LIGHTING CONSTRAINTS TO LUNAR SURFACE OPERATIONS; Dean B. Eppler, The Aerospace Corporation, Houston, TX [dean.b.eppler@aero.org]; and Nancy Ann Budden, Naval Postgraduate School, Monterey CA [nbudden@nps.edu].

Introduction: Human exploration of the moon's surface will be performed during 14-day lunar days and 14-day lunar nights. An investigation into the levels of ambient lighting on the lunar surface indicates that for most nearside locations, illumination will be adequate throughout a large portion of the lunar night to conduct most surface activities, including driving, extravehicular activities (EVAs) and potentially spacecraft arrival and departure. It is expected that special illumination may be required for specific tasks where the area of activity is shadowed by natural or manmade structures. An example would be vehicle landing sites, where surface orientation or location is critical.

Surface Lighting Conditions: Because of the captured rotation of the Moon around the Earth, the location of the Earth in the lunar sky will be constant (no Earth rise or set), but the resultant illumination will vary over the course of the lunar night due to the shifting phase angle of the Earth. At the sub-Earth point, the illumination at sunset will be 1 order of magnitude brighter than illumination under a full Moon on Earth, or about 2.8 lumens m^{-2}[1]. At the same location, the illumination will rise to a maximum of 13.5 lumens m^{-2} at lunar "midnight", and decrease back down to 2.8 lumens m^{-2} at sunrise. This maximum will be similar to the light level on a July evening at 8:00 p.m. in the southern United States, equivalent to the illumination occurring about 15 minutes after sunset. Numerous orbital experiments conducted during Apollo, (e.g., [2]), showed that with 1600 ISO film, Earthshine was sufficient to photograph surface features from orbit.

As surface locations shift toward the eastern or western limbs, illumination will vary from nominal sub-Earth illumination. At surface locations on the far western limb, the maximum illumination from Earthshine (13.5 lumens m^{-2}) will occur at sunset and decrease to zero at dawn. The reverse sequence (zero illumination at sunset, maximum illumination at sunrise) will occur at the far eastern limb. The lunar farside will experience no illumination other than starlight during the lunar night, requiring artificial lighting or night-vision hardware for external operations. Polar locations will experience illumination conditions similar to the sub-Earth point, but the lighting will be at angles < 10°, making artificial illumination necessary for most exterior activities (P. Spudis, personal communication).

Apollo surface operations conducted during late lunar morning illumination suggests that activities conducted around lunar noon may be difficult due to low sun angles yielding reduced shadowing with decreased surface definition. Extremely low sun angles (< 20 degrees) are likely to make meter-scale irregular topography, typical of the lunar surface, difficult to see, similar to flat lighting conditions in Antarctica. In conclusion, Earthshine will enable effective exploration during the lunar night. However, lighting limitations 2-3 days around lunar noon may complicate or deter full-scale surface operations.

[1] Eppler, D. (1991) NASA TM-4271; [2] Lloyd, D. (1971) Unpubl. Bellcom Rpt., https://ntrs.nasa.gov/archive/nasa/casi.ntrs.nasa.gov/19720006805.pdf.

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