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Powder Removal in Microgravity Environments (PRIME)

Team 518

Team Introductions

Kyle Evans
Thermal Fluids Engineer

Tripp Lappalainen
Manufacturing and Design Engineer

Chelsea Kiselewski
Quality and Design Engineer

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Team Introductions

Cole Daly
Mechatronics Engineer

Lauren McNealy
Systems Engineer

Alexander Fryer
Project and Test Engineer

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Sponsor

Project Sponsor
Justin McElderry
Materials Engineer -
NASA Marshall Space Flight Center

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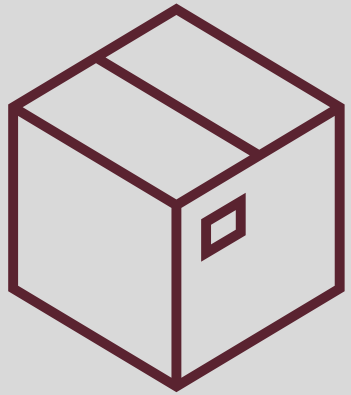
Objective

The objective of this project is to develop a proof-of-concept device for removing powder residue from additive manufactured parts in microgravity environments.

Clean → Move → Contain



Project Background

SLM/SLS (Selective Laser Melting/Selective Laser Sintering) is a process in which metal powder is fused by laser, creating new objects layer by layer.

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Project Background

SLM printing has multiple benefits:

- Rapid Prototyping
- Complex Geometry
- Cost Reduction

Project Background

SLM parts must be cleaned due to potential dangers:

- Risk of Combustion
- Respiratory Hazard
- Poor performance

Key Goals

- Automatic Operation

- Contain Dirty Solvent

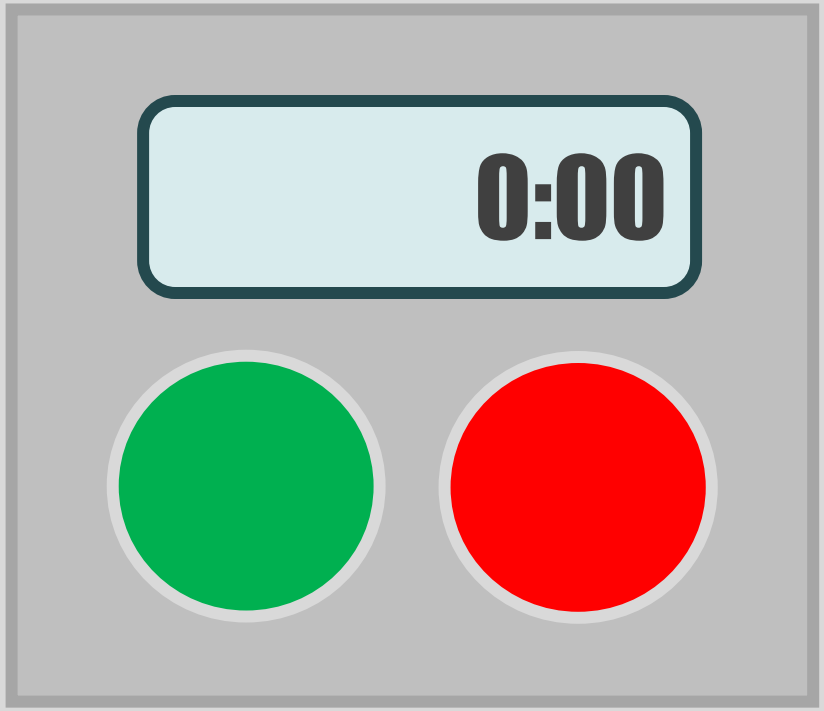
- Clean Internal Features

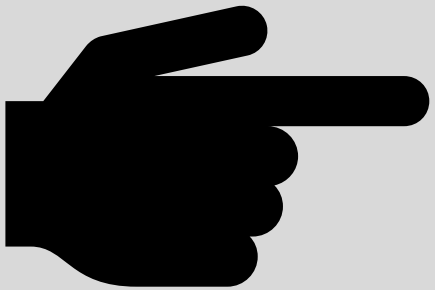
- Durable

- Functions in Microgravity

Key Goals

Automatic Operation





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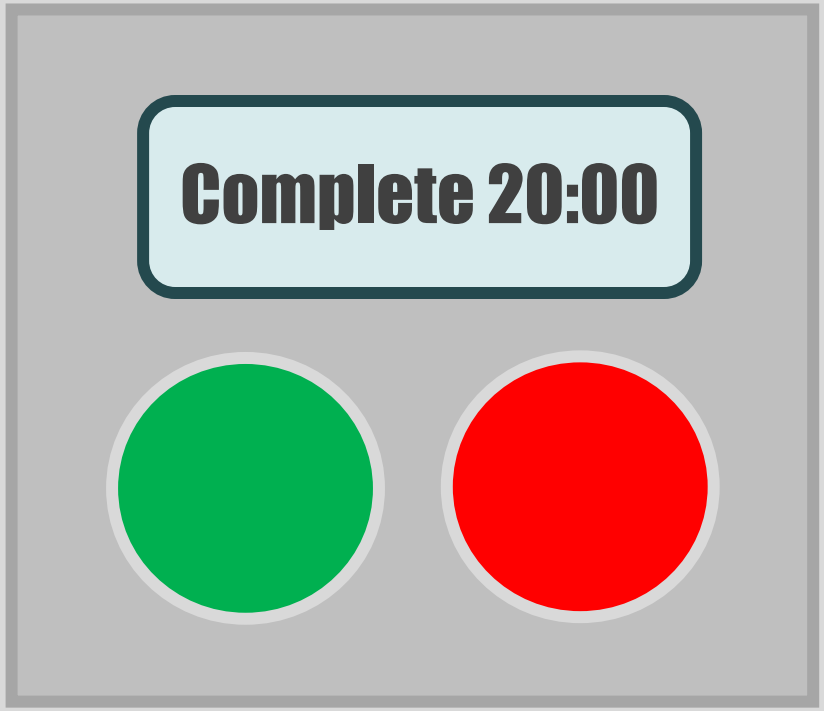
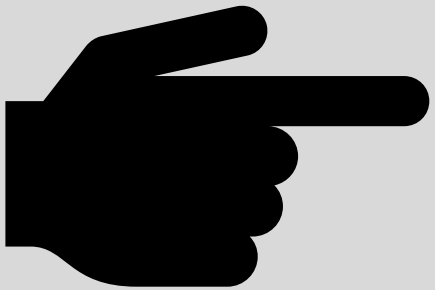
Key Goals

Automatic Operation





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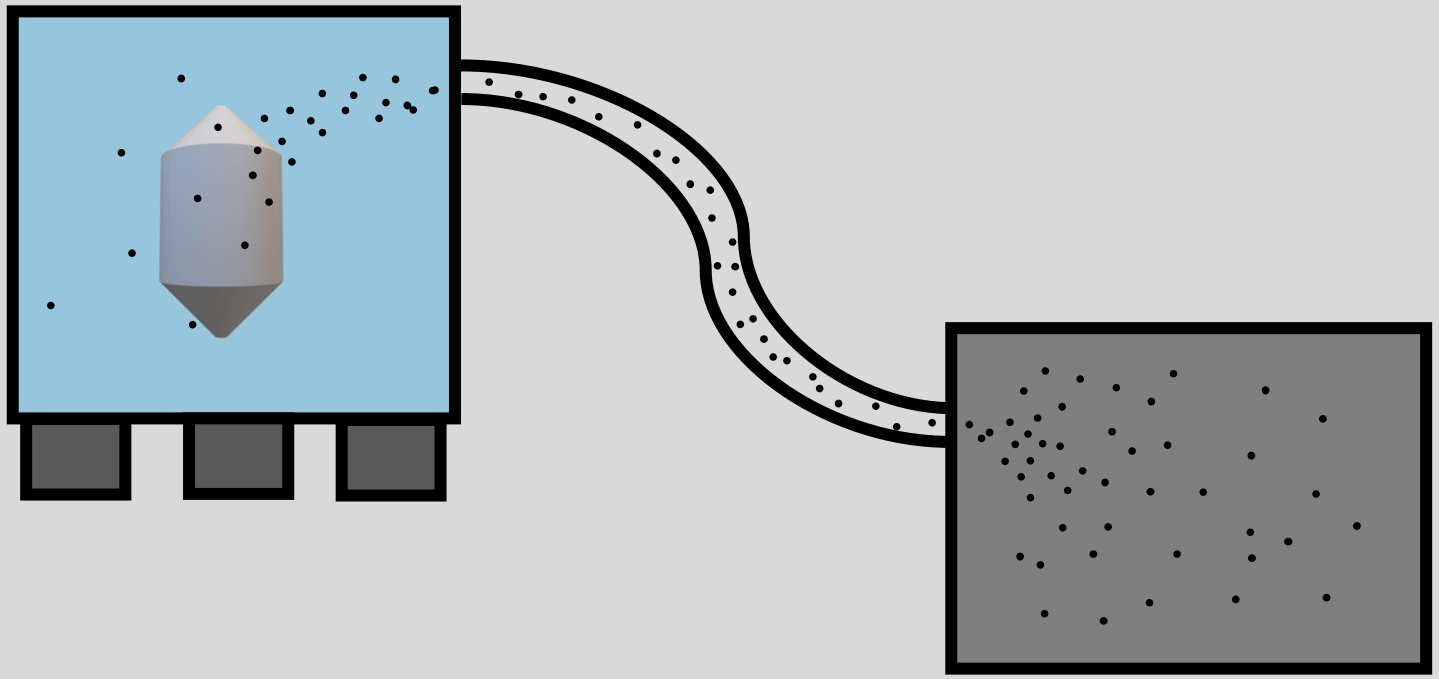
Key Goals

Contain Dirty Solvent



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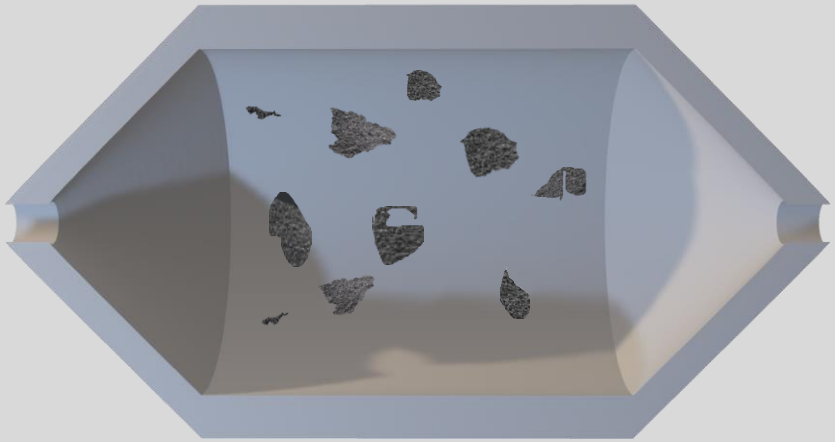
Key Goals

Clean Internal Features



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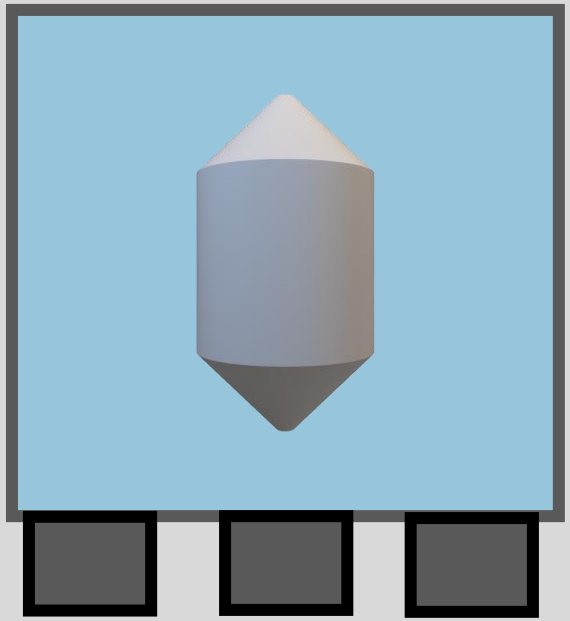
Key Goals

Durability



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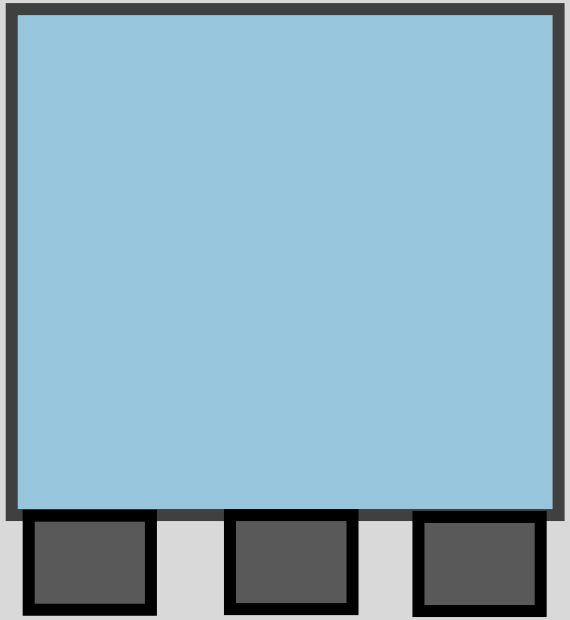
Key Goals

Functions in Microgravity



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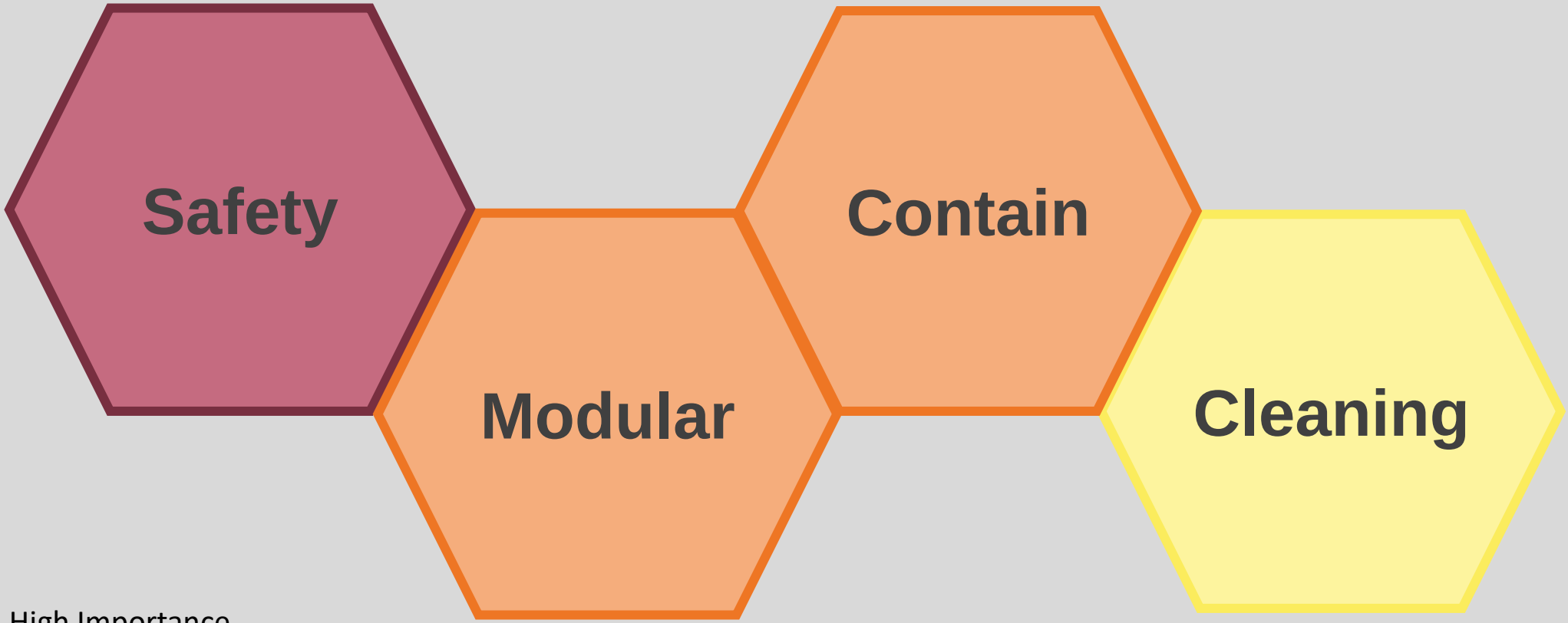
Targets and Metrics



- High Importance
- Medium Importance
- Low Importance

Targets and Metrics

Safety: Operation will be safe and will not harm the user in any way.

- Modular
- Contain
- Cleaning

- High Importance
- Medium Importance
- Low Importance

Targets and Metrics

Modular: Modules will be 8" x 8" x 8" max length

Safety

Contain

Cleaning

- High Importance
- Medium Importance
- Low Importance

Targets and Metrics

Contain: Particles are contained with no leaks in the device

Safety

Modular

Cleaning

- High Importance
- Medium Importance
- Low Importance

Targets and Metrics

Cleaning: Design will be able to clean 85-90% of debris

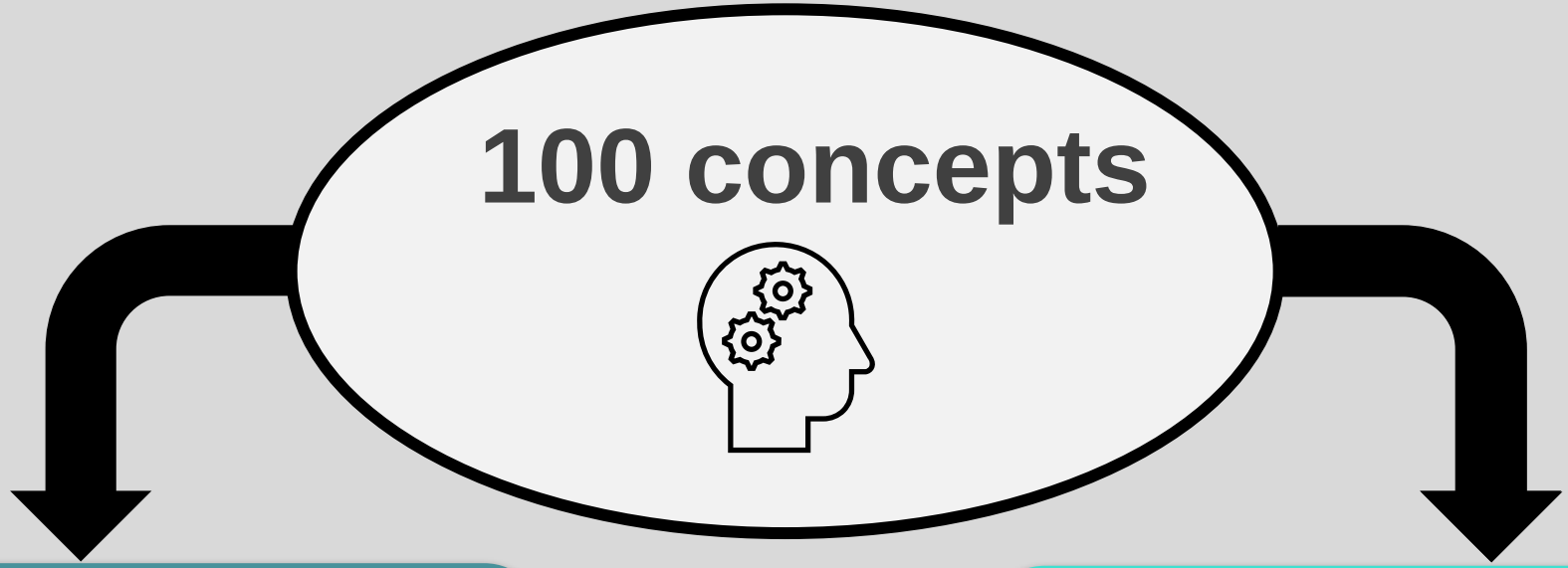
- High Importance
- Medium Importance
- Low Importance

Safety

Modular

Contain

Concept Generation

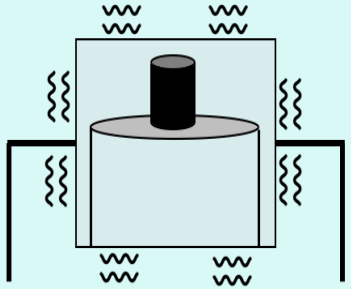


5 Medium Fidelities

3 High Fidelities

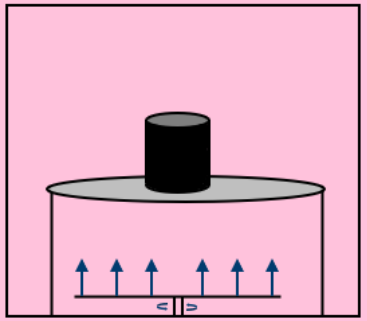
Medium Fidelities

Momentum Shaker



1

Dishwasher



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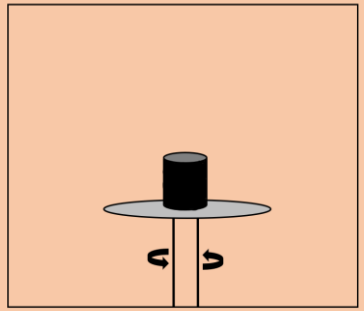
Spinning Plate



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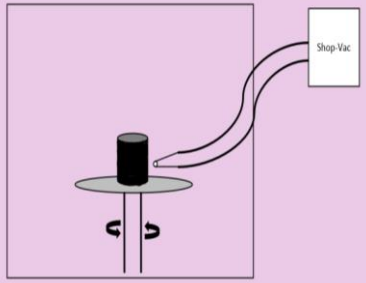
Shop-Vac



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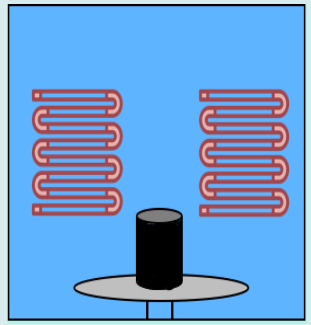
Boiling Water



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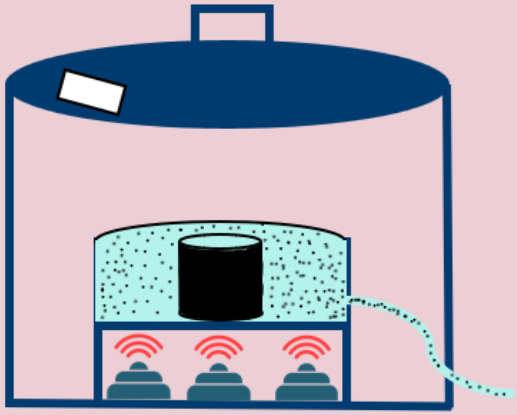
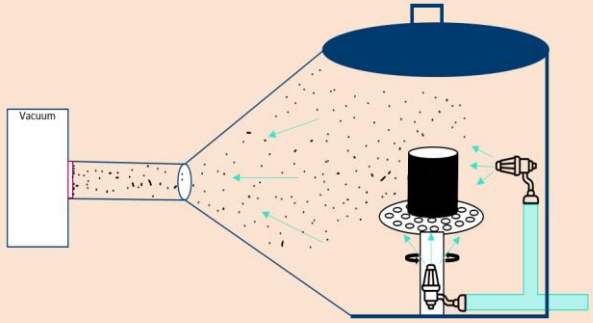
High Fidelities

Sonic Wave Cleaner



1

Liquid Nitrogen Spray



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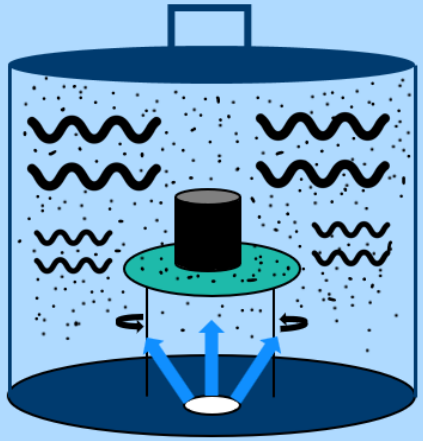
Vacuum Nucleation



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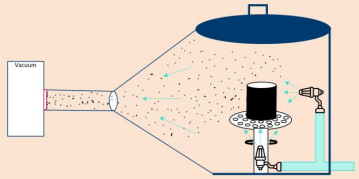
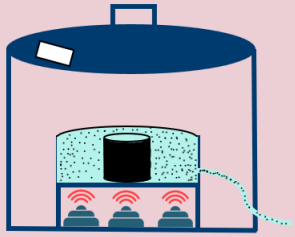
Binary Pairwise → House of Qualities → First Iteration Pugh chart → Second Iteration Pugh chart → AHP

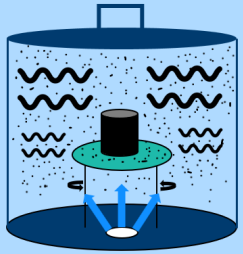
Liquid Nitrogen Spray



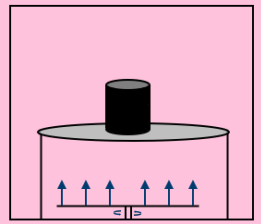
Sonic Wave Cleaner



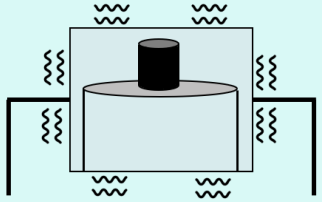
Vacuum Nucleation



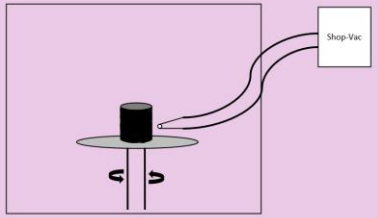
Dishwasher



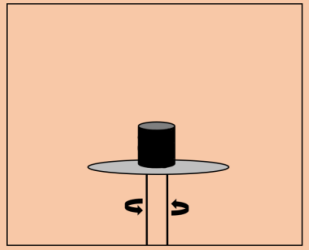
Momentum Shaker



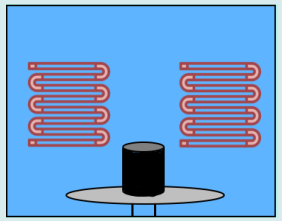
Shop-Vac Hose



Spinning Plate



Boiling Water



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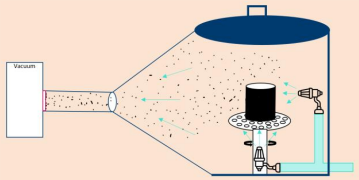
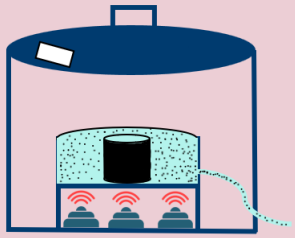
Binary Pairwise → House of Qualities → First Iteration Pugh chart → Second Iteration Pugh chart → AHP

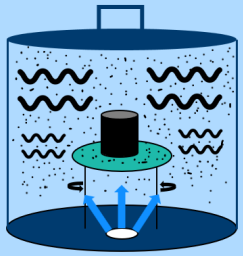
Liquid Nitrogen Spray



Sonic Wave Cleaner

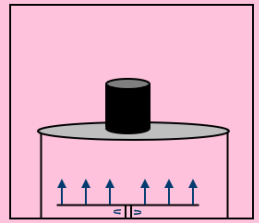


Vacuum Nucleation

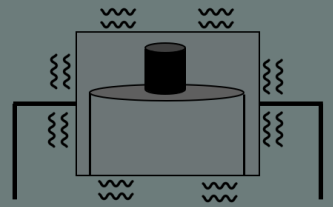


NEW DATUM

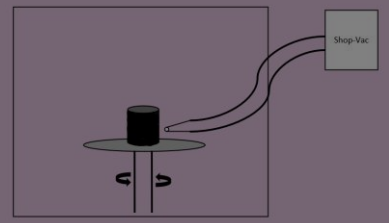
Dishwasher



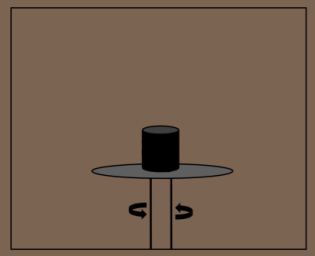
Momentum Shaker



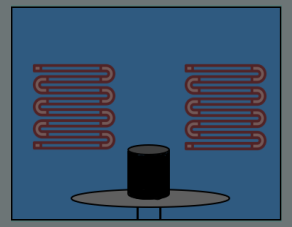
Shop-Vac Hose



Spinning Plate



Boiling Water



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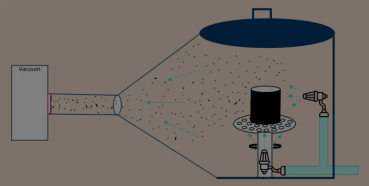
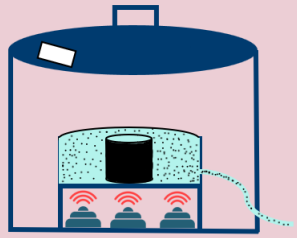
Binary Pairwise → House of Qualities → First Iteration Pugh chart → Second Iteration Pugh chart → AHP

Liquid Nitrogen Spray



Sonic Wave Cleaner



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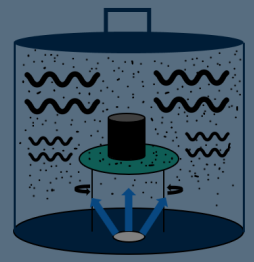

NEW DATUM

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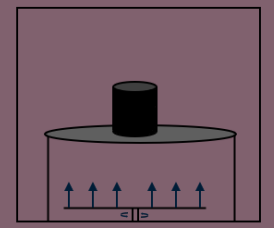
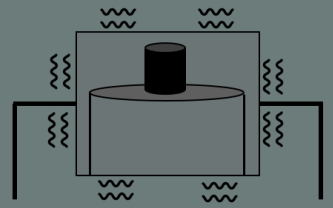


Momentum Shaker



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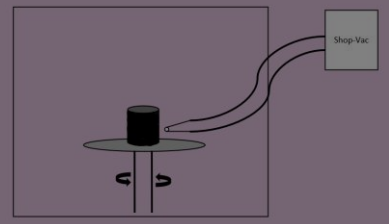
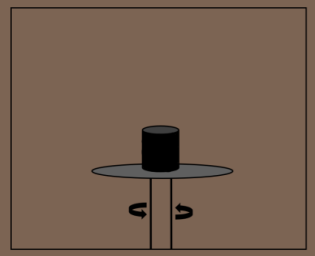
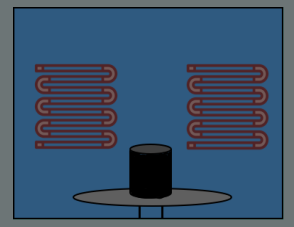


Spinning Plate



Boiling Water



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Binary Pairwise → House of Qualities → First Iteration Pugh chart → Second Iteration Pugh chart → AHP

Final Selection	
Concept	Alternative Value
Sonic Wave Vibrational Cleaning	0.533
Liquid Nitrogen Sprayer	0.333
Pulsing Vacuume Nucleation	0.134

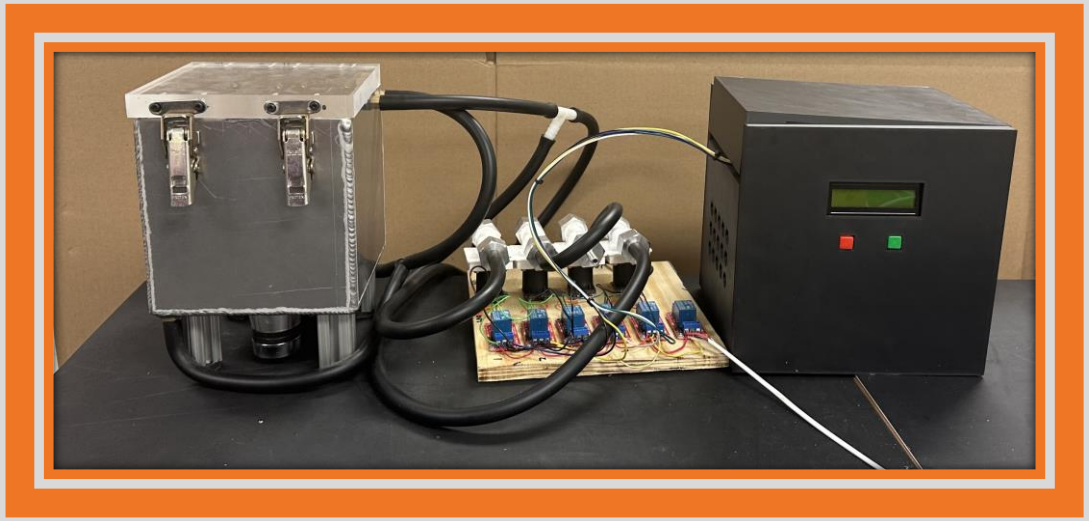
The Sonic Wave Cleaner

1. Cleaning fluid is supplied

2. Sonic waves pulsed underneath fluid creating scrubbing force

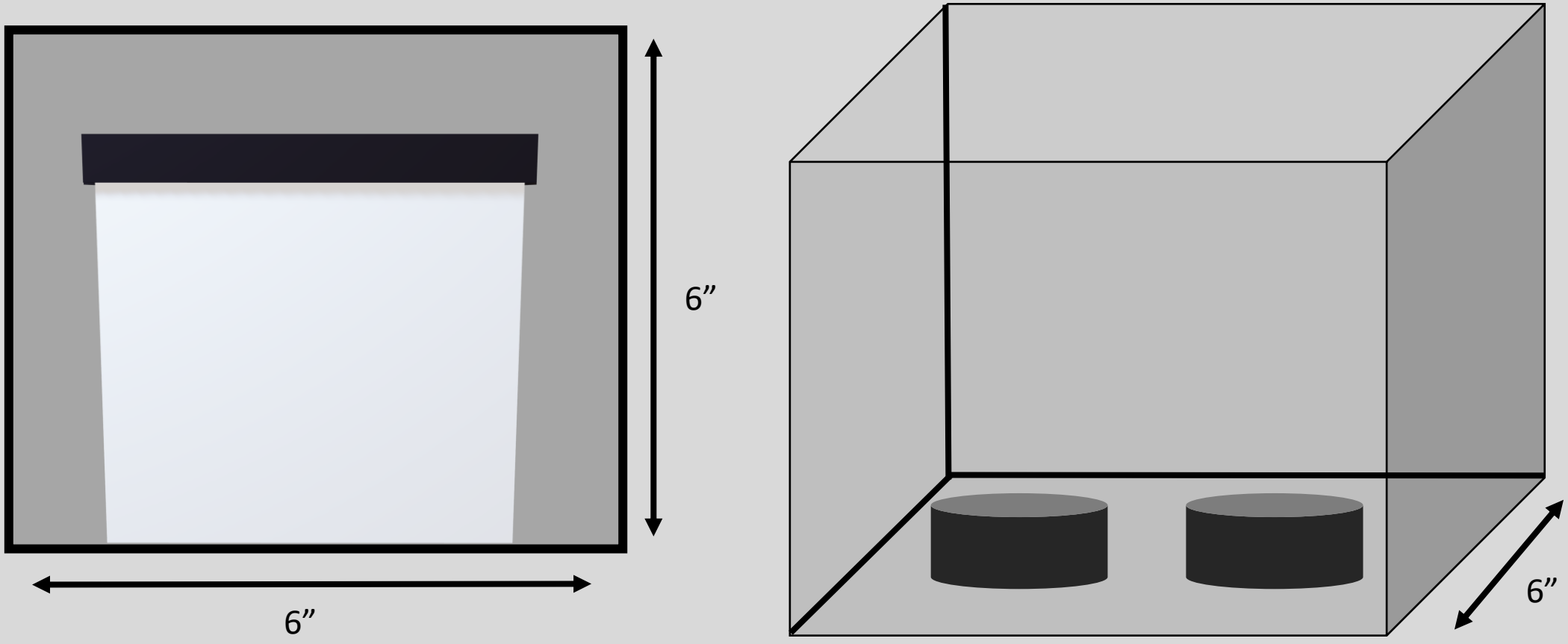
3. Air will be pushed into the main body, while drain valve is opened

The Sonic Wave Cleaner



- Closed system to contain medium
- Fill and drain system
- Able to test in any orientation

The Sonic Wave Cleaner



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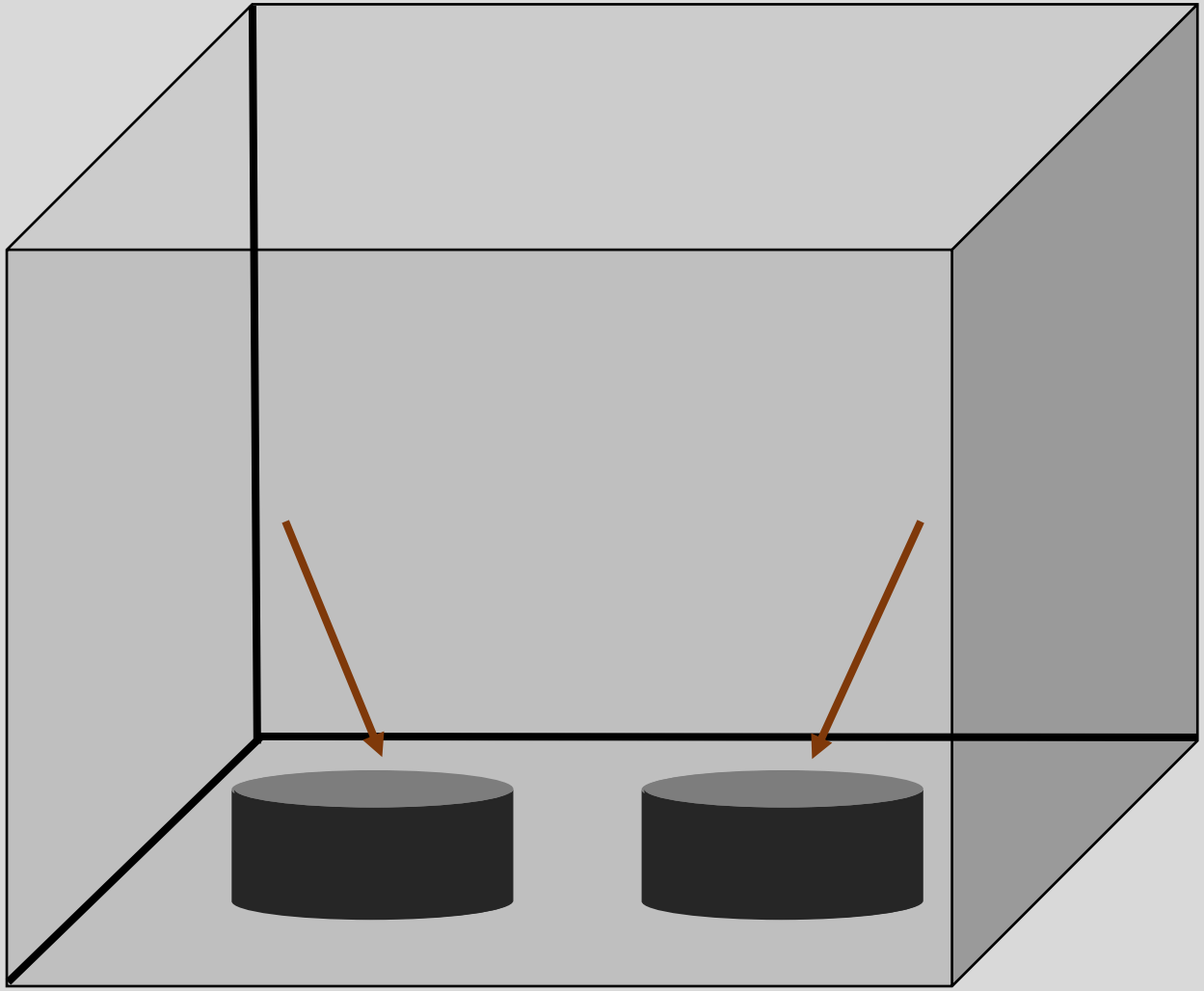
Inner Components – Mesh Basket

- The mesh basket will be secured to the sides of the main body
- It will hold contaminated part to avoid damage
- Size is 5" x 5" x 4.5" to account for microgravity conditions

Overview

How prototype functions:

- Two sensors (40kHz)
- Maximum coverage of the box
- Mesh basket inside above sensors



Overview

How prototype functions:

- Two sensors (40kHz)
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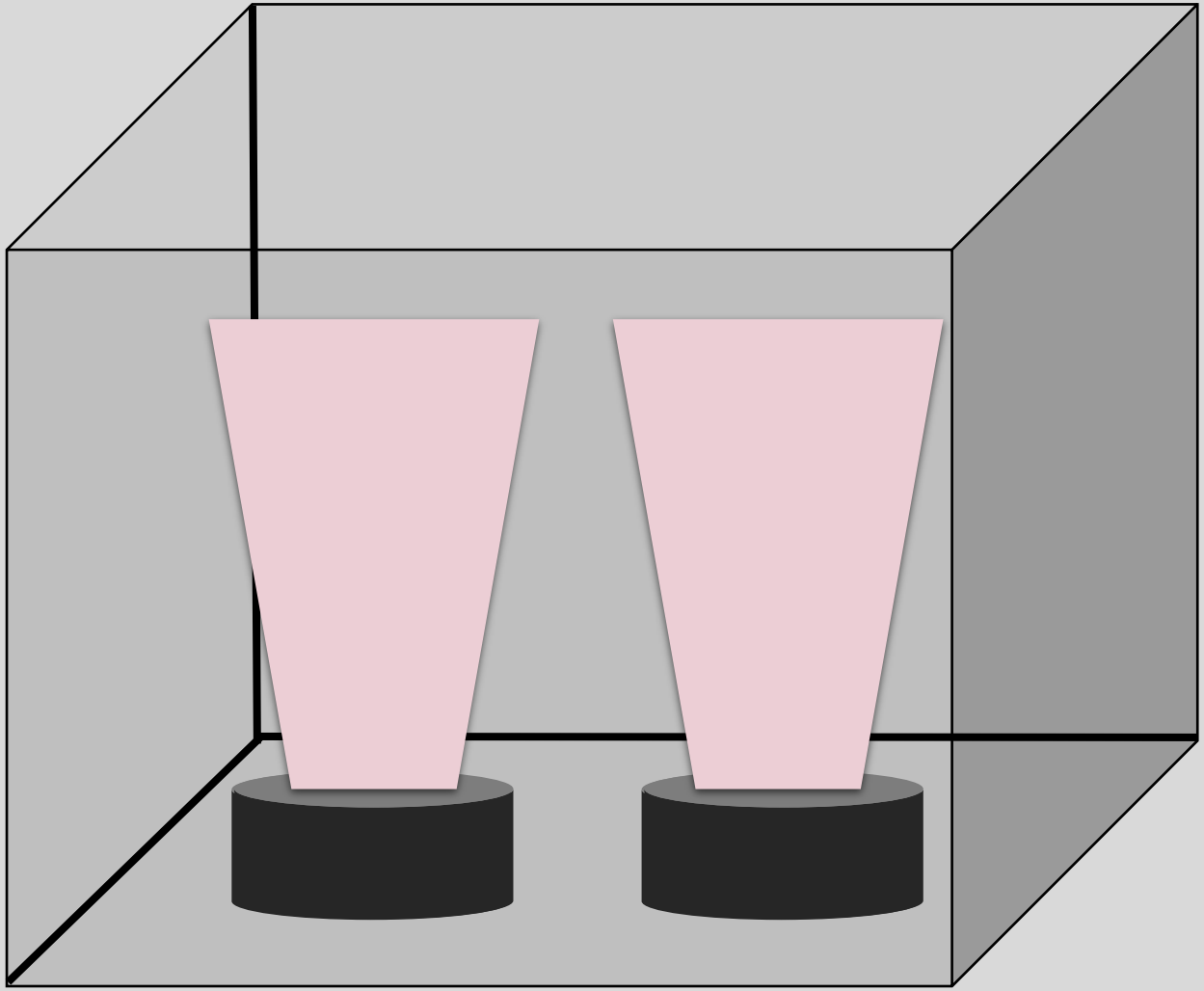

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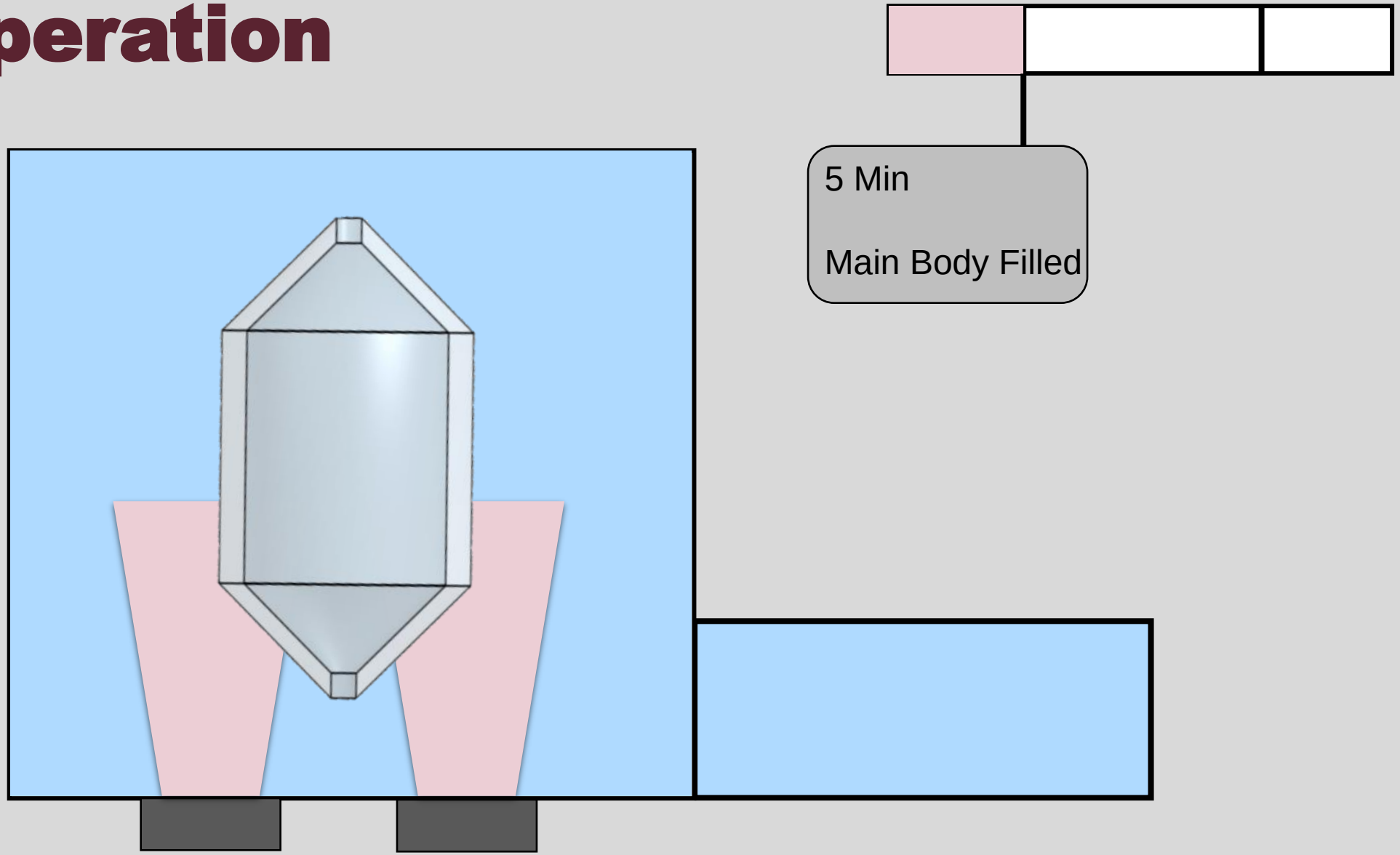
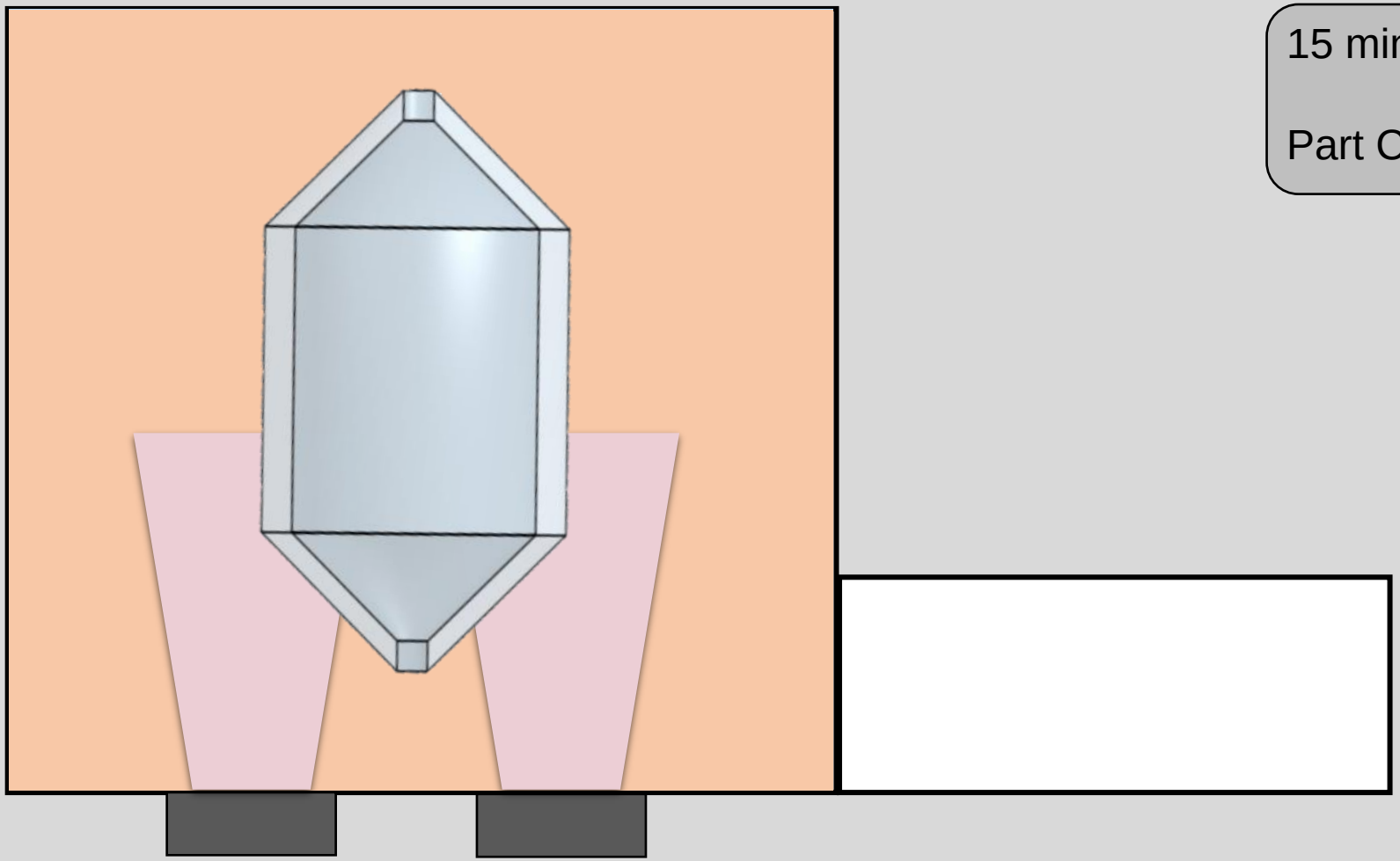
Operation



Operation



15 min

Part Cleaned

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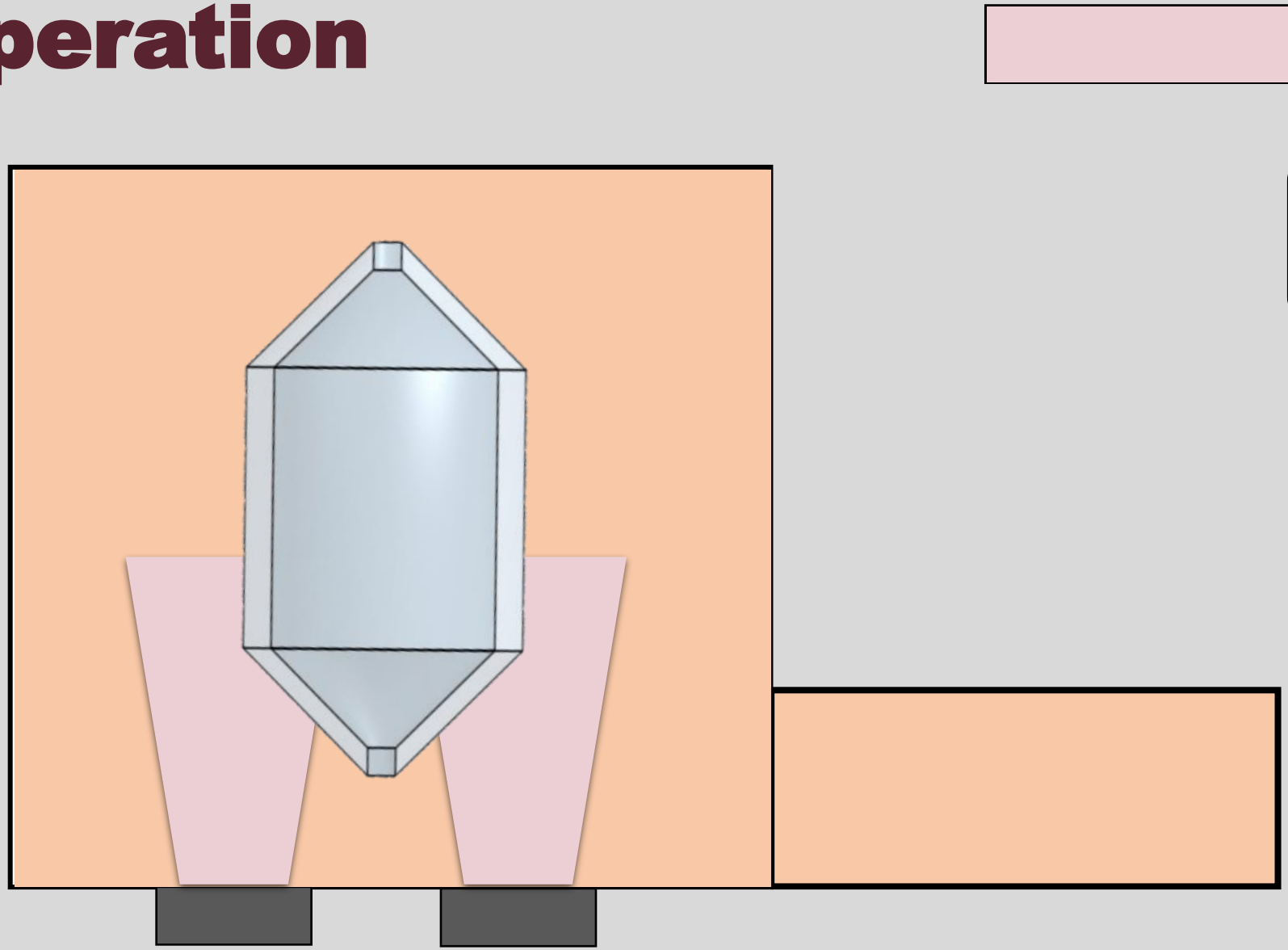
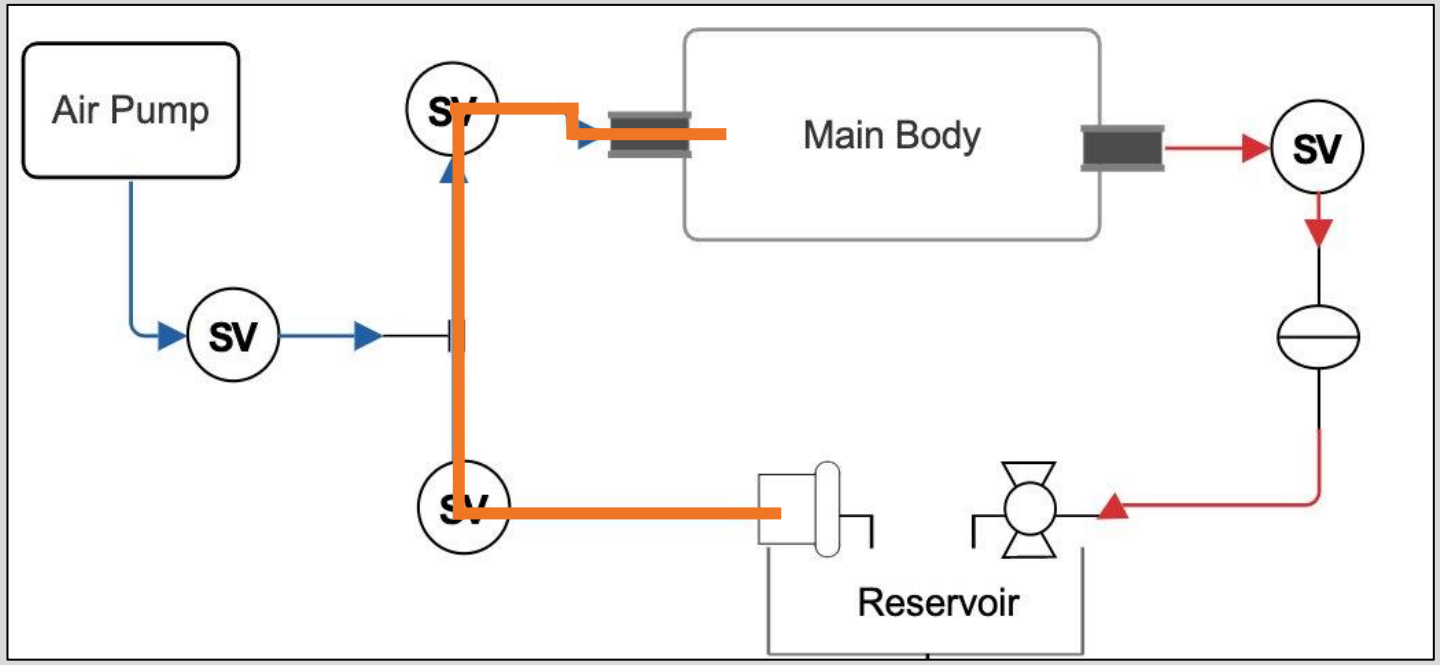
Operation

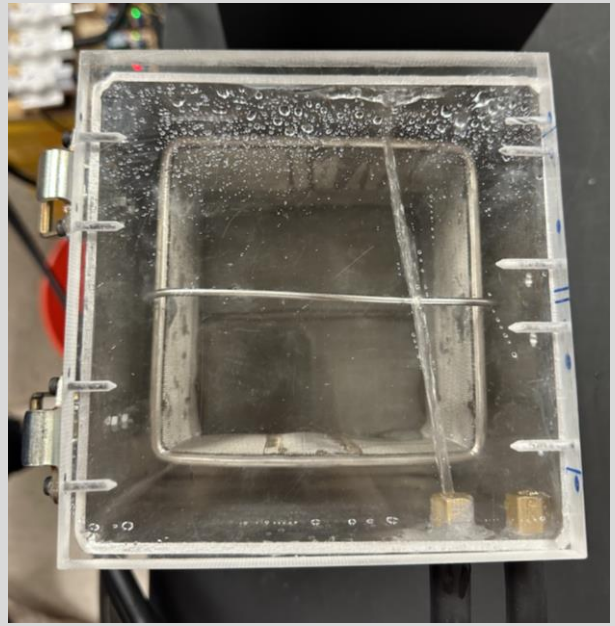


20 min

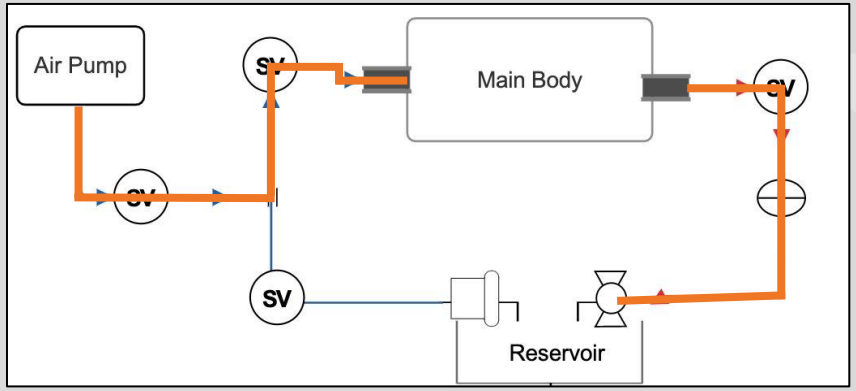
Drained

Filling Process





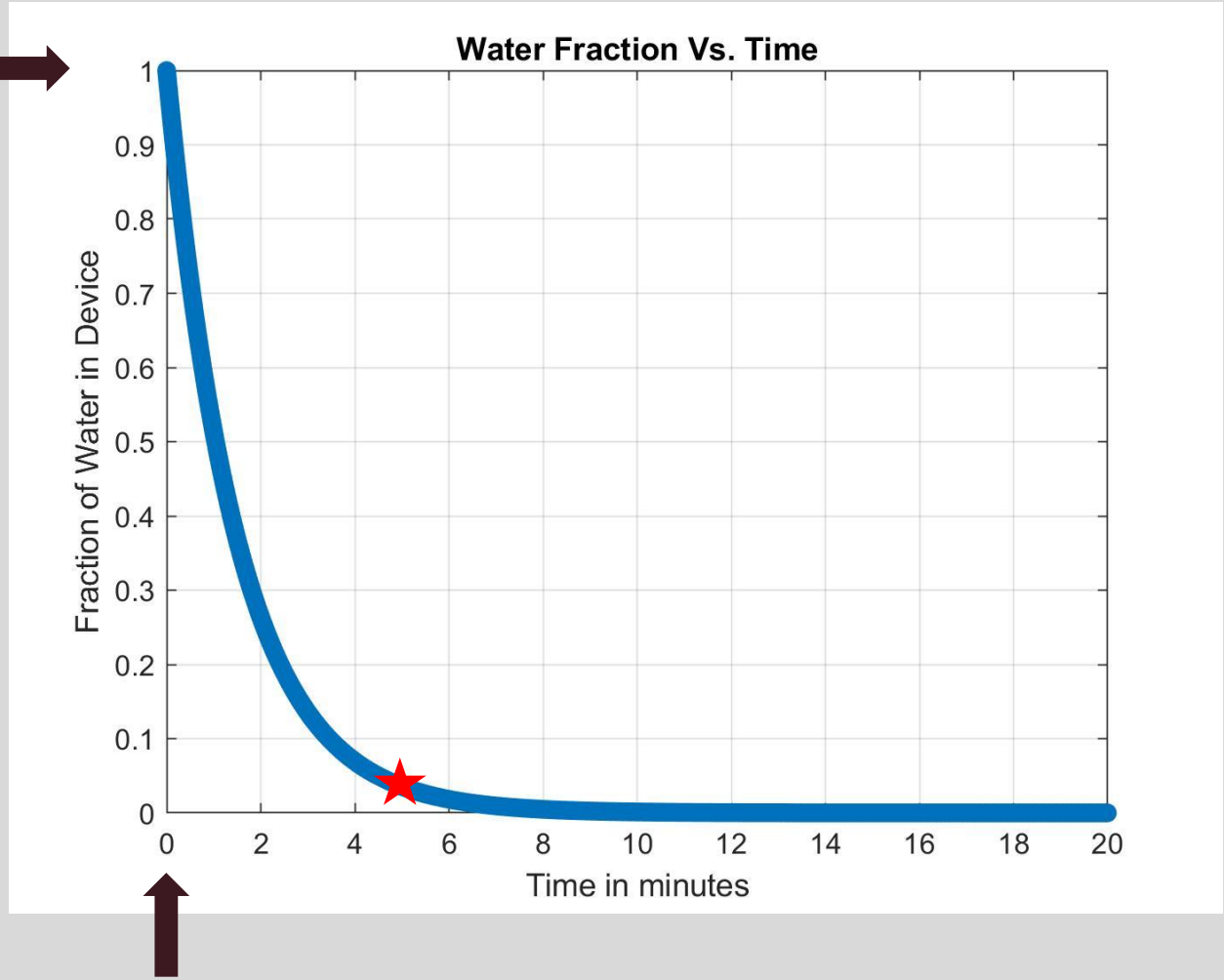
Draining Process



Compressed Air

Solution

Percent Water During Draining

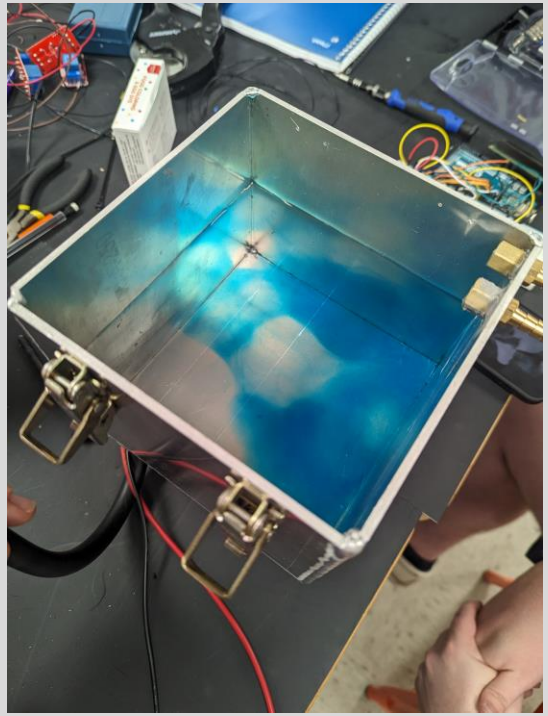


Ultrasonic Strength + Dye Mixing Experiment

Tested with water

Hooked up to power

A drop of food coloring

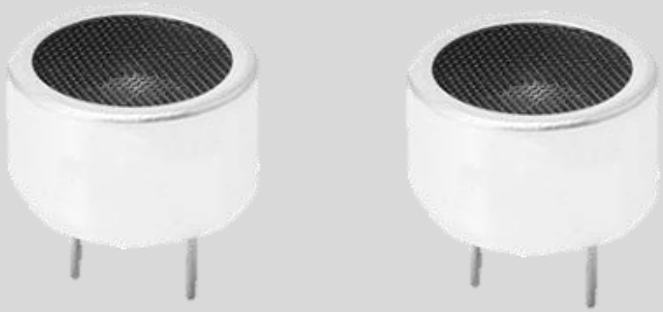


Sensors turned on to visualize flow

Improved Ultrasonics

OLD

- 15V – 40 kHz

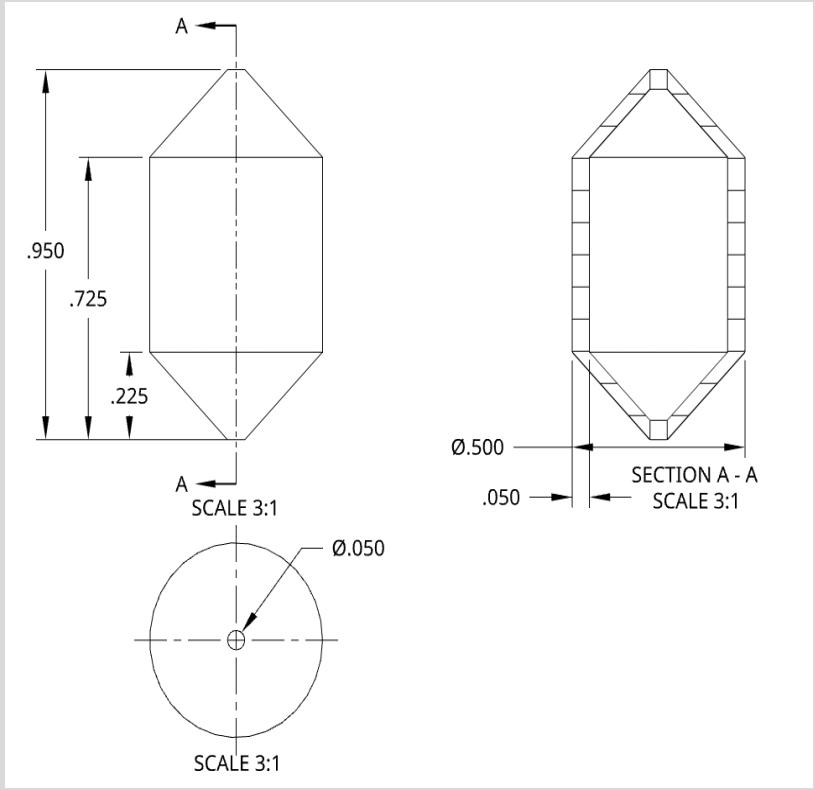


NEW

- 50V – 40 kHz

Test part

- Made with SLS printing
- Particle size 40 micron
- Nylon 12 part created on Formlabs Fuse 1+



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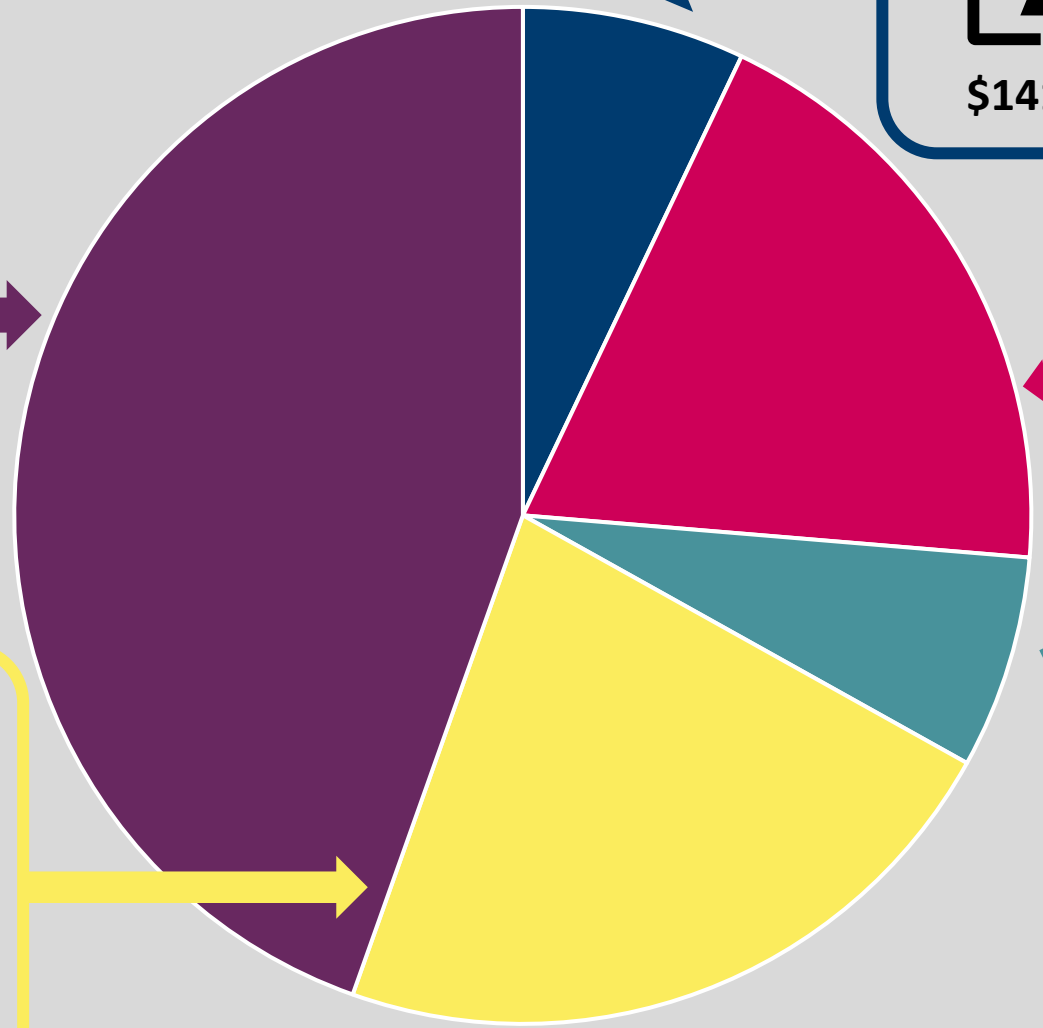
Validation method

Specimen with metal powder gets weighed before it enters the machine

The machine cleans the part

Cleaned specimen gets weighed, compare to previous weight and theoretical weight (CAD)

Project Budget



Electrical Components

$141.52

Plumbing Components

$384.94

Materials

$135.49

Internal Parts

$446.69

Remaining Budget

$891.35

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Conclusion

Goal: Develop a proof-of-concept device for removing powder residue from additive manufactured parts in microgravity environments.

- Safety
- Modular
- Contain
- Cleaning

Safety

Goal

- Operation will be safe and will not harm the user in any way.

Results

- The device has been tested to ensure powder is contained.
- No sparks/smoke have been observed.
- The box has not been heated to unsafe levels for the sensors.

Modular

Goal

- Modules will be 8" x 8" x 8" max length

Results

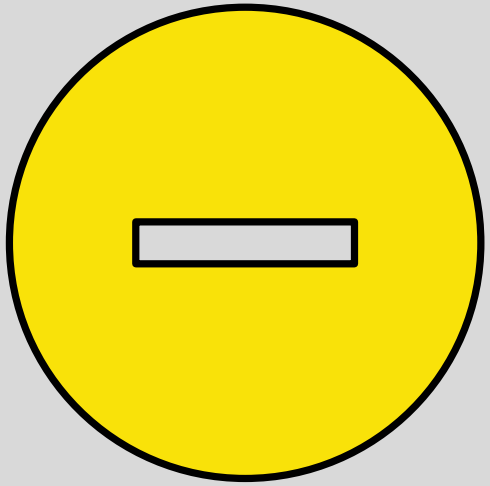
- Every module has been measured to be within the target of 8”

Module	Length	Width	Height	Outcome
Cleaning Module	6”	6”	8”	
Plumbing Module	8”	8”	Find	
Electronics Module	7”	8”	8”	

Contain

Goal

- Particles are contained with no leaks in the device



Results

- Open lid/plumbing testing has shown to contain the solvent.
- Still need watertight testing of the drains to test containment.

Cleaning

Goal

- Design will be able to clean 85-90% of debris

Results

- Sensors have shown to not be sufficient to clean the part. Further testing will be used to find solutions such as adding abrasives to the cleaning fluid or having more higher power sensors.

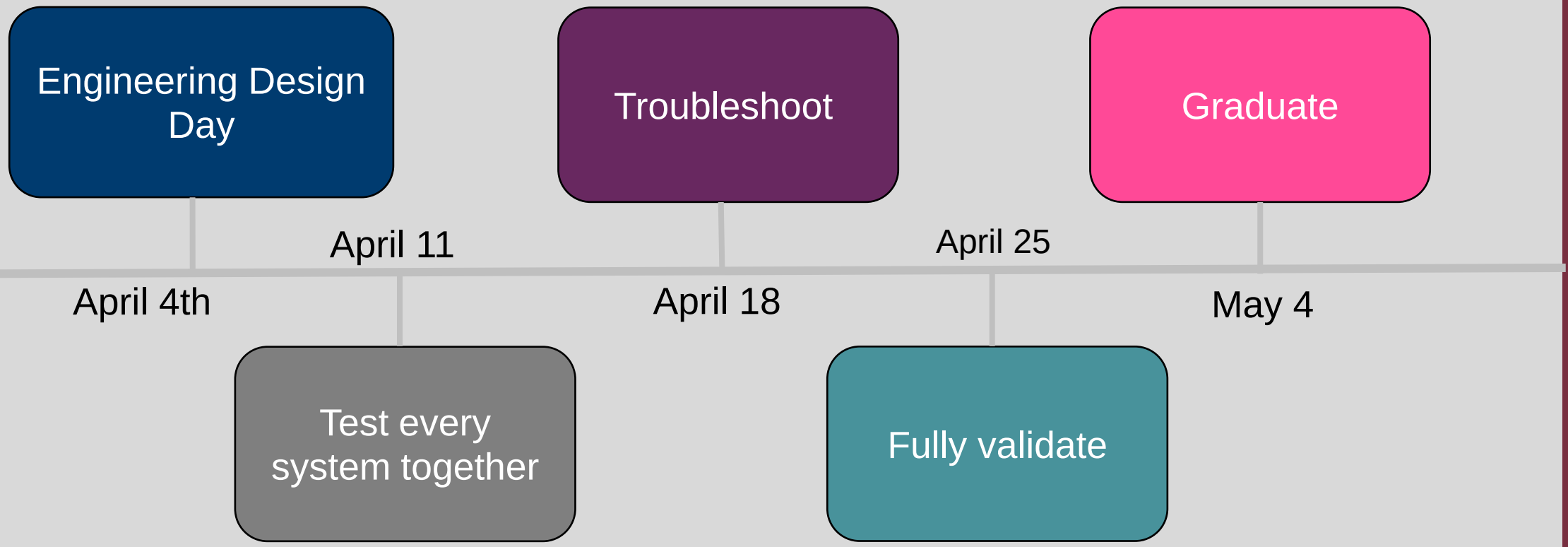
Reasons for Failure

- A thick “armor” on the SLS part is preventing the cleaning.
- Sensors may not be powerful enough

Possible Solutions

- Adding abrasives to the cleaning fluid
- Different cleaning solution (Proponal-2, Acetone)
- Different Sonication method (Tip Sonication)

Incomplete Work



Lessons Learned

Lauren- Unexpected things happen

Kyle- Order parts ahead of when you need them

Alex- More preliminary research

Tripp- Use standard/common sizes when ordering

Cole- Organizing better

Chelsea- Appreciate the experience

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Questions

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Project Background

NASA's Current Vacuum Nucleation Design

Benefits

- Cleans small spaces

Drawbacks

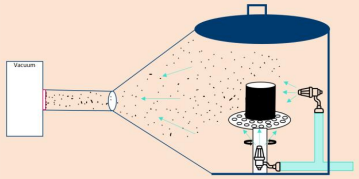
- Size and weight concerns

Our Objective

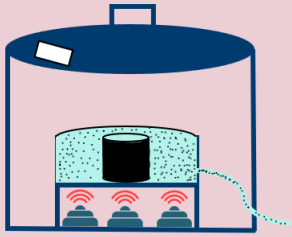
- Portable cleaning device to bring to ISS
- Solve size and weight concerns

Concept Overview

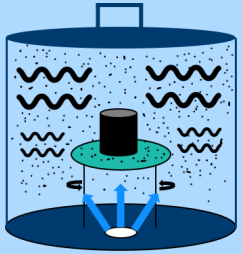
Liquid Nitrogen Spray



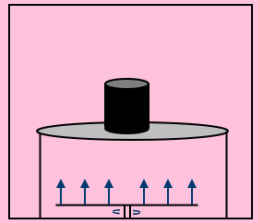
Sonic Wave Cleaner



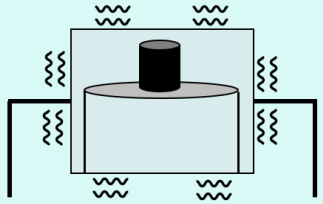
Vacuum Nucleation



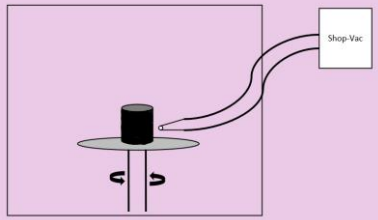
Dishwasher



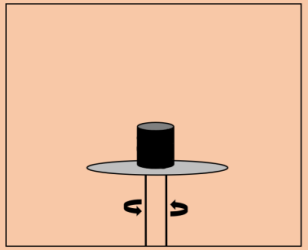
Momentum Shaker



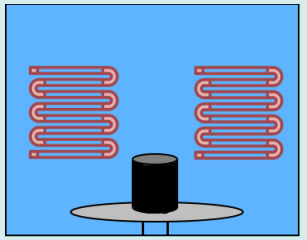
Shop-Vac Hose



Spinning Plate

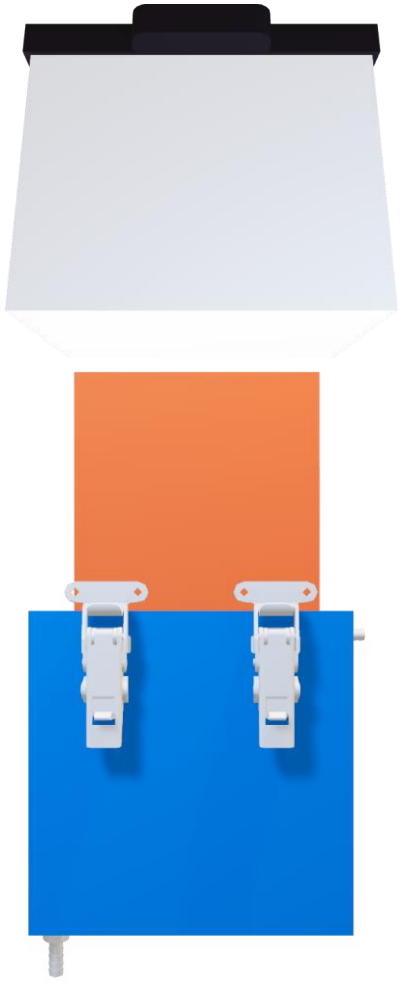


Boiling Water



Current Work

Preliminary Creo Design



- The mesh will go into the machine fitted with the black lid on top
- Sealed with two latches