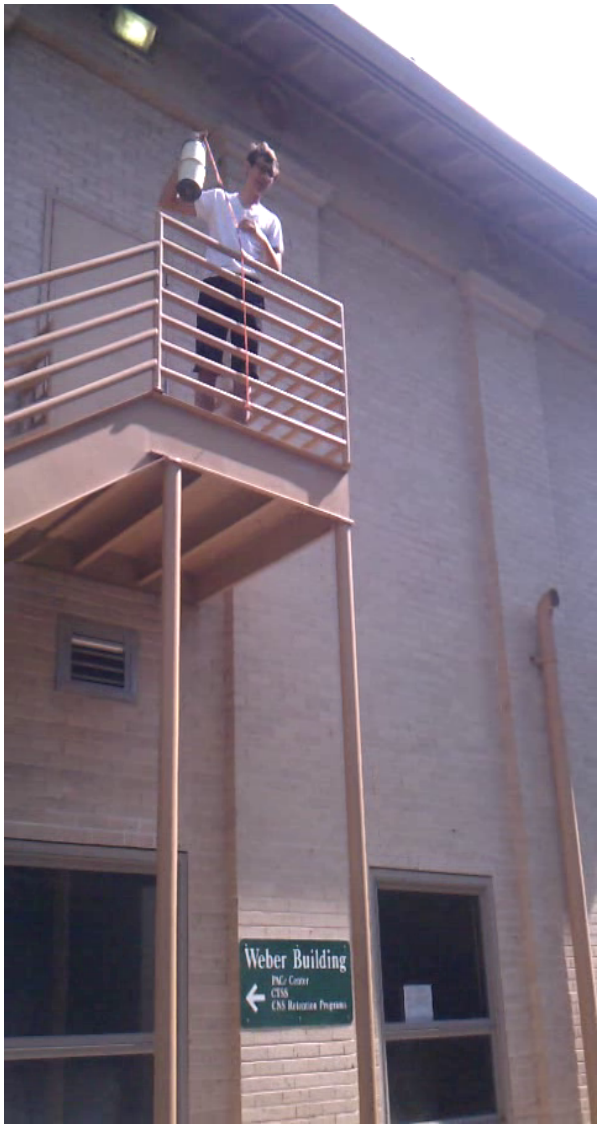
Budget and Parts List

Products	Quantity	total Price ($)	supplier
Water Trap	1	19.59	CO2meter.com
Particulate Filter, 200 micron	10	25	CO2meter.com
Sensor Communication Cable	1	40	CO2meter.com
Sensor Tube Cap	1	15	CO2meter.com
K-33 ELG Sensor	1	250	CO2meter.com
3LB Density Foam	1	34.38	US Composites
Synflex Tubing	2'	Donated	NCAR
Pressure Sensor	1	38.17	DigiKey
Buckets (shell for molding)	1	15.38	Home Depot
.022 Solder	1	5.79	Mountain States Electronics
DPDT Switch	1	3.99	Mountain States Electronics
5Volt Regulator	1	1.79	Mountain States Electronics
8Ω 20W Resistor	3	8.07	Mountain States Electronics
9 Volt Batteries	2	Donated	ERC
Flight Cord Supplies	1	19.02	Ace
CTS Mini Pump	1	54.72	Cole Parmer
Sealant	1	Donated	MIL
Protoboard	1	Donated	Ram Lab
PIC16F882	3	Donated	Ram Lab
.03 Gage Wire	10'	Donated	Ram Lab
Soldering Iron	1	Donated	Ram Lab
AA batteries	4	4.12	CSU Bookstore
Custom Heat Exchanger	1	6.49	Home Depot
Air Hose	1	4.86	Ace
Plastic Fasteners	6	5.07	Ace
Sealing Supplies	1	16.26	Ace
Sealing Supplies 2	1	72.88	Ace
9 Volt Batteries	6	51.24	McMaster-Carr
9 Volt Batteries	8	13.97	King Soopers
Cooler/ foam insulation	1	Donated	Ram Lab
liquid nitrogen		Donated	Thermo Lab

Total Spent = $ 705.79

Shell Testing

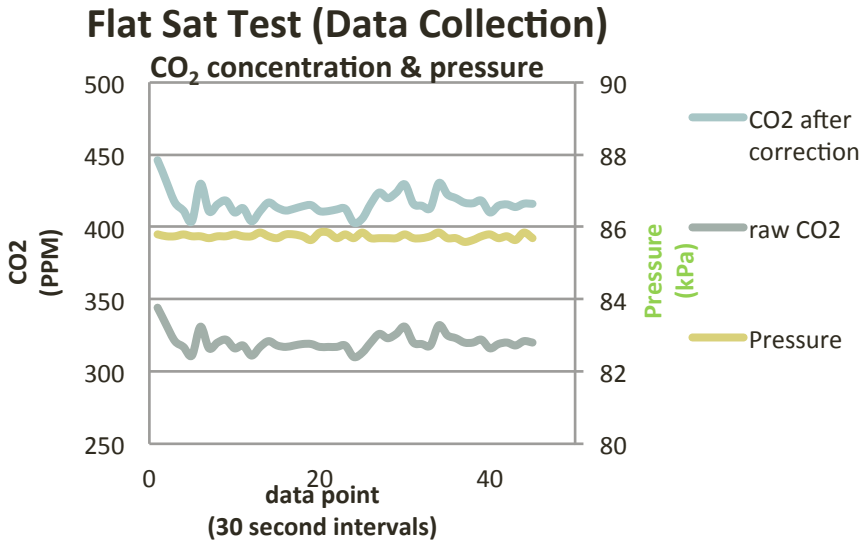
Modified Whip Test



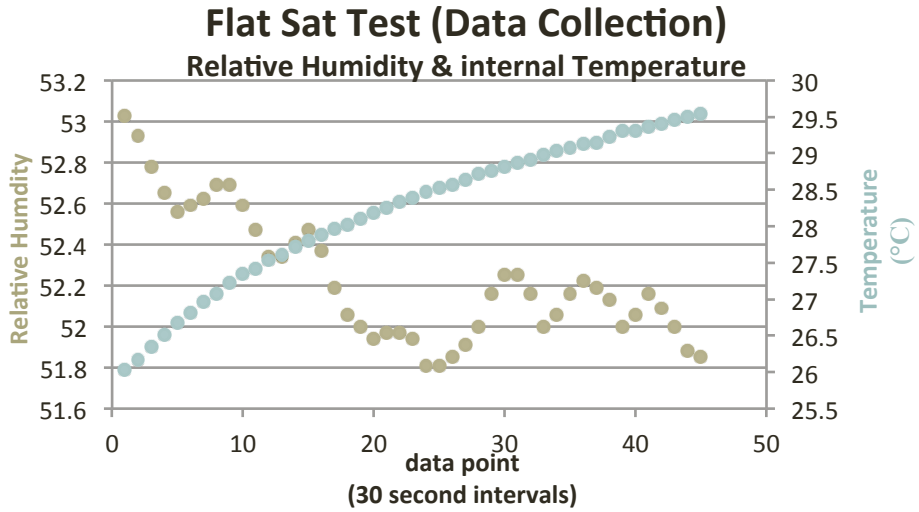
30 ft. Drop Test

Stair test

Outdoors Bench Test

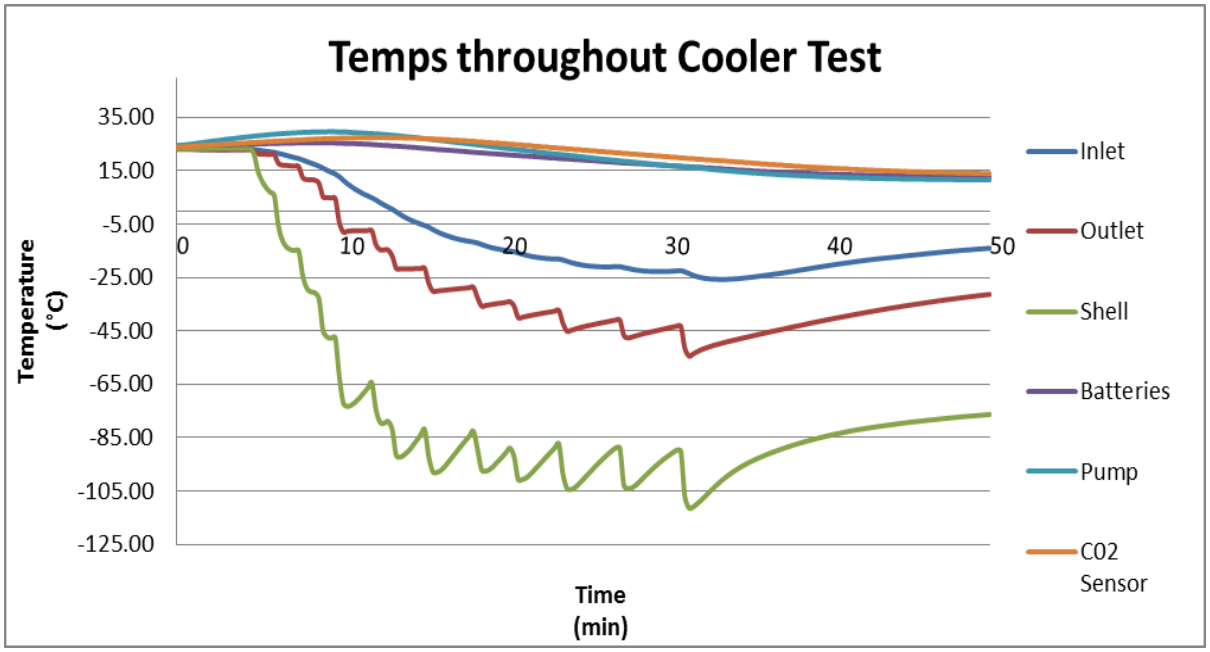


- Data showing uncorrected and corrected CO2 readings as well as ambient pressure



- Data showing temperature and relative humidity measure during test

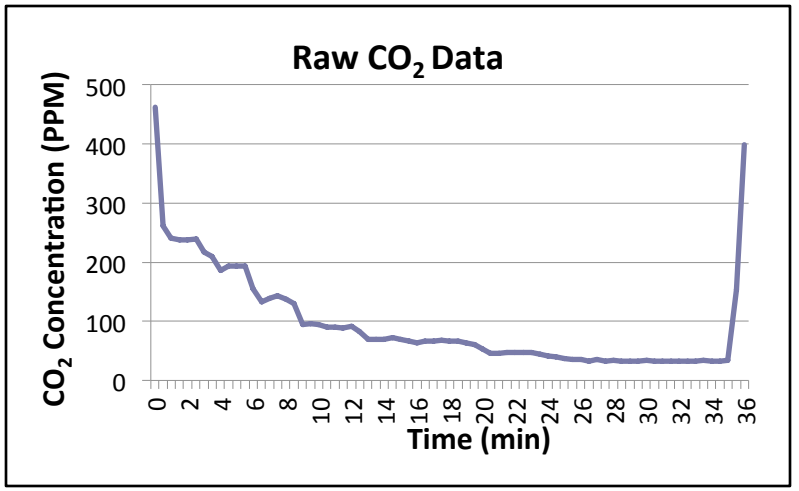
Cooler Testing



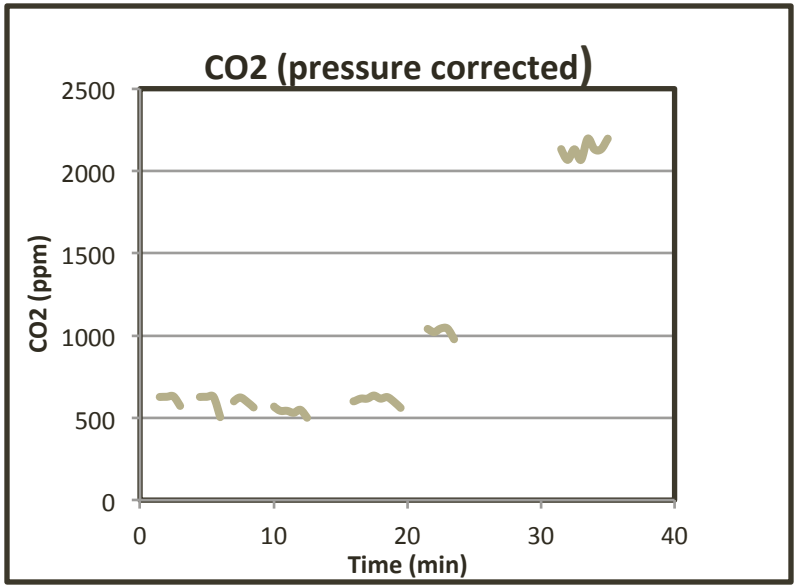
- Data showing temperature at different parts of payload during cooler testing

Vacuum Chamber Test

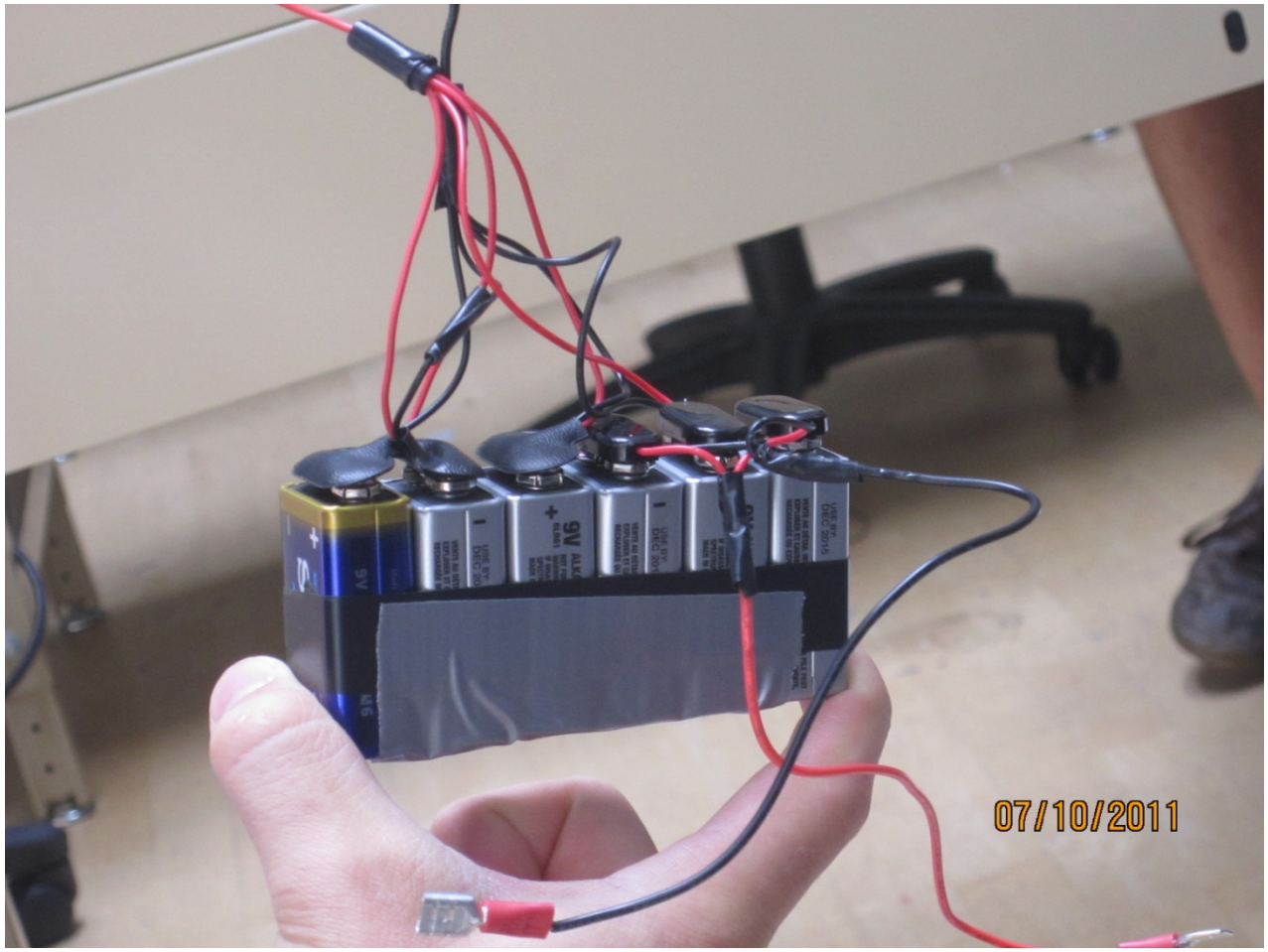
- Data taken from testing done inside a vacuum chamber



Dwell Pressure (kPa)
53.329
45.996
36.93-38.13
29.064
20.531
9.999
3.653



Battery Test



After a series of battery tests, it was found that the use of six 9 volt batteries would insure power for a 200 minute flight

Flow Rate Test

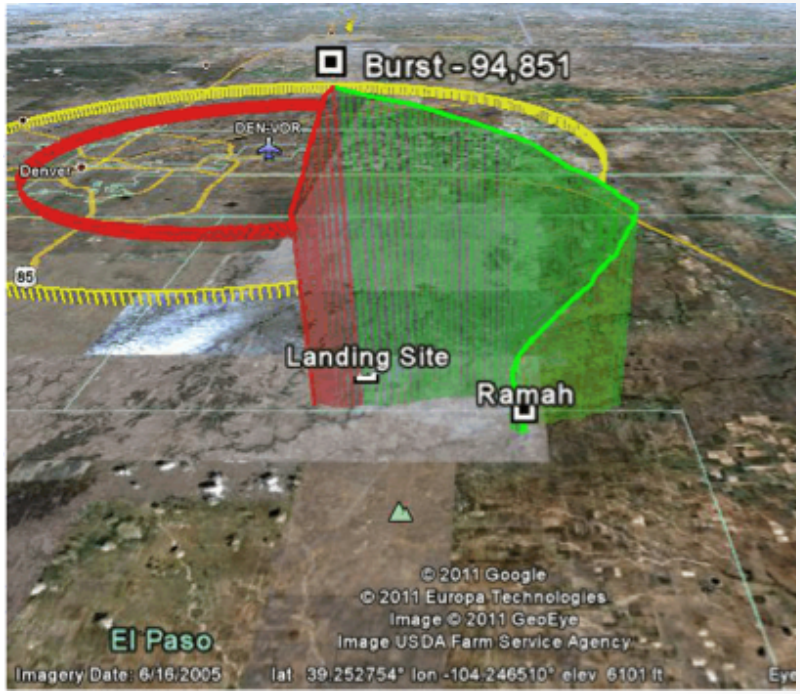
A bubble test was then performed to measure the flow rate of the pump, a flow rate of .3 SLPM was required for accurate carbon dioxide data

Mission Requirements Matrix

Requirement	Method	Status
The payload must not exceed a weight of 1.5 kg.	Design, Test	
The payload must operate on 9V or less.	Design, Test	
The payload's center of gravity (CG) shall be as close to the geometric central axis as possible.	Design, Analysis	
The inlet air must be heated to approximately 0 C before interacting with the CO_2 sensor.	Design, Analysis	
The payload will record CO_2, temp, RH, pressure values every 30 seconds for a minimum of 200 minutes.	Design, Analysis	
The payload's shell will protect the internal components against a load of 15 g's.	Design, Analysis	
The internal components will remain secured to the mounting plate when exposed to a load of 15 g's.	Design, Analysis	
Completed project must cost under $1000.	Plan	
The spacecraft must be capable of meeting all mission objectives.	Design, Test	

Launch

- July 30th, 2011
- 2000g latex weather balloon filled with Helium
- Emptied Ramah reservoir in Eastern Colorado Springs, CO
- Altitude at burst=94,851 ft. (above sea level)
- Landed 9.35 miles from launch site



Flight Profile

Results

- Grass Field
- Data Logger experienced catastrophic failure.
- NO DATA LOGGED
- All sensors still work
- No data logging abilities
  - Reverse connection to power

Project Conclusions

- Work with your team strengths and weaknesses
- Start building early
- Plan, research, test, test and test again
- Be adaptive
- Expect the unexpected
- Be aware of lead times

Questions?