TOWARD A SUITE OF STANDARD LUNAR REGOLITH SIMULANTS FOR NASA'S LUNAR MISSIONS: RECOMMENDATIONS OF THE 2005 WORKSHOP ON LUNAR REGOLITH SIMULANT MATERIALS

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Introduction: As NASA turns its exploration ambitions towards the Moon once again, the research and development of new technologies for lunar operations face the challenge of meeting the milestones of a fast-pace schedule, reminiscent of the 1960's Apollo program. While the lunar samples returned by the Apollo and Luna missions have revealed much about the Moon, these priceless materials exist in too scarce quantities to be used for technology development and testing. The need for mineral materials chosen to simulate the characteristics of lunar regoliths is a pressing issue that is being addressed today through the collaboration of scientists, engineers and NASA program managers. The issue of reproducing the properties of lunar regolith for research and technology development purposes was addressed by the recently held Workshop on Lunar Regolith Simulant Materials at Marshall Space Flight Center. The conclusions from the workshop and considerations concerning the feasibility (both technical and programmatic) of producing such materials will be presented here.

Present Status of Lunar Simulant Materials: No standard reference lunar simulant materials currently exist in the U.S.A.. NASA defined and provided such materials in the past for the development of the Apollo Landing Module and Lunar Rover Vehicle. While no Apollo lunar simulants remain today, the more recent efforts led to the development and distribution of materials such as MLS-1, a titanium-rich basalt from Minnesota and JSC-1 [1], a glass-rich basaltic ash from the volcanic fields of the San Francisco mountains of Arizona. Both of these simulant materials were successful in the sense that they provided known source materials for researchers but were not standardized and were only adequate for certain applications. The lack of funding and the waning interest from NASA in the 1990's resulted in disappearing stocks and the resurgence of a variety of 'home-made' lunar simulants and independent commercial materials. In parallel to NASA-funded simulants, the Japanese space agency JAXA, has developed lunar simulants such as FJS-1, and MKS-1 in the last ten years [2] and canadian anorthosite materials are being evaluated. These materials have been characterized extensively in terms of bulk chemical composition, mineralogy, geotechnical properties and are used in Japan but are only available in modest quantities. In the wake of the 2005 Workshop on Lunar Regolith Simulants, a renewed effort is underway to make JSC1-like materials (labeled JSC1a) available.

Recommendations and requirements for Lunar Regolith Simulants: The participation of many experts in lunar science, materials development, space resource utilization, dust toxicity, and soil mechanics enabled the workshop to issue specific recommendations to NASA. The expert group recommends the development of dictinct standard *root* lunar simulants representing low-Ti mare basalts and high-Ca highland anorthosites to address the basic rock types found on the Moon. These materials would serve as end-members to elaborate *derivative* simulants through mixing and addition of specific components. Additions of minerals such as ilmenites, glass components mimicking agglutinates and concentrations of nanophase iron are recommended to achieve higher fidelity of lunar materials simulation. Experimental development of a dust fraction (< 20 μm) mainly comprised of glass and mineral fragments is also strongly recommended since this fraction of the lunar regolith can represent up to 30% by mass [3]. One major obstacle to this task is the strong dependence of several regolith properties on the lunar environment itself. Surface properties such as adsorption, adhesion, chemical reactivity, and electrocharging are defined by the absence of oxidation, the ambient vacuum and the illumination by the full solar light spectrum. In fact, one should consider carefully the problems raised by the accumulation of requirements such as mineral chemistry, crystallinity, glass content, aspect ratios and surface properties that may render the production of simulants unfeasible technically and economically. In the end, the choice of standard reference materials for lunar simulants must be made now to support NASA's technology development for the early Robotic Exploration Program missions and extended duration missions to the lunar surface.

References: [1] D.S. McKay et al. (1997) *LPS XXIV*, 963. [2] H. Kanamori (1998) *Space98-ASCE*, 462-468. [3] D.S. McKay (1991) *Lunar Sourcebook*, 285-356.