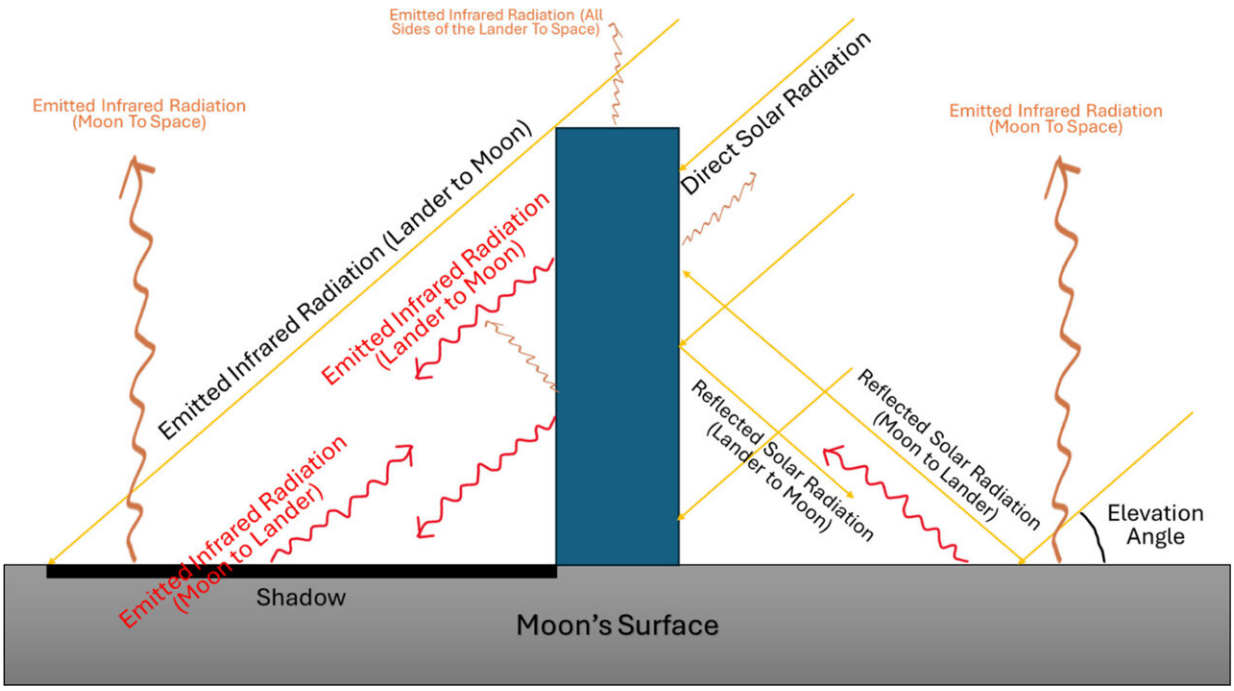
Establishing a permanent lunar presence will depend on ingenuity and the moon's own resources, researchers say

January 22 2025, by Patrick Lejtenyi



Credit: *Progress in Aerospace Sciences* (2024). DOI: 10.1016/j.paerosci.2024.101045

NASA's Artemis program goal of establishing a human presence on Earth's moon is closer than ever to becoming a reality within the next few decades. But today's starry-eyed dreamers are reckoning with the gritty reality of building a permanent base on an airless, dusty, radiation-

blasted rock thousands of miles from home. How hard can it be?

The answer, obviously, is very hard. But with a lot of planning and innovation, it does not appear impossible.

In a comprehensive review paper led by Concordia researchers, published in the journal *Progress in Aerospace Science*, the authors break down the many very serious challenges of lunar-based manufacturing and construction essential for establishing a sustainable, long-term lunar presence. But they also provide solutions that can overcome them.

"A crucial step is to be able to manufacture whatever is needed on site," says Mohammad Azami, a Ph.D. candidate at Concordia University's Aerospace Robotics Lab (CUARL). "We must establish the infrastructure needed to produce the essential tools, structures and systems for habitation on the moon."

The researchers say that this will require close use of three critical technologies: 3D printing, robotics and artificial intelligence (AI).

First-time solutions to first-time challenges

"These three technologies operating together offer versatility," says co-author Krzysztof Skonieczny, associate professor in the Department of Electrical and Computer Engineering at the Concordia Institute of Aerospace Design and Innovation.

"They allow us to adaptively and flexibly respond to challenges as they arise. We can't foresee everything in advance."

A small 3D printing machine will be able to produce specialized parts and structures essential to building, maintaining and repairing lunar infrastructure. Given the unique environment in which they will be used,

Skonieczny says many of the instruments will be equally unique.

"For everything that needs to be built, it will probably be the first time," he says. "It will have to be done based either on inputs from astronauts on site or from specialists on Earth who can beam up designs and have the machines produce them while the astronauts are asleep."

The promise of moon dust

The moon also has a critical natural resource that can cut down the total payload from Earth-launched supply missions: the lunar regolith, which is a layer of fine but highly abrasive dust that covers the moon's surface.

Azami's research at CUARL and the Concordia Centre for Composites (CONCOM), recently published in the journal *Progress in Additive Manufacturing*, has led to successful breakthroughs that can be critical to lunar manufacturing and construction: a mobile 3D printing robot that uses a composite of space-grade polymer called polyether ether ketone and a lunar dust simulant for on-demand fabrication of complex geometries.

Regolith has the additional benefit of being an effective barrier against solar radiation. Using it in construction as a radiation insulation layer would reduce the need to bring similar materials from Earth.

"The longer-term challenge is transitioning toward using local materials primarily not just as filler, but as the main ingredient. However, the current solutions for this are very energy-intensive," Azami says.

Both the United States and China have stated that they aim to establish a longer-term presence on the moon by the middle of the next decade. Skonieczny says those goals are feasible for smaller and shorter missions, along the lines of trips to the International Space Station or

Antarctic research centers.

A longer-term presence will present even more challenges, particularly regarding the effects extended duration has on human biology as well as legal issues around lunar territorial rights.

"These are very important, big-picture challenges. Manufacturing is one piece of a very large puzzle," he says.

More information: Mohammad Azami et al, A comprehensive review of lunar-based manufacturing and construction, *Progress in Aerospace Sciences* (2024). DOI: 10.1016/j.paerosci.2024.101045

Mohammad Azami et al, Enhancing economical lunar-based manufacturing by incorporating lunar regolith into polyether–ether–ketone (PEEK): material development, additive manufacturing, and characterization, *Progress in Additive Manufacturing* (2025). DOI: 10.1007/s40964-024-00934-0

Provided by Concordia University