Experiences with Radiance in Daylighting Design, Part III

6th Annual Radiance Conference
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October 2nd, 2007

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SPOT Sensor Placement + Optimization Tool

LIGHTLOUVER

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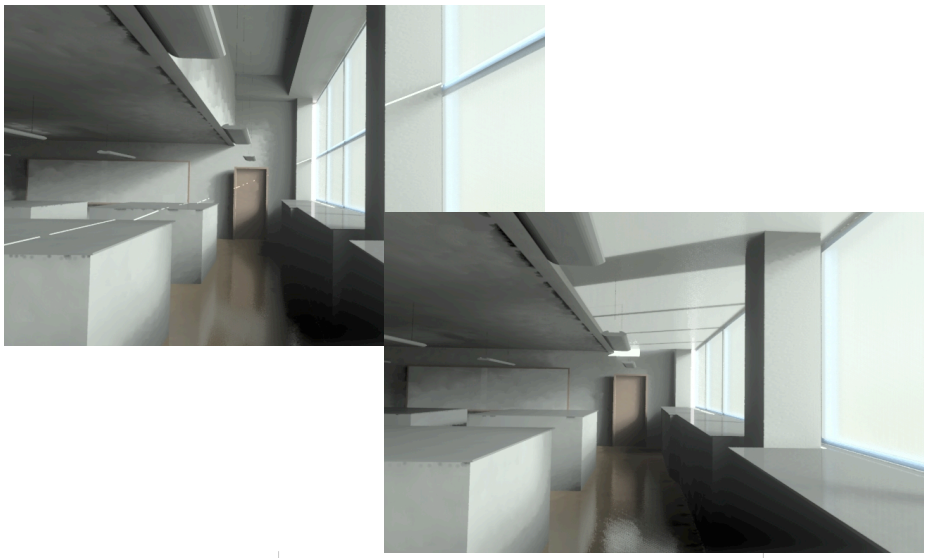
Integrated Engineered Solutions

Presentation Outline

- Office and Laboratories Case Studies
  - Auraria Science Building, Denver, Colorado
  - Boston Museum of Science Office Building, Boston, Massachusetts
  - Shams Tower 1, Abu Dhabi, United Arab Emirates
  - Shams Tower 2, Abu Dhabi, United Arab Emirates
  - Palazzo Verdi Office Building, Greenwood Village, Colorado
- Miscellaneous Projects
  - Denver Zoo, Denver, Colorado
  - Aspen Fire Station, Aspen, Colorado
  - Yale Universities Galleries, New Haven, Connecticut
  - Eastern Washington University Recreation Center
- Higher Education Case Studies
  - Middle Tennessee State University, Murfreesboro, Tennessee
  - Colorado University Visual Arts Center, Boulder, Colorado
  - Colorado School of Mines – Marquez Hall, Golden, Colorado
- Lower Education Case Studies
  - Bear Creek High School, Littleton, Colorado
  - Douglas County Prototype Elementary School, Colorado
  - Cougar Upper Elementary School, North Carolina

Auraria Science Building



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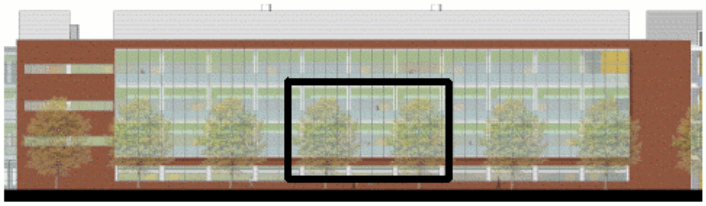
Auraria Science Building

Auraria Science Building



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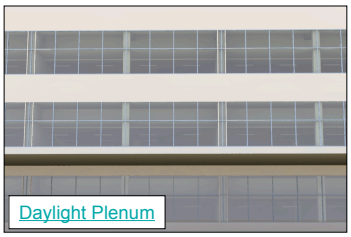
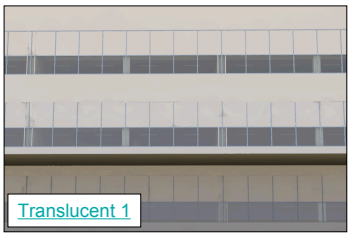
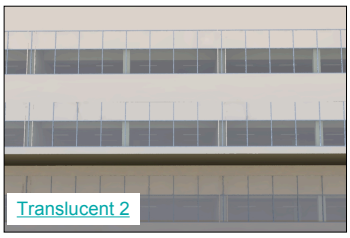
Auraria Science Building

Fenestration comparison for exterior view







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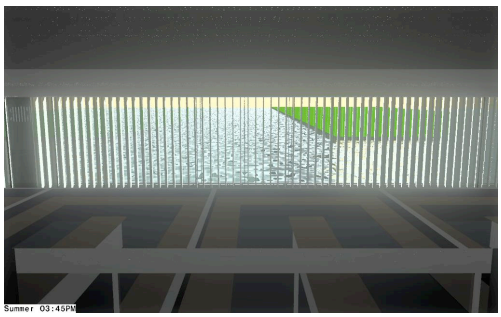
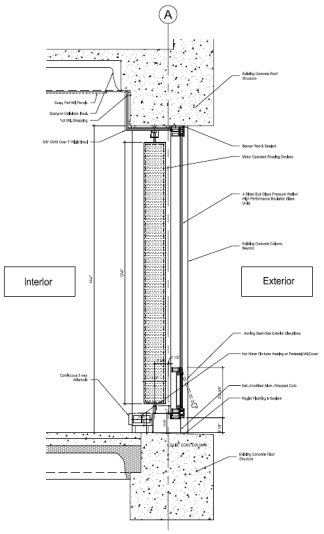
Boston Museum of Science

- Office wing over the Charles River, glare from sun and water surface evaluated

Boston Museum of Science

- Vertical sun-tracking louver was evaluated



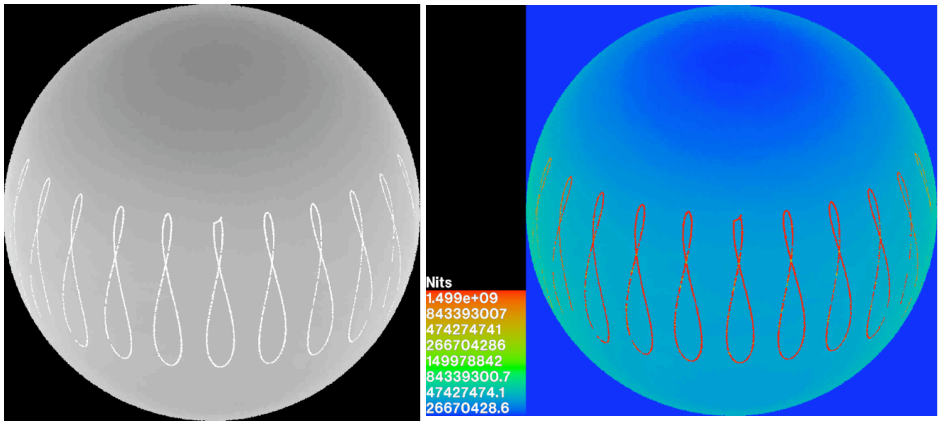


Boston Museum of Science

```
# Append the contents of sky.rad to hour.sky
fpIn  = open( (sWorkingDir + os.sep + 'skies' + os.sep + sSkyFile), 'r')  # Input File pointer
fpOut = open( (sViewDir + os.sep + 'hour.sky'), 'a') # Output File pointer
data = fpIn.read()
fpOut.write( data)
fpIn.close()
fpOut.close()
# Determine solar azimuth
aTmp = string.split(data,'|')
aTmpA = string.split(aTmp[0])
aTmp2 = string.split(aTmp[1])
fBAzi = float(aTmp2[2])
ifp = os.popen( 'gensky %s %s %s +%s %s' % (sMonth[iSeason], sDay, sTime, sSky, aTmp[0]), 'r')
aTmp3 = string.split(ifp.read())
fAzi = float(aTmp3[17+len(aTmpA)])-fBAzi

# Determine slat rotation angle
if fAzi < -45:
    fSlatAngle = 90
elif fAzi > 45:
    fSlatAngle = 90
else:
    fSlatAngle = -2*fAzi

# Write louver_rotated.rad
fpOutFile = open ((sWorkingDir + os.sep + 'louver-temp.rad' ), 'w')
fpOutFile.write ('!xform -rz %f scene/louver.rad' % (fSlatAngle))
fpOutFile.close()

# Create Octree from base octree and sky
if fAzi < -75 or fAzi > 75:
    os.system( 'oconv -w -i %s %s >%s' % \
               (sOctree, (sViewDir + os.sep + 'hour.sky'), \
                (sViewDir + os.sep + 'tmp.oct')))
else:
    os.system( 'oconv -w -i %s %s %s >%s' % \
               (sOctree, (sViewDir + os.sep + 'hour.sky'), (sWorkingDir + os.sep + 'all-louvers.rad'), \
                (sViewDir + os.sep + 'tmp.oct')))
# Animated Clock
```

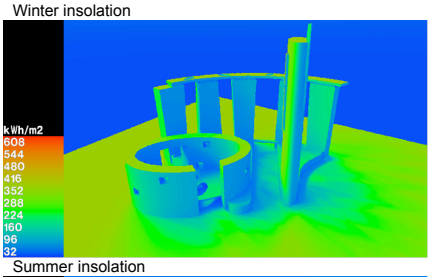

Shams Tower 1

Annual Skies

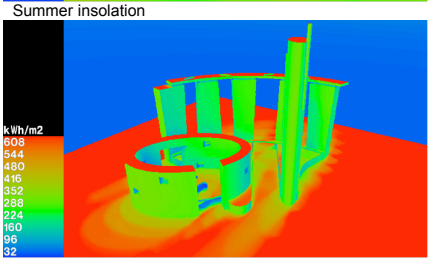


Shams Tower 1, Al Reem Island, Abu Dhabi

Winter insolation

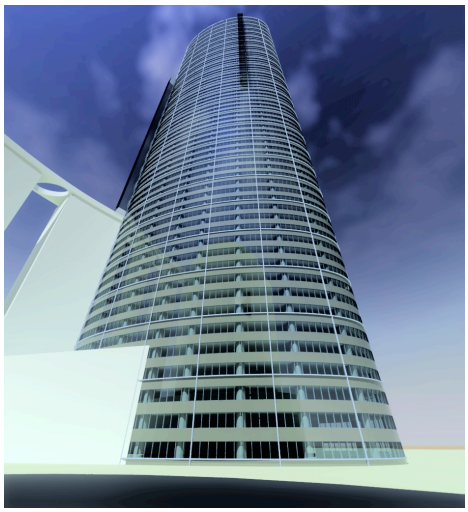


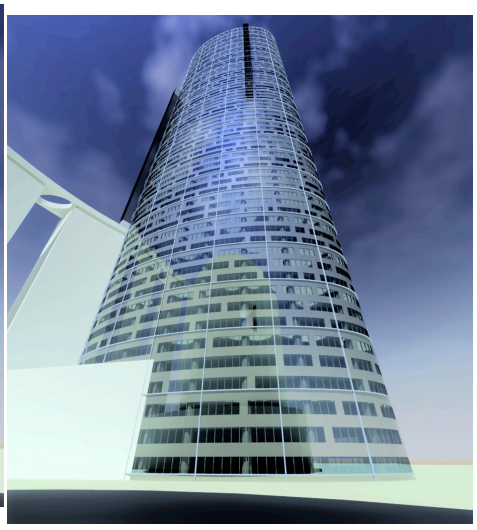
Summer insolation



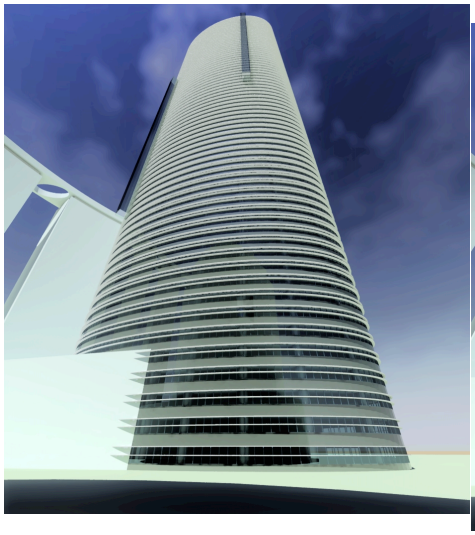
- Indication of Photovoltaic energy production potential
- Extent of necessary summertime solar gain control
- Low latitudes, 24º N, have little direct sunlight on southern facades – east and west and overhead control essential

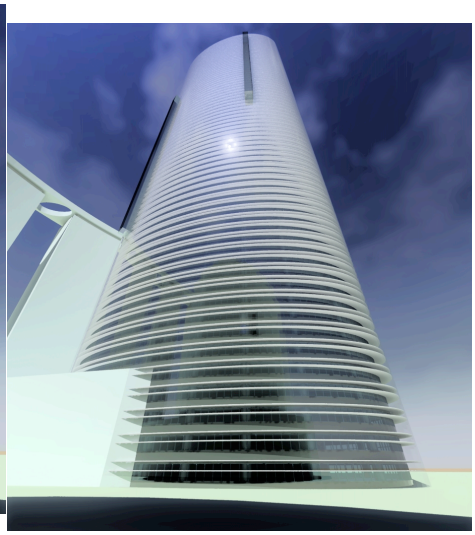
Shams Tower 1





Shams Tower 1





Shams Tower 2, Al Reem Island, Abu Dhabi

Shams Tower 2

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Shams Tower 2

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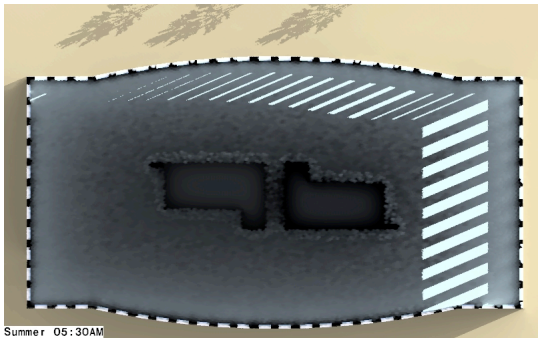
Palazzo Verdi Office Building

- 300,000 sf, 15 story office building in Greenwood Village, Colorado
- **Analysis performed:** Illuminance calculations and photosensor analysis with the Sensor Placement and Optimization Tool (SPOT)



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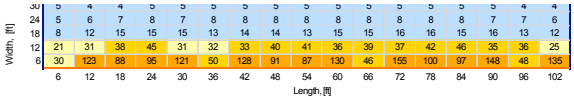
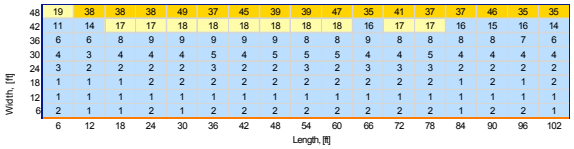
Palazzo Verdi Office Building

SPOT comparative analysis based on daylight saturation

South open office



North open office



Control Algorithm:	On/Off		Dimming	
Electric Fixture Type:	Indirect	Direct	Indirect	Direct
South Office	X	X	X	X
North Office	-	-	X	X

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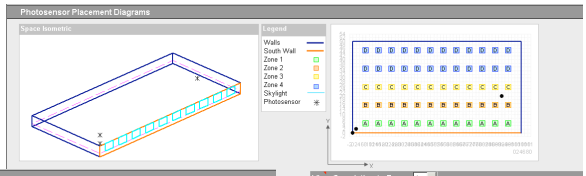
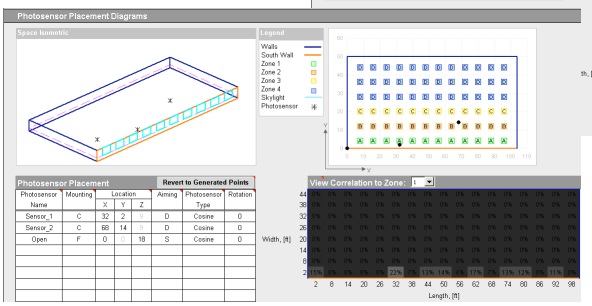
Palazzo Verdi Office Building

South perimeter electric lighting zone photocell placement recommended by SPOT

Placement with indirect fixtures

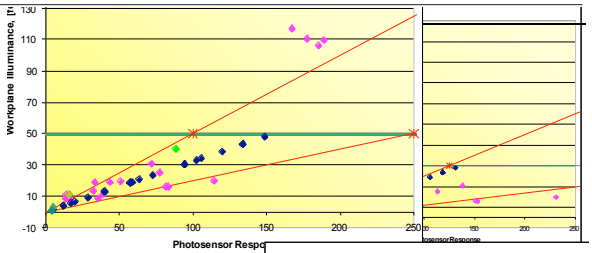


Placement with direct fixtures

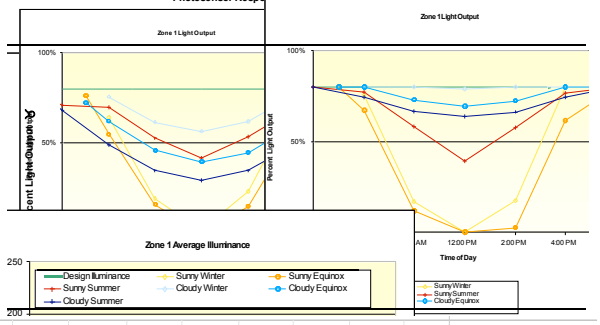


Palazzo Verdi Office Building

SPOT Photosensor Analyzer page shows more consistent photosensor readings between electric light and daylight for the suspended indirect fixtures



Therefore more dimming occurs with the indirect layout versus the direct fixture layout



Palazzo Verdi Office Building

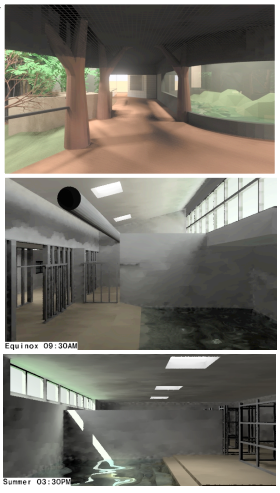
Despite the advantage in controllability for the indirect system, the higher LPD takes its toll and causes the system to consume more energy than a direct photocell system

Control Algorithm:	On/Off				Dimming			
Electric Fixture Type:	Indirect		Direct[1]		Indirect		Direct	
Electric Lighting Row:	1	2[2]	1	2	1	2	1	2
Average Light Output	0.27	0.80	0.50 (.29)	0.79 (.45)	0.30	0.70	0.46 (.27)	0.57 (.33)
Electric Savings [kWh/yr]	2970	816	1009	424	2839	1222	1101	874
Average Illuminance [fc]	88	65	98	74	88	62	93	64
Total Annual Savings [$]	400		150 + 365 = 515		450		207 + 365 = 572	

1. The values in parentheses are adjusted to give an equal LPD for both fixture types
2. The maximum light output for all analysis is 0.8 to make the nighttime illuminance is equal among scenarios

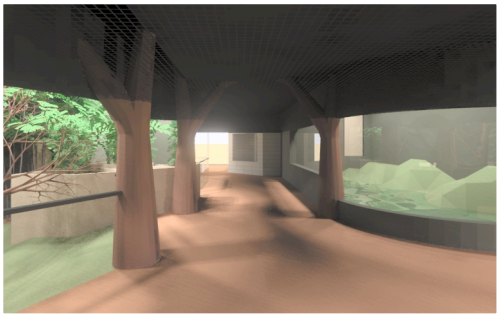
Denver Zoo Asian Tropics

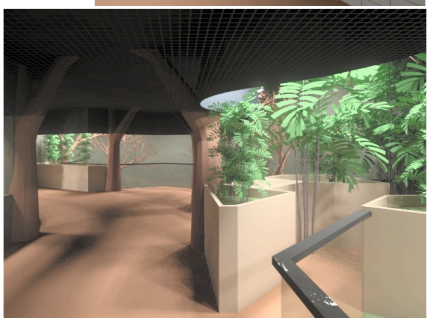
- Three new Asian Tropics buildings in the Denver Zoo complex
- **Spaces modeled:** Asian Pavilion, Elephant Holding building, Rhino/Tapir Holding
- **Analysis performed:** Illuminance calculations, renderings, visual comfort analysis, solar control, façade design
- **Challenges:** Daylight criteria for animals?



Denver Zoo - Asian Pavilion

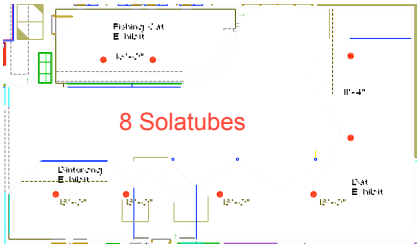
- Asian Pavilion houses bats, fishing cats, storks, binturongs, and more.
- Goal was to highlight exhibit areas with daylight using Solatubes
- Sufficient daylight needed in planter areas to maintain healthy plant growth

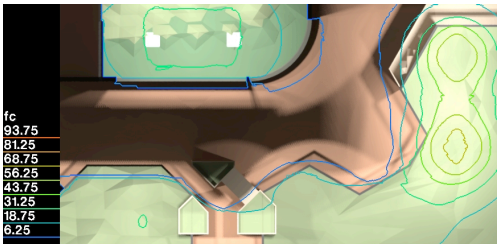


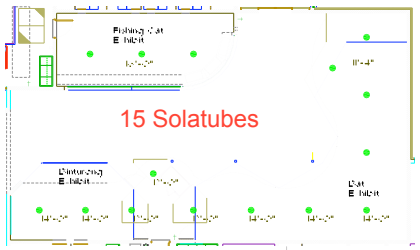


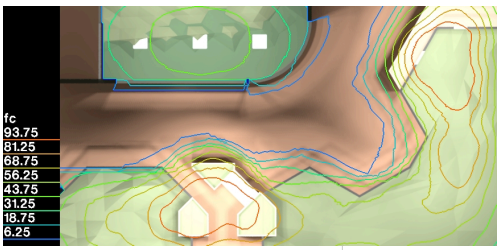
Denver Zoo - Asian Pavilion

Radiance analysis used to determine appropriate quantity and location of Solatubes

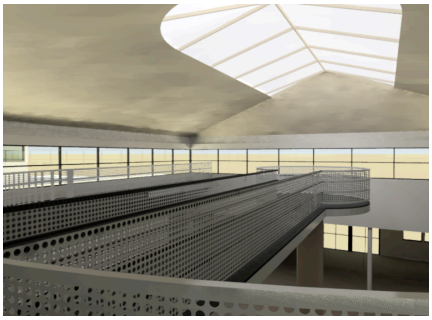


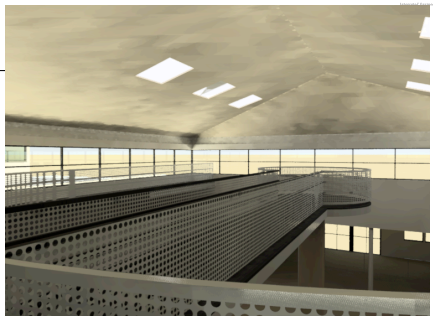


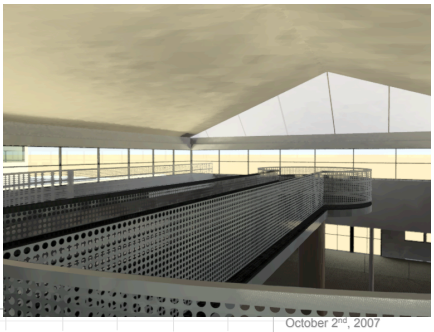




Denver Zoo – Elephant House







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Denver Zoo – Elephant House

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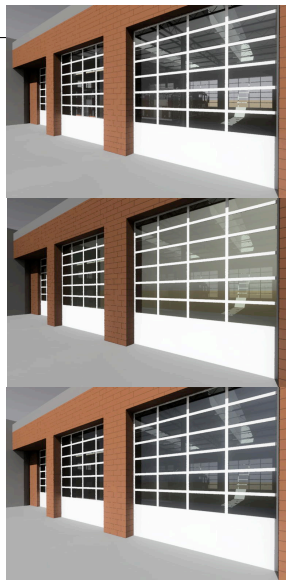
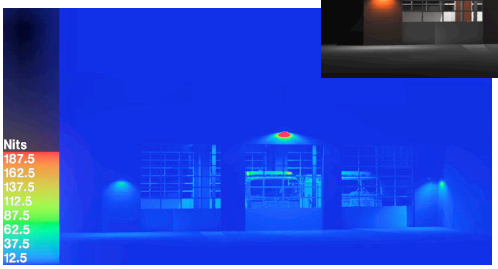
Aspen Fire Station

- Fire truck visibility was priority; various glazings were studied for tint and reflectance
- Garage door elevations also simulated



Aspen Fire Station

Radiance analysis used to determine nighttime luminances for concerned neighbors



Yale University Galleries

Create Table | Header | Formula

Average 8
Minimum 1
Maximum 12

E: 30 fc | Illuminance | Floor | floor_12_21_10_1_ | Change Transmittance

41	3	4	4	5	5	5	6	6	6	7	7	7	7	7	7	7	7	8	7	8
39	4	4	5	5	6	6	7	7	8	8	8	8	9	9	9	9	9	9	9	9
38	4	5	5	6	7	7	7	8	8	8	9	9	9	9	9	9	9	9	10	9	9
36	4	5	6	7	7	8	8	8	9	9	9	9	10	10	10	10	10	10	10	10	10
34	5	6	6	7	7	8	8	8	9	8	9	9	10	9	10	10	11	10	11	11	11
33	5	6	7	7	8	8	9	9	9	9	8	7	8	9	10	10	11	11	11	11	11
31	6	7	8	8	9	9	9	10	9	9	8	7	8	9	10	11	11	11	11	11	11
30	6	7	8	9	9	9	10	10	10	9	9	8	8	9	10	11	11	12	12	12	12
28	6	8	8	9	9	10	10	10	10	10	9	8	8	9	10	11	11	11	12	12	12
26	6	8	9	9	10	10	10	11	10	10	9	8	8	9	10	10	11	11	11	11	11
25	6	8	9	9	10	10	11	11	11	10	9	8	7	8	9	10	10	10	11	11	10
23	7	8	9	9	10	10	11	11	11	10	9	8	6	7	8	9	9	9	10	10	9
21	6	8	9	9	10	10	11	11	11	10	9	8	1	1	1	1	1	1	1	1	1
20	6	8	9	9	10	10	11	11	10	10	9	8	6	6	7	8	8	8	8	9	8
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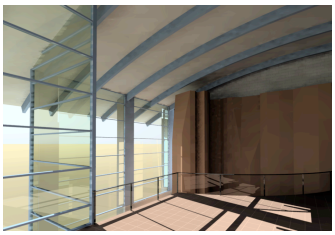
2	3	4	4	4	4	5	5	5	5	5	5	6	6	6	6	6	6	6	6	6	6
	2	3	5	7	8	10	11	13	15	16	18	20	21	23	25	26	28	30	31	33	34

Eastern Washington University

- 100,000 sf recreation center in Cheney, Washington
- **Spaces modeled:** Gymnasium, ice rink, lobby/climbing gym, cardio studio
- **Analysis performed:** Solar control studies, glare studies, illuminance calculations, reflection studies

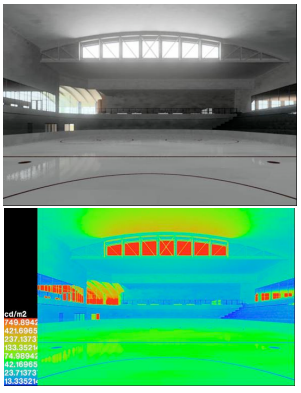


Eastern Washington University Rec Center

- Optimized skylight area and layout in the Gymnasium
- Performed shading and skylight studies for cardio studio

Eastern Washington University Rec Center

- Studied veiling reflection on ice rink surface
- Analyzed various clerestory configurations for glare and daylighting impact



Middle Tennessee State University

- New University project in Murfreesboro, TN
- **Spaces modeled:** Laboratory classroom, office, and atrium
- **Analysis performed:** Solar animations performed for all spaces to demonstrate need for shading devices
- Glazing transmittance and area, and daylight reflection devices fine tuned using Radiance simulations

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Middle Tennessee State University

- External louvers, sunshades and ceramic frit patters were all explored to minimize solar heat gains in the atrium

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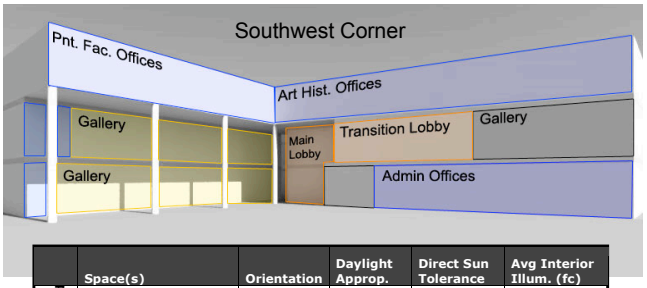
Middle Tennessee State University

- Daylighting and solar control analysis performed for laboratories
- Several solar control options considered, including a translucent window, operable lightshelf and external louvers
- Higher glazing height and sloped ceiling had the largest influence on illuminance levels in the laboratory

University of Colorado Visual Arts Complex



	Space(s)	Orientation	Daylight Approp.	Direct Sun Tolerance	Avg Interior Illum. (fc)
Ground Floor	Seminar Room	South	Medium	Low	50
	South Corridor	South	High	Medium	100
	Main Lobby (Entry)	West	High	High	200
	Admin Offices	West	High	Low	50
2nd Floor	Ceramic Display	South	Medium	Medium	30
	South Corridor	South	High	Medium	100
	Exhibit Gallery	West	Low	Low	10
	West Transition Corridor	West	High	Low	50
3rd Floor	Pnt. Faculty Offices	South	High	Low	50
	AH Offices	West	High	Low	50

Daylight appropriateness, direct sun tolerance, and desired interior illuminance determined for each typical space

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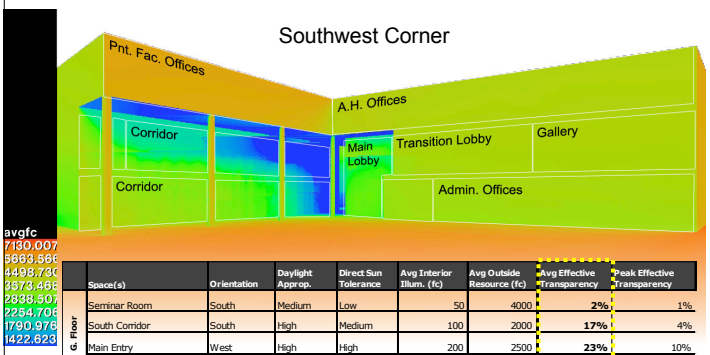

	Space(s)	Orientation	Daylight Approp.	Direct Sun Tolerance	Avg Interior Illum. (fc)	Avg Outside Resource (fc)	Avg Effective Transparency	Peak Effective Transparency
G. Floor	Seminar Room	South	Medium	Low	50	4000	**2%**	1%
	South Corridor	South	High	Medium	100	2000	**17%**	4%
	Main Entry	West	High	High	200	2500	**23%**	10%
	Admin Offices	West	High	Low	50	2900	**7%**	2%
2nd Floor	Ceramic Display	South	Medium	Medium	30	2200	**4%**	1%
	South Corridor	South	High	Medium	100	1500	**23%**	6%
	Exhibit Gallery	West	Low	Low	10	3600	**0%**	0%
	Transition Corridor	West	High	Low	50	3500	**4%**	2%
3rd Floor	Pnt. Faculty Offices	South	High	Low	50	6000	**3%**	2%
	AH Offices	West	High	Low	50	3600	**5%**	2%

Daylight resource and effective Transmittance calculated for each facade

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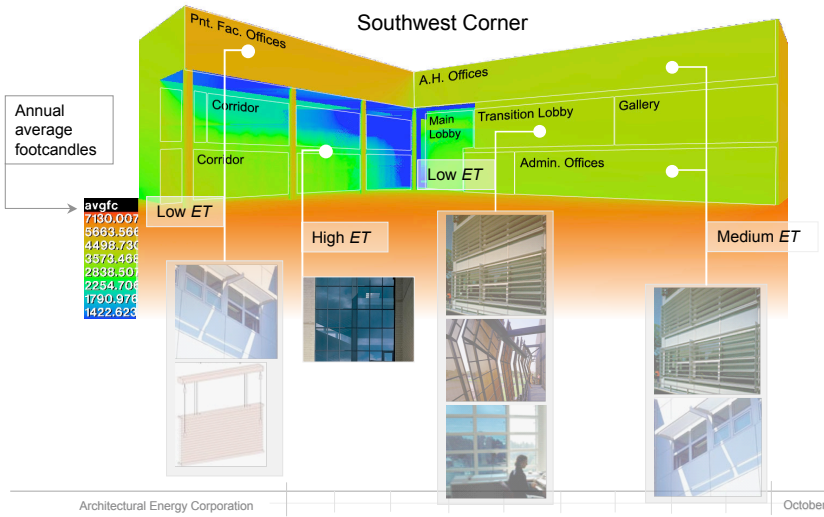
Appropriate strategies suggested based on high, low or medium *ET:*



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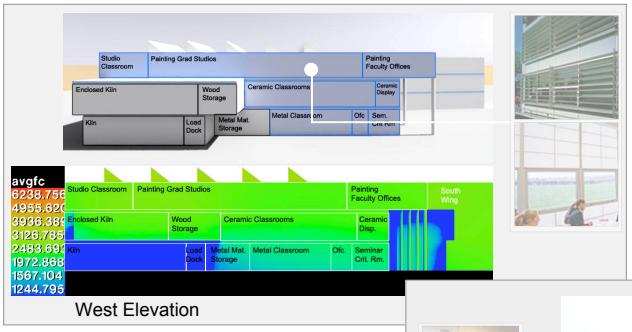
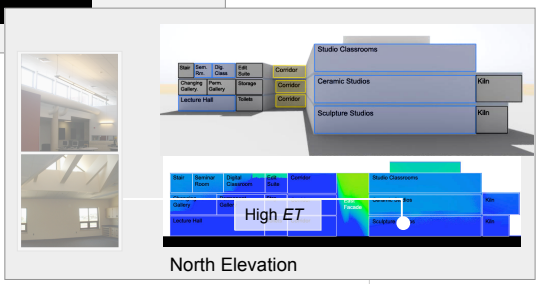


West Elevation

Other elevations



North Elevation

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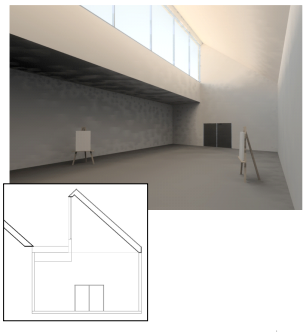
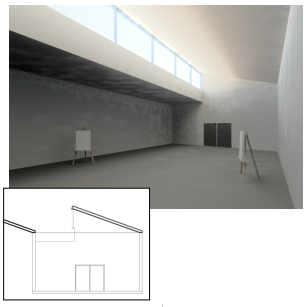
Roof monitor modeled for the quality of north light

- Determine vertical and horizontal illuminance
- Reveal roof-glazing coupling issue





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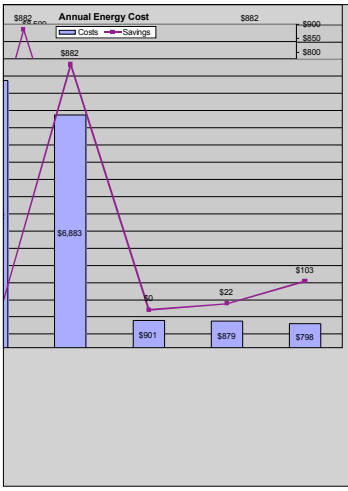
Skylight option proved to be most effective for saving energy and construction costs



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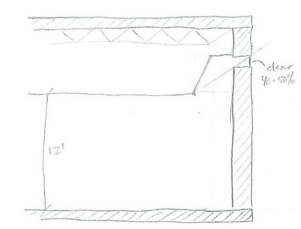

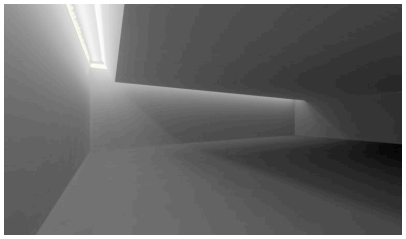

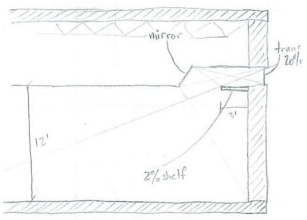

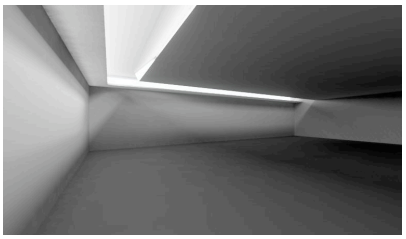

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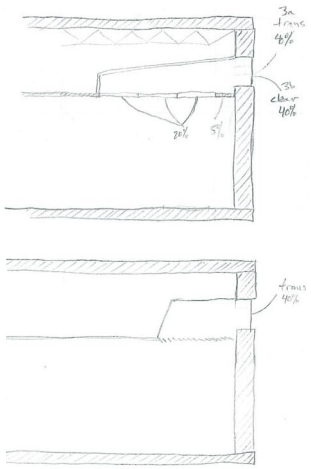

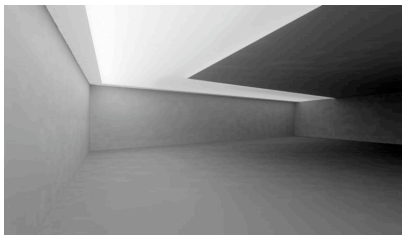

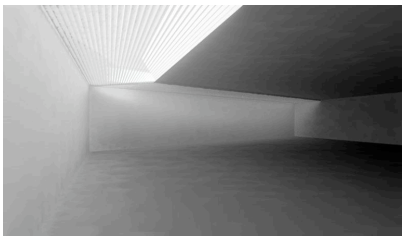

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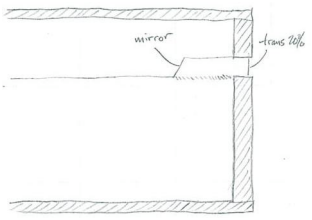
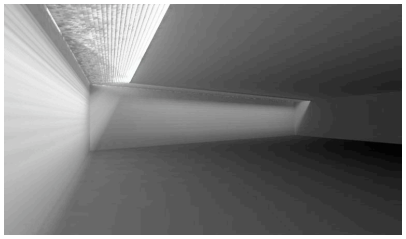
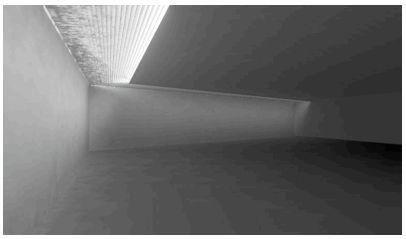
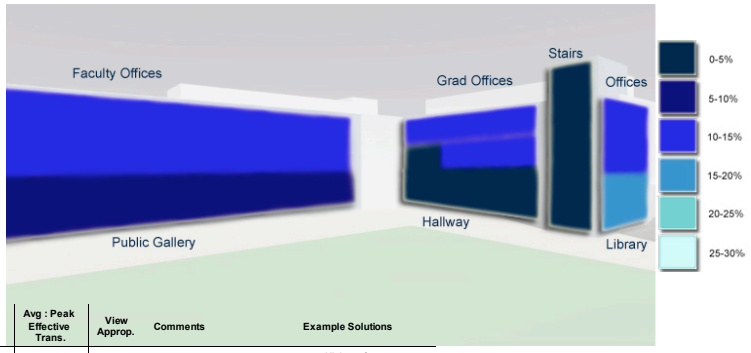






Colorado School of Mines New Science Hall

Mass Model Animation



Average Effective Trans.	Spaces	Avg : Peak Effective Trans.	View Approp.	Comments	Example Solutions
0-5%	Hallway Stairs Greeting Waiting	3:1 2:1 3:1 2:1	High	These spaces require a low effective transmittance with some variability throughout the year	• High performance glazing • North facing monitor with small/narrow punched view windows
5-10%	Gallery	2:1	High	The gallery will receive a high daylight resource most of the day and there will be little variation throughout the year	• Overhangs with daylight and view window division

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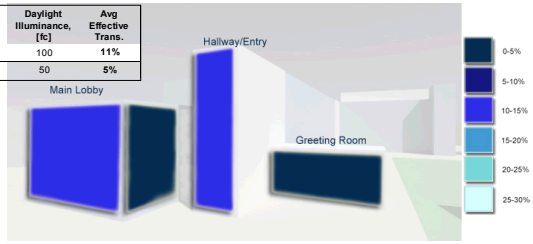
Colorado School of Mines New Science Hall

Southwest Perspective Effective Transmittance Continued

Space	Orientation	Daylight Approp.	Direct Sun Tolerance	Design Illuminance, [fc]	Daylight Illuminance, [fc]	Avg Effective Trans.
Main Lobby	SW	High	Medium	30	100	11%
Greeting	SW	High	Medium	10	50	5%



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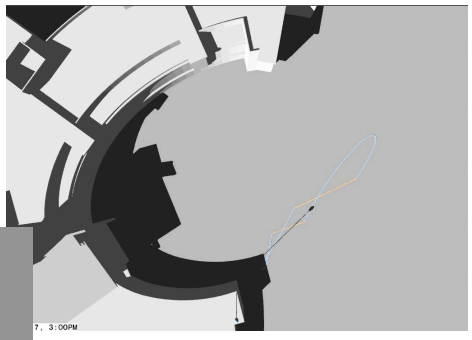
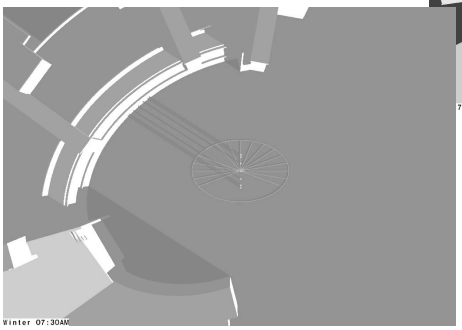
Bear Creek High School, Littleton, Colorado





Douglas County Prototype Elementary School, Colorado

Douglas County Prototype Elementary School

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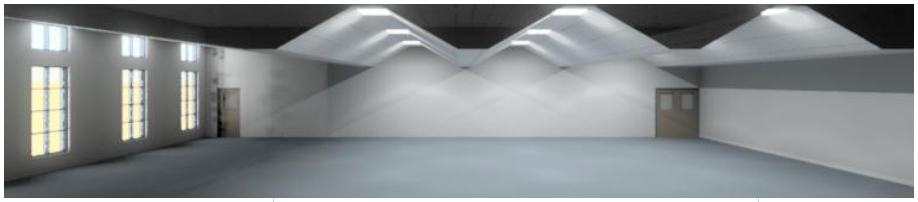
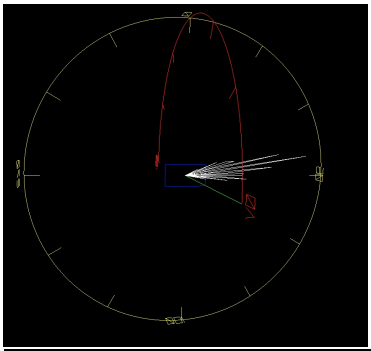
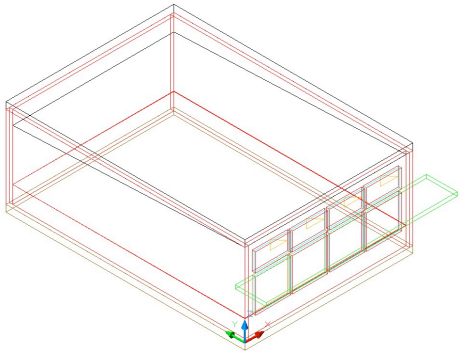
Douglas County Prototype Elementary School

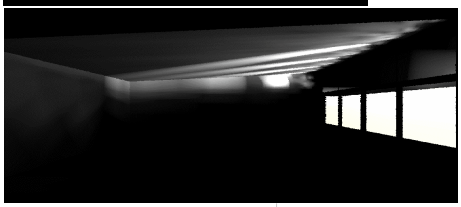


Center for Disease Control - Building 18

Cougar Upper Elementary School, North Carolina







Experiences with Radiance in Daylighting Design, Part III

Questions?

SPOT
Sensor Placement + Optimization Tool

6th Annual Radiance Conference
Minneapolis, Minnesota
October 2nd, 2007

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