Computational Modeling to Limit the Impact Displays and Indicator Lights Have on Habitable Volume Operational Lighting Constraints

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ISS Cupola Lit by Glow of Displays & Controls

https://www.nasa.gov/content/interior-view-from-the-international-space-station-cupola

The ISS cupola does not have its own ambient lighting system, however the robotic work stations and laptop display provide enough illumination for a quality camera image.

NASA has demonstrated an interest in improving astronaut health and performance through the installment of a new lighting countermeasure on the International Space Station. The Solid State Lighting Assembly (SSLA) system is designed to positively influence astronaut health by providing a daily change to light spectrum to improve circadian entrainment. Unfortunately, existing NASA standards and requirements define ambient light level requirements for crew sleep and other tasks, yet the number of light-emitting diode (LED) indicators and displays within a habitable volume is currently uncontrolled. Because each of these light sources has its own unique spectral properties, the additive lighting environment ends up becoming something different from what was planned or researched. Restricting the use of displays and indicators is not a solution because these systems provide beneficial crew feedback.

Using real-world data, computer models were built in the commercially available optics analysis software Zemax OpticStudio™. A mockup test facility, that had the same volume and configuration as the computer model was built and used to validate computer models. The team focused on understanding the impacts of long-term tasks located in front of computer displays. Options for mitigating the changes to the ambient light spectrum in the interest of maintaining the performance of a lighting countermeasure, was evaluated. Direct relationships on system implementation were found. Over 1200 spectral irradiance measurements, each representing a different configuration of the mockup, were captured. Analysis of the data showed a measurable impact on ambient light spectrum. This data agreed with computer models and showed obvious design techniques exist that can be used to bind the ambient light spectrum closer to the planned spectral operating environment for the observer's eye point.

Observations:

- When more light is directed into the field of view of the observer, the greater the impact it will make on human performance requirements that depend on spectral shape and intensity. Viewing angle impacts the amount of light flux on the crewmember's retina. Beam shape, combined with light source location is an important factor for determining percent probable incident flux on the observer from any combination of light sources.
- Computer graphics design and display lumen output are major factors influencing the amount of spectrally intense light projected into the environment and in the viewer's direction. Adjustable white point display software was useful only if the predominant background color was white and if it matched the ambient light system's color. Display graphics that used a predominantly black background had the least influence on unplanned spectral energy projected into the environment.
- Percent reflectance makes a difference in total energy reflected back into an environment, and within certain architectural geometries, reflectance can be used to control the amount of a light spectrum that is allowed to perpetuate in the environment.
- Room volume and distance from significant light sources influence the total spectrum in a room. Smaller environments have a homogenizing effect on total light spectrum, whereas light from multiple sources in larger environments is less mixed.

Application:

- System Design of the Spectral Environment: the ambient lighting system, surface reflectance, and display and indicator implementation all impact the users' spectral environment.
- Innovation & Mitigation of Problems: Innovation and planning in the automation and integration of display systems with the ambient environment can improve the quality of the user's environment while reducing power, weight, and cost of the system.
- Validation: Human-in-the-loop evaluations, real-world test and measurement, and computer modeling can be used to determine how changes to a process, display graphics, and architecture maintain the planned spectral lighting environment.

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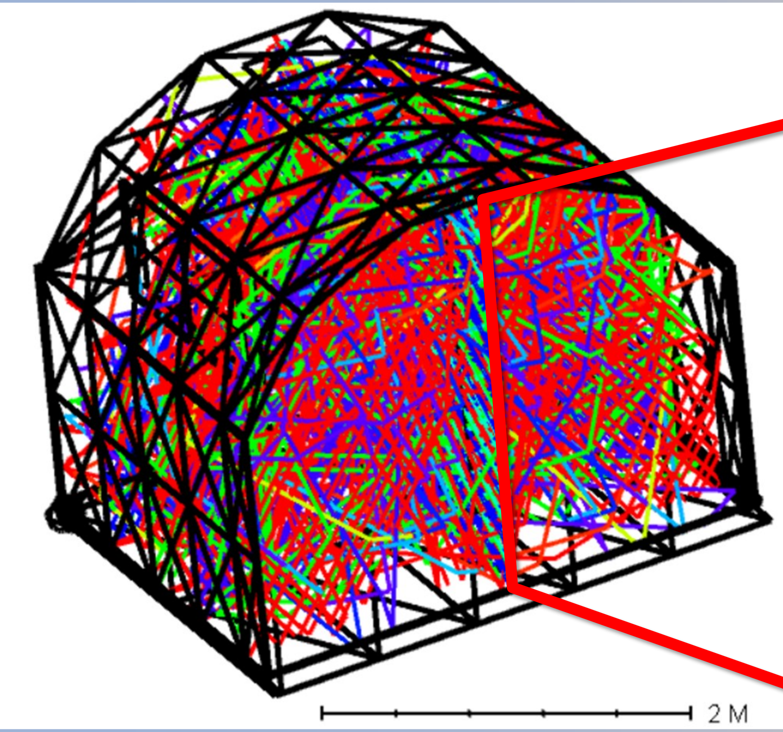
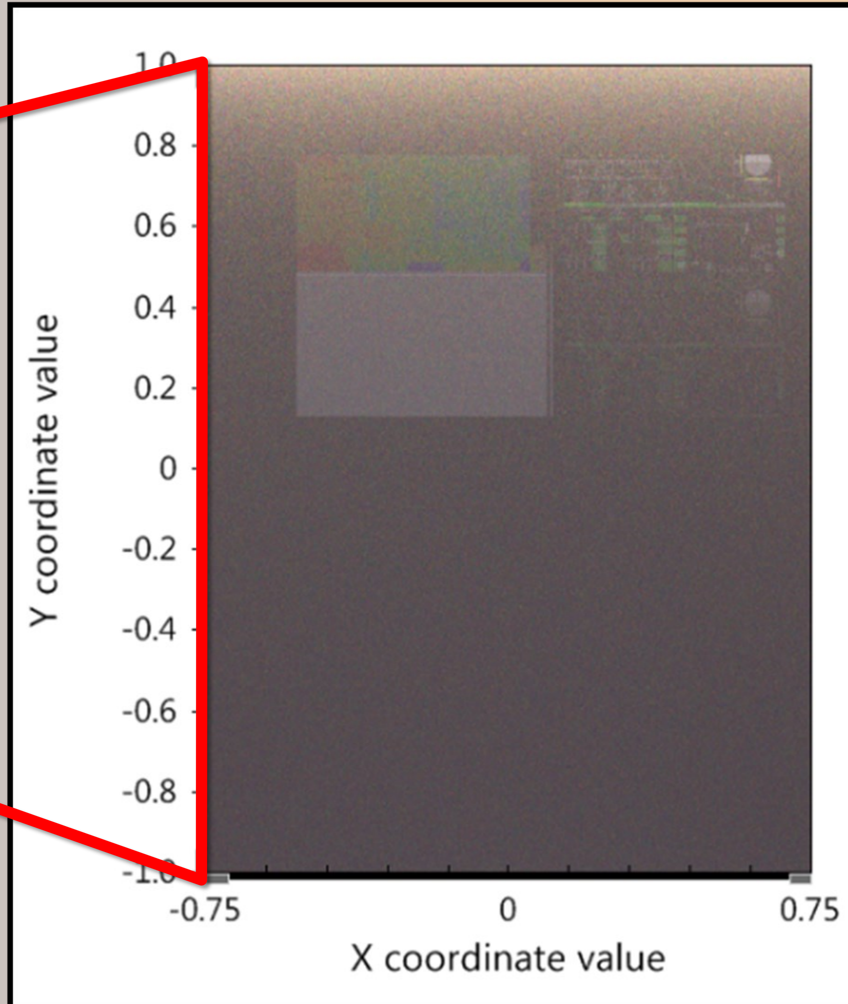
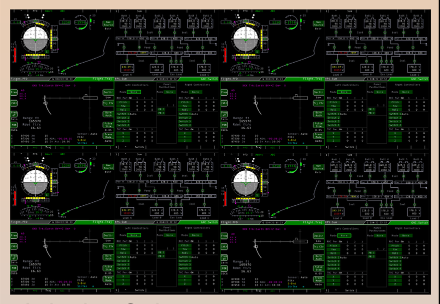




Two hundred twenty million rays were launched for this Zemax OpticStudio™ lighting simulation of the mockup facility, showing light rays scattered with in the environment. A virtual detector shows light as it passes through the middle of the volume and that image coherency of the displays are maintained. The image is brighter near the top due to the overhead lighting system.

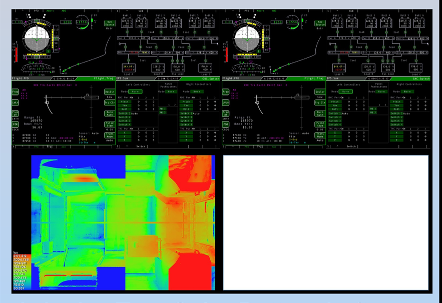
Mockup Facility. Spectrometer is shown facing a quad monitor configuration. Analysis from this orientation is shown in bar charts.

Quad Display Test Configurations

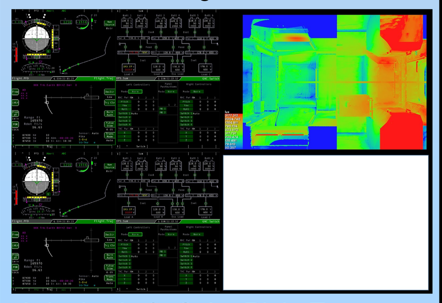


Avionics Only

Avionics Top, White Bottom

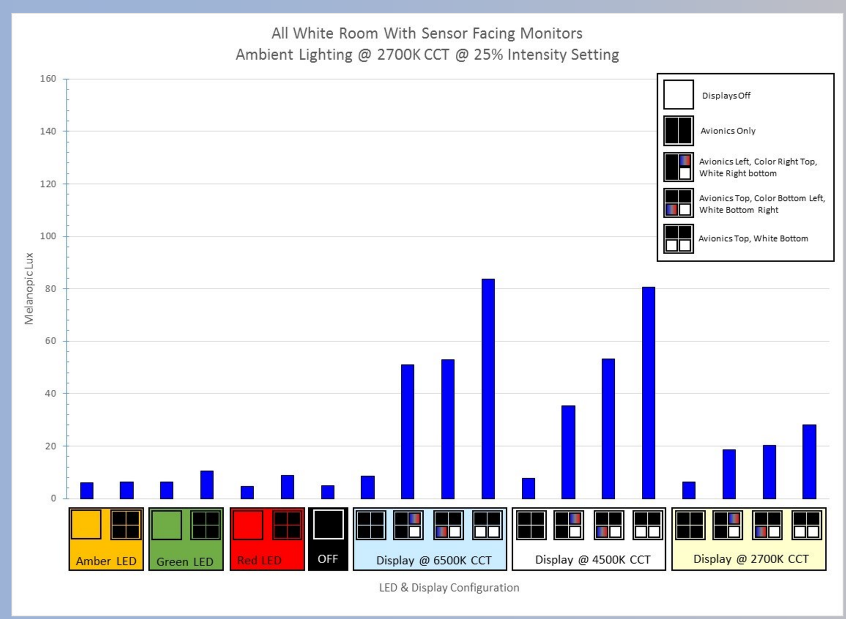


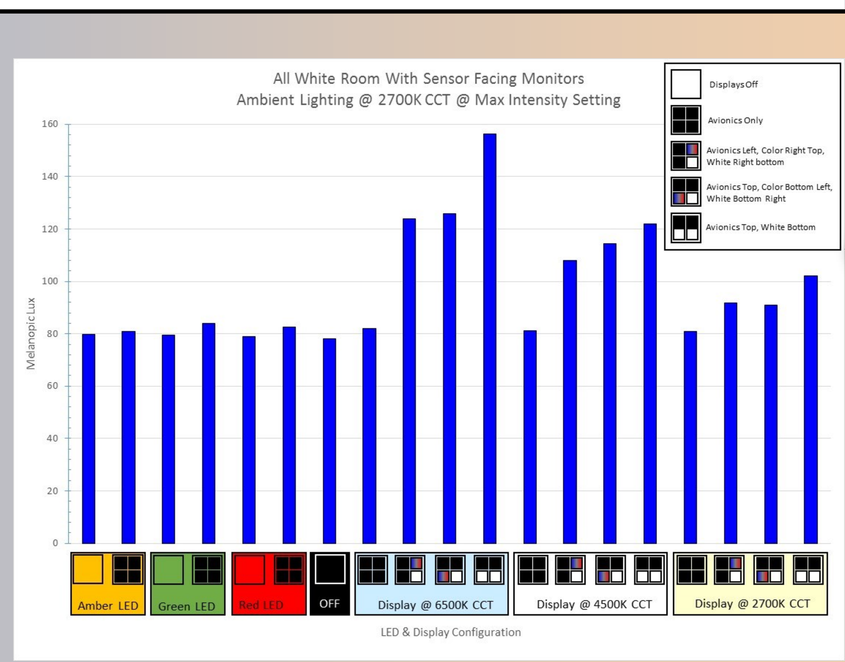
Avionics Top, Color Bottom Left, White Bottom Right



Avionics Left, Color Right Top, White Right Bottom

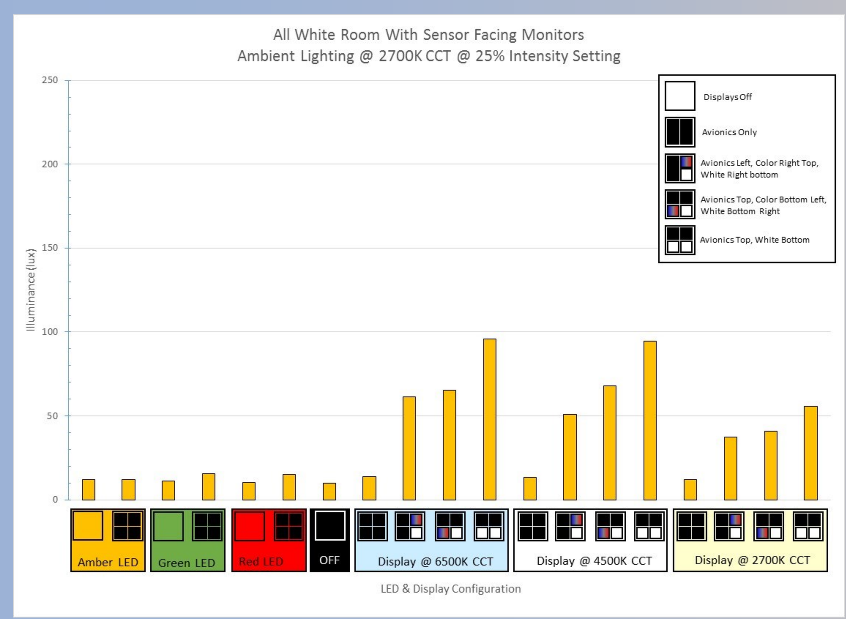
System Performance Comparison Charts: Lighting Impacts With Respect to Device Configuration & Viewing Angle

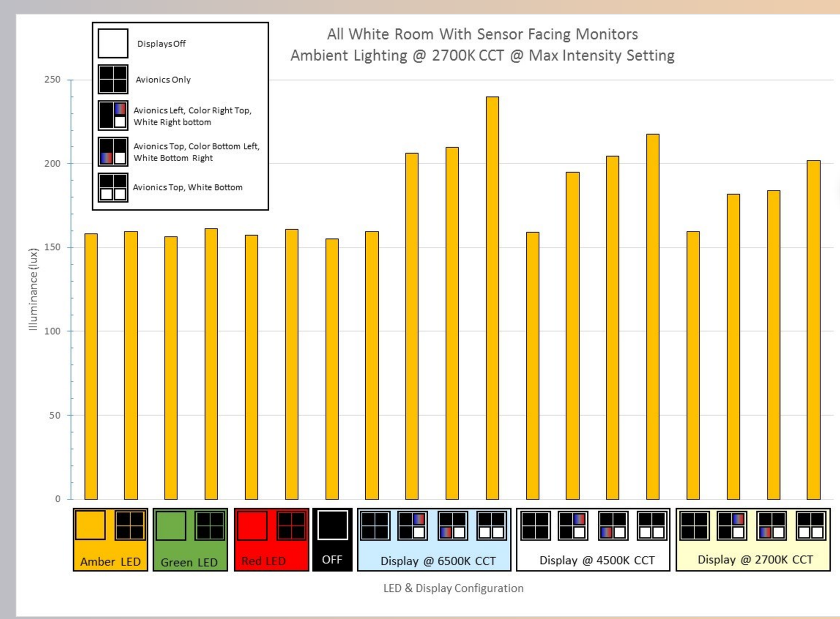




Melanopic Lux Comparison

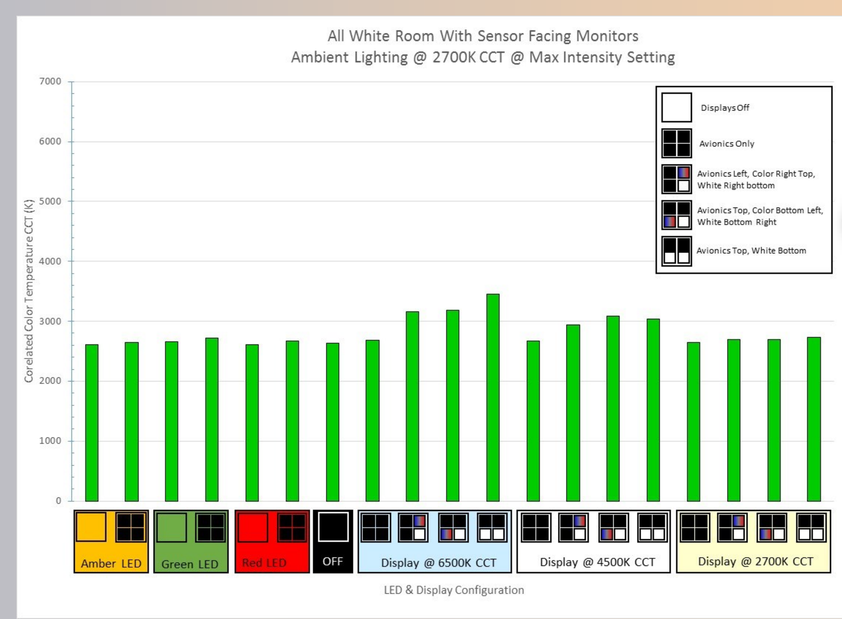
The display content was a major driver in the amount of melanopic lux generated. Viewing angle is also important since the sensor facing the display monitors collects enough flux from the displays to equal the reflected flux from the overhead lighting system. Changing the white point of the display drops the melanopic by half.





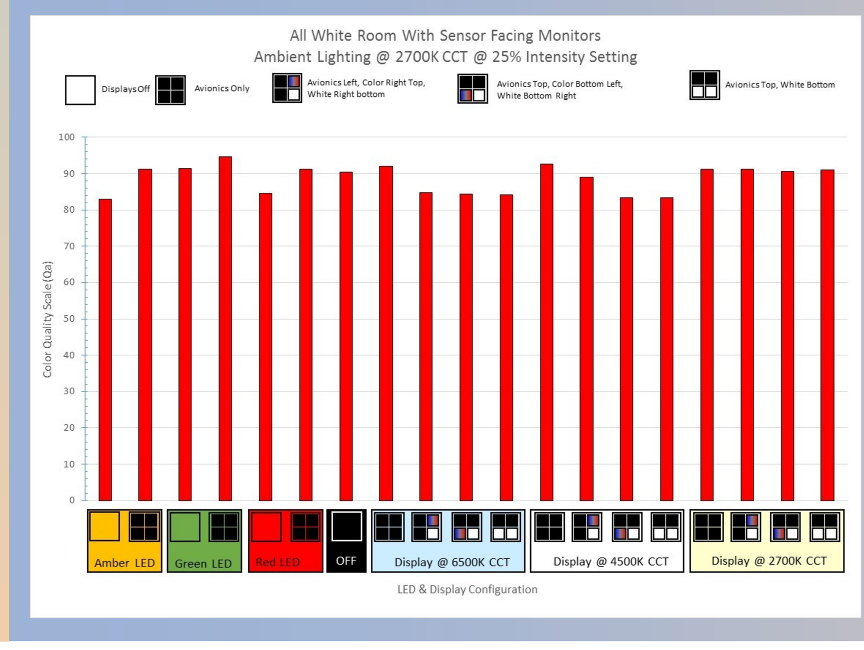
Illuminance Comparison

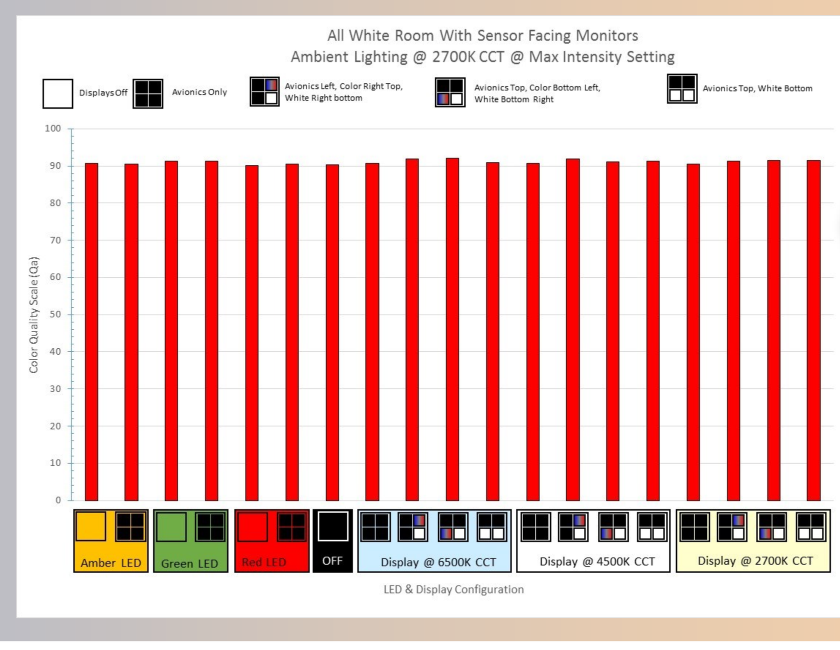
Melanopic lux is a better indicator of blue light content from the displays than illuminance. Illuminance however, still shows the relationship between display content and light received by the observer. Illuminance is less sensitive to changes in display white point than melanopic lux.



Correlated Color Temperature

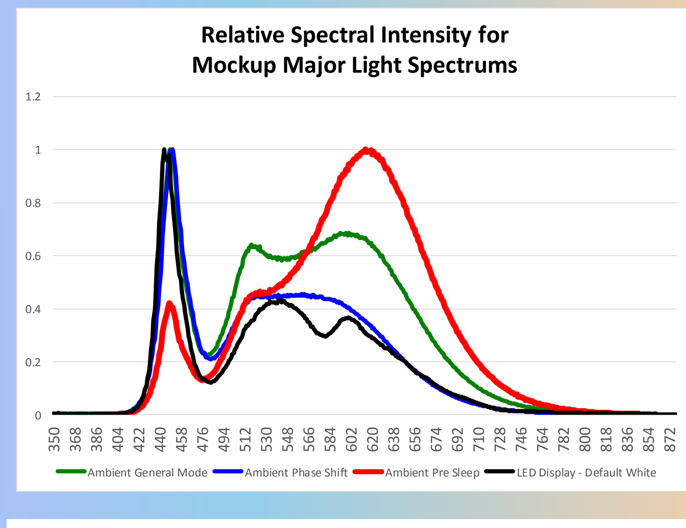
CCT shows how the apparent color of the ambient lighting system is overcome by the content of the display. Note, however, that increasing the light level from the overhead lighting system counteracts this effect.



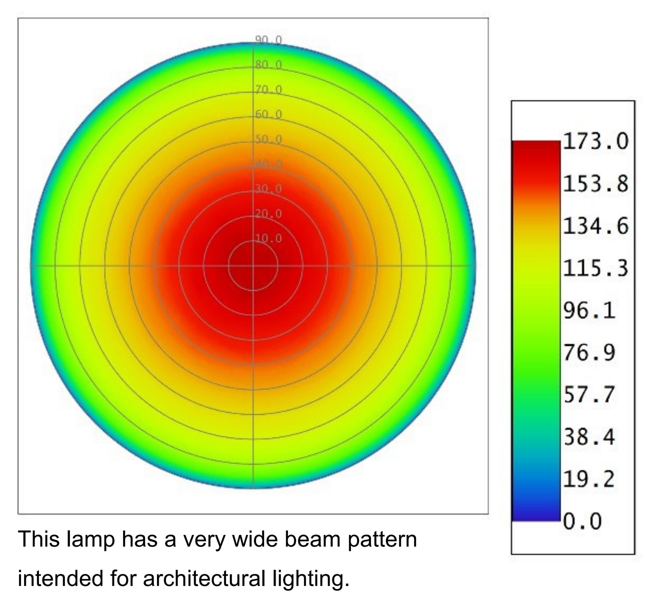


Color Quality Scale (CQS)

CQS, a color fidelity measurement for lighting systems, shows that the additional spectral features from the displays did alter color accuracy scores. However, raising the light level of the ambient lighting system counteracts the problem.



Isocandela Beam Pattern Plot for Mockup Facility Ambient Light System Lamps.



This lamp has a very wide beam pattern intended for architectural lighting.

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12/22/2016
IESNA source file: BeamPatternMockupLamp-General.IES
Peak intensity: 1.7300E+02 Candela
Total Lumens in File: 7.6822E+02 Lumens
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