

Technical Data Sheet: TLH-0

TDS-TLH-0-v1.4

1. Overview:

- ❖ **Type:** Highlands
- ❖ **Series:** TerraLun®- Core
- ❖ **Composition:**
 - Anorthosite
 - Basalt
 - Altered Peridotite
- ❖ **Mean NASA FoM Score:** 88.7%
- ❖ **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.

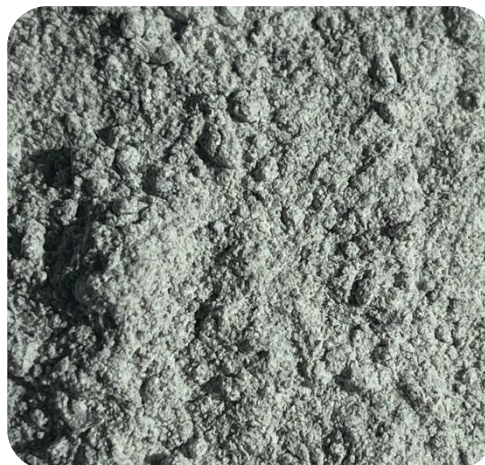


Figure 1: TLH-0 Close-up View

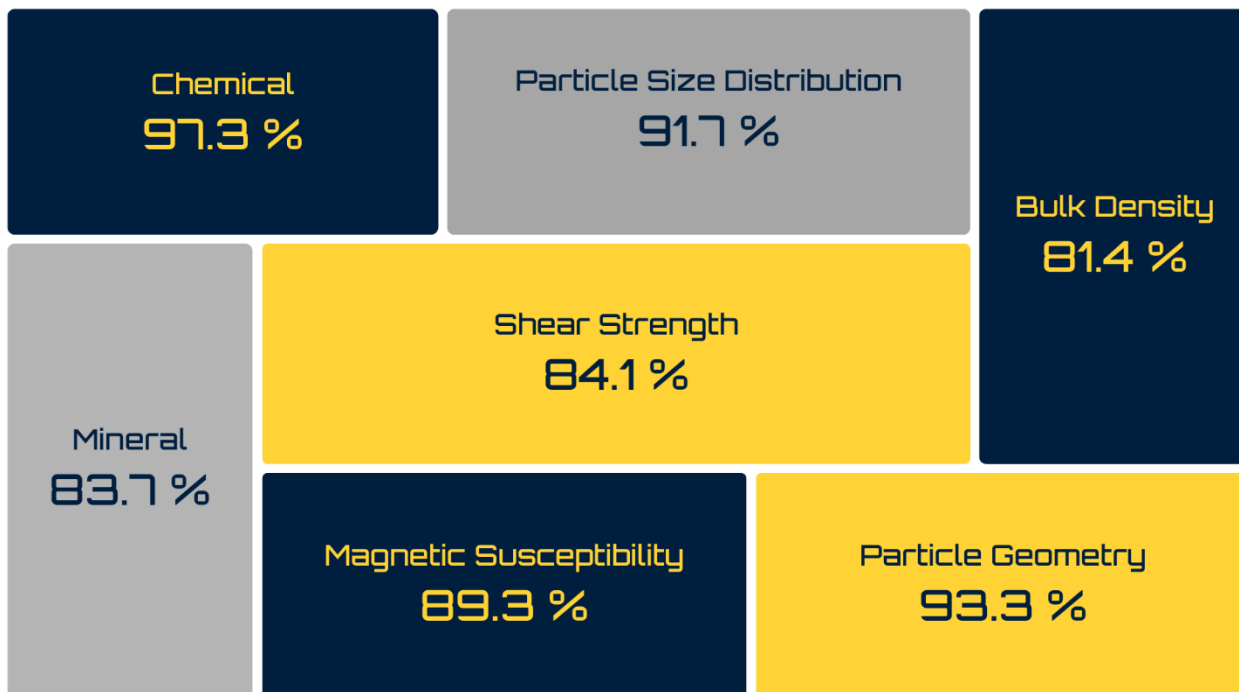


Figure 2: NASA Figures of Merit Results for TLH-0

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 ₂ O ₃	FeO	MgO	CaO	Na ₂ O	K ₂ O
46.08	0.81	24.87	6.73	5.05	14.02	1.51	0.66

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

SiO ₂	TiO ₂	Al ₂ O ₃	FeO	MgO	CaO	Na ₂ O	K ₂ O
45.62	0.84	24.47	6.6	6.98	14.65	0.48	0.2

Table 2: Apollo Bulk Chemistry – Highlands Reference (%)

Values obtained from Slabic et al. 2024 - Lunar Regolith Simulant User's Guide: Revision a. NASA/TM-20240011783

Nb	3.25	La	2.62	Sn	0.165
V	9.55	Ce	4.6	Pb	0.387
Co	2.79	Nd	1.8	Cu	6.52
Ni	39.2	Sm	0.304	Zn	3.27
Ba	45.1	Eu	0.095	Er	0.135
Sr	140.4	Tb	0.039	Gd	0.26
Hf	0.206	Dy	0.232	Rb	2.91
Ta	0.188	Ho	0.033	Pr	0.507
Th	0.352	Tm	0.015	Cs	0.057
U	0.079	Yb	0.116	Cr	51.77
Zr	11.33	Lu	0.015	Mn	759.4
P	2556.3				

Table 3: Trace Elemental Composition of TLH-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	Fosterite	Lizardite	Analcime	Smectite	Illite	Quartz	Chlorite	Hornblende	Amorphous / Glass
57	5.7	1.8	6.5	2.6	0.5	1	1.2	2.4	2.1	19.2

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

Pyroxene	Plagioclase Feldspar	Olivine	Ilmenite	Glass
5.7	57	1.8	0	19.2

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

Pyroxene	Plagioclase Feldspar	Olivine	Ilmenite	Glass
7.92	59.05	5.11	0.15	27.77

Table 6: Apollo Mineral Group Classification – Highlands Reference (%)

Values obtained from Slabik et al. 2024 - Lunar Regolith Simulant User's Guide: Revision a. NASA/TM-20240011783

2.3 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: 1.45 g/cm³

Maximum Density: 2.14 g/cm³

Mean Density: 1.80 g/cm³

Particle Density: 2.78 g/cm³

2.4 Particle Size Distribution

Particle size distribution (PSD) measured through Dynamic Image Analysis performed by a third-party entity with a CAMSIZER X2.

Range: 0.01-3000 µm

D10: 9.6 µm

D90: 1398.9 µm

Median(D50): 137.56 µm

Mean: 389.81 µm

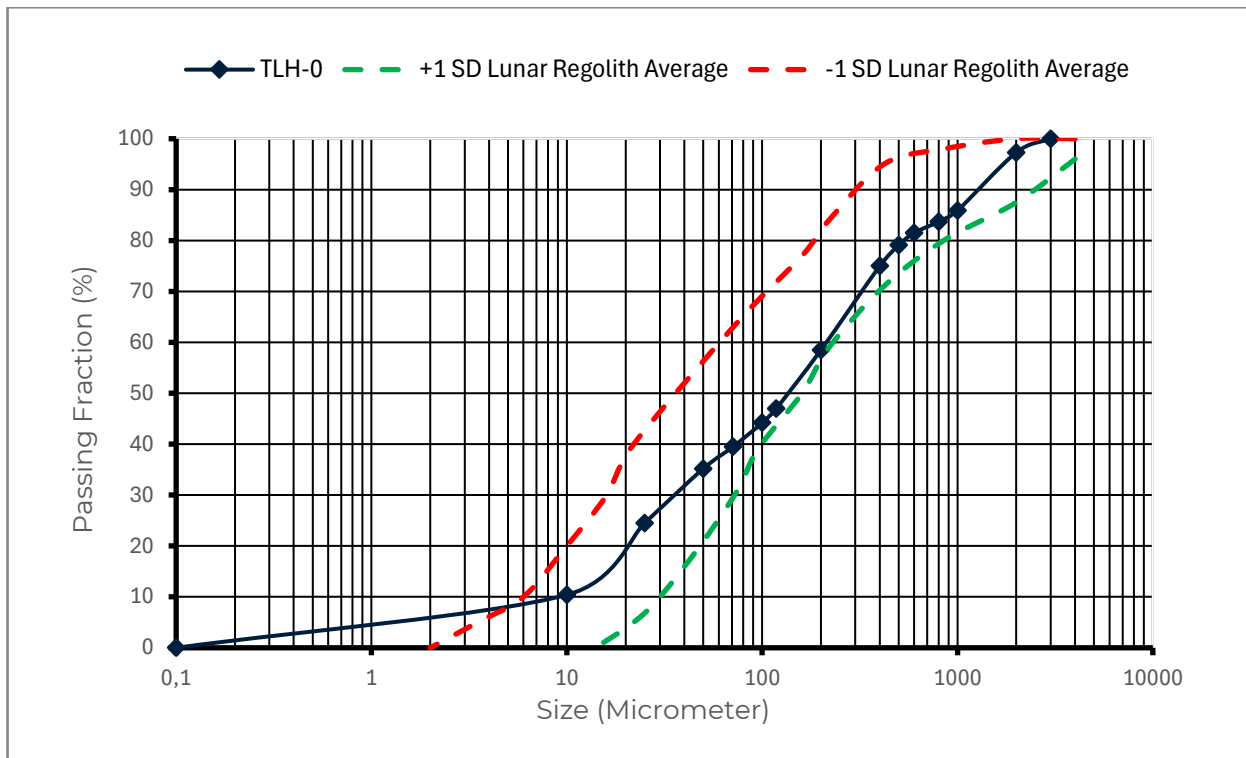


Figure 3: Particle Size Distribution of TLH-0 compared with the lunar regolith average and its ± 1 standard deviation envelope after Zeng et al. 2010

2.5 Particle Geometry

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

Aspect ratio: 0.70287

Root Form Factor/Circularity: 0.88048

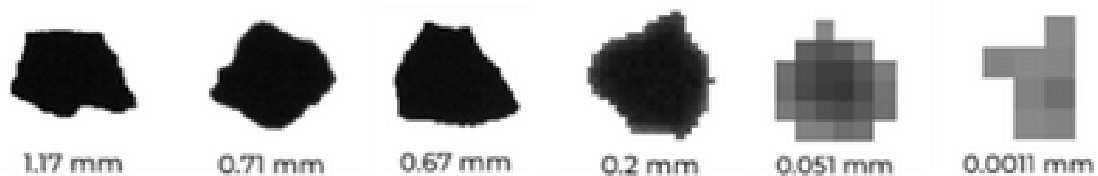


Figure 4: TLH-0 Particle Shape Example at Different Sizes

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

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, with a displacement rate of 0.5 mm/min up to a maximum displacement of 7 mm.

Internal Angle of Friction (ϕ°): 46.12 °

Cohesion (c): 2.896 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.

$$\chi_m = 4495.7 \times 10^{-9} \text{ m}^3/\text{kg}$$

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 $i = 30^\circ$, $e = 0^\circ$, $\phi = 180^\circ$, 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 TLH-0 reflectance spectrum falls within the Apollo 16 mission mean ± 1 standard deviation envelope. Mean absolute reflectance difference is the average absolute difference between the TLH-0 spectrum and the Apollo 16 mission mean spectrum over the measured wavelength range. Apollo 16 provides the most appropriate feldspathic highlands comparison.

Wavelength	TLH-0	Apollo 16 mean	Apollo 16 mean $\pm 1\sigma$ range
450 nm	0.368	0.160	0.079–0.241
550 nm	0.408	0.184	0.098–0.270
750 nm	0.415	0.221	0.126–0.315
1000 nm	0.414	0.235	0.141–0.328
1500 nm	0.423	0.303	0.195–0.411
2000 nm	0.409	0.331	0.222–0.439
2500 nm	0.366	0.376	0.262–0.489

Table 7: Reflectance Spectra Values of TLH-0 and Apollo 16

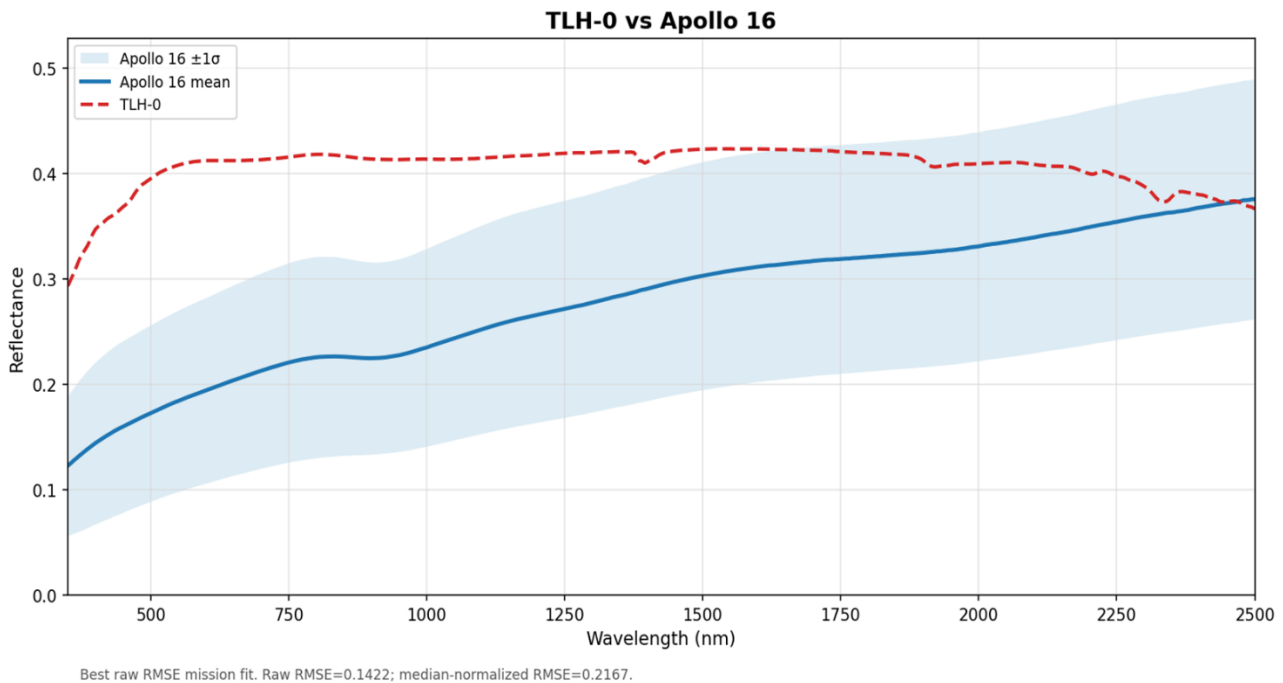


Figure 5: UV-VIS-NIR reflectance comparison between TLH-0 and Apollo 16 highlands regolith reference spectra.

TLH-0 shows 39.9% agreement with the Apollo 16 mean $\pm 1\sigma$ envelope over the full 350–2500 nm range. The mean absolute reflectance difference between TLH-0 and the Apollo

16 mean spectrum is 0.127 reflectance units. Agreement is strongest in the SWIR region, where the TLH-0 spectrum more frequently falls within the Apollo 16 reference envelope.

Apollo reference	Geological relevance	Envelope agreement	Mean absolute reflectance difference	RMSE
Apollo 16	Primary highlands reference	39.9%	0.127	0.142
Apollo 14	Secondary spectral comparison	9.3%	0.190	0.198
Apollo 17	Secondary spectral comparison	3.0%	0.215	0.220

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.