TEXTILE CHALLENGES OF MANNED LUNAR MISSIONS

Presentation by:

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MY ROLE AT NASA

- Crew and Thermal Systems Division (CTSD)
  - Responsible for the design, development and testing of life and thermal control systems, extravehicular activity (EVA) tools, and crew equipment/space suits
  - Comprised of ~150 personnel across seven branches
- EC2 Design and Analysis Branch
  - Known as the support branch of CTSD
  - Comprised of experts in CAD Design, analysis, testing, softgoods, and materials
- Textile Engineer
  - 80% - Research: Executing research projects in key challenge areas
  - 20% - Development: Creation of hardware for both flight and testing projects

CTSD Logo (Credit: NASA)

NASA JSC (Credit: NASA)

PRESENTATION OVERVIEW

- Why we are going back to the moon
  - Difference Between Apollo and Artemis missions
  - Scientific Objectives
  - Operational Objectives
- Textile Challenge Areas
  - Two Major Textile Challenges
  - Apollo Program Solutions
- What We Need Going Forward
- Questions/Discussion

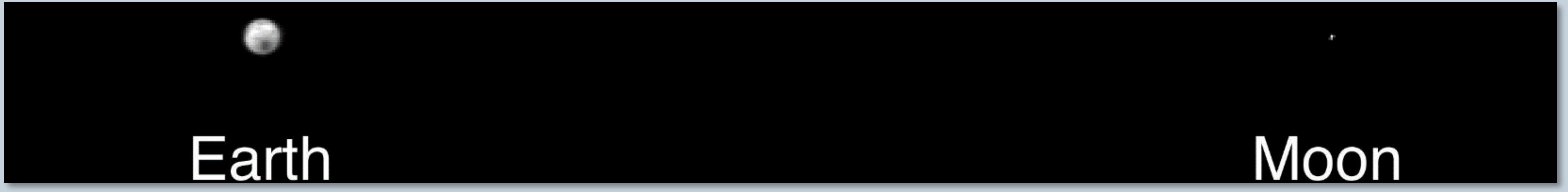
WHY THE MOON

- We've been there already, why not Mars?
  - In short, Mars still is the ultimate goal
    - We need the Moon program to prepare for a Mars mission
    - Significant hardware advancements are needed
  - Scale of the Solar System:
    - The Moon is 0.27% of the way to Mars
    - A Mars mission will be a minimum of 3 years
      - 6 months travel time each way

SLS Block 1 Mockup (Credit: NASA)

Earth/Moon as seen by DSCOVR (Credit: NASA)

Earth/Moon as seen by OSIRIS-REx (Credit: NASA)



APOLLO AND ARTEMIS DIFFERENCES

Apollo Program Logo(Credit: NASA)

- Apollo
  - Short Missions
    - Max 75 hours on surface
      - Max EVA time; 22 hours
    - Round-trip only
  - Limited Operations
    - Location limited to the Lunar equator
    - 2 Person Max
    - All-In-One Lander
    - 12ft 8in Crew Module (Command Service Module [CSM])

- Artemis
  - Long Term Missions
    - Weeks on Surface
      - EVAs up to 800 hours
    - Months in orbit on Gateway
  - Greatly Expanded Operations
    - Capable of landing nearly anywhere on the lunar surface
    - Minimum of 4 people
    - Separate Cargo Missions
    - 16ft 4in Crew Module (Orion)

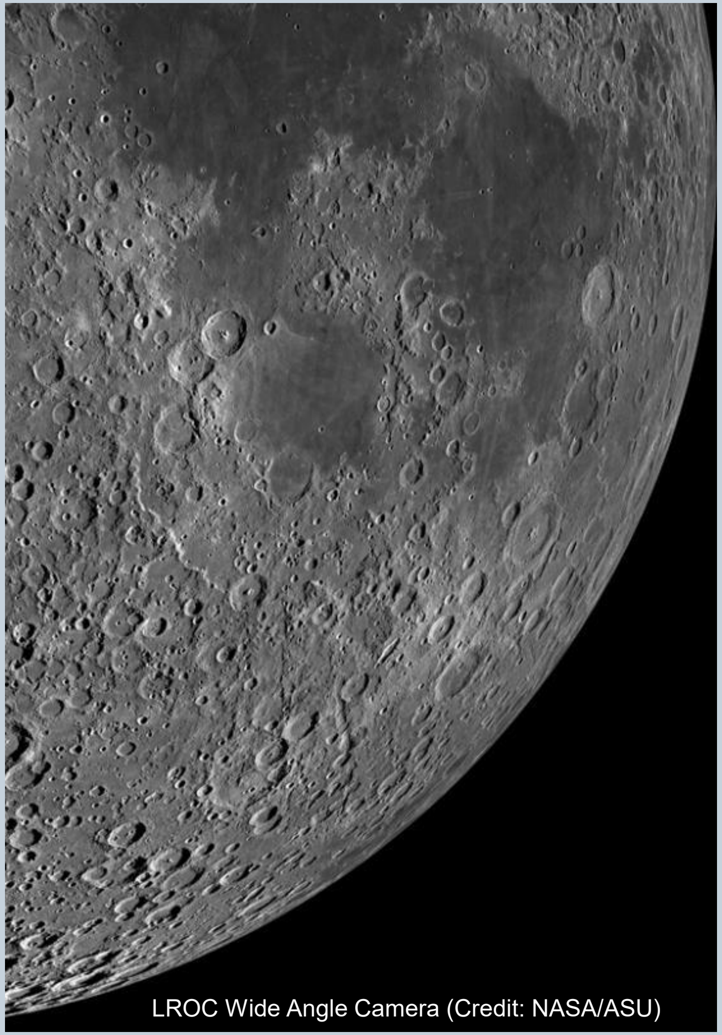
Artemis Program Logo(Credit: NASA)

Apollo Program Command Service Module (Credit: NASA)

Orion Crew Module(Credit: NASA)

SCIENCE OBJECTIVES

- Lunar South Pole
  - Access to potentially usable compounds like Hydrogen and Oxygen.
    - Permanently Shaded Regions (PSRs)
- Geological Study of the Moon
  - The Moon is a 'dead' object in space which has preserved its history better than the earth.
  - Studying the Moon can tell us more about the Earth
- Understanding the history of our Sun
  - The airless Moon serves as a blank canvas that records changes in our solar system.
  - Studying the Moon gives us insights into how our Solar System and Sun were formed.


LROC Wide Angle Camera (Credit: NASA/ASU)

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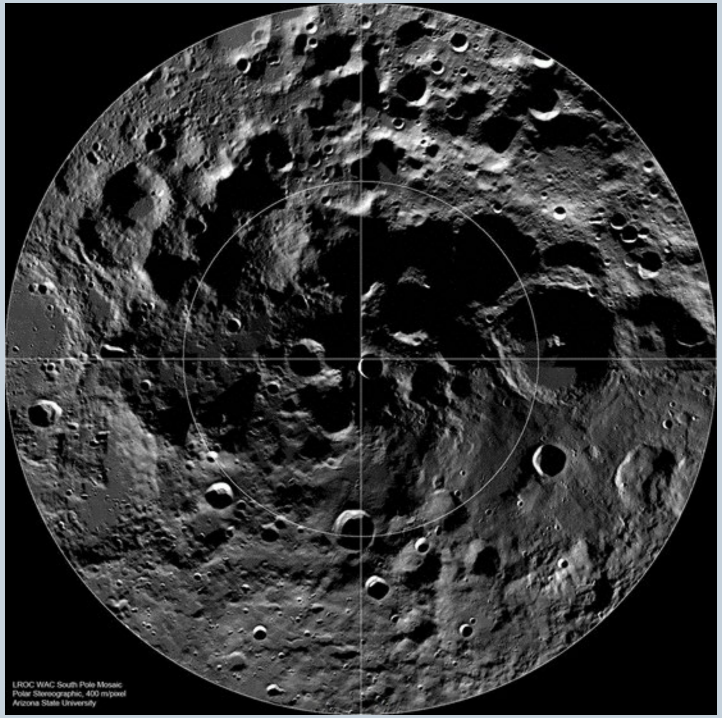



Harrison Schmidt Apollo 17 (Credit: NASA)

OPERATIONAL OBJECTIVES

- Deep Space Logistics
  - Bridging the gap between Apollo Moon Missions and a Mars Program
  - Clothes Cleaning vs Disposal
- Space Suit Design Improvements
  - Mid-Mission Suit Care and Maintenance Opportunities
- Planetary Habitat Requirements
  - What does it take to build long term habitation on another planet/moon
- Larger Crew Operations

THE MAJOR TEXTILE CHALLENGES FOR LUNAR MISSIONS

CHALLENGE 1: DUST MITIGATION

- Lunar Regolith is unlike anything on Earth
  - Without terrestrial erosive processes, lunar regolith tends to remain very sharp and irregularly shaped
  - Due to impact gardening and interactions with various forms of space radiation, rocks and dust continually erode and get smaller and smaller over time
    - Down to the sub-micron level (extremely fine powder-like particles)
- Surface particles interact with the UV light from the Sun (photoelectric charging).
  - Free electrons are “knocked” away during the lunar day and accumulate during the lunar night and in the shadowed regions, such as the PSRs
    - +3V during the lunar day and -200V to -1000V at night
  - This environment makes the Lunar Regolith very “sticky” through electrostatic adhesion forces

Lunar regolith on the Apollo 17 spacesuit (Credit: NASA/TP-2009-214786)

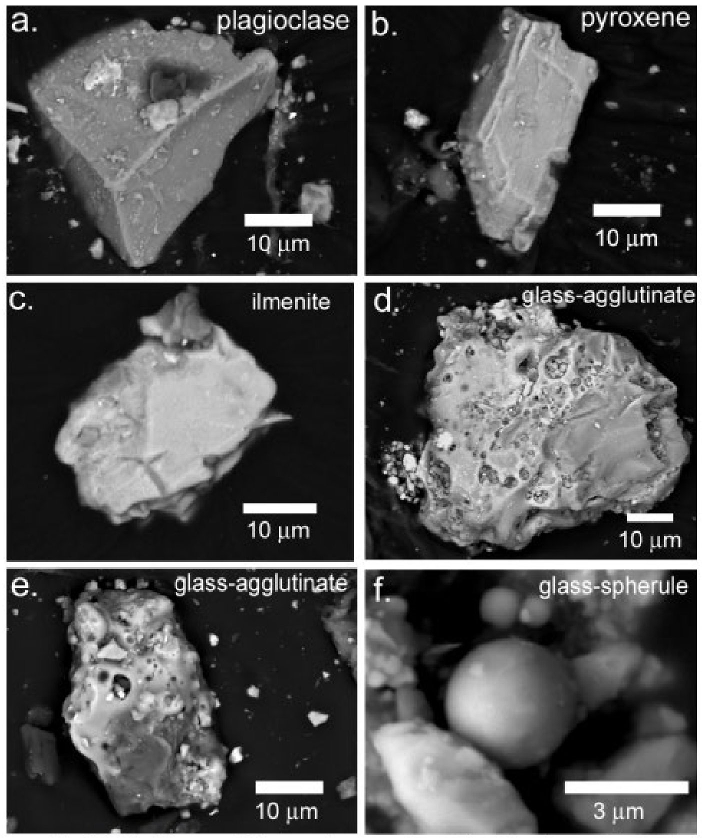


Figure 18. SEM backscattered electron images of particles of various mineralogical types from the surface of the Apollo 17 LMP ITMG T-164 Teflon® fabric. (a) plagioclase feldspar, (b) pyroxene, (c) ilmenite, (d) agglutinitic glass, (e) agglutinitic glass, and (f) impact glass spherules.

Gene Cernan During and After an EVA on Apollo 17 (Credit: NASA)

Astronauts John Young and Charles Duke on the Lunar Surface – Apollo 16 (Credit: NASA)

APOLLO DUST MITIGATION

- Apollo Suits (see NASA/TP-2009-214786)
  - Utilized a woven Teflon coated glass fiber fabric, called Beta Cloth, as the outer layer
    - This material was robust but suffered severe degradation
  - Max exposure to lunar surface: 22 hours (Apollo 17)
    - Crews found that suit components progressively showed wear and tear that could eventually affect suit safety and operations. Gloves difficult to lock in place, zippers nearly inoperable.
    - Within 1-2 EVAs of suit failure
- Cleaning and Inspection Methods
  - Simple Brushes/Wipes
    - Not highly effective as the Lunar Rover's radiators still overheated after brushing to visibly clean
  - Visual Clean Inspection
    - Not a good indication of cleanliness due to sub-micron dust.

Apollo Lunar Surface Brush (Credit: NASA)

Image of seal protectors on Lunar Sample Return Canister (Credit: NASA)

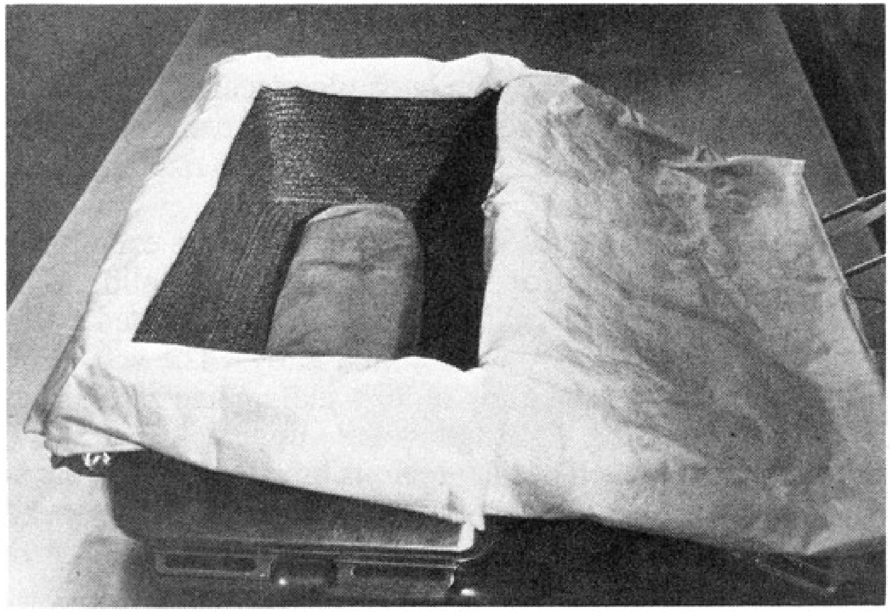


Fig. 74. Teflon cloth seal protector, deployed as if on lunar surface, during packing of ALSRC prior to flight. The box lining is York mesh (NASA photo S88-52674).

DUST MITIGATION NEEDS

- Exceptional Abrasion/Cut Resistance
- Very Tightly Woven or coated fabrics
  - To prevent easy dust penetration
- Electrostatically inert materials
  - To minimize charged particle adhesion
- Cleaning Methods
  - Ways to remove dust gently without further damage to the fabric.
- Outside the Box Thinking
  - Novel concepts for dealing with dust
    - Electrostatic Dust Shields
    - Disposable outer layers
    - Active/Passive Dust repellants

xEMU (Artemis Space Suit Concept)
(Credit: NASA)

CHALLENGE 2: FLAMMABILITY

1972 Skylab Crew Training (Credit: NASA)

- Human Landing System (HLS)
  - The vehicle that will carry astronauts to and from the lunar surface
  - Will operate at elevated oxygen levels compared to Earth
    - Greatly increasing flammability risk
- Reason for Elevated Oxygen Levels
  - Shortening the pre-breathe time required to get into a space suit
    - A set period prior to an EVA breathing elevated O2 at a lower pressure
    - ISS (at 21-24% O2); Require 3-4 hours of pre-breathe time
    - HLS will need to get that time down to <1hr
      - Moon missions will be short compared to ISS missions

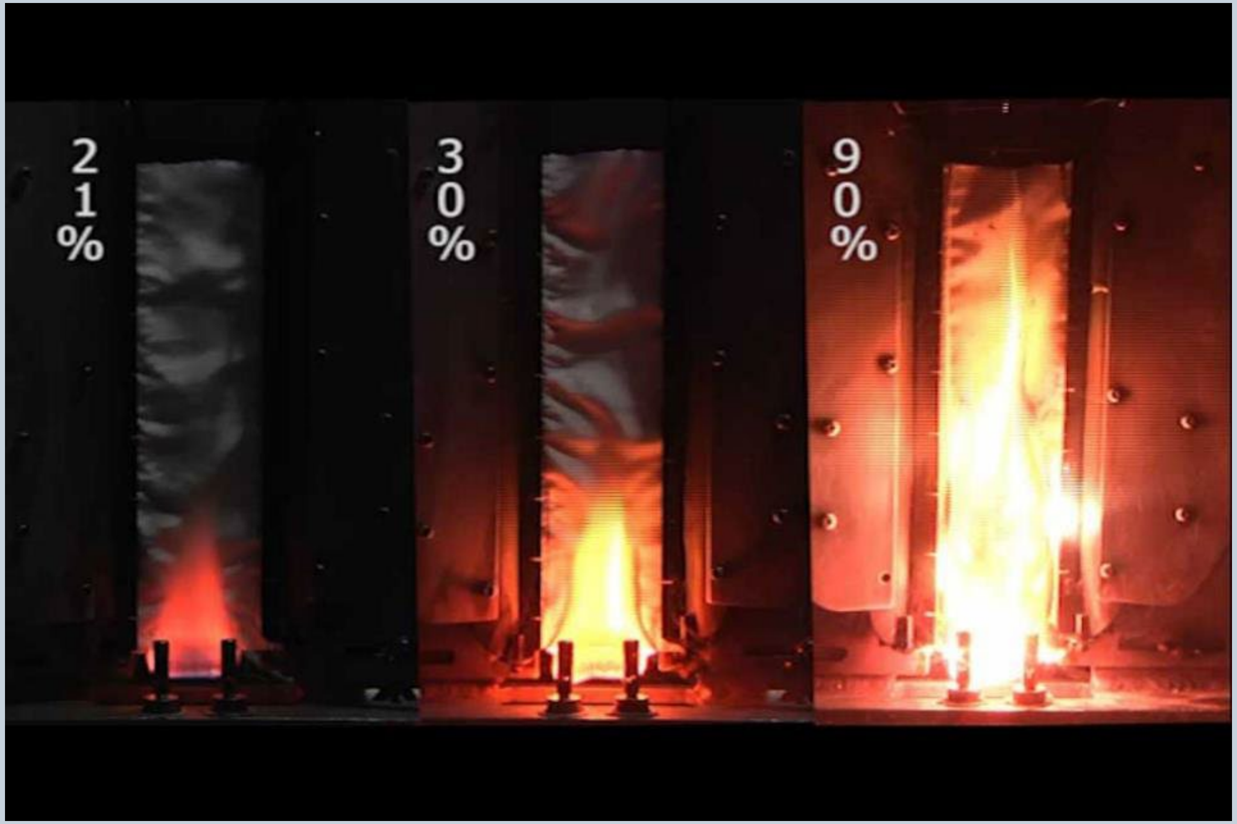
2022 Exploration Atmosphere Test B7 (Credit: NASA/JSC)

NASA'S FLAMMABILITY NEEDS

- Why this challenge is unique to NASA
  - Most fire safety fabrics are designed for Earth applications
    - 21% O2 at 14.7 psia
  - Traditionally flame-resistant materials fail above 30% O2
  - No quick way out of a fire scenario
- What NASA needs
  - Intrinsically flame-resistant fabric at >40% O2.
    - Both next to the skin clothing and structural textiles (for bags, curtains, covers, etc.)
  - Must have minimal outgassing for use in the confined spacecraft.

NASA White Sands Test Facility(Credit: NASA)

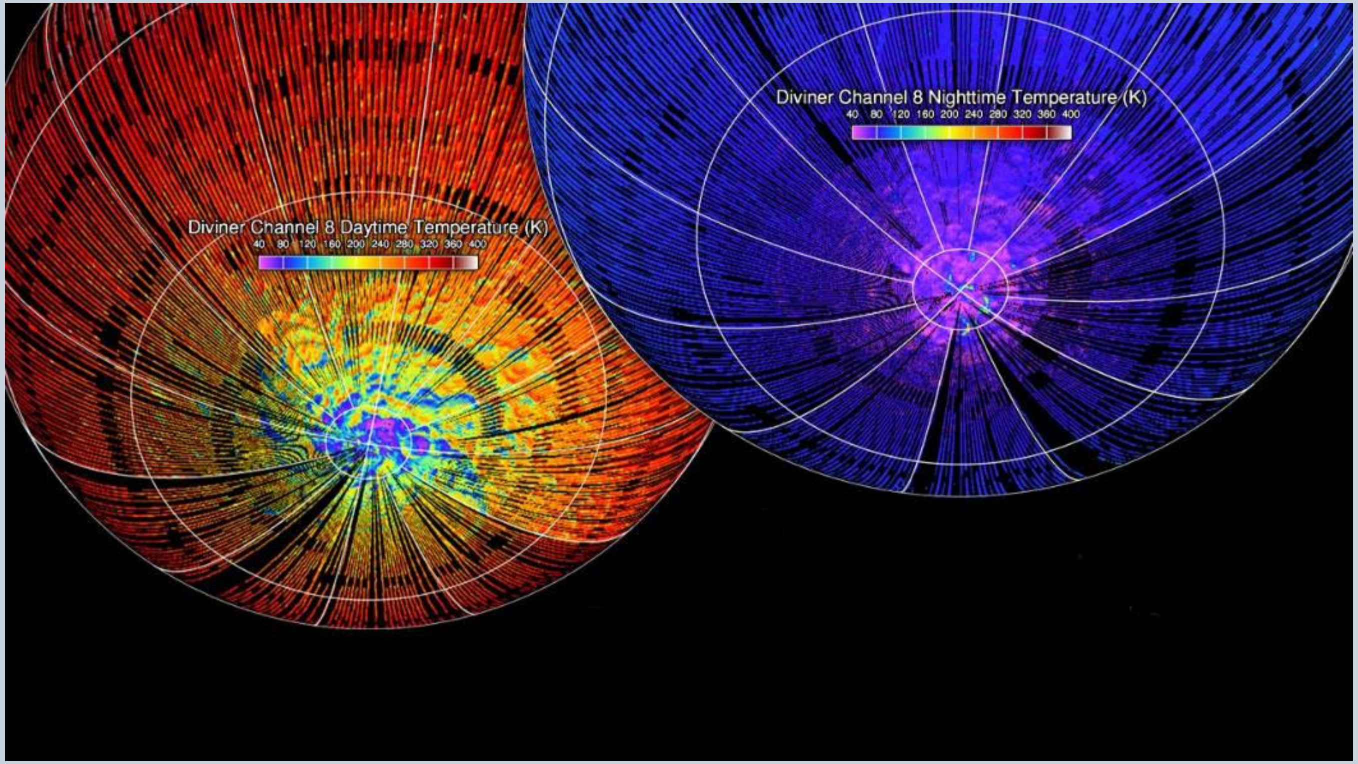
NASA White Sands Test Facility(Credit: NASA)



ADDITIONAL CHALLENGES

- Lunar Simulant
  - For testing materials, we use Earth-made Lunar Simulant
    - There are dozens of different simulants out there
  - None of them accurately depict all characteristics of the actual lunar soil
- Surface Temperature
  - The Lunar south pole has the most extreme temperatures that we have ever seen on a manned mission
  - As low as -390F (-234C) in the PSRs
  - As high as 220F (104C) during the Lunar day
  - The suit materials and all equipment must be able to operate in these extremes

Diviner Lunar Radiometer Experiment – Lunar South Pole Temperatures (Credit: NASA)



WHAT WE NEED FROM INDUSTRY

- Polymer and coating development
  - New/Novel Materials
    - 95% of what we use today has been around since the 1970s
- Moon optimized materials
  - Ultra fine dust rated products
    - That don’t sacrifice mobility, durability, or UV resistance
  - Coatings that don’t harden at lower extremes or melt at higher extremes
- Cleaning and Repellency Techniques
  - Methods of removing dust to prevent further damage to textiles.

SpaceX HLS Concept Image (Credit: SpaceX)

OPPORTUNITIES FOR INTERACTION

- SBIR/STTR Programs
  - NASA Funded Research Programs with Academia and Industry
  - New Proposals Accepted in Spring 2023
  - https://sbir.nasa.gov/
- Connect with me.
  - Always looking to new materials
- Requirements
  - Companies/Individuals must have US Offices
    - Preferably operating completely within the US

QUESTIONS/DISCUSSION

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