LANDER LIGHTING SOLUTION TO REDUCE PILOT & AUTONOMOUS APPROACH ERRORS

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The south pole lighting environment will have harsh low inclination sunlight, making overhead judgement of surface features difficult. Autonomous solutions are great, however, the need for visual monitoring and independent go/no-go decisions remain. Our project proposes that lunar landing systems will be better served by including a powerful landing light system that improves visibility of surfaces from overhead by illuminating the ground at critical distances for the crew to make last minute decisions regarding an approach. The project utilized computer-based optical modeling software to predict requirements for a potential landing light system. The analysis based the lamp prediction from commercially available LED chip sets and lamp optics. The goal was to illustrate a method to raise the surface contrast of a landing site within an acceptable contrast threshold for most camera systems and human observers to recognize hazards that would not be noticed with low inclination sunlight alone.

The Apollo lunar landings benefitted from overhead sun or dark conditions. The surface lighting at the Lunar South Pole is a harsh environment where surfaces are lit from a low inclination angle by the sun (from the side). This change in lighting condition precipitates a need for updated lunar landing systems that facilitate improved recognition of landing sites, and thereby increase pilot awareness of landing hazards. The reliance on LIDAR and other autonomous mechanisms alone is risky given the known usage of visual monitoring for operator concurrence on current spacecraft programs and present-day autonomous land-based vehicles. Visual monitoring via cameras or windows requires the surface contrast to be within 3 orders of magnitude for reasonable recognition of objects. Artificial overhead illumination, when sufficiently sized, provides a means to even out contrast problems created by low inclination sunlight, potentially reducing piloting errors. Current vehicle requirements do not specify this type of guidance for the purpose of increasing mission success.

An optical ray-trace simulation model was developed in Zemax Optics Studio to predict the best combination of LED power, LED optics, lamp quantity, and lamp location to raise the surface contrast to within 2 orders of magnitude from 3 orders required to further increased visibility and reduce risk. The project considered the following design constraints: potential base diameter of lander, approach distance(s) for a go-no-go decision point (200 meter), solar inclination angle (2-7°), lunar surface reflectance (10%), LED chip sets, LED focusing optics, LED power, lamp quantity, lamp locations, and illumination diameter of lunar surface landing zone. The results can be used to establish minimum design constraints for vehicle landing light systems.

With a solar inclination angle ranging from 2-7 degrees, the horizontal illumination of the lunar surface is attenuated by about 10% when compared to overhead illumination from the Sun. This modifies the sun's maximum of 130,000 lux to 13,000 lux horizontal illuminance. The artificial lighting system was designed to provide an 18-meter-wide illumination zone, to create viewing clearances around a 6-meter-wide lander. The system provides an average illuminance of 300 lux, meeting the 2 orders of magnitude criteria.

The solution utilized modern Chip On Board LEDs, that each utilized 17 watts, with focusing Total Internal Reflection (TIR) lenses. A lighting system of 300 LEDs was arrayed along the "bottom" of a “lander”. With 17 watts per LED, the system is estimated to require 5100 watts. This is a large amount of power, but it would only be needed during critical phases during the landing. LED lighting systems can be dimmed, and it is assumed that as the lander arrives closer to the landing site, the lighting system power can be adjusted as needed to produce the necessary surface illuminance. The designed reduction of contrast improves reliability of safety assessments using real time visible light camera systems and out the window viewing by the crew.