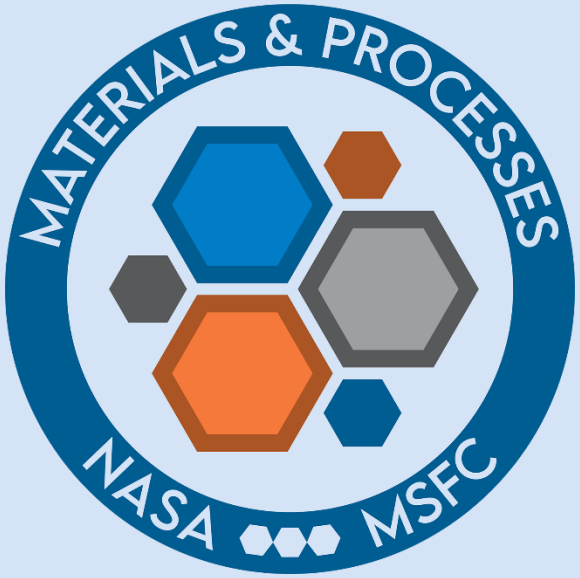

P.R.I.M.E.

(Powder Removal In Microgravity Environment)

EM22 Contamination Control

Henry Kaplan

Justin McElderry

About Me

- Rising senior at Yale University, majoring in Physics and Mechanical Engineering
- From Brooklyn, NY
- Interned in EM31 at MSFC last summer
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Motivation

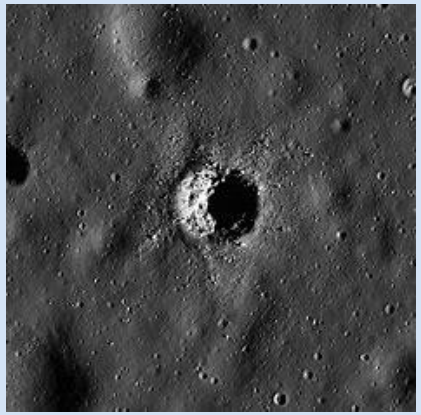
Current methods of cleaning residual unfused powder from additively manufactured parts cannot be safety used in microgravity environments, limiting our capabilities of In-Space Manufacturing.

- Compressed air, ultrasonics, brushing, Vacuum Cycle Nucleation (VCN)

PRIME purpose is to translate these methods into the microgravity environment, with the ISS in mind

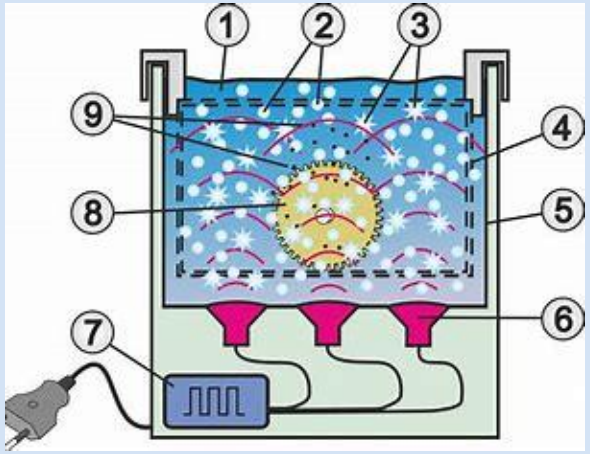
- Chose ultrasonics and pressurized fluid as the desired cleaning method given the size constraints abord the ISS.

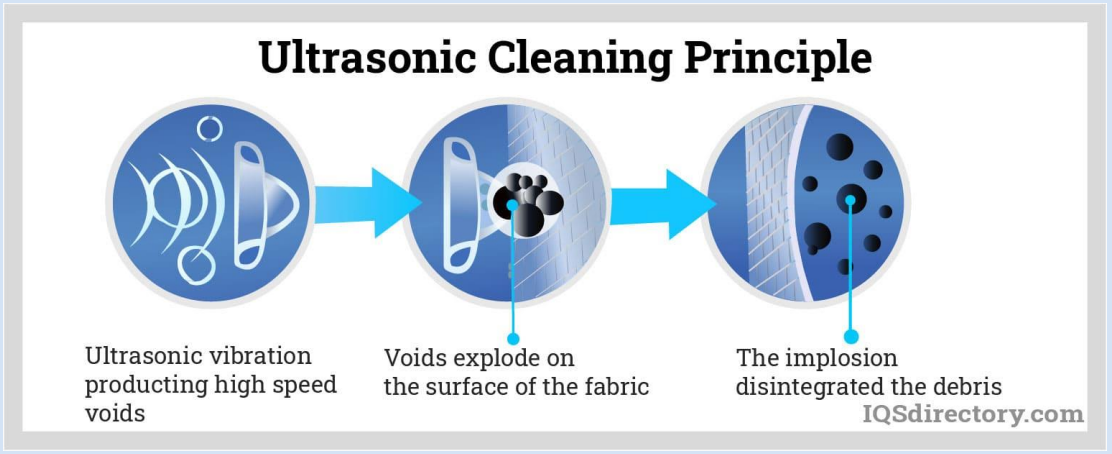
PRIME can be further expanded to cleaning other contaminates in space, such as lunar regolith.



Background on Ultrasonic Cleaning

Ultrasonic cleaners work by using transducers to generate sounds at the ultrasonic frequency (40 khz for PRIME) which creates pressure waves in a tank of a solvent (DI water, acetone, etc.). This pressure waves create cavitation bubbles, which are what cleans the part.





Design Constraints

Be of limited size
- Solution: Ultrasonics

Able to work in microgravity
- Solution: Rotating drum

Powered from one DC power source
- Solution: Relays

Easy to use
- Solution: LCD screen and single button to run fully automated cleaning process

Prototype with a limited budget
- Solution: 3D printing and laser cutting

Design

Main design ideas:

- Using rotation to drain and contain the fluid during and after cleaning.
- Using a pressured nozzle to fill the cleaning chamber, thus cleaning the part as a bonus

+

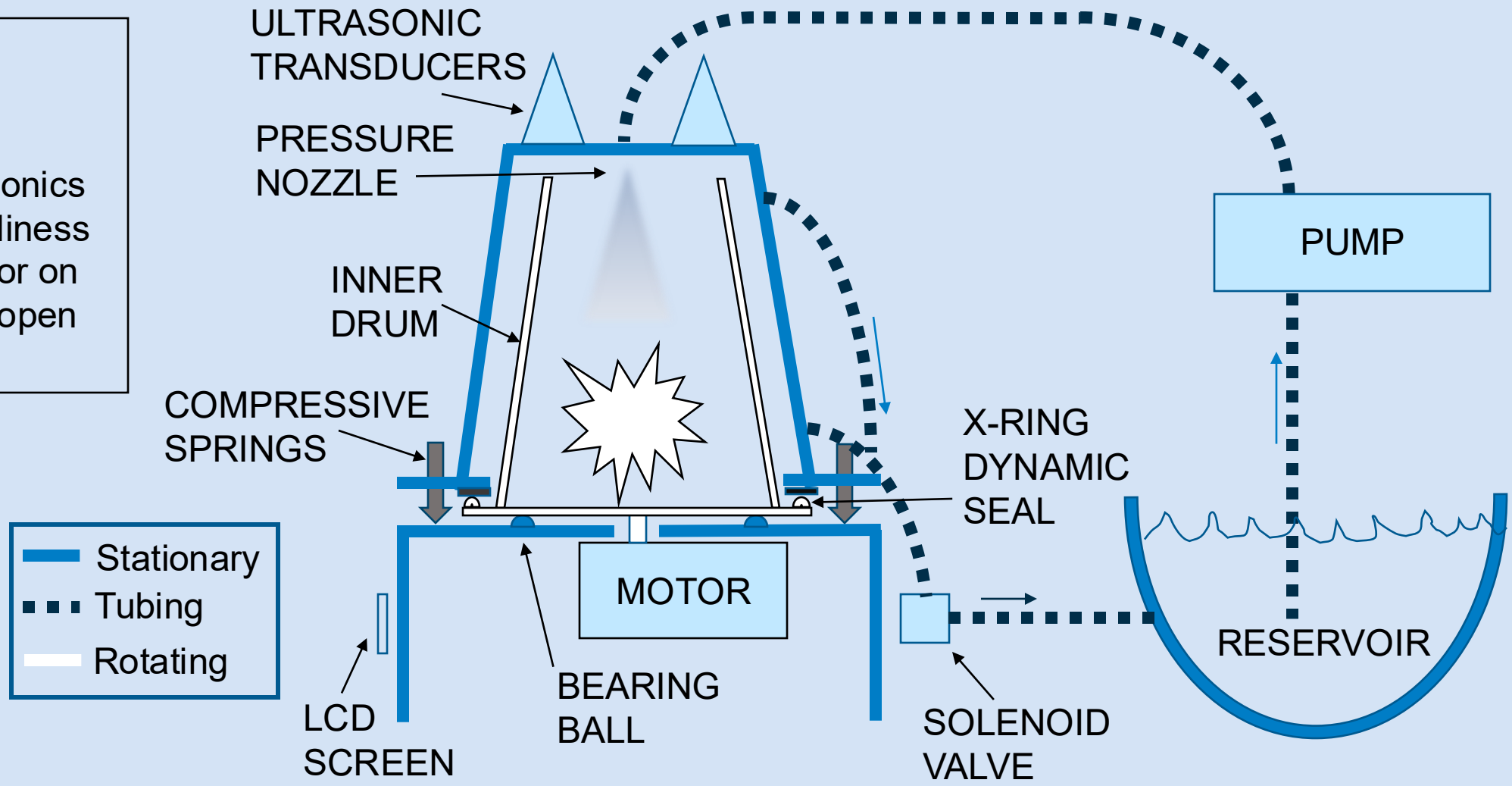
+

= PRIME

Design Cont.

CLEANING CYCLE:

- Pump turns on till chamber is filled
- Pump off and ultrasonics on till desired cleanliness
- Ultrasonics off. Motor on and solenoid valve open to drain chamber



Design CAD

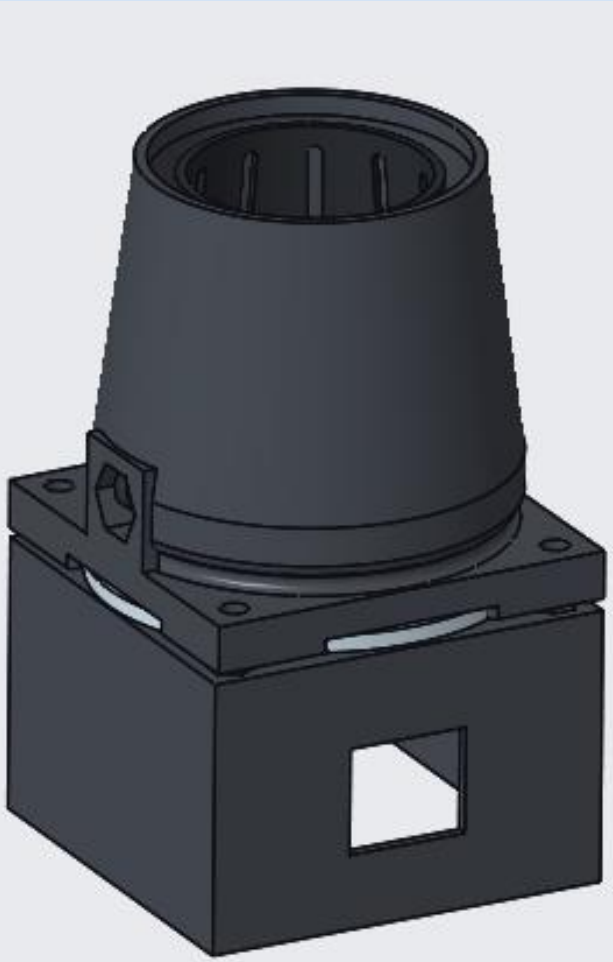
INNER ROTATING DRUM

ROTATING PLATE

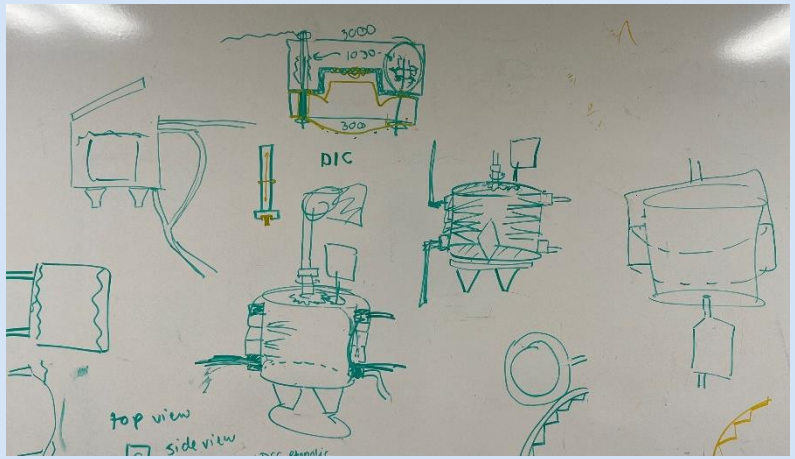
BASE WITH BEARING BALL HOLES

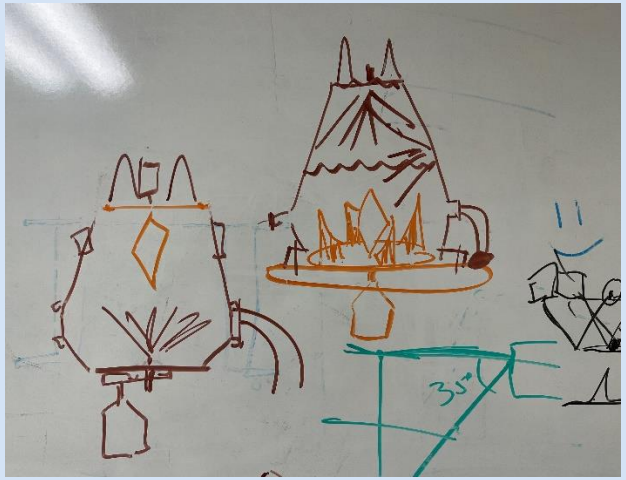
TOP WITH ULTRASONIC MOUNTS

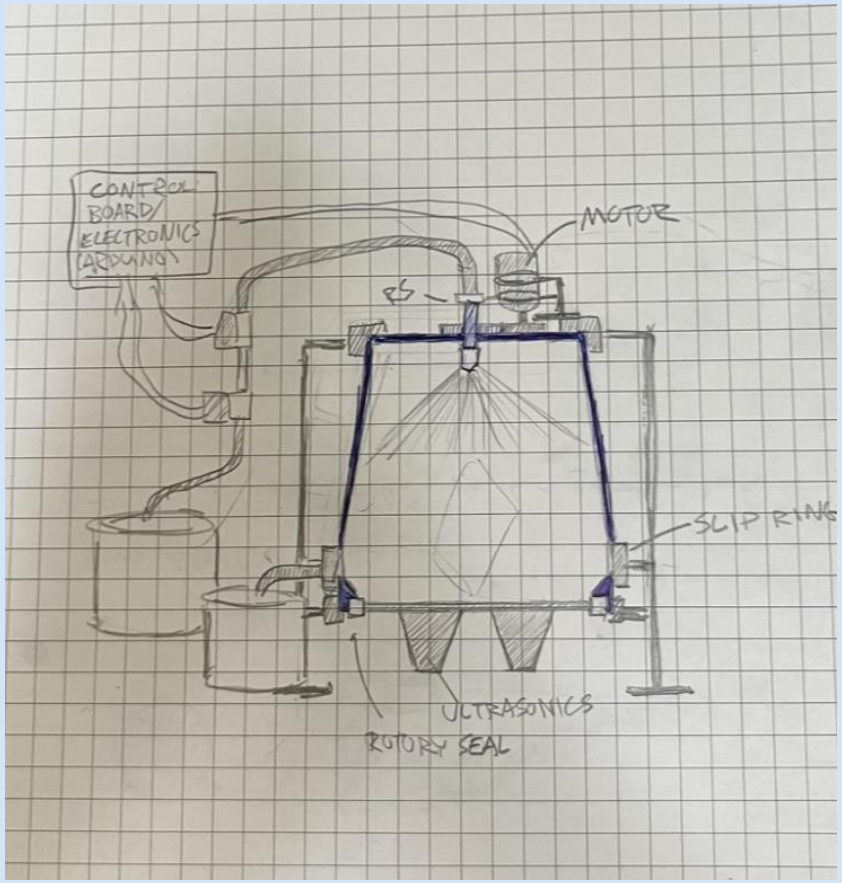
OUTER STATIONARY DRUM

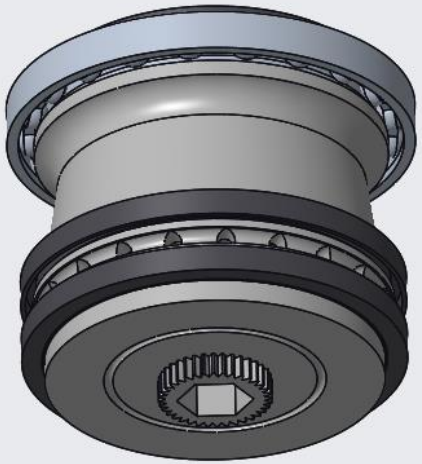


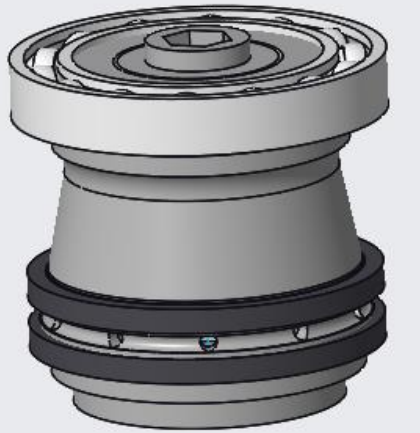
Previous Designs and Concepts











Challenges

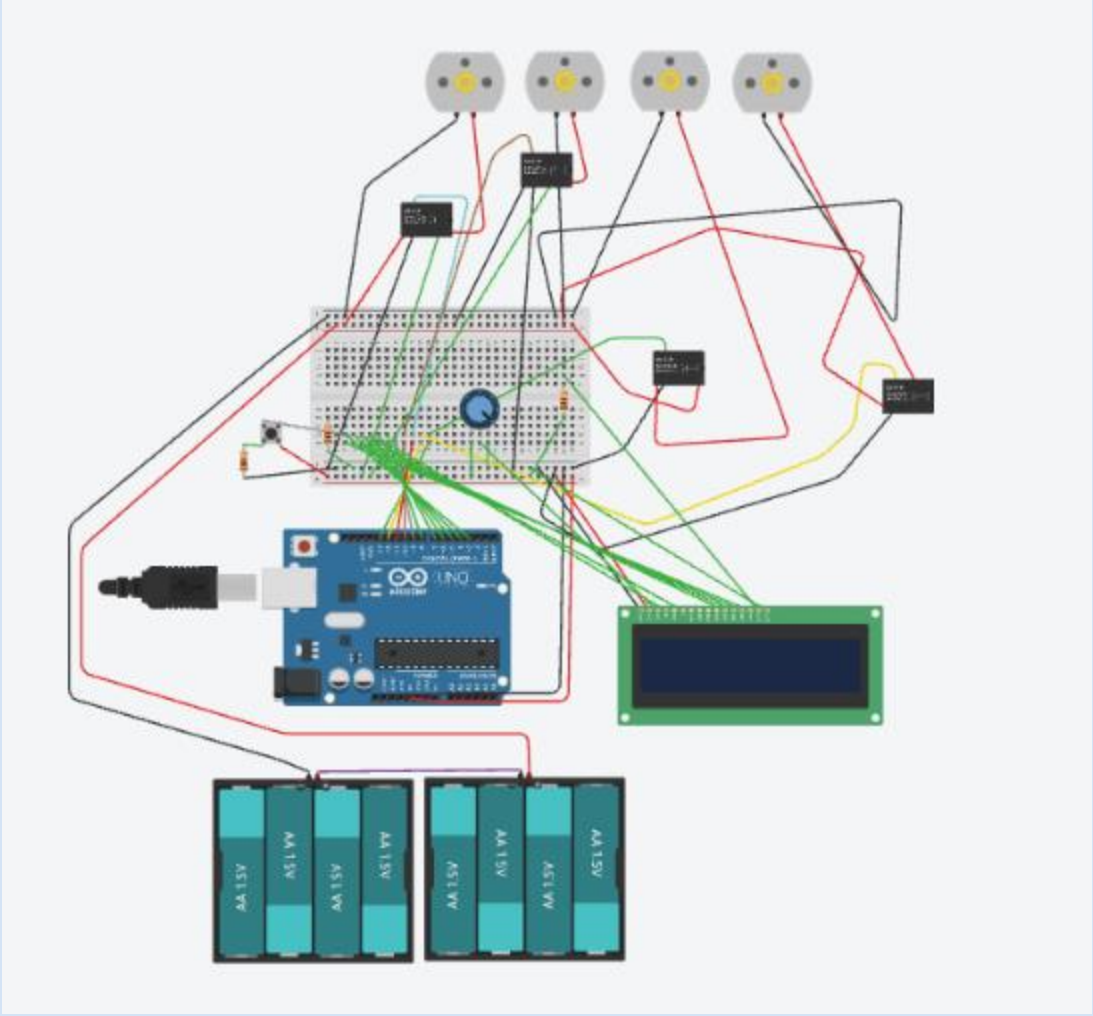
Main challenge was getting PRIME to be watertight:
3D printing doesn't mesh well with the exact tolerances you need to create watertight seals and chambers.
Getting the seal between the interface of the rotating plate and stationary drum fully watertight proved to be my most difficult challenge.
Settled on an X-Ring seal against an acrylic ring
Ideally PRIME would use a large mechanical seal

Arduino Code and Simulation Circuit

```
#include
<LiquidCrystal.h>
const int rs=6, en=12, d4=7, d5=5, d6=9, d7=13;
LiquidCrystal lcd(rs, en, d4, d5, d6, d7);
int buttonpin = 0;

void setup() {
 lcd.begin(16,2);
 pinMode(10, INPUT);
 pinMode(2, OUTPUT);
 pinMode(3, OUTPUT);
 pinMode(4, OUTPUT);
 pinMode(8, OUTPUT);
}

void loop() {
 buttonpin = digitalRead(10);
  if (buttonpin == HIGH) {
   digitalWrite(2, HIGH);
   digitalWrite(8, LOW);
   lcd.print("SPRAYING ON");
   delay(3000); // Wait for 3000 millisecond(s)
   lcd.clear();
   lcd.print("ULTRASONICS ON");
   digitalWrite(2, LOW);
   digitalWrite(3, HIGH);
   delay(3000);
   lcd.clear();
   lcd.print("DRAINING");
   digitalWrite(4, HIGH);
   digitalWrite(8, HIGH);
   digitalWrite(3, LOW);
   delay(3000);
   lcd.clear();
   lcd.print("WASHING COMPLETE");
   digitalWrite(8, LOW);
   digitalWrite(4, LOW);
   delay(1000);
   lcd.clear();
} else {
   digitalWrite(8, LOW);
   digitalWrite(4, LOW);
   digitalWrite(2, LOW);
   digitalWrite(3, LOW);
  }
}
```



Electronics

COMPONENTS:
4 SPDT 5VDC Relays
LCD Display
Arduino Uno
10kΩ Resistor
220Ω Resistor
Potentiometer
Push Button Switch

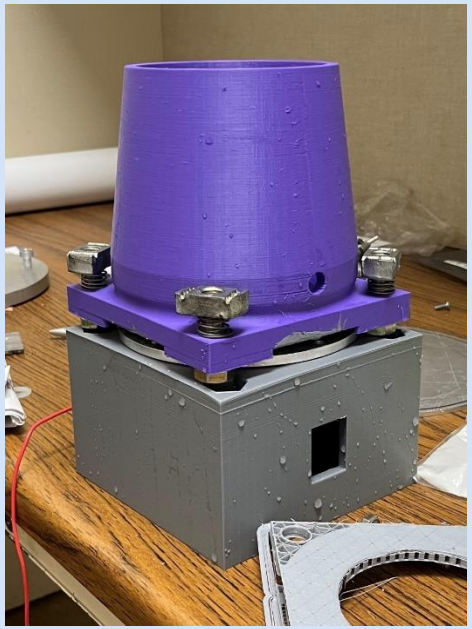
12VDC Solenoid Valve
12VDC Gear Motor (90rpm)
12VDC Self Priming Diaphragm Pump
3 40khz Ultrasonic Transducers

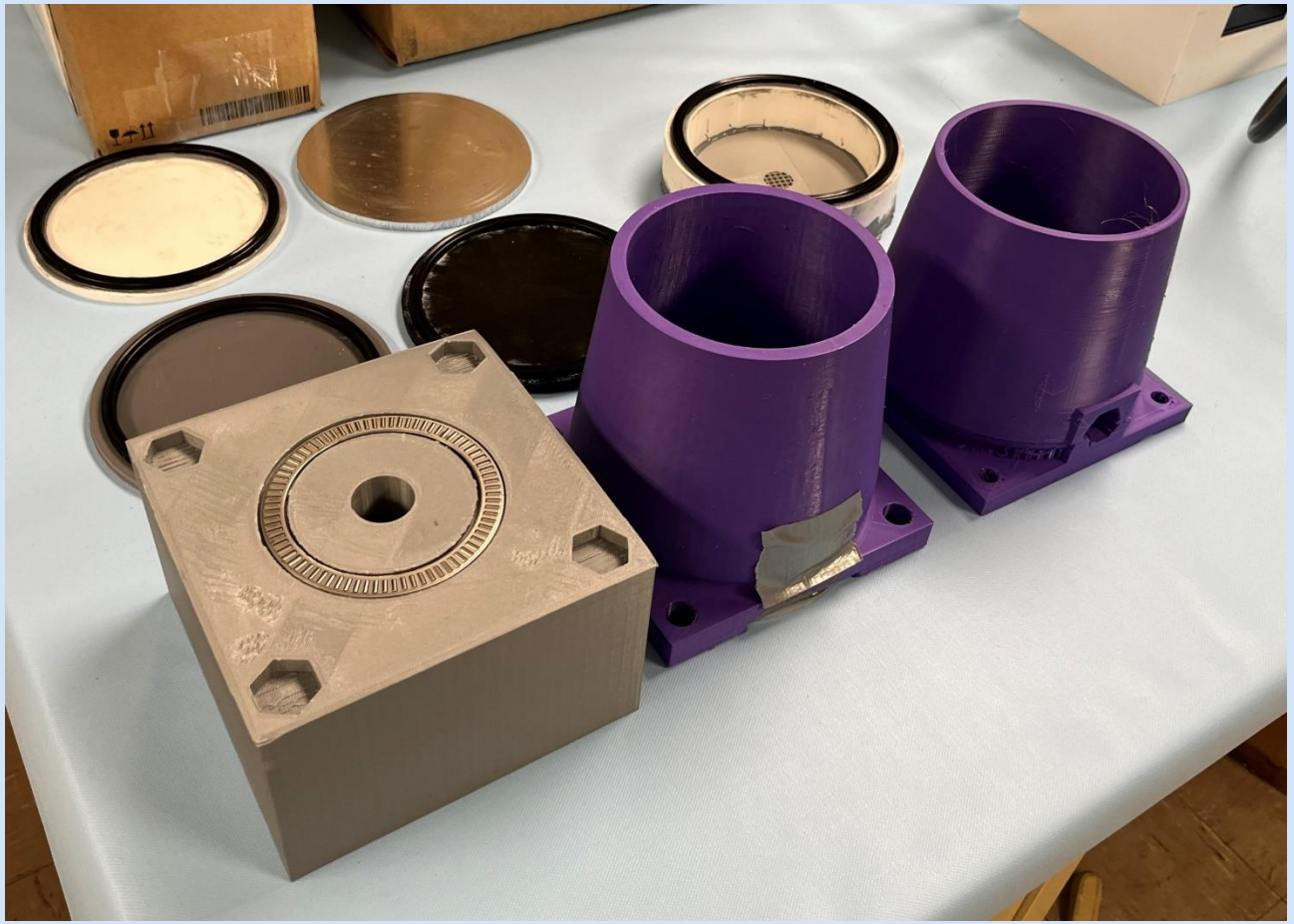
DC Power Supply

Early Prototypes

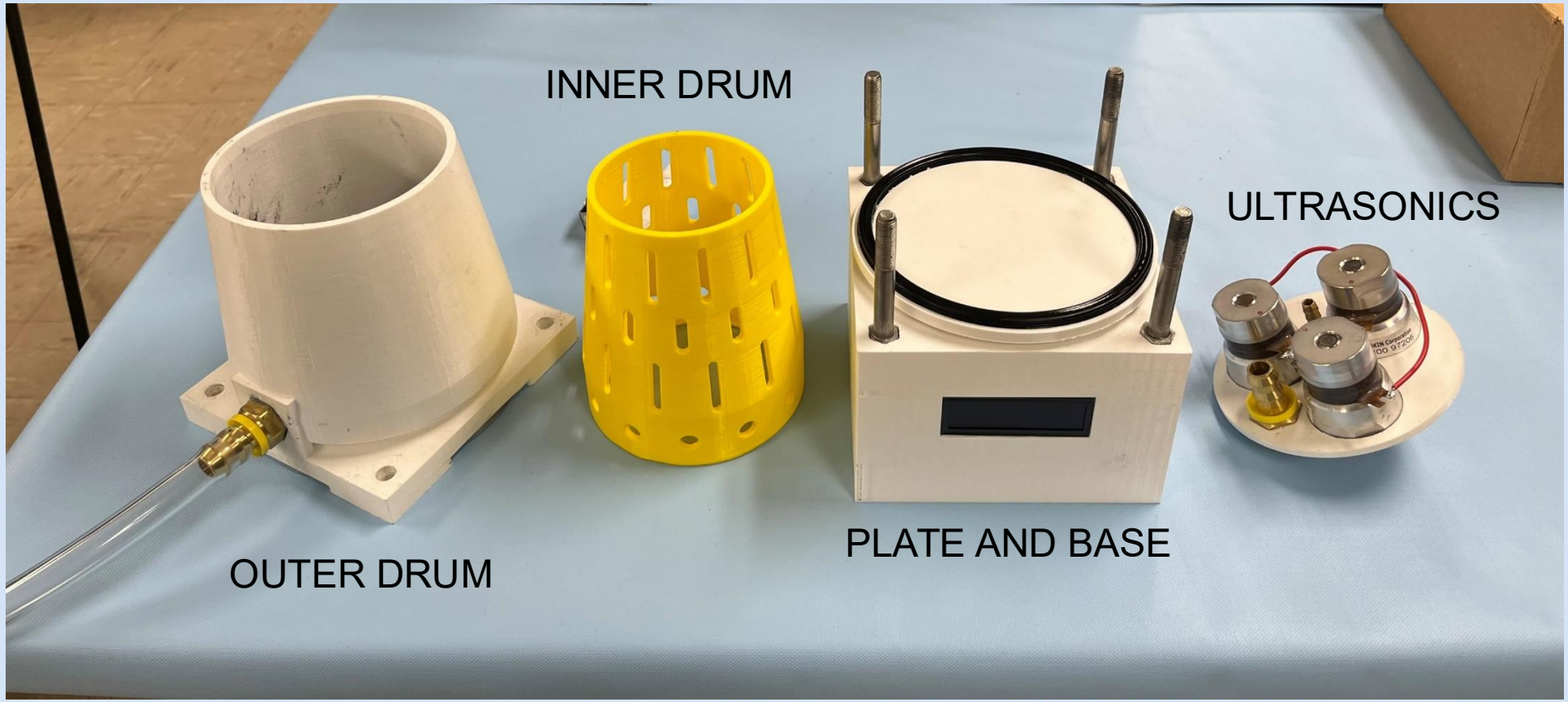
Problems:

- Seals did not work well
- 3D printed walls leaked
- Parts did not fit/rotate well together

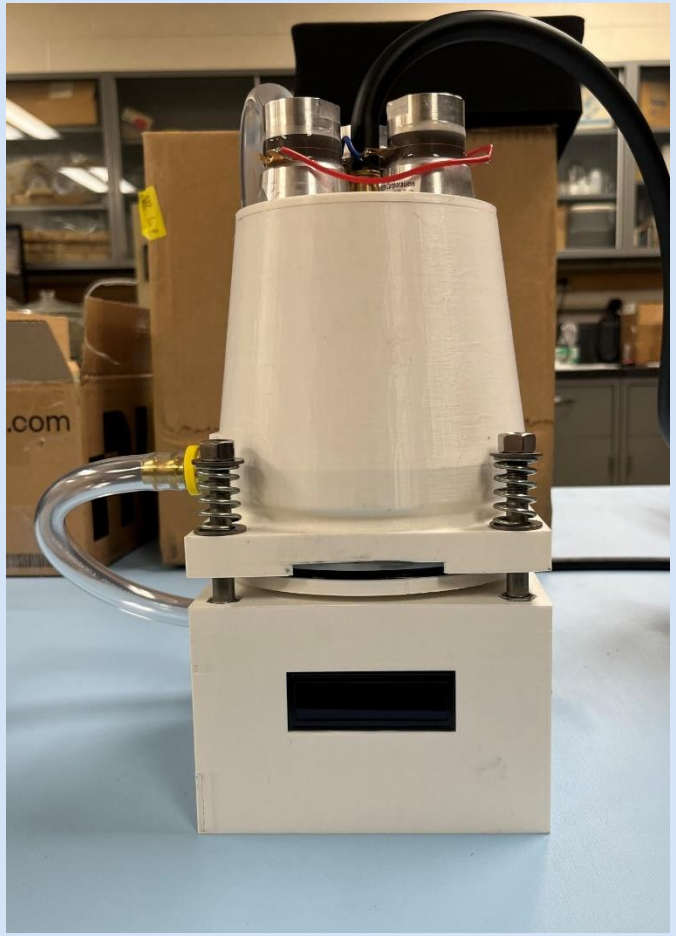




Final Prototype Disassembled



Final Prototype Assembled



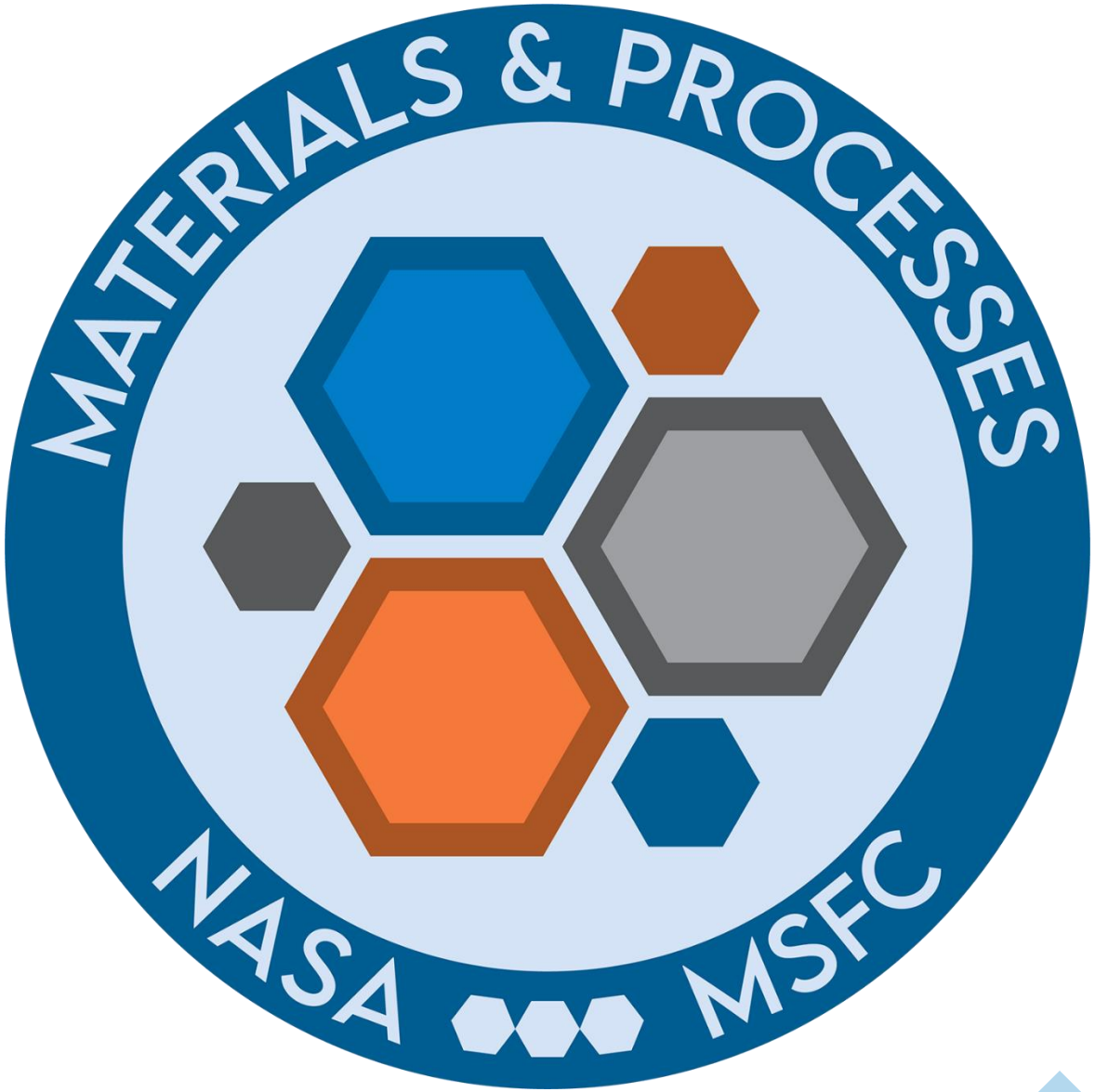
Next Steps

- Testing with AM parts to measure percentage of residual powder PRIME can remove with EM42
- Testing on a parabolic flight (if sufficient budget)
- Replace X-ring with ceramic or silicon carbide face.
- Create a way to mount AM parts in the inner drum
- Tec-Masters, Inc. is an interested customer who want a demo
  - Launched EM experiments to ISS in past
- Technical Excellence proposal submitted for FY25 for funding prototype work
- Fall intern (Gabe Holden) will continue PRIME prototyping

Questions?

Acknowledgements

- Justin McElderry
- Meghan Carrico
- Annette Gray
- Kayla Carneal
- Hannah Epstein
- Myah Pablo
- Bill Battle
- Curtis
- Brandon Bailes
- Richard Boothe
- And everyone else in 4711!


MATERIALS & PROCESSES
NASA
MSFC