Design and Testing of a Sample Container to Preserve Rock Cores for Proposed Mars Sample Return

Mimi Parker
Mechanical Engineering Undergrad, UC Berkeley
mimiaudiaparker@gmail.com

Mentors: Charles Budney (JPL) and Paulo Younse (JPL)

Sponsored by the National Science Foundation (REU grant #AST-1156756) and Consortium for Undergraduate Research Experience (CURE)

August 14, 2013
Objective
To design hardware to test the sealing methods for hermeticity, to preserve
• Mineral structures
• Potential biosignatures
• Earth’s atmosphere

Motivation
Direct impact on biology and philosophy
Sealing methods applicable to future human explorations

Approach
Design hardware to fit for use in testing
Conduct tests through simulations and check for any leakage
Overview

- Mars Sample Return
- Previous studies
- New focus for this summer
- Test hardware designs
  - Shock
  - Vibe
- Vibe test
- Conclusion
- Further research
Proposed Mars Sample Return

Sample Integrity Research Team for Mars Sample Return Campaign

1. The samples are left on the surface of Mars for ~10 Earth Years

2. Samples are launched off the Mars surface by a rocket (Mars Ascent Vehicle)

3. Orbiter catches samples and brings them back to Earth

Vibe Tests

Shock Tests
Shock Block

- Designed last summer
- Aluminum, 45 kg (100 lbs.)
- The clamshells sit in 3 positions
- The new clamshell must fit the previous clamshell mold

The 9 meter (30’) Drop Tower with the shock block
Previous Research

NASA Langley Research Center’s Impact Dynamics Research Facility *(Hampton, VA)*

- Formally known as the Lunar Landing Research Facility
- Bungee accelerator under gantry structure
- Different amount of shock felt by different regions of Earth Entry Vehicle
  - Impact velocity = 42 m/s (94 mph)
  - 2,500 G to maintain scientific value
  - 3,500 G to maintain sample containment

Figure 12 – Cross section of deformed impact structure at 0.002 s showing maximum crush.
Previous Interns at Jet Propulsion Laboratory in 2012 (Pasadena, CA)

Focused on:
- Rock core fracture and shock load
- Achieving ideal G-force
- Composed initial test procedure
- Design and testing of the hardware

No tests conducted on seal integrity.
Sealing Methods

- SMA Cap
- SMA Ring Plug
- SMA Fin Plug
- Torque Plug

Sealing Methods are crucial for the Mars Sample Return Campaign. The Sample Integrity Research Team focuses on developing and testing various sealing methods to ensure the integrity of samples during their return to Earth. The methods include SMA Cap, SMA Ring Plug, SMA Fin Plug, and Torque Plug. These seals are designed to withstand the harsh conditions of space travel and to prevent contamination.
Sample Tubes

- Cores about the size of a chalk fit snugly inside
- Different materials are used for the various seals
- Adapter attachment used for helium leak test
- Rock samples are cored in metal tubes to which seals are applied
Clamshell Design

Previous Design
- Holds 6 core samples
- The cores held in place by bolts
- The cores sit directly in the clamshell

New Design
- Holds 4 sample tubes
- Based on the previous design
- Bolt pattern, screws
- Aluminum, 875 grams (~2 lbs.)
- Clearance between the tubes and channels
- Clearance between the top and bottom pieces
- Shims
- Not too loose or tight
- Clearance around the whole piece
- Chamfer and fillets
Vibe Mount Design

Purpose: Lift-off simulation

Hardware Design
• Bolt patterns from vibe table
• Vertical, horizontal, and diagonal orientations
• Sturdy – solid aluminum
• Lightweight at 4.5 kg (10 lbs.)

Design Considerations
• Lightening holes?
• Not sturdy enough?
• Resonance frequencies
• The placement of the clamshell
• Gussets

An abandoned design with too many lightening holes

Predecisional: for planning and discussion purposes only.
Vibration Test

- Qualifications for qual/protoflight level
- 2 minutes per run (including set-up time, 1 to 1.5 hours per run)

<table>
<thead>
<tr>
<th>Freq. (Hz)</th>
<th>ASD (G^2/Hz)</th>
</tr>
</thead>
<tbody>
<tr>
<td>20</td>
<td>0.02</td>
</tr>
<tr>
<td>40</td>
<td>0.08</td>
</tr>
<tr>
<td>450</td>
<td>0.08</td>
</tr>
<tr>
<td>2000</td>
<td>0.004</td>
</tr>
</tbody>
</table>

Overall Acceleration = 7.85 G<sub>rms</sub>

ASD = Acceleration Spectral Density
For more info on ASD, please refer to [http://tinyurl.com/ny2mdbw](http://tinyurl.com/ny2mdbw)
Helium Leak Test

- Pumps out air and creates a vacuum
- Helium is sticky
- A solution to a problem

Target Rate: $< 1 \times 10^{-8}$ atm·cc/sec He
**Helium Leak Test**

- Leybold UL 200 helium leak detector
- Leak rate shown in reverse (upside-down) logarithmic scale
- Less leaky until Horizontal orientation
  - The higher frequency?
  - The resonance?
  - Seals settling?
- Clean vs. Dusty

### Helium Leak Rates

*(SMA Ring Plugs - Pre and Post Vibe Tests)*

<table>
<thead>
<tr>
<th>Tube ID</th>
<th>Pre Vibe</th>
<th>To 500 Hz</th>
<th>Vertical</th>
<th>Horizontal</th>
<th>Diagonal</th>
</tr>
</thead>
<tbody>
<tr>
<td>RP-2-SS-C1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>RP-2-SS-D1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>RP-2-SS-D2</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>RP-2-SS-D3</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Predecisional: for planning and discussion purposes only.
Further Research

Shock Test

- Start testing
- All four seal types
- Repeat using cache

Vibe Test

- Continue testing
- Changing the order of the orientations

The bigger picture . . .
Conclusion

What I learned

- How to design hardware with the assembly procedure in mind
- How to measure parts with the machining procedure in mind
- How to work with a team of people – other engineers, scientists, manufacturers

- A practical realization – It takes a great effort to get through a project!
  - Availability of testing equipment
  - Unexpected results
Conclusion

What I learned

• How to design hardware with the assembly procedure in mind
• How to measure parts with the machining procedure in mind
• How to work with a team of people — other engineers, scientists, manufacturers
• A practical realization — It takes a great effort to get through a project!
  – Availability of testing equipment
  – Unexpected results

I enjoy mechanical engineering more than ever and had a great time at JPL!
Acknowledgements

Dr. Charles Budney (Jet Propulsion Laboratory)
Paulo Younse (Jet Propulsion Laboratory)
Patrick DeGrosse, Jr. (Jet Propulsion Laboratory)
Dr. Rajeshuni Ramesham (Jet Propulsion Laboratory)
Juan Fernandez (Jet Propulsion Laboratory)
Julio Urrutia (Jet Propulsion Laboratory)
Dr. Rohit Bhartia (Jet Propulsion Laboratory)
Bill Abbey (Jet Propulsion Laboratory)

Katie Acord (University of California, Davis)
Emma Dodd (Brown University)
Becky Smith (Arizona State University)
Prof. Paul McCudden (Los Angeles City College)
Dr. Jayesh Bhakta (Los Angeles City College)
Prof. Dean Arvidson (Los Angeles City College)

Consortium for Undergraduate Research Experience
Jet Propulsion Laboratory/Caltech
National Aeronautics and Space Administration
National Science Foundation

Friends and family
<table>
<thead>
<tr>
<th>MSR</th>
<th>Previous Studies</th>
<th>Seals</th>
<th>Hardware Designs</th>
<th>Tests/Results</th>
<th>Future Research</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Thank You!