SD T501 Technology Demonstration of Prototype

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

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## Background

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. Psyche is believed to be an exposed metallic core of an early planetesimal, primarily composed of iron-nickel and silicates. Its outer rocky layers were likely formed during collisions that occurred billions of years ago, making it an opportunity to study core material, which is not possible on Earth.

Currently, a spacecraft that was launched by NASA in 2023 is set out for arrival to the Psyche asteroid in 2029 to observe the Psyche surface and to determine if conditions are favorable for sample extraction. The early-stage prototype presented by Team 501 demonstrates the proof-of-concept for potential integration for the future of the Psyche mission.

## Current State of Design

Physical Prototype

- A 70% scale model of the design has been 3D printed using PLA. The current physical prototype includes a NEMA17 stepper motor, a small drill motor, a chuck, and an engraving bit. An Arino Mega is being used as the micro controller and can currently rotate the stepper motor. The prototype will also incorporate a pressurized gas system to excite ground particles and prove that the method of material collection is viable. This iteration enables rapid prototyping, unlike the full-scale model, which would take several days to print each time.

The function of the current state of the design is as follows:

- The sampler, after identifying a viable extraction site, will release a gas blast using solenoids connected to a regulated pressure vessel. At this moment, the sampler will also release a blast in the opposite direction to counteract normal reaction forces generated by the original gas blast that could destabilize the device. This blast towards the surface will excite surface material, which will then be directed into the collection chamber using the flap connected to the geartrain.
- Once the first sample is collected, the stepper motor connected to the geartrain will rotate to allow future material to be directed into an empty collection chamber, this action will also prevent any material from contaminating the previously captured sample.
- Once a hard surface has been identified (not loose regolith), the rotating abrasive bit will activate, and the linear actuator will push the abrasive bit into the surface. At the same

time, the solenoid connected to the thrusters oriented up will activate to generate additional downforce needed to counteract the normal forces generated due to drilling.
- Once the abrasive bit has ground the surface material, a gas blast will be released to direct the ground material into its collection chamber, following similar protocol for vehicle stabilization.

A fourth iteration of the sampling system CAD model has been developed using SolidWorks. System integration will be assessed through the model and verified through the use of the preliminary prototype. The current 3D model contains the main housing components for the entire system, but additional developments are being made for wire management and motor housing. COMSOL simulations are also being developed to analyze optimal geometry for the sample containment chambers and gas blast flow direction and speed.

## Forecast

The project will now transition from preliminary modeling to detailed simulations and testing to verify model functionality under ideal conditions. Over time, additional tasks may be added, which will be dependent on the success of test results. Expected next steps include:

- Running COMSOL simulations for heat transfer and gas-blast flow behavior
- Completing CAD motion analysis for successful movement of the system
- Begin developing a testing procedure for the Earth-based prototype
- Verify and test motor torque requirements
- Fabricating components for the functional Earth-based prototype

## Problem Areas

Several challenges have been identified throughout the initial developments of the Psyche sampling system. One main concern is scope creep, due to the number of subsystems that will need to be integrated together successfully to function effectively with the asteroid's conditions. Developing an Earth-based prototype while also validating the feasibility for Psyches environment adds additional difficulty. Testing also presents difficulty as material flow, heat transfer, gravity, and many other conditions vary between the testing location on Earth and the actual sampling location on Psyche. Another point of contention is our measurement accuracy. We want our system to acquire 9 cubic centimeters of material per sample, but how this will be monitored is currently unknown. Additionally, collecting the abraded material may present challenges due to the drilling location being at the center of the system. We also anticipate potential issues related to reaction forces generated during the drilling and gas-blast processes.