

Defeating the Glare - Lunar High-Contrast Imaging Device (LuCID) for Low Sun Angles and High Contrast Conditions at the Lunar South Pole: B&P Project 24-6

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NTR: KSC-14645: Lunar High-Contrast Ratio Imaging Device (LuCID) Viewer

Start TRL: 2

End TRL: 4

Prime STMD Taxonomy:

TX08 Sensors and Instruments

TX08.1 Remote Sensing Instruments and Sensors

Secondary STMD Taxonomy:

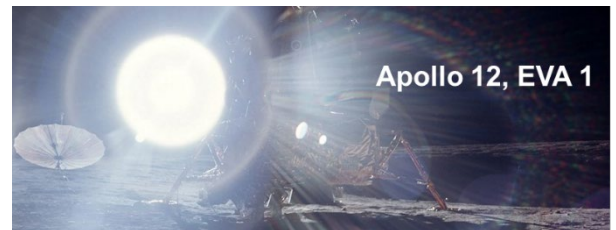
TX13 Ground, Test, and Surface Systems

TX13.X Other Ground, Test, and Surface Systems

Project Description: Since the Sun doesn't rise more than a few degrees above the horizon at the lunar south pole, the unique high-contrast lighting environment will affect visibility when operating in the direction of brightly sunlit areas or into deeply shadowed regions. The Lunar High-Contrast Imaging Device (LuCID) project demonstrated the benefits of using th charge-injection device imaging technology to address visibility risks to crewed and uncrewed vehicles in safely navigating the terrain and around hazards during lunar surface exploration missions, including at equatorial latitudes on the Moon.

(1) The illuminated lunar surface is a high-contrast ratio environment.

- Sunlight is direct at lunar surface, where solar irradiance is 1361 W/m^2 and $\sim 1.4\text{X}$ higher than at Earth, and is not scattered by an atmosphere.
- Shadows are, therefore, very dark.



(2) High-contrast scenes increase as the Sun angle (SA) decreases.

- Low SA occurs close to sunrise/sunset.
- Constant low SA at the poles.
- Low SA caused significant operational issues for Apollo 12 (SA 7.6°).
- Expecting SA of $\sim 1.5^\circ$ for Artemis landing at the lunar south pole.

(3) Future lunar surface operations will be enabled by using imaging devices with a high dynamic range:

- To enable surface characterization in shadows, e.g., permanently shadowed regions like Shackleton Crater.
- For terrain-relative navigation.
- For hazard avoidance during traverses.



Anticipated Benefits: A high-contrast ratio imaging capability is lacking for normal imaging devices, such as standard commercial-off-the-shelf (COTS) complementary metal-oxide-semiconductor (CMOS) cameras, which can result in:

- Saturation
- Charge bleeding/blooming
- Limited dynamic range

Charge Injection Device (CID) image sensors are unique imaging devices that are:

- Saturation protected
- Anti-blooming
- Have high dynamic range (demonstrated passed 1:100 million)
- *Radiation hardened (e.g., flown outside the ISS as tech demo)*
- CIDs are high contrast ratio sensors due to their unique pixel architecture and readout process based on:
 - Random access integration of pixels
 - Non-destructive read of pixels
 - Continuous wavelength coverage
 - Simultaneous background corrections

Project Closeout Summary: The LuCID project developed a low-angle, simulated lunar south pole lighting environment at NASA KSC, and produced image processing and analysis software (in Python) to dynamically adjust the contrast ratio for CID images of the scene to that of the human eye, which resulted in an NTR. The project successfully demonstrated a TRL 4 in a controlled lighting environment by repeatedly imaging a lunar-like terrain scene under simulated lunar south pole lighting conditions using the CID and simultaneously using a standard CMOS camera to compare the imaging performance of both devices in the same, challenging low-angle lighting environment. Compared to the performance of the CMOS camera, the CID demonstrated superior high dynamic range using the project's CID software to enable the CID's images to easily visualize ground obstacles including rocks, boulders, and image calibration targets, while looking in the direction of a low-angle light source, which the standard CMOS camera was unable to visualize.