THE STATUS OF SIMULANT MATERIALS OF LUNAR REGOLITH: REQUIREMENTS, FEASIBILITY, AND RECOMMENDATIONS.

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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. While the larger size fraction of the lunar regolith has been reproduced in several simulants in the past, little attention has been paid to the 'fines' fraction, commonly refered to as lunar dust. As reported by McKay and Carrier, this fraction of the lunar regolith below 20 microns can represent up to 30% by mass of the total regolith [1]. 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. Preliminary conclusions from the workshop and considerations concerning the feasibility of producing such materials will be presented here.

Present Status of Lunar Simulant Materials: No coordinated program currently exists in the U.S.A. to define reference materials to be used as analogs of lunar materials. Such coordinated efforts have existed at different times in the past to either provide these materials to specific technology development programs such as the Apollo Landing Module and Lunar Rover or when NASA policies showed a renewed interest in lunar missions as was the case in 1989 and the early 1990's. While no Apollo lunar simulants remain today, the more recent efforts led to the development and distribution of materials such as MLS-1 [2], a titanium-rich basalt from Minnesota and JSC-1 [3], 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 and engineers but were only adequate for certain applications. These deficiencies led to efforts to ameliorate their characteristics, particularly to better duplicate the content of glassy agglutinates in lunar regoliths (MLS-2). 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. Today, neither of the simulants mentioned above are available from their manufacturers. In parallel to NASA-funded simulants, the Japanese space agency NASDA, which is now the Japan Aerospace Exploration Agency, has funded a development program for lunar simulant materials for the past decade. As a result, simulants such as FJS-1, MKS-1 are used in Japan, but are not well known or used in the USA [4]. These materials have been characterized extensively in terms of bulk chemical composition, mineralogy, geotechnical properties and are available in modest quantities.

Requirements for Lunar Dust Simulants: The previous simulant materials outlined above contained a portion of fines although the fraction below 20 microns was not specifically characterized. Multiple direct observations of the behavior of lunar dust were made by the Apollo astronauts and reveal a potentially serious threat to crew health and mission hardware. The study of the interactions of lunar dust with humans and hardware will require the use of some of the actual lunar samples available but also the elaboration of specific materials that reproduce several properties of lunar dust at a time. One major obstacle to this task is the strong dependence of these properties on the lunar environment itself. Surface properties such as adsorption, adhesion, chemical reactivity, and electro-charging are defined by the absence of oxidation, the ambient vacuum and the illumination by the full solar light spectrum. The reproduction of complex grain shapes and surfaces created by micrometeoritic bombardments and aggregation of charged grains is indeed difficult at best. While many techniques of particle synthesis can be used to create nano- and micro-particles of varying shapes and compositions, the feasibility of producing simulant materials depends strongly on the actual requirements imposed by the researchers who will use these dust particles. 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. The combination of these very varied properties into a single processed material is doubtful from a technical point of view and may be unfeasible economically. The choice of which properties to be simulated are critical and in what combinations must be made by the user community while keeping these factors in mind. The chaotic situation concerning lunar simulant materials calls for a focused and coordinated development of large quantities of simulant materials in the near future to meet the needs of present and future efforts to develop technologies and test new hardwares for lunar precursor missions and lunar base development.

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