Predicting and Managing Lighting and Visibility for Human Operations in Space

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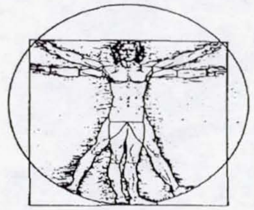
Lighting is critical to human visual performance. On earth this problem is well understood and solutions are well defined and executed. Because the sun rises and sets on average every 45 minutes during Earth orbit, humans working in space must cope with extremely dynamic lighting conditions varying from very low light conditions to severe glare and contrast conditions.

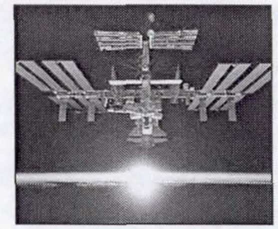
For critical operations, it is essential that lighting conditions be predictable and manageable. Mission planners need to determine whether low-light video cameras are required or whether additional luminaires, or lamps, need to be flown. Crew and flight directors need to have up to date daylight orbit timelines showing the best and worst viewing conditions for sunlight and shadowing. Where applicable and possible, lighting conditions need to be part of crew training. In addition, it is desirable to optimize the quantity and quality of light because of the potential impacts on crew safety, delivery costs, electrical power and equipment maintainability for both exterior and interior conditions.

Addressing these issues, an illumination modeling system has been developed in the Space Human Factors Laboratory at NASA Johnson Space Center. The system is the integration of a physically based ray-tracing package ("Radiance"), developed at the Lawrence Berkeley Laboratories, a human factors oriented geometric modeling system developed by NASA and an extensive database of humans and their work environments. Measured and published data has been collected for exterior and interior surface reflectivity; luminaire beam spread distribution, color and intensity and video camera light sensitivity and has been associated with their corresponding geometric models. Selecting an eye-point and one or more light sources, including sun and earthshine, a snapshot of the light energy reaching the surfaces or reaching the eye point is computed. This energy map is then used to extract the required information needed for useful predictions.

Using a validated, comprehensive illumination model integrated with empirically derived data, predictions of lighting and viewing conditions have been successfully used for Shuttle and Space Station planning and assembly operations. It has successfully balanced the needs for adequate human performance with the utilization of resources.

Keywords: Modeling, ray tracing, luminaires, reflectivity, luminance, illuminance.





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Organizations

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Space and Life Science Directorate

Habitability and Environmental Factors Office

Habitability and Human Factors Office

Space Human Factors Laboratory

- Lighting Environment Test Facility (LETF)
- Graphics Research and Analysis Facility (GRAF)

Lighting Environment Test Facility (LETF)

- measures material reflectance properties
- measures the performance of luminaires
- measures low light performance of cameras

Graphics Research and Analysis Facility (GRAF)

- integrates measured lights and materials with geometry (computer models)
- modeling with Radiance (Lawrence- Berkeley Laboratory) and PLAID (in-house software).

Measurement of Material Reflectance and Color Tools

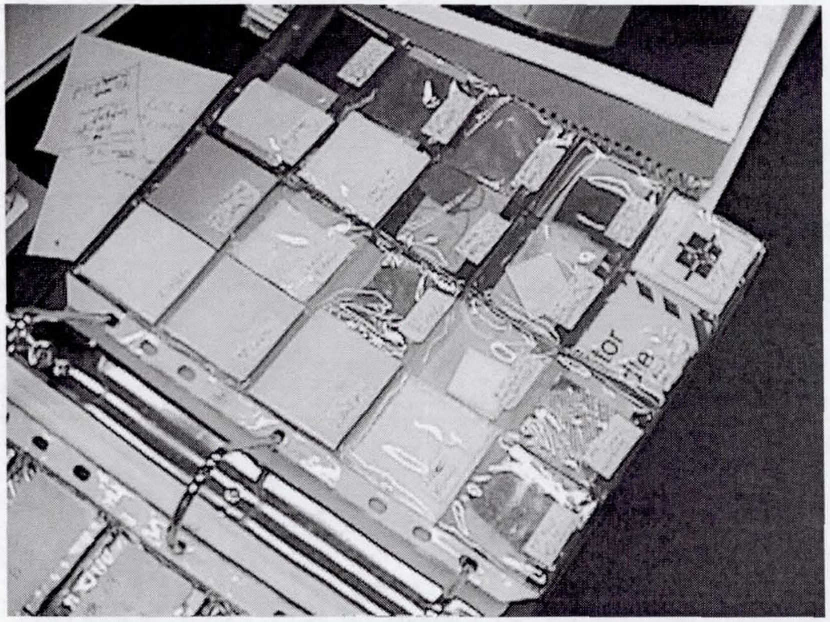
Total reflectance meter - measures the spectral characteristics of material and light.

Gonio-reflectometer- measures the diffuse and specular characteristics of a material's reflectance of light as a percentage of total reflectance.

Colorimeter - measures the spectral characteristics of material and light.

Samples of paints and other surface materials used or to be used on the Shuttle and on the Space Station have been measured for color and reflectance.

The values are then associated with computer generated models of the Shuttle and Space Station.



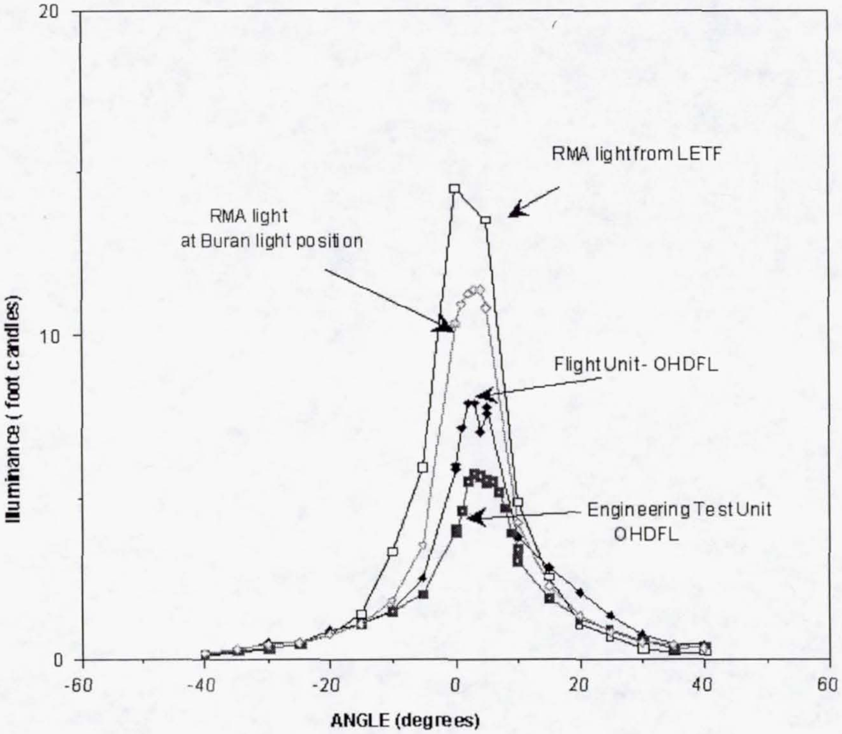
Measurement of Luminaire Performance

beam spread distribution and intensity.

Tools

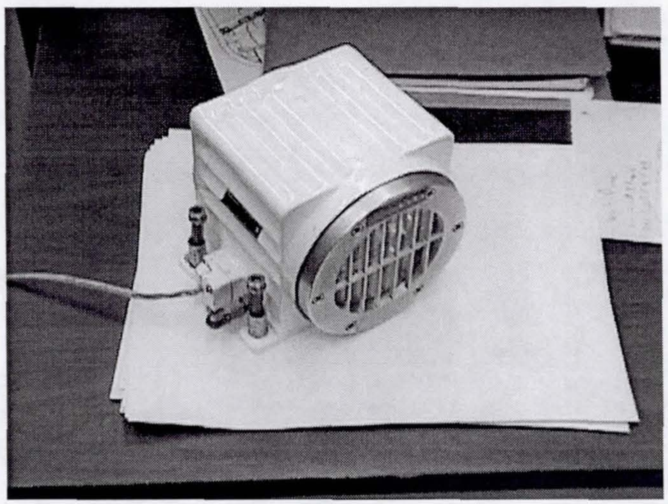
Illuminance Meter - measures light from luminaire

Colorimeter - measures the color of the light



General purpose light (RMA Light) is flown on the shuttle. It is also used on Space Station

Beam spread distribution and intensity for multiple types of RMA lights.



Computer Modeling of Illumination

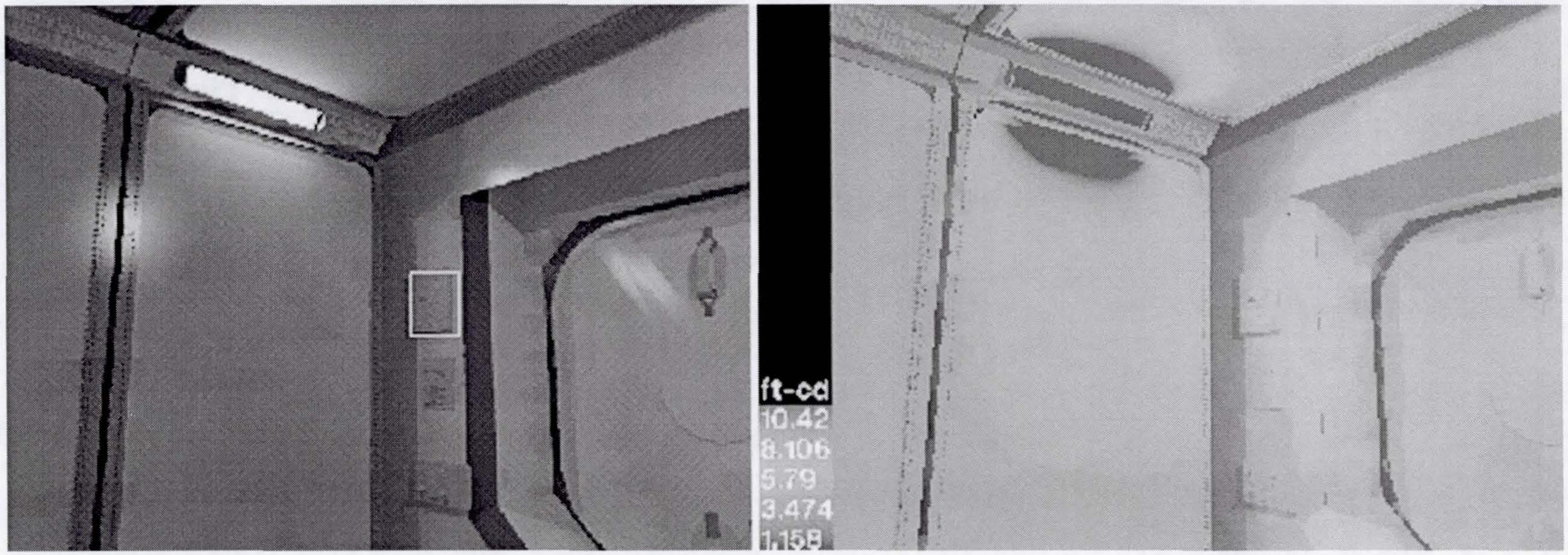
Computer modeling of illumination permits predictions of light and camera performance for a wide variety of configurations. This permits optimization of light and camera selection pre-flight.

Tools

PLAID - in house computer model system.
Integrates lighting, material specifications and model configurations for input to Radiance.

Radiance - public domain software package. Receives model configurations with lights and materials and performs lighting computations on this geometry.

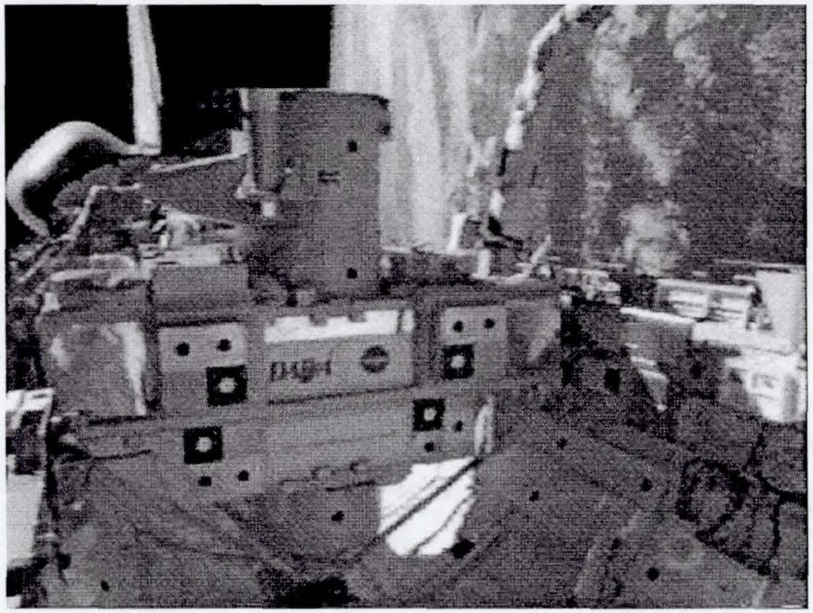
ISS Node 2 Interior. Example of predicting performance.
What is illumination on ATU panel (see white box)?



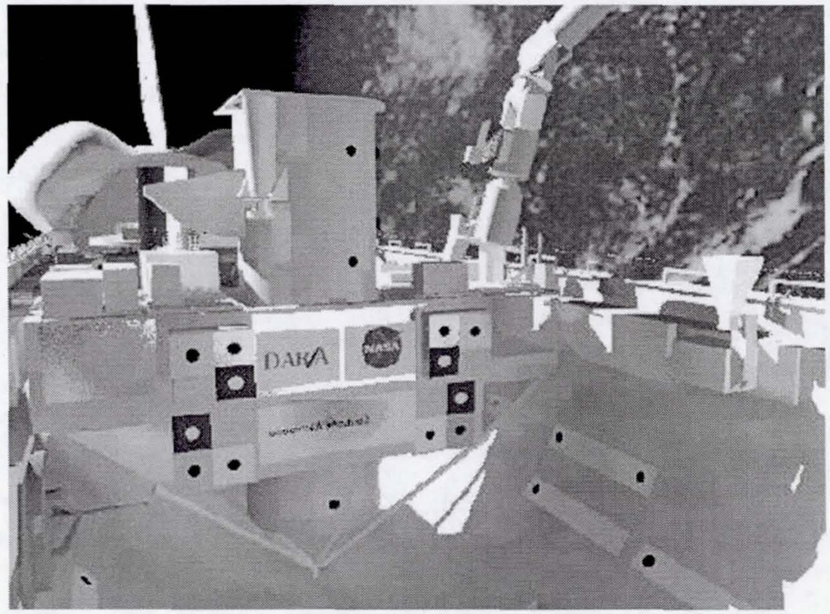
Condition: 2 Fluorescent Lights at Full Bright
Model: Predicted Illuminance at ATU Panel: 5.8–8.1 ft-cd
Validation: Measured Illuminance at ATU Panel: 6.0-7.6 ft-cd

Example of system validation - predictions of shadowing and potential glare.

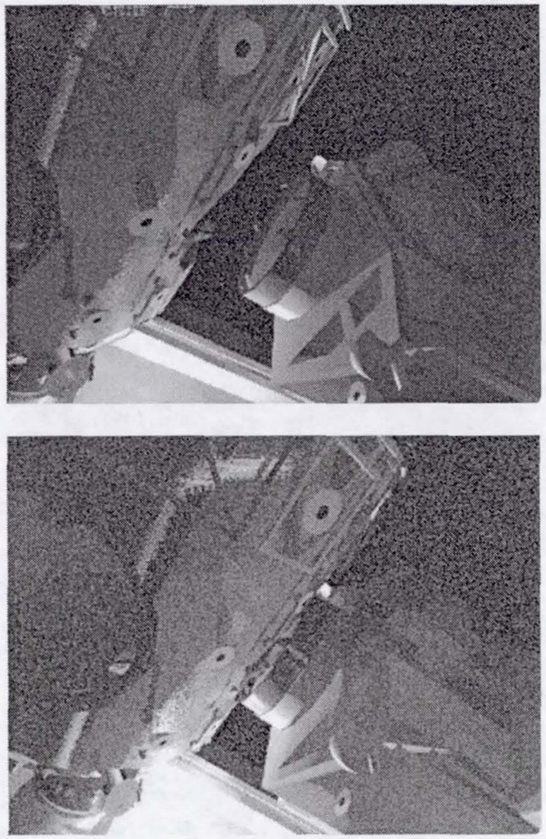
Actual - from downlinked video from STS-80



Predicted - computed 6 months prior to flight.



Flight 3A Night operations with CTVC-type RMS Elbow camera



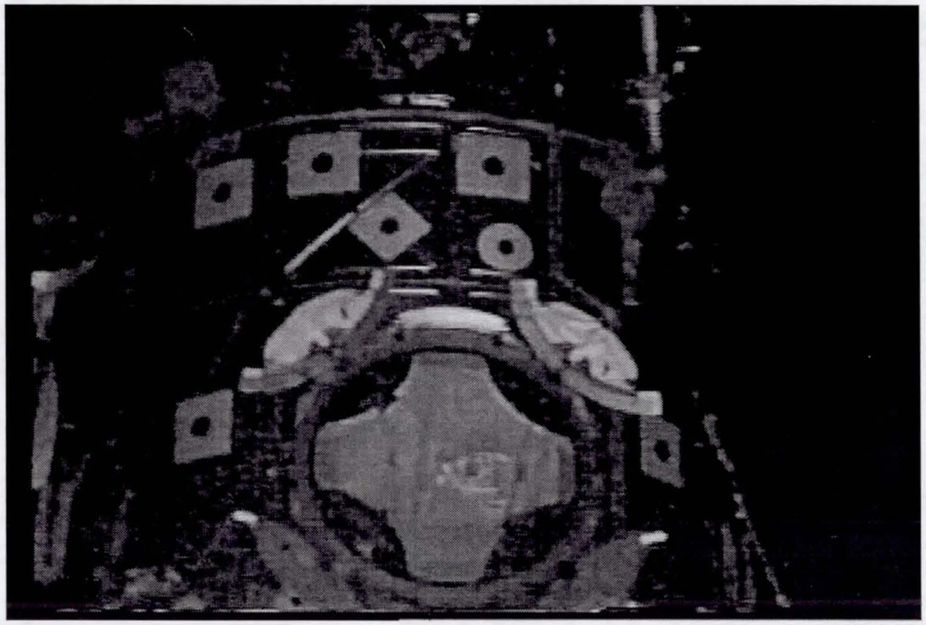
Post processed Radiance images modeling camera response.

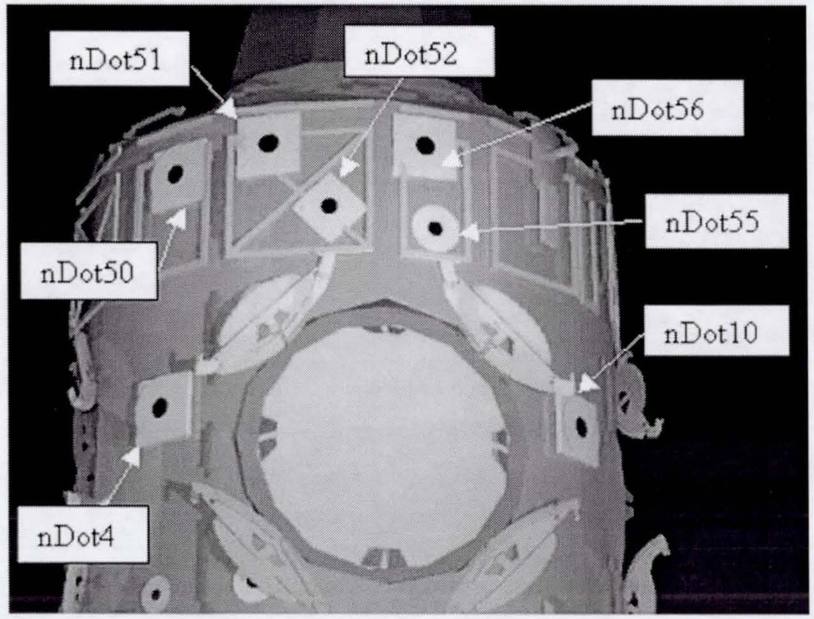
False colored Radiance images. When luminance falls below .28-.25 foot lamberts image quality becomes unacceptable for certain tracking operations.

An example of analysis to determine camera type based on predicted luminance values on targets

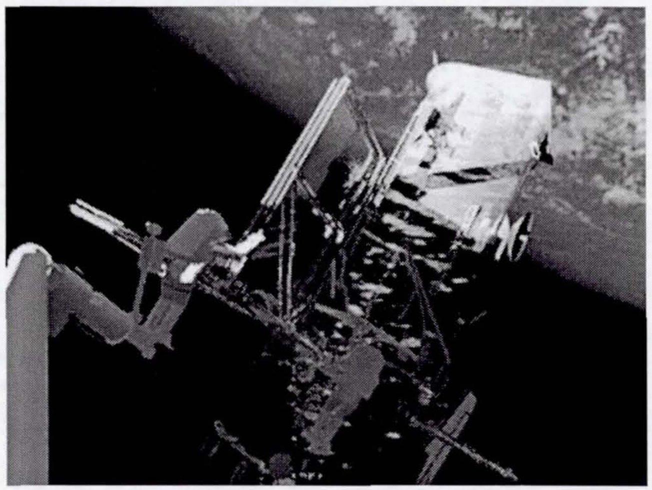
	Target Id	Predicted Min. Foot Lamberts	Shadow on target	Critical	Camera Choice
Node	nDot4	0.37	no	yes	ITVC, CTVC
Node	nDot50	0.30	no	yes	ITVC, CTVC
Node	nDot51	0.34	no	yes	ITVC, CTVC
Node	nDot52	0.49	no	yes	ITVC, CTVC
Node	nDot55	0.48	no	yes	ITVC, CTVC
Node	nDot56	0.39	no	yes	ITVC, CTVC
Node	nDot10	0.21	no	yes	ITVC

Night - Node 1 Target Array for Z1 Installation - LED Light from B, C, Keel (Xo = 715), and RMS Elbow Camera





Animation of an Extra-vehicular operation on the Hubble Telescope during day time.



Conclusions

An accurate modeling system has been developed and is actively used in space flight applications. Material reflectance properties, light and camera performance criteria and computer based models of the environment are the key components.

Improvements in the speed of data collection and computation are always needed. Integration of light modeling into computer aided design and virtual environments should become standard in the future.