PERMANENTLY SHADOWED REGION (PSR) Icy Regolith Simulant

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1. Introduction
• PSR simulants are necessary for testing robotic and mining techniques destined for PSRs.
• It is difficult to produce high fidelity icy simulant with expected properties at PSR and with controllable H₂O content.
• Simplest icy simulant is made by freezing wet simulant, this is so called mud-pie method, but it doesn’t have moonlike porosity [1-3]. Mixture of ice spheres and minerals does not have intimate contact between the grains [4]. But vapor deposition is slow and expensive [5]. (Figure 1)
• We are developing high fidelity, high porosity Lunar PSR icy simulant with controllable H₂O ice content. (Figure 2)

2. Production
• We use Lunar highland simulant (LHS-1, made by CLASS, Exolith lab, UCF, https://exolithsimulants.com).
• With our method, LHS-1 falls at a controlled rate under gravity. Water is sprayed from misters at a controlled rate. The wet LHS-2 falls into a LN₂ vessel, and after the evaporation of nitrogen, icy simulant remains (Figure 3).
• By freezing the wet grains somewhat separately, the icy simulant exhibits low cohesion and high porosity.
• With our method icy simulant is a homogeneous mixture that can be produced in large amounts and with consistent fidelity.

3. Properties/Testing
• Ice content and porosity are measured by recording the mass and volume of the simulant before and after heating where all the H₂O evaporates (Figure 4).
• Re-dried simulant maintains a high porosity like the initial icy simulant. However, after handling, shaking or somehow disturbing the re-dried samples, they collapse to the same porosity as fresh LHS-1 (Figures 4 and 5).
• Angle of Repose (AoR) experiments (Figures 6 and 7) were performed with icy simulants with various water-ice contents. The AoR experiment was performed on cryogenic (~80K) and slightly warmer (~250K) icy simulant [6].
• Based on [7] we had hypothesis that there might be nitrogen inclusions inside amorphous ice, that might form in this production process. But after simple heating experiments we found no mass loss, meaning that ice is crystalline.

4. Results
• Our icy simulant contains evenly distributed waterfrost with roughly controllable H₂O content (±1 wt%). The simulant has high porosity (60-70%) like that predicted at the poles [6].
• Angle of repose experiments reveal significantly lower AoR than dry LHS-1, which can be explained with higher porosity. But no dependence on H₂O content or temperature was found. (Figures 6 and 7)

5. Future work
• Our production design should be improved to have better control over both LHS-1 falling and H₂O spraying rate, so that icy simulant would have more predictable H₂O content.
• Fresh icy simulant should be observed under a microscope to find out if frost really covers the surface of LHS-1. It is possible, that water separates from other minerals upon touching the LN₂.
• The current method requires stirring after production, because some large water droplets fail into LN₂, updated design will solve this.

References