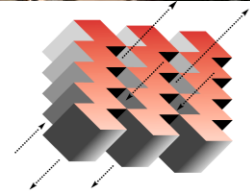


Experiences with Radiance in Daylighting Design

2nd Annual Radiance Conference
September 22-26, Berkeley, CA

Zack Rogers
Architectural Energy Corporation



ARCHITECTURAL ENERGY
CORPORATION
Integrated Engineered Solutions



Presentation Outline

- ❖ Company Overview
- ❖ Daylighting Design Project Experiences
- ❖ LightLouver Daylighting System
- ❖ Classroom Photosensor System Design Tool



Architectural Energy Corporation

- ❖ Diverse Sustainable Engineering Consultants
- ❖ 40 Employees Comprised primarily of Architects; Architectural, Mechanical, Electrical Engineers, and Computer Programmers
- ❖ Broken up into 6 different Business Area Teams
 - ❖ Building Science R & D
 - ❖ Commercial Kitchen Ventilation Lab
 - ❖ Hardware and Software Development
 - ❖ Utility and Energy Services
 - ❖ Commissioning
 - ❖ Sustainable Design Assistance

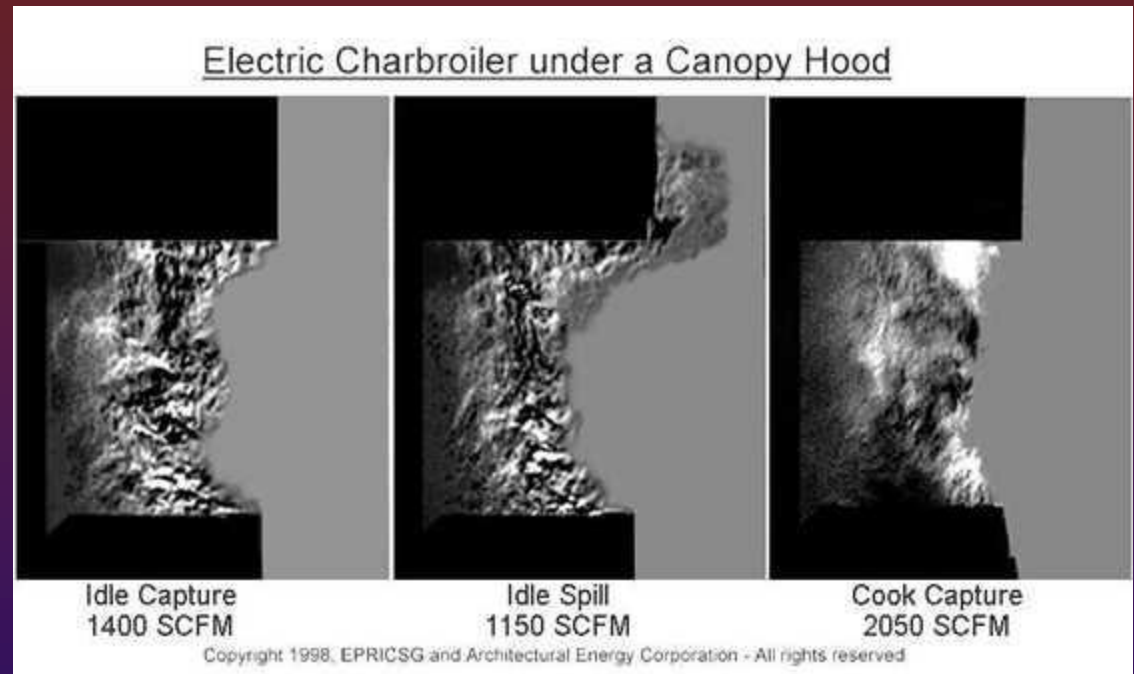


Building Science R & D

- ❖ Daylighting Productivity Studies
 - ❖ Retail (Wal-mart Studies)
 - ❖ Educational
- ❖ Daylighting Systems
- ❖ Energy Efficient Mechanical Systems
- ❖ Renewable Energy Systems
- ❖ Indoor Environmental Quality
- ❖ Foodservice Equipment

Commercial Kitchen Ventilation Lab

- ❖ Commercial exhaust hood effectiveness
- ❖ Building HVAC system impacts on exhaust hood effectiveness
 - ❖ Diffuser layout
 - ❖ Control Strategy
- ❖ Equipment Heat Gains to space
- ❖ Investigate Air Flow Patterns
- ❖ Kitchen Equipment and Hood Design





Hardware Development

- ❖ Micro Data Loggers
- ❖ WattWiser Monitoring System
- ❖ MicroDataNet Systems
- ❖ LightLouver™ Daylighting System (previously the Mini-Optical Lightshelf MOLS)





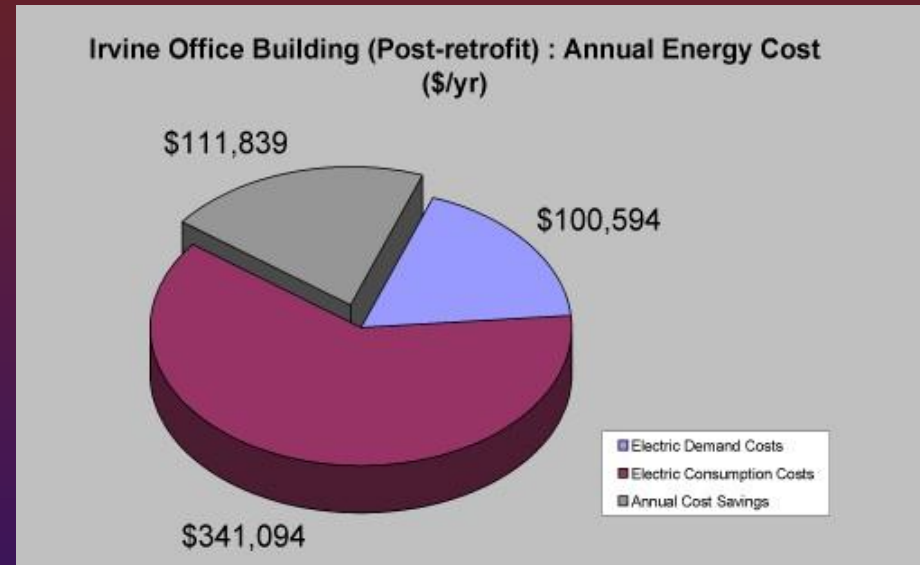
Software Development

- ❖ Enforma – Monitoring and Analysis Tools
- ❖ Data Manager – Interface for Data Loggers
- ❖ DG Pro – Distributed Generation Screening Tool
- ❖ REM/Rate – Home Energy Rating Software
- ❖ REM/Design – Home Energy Design Analysis



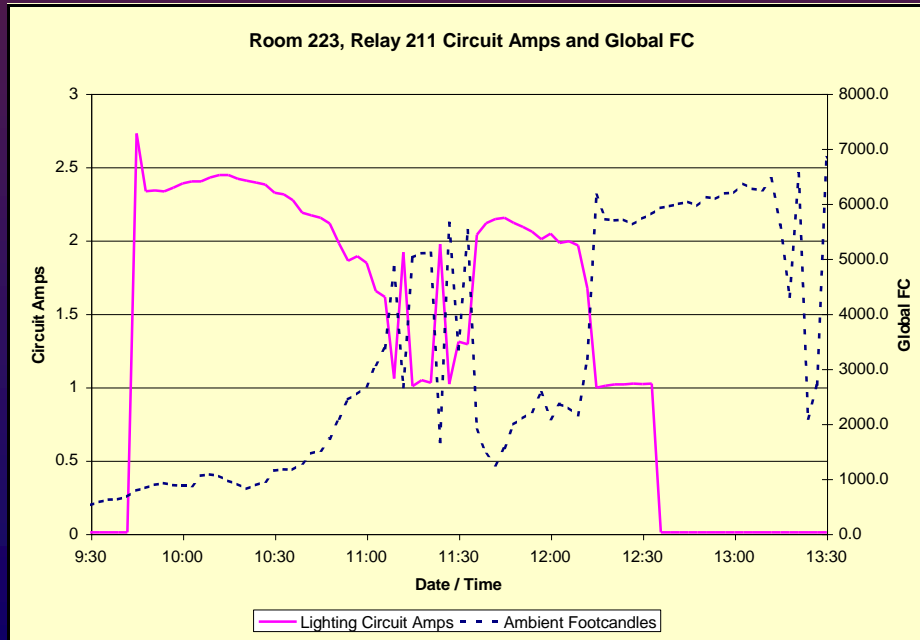
Utility and Energy Services

- ❖ Monitoring and Energy Baseline Services
- ❖ Operation and Maintenance Diagnostics
- ❖ Computer Energy Simulation Modeling for Existing Buildings
- ❖ Market Transformation Services and Documentation of Utility Programs
- ❖ Verification that Existing Energy Systems Function as Designed
- ❖ Short-Term Building Energy Monitoring with Micro Data Loggers



Building Systems Commissioning

- ❖ Verify Building Systems are functioning according to the design intent

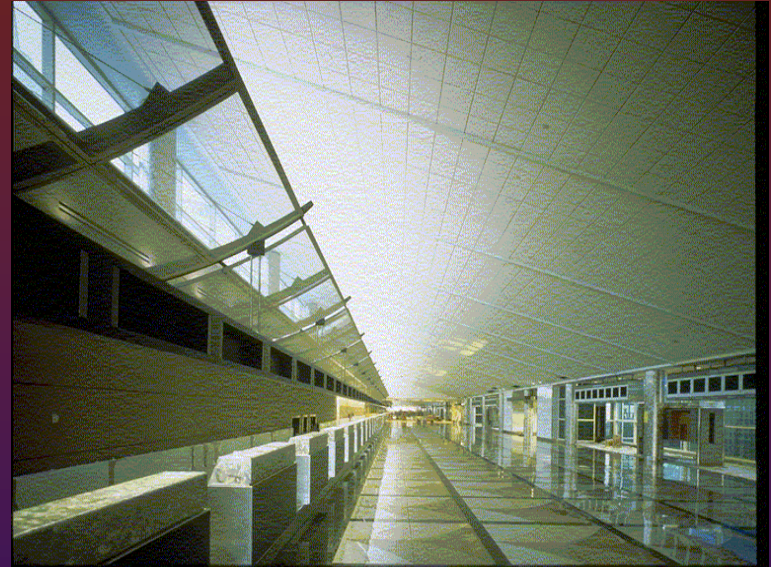


- ❖ Week long Performance Measurements
- ❖ Deficiency Report



Sustainable Design Assistance

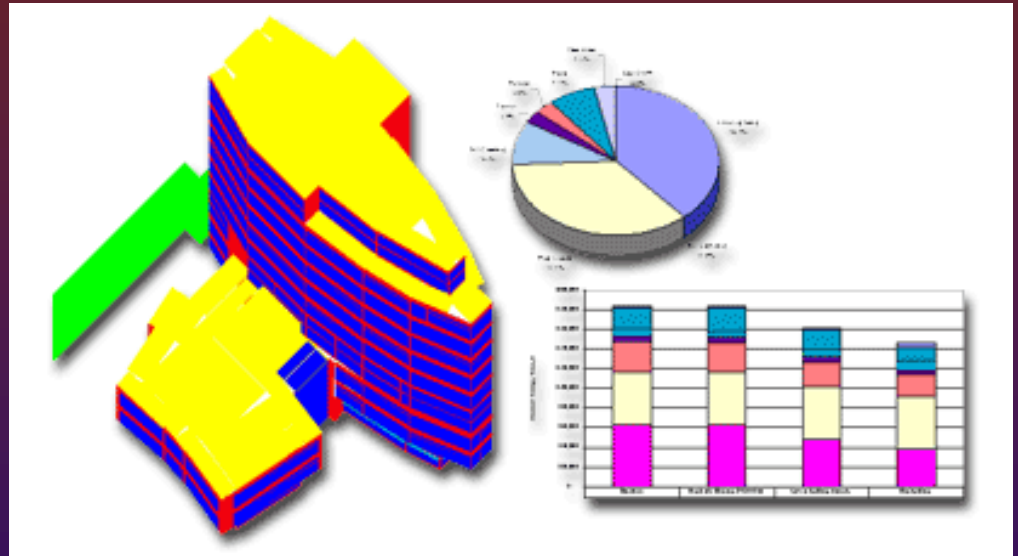
- ❖ DOE-2 Building Energy Modeling and Analysis
- ❖ LEED Certification
- ❖ Daylighting Modeling and Analysis
- ❖ CFD (natural and forced air flow) Modeling
- ❖ General Sustainable Design Consultation





DOE-2 Energy Analysis

- ❖ Create Baseline Building Model
- ❖ Determine Energy Use Characteristics
- ❖ Determine and Analyze cost-effective ECM's (Energy Conservation Measures)
- ❖ Predict Peak Loads and Annual Energy Use





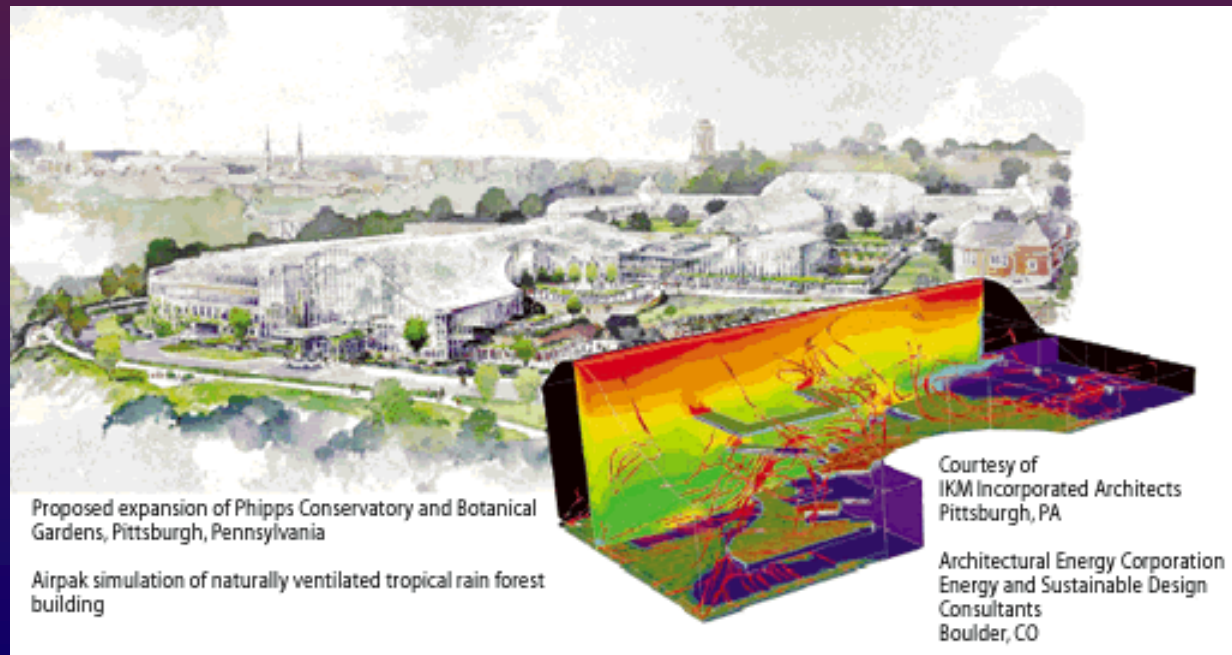
LEED Consultation

- ❖ Sustainable Building Rating / Certification Program
Developed by U.S. Green Building Council
- ❖ LEED attempts to establish what constitutes a sustainable building
- ❖ 7 prerequisite and 69 criteria in 6 categories;
 - ❖ Site
 - ❖ materials and resources
 - ❖ water efficiency
 - ❖ indoor environmental quality
 - ❖ energy and atmosphere
 - ❖ innovation and design process
- ❖ 4 levels of certification – certified, silver, gold, and platinum



CFD Modeling

- ❖ Natural and Forced Air Ventilation Modeling and Analysis
- ❖ Air Flow Velocities
- ❖ Surface Temps
- ❖ Air Flow Paths
- ❖ Ventilation Sizing
- ❖ Interior Air Stratification





Radiance in Daylighting Design

- ❖ Radiance has taken our Daylight Design consulting abilities to a new level
- ❖ Beauty of Radiance is that its completely limitless to what it can model - may not be the most user friendly but is completely capable
- ❖ Even with limited knowledge of the software, it is an extremely effective tool for analyzing the luminous environment
- ❖ Since it's essential a programming language - helps increase efficiencies by writing other scripts to automate Radiance simulations



Daylighting Design Process

- ❖ Exterior Shading and Solar Exposures
 - ❖ “Ranimate.py” python script
- ❖ Space Characteristics
 - ❖ Textures and Patterns
 - ❖ Image mapping and inserting objects
- ❖ Daylight Calculations
 - ❖ Rautomate python script
 - ❖ Excel Radiance import tool
 - ❖ Skylight Density Studies
 - ❖ Illuminance renderings and plots
 - ❖ Integration with IQCam for calibration
- ❖ Daylighting System Design
 - ❖ Integrated daylighting design
- ❖ Glazing Selection
 - ❖ Integration with Optics 5
- ❖ Electric Lighting Integration
 - ❖ Integration with DOE2
 - ❖ Photosensor Correlation Studies
- ❖ Space Renderings
 - ❖ Panoramic animations

Other Daylighting Modeling Techniques



Fort Collins Office Building,
Fort Collins, CO



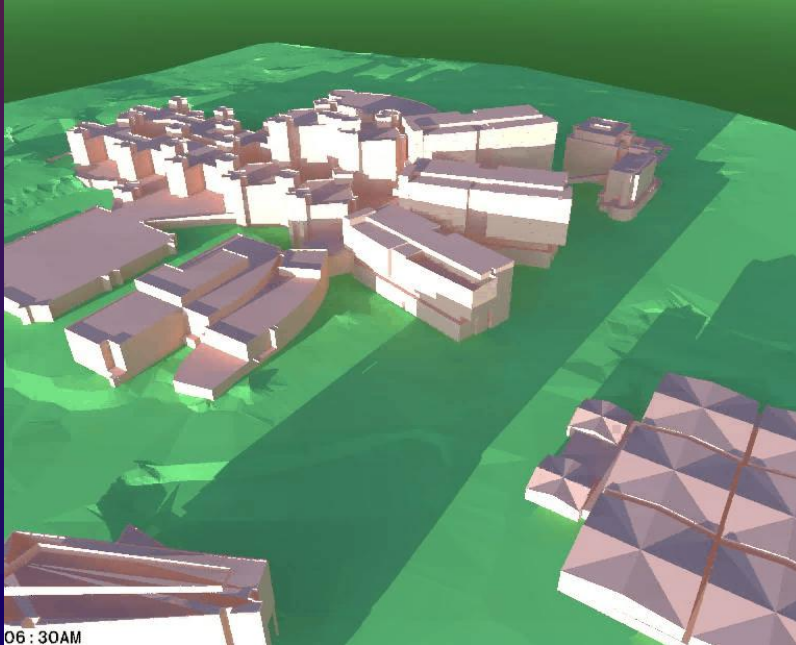
University of Wisconsin, Green Bay, WI



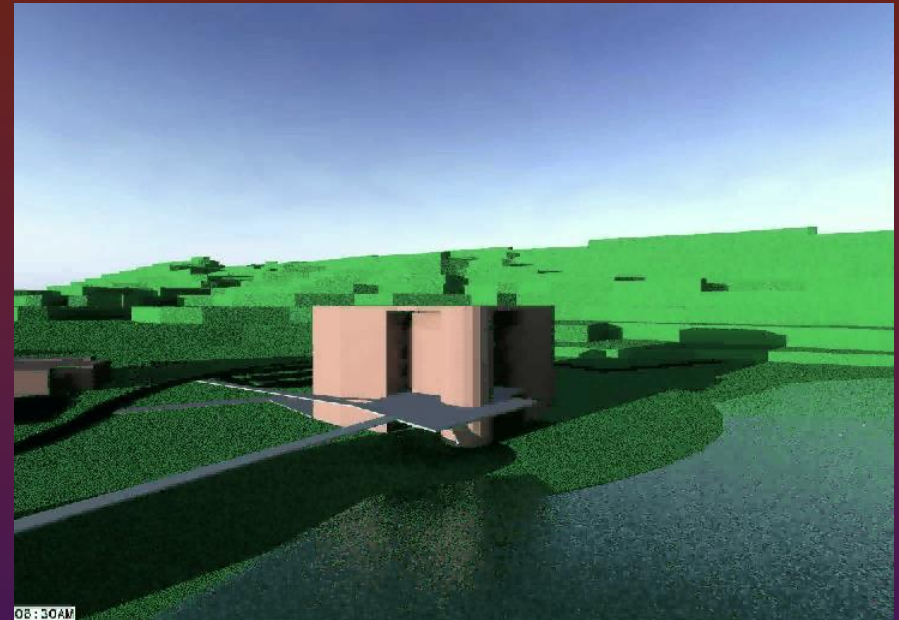
Center for Technology Learning Media
School of Mines, Golden, CO

Exterior Shading and Solar Exposure

- ❖ Exterior animations clearly illustrate;
 - ❖ Extent of shading from surrounding structures and landscape
 - ❖ Daylight resource availability on various facades



Univ. of Wisconsin Healthstar Building, Madison, WI

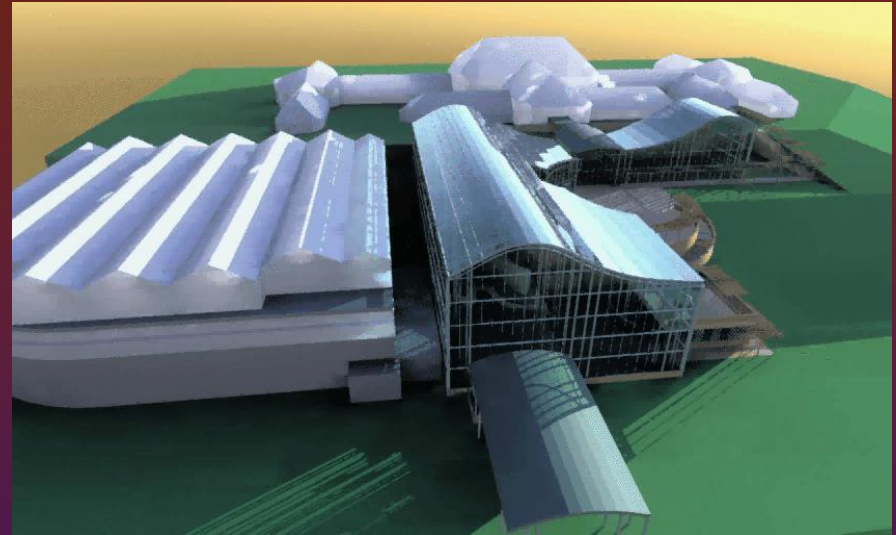


New CDC Laboratories, Fort Collins, CO

- ❖ Exterior animations are helpful during the conceptual design to;
 - ❖ Compare alternative building footprints and orientations
 - ❖ Determining potential daylighting design strategies

Interior Shading and Solar Penetration

- ❖ Interior animations are used throughout design process and help;
 - ❖ Illustrate interior sunlight penetration due to exterior objects and fenestration treatment
 - ❖ Visualize location and duration of direct sunlight – important for plant placement and glare control



Phipps Conservatory, Pittsburgh, PA



Victor Valley College, Victorville, CA

Interior Shading and Solar Penetration

- ❖ Upper Canopy and Under-story level of plants shade floor level plants
- ❖ Animation to help determine locations for floor level plants – ie areas with least shading



Exterior Shading Device Design and Analysis

- ❖ Animations created in Python program “`ranimate.py`”
 - ❖ Takes .rif file as input
 - ❖ Produces sets of images that get animated with Quicktime



Dunstan Middle School, Lakewood, CO



Tricon (Tacobell, KFC, Pizza Hut) Shading Studies

Space Characteristics – Model calibration

- ❖ IQCam and digital images used to calibrate base case
- ❖ Then Radiance is used to illustrate relative improvements in glare conditions
- ❖ Illustrated with Radiance that glare and underwater visibility related to vertical to horizontal illuminance ratio – the greater the ratio the better
- ❖ Polarizing film in Radiance? ...Holographic films?



Chilson Rec Center, Loveland, CO

Space Characteristics

- ❖ Limited opportunities to embellish models with detail in our daylighting design consulting
- ❖ Image mapping for background Washington Mall and Logo on wall
- ❖ 3D objects (chessboard, IMac etc.) imported from 3D studio

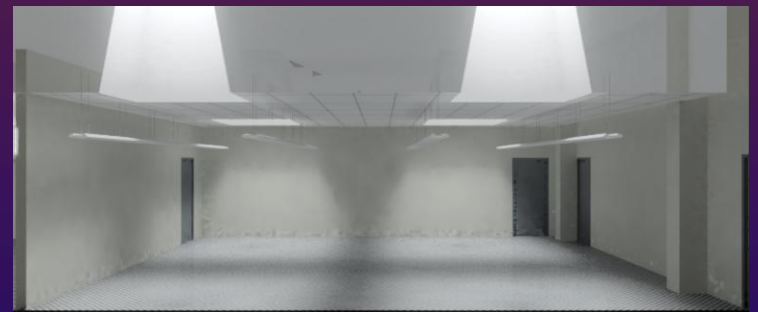
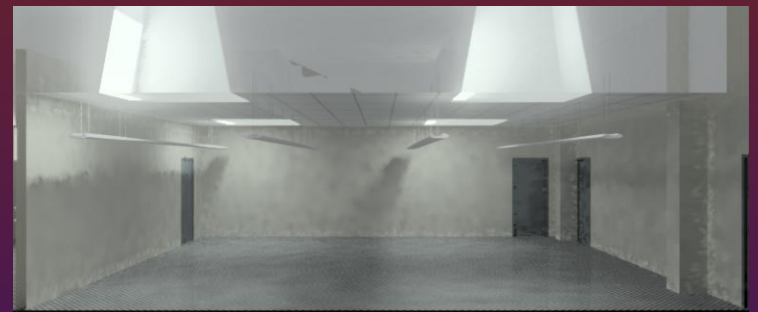


Space Characteristics

- ❖ Typically Radiance models contain minimal details since;
 - ❖ They are meant to just show the daylight distribution in the space
 - ❖ Multiple daylighting design alternatives are often explored

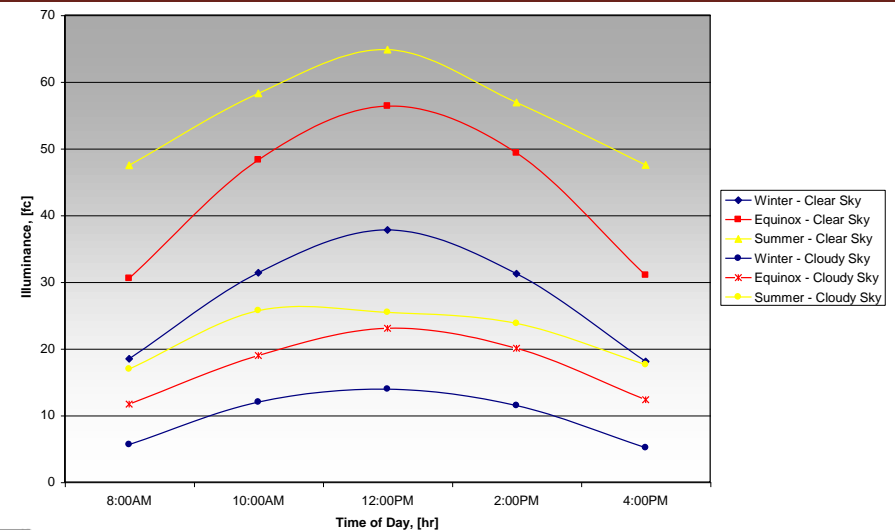


Cuyamaca Community College, San Diego, CA



Daylight Calculations – Output Processor

- ❖ Allows for different zones of data to be selected for summary tables

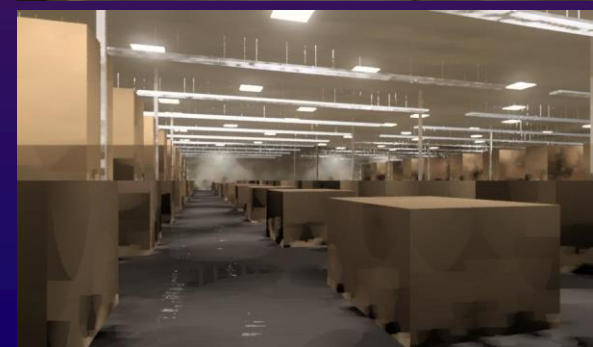
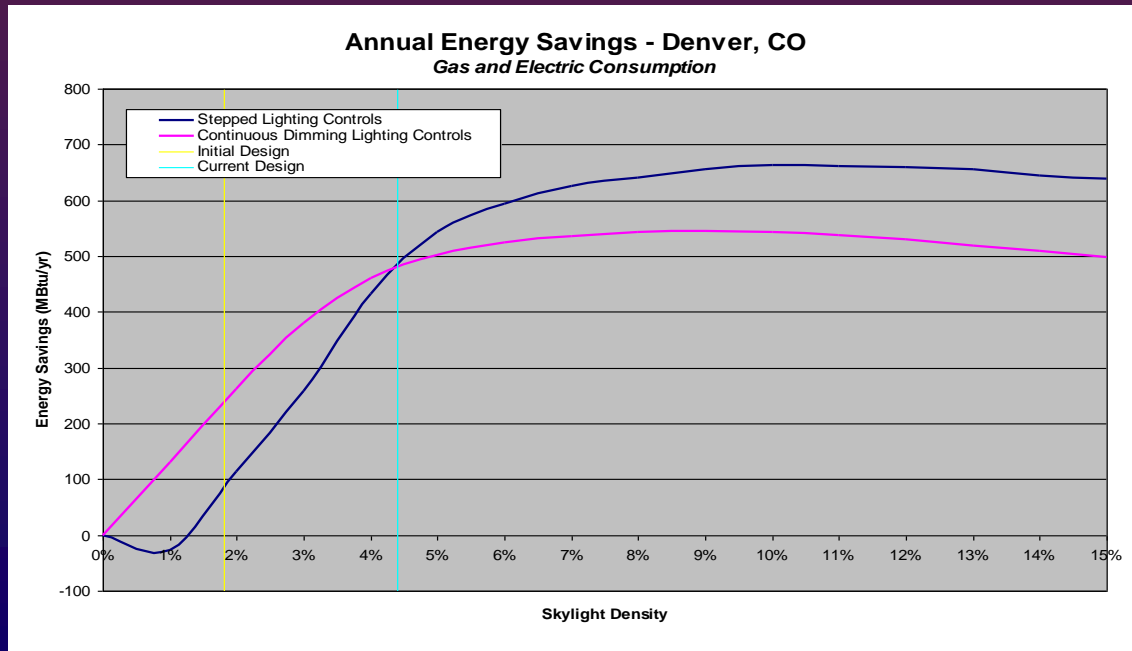


		Clear Sky					Cloudy Sky				
		SE Zone	SW Zone	NE Zone	NW Zone	All Zones	SE Zone	SW Zone	NE Zone	NW Zone	All Zones
Winter	8:00AM	16	16	18	23	18	4	5	7	6	6
	10:00AM	32	31	35	27	31	9	9	18	12	12
	12:00PM	40	39	39	33	38	10	10	22	13	14
	2:00PM	34	32	33	27	31	8	9	17	11	11
	4:00PM	18	13	26	15	18	4	4	7	5	5
	Average	28	26	30	25	27	7	7	14	10	10
Equinox	8:00AM	29	26	42	25	31	9	8	19	11	12
	10:00AM	50	47	57	39	48	13	13	31	19	19
	12:00PM	60	60	63	44	56	16	16	38	22	23
	2:00PM	50	51	57	40	49	14	14	32	19	20
	4:00PM	28	29	39	28	31	9	9	18	12	12
	Average	43	43	51	35	43	12	12	28	17	17
Summer	8:00AM	39	36	72	43	47	12	12	26	17	17
	10:00AM	49	46	88	50	58	18	17	43	25	26
	12:00PM	55	56	91	57	65	18	18	42	24	25
	2:00PM	45	47	82	53	57	16	17	38	23	24
	4:00PM	38	37	69	46	48	13	13	27	18	18
	Average	45	44	80	50	55	16	15	35	21	22
Annual Average		40	39	53	36	42	12	12	26	16	16

- ❖ Eases assembly of average, max and min zone illuminance data
- ❖ Point calculations (photosensor) can be integrated into field calculation results

Daylight Calculations - Parametric Studies

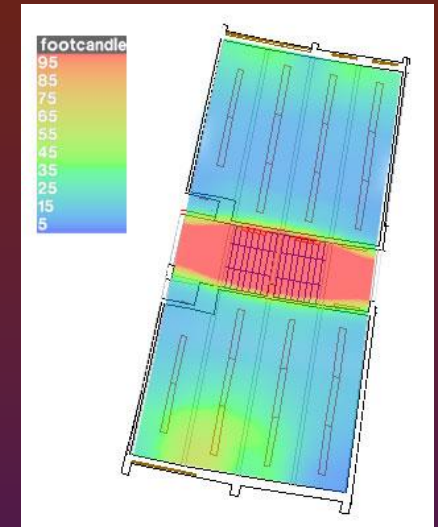
- ❖ Skylight density (SFR) study for Sam's Club Prototype
- ❖ Calibrate Radiance and DOE-2 models with measured data
- ❖ Used both models to analyze range of SFR and determine optimum



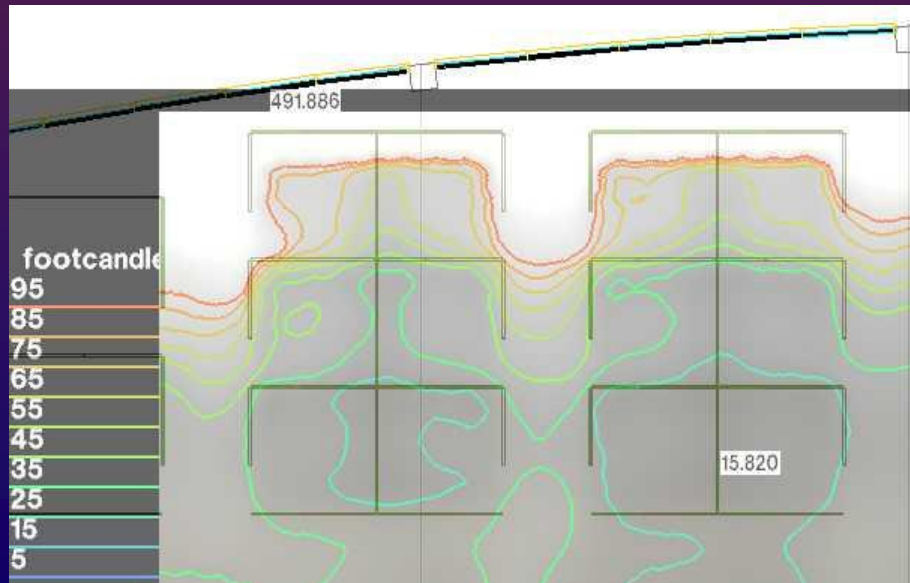
Sam's Club Prototype Studies

Daylight Calculations - Illuminance Plots

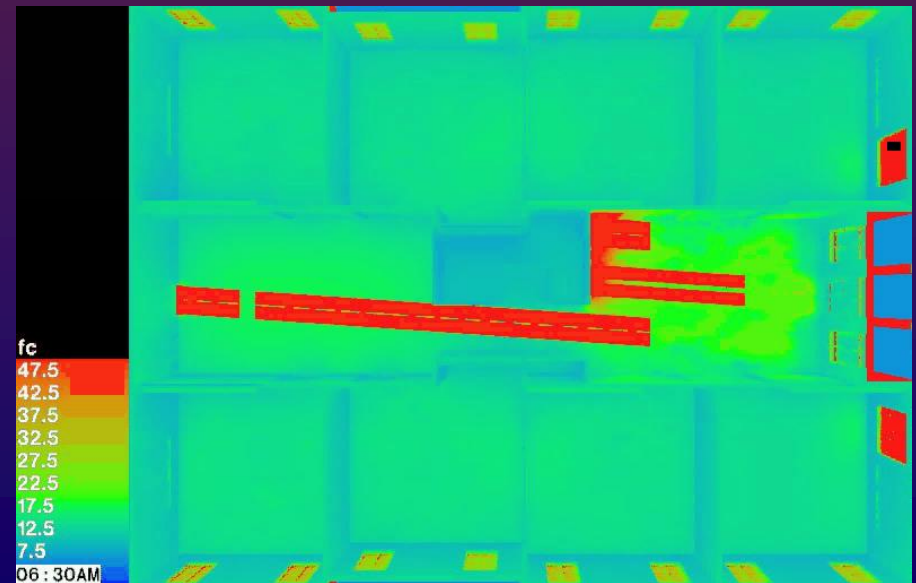
- ❖ Visual representation of daylight illuminance helps clarify lighting level to client, either by;
 - ❖ Overlaying Radiance illuminance plots onto floor plans
 - ❖ Rendering with -i Irradiance option



Aspen High School, Aspen, CO



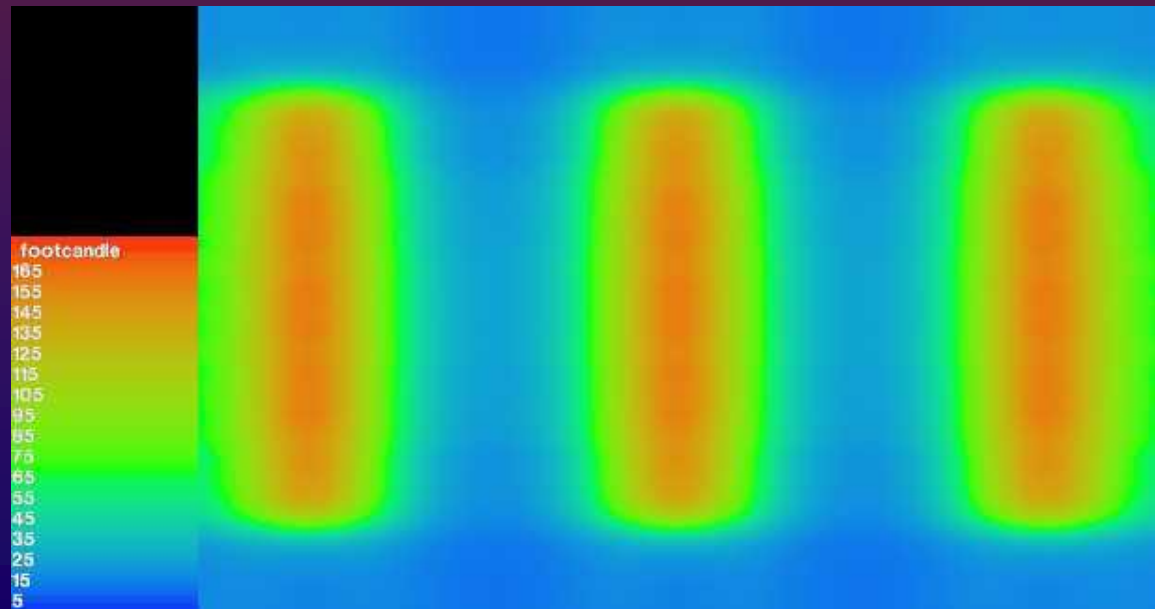
Olde National Bank, Evansville, IN



Elementary #30 Prototype School, Denver, CO

Daylighting Calculations - Ceiling Gradients

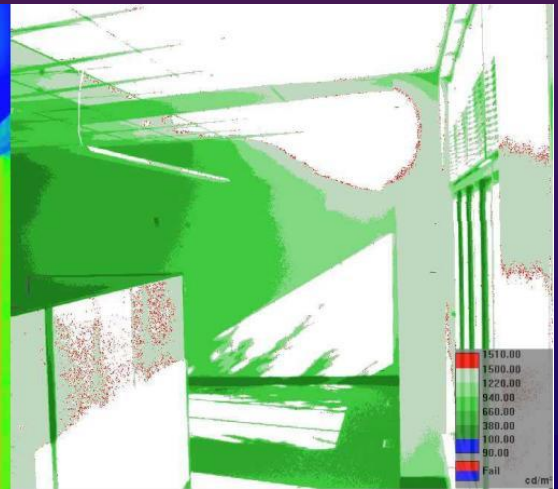
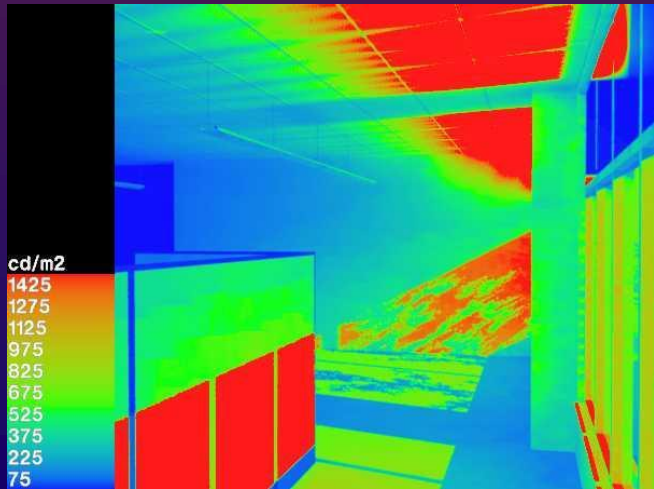
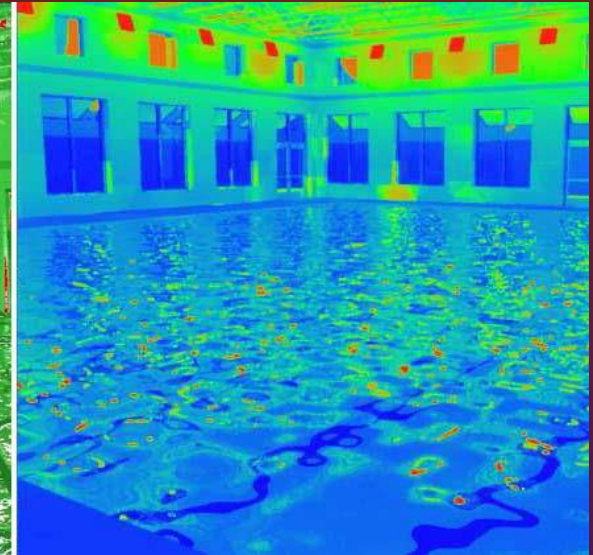
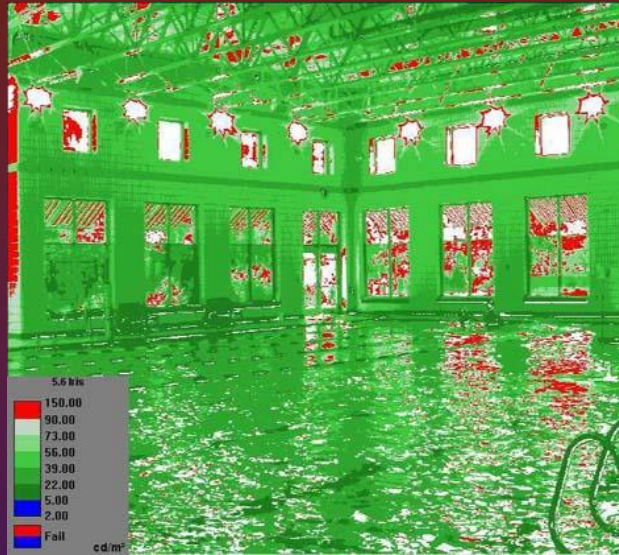
- ❖ Indirect and direct ambient lighting studies
- ❖ Ceiling illuminance gradients
- ❖ Determine acceptable spacing and suspension heights



Generic Open Office Model

Daylight Calculations - IQ Cam

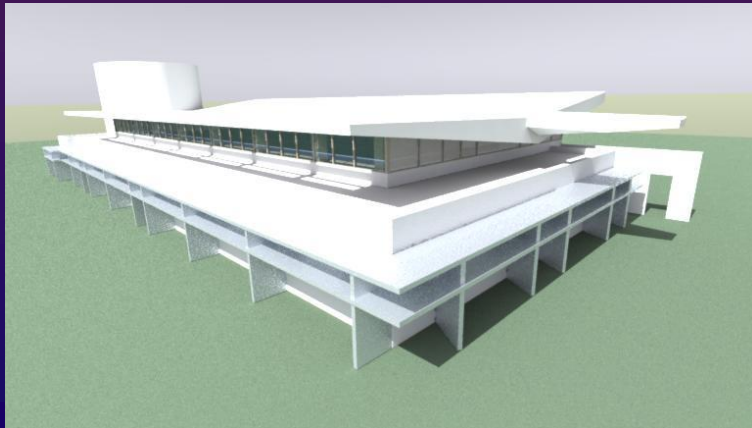
- ❖ Digital Camera Device that measures Luminance throughout a scene
- ❖ Images used to help calibrate Radiance models





Daylighting System Design

- ❖ Best Daylighting Designs are ones that integrate well with the architecture
- ❖ Radiance used to optimize daylight distribution

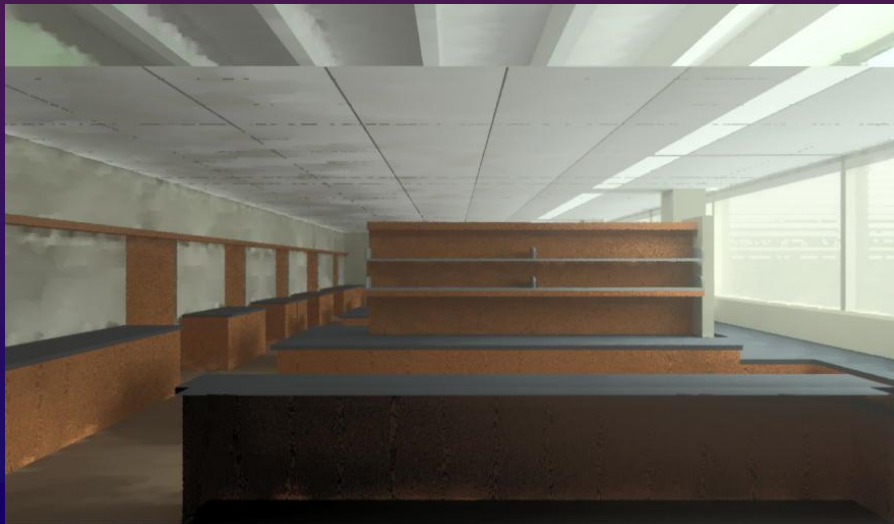


NREL Science & Technology Facility, Golden, CO



Daylighting Design

- ❖ Examples of other integrated daylighting solutions
- ❖ Daylight plenum concepts
- ❖ Solutions that provide direct sunlight control for sensitive interior environments



CDC and Univ. Wisc. Lab Studies



CDC Building 18, Schematic Design, Atlanta, GA



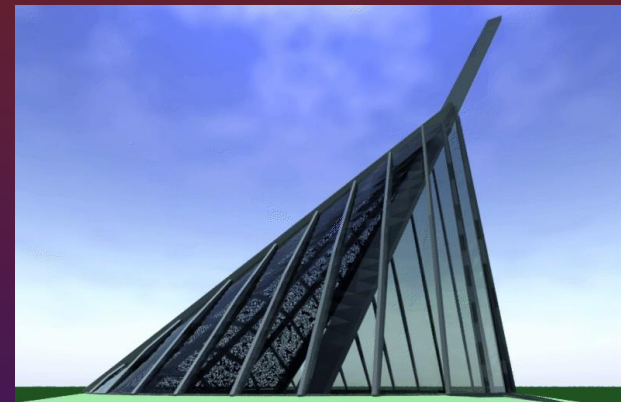
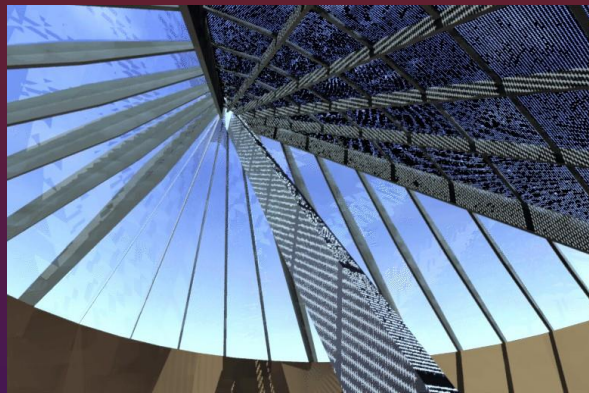
Glazing Selection

- ❖ Optics 5 glazing analysis and database software used to define glazings in Radiance
- ❖ Illustrates to client color blending of Daylight and Electric Light
- ❖ Viracon clear glass on top - Azurblue tint on bottom
- ❖ Azurblue seems to create an overly blue hue to the space

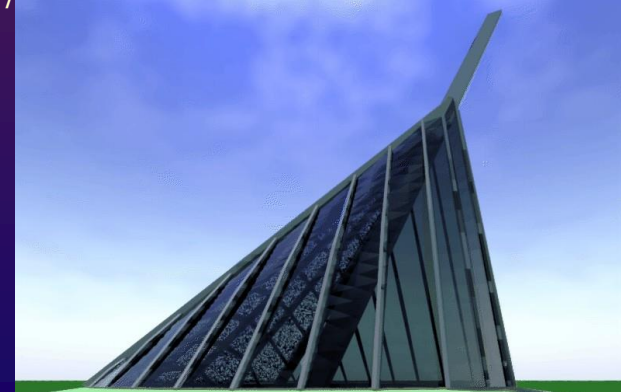
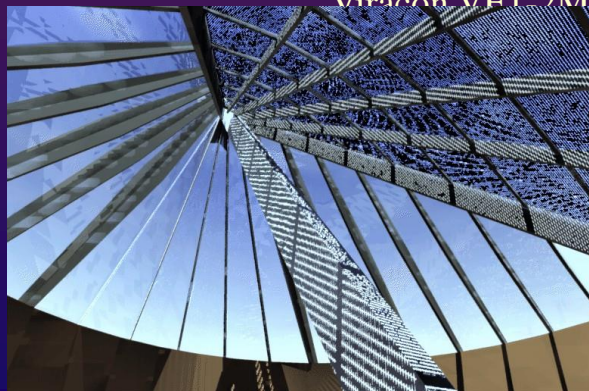


Glazing Modeling and Analysis

- ❖ Balance between spire transparency from exterior, interior brightness, and solar gains
- ❖ Integrated BiPV glass modeled for Spire “roof”
- ❖ Solar radiation analysis both interior and exterior
- ❖ Orientation Studies



Viracon VE1-2M 70% Tvis Glass



Viracon VE1-40 36% Tvis Glass

Electric Lighting Integration

- ❖ Purely electric light modeling rare
- ❖ Daylighting calculation informs the location of electric lights and control zones
- ❖ Previously have manually dimmed lights - assumes a perfect photosensor control system
- ❖ Use of Daydim and psens on radar for future analyses



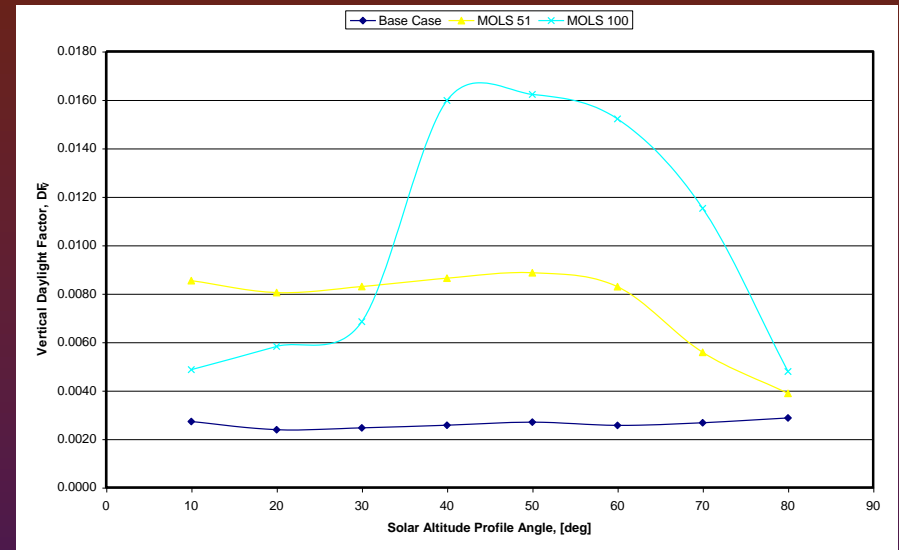
Old National Bank - Lighting Control Zones, Evansville, IN



Rags to Riches Lighting Design Alternative, Boulder, CO

Electric Lighting Integration – DOE2

- ❖ Use Radiance to produce DOE-2 daylight functions
 - ❖ DOE-2 Functions based on concept of Vertical Daylight Factor DF_v
 - ❖ DOE-2 weather data provides illuminance and sunangles
 - ❖ Function determines workplane illuminance
 - ❖ Function based on photosensor signal or “ideal” average workplane

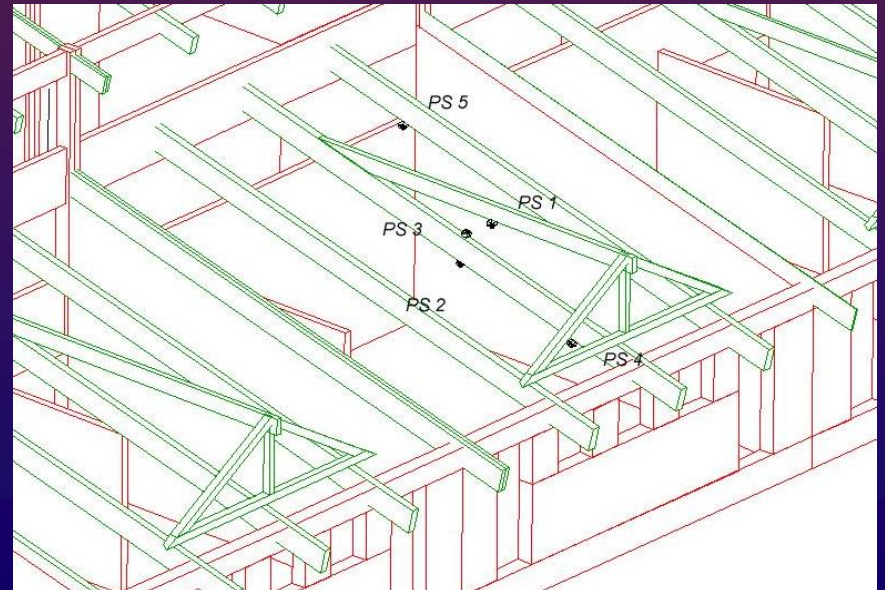
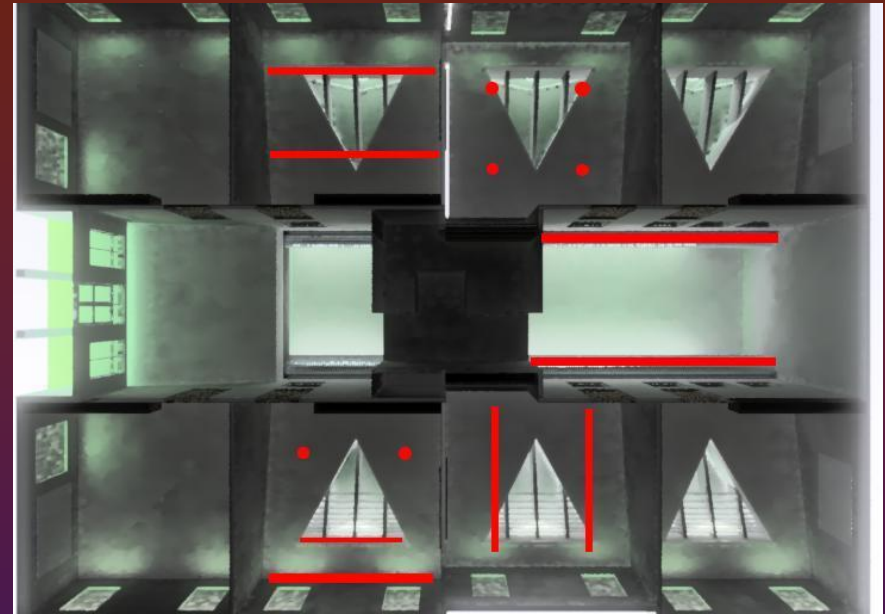


DF_v vs. Altitude Profile Angle, LightLouver 51 & 100



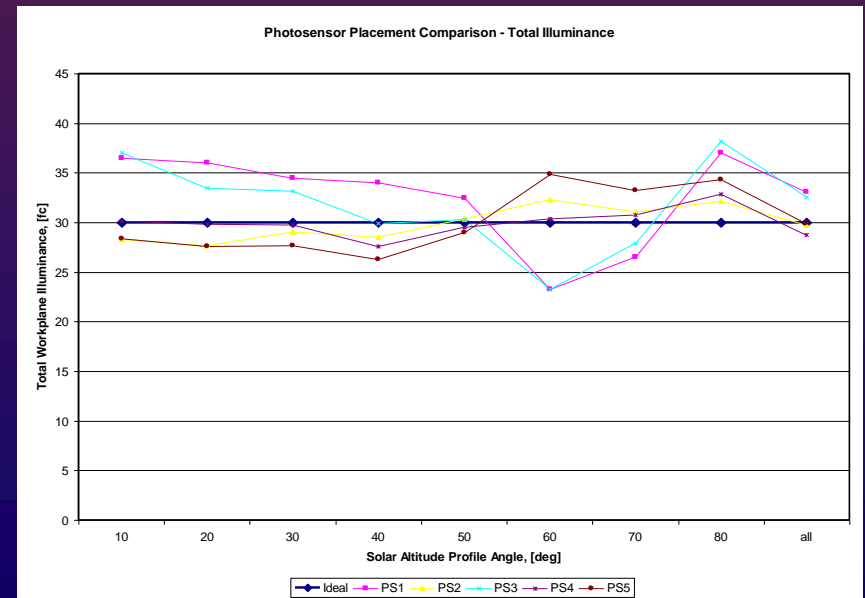
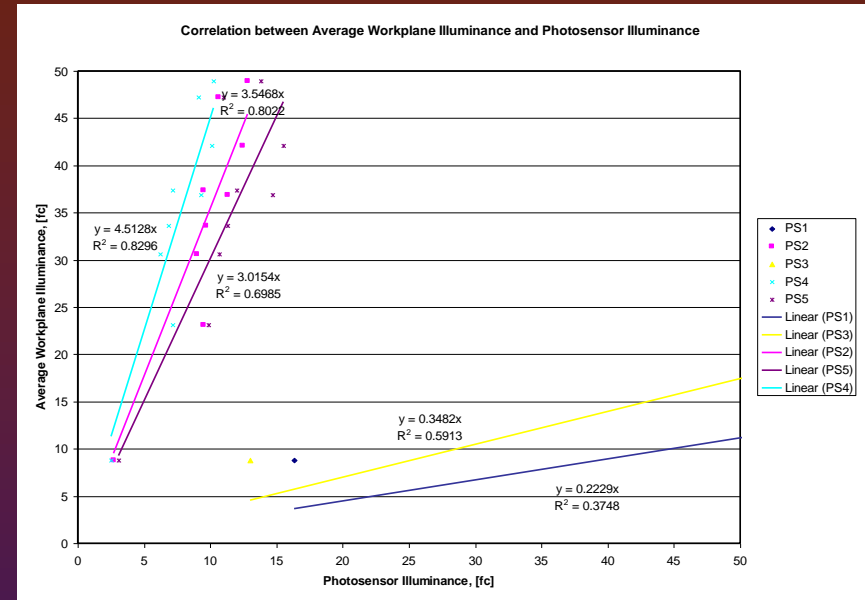
Electric Lighting Integration – Photosensor Placement Studies

- ❖ Photosensor placement studies to determine best correlation between photosensor illuminance and average zone illuminance
- ❖ Control zones determined by electric lighting layout and available daylight



Electric Lighting Integration – Photosensor Placement Studies

- ❖ Photosensor correlations rarely exceed an R^2 of 0.85
- ❖ Resulting daylight and electric light average illuminance fluctuates - giving 30fc +/- 7fc
- ❖ Spot illuminance can fluctuate even more
- ❖ Calibration of system to critical point (worst case condition) helps ensure minimum illuminances are met but reduces energy savings - important so system does not get overrode



Space Renderings

- ❖ Calibrations with digital photographs
- ❖ Followup with measurements and photographs to verify Radiance predictions



Chilson Rec Center, Loveland, CO



Aspen High School, Aspen, CO



Xilinx, Longmont, CO



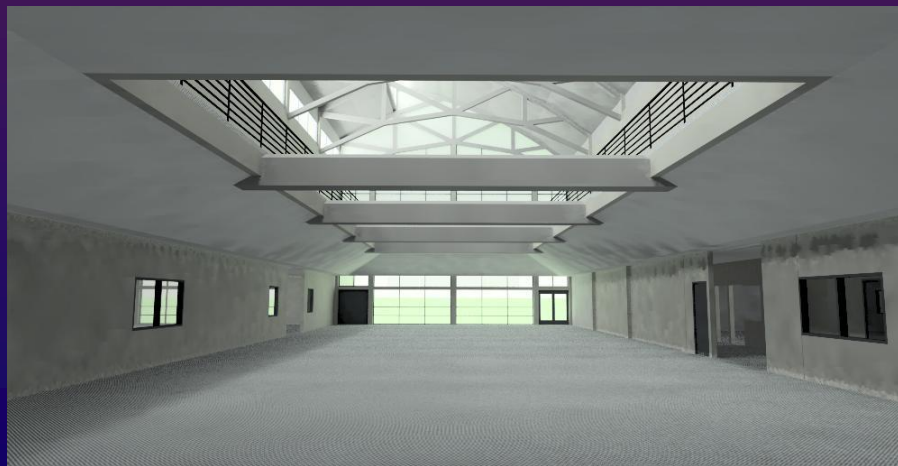
Space Renderings



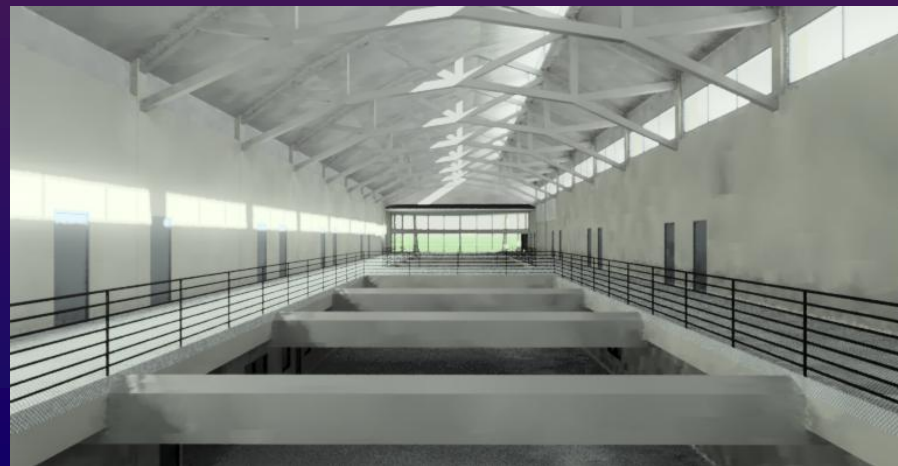
New CDC Laboratories, Fort Collins, CO



Phipps Welcome Center, Pittsburg, PA



Cuyamaca Community College, El Cajon, CA



Space Renderings

- ❖ Panoramic animations effective in illustrating the design to client



Phipps Conservatory, Pittsburgh, PA



Shumei International Institute - Sanctuary, Design Alternative, Crestone, CO



LightLouver™ Daylighting System

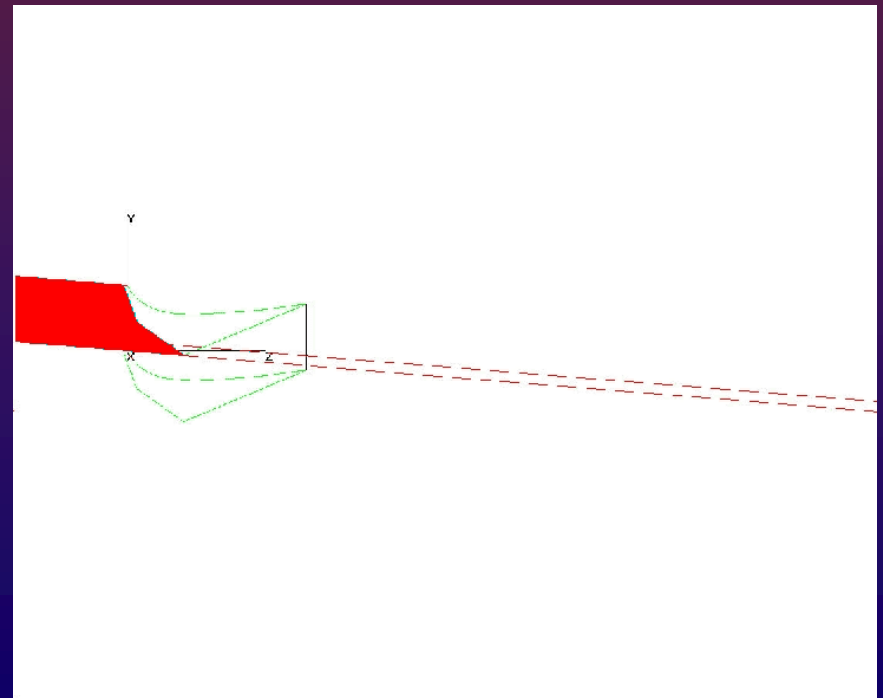
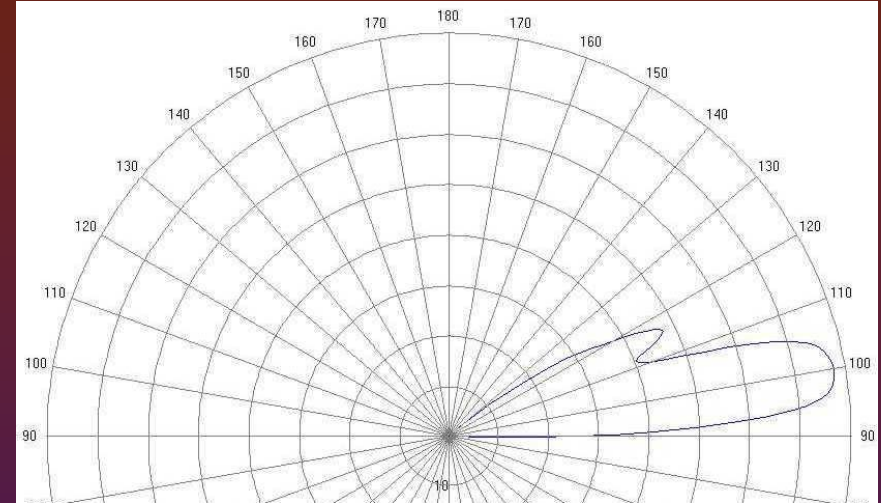
- ❖ Located in daylight window, above 7' AFF, and mounted to mullions
- ❖ Accepts range of sun angles and redirects daylight to ceiling plane
- ❖ Pivots from window for cleaning
- ❖ Provides complete direct sunlight control
- ❖ 1 vertical foot of unit provides adequate ambient lighting (30fc) for 12 foot zone





LightLouver™ Daylighting System

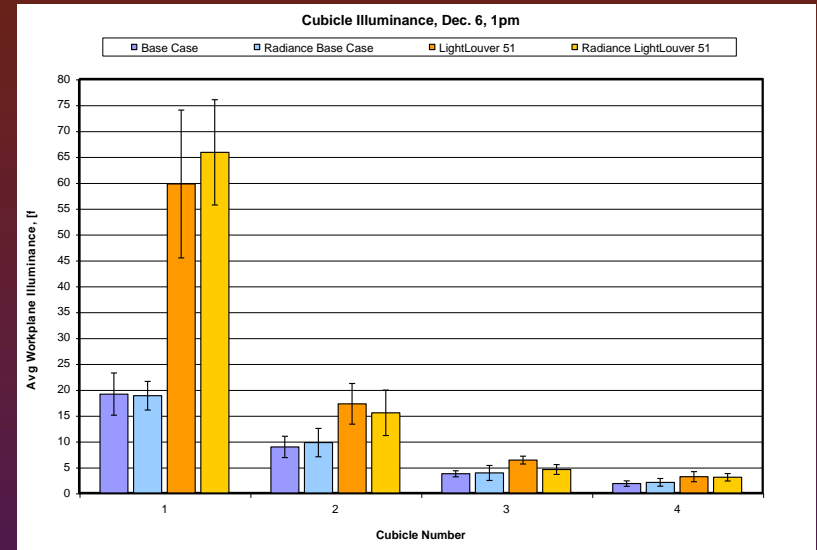
- ❖ Designed with TracePro Forward Raytracing software
- ❖ Upper image – Candela Plot for all sun angles
- ❖ Animation – Visual representation of Sunlight Rays for range of Altitude Profile Angles



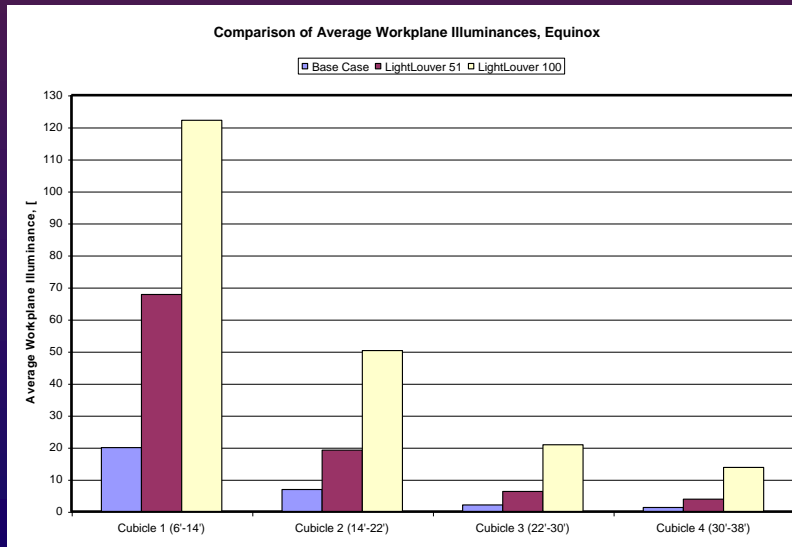


LightLouver™ Daylighting System

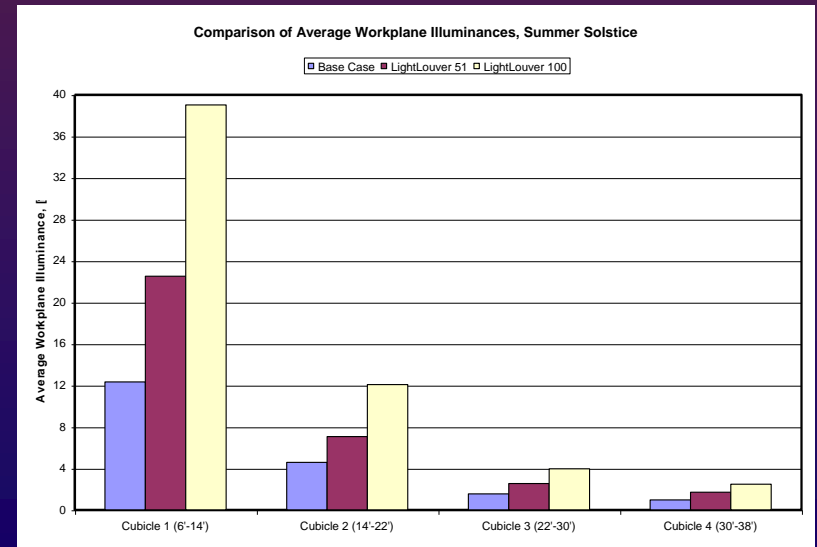
- ❖ Numerical verification of accuracy of Radiance predictions
- ❖ Extrapolate from calibrated model to predict performance at other times throughout the year



Measurements vs. Radiance



LightLouver 51 and 100 performance, Equinox



LightLouver 51 and 100 performance, Summer



LightLouver™ Daylighting System

- ❖ Prototype relocatable classroom design
- ❖ Previously, IES files created to describe LightLouver distributions for Radiance models
- ❖ Raydirect now used to interactively model LightLouver



Relocatable Classroom Prototype



LightLouver™ Daylighting System

- ❖ Customer Technology Application Center (CTAC) showcases energy efficient technology
- ❖ LightLouver showcased in demonstration classroom
- ❖ Less than ideal application but illustrates its effectiveness as a cost effective solar control device if nothing else





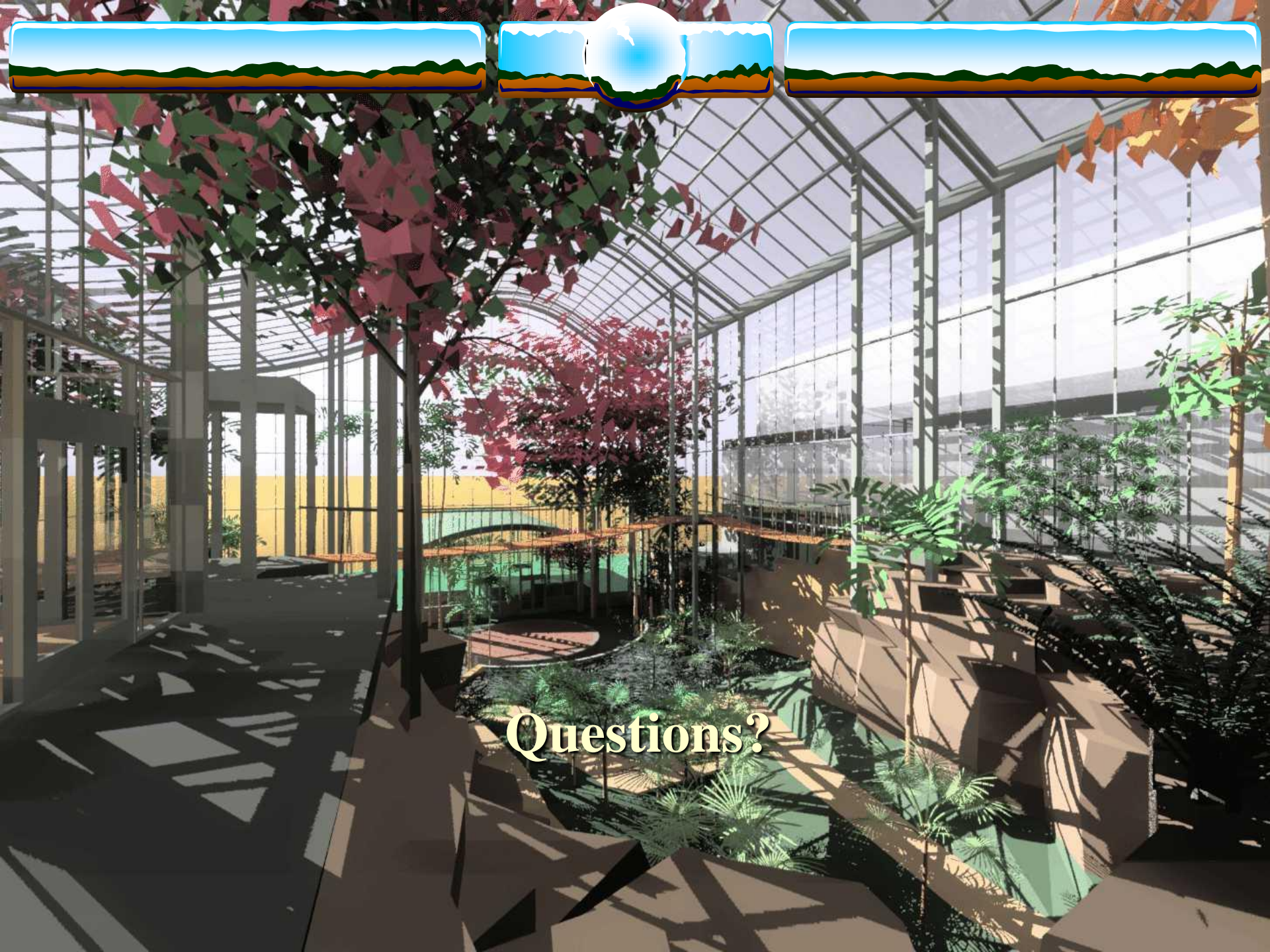
Classroom Photosensor System Design Tool

- ❖ Public Interest Energy Research PIER Lighting Program funding various lighting energy efficient technologies
- ❖ AEC is responsible for making design tools for the most applicable technologies
- ❖ Classroom photosensor system top technology for tool development - research being performed by Prof. Mistrick at Penn State Univ.



Classroom Photosensor System Design Tool

- ❖ Prof. Mistrick study uses Radiance to analyze multiple photosensor types, classroom sizes, daylighting systems, zoning layouts, and photosensor placements
- ❖ Daydim and psens used for these studies
- ❖ Public design tool will essential create a simple user interface to help design and analyze various photosensor systems and layouts
- ❖ Hopefully tool will help create more successful Photosensor control system designs



Questions?