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Advanced Textiles

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Engineering Textiles for Artemis: Surviving the Moon and Beyond

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Agenda

- Why Are We Going Back To The Moon?
- Textile Challenges
- What We Need Going Forward
- Open Discussion



Why the Moon

- We've been there already, why not Mars?
 - Mars remains the ultimate goal, but a mission will take ~3 years.
 - Artemis missions bridges the gap between Apollo and Mars program by exploring the lunar South Pole.
- Science objectives
 - Study ancient materials to uncover the history of the Moon, Earth, and solar system.
 - Explore access to water ice in Permanently Shaded Regions (PSRs)- a vital resource for future human exploration and long-term lunar presence.
- Operational objectives
 - Develop capabilities for sustained exploration and habitation on another planet/moon.

Artemis Program At A Glance



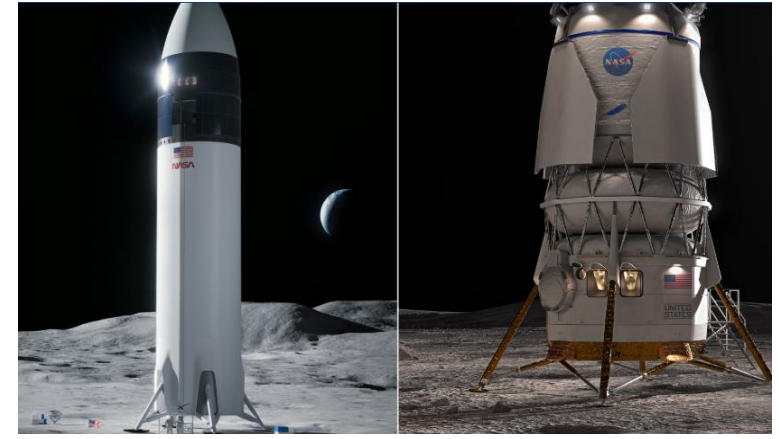
Space Launch System Rocket: The only rocket that can send Orion, astronauts, and cargo to the Moon on a single mission.



Orion Spacecraft: The NASA spacecraft that will carry astronauts from Earth to lunar orbit and back.



Gateway: The spaceship in lunar orbit where astronauts will transfer between Orion and the lander on regular Artemis missions. Gateway will remain in orbit for more than a decade, providing a place to live and work, and supporting long-term science and human exploration on and around the Moon.



Human Landing System: The final mode of transportation that will take astronauts from lunar orbit to the surface and back to orbit.



Surface Mobility: Next-generation spacesuits, human-rated rovers, and spacewalking support systems to help astronauts traverse the lunar surface.

Artemis Program Architecture

Artemis I

An uncrewed flight test of the Space Launch System and the Orion spacecraft around the Moon, successfully executed in 2022.

Artemis II

Artemis II will be the first crewed flight test of the Space Launch System and the Orion spacecraft around the Moon, scheduled as early as February 5th, 2026.



The Artemis 2 crew, from left: pilot Victor Glover, commander Reid Wiseman and mission specialists Jeremy Hansen and Christina Koch.



Establishing the first long-term presence on the Moon to serve as a stepping stone for future crewed missions to Mars

Artemis III

Artemis III will send the first humans to explore the region near the lunar South Pole. Estimate launch date Mid-2027.

Artemis IV

Artemis IV will debut humanity's first lunar space station – Gateway – and complete the 2nd crewed lunar surface expedition.

Artemis V

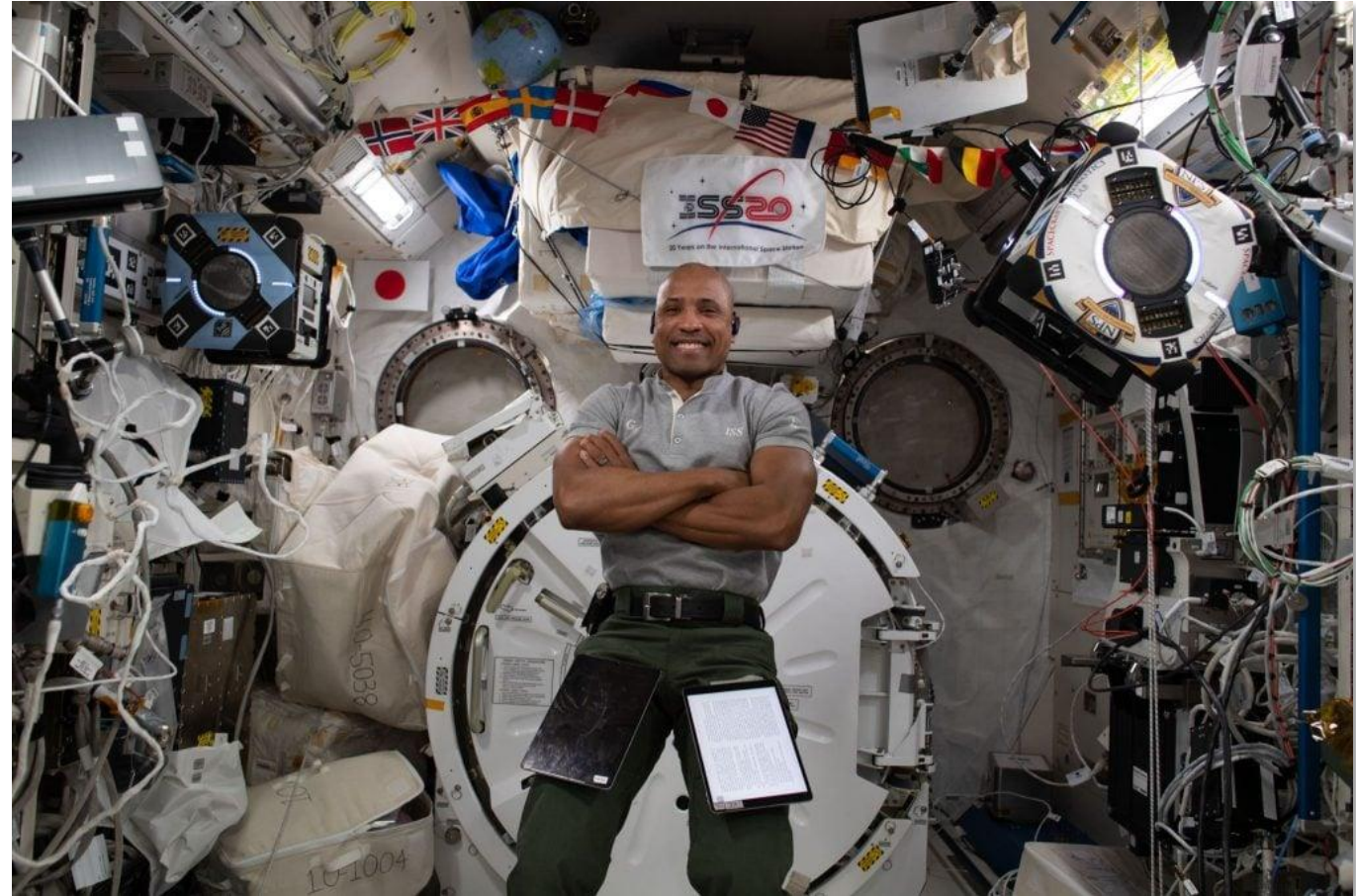
Artemis V will integrate Lunar View module with Gateway and complete the 3rd crewed lunar surface expedition.

Artemis VI+

Artemis VI+ will integrate additional modules with Gateway, deliver a Lunar Habitat and additional surface logistics to continue crewed lunar surface expeditions.

Textile Challenge: Flammability

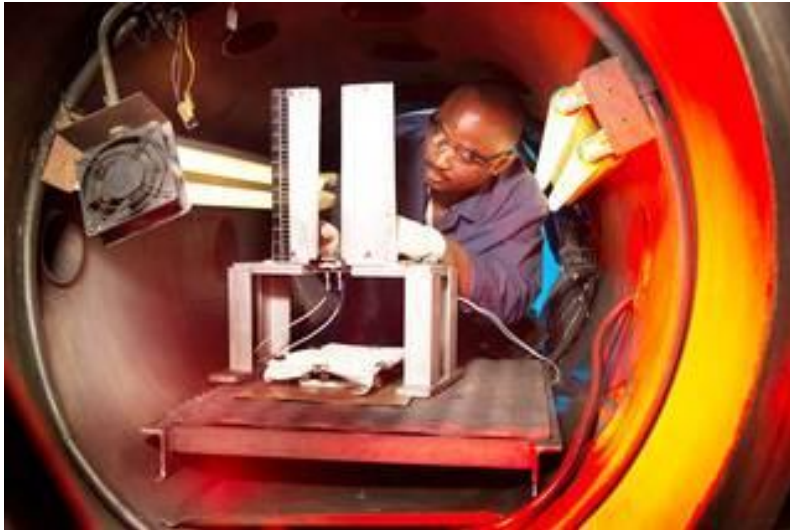
- HLS lunar lander cabin will operate at elevated oxygen concentration (>30%), which greatly increases flammability risk.
- The main benefit of enriched oxygen cabin environments is a shorter spacewalk preparation process (“pre-breathe”)
 - Maximizing time on a spacewalk
- Textile materials are widely used on the inside of spacecraft cabin for Intravehicular Activity (IVA), such as crew clothing, cargo transfer bag, acoustic wall covering, bungee cord, hook & loop fastener, etc.



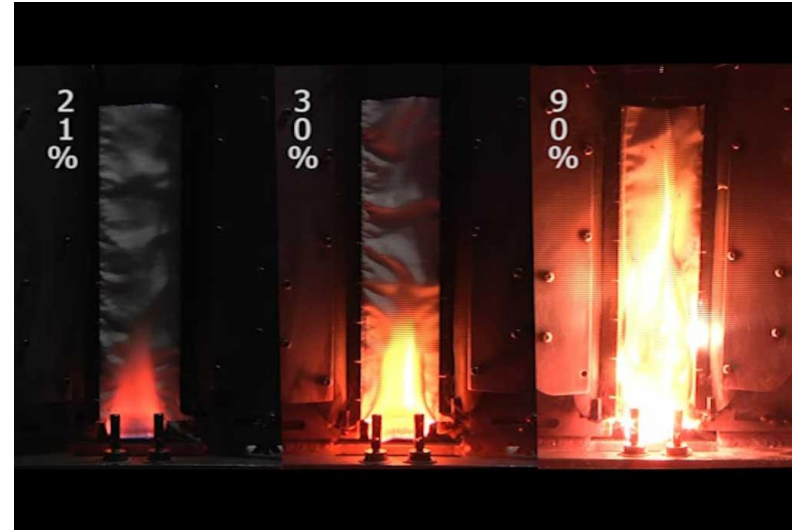
Various Textiles Used for Intravehicular Activity (IVA)

Textile Challenge: Flammability

- Flame-resistant (FR) textiles are essential to ensure large-scale flame propagation events do not occur.
- Most fire safety fibers and textiles are designed for Earth environment (21% O₂), traditional FR materials fail at above 30% O₂ atmosphere per NASA-STD-6001, Test 1, Upward Flame Propagation
- There is an immediate need for improved FR textiles for oxygen-enriched environments up to 40% O₂ to ensure mission safety
- Textiles in need including fabrics, sewing thread, felt, elastics, webbing, hook & loop fasteners, etc.



NASA Flammability Test Set Up



Textile being tested at various O₂ concentrations

Textile Challenge: Dust Mitigation

- Lunar regolith is unlike anything on Earth
 - **Highly abrasive:** without an atmosphere, lunar soil remains razor sharp
 - **Electrostatic charging:** dust clings to surfaces and is difficult to remove, increasing contamination risk.
 - **Penetration risk:** micron-sized particles can easily get into fabric
 - **System impacts:** can damage zippers, joints, and seals, reduce long-term reliability
- Apollo suits outer layer utilized Beta Cloth - a PTFE coated fiberglass woven fabric, which suffered severe degradation after max 22 hours on lunar surface



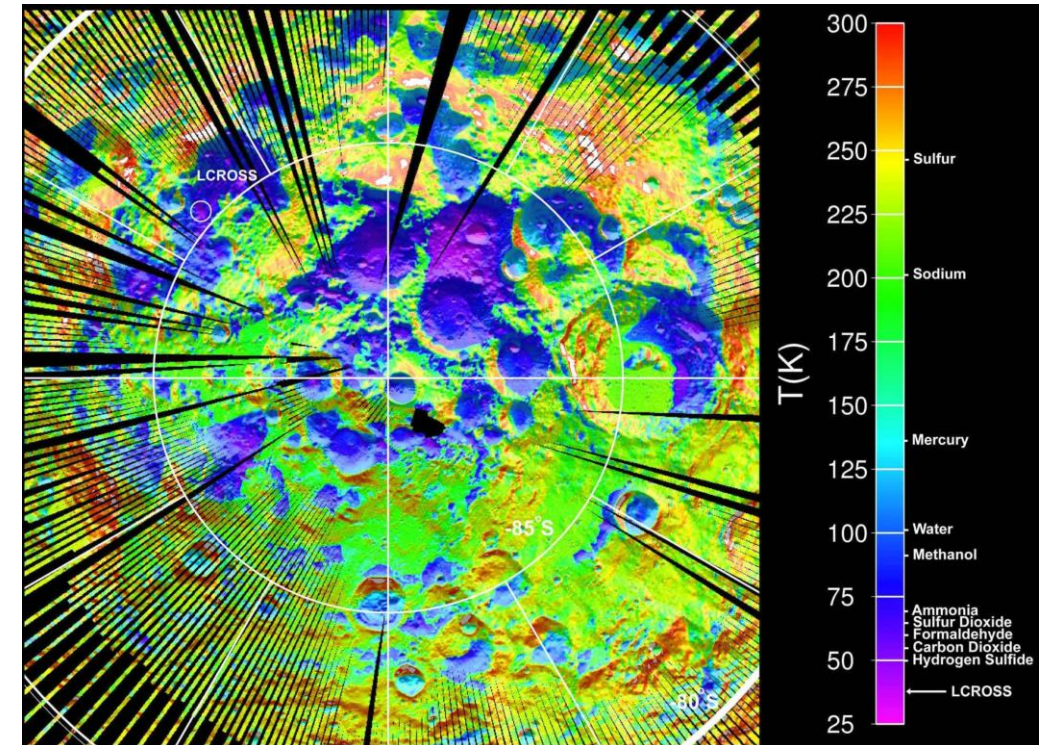
Gene Cernan During and After an EVA on Apollo 17

Astronauts John Young and Charles Duke on the Lunar Surface – Apollo 16



Textile Challenge: Extreme Temperatures

- The lunar south pole has the most extreme temperatures that we have ever seen on a manned mission
 - **Severe range:** from cryogenic cold (~ -225 °C in shadow) to high heat ($\sim +120$ °C in sun).
 - **Rapid transitions:** moving between light and shadow creates extreme thermal cycling.
 - **Material brittleness:** many polymers lose toughness and flexibility in extreme low temperatures.
- Thermal stability: textiles must retain strength, flexibility, and coating integrity across this range.



Temperature map of the Moon's south pole

What We Need Going Forward

- NASA will be kicking off a series of projects to collaborate with industry on developing flame-resistant textiles for oxygen enriched environment (up to 40% O₂)
 - Material shall pass NASA-STD-6001 flammability testing at specified O₂ concentration
 - Additional key requirements for IVA textiles:
 - Minimal toxicity, Thermal vacuum stability (if material is exposed to vacuum), Comfort (for crew clothing), Durability, etc.
- NASA is developing an outer shell fabric of the lunar spacesuit for long term lunar operations to survive the extreme lunar environment
 - Exceptional abrasion and cut resistance against lunar regolith
 - Very tightly woven and/or coated fabrics to prevent dust penetration
 - Textiles that are easy to clean and/or can minimize charged particle adhesion
 - Polymers and fibers that can maintain strength and flexibility in extreme thermal cycling condition
- Future Mars mission needs:
 - Aluminized Mylar Multi-Layers Insulation (MLI) is only effective in high vacuum environment (Low Earth Orbit and the Moon). Advanced thermal insulation material is needed to provide sufficient thermal protection for the gaseous environment on Mars (median surface temperature -65 °C).
 - Reduce the amount of clothing needed for long term missions: NASA is seeking technologies, methods, or products that could extend the life of clothing or enable laundry in space.

Open Discussion

- Opportunities for working with NASA
 - Small Business Innovation Research (SBIR)/Small Business Technology Transfer (STTR) Programs
 - NASA funded research programs with industry and academia, <https://sbir.nasa.gov/>
 - Space Technology Mission Directorate (STMD)
 - <https://www.nasa.gov/stmd-solicitations-and-opportunities/>
 - <https://techport.nasa.gov/help/fundingOpportunities>
 - Development projects through simplified acquisitions or contracts
 - At NASA, we are always looking for new textile materials
 - POC: Wendy Gao, Tianqi.gao@nasa.gov
- Questions?



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