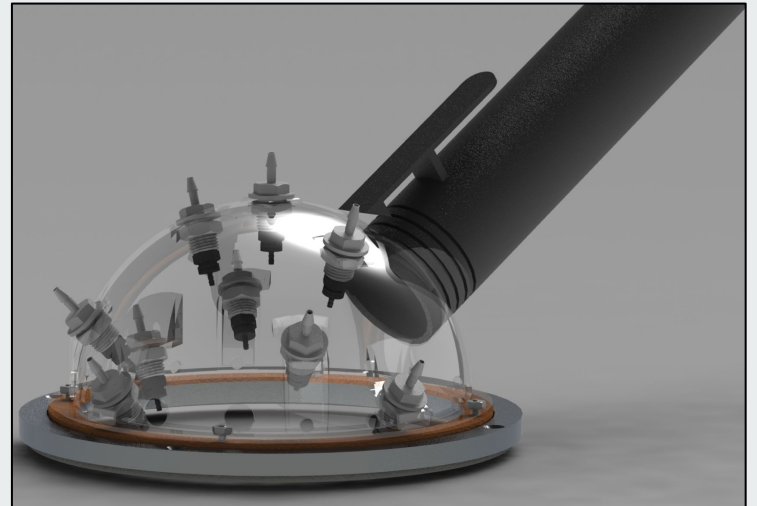


---

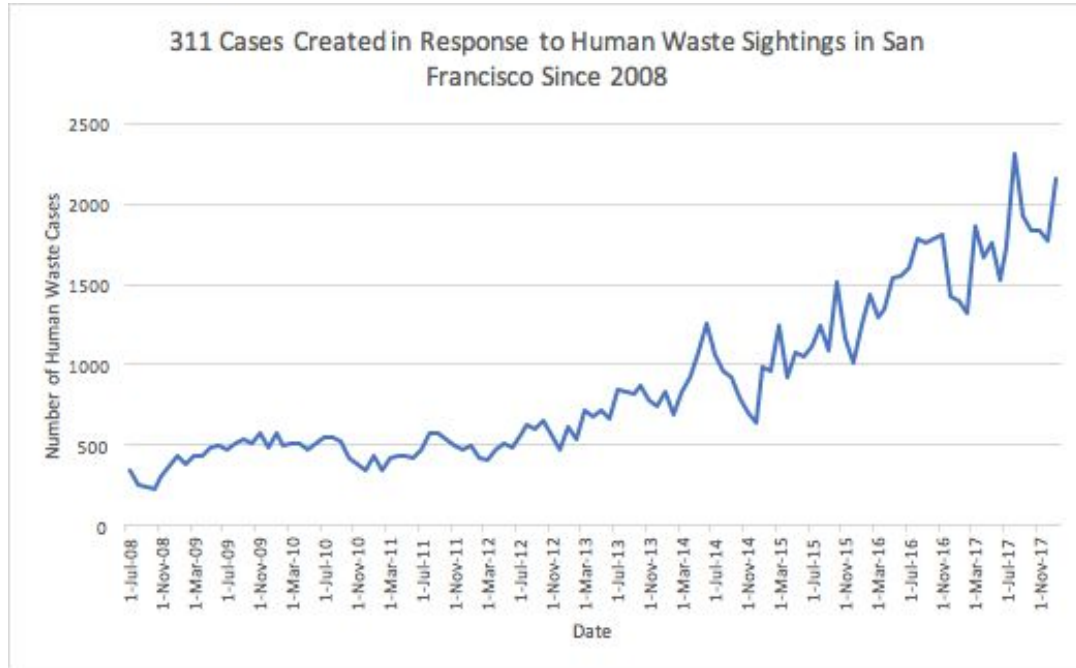
# Engs 90 Group #20 - Street & Sanitation System

Alyssa Baker, Cara Cavanaugh, Julia Jackson, Rafananda Tejada, Brandt Slayton

Sponsor: Paul Ronzano  
Faculty Adviser: Vicki May



# Overview



- Number of 311 calls for human waste has **quadrupled** over past 10 years
- Street cleaning budget has **doubled** over last 5 years--problem persists
- Dried human waste can transmit airborne diseases such as rotavirus, Hep A
- Sanitation has become hot-button issue on Mayor Breed's agenda

# Problem Statement



The San Francisco (SF) government and Department of Public Works are currently working to rid the city streets of human excrement. The city launched “Poop Patrol,” who use power washers and steam cleaners to rid the streets of feces. **The current method of feces removal is inefficient, time-consuming, and does not sufficiently contain fecal matter.**

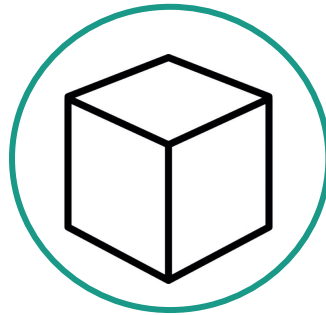
Categories	Objectives	Requirements	Metric	Test	Importance
Functions	<b>Remove</b> excrement	Leave minimal trace	Remove 95% or more	Complete trade studies	<b>5.0</b>
	Complete task faster than SOA	For all consistencies on surfaces	complete <5 minutes	Time each trade study	<b>3.8</b>
	<b>Contain</b> excrement until it can be disposed of	Keep waste in controlled area	No spreading past enclosure	Use fluorescent dye to test containment system	<b>4.6</b>
		Hold waste for 10 uses	Volume <10 Gallons	Remove 5 samples without disposing	
		Ensure potential aerosols created are contained	Yes/No	Test with coffee filter	
Dispose of collected waste	Easy transfer from device to final destination	1 person can dispose of > 5 minutes	Time how long it takes for one person to complete task	<b>3.2</b>	
Means/ Implementations	Manufacturability	Reproducible	Yes/No	Make functional prototype	<b>4.2</b>
	Power	Capable of supplying 120V AC power for minimum time	1 hour	Fulfill functional requirements for an hour	<b>3.2</b>
	Ease of cleaning	Minimize steps required to clean	1/day; minimal devices/self cleaning	User testing with fake fecal matter	<b>3.4</b>
Constraints	<b>Safety</b>	Safe for user and passersby	Yes/No	OSHA regulations	<b>5.0</b>
	User-Friendly	Easy for workers to operate	Hours of training to operate <2hrs	Perform testing with prototype and interview users	<b>3.4</b>
	Portability	One person can transport	<100lb total	1 person move prototype	<b>3.8</b>
	Durability	Meets minimum stress test	>1lb/in impact strength (dome)	Material properties	<b>2.8</b>
	<b>Reliability</b>	Successfully removes feces in each instance	<1% failure to remove feces	Test prototype through multiple scenarios	<b>5.0</b>

# Deliverables

A single device capable of removing, containing, and disposing of human excrement.



CAD Model



Functional  
Prototype



Manufacturing  
Plan

# Methodology of Approach

---

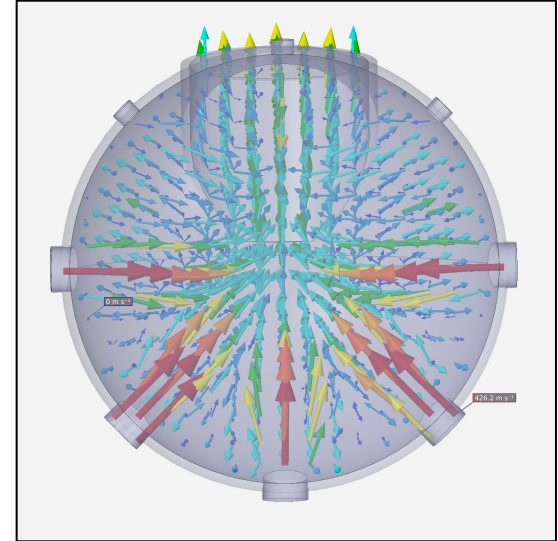
# Trade Studies



Dislodgment Method:  
Power Wash

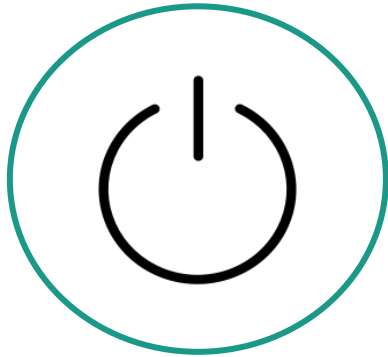


Removal Method: 150 cfm  
Wet-Dry Vacuum



Containment Method: Dome

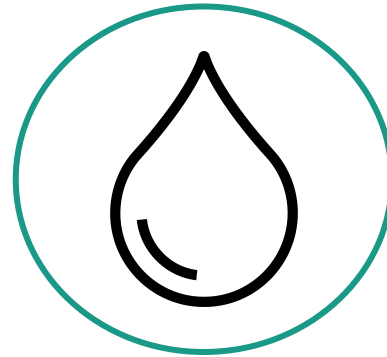
# Development of Subsystems



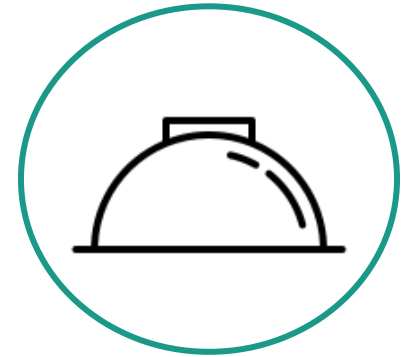
Power



Vacuum



Water



Dome



# Option 1: Battery

## Known Variables:

Vacuum: 120V at 10.5A(max)

Pump: 115V at 1.0A(max)

## Assume:

12V battery with 120Ah

Average run time = 28sec = 0.077hr

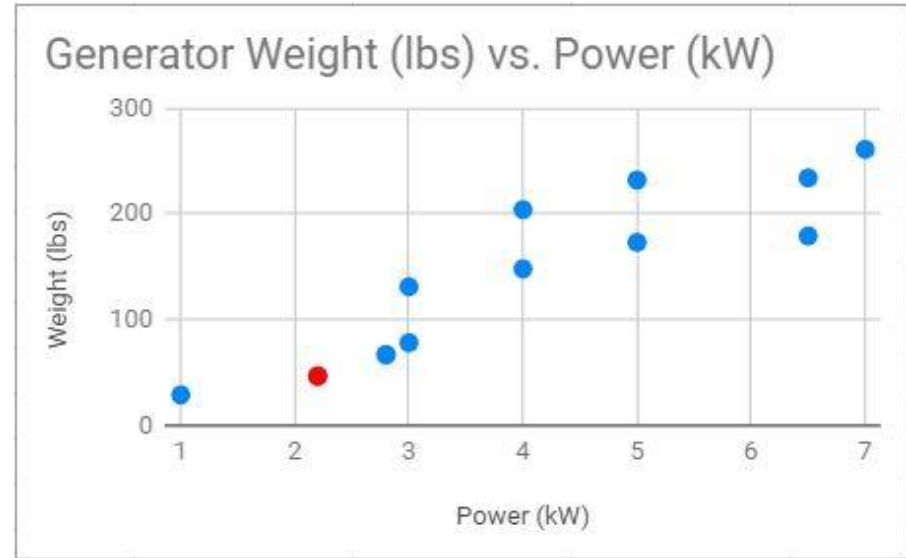
Max Total Current = 10.5A + 1.0A = 11.5A.

For 1 Run: 11.5A \* 0.077hr = 0.9Ah

$$\frac{120\text{Ah}}{(0.9\text{Ah/run})} =$$

133 runs

# Option 2: Generator



## Minimum Power Needs

1.2 kW for vacuum motor

0.14 kW for pump

=1.4kW Total

## Honda EU2200i

Weight: 46.5 lbs

Price: \$1,159.95

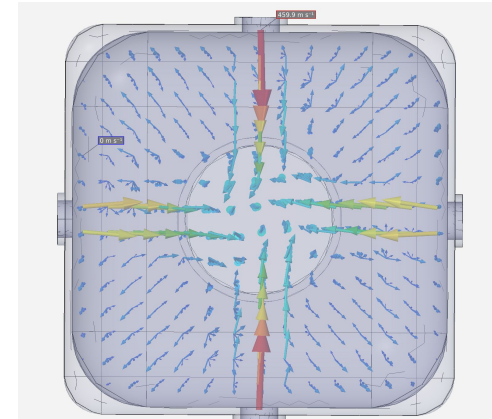
# Prototypes



# Prototype 0

"Proof of concept prototype developed for PDR presentation, using tupperware and hose-attached pressure washer."

- 6"x5"x2" rectangular prism
- 4, 1/4", symmetrically-spaced holes
- 150CFM vertically mounted vacuum
- 1 stream, hose mounted pressure washer



# Prototype 1

"Preliminary prototype incorporating water tubing, pressurized jets and approximation of spherical shape"

- 7" tupperware
- 6, 1/2" air holes evenly-spaced
- Faucet attached tubing
- 4, 1/8" jets, split using bulky manifold



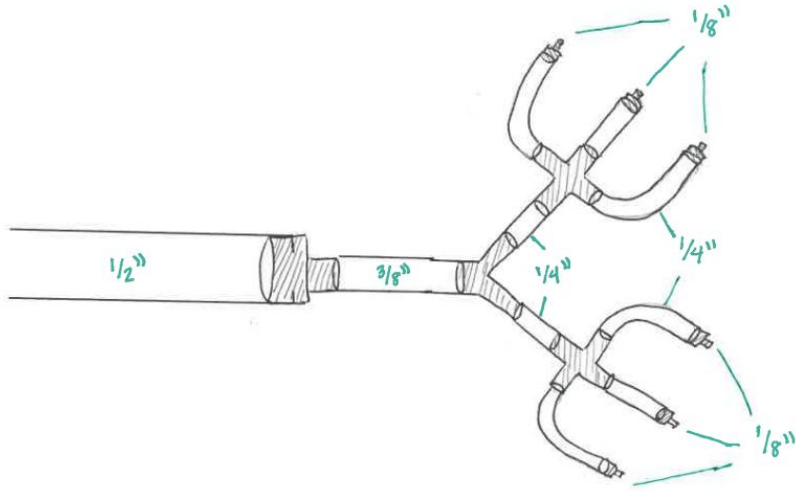
# Prototype 2

"First prototype to incorporate hemispherical shape -- extensive air hole placement development"

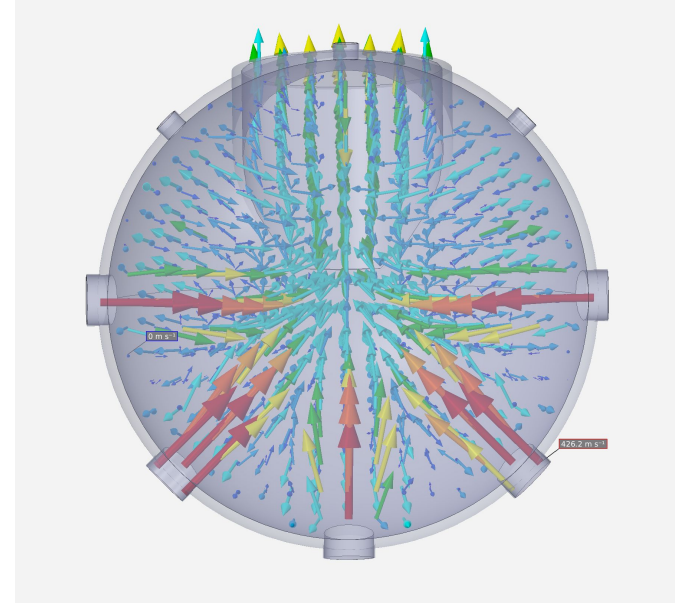
- 5" acrylic dome
- 6 total air holes 3, 1/2" holes opposite suction, 3, 1/4" holes close to suction
- 6, 1/8" jets -- flow speed 1.33m/s
- Water jet placement -- top of dome facing center



## Tubing



## Fluent Simulation



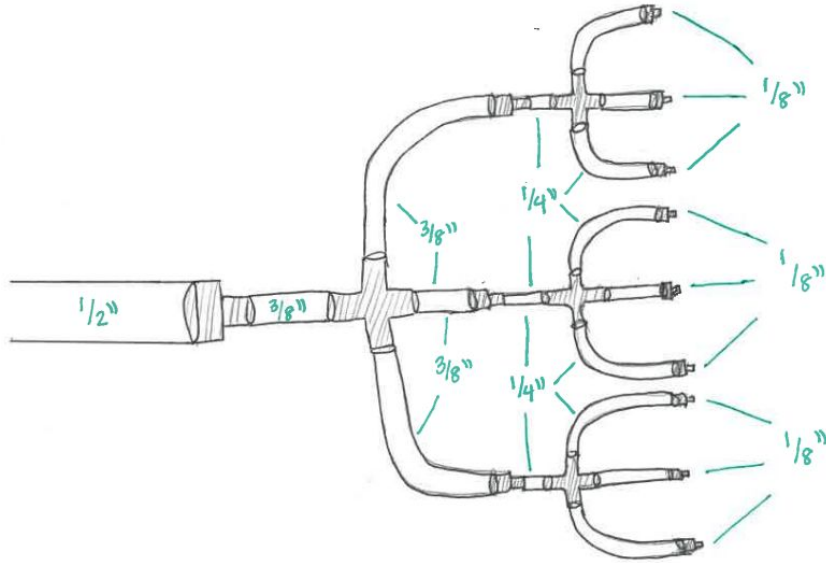
# Prototype 3

"Finalized 7" dome diameter, functional prototype presented at CDR"

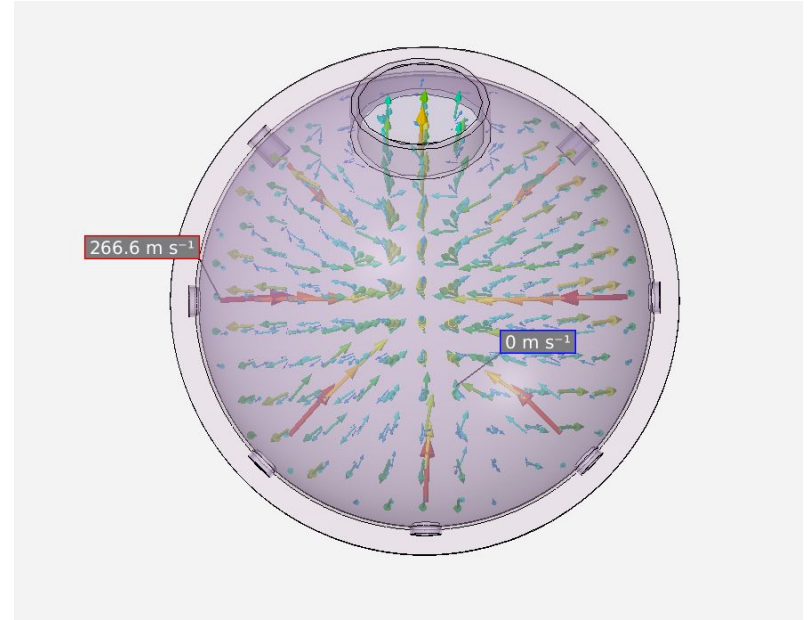
- 7" acrylic dome
- 7 air holes, 3 1/2" opposite suction, 4 1/4" close to suction
- 9 1/8" jets -- flow speed = 0.885m/s
- Water jet placement -- 5 placed on top, 4 opposite suction near ground



## Tubing



## Fluent Simulation



8 inch dome



# Prototype 4

"First incorporation of swivel bearing, kept dome aspects the same from prototype 3"

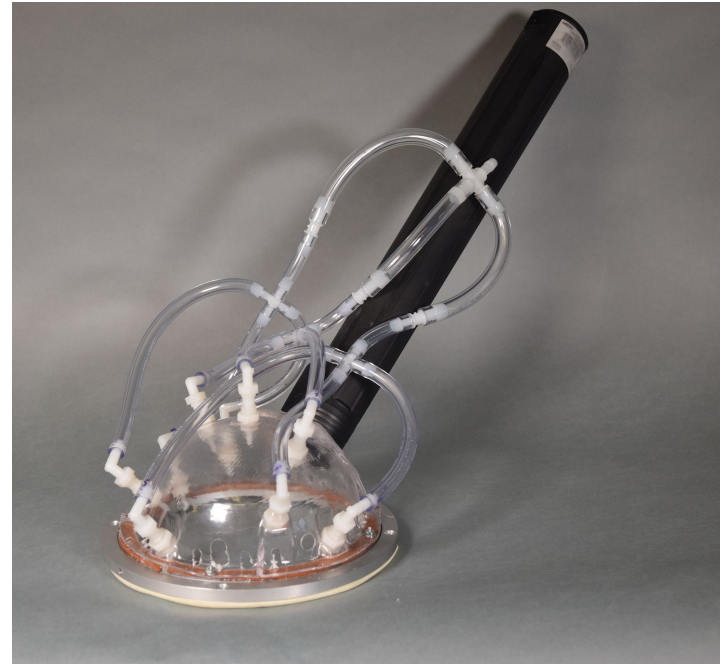
- 7" acrylic dome
- 7 air holes, 3 1/2" opposite suction, 4 1/4" close to suction
- 9 1/8" jets -- flow speed = 0.885m/s
- Water jet placement -- 5 placed on top, 4 opposite suction near ground



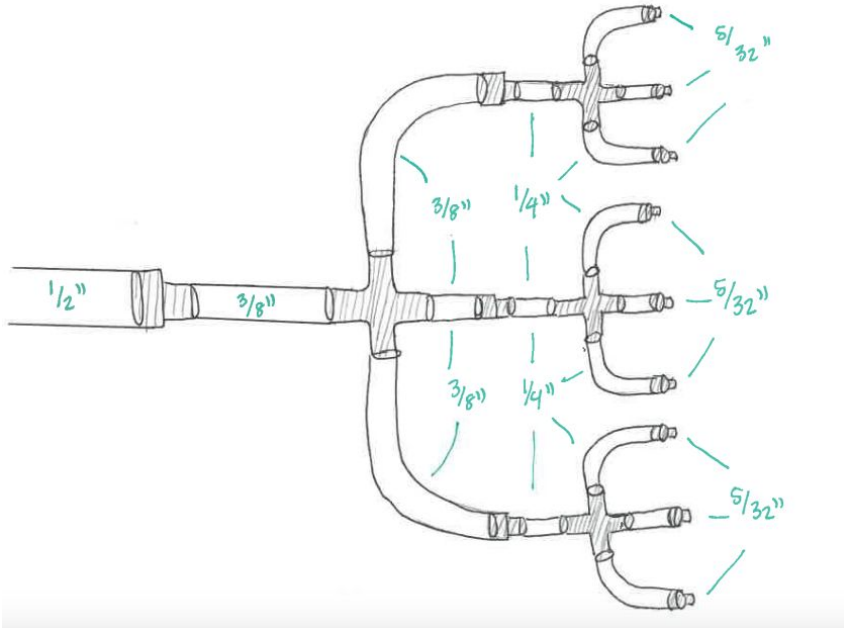
# Prototype 5

"First thermoformed dome: water jet speed and suction failed to meet specifications"

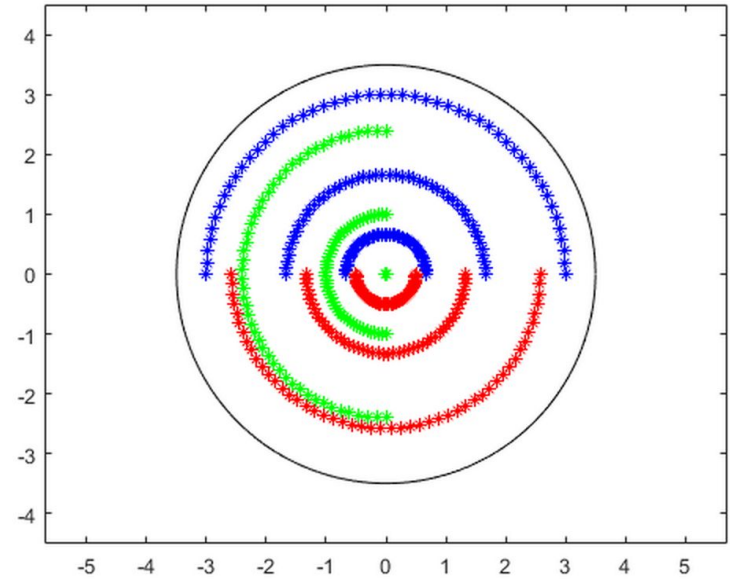
- 7" PETG thermoformed dome
- 7 air holes, 3 1/2" opposite suction, 4 1/4" close to suction
- 9, 5/32" jets -- flow speed = 0.567m/s
- Water jet placement -- angled faces to hit concentric circles on ground



## Tubing

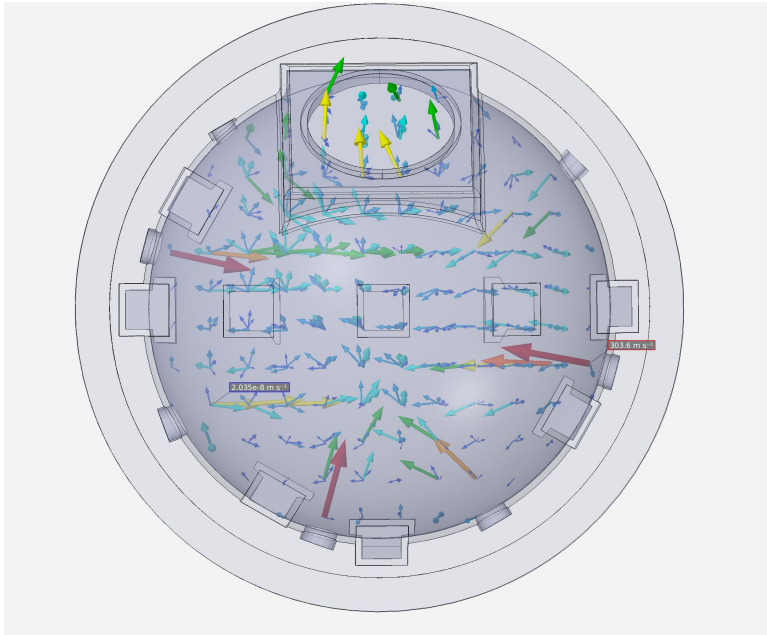


## Jet Angles



Matlab code showing concentric circles

## Fluent Simulation



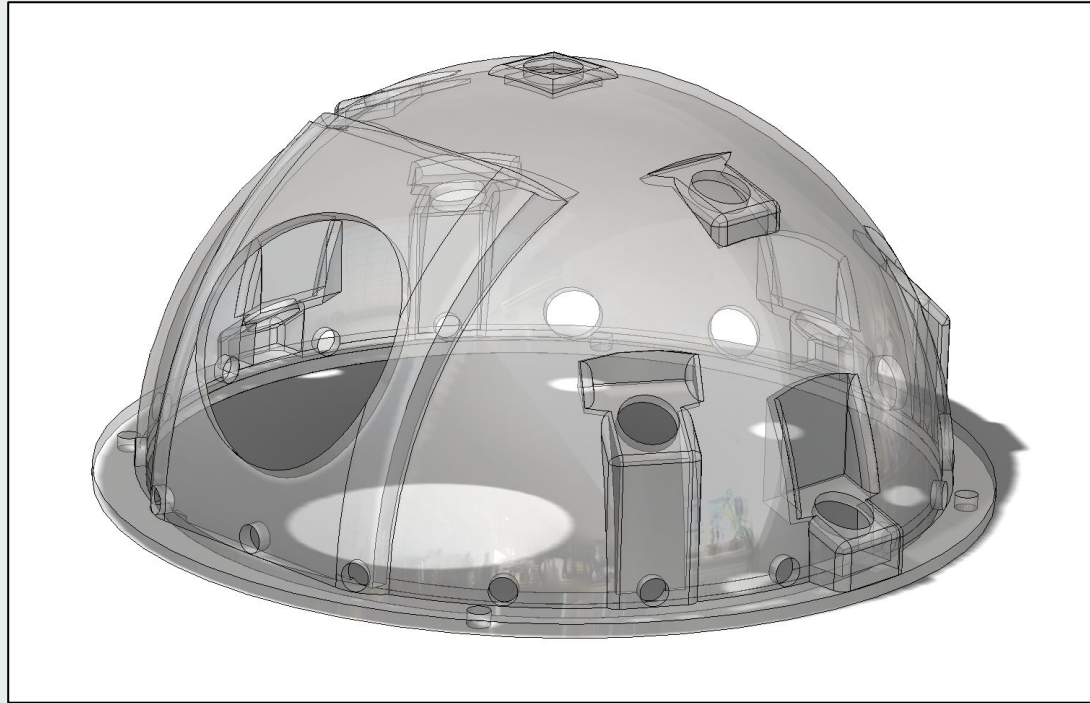
## Dome



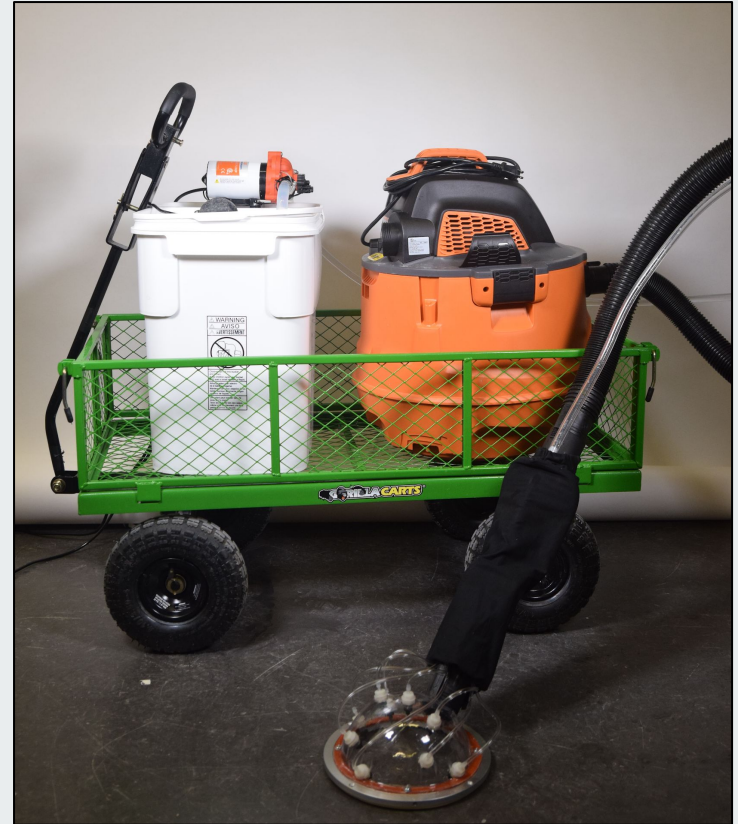
# Deliverables

---

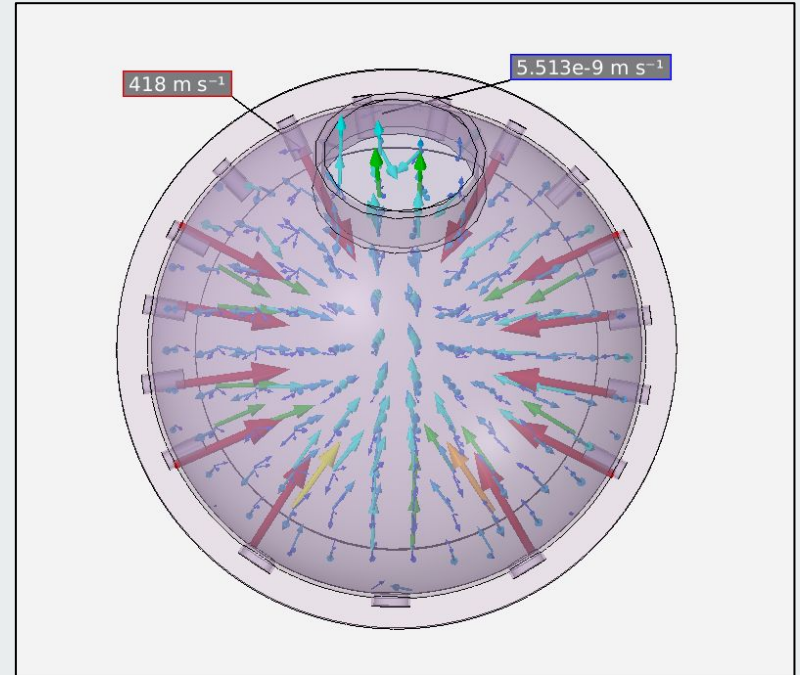
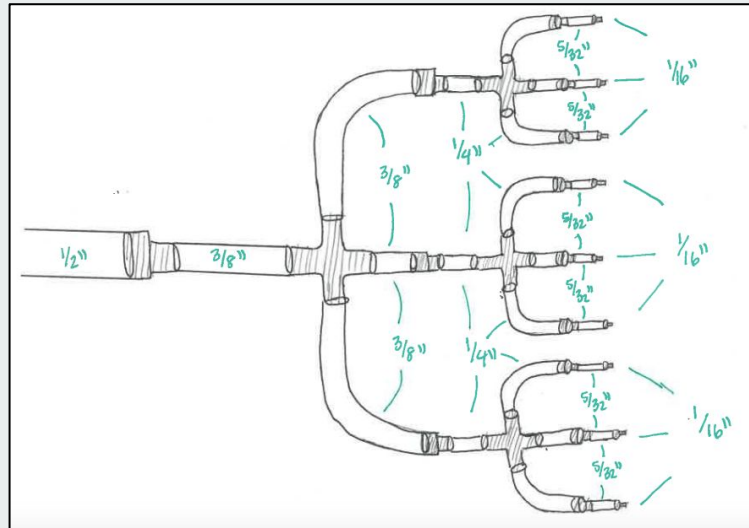
# CAD Model



# Final Prototype

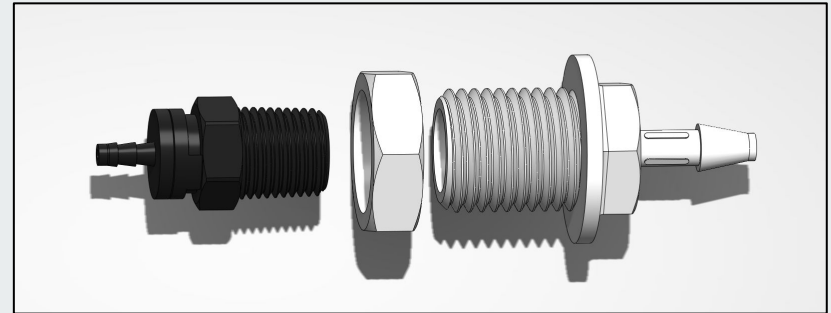
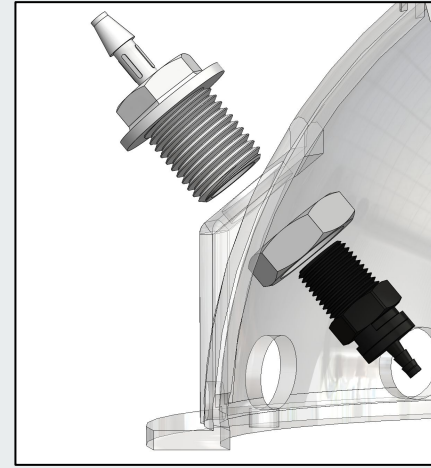


# Final Prototype





# Manufacturing Plan



# Artificial Feces Testing

Final Prototype Testing Summary		
Type of Sample	Average Run Time (seconds)	Average Water Use (gallons)
Stepped On	28.3	0.6
Smoothed	49.4	1.2
Dried	79.3	1.4

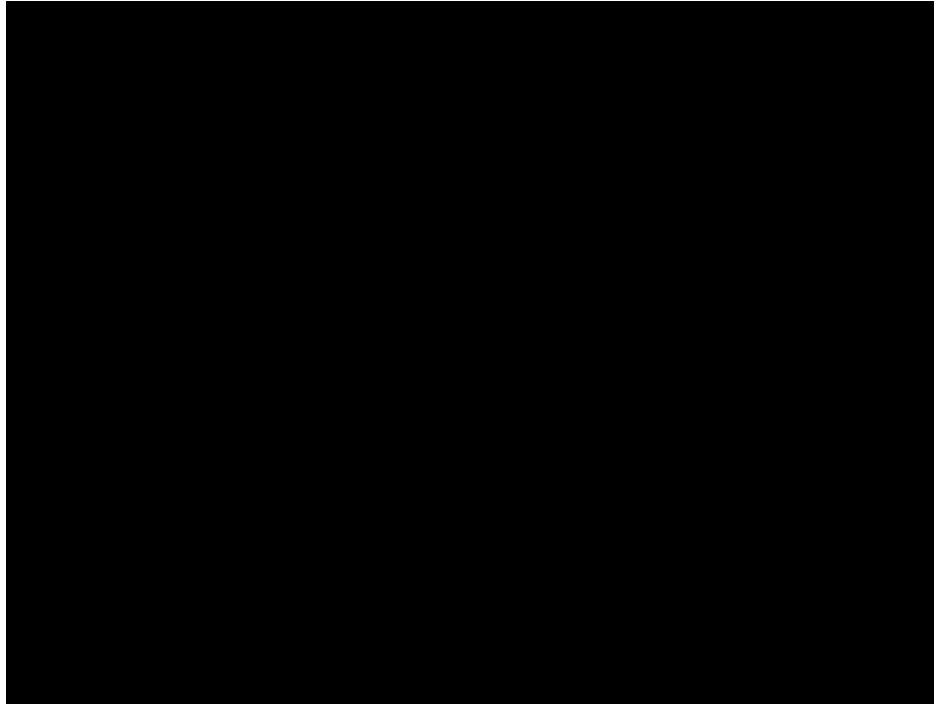


Smeared



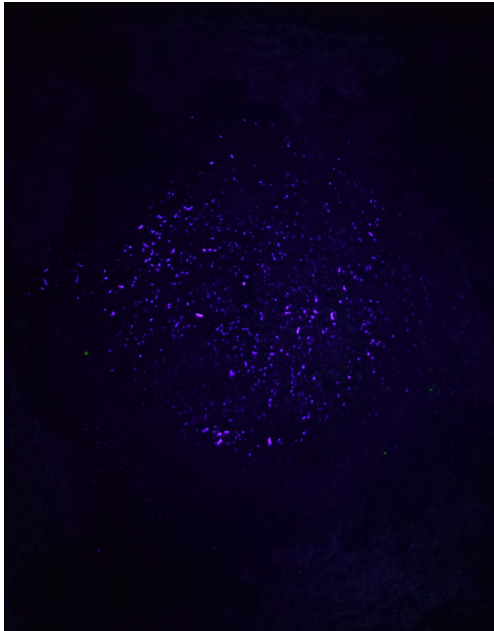
Stepped In

# UV Testing: Video

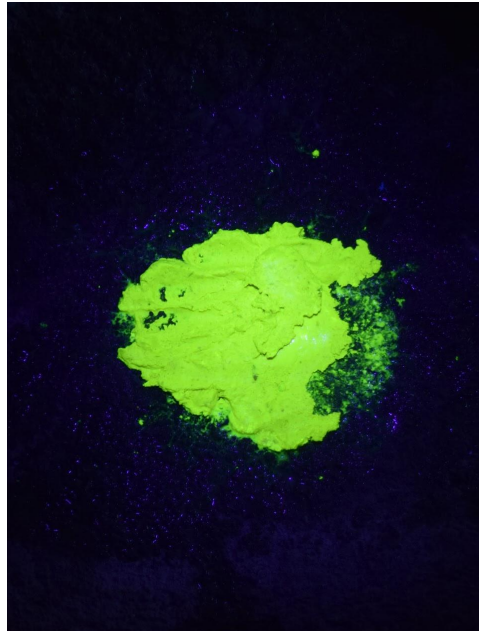


Actual time:  
65 seconds

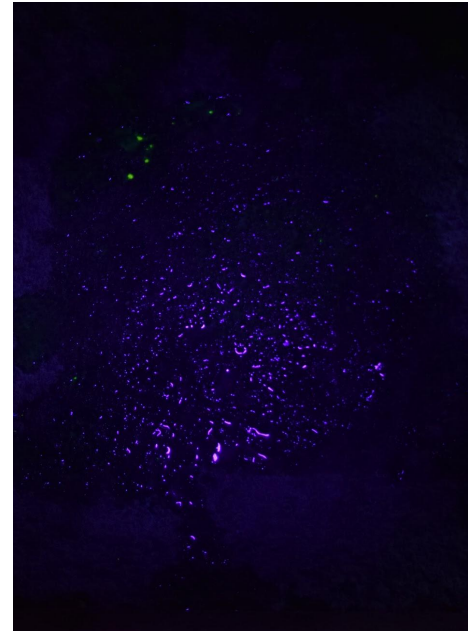
# UV Testing



Before Adding Sample



Initial Sample



After Removal

# Additional Aerosol Testing



Blue Dye Aerosol Testing



UV Aerosol Testing

# Dog Poop Testing



Feces and Liquid Soap

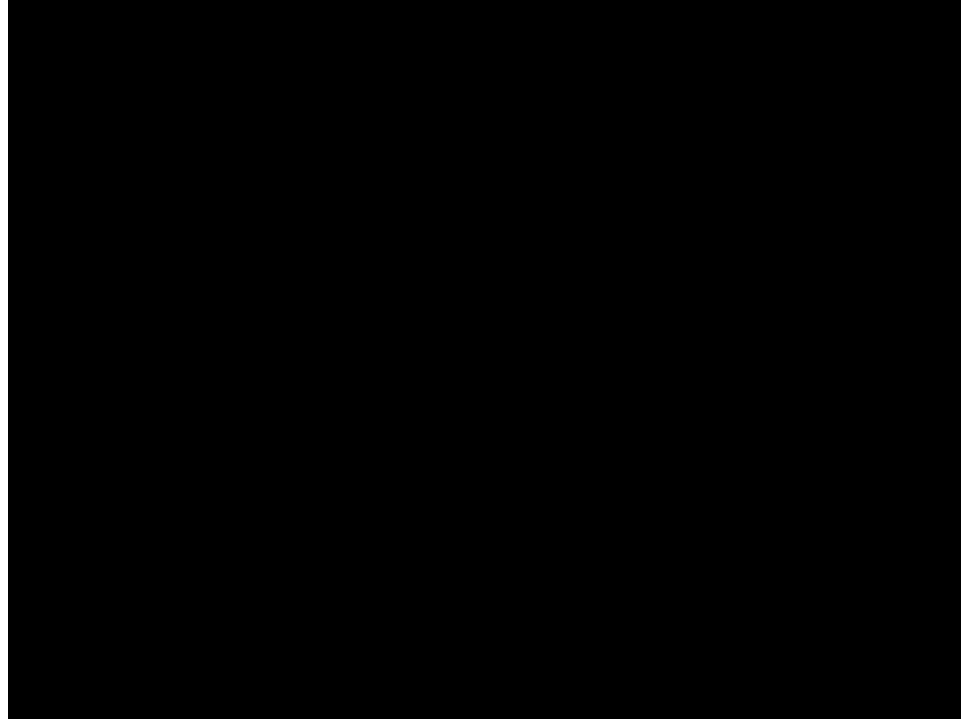


Stepping on Feces



After dome was run

# Dog Poop Testing: Video



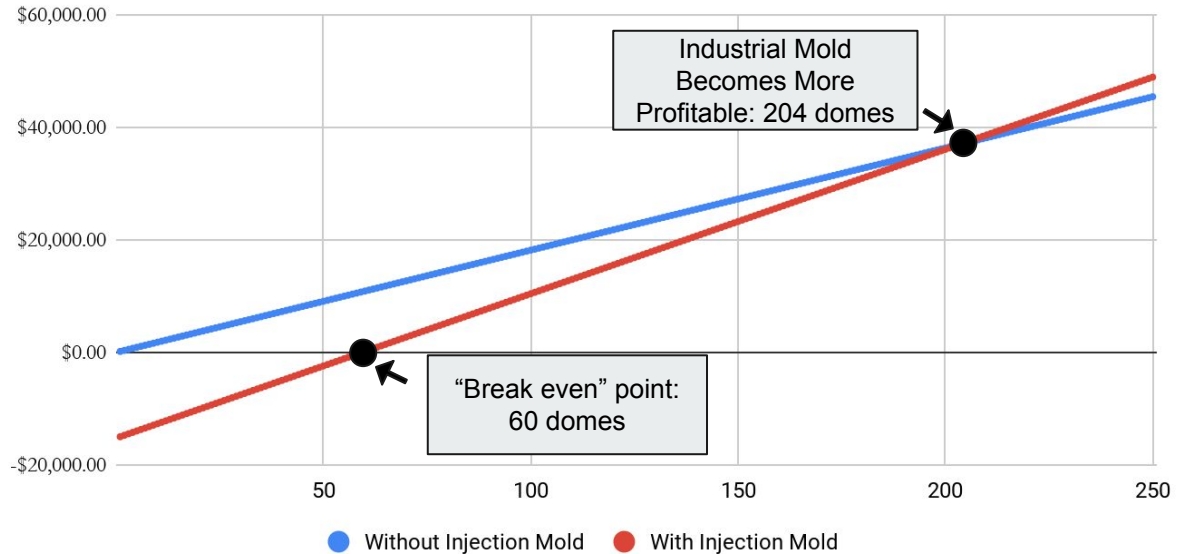
Actual time:  
48 seconds

# Economic Analysis



<b>Total Material Cost</b>		\$168.04
<b>Total Labor Cost without Injection Mold</b>	2 hours per dome at \$75/hr	\$150.00
<b>Total Labor Cost with Injection Mold</b>	1 hour per dome at \$75/hour	\$75.00
<b>Total Cost Without Injection Mold</b>		\$318.04
<b>Total Cost with Injection Mold</b>		\$243.04

**Profit from Domes with and without Injection Mold**  
Sold at \$500/dome

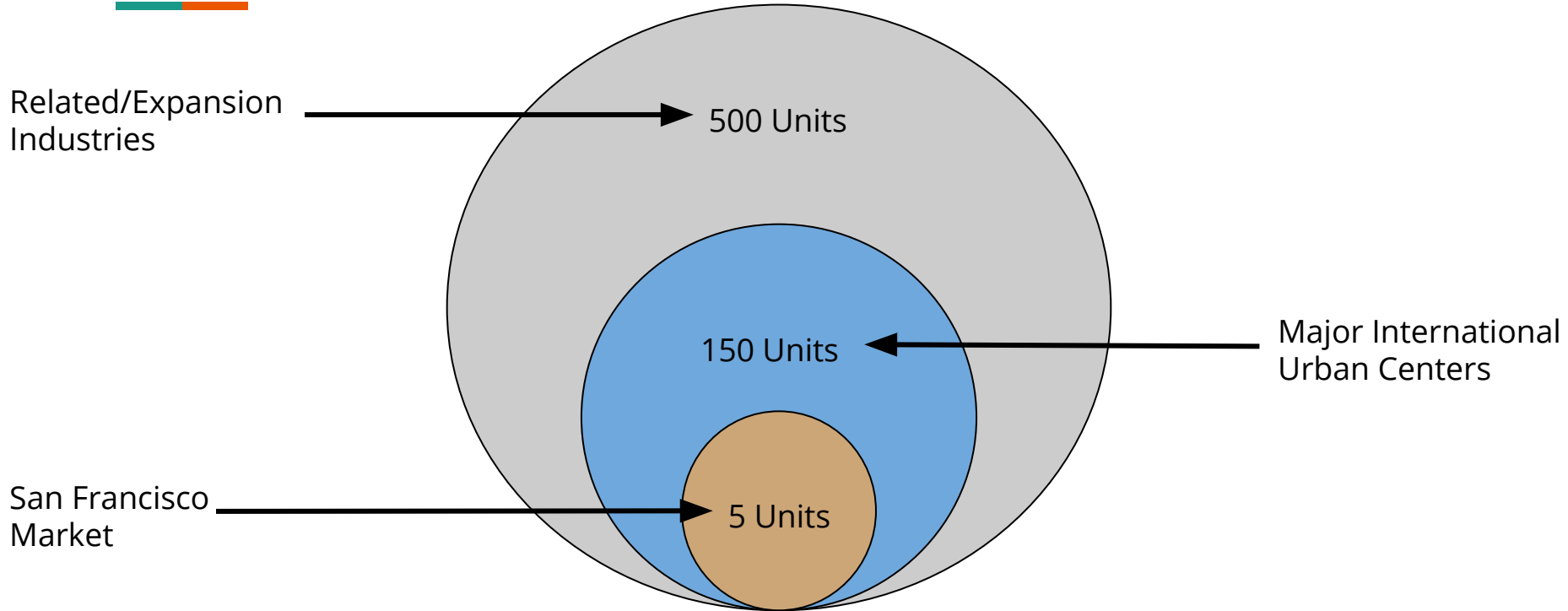




# Economic Analysis

<b>Cost of Additional System Components</b>	
Dome	\$500
Vacuum	~\$120 [20]
Pump	~ \$260[21]
Wagon	~\$100 [22]
<b>Total Cost of System without Powering Option</b>	<b>~\$980</b>
Generator	~\$1,000 [23]
<b>Total Cost with Generator Powering Option</b>	<b>~\$1,980</b>
Deep Cycle Marine Battery	~\$110 [24]
12 Volt Power Inverter	~\$130[25]
<b>Total Cost with Battery Powering Option</b>	<b>~\$1,220</b>

# Market Size



# Economics Summary

## Negative Externalities

- SF street cleaning budget:
  - \$35m increase since 2014
  - \$13m increase projected by 2029
- Case Study: San Diego Hep A Outbreak Cost \$13m
- \$9bn Tourism Industry, \$2bn focused on conventions: \$40m lost/convention

## Current System

- \$1500 for Pressure Water System
- \$1000 for Steam Cleaning System

## New Dome System

- \$500 per dome
- \$1,220 for entire battery powered system (including dome)
- \$1,980 for entire generator system (including dome)

## Benefits from Dome

### *User*

- Contained system: Chance of spread of disease lowered
- Higher quality of work for \$150k/yr salaried Poop Patrol Workers

### *Seller*

- With \$500 price per dome: \$113,000 profit from 500 domes

# Recommendations for Future Work

---

# Next Steps

- Streamlining tubing, custom splitters
- Vacuum wand attachment, not use glue, injection mold
- Ergonomic handle for vacuum wand
- Insert for easier cleaning
- Patent



Custom 3D-printed splitters

# Questions?



# Citations

---

- [1] Robinson, N. (2018, August 18). Why is San Francisco... covered in human feces? Retrieved September 30, 2018, from The Guardian website: <https://www.theguardian.com/commentisfree/2018/aug/18/San-francisco-poop-problem-inequality-homelessness>
- [2] Weber, L. (2018, June 13). Remember Last Year's Hepatitis A Outbreak? This Year It's So Much Worse. Retrieved from [https://www.huffingtonpost.com/entry/hepatitis-a-outbreak-this-year-much-worse\\_us\\_5b204e83e4b09d7a3d7829bd](https://www.huffingtonpost.com/entry/hepatitis-a-outbreak-this-year-much-worse_us_5b204e83e4b09d7a3d7829bd)
- [3] ECO John. Waterless Incinerating Toilet. Retrieved from [http://ecojohn.com/ecojohn\\_sr.html](http://ecojohn.com/ecojohn_sr.html)
- [4] "Airborne Germ Transition." *Delaware Health and Social Services*, dhss.delaware.gov/dhss/dph/files/airbornetranspi.pdf.
- [5] "N100 AND P100 RESPIRATORS." *Envirosafety*, [www.envirosafetyproducts.com/n100-and-p100-respirators.html](http://www.envirosafetyproducts.com/n100-and-p100-respirators.html).
- [6] "Polycarbonate vs. PETG." *Cut Plastic Sheeting*, [www.cutplasticsheeting.co.uk/blog/hints-and-tips/polycarbonate-vs-petg/](http://www.cutplasticsheeting.co.uk/blog/hints-and-tips/polycarbonate-vs-petg/).
- [7] "Water Soluble Portable Restroom Dry Toss Odor Control Packets." *Surco*, 24 July 2018, [www.surco.com/odor-control-solids/xtreme-dry-toss-packets/](http://www.surco.com/odor-control-solids/xtreme-dry-toss-packets/).
- [8] "Tap-A-Drop Air Freshener (Nested Carton)." *NilOdor*, 2018, [www.nilodor.com/OnlineCatalog/Tap\\_A\\_Drop\\_Air\\_Freshener\\_\\_Nested\\_Carton-b-details.aspx](http://www.nilodor.com/OnlineCatalog/Tap_A_Drop_Air_Freshener__Nested_Carton-b-details.aspx).
- [9] "Foot Switches." *McMaster-Carr*, [www1.mcmaster.com/foot-switches](http://www1.mcmaster.com/foot-switches).
- [10] Shaban, B., Campos, R., Rutanashoodech, A., Carroll, J., & Horn, M. (2018, April 23). Empty Shops Rise in San Francisco, Some Blame Dirty Streets. Retrieved from <https://www.nbcbayarea.com/investigations/Vacant-Businesses-Rising-in-San-Francisco-Real-Estate-Agents-Believe-Dirty-Streets-Partly-to-Blame-479041303.html>
- [11] Bendix, A. (2018, August 24). San Francisco has a 'Poop Patrol' to deal with its feces problem, and workers make more than \$184,000 a year in salary and benefits. Retrieved from <https://www.businessinsider.com/san-francisco-poop-patrol-employees-make-184000-a-year-2018-8>
- [13] Shaban, B., Campos, R., & Rutanashoodech, A. (2018, July 16). SF Mayor: 'There's More Feces ... Than I've Ever Seen'. Retrieved from <https://www.nbcbayarea.com/news/local/SF-Mayor-Theres-more-feces-on-the-sidewalks-than-Ive-ever-seen-488156431.html>



[14] Knight, H. (2018, January 30). SF tourist industry struggles to explain street misery to horrified visitors. Retrieved from <https://www.sfchronicle.com/news/article/SF-tourist-industry-struggles-to-explain-street-12534954.php>

[15] San Francisco Travel Association Research. (2018, March). Visit Volume and Direct Spending Estimates | 2017. Retrieved from <https://sftavel.ent.box.com/s/3oq7bqv1vj6j32catxluhl4ltagydnmx>

[16] Shaban, B., Campos, R., Horn, M., & Villarreal, M. (2018, July 04). San Francisco's Dirty Streets Scare Off Long-time Convention. Retrieved from <https://www.nbcbayarea.com/investigations/Dirty-Streets-Threaten-San-Francisco-Convention-Industry-487266591.html>

[17] Shaban, B., Campos, R., Rutanashoodech, A., Carroll, J., & Horn, M. (2018, April 23). Empty Shops Rise in San Francisco, Some Blame Dirty Streets. Retrieved from <https://www.nbcbayarea.com/investigations/Vacant-Businesses-Rising-in-San-Francisco-Real-Estate-Agents-Believe-Dirty-Streets-Partly-to-Blame-479041303.html>

[18] County of San Diego. (2018, May) Hepatitis A Outbreak 2017-2018. Retrieved from <https://www.sandiegocounty.gov/content/dam/sdc/cosd/SanDiegoHepatitisAOutbreak-2017-18-AfterActionReport.pdf>

[19] "Protoquote." *ProtoQuote* - 637632, 2019, [www.protomold.com/ProtoQuote.aspx?p=1265807f25p](http://www.protomold.com/ProtoQuote.aspx?p=1265807f25p).

[20]"RIDGID 14 Gal. 6.0-Peak HP NXT Wet Dry Vac with Wet Filter-HD1400B." *The Home Depot*, The Home Depot, 2019, [www.homedepot.com/p/RIDGID-14-Gal-6-0-Peak-HP-NXT-Wet-Dry-Vac-with-Wet-Filter-HD1400B/307814799](http://www.homedepot.com/p/RIDGID-14-Gal-6-0-Peak-HP-NXT-Wet-Dry-Vac-with-Wet-Filter-HD1400B/307814799).


[21]"SEAFLO 33-Series Industrial Water." *Amazon*, [www.amazon.com/gp/product/B076TGWYDK/ref=ppx\\_yo\\_dt\\_b\\_asin\\_title\\_o05\\_s00?ie=UTF8&psc=1](http://www.amazon.com/gp/product/B076TGWYDK/ref=ppx_yo_dt_b_asin_title_o05_s00?ie=UTF8&psc=1).

[22]"Gorilla Carts 800 Lb. Steel Utility Cart-GOR801." *The Home Depot*, The Home Depot, 18 Feb. 2019, [www.homedepot.com/p/Gorilla-Carts-800-lb-Steel-Utility-Cart-GOR801/206740078](http://www.homedepot.com/p/Gorilla-Carts-800-lb-Steel-Utility-Cart-GOR801/206740078).

[23]"Honda EU2200i Super Quiet 2200 Watt Portable Industrial Inverter Generator EU2200ITA." *Ohio Power Tool*, [www.ohiopowertool.com/p-20152-honda-eu2200i-super-quiet-2200-watt-portable-industrial-inverter-generator-eu2200ita.aspx?gclid=CjwKCAiAqt7jBRACeIwAof2uKxyuQxnh9a9WeaJo9fHLTN92RykiMIR82F01ggv-bwDsmYSW9Pc0ChoC6aoQAvD\\_BwE](http://www.ohiopowertool.com/p-20152-honda-eu2200i-super-quiet-2200-watt-portable-industrial-inverter-generator-eu2200ita.aspx?gclid=CjwKCAiAqt7jBRACeIwAof2uKxyuQxnh9a9WeaJo9fHLTN92RykiMIR82F01ggv-bwDsmYSW9Pc0ChoC6aoQAvD_BwE).

[24]"Nautilus 31 Deep Cycle Marine Battery-31MDC." *The Home Depot*, The Home Depot, 27 Mar. 2018, [www.homedepot.com/p/Nautilus-31-Deep-Cycle-Marine-Battery-31MDC/205309650](http://www.homedepot.com/p/Nautilus-31-Deep-Cycle-Marine-Battery-31MDC/205309650).





[25]“HAMMERDOWN 1500-Watt 12-Volt Power Inverter-HD1500.” *The Home Depot*, The Home Depot, 30 Jan. 2019, [www.homedepot.com/p/HAMMERDOWN-1500-Watt-12-Volt-Power-Inverter-HD1500/306133292](http://www.homedepot.com/p/HAMMERDOWN-1500-Watt-12-Volt-Power-Inverter-HD1500/306133292).

[26] IBISWorld. (n.d.) Colleges & Universities in the US: Industry Data. Retrieved November 9, 2018, from <https://clients1.ibisworld.com/reports/us/industry/keystatistics.aspx?entid=1970#ID>

[27] Kapur, Mallika. “Desperate and Disgusted: India’s Human Waste Removers.” *CNN*, Cable News Network, 2 Oct. 2014, [www.cnn.com/2014/10/02/world/asia/india-waste-scavengers/index.html](http://www.cnn.com/2014/10/02/world/asia/india-waste-scavengers/index.html).

[28] Fravel, L. (2018, October 02). Critics Question Zoos’ Commitment to Conservation. Retrieved November 9, 2018, from <https://www.nationalgeographic.com/animals/2003/11/news-zoo-commitment-conservation-critic/>.

[29] National Association of State Park Directors. (n.d.). State Park Facts. Retrieved November 9, 2018, Retrieved from <https://www.stateparks.org/about-us/state-park-facts/>

[30] Buell, S. (2016, September 28). Boston’s Canada Goose Problem Is Bad, And Here’s What We Can Do About It. Retrieved November 9, 2018, Retrieved from <https://www.bostonmagazine.com/news/2016/09/28/canada-geese-boston/>.

[31] Kidd, K. (2017, June 20). Yes, dog parks can be poop pastures, but are they unsafe? Retrieved November 9, 2018, from <https://www.denverpost.com/2017/04/16/dog-park-safety-denver-colorado/>.

[32] Amir, A. (2018, May). Janitorial Service in the US. Retrieved from <https://clients1.ibisworld.com/reports/us/industry/default.aspx?entid=1496>

[33] Lecture 34: Analytical solution of diffusion equation for 2D and 3D system. (n.d.). Retrieved November 9, 2018, from <https://nptel.ac.in/courses/105103026/34>

[34]“Tap-A-Drop Air Freshener (Nested Carton).” *NilOdor*, 2018, [www.nilodor.com/OnlineCatalog/Tap\\_A\\_Drop\\_Air\\_Freshener\\_Nested\\_Carton-b-details.aspx](http://www.nilodor.com/OnlineCatalog/Tap_A_Drop_Air_Freshener_Nested_Carton-b-details.aspx).

[35]“Water Soluble Portable Restroom Dry Toss Odor Control Packets.” *Surco*, 24 July 2018, [www.surco.com/odor-control-solids/xtreme-dry-toss-packets/](http://www.surco.com/odor-control-solids/xtreme-dry-toss-packets/).