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BRINGING LIGHT TO THE DARK SIDE: AUTOMATED OPTIMISATION OF MIRROR PLACEMENT FOR LUNAR BASE ILLUMINATION

Abstract

Permanently shadowed regions offer great potential for future lunar bases due to their protective properties and close proximity to water sources. Reflecting natural sunlight is an attractive strategy for illumination of future lunar bases as it uses a passive strategy i.e. sunlight and enables adjustment of light to the circadian rhythm of the crew - a vital component in crew and organic life support systems' wellbeing and health.

For this, mirrors able to withstand the harsh lunar conditions e.g. temperature changes and micrometeoroid impacts, and avoid reflecting harmful radiation into the habitat need to be strategically placed to optimise the light reflected into the habitat. The manufacturing method for these mirrors will significantly impact the size and complexity of the mirror design. The use of in-situ resources on the Moon or the delivery of dismantled pieces from Earth will also affect the manufacturing process.

Here, we present *Illuminate* - a tool for designing mirror arrays for the illumination of habitats in permanently shaded regions, which builds upon preliminary studies by providing a resource for the design of mirror arrays at any location on the Moon. *Illuminate* is available as both a command line tool and a web-based resource, and provides estimates for intensity, duration, and area of light illumination. The tool has various user-definable parameters, such as reflectance, size, and shape of the proposed mirror, and outputs all potential positions for mirror arrays, highlighting the optimum locations for each variable - intensity, duration, and area of illumination. Illuminate is written in Python and uses packages including Skyfield, Numpy, and Rasterio to integrate existing digital elevation models from LOLA with solar position to determine shadowing of locations and calculate light reflection vectors, with mirrors at varying angles.

A case study within Shackleton crater is used to build upon existing research and demonstrate the value of this automated approach in identifying optimum mirror placements, highlighting how different arrays have different illumination characteristics and the importance of defining the use case for mirror arrays in the design process.

This work provides space architects and systems engineers with the tools needed to develop sustainable illumination systems for lunar habitats and has the potential to be extended to remote locations on Earth, in lava tubes, or other planetary bodies e.g. Mars.