CAMERA EXPOSURE TIME DETERMINATION FOR ARTEMIS I LUNAR FLYBY

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Abstract. *During Artemis I, a flight test was conducted using the Optical Navigation Camera to image Lunar terrain at low altitude prior to the Return Powered Flyby (RPF) burn. The vehicle descended rapidly toward the surface and transitioned over the Lunar Terminator during the time frame in which the images were to be gathered, creating challenging lighting conditions which required the development of a novel technique for exposure time determination to gather imagery of appropriate quality for post flight analysis. The resulting technique leveraged simple photometric models and simulations, as well as the spacecrafts altitude and pointing direction to determine the necessary change in exposure times over the course of the flyby, resulting in a successful flight test.*

Introduction. Imagery can play an impactful role in spacecraft navigation at almost any point during a mission. Determining the correct camera settings for a particular scenario is a critical component in implementing any imaging system for spacecraft navigation. These settings are dependent on the properties of the specific imaging system and specific navigation task for which it is being used. Different camera settings, particularly exposure time, will be required to perform different navigation functions on future missions, such as starfield imaging, long range bearing, or terrain imaging for Terrain Relative Navigation (TRN)[132] . Each of these cases requires unique camera settings to maximize the performance of image processing algorithms and the generation of measurements. Particularly with respect to terrain imaging, the lighting environment at the surface can cause a large variation in required exposure settings for TRN. Lighting conditions impacting the imagery are not only a function of the position and orientation of the planetary surface with respect the illumination source, but also of the observer's relative pose to the surface at the time the images are gathered. While imagery can be simulated via rendering engines to test image based navigation algorithms, determining realistic camera settings is near impossible without some kind of experimental or flight data to inform the selected settings. During Artemis I, the Optical Navigation camera was utilized in a Lunar terrain imaging flight test during a low altitude lunar flyby. Over the course of the time frame in which the images were to be gathered, the spacecraft changed altitude rapidly. The illumination conditions at the surface also changed considerably as the spacecraft transitioned from the lit to the dark side of the Moon over the course of the flyby. This required the determination of a novel technique for terrain imaging exposure times as a function of the dynamics, surface reflectance properties, and pointing direction expected during the flyby to ensure the flight test was completed successfully

Methods and Approach. Preflight hardware in the loop (HWIL) testing of the OpNav camera on the ground led to the creation of a table which related the phase angle of observed the Moon (when imaged as an extended body) to the required exposure time necessary to obtain lit limb measurements for horizon based OpNav.[4] However, these values were not directly applicable to the RPF case owing to the proximity of the Moon to the camera, meaning it exceeded the field of view and no longer appeared as an extended body. An attempt during the Outbound Powered Flyby (OPF) earlier in the flight directly applying these values led to several extremely overexposed images. This required the creation of a novel technique to relate the experimentally determined exposure values to the lighting environment expected during the flyby. Simplified lighting models were used to create rendered images of a sphere (approximating the Moon) at different phase angles, which could be correlated to the exposure time and phase angle relationship previously determined for OpNav. The simulated imagery was then processed to determine the average lit pixel intensity correlated with a specific exposure time. The trajectory for the upcoming flyby and knowledge of the spacecraft's pointing direction indicated that as the spacecraft descended it would view the lit limb before rapidly traversing the Moon's surface toward the terminator and into darkness. A rough approximation of the spacecraft FOV as a function of trajectory was then projected onto the simulated imagery and scaled/translated based on the expected altitude and path of the spacecraft. For each of these simulated images, the average lit pixel intensity was computed. Using the trend defined by the experimental data, this could then be related to a specific exposure time. Exposure times determined using the method were uploaded to the spacecraft, and the camera collected the imagery as commanded over the course of the flyby up until overflying the terminator and transitioning into darkness.

Results. Figure 1 shows one of the images obtained of the terrain during the flight test. The exposure times computed led to a successful flight test which obtained high quality imagery of the Lunar surface over the course of the flyby despite the rapidly changing lighting conditions on the viewed surface. These contained highly distinguishable details and terrain features suitable for Terrain Relative Navigation (TRN) based analysis.

References.

[1] K. R. Kobylka, *Photometric and geometric methods for enhanced image-based spacecraft navigation.* Rensselaer Polytechnic Institute, 2021.

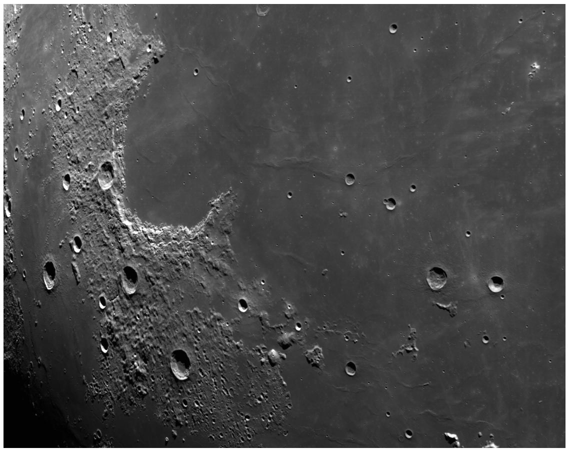

Figure 1. Image of the Lunar Terrain obtained by the OpNav camera during the Artemis I Return Powered Flyby (Photo Credit: NASA).

[2] K. R. Kobylka and D. A. Hutton, "Methods for analytic reflected radiant flux modeling in observing space vehicles," AAS G&C Conference, AAS-24-191, Feb. 2024.

[3] K. Smith, A. Olguin, M. Fritz, R. Lovelace, R. R. Sostaric, S. Pedrotty, J. Estes, T. Tse, and R. Garcia, *Operational Constraint Analysis of Terrain Relative Navigation for Landing Applications*.

[4] J. A. Christian, "Accurate planetary limb localization for image-based spacecraft navigation," *JSR*, vol. 54, no. 3, pp. 708–730, 2012. doi: 10.2514/1.A33692.