Design of Particle Capture System for PM2.5 on a Drone

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Background Information

Importance of Particle Analysis

COVID-19 Pandemic

- Significance of gathering information about particles in air increased

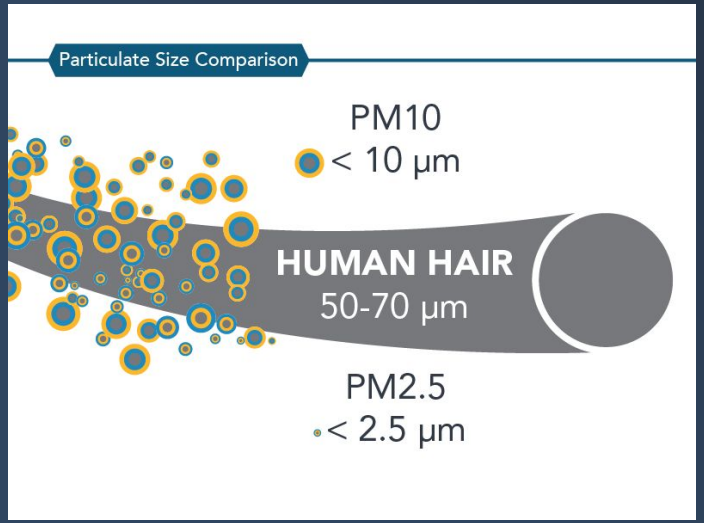
Grand Challenge - Advance Health Informatics

- Necessity in technology to analyze particle concentration
- Pandemic preparedness, danger assessment of atmospheres

Particulate Matter

Fine Particulate Matter ($PM_{2.5}$)

- Fine particles under 2.5 microns (10^{-6} m) in diameter
- Affects lung function when inhaled, and worsens medical conditions
- People with breathing and heart problems, children, and elderly particularly sensitive
- Long-term exposure linked to death



https://ww2.arb.ca.gov/resources/inhalable-particulate-matter-and-health

Past Work

Mapleseed MDP Team

- Several projects focused on improving data acquisition in atmospheres

Particle Collector Drone

- Collects and analyzes concentration of various particles, namely $PM_{2.5}$

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Problem Statement

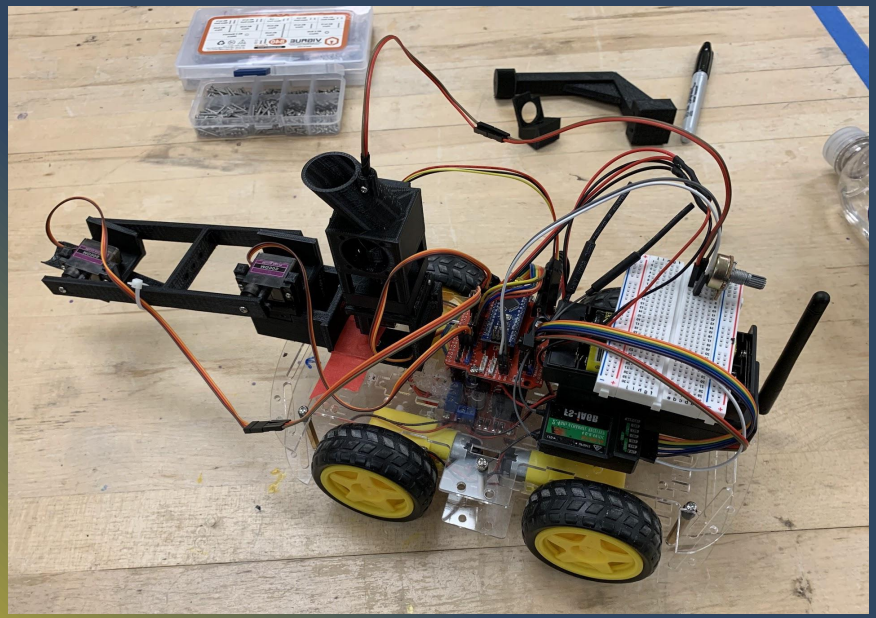
Problem Statement

The goal of this project:

Improve the drone's ability to collect particles in the air for analysis

- More effective than previous efforts
- Easy to operate
- Easy to integrate
- Inexpensive

Problem Statement



Particle Collector Rover from ENGR100

Inaccessibility of the Drone

→ Rover will be used

Same microscope assembly utilized

Stakeholders

Stakeholder	Proximity	Resource Providers	Beneficiaries of the Status Quo	Complementary Organizations	Beneficiaries and Customers	Opponents and Problem Makers	Affected/ Influential Bystanders
Mapleseed	Primary	X					
Prof. Liang	Primary	X					
Communities with $PM_{2.5}$	Primary				X		
Drone Manufacturers	Secondary			X			
Particle collection technology developers	Secondary				X		
Immunocompromised people	Secondary				X		
Elderly and children	Secondary				X		
Air Quality Researchers	Secondary						
Health Care Companies	Tertiary		X				
Government	Tertiary					X	
Hospitals	Tertiary				X		

03

Requirements/Specifications

Requirements and Specifications

Requirements	Specifications
Effective	Collects maximum particles in minimum time frame Creates an airtight seal for any collection mechanism
Non-Impeding	Does not alter the device's movement by more than 10% Does not require power from device's power source
Easy to Integrate	Can be integrated into different devices Can be built/attached with a maximum of 2 tools
Inexpensive	Total cost should be below $40
Easy to Operate	Does not add complex operating mechanism People with minimal technical background can operate intuitively

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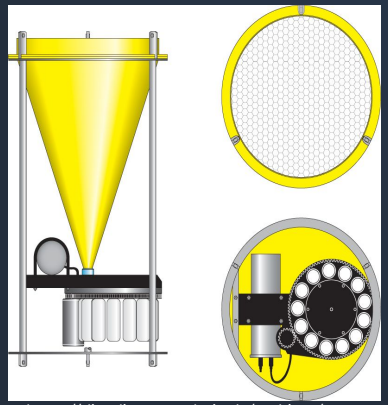
Concept Generation

Inspirations

Funnel and Movement



https://divediscover.whoi.edu/archives/expedition13/hottopics/images/trap1.jpg

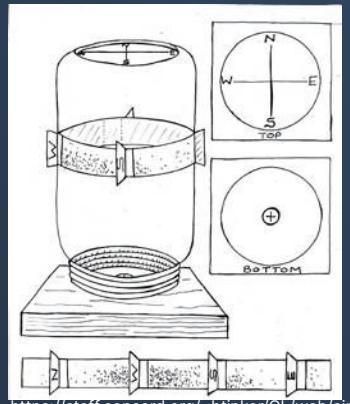
- Wide collection range
- Reliant on movement
- Surface roughness invites decreased efficiency

Air Pump

https://s19534.pcdn.co/wp-content/uploads/2021/01/CP-dust-extractor.jpg

- High efficiency for particle flow
- Potential for higher cost
- Large size inhibits design

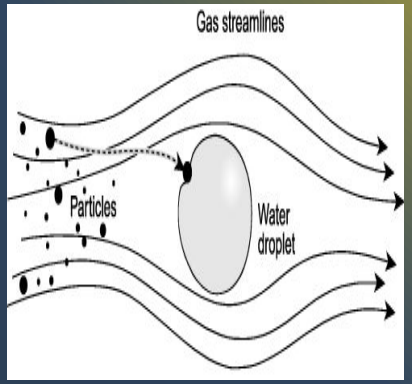
Adhesives



https://staff.concord.org/~btinker/GL/web/air/particles/airborne_particle_collectors.htm

- No mechanical energy
- Great long term collection
- Difficult to remove collected particles

Liquid Collection



https://en.wikipedia.org/wiki/Particle_collection_in_wet_scrubbers

- Loss in microscope's analysis capability
- Difficult to integrate
- Potential for higher cost

Pugh Chart Analysis

Requirement	Importance	Funnel		Air Pump		Adhesive		Liquid	
		Rating	*W. Total*	*Rating*	*W. Total*	*Rating*	*W. Total*	*Rating*	*W. Total*
Effective	10	1	10	4	40	0	0	3	30
Non-Impeding	8	3	24	2	16	4	32	4	32
Easy to Integrate	7	4	28	3	21	4	28	1	7
Inexpensive	5	4	20	2	10	4	20	3	15
Easy to Operate	5	4	20	4	20	4	20	2	10
Total (out of 35 x 4 = 140)	35		102		107		100		94
Relative Total (div by 140)			**0.73**		**0.76**		**0.71**		**0.67**

4 = very good (ideal)
3 = good
2 = adequate
1 = just tolerable
0 = unsatisfactory

- Air Pump is the best option
- Seems to be marginally better than Funnel and Adhesive, however Funnel and Adhesive have very poor scores for the most important requirement

Air Pump

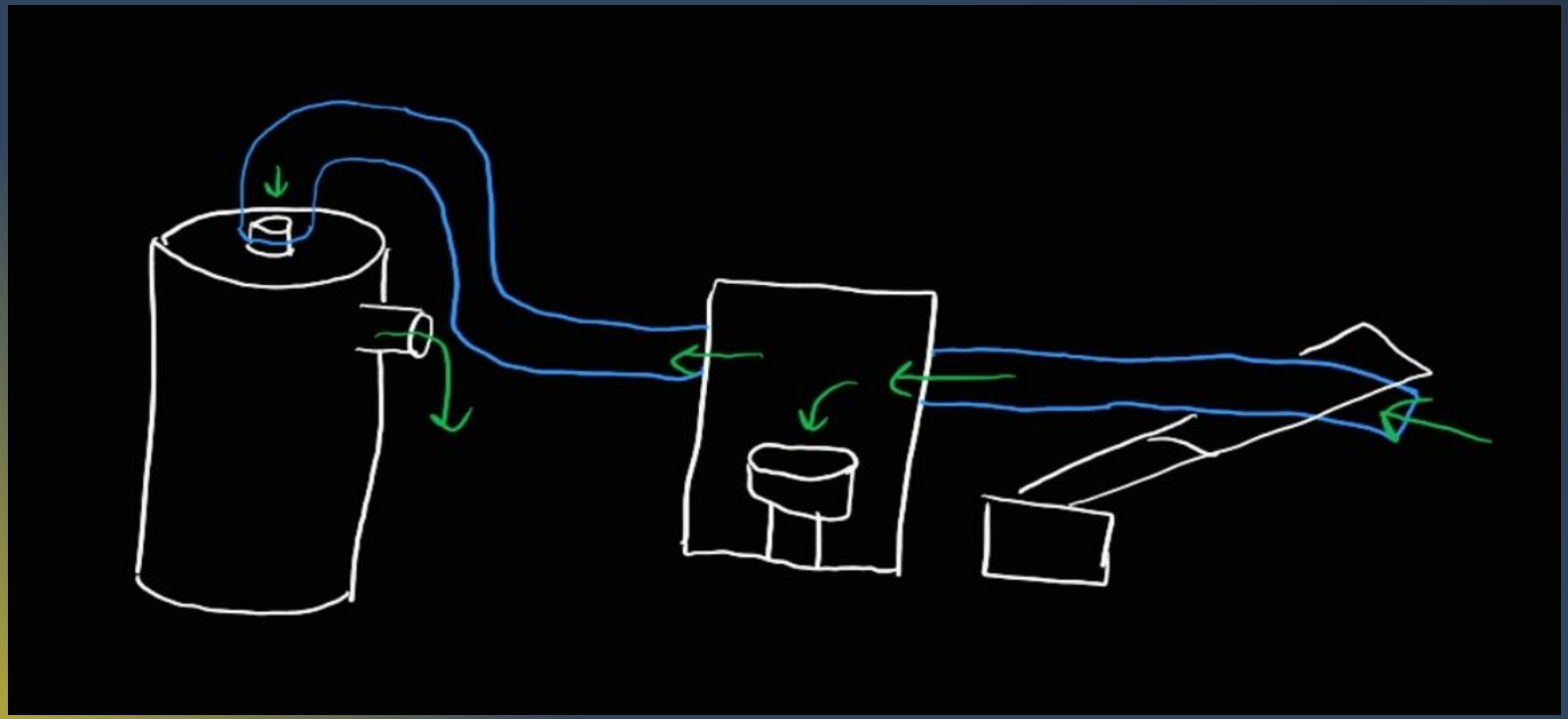
FLEXTAIL GEAR MAX PUMP 2020

- $28.99, 0.33 lbs
- 2.2 kPa air pressure, 300 L/min wind speed

Selected as Air Pump for project

- Ease of use
- Relatively inexpensive price point
- Small size
- Helpful adaptors for inlet and outlet

Alpha Design Sketch



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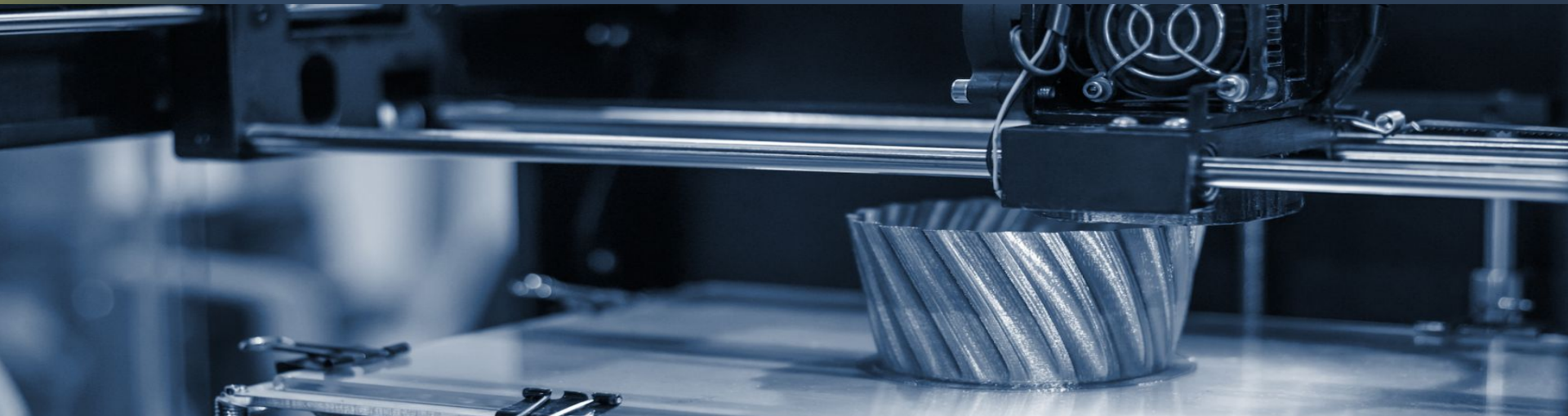
Prototyping/Testing

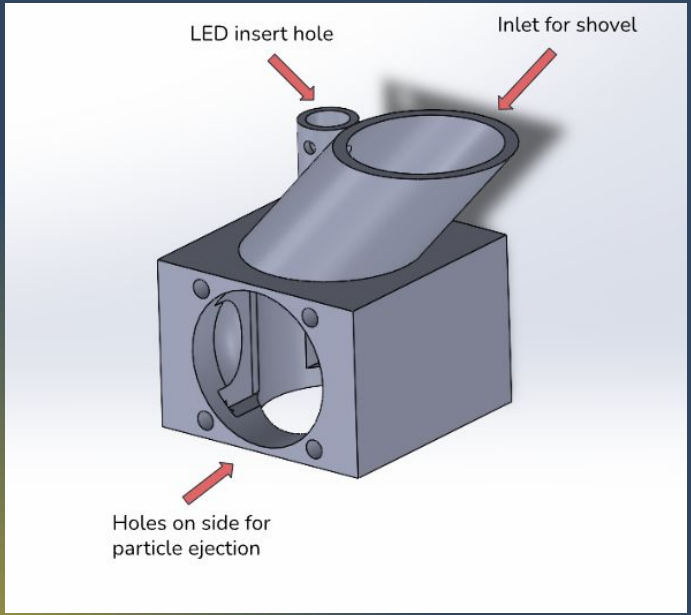


Original Microscope Design

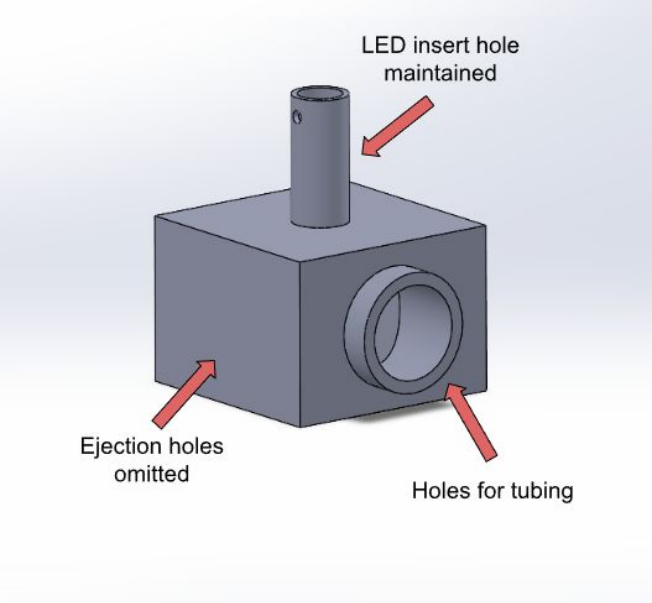
Particle Inlet Assembly

- Includes a large inlet on top
- Concentrator inside to guide particles
- Microscope underneath concentrator
- Holes on the side for particle ejection

Microscope Component Redesigns



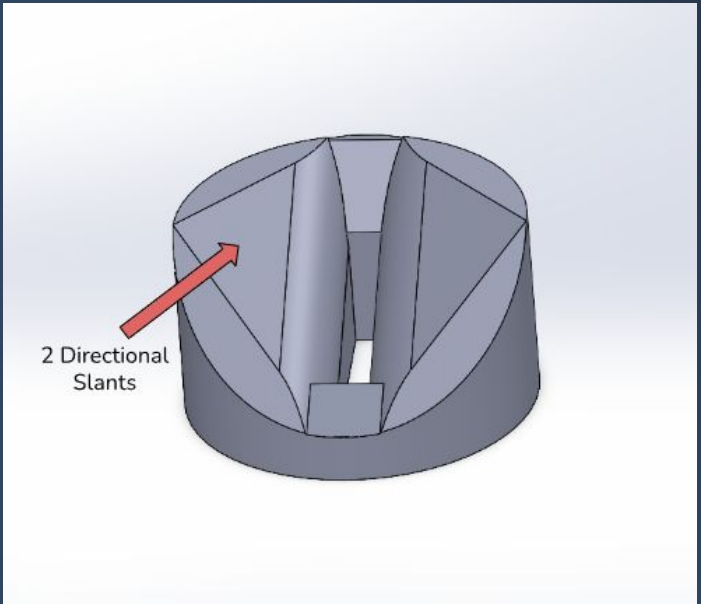
Original Housing Design



New Housing Design

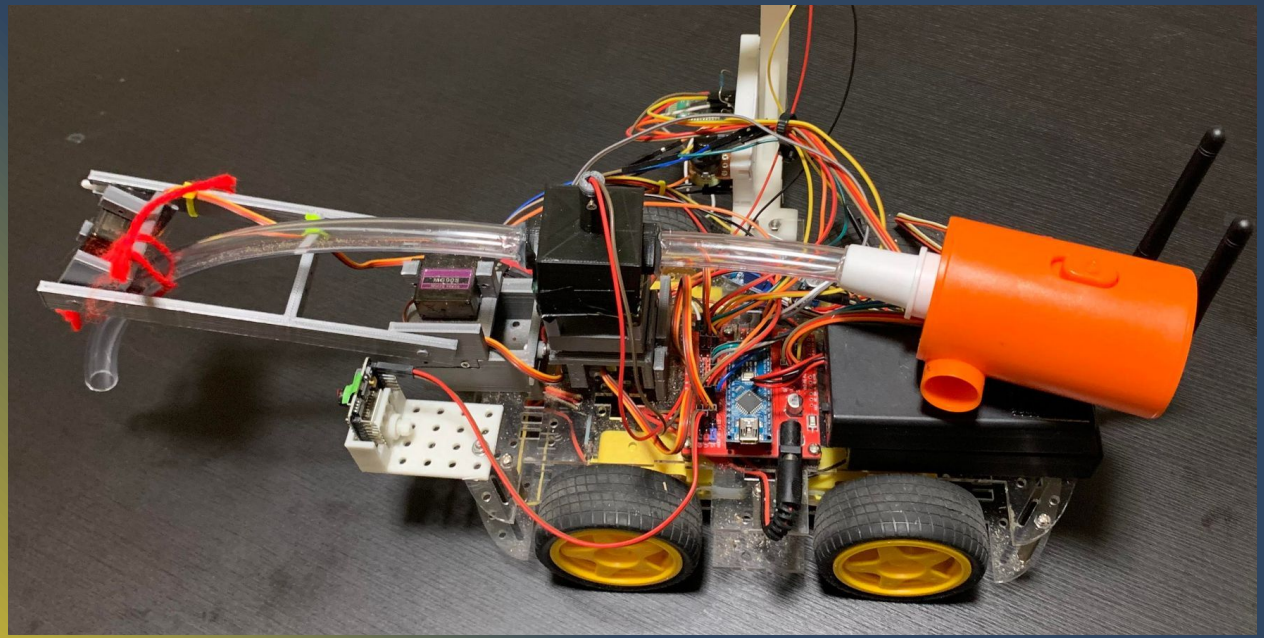
Microscope Component Redesigns

Original Concentrator Design



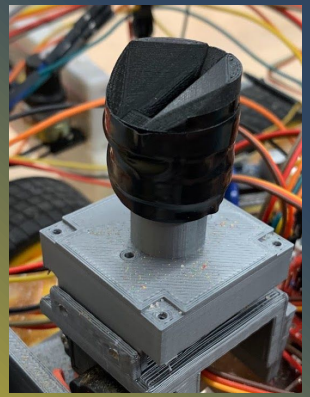
New Concentrator Design

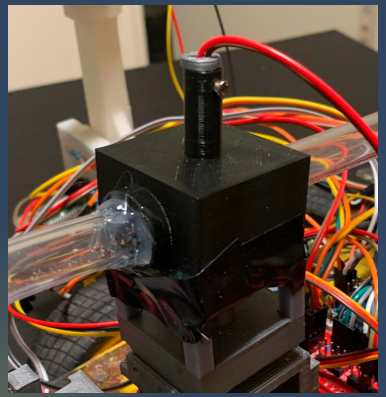
Prototype



- Straight tubing throughout
- Air Pump on Battery Pack to maintain elevation
- Air pump works as a vacuum, no particles enter

Prototype





- 3D Printed parts for ease of manufacturing
    - PLA filament selected for inexpensive price point
- Hot glue for tubes for airtight seal
- Epoxy and electrical tape used for adhering

Test Setup


Salt and
Colored Sand
Microscope
Display
Rover
Controller
Prototype

Testing

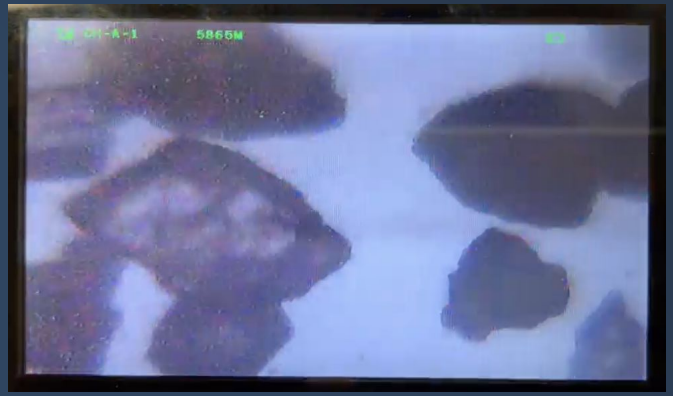
Much higher collection speed

- Without air pump, particle collection required 10+ seconds

Much higher particle density

- Without air pump, averaged 5 less particles at end of trial

Limited testing conducted due to **prototype design issues** — will be addressed



Trial	Time of collection	Particle	Particles Shown
1	3 seconds	Sand	12
2	3 seconds	Sand	11
3	3 seconds	Sand	13
4	5 seconds	Sand	15
5	5 seconds	Sand	15
6	3 seconds	Salt	8
7	3 seconds	Salt	7
8	3 seconds	Salt	8
9	5 seconds	Salt	10
10	5 seconds	Salt	12

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Future Considerations

Testing Considerations

Prototype Issues

- Tubing severely limits range of motion
- Did not include an ejection mechanism
- Better airtight seals

Further tests to be conducted

- Gathering weight as a quantifiable measure
- Smaller particles to more closely imitate $PM_{2.5}$

Adapting Design to Drone

Factors to consider when adapting

- Movement inhibition
- Air flow direction
- Space and weight concerns
- Remote pump operation

Summary

- COVID-19 and the prevalence of $PM_{2.5}$ commands developments in particle analysis technology
- The implementation of Air Pumps have the potential to improve particle collection of devices
- Further development of the prototype and tests will be necessary for more informative data
- Adaptation of Air Pump design to a drone will require consideration of various factors

References

https://ww2.arb.ca.gov/resources/inhalable-particulate-matter-and-health

http://www.engineeringchallenges.org/challenges/informatics.aspx

https://www.epa.gov/pm-pollution

https://divediscover.whoi.edu/archives/expedition13/hottopics/images/trap1.jpg

https://s19534.pcdn.co/wp-content/uploads/2021/01/CP-dust-extractor.jpg

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