TDC-86 Integrated Camera and Lighting System

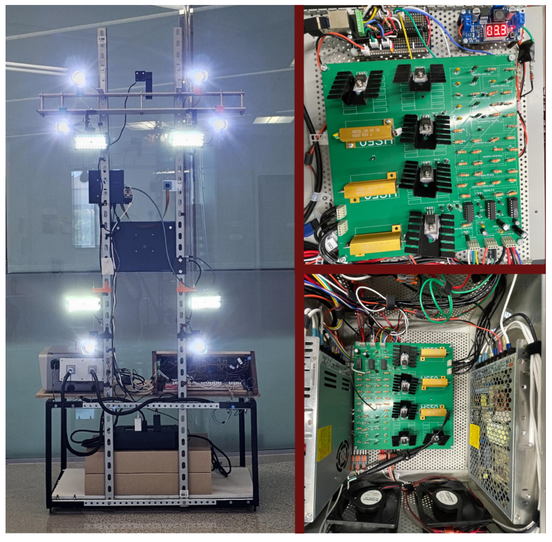
Erika Griffin, Jonah Hartley, Collin Peters
Texas State University - Lights, Camera, Bobcats!

Problem Description

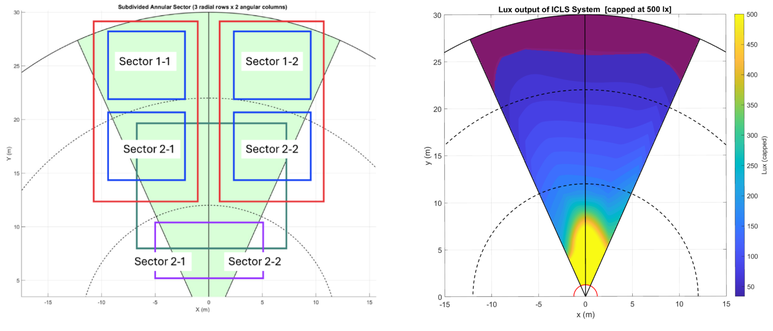
NASA's upcoming missions to the lunar surface present extreme contrast lighting conditions, from brilliant sunlight on the surface to the deep darkness of shadowed craters. Traditional lighting systems force a trade-off between underexposure and power efficiency while many existing Pulse Width Modulation systems used to drive LEDs are incompatible with video capture. Future exploration also demands real-time monitoring for both astronaut safety and mission efficiency.

Our Solution

We developed the Integrated Camera and Lighting System (ICLS), which dynamically adjusts LED floodlights and spotlights in real time based on embedded vision processing. A Raspberry Pi 5 automatically detects low-light sectors, activating only the necessary lights to maintain safe illumination. Manual override mode is provided for operators who need direct control. Power stability is ensured through an Uninterruptible Power Supply (UPS), with an emergency mode that conserves energy by disabling nonessential lights.

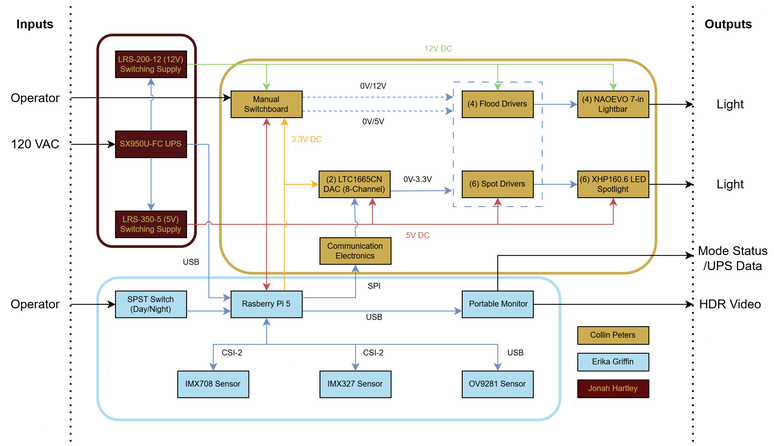


Left: Lighting arrays with UPS, enclosure, cameras, and switching controls. Right: Inside view of drive electronics, power supplies, and thermal management nested in the ICLS drive electronics enclosure.



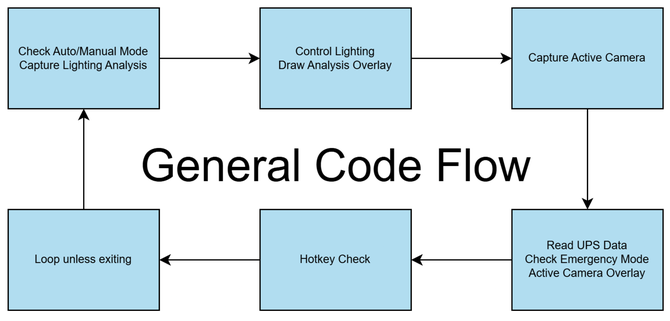
Sector map corresponding to lighting coverage. Different color boxes correspond to different light categories. The color contour indicates lux output to zones of coverage with purple indicating values below the 50 lux target.

System Architecture & Top-Level Diagram



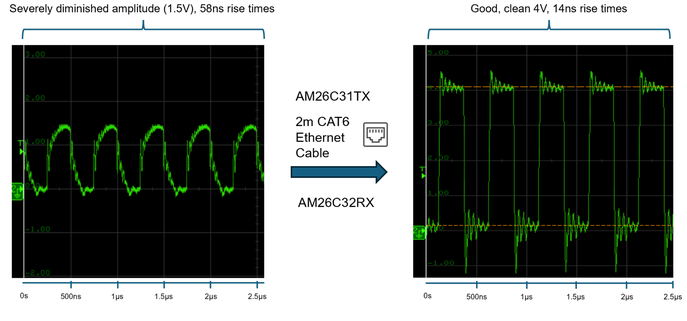
Embedded Vision

Our embedded vision pipeline uses a Arducam B0332 for brightness analysis, plus HDR and low-light cameras for day/night scenarios. Real-time image processing on the Pi 5 identifies underexposed sectors, activating the corresponding lights.



Communication System Electronics

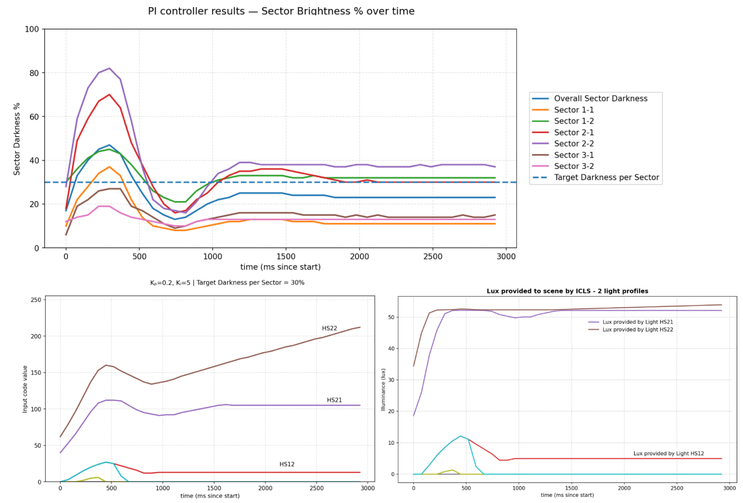
Our communications system is designed around an RS-485 standard, allowing the ICLS to send and receive clock signals of up to 10Mbits over 40 feet. RS-485 was chosen to mirror existing NASA lighting controls that run on a DMX512 standard.



2MHz clock cycles before & after implementation of communications stack

System Controls & Response

Our system is capabale of lighting distances of up to 30 meters with a single frame response time of 90ms. The system's time to rise is under 500ms, delivering illumination to a zone with adequate time for operator saftey.



Sector brightness values during a perturbation are displayed above the lighting profiles corresponding to two channels that display different, but expected, behavior.

Power & Heat

To ensure continuous operation, the system requires a reliable power source at all times, with a backup available if the primary supply fails. It will include a reserve battery (UPS) that automatically switches to an emergency mode when the main supply is lost. In this mode, the UPS can sustain the system for approximately 73 minutes.

High-power LEDs and driver electronics require robust cooling. Each MOSFET has its own heat sink, sense resistors are over-specked to not require additional heat management, and the Pi 5 is housed in an enclosure pre-equipped with passive and actively cooling. Two internal fans circulate air through vented panels, preventing localized hotspots around power supplies or PCBs. Testing demonstrated no components exceed their maximum operating temperatures after prolonged operations of 100 minutes.

Future Work

Future work will generate a custom spotlight stack and extend the multi-input, multi-output control framework to include Model Predictive Control (MPC). This will enable better decoupling between lighting channels and more precise, predictive adjustment of illumination across the field of view. Continued testing will focus on validating controller performance under dynamic lighting conditions.

Acknowledgements

TXST Faculty: Dr. Compeau, Mr. Stevens, Mr. Welker
NASA mentor: Ms. Toni Clark
Independent collaborators: Tyler Nuckols, Cassidy Miskovitz, Erich Ellsworth