Bendix
Aerospace
Systems Division

Human Visual Performance During Deployment of ALSEP in a Lunar Visual Environment

NO. ATM-746
REV. NO.
PAGE 1 OF 8
DATE 3/29/68

Prepared by:
W. L. McIntire
Mission & Crew Engineering

Approved by:
H. Y. Grubbs, Jr., Mgr.
Mission & Crew Engineering

Attachment: 3 Figures

INTRODUCTION

Any professed simulation of visual tasks on the lunar surface must involve both specular and diffusive reflectance as well as the lack of a scattering atmosphere. The absence of an atmosphere to scatter light eliminates some visual cues we commonly use on Earth and in many simulators, especially in viewing high luminance targets. Any simulated test must be designed to allow the human visual system to operate at the level at which it would operate in the real world.

The reflectance of the lunar surface to incident visible radiation has been observed to be characterized by a peaked back-scatter in the direction of the source. The shape of this characteristic depends almost entirely on the three directional angles in a spherical geometry. Thus, whereas diffuse surfaces obeying the Lambertian distribution law produce a directional reflectance or albedo depending only on the emittance angle, the directional reflectance of the lunar surface is the product of the albedo and a function of the three angles referenced to the local surface plane and is known as the lunar photometric function.

The reflectance from ALSEP as it is situated during the numerous deployment operations on the background lunar surface will be specular and diffusive. The amount of luminance and pattern of reflected light from a diffusive surface is different than the reflected light from a specular surface.

The purpose of this investigation is to analyze the light reflected from the lunar surface, the light reflected from ALSEP, the contrast between the luminance of ALSEP and the lunar surface, the absence of scattered light, the capabilities of the astronaut, and effect on human visual performance when operating in this lunar visual environment.

DISCUSSION

The lunar photometric function is the product of the albedo and a function of the three angles referenced to the local surface plane. ① The angle of incidence is the angle between the local vertical and the direction of the source. ② The angle of emittance of reflectance is the angle between the local vertical and the view direction of the astronaut. ③ The source-astronaut phase angle is the angle between the line of the source and the view direction of the astronaut.

Generally, the angle of incidence and the angle of emittance are noncoplanar and the angle between them must be solved by employing spherical trigeometry relationships. However, when the source and the view direction of the astronaut lie in the same plane it becomes planar and simplier plane geometry relationships can be used. The lunar photometric function can be described as that of a strongly back-scattering surface. Almost all common terrestrial materials are diffuse reflectors (Lambertian) while some have specular or forward scattering components. In addition, the earth's atmosphere introduces an isotropic illuminance even in the shadowed area. Since this is completely absent on the moon, much blacker shadows prevail. It is obvious, therefore, that the lunar terrain will present a much different appearance from terrestrial terrain in both luminance and contrast, having lower luminance and higher range contrast values.

A mean lunar photometric function of the lunar maria has been approximeted by JPL(9) as observed from earth-based telescopes. There was not enough information included with the JPL model to warrant any application of the photometric relationship.

Another form of the lunar photometric function has been derived by Hapke(8), from a theoretical model of the lunar surface which in turn is based on extensive photometric measurements made on various specially prepared materials. Hapke's function is valuable in that it allows analytical studies to be carried out, in addition to experimental studies. Hapke's theoretical function has predicted what the lunar surface will look like when viewed out of the direct source-viewing plane.

Bendix(2, 3, 4) constructed and calibrated a lunar surface model which was used to provide a quantitative evaluation of photometric and photogrammetric methods for vehicle remote control analyses on the lunar surface. The surface albedos, the photometric function and the surface slopes were all known to a high degree of accuracy. Good agreement was obtained with the theoretical lunar data from the work of Hapke. The photometric functions as a function of astronaut viewing angle are presented in figures 1, 2 and 3 for selected sun angles and planar geometric conditions.

From the figures, it can be seen that the lunar model photometric function is strongly dependent on the sun angle, the astronaut view angle and the planar geometry. For the coplanar geometry ($a = 0^\circ$) and for small values of "a", the photometric function is quite strongly differentiated in both sun and astronaut viewing angle. That is, the particular curves are well separated from each other. For the noncoplanar geometry case and for all large values of "a", however, the function is even more strongly differentiated in sun angle, while the function is very weakly dependent on the astronaut view angle except for the smallest sun angles. This means that the apparent luminance of the lunar surface for a noncoplanar geometry will change only slightly when viewed from different astronaut viewing angles, but will change greatly for different sun angles.

An analytical equation which closely matches the lunar model photometric function can be obtained by modifying the Hapke function.

$$B_{eye} = \frac{E_{s-m} \rho \, T_h \, \phi(i, \epsilon, \alpha)}{10}$$

E_{s-m} = surface illuminance from sun (luman/m^2)

ρ = surface albedo

$\phi(i, \epsilon, \alpha)$ = surface photometric function which is a function of the sun angle, astronaut viewing angle and the planar geometry

B_{eye} = surface luminance to the eye through helmet (millilamberts)

T_h(7) = helmet visors total visible transmittance

= 0.0923 (pressure visor, impact visor, and sun visor)

E_{s-m} = 15.1 x 10^4 lux (luman/m^2)

ρ = 0.079

$$B_{eye} = \frac{E_{s-m} \, T_h \, \rho \, \phi(i, \epsilon, \alpha)}{10} = \frac{(15.1\,(10^4)\,(T_h)\,(0.079)\,\phi(i, \epsilon, \alpha)}{10}$$

$$B_{eye} = 1.19 \times 10^3 \, \phi(i, \epsilon, \alpha)$$

The surface luminance to the eye is now a function of the transmittance of the helmet configuration and the photometric function.

The surface luminance as applied to ALSEP deployment will be the background contrast level. Observe the coplanar photometric function figures for the maximum and minimum values for a sun angle which will vary from 10° to

30°. The maximum value of the photometric function is about 0.40 and the minimum of about 0.05. The luminance to the eye through the helmet sun visor and impact shield will be about 44 millilamberts (ml) for the low viewing angles by the astronaut. When the astronaut viewing angles increase to the normal of the lunar surface or even beyond normal the luminance to the eye decreases to about 5.5 millilamberts. However, if the astronaut removes the sun visor and obtains a total optical transmittance of 0.543 and if he is still in the coplanar condition, then the luminance to the eye will be about 260 millilamberts for the astronaut during low viewing angles with the lunar surface. The astronaut high viewing angles of normal to the lunar surface decreases the luminance to the eye to about 32 millilamberts. The photometric function during the sun angles between 10° and 30° are strongly dependent on the astronaut view angle and slightly dependent on the sun position.

The noncoplanar geometry ($a = 90^\circ$) lunar illumination conditions are quite different from the coplanar geometry. The figure of the photometric function as a function of astronaut viewing angle displays that the value of the photometric function for low sun angles between 10° and 30° will be a constant of about 0.05 for all possible astronaut view angles. The value of 0.05 for the photometric function is the same value obtained in the coplanar geometry with astronaut high viewing angles on the lunar surface. There is not any data available for photometric function values in noncoplanar geometric conditions between 90° and 0° ($0^\circ > a > 90^\circ$). The noncoplanar geometry ($a = 90^\circ$) conditions reflects a luminance of about 5.5 millilamberts to the eye through the sun visor and about 32 millilamberts to the eye through the impact shield without the sun visor. It is of interest to note that the luminance from the lunar surface will produce a background with and without the use of a sun visor which varies from about 5.5 to 260 millilamberts to the eye.

The next step is to determine the ALSEP reflectivity and its contrast as it is situated during deployment operations in this variable background lunar surface luminance. The following is a listing of items for the Flight 1 configuration and their general reflective characteristics.

SIDE - Completely diffusive.

PSE & Stool - Highly specular.

PSE Blanket - High specularity with wrinkles.

SWSE - Diffusive except for specular PRA.

LSM	- Specular except for certain areas around EGFU.
RTG	- Completely diffusive.
Subpackage #2	- Top, sides and bottom completely diffusive.
Subpallet	- Completely diffusive.
Subpackage #1	- Top of mounting plate is diffusive.
	- Bottom (underside) is highly specular.
	- Reflectors are highly specular.
	- Side curtains are highly specular with wrinkles.
	- Edges of pallet are diffusive.
ALHT	- Highly specular.

Generally, diffusive surfaces have about 80% reflectivity and specular surfaces have 80% to 85% reflectivity. The amount of luminance and pattern of reflected light from a diffusive surface is different than the reflected light from a specular surface. However, the greater amount of luminance or intensity of glare spots will be caused by the various specular surfaces of ALSEP. The maximum specular luminance to the eye through the helmet sun visor by the astronaut looking directly into a bright spot on the undeployed ALSEP will amount to about 1200 millilamberts.

The Bioastronaut Data Book(1) discusses the capabilities of the eye in terms of threshold, dark adaptation, operating characteristics, target size and background luminance. The instantaneous threshold brightness of the human eye from this preadapted luminance of about 1200 ml will be about 3 ml. This means that the astronaut adapted to a luminance of 1200 ml will be able to see a 10 minute (1/4 in. at 80 in.) square target about one four hundredth as bright immediately after looking away from the bright object. The above previous calculations estimated that the minimum luminance from the lunar surface at any astronaut viewing angle would be at least 5.5 ml. The astronaut while employing the sun visor will be able to observe any bright area on ALSEP and immediately observe items which are exposed to the sun on the lunar surface located next to ALSEP. The astronaut without the use of the sun visor would be preadapted to about 7550 ml from the specular surfaces on ALSEP. If the astronaut instantaneously turned to observe objects next to ALSEP his visual performance would have a threshold brightness of about 10 ml. This means that the astronaut adapted to a luminance of 7550 ml without the sun visor would not be able to see the local lunar surface near the ALSEP because the lunar surface would illuminate less than 10 ml. Therefore, the astronaut would be required to use the sun visor while working with ALSEP specular reflective surfaces.

RESULTS AND RECOMMENDATIONS

The resultant situation expected would be that the astronaut will be using the sun visor during ALSEP deployment, that he probably will be able to observe objects on the lunar surface next to the ALSEP, but that he most likely would not be able to observe objects that are not exposed to direct sunlight. The shaded areas around and on ALSEP must be illuminated by reflected light. The required reflected light into the areas that are shaded because of the absence of scattering by the direct sunlight must be on the order of 1/2 the luminance from the specular glare spots to be assured a 50% probability of detecting an object in those shaded areas. However, the astronaut can obtain about a 95% probability of detection if the luminance reflected into areas shaded because of the absence of scattering by the direct sunlight are on the order of 1/5 the luminance from the specular glare spots. This means that the magnitude of the luminance reflected from the shaded areas must be from 240 to 600 millilamberts at the eye while the astronaut employs the sun visor. The amount of secondary reflected illumination from the astronaut's space suit, the art of properly positioning the reflecting surface of the space suit, and the capability or feasibility of the astronaut performing the required ALSEP deployment tasks from the standing positions needed for reflected light to illuminate shaded areas cannot be evaluated by analytical methods and must be evaluated by actual model size in simulated experimental tests. The purpose of such tests would be to continue the accumulation, evaluation and publication of human engineering data, criteria related to the astronaut capability and/or feasibility of deployment task execution, in a form useful to conduct astronaut task analysis. Past and current studies on the capabilities of the suited astronaut will be available; however, much experimental data remains to be done. Therefore, if a useful supporting technology is to be developed to facilitate the design of hardware such as ALSEP, then research on human engineering for ALSEP lunar lighting environments must be achieved.

While the capability exists to analytically predict luminance from simulated lunar surfaces and specific form factor luminance from specular or diffusive type surfaces, the Crew Engineering function of the ALSEP cannot effectively use the analytical approach to determine the secondary reflected illumination obtainable to satisfactorily execute deployment tasks.

REFERENCES

1. NASA SP-3006, Bioastronautics Data Book, 1964.

2. BSR-1362, Lunar Simulation Model and Optical Studies for Lunar Orbiter System Support by H. Graboske and E. Marsh, September, 1966.

3. BSR-1238, Application of a Photometric Technique for Mapping the Lunar Surface by M. E. Amdursky, October, 1964.

4. BSR-946, Photometric Environment on the Lunar Surface, May 1964.

5. AIAA No. 67-251, Need for Validity in Simulation of the Extraterrestrial Visual Environment by W. H. Allen, February 1967.

6. BxA Dept. 975 M & C Engineering, Lunar Illumination Test Report, Design, Test and Evaluation Report No. 27, December 1966.

7. General Electric TIR 580-S-8023, Thermal Effects of the ALSEP Equipment on the EVVA by C. W. Nelson and R. E. Ober, January 1968.

8. Hapke, B., Journal Geophysics Research, 68, 4571, 1963.

9. Harriman, A. G., Washburn, H. W., Willingham, D. E., Ranger Preflight Science Analysis and the Lunar Photometric Model, JPL TR-32-384 (Rev.), 1963.

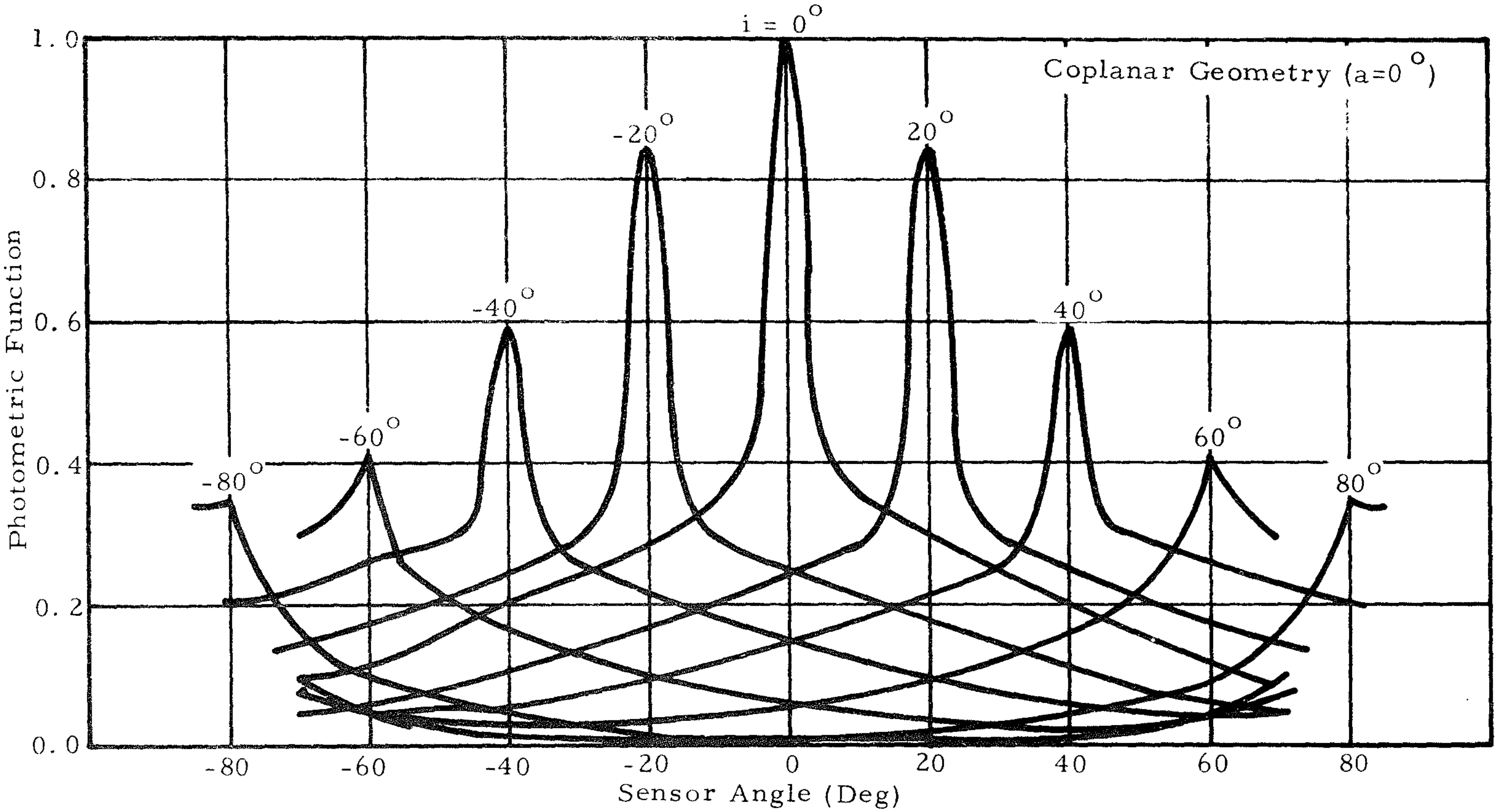

Figure 1. Lunar Model Photometric Calibration

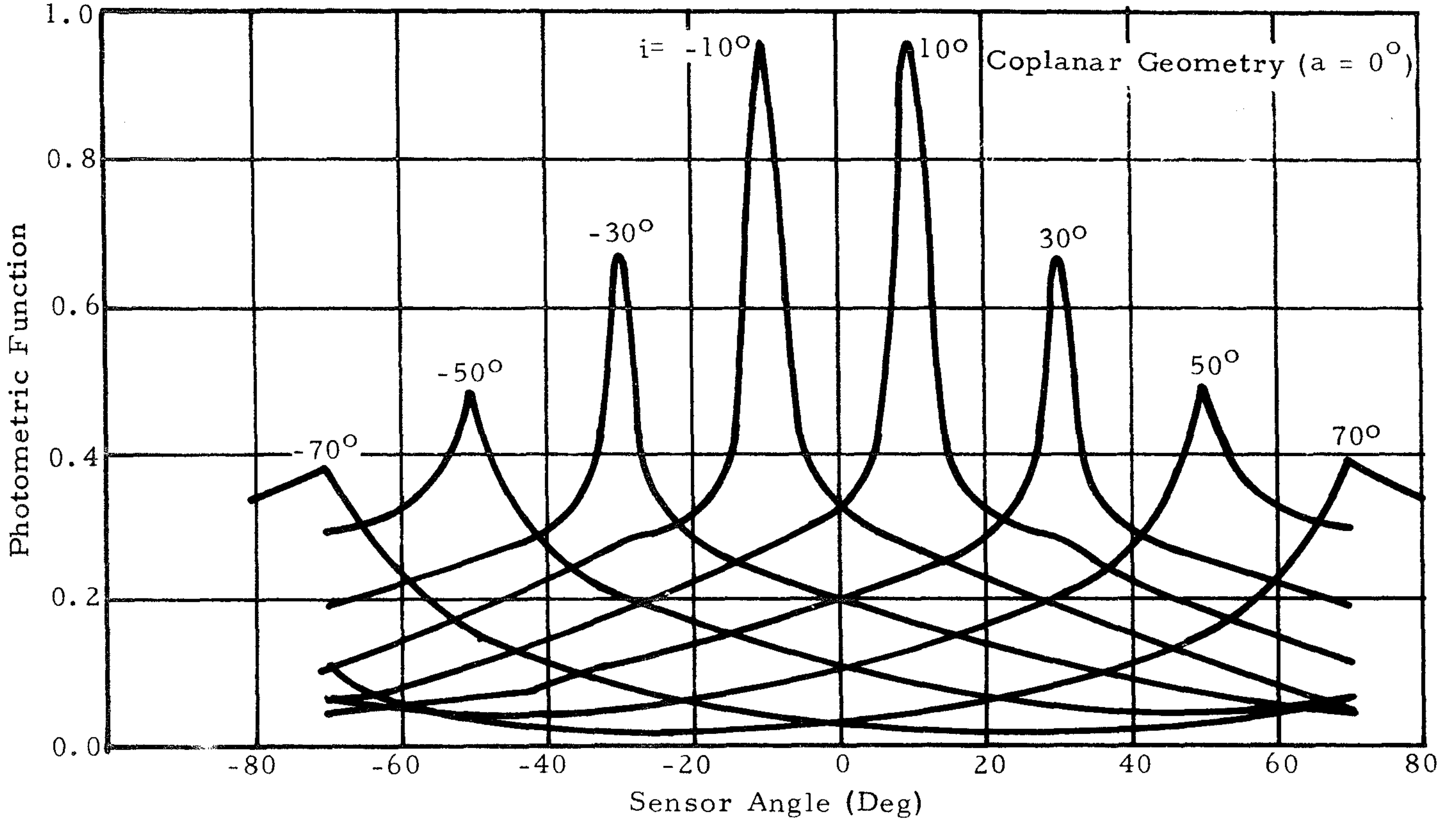

Figure 2. Lunar Model Photometric Calibration

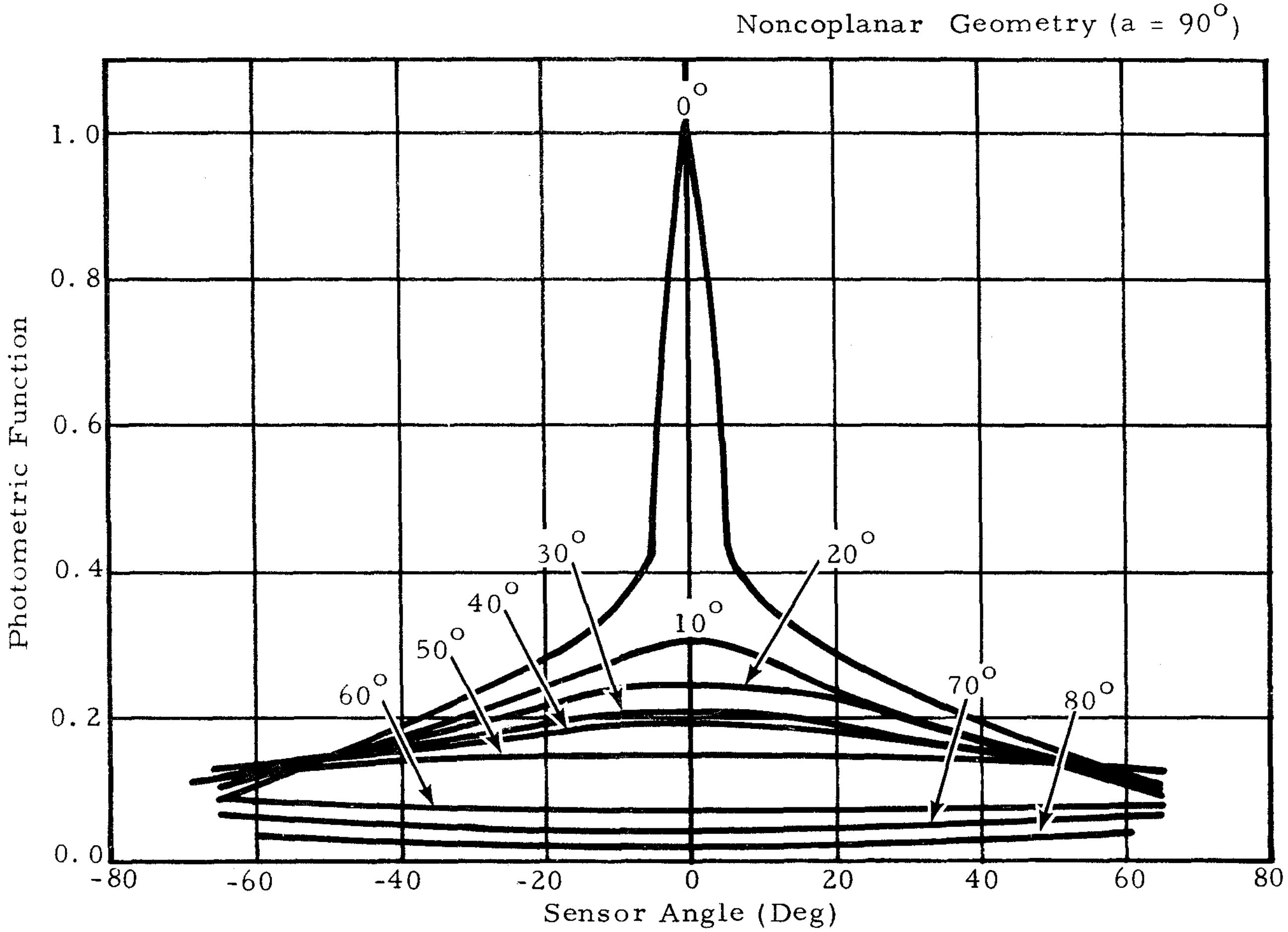

Figure 3. Lunar Model Photometric Calibration