Technical Data Sheet: TLM-0

TDS-TLM-0-v2.2

1. Overview:

Figure 1: TLM-0 Close-up View

- **Type:** Low-Ti Mare
- **Series:** TerraLun®- Core
- **Composition:**
  - Basalt
  - Anorthosite
  - Altered Peridotite
- **Mean NASA FoM Score:** 90.9 %
- **100 % European** Sourced & Manufactured.
- **Uses:** High-fidelity general simulant suitable for geotechnical and mobility testing, excavation and construction trials, large-scale testbeds, ISRU process development, dust and environmental studies, filtration and sealing validation, scientific research, and technology demonstration.

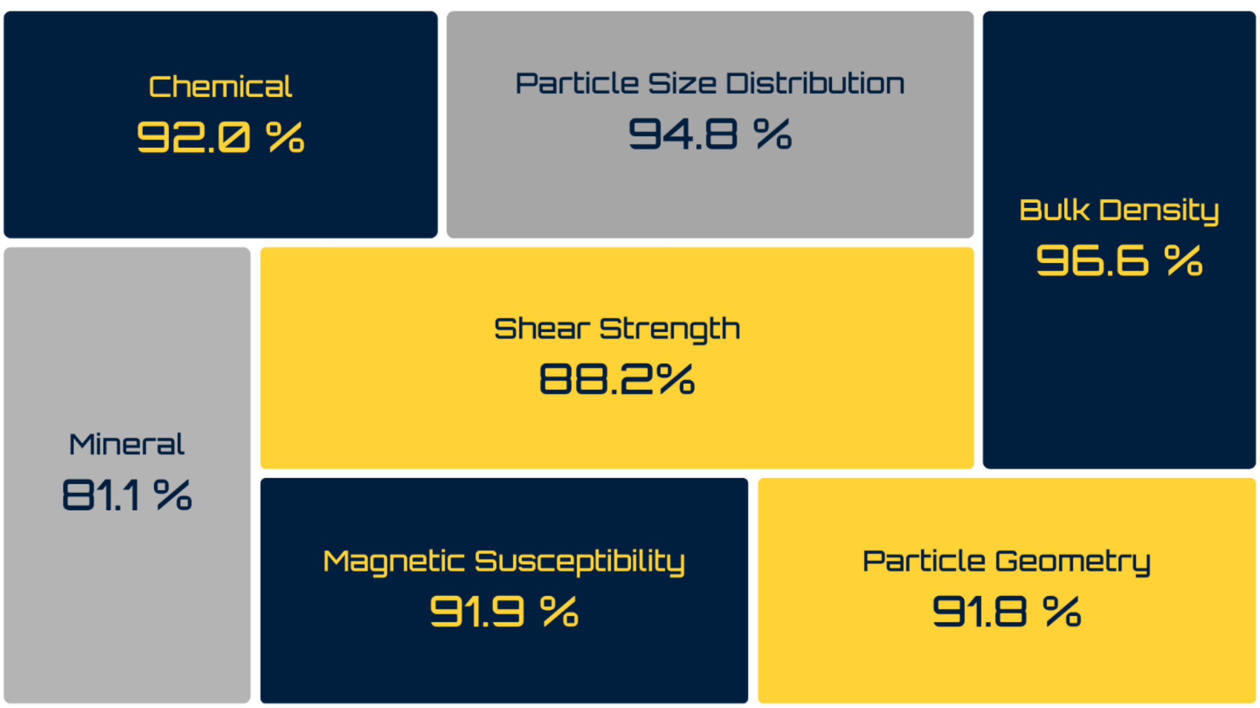

Figure 2: NASA Figures of Merit Results for TLM-0

2. Product Characterization

2.1 Chemical Composition

Chemical composition obtained through X-ray fluorescence analysis (XRF) performed by UPV/EHU with a Bruker M4 TORNADO and through Inductively Coupled Plasma Mass Spectrometry (ICP-MS) with a PerkinElmer NexION 2200 ICP/MS to supplement the XRF and obtain trace elemental composition.

SiO_2	TiO_2	Al_2O_3	FeO	MgO	CaO	Na_2O	K_2O
47.01	1.71	14.28	12.35	12.30	8.32	2.07	1.27

Table 1: Bulk Chemistry of TLM-0 (%)

SiO_2	TiO_2	Al_2O_3	FeO	MgO	CaO	Na_2O	K_2O
45.62	2.09	13.20	16.45	10.19	10.65	0.42	0.19

Table 2: Apollo Bulk Chemistry – Low-Ti Mare Reference (%)
Values obtained from Slabic et al. 2024 - Lunar Regolith Simulant User's Guide: Revision a. NASA/TM-20240011783

Nb	7.63	La	5.49	Sn	0.089
V	19.79	Ce	10.03	Pb	0.458
Co	4.65	Nd	3.62	Cu	13.54
Ni	57.5	Sm	0.629	Zn	6.87
Ba	89.8	Eu	0.191	Er	0.217
Sr	82.1	Tb	0.074	Gd	0.559
Hf	0.438	Dy	0.431	Rb	5.88
Ta	0.406	Ho	0.068	Pr	1.12
Th	0.685	Tm	0.032	Cs	0.082
U	0.163	Yb	0.204	Cr	73.1
Zr	25.53	Lu	0.029	Mn	1395.7
P	5337.4				

Table 3: Trace Elemental Composition of TLM-0 (ppm)

2.2 Mineral Composition

Mineral composition and quantification of glass/amorphous fraction through X-Ray Diffraction analysis (XRD) performed at UCLM by Jacinto Alonso-Azcarate with a PANalytical Xpert PRO machine. Supplemented by a Raman Spectroscopy performed at UPV/EHU with a Raman Renishaw InVia micro spectrometer.

Anorthite	Augite	Enstatite	Fosterite	Lizardite	Analcime	Smectite	Illite	Quartz	Hornblende	Amorphous/ Glass
35.2	17.2	1.9	2.1	5.7	3.8	1.2	0.6	0.6	0.3	31.4

Table 4: Modal Mineralogy of TLM-0 (%)

Pyroxene	Plagioclase Feldspar	Olivine	Ilmenite	Glass
19.1	35.2	2.1	0	31.4

Table 5: Mineral Group Classification of TLM-0 (%)

Pyroxene	Plagioclase Feldspar	Olivine	Ilmenite	Glass
24.97	28.46	6.89	3.86	32.98

Table 6: Apollo Mineral Group Classification – Low-Ti Mare Reference (%)
Values obtained from Slabic et al. 2024 - Lunar Regolith Simulant User's Guide: Revision a. NASA/TM-20240011783

2.3 Bulk Density

Bulk minimum, maximum, mean density as well as particle density were measured by TÜV SÜD's Geotechnics Department. The tests were performed following norms; UNE-EN ISO 17892-3:2018 (Particle Density), UNE 103015:1993 (Minimum Density) and UNE 103106:1993 (Maximum). The norms applied for maximum and minimum density are not specifically designed for materials with high fine fractions and in the case of the maximum density it can result in values higher than reality.

Minimum Density: 1.33 g/cm^3

Maximum Density: 2.01 g/cm^3

Mean Density: 1.67 g/cm^3

Particle Density: 2.79 g/cm^3

2.4 Particle Size Distribution

Particle size distribution (PSD) measured through Dynamic Image Analysis performed by a third-party entity with a CAMSIZER X2 and through sieve analysis for the coarse fraction (> 1 mm).

Range: 0.01-3000 µm

D10: 9.59 µm **D90:** 873.9 µm

Median(D50): 74.7 µm

Mean: 294.77 µm

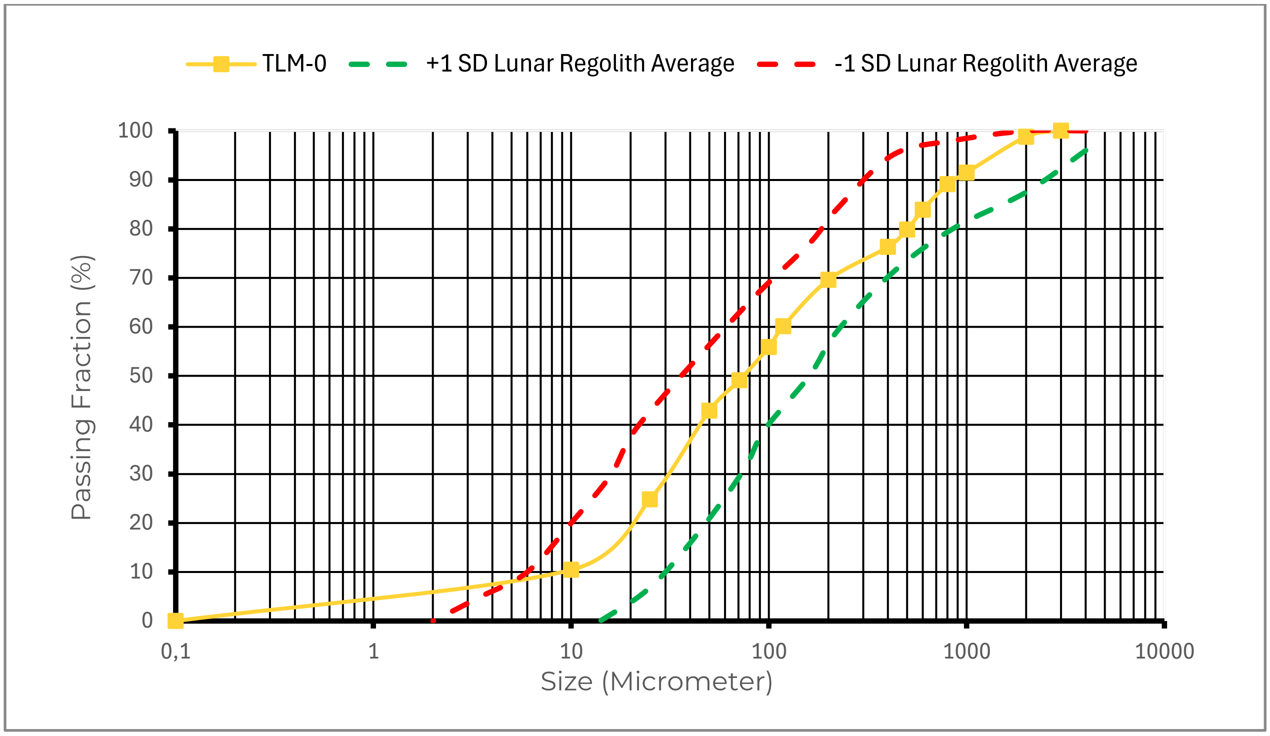

Figure 3: Particle Size Distribution of TLM-0 compared with the lunar regolith average and its ±1 standard deviation envelope after Zeng et al. 2010

2.5 Particle Geometry

Particle geometry measured through Dynamic Image Analysis performed by a third-party entity with a CAMSIZER X2.

Aspect ratio: 0.69451

Root Form Factor/Circularity: 0.86994

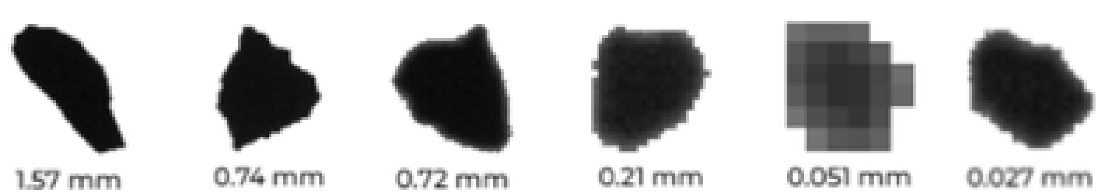

Figure 4: TLM-0 Particle Shape Example at Different Sizes

2.6 Shear Stress - Cohesion (c) and Angle of Internal Friction (φ^o)

Cohesion and Internal Angle of Friction measured through Direct shear test Performed in combination at UPM-ETSIME by the Space Mining Group with a Mecánica Científica S.A. - Direct Shear Cut Machine and TÜV SÜD's Geotechnics Department with a CONTROLS-CODEIN Model 27-T2 160 Direct Shear Cut Machine following norm UNE-EN ISO 17892-10:2019. Measurements were performed at ~15 kPa, ~25 kPa, ~50 kPa, ~74 kPa and ~98 kPa.

Internal Angle of Friction (φ^o): 44.58 °

Cohesion (c): 2.503 kPa

2.7 Magnetic Susceptibility

The massive magnetic susceptibility was obtained through a magnetic susceptibility analysis performed by UGR-CIC with a PPMS DynaCool Magnetometer with an ACMS II Module.

χ_m **=** 7279.5 x10^{-9} m^3/kg

2.8 UV–VIS–NIR Reflectance Spectra

Reflectance measurements were performed by Dr. Edward Cloutis, Department of Geography, University of Winnipeg, using an ASD LabSpec 4 Hi-Res spectroradiometer over 350–2500 nm. Spectra were acquired at a viewing geometry of i = 30°, e = 0°, φ = 180°, under laboratory air conditions at approximately 21.5 °C and 15.9% relative humidity. The sample was gently poured into a bevelled aluminium sample cup, lightly tapped, and levelled using a glass slide to minimise packing effects. The reported spectrum was corrected for Fluorilon absorption features and resampled to 1 nm intervals using a cubic spline. The data were not corrected for the non-Lambertian behaviour of the Fluorilon reference standard.

Apollo returned-sample reflectance spectra were obtained from the RELAB Spectral Database / NASA Planetary Data System Spectral Library. Apollo spectra were filtered to retain mixture/regolith measurements only. Repeated measurements of the same Apollo specimen under different viewing geometries were reduced to one representative spectrum per specimen, and spectra were interpolated to a common wavelength grid before calculating mission mean ±1 standard deviation.

For the comparison metrics below, envelope agreement is defined as the percentage of measured wavelengths where the TLM-0 reflectance spectrum falls within the Apollo 12 mission mean ±1 standard deviation envelope. Mean absolute reflectance difference is the average absolute difference between the TLM-0 spectrum and the Apollo 12 mission mean spectrum over the measured wavelength range. Apollo 12 provides the most appropriate low-Ti mare regolith comparison.

Wavelength	TLM-0	Apollo 12 mean	Apollo 12 mean ±1σ range
450 nm	**0.191**	0.087	0.056–0.117
550 nm	**0.240**	0.102	0.069–0.134
750 nm	**0.270**	0.129	0.091–0.167
1000 nm	**0.267**	0.126	0.087–0.165
1500 nm	**0.277**	0.194	0.147–0.241
2000 nm	**0.270**	0.209	0.158–0.259
2500 nm	**0.244**	0.255	0.198–0.312

Table 7: Reflectance Spectra Values of TLM-0 and Apollo 12

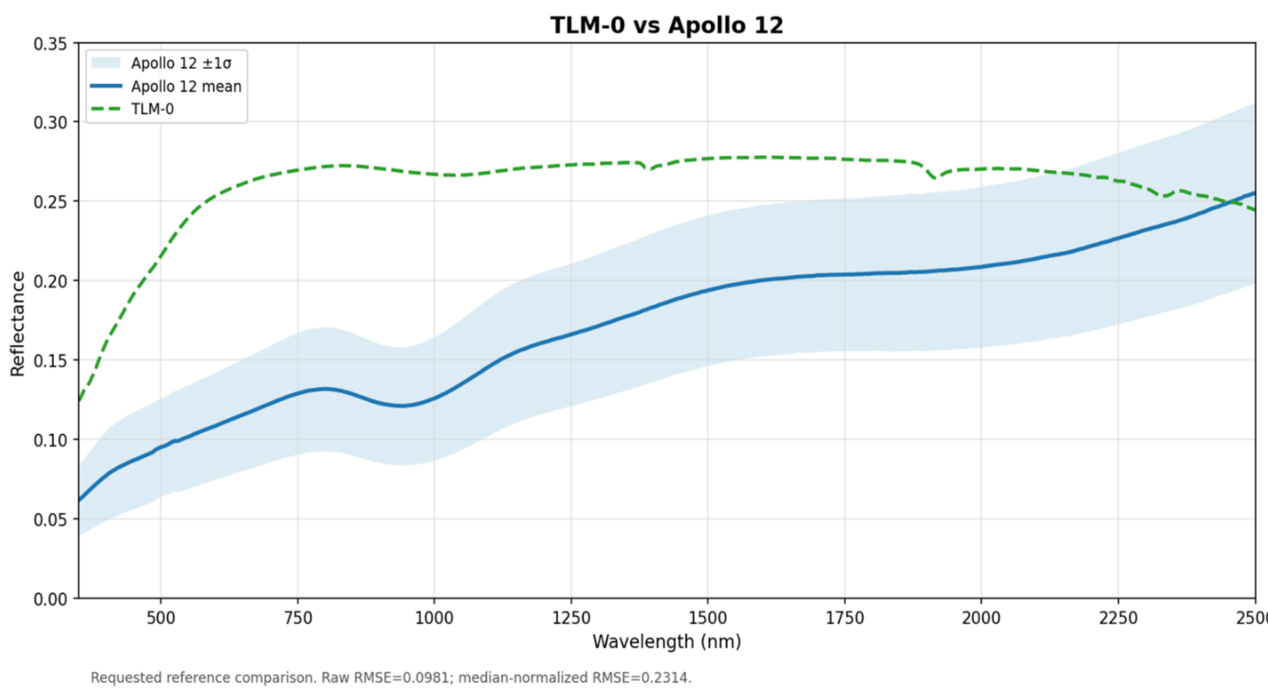

Figure 5: UV–VIS–NIR reflectance comparison between TLM-0 and Apollo 12 low-Ti mare regolith reference spectra.

TLM-0 shows 17.2% agreement with the Apollo 12 mean ±1σ envelope over the full 350–2500 nm range. The mean absolute reflectance difference between TLM-0 and the

Apollo 12 mean spectrum is 0.089 reflectance units. The highest agreement is concentrated mainly in the SWIR region, while larger offsets occur in the VIS–NIR region.

Apollo reference	Geological relevance	Envelope agreement	Mean absolute reflectance difference	RMSE
Apollo 16	Closest numerical spectral fit	94.9%	0.048	0.057
Apollo 17	Secondary spectral comparison	72.4%	0.072	0.080
Apollo 14	Secondary spectral comparison	66.6%	0.055	0.066
Apollo 12	**Primary low-Ti mare reference**	**17.2%**	**0.089**	**0.098**

Table 8: Apollo Spectral Comparison Summary

3. Other Information

- Safety data sheet available on request.
- Available for purchase at **https://www.hispansion.io/shop** for low-volume orders.
- For high-volume orders, reach out at **info@hispansion.io** to check availability and get a personalized quote.
- **Revision date**: June 11th, 2026.