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Particle Containment Assurance

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INTRODUCTION

In 2020, the National Aeronautics and Space Administration (NASA) will launch the Mars 2020 rover, the first phase of the Mars Sample Return mission. Geological samples will be collected from the surface of Mars to further analyze rock, soil, and dust particle compositions that require laboratory procedures only feasible on Earth. The samples will then be launched into orbit around Mars in a sample containment sphere, known as the Orbiting Sample **(OS)**. The OS will be captured by spacecraft and is required to be contained for safe transport to Earth without risk of contaminating Earth's biosphere or the geological samples. NASA has established Category V requirements for the mission, mandating redundant, fail-safe containment requiring a probability of inadvertent release of a single dust particle of <10e-6. Thus, this project will focus on clean containment of the OS via a study on the use of a combined *labyrinth and grease* seal as a secondary and final means of particle containment assurance.

METHODS & MATERIALS

(1) Grease is applied to the interface of the male and female sides of the labyrinth seal, **(2)** dust is loaded into the pressurized chamber, and **(3)** the labyrinth seal assembly is placed into the testing rig with a strip of velvet to catch dust migrating through the seal. The **(4)** chamber is pressurized up to 15 psi in order to resemble the pressure differential between Earth and space. After each test, **(5)** seals are examined for dust migration and cleaned for the next trial.

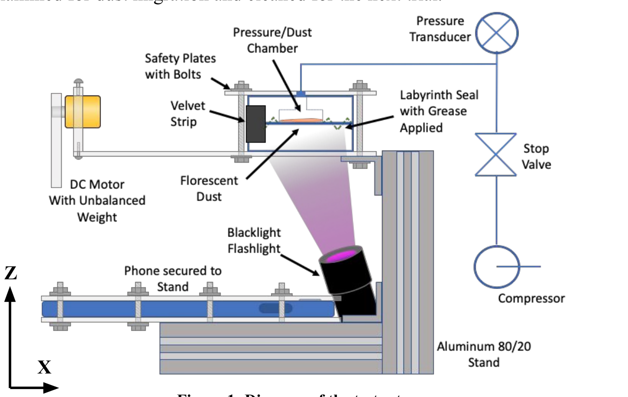

Figure 1: Diagram of the test setup

RESULTS

Tests Without Vibration

(a) Flat (b) Single Triangle (c) Double Triangle

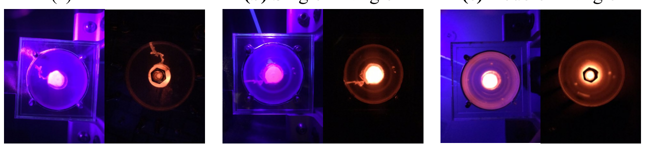

Figure 2: Static test photos

Depressurized seals of both the test assembly (with UV light, left) and excited fluorescent dust (without UV, right) demonstrate dust migration due to a "*tunneling phenomenon*" that begins as a radial migration and eventually punctures the seal in the flat (a) and single triangle (b) geometries; the double triangle (c) test effectively contained the dust within the chamber.

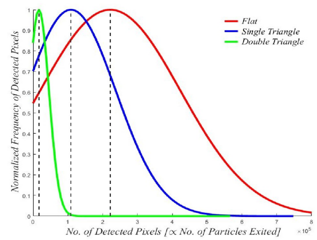

Figure 3: Normalized distribution functions of detected pixels of escaped dust particles under static conditions

Upon completion of each test (5 for each geometry), observational analyses of each velvet strip via computer vision techniques (OpenCV) produced statistical results that quantified the number of dust particles that escaped the seal based on detected pixels.

Tests With Vibration

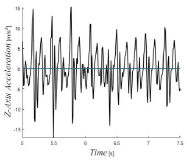

Figure 4: Vibration data along Z-axis

(d) Single Triangle (e) Double Triangle

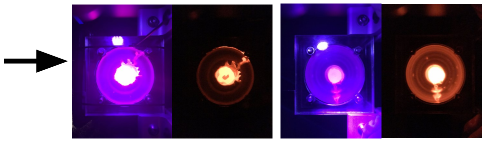

Figure 5: Vibration test photos

Vibration was added to the system through the use of an unbalanced DC motor (7770 rpm max efficiency) attached to the test assembly by a cantilevered arm and was active during the pressurization stage. This was done to test containment while simultaneously mimicking the movement of dust in a low gravity environment. The tunneling effect was more pronounced in vibrating tests (Figure 5) than in the static tests (Figure 2).

DISCUSSION

The results inform the following:

- Particle containment "success" is achieved when *no dust particles escape* a pressurized and vibrated seal over a statistically significant number of tests
- Based on a Gaussian curve fit, the labyrinth - grease seal tests without vibration presented a noticeable trend where more triangular (tortuous) geometries were *statistically more likely* to prevent particle migration out of the seal
- Preliminary observations suggest vibration increases particle migration
- *More data is necessary* to address Category V requirements and to ensure a fail-safe system is sent on the Mars Sample Return Mission

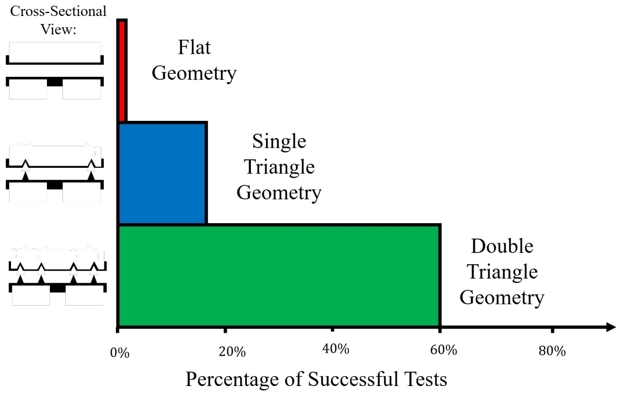

Figure 6: Success by geometry

Future work includes:

- Repeat static and vibration tests to improve data sample size
- Explore the significance of various measures to prevent tunneling, e.g., surface area, more tortuous geometries, grease properties, etc.

ACKNOWLEDGMENTS

Thank you to Charles Dandino, Morgan Hendry, Dr. Gilpin, Dr. Radovich, Rod Yates, & Dan Cordova.