Astronauts will be tracking dust into the Lunar Gateway. Is this a problem?

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Artist's impression of astronauts on the lunar surface, as part of the Artemis Program. Credit: NASA

Lunar regolith (aka. moondust) is a major hazard for missions heading to the moon. It's everywhere on the surface—5 to 10 meters (~16.5 to 33 feet) in depth in some places—not to mention jagged and sticky. During the Apollo missions, astronauts learned how this dust adhered to everything, including their spacesuits. Worse, it would get tracked back into their lunar modules (LMs), where it stuck to surfaces and played havoc with electronics and mechanical equipment, and even led to long-term respiratory problems.

This is a major concern for the Artemis Program, which aims to establish a "sustained program of lunar exploration and development." One of the key elements of this program is the Lunar Gateway, a lunar habitat that will orbit the moon for a planned 15 years and facilitate long-term missions to the surface. The impact that regolith introduced by astronauts returning from the surface will have is not well understood. In a recent paper, a NASA-led team of researchers created a physics-based model to asses how regolith could impact the habitat over time.

The team was led by Ronald G. Lee, the lead aerospace engineer with Houston-based consulting, analytics, and government/military contractor Booz Allen Hamilton. He was joined by scientists from NASA's Johnson Space Center, NASA's Marshall Space Flight Center, the ESA's European Space Research and Technology Center (ESTEC), and Houston-based engineering firm Jacobs Technology and aerospace contractor Barrios Technology. The paper that describes their model recently appeared in *Acta Astronautica*.

While most meteors entering Earth's atmosphere burn up before reaching the surface, the moon is an airless environment. As a result, billions of years of impacts have pulverized the surface, producing fine silica particles. The absence of an atmosphere also meant that these particles experienced no weathering from wind or precipitation, leaving them misshapen and jagged. The interaction between these particles and charged plasma from the sun's corona (aka solar wind) has left the regolith electrostatically charged, causing it to stick to electrically charged surfaces.

This dust caused numerous problems during the Apollo missions, including thermal control issues of the Lunar Reconnaissance Vehicle's (LRV) batteries during the Apollo 16 and 17 missions. Eugene Cernan, Commander of the Apollo 17 Mission, went as far as declaring lunar regolith to be the greatest challenge to lunar exploration. "I think dust is probably one of our greatest inhibitors to a nominal operation on the moon," he said. "I think we can overcome other physiological or physical or mechanical problems except dust."

In the coming years, the Artemis Program will send astronauts to the moon for the first time since the Apollo Era. But unlike the previous crewed landings, which left behind various science experiments and "footprints and flags," the Artemis Program will establish lasting infrastructure. In addition to the Lunar Gateway, astronauts will rely on the Artemis Base Camp while performing science operations on the surface. The ESA and China also have plans for lunar infrastructure, known as the Lunar Village and the International Lunar Research Station (ILRS), respectively.

This means multiple space agencies and commercial partners launching to and from the surface and astronauts performing regular extravehicular activities (EVAs). The amount of lunar regolith kicked up and tracked back to vehicles and habitats will cause wear and tear on spacesuits and vehicles, being so incredibly abrasive. It will also play havoc with machinery, power systems, life support systems, and other vital components. There are also the health risks that airborne regolith will pose to astronauts, commercial crews, and lunar tourists.

The situation will be significantly more complicated due to the presence of several interacting mission elements. As they wrote, "The unique challenge posed to Gateway is it will not endure a one-time exposure to lunar dust, such as was possibly the case with Apollo Command and Service Modules, over the planned 15-year lifetime, but one for each of the several surface missions involving Gateway proposed in the Artemis architecture. The exterior of Gateway and Visiting Vehicles which dock to it are covered in critical systems such as solar arrays, radiators, docking mechanisms and seals, fluid transfer connectors, communication antennae, external robotic systems, and scientific payloads."

Luckily, a lot of research has been conducted since the Apollo missions to characterize the physical properties of lunar regolith. Based on this, scientists have deduced that the hazard posed by lunar regolith is dynamic and dependent upon spacecraft configuration, attitude (with respect to the sun), and the plasma environment. In a previous study, Lee and co-author Gary L. Brown (Barrios Technology) developed a new model for characterizing the threat it posed to the Lunar Gateway, which they named the Gateway On-orbit Lunar Dust Modeling and Analysis Program (GOLDMAP).

Using this model, Lee, Brown, and their team considered the Artemis mission architecture and modeled different aspects of it. This included the natural environment and spacecraft charging using NASA's Design Specification for Natural Environments (DSNE), the open-source Spacecraft Plasma Interaction Software (SPIS), and data from the Steward Observatory Mirror Laboratory (SOML). This was combined with a time-dependent particle transport model, which used Siemens STAR-CCM software to characterize the fluid dynamics.

From this, they came to various conclusions regarding the Gateway and possible contamination by astronauts coming and going using the Human Landing System (HLS). As the researchers wrote, "During lunar surface missions, the HLS vehicle elements will likely be subjected to contamination by small lunar regolith particles on the lunar surface due both to natural phenomena, such as electrostatic lofting and levitation within a few meters above the lunar surface, and micrometeoroid impacts, which have been shown by both experiment and modeling to contribute to both the near-surface and high altitude dust populations, and human surface activities including PSI of the thrusters during descent and ascent."

Based on this, it is clear that the Lunar Gateway—the nexus point for future lunar exploration and development—will be vulnerable to dust transfer. As such, the need for decontamination measures for astronauts returning from the lunar surface is also made clear. Looking forward, Lee and his colleagues emphasize that model validation is necessary using laboratory experiments conducted by NASA experts and academics. They also recommend future on-orbit dust detection and dust-collecting payloads on the exterior of the Gateway.

The results of these experiments will help inform NASA's mission planners and operations aboard the Gateway as the Artemis Program unfolds. It will also likely inform future guidelines and "best practices" for operating on the lunar surface.

More information: Ronald G. Lee et al, Development of a comprehensive physics-based model for study of NASA gateway lunar dust contamination, *Acta Astronautica* (2023). DOI: 10.1016/j.actaastro.2023.05.025

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