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

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ISS Interior with Ambient Lighting System Turned Off
Image credit: NASA

Even with no ambient lighting system "on", the International Space Station glows at night. The glow is caused by indicator lamps and displays that are not included with the specification of the ambient lighting system.

How does this impact efforts to improve the astronaut's lighting environment to promote more effective sleep patterns?

Do the extra indicators and displays add enough light to change the spectrum of light the crew sees during the day as well?

If spacecraft environments are specifically engineered to have an ambient lighting system that emits a spectrum promoting a healthy circadian response, is there a way control the impact?

The goal of this project is to investigate how additional light sources, such as displays and indicators change the effective light spectrum of the architectural lighting system and how impacts can be mitigated.

The investigation will focus on the following:
- Development of a computer model of a spacecraft lighting environment.
- Use of computer model to determine how changes to architecture impact lighting conditions for a virtual observer.
- Fabrication of mockup of avionics command center for lighting measurement.
- Evaluation to determine impacts to lighting performance metrics such as color perception and melanopsin production.

The International Space Station is updating its architectural lighting system, in 2016, with a lamp that has a lighting health countermeasure called the Solid State Lighting Assembly (SSLA). To effectively use innovations in lighting countermeasures for improvement of circadian health a better understanding on the impact of other light emitting tools required by the crew for spacecraft operations is necessary.
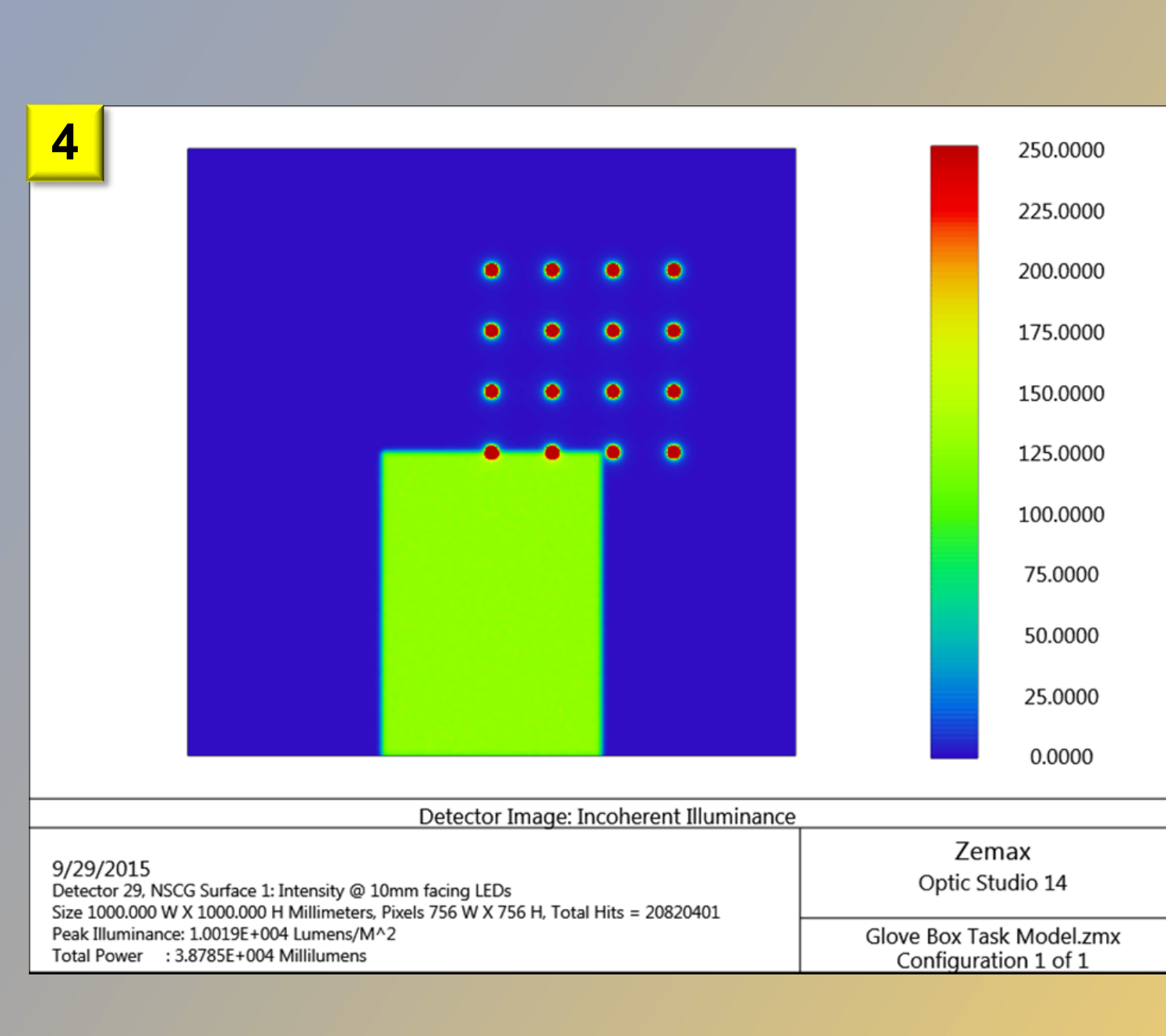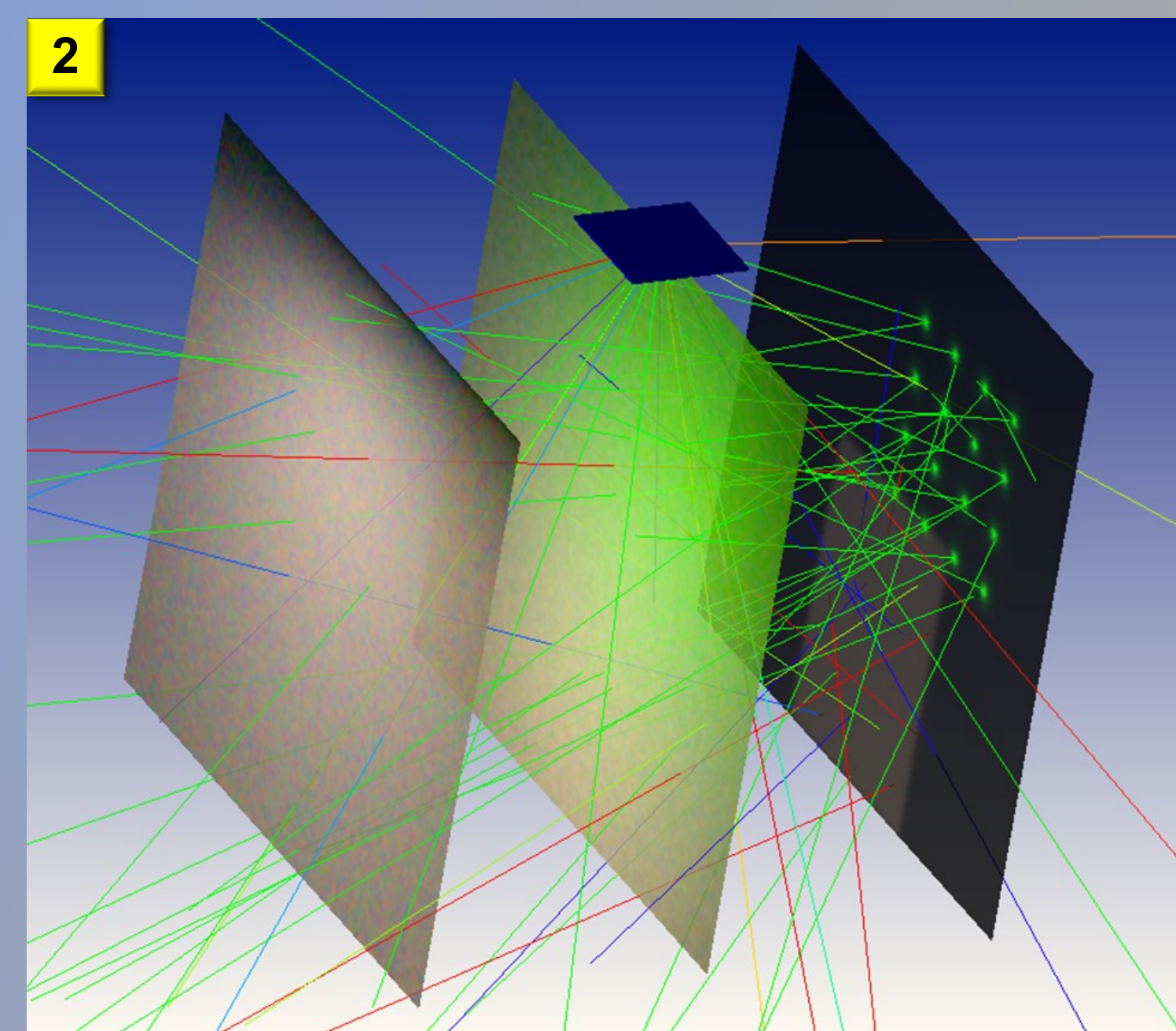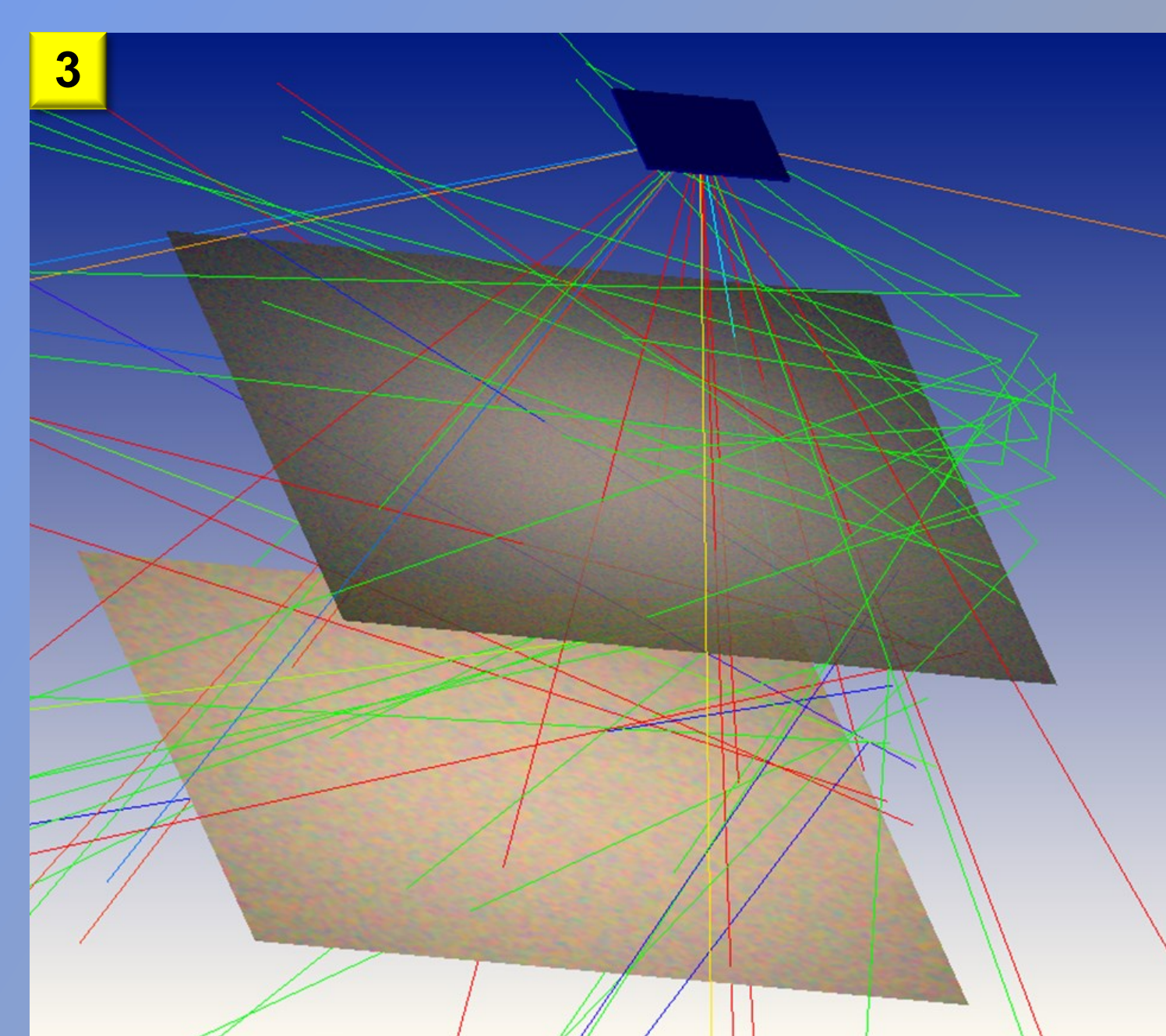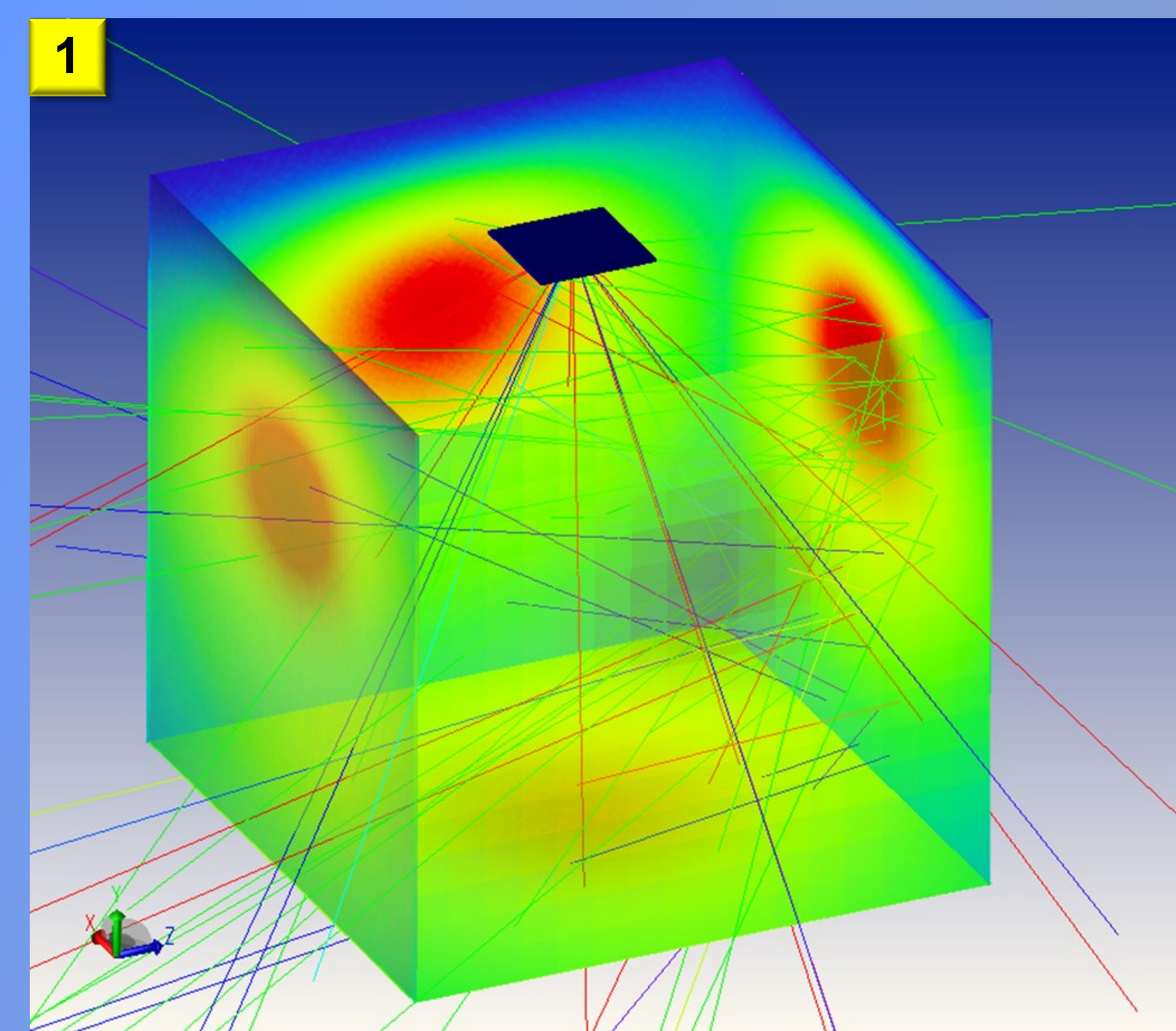
One Meter Cubed Envelope around 1500 Lumen Light Source—Transparent Walls—Computer Model

Walls are transparent. The top of the cube contains a 1500 lumen light source with a beam distribution and spectrum identical to the ISS SSLA. The right side top of cube contains 4x4 array of green LEDs each with an output of 1 lumen. Underneath LED array is a display modeled with a wide angle distribution and peak intensity of 130 lux at 10 mm. The LED's spectrum is set to 550nm. The display spectrum modeled with wavelengths (465, 546, and 614 nm).
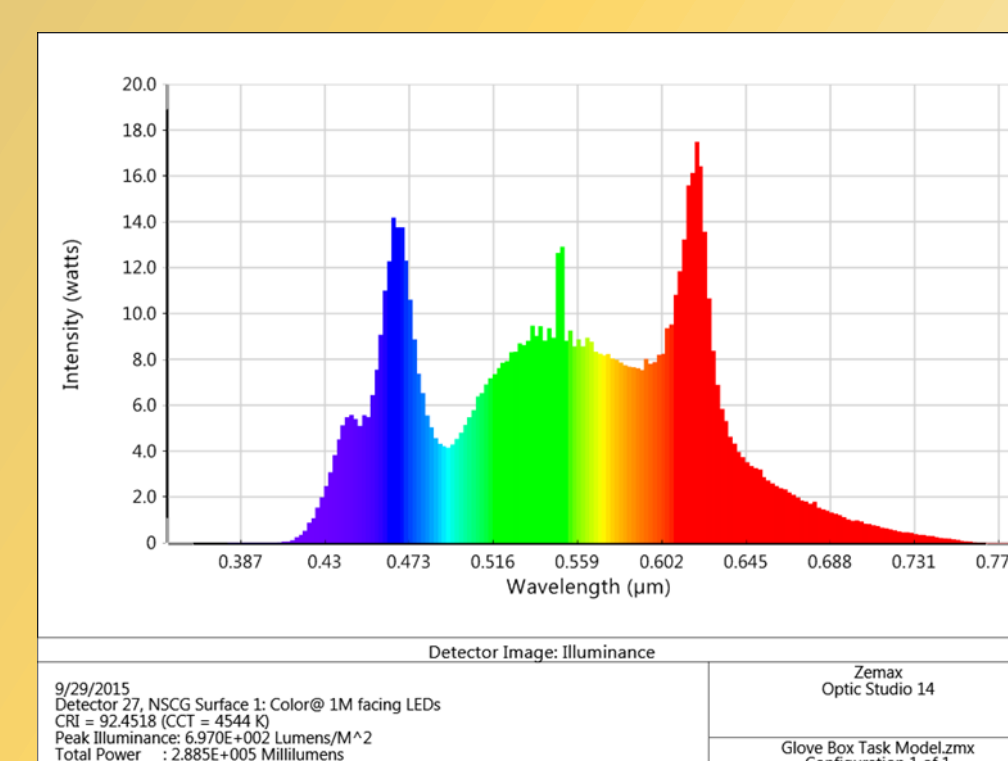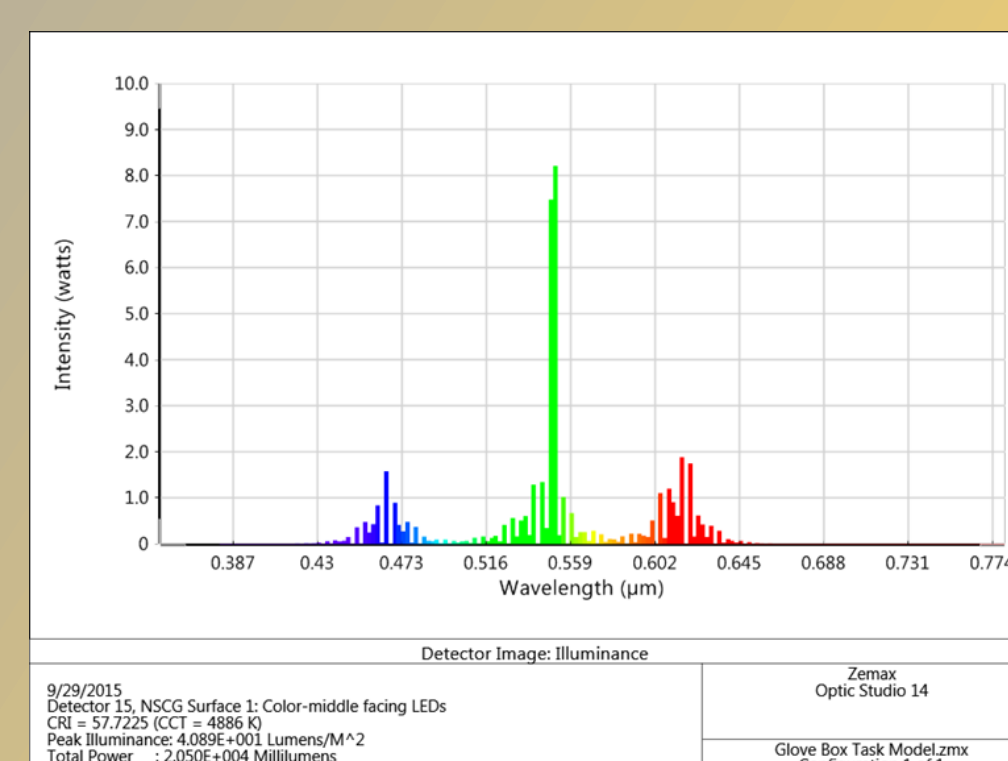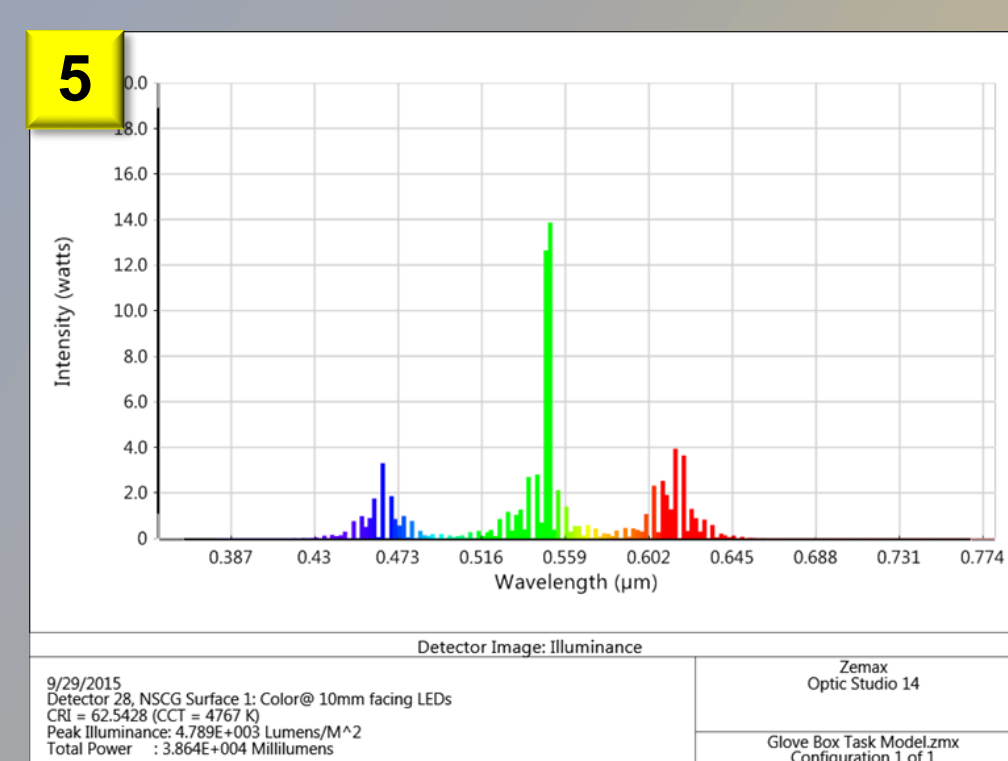
Figure 1: False color illuminance on cube walls. Illuminance range is 0-620 Lux. Intensity at the floor is approximately 500 lux. Peak hotspot on sides is 615 to 620 lux. Intensity of light striking wall at display averages 300 lux.

Figure 2: "True Color" detectors directed towards the LEDs and display. The detector farthest to the right is located 10mm from the LEDs and display. The detector located in the middle is 0.5 meters from the display. The detector located farthest to the left is one meter from the LEDs and display.

Figure 3: "True Color" detectors directed up towards primary architectural light source at 1 and 0.5 meters.

Figure 4: False color illuminance map at 10mm from the LED array and display. The false color was scaled to show the intensity of the display. The LEDs in this image have a high illuminance value due to the concentration in flux.

Figure 5: Three spectrums corresponding to detectors facing the LEDs and display. From left to right, the detectors are located respectively at 10 mm, 0.5 m, and 1 m away from the display. The overhead lamp's spectrum is not noticeable until the detector is one meter away from the display and in the field of view of the overhead lamp.

One Meter Cubed Envelope around 1500 Lumen Light Source—White Diffuse Reflective Walls—Computer Model

All walls are opaque and with a diffuse white surface treatment, except for the left wall which is transparent. Overhead light source, the display, and LED array are modeled exactly the same as the model represented in figures 1-5. Display or indicators are not designed to block reflected light from wall.

Figure 6: False color illuminance on cube walls. Illuminance range is 0-1000 lux. Rays are exiting out of open end of cube. Note that illumination levels are very uniform. When comparing Figure 7 to figure 1, note that the walls created an additive effect.

Figure 7: True Color" detectors directed towards the LEDs and display. The detector farthest to the right is located 10mm from the LEDs and display. The detector located in the middle is 0.5 meters from the display. The detector located farthest to the left is one meter from the LEDs and display.

Figure 8: "True Color" detectors directed up towards primary architectural light source at 1 and 0.5 meters.

Figure 9: False color illuminance map at 10mm from the LED array and display. The false color was scaled to show the intensity of the display. The LEDs in this image have a high illuminance value due to the concentration in flux.

Figure 10: Three spectrums corresponding to detectors facing the LEDs and display. From left to right, the detectors are located respectively at 10 mm, 0.5 m, and 1 m away from the display. The wall is reflecting significant energy from the overhead light in the direction of this detector. The overhead light's spectrum is recognizable regardless the location of the sensor. The light contribution from the LED array is still noticeable.

Structure for Cockpit Mockup

This image is of a reconfigurable mockup that will be developed to model a command console or cockpit for a spacecraft. When completed it will have realistic avionics display configurations and architectural surfaces that are designed to enclose the volume per design constraints.

Computer model images on this presentation were developed using Zemax Optic Studio©. Photo of reconfigurable mockup courtesy Brian Schwing, NASA. Imaging colorimeter data courtesy Lighting Environment Test Facility, NASA Johnson Space Center.

Development of a Realistic Optical Model of a Display

The following images show process for optimizing a computer model of an LED backlit display. An LED display with an avionics control screen interface was measured with an imaging colorimeter and a spectral radiance meter at the Lighting Environment Test Facility at JSC. Measured data is used to optimize the computer model.
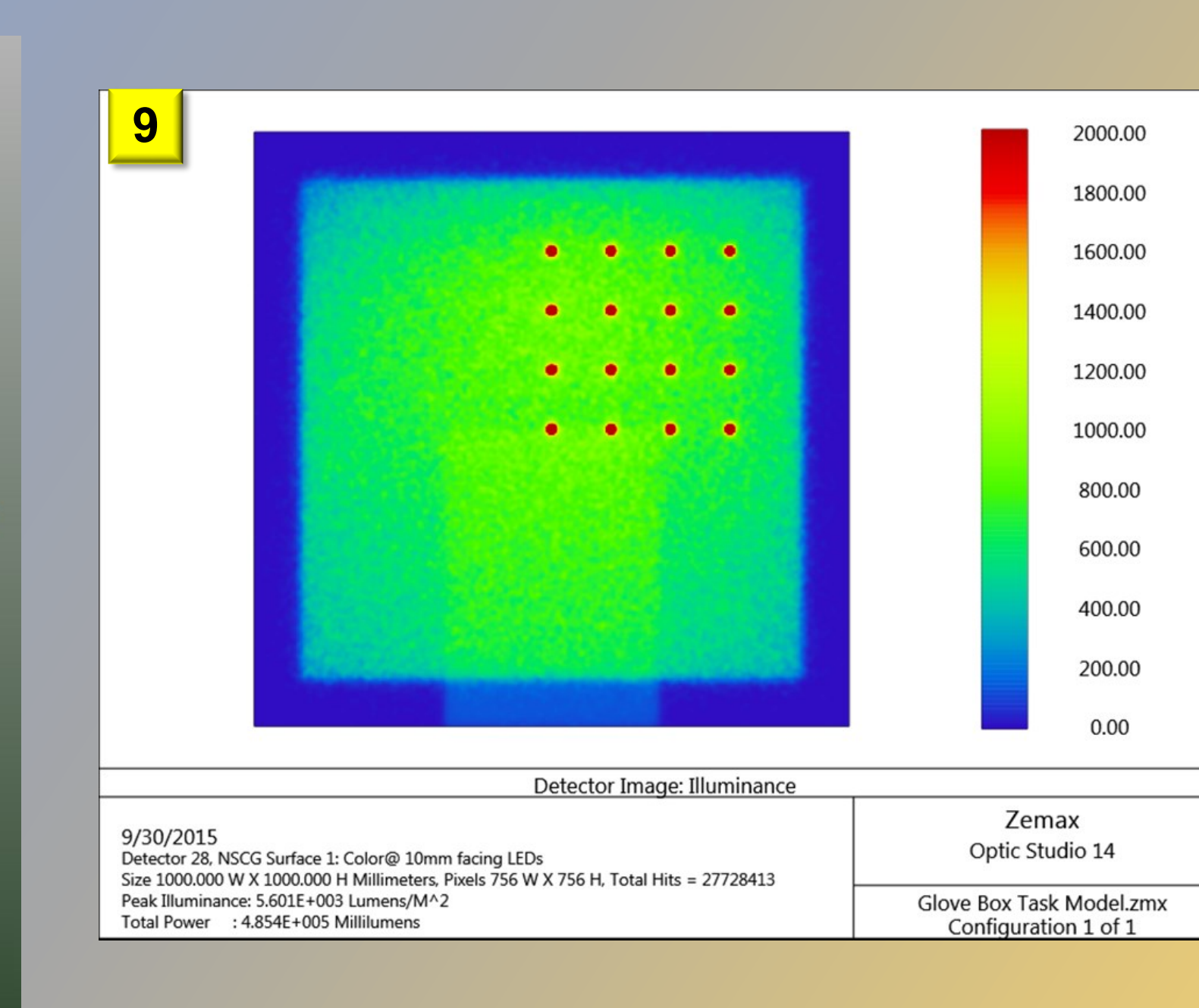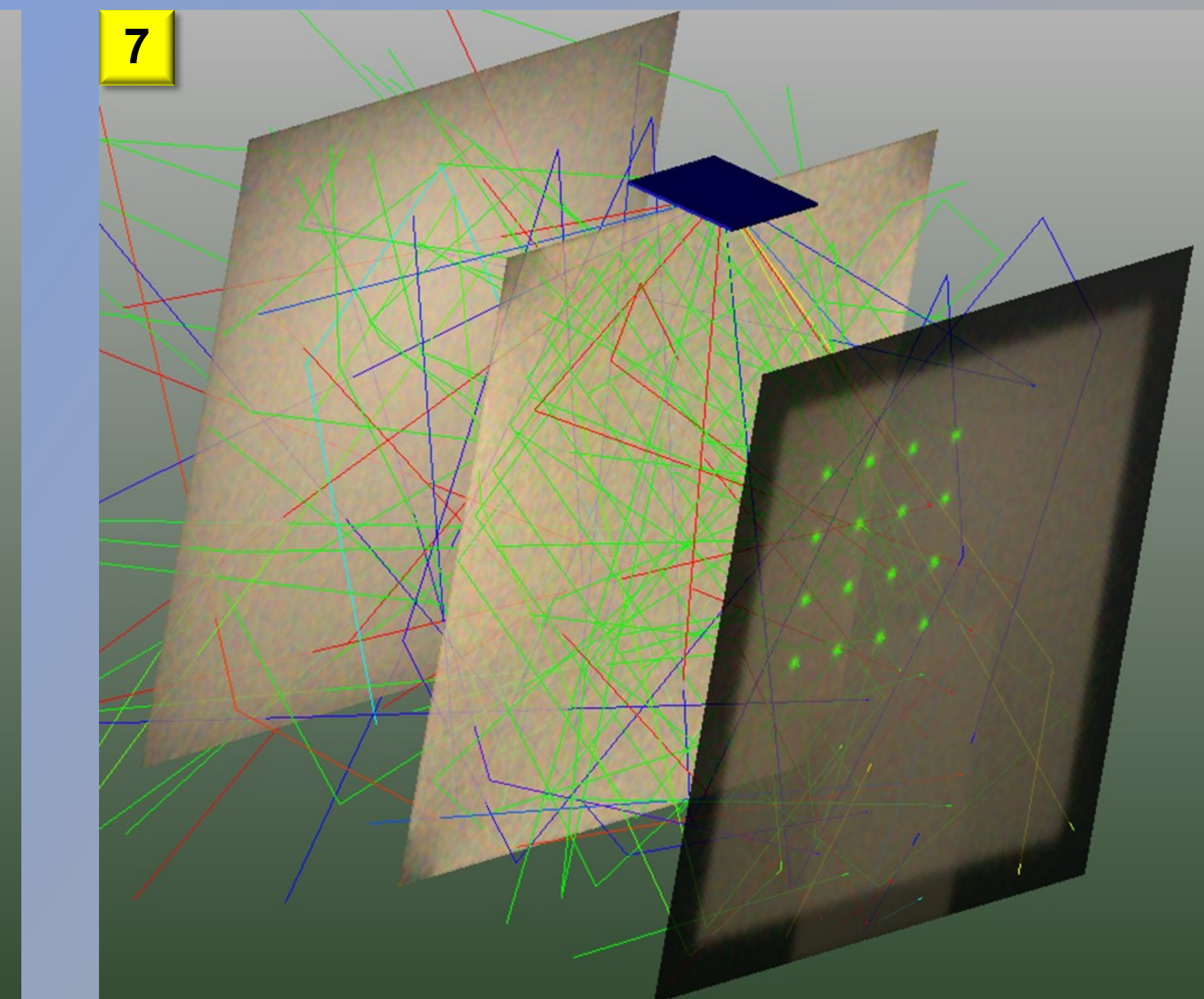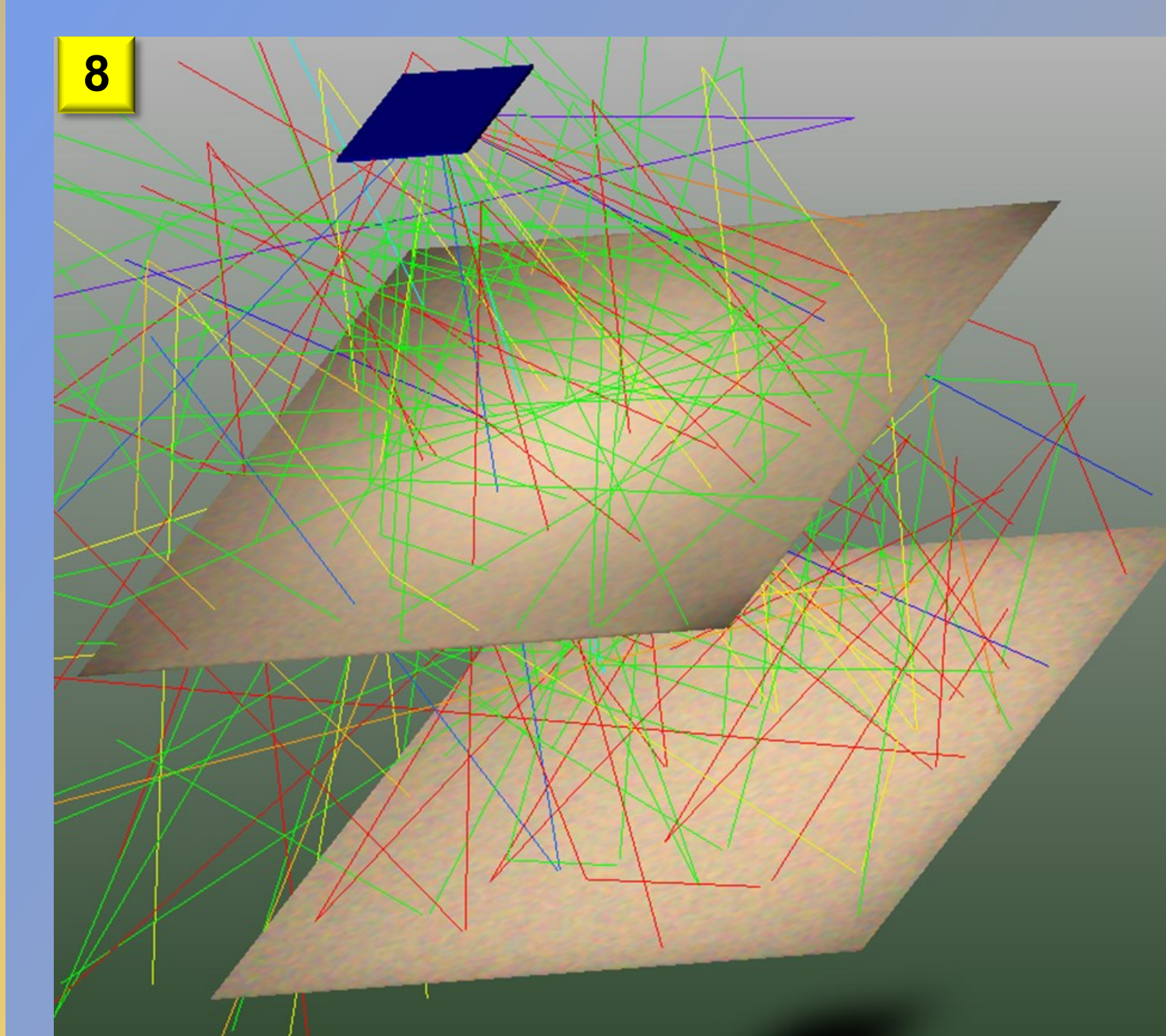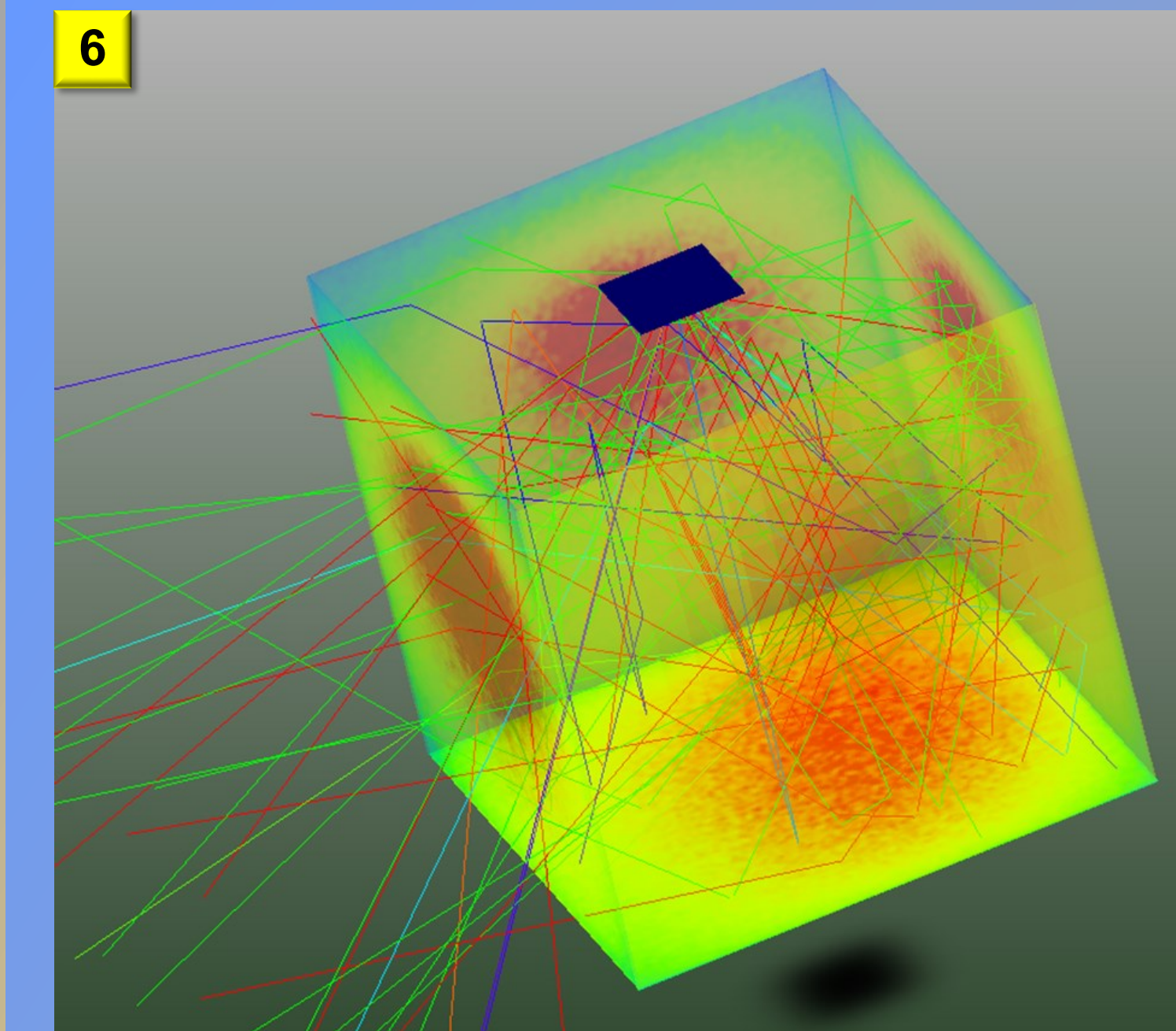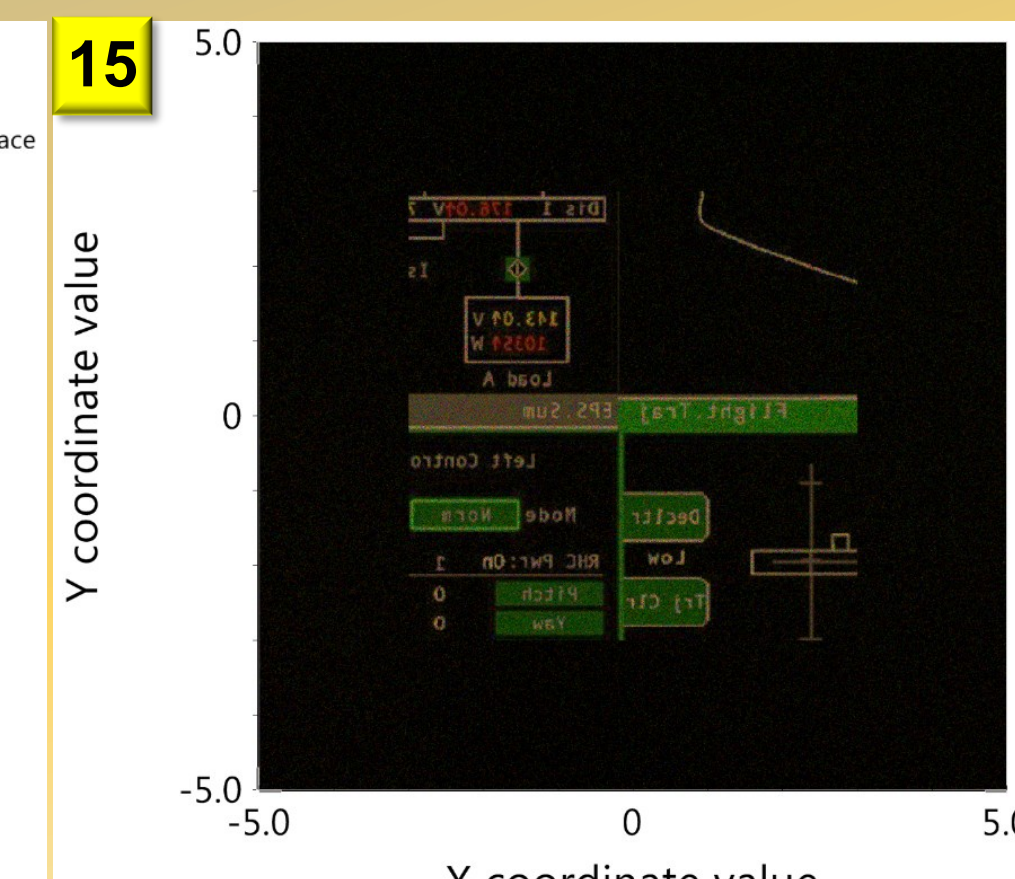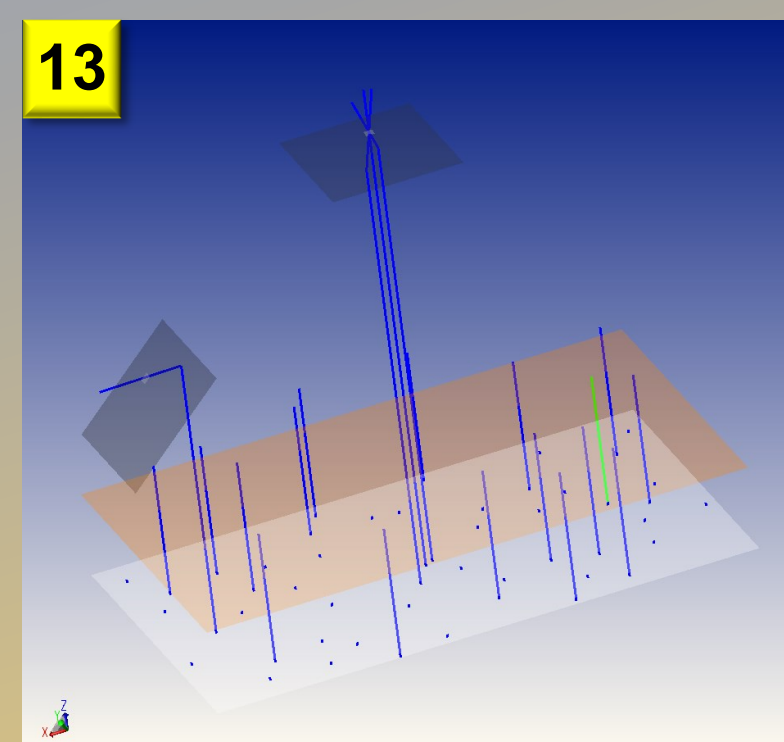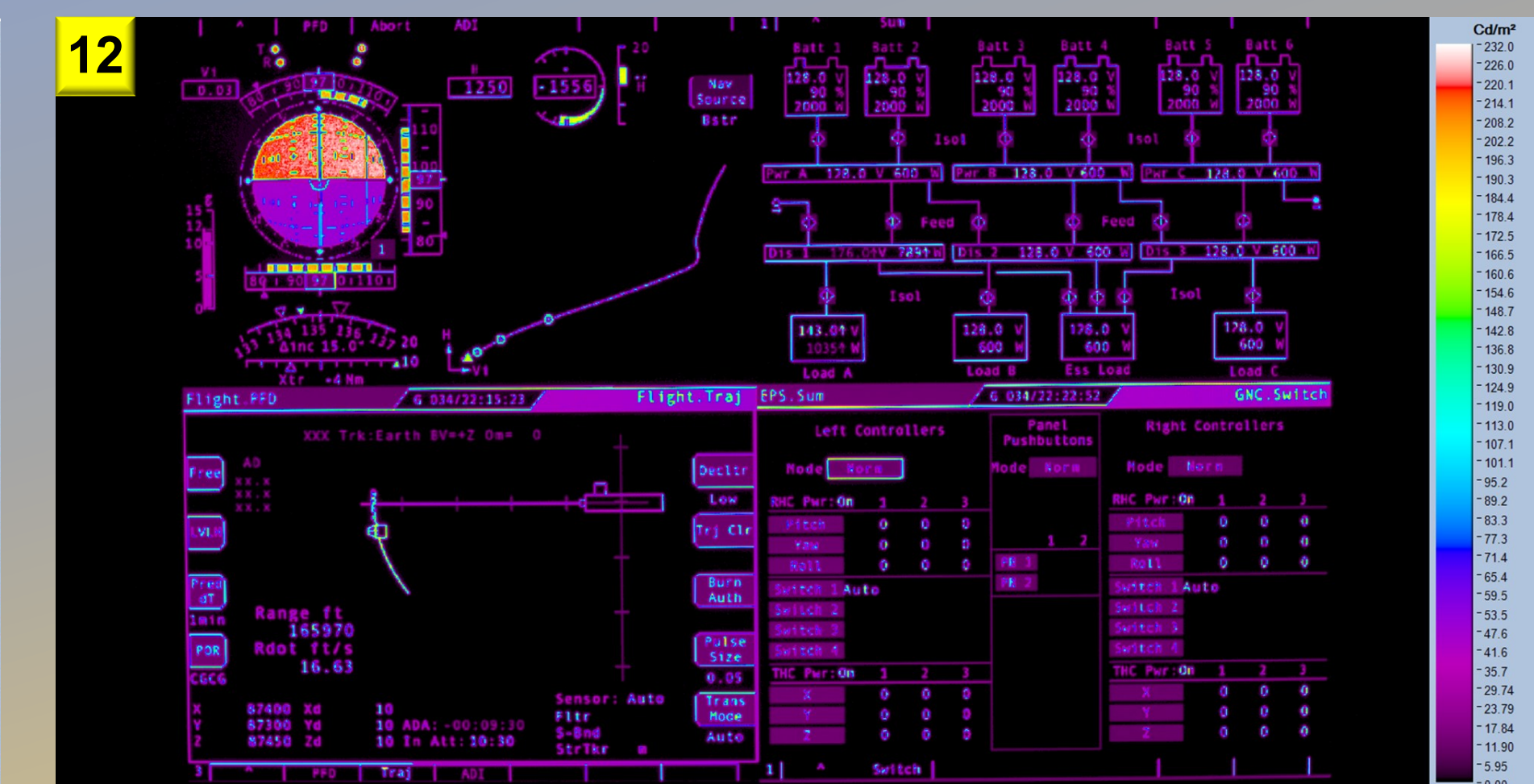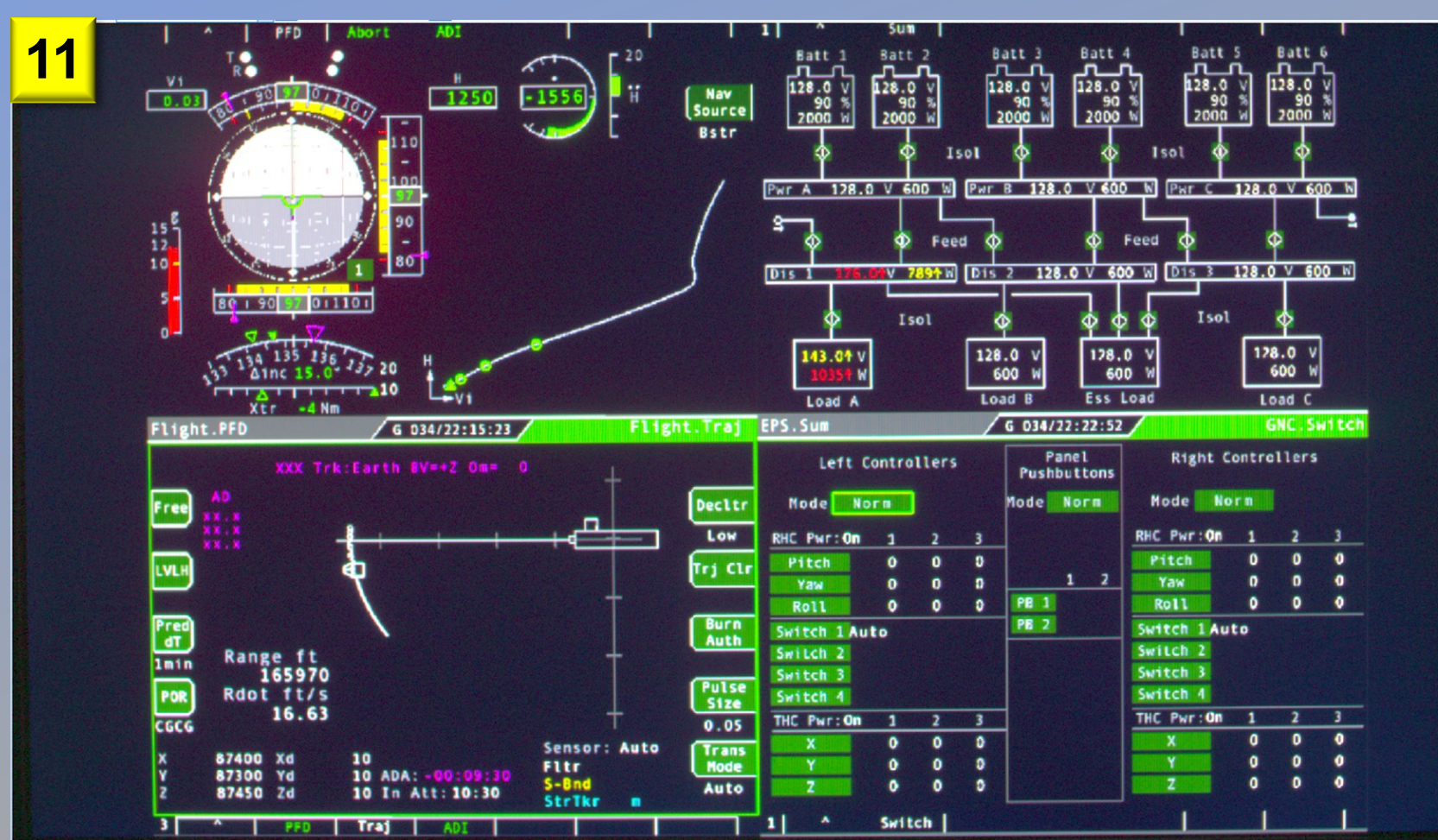
Figure 11: True color measurement of the display from an imaging colorimeter.

Figure 12: False color radiance data, in units of candela/m^2 of the display using from an imaging colorimeter. Spectrometer measurements of the brightest white on the screen indicated a radiance values 0.782 W/sr/m^2 and luminance value of 226 cd/m^2.

Figure 13: Computer model was simulated with a collimated light source and a pixelated image. Model has the ability to disperse flux pending on viewing angle requirements.

Figure 14: Computer model's false color radiance map from a virtual detector located a few millimeters from the display.

Figure 15: Computer model's true color simulated data from a virtual detector located a half meter away from the display, showing that coherence was maintained.