STATUS OF LUNAR REGOLITH SIMULANTS – AN UPDATE

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Since man first set foot on the Moon, the desire to study the engineering properties of lunar regolith/soil has presents an enigma. With some 840 lbs of lunar samples, NASA has been reluctant to allocate much of these national treasures, in quantities suitable for the proposed studies, instead, suggesting use of lunar regolith simulants. In January 1971, enter Prof. Paul Weiblen with his Minnesota Lunar Simulant (MLS) and his key-chain lunar-simulant holders. This high-Ti diabase from Diluth, MN was the first simulant, 'close' to the high-Ti basalts and soils of Apollo 11. But, lunar soils contains some 40-50% of glassy agglutinates. Hence, the MLS simulant was dropped through a 750 K-Watt plasma furnace to melt the grains into glass, which was subsequently ground and became part of the MLS-1. This was lunar simulant No.1.

Fast-forward 40 years, to witness the use and abuse and mega-$ spent making lunar simulants (Table 1, page 2) with improper physical/chemical properties and used wrongly (e.g., JSC-1A for hydrogen reduction of ilmenite. Finally in 2010, the Planetary Science Sub-Committee (PSS) of the NASA Advisory Council (NAC) issued a request (Table 2) for a detailed study be performed and a report generated by the LEAG – CAPTEM Simulant Working Group (Table 2).

This paper discusses and reviews the tasks put forth by the PSS, and includes the unique properties of lunar soils, the principle motivations that the scientific/engineering properties must be address, and the tasks listed below.

TABLE 2. Charter for LEAG-CAPTEM Simulant Working Group 2010

"The PSS recommends that a comprehensive study be undertaken by LEAG and CAPTEM to define the types of simulants that the various communities require in order to facilitate important lunar investigations as well as to preserve the Apollo lunar sample collection for future generations."

TASKS: **Identify all available lunar simulants**
Identify all potential areas of study

- ☺ **The product will basically address**
- ☺ **1) what is needed for lunar simulants;**
- ☺ **2) what lunar simulants already exist;**
- ☺ **3) protocols for their proper usage, and**
- ☺ **4) needs for Apollo lunar samples.**

TABLE 3. LEAG-CAPTEM Simulant Working Group

Working Group members: **Larry Taylor,** (Chair), Univ. of Tenn., LADTAG, Lunar Soil Expert; **Jennifer Edmunson,** MSFC, Simulant Engr.; **Bob Ferl,** Univ. of FL, Bio Expert; **Bob Gustafson,** ORBITEC, Simulant Engr.;**Yang Liu,** Univ. of Tenn., Lunar Soil & Simulant Expert; **Gary Lofgren,** JSC, Lunar Sample Curator; **Carole McLemore**, MSFC, ISRU/Dust Project Mgr.; **Dave McKay**, JSC, LADTAG, Lunar Soil Expert (Dust/Biomedical); **Doug Rickman,** MSFC, Simulant developer and tester; **Jerry Sanders,** JSC, ISRU Head Honcho; **Mini Wadhwa,** CAPTEM Chair; **Chip Shearer,** Ex-Officio; Chair of LEAG.

TABLE 1. LUNAR REGOLITH SIMULANTS (as of 2011)	Type of simulant
MLS-1* Minnesota Lunar Simulant Weiblen et al., 1990	High-Ilmenite mare (general use)
MLS-1P* Weiblen et al., 1990	High-Ti mare (experimental
MLS-2* Tucker et al., 1992	Highlands (general use)
ALS Arizona Lunar Simulant Desai et al., 1993	Low-Ti Mare (geotechnical)
JSC-1* Johnson Space Center McKay et al., 1994	Low-Ti mare (general use)
FJS-1 (type 1) Fuji Japanese Simulant Kanamori et al., 1998 FJS-1 (type 2) FJS-1 (type 3)	Low-Ti mare Low-Ti mare High-Ti mare
MKS-1 Carpenter, 2005	Low-Ti mare (intended use unknown)
JSC-1A, -1AF anonymous, undated, http://www.orbitec.com/ store/ JSC-1A-Bulk-Data-Characterization.pdf	Low-Ti mare (general use) (JSC-1A produced from the same source
OB-1 Olivine-Bytownite Battler & Spray, 2009	Highlands (general use geotechnical)
CHENOBI undocumented, see http://www.evcltd.com/ index.html	Highlands (geotechnical)
CAS-1 Zheng et al., 2008	Low-Ti mare (general use)
GCA-1 Goddard Space Center Taylor et al., 2008	Low-Ti mare (geotechnical)
NU-LHT-1M & 1D NASA/USGS-Lunar Highlands Stoeser 2009	Highlands (general use)
NU-LHT-2M & 2C Stoeser et al., 2009	Highlands (general use)
Oshima base simulant Sueyoshi et al., 2008	High-Ti mare (general use)
Kohyama base simulant Sueyoshi et al., 2008	Intermediate: highlands and mare
NAO-1 Li et al., 2009	Highlands (general use)
CLRS-1 Chinese Lunar Reg. Sim. Chinese Acad. of Sciences, 2009	Low-Ti mare (general use?)
CLRS-2 Chinese Academy of Sciences, 2009	High-Ti mare (general use?)
CUG-1 He et al., 2010	Low-Ti mare (geotechnical)
GRC-1 & -3 Glenn Research Center Oravec et al., in press	Geotech. For vehicle mobility simulant
TJ-1 Tongji University Jiang et al., in press TJ-2	Low-Ti mare (geotechnical)
KOHLS-1 Koh Lunar Simulant Jiang et al. 2010	Low-Ti mare (geotechnical)
BP-1 Black Point Rahmatian & Metzger, in press	Low-Ti mare (geotechnical)
CSM-CL Colorado School of Mines – Colorado Lava - Unpubl.	geotechnical