Testing and Application of Regolith Parts, Produced by Additive Manufacturing Technologies

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BACKGROUND

Additive Manufacturing (AM), and its use on the lunar surface has often only been researched in terms of large-scale construction operations. Technology types have varied, ranging from direct microwave sintering of the lunar surface [1], to polymer composite concrete [2] extrusions for habitats and other structures. A prime consideration for all these technologies is the overall size of both the AM machine, as well as the size of the parts which can be produced. Outward Technologies has developed a Solar Additive Manufacturing system (SAM) that enables production of small-scale regolith parts to be manufactured with in-situ material, for use in infrastructure development as well as for construction projects.

Throughout 2022, several lab scale tests were completed at the Colorado School of Mines (Mines) to determine the viability of regolith printed parts produced by Outward Technologies' SAM system.

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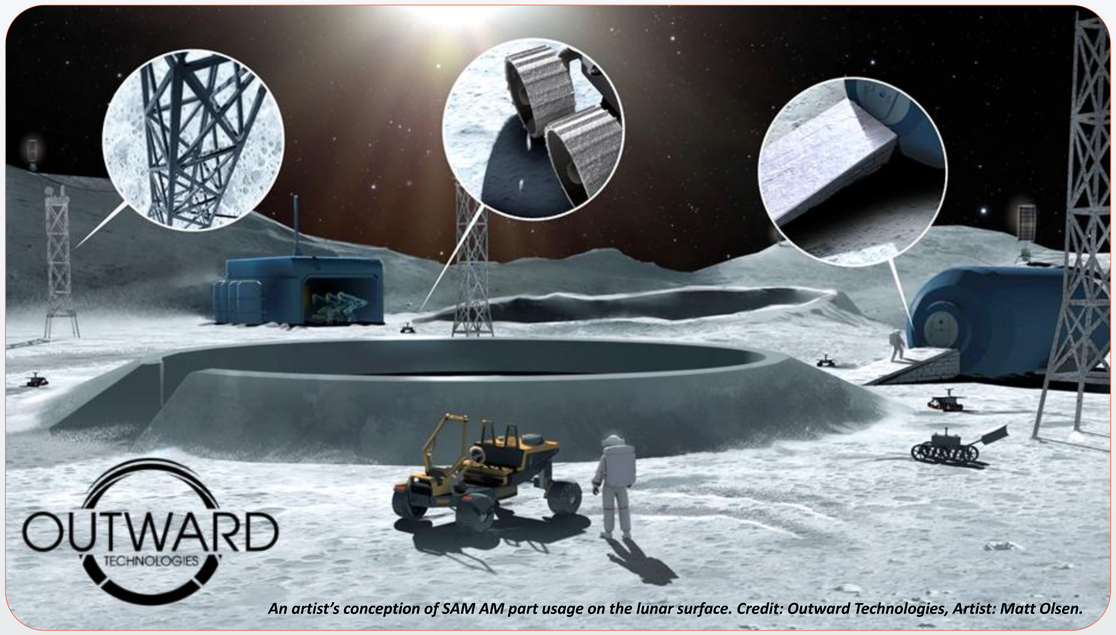
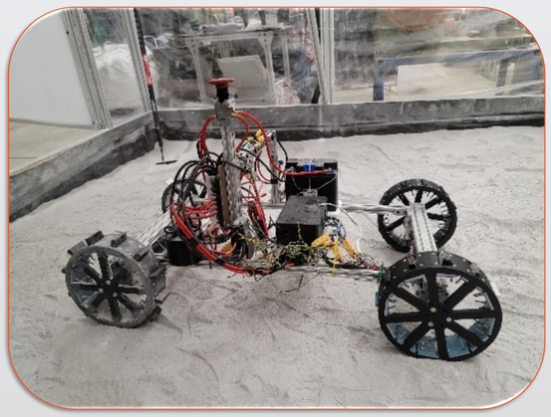


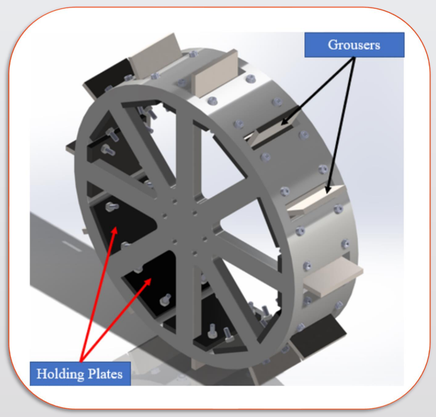
An artist's conception of SAM AM part usage on the lunar surface. Credit: Outward Technologies, Artist: Matt Olsen.

GROUSER TESTING

Grousers (also known as cleats, or lugs) are components used to increase traction and maneuverability of rover wheels, similar to the tread of a tire. Grousers were chosen for physical testing due to the numerous advantages offered by having access to custom, AM grousers that could be altered to meet terrain requirements and be produced on demand. Modular grousers were designed for testing on a "Lunabotics" class rover (1.1m length x .6m width x .6m height, 30kg mass) driving in the Mines Lunar Testbed. Multiple grouser types were designed by Outward Technologies, with variations in print orientation, grouser thickness, and total grouser height. SAM printed grousers were evaluated through multiple test drives, with visual inspection for damage completed after each testing regime.

*Modular wheels, designed to test different grouser geometries. Regolith parts pictured were produced by **Outward Technologies SAM system**. Undamaged grousers (left) were installed prior to testing, with damaged grousers (right) inspected once testing was complete.*





Lunabotics class rover (left), equipped with modular grouser wheels (right) in Mines Lunar Testbed.

*Grousers produced by **Outward Technologies SAM system**, showcasing different print orientations, the Glass Top grouser (left), and Glass Dove grouser (right). Provided photo is the property of Outward Technologies.*

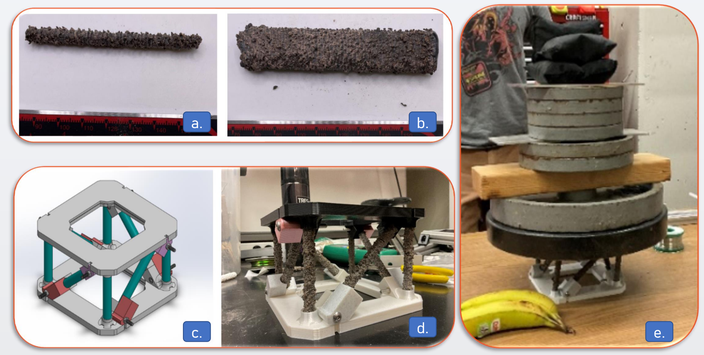
CONCLUSION

Experimental testing and computer modeling have shown that Outward Technologies' SAM system can produce robust, viable regolith parts, and could be used extensively with in-situ feedstock on the lunar surface. Physical parts were tested for interface capability and strength, providing both qualitative and quantitative data for review. Outward Technologies' SAM system illustrates how advances in AM capabilities can aid engineers in designing and manufacturing a wide variety of in-situ components on demand.

Note: All images on this poster have been provided by Outward Technologies directly, by their research group partners (Mines), or private artists (Matt Olsen). No image presented on this slide is suitable for reproduction.

TRUSS TESTING

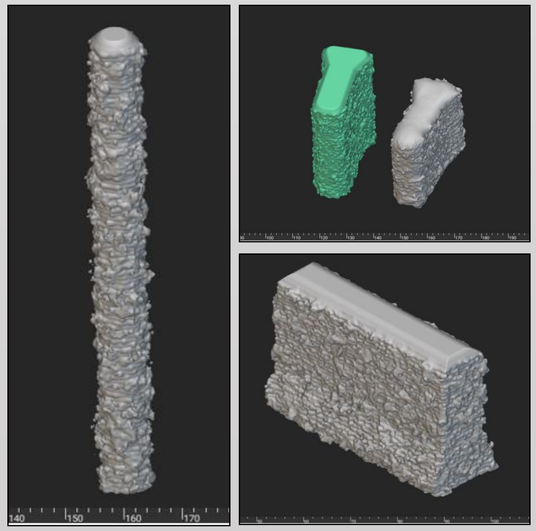
Several structures which could be built on the lunar surface with the aid of Outward Technologies' SAM system were identified over the course of the project and included truss-based large towers used for vertical solar arrays [3]. Dovetail and circular rod SAM parts were tested for compressive strength, and interface capability. The final experimental truss was designed and assembled at a desktop scale (143mm long, 143mm wide, 93.25mm tall) with circular regolith truss members loaded at set increments in order to determine the maximum possible load before failure, in addition to their interface capability.



Circular SAM truss rod (a), Dovetail SAM truss rod (b), Experimental Truss CAD model (c), Assembled Experimental Truss (d), and Experimental Truss loading (e). Images in (a) and (b) have been provided by/are the property of Outward Technologies.

TEXTURE MODELING

Due to the nature of the physical testing completed, alongside the availability of regolith SAM parts, nTop (previously known as nTopology) was utilized to generate polymer grousers/truss members which emulated the surface textures and dimensional tolerances of SAM components. Each polymer model was generated with unique surface features, which enabled in-depth examination of how best to design mechanical interfaces for regolith components produced with SAM, or similar technologies.



Textured CAD models, generated in the nTop software platform. Images rendered in nTop Version 4.2.3.

References:[1] Taylor, L. A. and Meek, T. T. (2005) *Journal of Aerospace Engineering*, Vol. 18, Issue 3 [2] Lee, T. S. et al. (2015) *Acta Astronautica, Vol. 114, pp. 60-64* [3] Sephora, R. et al. (2022), *Tall Towers on the Moon*.