

**DEVELOPING AND TESTING LUNAR TECHNOLOGIES IN A CONTROLLED SIMULATION LAB USING SIMULANTS BUILT FROM THE PARTICLE LEVEL UP.** Vincent G. Roux<sup>1</sup> and Melissa C. Roth<sup>2</sup>,  
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**Introduction:** With the renewed urgency of returning to the moon and the resulting need to conduct testing of moon-bound technologies, the natural urge is to repeat past patterns and buy a batch of “good enough” simulant that is similar to, but not the same as previously produced simulants. The additional commitment of building and operating the required testing facility has often been forsaken in favor of something that was again, “good enough”. This pattern emerged due to missions that were one-off and underfunded.

Manufacturing very high fidelity simulants and operating a large scale environmentally controlled simulation laboratory can only happen when the motivation arises from a long-term commitment focused on the success of the missions rather than the occasional sale of the simulant. Off Planet Research (OPR) does not sell its simulants for reasons discussed later.

**Background:** Making lunar regolith simulant for sale is not a sustainable business. Despite good intentions, existing simulants of limited quality were produced quickly, and were disbursed and compromised.

The simulation lab is equally important. It is well known that a large quantity of high quality lunar regolith, maintained and held in a controlled laboratory environment is needed. This lab needs to be large enough for multiple lunar landscapes with appropriate simulants. The environments in the simulation labs at OPR are very tightly controlled.

The overwhelming majority of the surface of the moon is highland, while almost all of the simulant ever made is lowland. Because of this need, OPR is producing over 30 tons of highland simulant for use in its labs.

Almost all available simulants lack actual agglutinates which are a critical component that makes up to 90% of lunar regolith. There is simply no way that any simulant without agglutinates can realistically behave like actual lunar regolith. Crushed melt product added to simulant is better than nothing but it is not agglutinate just as croutons are not bagels.

**Particle-up Production Method:** Most simulants are produced in a top-down manner where large scale sintering, modification, and milling is performed followed by inspection of the product and adjustment of the processes until available time and funds run out. This method tends to produce adequate simulants given the conditions under which they are

made, although the products retain many decidedly Earth-like qualities.

OPR was not constrained by the time and budget limitations of previous efforts, so each component within these simulants can be built from the particle level up. For each type of particle within the lunar regolith, OPR replicated the natural formation processes on the moon and then fully characterized regolith formation at the particle level. The rate of formation was then meticulously scaled up so that the particles that make up OPR’s simulants are very close approximations of true lunar particles. This includes crushed minerals with the correct morphology, and the formation of glass spherules, breccia, and of course, true agglutinates.

OPR manufactures true agglutinates by replicating the natural formation process by micro-meteorite strikes that occur on the moon, which produces simulated lunar agglutinates that are mechanically nearly identical to the real thing.

After building the individual simulant components, OPR mixes them in the correct ratios to create the simulants. The result of this particle-up effort is simulants which are superior to those that currently exist. What this means is that simulants made by OPR are much closer to lunar regolith with fewer Earth-like characteristics than other current simulants.

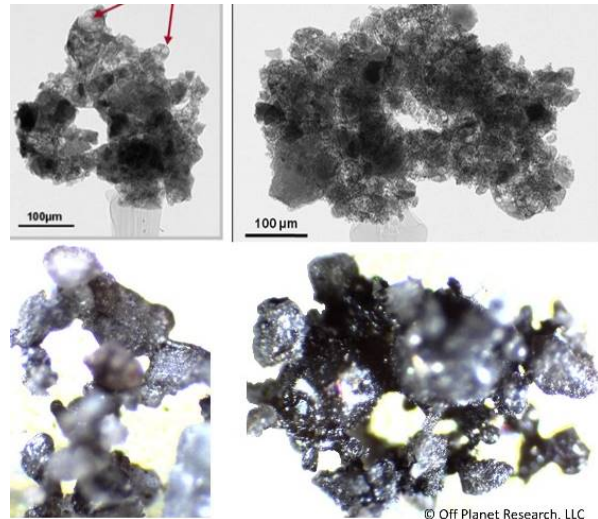


Figure 1 : Upper images used by permission from *An X-ray Ultra microscopy Study of Apollo 11 Lunar Regolith* paper by Kiely, C and Kiely, C.J. (2010). Lower images are simulated highland agglutinates produced by Off Planet Research, LLC. All particle sizes are similar.