Lighting and the lunar surface environment

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NESC Lunar Lighting Workshop

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Outline

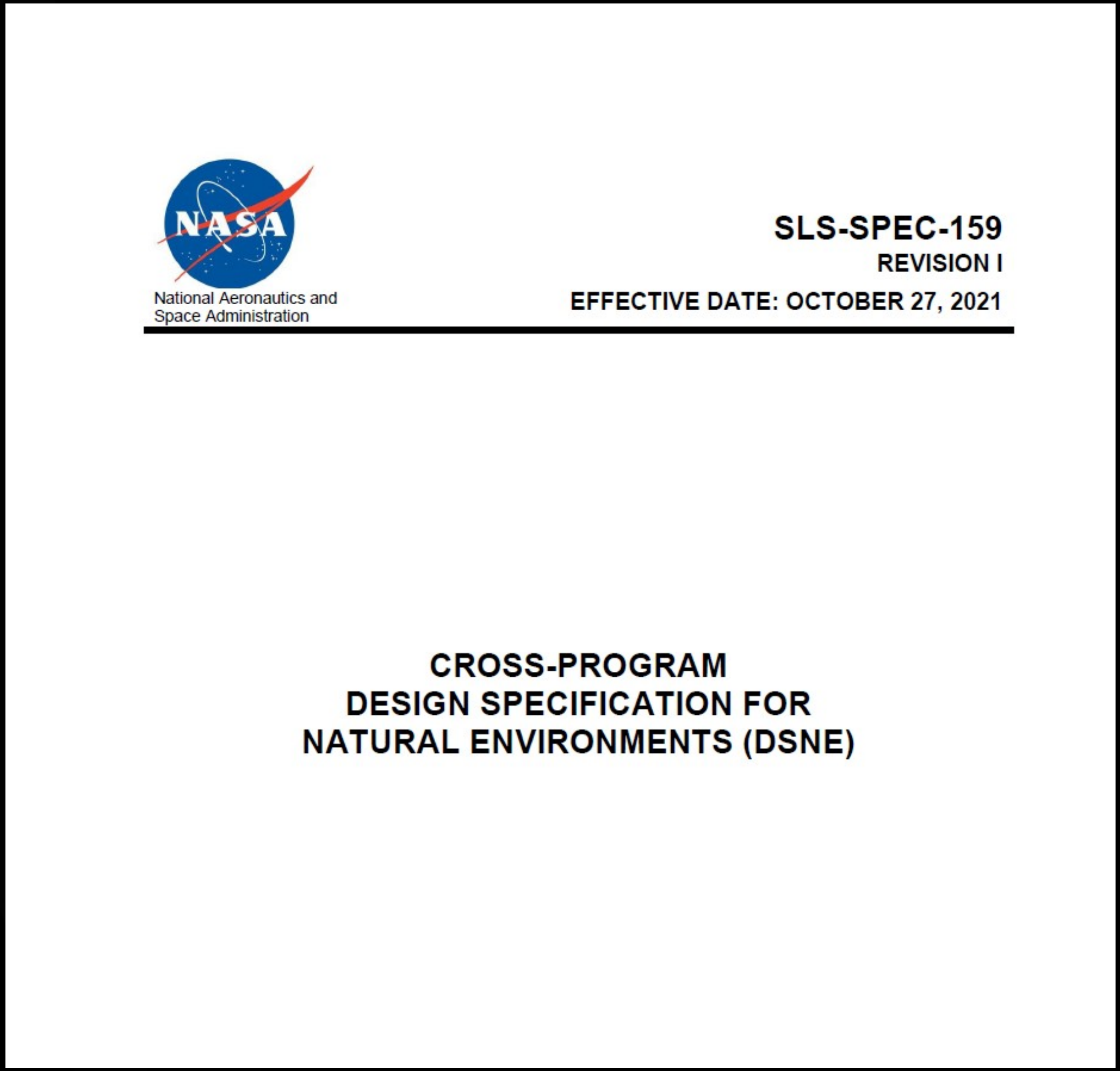
- Natural environments and SLS-SPEC-159 DSNE
- Natural light sources
- Lighting and environmental effects
- Lunar surface properties
  - Regolith properties
    - Albedo
    - Phase dependent reflectance
  - Surface features
    - Rock distributions
    - Slope distributions
    - Crater distributions

SLS-SPEC-159 DSNE

- The **Cross-Program Design Specification for Natural Environments** *defines the natural environment for crewed, deep-space NASA programs*
- Baselined for SLS, Orion, Gateway, and HLS
- Latest revision (Rev I) available through the NASA Technical Reports Server (NTRS)
  - https://ntrs.nasa.gov/citations/20210024522
  - When searching, latest revision is not always the first result
  - Best to filter by Report Number using "SLS-SPEC-159"

SLS-SPEC-159 DSNE

3.4	Lunar Surface Operational Phases
3.4.1	Lunar Surface Geological and Geomorphological Environment
3.4.2	Lunar Regolith Properties
3.4.3	Lunar Surface Plasma Environment
3.4.4	Lunar Regolith Electrical Properties
3.4.5	Optical Properties
3.4.6	Lunar Thermal Environment
3.4.7	Lunar Ionizing Radiation Environment
3.4.8	Lunar Meteoroid and Ejecta Environment
3.4.9	Lunar Illumination



National Aeronautics and Space Administration

SLS-SPEC-159
REVISION I
EFFECTIVE DATE: OCTOBER 27, 2021

CROSS-PROGRAM
DESIGN SPECIFICATION FOR
NATURAL ENVIRONMENTS (DSNE)

Natural light sources

- Solar illumination
  - Average solar flux at Moon same as that at Earth
  - Maximum and minimum affected by lunar orbit
  - Incident light nearly collimated (angular diameter)
  - Lunar day, or synodic period, is 29.5 Earth days

Solar Flux at Lunar Orbit	
Maximum	
Mean	
Minimum	

DSNE Section 3.3.9.1.1

Natural light sources

- Earthshine as illumination source studied by Glenar et al. 2019
  - Broadband flux ranges from approximately (thermal) up to depending on phase angle
  - Earth "would appear some 20–30 times brighter at visible wavelengths than would the Moon at similar phase over a terrestrial landscape" (Glenar et al. 2019)
  - Possible use for science/exploration
  - May affect lighting/thermal environment of PSRs

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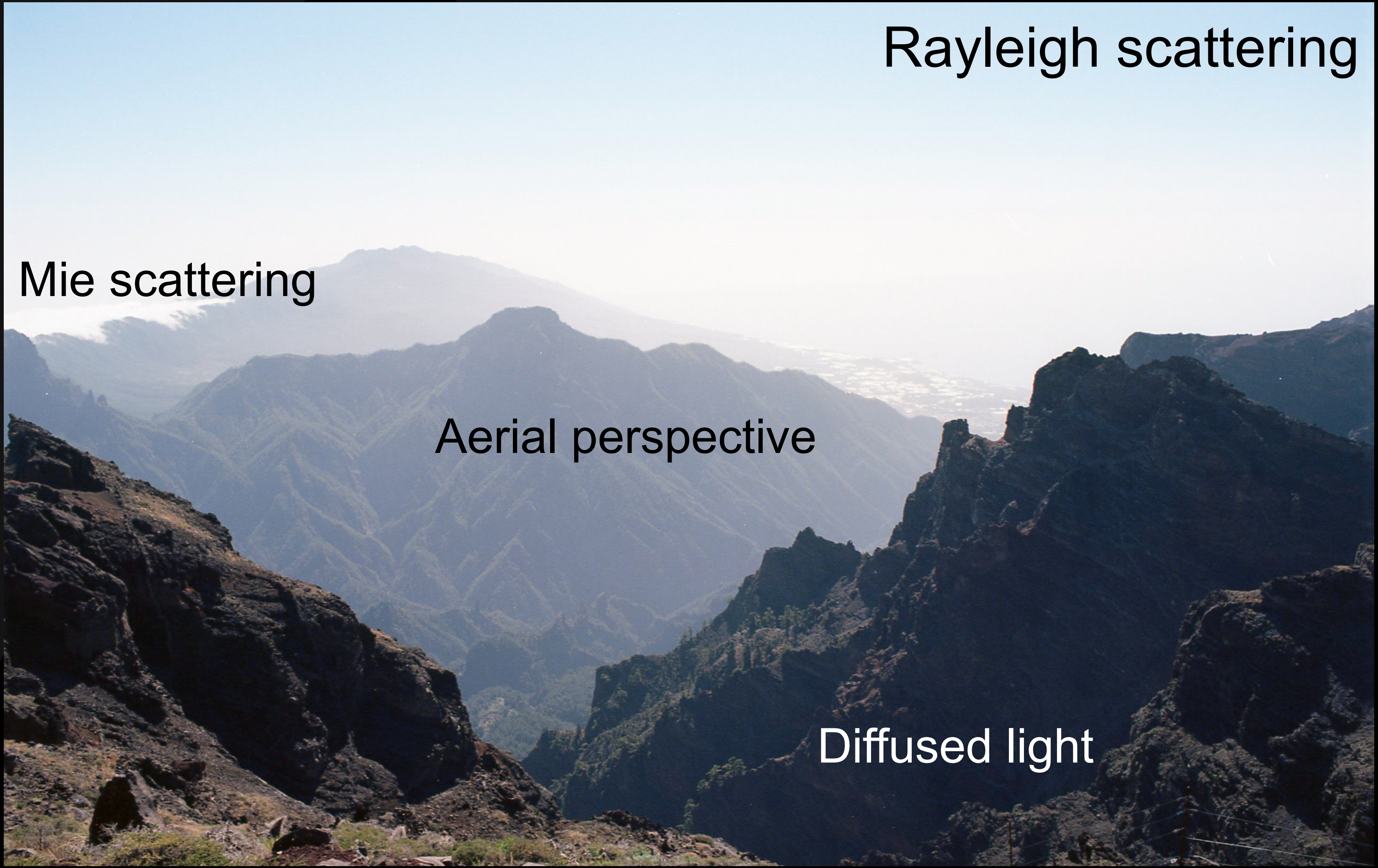
Earth's lighting environment



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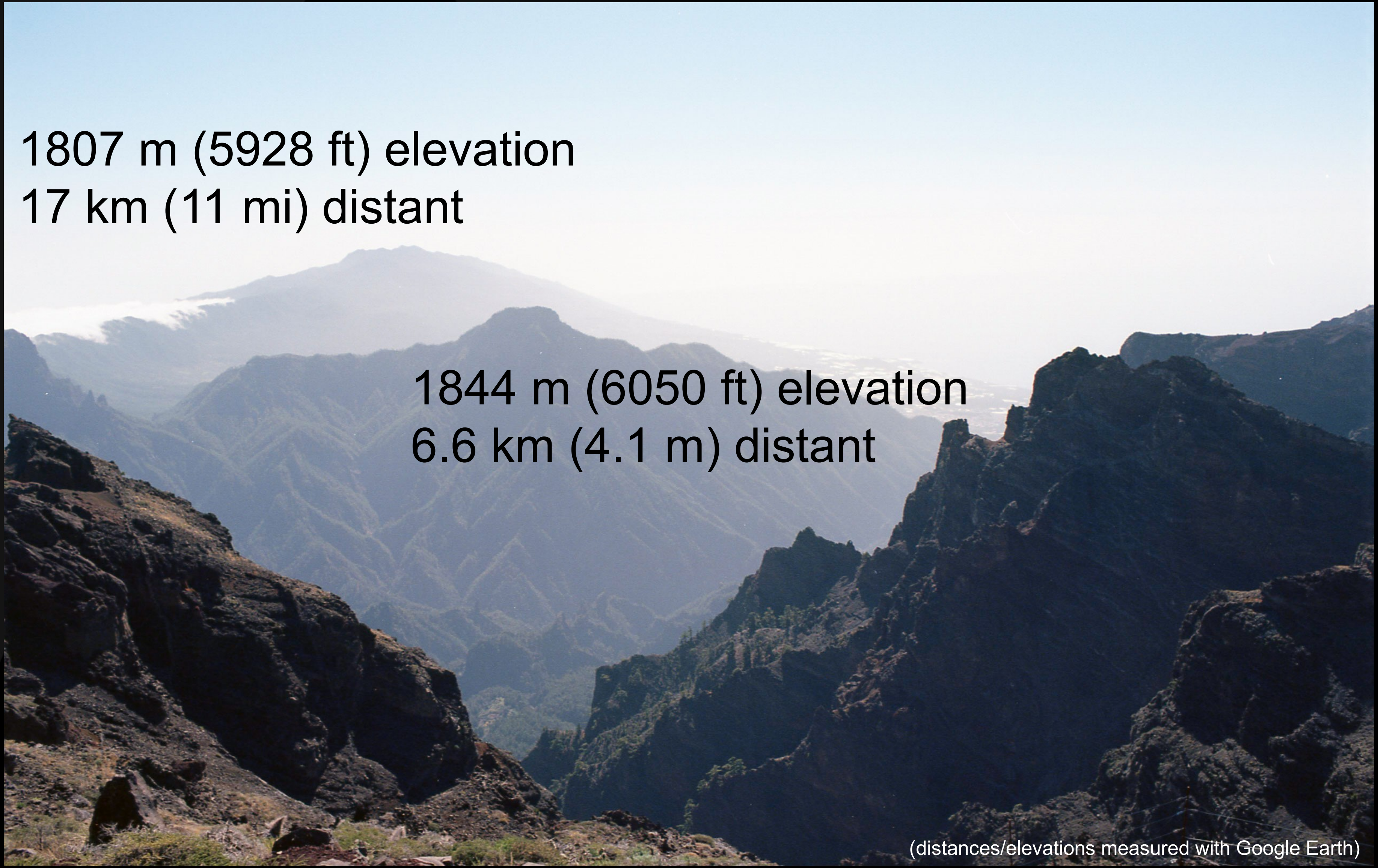
Earth’s lighting environment



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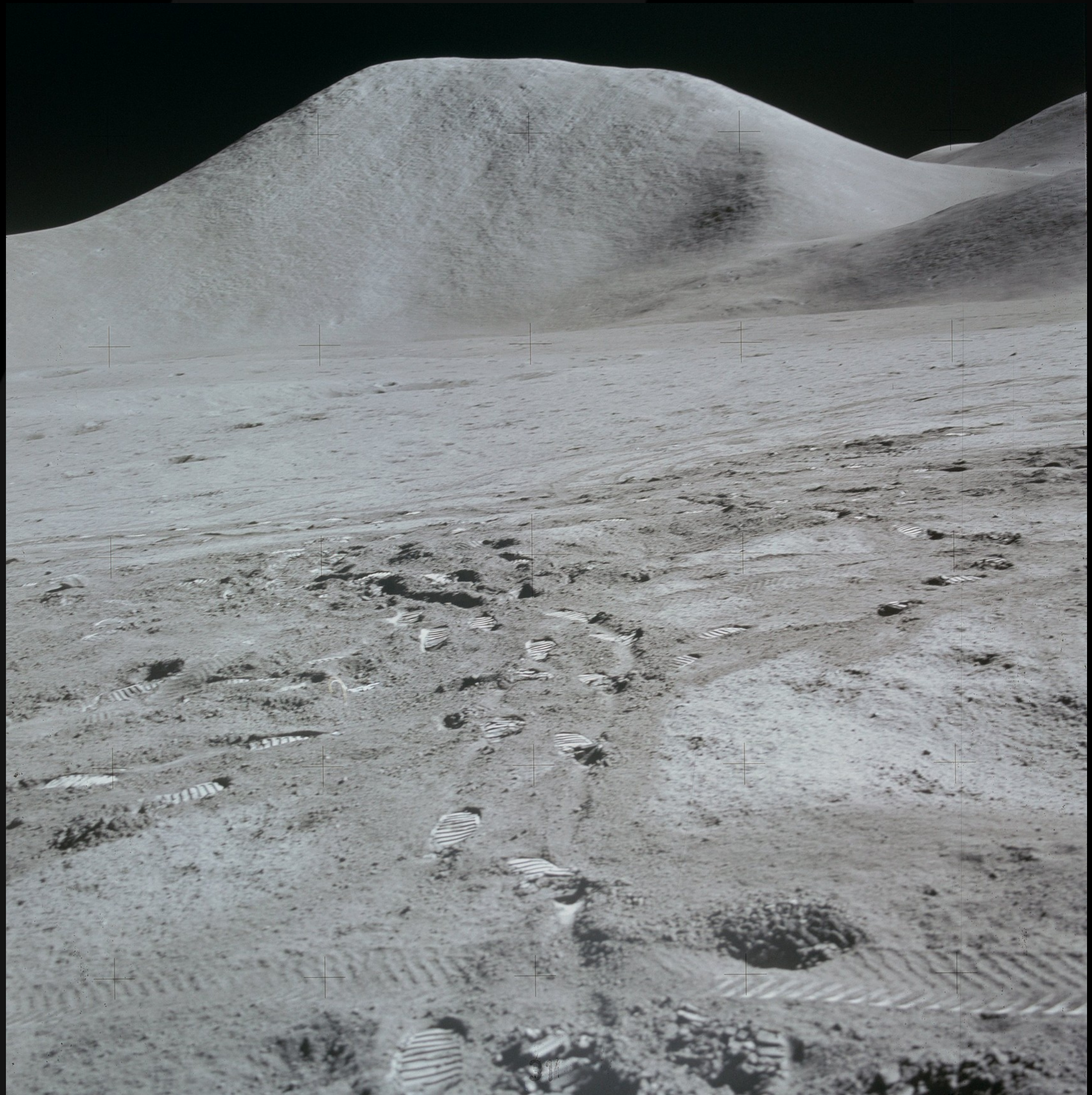
Mons Hadley

4100 m (13,000 ft) elevation change

20 km (12 mi) distant



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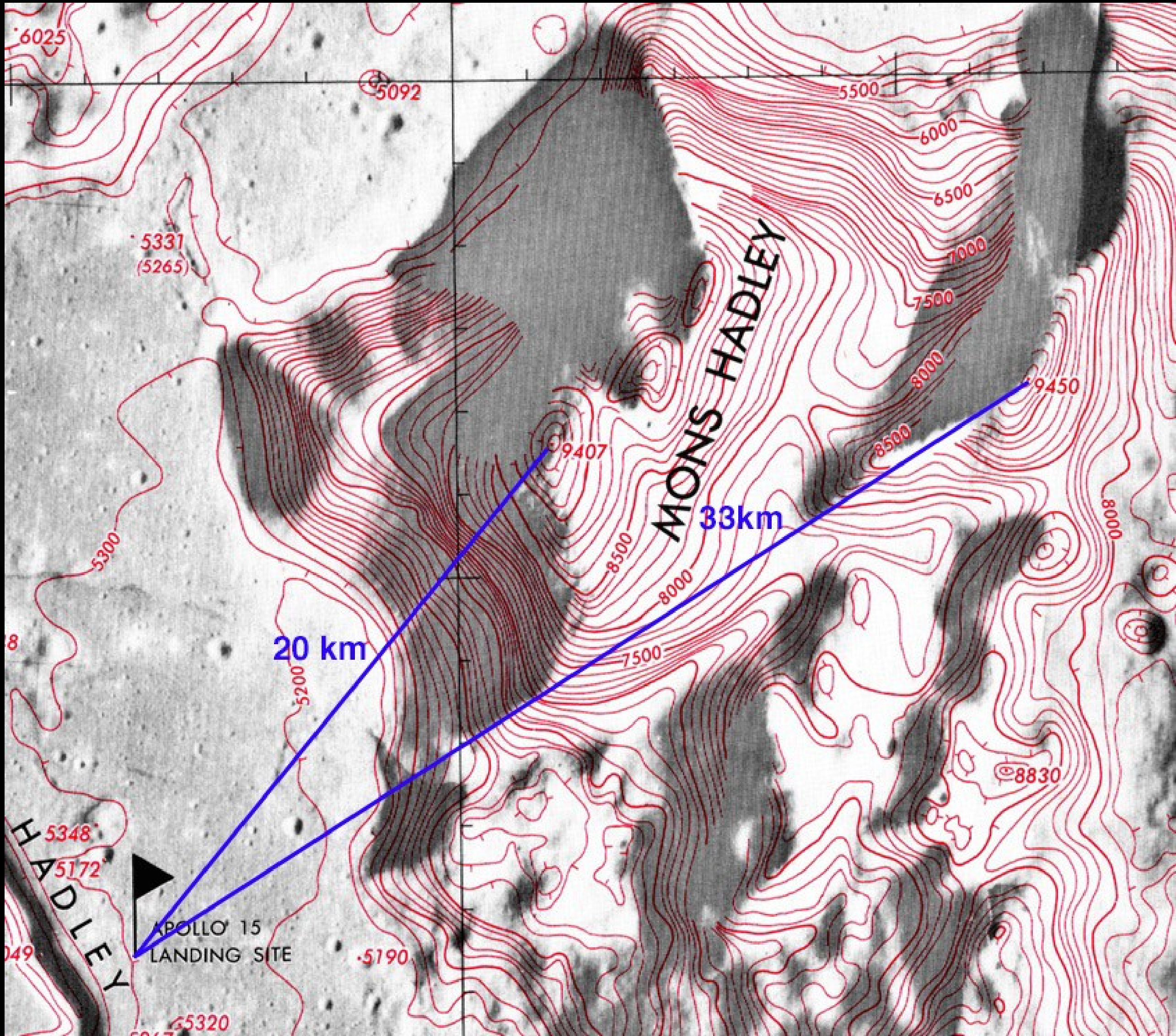

Labeled detail from LTO41B4

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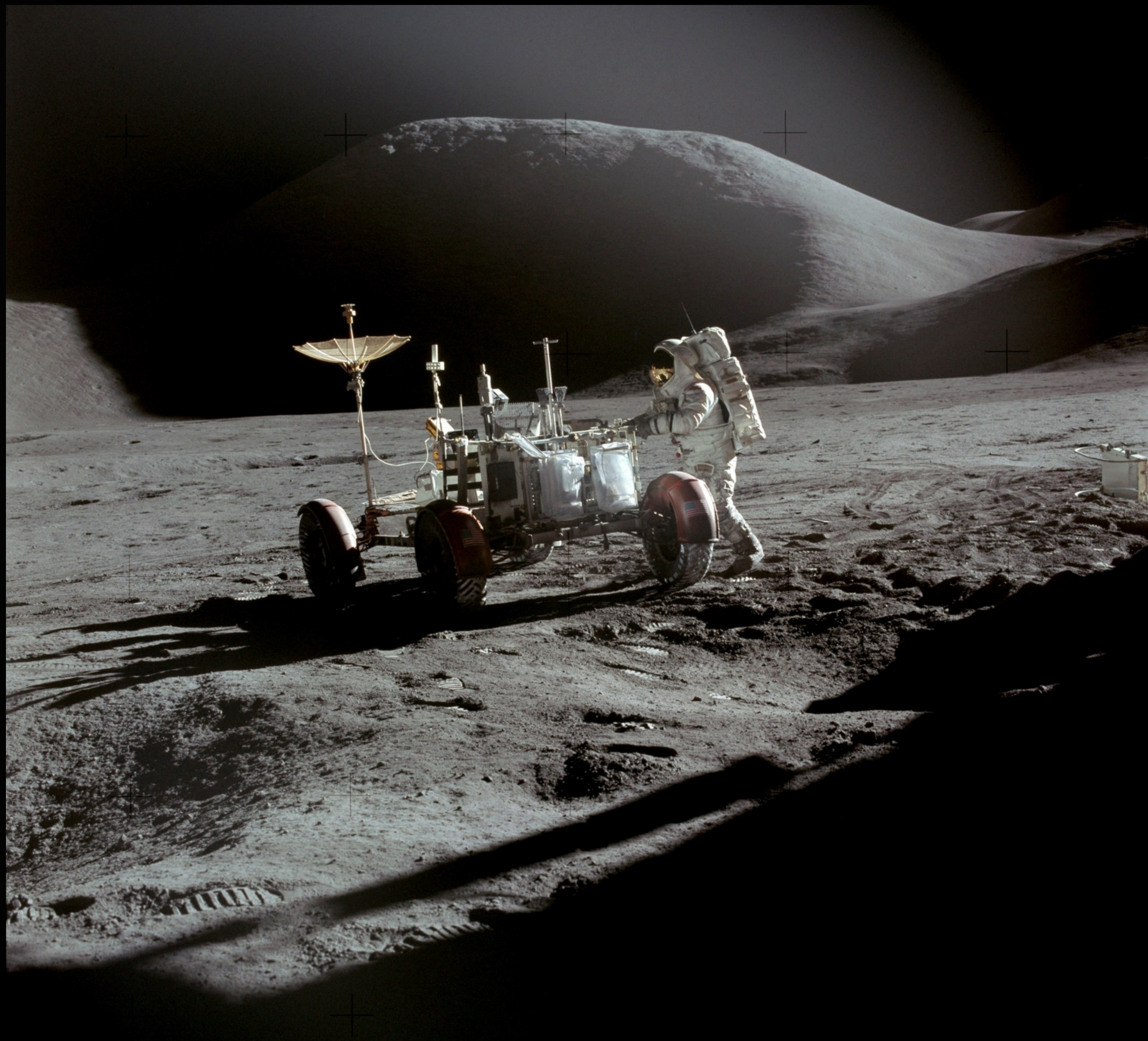
Lunar lighting environment

- Lack of lunar atmosphere has a significant effect on lighting environment, and therefore on human perception
  - No atmospheric scattering
    - Solar flux nearly a point source
  - No atmospheric distortion
    - Ground: no heat haze, mirages
    - Sky: stars do not twinkle or blur
      - Perfect “seeing”
  - No atmosphere → no clouds or trees for visual scale
    - Lack of familiar visual cues



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Lunar regolith properties

“The lunar regolith is the surficial layer of fragmented material (rocks, soil, and dust) that covers virtually the entire surface of the Moon.” –DSNE Section 3.4.2.1, General Description of the Lunar Regolith

Median Regolith Depth	
Mare	
Highlands	

DSNE Section 3.4.2.1

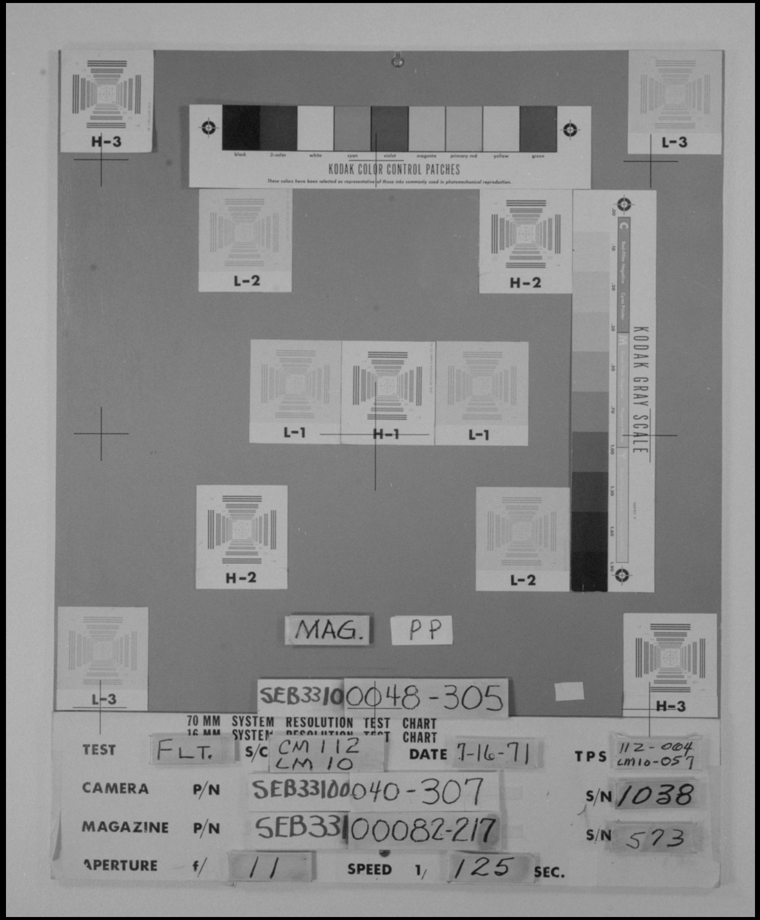
Lunar regolith properties

- Lunar albedo varies with terrain type
  - Highlands/South Pole albedo = 0.16
  - Mare albedo = 0.07

Table 3.4.6.1.1-1 Albedo and emissivity extremes for global and south polar regions. Since the south polar region is essentially highland regolith, we use highland equatorial values for a and ε. The infrared emissivities are taken from Vasavada et al. 2012 and Hayne et al. 2017 and the global albedo is from Williams et al. 2017.

Location	Albedo a	Emissivity ε
Highland mean (0^{o} lat)	0.16	0.95 – 0.98
Mare mean (0^{o} lat)	0.07	0.95 – 0.98
South Pole (84-90^{o}S) nominal	0.16	None available. Use 0.95 – 0.98

DSNE Table 3.4.6.1.1-1



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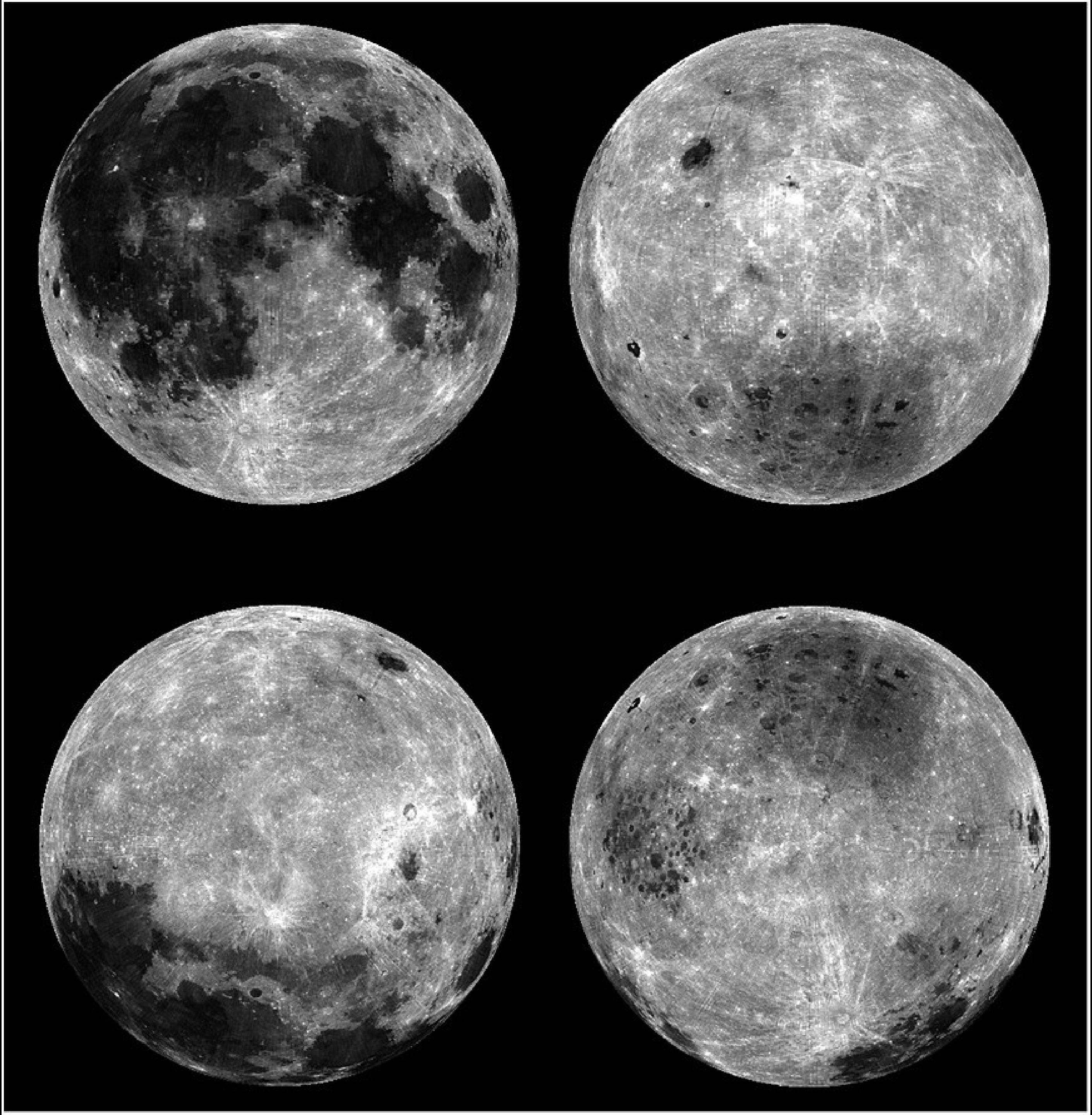
Lunar albedo



Four views of the normal albedo of the Moon at 1064 nm in orthographic projection: (top left) Earth-facing view, (top right) farside view, (bottom left) north pole view, and (bottom right) south pole view.

Figure and caption source: Lucey, P. G., et al. (2014), The global albedo of the Moon at 1064 nm from LOLA, *J. Geophys. Res. Planets*, 119, 1665– 1679, doi:10.1002/2013JE004592.

Phase-dependent reflectivity

- Reflectivity of the lunar regolith increases for phase angle approaching
  - Zero phase angle = looking directly away from the Sun
  - Increased backscatter

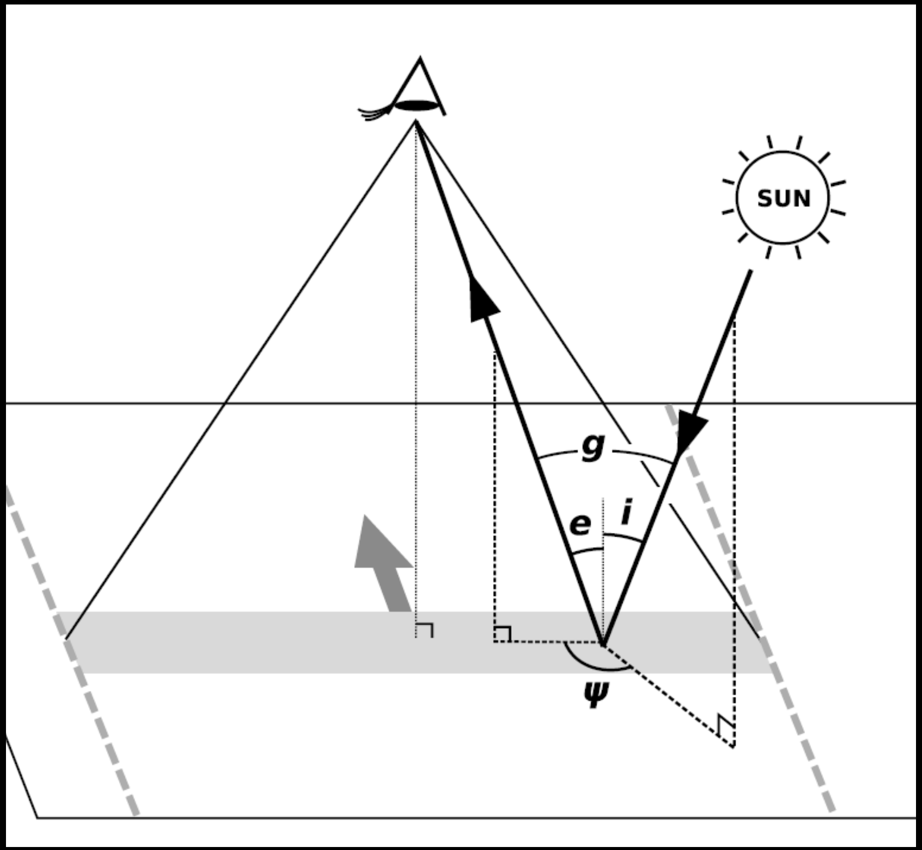
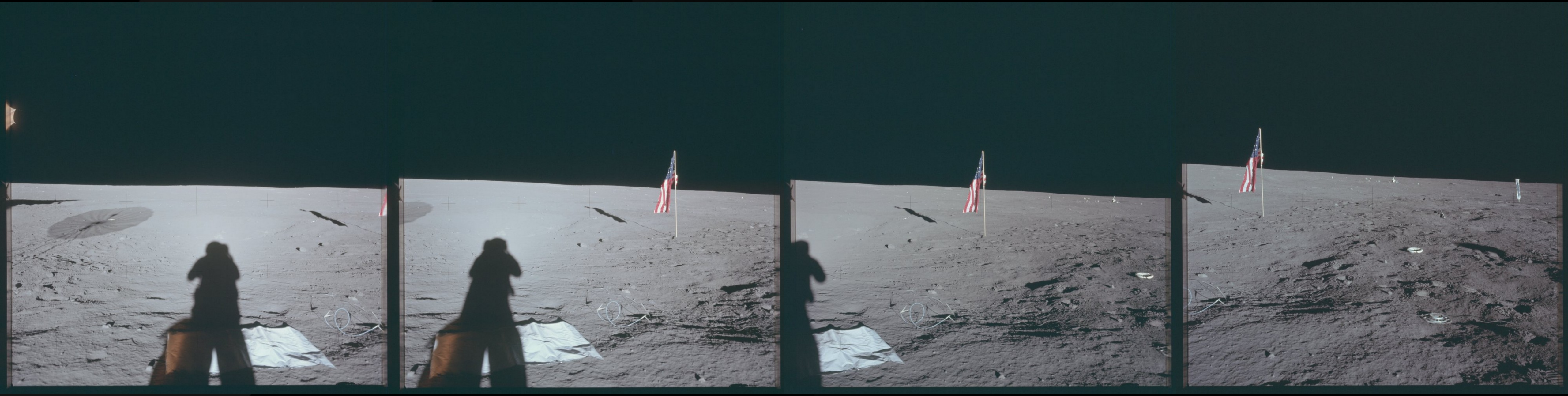


Figure source: Sato, H., Robinson, M. S., Hapke, B., Denevi, B. W., and Boyd, A. K. (2014), Resolved Hapke parameter maps of the Moon, *J. Geophys. Res. Planets*, 119, 1775– 1805, doi:10.1002/2013JE004580.



AS12-47-6982 through AS12-47-6985
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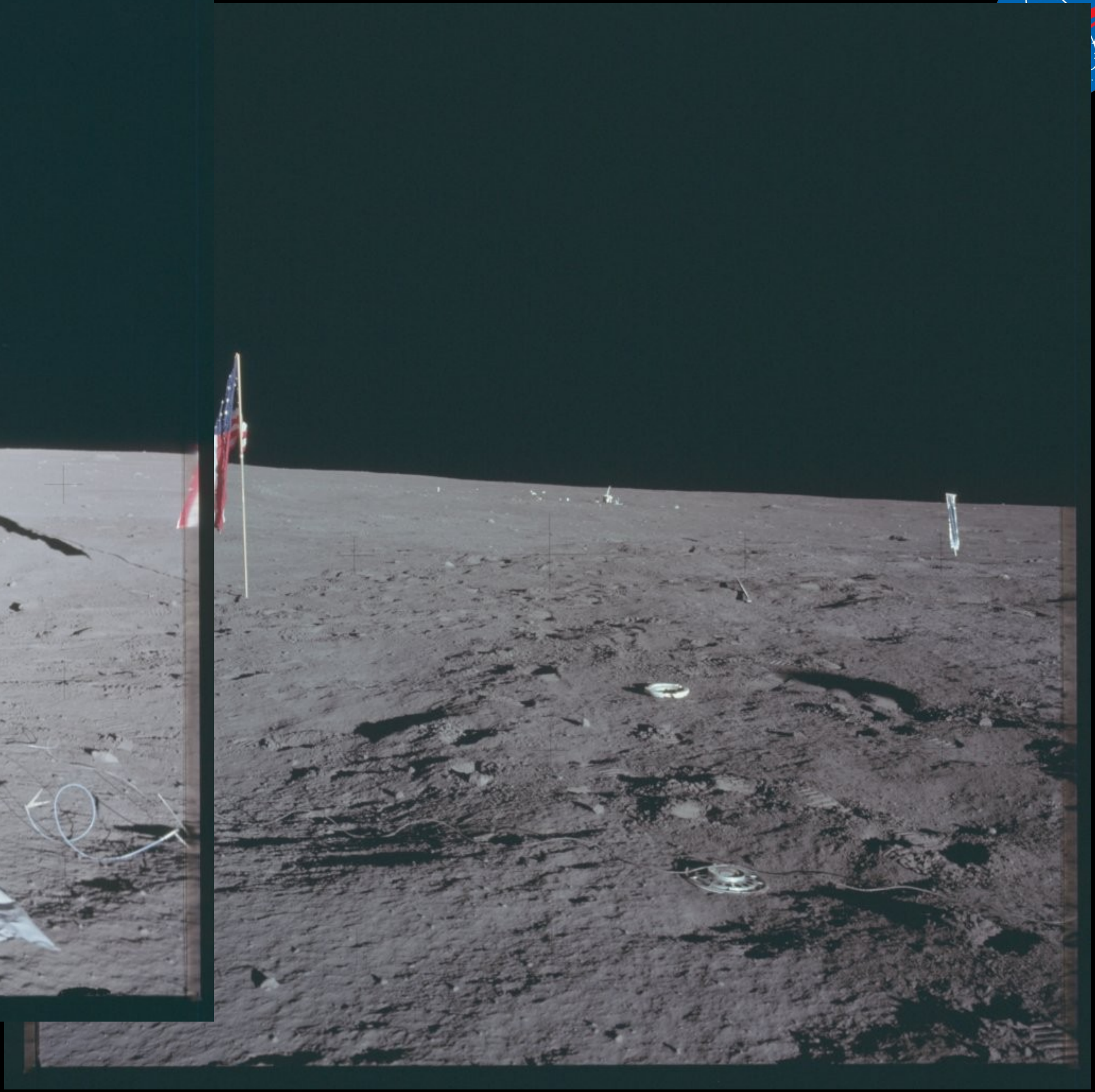
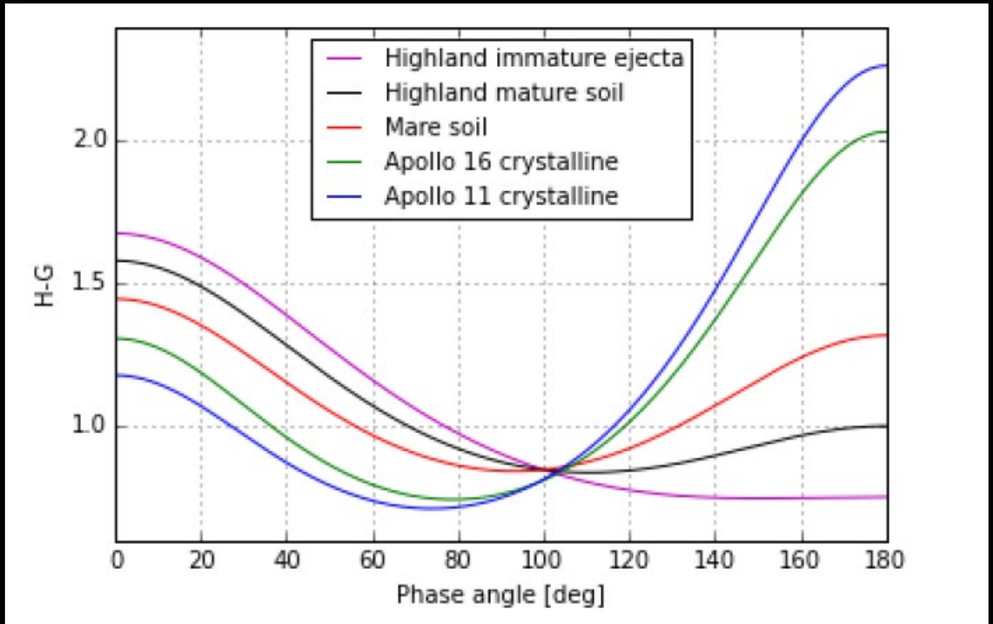


AS12-47-6982 and AS12-47-6985
NASA/JSC

Phase-dependent reflectivity

- Light scattering from regolith modeled in detail by the Hapke function (Sato et al. 2014)
- The simpler Henyey-Greenstein (H-G) phase function is sufficient for engineering analyses
  - H-G function and parameters provided in DSNE section 3.4.5.1
- For simulation purposes, full Hapke function from Sato et al. 2014 may be preferred

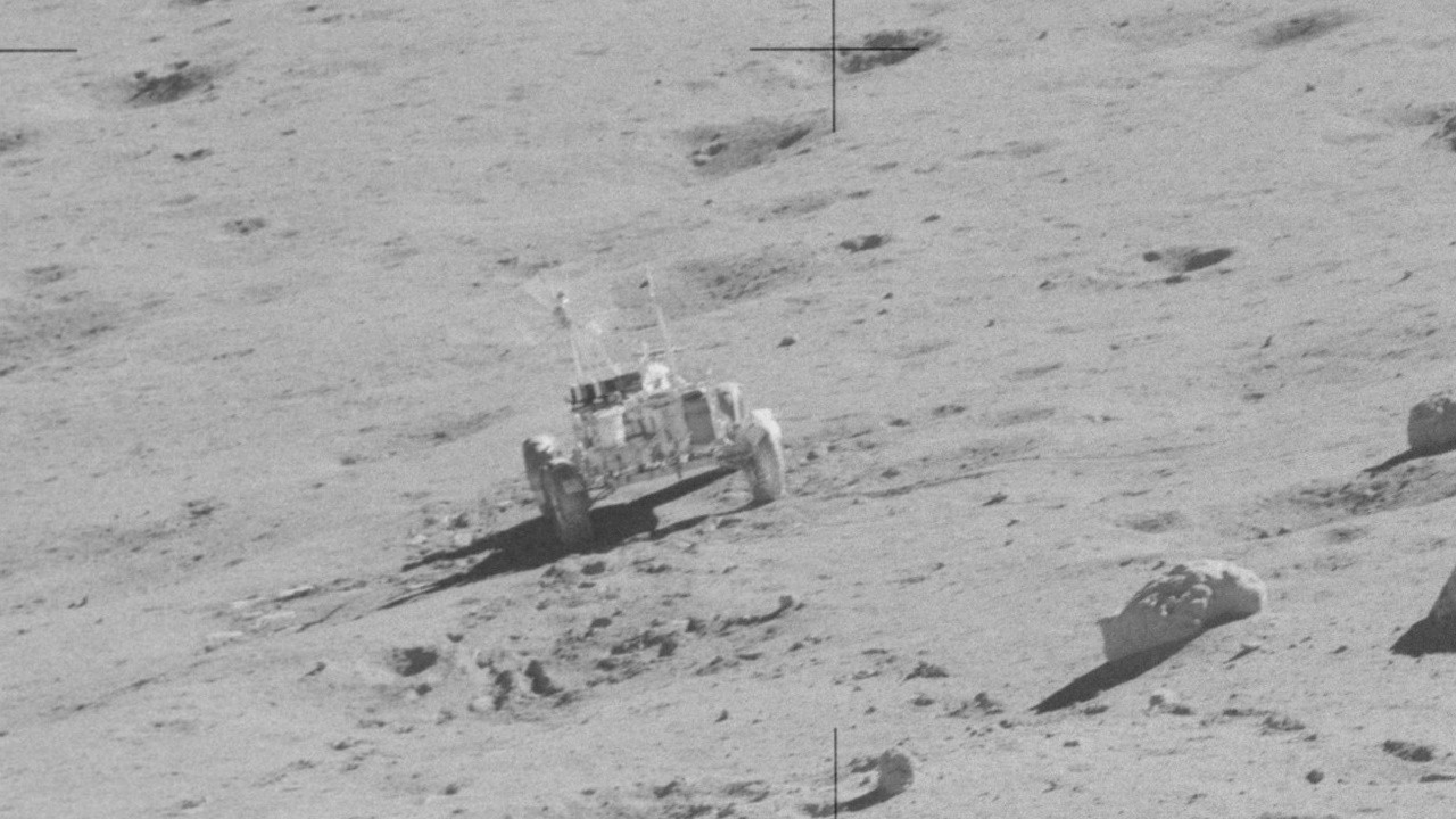


DSNE Figure 3.4.5.1-1 Henyey-Greenstein phase functions using the parameters listed in DSNE Table 3.4.5.1-1.

Rock distributions
DSNE 3.4.1.4

- Rocks are relatively rare on lunar surface; fractional area of rocks typically .
- Rocks are not randomly distributed, fractional area can be high () in certain regions.
- Rock abundance should be locally assessed during site characterization; size-frequency distribution may be used for sizes .

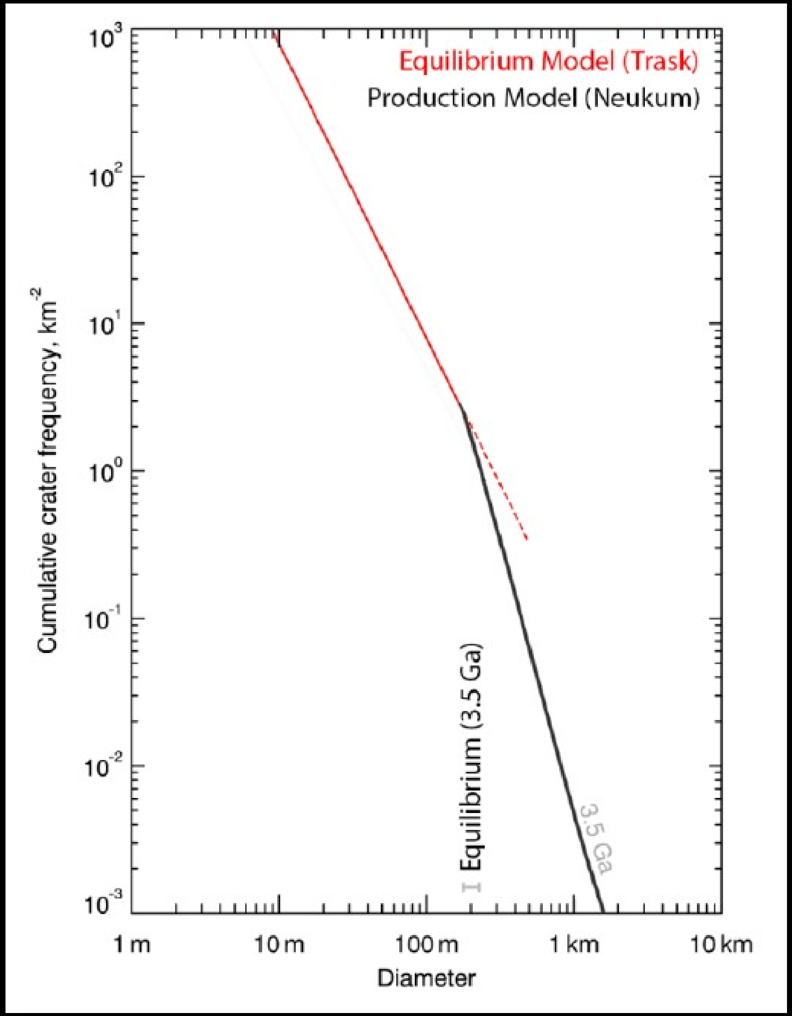
NASA/JSC/AS17-138-21039



Crater size-frequency distributions, topography

DSNE 3.4.1.1, 3.4.2.2, and 3.4.1.3

- Global slope distributions
- Generalized crater statistics
  - Larger craters using Neukum production function
  - Smaller craters using Trask equation
- Site analysis should be performed as local distributions may differ
- Descriptions of crater morphology, features, depth/diameter ratios provided



DSNE Figure 3.4.1.1-1

Questions?

AS12-47-6982 through AS12-47-7006
NASA/JSC

Resources & References

- Project Apollo Archive: https://www.flickr.com/people/projectapolloarchive/
- Apollo Lunar Surface Journal: https://www.hq.nasa.gov/alsj/
- SLS-SPEC-159 Cross-Program Design Specification for Natural Environments: https://ntrs.nasa.gov/citations/20210024522
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