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Psyche Asteroid Sample Acquisition
Team 501

Michael G., Conner H., Claudia I., Jake M., Janna R., Jerry R.

03/26/2026

Team 501: Introductions

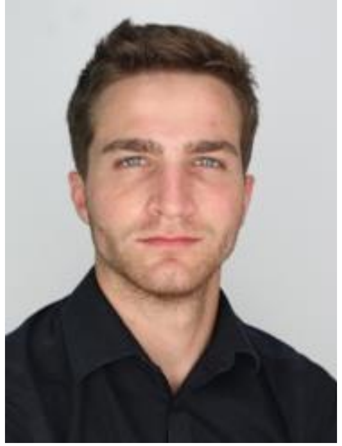
Michael Gregory
Mechanical Engineer

Jake Marcus
Design Engineer

Claudia Irausquin
Structural Engineer

Janna Rhodes
Test Engineer

Conner Holmes
Mechanical Engineer



Jerry Richardson
Systems Engineer

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Sponsor and Advisor

Dr. Cassie Bowman
Project Sponsor

PSYCHE NASA Arizona State University

Dr. Shreyas Balachandran
Faculty Advisor

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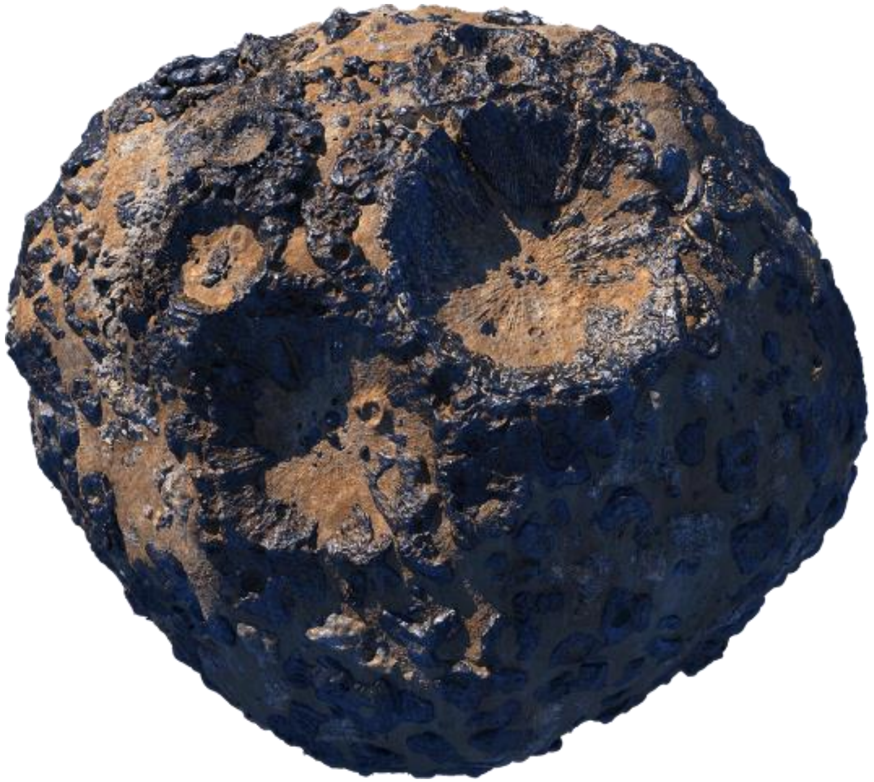

NASA Rendering of Asteroid (16) Psyche

Objective

The objective of this project is to acquire and cache samples across multiple surface types on asteroid (16) Psyche. This effort is coordinated with Team 502, who is focused on sample retrieval.

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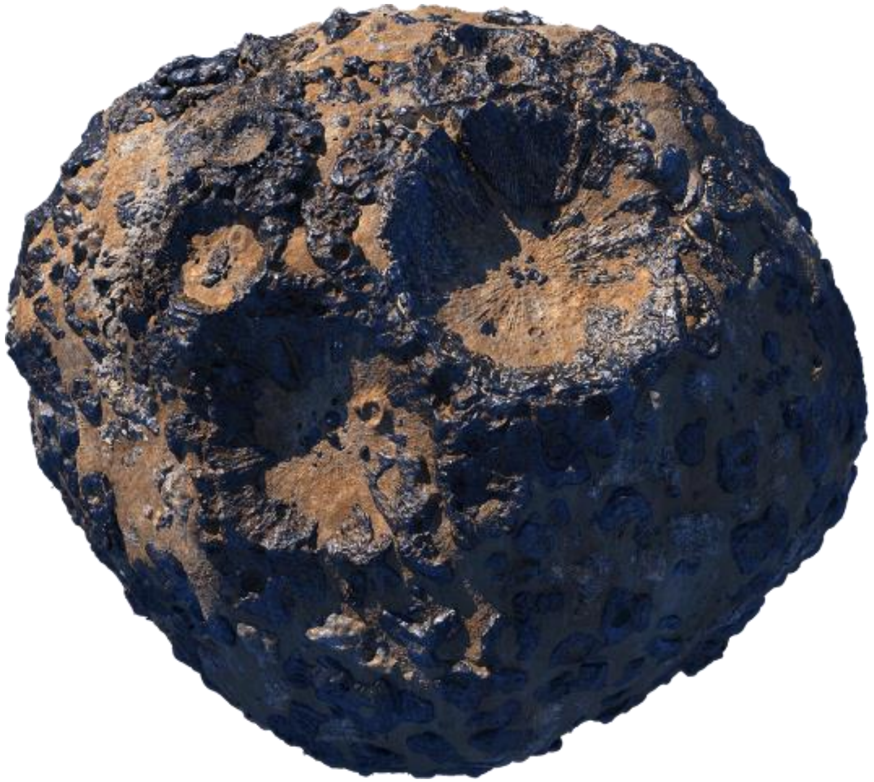
About Psyche

- Psyche is believed to be an exposed core of an early planetesimal.
- Hypothesized to be composed of iron-nickel and silicates.
- Collisions with other asteroids created layer of regolith containing material from the asteroid and Psyche's surface
- Spacecraft sent by NASA in 2023 will arrive in 2029 to observe and map Psyche's surface.



NASA Rendering of Asteroid (16) Psyche

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Customer Needs and Assumptions

Customer Needs

- Take multiple samples
- Keep integrity of samples
- Remain compatible with Team 502

Assumptions

- Sampling system is on host of our choice
- Host begins on Psyche asteroid
- Host provides power to sampling system
- Host safely traverses to extraction points

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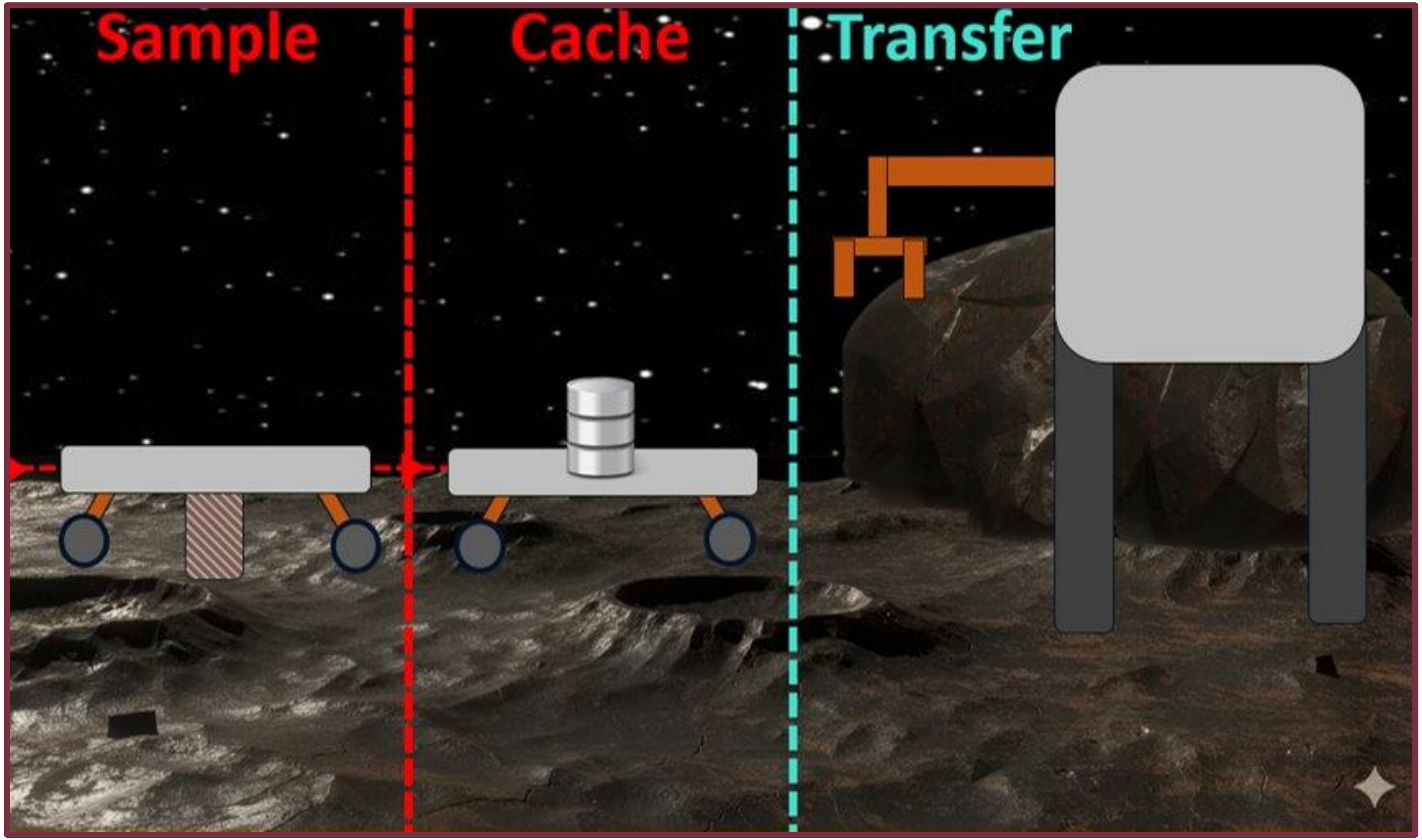
Critical Functions



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Sampling Method Overviews

Regolith Collection

- Gas blast moves surface material
- Material is directed into the collection chamber
- Sample is held in collection chamber

Subsurface Collection

- Drill extracts subsurface material
- Gas blast moves the extracted material
- Material is directed into the collection chamber
- Sample is held in collection chamber

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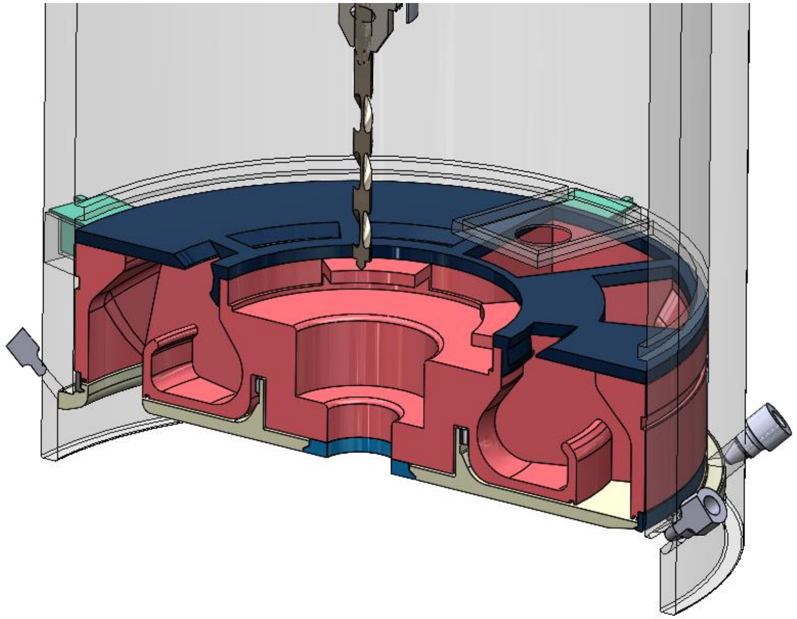
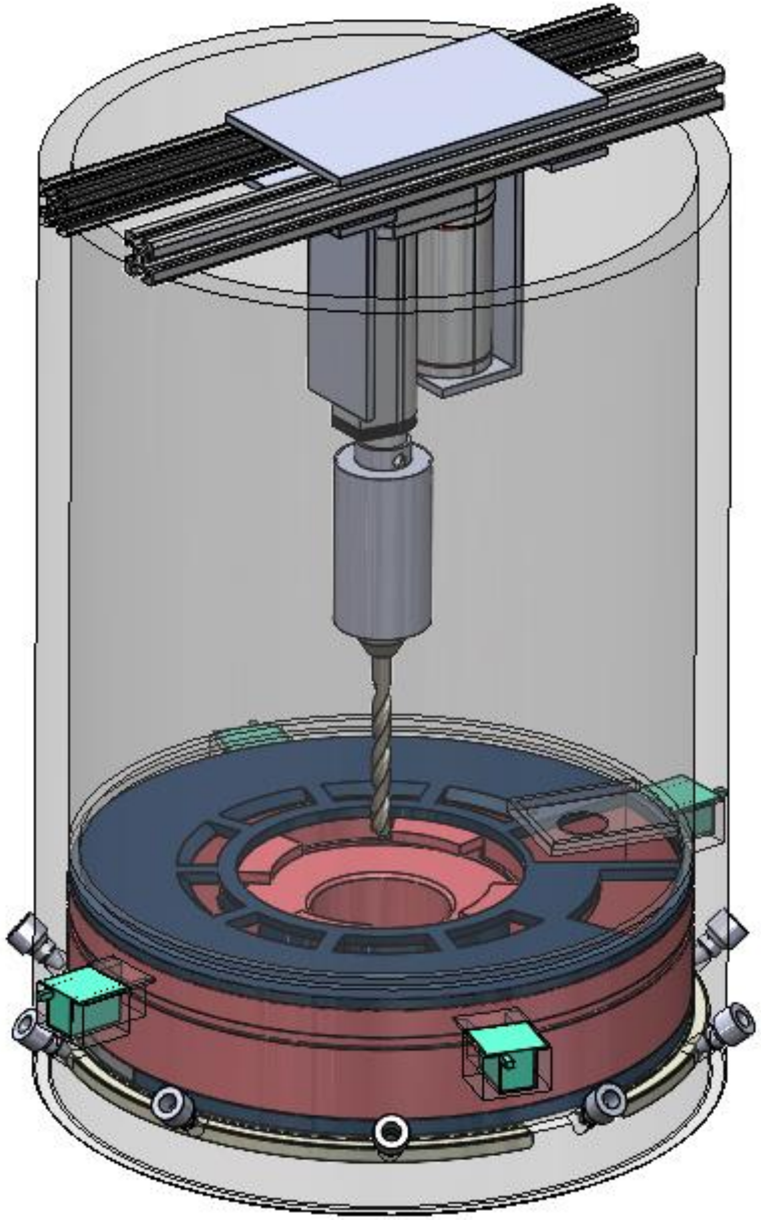
Current Design





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Sampler Ready, Begin Extraction

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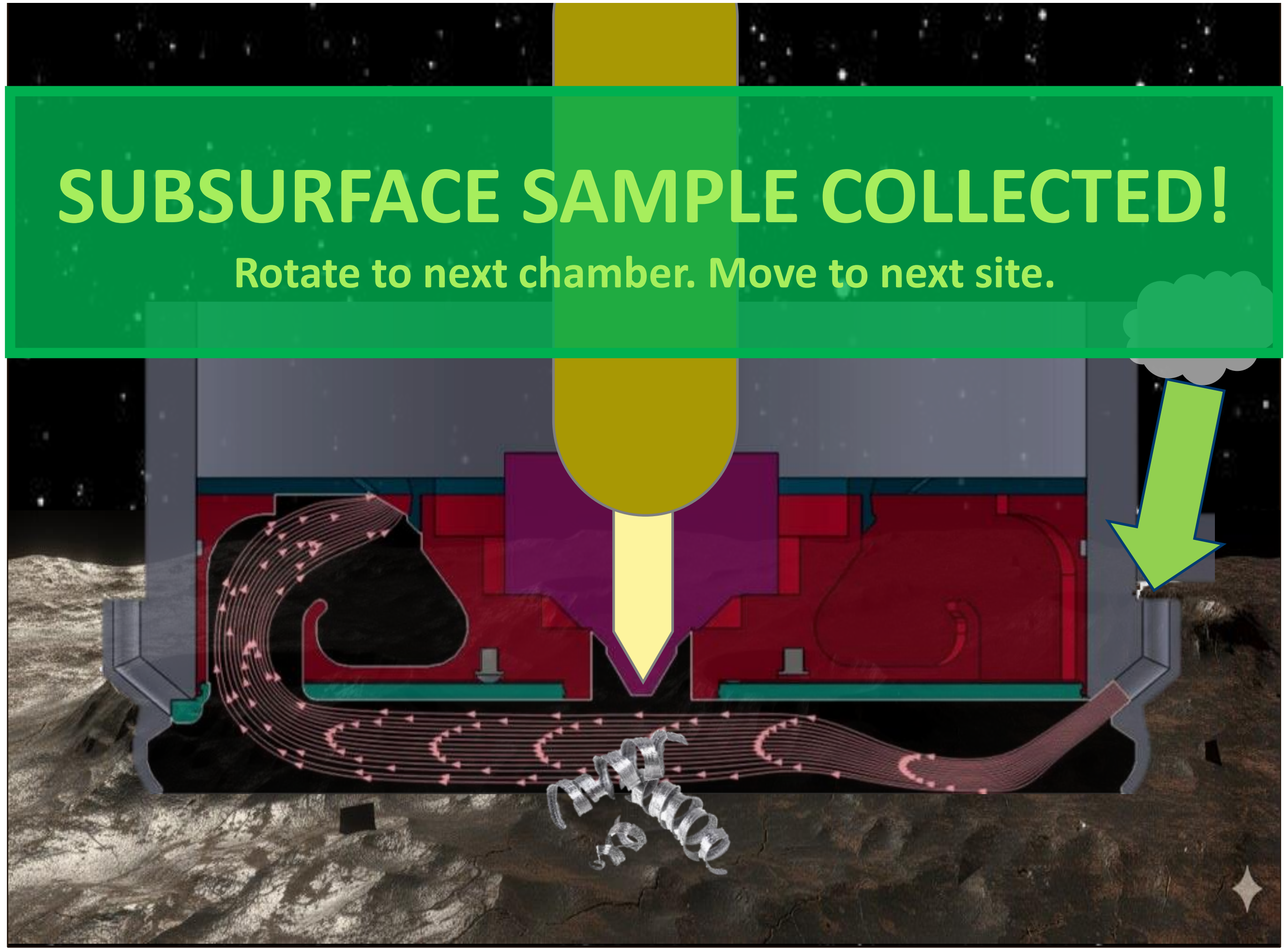
Extraction Continues



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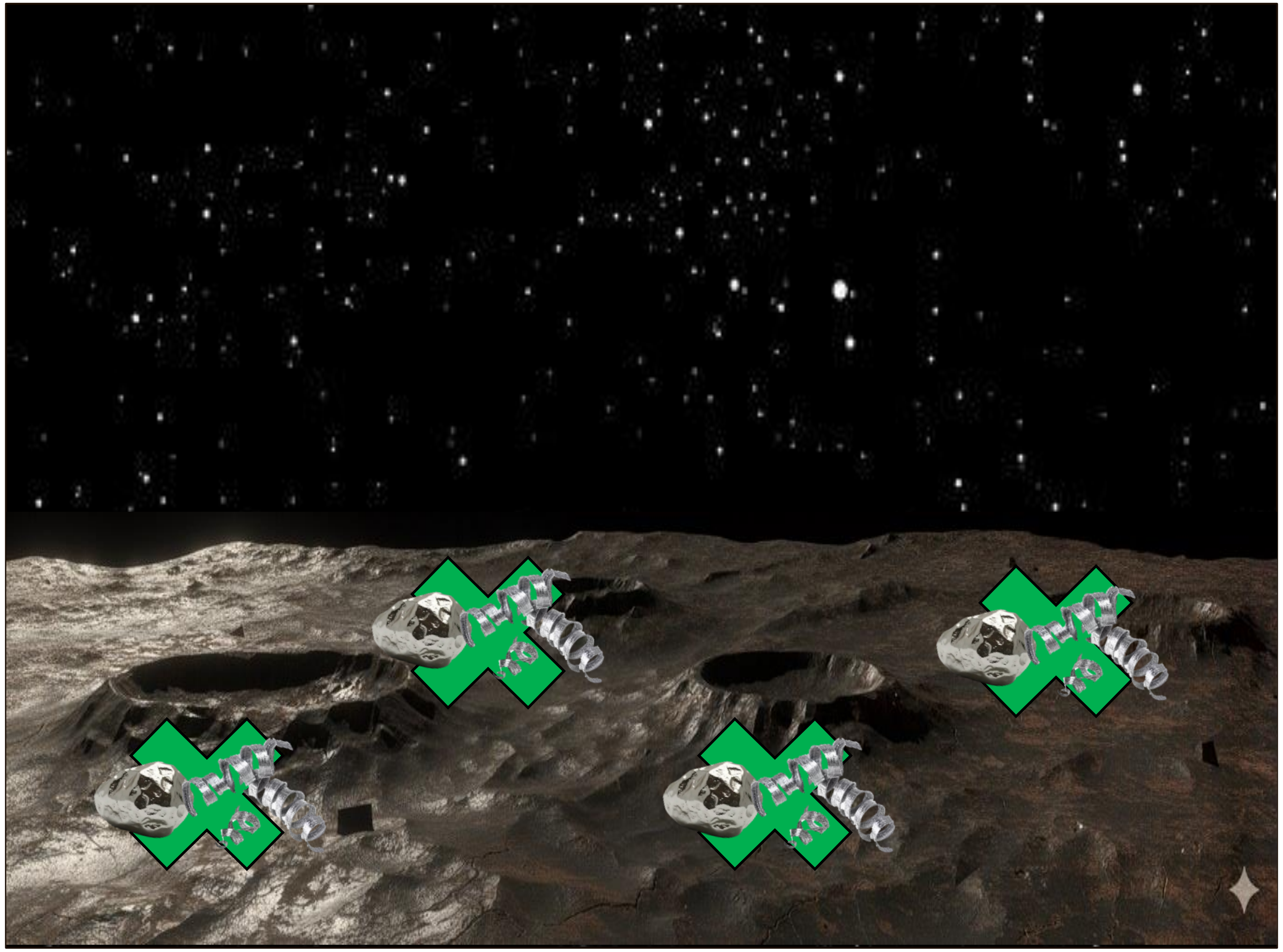
Additional Site Extractions



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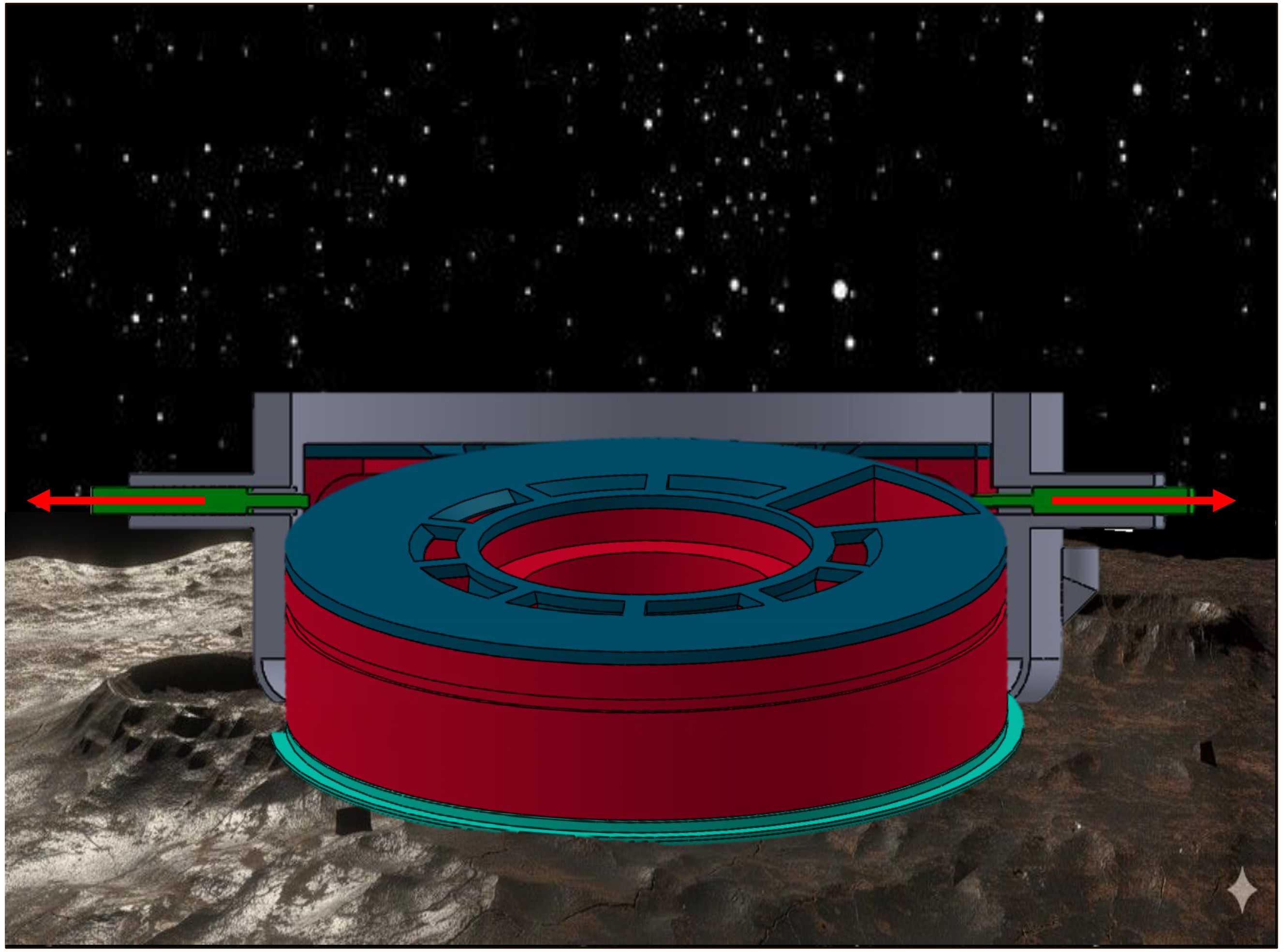
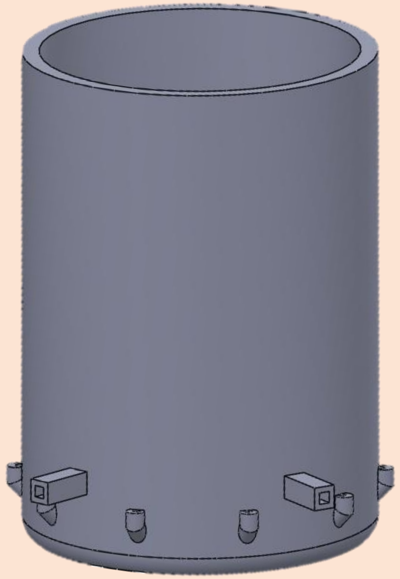
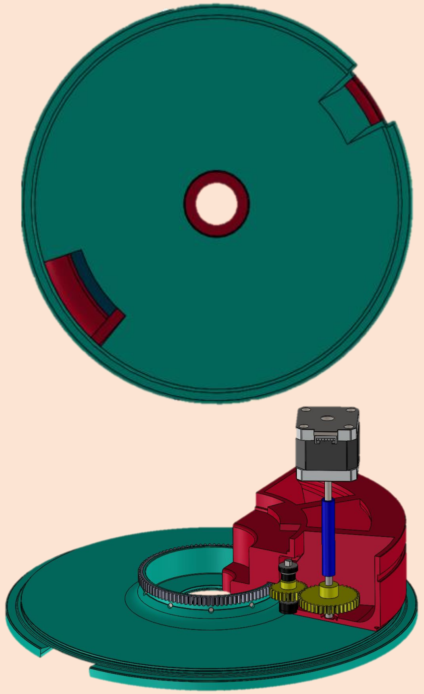
Cache Drop-Off



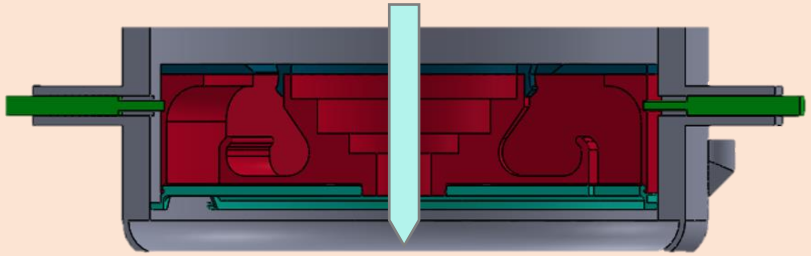
Subsystem Highlights



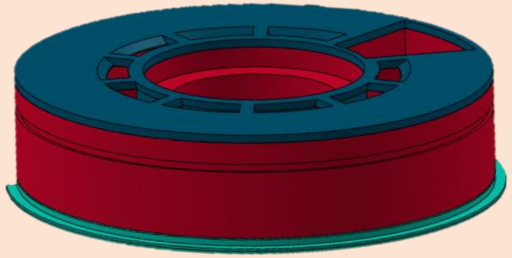
Gas Blast & Housing Capsule



Rotating Flap



Drilling Mechanism



Transfer Cache

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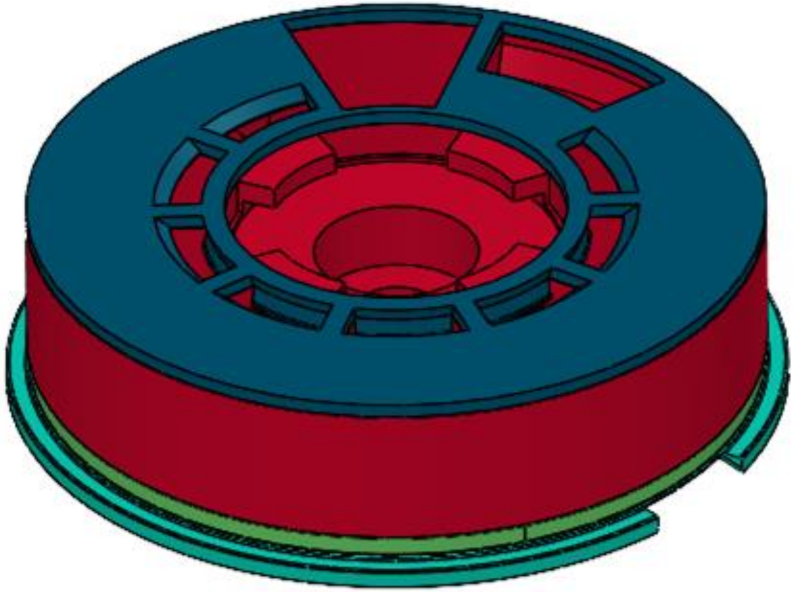
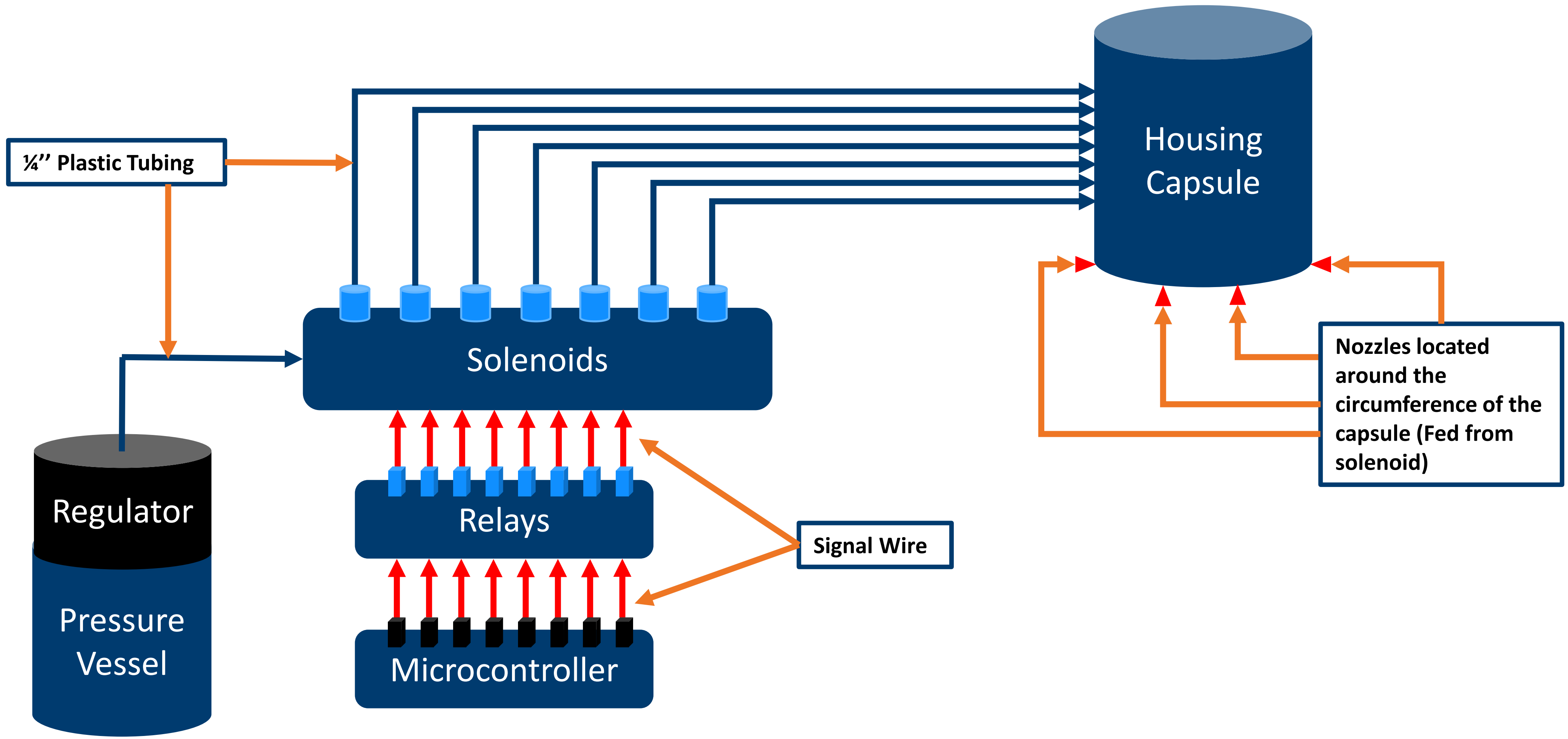
Gas Blast Flow Model Validation



Gas Blast Architecture



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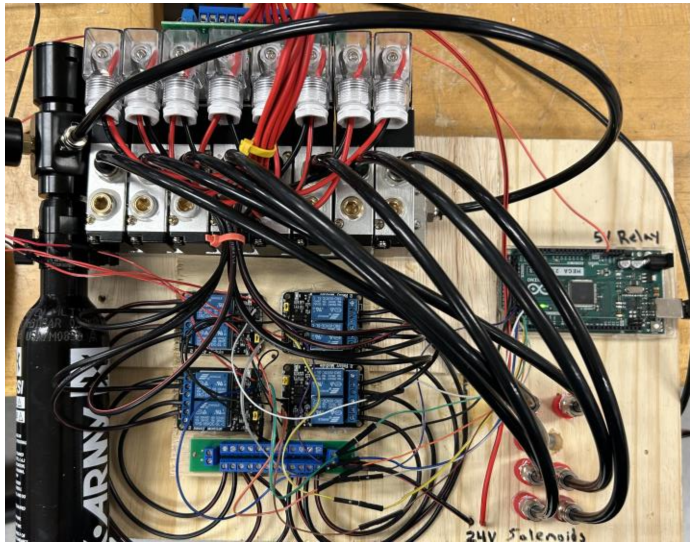
Blast System Prelim. Assembly

Delay during manufacturing of housing capsule.

Developed mobile testing fixture to validate blast system.



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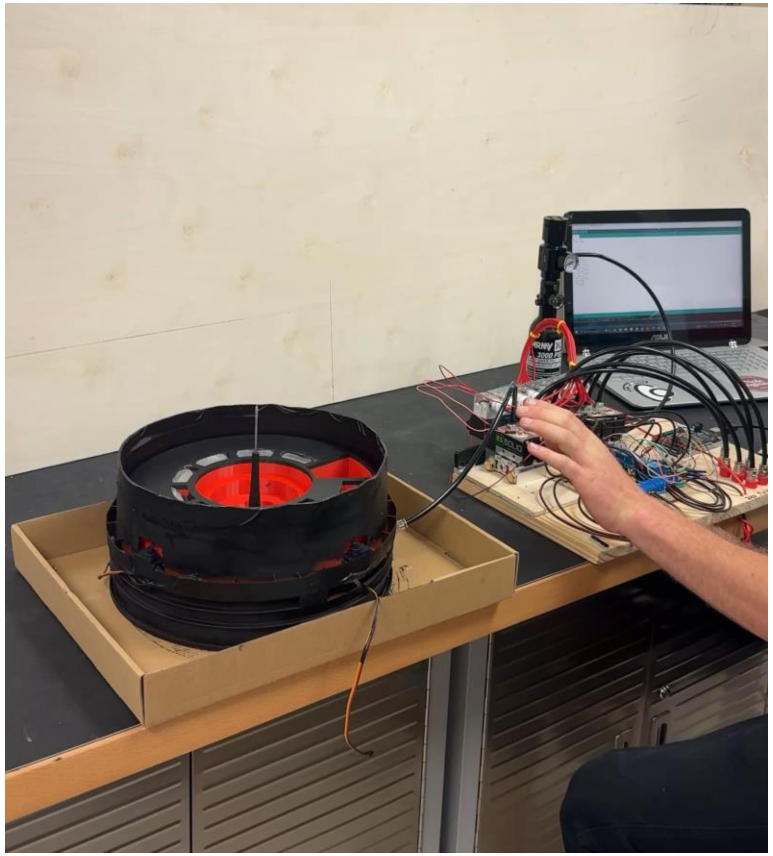
Gas Blast Results

☑ Tests demonstrate system operates as expected

- Solenoids open/close under load
- Particles excited and enter chamber



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Gas Blast Validation

To validate this subsystem, we look back to our targets.

Validated

8 samples

Surface and subsurface material

In Progress

$9cm^3$ per sample

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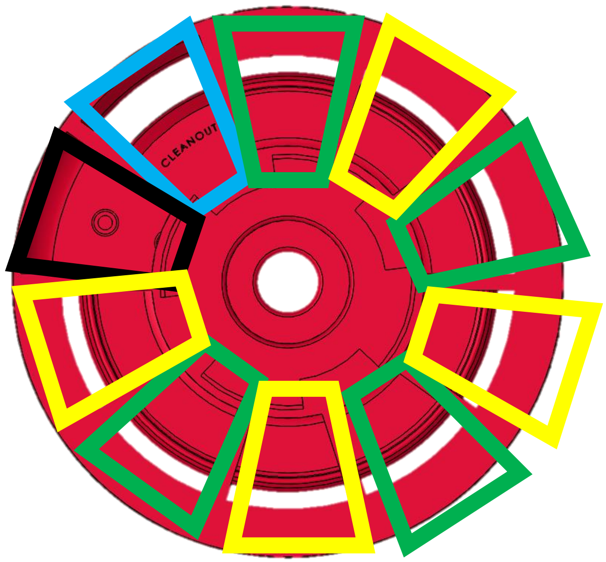
Gas Blast Head Chambers

- 10 Sections
- Gear Chamber
- Clean out
- 8 Sample chambers
  - 4 Regolith sample chambers
  - 4 Subsurface sample chambers

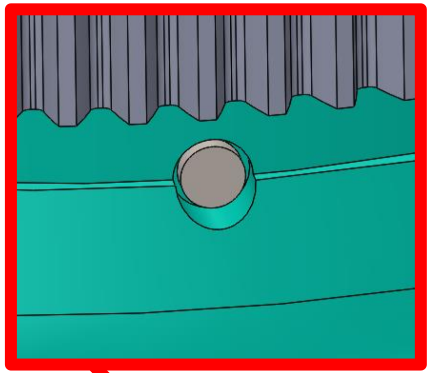


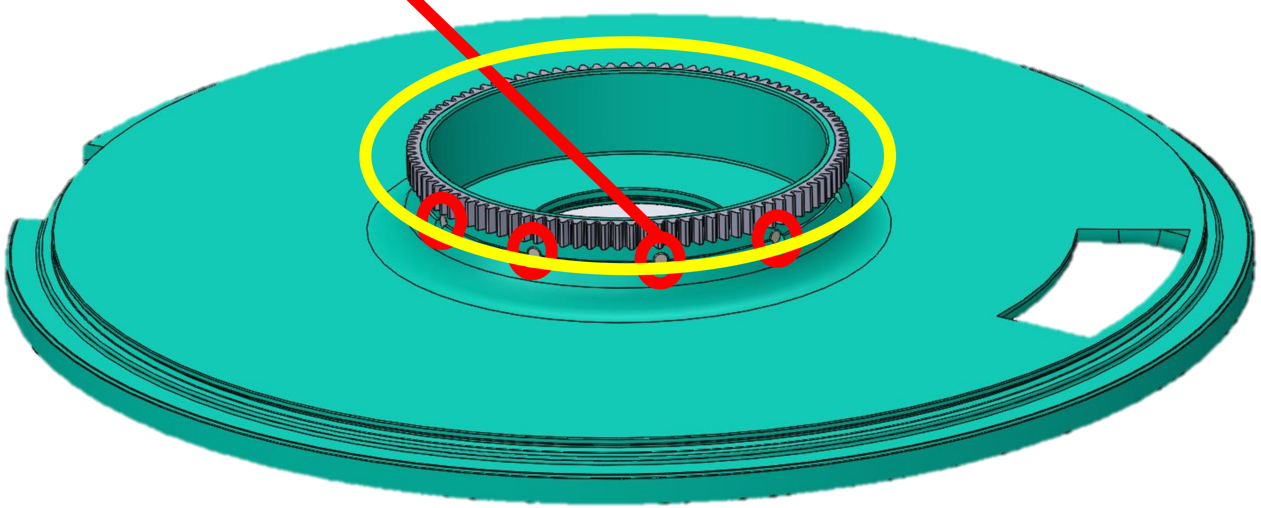
Gas Blast Head Top Side View

Gas Blast Head Bottom Side View

Rotating Flap

- 10 rotations
  - Each 36 degrees apart
- Hall Effect Sensors to determine section location
- Neodymium magnets imbedded in flap
- Gear built into flap integrates with gear train





A3144 Hall Effect Sensor

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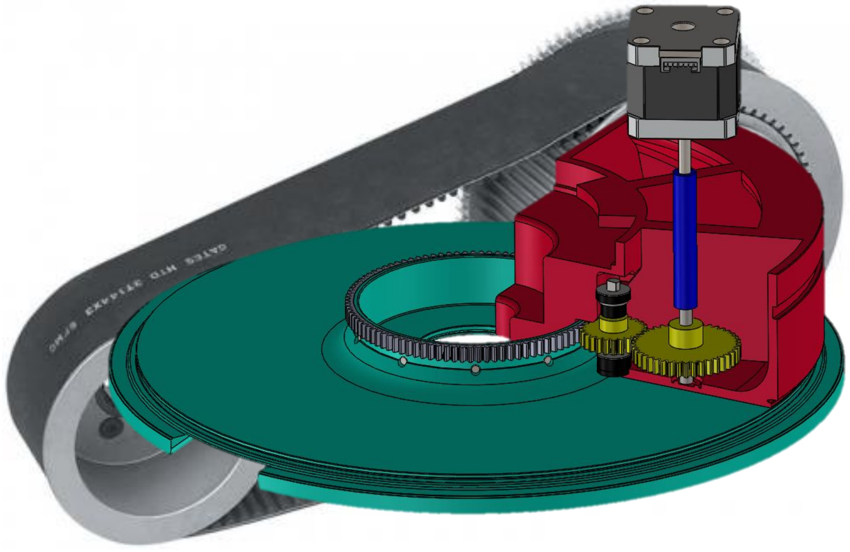
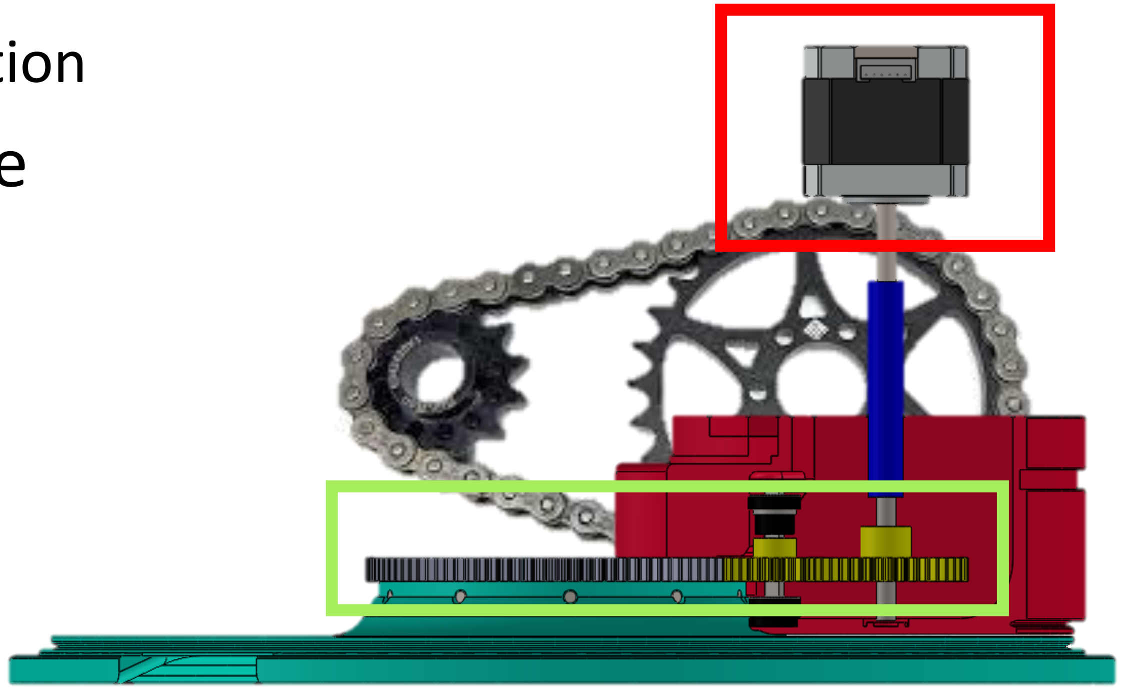
Gear Train

- Driven by a NEMA 17 stepper motor
- Gear ratio of 2.45:1
  - 49 full steps for one 36° rotation
- Other forms of rotation were considered
  - Belt drive
  - Chain drive
- Not space compatible





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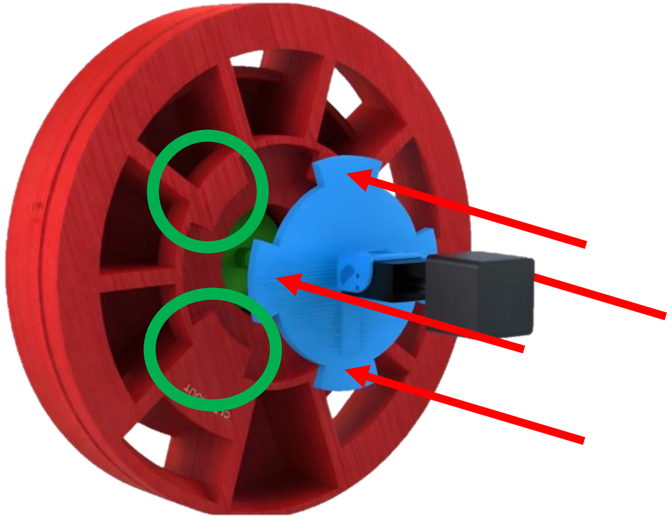
Team 502 Integration

- Two end defector designs
- Currently compatible with one design
  - End defector has 4 flaps
  - Top of gas blast head has 4 extrusions
  - End defector will insert into openings and pick up with flaps
- Working with T502 for compatibility with other design

T502 End Defector Design One



T502 End Defector Model One Integration

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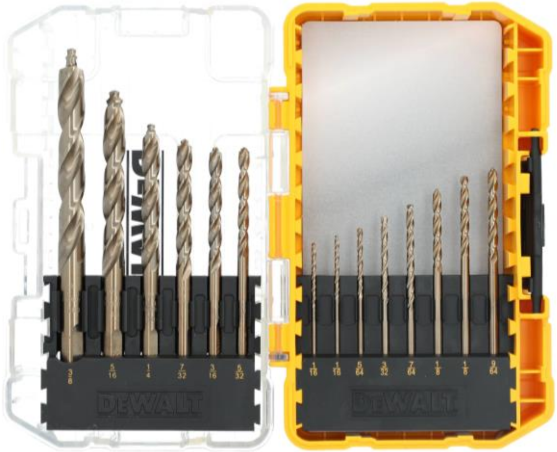
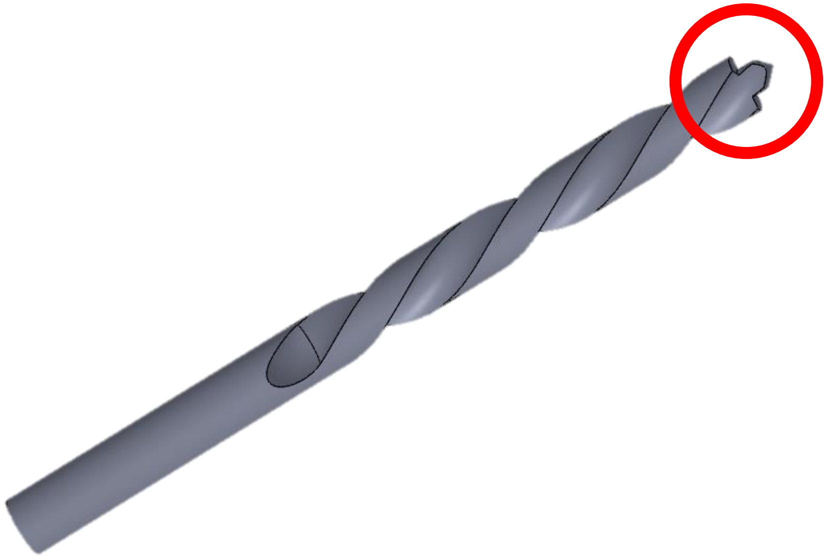
Drill Bit Selection

- Pilot head
  - Prevents slipping
- Cobalt Alloy Steel material
  - Can also work for Cryogenic applications





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Drilling Calculations

Parameter	Value
Speed	600 RPM (Range: 401-802 RPM)
Feed Rate	60 mm/min
Metal Removal Rate	2.971 cm^3/min
Power	248 W
Torque	2.96 Nm
Feed Force	1490 N
Chip Thickness	0.05 mm
Drill Time	30 seconds
Specific Cutting Force	3752 N/mm^2

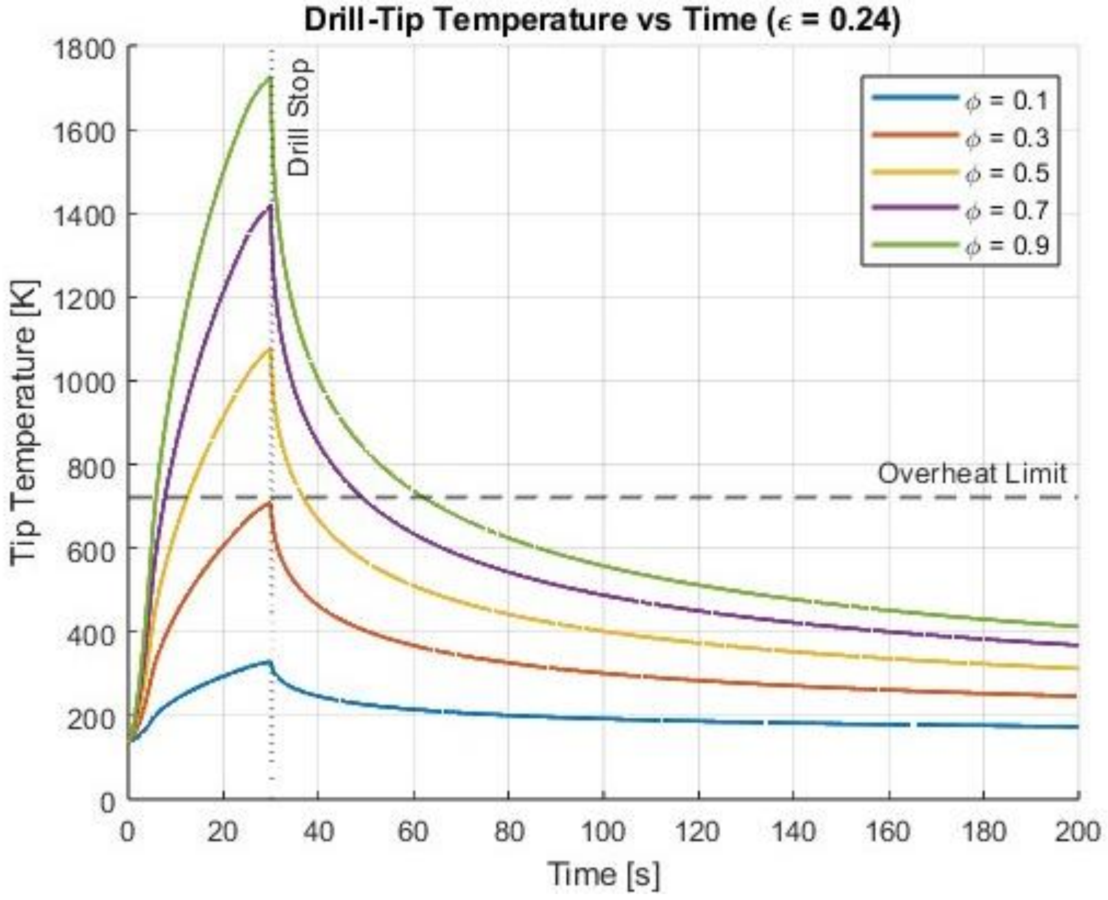
Material removal rate meets the desired requirement.

System operates at an achievable power range.

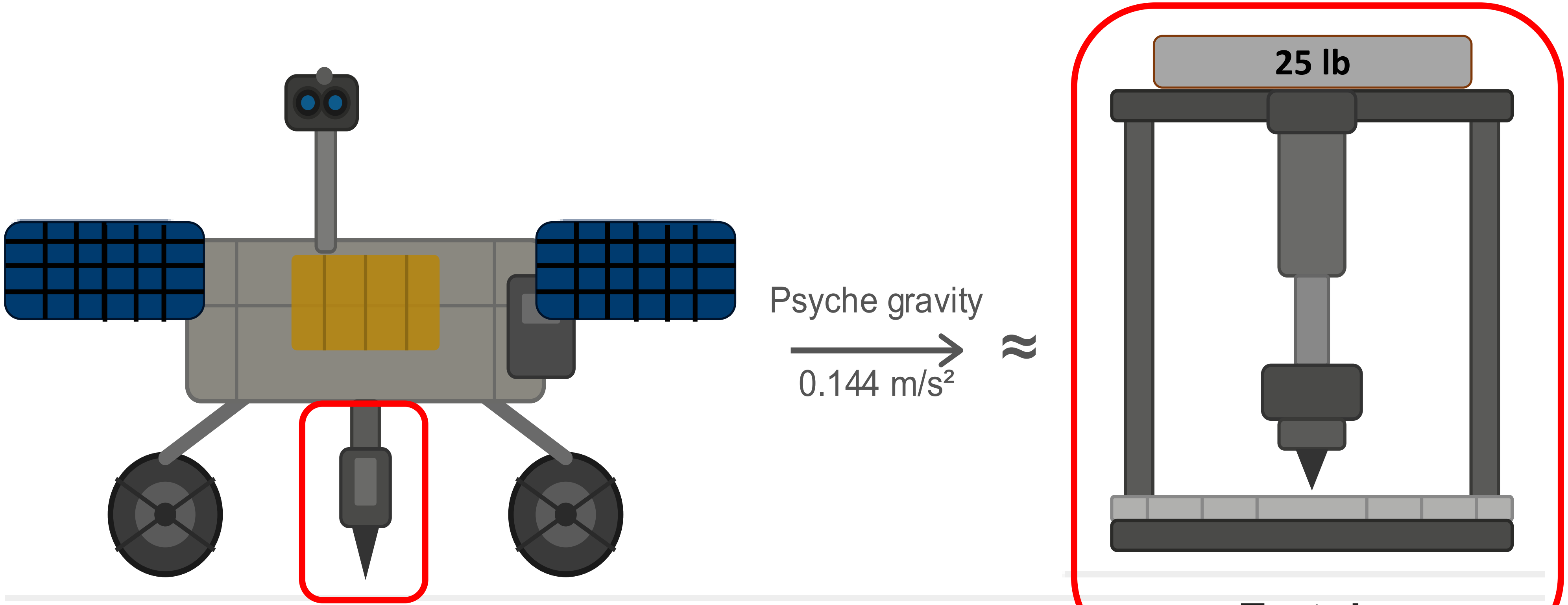
Feed Force is primary system constraint.

Thermal Data

Parameter	Value
Initial Temperature	137 K
Space Temperature	3 K
Max Allowable Drill Tip Temperature	723 K
Drill Material	M42 Cobalt Steel
Thermal Diffusivity of Drill Material	6.85 x 10^{-6} m²/s



Drilling Operation



Perseverance

~1,000 lbs on Earth

Test rig

~35 lbs under Psyche gravity

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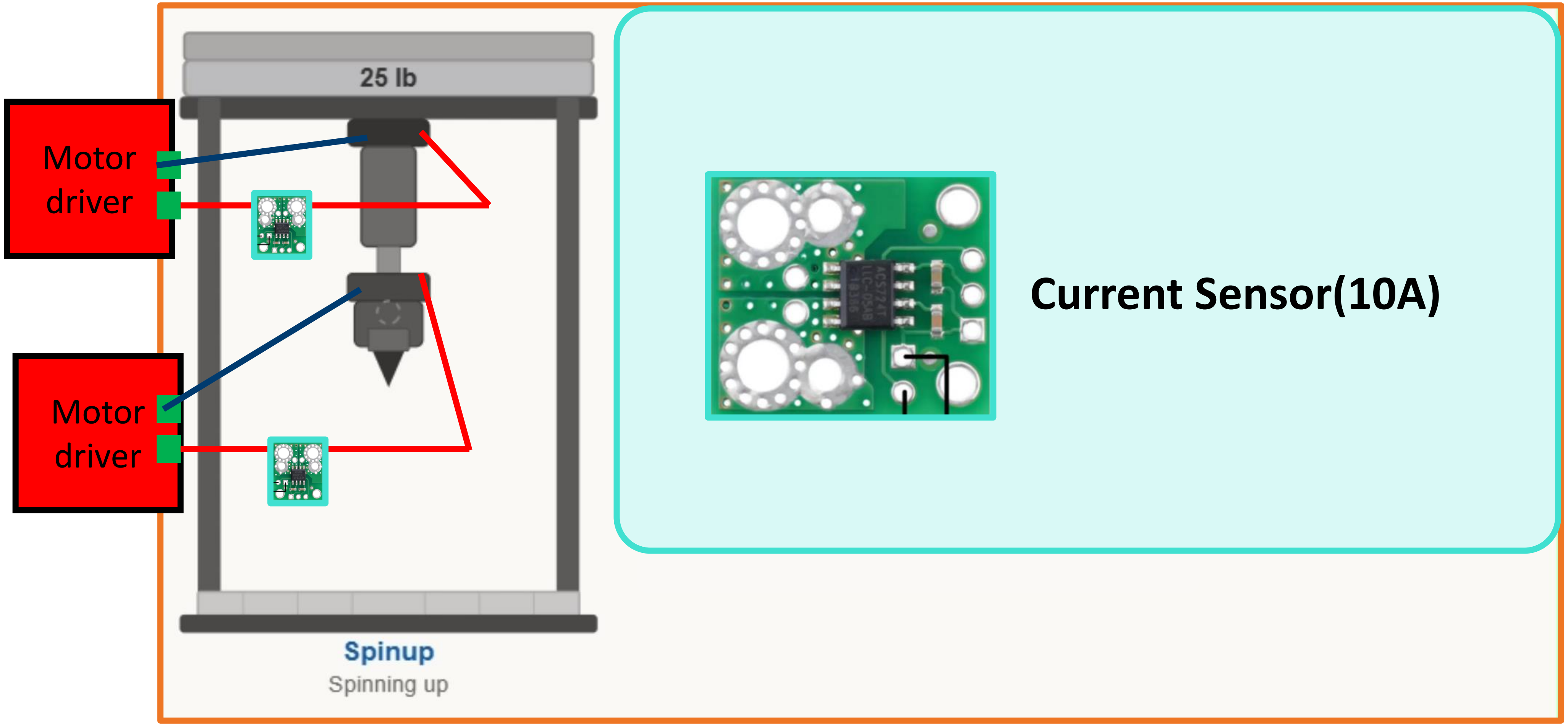
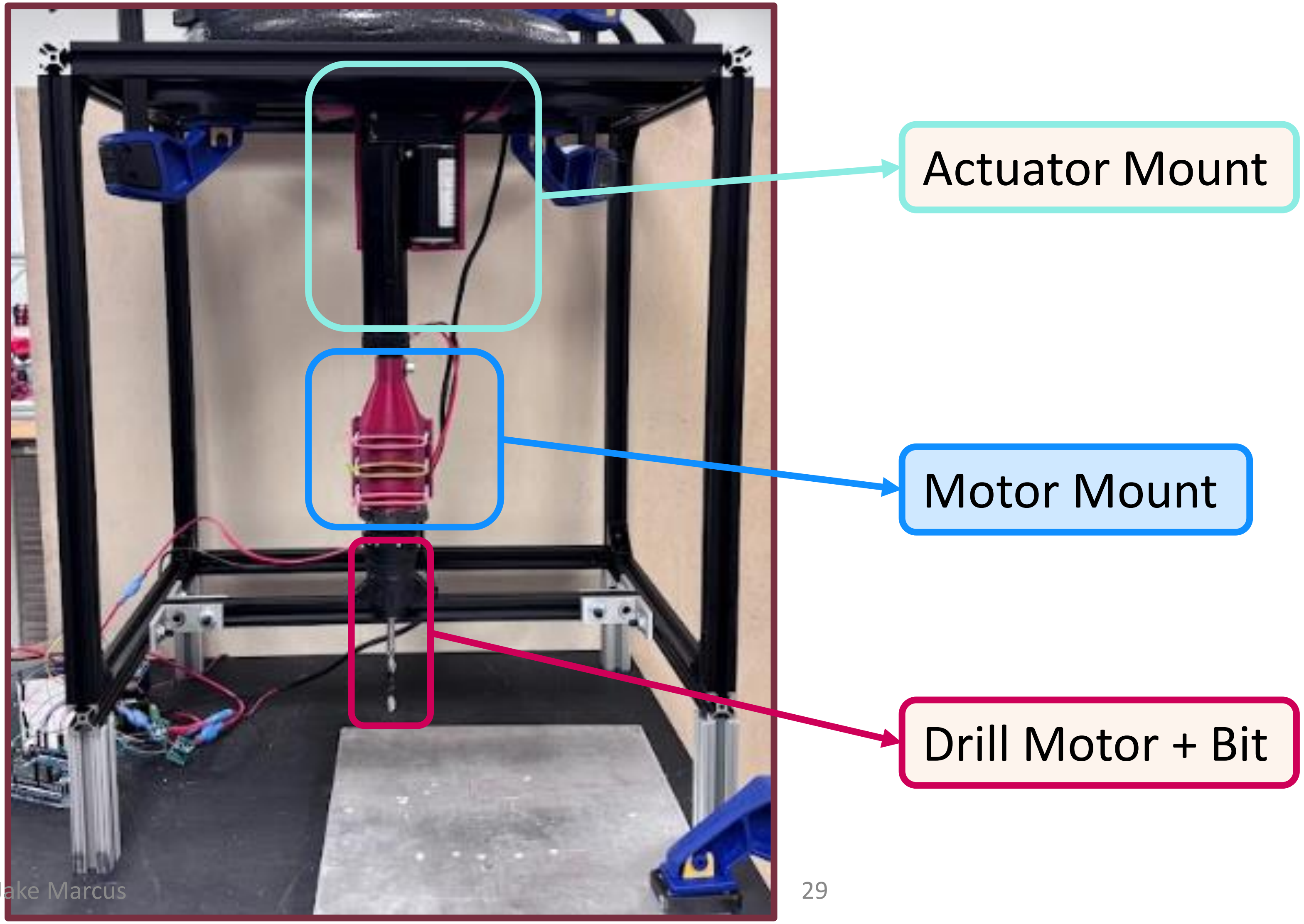
Drilling Operation

Feed Rate Controller



Drill Mount Assembly



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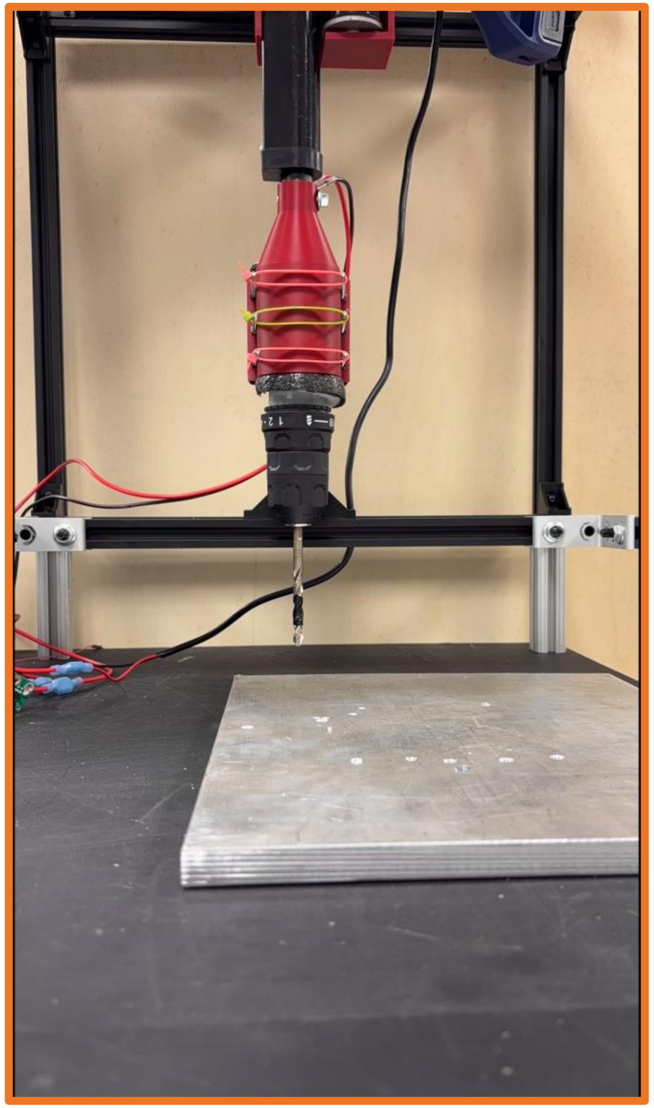
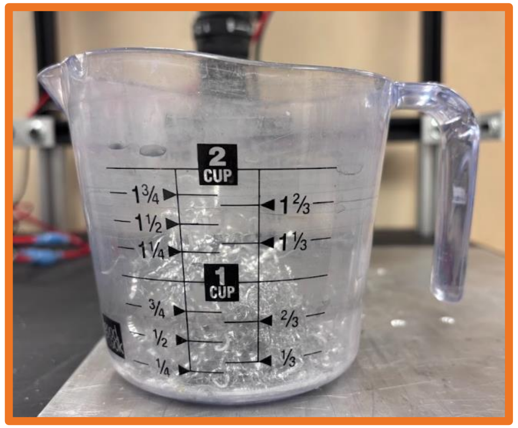
Drilling Validation



Drilled 1cm hole through aluminum

Capable of freeing 9 cm^3 of subsurface material



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Detaching Operation

- Electromagnetic actuators ❌
  - Unable to release cache of1.6 lbs
- Servo Motors ✅
- Initial testing confirms reliable drop mechanism performance

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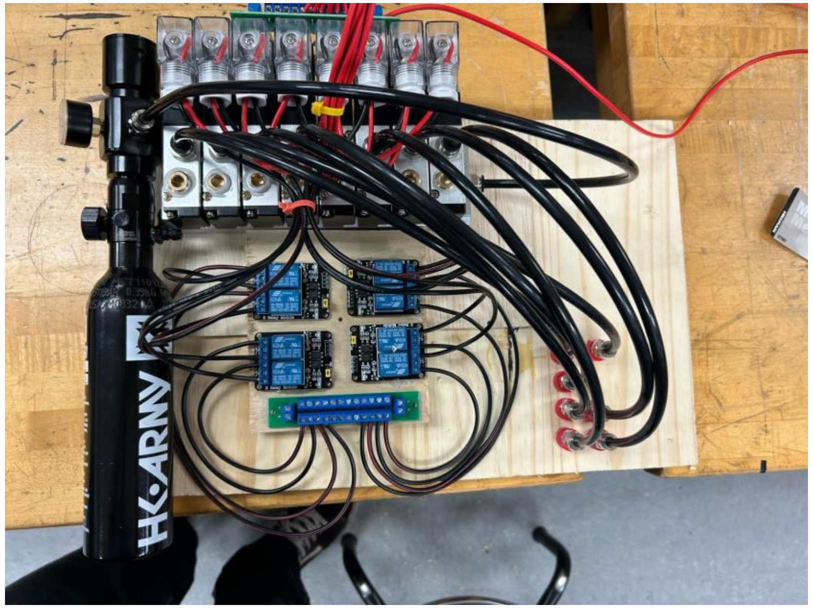
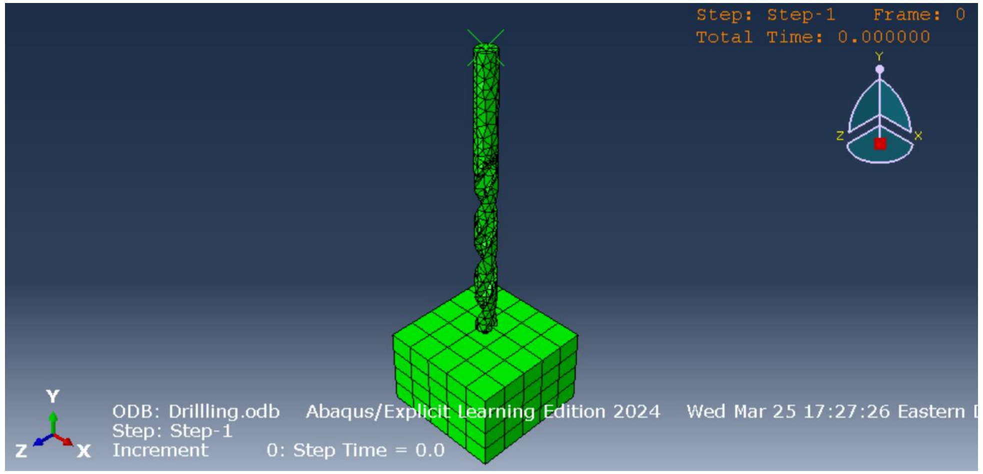
Current Progress

- Solenoid Test Rig
- Gear train with hall effect sensors
- 3D printed parts being made
- Abaqus drill modeling





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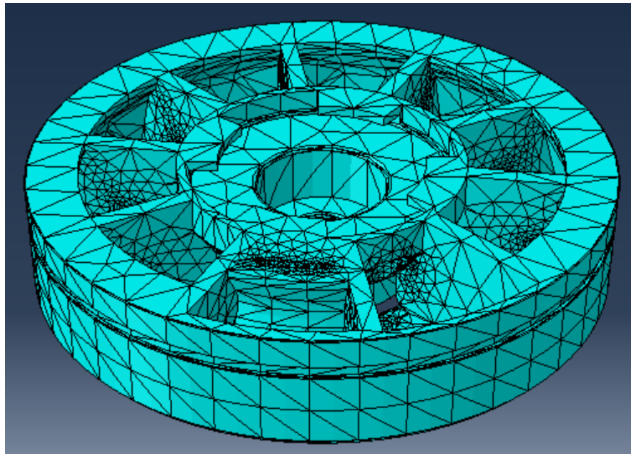
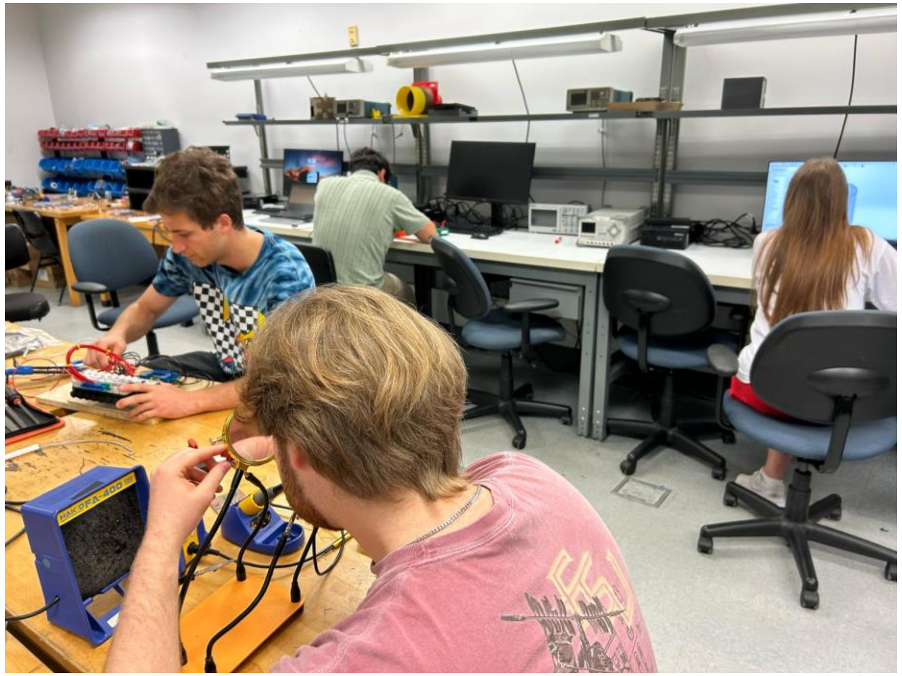
Present Challenges

Clearances & Wiring

Abaqus Modeling Capacities





Part Integration with Team 502

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Accomplishments

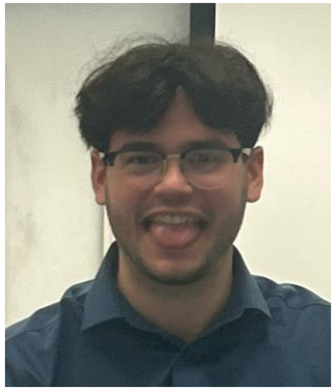
- 13 Iterations
- Software acclimation
    - COMSOL
    - SOLIDWORKS
    - Arduino
    - Abaqus
- “Working” System

Takeaways

This class is a better example of real-world project development

Design intent makes life much easier down the road

Coherence is preferable to complexity in a design



Don’t do tomorrow what you can do today

You need to plan, expect issues, and adapt

Extensive research done early will save future efforts

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Next Steps to SD Day

- Integrate gas blast subsystem
- Unify control code
- Assemble physical prototype
- Run validations

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Questions?

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Back Up Slides

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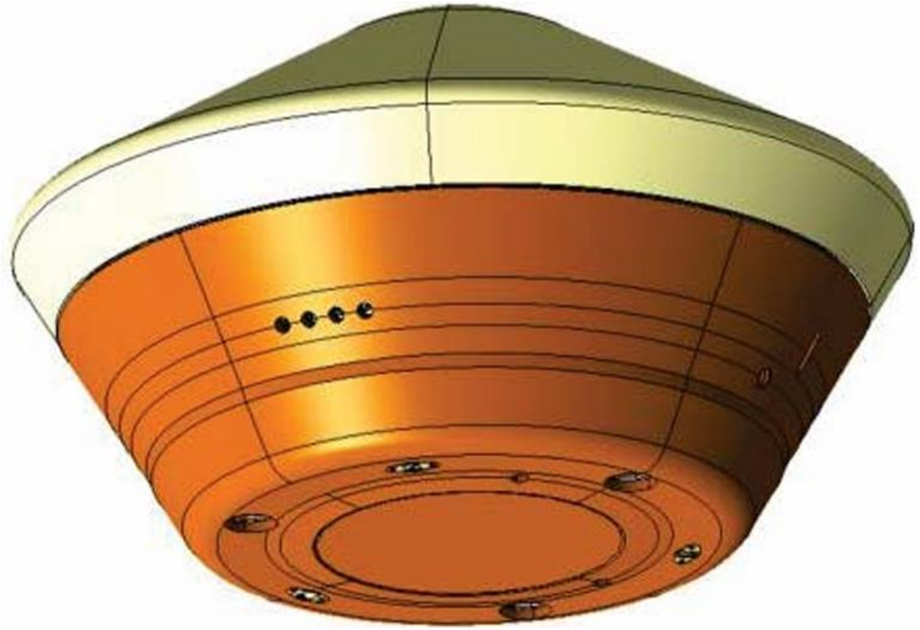
Integrating With T502



OSIRIS-REx: Returning the asteroid sample [PDF]. NASA/Lockheed Martin.

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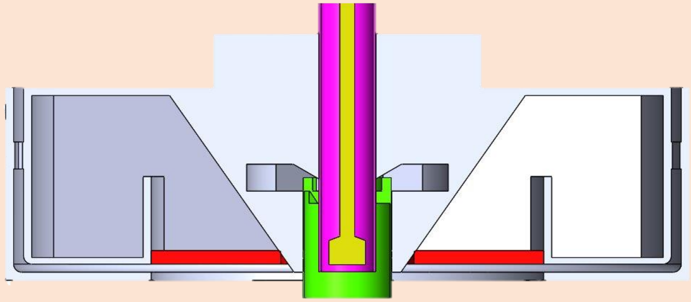
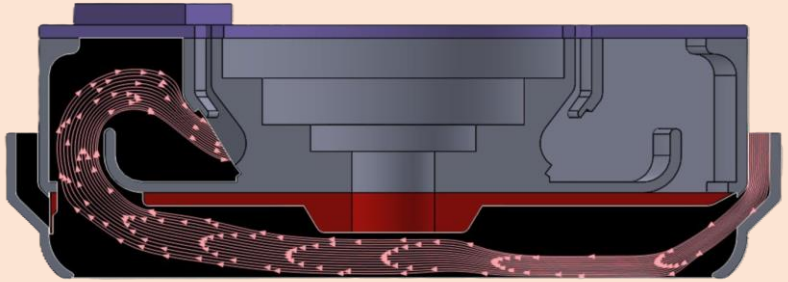
Design History

Generated Concept



Version 7



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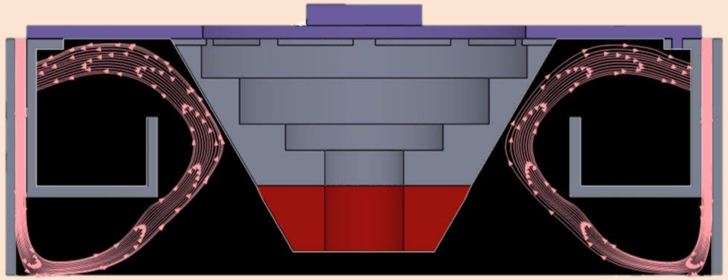

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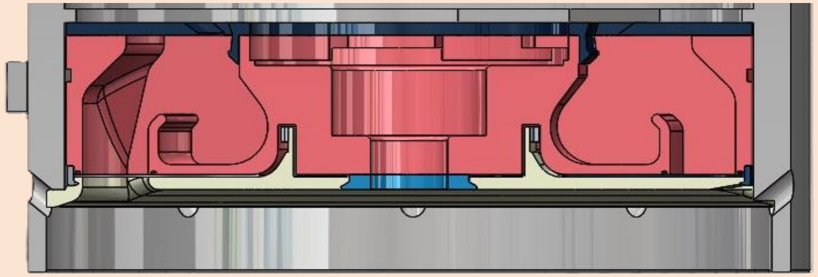

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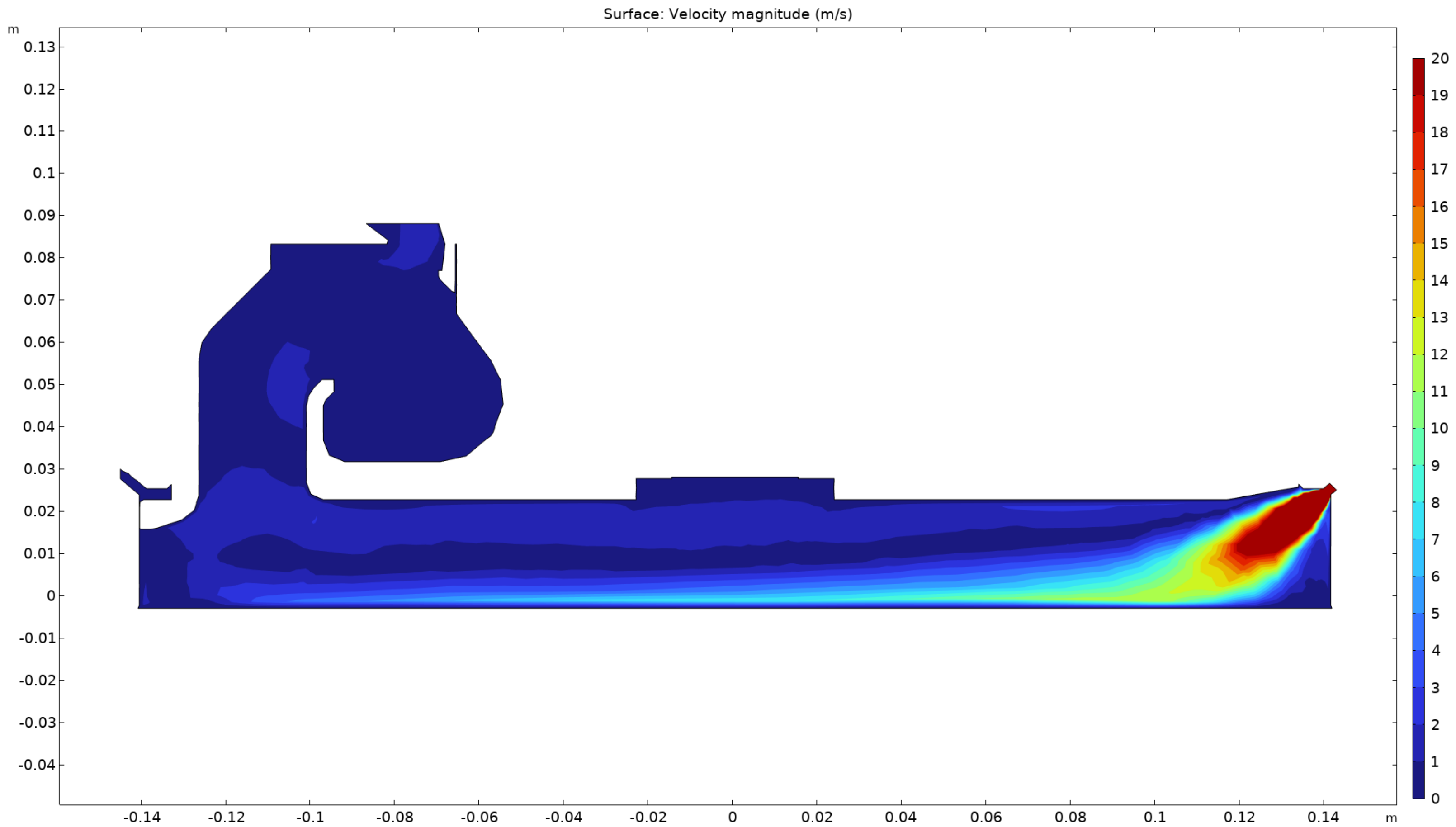
Gas Blast Flow Model Validation



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Reduced Friction Between Flap and Collection Chambers

Jake Marcus

- Roller bearings between parts
- 2mm Silicone tubing around chamber opening bases to decrease particle contamination in open gap between parts
- Insert pic or solidworks animation of the sorts to show??

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Changes still need to be made

Better contain the motors and mechanics from Psyche particles

- Adjustments in flap size and redesign of outside container for T502’s change in securing mechanism

Rotating Flap

- Gear system plan
- Reason for rotating flap from top and not bottom (simplify separation)
- Locking mechanism when separating
- Drawing or something
- Why the flap has to have such a fat rim and why it messes up are flow but theres NOTHING we can do about it ☺

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Friction Heat Rate Calculation

The given heat transfer rate resulting from a friction is governed by the equation

$$Q_{friction,} = F_f d$$

Where F_f a is the friction force, t is time, and d is the distance over which the friction acts upon. Given that the frictional force is unknown, we change the equation to a rate of heat equation

$$\dot{\boldsymbol{Q}}_{friction,} = F_N \mu v$$

Where F_N is the normal force, μ is the friction coefficient, and v is the sliding speed, which occurs at the interface. The sliding speed is also a variable, shown in the equation below

$$v = 2\pi r N$$

N is the number of revolutions per minute, and r is the radius of the drill bit. So, the expanded equation for the friction heat transfer is

$$\dot{\boldsymbol{Q}}_{friction,\ \ drill\ bit} = F_N \mu 2\pi r N$$

It's important to know that specifically for a drill bit, the friction heat transfer does NOT equal the heat transfer on the bit. Instead, a drill bit gets a fraction of this heat transfer, which is determined by the drill bit's heat partition coefficient. For this analysis, we will denote this as α. Thus, the full equation for the friction heat transfer to the drill is denoted by

$$\dot{\boldsymbol{Q}}_{friction,\ \ drill\ bit} = F_N \mu \alpha 2\pi r N$$

Regarding the coefficients, friction coefficient and heat partition coefficient cannot be calculated directly, thus they must be estimated. The friction coefficient is estimated to be 0.8 from a source that gives the coefficient value for Tungsten Carbide and Iron. A separate study suggests that coating has no large effect on friction coefficient, so we do not need to address the Titanium Nitride coating of the drill. As for the heat partition coefficient, this value has a range of 0.5-0.8 for an uncoated Tungsten Carbide Drill. We will estimate it to 0.65. With the assumed coefficients we get the equation

$$\dot{\boldsymbol{Q}}_{friction,\ \ drill\ bit} = F_N (0.65)(0.8) 2\pi r N \Longrightarrow$$

$$\dot{\boldsymbol{Q}}_{friction,\ \ drill\ bit} = 1.04\pi F_N r N$$

$$\dot{\boldsymbol{Q}}_{friction,\ \ drill\ bit} = 324.2\ J/s$$

Temperature Rate Calculation

We know that $\dot{Q}$= 324.2 J/s. The mass of the drill is 0.00478 kg, with a heat capacity of 280 ($\frac{J}{kg*K}$). The thermal energy of an object is given by:

$$\dot{Q} = mc\Delta T$$

So that,

$$\frac{dQ}{dt} = \frac{d(mcT)}{dt} \quad \Longrightarrow$$

$$\dot{Q} = mc\frac{dT}{dt} \quad \Longrightarrow$$

$$\dot{Q} = mc\dot{T} \quad \Longrightarrow$$

$$\dot{T} = \frac{\dot{Q}}{mc} \quad \Longrightarrow$$

$$\dot{T}_{friction,\ drill\ bit} = \frac{\dot{Q}_{friction,\ drill\ bit}}{mc}$$

Hence, we know that the drill will increase by about 242 K per second.

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