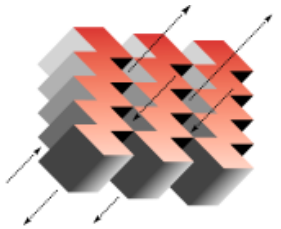
SPOT on!

Accurate Prediction of Electric Lighting Reduction due to Daylighting using rsensor

Zack Rogers, Integrated Design Associates, Inc

SPOT v4.0



Developed by Architectural Energy Corporation

Produced with support from CEC, NEEA, PG&E, SCE and CIEE

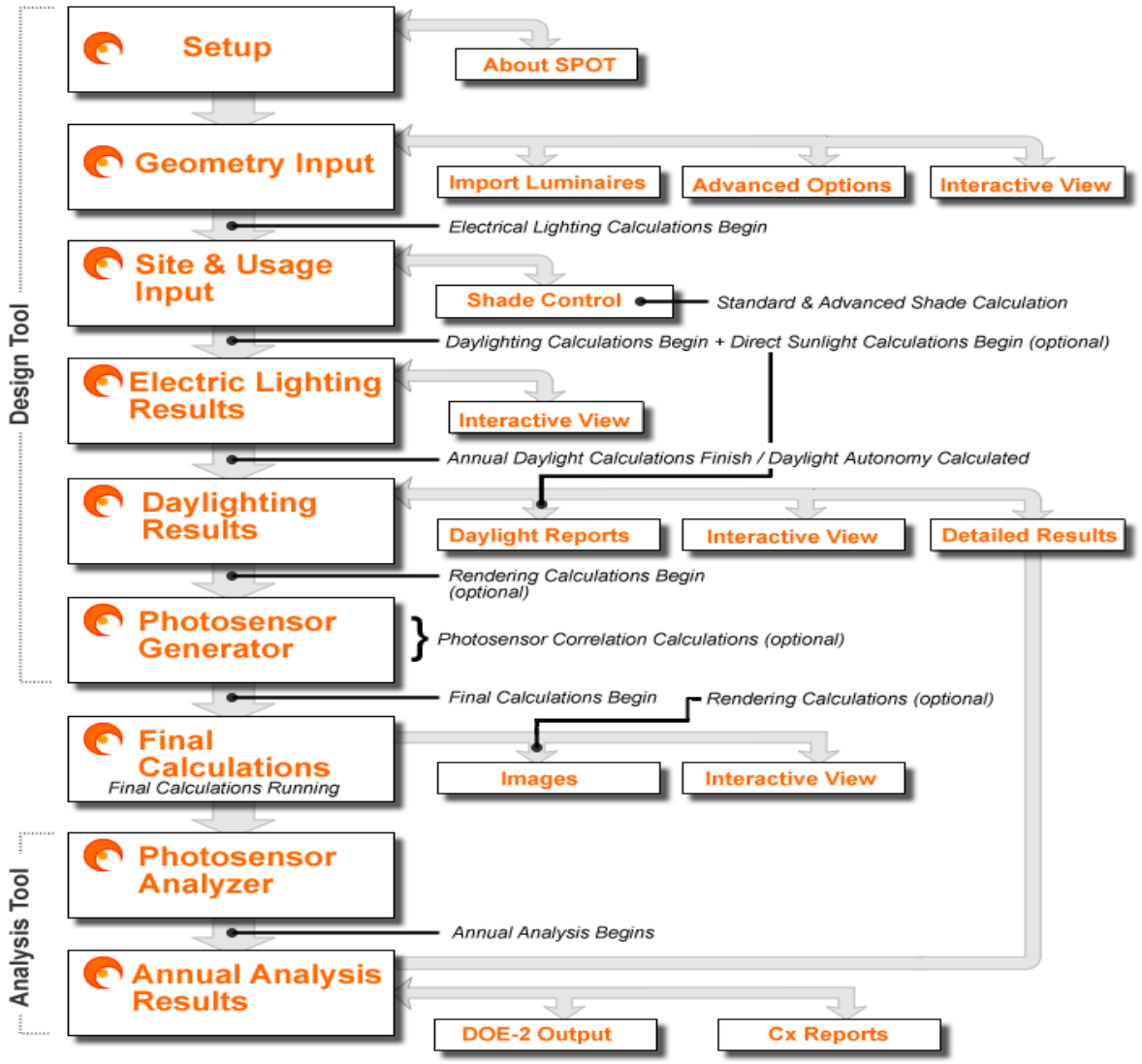
Radiance v3.9

MinGW Radiance Installer by Francesco Anselmo

Daylighting Design Pieces

- Daylighting and electric lighting design
- Control system design (assume photosensor)
  - NLPIP Photosensor Report
  - Rsensor
- Account for daylighting in whole building energy use (model)
- Commission photosensor system

Daylighting Design Pieces



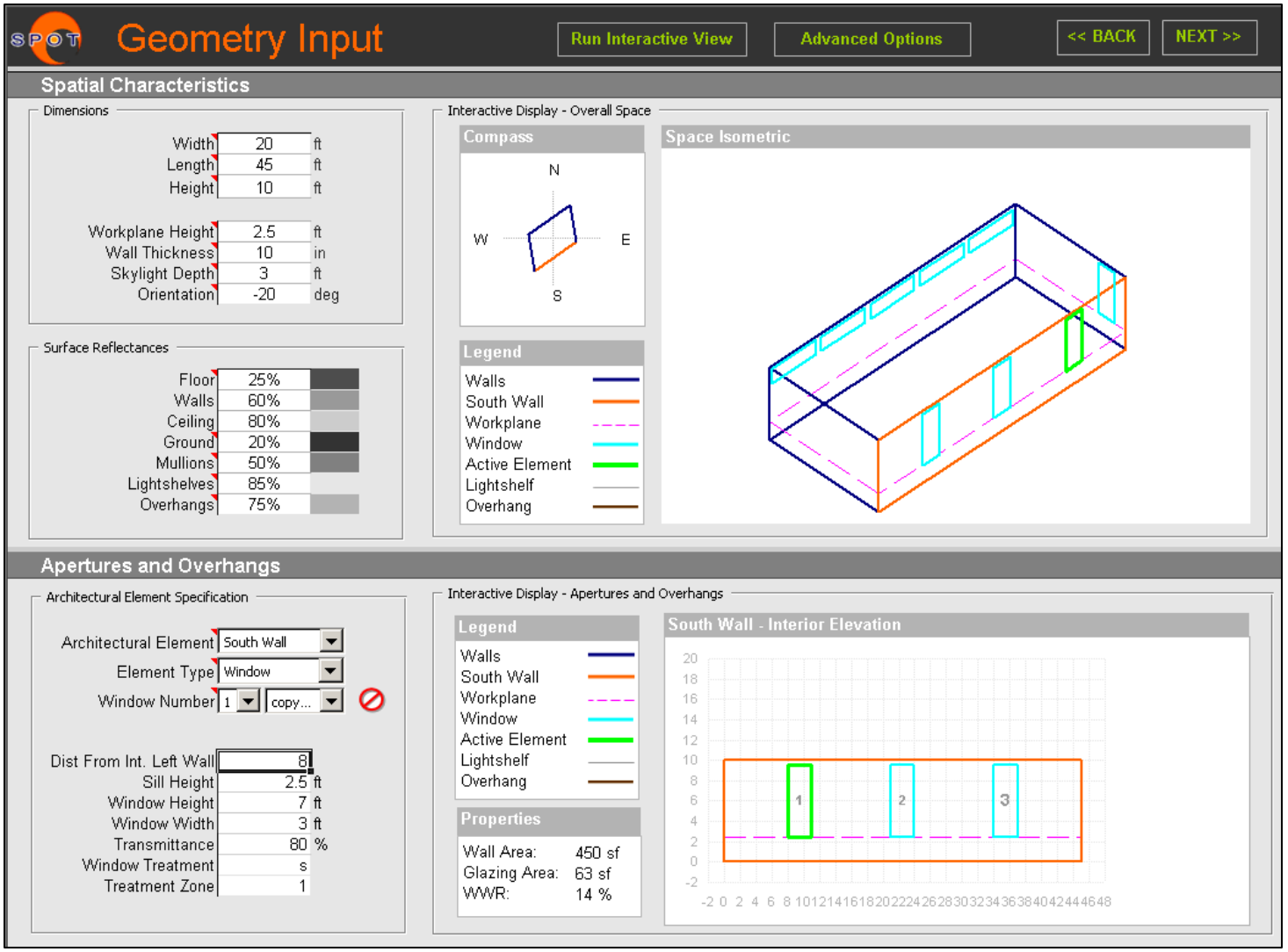
Lighting Design Control Design Energy Model Commissioning

Daylighting Design

- What is good design?
- Tools
  - Animations
  - Physical models
  - Annual simulation

- Annual simulation versus key design conditions

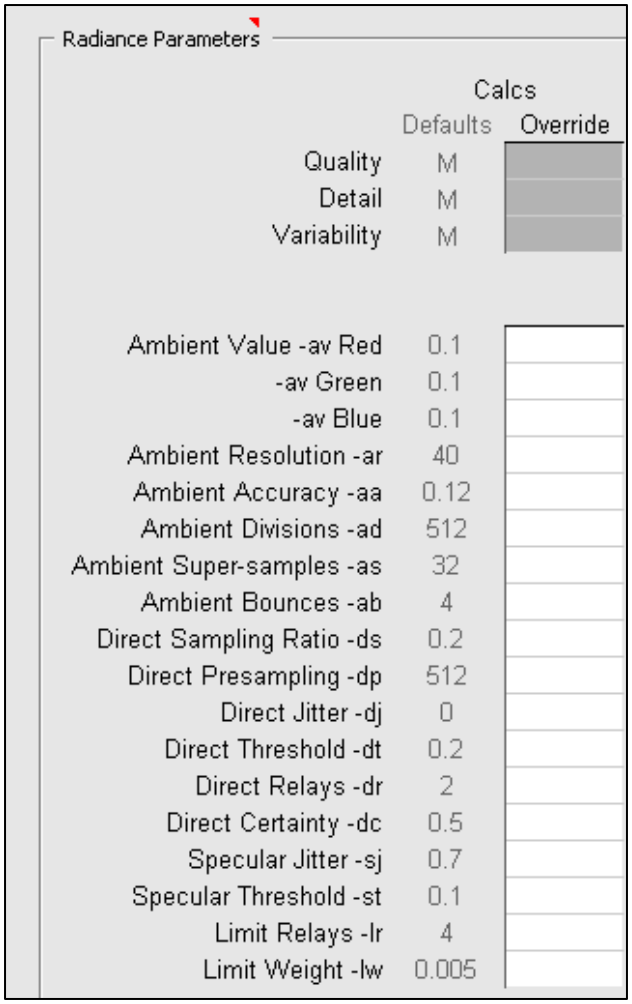
Daylighting Design

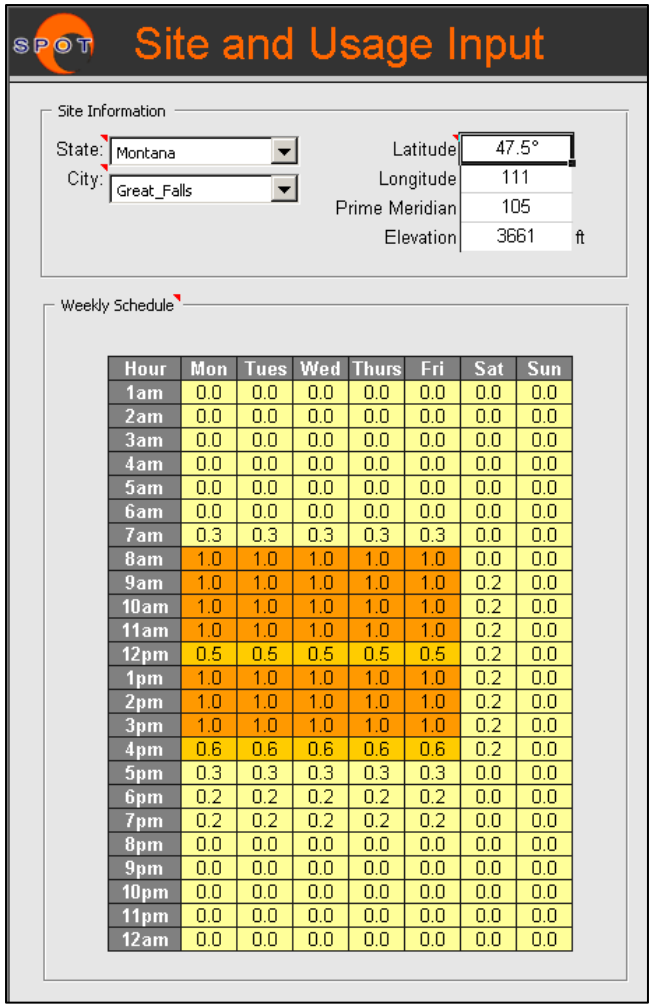


Lighting Design Control Design Energy Model Commissioning

Electric Lighting Design

Annual Simulation Parameters





Illuminance Results

Nighttime Workplane Illuminance, [fc]

	Average	Max	Min	Max/Min	LPD
Zone 1	32.0	40.9	19.4	2.1	0.75
Zone 2	33.6	41.2	21.3	1.9	0.75
Total	32.8	41.2	19.4	2.1	0.75

Light Loss Factor: 0.8

Design Illuminance: 30 fc

Width, [ft] \ Length, [ft]	3	6	9	12	15	18	21	24	27	30	33	36	39	42
18	21	25	29	30	31	32	31	32	31	32	31	30	27	24
15	25	30	34	36	37	37	37	37	38	37	36	36	32	29
12	27	33	37	39	40	41	41	41	40	40	39	38	36	31
9	26	33	36	38	39	40	41	40	41	40	39	37	35	30
6	24	29	32	34	35	36	36	35	36	36	34	33	31	26
3	19	24	26	27	29	30	29	28	30	30	28	26	25	22

Annual Daylight Workplane Illuminance, [fc]

	Design Condition		Zone 1 Avg	Zone 1 Max	Zone 1 Min	Zone 2 Avg	Zone 2 Max	Zone 2 Min	Shades?
	Clear Sky								
○	Winter	9:00 AM	17	33	8	12	17	8	Z1Z2
○		12:00 PM	58	193	17	38	115	19	Z1Z2
○		4:00 PM	27	58	10	16	51	10	Z2
◉	Equinox	8:00 AM	32	78	12	24	72	14	Z1Z2
○		12:00 PM	75	342	23	44	49	32	Z1Z2
○		4:00 PM	23	34	13	31	38	20	Z1Z2
○	Summer	8:00 AM	40	157	20	38	45	28	Z1Z2
○		12:00 PM	64	374	21	58	71	39	Z1Z2
○		4:00 PM	34	43	18	60	74	35	Z1Z2

Workplane Area	< 33%	33%-66%	66%-100%	> 100%
	0%	26%	45%	29%

Width, [ft] \ Length, [ft]	3	6	9	12	15	18	21	24	27	30	33	36	39	42
18	14	15	15	15	15	16	16	19	46	35	18	19	20	20
15	17	28	19	20	21	35	21	21	20	37	67	24	27	23
12	15	17	20	20	18	21	47	22	21	21	23	72	24	24
9	17	19	20	19	25	20	22	44	28	23	23	29	40	46
6	58	19	25	26	27	22	24	30	26	66	27	31	35	44
3	12	19	41	36	19	21	57	46	26	20	78	56	41	43

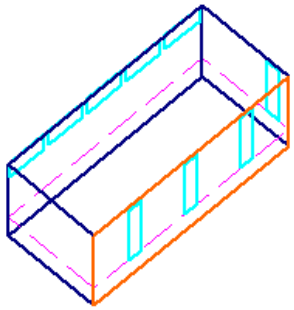
Metric Comparison

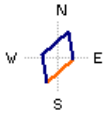
Printable Area

SPOT Daylight Autonomy-Daylighting Report

Space Setup Summary

Isometric View





Space Properties

Dimensions

Width	20	ft
Length	45	ft
Height	10	ft
Wp Height	2.5	ft
Wall Thickness	10	in
Skylight Depth	3	ft

Element Description

Apertures			Overhangs
South Wall			
3	7ft x 3ft	80%	
North Wall			
5	2ft x 8ft	80%	
East Wall			
1	7ft x 3ft	80%	

Surface Reflectance

Floor	20	%
Walls	60	%
Ceiling	80	%
Ground	20	%
Mullions	50	%
Lightshelves	85	%
Overhangs	75	%

Prerequisite Checks

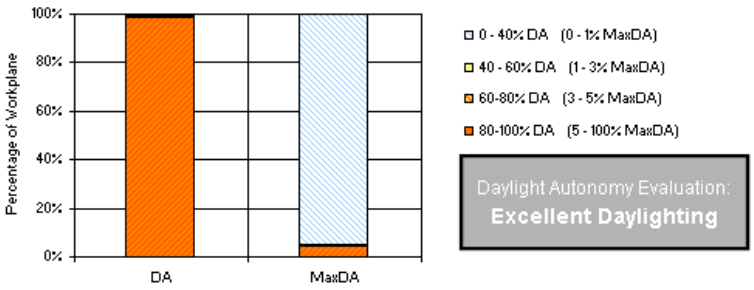
Lightshelf Workplane Height (30in AFF)
Pass
Grid Spacing (4ft x 4ft max)
Pass

Design Performance

Workplane Annual Daylight Illuminance

Zone	Average	Maximum	Avg:Max
1	74 fc	670 fc	9
2	54 fc	263 fc	5

Stacked Daylight Autonomy Percentage



Daylight Autonomy Evaluation:
Excellent Daylighting

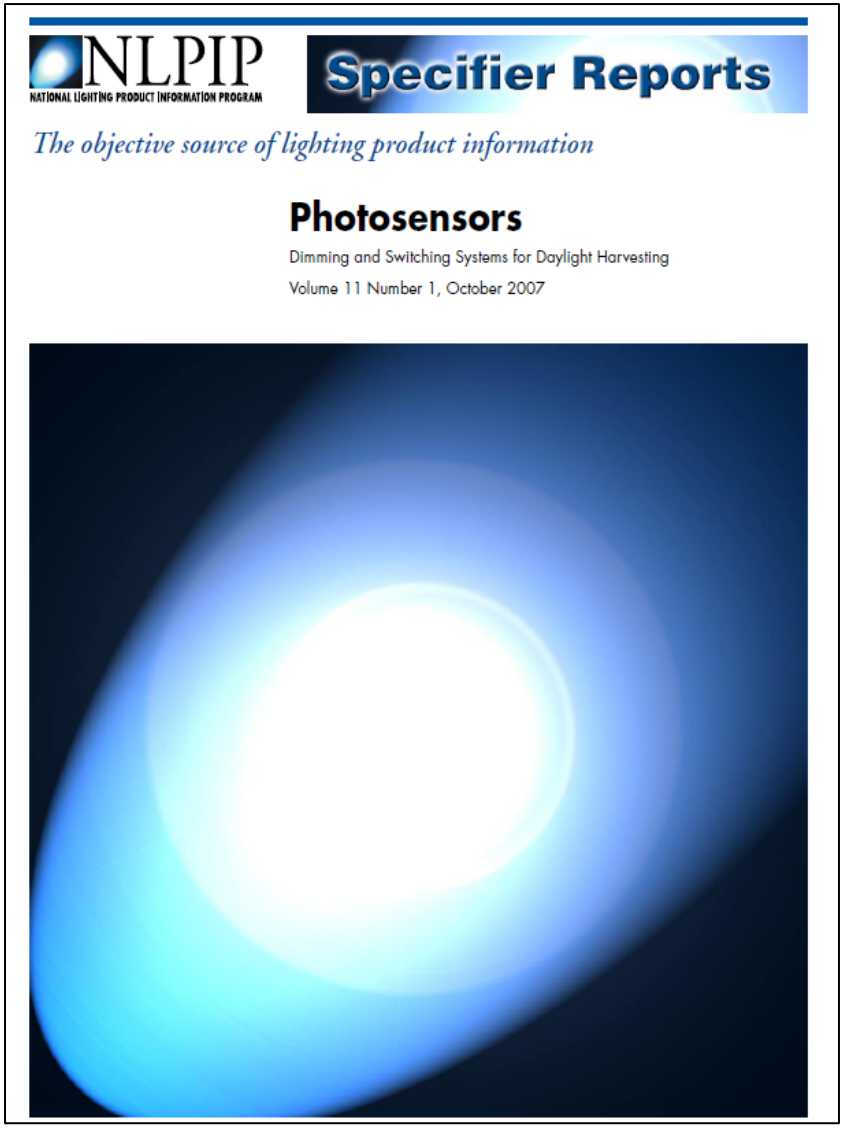
Lighting Design Control Design Energy Model Commissioning

Tools and Current Methods

- Rules of thumb (Mistrick, Rubenstein)
  - Sensor location and spatial sensitivity to avoid view of glazing
- EnergyPlus and DOE-2
  - Split flux methods
  - Assume photosensor signal is proportional to workplane illuminance
- SPOT and other tools
  - Radiance
  - Accurately represent photosensor signal

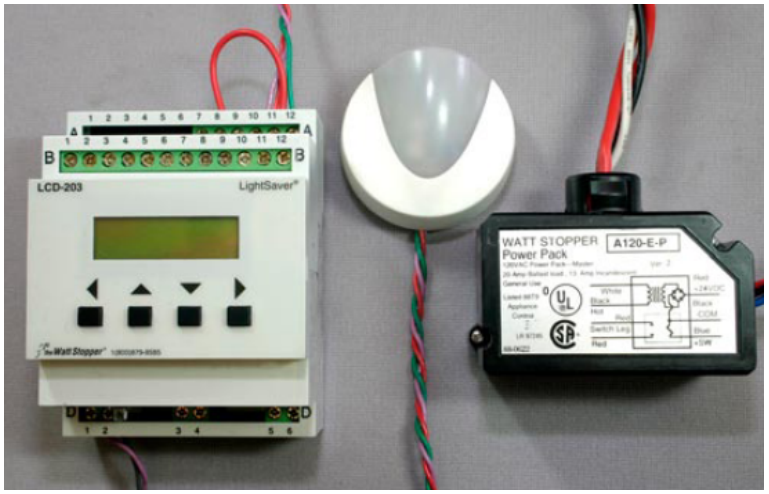
NLPIP Report

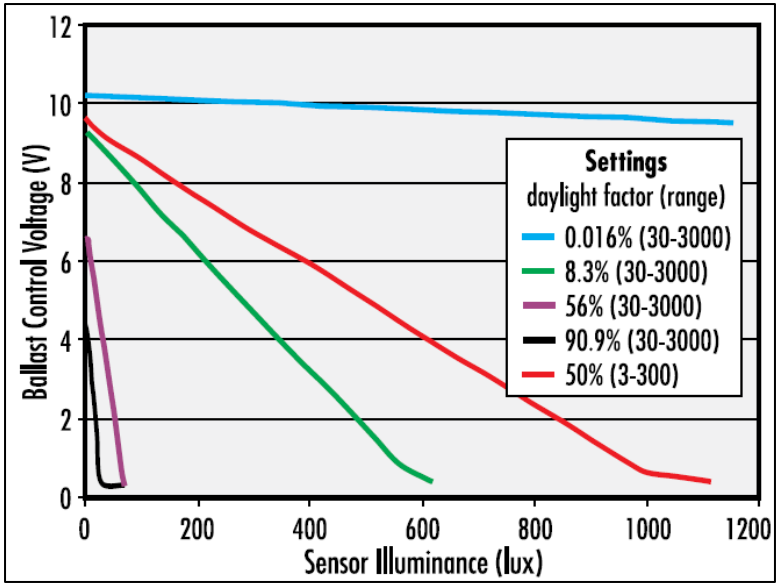
- Sponsored by CEC et al.
- Rennselaer Polytechnic Institute's Lighting Research Center performed photosensor testing
- Spatial, spectral and control response



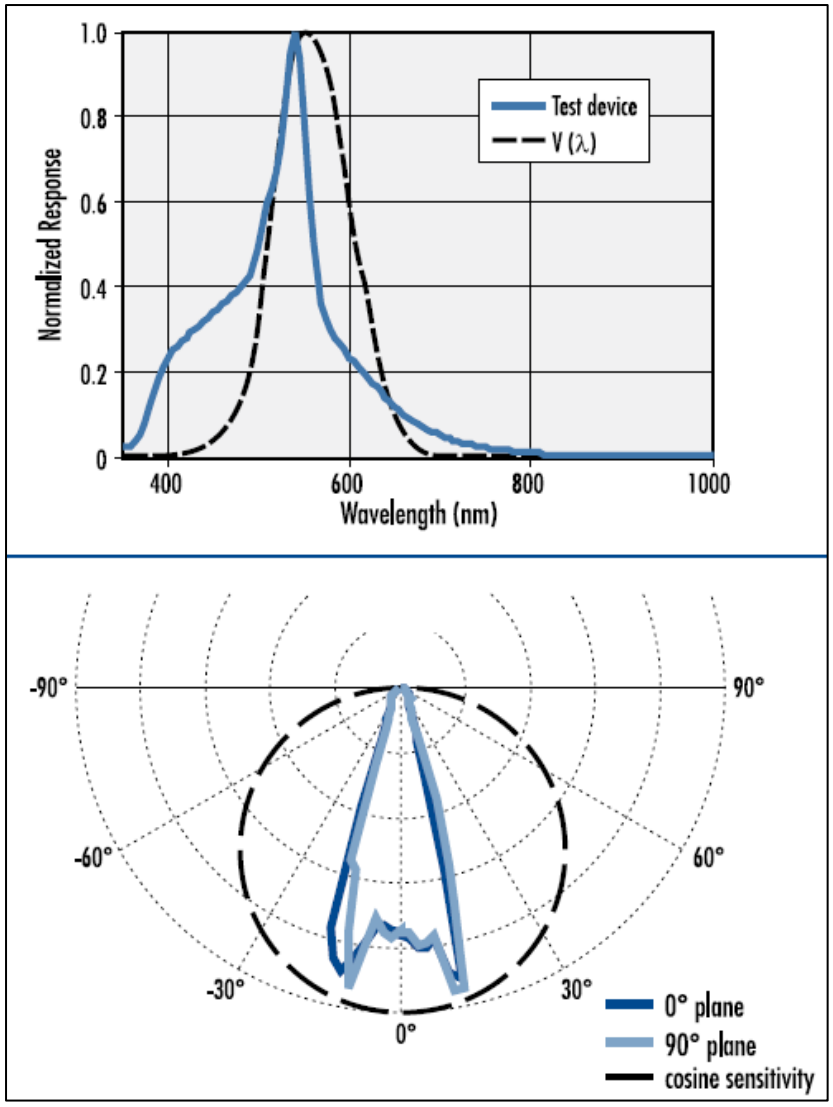
NLPIP Report

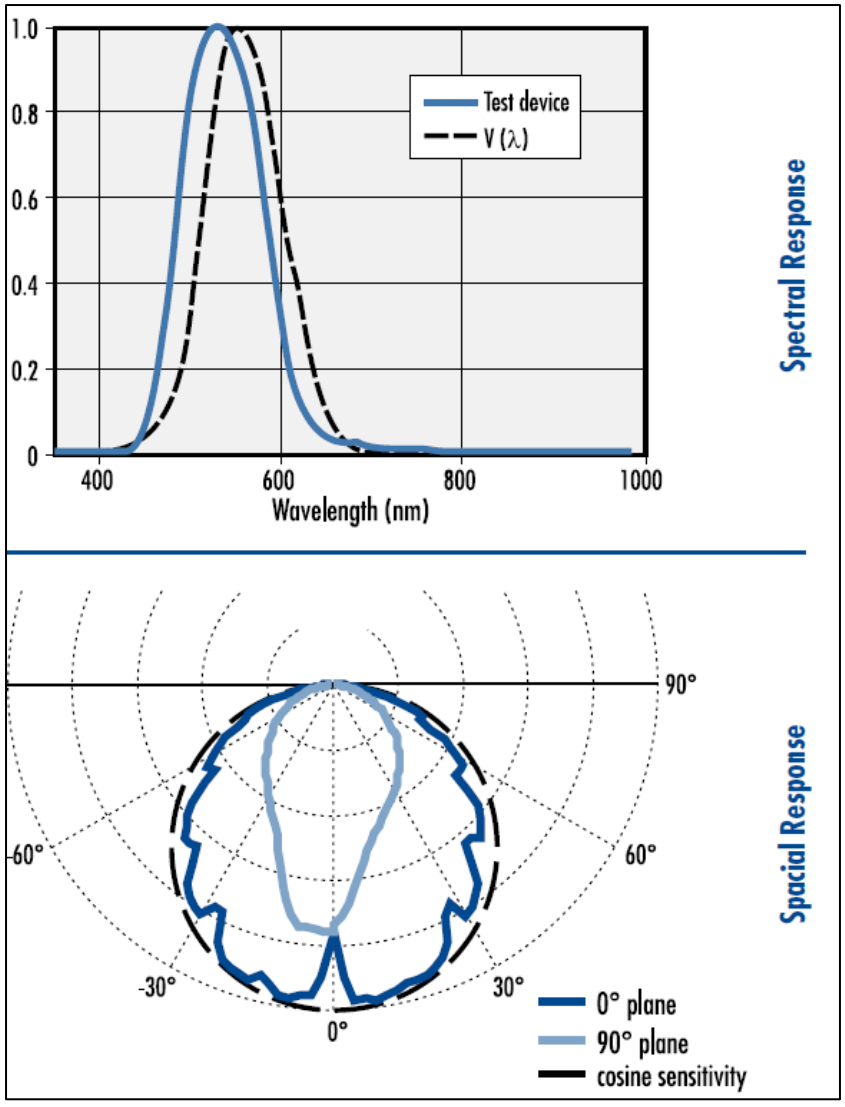
Company
Axis Technologies, Inc.
Douglas Lighting Controls, Inc.
Easylite Lighting Systems
Leviton Manufacturing Co.
Lithonia Lighting - Acuity Brands
Lutron Electronics Co., Inc.
Novitas
PLC-Multipoint, Inc.
Sensor Switch, Inc.
Watt Stopper/LeGrand





NLPIP Report





rsensor

- Developed by Greg Ward for SPOT v4.0 and compiled using MinGW by Francesco Anselmo

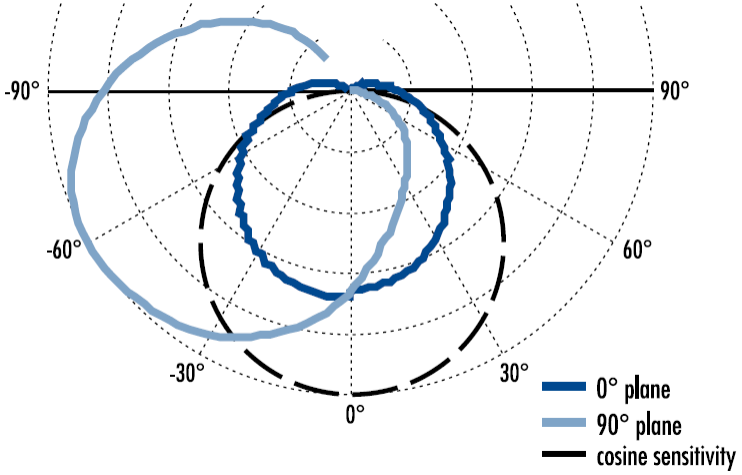
- Differs from psens (written by Ehrlich, et al.)
  - psens uses pic
  - psens applies square projected pixel shape
  - rsensor acts like rtrace
  - rsensor allows calculation of multiple sensors
  - rsensor cross-platform

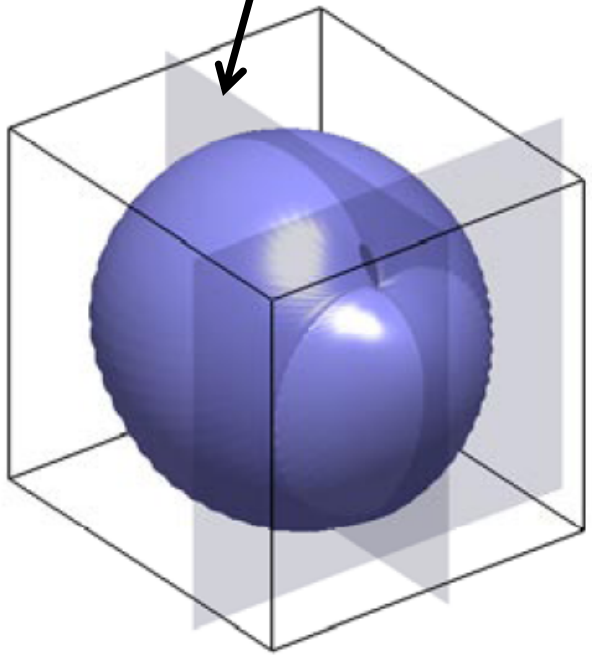
rsensor Input

- -rd, -dn, -h, -n and other render options
- View origin (-vp), orientation (-vd) and rotation (-vu), where rotation gives zero azimuthal direction
- Sensor file (one per view)
  - Evenly spaced data
  - Rows give polar angle, columns give azimuth angle

rsensor Input

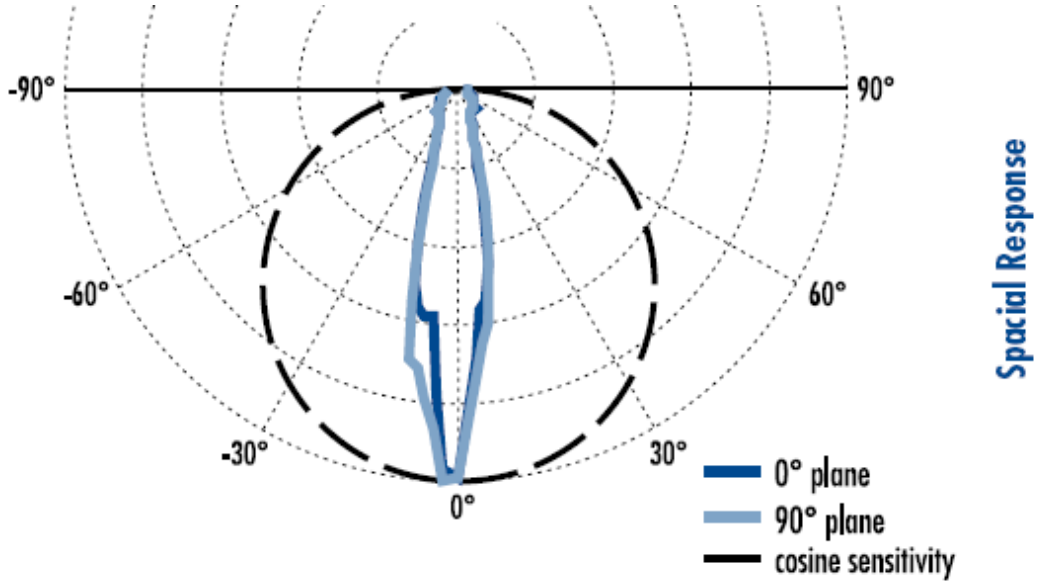
degrees	0	90	180	270
0	0.66	0.66	0.68	0.67
44	0.48	0.28	0.52	0.98
90	0.16	0.02	0.19	0.81



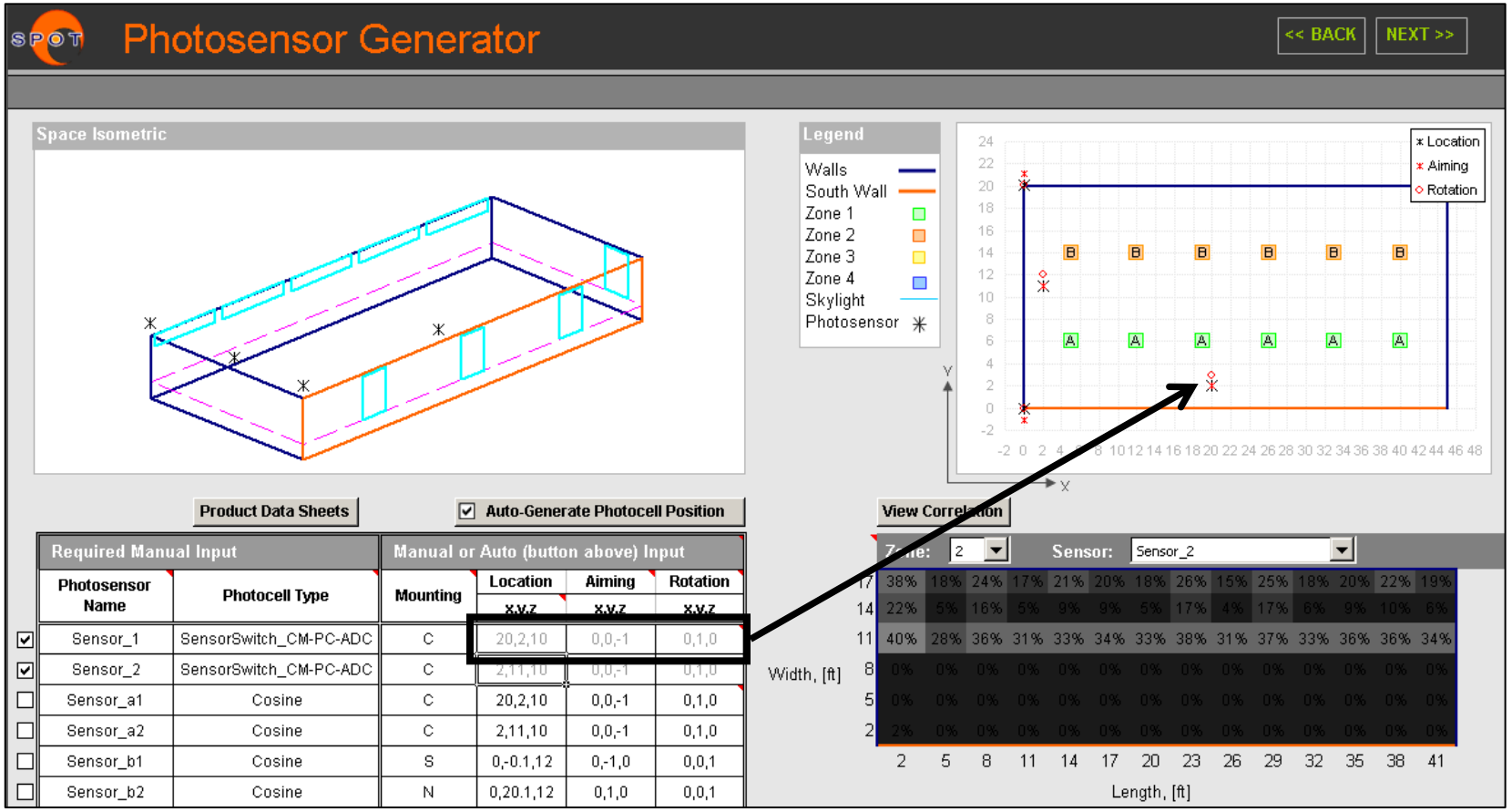


rsensor Output

- RGB values for use with human visual system or sensor spectral weights
- Example output with standard photometric RGB weights:
  - Cosine
    - **35**
    - **fc**
  - Product
    - **3**
    - **relative signal**



Photocell Correlation

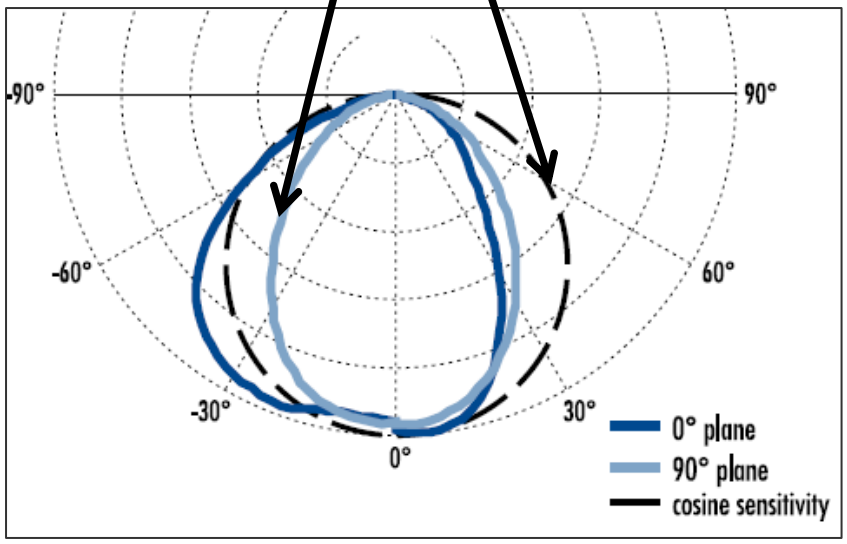


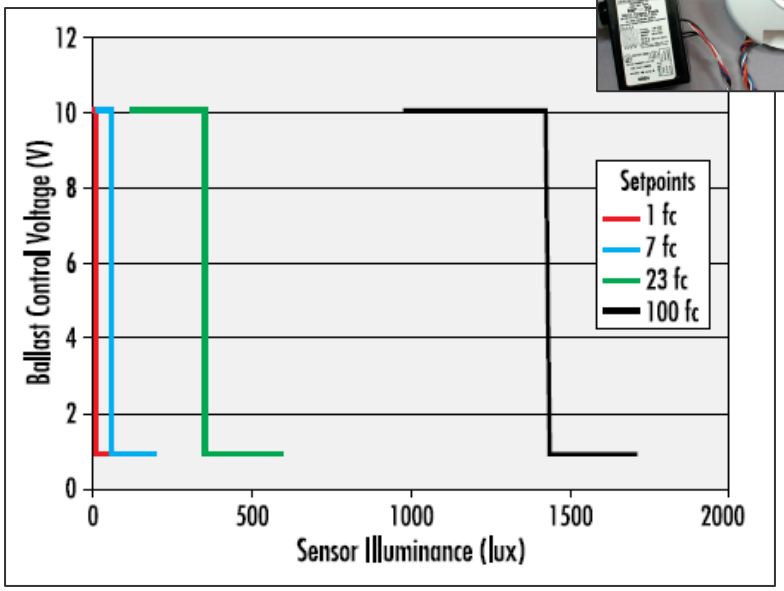
-vp 20 2 10 -vd 0 0 -1 -vu 0 1 0

Lighting Design **Control Design** Energy Model Commissioning

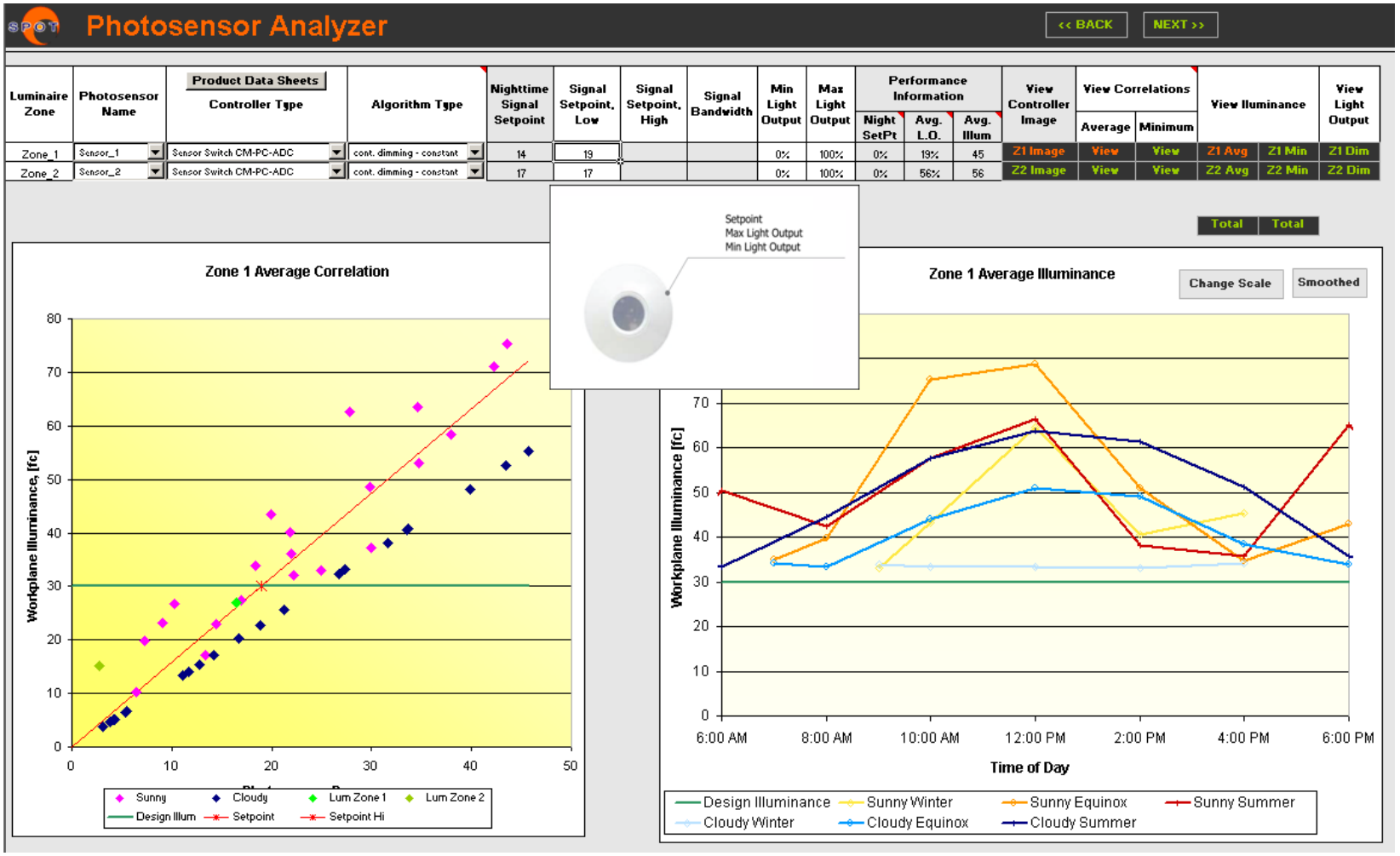
Photosensor Comparison

Luminaire Zone	Photocell Type	Controller Algorithm	Nighttime Signal
Zone 1	Product Specific	Continuous Dimming, Constant Setpoint	14
Zone 1	Generic Cosine	Continuous Dimming, Constant Setpoint	26

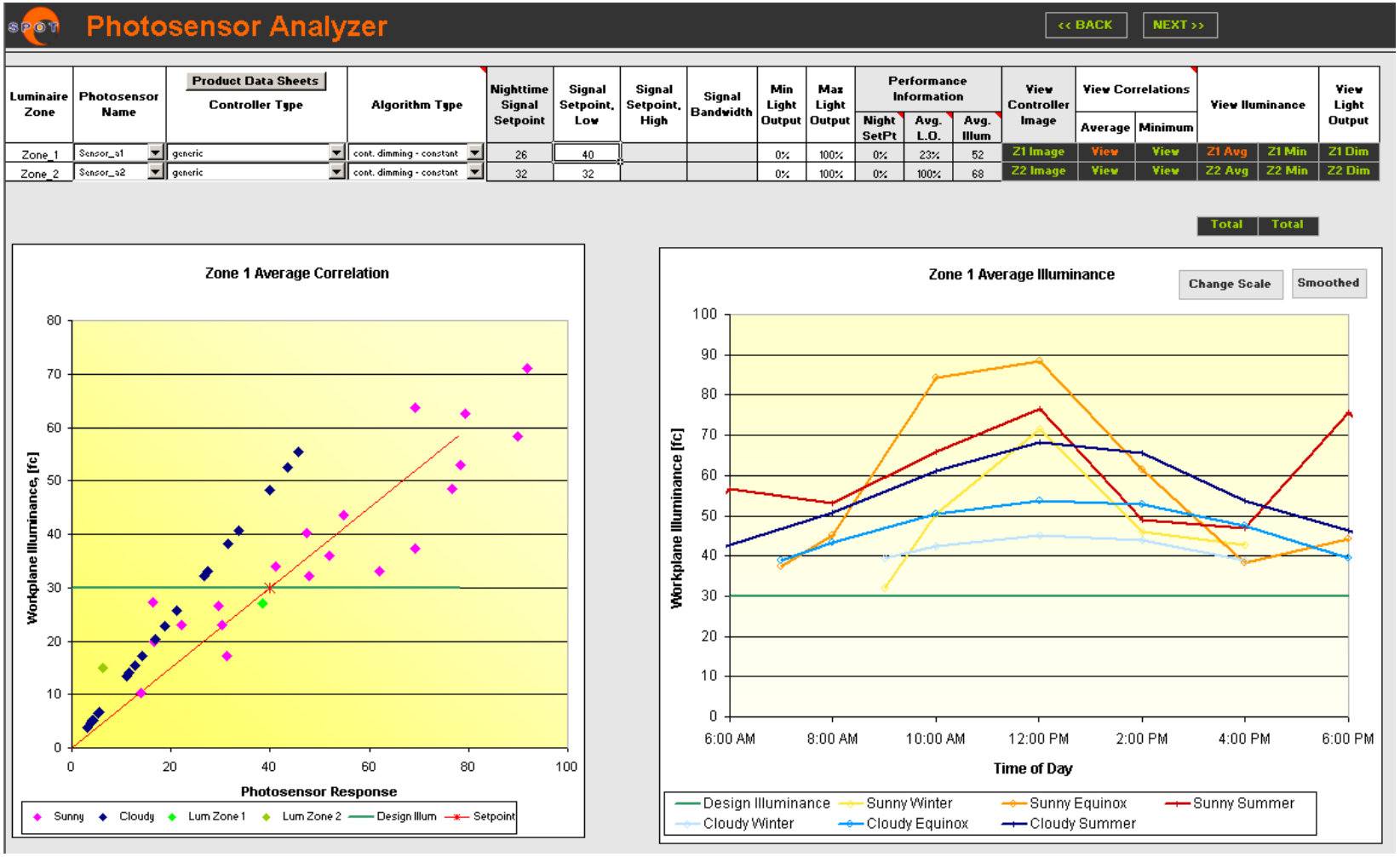




Photosensor Analyzer - Product

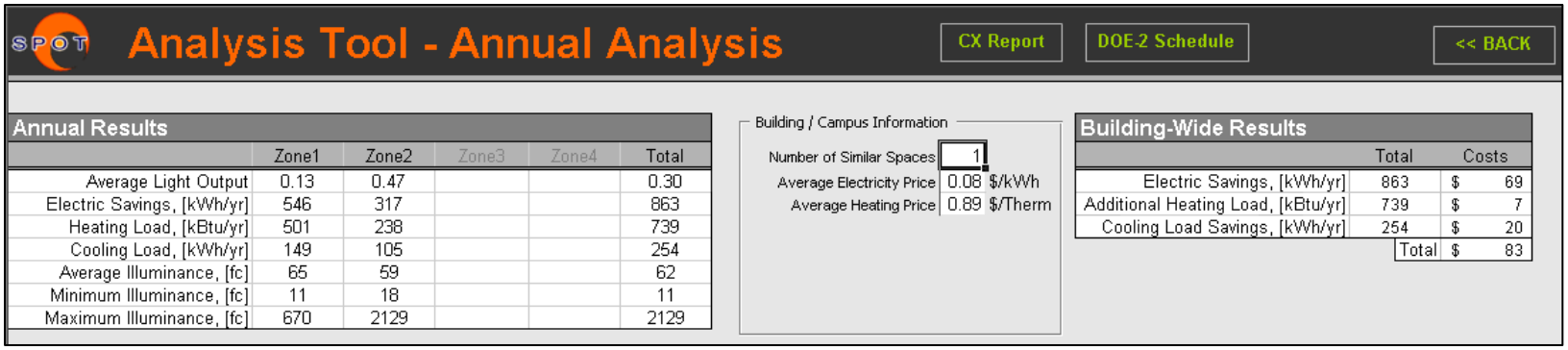


Photosensor Analyzer - Generic



Annual Results

- Product – 30% output



Analysis Tool - Annual Analysis

CX Report | DOE-2 Schedule | << BACK

Annual Results

	Zone1	Zone2	Zone3	Zone4	Total
Average Light Output	0.13	0.47			0.30
Electric Savings, [kWh/yr]	546	317			863
Heating Load, [kBtu/yr]	501	238			739
Cooling Load, [kWh/yr]	149	105			254
Average Illuminance, [fc]	65	59			62
Minimum Illuminance, [fc]	11	18			11
Maximum Illuminance, [fc]	670	2129			2129

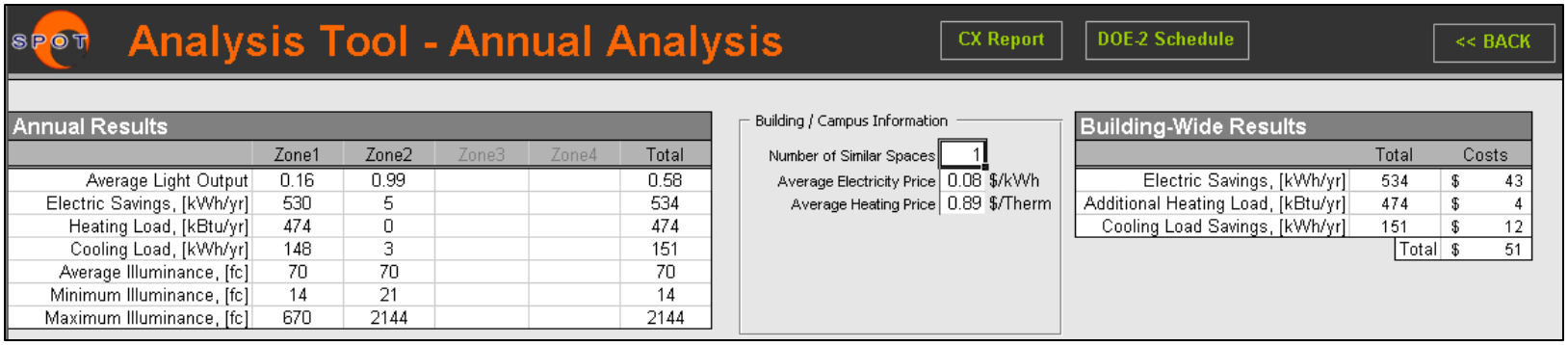
Building / Campus Information

Number of Similar Spaces	1	
Average Electricity Price	0.08	$/kWh
Average Heating Price	0.89	$/Therm

Building-Wide Results

	Total	Costs
Electric Savings, [kWh/yr]	863	$ 69
Additional Heating Load, [kBtu/yr]	739	$ 7
Cooling Load Savings, [kWh/yr]	254	$ 20
	Total	$ 83

- Generic – 58% output



Analysis Tool - Annual Analysis

CX Report | DOE-2 Schedule | << BACK

Annual Results

	Zone1	Zone2	Zone3	Zone4	Total
Average Light Output	0.16	0.99			0.58
Electric Savings, [kWh/yr]	530	5			534
Heating Load, [kBtu/yr]	474	0			474
Cooling Load, [kWh/yr]	148	3			151
Average Illuminance, [fc]	70	70			70
Minimum Illuminance, [fc]	14	21			14
Maximum Illuminance, [fc]	670	2144			2144

Building / Campus Information

Number of Similar Spaces	1	
Average Electricity Price	0.08	$/kWh
Average Heating Price	0.89	$/Therm

Building-Wide Results

	Total	Costs
Electric Savings, [kWh/yr]	534	$ 43
Additional Heating Load, [kBtu/yr]	474	$ 4
Cooling Load Savings, [kWh/yr]	151	$ 12
	Total	$ 51

Energy Model Integration

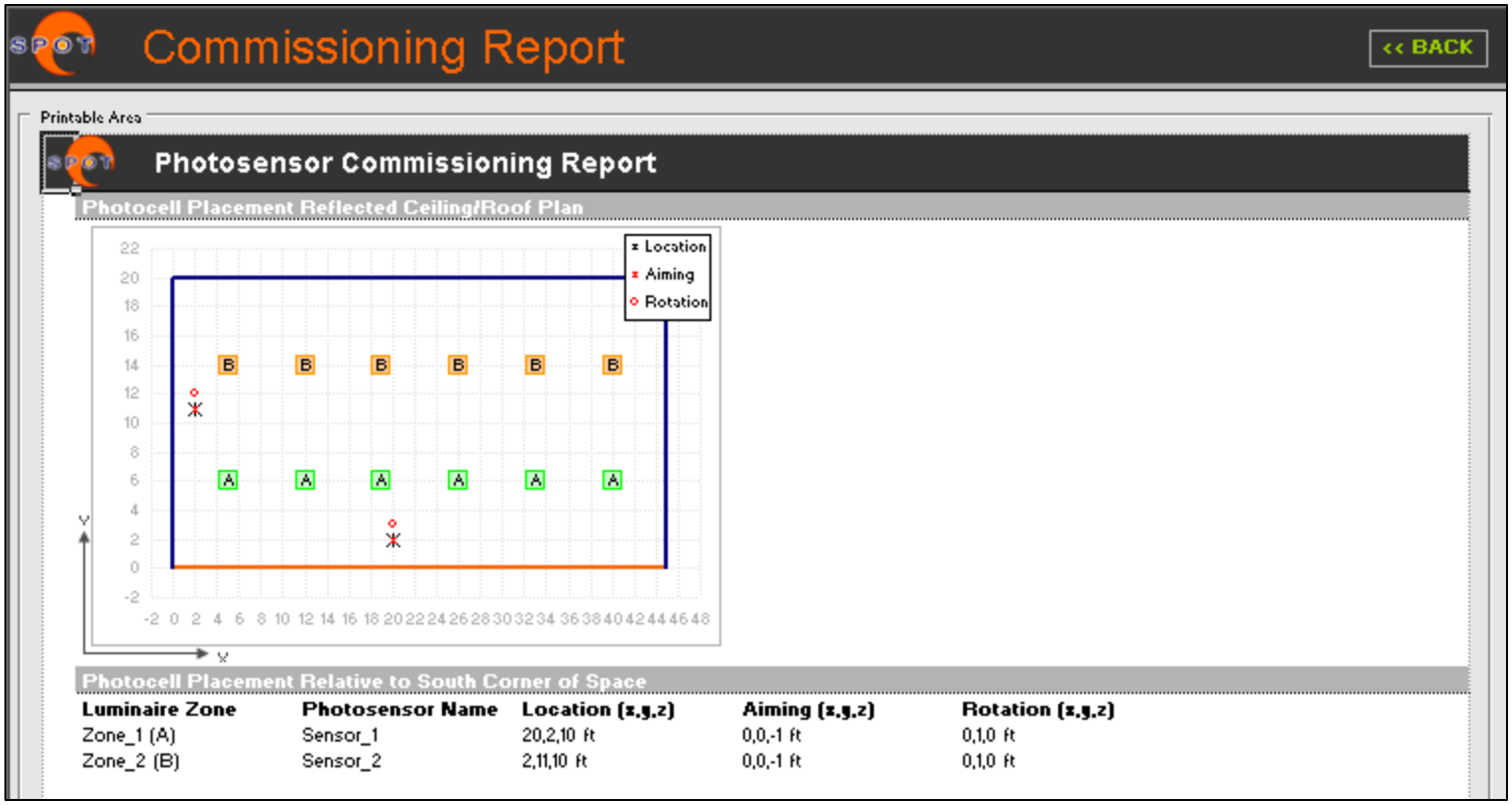
- Hourly LPD multiplier schedule
- Account for power curve of dimming ballasts
- Must match other schedules in energy and SPOT models
  - Weather file
  - Occupancy schedule
  - SHGC due to active daylighting device

Annual Lighting Schedule

LPD Fraction in DOE-2 Format

```
spot_2 = SCHEDULE
TYPE = FRACTION
THRU JAN 7
(MON) (1,24) (0.00 0.00 0.00 0.00 0.00 0.00 0.18 0.46 0.36 0.44 0.38
0.18 0.18 0.04 0.00 0.02 0.18 0.12 0.12 0.00 0.00 0.00 0.00 0.00 )
(TUE) (1,24) (0.00 0.00 0.00 0.00 0.00 0.00 0.18 0.45 0.19 0.43 0.38
0.18 0.12 0.07 0.02 0.14 0.18 0.12 0.12 0.00 0.00 0.00 0.00 0.00 )
(WED) (1,24) (0.00 0.00 0.00 0.00 0.00 0.00 0.18 0.39 0.15 0.41 0.37
0.08 0.00 0.00 0.00 0.15 0.18 0.12 0.12 0.00 0.00 0.00 0.00 0.00 )
(THU) (1,24) (0.00 0.00 0.00 0.00 0.00 0.00 0.18 0.38 0.17 0.30 0.24
0.10 0.02 0.00 0.00 0.00 0.18 0.12 0.12 0.00 0.00 0.00 0.00 0.00 )
(FRI) (1,24) (0.00 0.00 0.00 0.00 0.00 0.00 0.18 0.39 0.07 0.17 0.00
0.07 0.01 0.00 0.00 0.03 0.18 0.12 0.12 0.00 0.00 0.00 0.00 0.00 )
(SAT) (1,24) (0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00
0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 )
(SUN) (1,24) (0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00
0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 )
(HOL) (1,24) (0.0)
```

Commissioning Report - Position



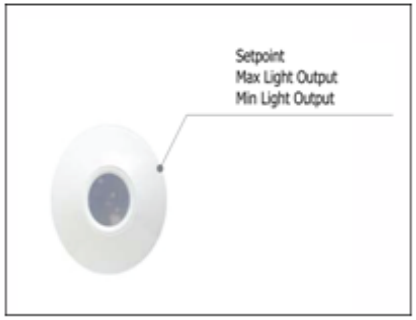
Commissioning Report - Settings

Printable Area

Photosensor Commissioning Report — TestClass_1, Zone 1 Sensor Switch CM-PC-ADC

Summary

Controller Image



CX Settings

"fc" Setpoint: 19

Notes

All sensor programming is done by pressing the button on the side of the unit the number of times corresponding to the function.
LED will blink back the current FN setting. Press button number of times for new desired setting

Setpoint
(Use FN #5 to set the ten's digit and FN #6 to set the one's digit of the setpoint given in the top of the CX report.)
(Use FN #5 to set the ten's digit and FN #6 to set the one's digit of the setpoint given in the top of the CX report.)

Dimming Limits
(Use FN #15 to set the upper dimming level limit.)
(Use FN #16 to set the lower dimming level limit.)
(The percent levels given above should be related to volts using a power curve of the ballast used.)

Notes taken directly from the Sensor Switch Programming Instructions and Application Notes

Future of Daylighting Controls…

- Modeling
  - Photosensor report standard (Ian Ashdown – IESNA LM-74-05 XML)
  - Different design workflows
  - Optimization software
    - PIDO (Stanford) and OptE-Plus (NREL)
    - Others?
- System Design
  - Sensors optimized using rsensor
  - Smart sensors
  - Closed vs open vs dual loop

Future SPOT Development

- Integrate annual simulation of optical daylighting systems

- Validate annual sky approach and control algorithms?
- Include Energy + annual lighting reduction schedule format?
- Annual simulation for complex fenestration?
- Cross-platform?
- Plugin to Sketchup, revit, rhino?
- Importing of .rif files, dwg, obj, other?

References

- Download SPOT and other info at:
  - www.archenergy.com/SPOT
- SPOT support e-mail:
  - spotsupport@archenergy.com
- SPOT Users forum
  - http://community.archenergy.com/mailman/listinfo/spot
- NLPIP Photosensor Report
  - http://www.lrc.rpi.edu/nlpip/publicationDetails.asp?id=916&type=1

Questions?

Thoughts on
SPOT,
uses of rsensor or
the future of daylighting controls?