National Renewable Energy Laboratory
Innovation for Our Energy Future

Simulating for Nothing

Radiance's role in the design of a large net zero energy building

Eighth Annual Radiance Workshop, Harvard University

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October 22-23, 2009

Simulating for Nothing

Introduction

Acknowledgements

- Initial daylighting design developed by RNL Design (Architect), Stantec (Engineer), and Architectural Energy Corporation (Sustainable Design Consultant)
- Daylighting design refined by the speaker while employed by Architectural Energy Corporation
- Speaker is now employed by the National Renewable Energy Lab (NREL)
- Images and data were presented to NREL throughout the design process

Introduction

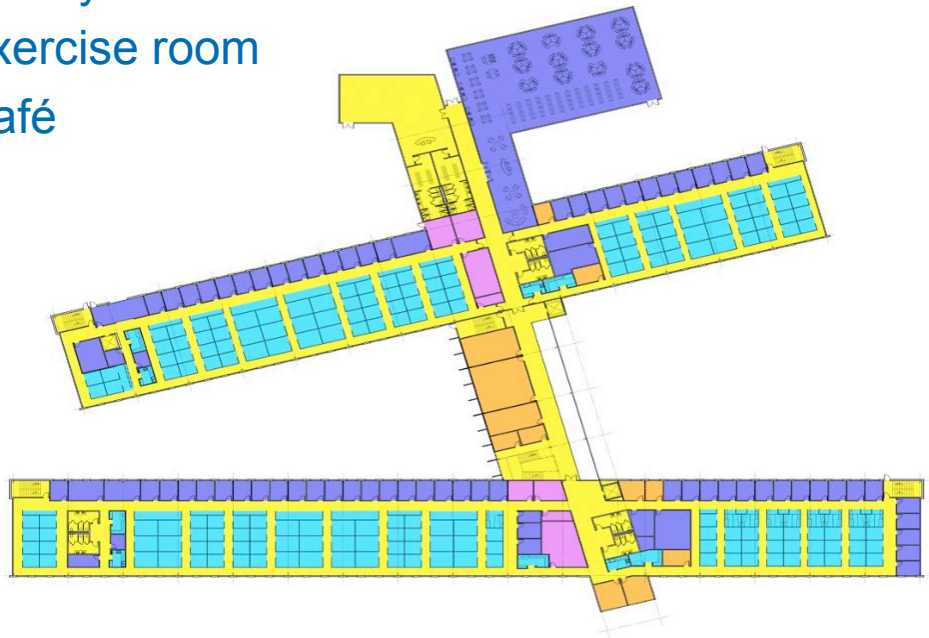
Project Goals

- Capacity: 750 people
- Size: 220,000 ft^2
- EUI: 25 Kbtu/ft^2/yr
- 50% energy savings over ASHRAE 90.1
- $250/ft^2
- LEED Platinum
  - LEED iEQ 8.1 (daylighting) credit *required*
- Net Zero Energy building, via:
  - Base building energy efficiency
  - On-site wood chip heating facility
  - Roof- and site mounted PV (power purchase agreement)

Introduction

Program

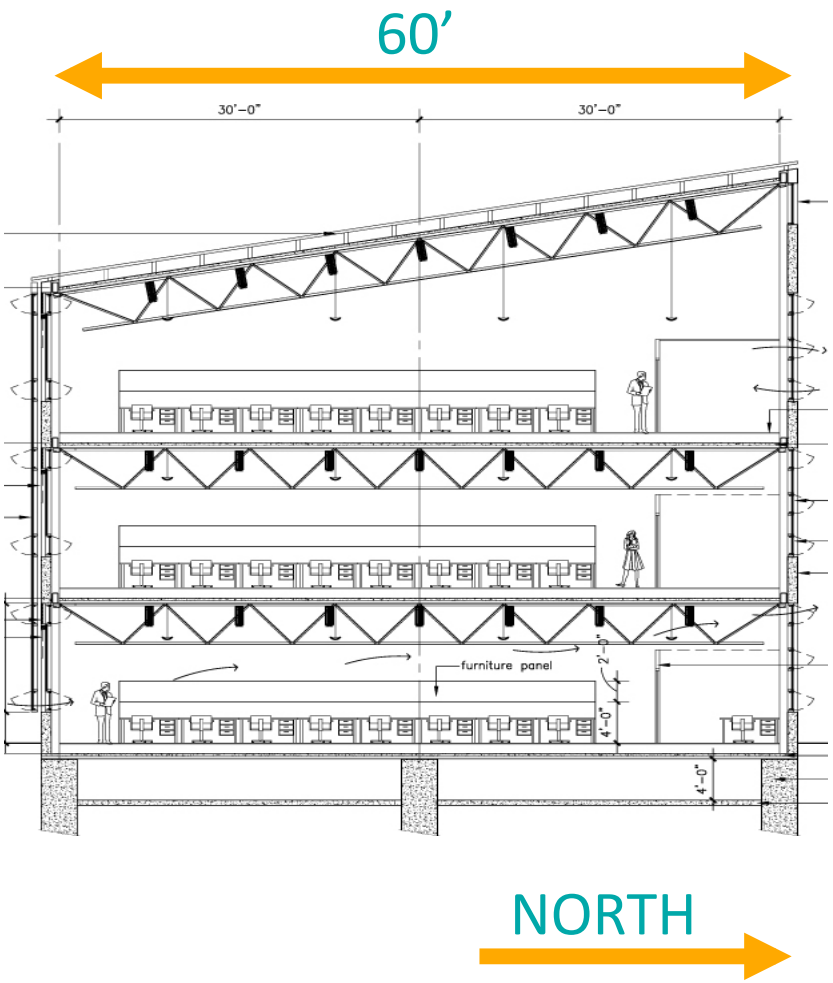
- Open and private office space
- Data center
- Conference rooms
- Library
- Exercise room
- Café



Design Response – Competition Phase

Daylighting

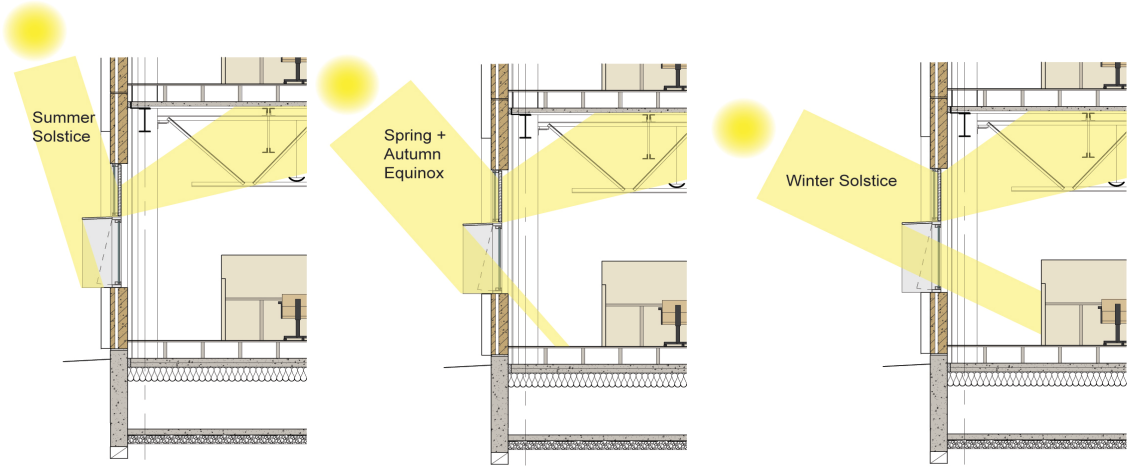
- Radiance modeling determined maximum allowable section depth (N/S)
- Achieves 25fc across majority of main wing floor plate (noon, equinox, clear sky), satisfying LEED iEQ 8.1 requirement



Design Response – Competition Phase

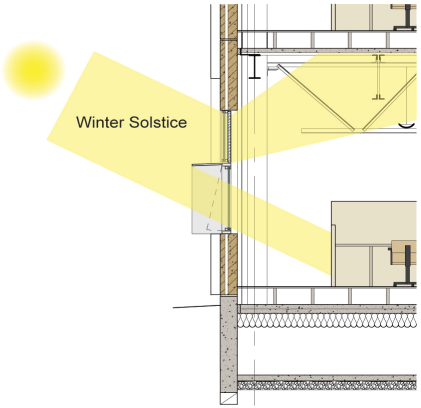
Daylighting

- Punched windows with “daylight” and “view” panes
- Daylight redirecting devices (Lightlouver) on daylight glazing
- Simple fixed overhang/vertical fin devices on vision glazing (ties into natural ventilation requirement)
- Office furniture



Design Response – Competition Phase

- Overhang sized to work in conjunction with furniture partition heights to control direct sun on work surfaces
- Entire space programming responsive to and supporting daylighting



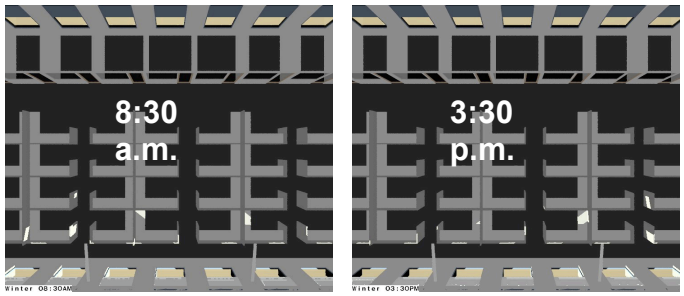
Design Development

- Confirmation of design
  - Overhangs blocking direct sun?
  - Adequate daylight throughout year?
  - Satisfy LEED iEQ8.1 requirement?
    - 25FC, 75% task area, Equinox/noon/clear sky
- Inform lighting control zones
- Estimate lighting control response for energy analysis
- Qualitative evaluation
  - Several space types

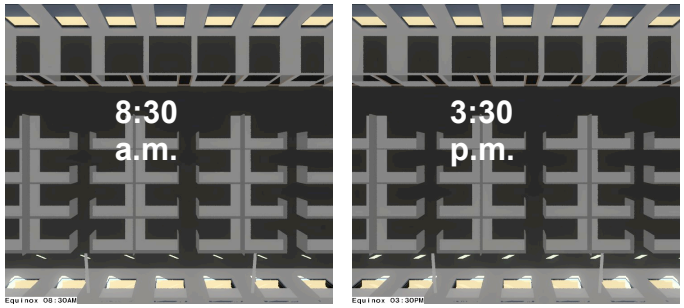
Design Development

- Overhang Performance
  - Minimal direct sun on desks

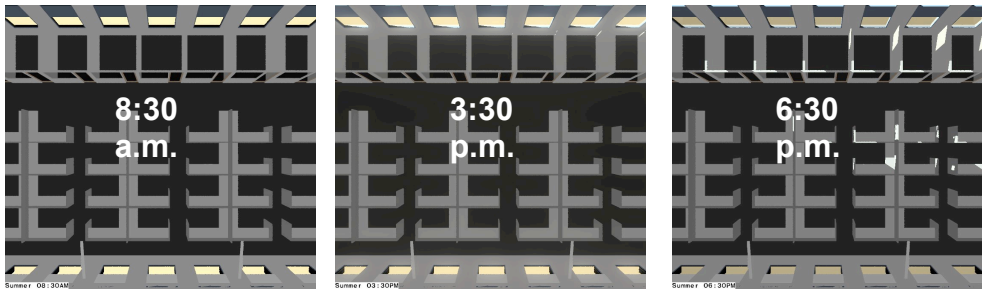
Winter

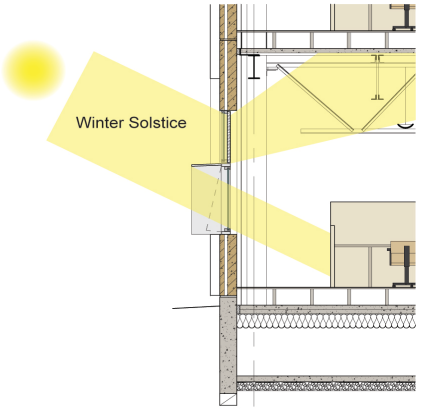


Equinox



Summer



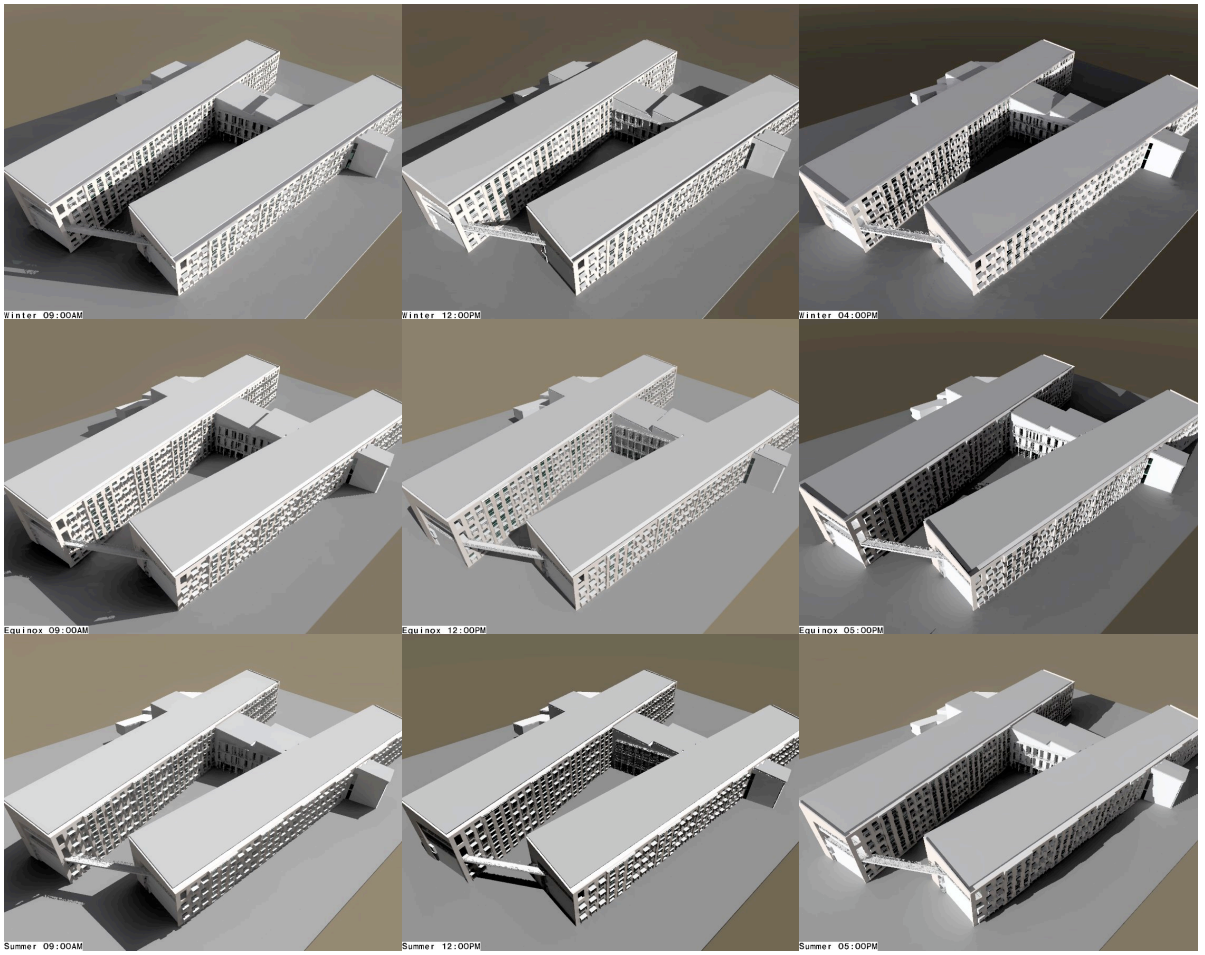


Design Development

Winter

Equinox

Summer



9:00 a.m. 12:00 p.m. 5:00 p.m.

Design Development

Main wings – interior analysis

- Created detailed Radiance model
- Used .ies photometric files to model Lightlouver performance

Model extents

Calc grid area

Design Development

E: 25 fc | Illuminance | new_bc_wp_3_21_12_1_

60	32	47	55	53	39	32	47	55	53	39	31	48	56	53	38	33	46	56	53	39	32	48	54	55	39	32	47	55	55	45
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NORTH

SOUTH

LEED-qualifying Area

210	153	153	136	652	**100%**
210	153	153	136	652	

LEED Analysis - Typical Floor

Design Development

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LEED-qualifying Area

210	153	153	136	652	1
210	153	153	136	652	

NORTH

SOUTH

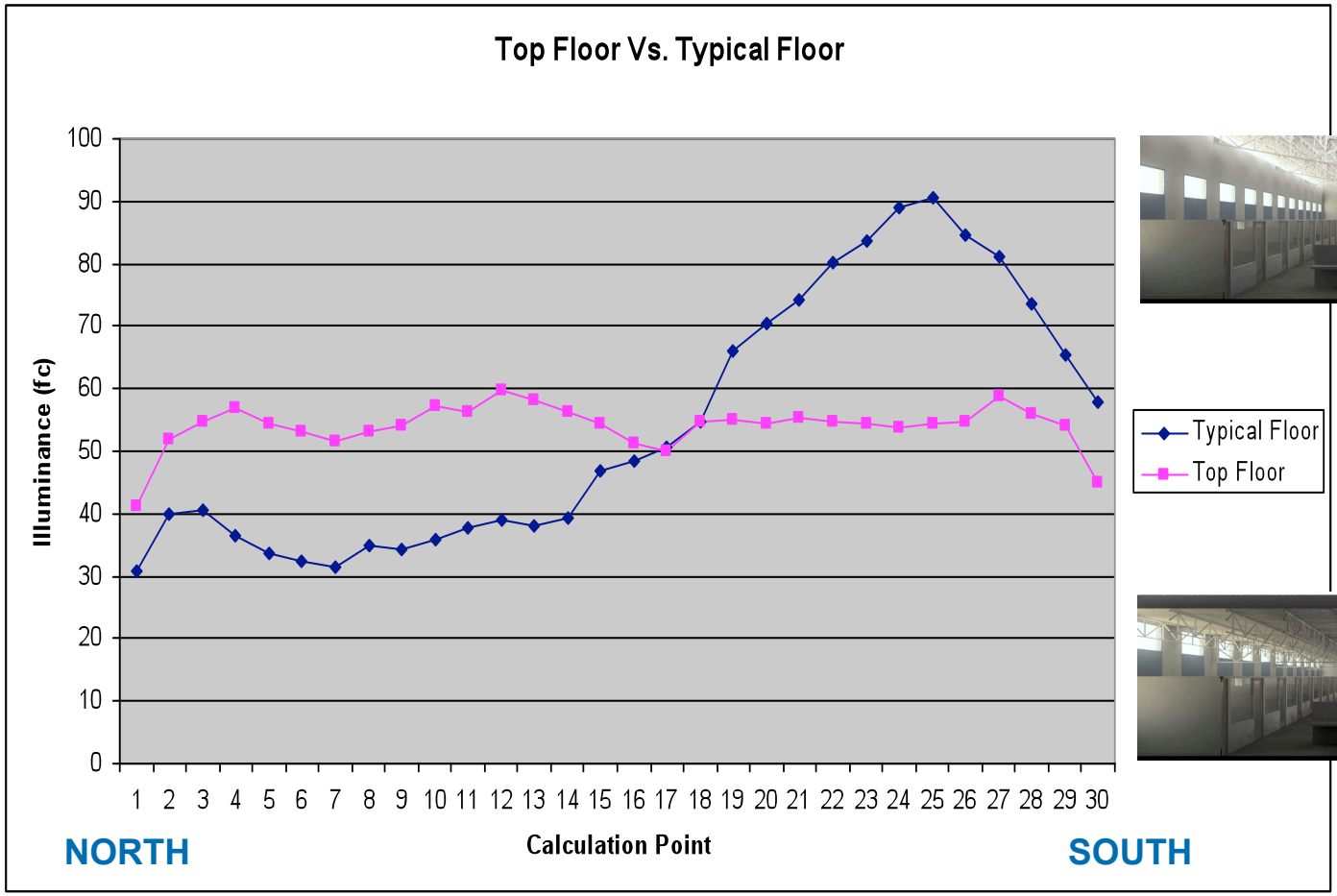
LEED Analysis - Top Floor

Design Development

Top vs. Typical Floor Illuminance Distribution

Design Development

Top vs. Typical Floor Illuminance Distribution



Design Development

LEED Analysis vs. Actual Space Conditions

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4	69	88	101	95	80	70	90	109	98	77	67	91	106	99	85	67	94	101	102	77	67	84	101	102	81	69	92	101	98	83
2	54	1827	1834	1835	60	55	1833	1836	1835	58	59	1832	1848	1836	66	57	1829	1837	1836	58	62	1829	1845	1839	62	55	1828	1837	1834	59
	2	**4**	**6**	**8**	**10**	**12**	**14**	**16**	**18**	**20**	**22**	**24**	**26**	**28**	**30**	**32**	**34**	**36**	**38**	**40**	**42**	**44**	**46**	**48**	**50**	**52**	**54**	**56**	**58**	**60**

Design Development

LEED Analysis (no furniture) vs. Actual Space Conditions

Design Development

Integrated Analysis – "What about the Energy Use?"

- LEED daylight credit "analysis" an inexact measurement of an incomplete performance metric
- "Point-in-time", misses things (good and bad)
- Need to measure annual, whole-building energy-use impacts of daylight-responsive lighting controls
- Lightlouver devices not easily simulated on annual basis; ies files were generated with forward raytracing for specific times
- rtcontrib and climate-based daylight modeling (CBDM) workflows are the next frontier for this work

Design Development

Integrated Analysis – "What about the Energy Use?"

For the RSF calculations:

– Lightlouver geometry was explicitly modeled in Radiance

– Radiance's light backwards raytracing was used (no mkillum, no photon map)

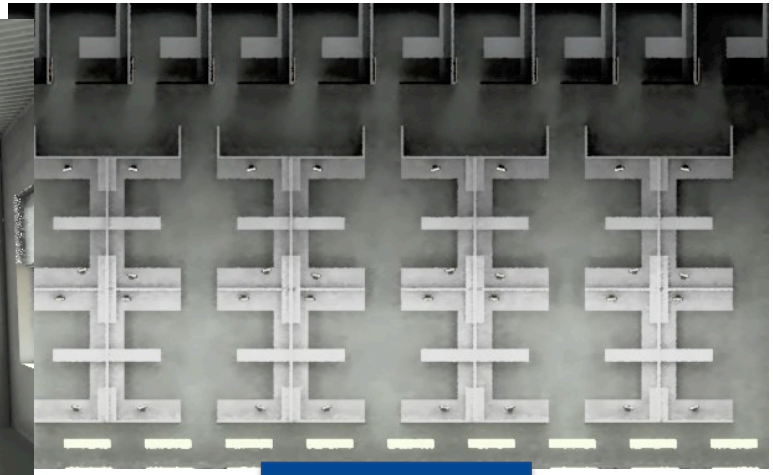
– Cranked up the rendering parameters, waited a long time, and STILL assumed there was a significant underestimation of the daylight contribution

– Used SPOT to perform annual simulation of daylight performance and dimming response, generated schedule "include file" for DOE2 energy analysis

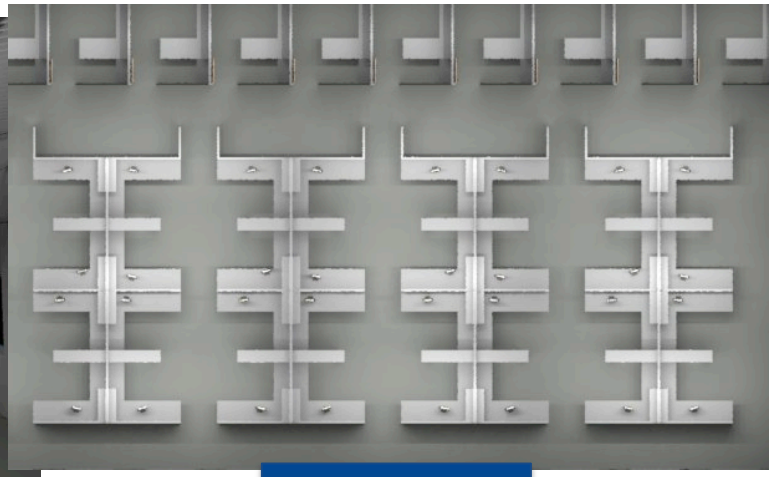
– Energy modelers included SPOT schedule in DOE2 energy runs

Construction Documents

Detailed Renderings



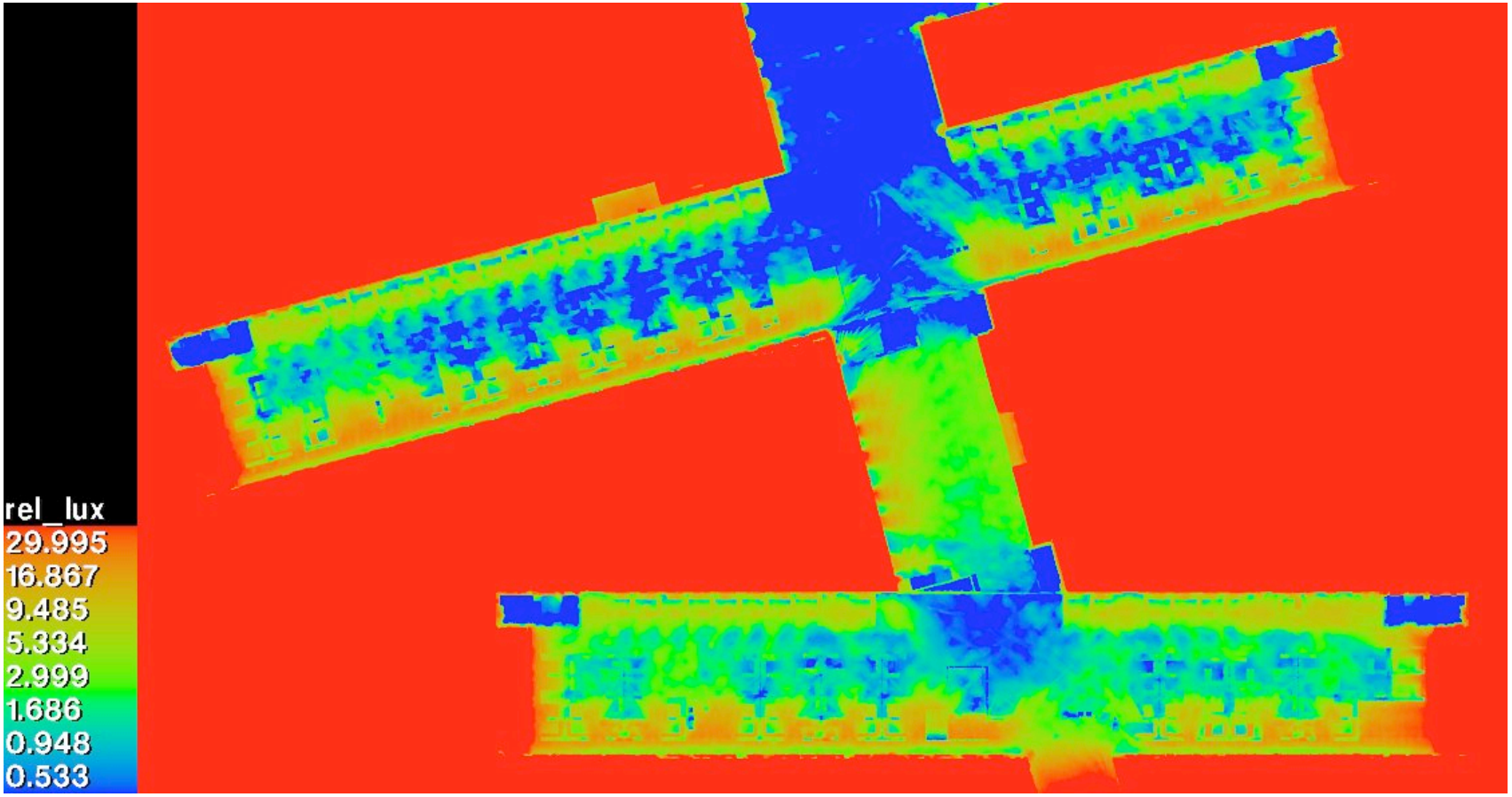
Day



Night

Construction Documents

Lighting Control Zones

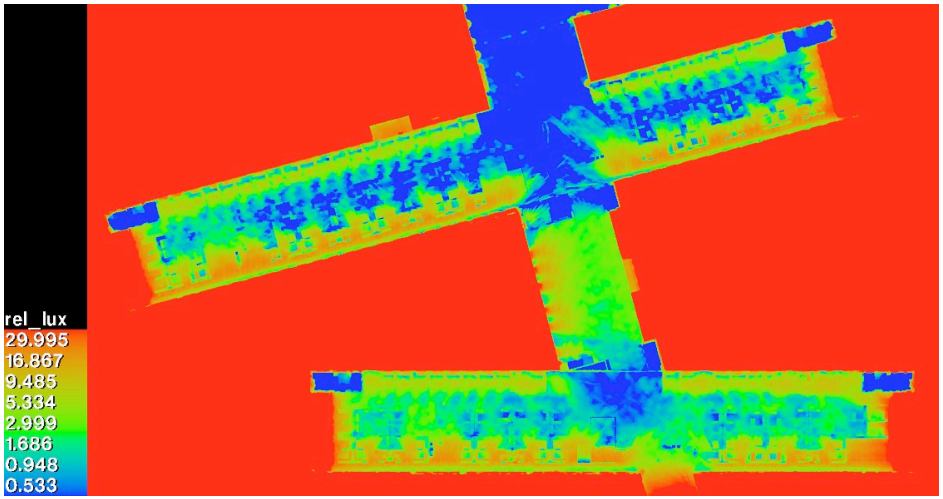


Annual Daylight Availability - Third Floor

Construction Documents

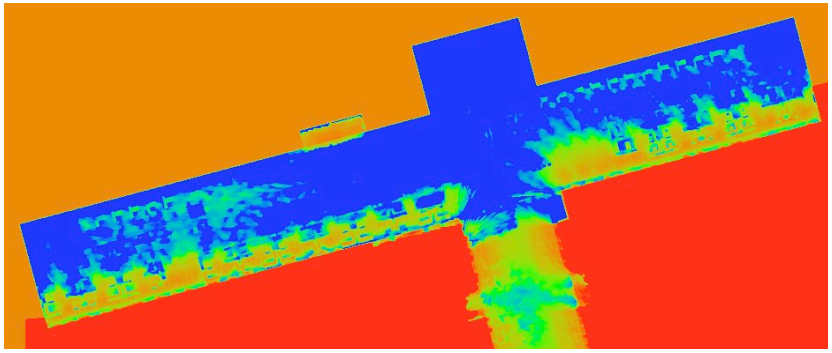
Lighting Control Zones

- Logical control zoning was determined through annual simulation
  - Francesco Anselmo's "radmap" used for annual sky simulations
  - Prevailing daylight availability dictated control zoning

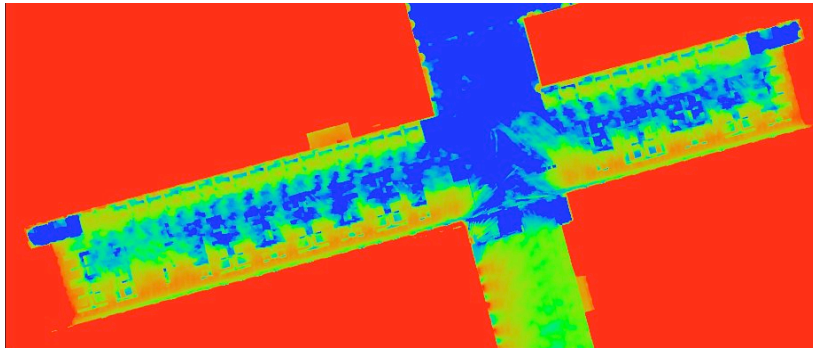


Construction Documents

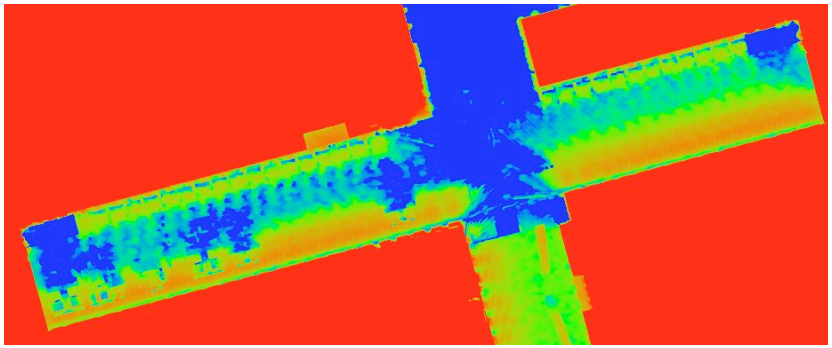
Lighting Control Zones



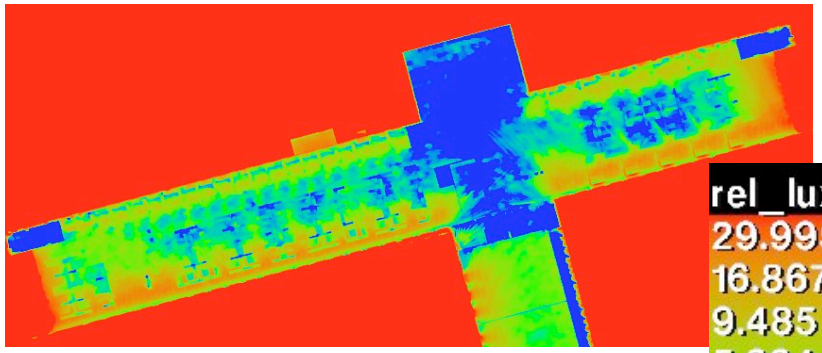
First Floor



Third Floor



Second Floor

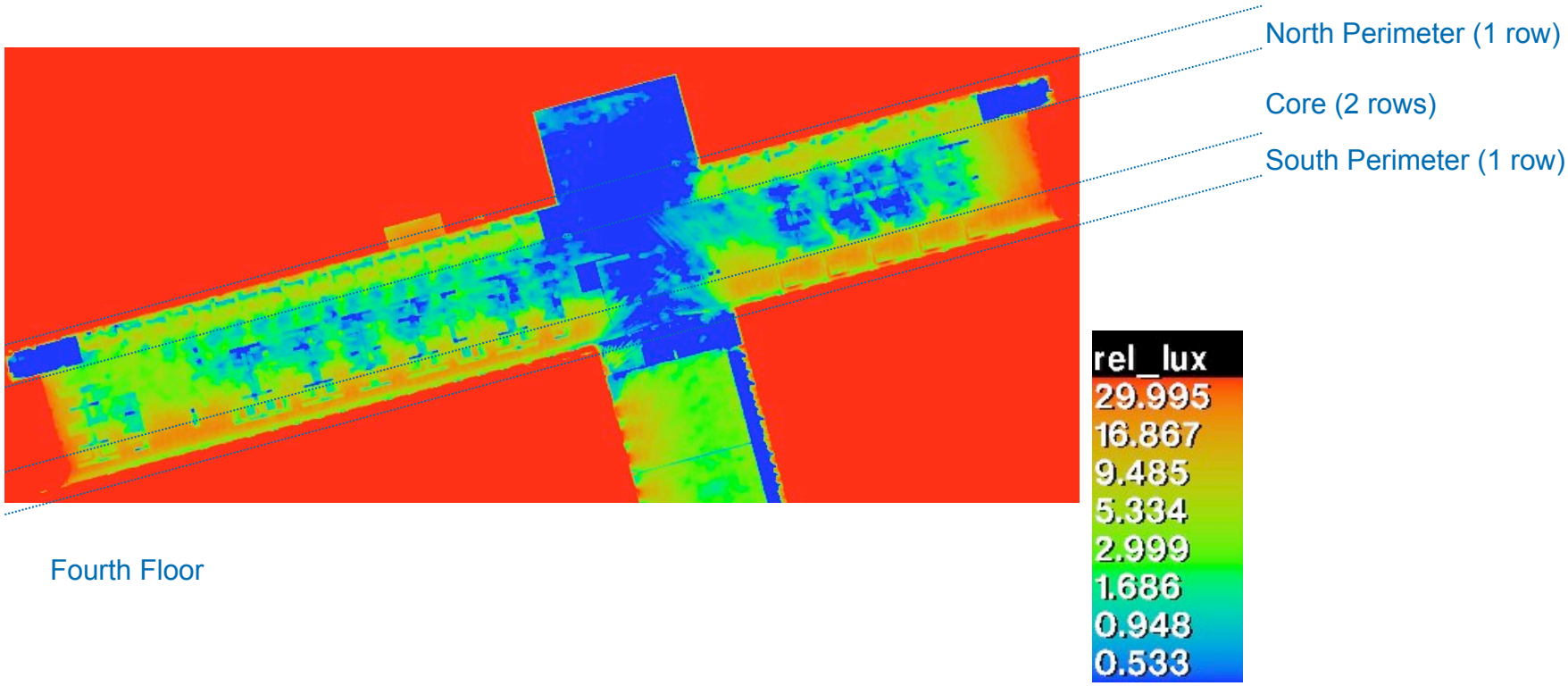


Fourth Floor

Annual Daylight Availability – North Wing

Construction Documents

Lighting Control Zones – East-West

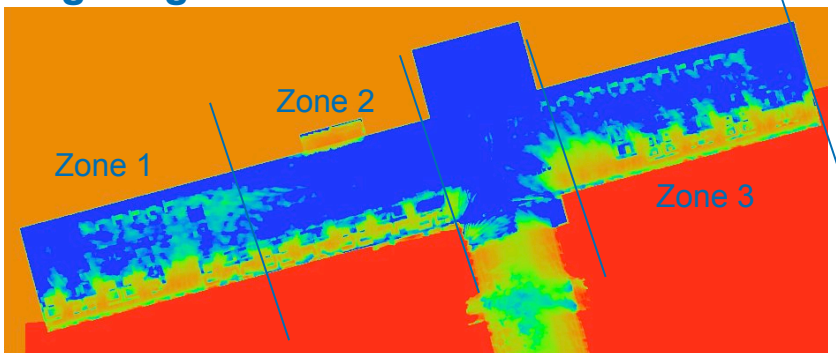


Fourth Floor

Annual Daylight Availability – North Wing

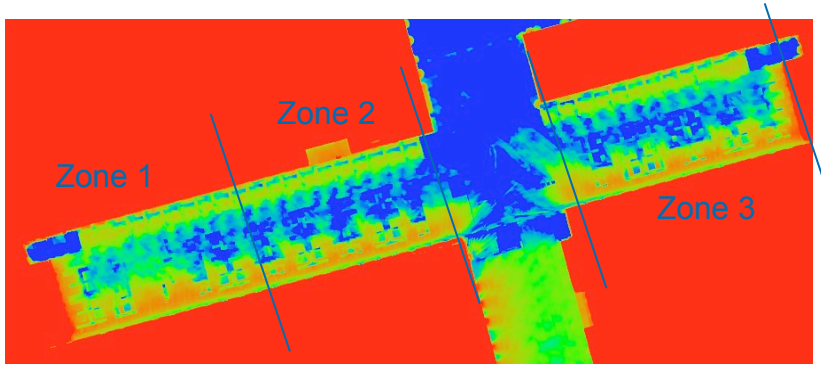
Construction Documents

Lighting Control Zones – North-South



First Floor

Applied to Floors 1 & 2 in energy model



Third Floor

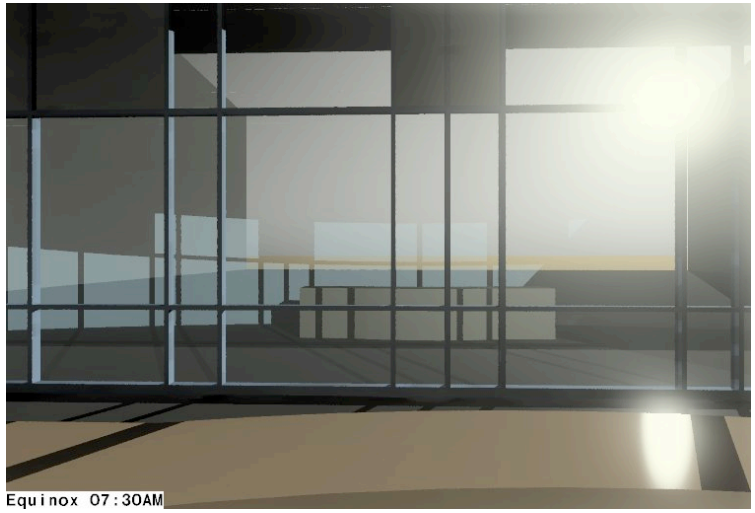
Applied to Floors 3 &4 in energy model

Annual Daylight Availability – North Wing

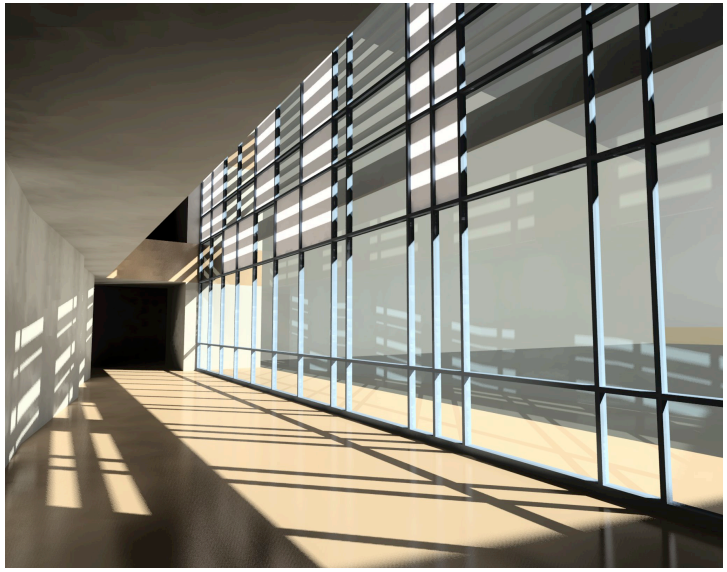
Additional Visualizations

Desk Placement Glare Issue

- **Repositioned Reception Desk**



Original View; Equinox, 7:30 a.m.



Relocated Desk View; Equinox, 7:30 a.m.

Additional Visualizations

2nd Floor Conference Room, Summer, 3:00 p.m.

Additional Visualizations

Café in Afternoon

Additional Visualizations

Sunshade Ineffective due to open sides/top; recommend adding solid sides

View Without Recommended Sunshade Modification

View with Recommended Sunshade Modification

Thank You