A NOVEL METHOD OF HEAT REJECTION AND STORAGE USING LASER VMX PROCESS ON LUNAR REGOLITH. R. Hayes[1] and V. Svaldi[2], Off-Planet Systems, ICON Technology Inc. Austin, Texas rhayes@iconbuild.com[1] & vsvaldi@iconbuild.com[2]

Introduction: Heat rejection is a critical aspect for lunar machines due to the extreme temperature variations on the Moon. During the lunar day, surface temperatures can soar up to 127 °C (260 °F), while at night, temperatures plummet to as low as -173 °C (-280 °F). To maintain optimal operating conditions, lunar machines must efficiently reject excess heat generated by their systems. One common method for heat rejection involves using radiators that dissipate heat into space through thermal radiation. These radiators are designed to withstand the harsh lunar environment and effectively regulate the temperature of vital components within the machines.

In addition to radiators, some lunar machines may utilize heat pipes to manage thermal loads and reject excess heat. Heat pipes are passive heat transfer devices that rely on phase change principles to transport heat from one point to another. By incorporating heat pipes into their design, lunar machines can efficiently transfer heat away from sensitive components to areas where it can be safely rejected. This technology is particularly useful in environments like the Moon, where traditional cooling methods may be less effective due to the lack of a substantial atmosphere.

Furthermore, the design of heat rejection systems for lunar machines must consider the challenges posed by the Moon's low gravity environment. Traditional cooling systems that rely on gravity for fluid circulation may not function as expected on the Moon. Engineers must develop innovative solutions to ensure that heat rejection mechanisms operate effectively in lunar conditions. By leveraging advanced thermal management techniques and materials, lunar machines can overcome the challenges of heat rejection and operate efficiently in the extreme lunar environment.

Lunar regolith, the layer of loose, fragmented material covering the Moon's surface, is a versatile resource that holds immense potential for energy storage in future lunar missions.

One of the most promising applications of lunar regolith for energy storage is through the creation of regolith-based thermal batteries. These batteries could store energy from intermittent sources like solar power or be directly charged using in-situ resources such as solar panels. By converting regolith into a usable form, such as ICON's laser VMX (Vitreous Multi-Material Transformation), energy could be stored efficiently, providing a reliable power source even during lunar nights when solar power is unavailable. VMX is a lunar regolith product of ICON's process of using a robotic-arm enabled high-powered laser end effector to provide successive heating and controlled cooling to produce a very strong, concrete-like, material that can be used for additive construction.

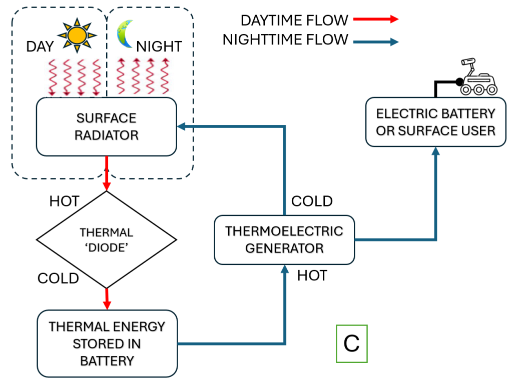

Figure 1: Thermal Battery system diagram illustrating an example configuration that could be used to generate electric power via the use of thermoelectric (Peltier) devices in the path from the battery to a dark sky facing radiator.

Using ICON's Laser VMX process to transform the lunar regolith into material that can be used as a thermal battery presents a promising avenue for sustainable energy storage on the Moon[5]. By harnessing the regolith's inherent ability to retain heat, we can effectively store excess thermal energy generated during the lunar day and release it during the frigid lunar night.

This innovative approach to energy storage not only maximizes the utilization of available resources on the Moon but also paves the way for sustainable energy solutions in space and could prove to be an efficient way to maintain a stable source of energy for future lunar habitats and missions.

ICON has developed a concept based on real work with Laser VMX and has performed analysis showing the proposed system is a viable solution for storing thermal energy collected during the lunar day for use during the lunar night to protect surface equipment.

ICON's design involved layering our VMX material with high thermal conductivity 'tendrils' of graphene or pyrolytic graphite. Building up a mass of this composite material in an excavated area on the moon. The tendrils would terminate in what is essentially a thermal strap that reaches above the surface (Figure 2).

An example of the analysis performed is show in Figure 3 below. In this case a constant temperature input is applied to the surface connector.

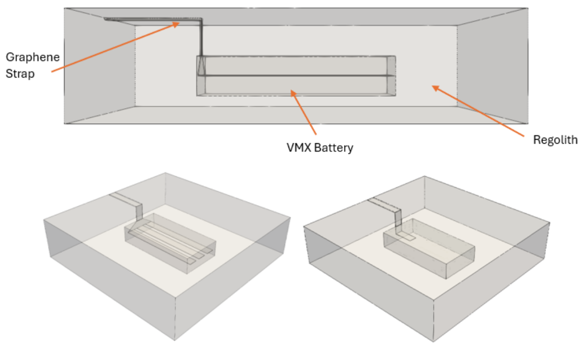

Figure 2: System configuration for proposed conductive battery. Graphene was chosen for this analysis as it has very high thermal conductivity and has been used in space flight applications in the form of thermal straps. The graphene strap to the left in the image above provides a "connector" for any device that needs to dump thermal energy. The thermal straps are placed and incorporated into the VMX melt to form a robust conductive interface. There are two variants shown here, on the bottom left is preferred and uses an array of thermal conductor "tendrils" embedded in the VMX battery to enhance bulk thermal conductivity. Bottom right of the image illustrates the device without the added tendrils

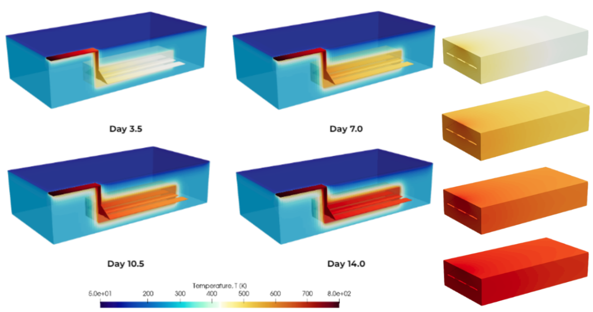

Figure 3: Graphical representation of simulation results for graphene tendrils configuration under constant 800 K input temperature condition. Color contour plot shown of surface temperatures; physical body is section cut.

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