SNOWCAT

System Naturally Observing Windborn Carbon & Aerosol Transportation

Critical Design Review
November 16th, 2017

Mission Overview

Background: Black carbon deposition on snow reduces snow albedo (amount of reflected light), contributing to worldwide melting of ice.


Roberto Venturini, *European Environmental Agency*, 2016

Mission Statement*: The Cryo-Aerosol Dust Collection team shall build an aerosol auto-sampler that adds context and quantifiable data to the Cryospheric dust collection process.*

Objectives:

1. Deploy on the surface of icy and mountainous regions for extended amounts of time with minimal human interactions.
2. Provide environmental data linking dust deposition patterns to wind events and atmospheric patterns.
3. Collect dust samples that will be turned over to NSIDC for further analysis.

Scope of Mission

MODEL 1:

St. George Research Station (Antarctica), January Deployment

- **Compare two different capsule designs**
- **One dust collection chamber on a pole with a sail (swings to face wind)**
- **All capsules are always open**

https://www.comnap.aq/Members/INACH/SitePages/Home.aspx

MODEL 2:

Niwot Ridge (CO) and Svalbard (Norway), February/March Deployment

- **Adding motor to control dust collection on timely basis (1 week sample period)**
- **Picking best capsule design based on results from Model 1**

Systems

Will Butler, Bekah Haysley, Kathy Vega

Requirements

Science Objective	Requirement	Design Traits
Investigate effect of black carbon **deposition** on snow albedo/melting in Cryospheric regions	**0.1**: Capable of deploying on surface of snow and ice across polar and mountainous regions for long periods of time with minimal human interactions ● Design is transferrable between Niwot Ridge, St. George Research Station, and Svalbard	● Staked into ground ● Stackable design = easy transport ● Battery powered ● Sails secured tightly = little chance of breakage ● Design easily transferable to future sites
Understand how the dust (in particular, the black carbon) is **transported**	**0.2**: Link dust deposition patterns to wind events and atmospheric patterns	● Rotating filter system for separation of samples (after January) ● Control when dust collection happens with electronics ● 3 chambers at different, adjustable heights up to 6 feet (after January) ● Electronics and sensors located in each chamber system record environmental data and timestamp ● Chamber openings face directly into the wind using a wind sail
Classify the **composition** of the dust deposited on the surface of snow and ice in Cryospheric Regions	**0.3**: Collect dust that can be turned over to NSIDC for analysis ● Collect a minimum of 0.5 g of dust per capsule per wind event	● Easily extractable samples ● Sterile capsules for individual collection periods (after January) ● Can collect micrograms to milligrams of dust

Passive vs. Active System

	Passive (No Pump)	Active (Pump)
Ideal Science	• Multiple samples • Separated into wind events	• Collecting smaller particles and higher quantity of dust
Engineering	1. 7 samples per dust collection chamber 2. Using motor to control when dust collection occurs 3. Sample must be taken over longer time interval (less separation into “Wind Events” 4. No separation of bioaerosols vs. black carbon 5. Longer deployment needed overall 6. Using snout to increase volumetric flow rate (collecting more dust)	1. 1 pump means limited to 1 sample per chamber 2. Sample must be taken over shorter period of time to save power 3. Better selection between bioaerosols & black carbon (depends on pump & filter) 4. Would have shorter deployment times and more frequent sample replacement
Actual Science	• Broad definition of “wind event” because we need to ensure a minimum sampling time • Hard to collect smaller sized dust particles	• Limited on number of samples we can collect • More focused on composition of dust than deposition of dust over time

Inclusion of a Pump

Pros	Cons
● More control over when dust collection occurs ● Greater quantity of dust and more samples ● Can collect smaller dust particles	● Added weight ● Complexity with spinning parts and wires ● POWER

POWER

Power pump constantly for 1 month:

- Would need 205 batteries (assuming pump draws 1A)

Power pump constantly limited to chosen battery:

- Would be able to power pump for less than 3 hours (assuming pump draws 1A)

Choice:
Passive System
(no pump)

Model 1 (December 14th):

St. George Research Station (Antarctica), two week deployment period

Design Traits

1. Structure will include two different capsule designs
2. System will track wind direction and speed
3. Sample is taken over 2 week period

Scientific Benefits

1. Two different designs will allow for comparison of dust collection
2. Will provide data to search for correlation between samples and wind events

Model 2 (February/March):

Niwot Ridge (CO) / Svalbard (Norway), month to year-long deployment

Design Traits

1. Structure will include one capsule design + motor
2. System will track wind direction and speed
3. Sample is taken over 1 week period

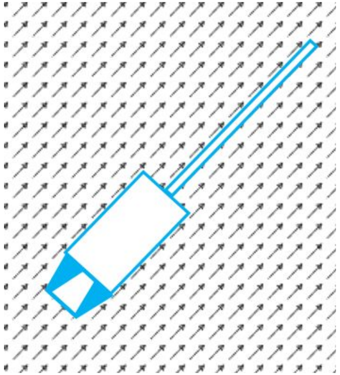
Scientific Benefits

1. Optimal design for dust collection
2. Will provide data to search for correlation between samples and wind events

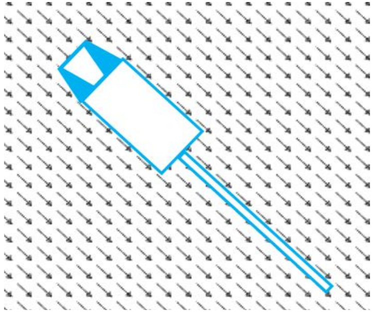
Minimum Criteria For Success (Model 1)

	Criteria	Verification
1	Able to compare the amount of dust collected by each capsule design.	Measure each collection chamber design before and after dust collection to calculate the amount of dust collected in chamber.
2	Collection chamber rotates to face the wind.	Dust chamber is still free to rotate and sail is still attached upon dust chamber retrieval.
3	Able to track wind direction and speed for the duration of the mission.	Data logs have a history of wind speed and wind direction over the duration of the mission.

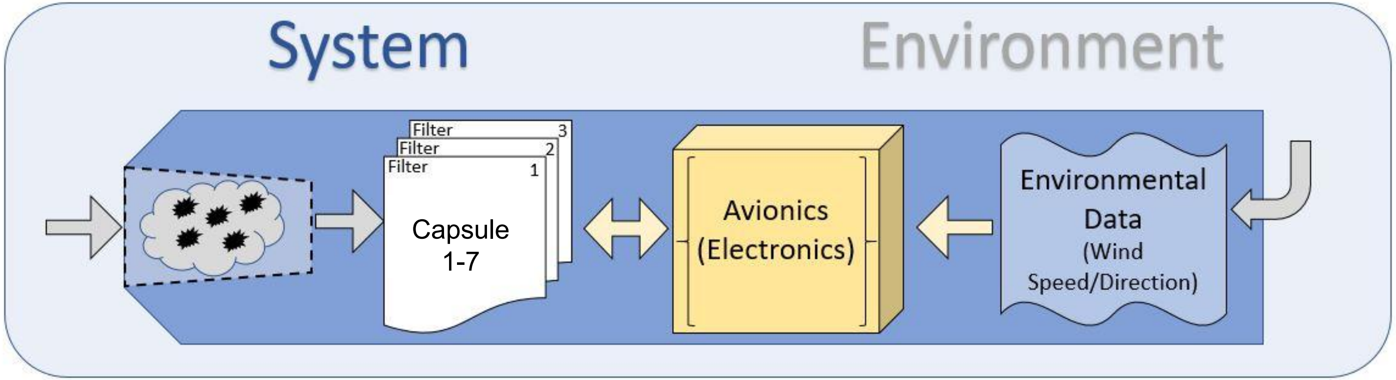
CONOPS (Model 1)



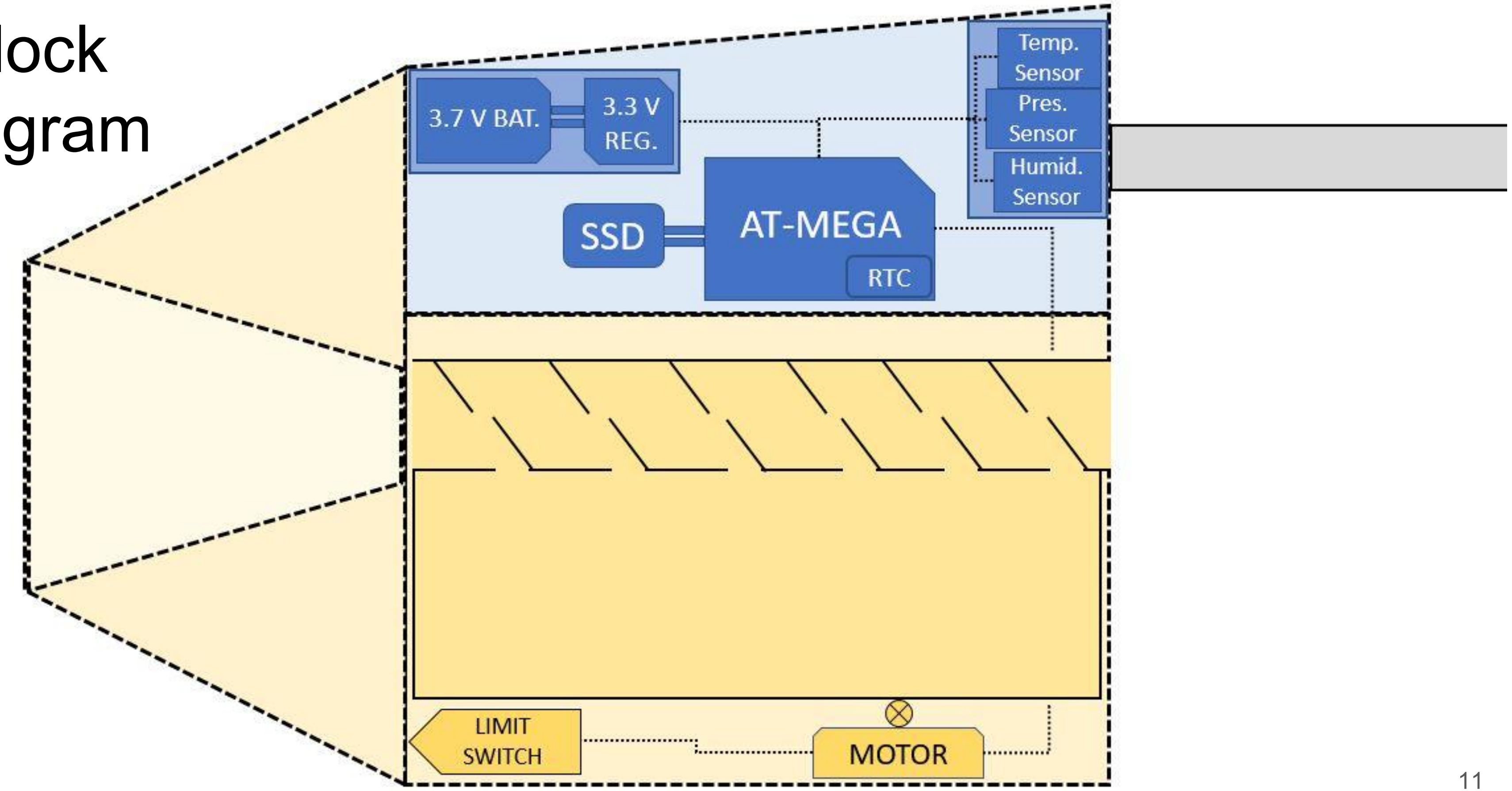
Time 1



Time 2

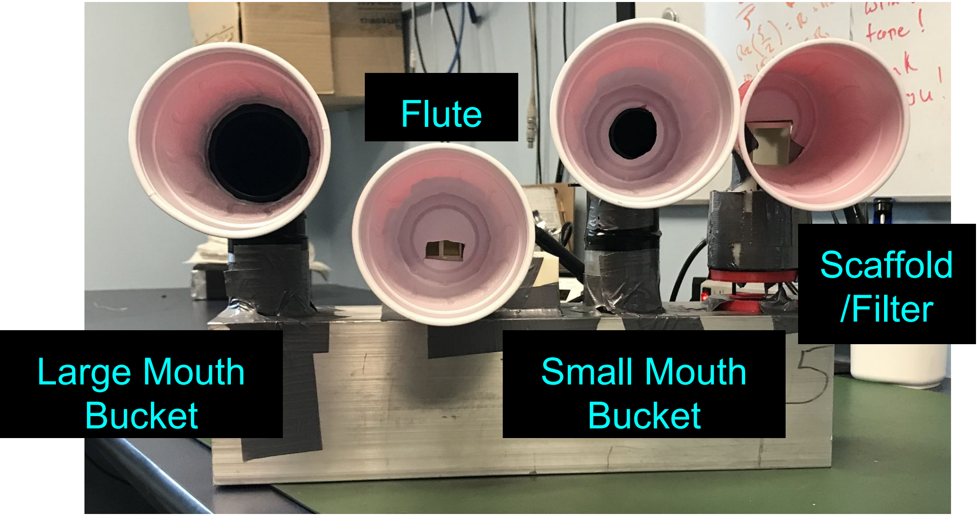


Functional Block Diagram

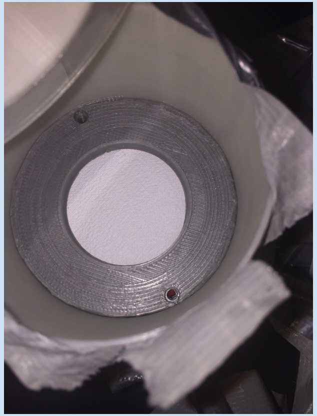
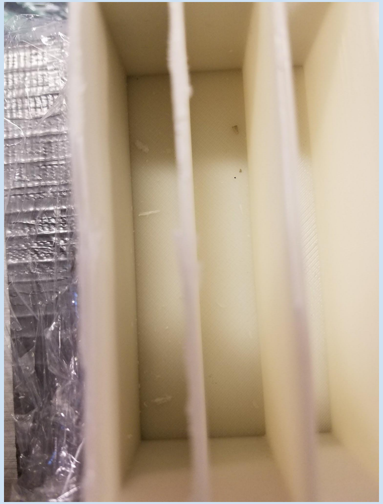


Testing (Model 1): Outdoor Capsule Comparison

- Faced West
- Avg. Wind Speed from Saturday (11/11) to Monday (11/13): **3 mph**
- Max. Wind Speed on Sat (11/11): **10 mph**

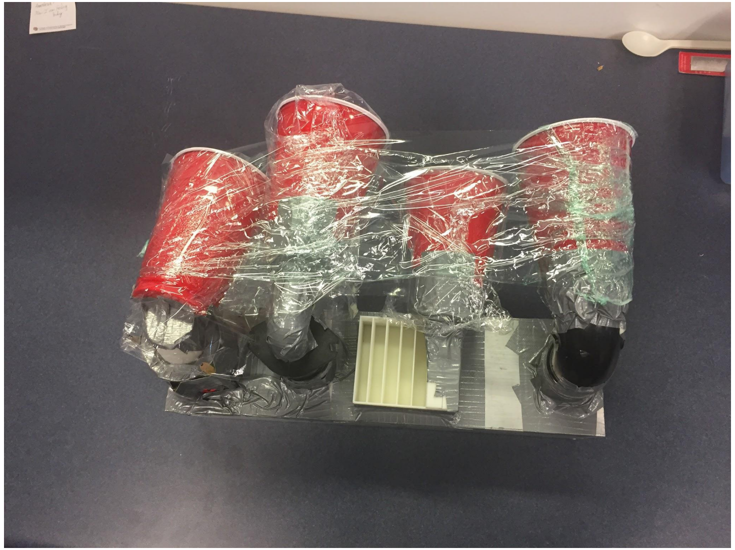


Testing (Model 1): Outdoor Results

Scaffold/Filtered	Small Mouth Bucket	Large Mouth Bucket	Flute Design
No visible dust 	Small particles, not enough to quantify 	Noticeable particulates, shows dust collection abilities over 4 days 	Noticeable particulates, shows dust collection abilities over 4 days 

Testing (Model 1): Dust Collection Comparison

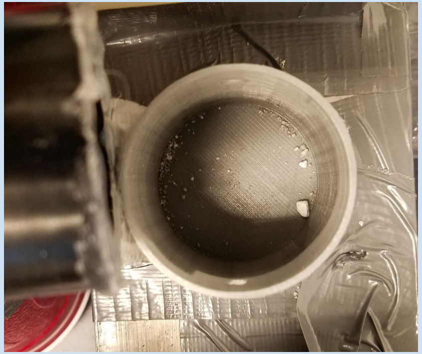
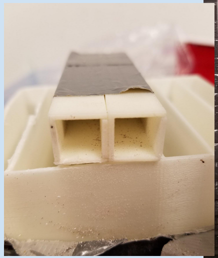
- “Dust”: rock chalk and coffee grounds
- Use of fan to replicate wind disturbance of particles



Testing (Model 1): Dust Collection Comparison

Testing (Model 1): Dust Collection Comparison

Testing (Model 1): Dust Collection (Results)

Scaffold/Filtered	Small Mouth Bucket	Large Mouth Bucket	Flute Design
-Most amount of chalk collected -Visible bubble of pressure 	-Least amount of dust collected 	-Significant amount collected -Visible bubble of pressure during test 	-Collected less dust than expected, but still significant amount -NO visible bubble of pressure during test 

Systems Next Steps (Model 1)

- Repeat dust collection test to verify results
  - Better control over dust blown into each nozzle
- Measure pressure difference across nozzle and verify calculation
  - Narrow down capsule designs for Model 1 (January deployment)
- Write capsule assembly and collector set-up procedure
  - Focus on sterility
- Integrate electrical and structural systems for January deployment
- Prepare for full scale model

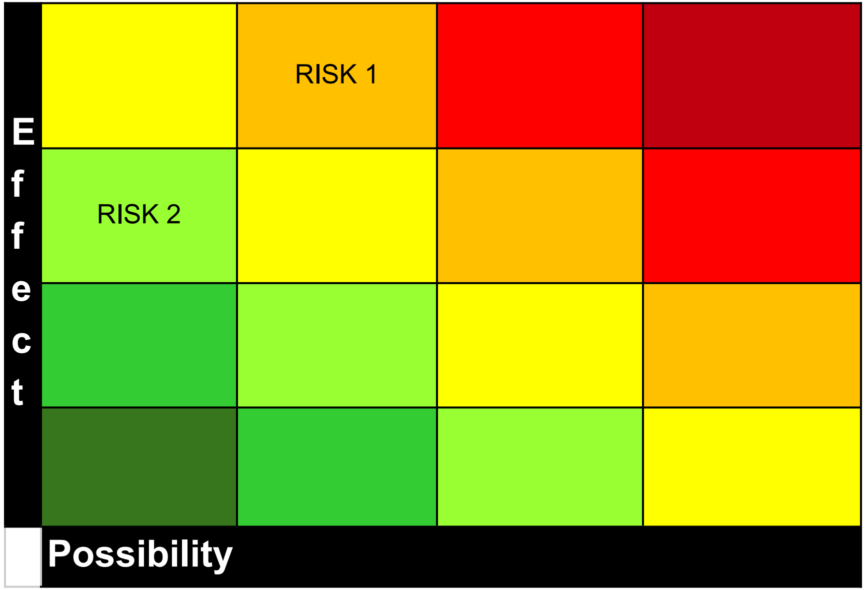
Big Picture: Changes from Model 1 to 2

Change	Reasoning
1. Add motor and rotate collection capsule on time basis in order to better link sample to wind event	1. Meet requirement of linking dust deposition patterns to wind events and atmospheric patterns
2. Stack 3 chambers (at different intervals, measuring up to 6 feet off the ground)	2. Investigate differences in dust composition for dust traveling at different heights from the ground
3. Better structural material for dust collection chamber	3. More time to invest in Model 2, can deploy for longer amounts of time
4. Longer deployment period	4. Meet requirement of deploying for extended time at Cryospheric regions

Systems Risks/Worries

- Verifying our requirements through testing
    - The accuracy of the dust collector aligning with the wind
        - Testing prototype during windy day in Boulder
- Structural failures
    - Dust collector or mounting pole failure
    - Dust collector intake allows unwanted materials or animals
- Electrical failures
    - Cold weather drains battery
        - Thermal testing

Systems Risk Matrix



RISK 1: Data collection will fail IF snow and ice become trapped in the chamber units and around the motor.

RISK 2: Dust collection will fail IF the wind sail cannot orient the collector to face into the wind.

Structures

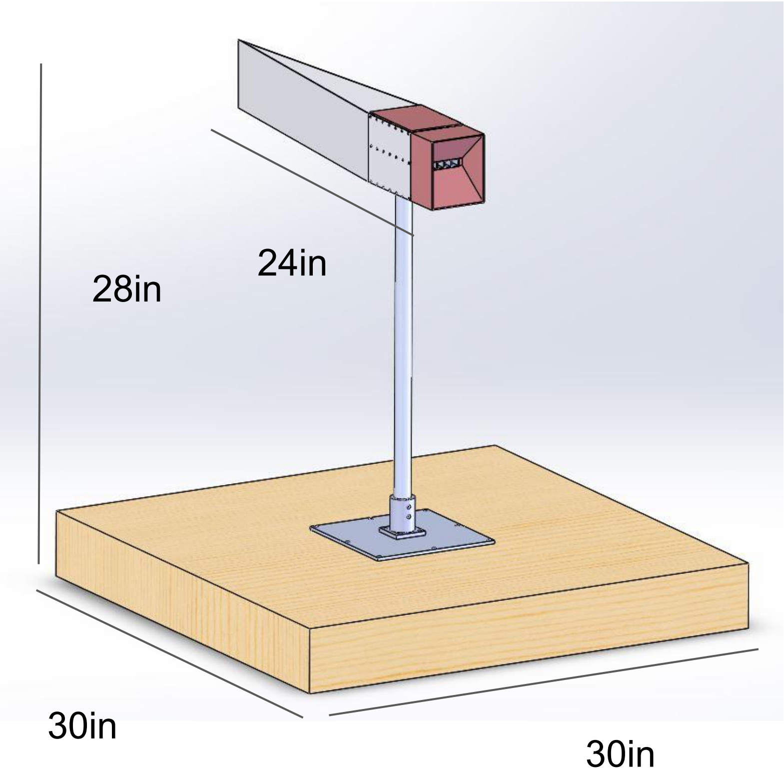
Sami Palma and Collin Doster

Requirements

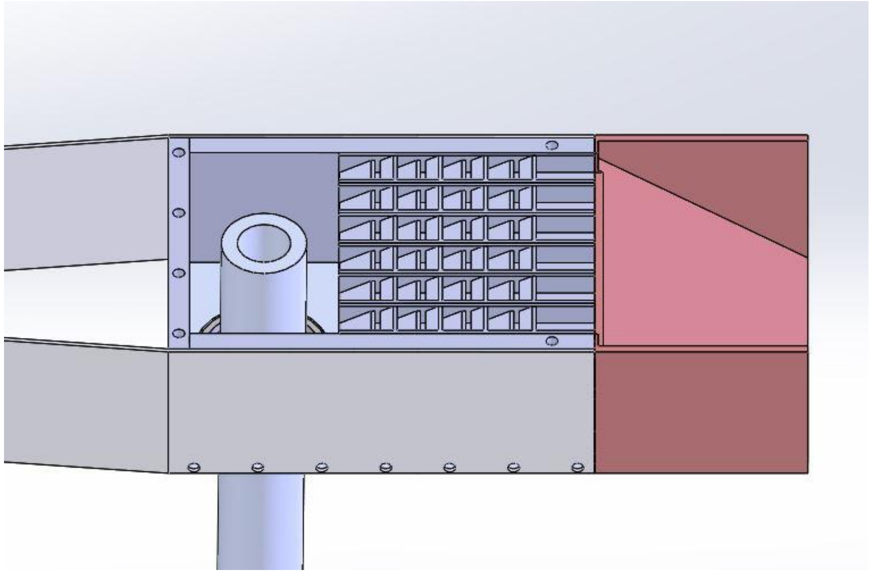
Science Requirement	Mechanical Trait
0.1: Capable of deploying on surface of snow and ice across polar and mountainous regions	• Baseplate • Stackable design = easy transport • Sails secured tightly = little chance of breakage • Design easily transferable to future sites
0.2: Link dust deposition patterns to wind events and atmospheric patterns	• Sterile capsules for individual collection periods (after January) • Rotating filter system for different samples (after January) • Control when dust collection happens with electronics • 3 chambers at different, adjustable heights up to 6 feet (after January)
0.3: Collect dust that can be turned over to NSIDC for analysis	• Opening facing directly into wind, in conjunction with sail • Easily extractable samples • Dust collected on glass fiber filters

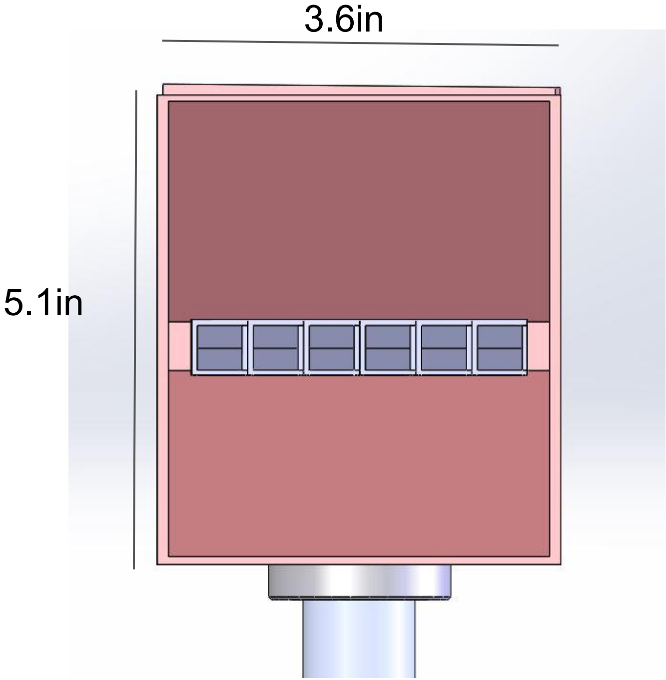
Design Overview (January mission)

- January Mission Goals:
  - Test different designs for dust collection
  - All capsules will be open during entire collection period to collect dust
- January Design:
  - One chamber
  - One pole unit
  - 6 capsules (no blank)
    - 3 capsules: baffle system A
    - 3 capsules: baffle system B



Design Overview

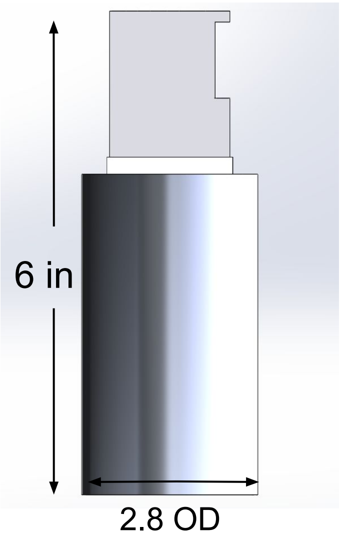


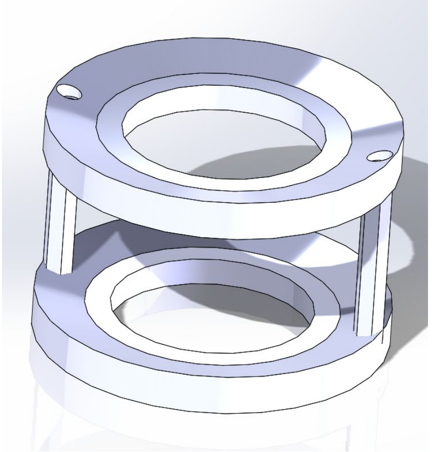


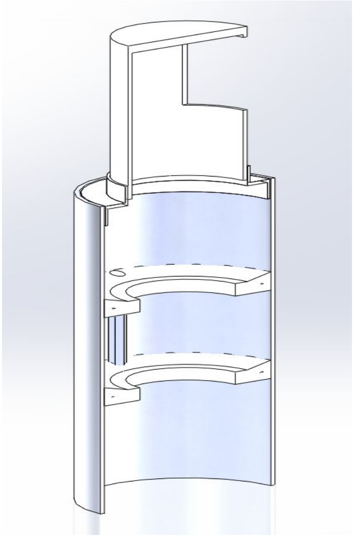
Capsule Design (Model 1: “Filter/Scaffold”)

Pros	Cons

● Allows for dust collection directly onto filters
● Ease of fabrication and assembly
● Low cost
● Potential success with addition of a pump
● 7 separate capsules for different wind events
	● Pressure differential across the filters is high
	  ○ Requires addition of pump to chamber design
	  ○ Adds complexity and cost to structure
	● Structure causes turbulent air within the system
	  ○ Potential failure of losing dust on filter



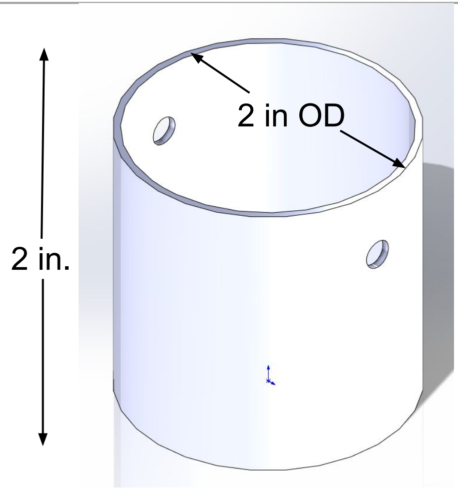




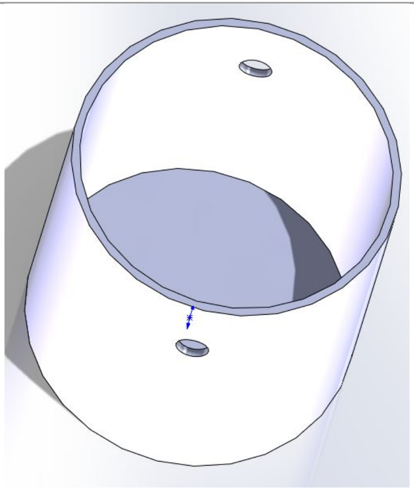
- Primary materials: PLA and aluminum

Capsule Design (Model 2: “Bucket”)

Pros	Cons
- Based on a previous model that works - Simple design - Low cost - Does not require a pump - Low weight - Potential solution of a honeycomb structure	- Losing finer particles in the grand collection of dust - Nature of structure will cause turbulent air within system - Potential loss of dust - Not a new design - No filters

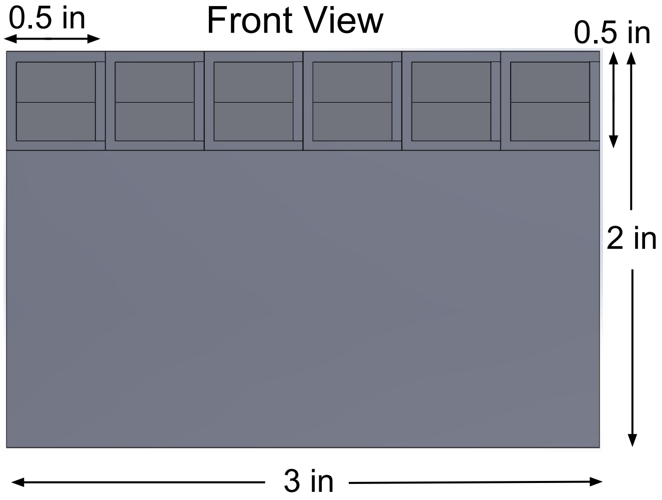


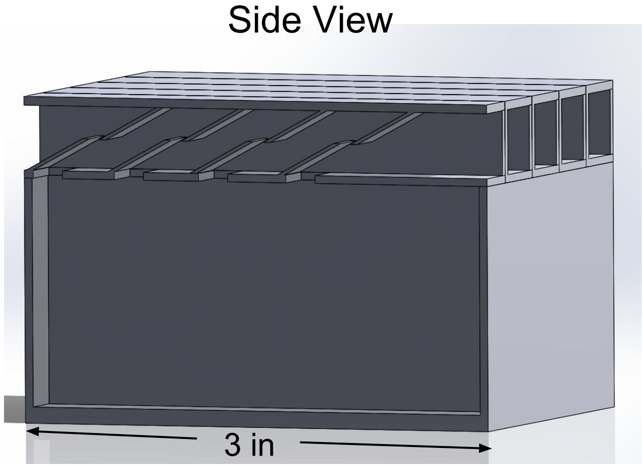
Primary material: PLA

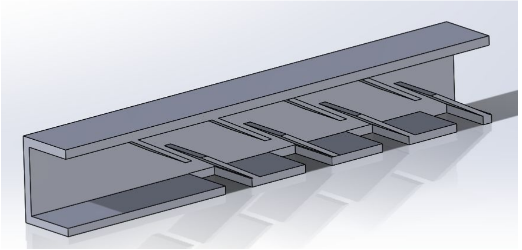


Capsule Design (Model 3: “Flute”)

Pros	Cons
● Uses turbulence of the air to collect dust particles, even fine particles ● Able to incorporate filter or similar substance to trap fine particles at the bottom of collection box ● Relatively simple design ● Lightweight and small	● Potential motor failures in extreme weather conditions ● Untested system







Primary material: ABSplus

Testing Capsule Designs

- Capsule Design and Dust Collection Comparison Tests: November 10-15
- Results:
  - Scaffolding: noticeable amount of particulates
  - Bucket: small nozzle - minimum amount of dust
  - Bucket: large nozzle - noticeable particulates
  - Flute: noticeable amount of particulates
- Conclusions:
  - Bucket design may lose finer particles without a filter
  - Flute design has been confirmed to work
  - Scaffolding method does seem to work even in a passive system
- Moving forward:
  - Repeat systems test to verify results and identify the better designs
  - Looking forward to a tentative black carbon test
  - Focus on flute design with different variations

Pressure Calculations

- Bernoulli and conservation of mass flow
- Flute model
  - Point 1: inlet of nozzle → Gage pressure = 0 Pa
  - Point 2: back of nozzle → Gage pressure = -27.90 kPa
  - Point 3: outlet of airflow → Gage pressure = -27.90 kPa
- Bucket model
  - Point 1: inlet of nozzle → Gage pressure = 0 Pa
  - Point 2: back of nozzle → Gage pressure = -761 Pa
  - Point 3: outlet of airflow → Gage pressure = -7.3 MPa
- Scaffolding model
  - Point 1: inlet of nozzle → Gage pressure = 0 Pa
  - Point 2: back of nozzle → Gage pressure = -7.5 kPa
  - Point 3: outlet of airflow → Gage pressure = -929 Pa

Verifying Sail Design

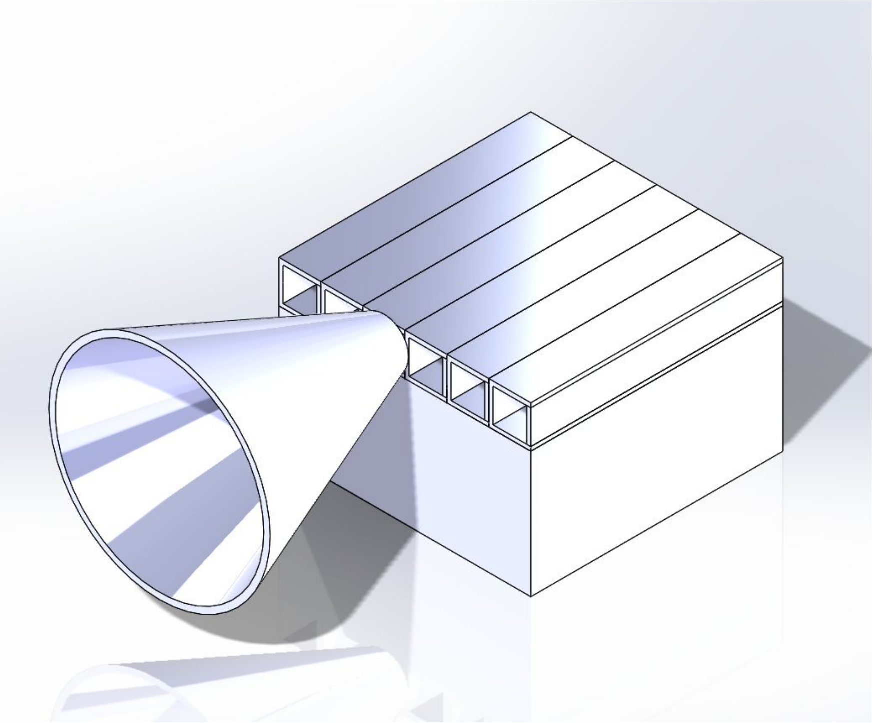
- Calculations
  - Moment from the wind = Distance between central bearing and center of sail*Drag force on sail
  - Necessary frictional moment to overcome = 6.779E-4 N*m
  - Calculated moment from wind with current sail dimensions and bearing location = $0.008378 * V_{avg}^2$ N*m
  - Conclusions: Sail should be able to provide a moment that will overcome frictional moment in the bearing - able to rotate the payload
- Testing
  - Wind Tunnel
  - Place payload at back end to test if the sail is aligning properly into the wind

Model 2 (after January mission)

- Addition of motor to chamber design
  - Allows linear motion of samples for different wind events
  - Collection chambers will move along rails to start a new collection for different events
  - Potential motor choice: HS-322HD Servo

Sample Rotation

- 8 total baffles (7 collectors, 1 blank)
- 8 collection boxes (where samples will be stored)
- Entire collection box and baffle system will be on rails
- Motor will move system respectively for different collection periods
- High tolerances to ensure the nozzle is flush against current baffle collection
- Baffle system will be able to slide off of collection box for easy extraction of dust sample



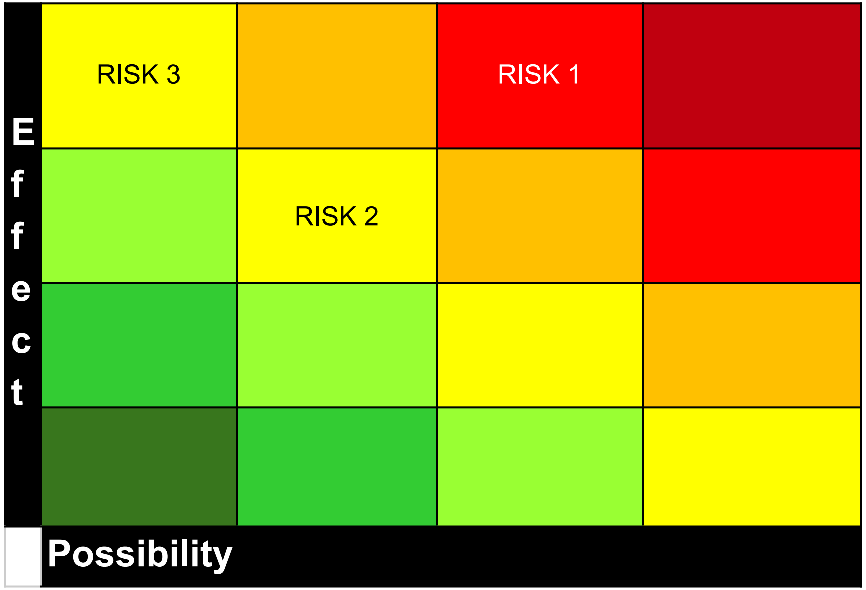
Structures Schedule

Task	Date Start	Amount of Time	Projected Finish Date
3D print 7 baffle sets	11/17/2017	1 day	11/28/2017
3D print 1 nozzle	11/17/2017	1 day	11/28/2017
3D print 1 roof, 2 walls, 1 front cover	11/17/2017	3 days	11/29/2017
3D print electronics house	11/17/2017	3 days	11/29/2017
Machine bottom of housing	11/17/2017	5 days	12/1/2017
Machine back wall of housing	12/1/2017	3 days	12/5/2017
Assemble chamber	12/5/2017	2 days	12/7/2017
Attach sail to chamber	12/7/2017	1 day	12/8/2017
Attach pole to base plate	12/7/2017	1 day	12/8/2017
Attach pole system to chamber system	12/8/2017	1 day	12/9/2017

Structures Risks/Worries

- Reliability of sail to direct opening into the wind
  - Weight of chamber system
- Weather conditions
  - How system fares in environment
- Time
  - January mission deliverables due date

Structures Risk Matrix



RISK 1: Dust collection will fail IF sail cannot orient chamber opening into the wind

RISK 2: Dust collection will fail IF snow enters into capsules

RISK 3: Dust collection will fail IF chamber breaks off of central pole

Structures Next Steps

- Finalize parts list
  - Order final parts needed for capsule choices
- Move forward with top 2 capsule choices
  - Finalize designs
  - Make drawings
  - Begin fabrication and assembly
- Incorporate motor and rotation system into current model for the future missions

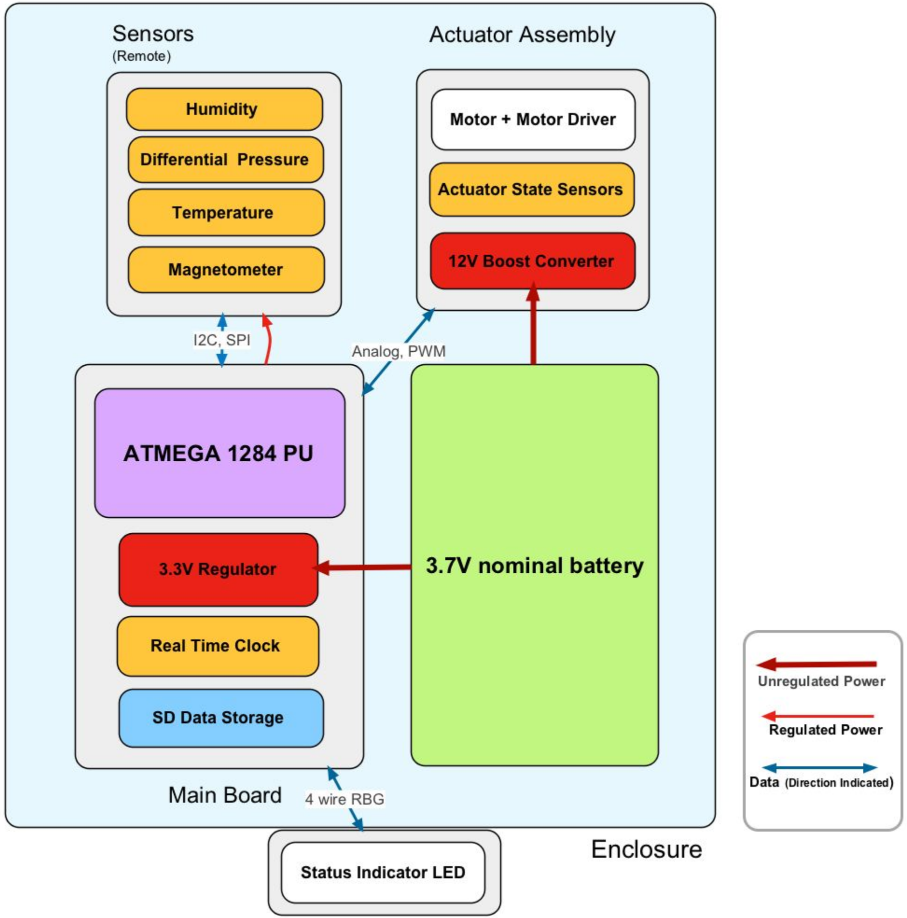
Electrical

Owen Lyke and Riley Hadjis

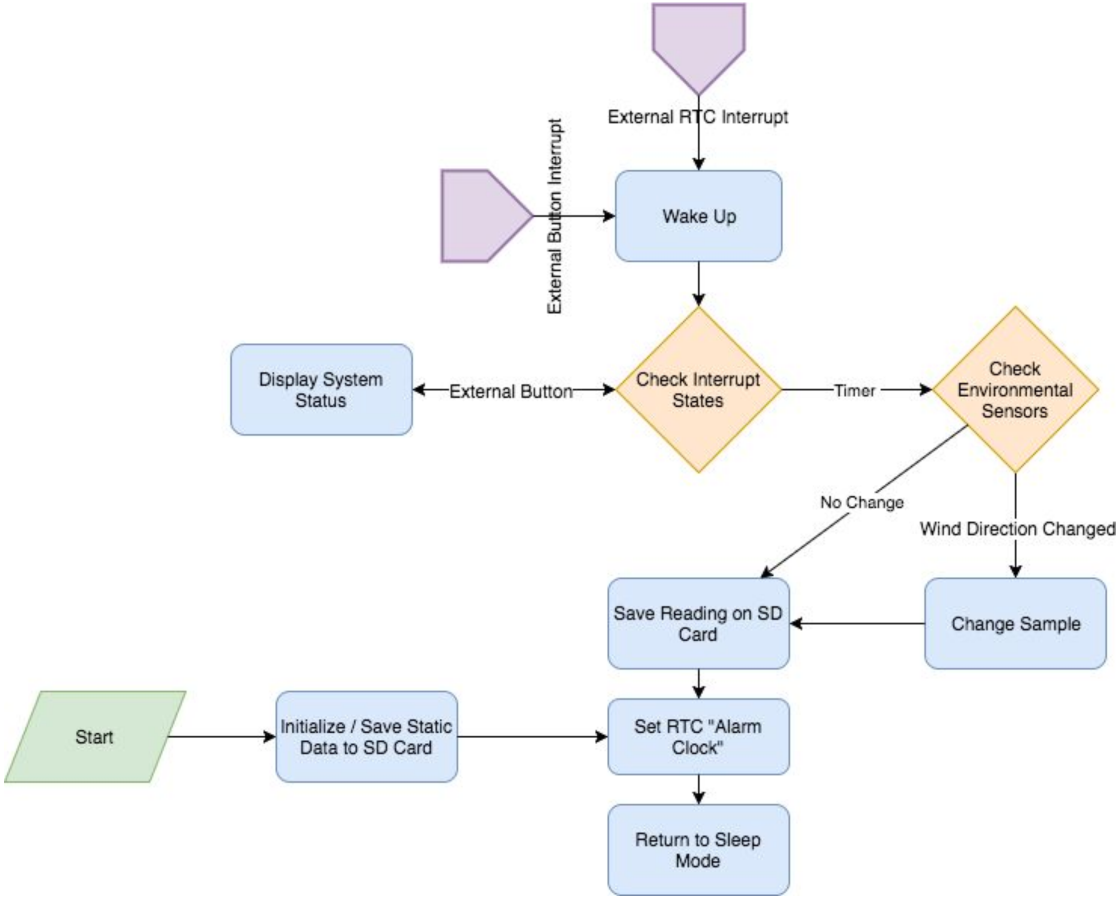
Requirements

Science Objective	Requirement	Design Traits
Quantify correlation of dust collection data to environmental conditions.	**0.2:** The Cryo-Aerosol Dust Collector shall record data that will link dust deposition patterns to wind events and atmospheric patterns.	Onboard microcontroller to sample sensors, record data, and control dust collection.
Record environmental conditions.	**1.21:** The Cryo-Aerosol Dust Collection Team shall record the time stamp, location, wind speed, wind direction, sample height from ground, temperature, and humidity.	Real time clock, differential pressure sensor, magnetometer, temperature sensor, and humidity sensor.
Control dust collection period.	**1.25:** The Cryo-Aerosol Dust Collector shall have the ability to start and stop dust collection selectively.	Collector selecting mechanism controlled by microcontroller, function determined by program loaded by the user.
Improve temporal resolution of dust collector.	**2.21.1:** The Cryo-Aerosol Dust Collector shall record the sample interval for each of the environmental sensors.	Real time clock will record the sample interval along with each measurement.
Characterize dust transport in different heights.	**2.21.2:** The Cryo-Aerosol Dust Collector team shall record wind speed as a function of height above the ground.	Wind speed will be recorded at each module, each module will be pre-programmed with its deployment height.
Enable long term data collection.	**2.22.1:** The system shall have enough power to operate for a one month deployment period.	A $LiNiMnCoO_2$ rechargeable battery will provide reliable long-term performance in an antarctic environment.

Functional Block Diagram



General Code Flow Chart



Microcontroller/Board Layout

- Microcontroller will be running off of around a 4 MHz crystal.
- The programming interface will be the 6 pin ISP.
- Still planning to use Atmel Studio and AVRDude to load the code.
- The code will be written in bare-metal C
- Again, all the parts chosen are rated from -40 c to 80 c

Sensors

Measurement	Type	Name	Supply Voltage	Communication
Windspeed	Pitot tube	HSCMRRN060MDSA3	3 - 3.6 V	SPI
Wind Direction	Magnetometer	MMC5883MA	2.16 - 3.3V	I2C
Humidity	IC	HDC1000YPAT	2.7 - 5.5 V	I2C
Time	RTC	AB0815-T3	1.5 - 3.6 V	SPI
Temperature	IC	G-NICO-018	2.2 - 3.6 V	SPI
Location and Sample Height	Static	Stored at deployment	N/A	N/A
Data Storage	SD Card	N/A	3.3V	SPI

Removed rotary resolver to reduce mechanical complexity — magnetometer sufficient for direction detection

Sensor Precision

Measurement	Required Accuracy	Resolution	Accuracy**
Wind Speed	+/- 5 mph	1.8 mph/count*	+/- 1.8 mph
Wind Direction	+/- 45 degrees	0.08 degree/count	+/- 1 degree
Temperature	Not specified	0.04 C/count	+/- 1 C
Humidity	Not Specified	0.006 %RH/count	+/- 3 %RH
Time	Not Specified	Not Applicable	+/- 150 ppm

* A future pressure sensor will provide 0.15 mph/count resolution
** Worst case values

Data Format and Storage

Data Budget:

- 80 bytes per sample using ascii encoding in CSV format
  - 8 GB storage allows for 35 Hz continuous sampling for 1 month

Data Format:

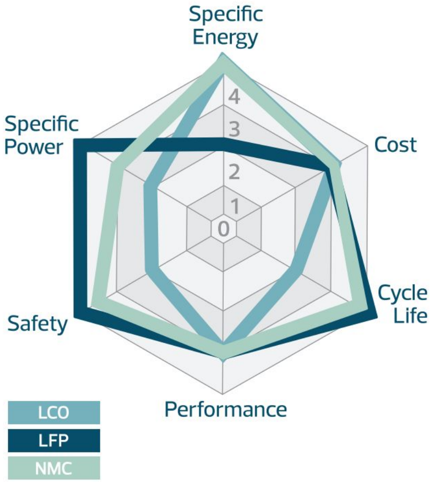
Timestamp	Windspeed (m/s)	Wind direction (CW from North, degrees)	Temperature (C)	Relative Humidity (%)	Dust Collection Status	Chamber Position	Battery Voltage (V)
11/15/17 12:17:0	xxx.xxxxx	xxx.xxxxx	sxx.xxxxx	xxx.xxxxx	Active/Inactive	[0,x]	x.xxxxxxx
11/15/17 12:18:0	1.15606	60.34999	22.39444	100	Inactive	0	3.7
11/15/17 12:19:0	0.02344	69.54223	22.12983	98	Active	1	3.69
11/15/17 12:20:0							

```
# SNOWCAT SENSOR
# SN:
0000001
#
# Deployed (Lat/Long [deg]):
40.0000
-105.262262
# Nozzle height above ground [meters]:
1.1
# Comments:
# This is a demonstration configuration file that is
# stored on the SNOWCAT sensor to hold static data
#
#

```

Power

- Updated power calculations using ten seconds of motor movement once per hour predict a required capacity of **5971.73 mAh** at **3.7V** for the mission duration of one month.
- A suitable battery using the $LiNiMnCoO_2$ chemistry with **7400 mAh** capacity has been chosen
  - Margin is **1428.27 mAh** or **23%** of the required capacity
  - If necessary more cells could be used in parallel to extend mission time
  - Alternately the mission could be extended significantly by reducing use of the chamber actuator



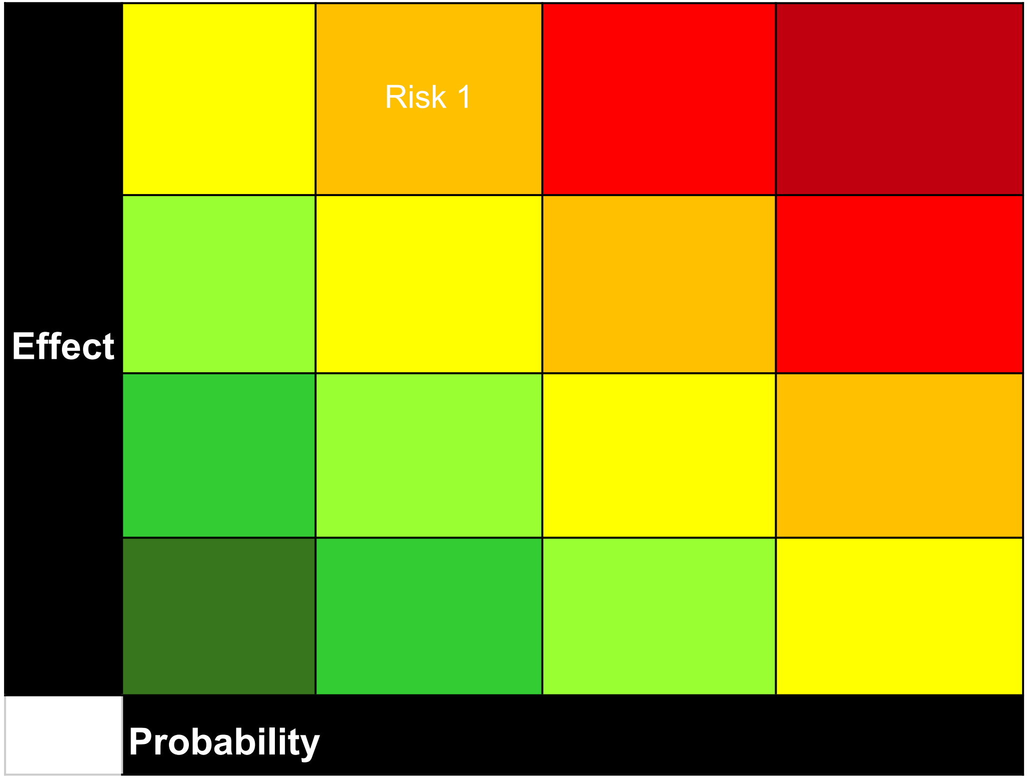
Lithium Nickel Manganese Cobalt Oxide: $LiNiMnCoO_2$, Graphite anode, Since 2008 Short form: NMC (NCM, CMN, CNM, MNC, MCN are similar with different medal combination)	
Voltage, nominal	3.60V, 3.70V
Specific energy (capacity)	**150–220Wh/kg**
Charge (C-rate)	1C, 4.20V peak; 3h charge time
Discharge (C-rate)	2C continuous; 2.50V cut-off
Cycle life	**1000–2000** (related to depth of discharge, temperature)
Thermal runaway	**210°C** (410°F) typical. High charge promotes thermal runaway
Applications	E-bikes, medical devices, EVs, industrial
Comments	Provides high capacity and high power. Serves as Hybrid Cell. This chemistry is often used to enhance Li-manganese.

System Reliability

- Integrated circuits rated to operate to -40 C, however pressure sensor only reliable to -10 C. All sensors can withstand -40 C environment.
- Cold environment will slow rate of chemical reaction in battery but not reduce total capacity. Low current draw makes this a non-issue.
- Electronics will be potted in polyurethane to repel moisture.
- External system status LED activated with a pushbutton to verify operation.

System State	Color
On, battery capacity greater than 50%	Green
On, battery capacity below 50%	Yellow
On, battery capacity below 10%	Red
System Failure	Blue

Electrical Risk Matrix



The most uncertain aspect of the electrical system is the power usage of the actuator. This is affected by all:

- Frequency of movement
- Duration of movement per cycle
- Voltage of the motor
- Current draw of the motor

As the mechanical design progresses the motor choice will solidify and more detailed analysis may occur.

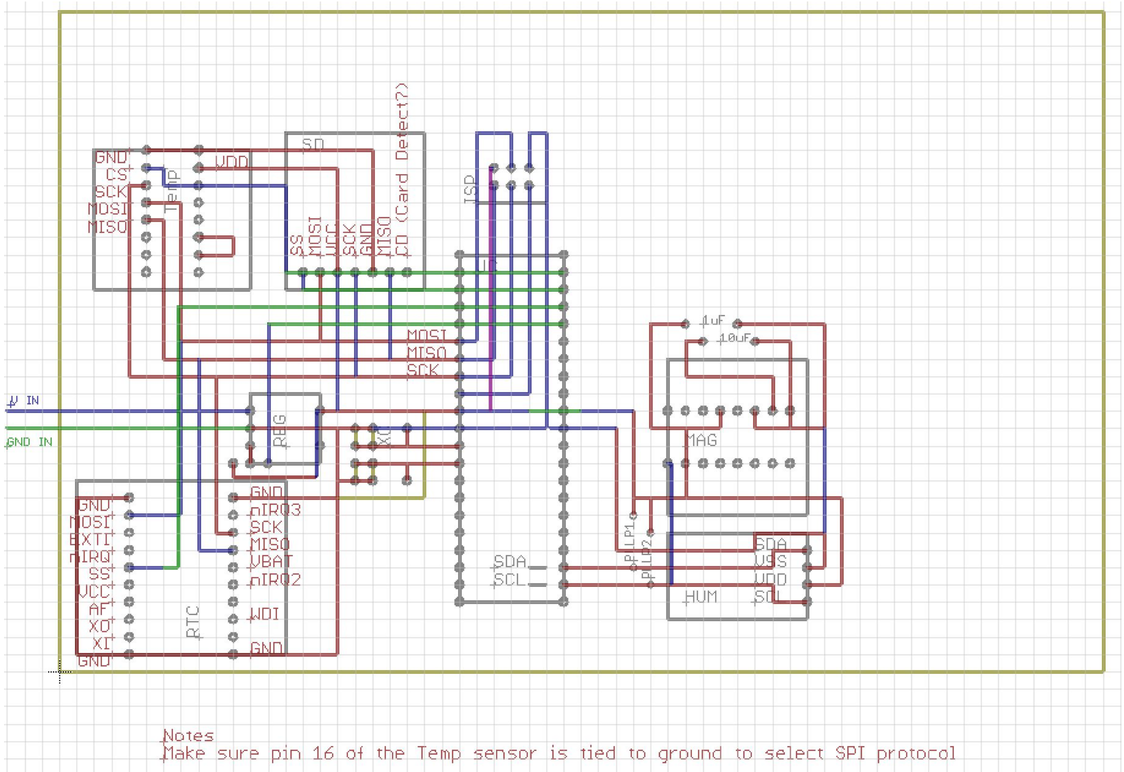
If the actuator uses more power than expected it will require a larger internal volume to store a battery with a larger capacity to complete the mission.

Electrical Next Steps

- Within the last week the parts for the prototype have arrived and a layout for the prototype has been created
- The next steps are to assemble the prototype and perform a proof of concept with a simple “blink” program

Action Item ID	Action Item Description	Status open,open(late),closed,escalated,cancelled	Priority high,med,low	Function Role classification	Stakeholder ONE Requesters name	Owner ONE responsible party	Open Date	Initial Due Date	Actual Due Date	Status follow-up Initials/Date: text Initials/Date: text
1	Hold first meeting and brainstorm questions in Electronics Manual	closed	high	Design	Haysley	Owen	9/13/2017	9/18/2017	9/21/17	
2	First system prototype	open	high	Design	Haysley	Owen	9/7/17	9/15/17	9/16/2017	
3	CDR slides	open	high	Presentation	Haysley	Owen	9/7/17	9/15/17	9/16/2017	
4	Solder traces and jumpers on protoboard	open	med	Prototyping	Haysley	Owen	11/14/17	11/17/2017		
5	Test for continuity and shorts	open	med	Prototyping	Haysley	Owen	11/14/17	11/17/2017		
6	Solder in components	open	med	Prototyping	Haysley	Owen	11/14/17	11/17/2017		
7	Write and test a simple "Blink" program	open	med	Prototyping	Haysley	Owen	11/14/17	11/27/2017		
8	Clearly define code structure	open	med	Prototyping	Haysley	Owen	11/14/17	11/27/2017		
9										
10										

Prototype Layout



- Ready to solder prototype
- Does not include motor control board, but pins are available
- Will begin testing software once assembly is complete

- This prototype will be available for the January test, can be mounted in a 3.5x6x2 inch sealed container

Proposed Testing

Proposed testing of the Micro Controller and prototype board:

- Test the board functionality for some duration in cold temperatures (3 days in dry ice)
- Test the logging ability for a week
- Test the rapid temperature change by heating the board in an oven and then quickly cooling it in a freezer and vice versa

Management

Schedule

DATE	GOAL
8/29	Team Organization
9/12	Team forming and literature study
10/13	Conceptual Design Review
10/27	Preliminary Design Review
11/16	**Critical Design Review**
12/14	Model 1 DUE
1/16	Winter Break
2/27	Model 2 DUE
3/27	End of Semester Report
4/10	Field Deployment

Design, Test, Build!

Testing Plan

- **Test 1:** Repeat dust collection test
- **Purpose:** Verify that we can repeat our results and make sure that our process is solidified
- **Test 2**: Measure pressure difference from inlet to exit and compare to calculated pressure difference
- **Purpose**: Verify that chosen nozzle and chamber design meets expectations

RAIL Schedule

Action Item ID	Action Item Description	Status	Priority	Function	Stakeholder	Owner	Open Date	Initial Due Date	Actual Due Date
2	Pressure Testing	open	high	Testing	Haysley	Butler/Vega	11/14/2017	11/29/2017	12/1/2017
4	Repeat of Dust Collection Testing	open	high	Testing	Haysley	Butler/Vega	11/15/17	11/27/2017	11/29/2017
5	3D Printing Completely Done	open	high	Build	Haysley	Palma	11/15/2017	11/29/2017	12/14/2017
6	Machining Completely Done	open	high	Build	Haysley	Palma	11/15/2017	12/5/2017	12/14/2017
7	Structure Assembled	open	high	Build	Haysley	Palma	11/15/2017	12/9/2017	12/14/2017
8	Solder Components	open	high	Build	Haysley	Lyke	11/15/2017	11/17/2017	12/14/2017
9	Electrical Testing Finished	open	high	Testing	Haysley	Lyke	11/15/2017	11/27/2017	12/14/2017
10	Order Final Model 1 Components	open	high	Design	Haysley	Haysley	11/15/2017	11/27/2017	12/1/2017

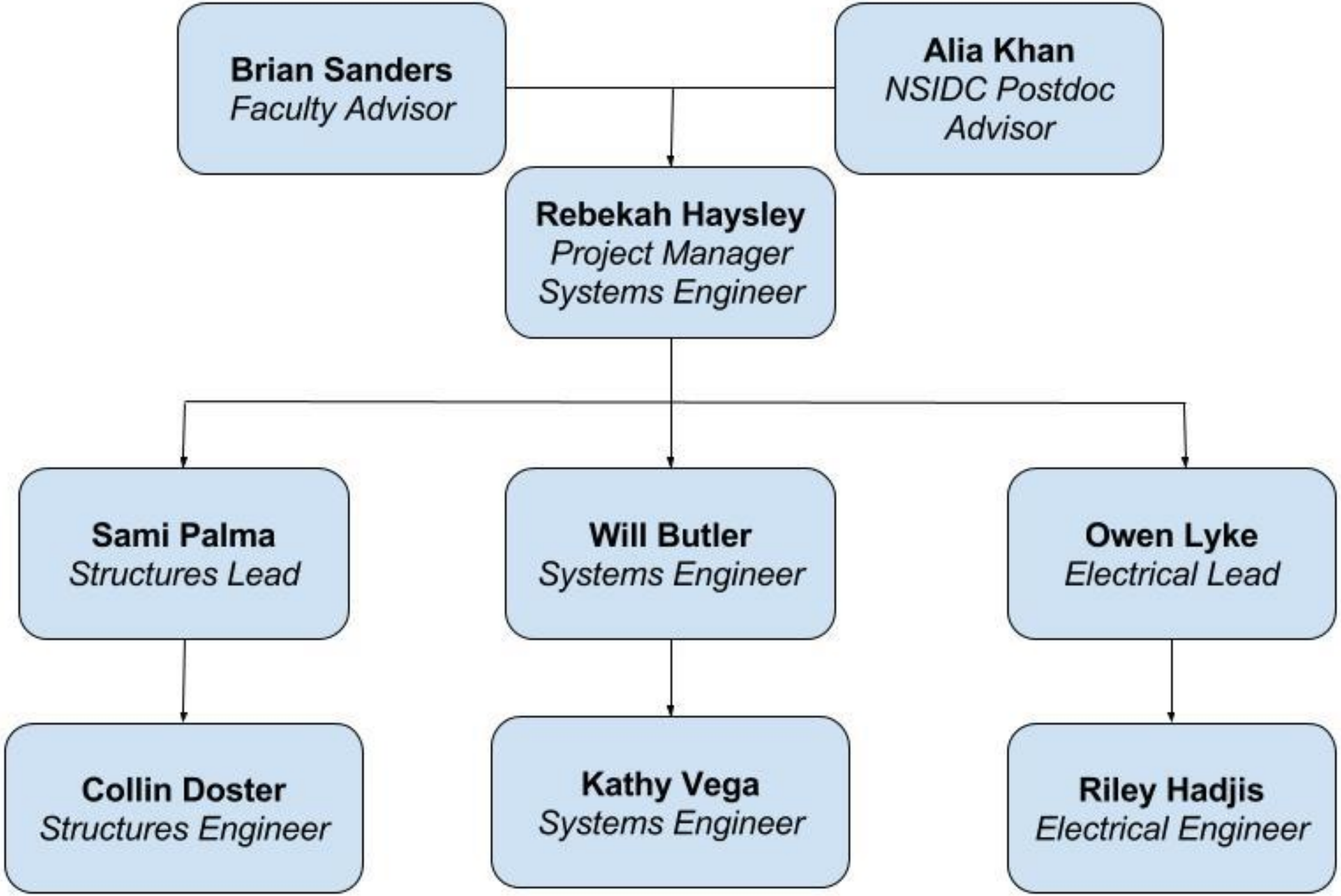
Budget Overview

Budget Overview		
Component	Cost ($)	Spent ($)
Model 1		
Electronics	400	149.85
Structures	350	61.98
Model 2		
Electronics	750	
Structures	1000	
Total	2500	
Allowed	4400	

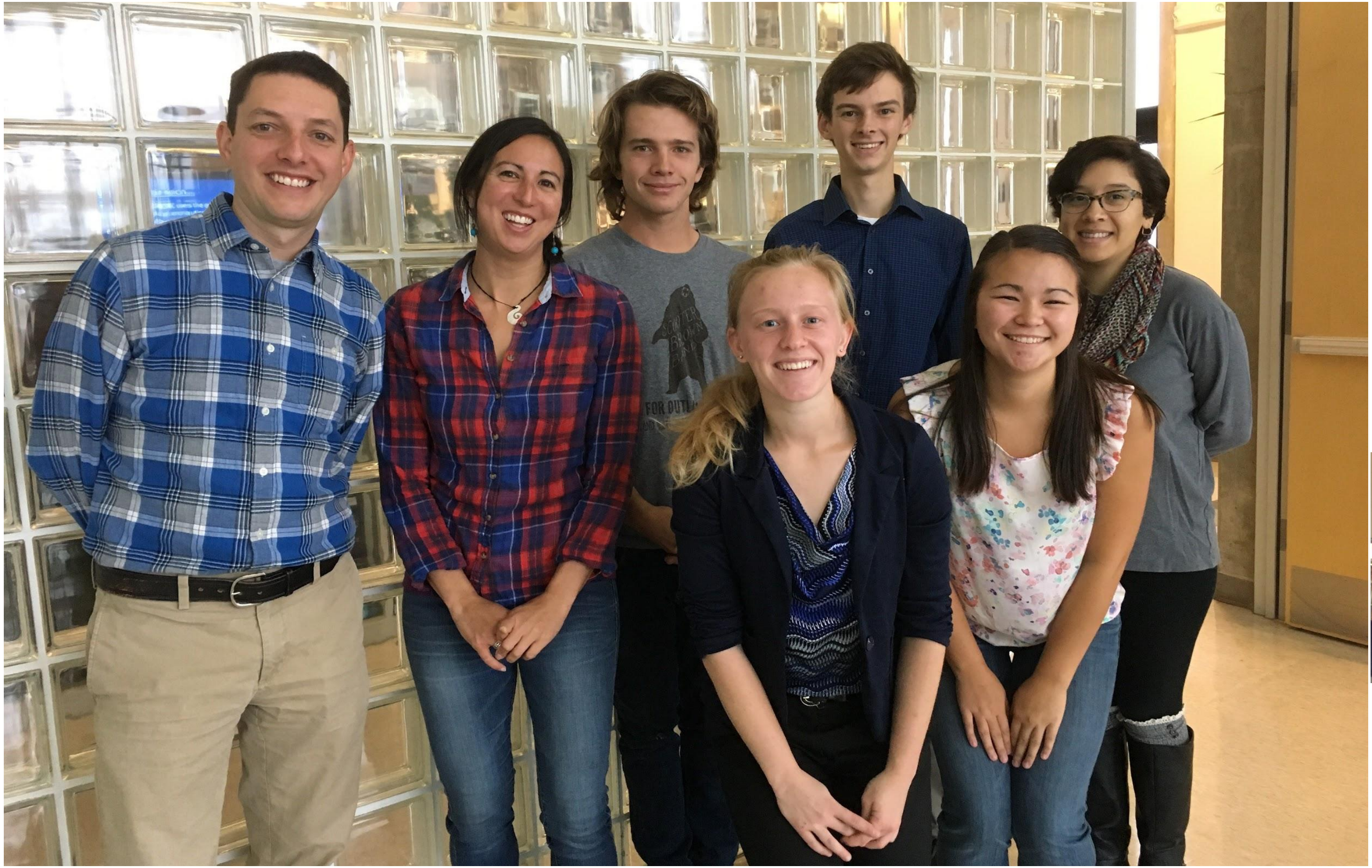
To Be Purchased (**Model 1**):

- Structures:
  - 3D printing ($100)
  - Bearing ($7)
  - Fasteners ($10)
  - Central pole ($35)
  - Pipe Clamp
  - Housing ($50)
  - Baseplate ($15)
  - Sail ($10)
- Electronics:
  - Rubber tubing for pressure test ($10)
  - Sensor press gauge pressure sensor ($40)

Team Structure



Team Picture!



Thank you!

Questions?

Sources

Cryo Dust Collection and NSIDC

Khan, A. L., S. Wagner, R. Jaffe, P. Xian, M. Williams, R. Armstrong, and D. McKnight (2017), Dissolved black carbon in the global cryosphere: Concentrations and chemical signatures, Geophys. Res. Lett., 44, doi:10.1002/2017GL073485.

http://www.soilerosionproducts.com/products/bsne2/

https://www.eea.europa.eu/highlights/black-carbon-better-monitoring-needed

Current Designs

http://www.sciencedirect.com/science/article/pii/S1352231014006645

Battery Chemistry Data

http://incellint.com/wp-content/uploads/2016/06/Comparison_Common-Lithium-Technologies_.pdf

SD Card Specifications

https://cdn-shop.adafruit.com/datasheets/TS16GUSDHC6.pdf