National Aeronautics and Space Administration

Lunar Surface Challenges TRISMAC 2024

NASA EHP SMA – Steven M. Fuqua

June 24-26, 2024

- Extravehicular Activity (EVA) and Human Mobility System Program (EHP)
- New NASA program established 2022
- Spacesuits, EVA Tools, and Rovers
- Early stages of Artemis surface exploration begin with EHP

Image: Artist's render of an Artemis astronaut collecting a sample on the lunar surface.

Next-Generation Spacesuits

- Being built to support both ISS and Artemis III+
- Increased flexibility and mobility for exploring new regions more efficiently
- Increased size range and modular design to accommodate a wider range of crew members
- Rechargeable systems enable more spacewalks and longer stays on surface
- Specialized tools to collect samples and returned them safely to Earth
- Axiom Space and Collins Aerospace have been chosen to provide EVA services

Image: Artist’s render of an Artemis astronaut collecting samples on the lunar surface.

Axiom Extravehicular Mobility Unit Spacesuit

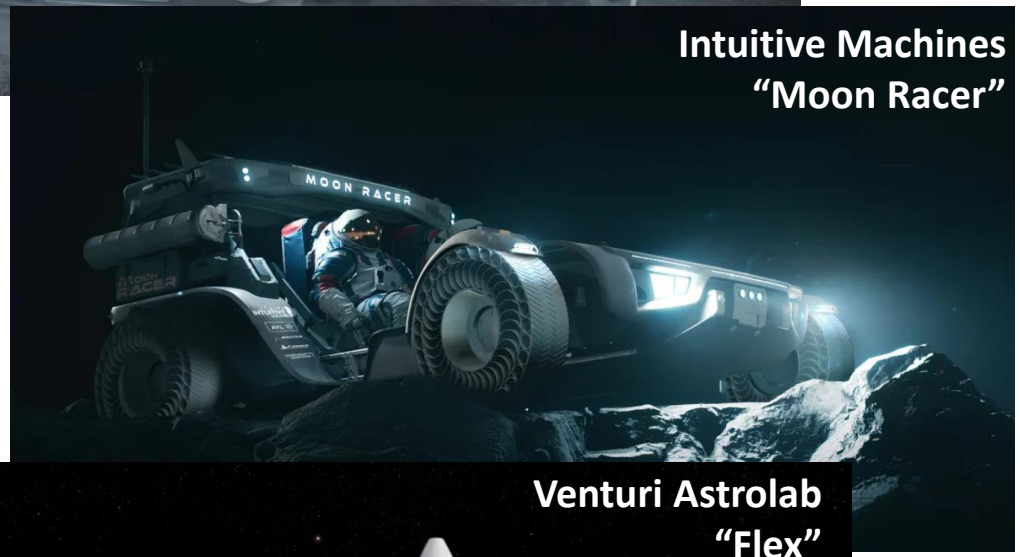
- Will be worn by the first woman on the Moon during the Artemis III mission
- Built on the heritage of NASA's xEMU design and the Agency's decades of spacesuit research and development
- Incorporates the latest technology, enhanced mobility, and added protection from hazards at the Moon
- Axiom will also provide next generation lunar tools to support the Artemis missions

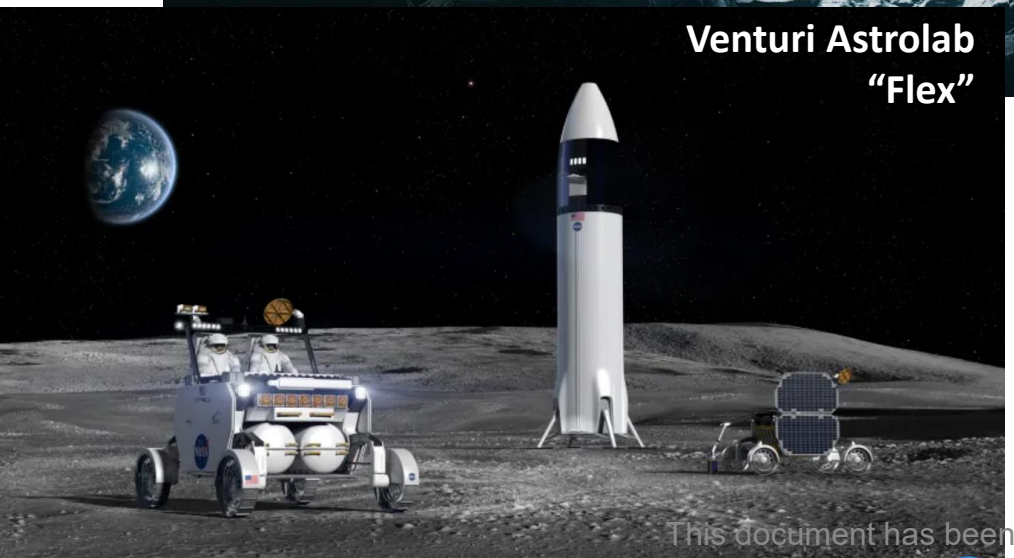
Image: An Axiom Space engineer uses tongs to pick up a simulated lunar rock while wearing the AxEMU (Axiom Extravehicular Mobility Unit) spacesuit during testing at NASA's Johnson Space Center.

Collins Aerospace Next-Generation Extravehicular Mobility Unit

- Will be the next-generation of spacesuits NASA astronauts wear on the International Space Station (ISS)
- Designed to fit the diverse astronaut corps size range and to provide increased range of motion and flexibility
- Will incorporate new technology that is more efficient, more durable, and requires less maintenance than the current suit used by NASA astronauts on the ISS

Image: Collins Aerospace's chief test astronaut John "Danny" Olivas demonstrates a series of tasks during testing of Collins' next-generation spacesuit while aboard a zero-gravity aircraft.





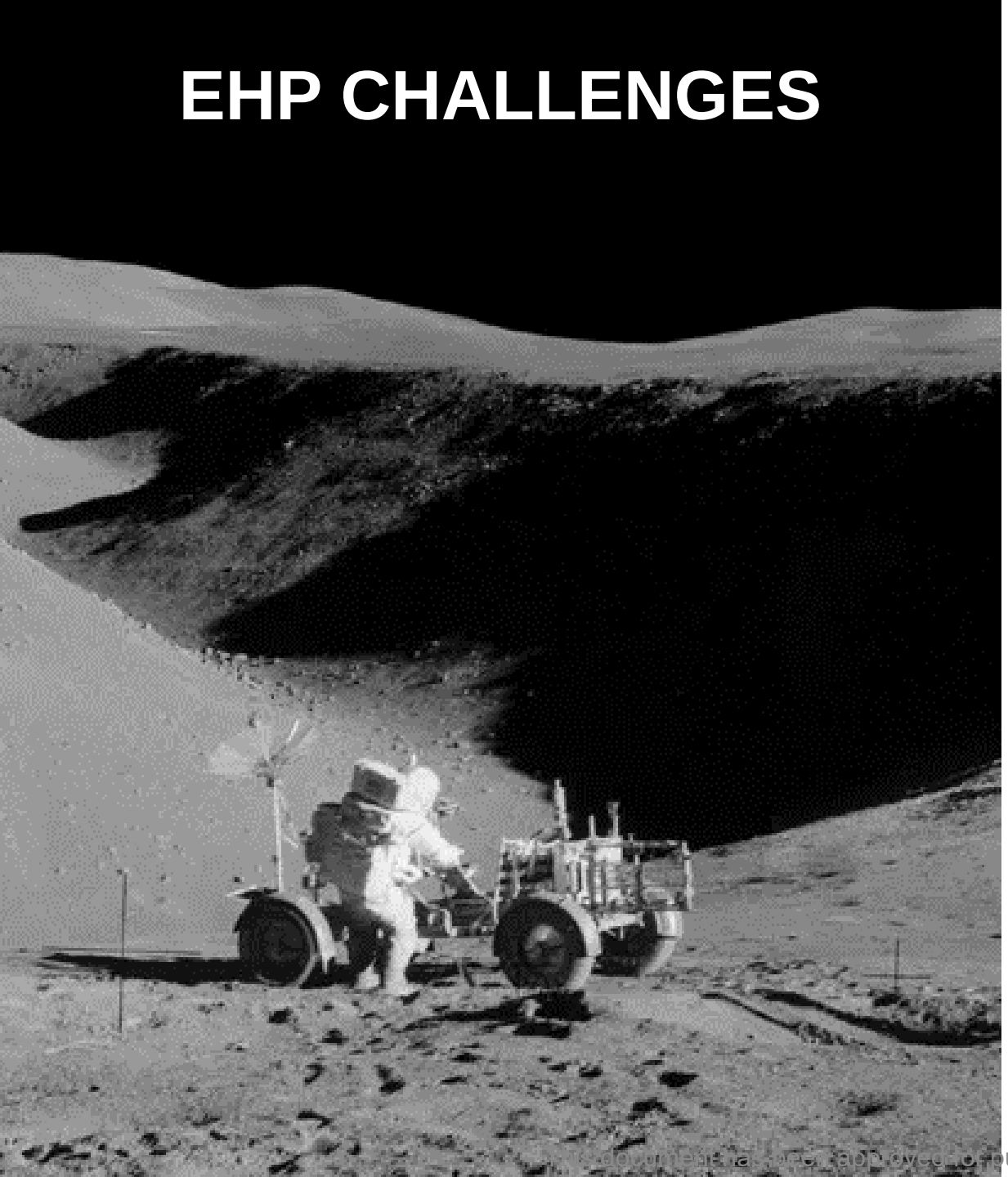
Lunar Terrain Vehicle

- Initial surface transportation system for Artemis V+
- Significantly extends the range of crew excursions
- Enables more science, resource prospecting, and exploration on the lunar surface
- Tele-operation performs remote science during the non-crewed periods
- Transports and deploys small payloads and logistics
- Robotic manipulator supports science activities
- Provides video and imagery of landings, points of interest, and crew activities
- Informs and guides the design and execution of future lunar and Mars surface mobility solutions
- April 2024 awardees: Lunar Outpost, Intuitive Machines, Venturi Astrolab

Pressurized Rover

- Pressurized mobile habitation to enable long-range surface exploration in shirtsleeve environment for Artemis VII+
- Allows astronauts to explore outside the vehicle in their spacesuits
- Habitation for up to 30 days for 2 crew
- Volume for spares and logistics
- Power generation and energy storage for lunar environment
- Dust and radiation protection
- Supports multiple missions over 10-year lifetime
- Capability identified in current concepts for first human mission to Mars
- April 2024 - International Partner agreement with JAXA completed

EHP CHALLENGES



“Survive the Night”

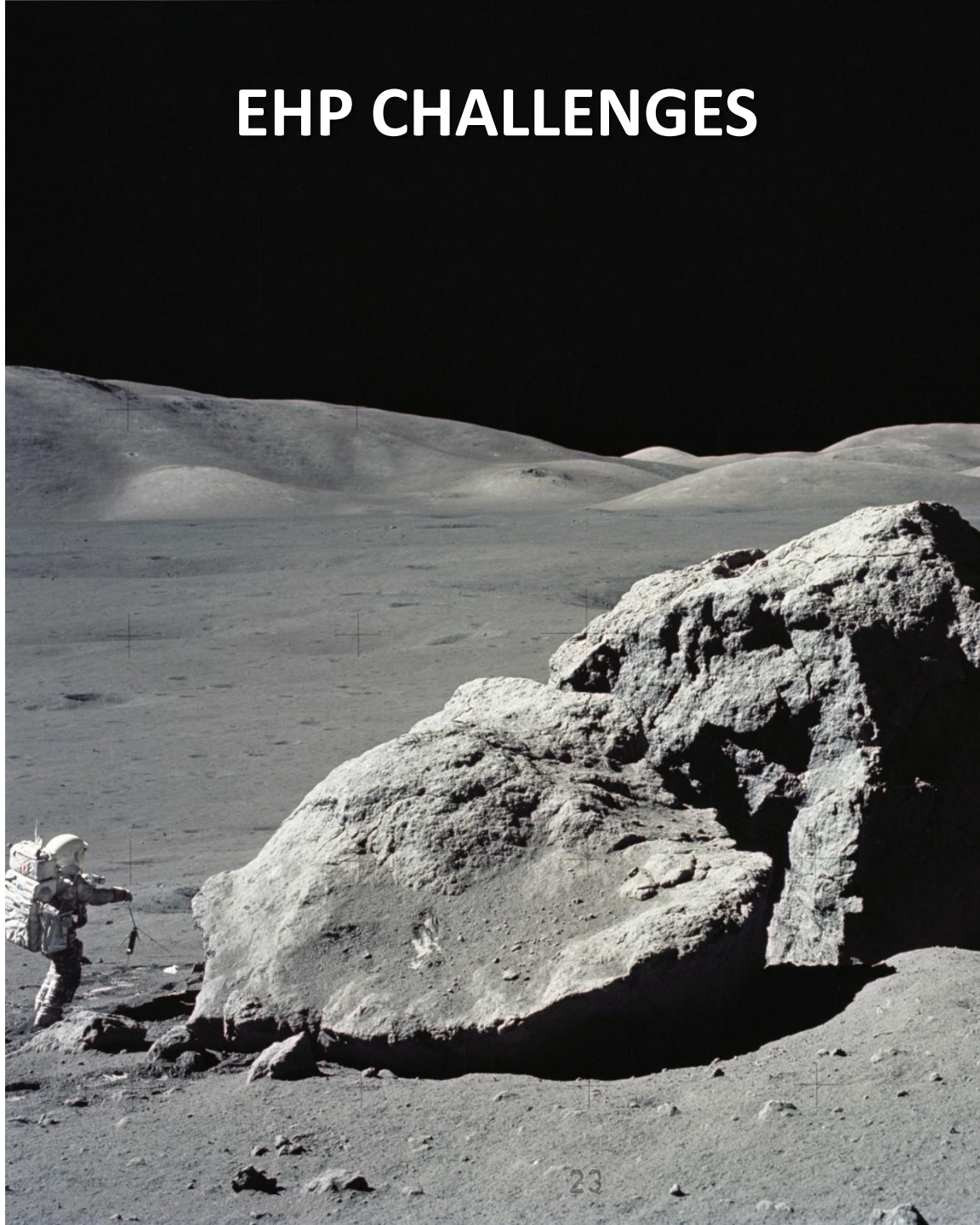
Lunar South Pole

- The rovers initially used on the surface of the Moon for Artemis missions will be at least partially solar powered
- On the lunar South Pole, sunlight is always low on the horizon and has extended night periods (can be two-week cycles of darkness)
- Analysis indicates a “follow the sun” strategy will not be feasible in the Moon’s South Pole regions
- Vehicles will need to “hibernate” and survive up to 150 hours of darkness

Image: Apollo 15 mission commander David R. Scott with the Lunar Roving Vehicle on the edge of Hadley Rille (Rima Hadley) during the first moonwalk of the mission.

Communications/Navigation

- No real communication or navigation infrastructure is in place for early Artemis missions (limited comm satellites, no cell towers)
- Surface vehicles and spacesuits serve as communication relay equipment on lunar surface
- South Pole's rocky and mountainous terrain interferes with communication signals and with limited sunlight and long dark shadows, extended periods of darkness complicate simple navigation techniques
- Signals require boosting after only a few kilometers, so traverse distances are limited until comm infrastructure is in place
- No consistent magnetic field like on Earth for navigation (no true North, standard compass will not work)
- Size and relative distance of objects is very difficult for the crew to ascertain



Dust Mitigation

During six Apollo missions, lunar dust clogged mechanisms, scratched optical covers, compromised seals, jammed geo-tools, irritated eyes and lungs, blocked vision during landing, and coated surfaces resulting in degraded system performance

- The Moon endures frequent micrometeorite impacts due to the lack of an atmosphere, creating a thin layer of highly broken and fragmented lunar material at the top of the regolith coating the lunar surface
- Lunar dust in the surface environment is negatively charged and susceptible to electrostatic buildup
- Lunar dust is abrasive; lack of water transport erosion and low gravity on the Moon allows dust to remain jagged
- Fine-grained, with a significant fraction that is smaller than the human eye can resolve...so visibly clean is NOT clean
- Unpredictable - behavior of lunar dust in space is governed by different forces than on Earth
- Difficult to analyze because behavior cannot be replicated without low gravity and zero atmosphere, making model validation difficult