# Metallic Environmentally Resistant Coatings Rapid Innovation Initiative (MERCRII) Mechanism Development and Testing

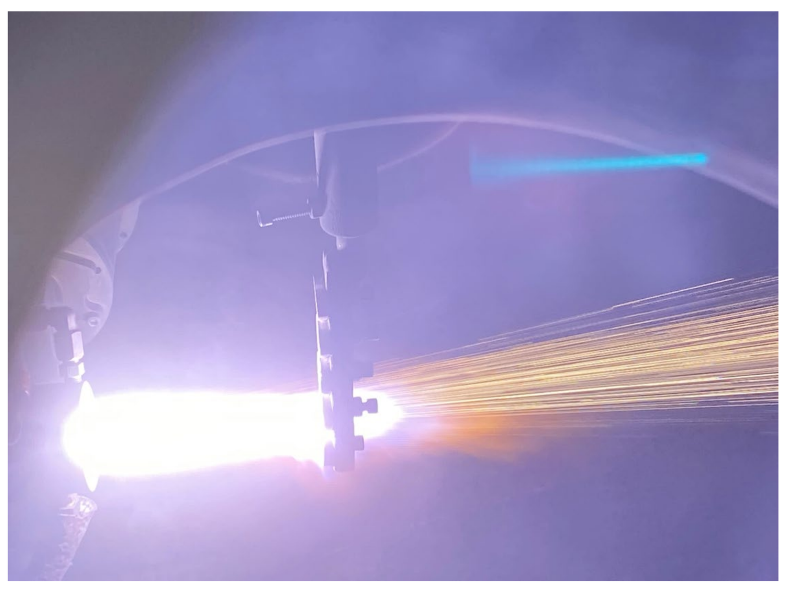
William Scott EM22, Annette Gray EM22, Abijith Sukumaran FIU, Sara Rengifo EM04, Malik Thompson EM41, Erin Hayward EM41, Patrick Lynn EM41, MacKenzie Pewitt ET40

## Background

- This project seeks to address the high friction and low wea resistance of lightweight aluminum (Al) and titanium (Ti) alloys to extend the lifetime and sustainability of both lunar and Martian assets missions by developing advanced wear- and radiation-resistant
- MERCRII started with 6 candidate coating materials and 3 candidate application methods that were down-selected through pathfinder and 2 phases of testing to one coating configuration:

### Ti64 with 2%hBN Vacuum Plasma Spray

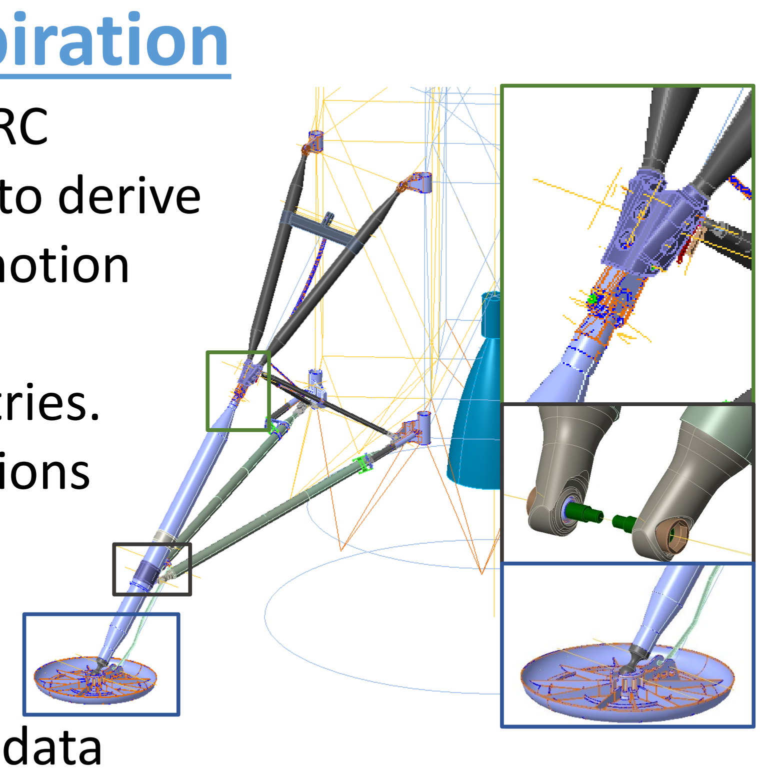
Pathfinder and Phase I and II Wear Testing



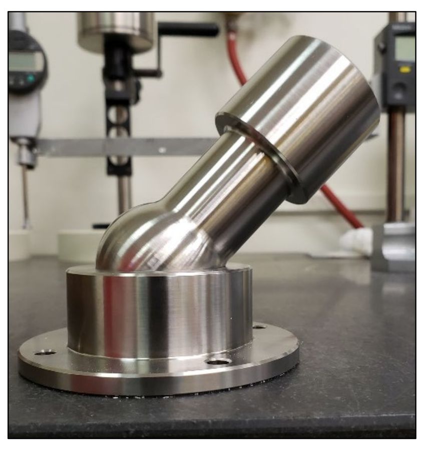
Vacuum Plasma Spray Process

## Mechanism Design and Inspiration

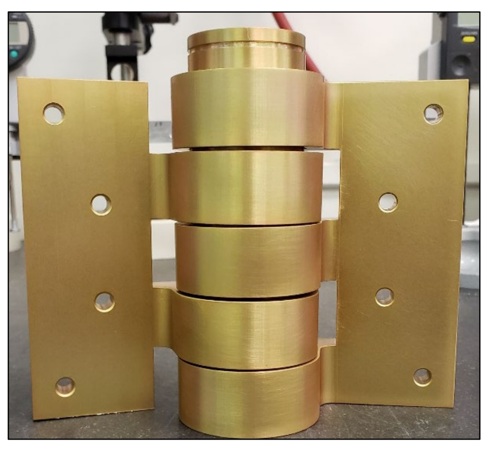
- Used lander concepts provided by LaRC combined with Apollo Lunar Module to derive types of mechanisms and ranges of motion
- Primarily considered joints with most actuation in use and complex geometries.
- Simple joints replicating types of motions found in lunar structures
- Each demonstrates a different type of wear-inducing motion while providing multiple surfaces to collect data



**Rod and Slot**
- Square cross section rod moves back and forth in channel
- Actuates linearly
- Coating only rod component



**Ball and Socket**
- Joint replicates those found in most lander architecture
- Actuates from 0-180°
- Coating ball component



**Hinge Joint**
- Direct analog to lander door hinge
- Actuates from 0-180°
- Coating rod component

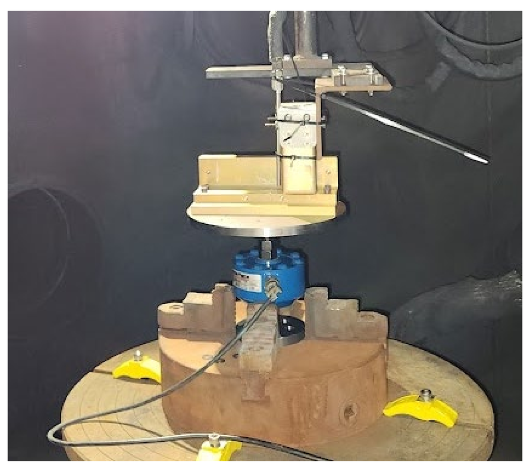
## Mechanism Testing with Partner

### Experimental Design

- Test matrix consists of conventionally and additively manufactured components
- Part of test population exposed to thermal vacuum and radiation
- Test designed to impart strenuous loading on coating without immediately failing it
  - Measured with a series of load cells and torque sensors
- Comparing wear performance between uncoated and coated samples
  - Wear depth and coefficient of friction
  - Mass loss or gain (possibility of regolith particle embedding)

Mechanism Test Chamber

| Environmental Parameters | | Pass Criteria | Failure Criteria |
|---|---|---|---|
| Temp (F) | Ambient | Little to no observed wear in coating | Surface cracking due to thermal exposure |
| Atmosphere (Torr) | 2-3 | | Wear tracks breach surface coating |
| Abrasion | JSC 1A Regolith Simulant | | Flaking of coating |



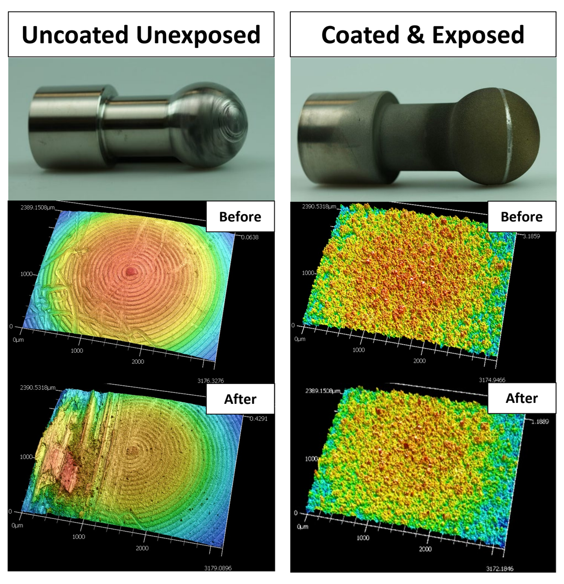
| Rod and Slot | |
|---|---|
| Cycle Count | 500 |
| Pressure (Torr) | 2 |
| Initial Force (lbf) | 50 |
| Track Speed (in/min) | 30 |

| Ball and Socket | |
|---|---|
| Cycle Count | 500 |
| Pressure (Torr) | 3 |
| Initial Force (lbf) | 75 |
| Track Speed (RPMs) | 3.3 |

| Hinge | |
|---|---|
| Cycle Count | 500 |
| Pressure (Torr) | 2 |
| Initial Force (lbf) | 40-60 |
| Track Speed (RPMs) | 3.3 |

### Conclusions

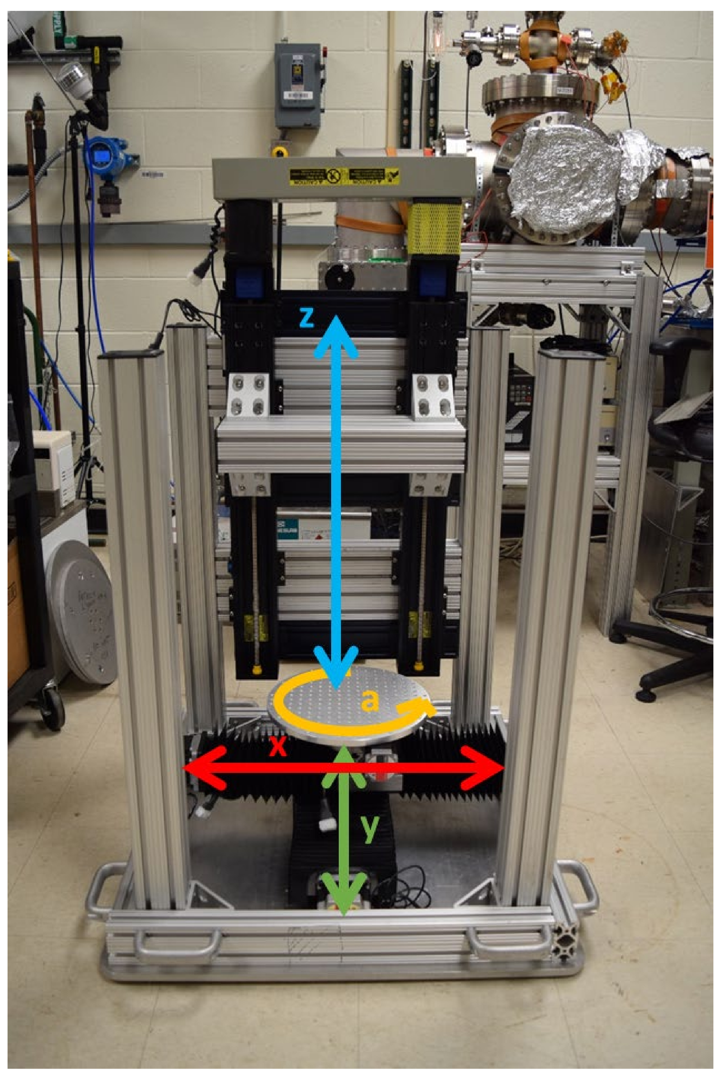
- Hardness on Ti-2hBN is significantly higher than uncoated samples and other candidate coating configurations
- Coatings are sensitive to thermal changes to processing environments leading to interlayer stress cracking
- Interlayer stress cracking due to improper post-application cooling




## MSFC Capabilities Developed with MERCRII

### Mechanism Test Rig

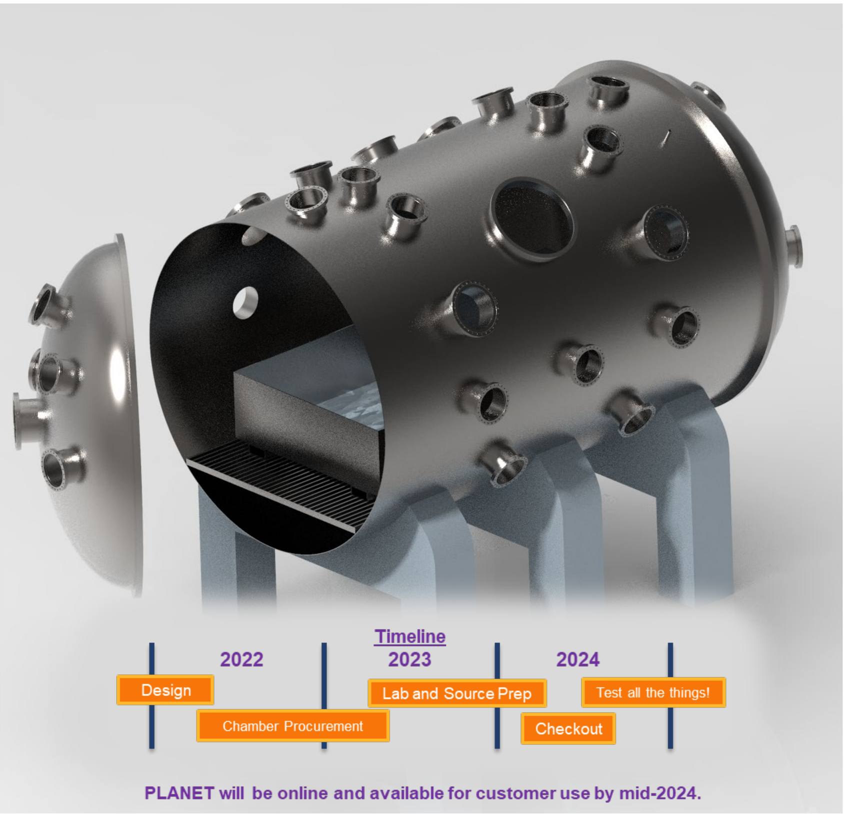
- Up to 200lbf compressive (normal) load
- Fully customizable motion for mechanism actuation:
  - 4 DOF Motion
  - Translation in the horizontal plane (x-y)
  - Vertical height adjustment (z)
  - Rotation about the vertical axis (a)
- Easily adaptable fixturing to allow for different mechanism configurations and sizes
- Up to ~26" of vertical clearance for full scale components
- Addition of lunar regolith simulant during testing
- Designed for deployment in upcoming PLANET vacuum chamber




Mechanism Test Rig

### PLANET (Planetary, Lunar, & Asteroid Natural Environment Testbed)

- 2-meter diameter x 3-meter long
- High vacuum (10^(−7) Torr), low density plasma, or planetary atmosphere
- Charged particle radiation
  - Electrons up to 100 keV
  - Protons up to ~30 keV
- Thermal extremes
  - Cryogenic to -180C/95K with LN2 system (Potential future upgrade to helium)
  - Heating to >140C
- Ultraviolet radiation (Near UV and Vacuum UV)
- Regolith simulant bed (lunar mare or highlands, Martian) up to 2,000 pounds

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