Psyche Additive Manufacturing

Team 501 – DR 6

FAMU-FSU
College of Engineering

Team Introductions

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Mechanical Engineer

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Multiphysics Simulation Engineer

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Design Engineer

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Design Engineer

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Test Engineer

Sponsor and Advisor

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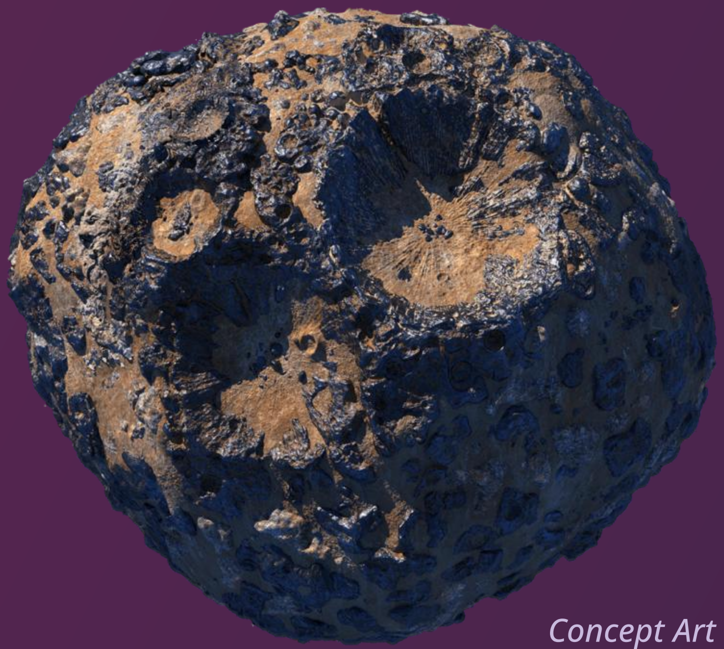
Sponsor

Dr. Dorr Campbell
Advisor

Objective

The objective of this project is to design a component for additive manufacturing that prevents metal powder from suspending in microgravity on the Psyche asteroid.

Psyche Mission



Concept Art

- Psyche is an M-type asteroid hypothesized to be a remnant from a planetesimal
- Believed to be composed of 30-60% metal
    - Particularly iron and nickel
- Has a mean surface gravity of 2% of Earth’s gravity
- In 2023, NASA sent a spacecraft to observe Psyche's surface set to arrive in 2029

Assumptions

Print Ready Material

- Surface material will be harvested and refined to necessary specifications

External Power Source

- Sufficient power will be provided

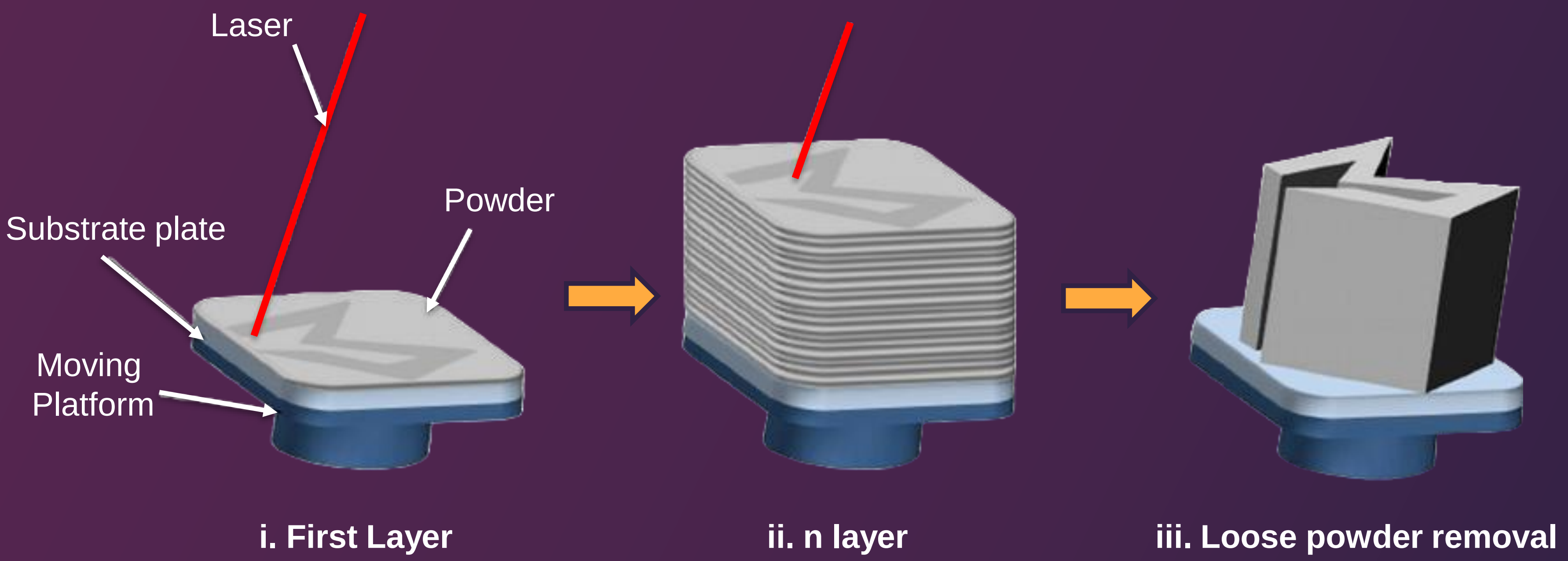
Repairability

- The system will be maintained by an external system

Product Delivery

- An external mechanism will be responsible for removing finished prints

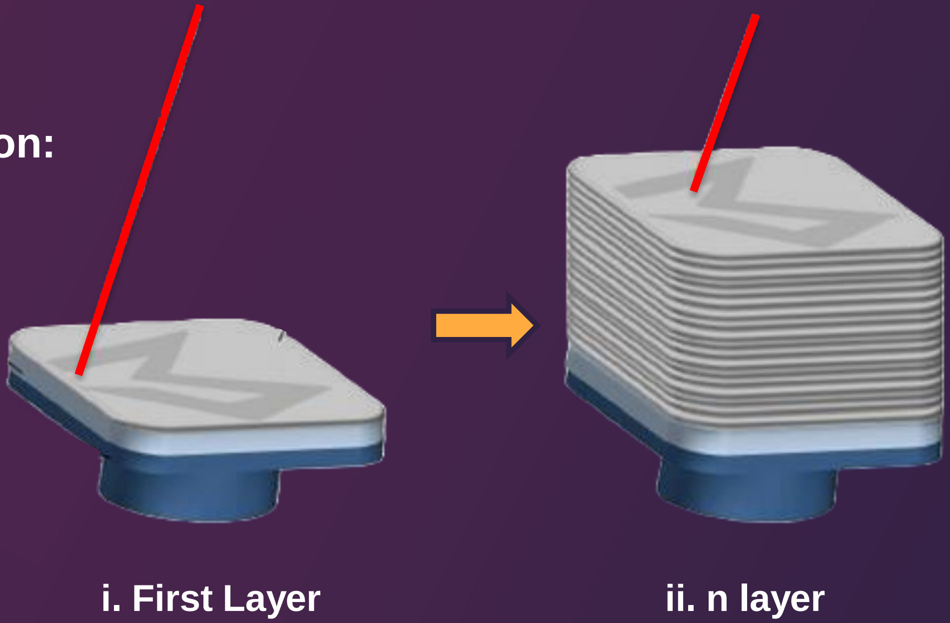
Selective Laser Melting



Powder Suspension

Potential causes for powder suspension:

- External vibrations
- Powder spreading
- Residual gas flow
- Laser induced plumes



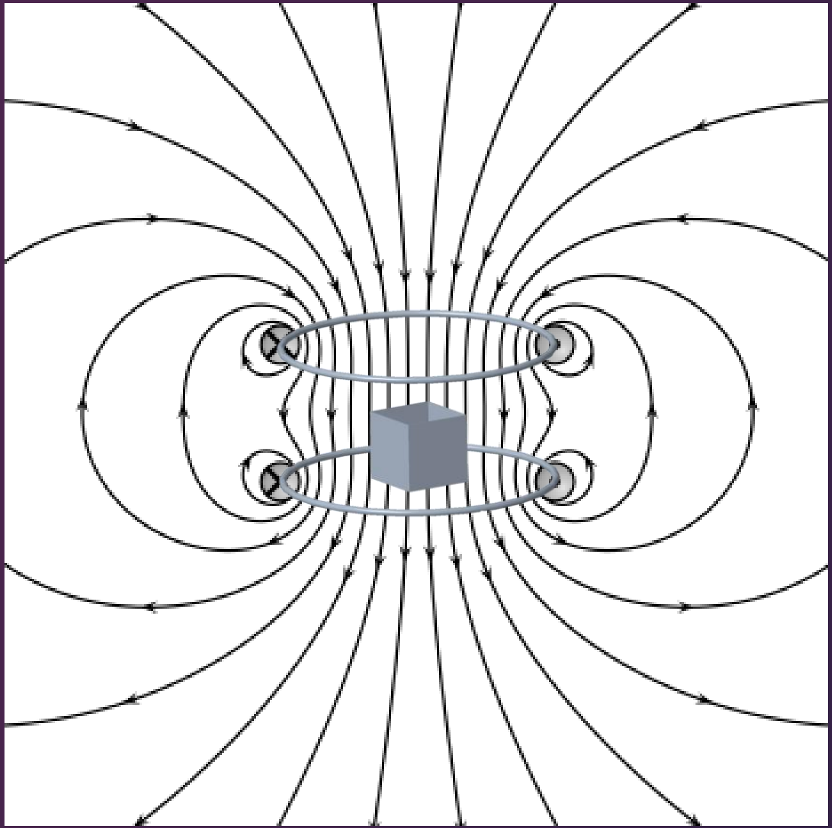
Helmholtz Coils

How they work

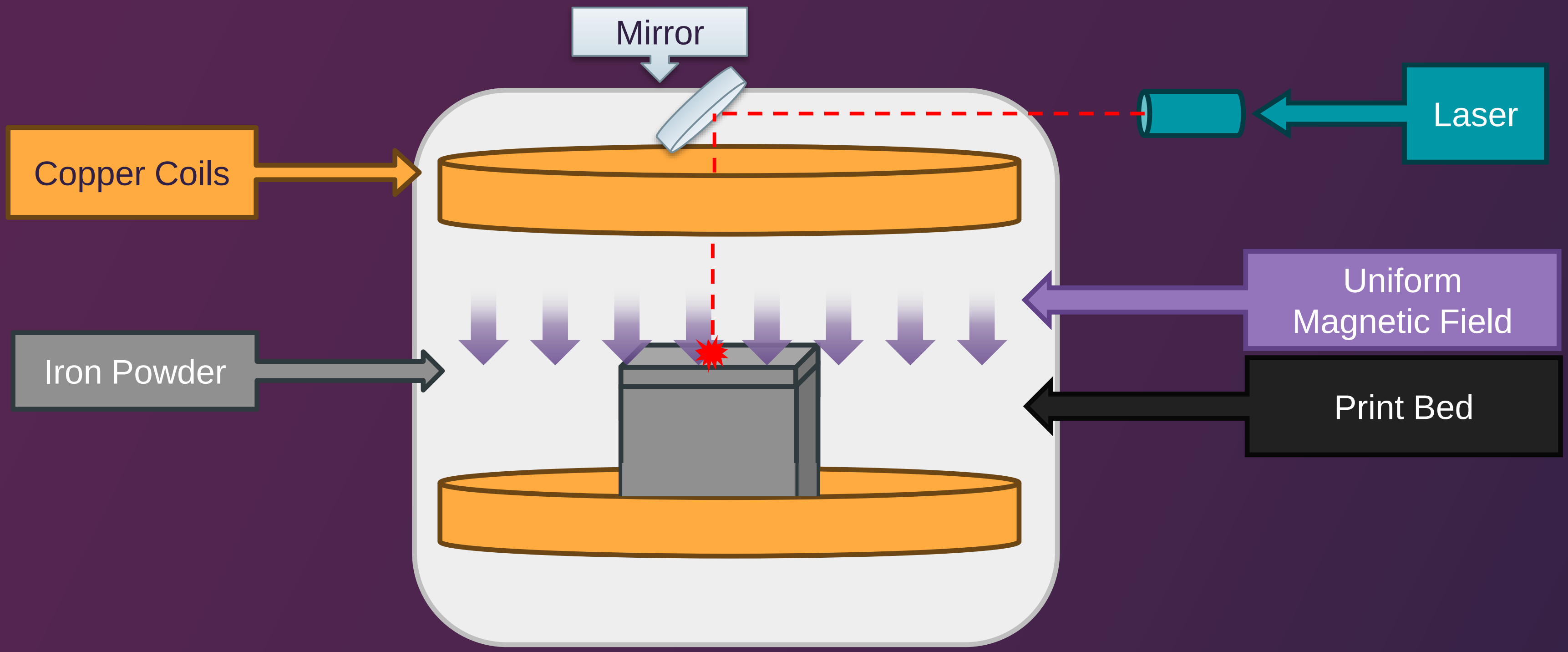
- Electromagnets
- Uniform Magnetic Field

Why we chose them

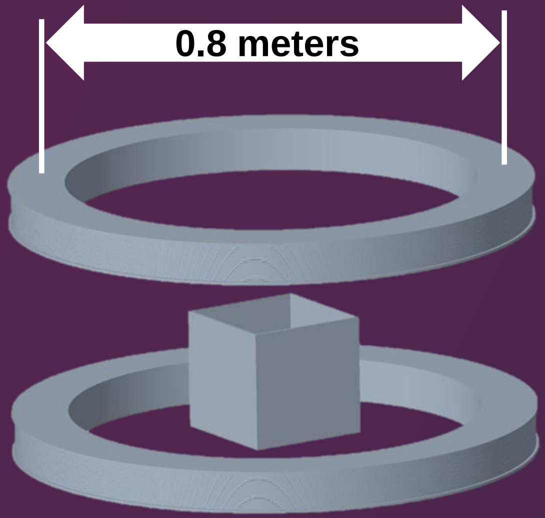
- Magnetic Artificial Gravity
- Scalable for Different Sizes/Strengths



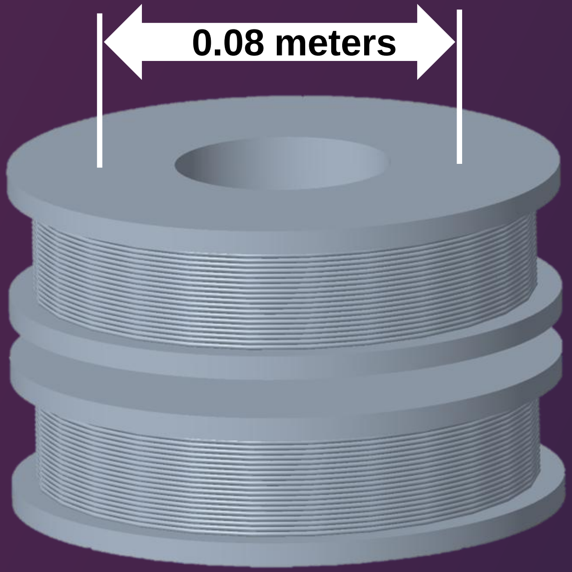
Magnet Assisted Granular Iron Control



Coil Designs

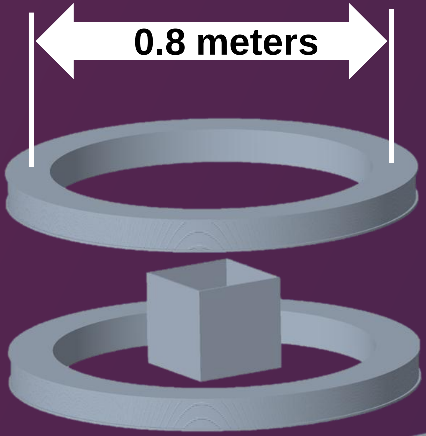


Full-Size Model

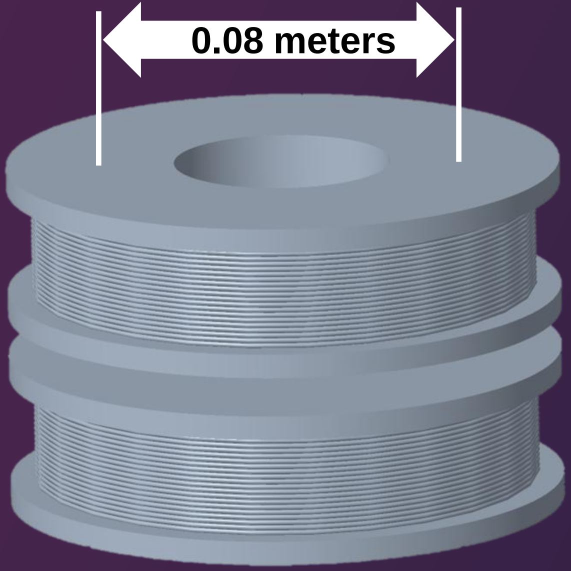


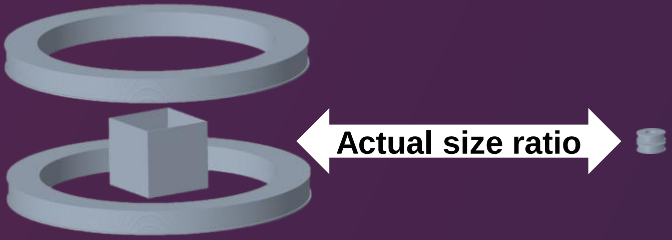
Tenth-Scale Prototype

Coil Designs



$$B = \left(\frac{4}{5}\right)^{3/2} \frac{\mu_0 n I}{R}$$



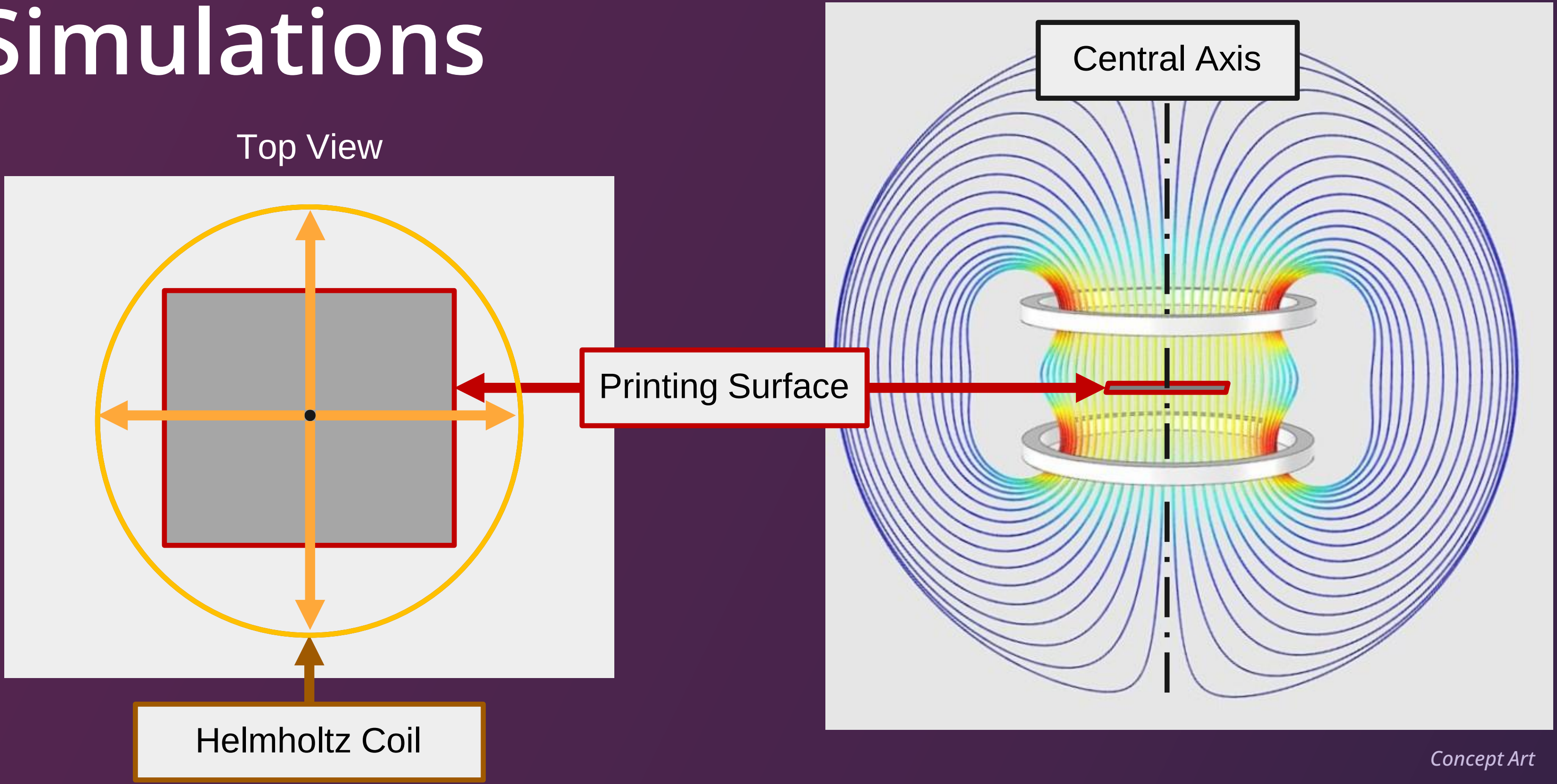


Full-Size Model

Tenth-Scale Prototype

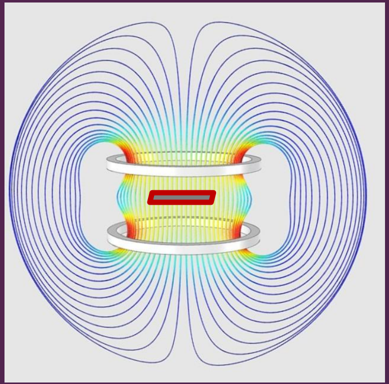
Simulations

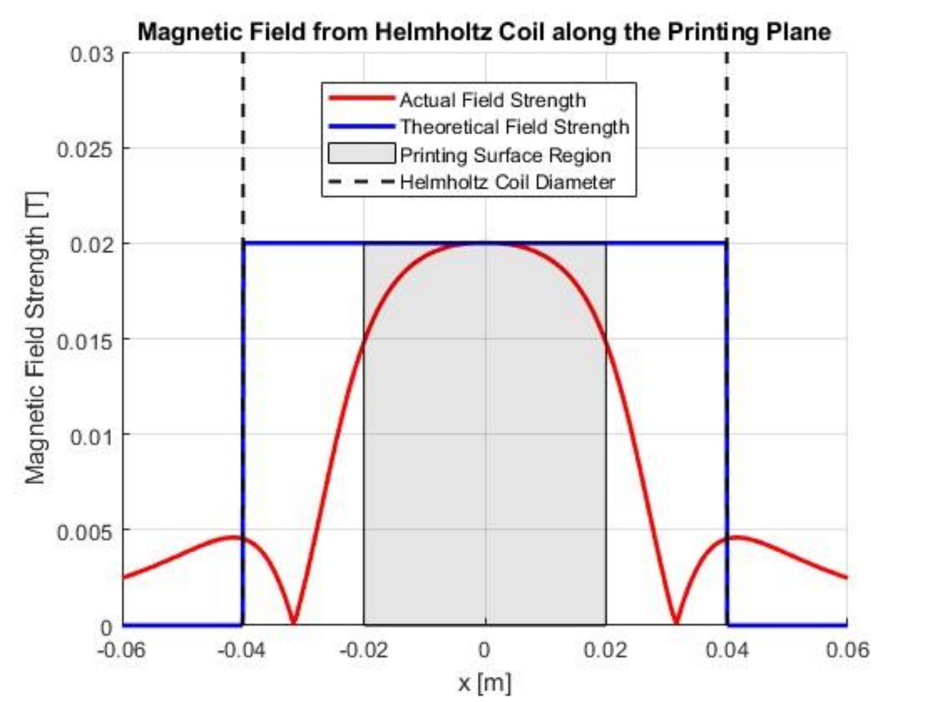
Top View



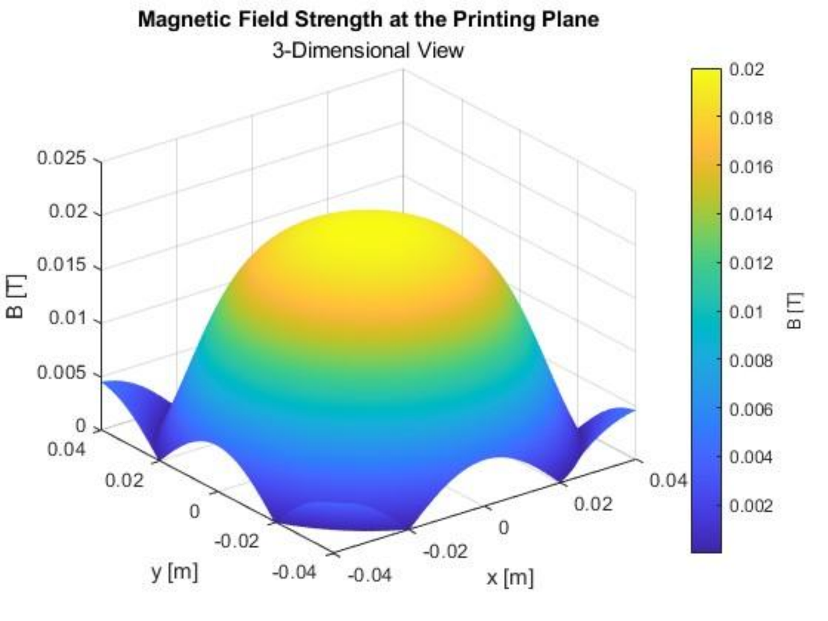
Concept Art

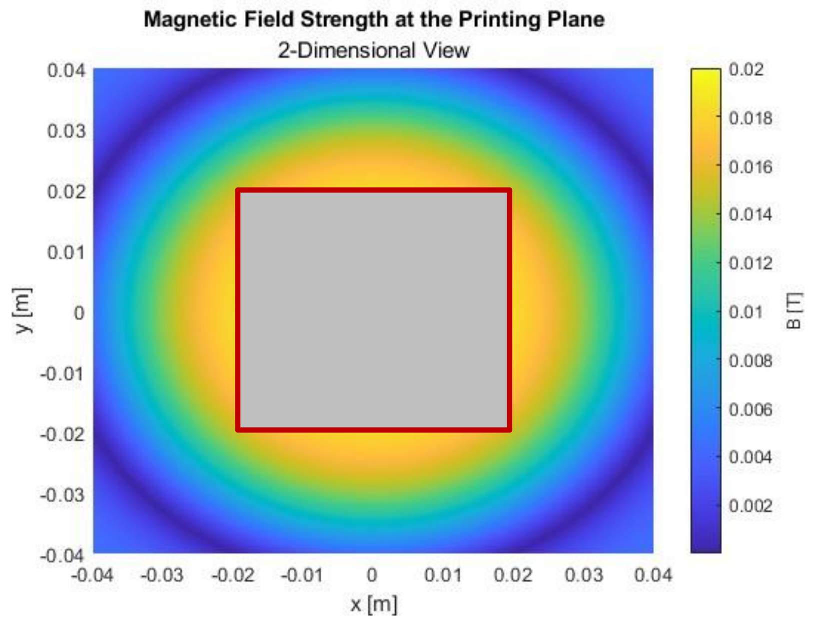
Simulations





Simulations

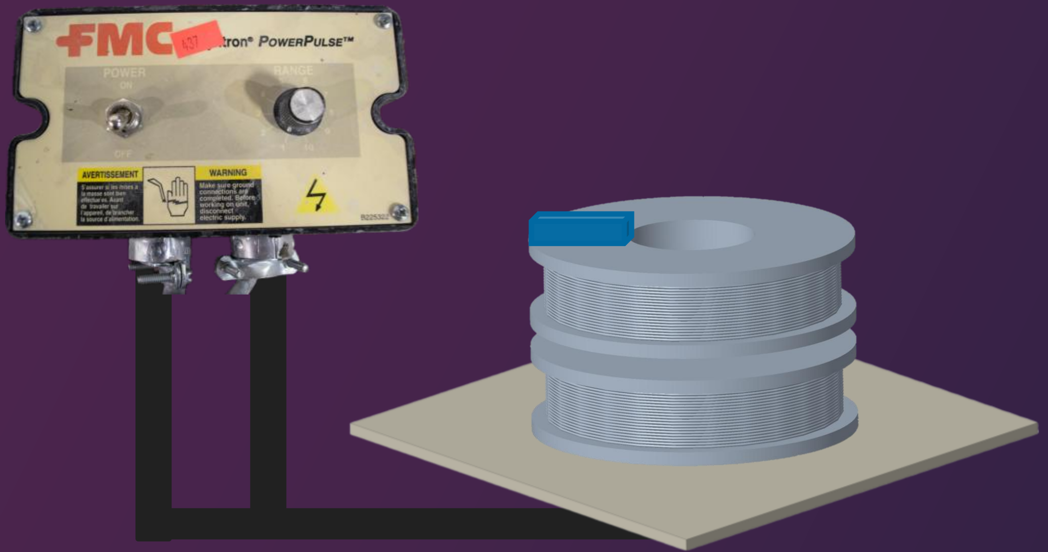




Rafe Erisman

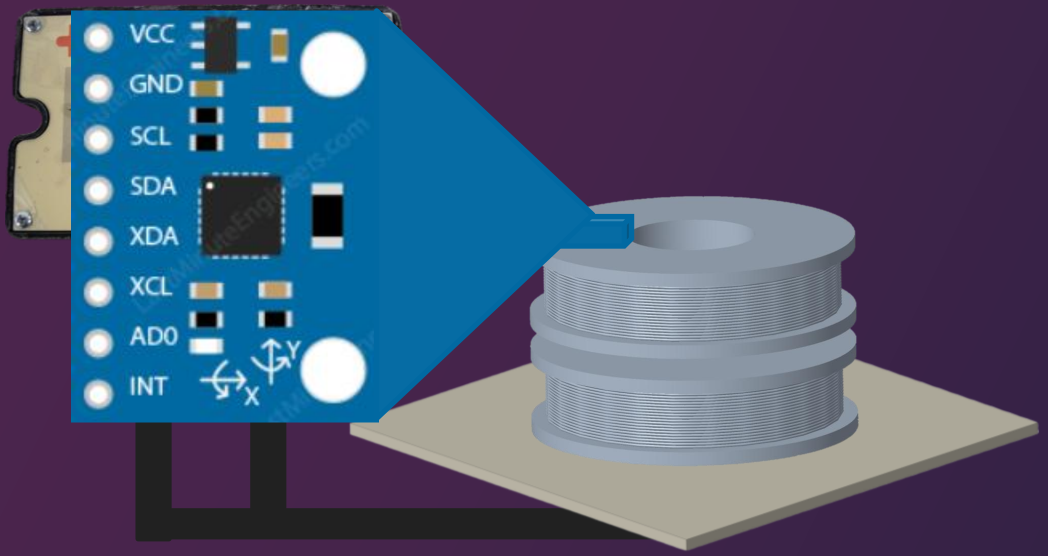
Vibration Test Overview

- The aim of the vibration test is to quantify the vibration levels that exceed the capabilities of the Helmholtz coil design
- A vibration table will be used to induce vibrations upon our physical prototype



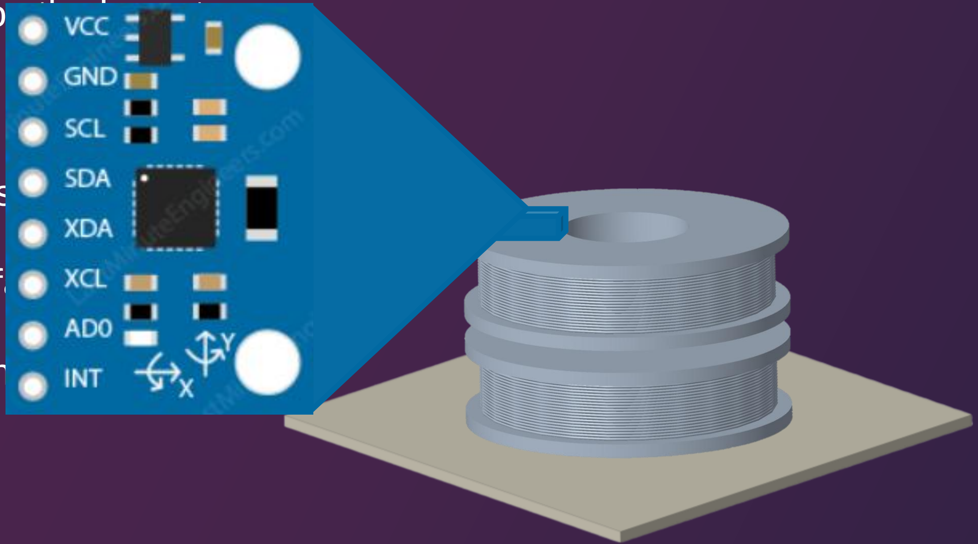
Vibration Test – Accelerometer

- Due to the limitations of the Vibration table remote, an accelerometer will be secured to the coils
- This will produce gyroscopic information which can be used to detail the vibration level at failure



Vibration Test - Methodology

- The process will begin by starting the machine o
  range and slowly increasing the intensity
- Powder loss from the print bed will be visually as
  failure determined when powder leaves test surf
- This process will be repeated 10 times and upon
  we will conduct a statistical analysis

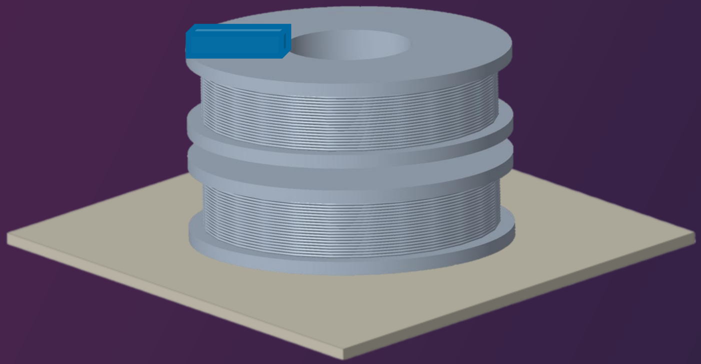


Vibration Test – Psyche Applications

- The net forces on the powder are represented by:

$$F = mg + mA\omega^2\ 2\sin(\omega t)$$

- If the vibrational acceleration exceeds the gravity constant, the powder particles will lose contact with the surface periodically, causing agitation
- This formula will allow us to analyze our results and compare how the device would fare when it is subjected to Psyche's gravitational forces



Statistical Framework for Failure Analysis

Data Transformation:

- RMS Acceleration: $a_{rms} = \sqrt{1/T * \int_0^T a(t)^2 \, dt}$
- Fast Fourier Transform: $A(f) = FFT[a(t)]$

Statistical Model:

- Logistic Regression: $P(\text{failure}) = 1 / (1 + \exp(-(\beta_0 + \beta_1 \cdot f + \beta_2 \cdot a_{rms})))$

Estimation Method:

- Maximum Likelihood Estimation (MLE) to determine β coefficients

Asteroid Environment Comparison

Confidence Intervals:

- Bootstrap or standard error to quantify variability in critical frequency

Asteroid Vibration Data:

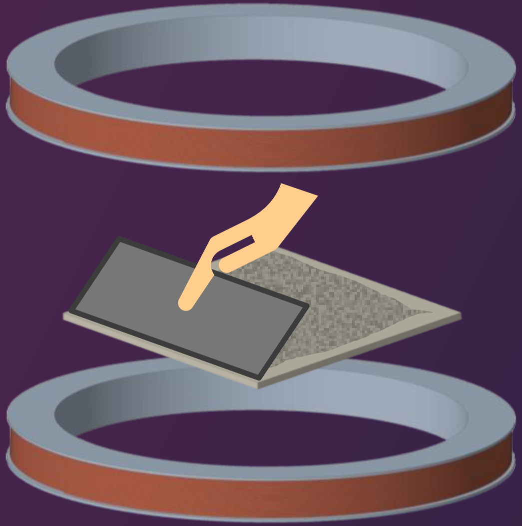
- Compare observed critical frequency and rms acceleration values to asteroid-induced vibrations

Final Output:

- Probability of failure under asteroid vibration conditions

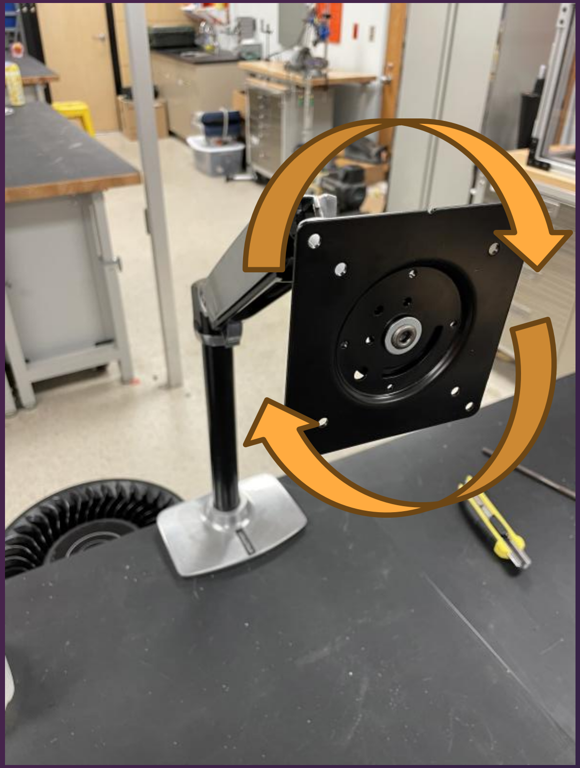
Flip Test - Introduction

- Determine if the device's magnetic field is strong enough to hold metal powder uniformly on the print surface
- Psyche has a gravitational force that is ~2% of Earth's
- If successful, it will ensure no powder will suspend on the asteroid
- The magnetic field strength needs to be at least .02 T

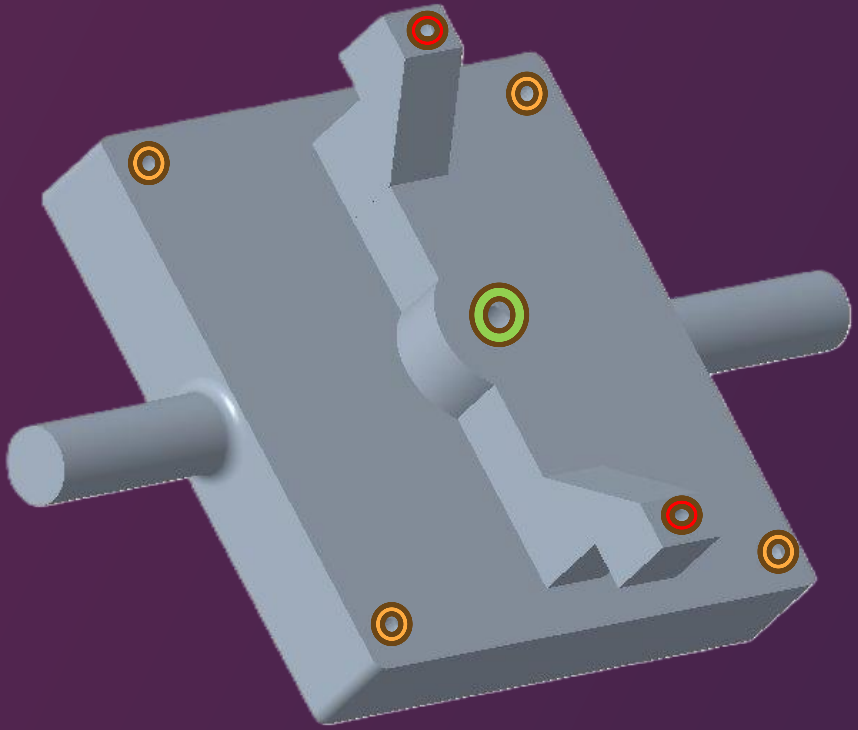


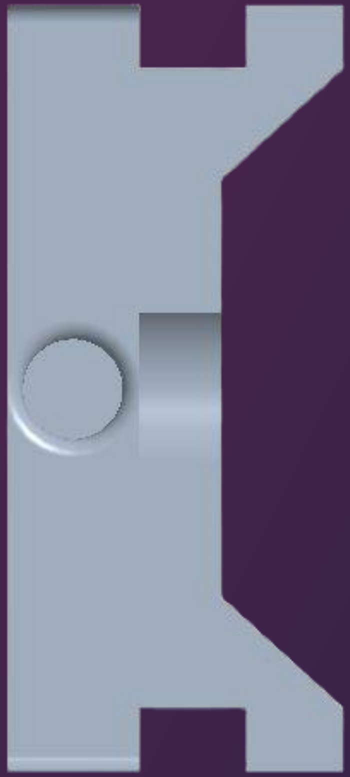
Flip Test – Methodology

- A Monitor mount will be the medium for this test, and it will be used for demonstrations on Design Day
    - Can attach firmly to any flat surface
    - Has 360 degrees of rotation
    - Will firmly hold the weight of coils
- The coils will be secured to the rotating plate through a 3D printed component
    - Will ensure user safety during test
    - Keep wiring from tangling

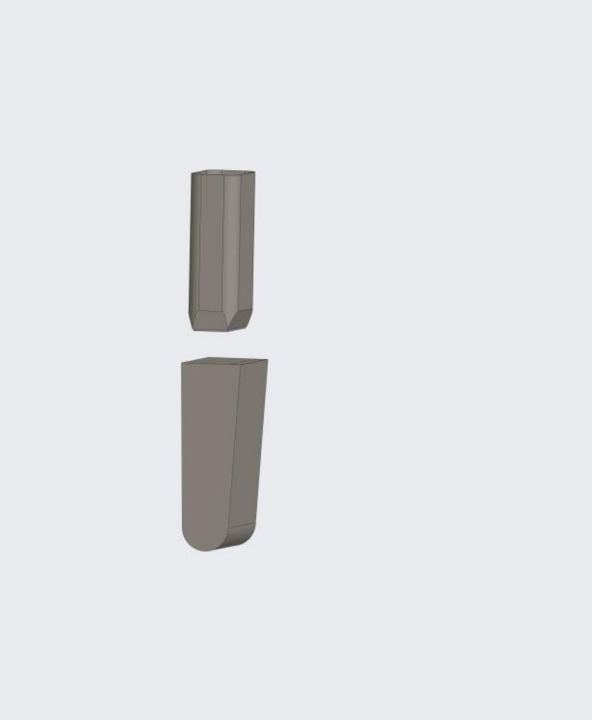


Flip Test – Mounting Component





Digital Twin



Specifications

- 1.5 x 1.0 x 1.0 cubic meters
- 0.8 meter radius coils
- Requires supply of inert gas or vacuum conditions

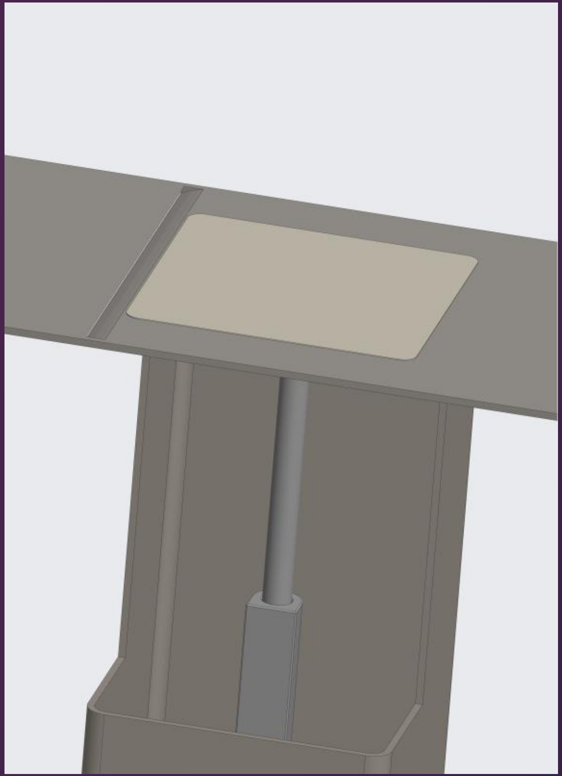
Key Components

- Helmholtz Coil
- Powder Recoater
- Build Platform
- Powder Reservoirs

Digital Twin

Build Platform

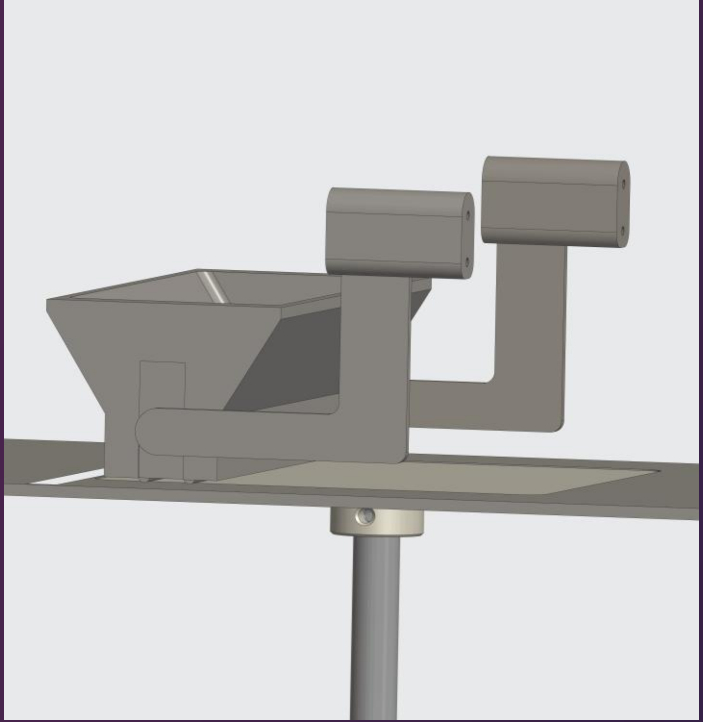
- 200 mm x 200 mm
- Rounded corners to prevent powder accumulation
- 406.4 mm (16 inch) Linear Actuator
- Maximum build height of 250 mm
- Titanium (TI-6al-4v) for high toughness
- Print bed cannot be easily replaced



Digital Twin

Powder Recoater

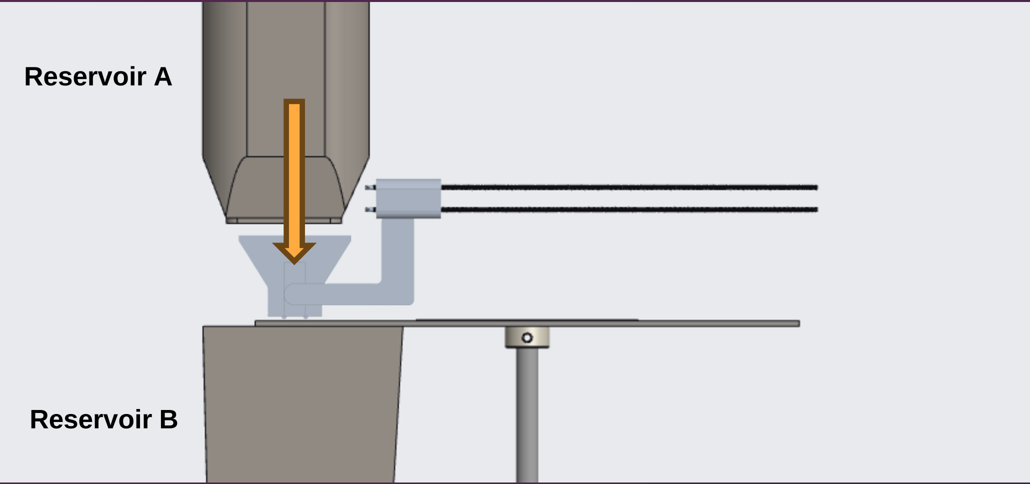
- Mounted on linear rail
- Uses two rollers to level powder surface on print bed
- Operates while Helmholtz coils are active
- Designed to be removed from linear rail arms for needed maintenance or replacement
- Several recoaters will be needed depending on lifespan of the system.



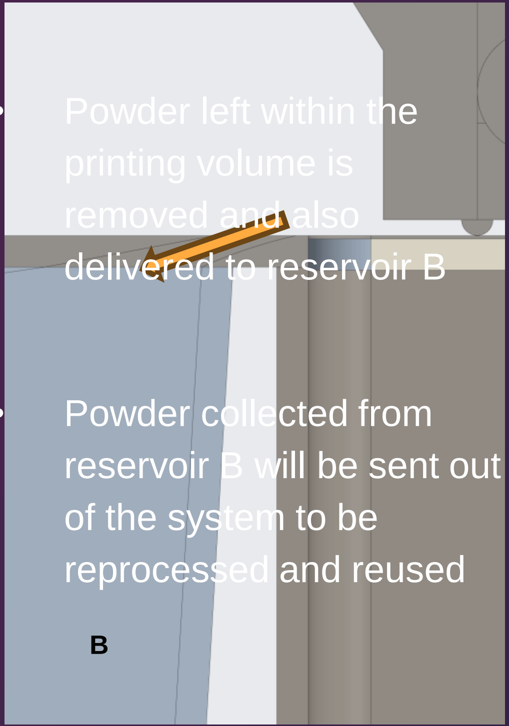
Digital Twin

Powder Recoater

- Receives powder from powder reservoir A
- For larger prints, it must be refilled during printing



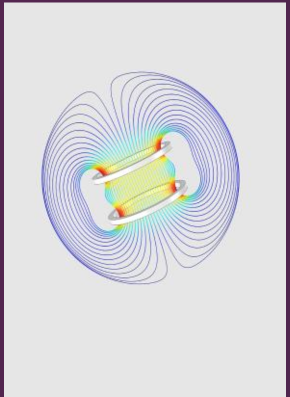
- Powder left within the printing volume is removed and also delivered to reservoir B
- Powder collected from reservoir B will be sent out of the system to be reprocessed and reused



Recap

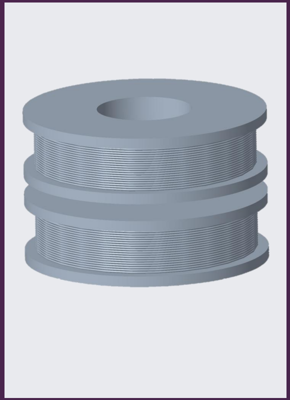
The objective of this project is to design a component for additive manufacturing that prevents metal powder from suspending in microgravity on the Psyche asteroid.

Helmholtz Coil

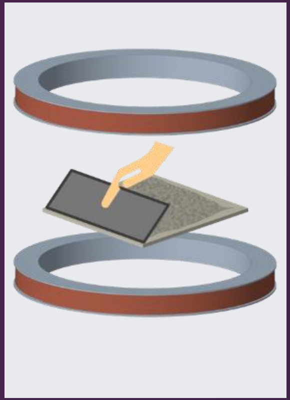


Digital Twin

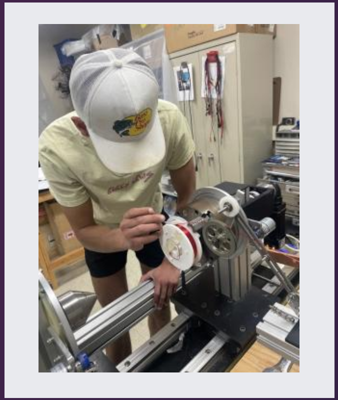
Prototype



Validation



Incomplete Work



Lessons Learned

Project Planning

- Define a realistic scope as soon as possible
- Work out a timeline with considerations for delays
- Reach out to experts to expedite the research process

Material Acquisition

- Source materials from reliable vendors to reduce delays
- Designs should consider the availability and accessibility of components

Contact Us

References

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