

APPROPRIATE SIMULANTS ARE A REQUIREMENT FOR MARS SURFACE TECHNOLOGY DEVELOPMENT. J. Edmunson¹, C. A. McLemore², and D. L. Rickman², ¹BAE Systems/Marshall Space Flight Center (Jennifer.E.Edmunson@nasa.gov, Huntsville AL 35812), ²NASA Marshall Space Flight Center (Carole.A.McLemore@nasa.gov, Doug.Rickman@nasa.gov, Huntsville AL 35812)

Introduction: To date, there are two simulants for martian regolith: JSC Mars-1A, produced from palaeogenic (weathered) basaltic tephra mined from the Pu'u Nene cinder cone in Hawaii [1] by commercial company Orbitec, and Mojave Mars Simulant (MMS), produced from Saddleback Basalt in the western Mojave desert by the Jet Propulsion Laboratory [2]. Until numerous recent orbiters, rovers, and landers were sent to Mars, weathered basalt was surmised to cover every inch of the martian landscape. All missions since Viking have disproven that the entire martian surface is weathered basalt. In fact, the outcrops, features, and surfaces that are significantly different from weathered basalt are too numerous to realistically count. There are gullies, evaporites, sand dunes, lake deposits, hydrothermal deposits, alluvium, etc. that indicate sedimentary and chemical processes. There is no "one size fits all" simulant. Each unique area requires its own simulant in order to test technologies and hardware, thereby reducing risk.

Not only are different simulants needed for different types of terrane, different simulants must be developed for different purposes. For example, an excavation simulant may not need to include expensive trace minerals; the cost of incorporating the trace minerals into the tons of material needed to test excavation equipment is unrealistic for a technology development budget. In addition, chemical and geophysical simulants do not need to be identical; each can be created for a specific purpose. In addition, lunar simulants are not applicable to martian environments. The two planets are chemically and mechanically distinct.

Mars Exploration Challenge Areas 1-3: NASA requires testing of any device for flight qualification in a relevant environment to mitigate risk. This includes the use of simulants to flight qualify technology that interacts with a planetary surface. The following are examples of how technologies for Mars would need simulant:

- calibration of remote sensing devices
- measuring the effectiveness of sounding, drilling, excavation, and penetrators for Mars
- testing in situ instrumentation for identification of trace minerals, or trace life forms, in regolith-like material
- making preliminary estimates of the toxicity of martian soil to humans (no martian soil is

available for this kind of test; actual lunar soil was used in previous tests but is not applicable to Mars visits)

- testing potential infrastructure, instruments, and investigation platforms
- testing lander "feet", rover mobility, and hazard avoidance technology
- development of in situ resource utilization technology (fuel, air, and water production)
- production of sealed and pressurized sample return capsules or containers
- development of devices for manipulation of rock/regolith for acquisition, transfer/handling, and storage and preservation of the surface, near-surface, or subsurface material
- development of technologies to extract resources (e.g., ionic liquids that can extract water, oxygen, and metals from regolith)

Mitigation of Risk: To illustrate the importance of using the appropriate simulant, one need only look at the challenges faced by rovers or humans in planetary environments. For example, the Apollo astronauts could not retrieve a full core sample. This is because of the nature of the lunar regolith; the grains essentially lock together and form almost a cement if they are disturbed by devices such as drills. Another example is the Lunar Roving Vehicle, used in the Apollo 15, 16, and 17 missions. The initial design of the rover did not take into account the ability of the regolith to adhere to the wheel and as a result, the regolith blanketed the crew and rover. Due to the thermally insulating properties of the lunar regolith, the batteries of the rover got very hot; this introduced a risk to the mission.

To mitigate risks on the martian surface, it is important to have a complete understanding of the effects of Mars regolith properties on technology. Due to an incomplete understanding/simulation of Mars regolith properties, the Phoenix lander experienced difficulties. The regolith on Mars was too "sticky" to fall into the hopper for the Thermal and Evolved Gas Analyzer. Another example is the Mars Exploration Rover Spirit, trapped permanently because of unanticipated regolith properties. A redesign of the Phoenix sampling system and the rover drive system may have occurred prior to launch had the properties of the martian soil at the landing sites been adequately known and replicated in simulants.

Precursor Science Analysis Group Strategic Knowledge Gaps B4, B7-9: Strategic Knowledge Gaps identified by the P-SAG committee addressed by this abstract include the following Gaps from Group B, “(4) Dust Effects. We do not understand the possible adverse effects of martian dust on either the crew or the mechanical/electrical systems. (7) Atmospheric ISRU. We do not understand in sufficient detail the properties of atmospheric constituents near the surface to determine the adverse effects on ISRU atmospheric processing system life and performance within acceptable risk for human missions. (8) Landing Site and Hazards. We do not yet know of a site on Mars that is certified to be safe for human landing, and for which we understand the type and location of hazards that could affect the ability to safely carry out mobile surface operations. (9) Technology: Mars Surface. In addition to the specific challenges listed above, we do not have the required technology available to land human-scale payloads on the martian surface, sustain humans on the surface of Mars, enable human mobility and exploration of the Mars surface environment; all within acceptable risk.” Designing simulants to reflect martian dust, atmosphere, and regolith will aid in filling these knowledge gaps.

The Production of Appropriate Simulants: To design appropriate simulants, it is important to gather the right kind of information. A “Figures of Merit” technique was developed at Marshall Space Flight Center to quantifiably determine how similar a simulant is to real planetary regolith. This evaluation takes into account four primary properties of regolith that determine most other derived properties: particle type/composition, particle size distribution, particle shape distribution, and density. Not only are the four parameters quantifiable themselves, they are the key to knowing things like grain size, particle density, glass composition, porosity, surface area, magnetic properties, bulk chemistry, and thermal properties [3].

A study by the Marshall Space Flight Center Planetary Regolith Simulant Team revealed key gaps in knowledge of the martian surface in order to produce simulants.

- There is bulk composition data provided by remote sensing, and some mineralogical data. However, there is very little information on the composition of individual particles and trace phases. Assumptions must be made regarding the composition and mineralogy of particles at landing sites.
- There is a serious lack of knowledge of martian particle shape. Most particle shape data is from in situ imaging [4, 5]. For example,

images were taken of soil sprinkled from Phoenix’s scoop. However, because of the sprinkling process, it may not be truly representative of the soil. Qualitative data (e.g., “the grains are more rounded than expected”) cannot be used to estimate risks. There is little other data.

- Risk exists in producing a simulant for a particular area for which we do not have surface data. Not only is very precise composition and mineralogical data difficult to acquire from orbit, particle size distribution, particle shape distribution, and density can only be grossly estimated from orbiter data. Data acquisition technology must be improved for improved simulant quality.
- The volatiles associated with the regolith are highly atmospheric temperature and pressure dependent; this will influence soil properties. Calculations would need to be made relating terrestrial and martian volatile environments for specific regolith compositions (particularly those heavy in phyllosilicates).
- This is not a comprehensive list; risks will present themselves during development.

Creating best and worst-case simulants can be completed using the information gathered today; but eliminating these knowledge gaps for the production of appropriate simulants requires not only higher resolution imagery and remote sensing of the surface, it requires sample return from potential research and human habitation sites.

Conclusions: Appropriate martian simulants are a critical necessity for developing technologies that will successfully interact and function on Mars. The simulants will not only determine and illustrate the efficiency of in situ resource utilization technology for planetary surfaces, they will also mitigate much of the risk for any planetary surface technology. It is exceedingly important for technology developers and flight hardware designers to keep in mind that their technology and hardware is only as good as the simulants used to test it. Therefore, the development and use of appropriate simulants is a mandatory element of any martian surface architecture.

References: [1] Allen C. C. et al. (1997) *LPS XXVIII*, Abstract #1797. [2] Peters G. H. et al. (2008) *Icarus* 197, 470-479. [3] Schrader C. M. and Rickman D. L. (2010) NASA/TM-2010-216443. [4] Velbel M. A. and Losiak A. I. (2009) *Workshop on the Microstructure of the Martian Surface*, Abstract #9011. [5] <http://www.spacetoday.org/SolSys/Mars/MarsExploration/MarsSoilPatches.html>.