

REGOLITH SIMULANT REPORT CARDS: A USER FRIENDLY SIMULANT CERTIFICATION SYSTEM. S. R. Deitrick^{1,2} and K. M. Cannon¹, ¹Colorado School of Mines Center for Space Resources, 1500 Illinois St., Golden, CO 80401, srdeitrick@mymail.mines.edu, cannon@mines.edu, ²Jacobs/NASA Johnson Space Center Astromaterials Research and Exploration Science Division, 2101 NASA Pkwy, Houston, TX 77058, sarah.r.deitrick@nasa.gov.

Introduction: As the nation prepares to return to the Moon, there is an increasing need for testing tools, instruments, and equipment in simulated lunar regolith to ensure successful operations during lunar missions. Because of this, it is important to use accurate lunar regolith simulants to prepare for these missions. To address this, we are building an objective certification and reporting system for regolith simulants to ensure suitable simulants are being used for the appropriate use cases. Previous systems like the Figures of Merit (FoM) [1] and the Lunar Regolith Simulant User's Guide fit-to-use matrices [2] for lunar simulants were not particularly user friendly. Some of the Figures of Merit were not clearly defined and did not include recommended baseline values of lunar regolith properties to compare simulants to, and the fit-to-use matrices are out of date and include simulants that are no longer in production and do not include simulants that have been developed since.

Certification System: Our simulant certification system takes in analytical data for a simulant and automatically generates a report card that emphasizes the most and least appropriate use cases for that specific simulant. We have defined a parsimonious set of five use cases that require testing with simulants: (1) Geotechnical, (2) Particle Bonding, (3) Particle-Surface Interactions, (4) Chemical Processing, and (5) Human Health. In the background our system takes in FoM values calculated for six properties of the simulant (bulk chemistry, modal mineralogy, particle size distribution, particle shape, grain density, and magnetic susceptibility) and outputs an overall score and suitability level for each of the five use cases. The front page of the simulant report card (Figure 2) summarizes the simulant suitability level for each use case followed by appendices with analytical data for the six properties.

Weighting System. The overall scores are calculated based on a weighting system (Figure 1). The relevant properties for each use case are assigned a weight according to the significance of the property to the use case. For example in the Geotechnical use case, particle shape has the most significance and is therefore assigned the highest weight. If no data exist for a property, the weights will be re-normalized to account for the missing property. The FoM value for each property is then multiplied by its respective weight for each use case to give a property score, which are then summed

to give an overall use case score. This score determines the suitability level of the simulant for the five use cases and clearly shows what the simulant is most suitable for.

Future Work: This system is currently being set up to automatically generate PDF report cards based on numerical input data, and the designs are being finalized before user testing. In the future we will produce a set of report cards for the most commonly used lunar simulants today, and report cards can be generated on an ongoing basis as new simulants are developed.

References: [1] International Organization for Standardization. (2014). *Space Systems – Lunar Simulants* (ISO 10788:2014). [2] Schrader C. M. et al. (2010) *NASA/TM – 2010 – 216446*.

Property FoM per Use Case					
Properties	Geotechnical	Particle Bonding	Particle-Surface Interactions	Chemical Processing	Human Health
Chemistry		0.7		0.7	0.7
Mineralogy		0.94	0.94	0.94	0.94
Particle Shape	0.2	0.2	0.2		0.2
Particle Size Distribution	0.49	0.49	0.49		0.49
Particle Density	0.3	0.3	0.3		0.3
Magnetic susceptibility			0.04		
Property Weight per Use Case					
Properties	Geotechnical	Particle Bonding	Particle-Surface Interactions	Chemical Processing	Human Health
Chemistry		20.00%		50.00%	25.00%
Mineralogy		20.00%	25.00%	50.00%	20.00%
Particle Shape	40.00%	20.00%	25.00%		25%
Particle Size Distribution	35.00%	20.00%	25.00%		25.00%
Particle Density	25.00%	20.00%	15.00%		5.00%
Magnetic susceptibility			10.00%		
	100.00%	100.00%	100.00%	100.00%	100.00%
Use Case Score					
Properties	Geotechnical	Particle Bonding	Particle-Surface Interactions	Chemical Processing	Human Health
Chemistry	0	0.14	0	0.35	0.175
Mineralogy	0	0.188	0.235	0.47	0.188
Particle Shape	0.08	0.04	0.05	0	0.05
Particle Size Distribution	0.1715	0.098	0.1225	0	0.1225
Particle Density	0.075	0.06	0.045	0	0.015
Magnetic susceptibility	0	0	0.004	0	0
	0.3265	0.526	0.4565	0.82	0.5505
Most Suitable	> 0.75				
Suitable	0.33 - 0.75				
Less Suitable	< 0.33				

Figure 1. Weighing system using example values for FoMs and property weights to calculate use case scores.

Regolith Simulant Report Card

Simulant Name CRH-1 **Developer** Colorado School of Mines
Simulant Batch Batch 1, created 01/31/2021 **Analysis Date** 04/07/2021

	Use Case	Score	Suitability
	Geotechnical Excavation, drilling, mobility, etc.	33	Less Suitable This simulant should give poor results that lack most characteristics of lunar regolith samples
	Particle Bonding Sintering, 3D printing, regolith-based concrete, etc.	53	Suitable This simulant should give moderate results that lack some characteristics of lunar regolith samples
	Particle-Surface Interactions Dust mitigation, plume-surface interactions, etc.	46	Suitable This simulant should give moderate results that lack some characteristics of lunar regolith samples
	Chemical Processing Oxygen/volatile/metal production	82	Most Suitable This simulant should give highly accurate results that compare well to lunar regolith samples
	Human Health Dust toxicity, respiratory, radiation shielding, etc.	55	Suitable This simulant should give moderate results that lack some characteristics of lunar regolith samples

	Mineralogy	Chemistry	Particle Size Distribution	Particle Shape	Grain Density	Magnetic Susceptibility
Figure of Merit Score	94	70	49	20	30	4

Signature

Date

Figure 2. Example of a regolith simulant report card main page. For the imaginary simulant CRH-1, it is clear that the simulant is most suitable for use in chemical processing tests.