

# Daylight Simulation

*its role in the design of a large NZEB*



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Group**

**Boulder Green Building  
Conference**

**April 26, 2010**

Daylight Simulation's Role in NZEB Design

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# **CASE STUDY**

# Case Study

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- Radiance's role in the design of a large net zero energy building
- National Renewable Energy Laboratory Research Support Facility (RSF)
- Net Zero Energy Office Building



# Introduction

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- 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)

# Introduction

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- Project Goals

- Capacity: 750 people
- Size: 220,000 ft<sup>2</sup>
- EUI: 25 Kbtu/ft<sup>2</sup>/yr
- 50% energy savings over ASHRAE 90.1
- \$250/ft<sup>2</sup>
- LEED Platinum
  - LEED iEQ 8.1 (daylighting) **credit required**

# 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

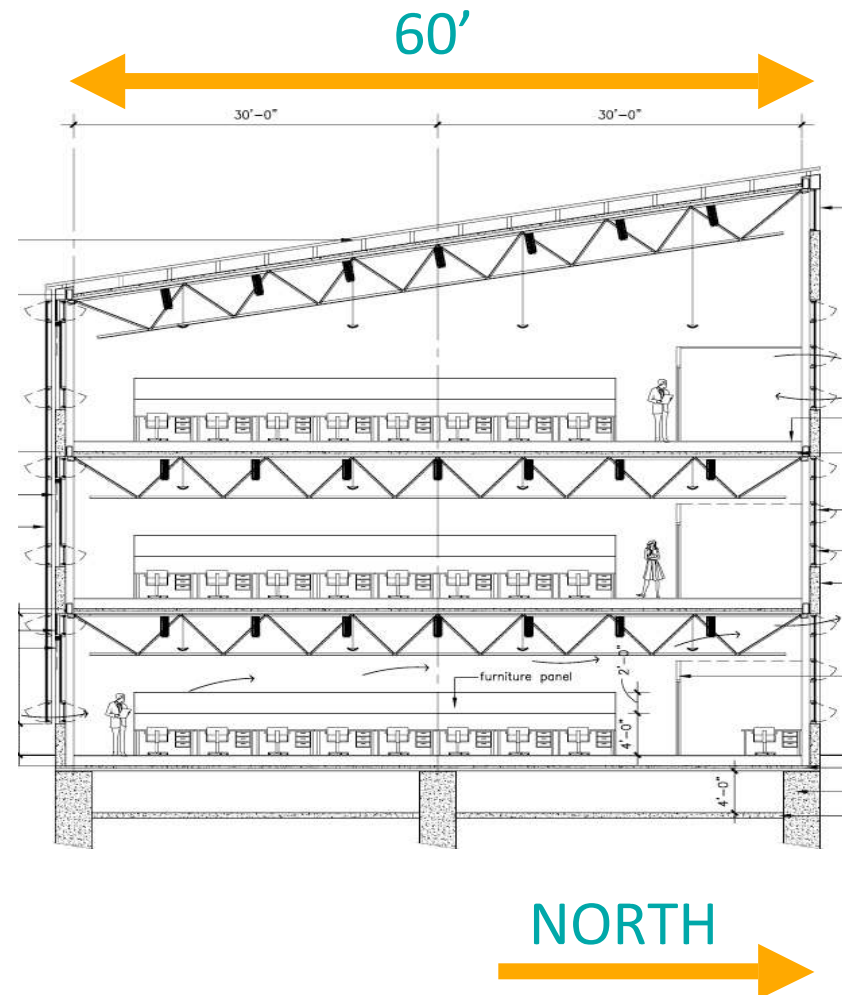


Image Used by Permission of RNL Design

# Design Response – Competition Phase

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- 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

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- 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



Image Used by Permission of RNL  
Design



NREL/PIX 16902

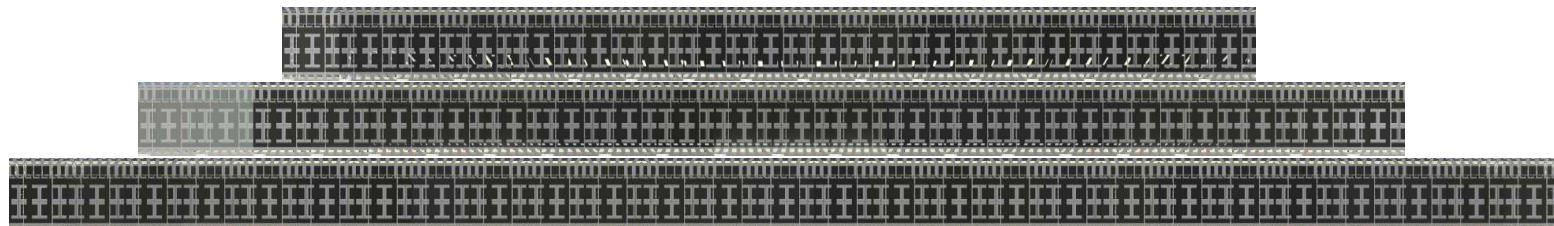
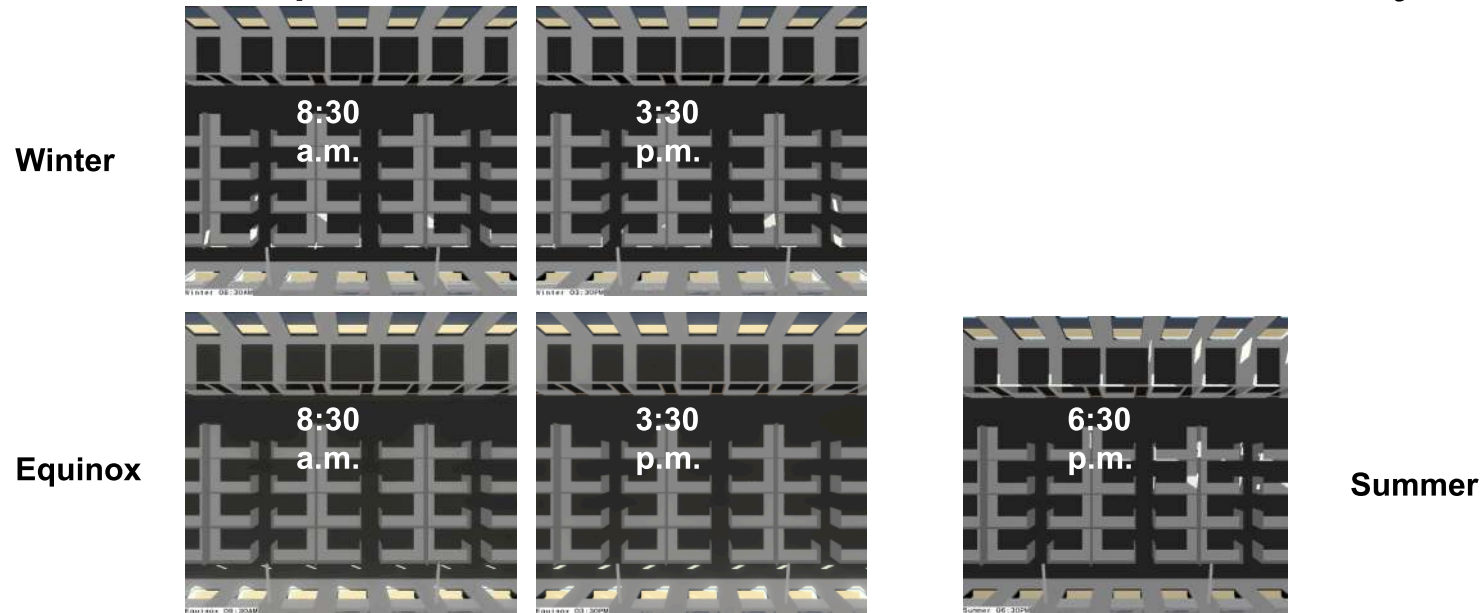
# Design Development

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- Confirmation of design
  - Overhangs blocking direct sun?
  - Adequate daylight throughout year?
  - Satisfy LEED iEQ8.1 requirement?
    - 25FC, 75% task area,  
Equinox/noon/clear sky (LEED 2.2)
- Inform lighting control zones
- Estimate lighting control response for energy analysis
- Qualitative evaluation
  - Several space types

# Design Development

- Annual overhang performance
  - Minimal direct sun on desks
  - Scripted time series animations, viewed key stills

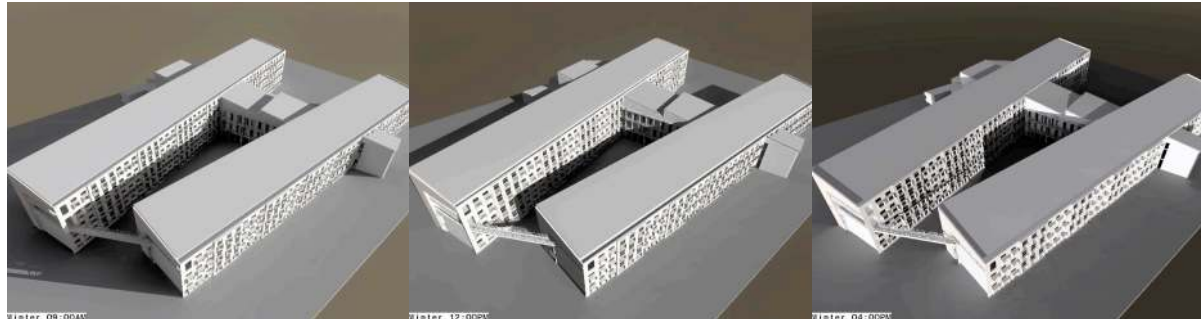


Images from R. Guglielmetti

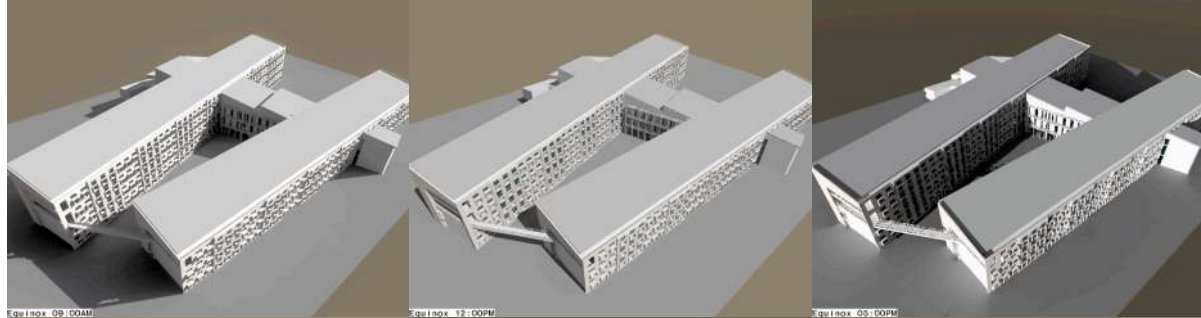
Time Series

# Design Development

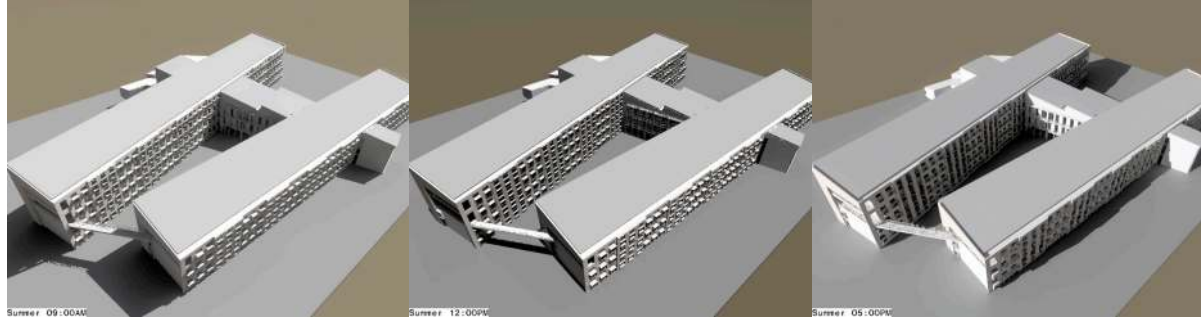
Winter



Equinox



Summer



9:00 a.m.

12:00 p.m.

5:00 p.m.

Shading Study

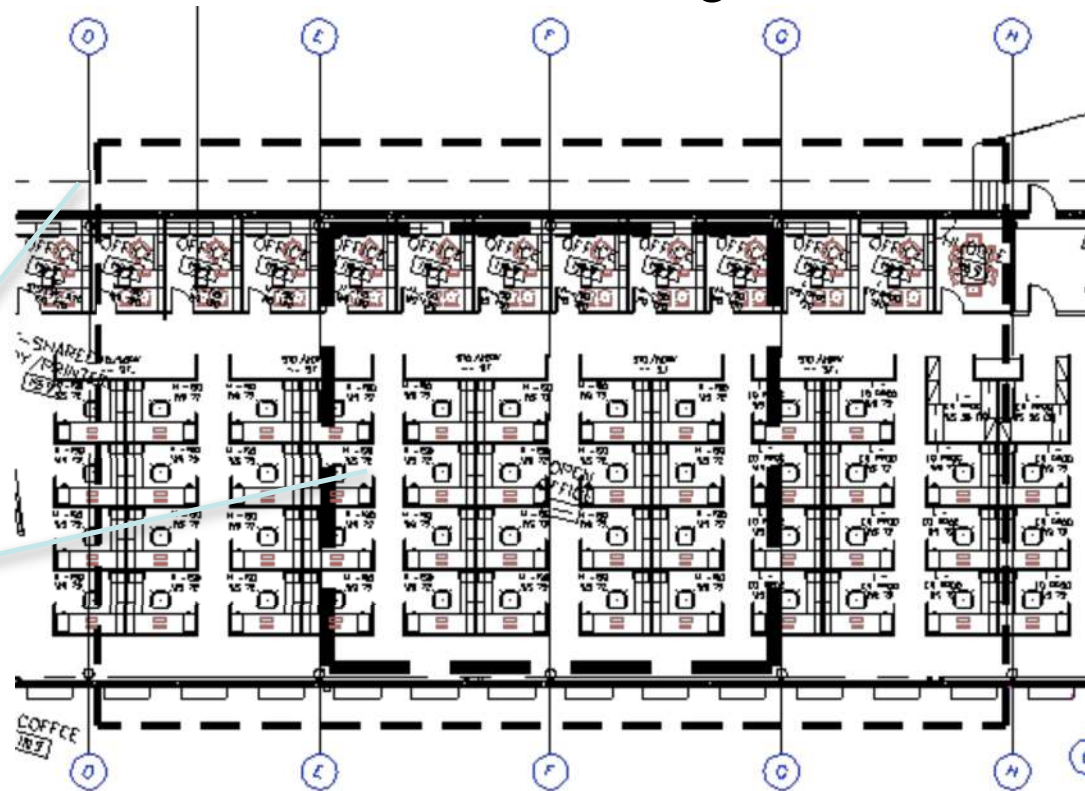
Images from R. Guglielmetti

# Design Development

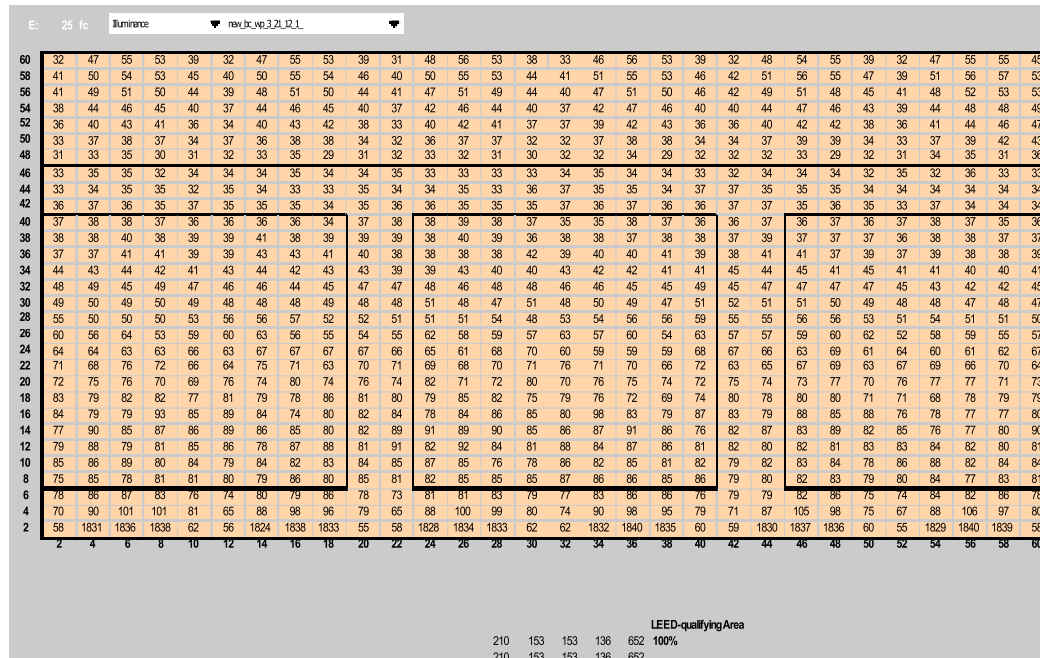
- Main wings – interior analysis
  - Created detailed Radiance model
  - Used .ies photometric files to model Lightlouver performance

Model extents

Calc grid area



# Design Development



NORTH

SOUTH



LEED Analysis - Typical Floor

Images from R. Guglielmetti

# Design Development

E: 25 fc Luminaire rev:bc.tp.v6.3.2.0.1

60	41	58	66	64	49	42	58	66	64	48	41	57	64	64	47	39	57	65	64	49	41	58	66	64	50	40	57	65	65	55
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LEED-qualifying Area  
210 153 153 136 652 1  
210 153 153 136 652

NORTH

SOUTH



## LEED Analysis - Top Floor

Images from R. Guglielmetti

# Design Development

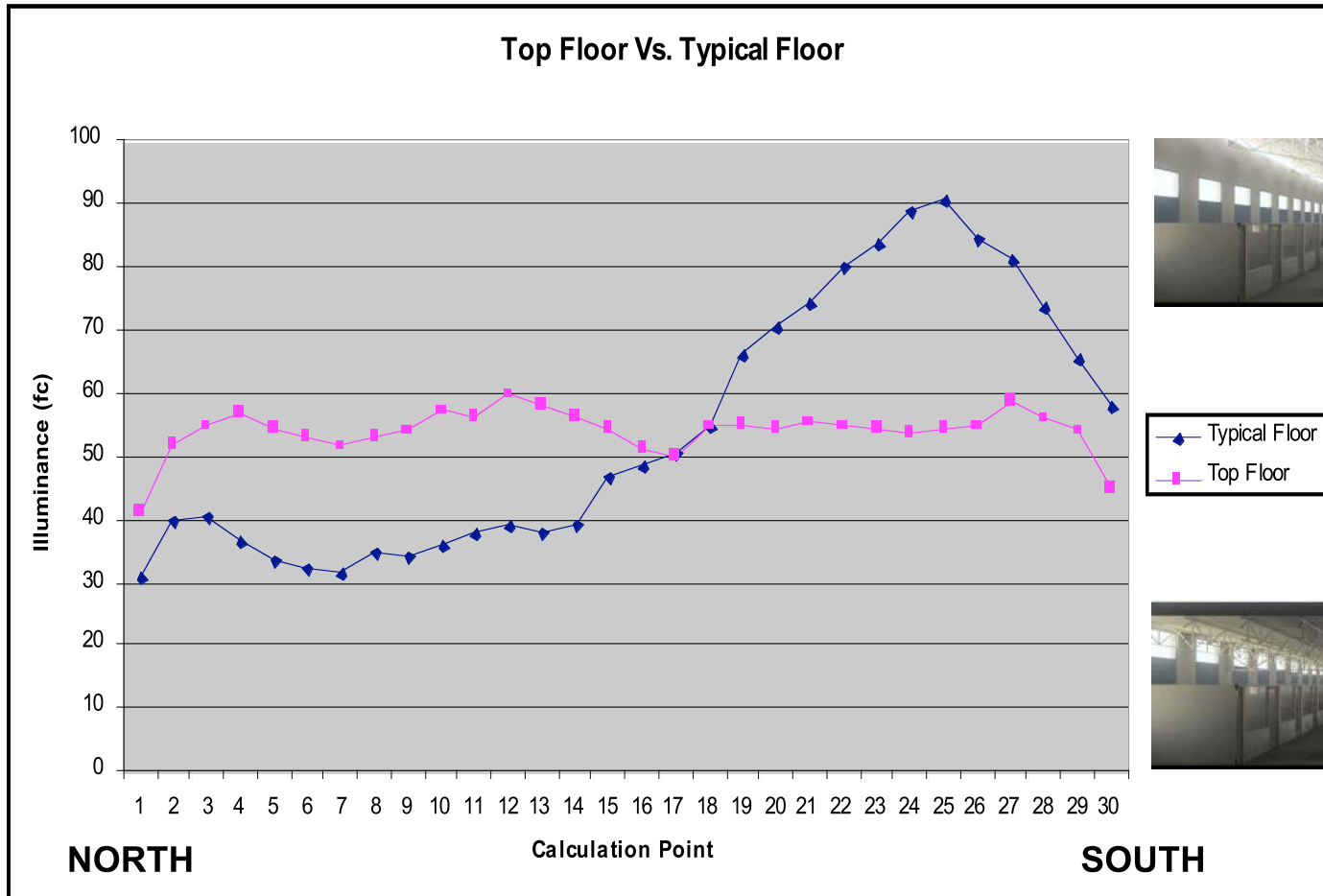
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**Top vs. Typical Floor Illuminance Distribution**

Images from R. Guglielmetti

# Design Development



**Top vs. Typical Floor Illuminance Distribution**

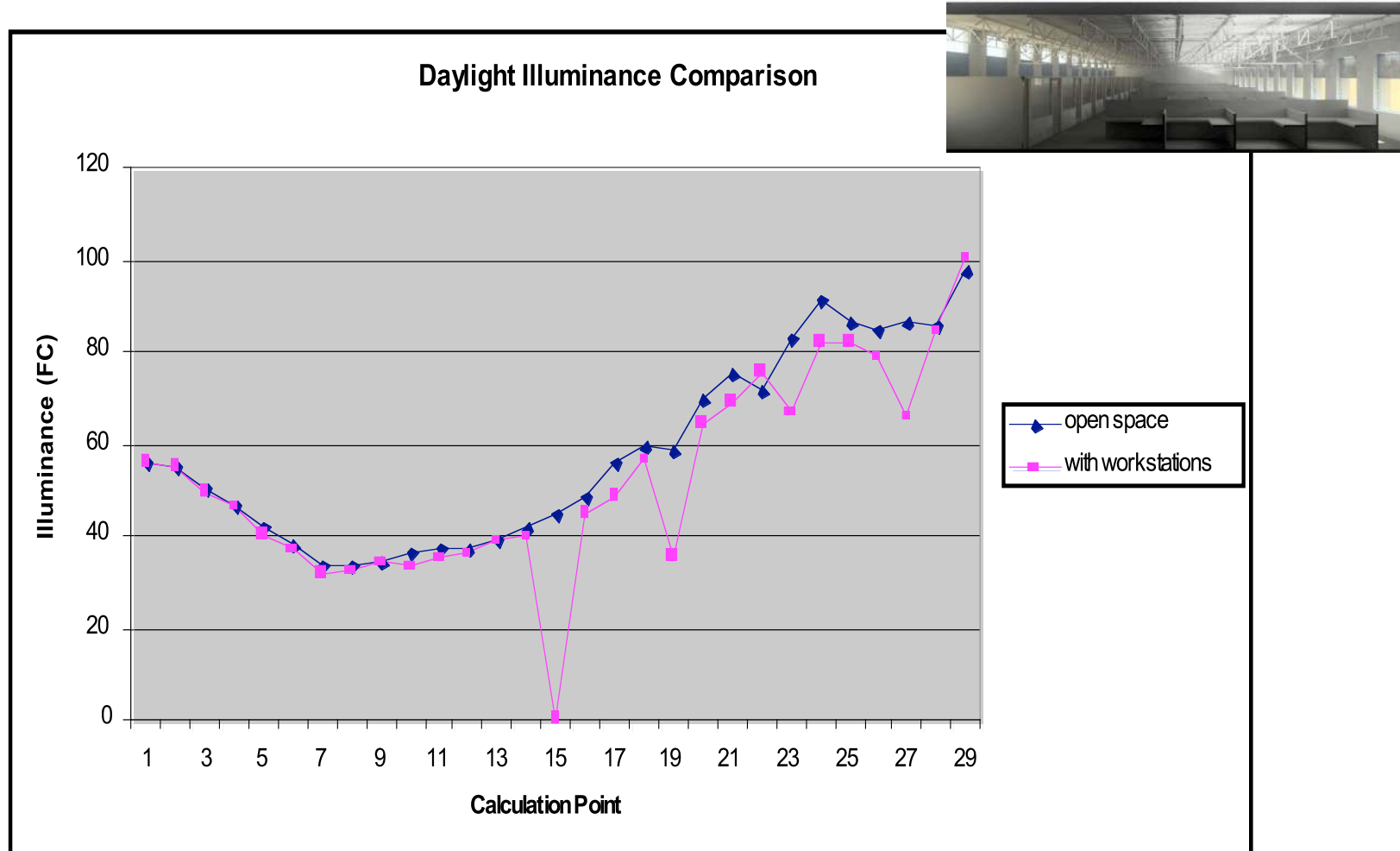
# Design Development

## LEED Analysis vs. Actual Space Conditions

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# Design Development

## LEED Analysis (no furniture) vs. Actual Space Conditions



# Design Development

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## Integrated Analysis

**“What about the Energy Use?”**

# Design Development

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- 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 (CBDMM) workflows are the next frontier for this work

# Design Development

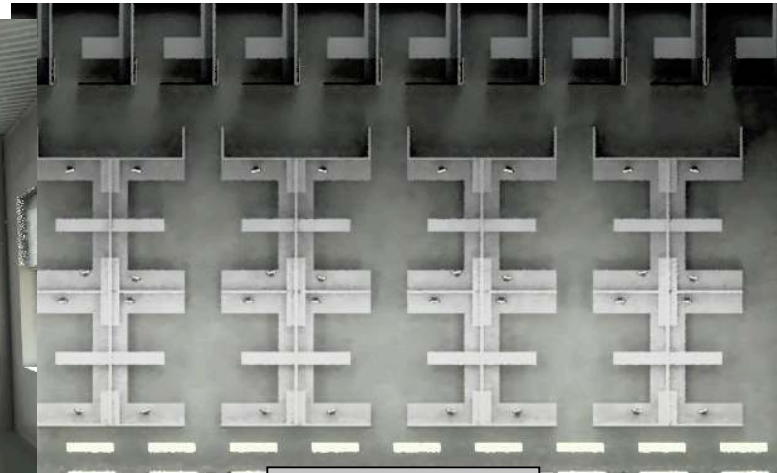
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For the RSF calculations:

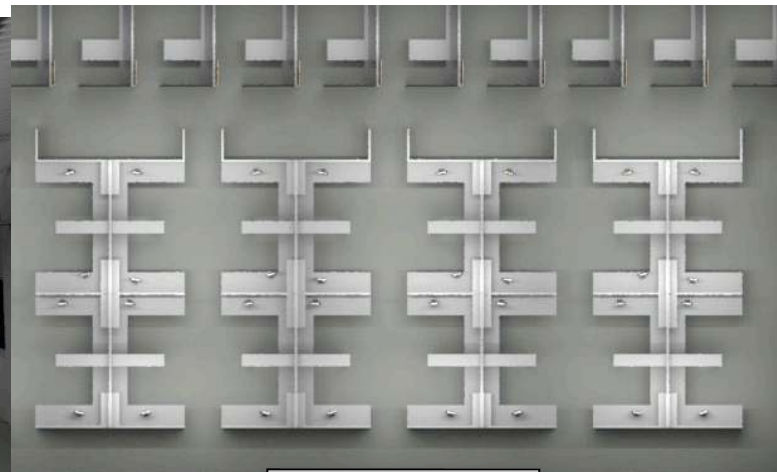
- Lightlouver geometry was explicitly modeled in Radiance
- Radiance's light backwards raytracing was used (no mkillum, no photon map)
- Cranked up the rendering parameters, waited a long time, and STILL assumed there was a significant underestimation of the daylight contribution
- Used SPOT to perform 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

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Day

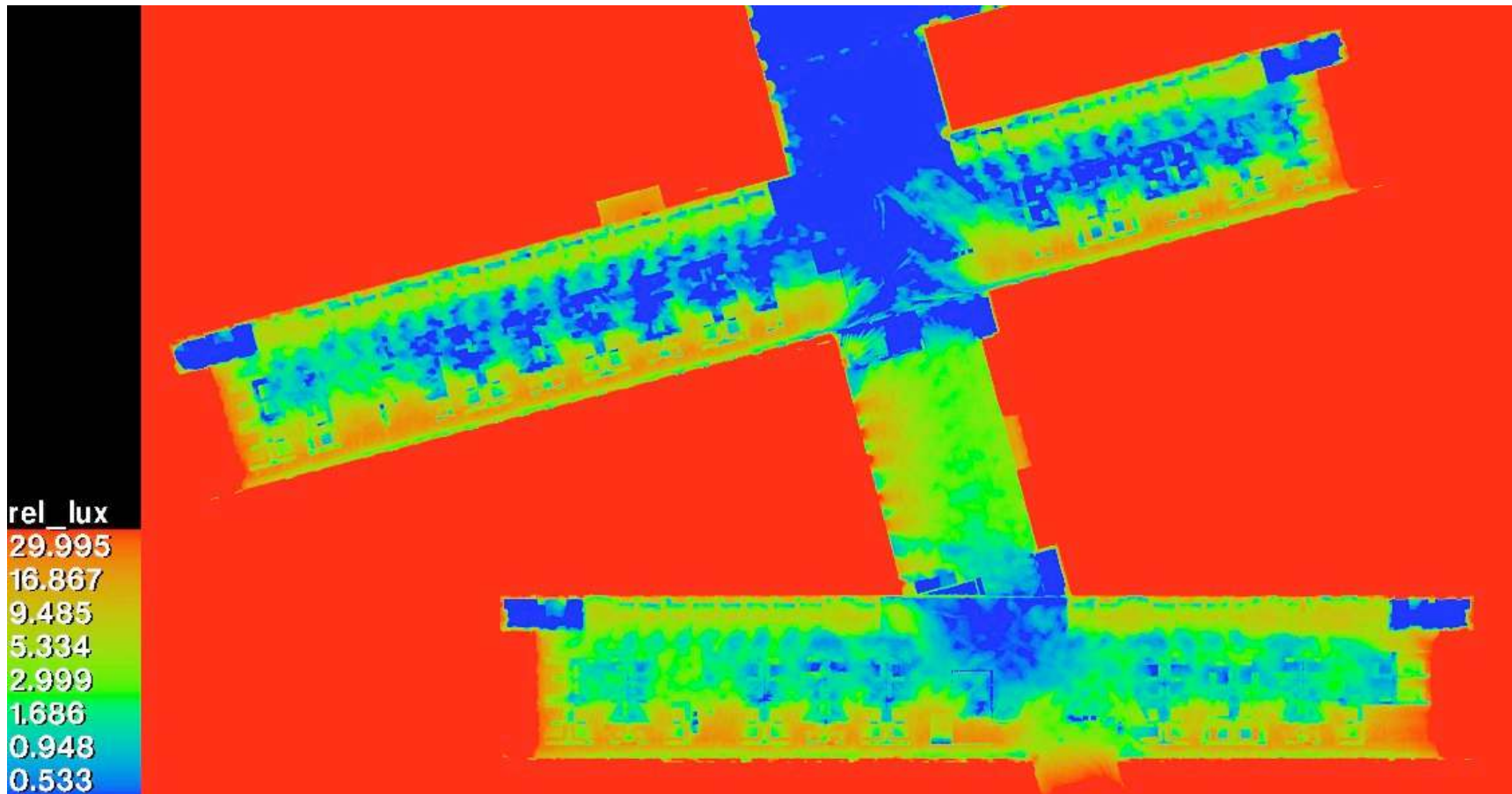


Night

Images from R. Guglielmetti

# Construction Documents

## Lighting Control Zones

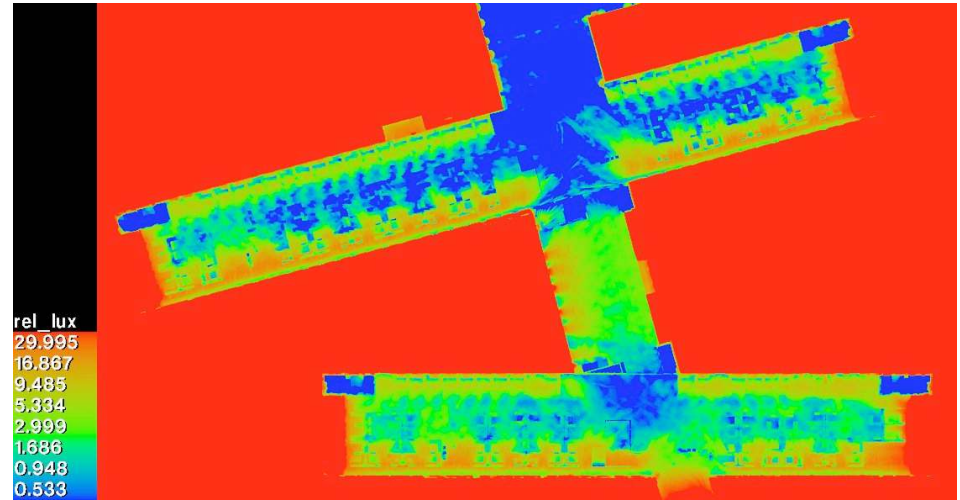


Annual Daylight Availability - Third Floor

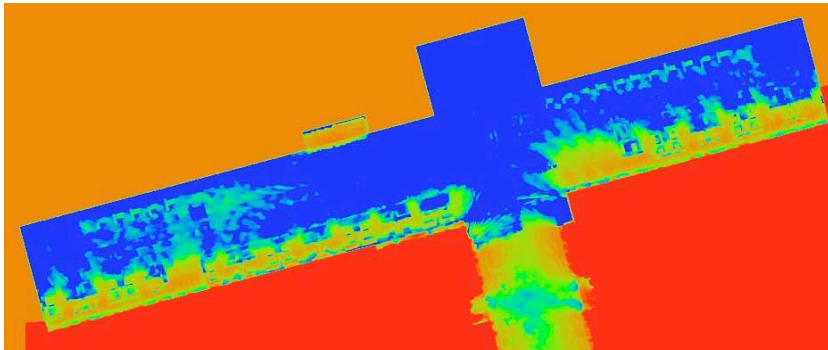
# Construction Documents

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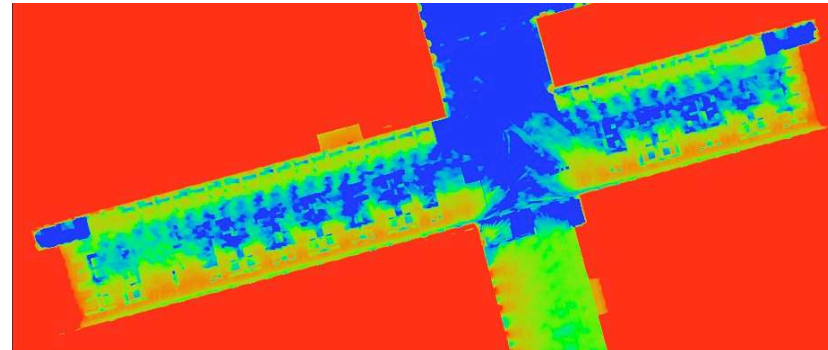
- Logical control zoning was determined through annual simulation
- Francesco Anselmo's "radmap" used for annual sky simulations
- Prevailing daylight availability dictated control zoning



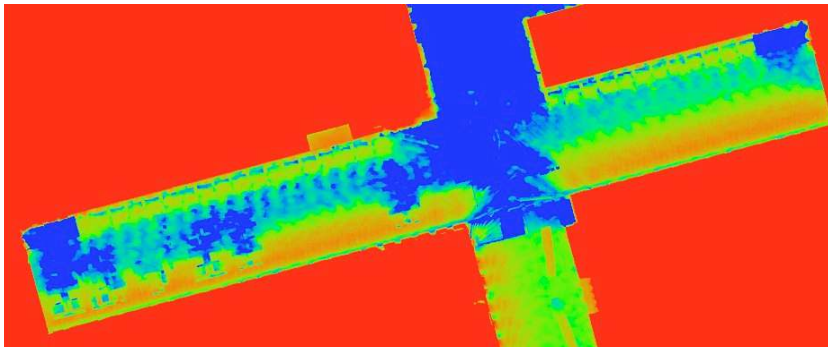
# Construction Documents



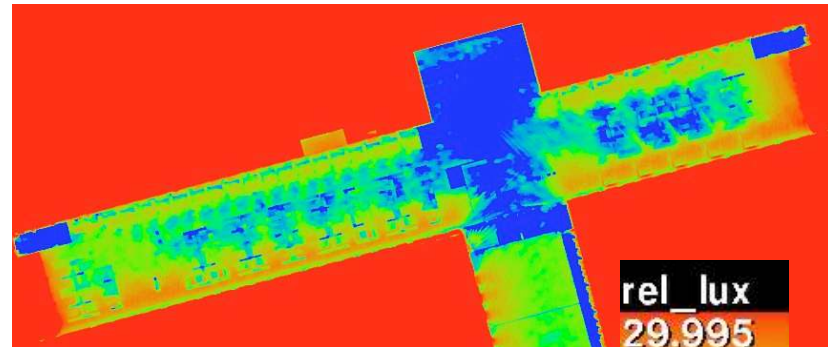
First Floor



Third Floor



Second Floor

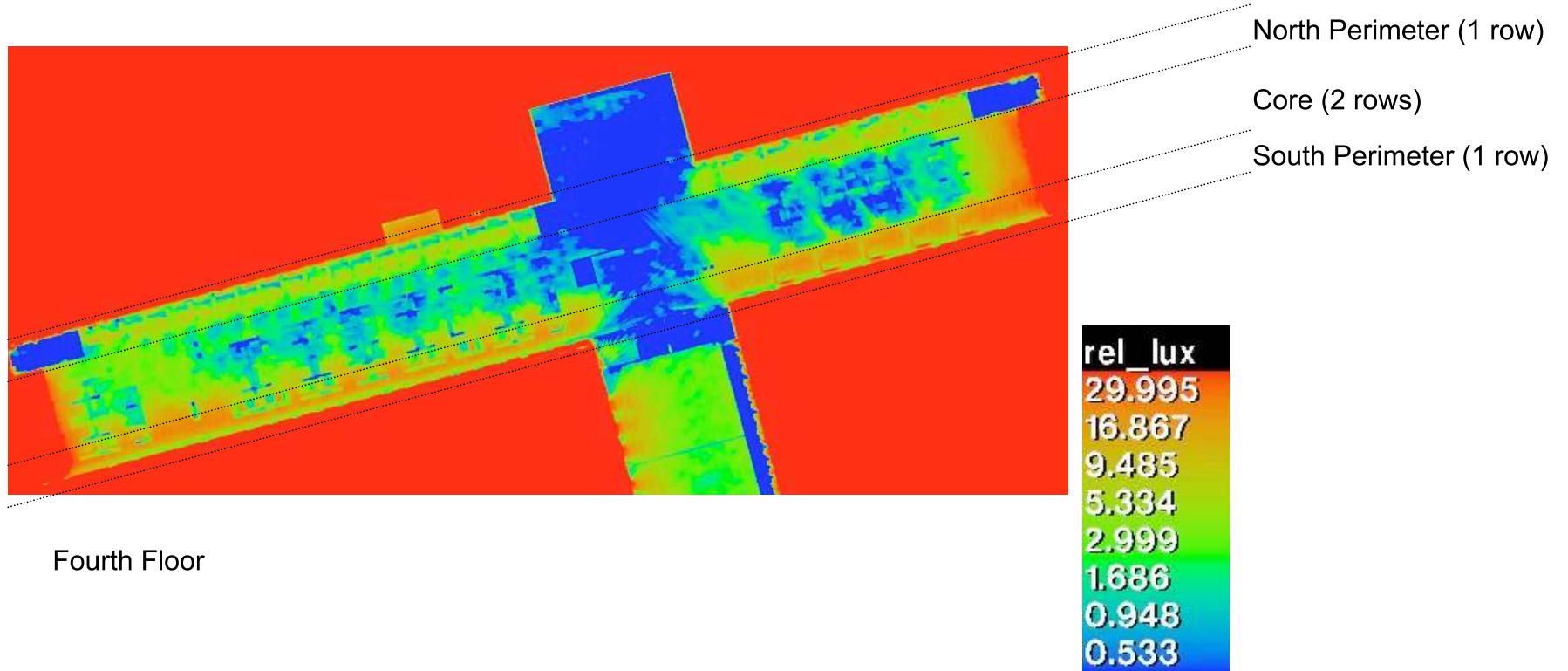


Fourth Floor



Annual Daylight Availability – North Wing

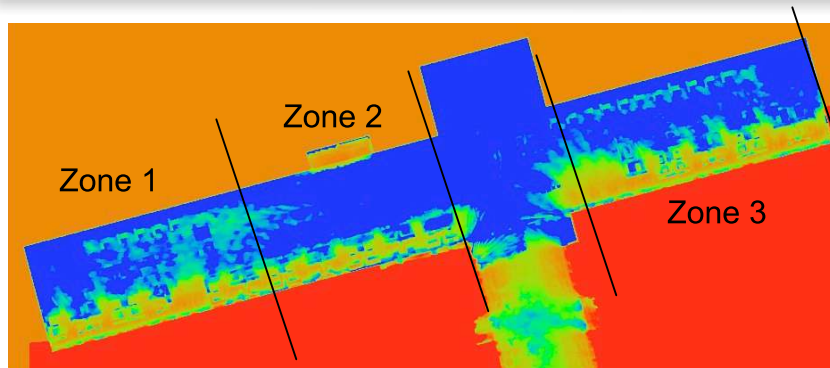
# Construction Documents



Annual Daylight Availability – North Wing

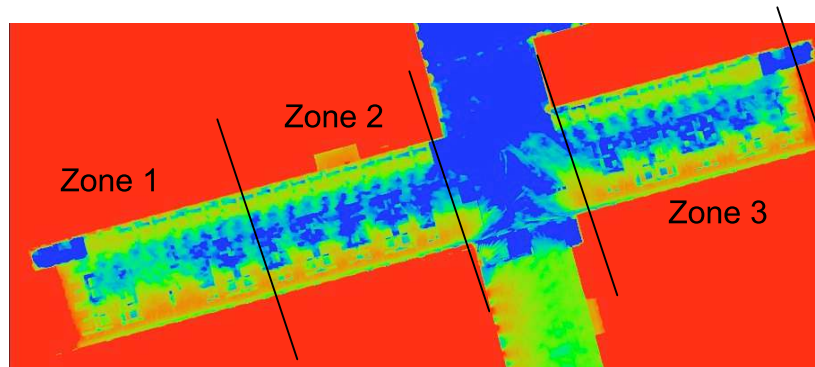
**Lighting Control Zones – North-South**

# Construction Documents



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

**Lighting Control Zones – East-West**

# Additional Visualizations

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## Desk Placement Glare Issue

- Repositioned Reception Desk



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



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

# Additional Visualizations

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**2<sup>nd</sup> Floor Conference Room, Summer, 3:00 p.m.**

# Additional Visualizations

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**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**

# Comparison

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**Design Rendering**

Images from R. Guglielmetti

# Comparison

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**Construction Photo**

Images from R. Guglielmetti

# Comparison

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**Construction Photo?**

Images from R. Guglielmetti

# Summary

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- Simulation is Vital to NZEB Design
- Validation of Design, Building Performance
- “Virtual Commissioning” of Lighting Controls
- Need to Integrate Energy Model with Lighting Model
  - Current Disconnect Hurts Practice
  - Emerging Tools Will Make this Possible
- Need Better Metrics to Define “Good” Daylighting
- Simulation can Guide Design, Practice, Metrics

**Thank You**