Experiences with Radiance in Daylighting Design, Part VI

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DAYLIGHTING INNOVATIONS

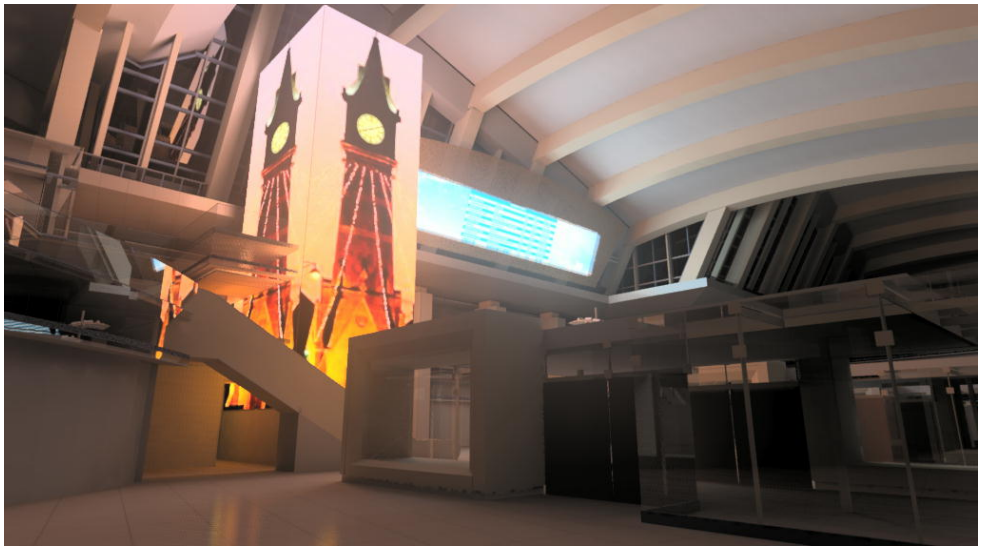
Presentation Outline

- Project Examples
  - LAX Bradley West Terminal
  - Solar Reflection Renovation
  - Leadville Greenhouse
  - Kelly Walsh High School
  - Movement Climbing Gym
  - Colorado Army National Guard Facility
- Optical Skylight System Modeling and Validation
- Building Daylight Profiler for Simulation (BDP4SIM)

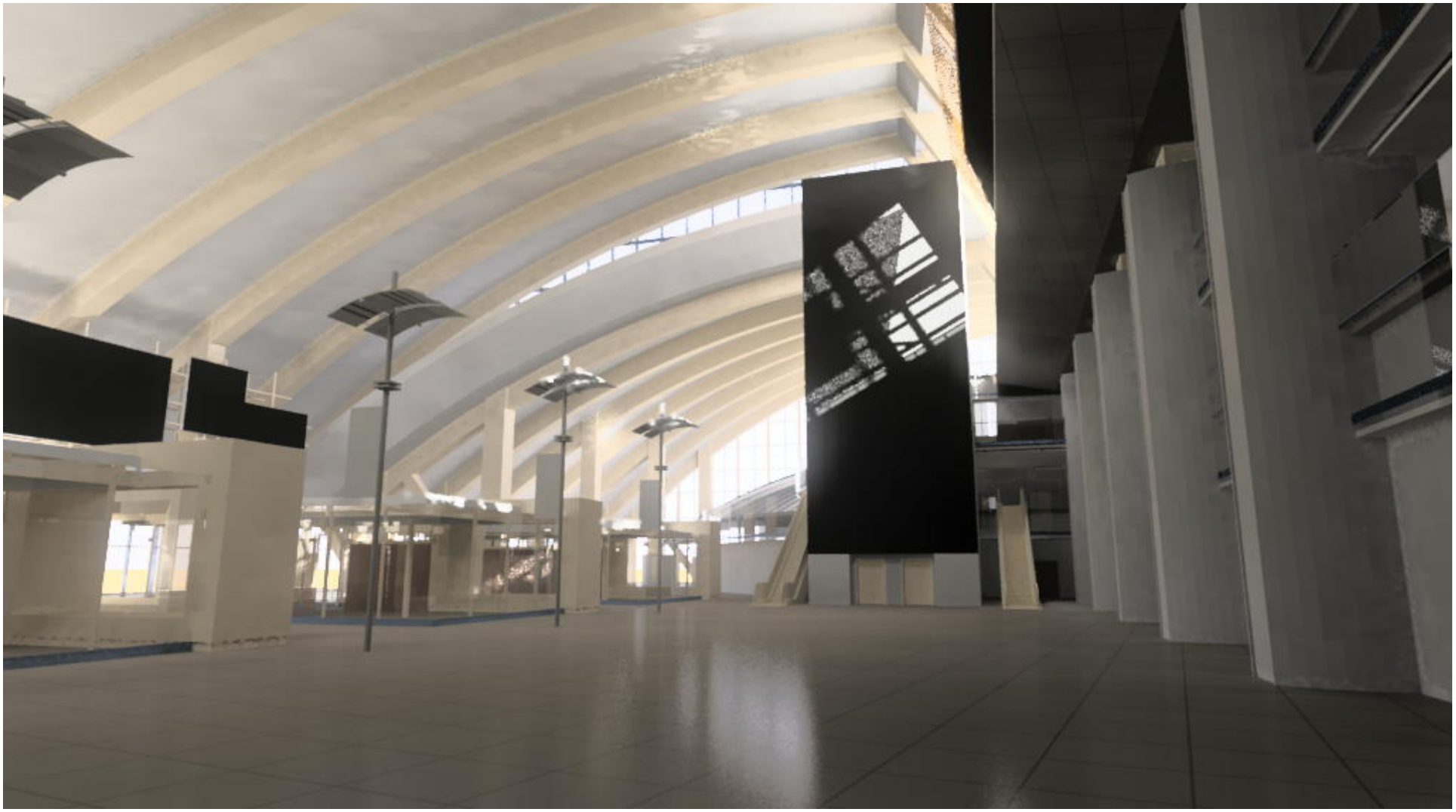
LAX Screen Visibility

- Concern about glare and direct sunlight impairing screen visibility

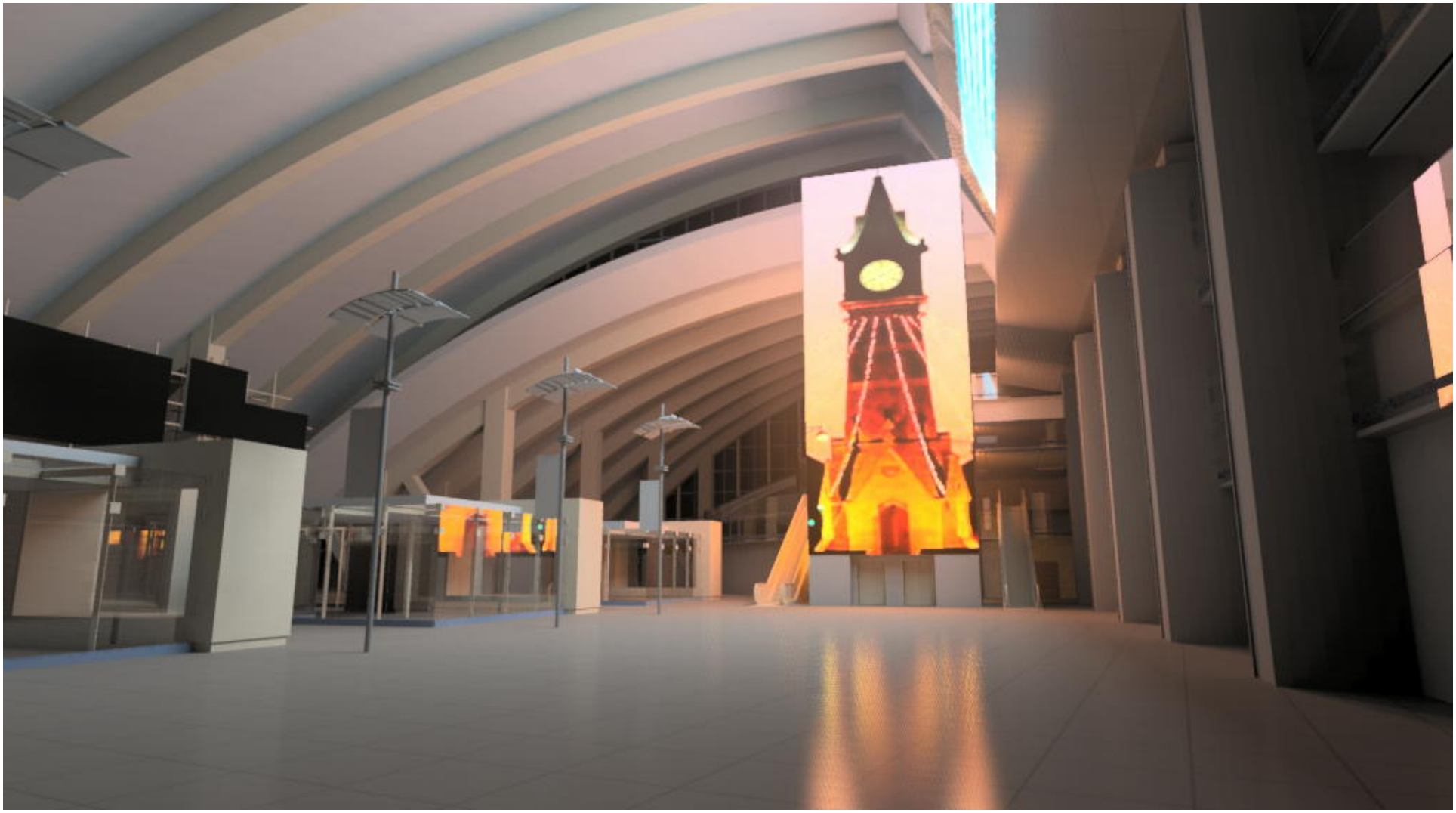
- Used Barco C7 LED Panel
  - Indoor model with 2000 Cd/m2 brightness
  - 20-60W/sf power consumption
  - Low reflectance black LED's



LAX Bradley West Hall – Clock Tower Visibility



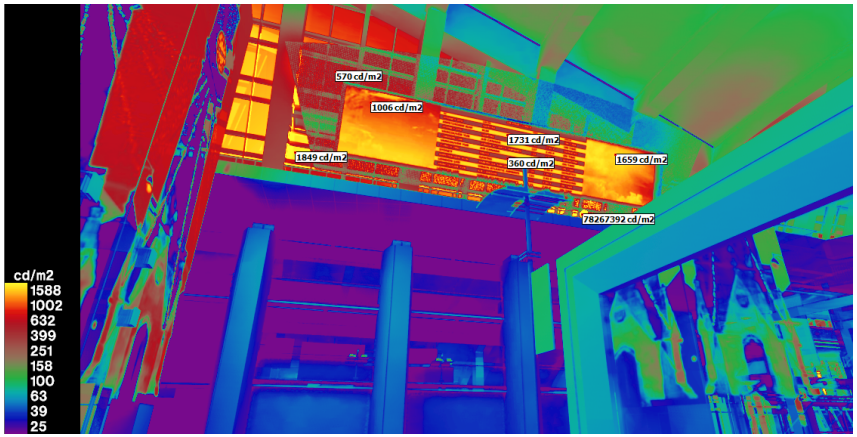
LAX Bradley West Hall – Clock Tower Visibility



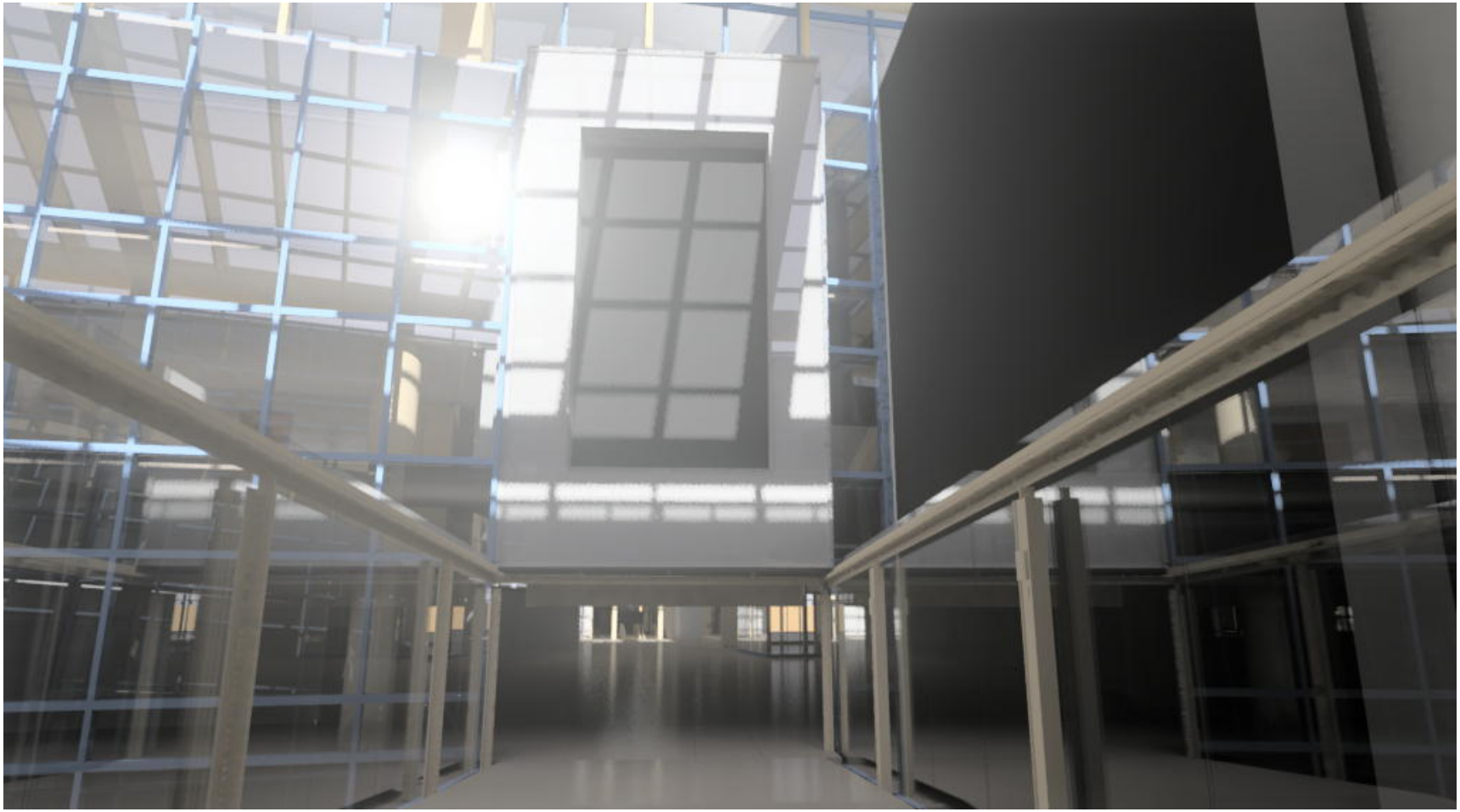
LAX Bradley West Hall – Clock Tower Visibility

Departure Screen Visibility

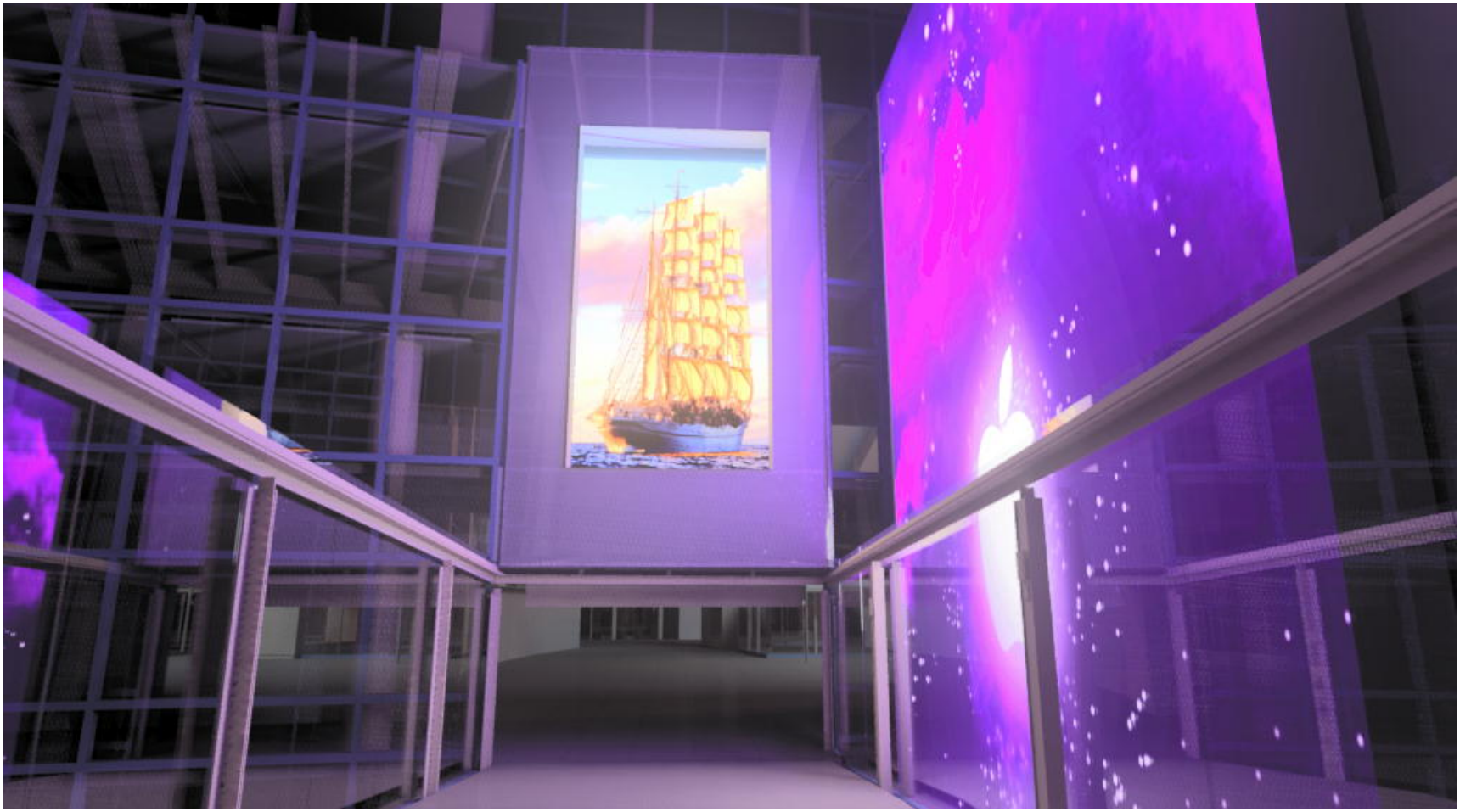
- Afternoon occurrence of direct sun glare
- Reduced visibility of departure screen from a few certain locations



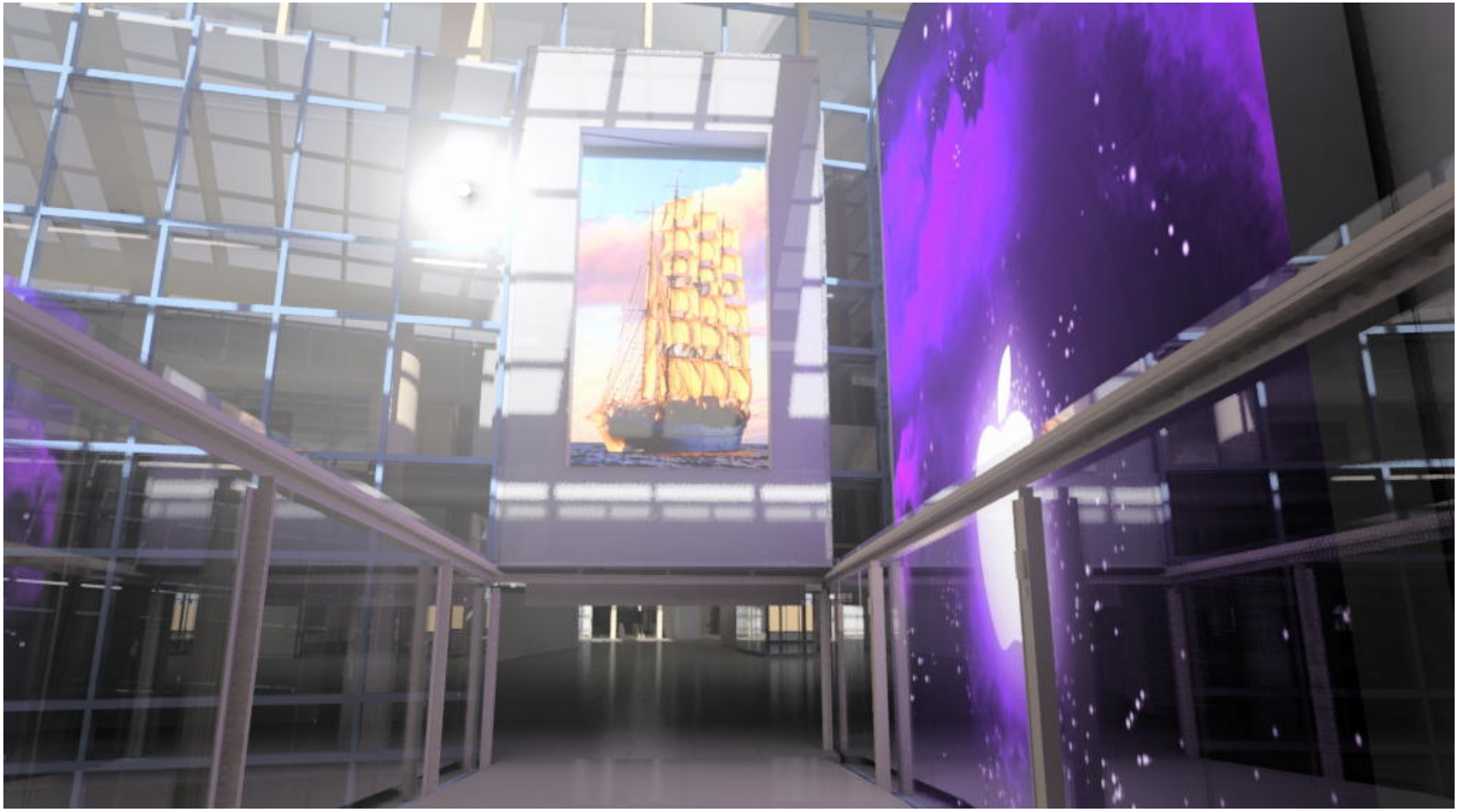
Bon Voyage and Welcome Wall Visibility



Bon Voyage and Welcome Wall Visibility



Bon Voyage and Welcome Wall Visibility



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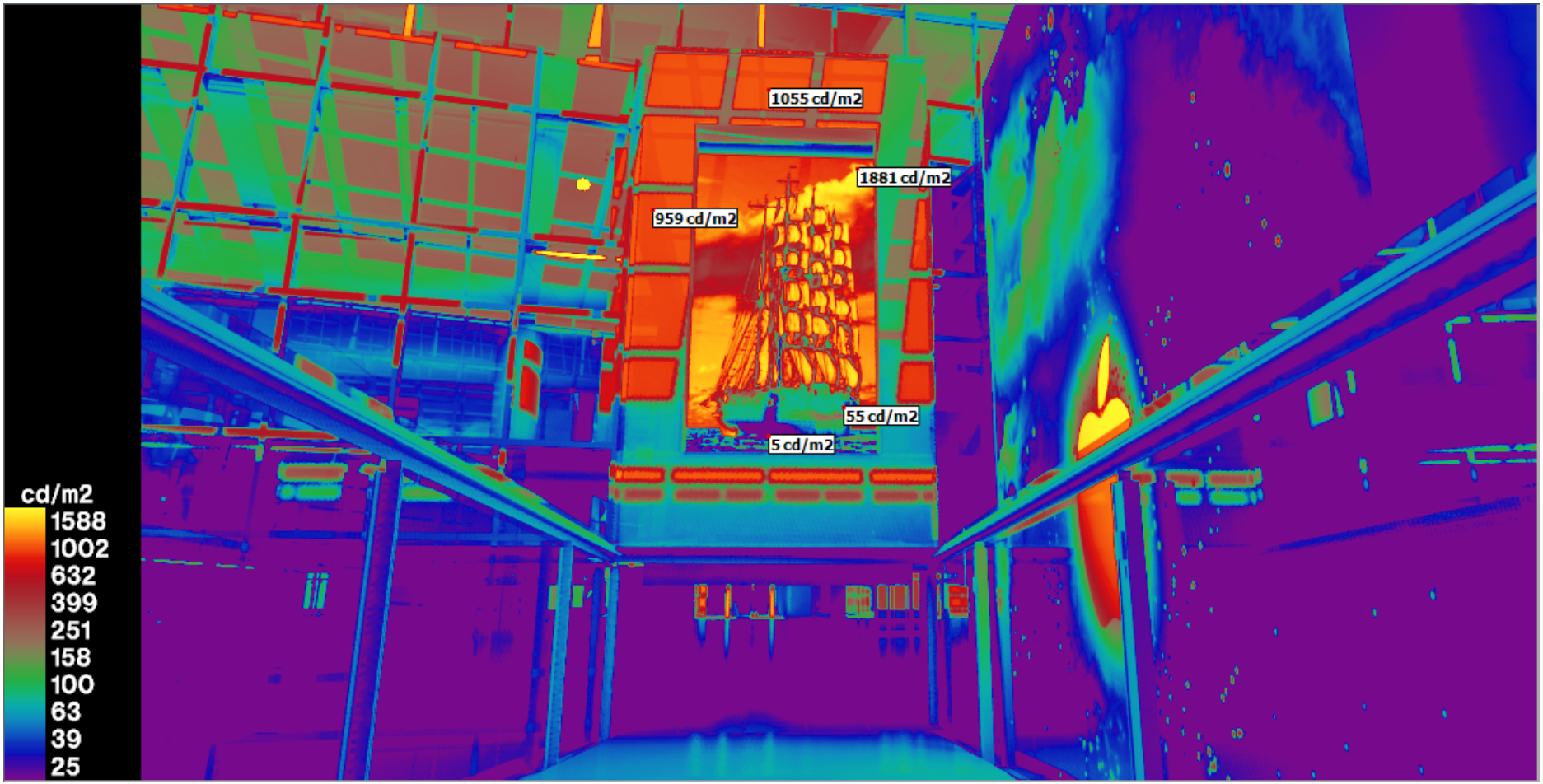


Welcome Screen

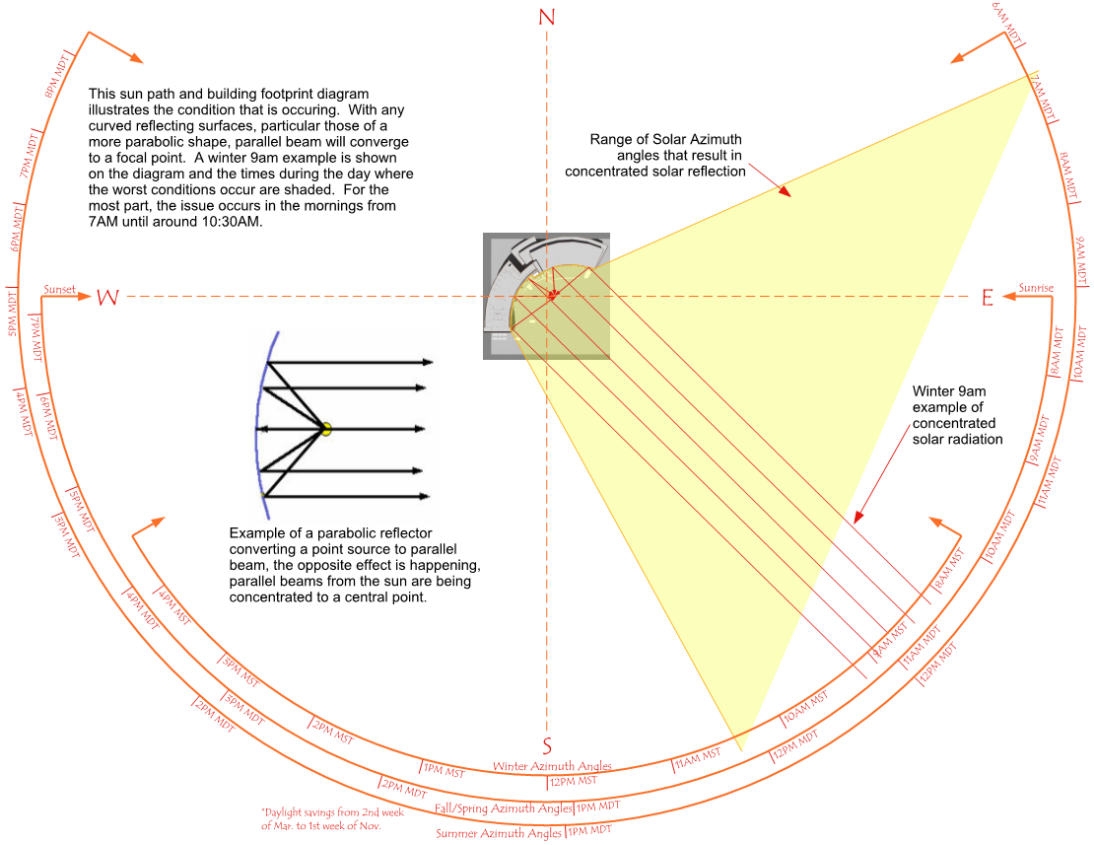
Aerial of Bradley West

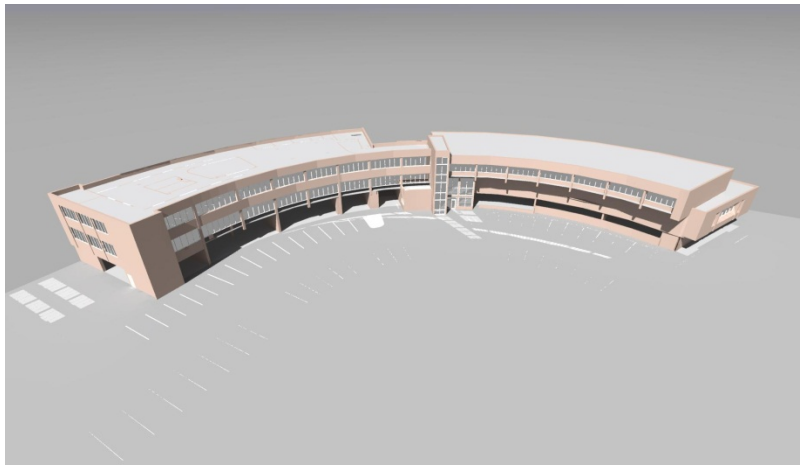
Compared to Projector Visibility

Office Building Remodel

Office Building Remodel

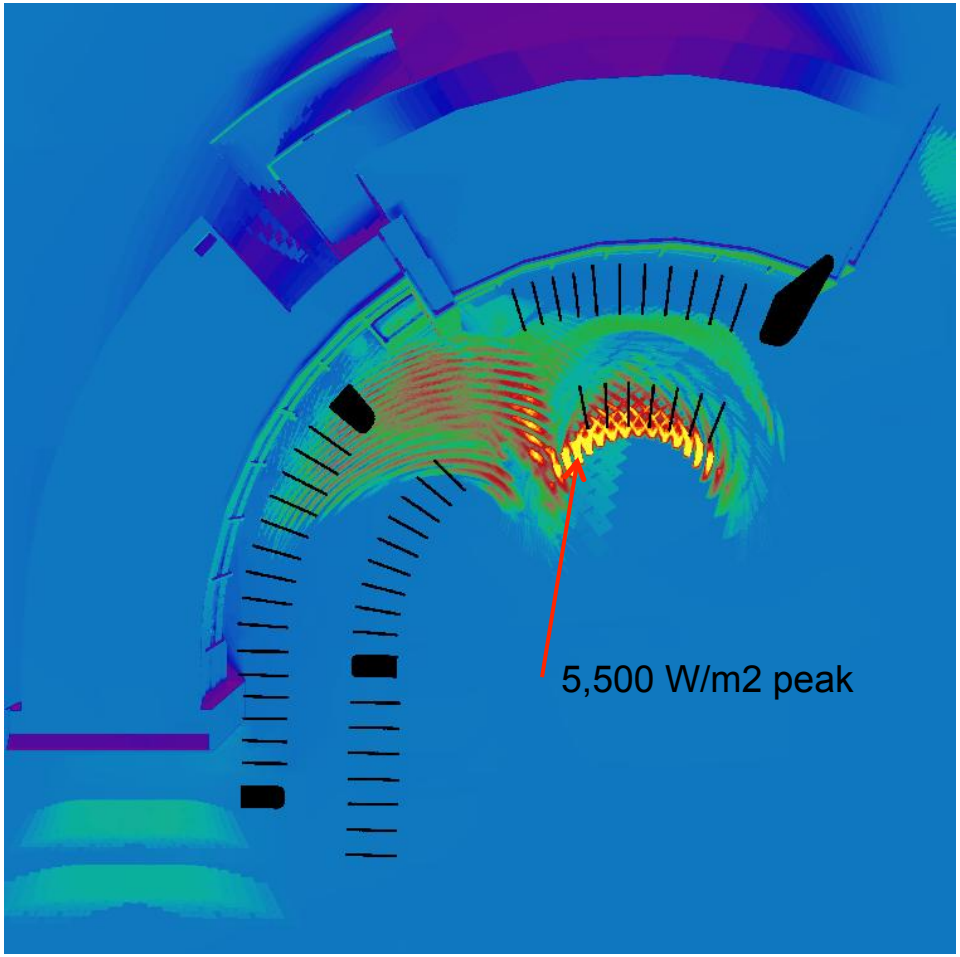
- New reflective glass with 2x the solar reflection
- Concentrated solar melting car parts!

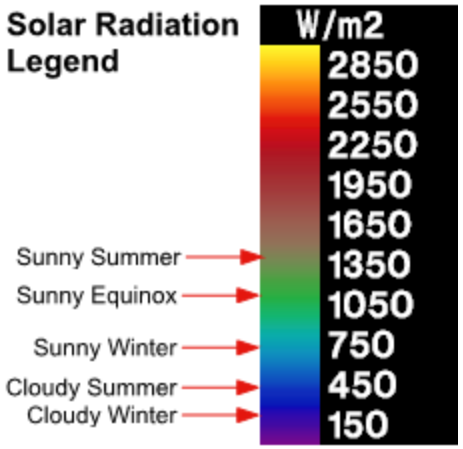




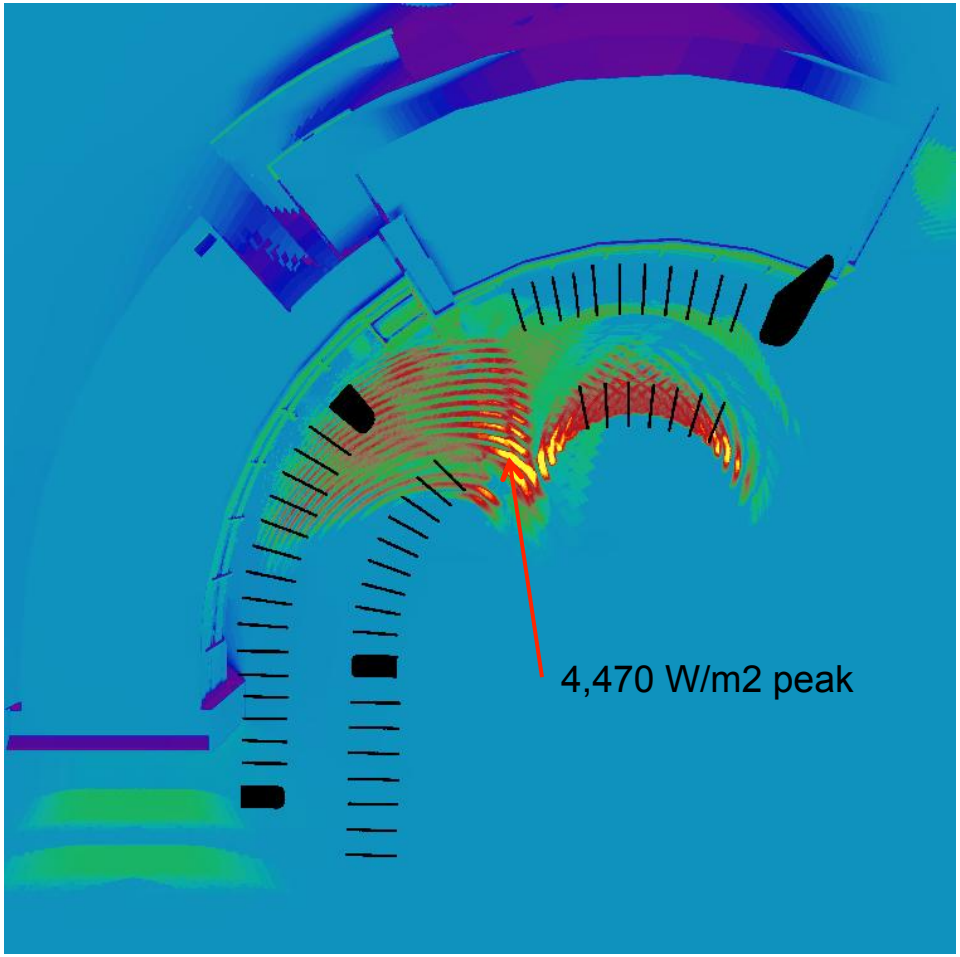
Office Building Remodel – Annual Animation

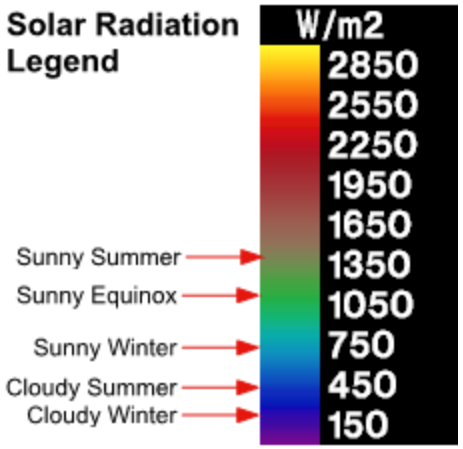
Office Building Remodel – December Max



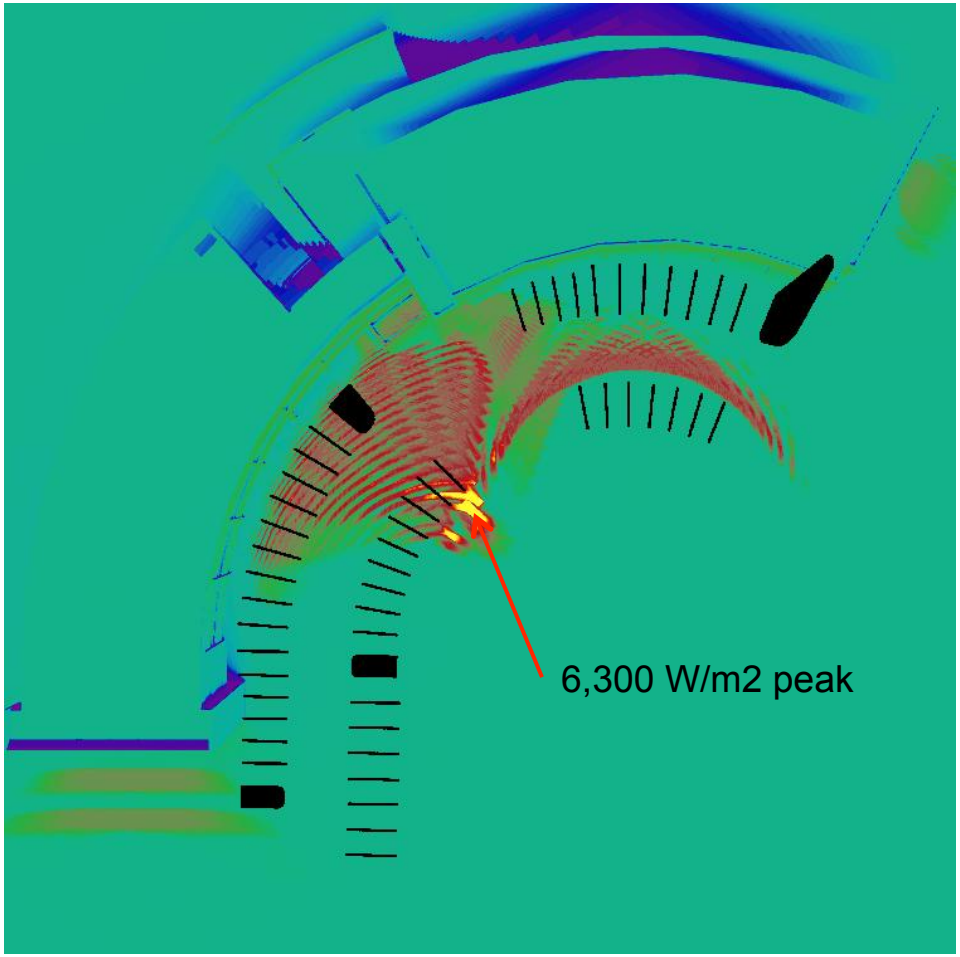


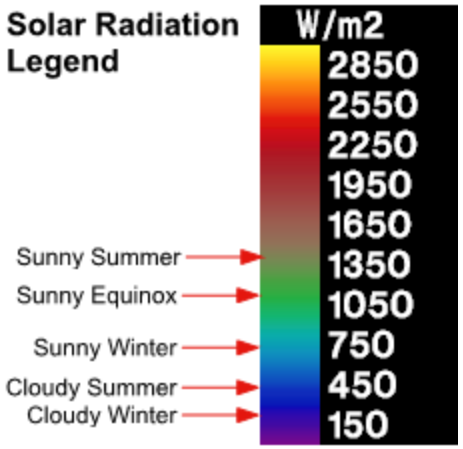
Office Building Remodel – January / November



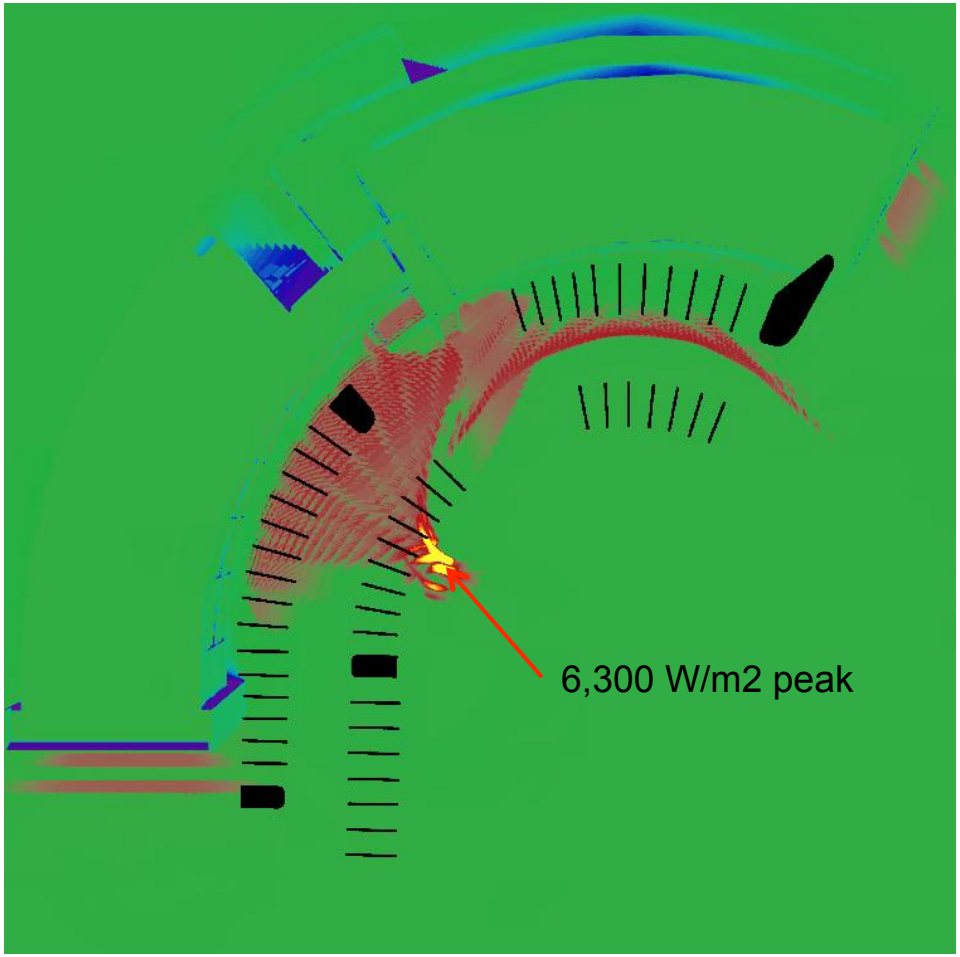


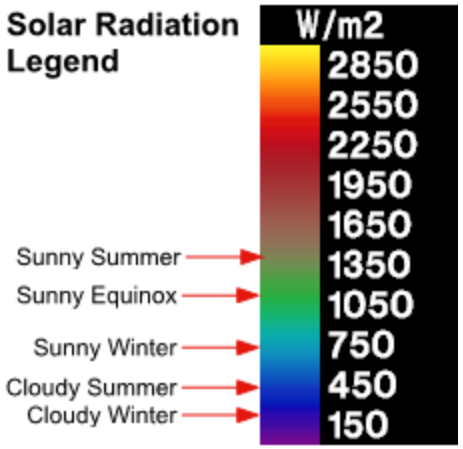
Office Building Remodel – February / October



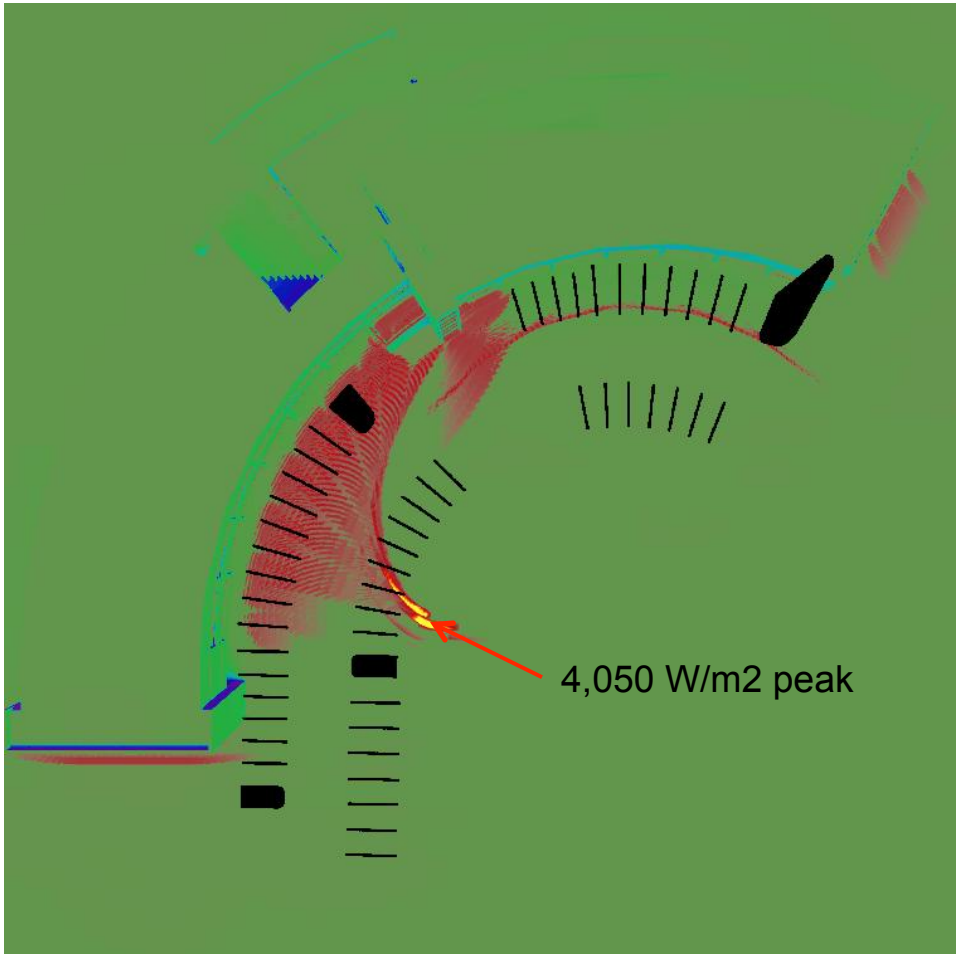


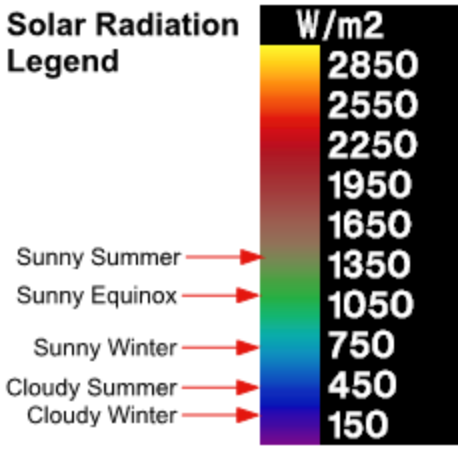
Office Building Remodel – March / September



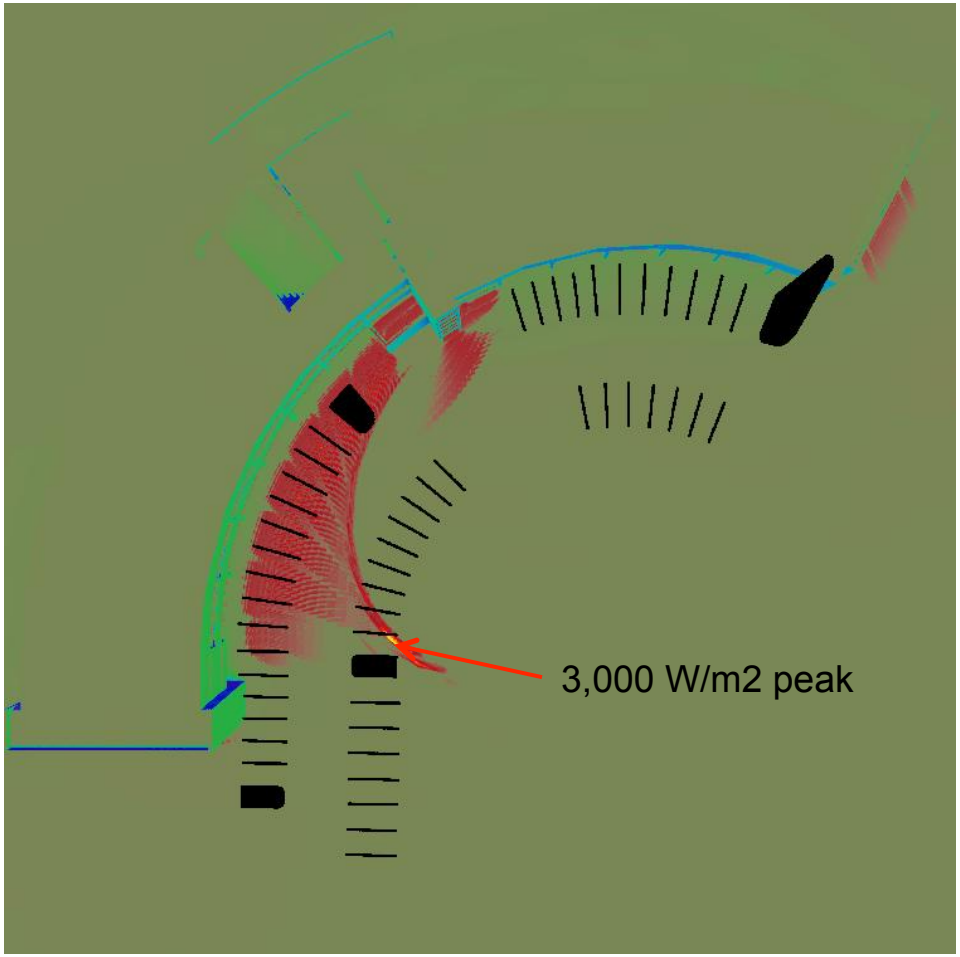


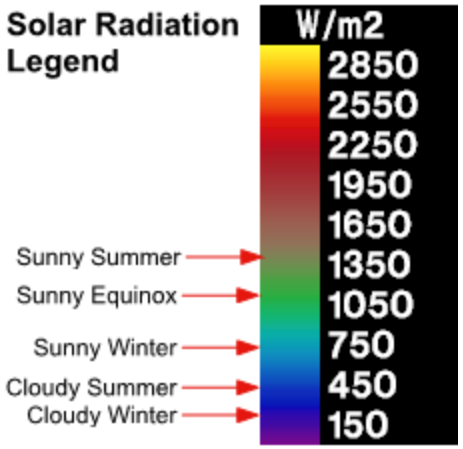
Office Building Remodel – April / August



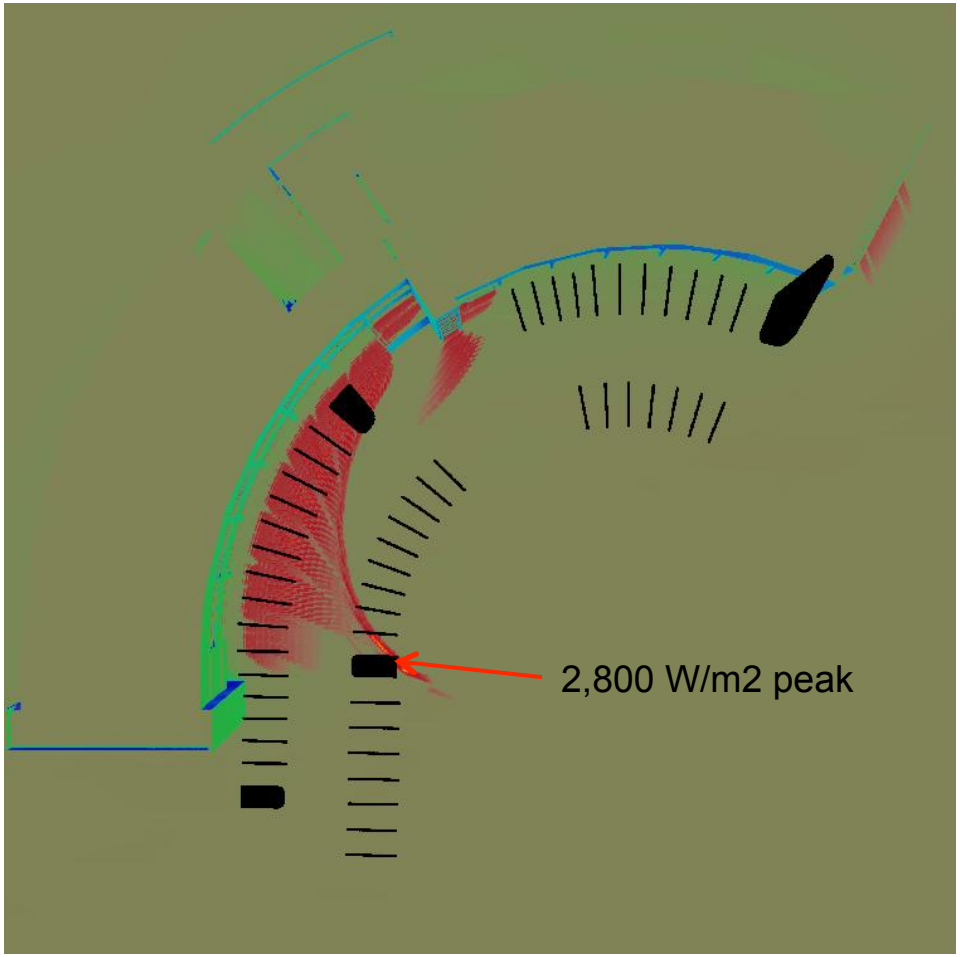


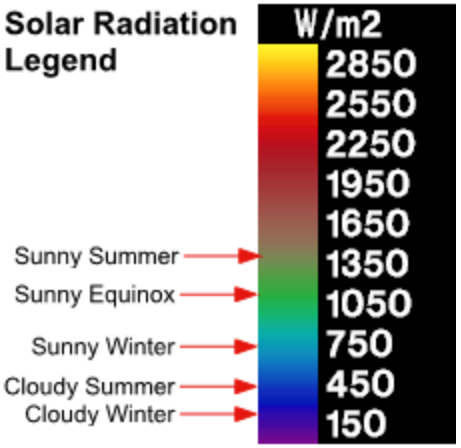
Office Building Remodel – May / July





Office Building Remodel – June

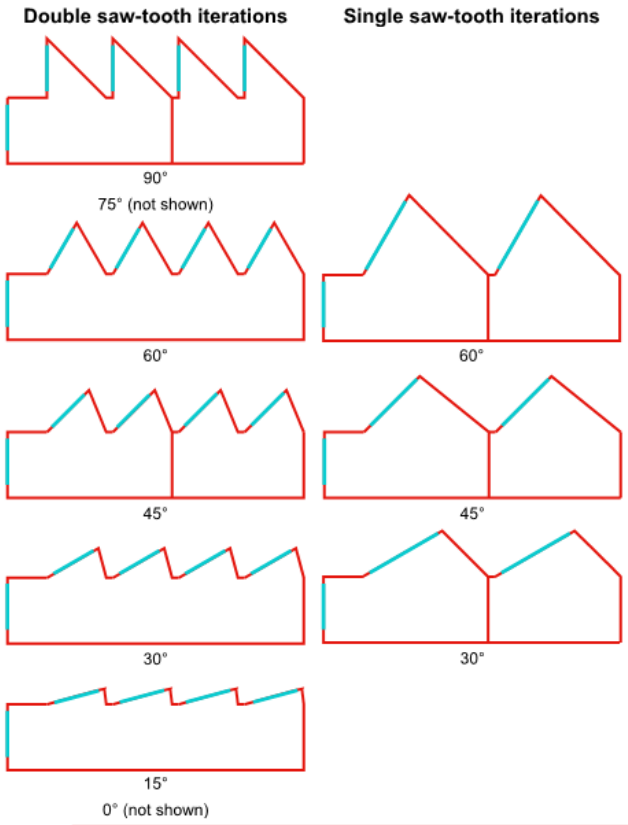


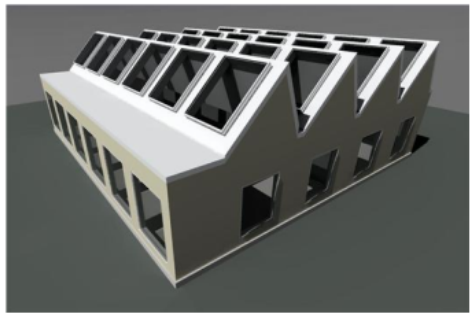


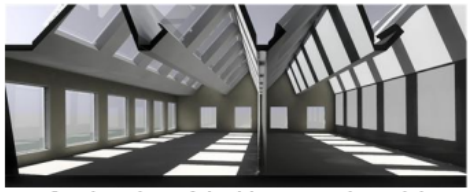
Vdara Death Ray!

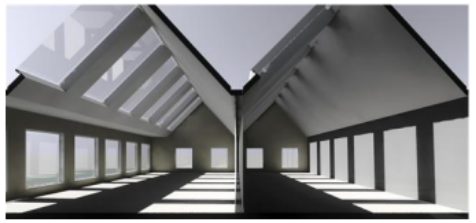
Leadville Greenhouse Design

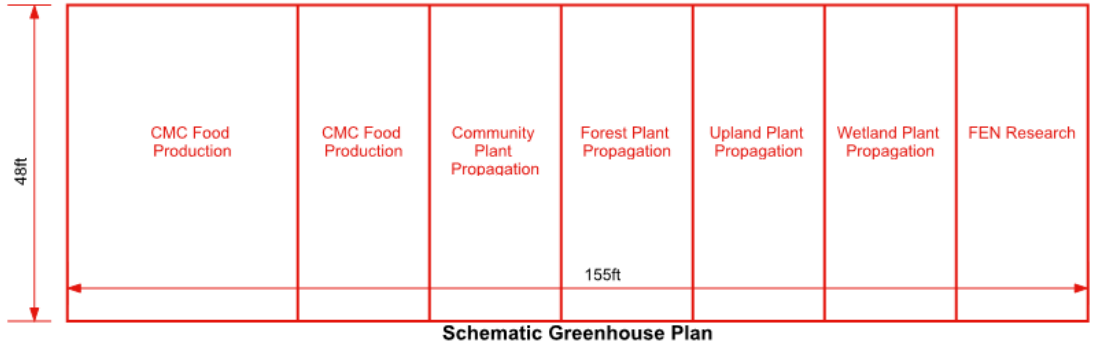
- Year round greenhouse at 10,000ft
  - High altitude wetland plants
  - General growing environment for community college
- Balance adequate daylight with and an insulated envelope
- Controlling winter time heat loss critical
- Small design iteration set explored




Perspective view of greenhouse model


Section view of double sawtooth model


Section view of single sawtooth model



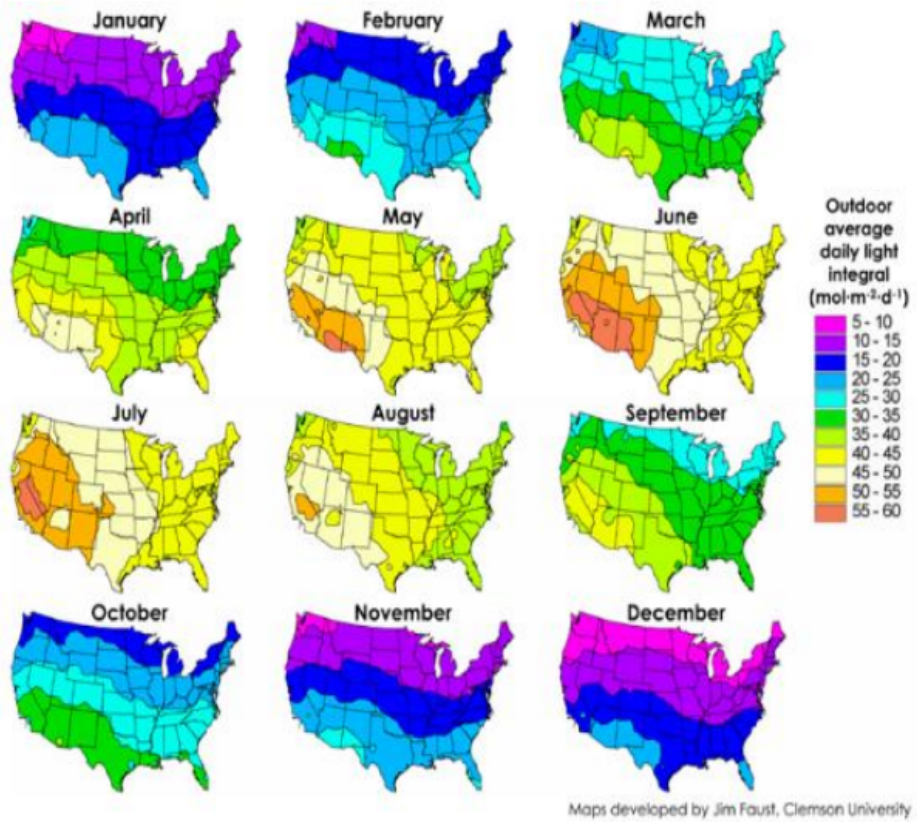
Schematic Greenhouse Plan

Leadville Greenhouse Design

- Daily Lighting Integral (DLI) metric used – basically the # of photons(mols)/area/day
- DLI ~ 0.0173*fc
- Min DLI established based on light intensive plants

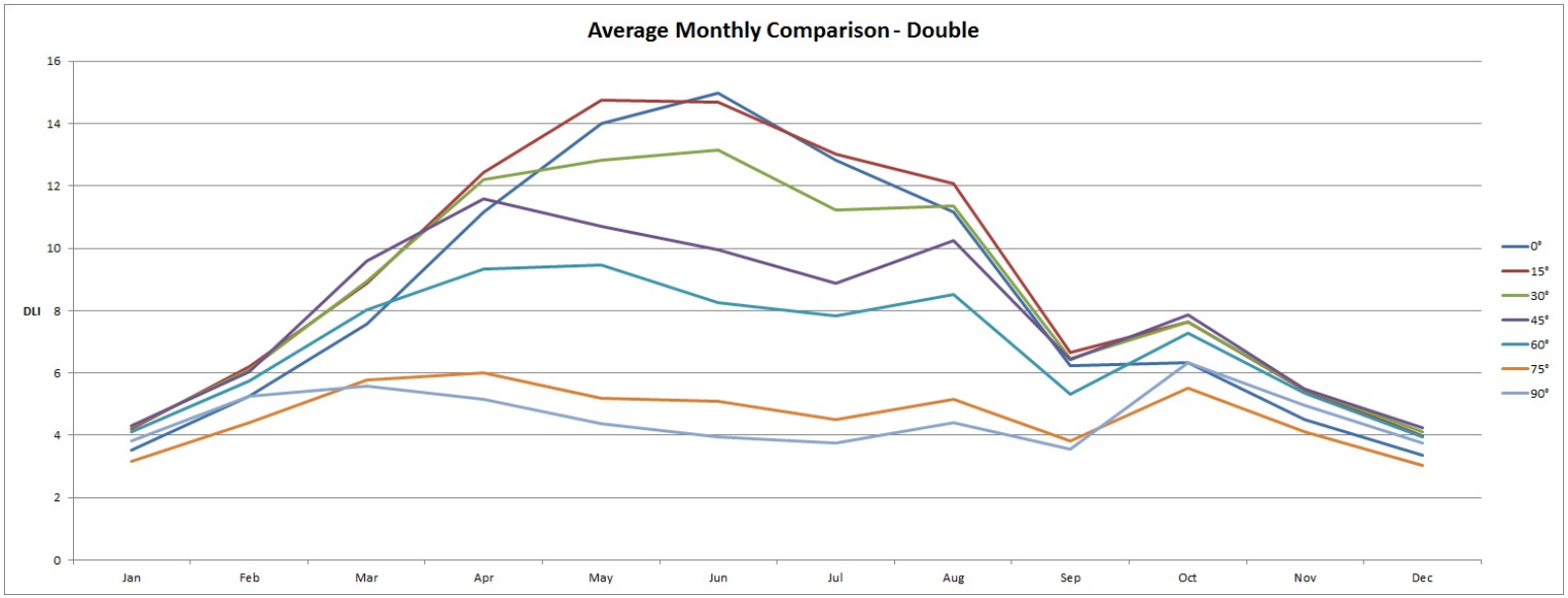
DLI Requirements for common but light intensive plants

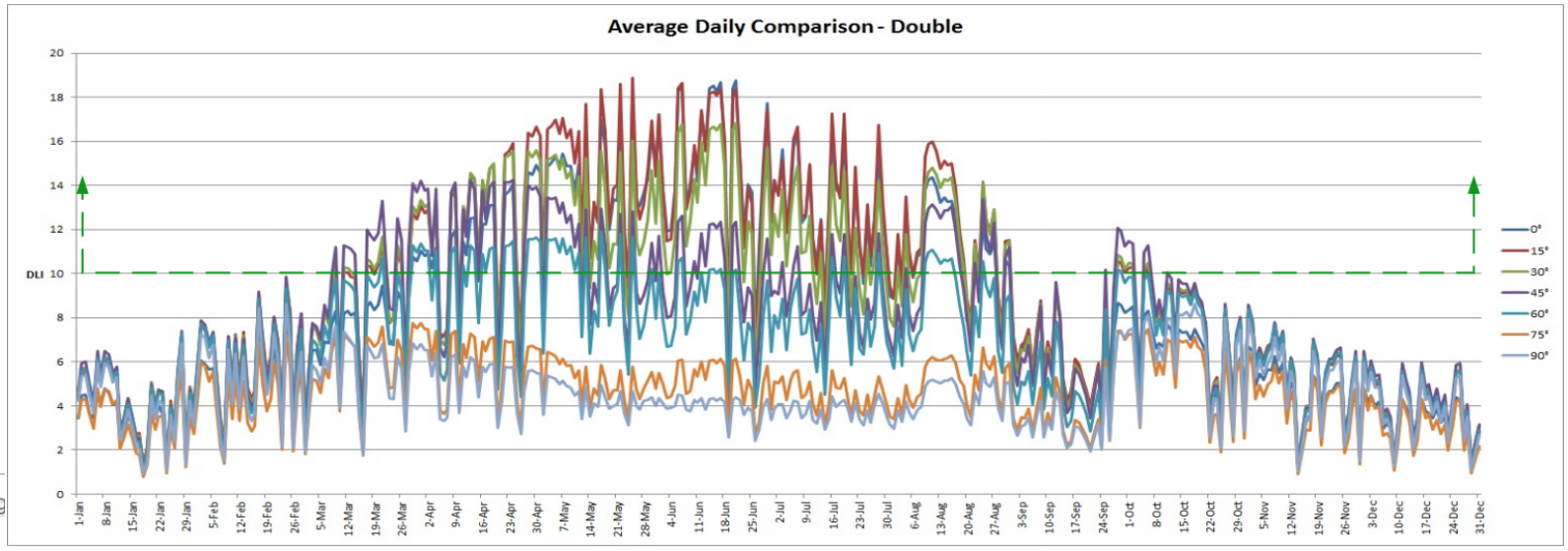
Species	Average Daily Light Integral (Moles/Day)														
	Greenhouse														
	2	4	6	8	10	12	14	16	18	20	22	24	26	28	30
Zinnia															
Alstroemeria (cut flower)															
Capsicum (pepper)															
Chrysanthemum (cut flower)															
Dianthus (carnation)															
Gladiolus (cut flower)															
Lycopersicon (tomato)															
Rose (cut flower)															



Monthly Daily Light Integral (DLI) Maps for the United States

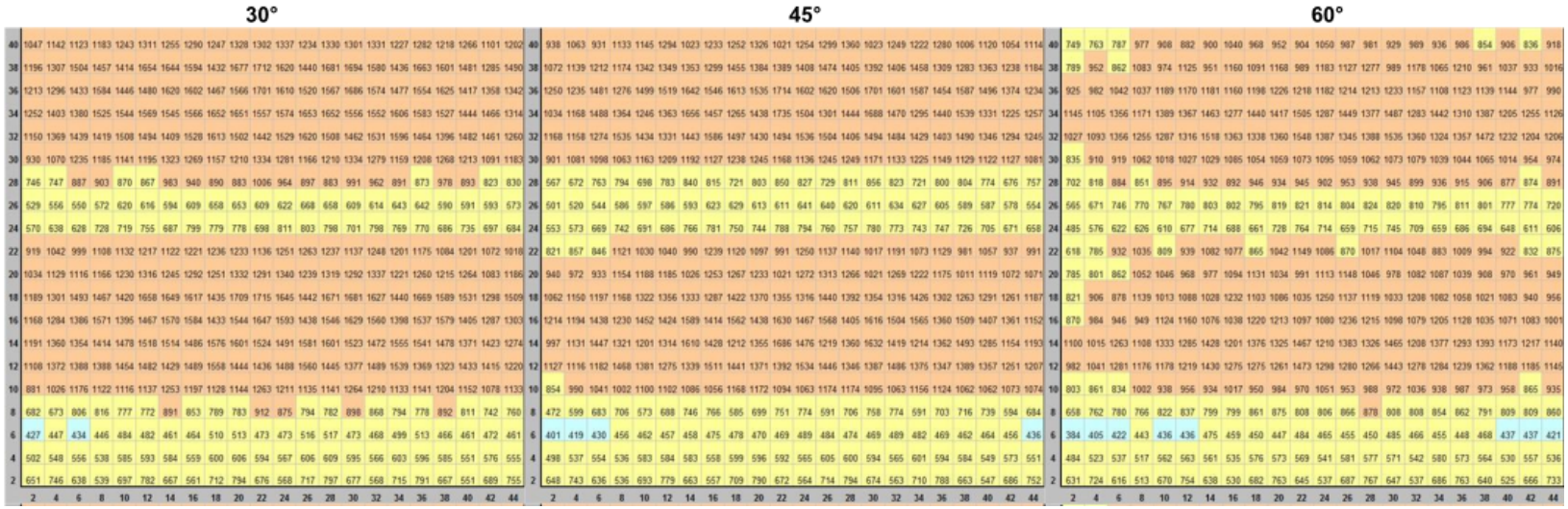
Leadville Greenhouse Design – Annual Results





Leadville Greenhouse Design – Spatial Results

Single



Kelly Walsh High School

- Used genBSDF to model a 6”x6” open cell ceiling
- Simulated with thickness and proxy geometry
- Goal to provide uniform ambient daylight in high school common / circulation areas

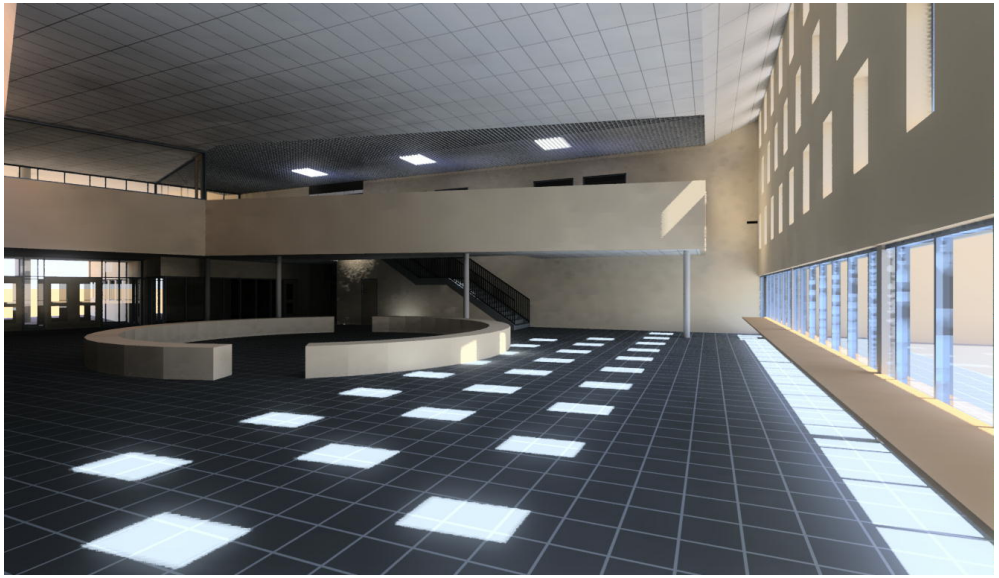
Kelly Walsh High School

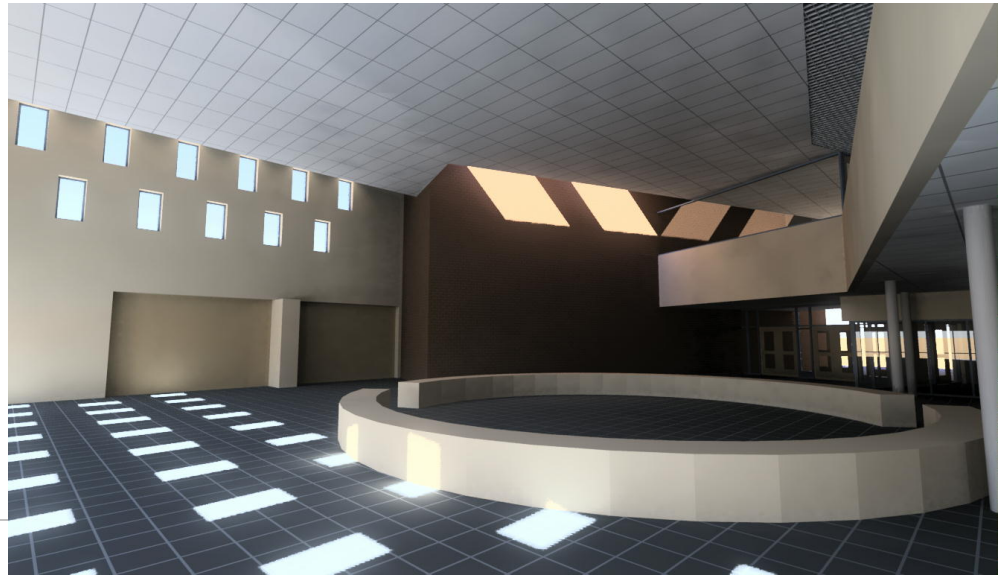
Kelly Walsh High School

Kelly Walsh High School

Kelly Walsh High School

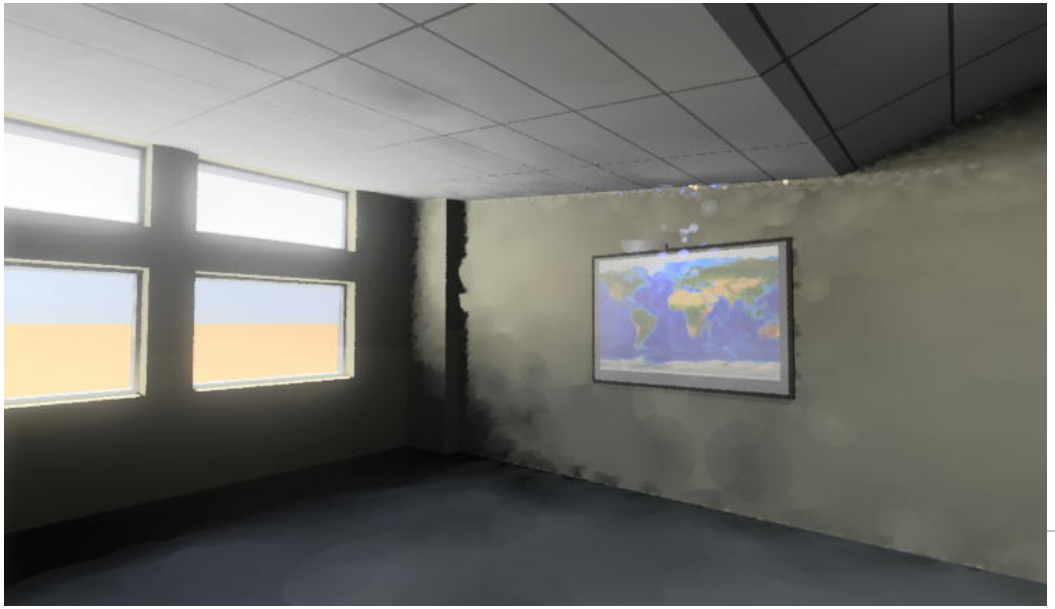
- Central commons - congregation and dining area for students
- Controlled Window-to-wall Ratios – minimized large curtain wall expanses of glass
- Goal to provide modest ambient level with some “sparkle”

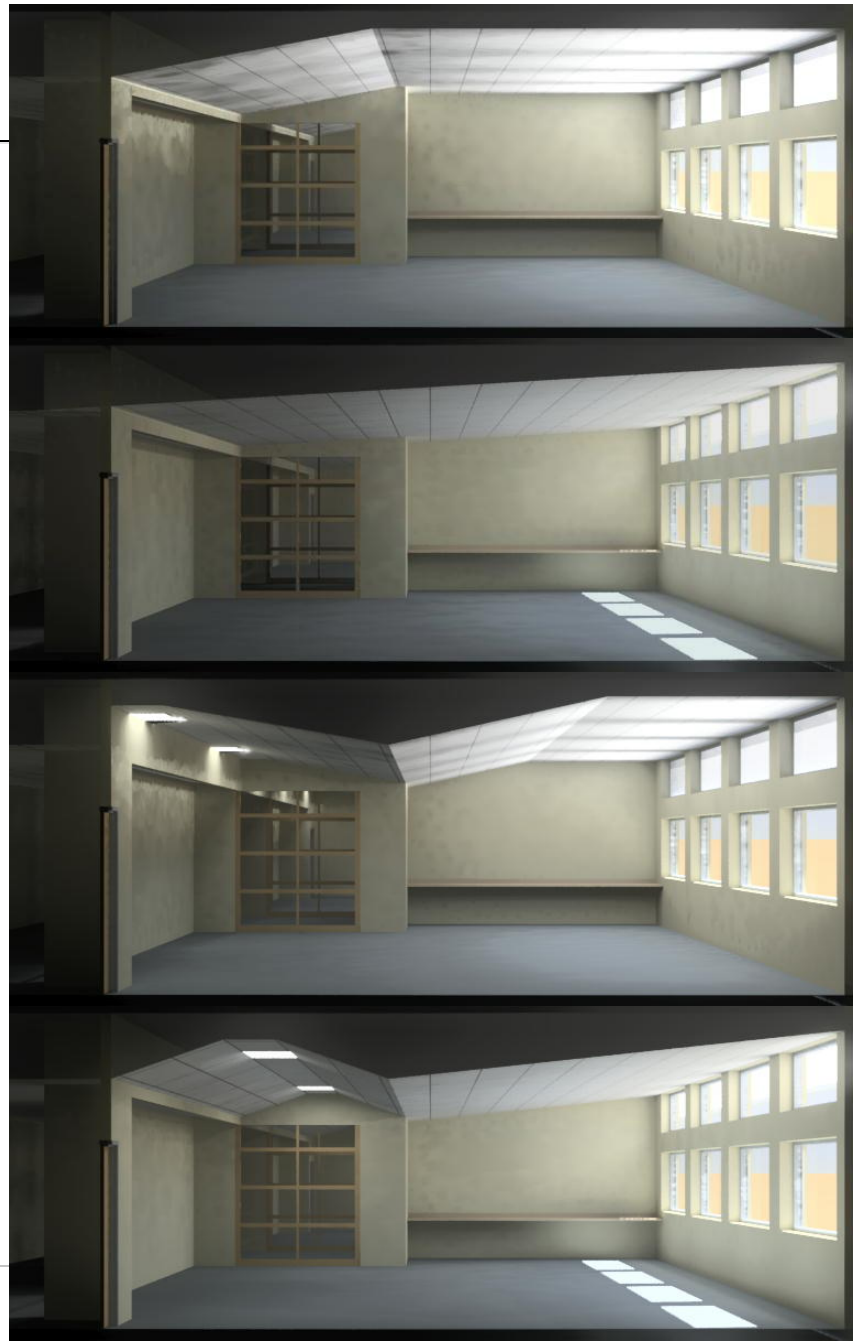




Kelly Walsh High School

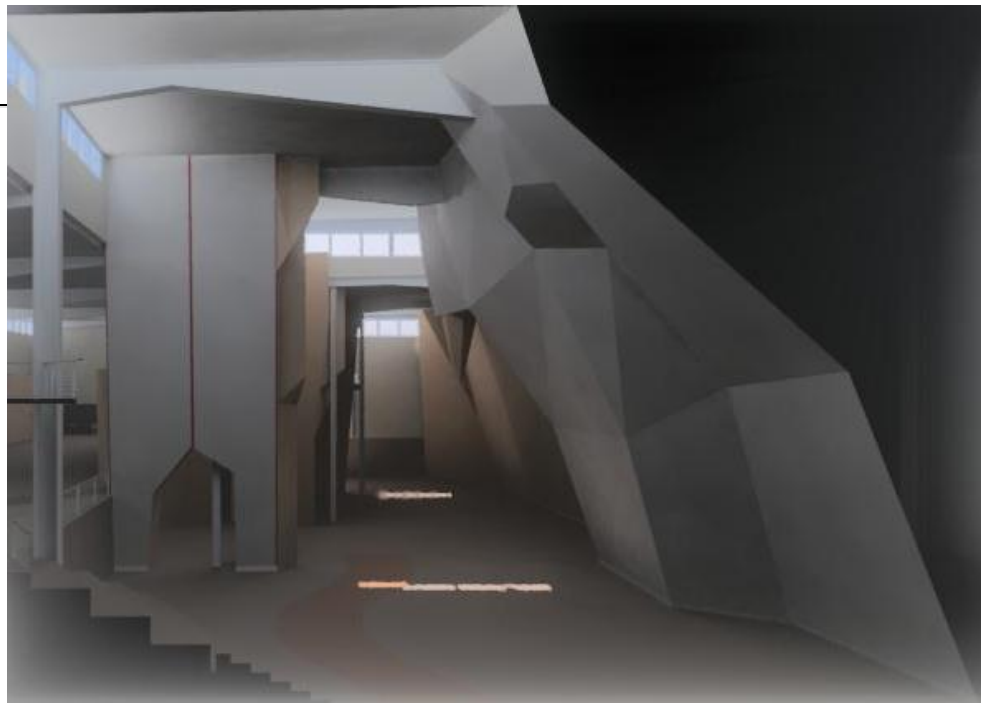
- Classroom iterations – using new LightLouver system BSDF – simulated without proxy geometry
- Will be available on website soon
- SMART board projector model – projector mounted 12” from wall
- Challenge to achieve uniform brightness





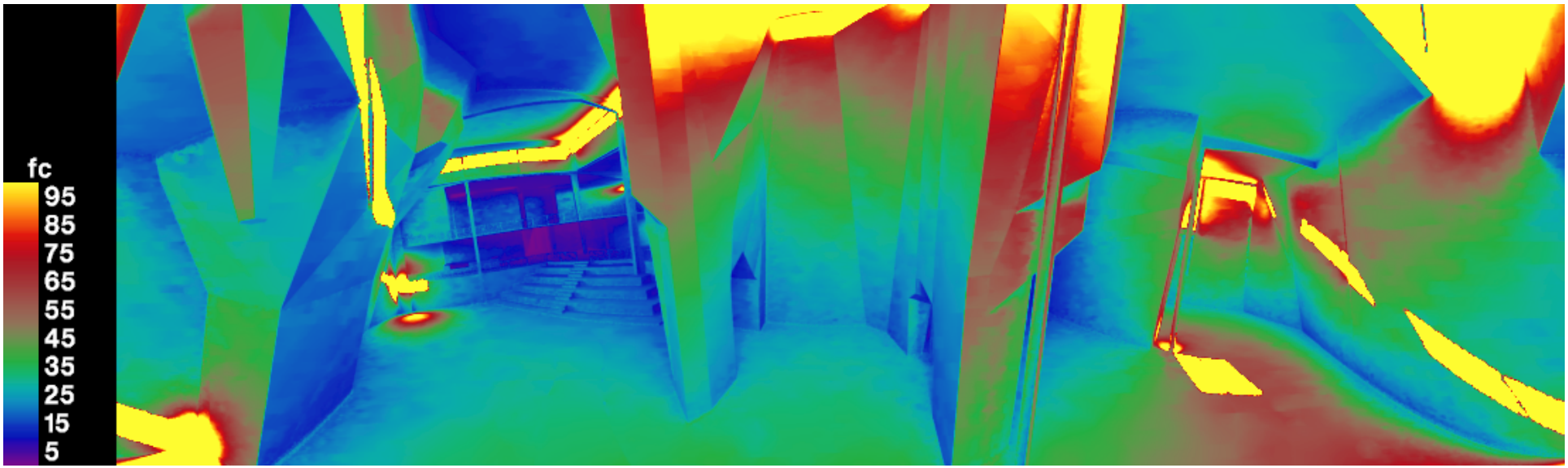
Movement Climbing Gym

- New climbing gym for Denver
- Replicating successful gym in Boulder – refining problems areas
  - Low illuminance canyons
  - Glare and excessive heat gain
  - Lighting controls



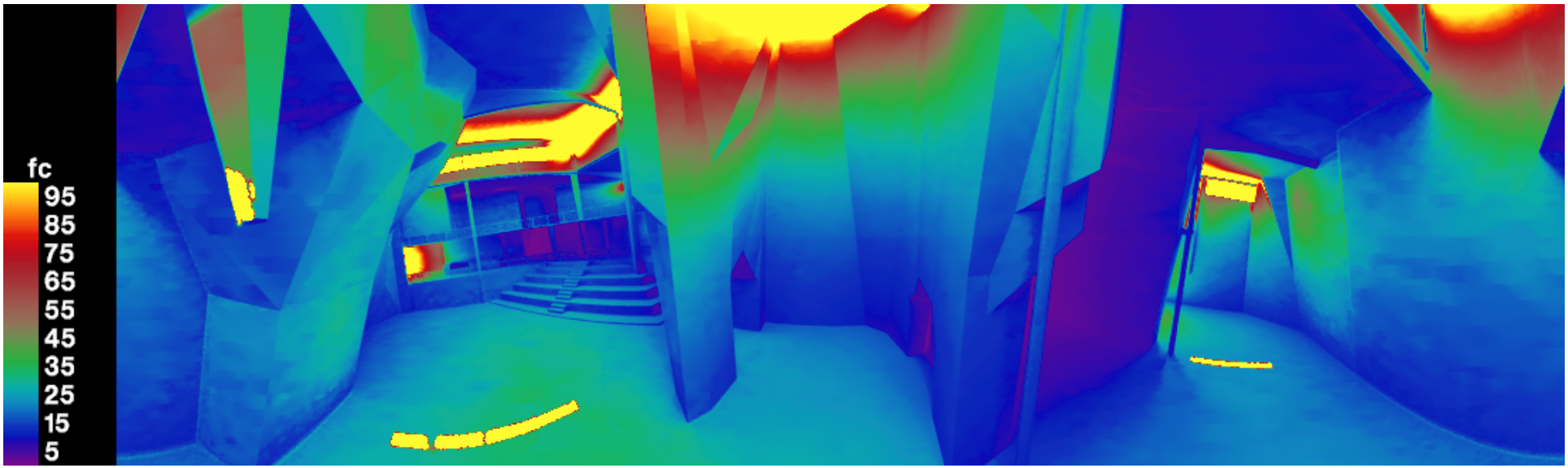
Movement Climbing Gym

- Sunny morning illuminance map



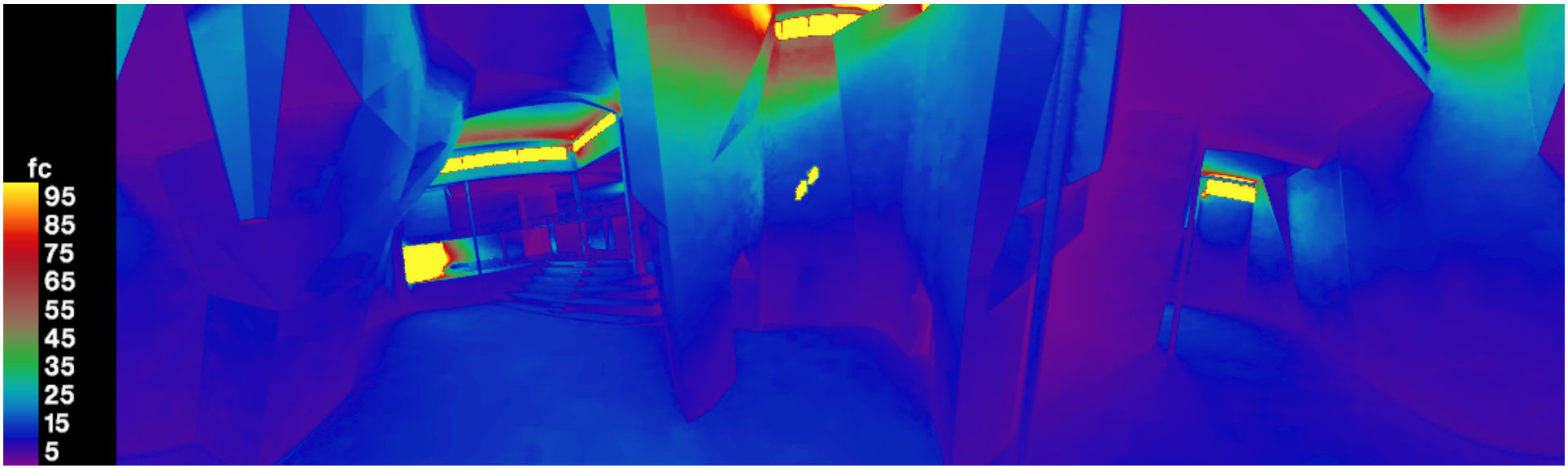
Movement Climbing Gym

- Sunny noon illuminance map



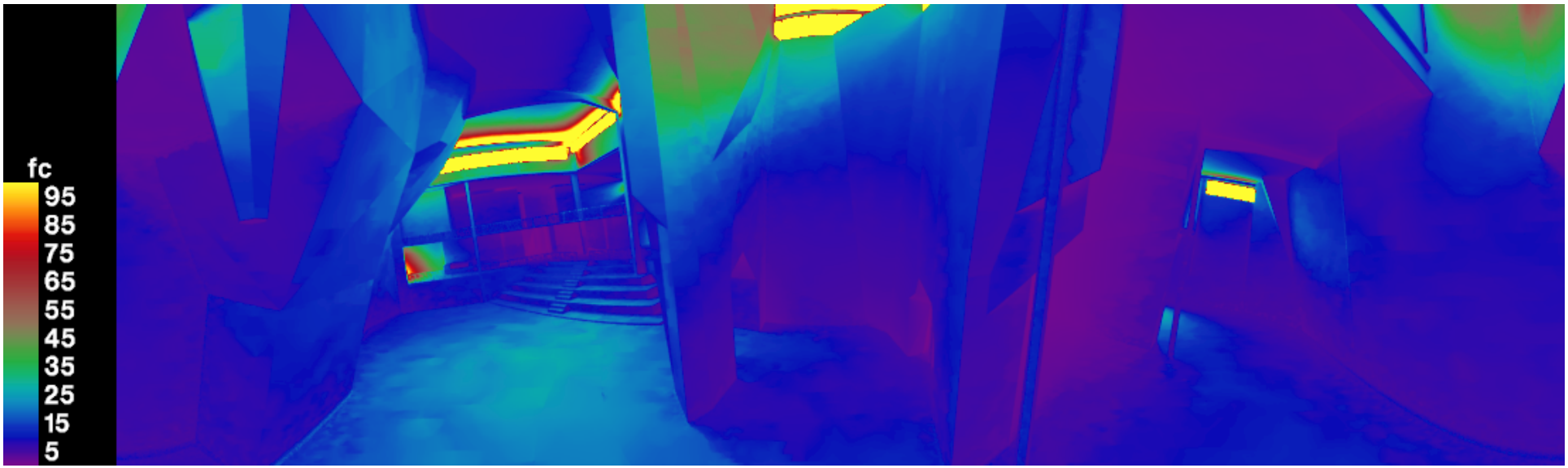
Movement Climbing Gym

- Sunny afternoon illuminance study

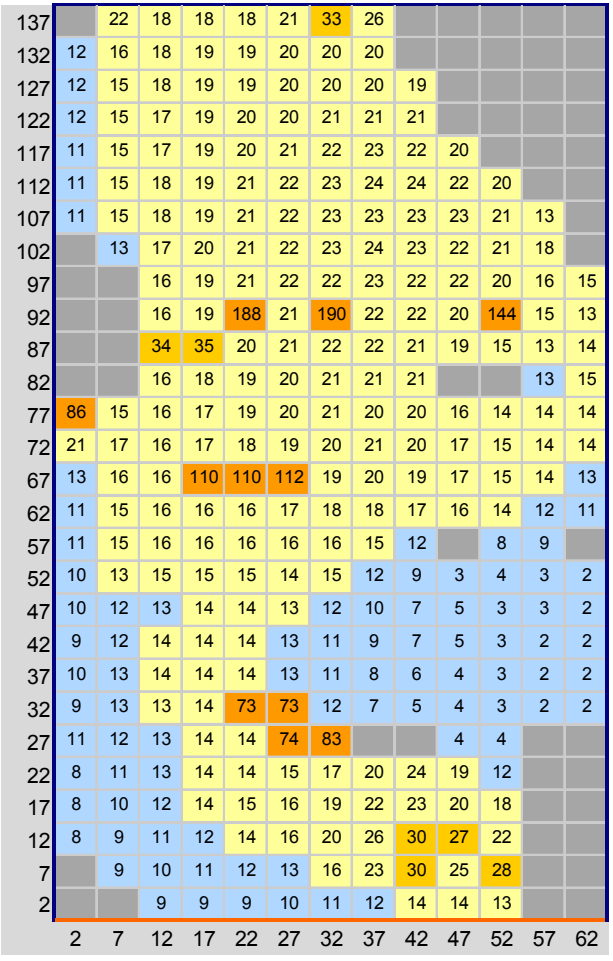


Movement Climbing Gym

- Typical winter overcast illuminance map

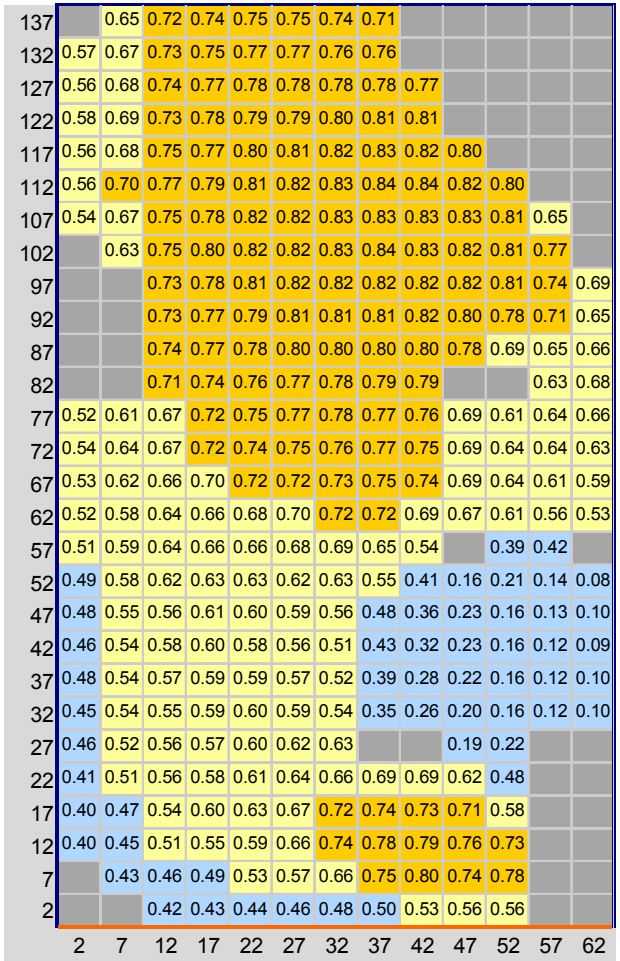


Movement Climbing Gym – Annual results



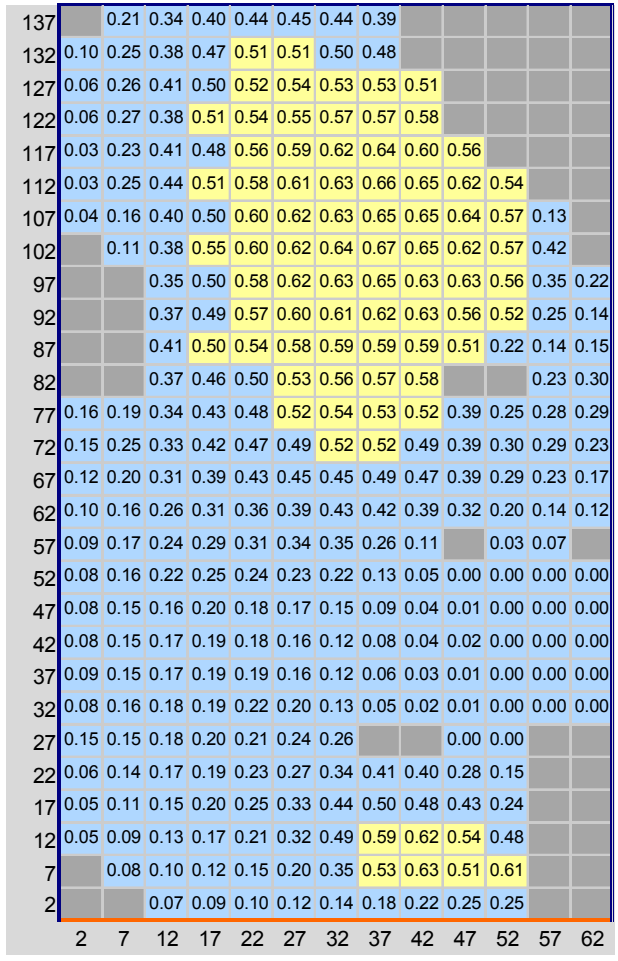
	2	7	12	17	22	27	32	37	42	47	52	57	62
137		22	18	18	18	21	33	26					
132	12	16	18	19	19	20	20	20					
127	12	15	18	19	19	20	20	20	19				
122	12	15	17	19	20	20	21	21	21				
117	11	15	17	19	20	21	22	23	22	20			
112	11	15	18	19	21	22	23	24	24	22	20		
107	11	15	18	19	21	22	23	23	23	23	21	13	
102		13	17	20	21	22	23	24	23	22	21	18	
97			16	19	21	22	22	23	22	22	20	16	15
92			16	19	188	21	190	22	22	20	144	15	13
87			34	35	20	21	22	22	21	19	15	13	14
82			16	18	19	20	21	21	21			13	15
77	86	15	16	17	19	20	21	20	20	16	14	14	14
72	21	17	16	17	18	19	20	21	20	17	15	14	14
67	13	16	16	110	110	112	19	20	19	17	15	14	13
62	11	15	16	16	16	17	18	18	17	16	14	12	11
57	11	15	16	16	16	16	16	15	12		8	9	
52	10	13	15	15	15	14	15	12	9	3	4	3	2
47	10	12	13	14	14	13	12	10	7	5	3	3	2
42	9	12	14	14	14	13	11	9	7	5	3	2	2
37	10	13	14	14	14	13	11	8	6	4	3	2	2
32	9	13	13	14	73	73	12	7	5	4	3	2	2
27	11	12	13	14	14	74	83			4	4		
22	8	11	13	14	14	15	17	20	24	19	12		
17	8	10	12	14	15	16	19	22	23	20	18		
12	8	9	11	12	14	16	20	26	30	27	22		
7		9	10	11	12	13	16	23	30	25	28		
2			9	9	9	10	11	12	14	14	13		

Avg Illuminance



	2	7	12	17	22	27	32	37	42	47	52	57	62
137		0.65	0.72	0.74	0.75	0.75	0.74	0.71					
132	0.57	0.67	0.73	0.75	0.77	0.77	0.76	0.76					
127	0.56	0.68	0.74	0.77	0.78	0.78	0.78	0.78	0.77				
122	0.58	0.69	0.73	0.78	0.79	0.79	0.80	0.81	0.81				
117	0.56	0.68	0.75	0.77	0.80	0.81	0.82	0.83	0.82	0.80			
112	0.56	0.70	0.77	0.79	0.81	0.82	0.83	0.84	0.84	0.82	0.80		
107	0.54	0.67	0.75	0.78	0.82	0.82	0.83	0.83	0.83	0.83	0.81	0.65	
102		0.63	0.75	0.80	0.82	0.82	0.83	0.84	0.83	0.82	0.81	0.77	
97			0.73	0.78	0.81	0.82	0.82	0.82	0.82	0.82	0.81	0.74	0.69
92			0.73	0.77	0.79	0.81	0.81	0.81	0.82	0.80	0.78	0.71	0.65
87			0.74	0.77	0.78	0.80	0.80	0.80	0.80	0.78	0.69	0.65	0.66
82			0.71	0.74	0.76	0.77	0.78	0.79	0.79			0.63	0.68
77	0.52	0.61	0.67	0.72	0.75	0.77	0.78	0.77	0.76	0.69	0.61	0.64	0.66
72	0.54	0.64	0.67	0.72	0.74	0.75	0.76	0.77	0.75	0.69	0.64	0.64	0.63
67	0.53	0.62	0.66	0.70	0.72	0.72	0.73	0.75	0.74	0.69	0.64	0.61	0.59
62	0.52	0.58	0.64	0.66	0.68	0.70	0.72	0.72	0.69	0.67	0.61	0.56	0.53
57	0.51	0.59	0.64	0.66	0.66	0.68	0.69	0.65	0.54		0.39	0.42	
52	0.49	0.58	0.62	0.63	0.63	0.62	0.63	0.55	0.41	0.16	0.21	0.14	0.08
47	0.48	0.55	0.56	0.61	0.60	0.59	0.56	0.48	0.36	0.23	0.16	0.13	0.10
42	0.46	0.54	0.58	0.60	0.58	0.56	0.51	0.43	0.32	0.23	0.16	0.12	0.09
37	0.48	0.54	0.57	0.59	0.59	0.57	0.52	0.39	0.28	0.22	0.16	0.12	0.10
32	0.45	0.54	0.55	0.59	0.60	0.59	0.54	0.35	0.26	0.20	0.16	0.12	0.10
27	0.46	0.52	0.56	0.57	0.60	0.62	0.63			0.19	0.22		
22	0.41	0.51	0.56	0.58	0.61	0.64	0.66	0.69	0.69	0.62	0.48		
17	0.40	0.47	0.54	0.60	0.63	0.67	0.72	0.74	0.73	0.71	0.58		
12	0.40	0.45	0.51	0.55	0.59	0.66	0.74	0.78	0.79	0.76	0.73		
7		0.43	0.46	0.49	0.53	0.57	0.66	0.75	0.80	0.74	0.78		
2			0.42	0.43	0.44	0.46	0.48	0.50	0.53	0.56	0.56		

Daylight Saturation, DS_{20}
aka DAcont

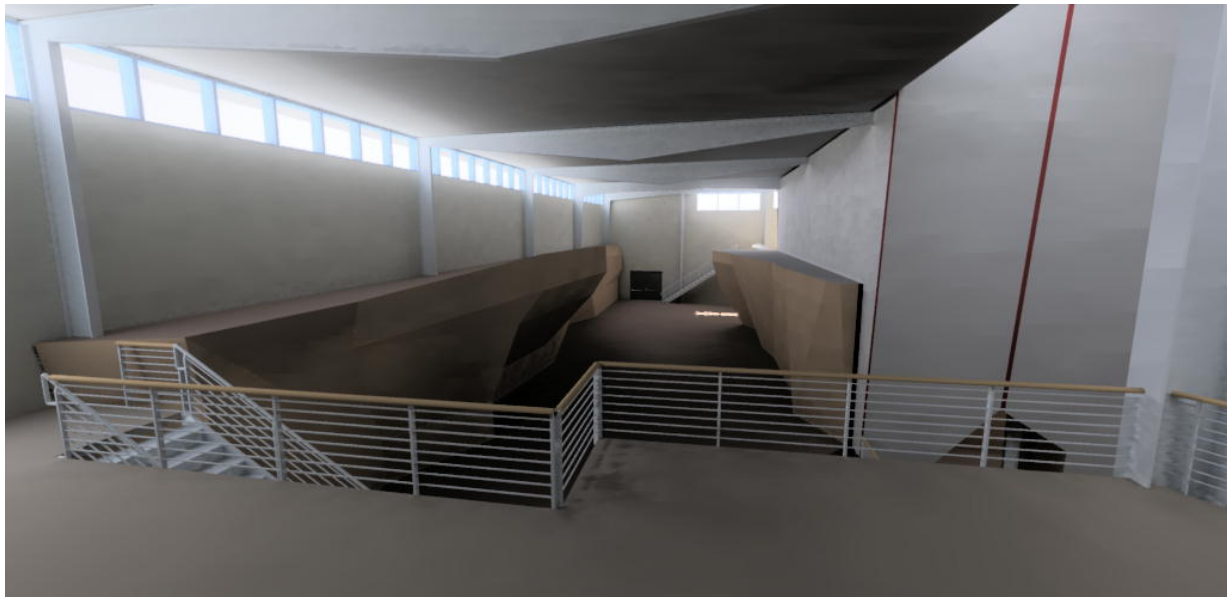


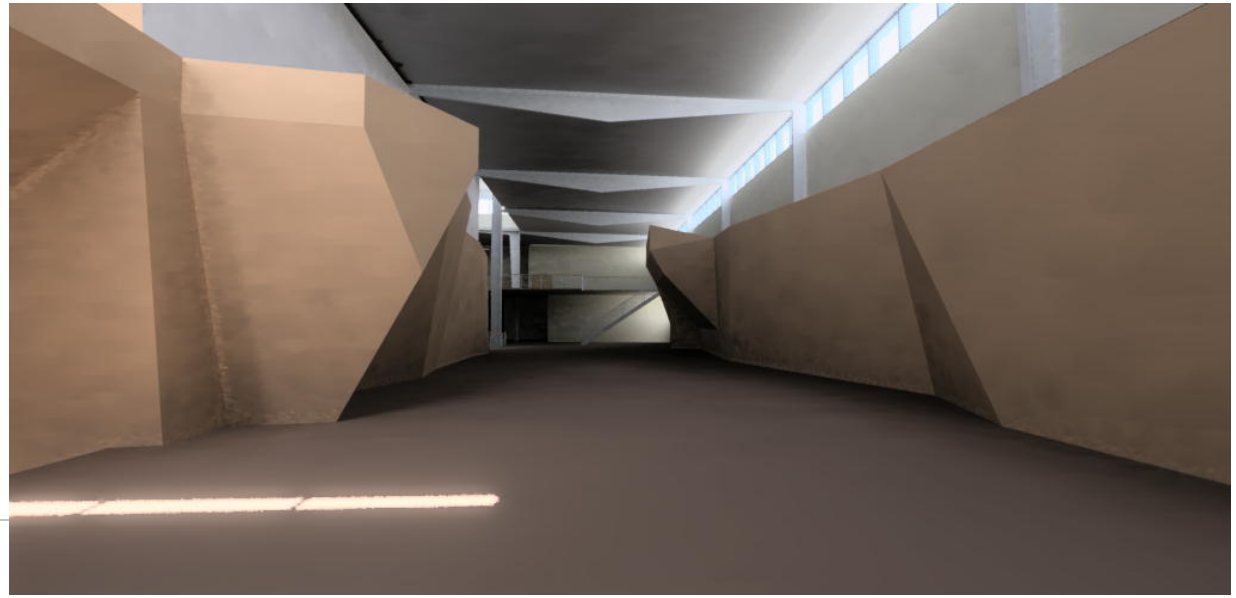
	2	7	12	17	22	27	32	37	42	47	52	57	62
137		0.21	0.34	0.40	0.44	0.45	0.44	0.39					
132	0.10	0.25	0.38	0.47	0.51	0.51	0.50	0.48					
127	0.06	0.26	0.41	0.50	0.52	0.54	0.53	0.53	0.51				
122	0.06	0.27	0.38	0.51	0.54	0.55	0.57	0.57	0.58				
117	0.03	0.23	0.41	0.48	0.56	0.59	0.62	0.64	0.60	0.56			
112	0.03	0.25	0.44	0.51	0.58	0.61	0.63	0.66	0.65	0.62	0.54		
107	0.04	0.16	0.40	0.50	0.60	0.62	0.63	0.65	0.65	0.64	0.57	0.13	
102		0.11	0.38	0.55	0.60	0.62	0.64	0.67	0.65	0.62	0.57	0.42	
97			0.35	0.50	0.58	0.62	0.63	0.65	0.63	0.63	0.56	0.35	0.22
92			0.37	0.49	0.57	0.60	0.61	0.62	0.63	0.56	0.52	0.25	0.14
87			0.41	0.50	0.54	0.58	0.59	0.59	0.59	0.51	0.22	0.14	0.15
82			0.37	0.46	0.50	0.53	0.56	0.57	0.58			0.23	0.30
77	0.16	0.19	0.34	0.43	0.48	0.52	0.54	0.53	0.52	0.39	0.25	0.28	0.29
72	0.15	0.25	0.33	0.42	0.47	0.49	0.52	0.52	0.49	0.39	0.30	0.29	0.23
67	0.12	0.20	0.31	0.39	0.43	0.45	0.45	0.49	0.47	0.39	0.29	0.23	0.17
62	0.10	0.16	0.26	0.31	0.36	0.39	0.43	0.42	0.39	0.32	0.20	0.14	0.12
57	0.09	0.17	0.24	0.29	0.31	0.34	0.35	0.26	0.11		0.03	0.07	
52	0.08	0.16	0.22	0.25	0.24	0.23	0.22	0.13	0.05	0.00	0.00	0.00	0.00
47	0.08	0.15	0.16	0.20	0.18	0.17	0.15	0.09	0.04	0.01	0.00	0.00	0.00
42	0.08	0.15	0.17	0.19	0.18	0.16	0.12	0.08	0.04	0.02	0.00	0.00	0.00
37	0.09	0.15	0.17	0.19	0.19	0.16	0.12	0.06	0.03	0.01	0.00	0.00	0.00
32	0.08	0.16	0.18	0.19	0.22	0.20	0.13	0.05	0.02	0.01	0.00	0.00	0.00
27	0.15	0.15	0.18	0.20	0.21	0.24	0.26			0.00	0.00		
22	0.06	0.14	0.17	0.19	0.23	0.27	0.34	0.41	0.40	0.28	0.15		
17	0.05	0.11	0.15	0.20	0.25	0.33	0.44	0.50	0.48	0.43	0.24		
12	0.05	0.09	0.13	0.17	0.21	0.32	0.49	0.59	0.62	0.54	0.48		
7		0.08	0.10	0.12	0.15	0.20	0.35	0.53	0.63	0.51	0.61		
2			0.07	0.09	0.10	0.12	0.14	0.18	0.22	0.25	0.25		

Daylight Autonomy, DA_{20}

Movement Climbing Gym

- Bouldering area – many inverted climbing surfaces
- Surface finishes important – high reflectance walls and mat





Movement Climbing Gym

Colorado Army National Guard Facility

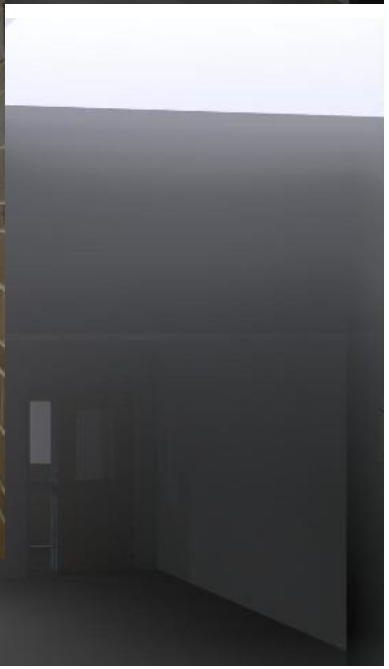
- Large assembly hall
- Highly variable occupancy
  - 150-200 once a month
  - 3 otherwise
  - Key to create a very passive / sustainable design
- Blast-proof glazing throughout
- Fiberglass clerestory balanced with skylights

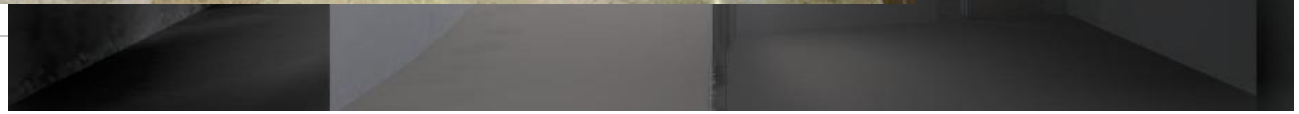
Colorado Army National Guard Facility

- Well saturated classroom space
- Electric lighting hardly noticeable

Colorado Army National Guard Facility

- Central entry / commons
- Internal “skylights” to light adjacent conference rooms





Enhanced Skylight Modeling - Study Objectives

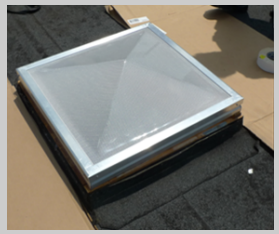
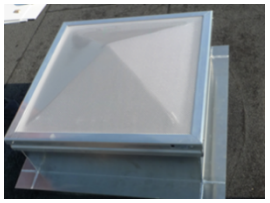
- Develop and validate computer modeling and simulation methods for producing daylighting system photometric information

- An alternative to the physical measurement methods laid out in IES LM81-10 "*Photometric Testing of Skylight and Tubular Daylighting Devices under Hemispherical Sky Conditions*"

- Addresses several physical measurement constraints
  - Size constraints: 5x rule, large light sources
  - Sky constraints: limited sun angles, subject to climate conditions
  - Photometric resolution: limited by number of physical sensors
  - Time constraints: measurement time delays, 3min per measurement set, climate conditions

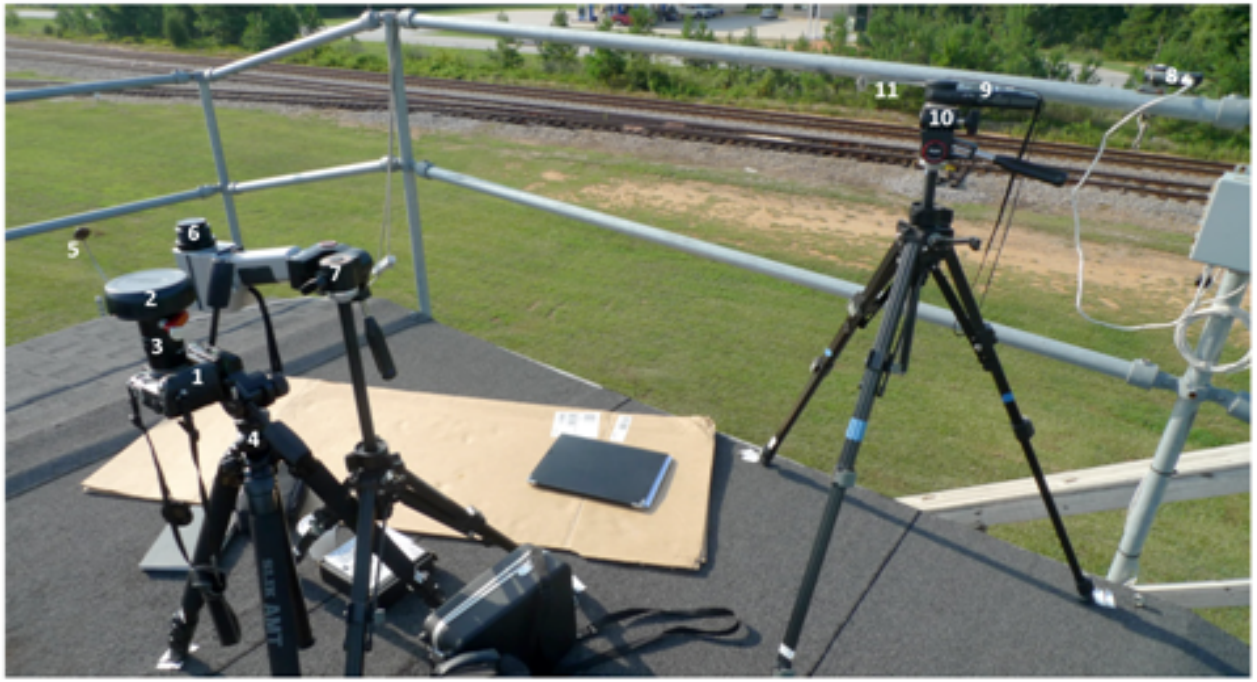
Skylight Systems

- Several levels of optical complexity
  - "low" aspect ratio, single prismatic lens, white foam lightwell
  - "med" aspect ratio, two prismatic lenses, specular lightwell
  - "high" aspect ratio, acrylic lens, prismatic lens, specular cylindrical lightwell

Skylight Type	Selected products	Image
1 **Basic skylight: minimal optics, "low" aspect ratio**	Sunoptics pyramid skylight Top prismatic lens White diffuse lightwell	
2 **Moderate skylight: dual optics, "med" aspect ratio**	Sunoptics pyramid skylight "light cube" Top and bottoms prismatic lens Reflective lightwell	
3 **Advanced skylight: multiple optics, "high" aspect ratio**	Sun Tunnel™ Top clear lens Bottom prismatic lens Reflective tubular lightwell	

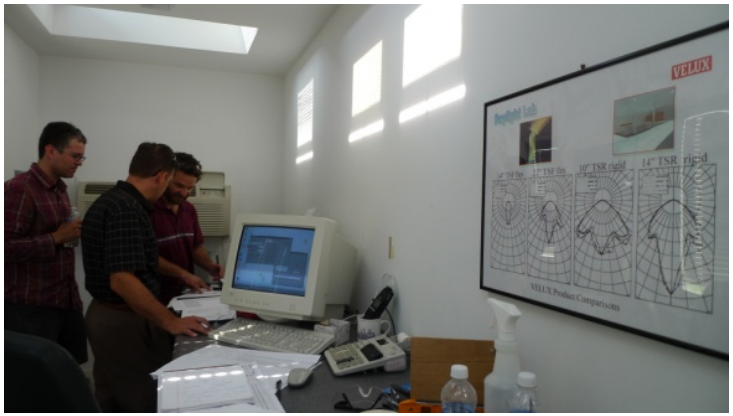
Measurement Equipment

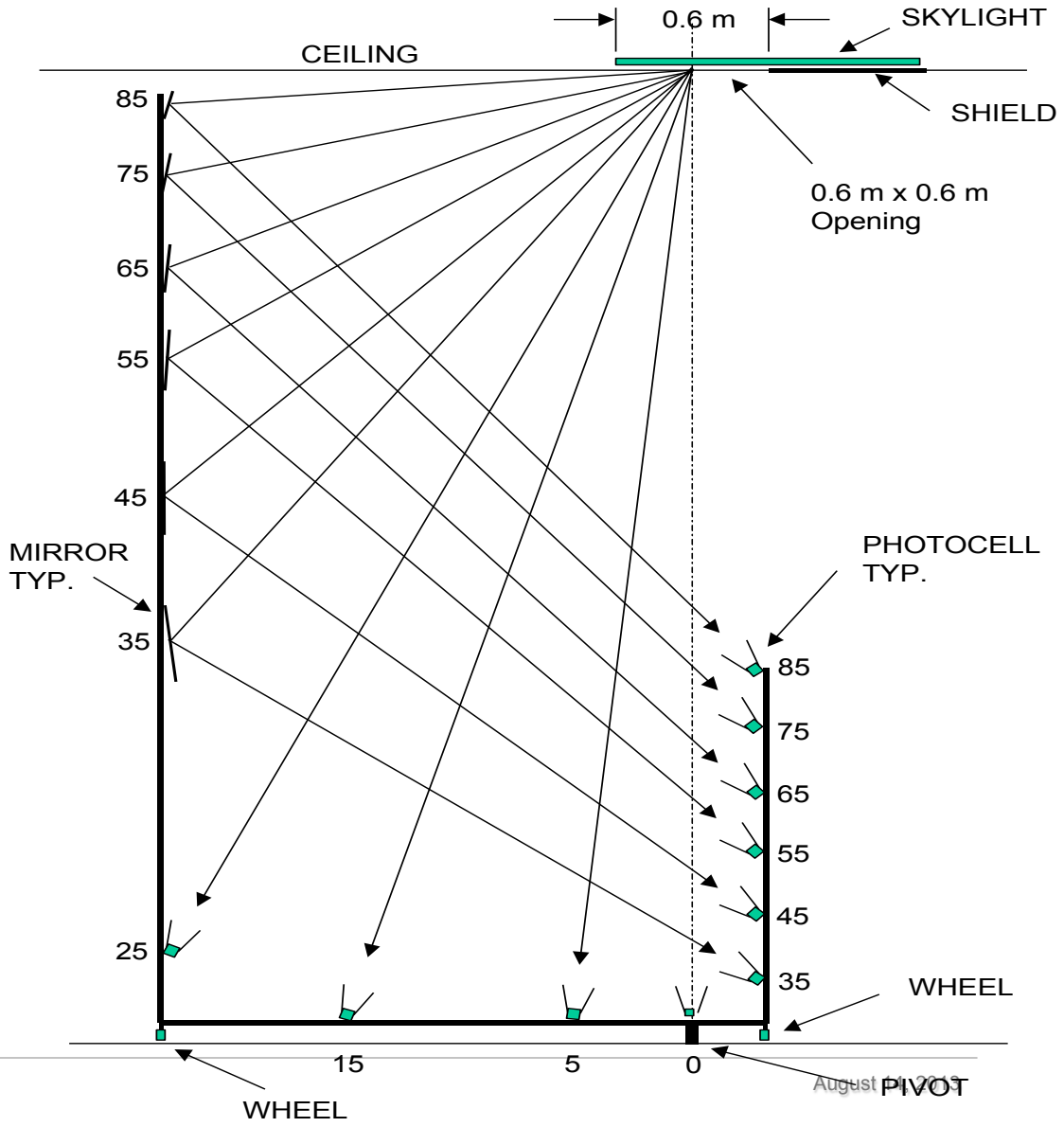
1) Nikon Coolpix 5400 camera
2) Nikon FCE9 Fisheye Converter Lens for the Nikon Coolpix 5400 camera
3) Nikon UR-E10 Converter Adapter for Coolpix for the Nikon Coolpix 5400 camera
4) Tripod for the Nikon Coolpix 5400 camera
5) Shading disk for the Nikon Coolpix 5400 camera
6) Minolta luminance meter LS 110
7) Tripod for Minolta luminance meter LS 110
8) Konica Minolta CL-200 Chromameter
9) Konica Minolta CL-200 Chromameter
10) Tripod for the Konica Minolta CL-200 Chromameter
11) Shading disk for the Konica Minolta CL-200 Chromameter



Goniophotometer

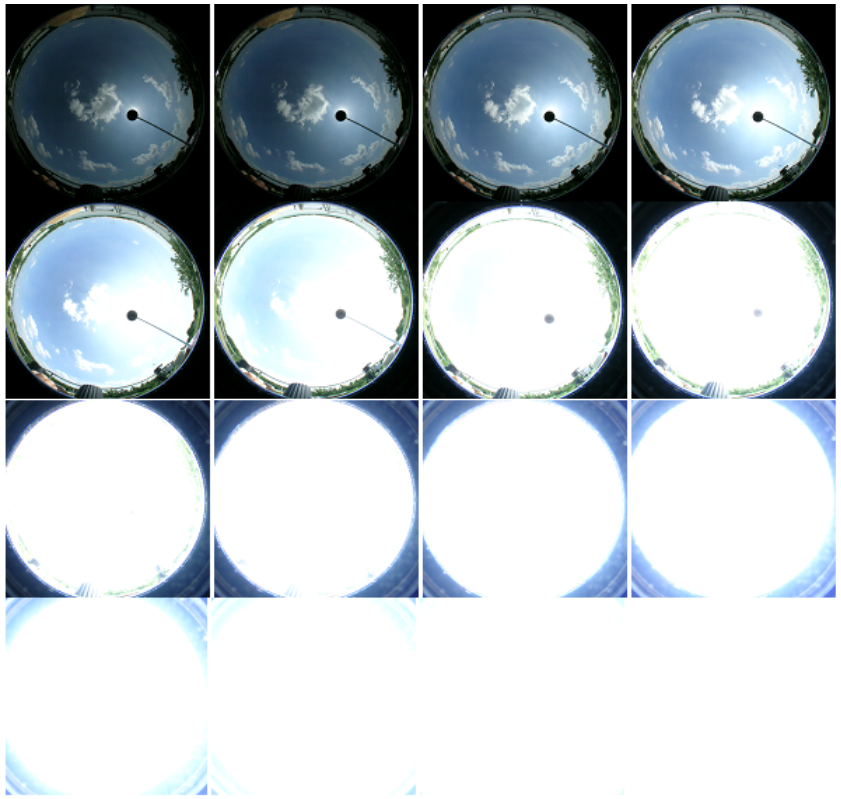
- Rotating arm of shielded illuminance sensors
- Angles 35°and sensor focused on mirror to obtain 5:1 requirements
- Facility had 2'x2' opening only

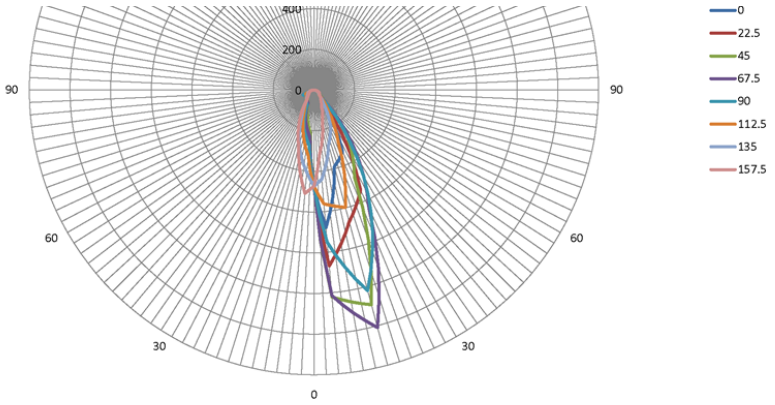


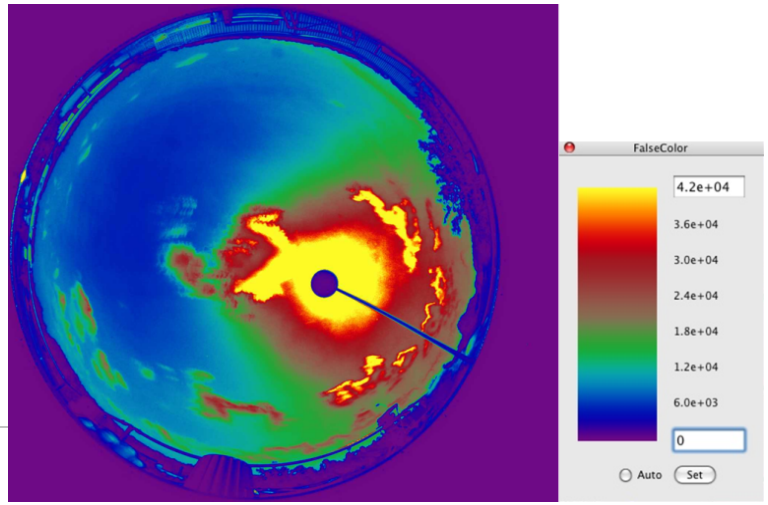


Measurement Results

- 31 skies measured in total
  - Partly cloudy, low sun, mid sun, high Sun
- High Dynamic Range (HDR) hemispherical sky images
- Measured luminous intensities

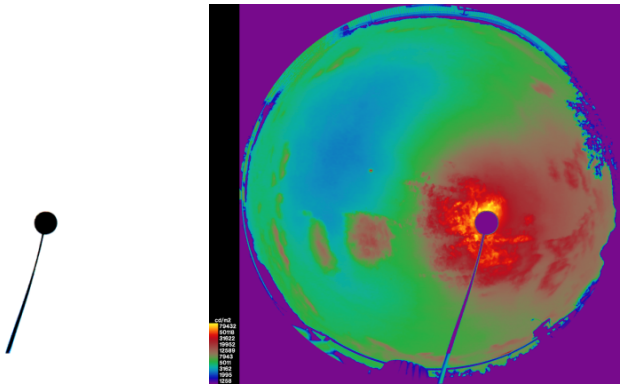




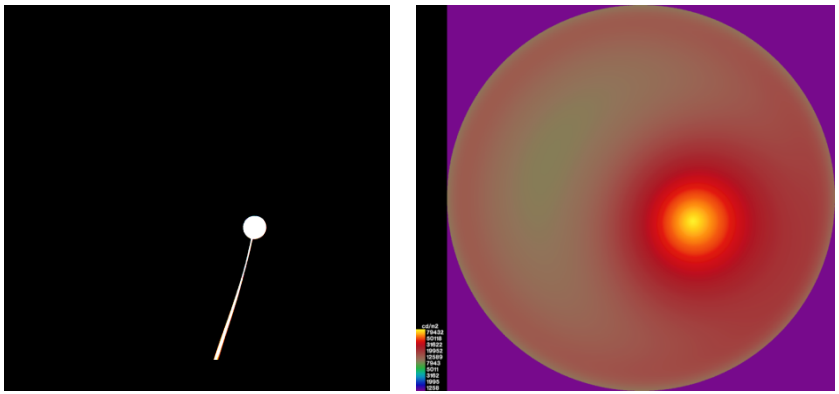


Sky map processing

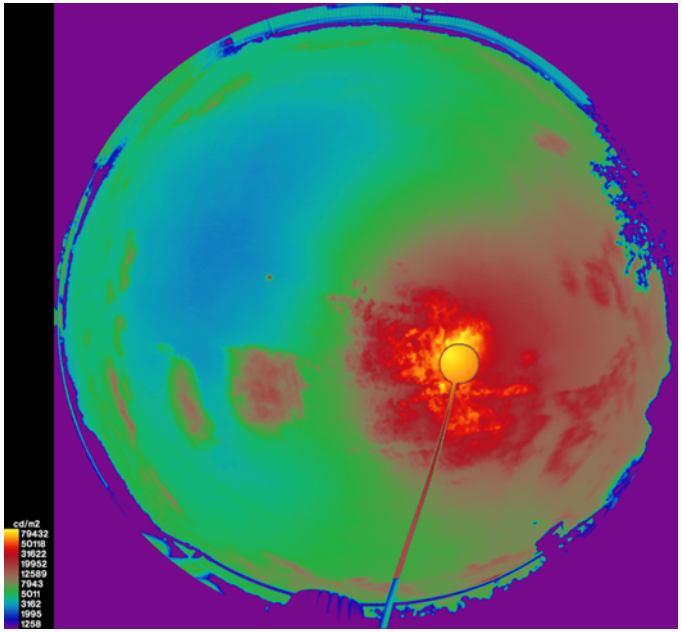
- Shading arm masked out
- Filled in with matching Perez sky
- Calibrated with direct and diffuse illuminance measurements



Shading arm mask



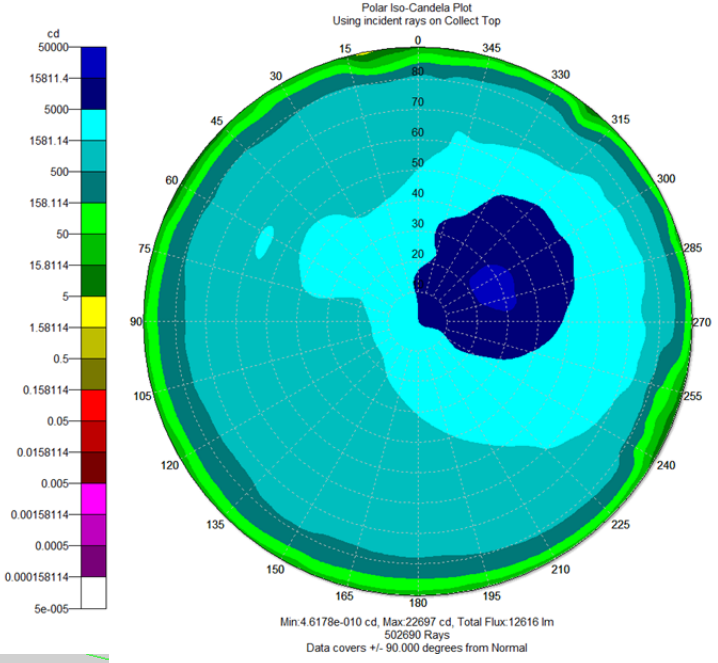
Perez Sky filler and mask



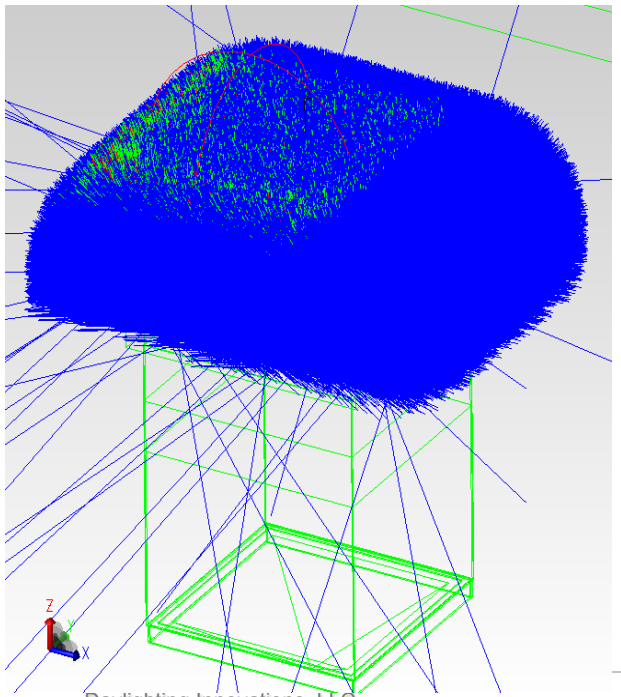
Final Calibrated Sky

Sky and Sun Ray Sets

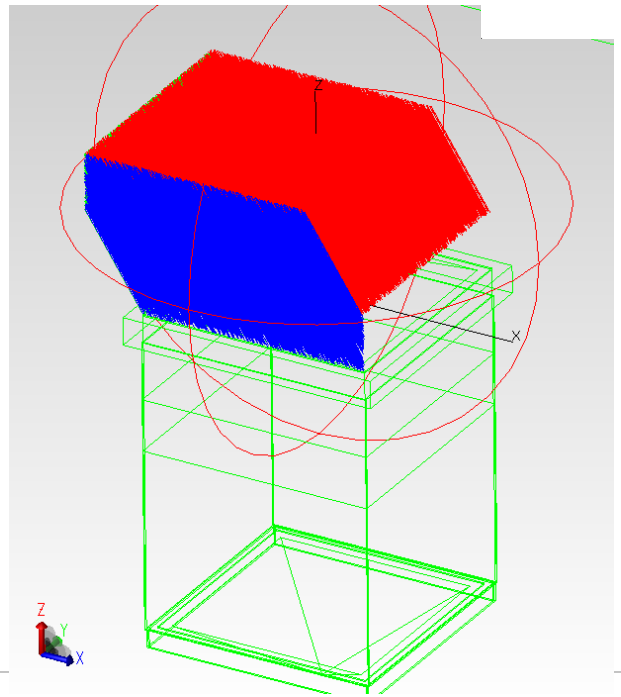
- Sky map and solar source converted to ray-set “hats”
  - Generated from encompassing box (5 sided, open bottom)
  - Sun source incident on 3 of 5



Sky Ray Set Candela Plot



Sky “hat”

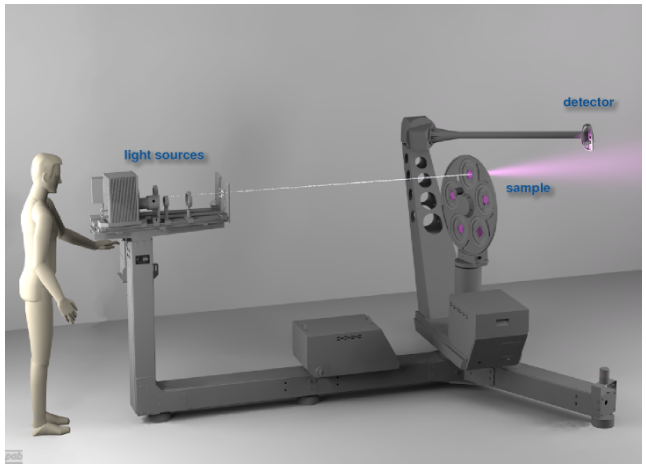


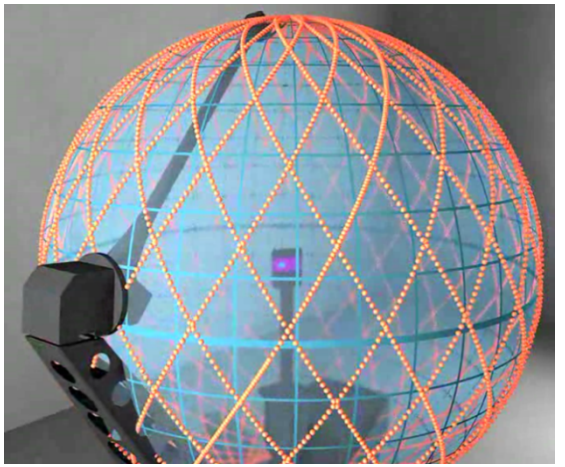
Sun “hat”

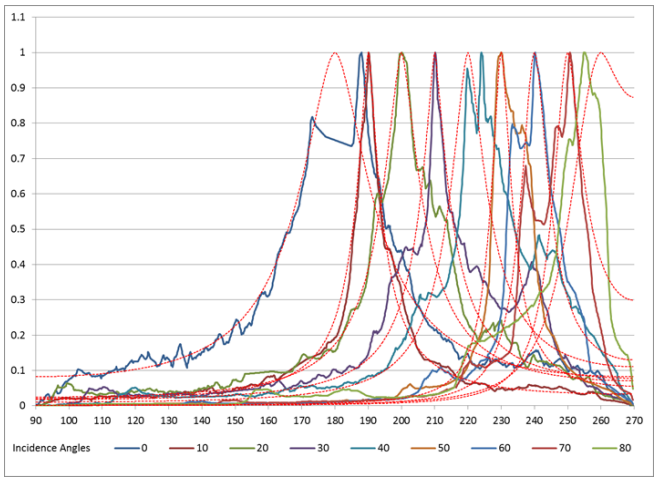
- Candela plot of box surfaces match sky maps

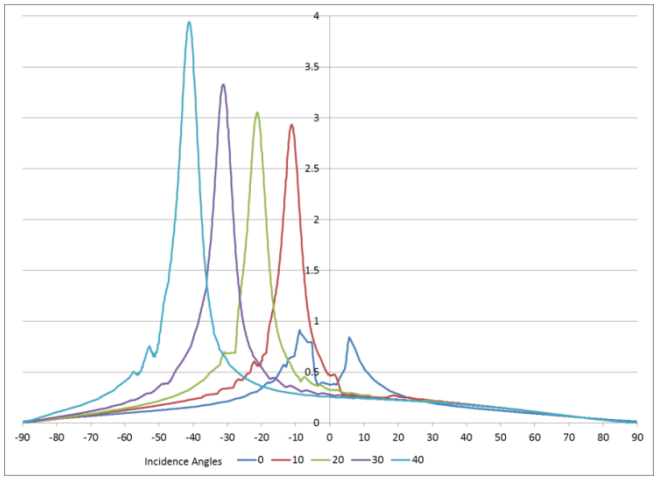
LBNL BSDF Measurements

- PAB Limited Gonio-photometer 2 at LBNL
- Adjustable density scan web-like patterns
- Anisotropic manual process, unavailable at the time

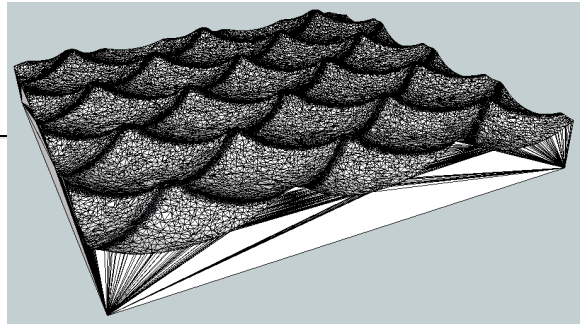








Radiance BSDF - SunOptics Lens



Load a BSDF XML file /Users/rgugliel/Desktop/SO_lasered-tadj-t45.xml

Save Image

Show Help

Show Patch Numbers

Equidistant | Orthographic

Log Scale | Linear Scale

Scale Maximum: 100

Number of Decades: 4

Incident Hemisphere

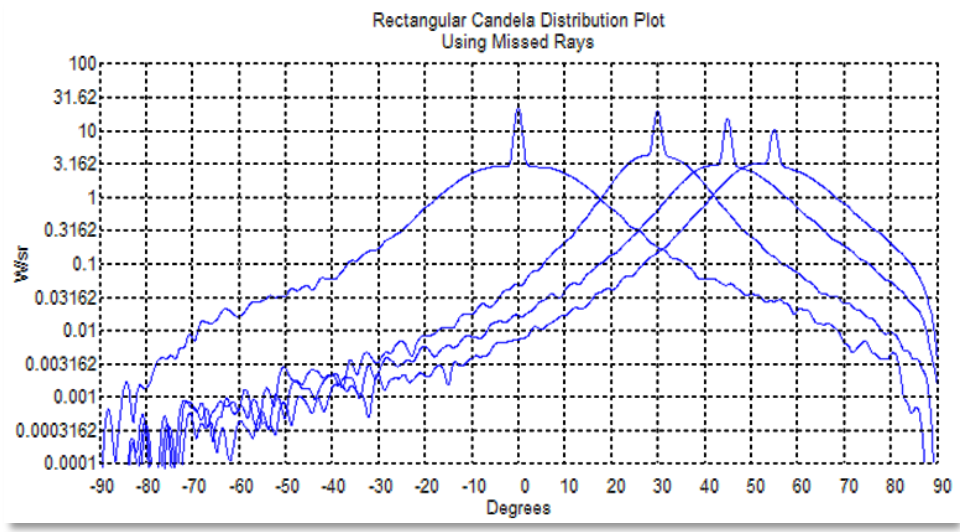
Theta: 0.0
Phi: 180.0

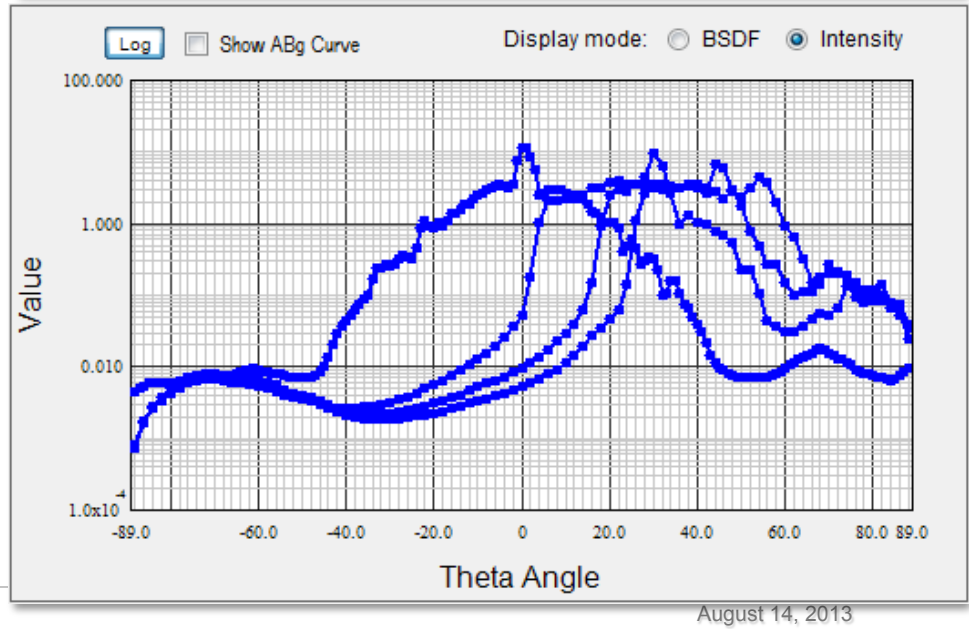
Visible Front Transmission
Direct Hemispherical = 83.1%

BSDF Value
100.0
39.81
15.84
6.309
2.511
1.000
0.398
0.158
0.063
0.025
0.010

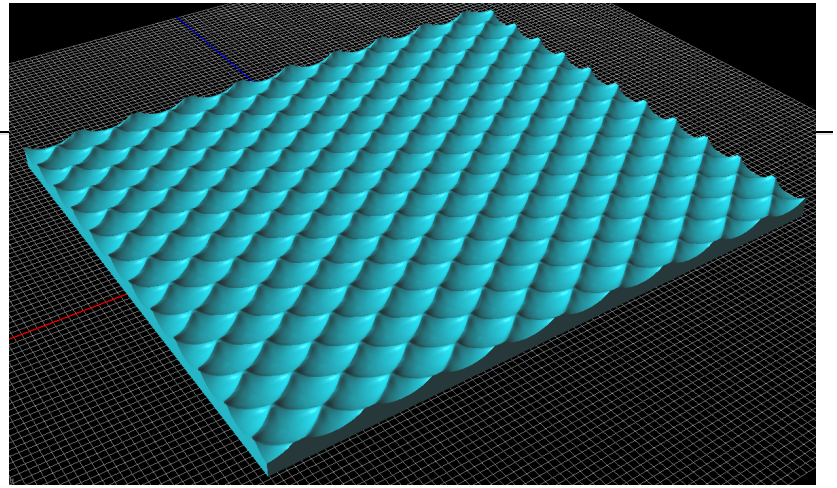
TracePro BSDF CASI Measurements

- Complete Angle Scatter Instrument (CASI)
- Measurements limited to 55° and below
- Decent curve fit for perpendicular angles
- Poor fitting for high angles

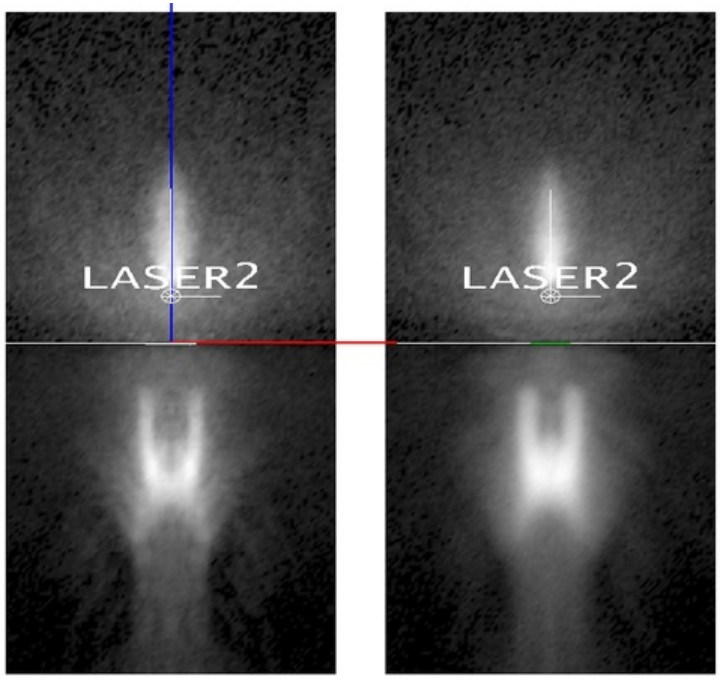




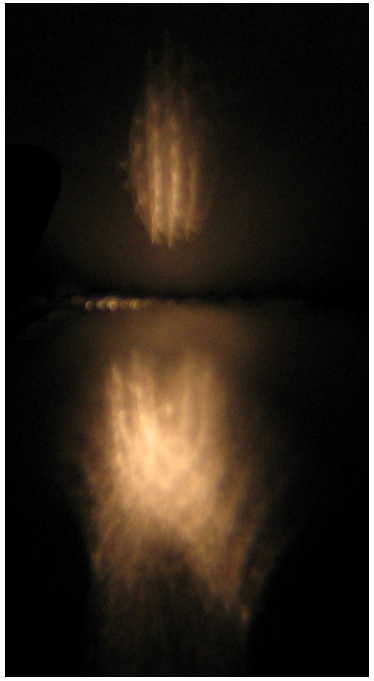
Photopia BSDF Generation



- Laser scan lens models simulated in Material Lab tool
- BSDF format native to Photopia
- Adjustable resolution
- 1-2° deg resolution used

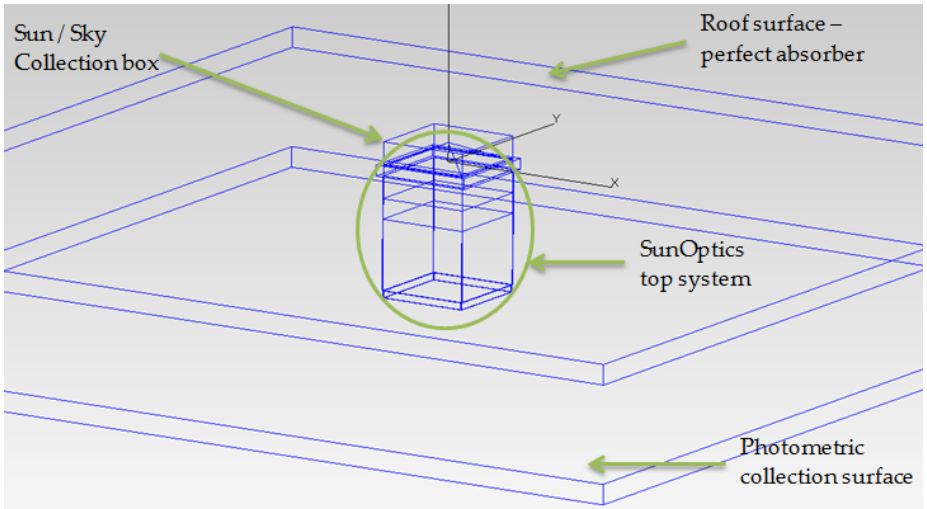


Simulated scatter (3d model on left, BSDF representation on right)

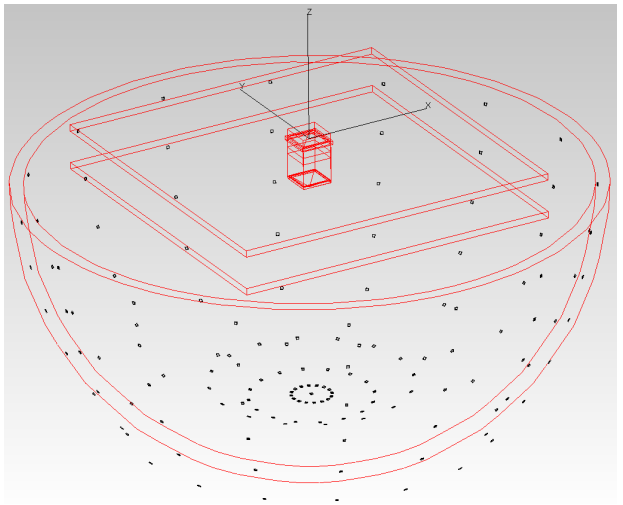


Photograph of scatter

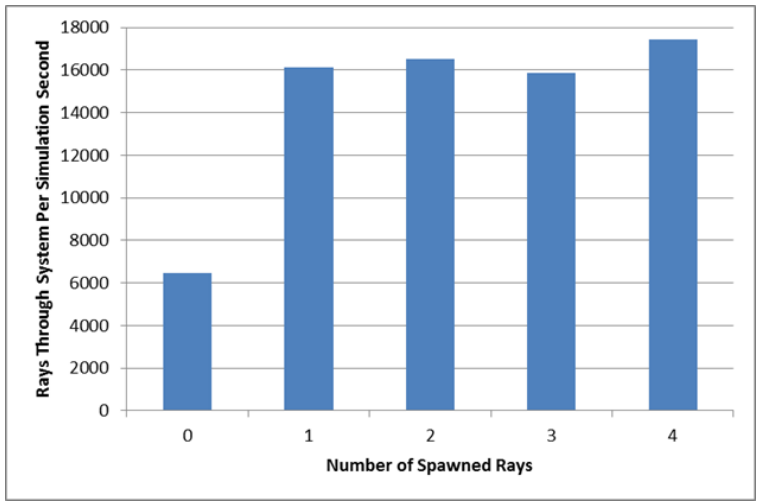
TracePro Simulation



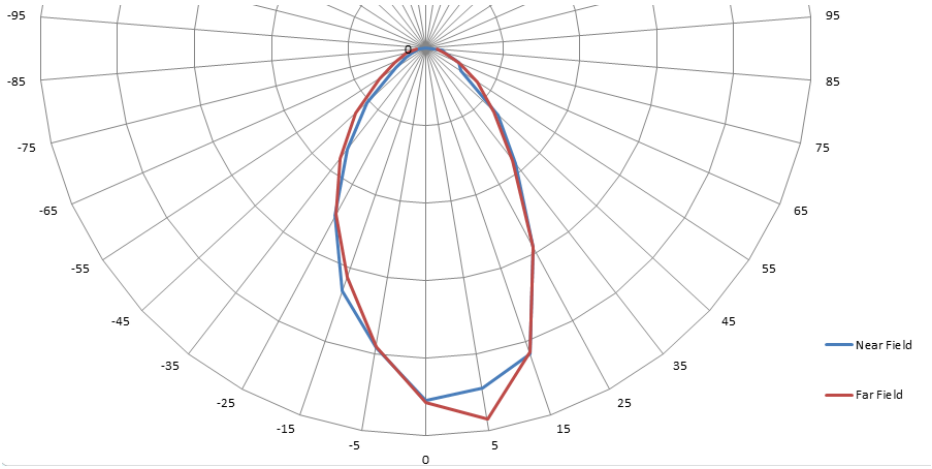
TracePro Model Geometry



Near Field Points



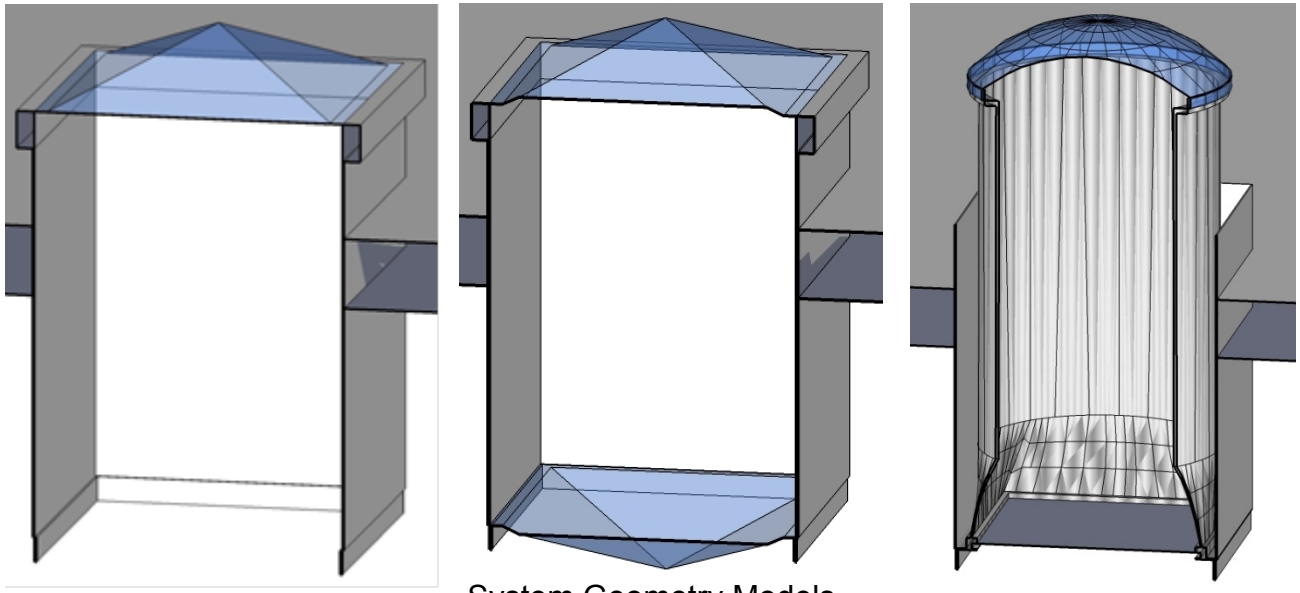
Ray Spawning Optimization Study



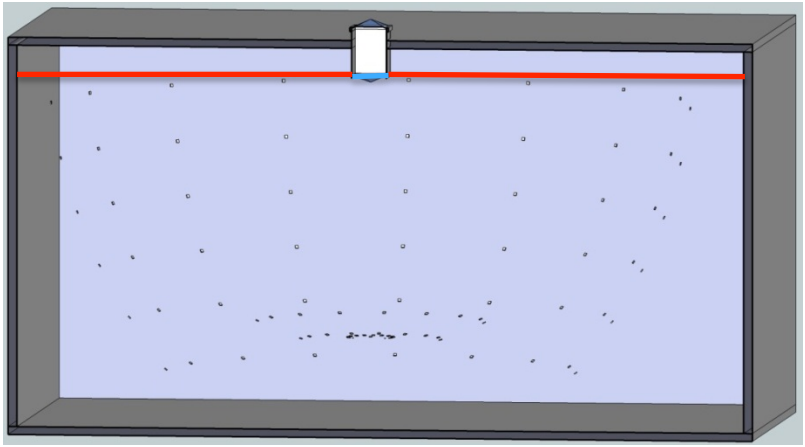
Near vs Far Field

Radiance Simulation

- Radiance classic – raytrace from final sensor points to sky and sun source
- "Mkillum" strategies – split into two components
  - Skylight opening to outside
  - Sensor points to skylight opening
- System BSDF – no proxy geometry required model refinements

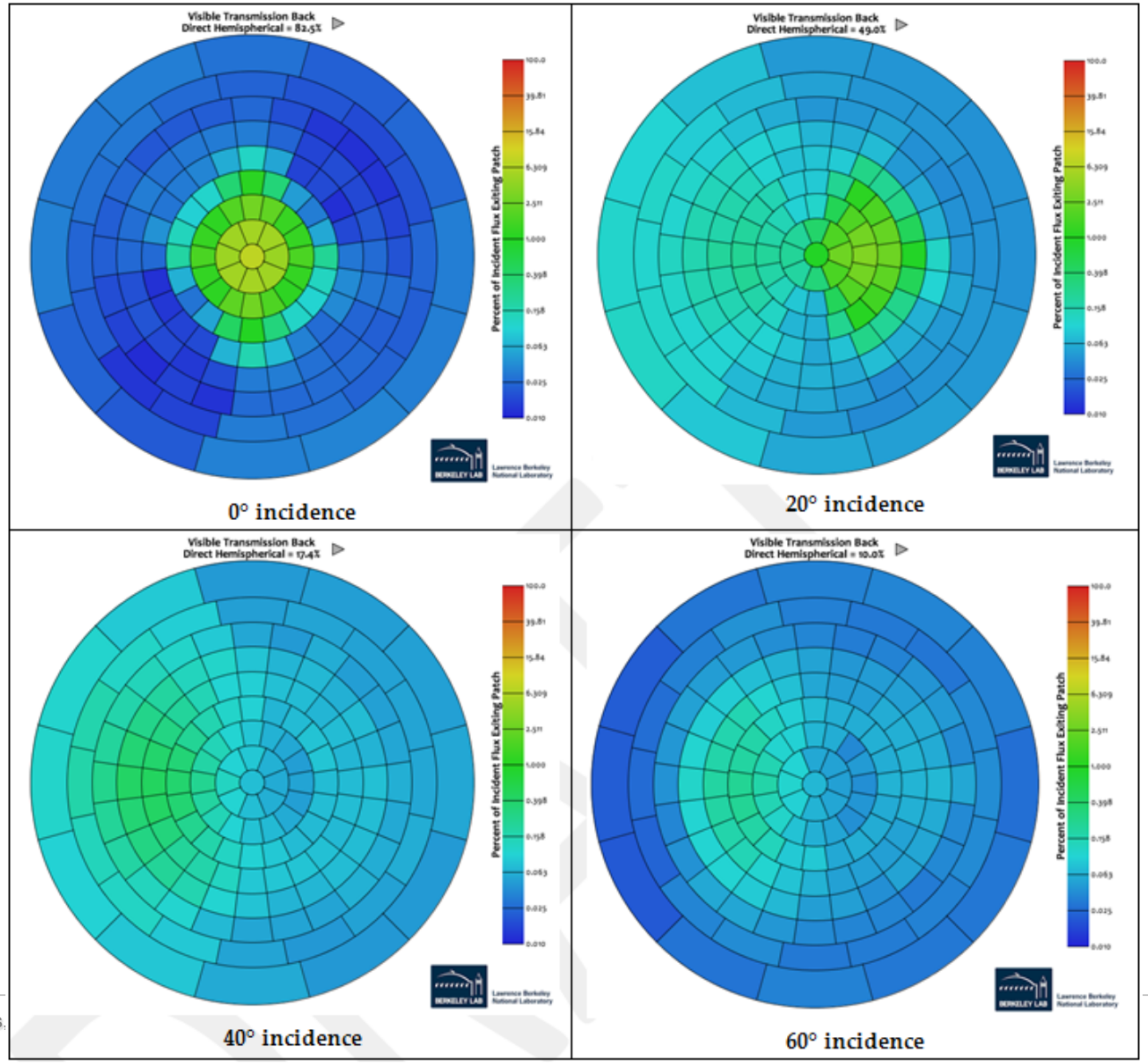


System Geometry Models

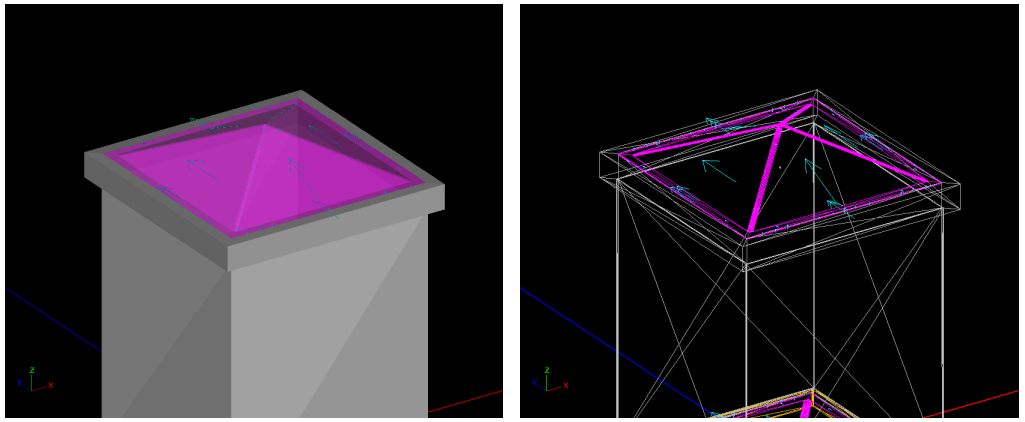


Radiance Simulation Model

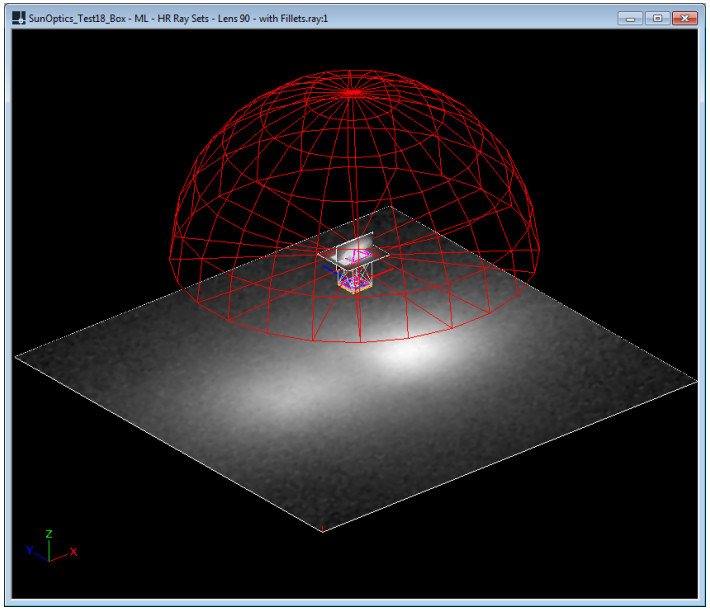
Radiance SunOptics Top System BSDF



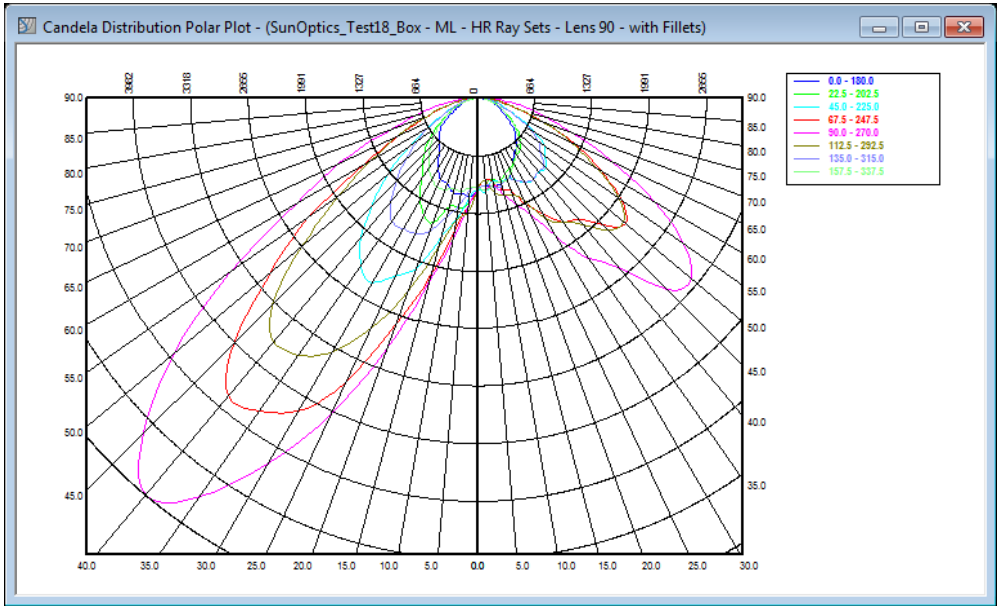
Photopia Simulation



Photopia geometry models

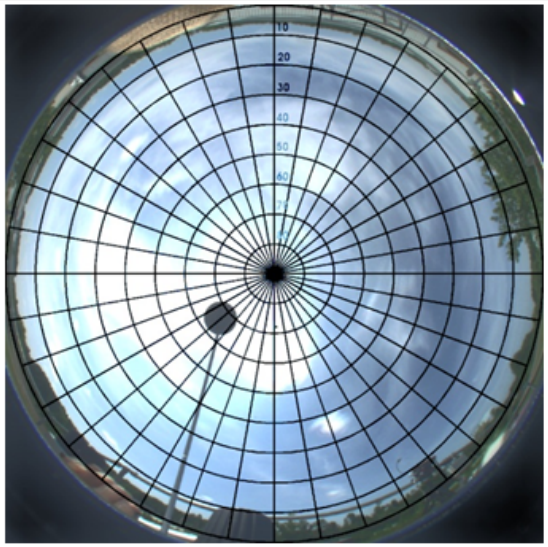


Illuminance plane output

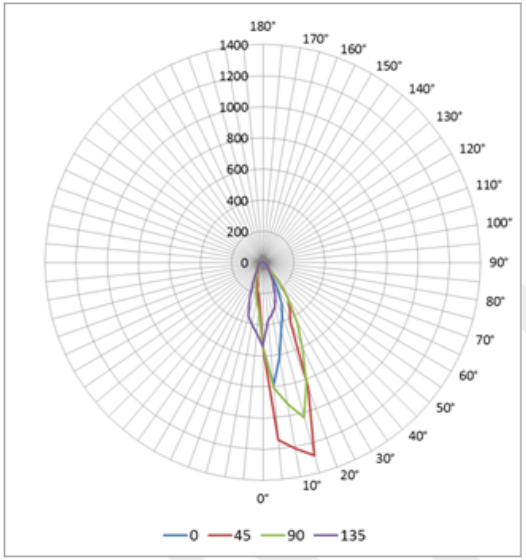


Luminous intensity photometric plot

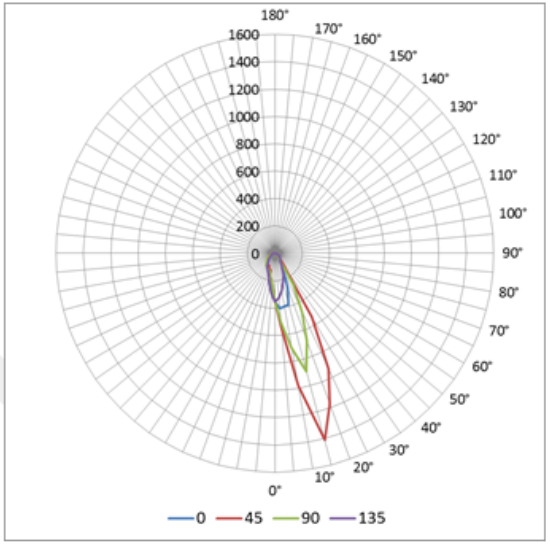
SunOptics Top – Sky 28



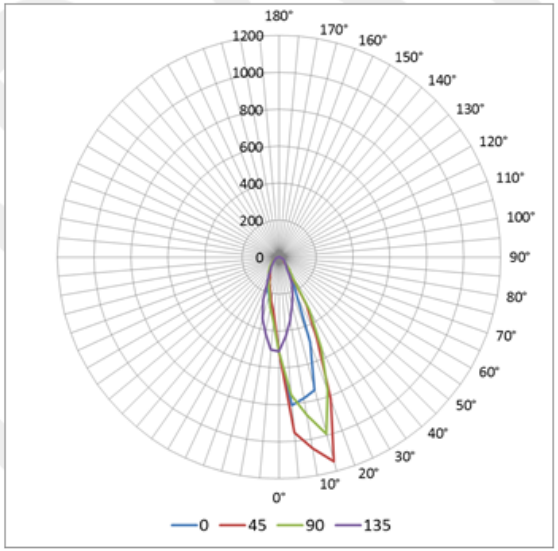
Measured Sky 28



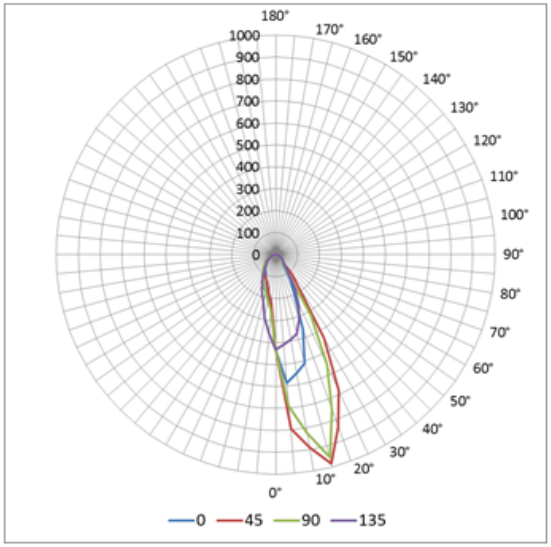
Measured



TracePro Simulated

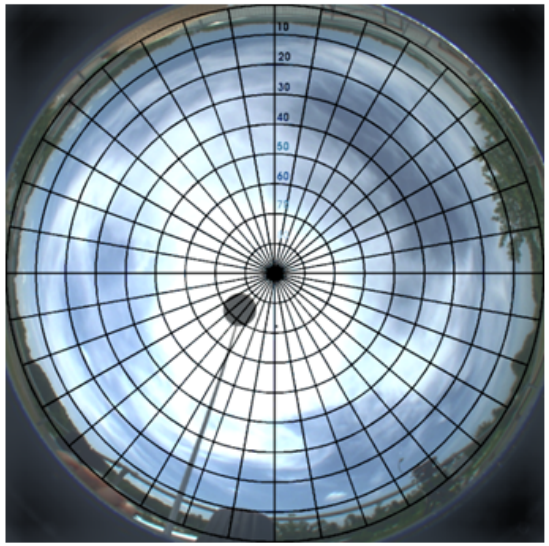


Radiance Simulated

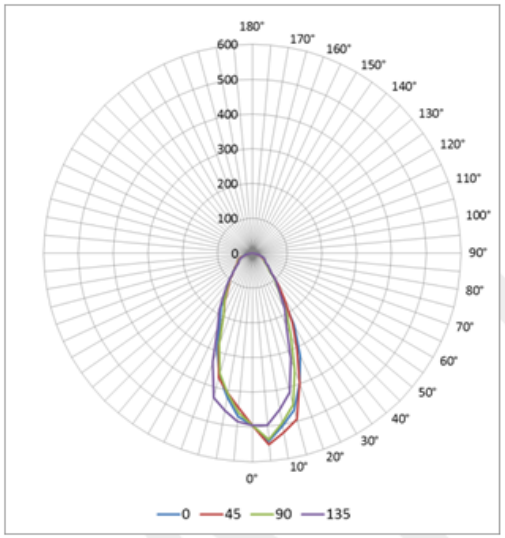


Photopia Simulated

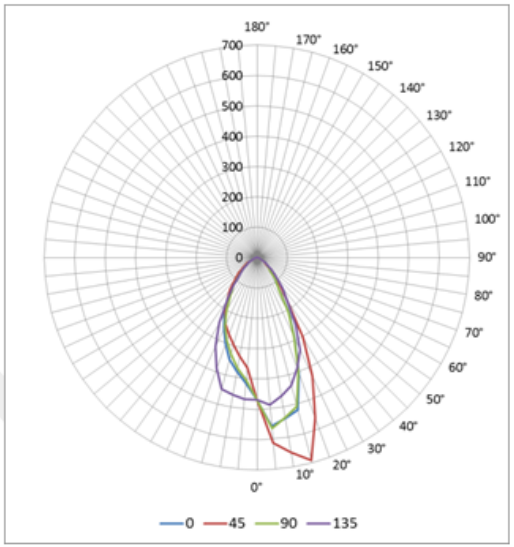
SunOptics Box – Sky 32



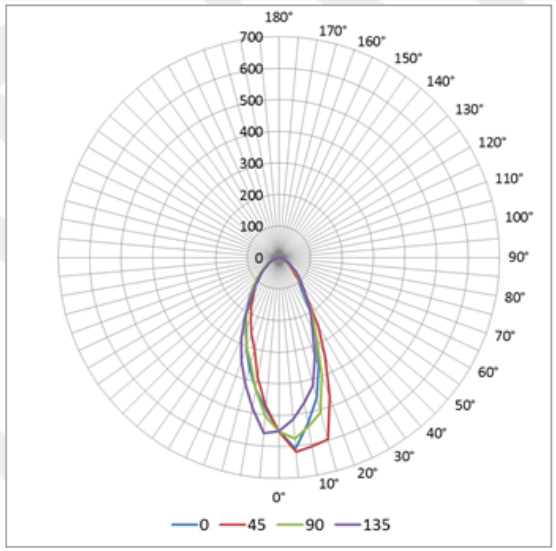
Measured Sky 32



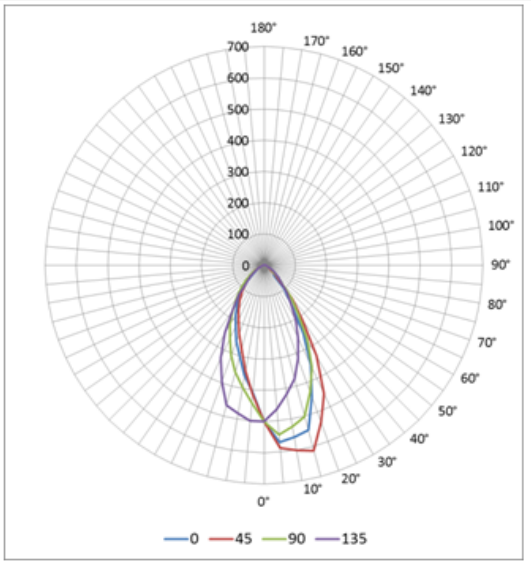
Measured



TracePro Simulated

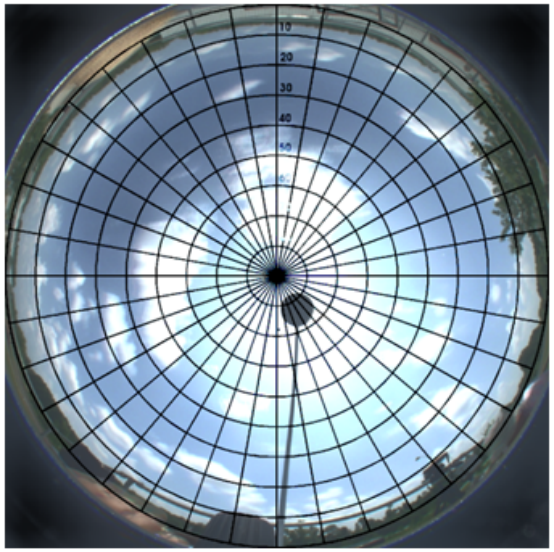


Radiance Simulated

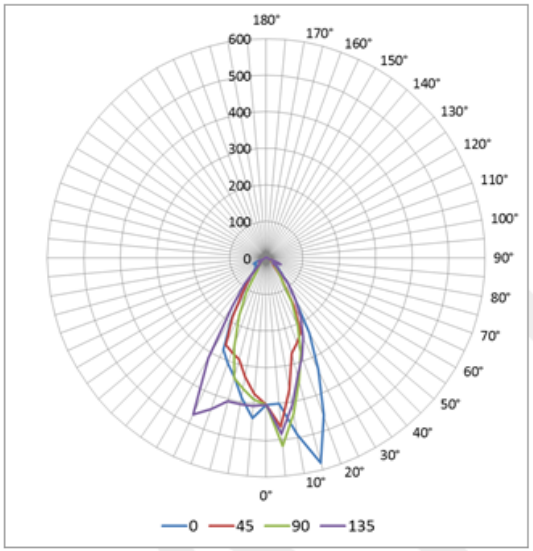


Photopia Simulated

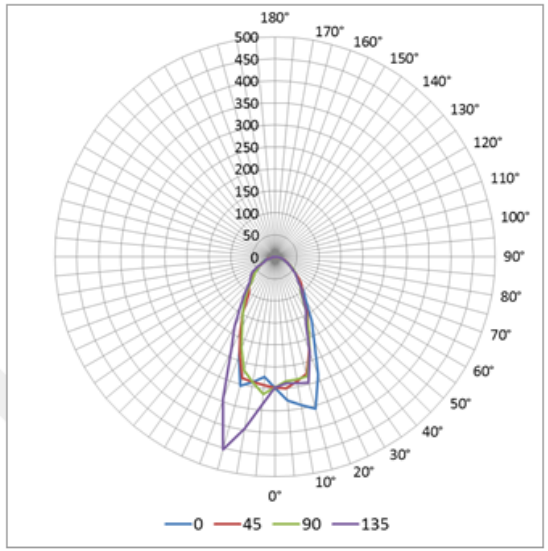
SunTunnel – Sky 6



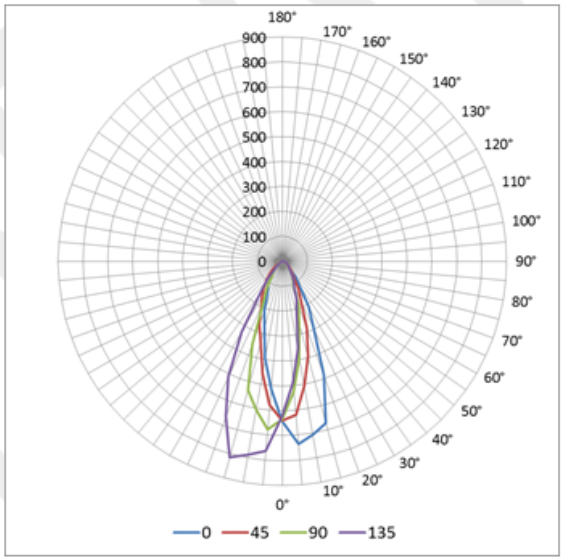
Measured Sky 6



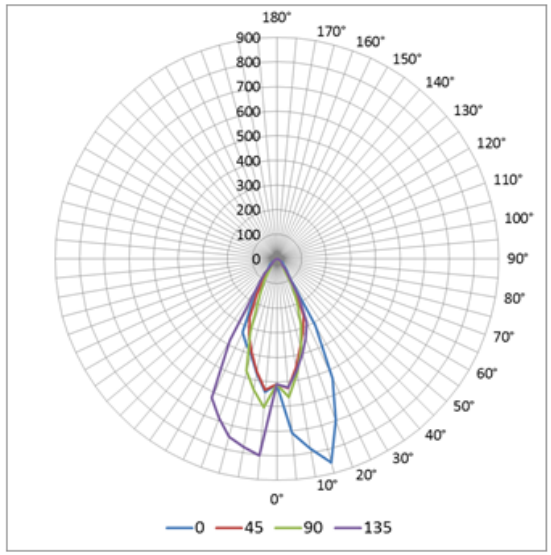
Measured



TracePro Simulated



Radiance Simulated



Photopia Simulated

Conclusions – BSDF Measurement

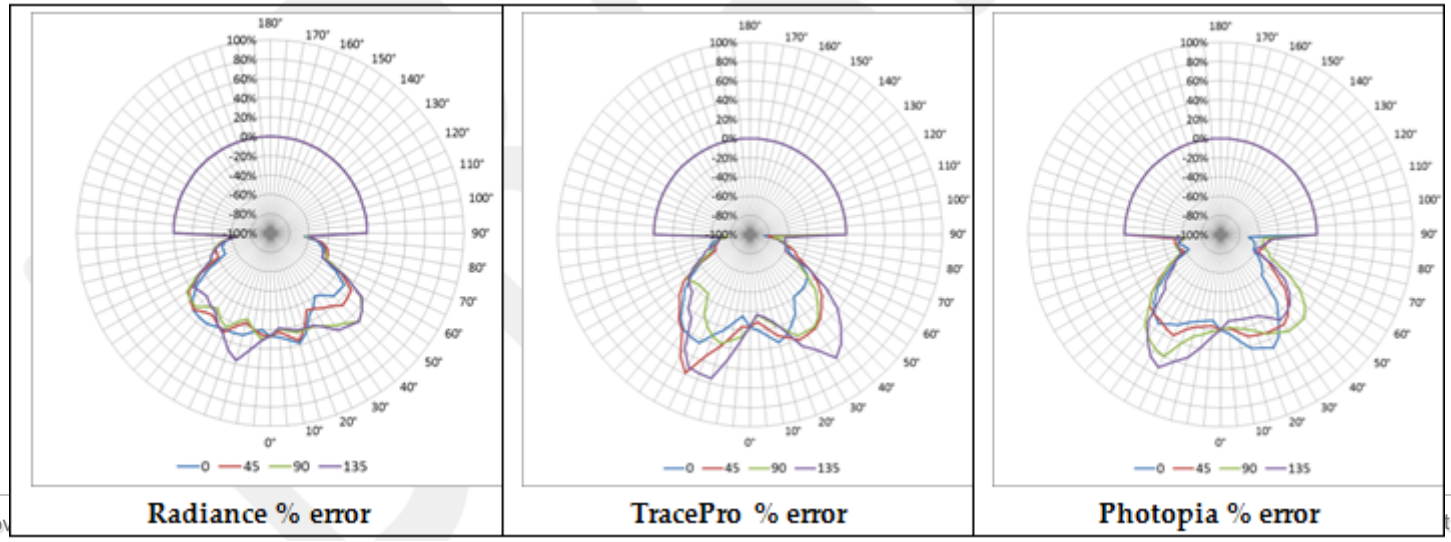
- Anisotropic and asymmetric data is necessary for materials that exhibit this type of behavior
- A BSDF measurement resolution of 1-2° provides adequate resolution for these systems
- Computer simulation of BSDF is a valid approach
  - Cannot detect some scatter due to manufacturing processes
  - Adequate model resolution to capture all optical geometry
- Harvey-Shack gaussian work well for specular and semi-specular
  - Gaussian representations not effective for anisotropic and asymmetrical materials (prismatic lens)
  - Full table BSDF increases simulation time significantly
- Photopia measurements accurate, proprietary format
- XML format good start
  - refine to expand angular definitions
  - eliminate redundancies

Conclusions – Simulation and Modeling

- Far field photometric simulation does not vary much from near field and is the preferred approach for future performance simulation
- An adequate number of rays leaving the system is necessary for “noise-free” simulation results – ~2-5 million leaving system good target
- Set a 30-50 bounce limit and low flux threshold to capture high angle exiting light
- System BSDF approach gives best Radiance matches and appears to be a valid approach
  - Radiance assumes a zero thickness system in this case
  - Modification suggested to allow for system thickness

Conclusions – Photometric Validation

- The accuracy and resolution of BSDF measurements critical, particular at lens entering system – parallel sun rays exacerbate the issue
- Small (in area) geometric details appear less important, ie. fillets
- All simulation engines struggle at high angle exiting light
- Measurements likely over predict high angle light as well due to ambient light in goniophotometer room
- General distributions of light match well



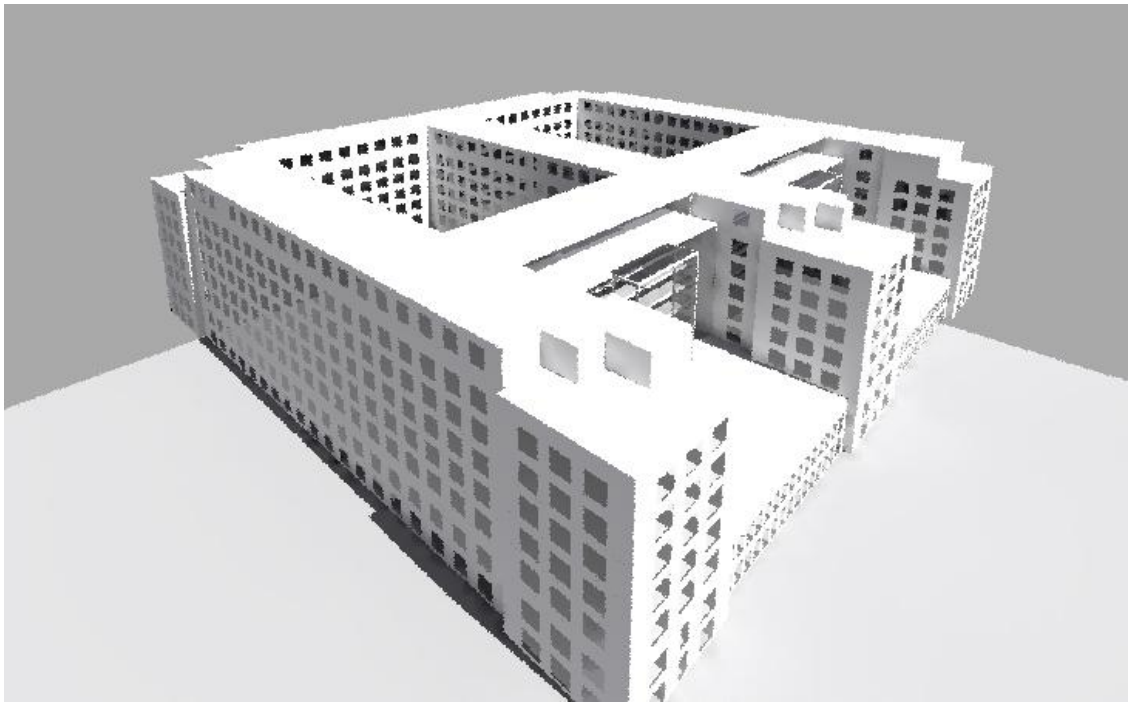
Next Steps

- IESNA Sub-committee for LM81-10 companion document
- Engage NFRC in expanding daylighting product metrics
- Create an openly available benchmark of sky sources and photometric for future validation
- Refine methods to improve accuracy
- Create IESNA sub-committee for daylight simulation methods
- Engage software developers regarding daylighting system photometric standards and annual simulation protocols
- Inform the architectural daylighting design community to the relevance of having detailed photometric data available

Building Daylight Profiler for Simulation (BDP4SIM)

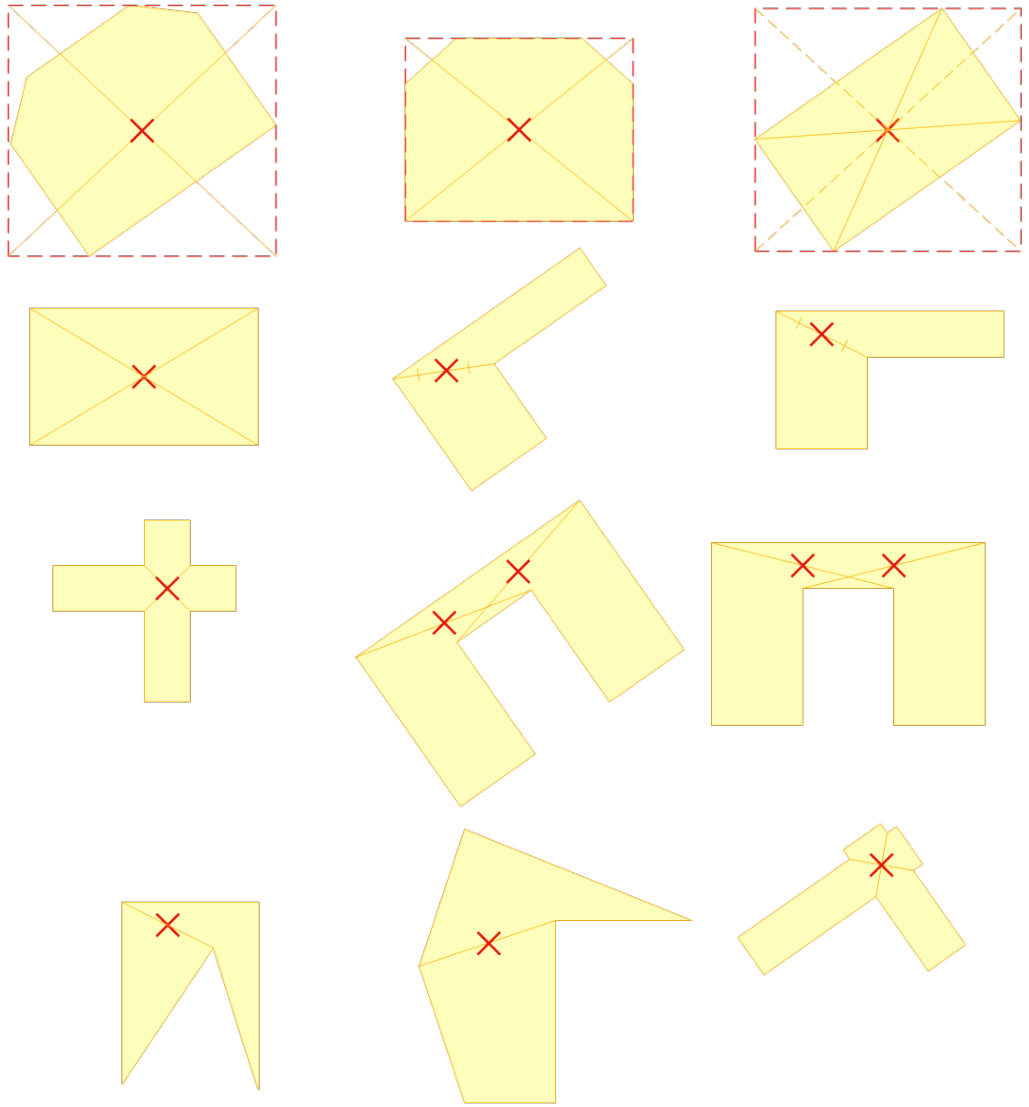
- Parametric modeler that creates Radiance and Energy Plus models via IFC files

- Challenge: how to efficiently automate daylight simulation for an entire building
  - Method to autogenerate illuminance grids for any shape of daylit space
  - Method to identify similar spaces to reduce overall calculation time

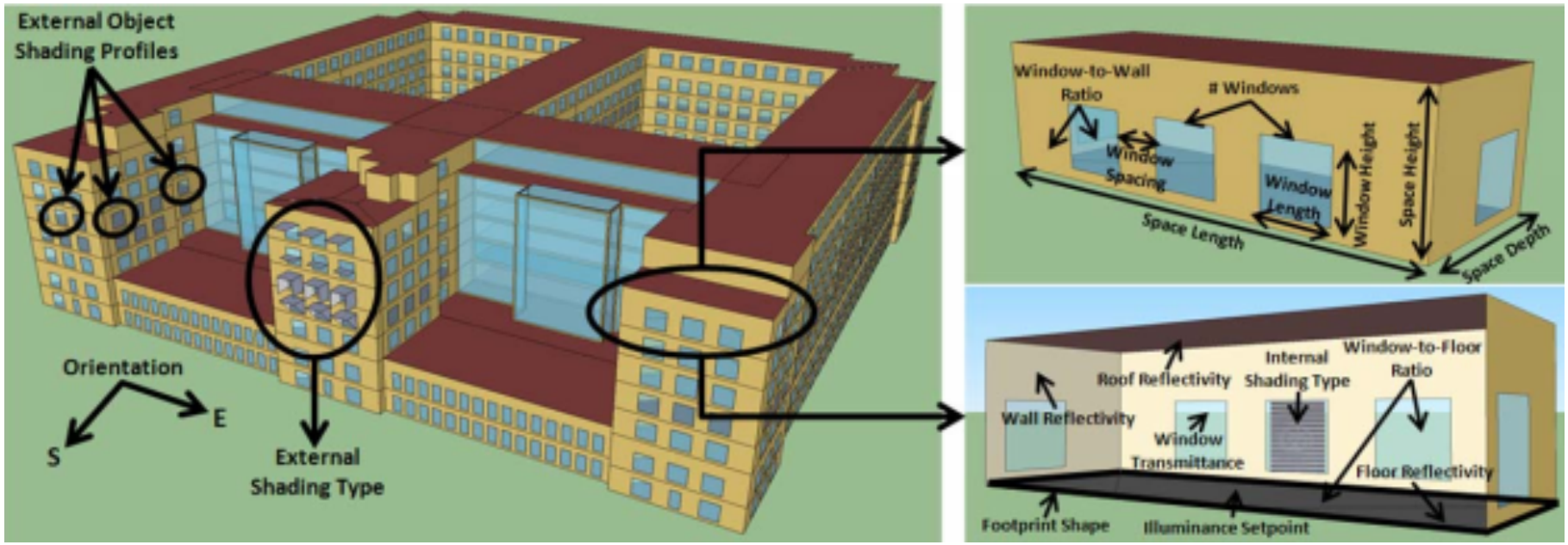


BDP4SIM – Vantage Point Generation

- Needed a consistent way to auto-generate a central vantage point

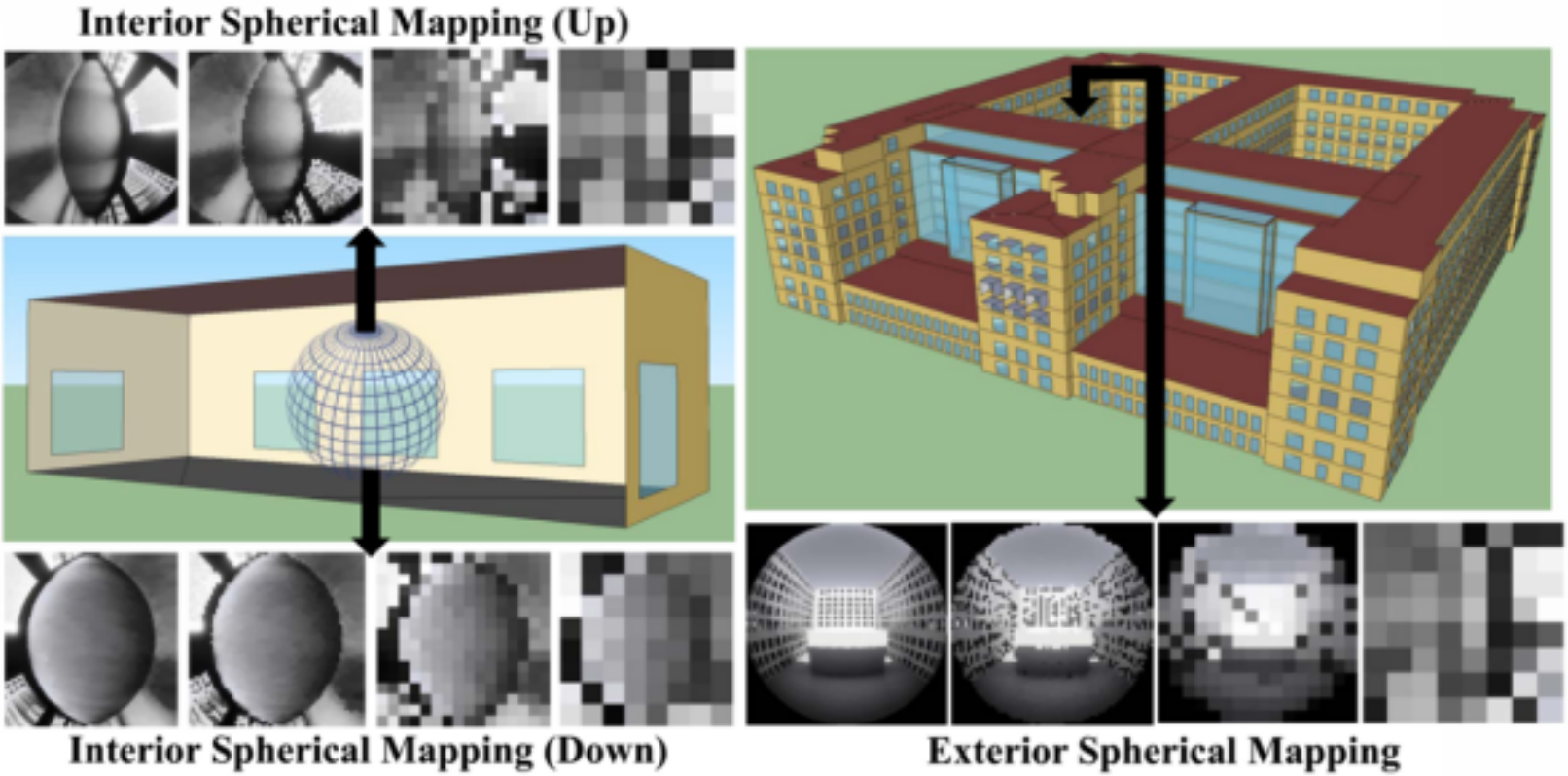


BDP4SIM – Variable daylighting elements



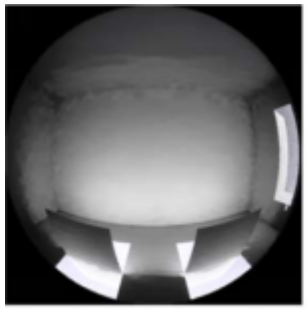
BDP4SIM – Spherical Mapping

- Rather than methodically checking space dimensions and orientation
- Employed idea of spherical maps to identify geometry and surface properties



BDP4SIM – Accuracy Dials

- Mapping type
- Interior up, interior down, exterior resolution
- Int / ext miss counts
- Transmittance and reflectance tolerance



Hemispherical mapping

Angular mapping

Stereographic mapping

- Case studies to understand the impact of these dials and appropriate thresholds

8x8 resolution material mapping
4 window hits (6%)
2 lightshelf hits (3%)
0 daylight window hits (0%)
46 wall hits (72%)
8 ceiling hits (13%)

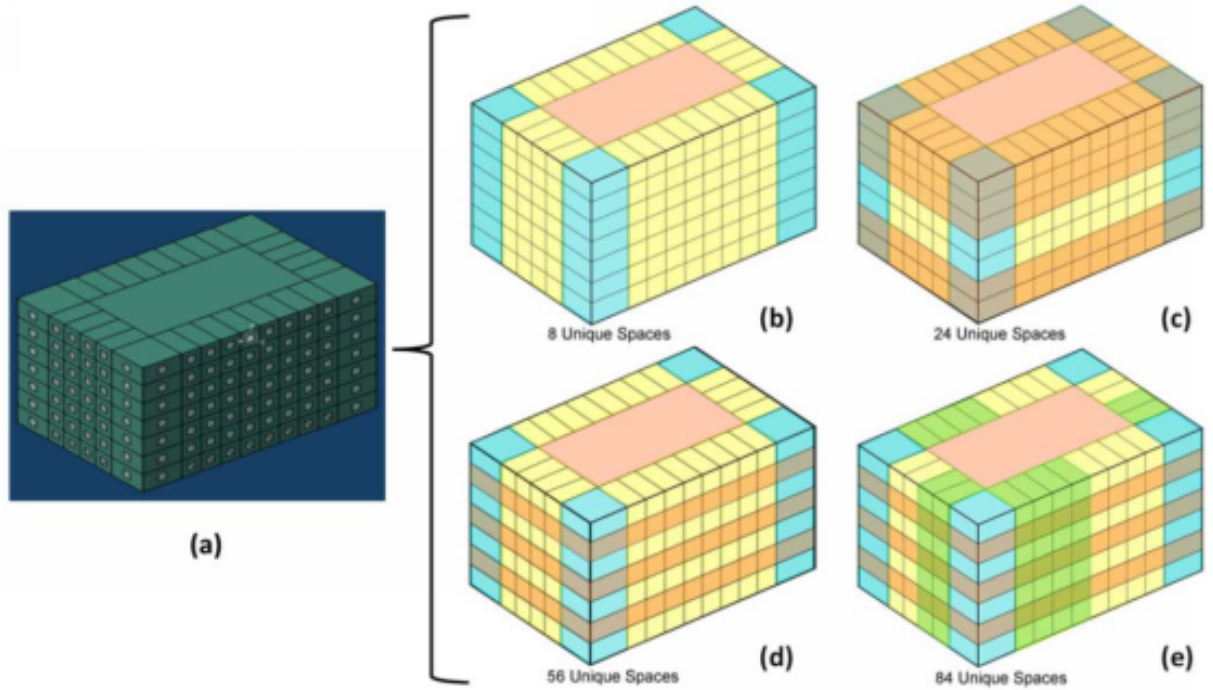
16x16 resolution material mapping
24 window hits (9%)
10 lightshelf hits (4%)
0 daylight window hits (0%)
170 wall hits (66%)
36 ceiling hits (14%)

32x32 resolution material mapping
102 window hits (10%)
40 lightshelf hits (4%)
6 daylight window hits (0.5%)
680 wall hits (67%)
144 ceiling hits (14%)

64x64 resolution material mapping
380 window hits (9%)
162 lightshelf hits (4%)
16 daylight window hits (0.4%)
2748 wall hits (67%)
568 ceiling hits (14%)

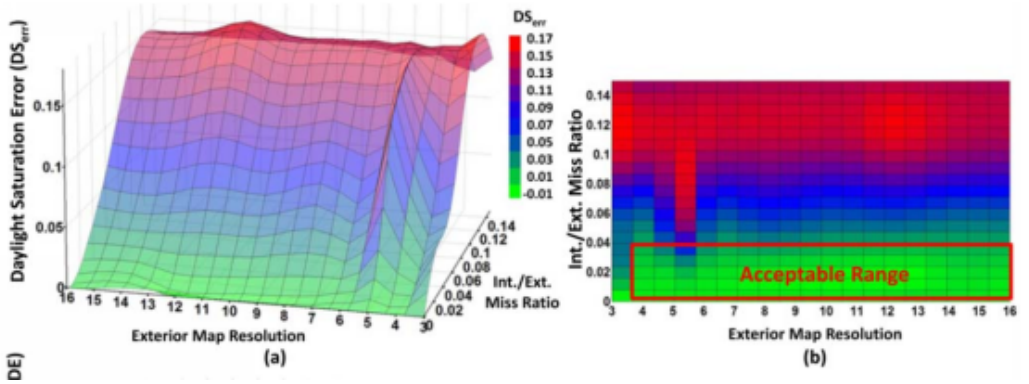
BDP4SIM – Case Study #1

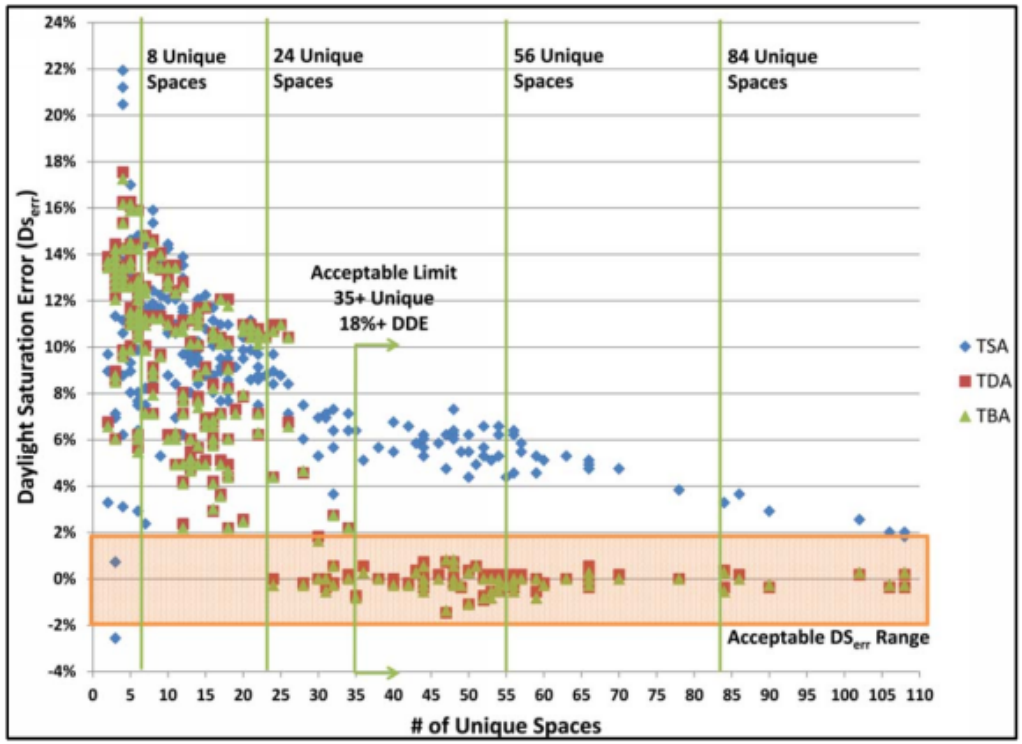
- Simple 7 story box
- Logic check for accuracy parameters
- Should see a range of 8 -84 unique spaces out of 196 spaces



BDP4SIM – Case Study #1

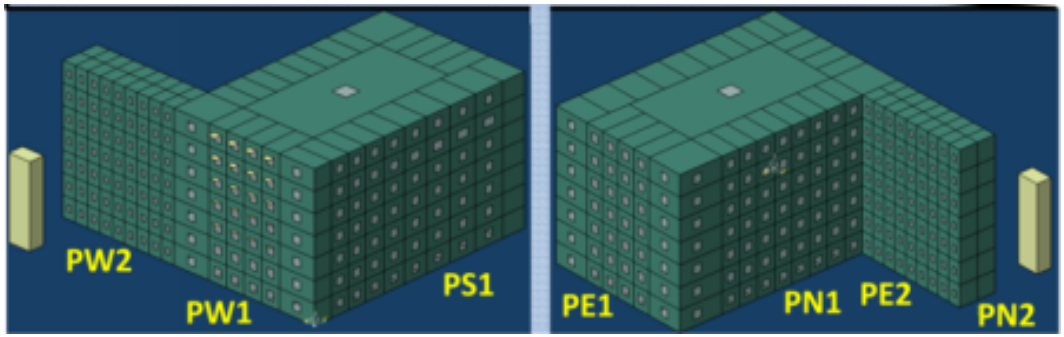
- Initial parameter set saw ranges from 4 to 108
- Fairly quickly saw
  - Ext resolution at least 4x4
  - Miss ratio no greater than 4%

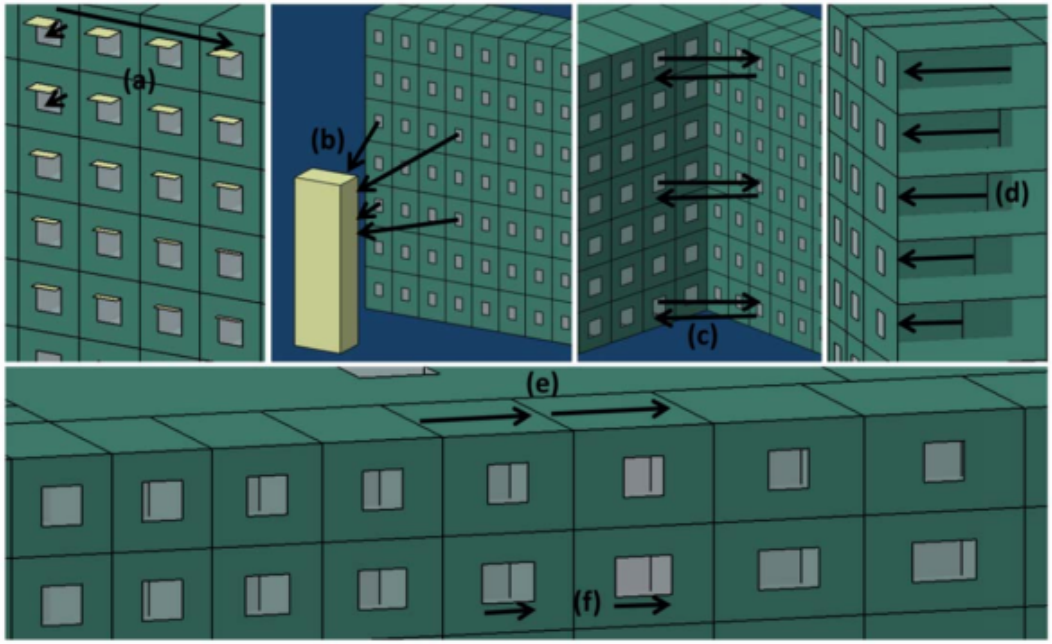




BDP4SIM – Case Study #2

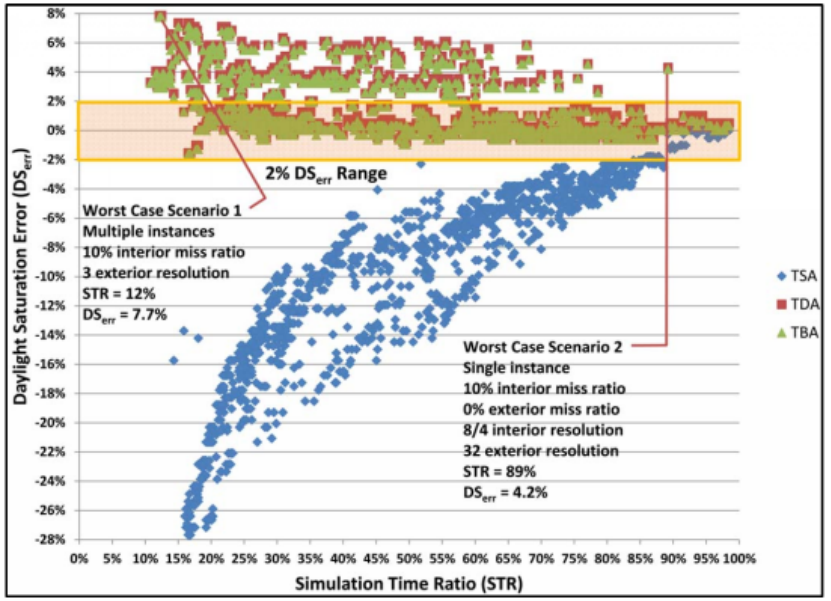
- More complex 7 stories with:
  - Exterior separate element and self shading
  - Variable window size, overhangs, interior treatments, transmittance and reflectance
  - Variable room dimensions
- Gave us a number of matching spaces and slightly varied spaces

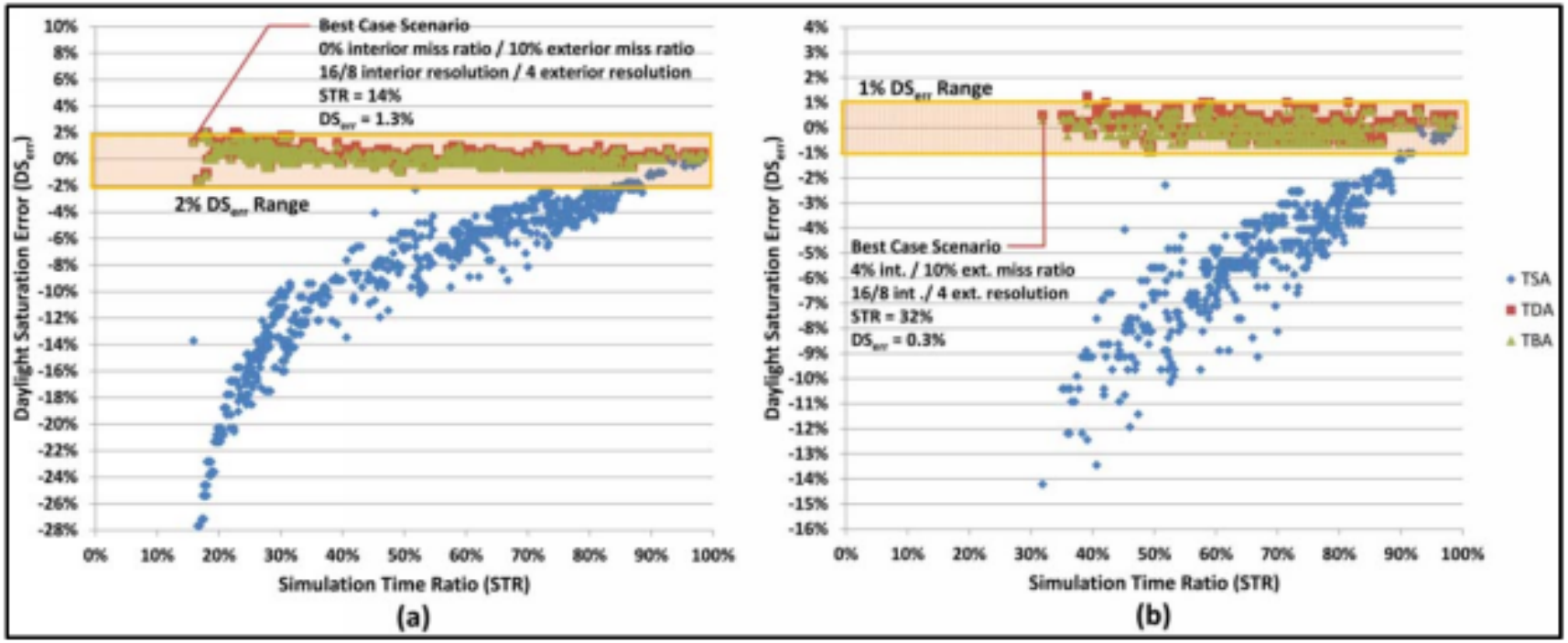




BDP4SIM – Case Study #2

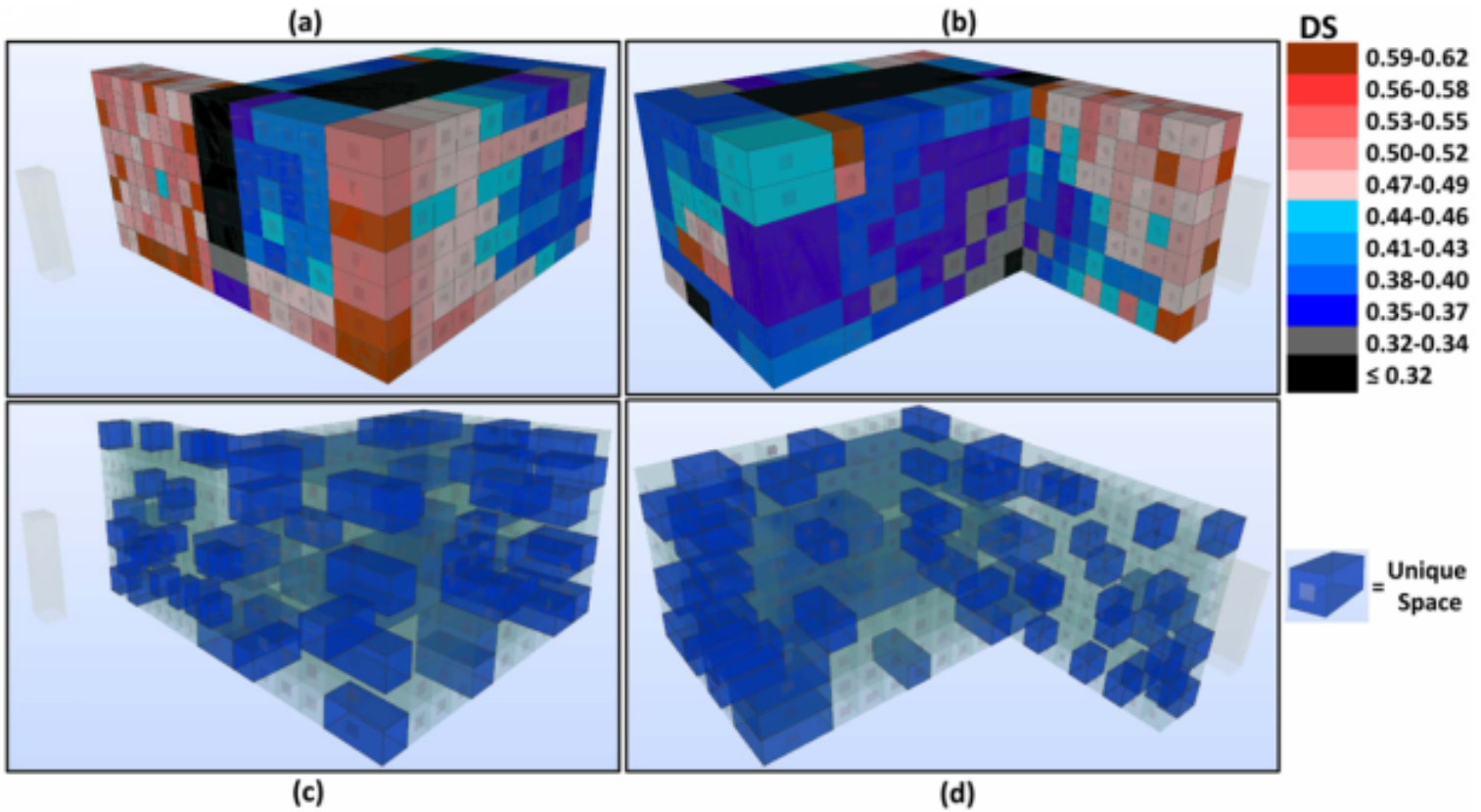
- Found same contraints as before
  - >4x4 miss ratio
  - <4% miss ratio





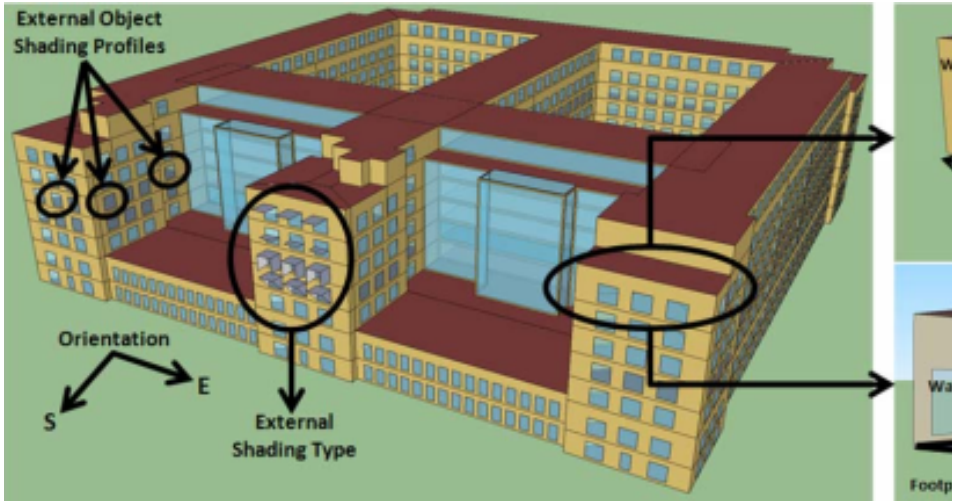
BDP4SIM – Case Study #2

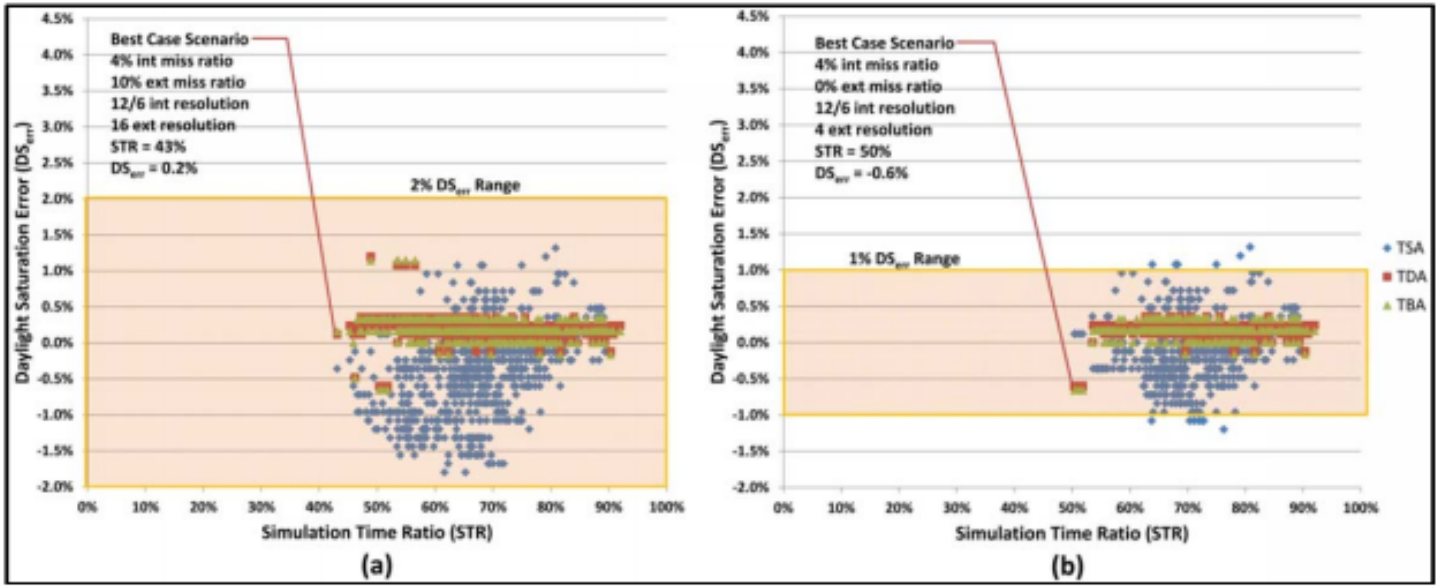
- Unique spaces identified and associated Daylight Saturation values



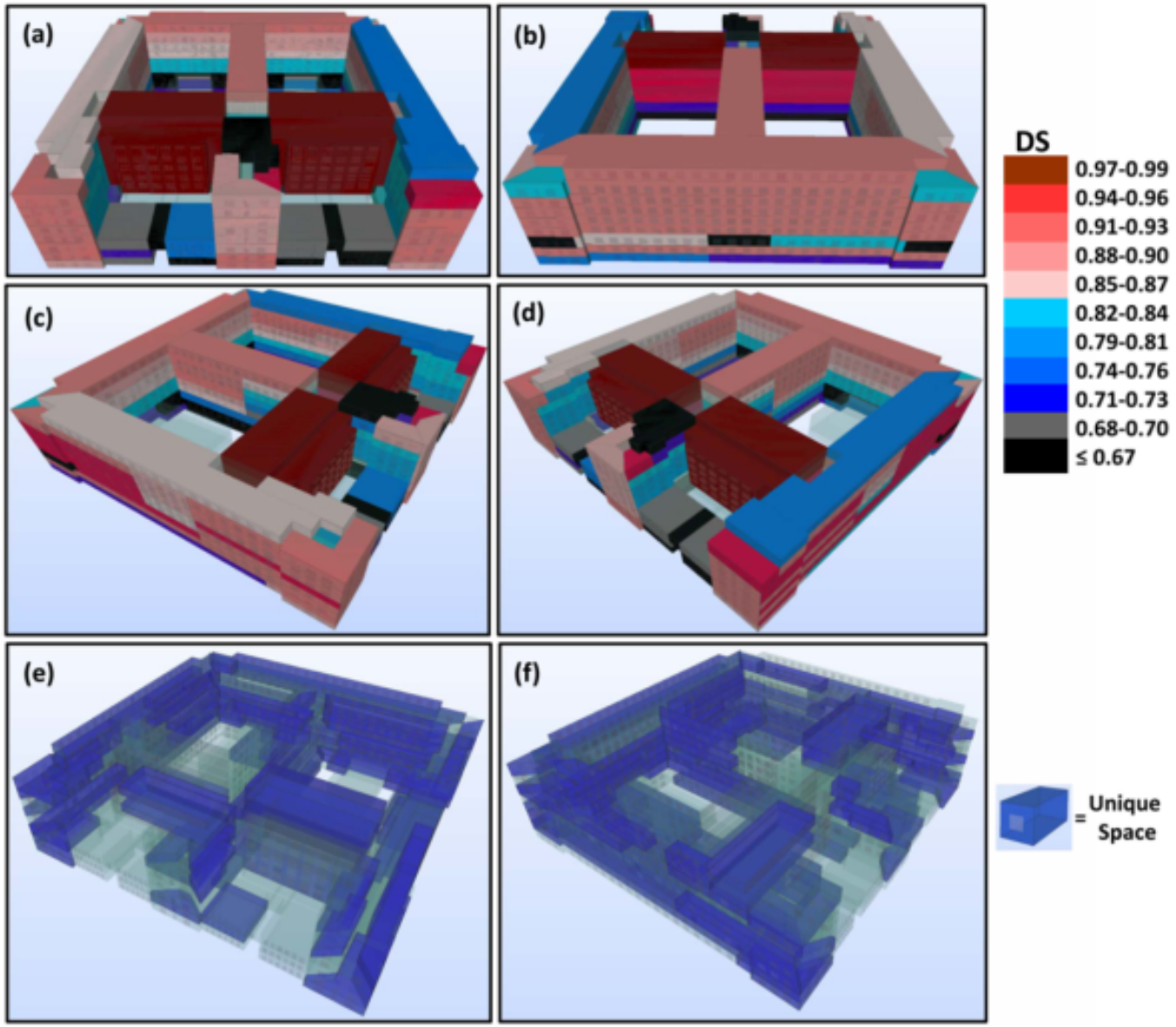
BDP4SIM – Case Study #3

- Large GSA building
  - Numerous orientations, exterior conditions, shared daylight
  - Large thermal zones type rooms modeled
- Again similar results





BDP4SIM – Case Study #3



Questions?

Experiences with Radiance in Daylighting Design, Part VI

2013 Radiance Conference
Golden, Colorado
August 12-14, 2013

Zack Rogers, P.E., IESNA, LEED AP BD+C
Daylighting Innovations, LLC

DAYLIGHTING INNOVATIONS

- Standard BSDF format
- Simulated BSDF protocols, standards and validation
- Annual Method benchmark
- CIE Test benchmark
- Standard BIM format
- Annual simulation – direct/diffuse vs global/diffuse
- Daylight simulation conference?

Annual Daylight Terminology

- Phases of light transfer
- 1-Phase – all daylight applied to Tregenza sky patches, 1 set of DC
- 2-Phase? – (DAYSIM 3.0) skylight applied to Tregenza sky patches, sun DC created separate either orientation independent or within a solar band – 2 sets of DC
- 3-Phase – all daylight applied to Tregenza sky patches, 3 sets of coefficients (Daylight matrix, transfer matrix, view matrix)
- 5-Phase – add skylight applied to Tregenza sky patches, 3 sets of coefficients. Solar DC generated seperately creating 2 more sets (Sun daylight matrix

- If the space has a fixed orientation, latitude and no moving façade elements – Is 2-phase best?