Communicating the Qualitative and Quantitative in Museum Daylighting

Kristen N. Garibaldi

2017 INTERNATIONAL RADIANCE WORKSHOP
PORTLAND, OREGON
AUGUST 23, 2017

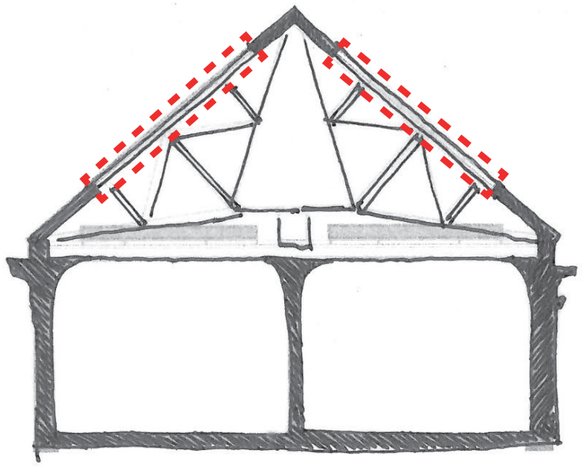
ARUP

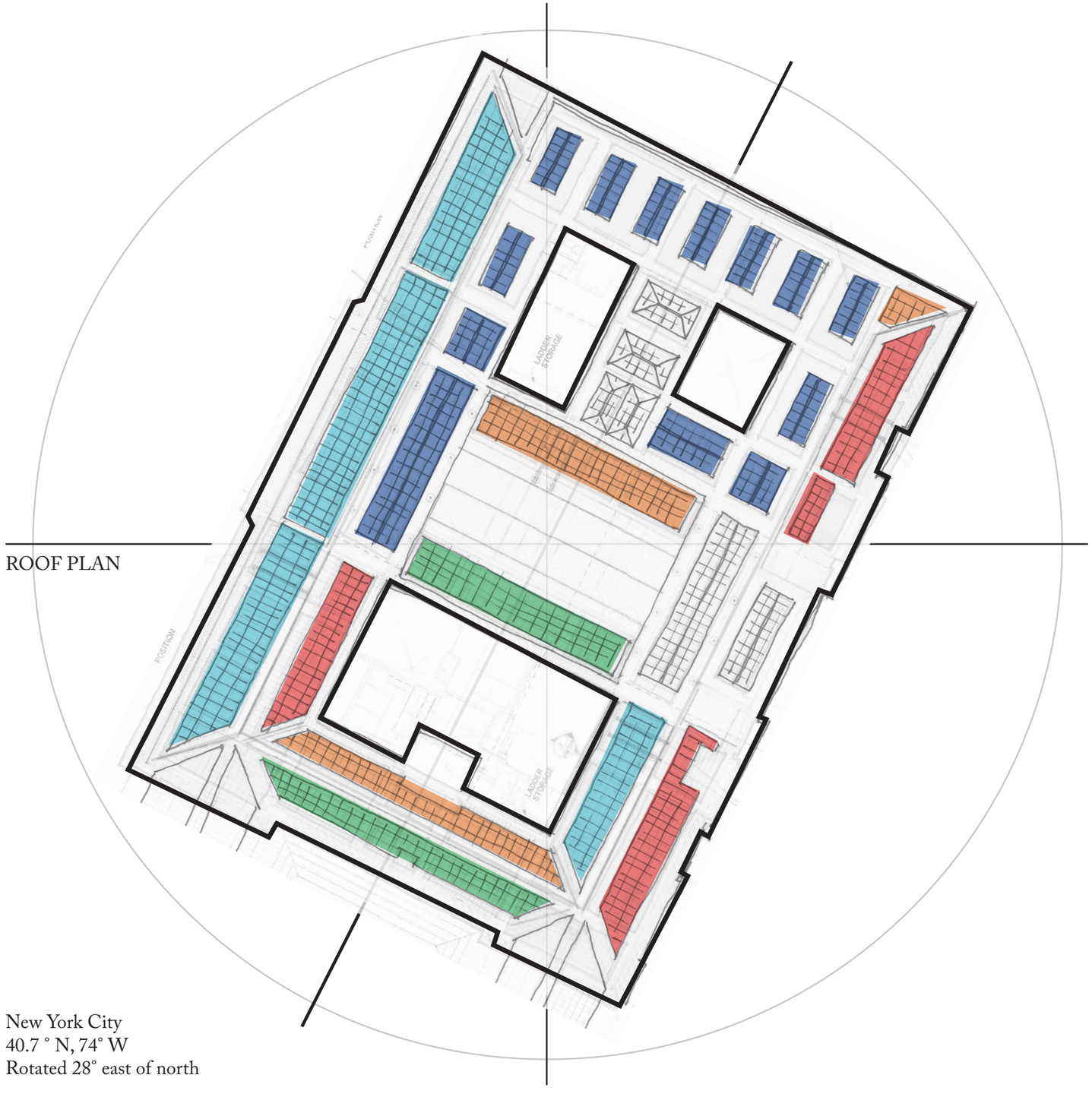
Project Scope

Skylight and laylight replacement
Daylight control
Electric lighting to remain

Existing Skylight System

- Northern Sloped Skylights
- Eastern Sloped Skylights
- Southern Sloped Skylights
- Western Sloped Skylights
- Pitched Skylight (Doghouse)

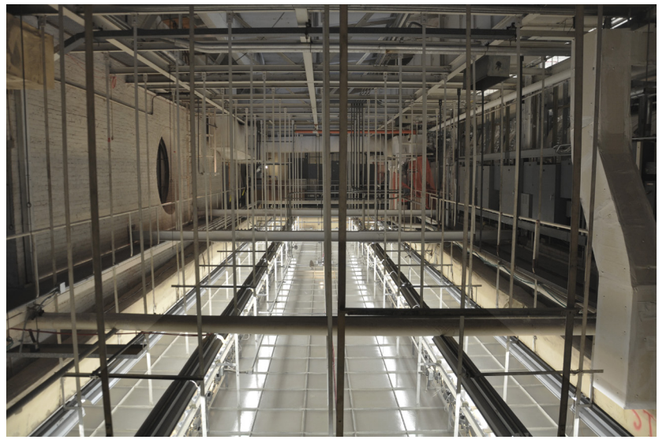


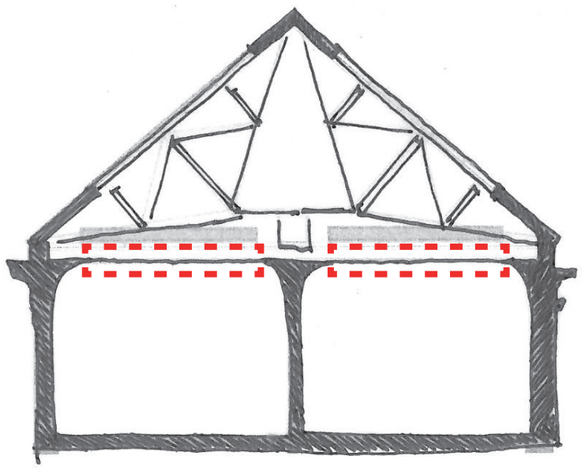


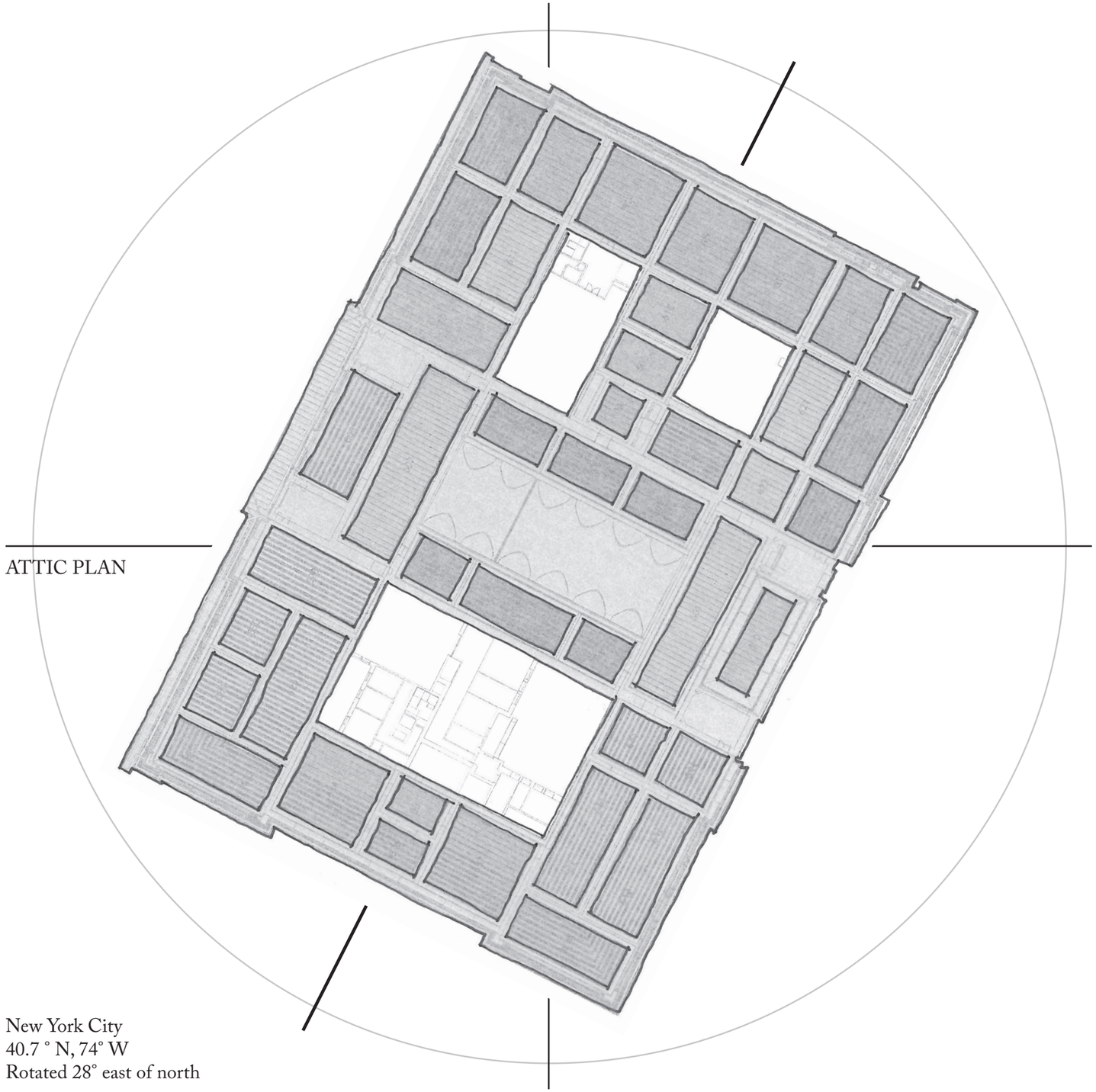
ROOF PLAN

New York City
40.7 ° N, 74° W
Rotated 28° east of north

Existing Laylight System



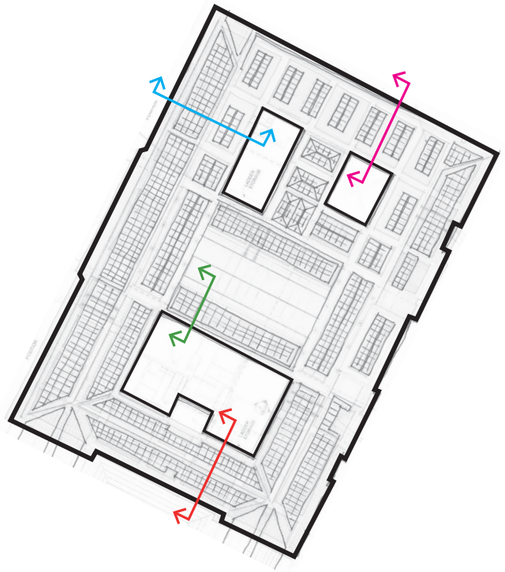


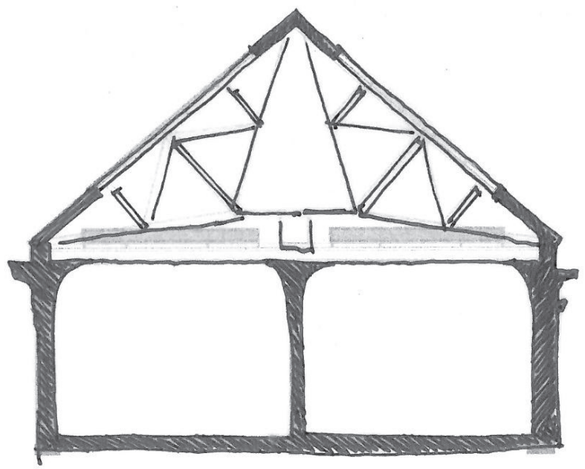


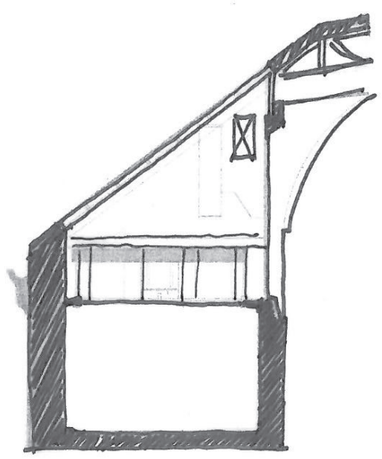
ATTIC PLAN

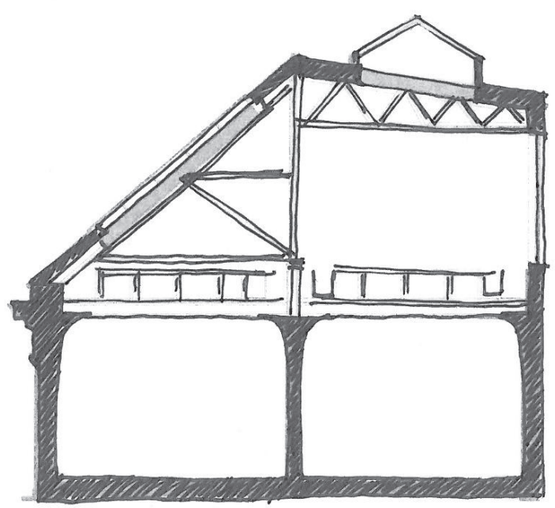
New York City
40.7 ° N, 74° W
Rotated 28° east of north

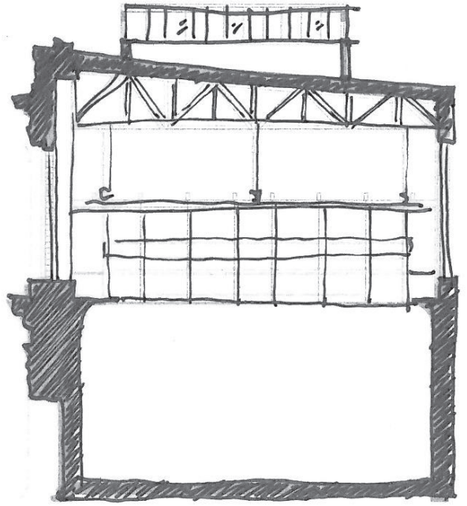
Various Assemblies

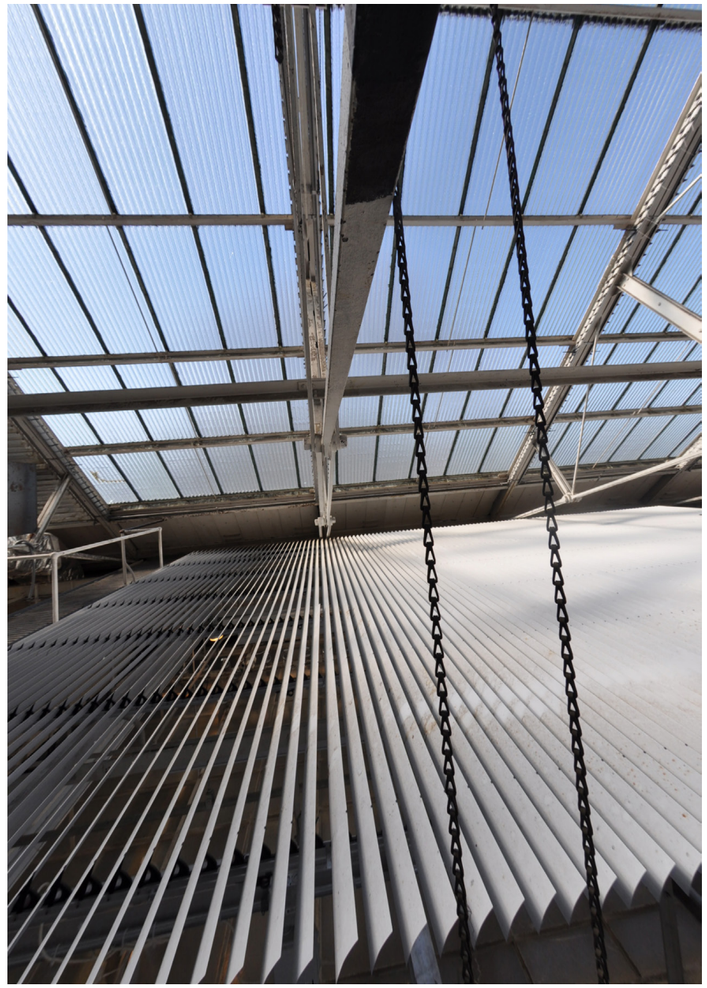








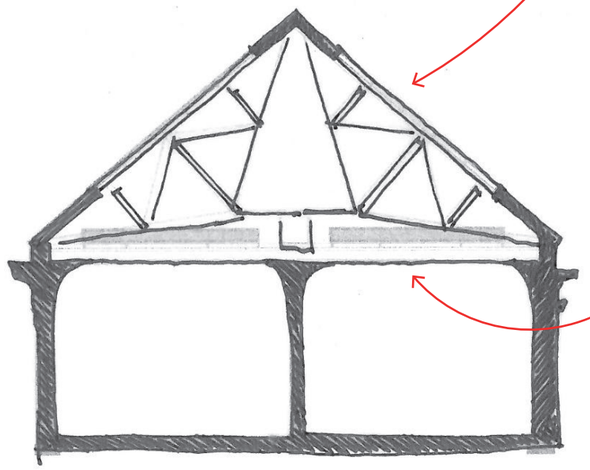


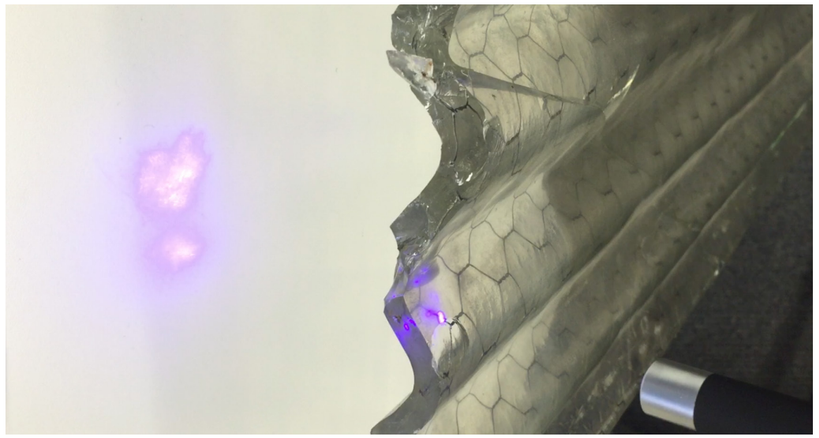


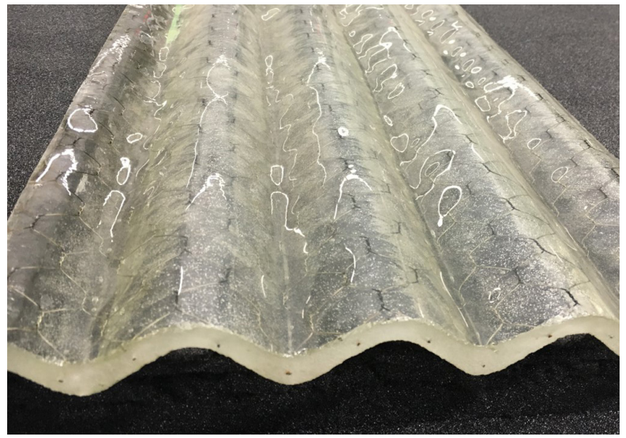
Material

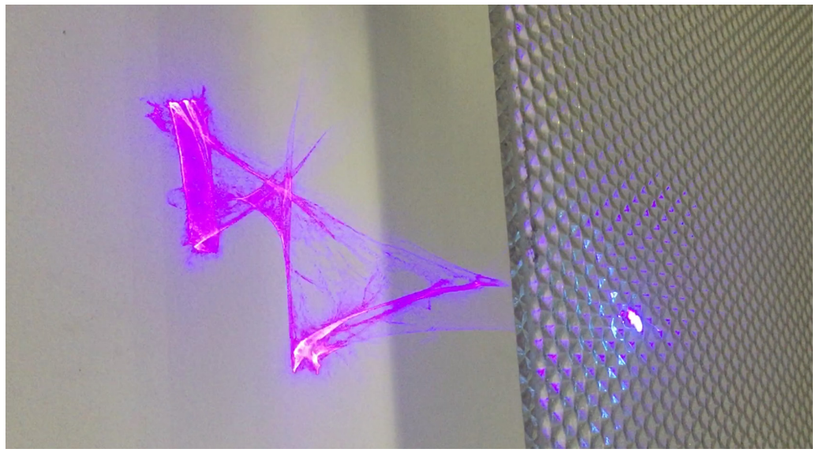
Skylights

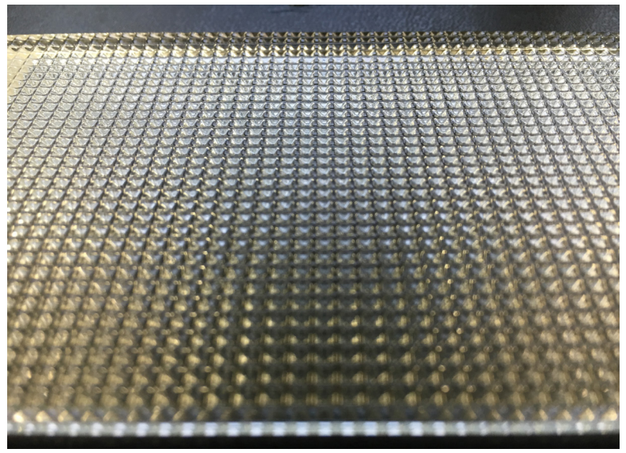
Laylights

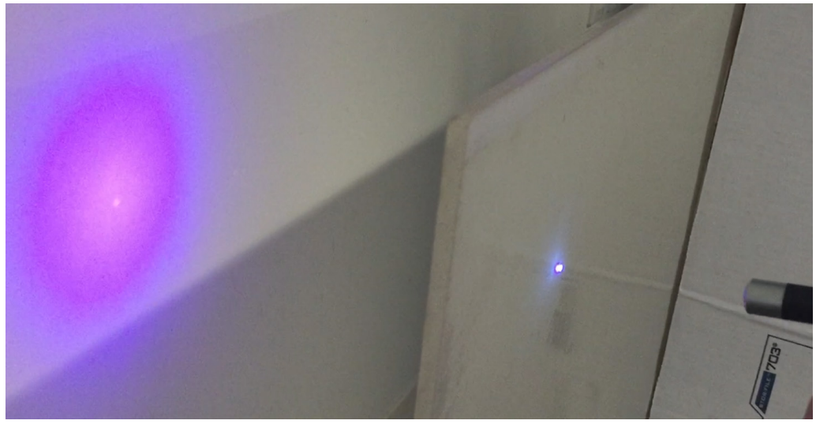


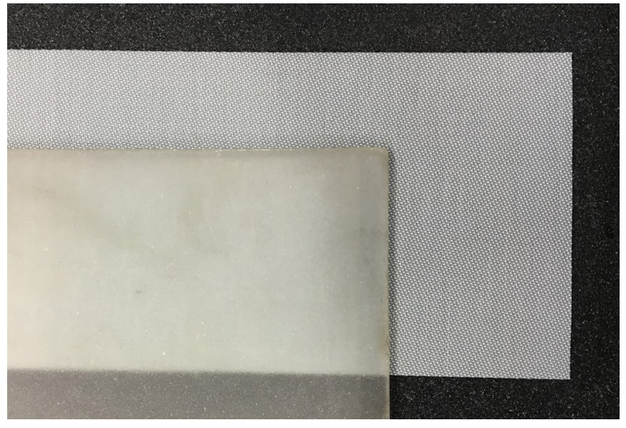












Existing Conditions Survey

LIGHTS ON

VIEW EAST

122 cd/m²

LIGHTS ON

VIEW NORTH

277 cd/m²

BRIGHTNESS
CD/m²

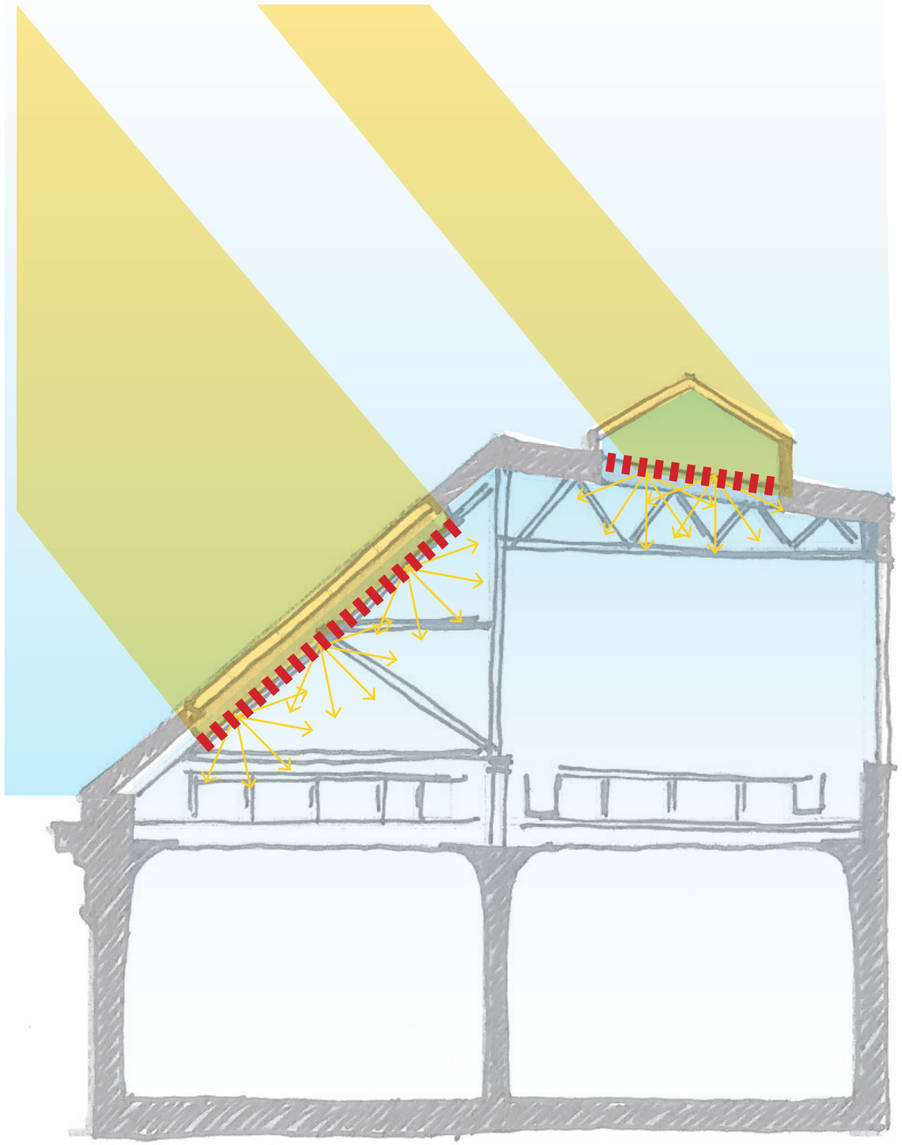
5000
1500
500
120
40
12
3
1

Design Priorities

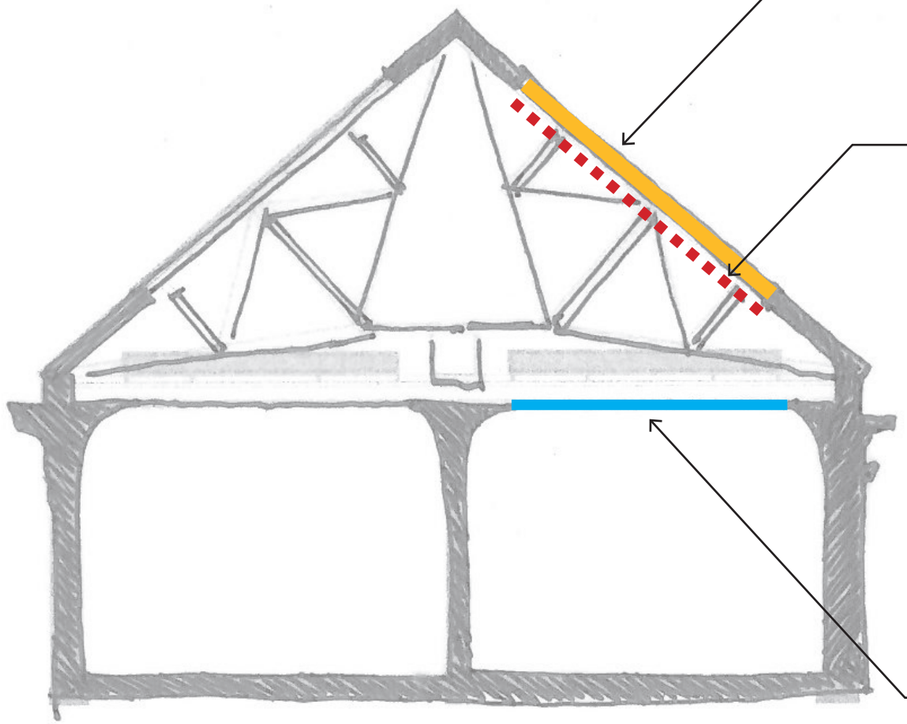
Curatorial
- Diurnal and Seasonal Variability
  - Perception of Movement/Animation
- High Uniformity
- Perception of spatial depth above laylights
  - Mitigate direct solar exposure onto laylight surface

Conservation
- Meet target conservation criteria
  - Annual Cumulative Exposure on the vertical surface
  - Instantaneous Exposure on the vertical surface

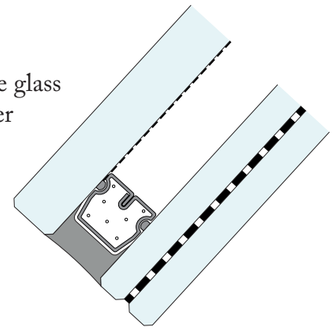
Maintenance
- Easy to maintain
- Cost-effective, Standard products
- Low operational requirements



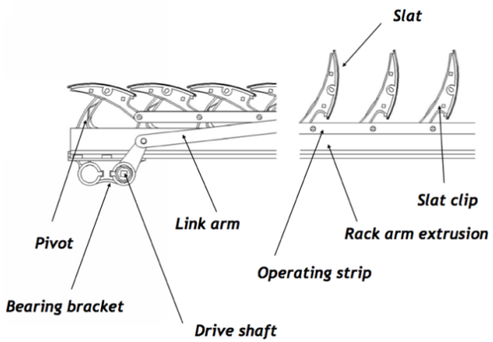
System Development



Skylight Glass
trans material for diffuse glass
Diffusing PVB interlayer



Louver
BSDF of louver system with varied rotations generated in WINDOW



Laylight Glass
trans material for diffuse glass
Diffusing PVB interlayer

Analysis Strategy

Curatorial
- Diurnal and Seasonal Variability
  - Perception of Movement/Animation
- High Uniformity
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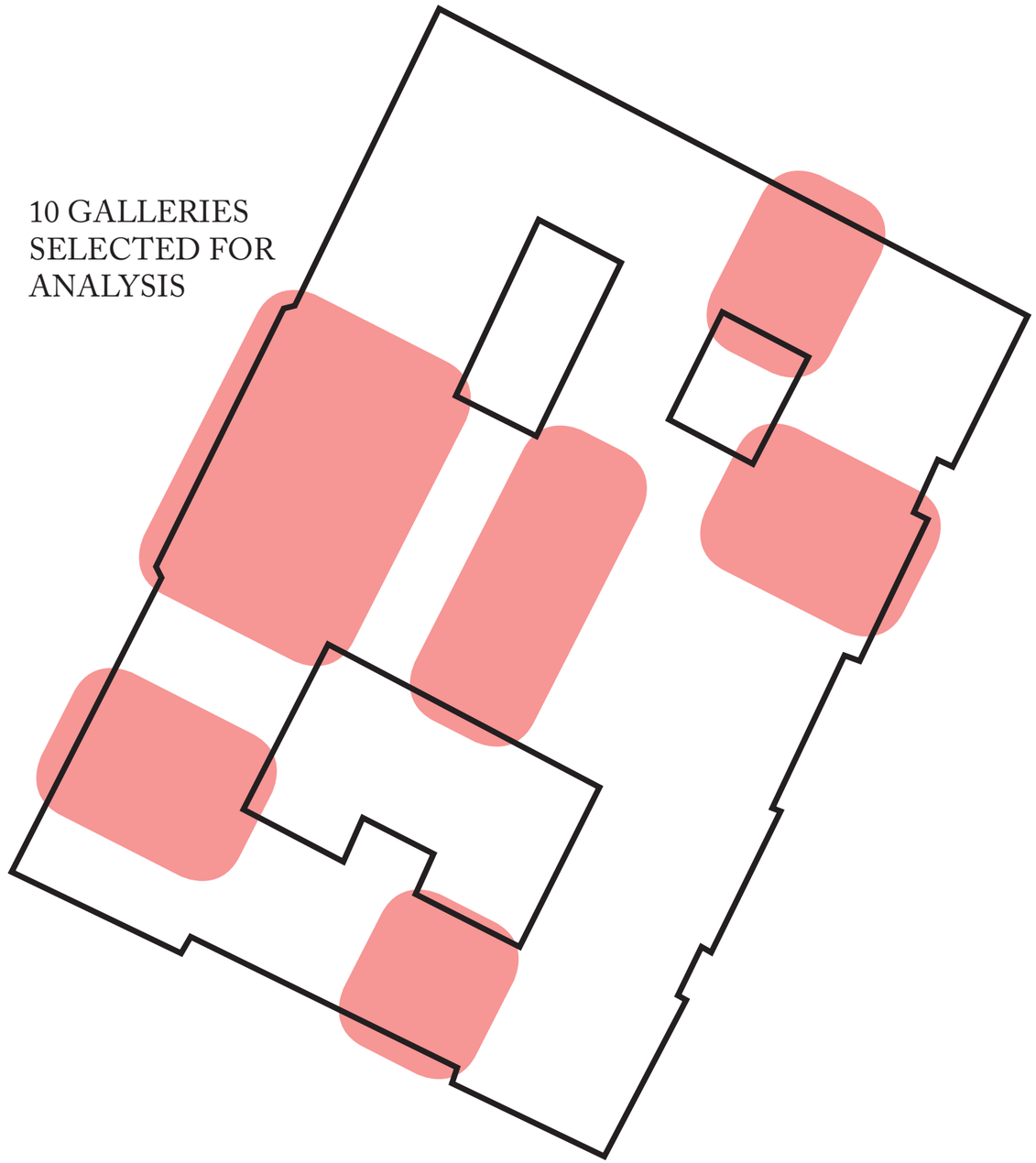
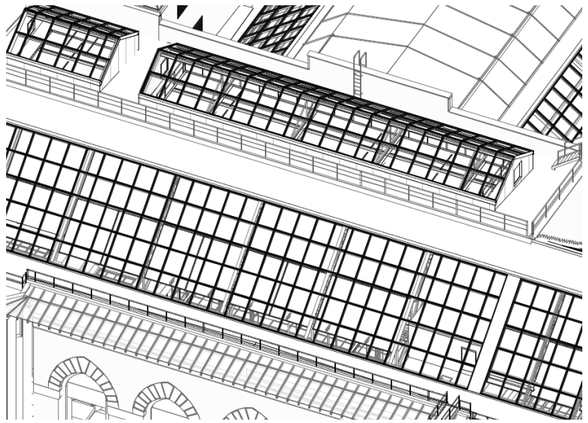
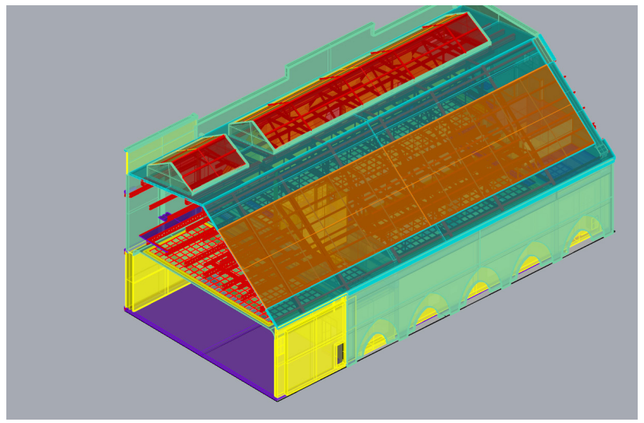


Workflow



ARCHITECTURAL REVIT MODEL



RHINO MODEL

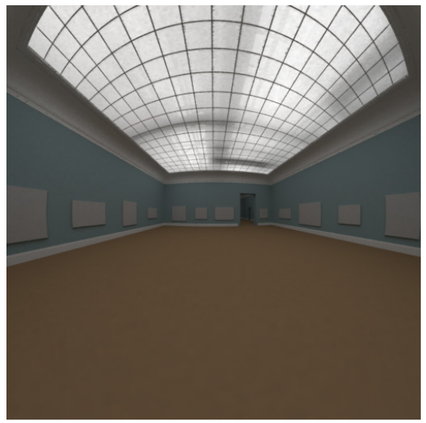
-BASE ARCHITECTURAL MODEL
(no glazing)

-SKYLIGHTS

-LAYLIGHTS

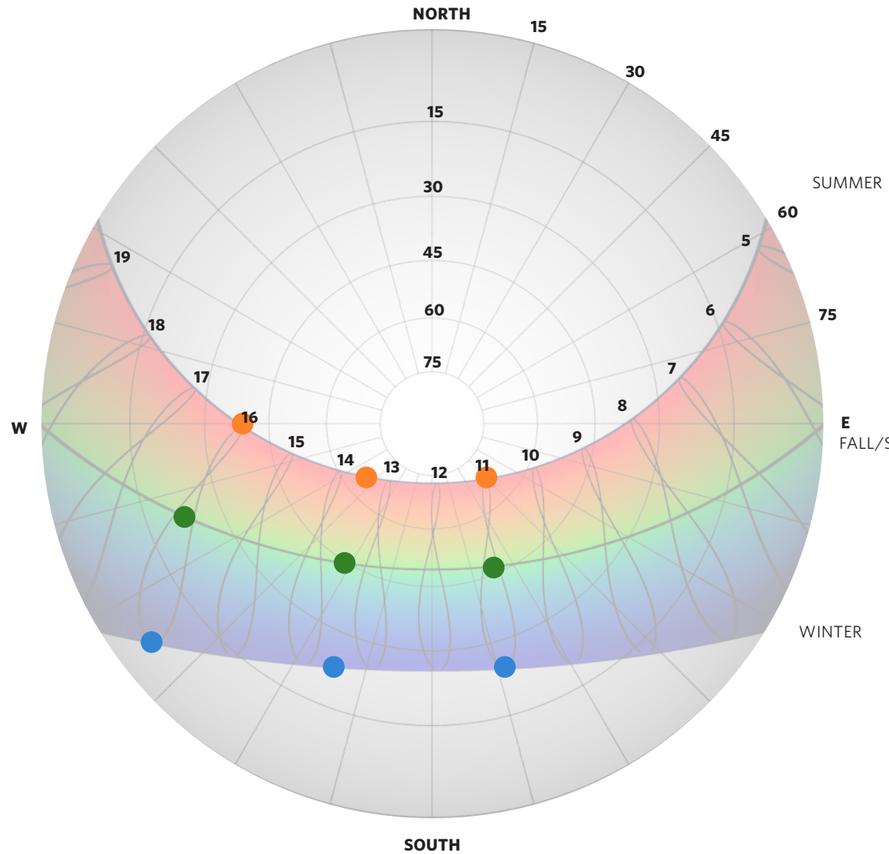
-LOUVERS

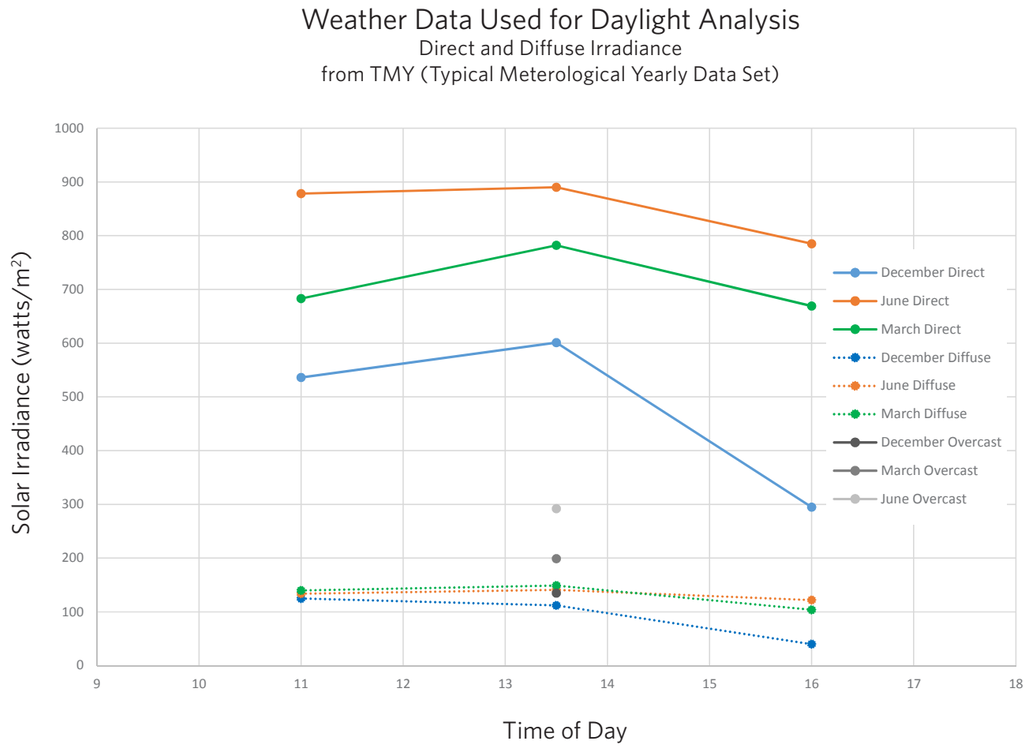
-MECHANICAL



RADIANCE SCENES

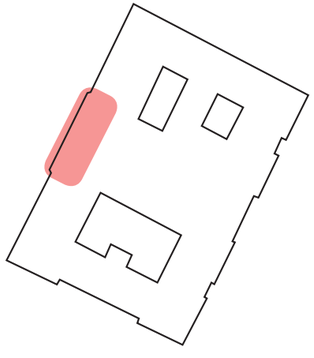
Analysis Conditions

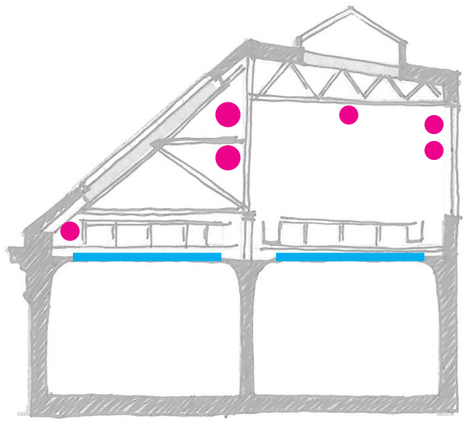




Selected weather data used for design conditions (above)

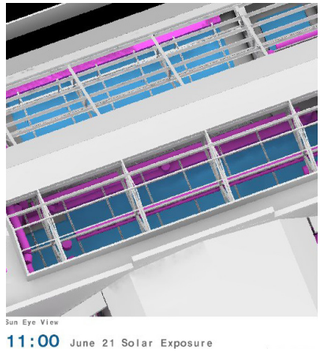
Daylight Access Studies





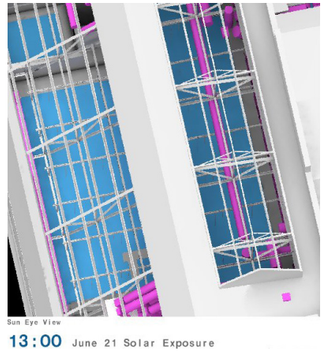
Sun Eye View

9:00 June 21 Solar Exposure



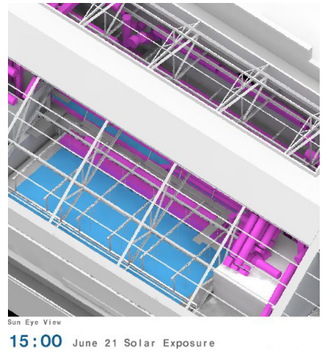
Sun Eye View

11:00 June 21 Solar Exposure



Sun Eye View

13:00 June 21 Solar Exposure

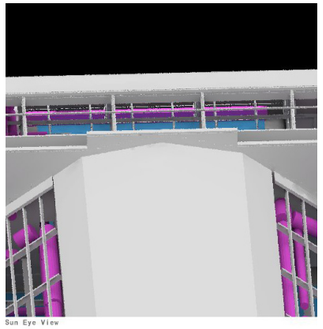


Sun Eye View

15:00 June 21 Solar Exposure

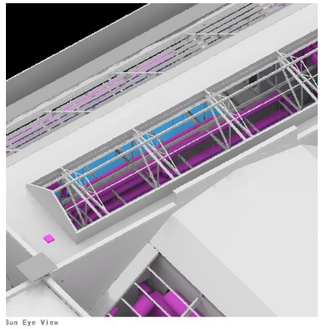
Sun Eye View

17:00 June 21 Solar Exposure



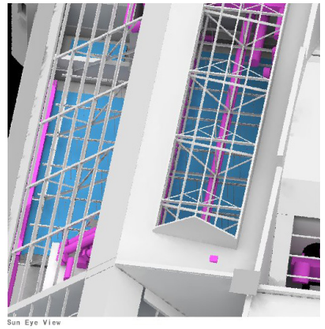
Sun Eye View

9:00 March 21 Solar Exposure



Sun Eye View

11:00 March 21 Solar Exposure



Sun Eye View

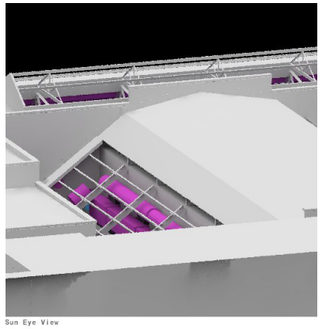
13:00 March 21 Solar Exposure

Sun Eye View

15:00 March 21 Solar Exposure

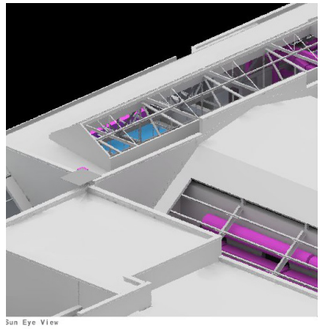
Sun Eye View

17:00 March 21 Solar Exposure



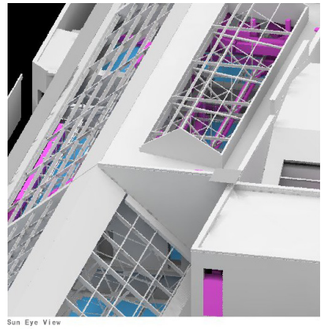
Sun Eye View

9:00 December 21 Solar Exposure



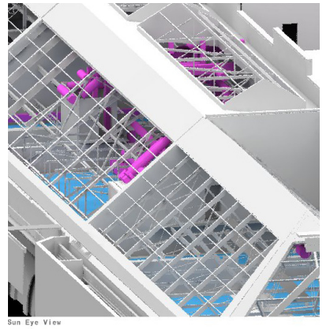
Sun Eye View

11:00 December 21 Solar Exposure



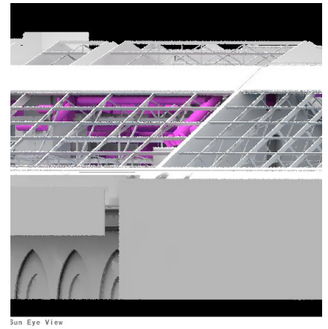
Sun Eye View

13:00 December 21 Solar Exposure



Sun Eye View

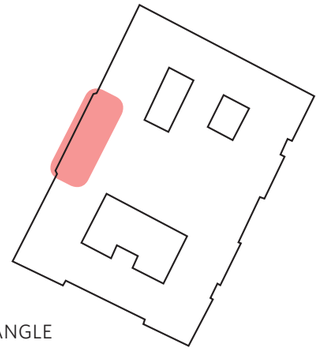
15:00 December 21 Solar Exposure



Sun Eye View

16:25 December 21 Solar Exposure

Daylight Access Studies



Summer Solstice

CRITICAL AZIMUTH ANGLE
108°

MAX DEGREE OPEN
30°

Equinox

CRITICAL AZIMUTH ANGLE
100°

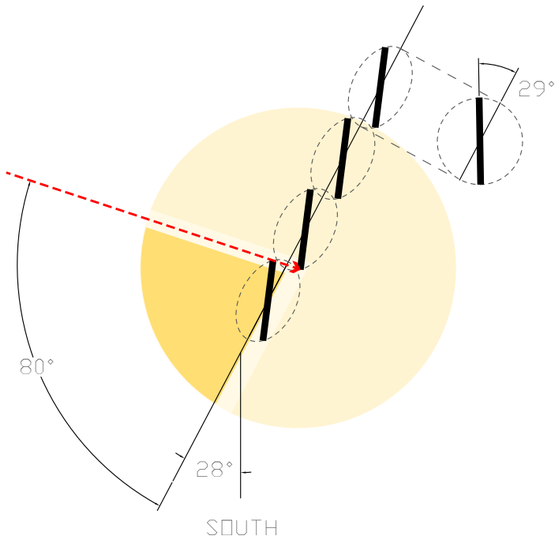
MAX DEGREE OPEN
35°

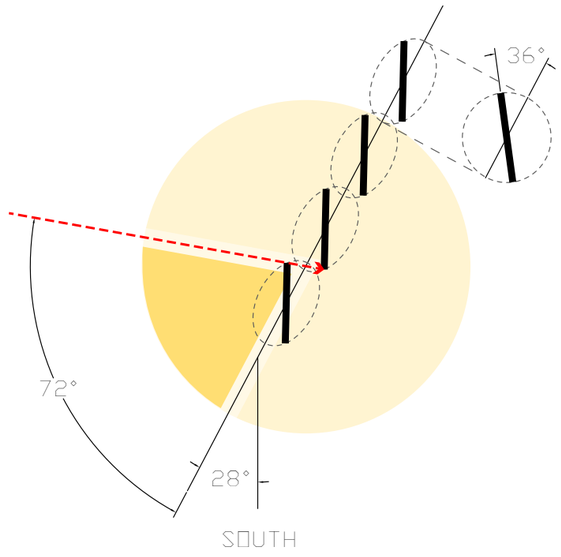
Winter Solstice

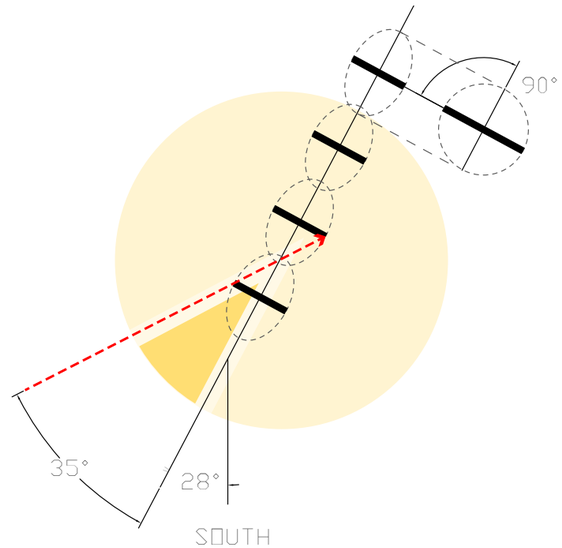
CRITICAL AZIMUTH ANGLE
53°

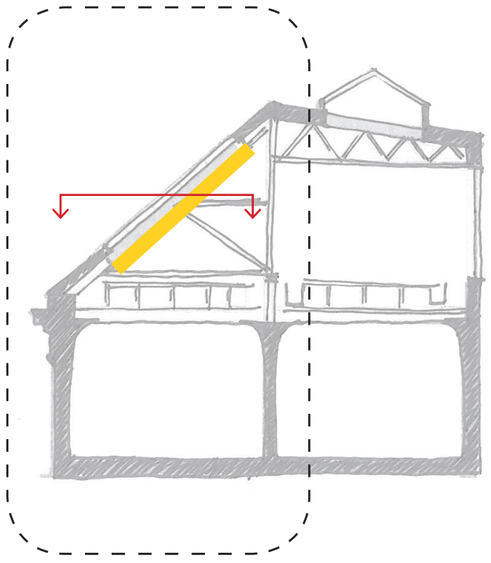
MAX DEGREE OPEN
90°

CRITICAL CUT-OFF GEOMETRY

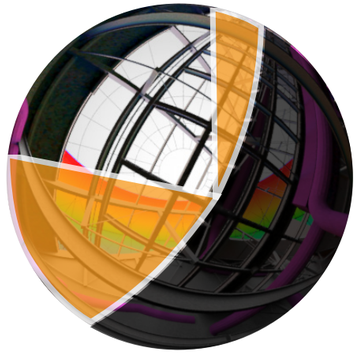


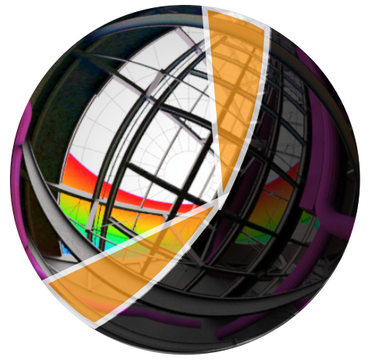




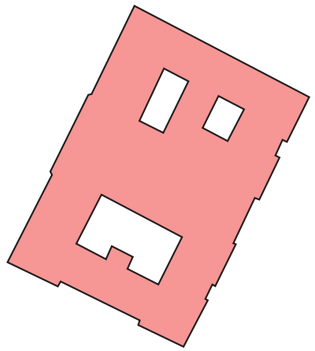


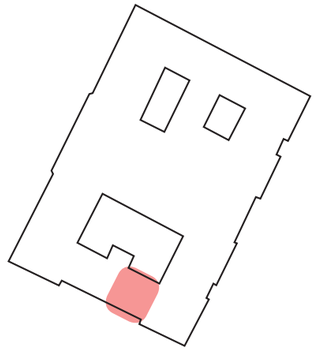
SUNPATH SHADING DIAGRAM

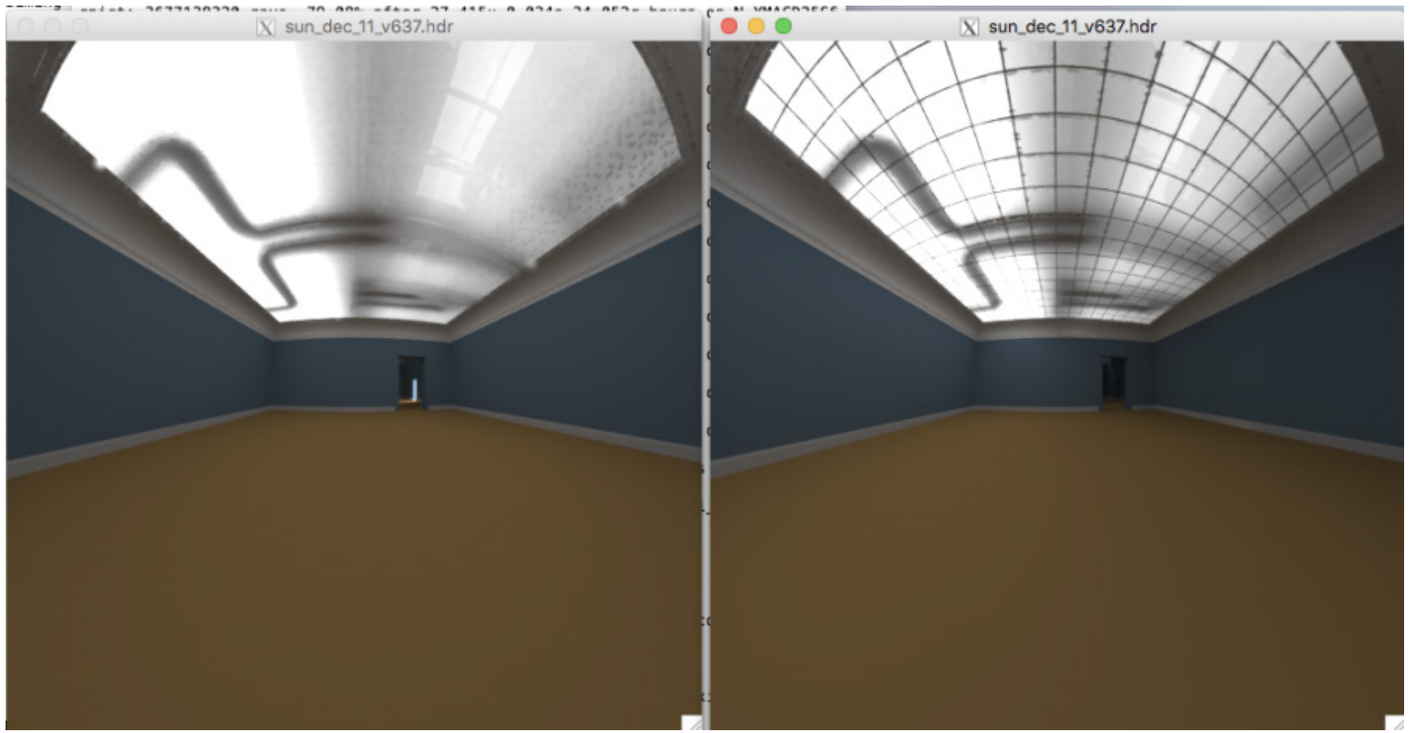




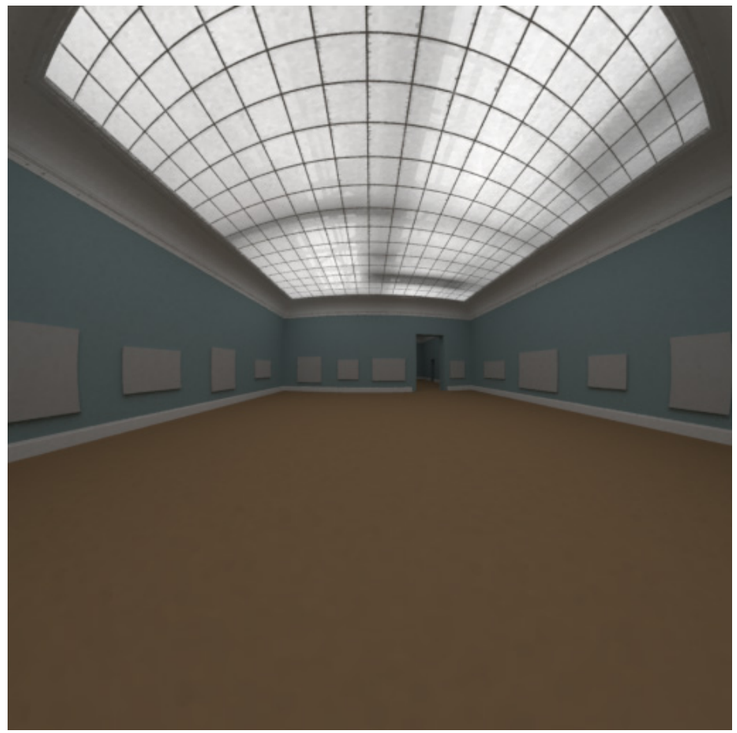
Interior Gallery Analysis







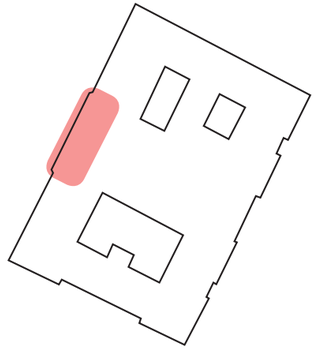
SINGLE MODEL - ALL ZONES AND GALLERIES



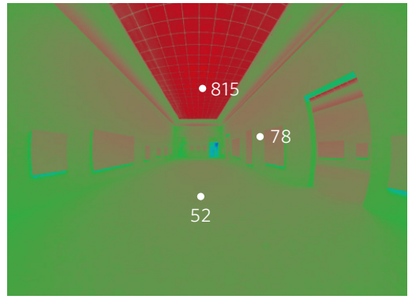
INDIVIDUAL MODEL FOR EACH ZONE

Calculated Luminance

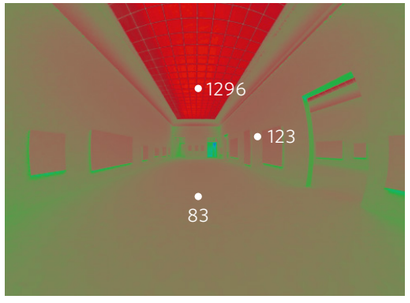
Louvers at 30 degrees OPEN



SUMMER SOLSTICE
JUNE 21



11 AM



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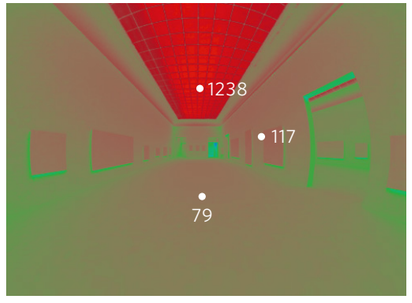

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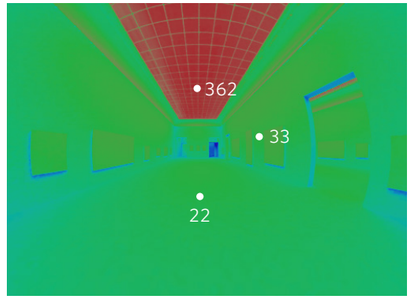
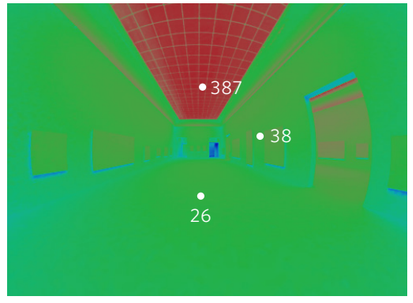


OVERCAST

EQUINOX
MARCH 21



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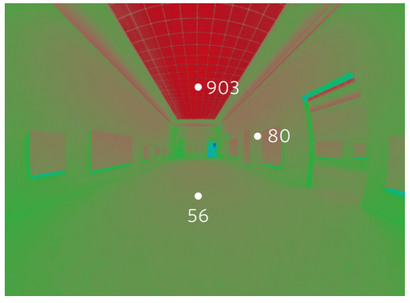

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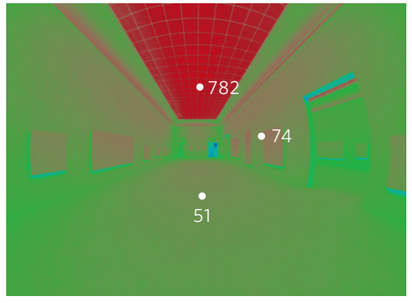

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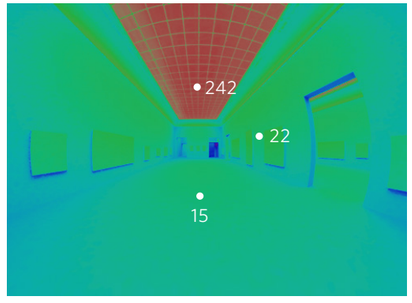
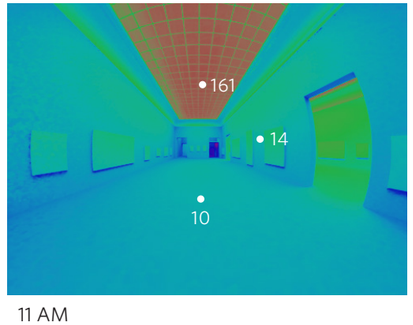


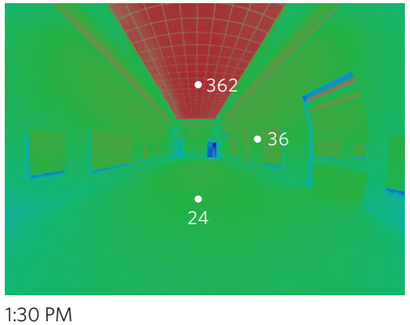
OVERCAST

WINTER SOLSTICE
DEC 21

CD/m²
5000
1500
500
120
40
12
3
1



11 AM



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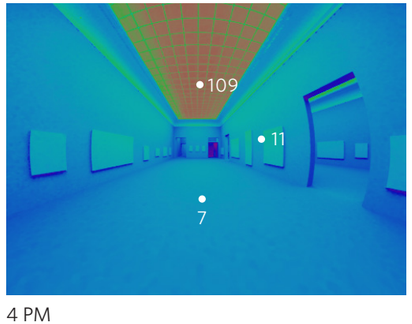

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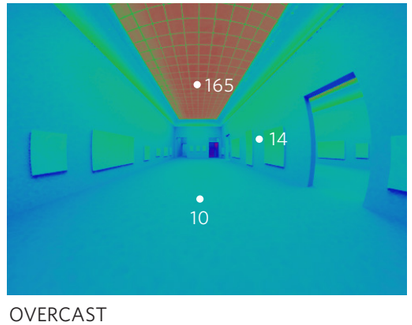
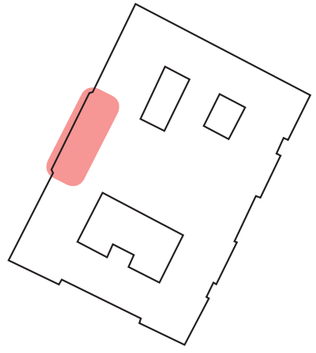


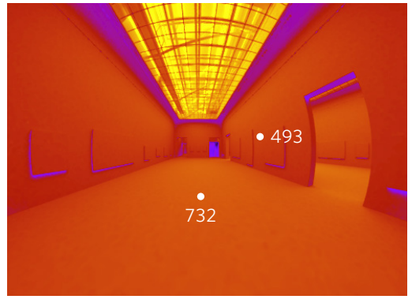
OVERCAST

Calculated Illuminance

Louvers at 30 degrees OPEN

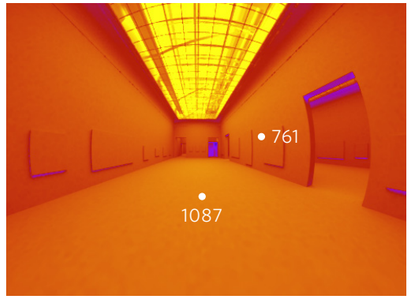


SUMMER SOLSTICE
JUNE 21



11 AM

1:30 PM



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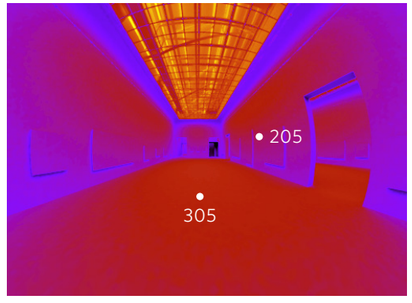
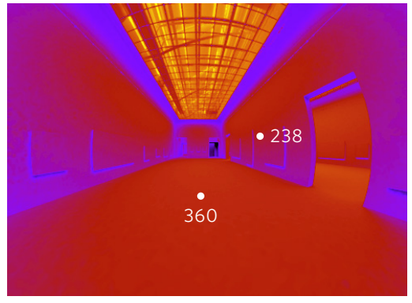
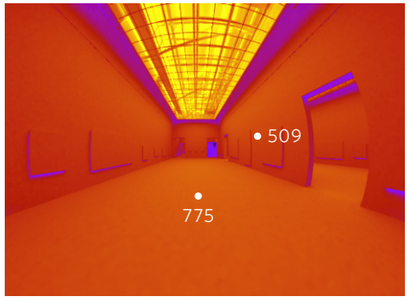


OVERCAST

EQUINOX
MARCH 21



11 AM



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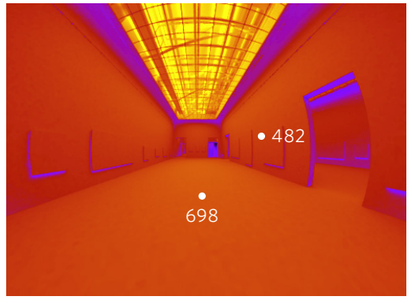

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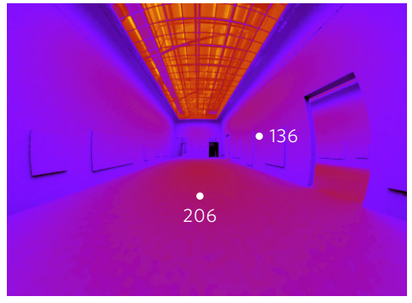
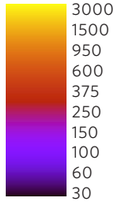


OVERCAST

WINTER SOLSTICE
DEC 21

LUX



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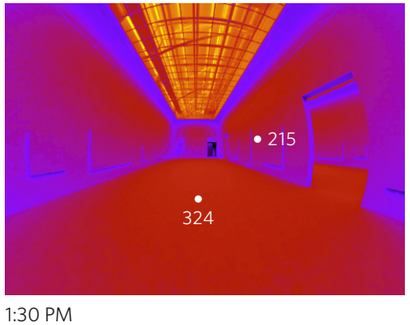

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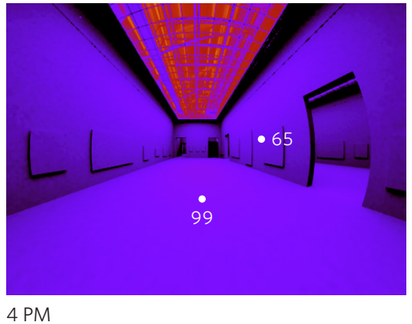

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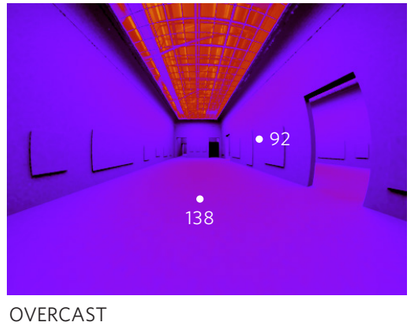
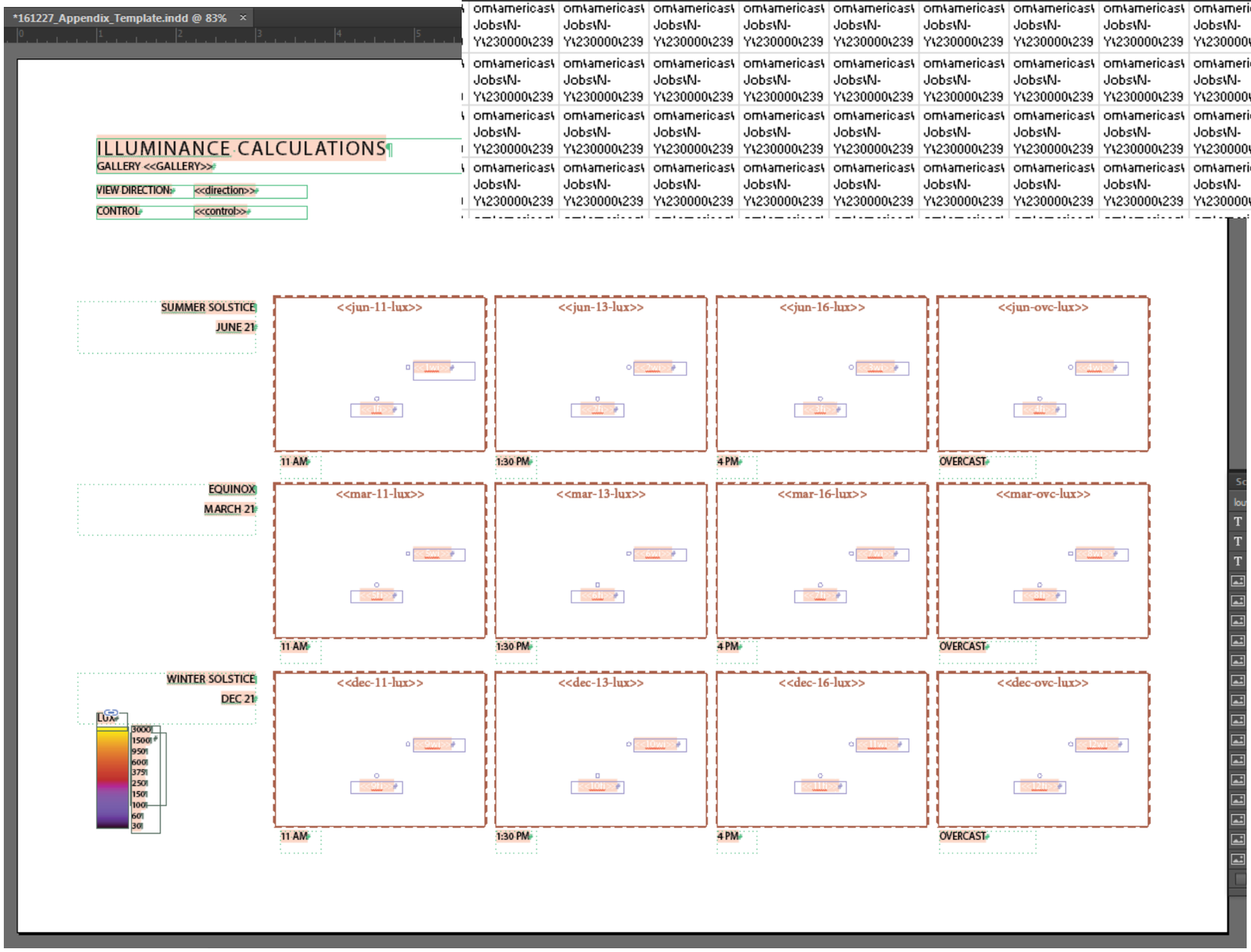


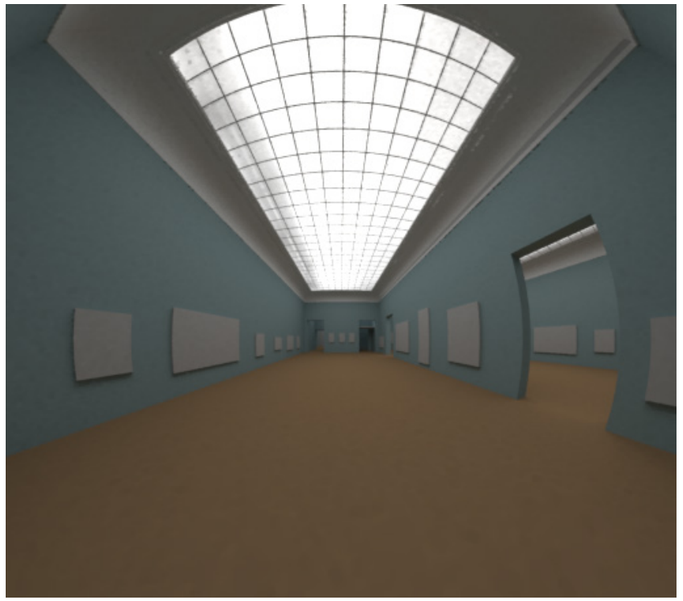
OVERCAST

Digression: Data Merge

S	T	U	V	W	X	Y	Z	AA	AB	AC	AD	AE	AF	AG	AH	AI	AJ	AK
@dec-ovc-lux	@mar-11-lux	@mar-13-lux	@mar-16-lux	@mar-ovc-lux	@jun-11-lux	@jun-13-lux	@jun-16-lux	@jun-ovc-lux	1wi	1fi	1wl	1fl	1cl	2wi	2fi	2wl	2fl	2cl
om\americas\Jobs\N-Y\230000\239	om\americas\Jobs\N-Y\230000\239	om\americas\Jobs\N-Y\230000\239	om\americas\Jobs\N-Y\230000\239	om\americas\Jobs\N-Y\230000\239	om\americas\Jobs\N-Y\230000\239	om\americas\Jobs\N-Y\230000\239	om\americas\Jobs\N-Y\230000\239	om\americas\Jobs\N-Y\230000\239	2483	304	173	2754	2065	2648	329	189	2676	1465
om\americas\Jobs\N-Y\230000\239	om\americas\Jobs\N-Y\230000\239	om\americas\Jobs\N-Y\230000\239	om\americas\Jobs\N-Y\230000\239	om\americas\Jobs\N-Y\230000\239	om\americas\Jobs\N-Y\230000\239	om\americas\Jobs\N-Y\230000\239	om\americas\Jobs\N-Y\230000\239	om\americas\Jobs\N-Y\230000\239	1804	2595	265	190	3211	2799	3877	419	277	4239
om\americas\Jobs\N-Y\230000\239	om\americas\Jobs\N-Y\230000\239	om\americas\Jobs\N-Y\230000\239	om\americas\Jobs\N-Y\230000\239	om\americas\Jobs\N-Y\230000\239	om\americas\Jobs\N-Y\230000\239	om\americas\Jobs\N-Y\230000\239	om\americas\Jobs\N-Y\230000\239	om\americas\Jobs\N-Y\230000\239	1163	1838	181	133	1845	920	1450	145	103	1468
om\americas\Jobs\N-Y\230000\239	om\americas\Jobs\N-Y\230000\239	om\americas\Jobs\N-Y\230000\239	om\americas\Jobs\N-Y\230000\239	om\americas\Jobs\N-Y\230000\239	om\americas\Jobs\N-Y\230000\239	om\americas\Jobs\N-Y\230000\239	om\americas\Jobs\N-Y\230000\239	om\americas\Jobs\N-Y\230000\239	1995	2911	321	210	1889	2255	3225	361	233	2214



Control Strategy Analysis



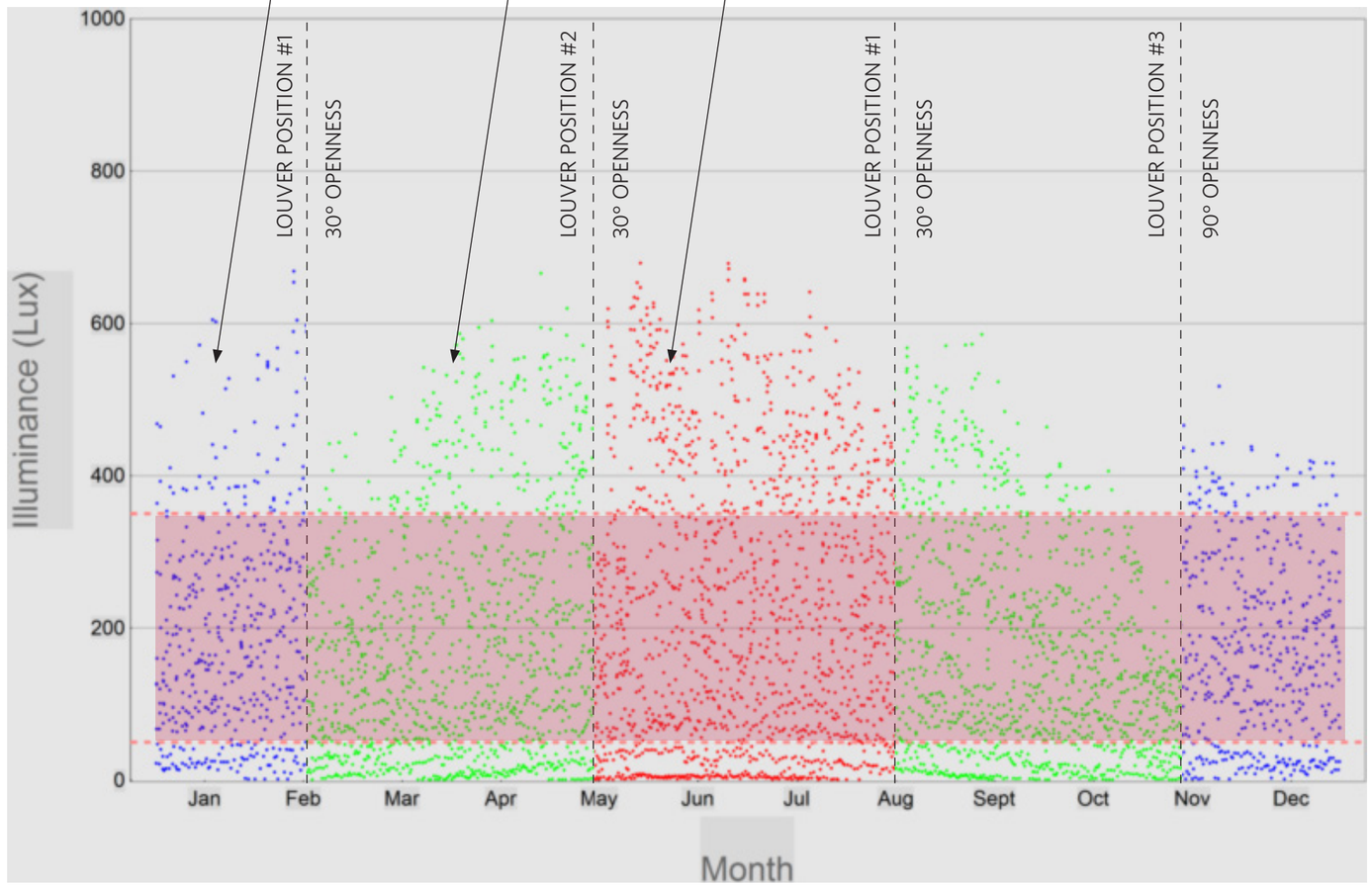
Target Annual Exposure: 650,000 lux-hr

Cumulative Annual Hourly Illuminance by Season based on described seasonal louver positions:

Winter:	169,235 lux-hr
Spring:	155,785 lux-hr
Summer:	217,945 lux-hr
Fall:	221,890 lux-hr
Total:	**794,855 lux-hr**

INTERIOR LIGHT LEVELS HIGHER THAN TARGETS WHEN ALL DIRECT LIGHT OMITTED.

POTENTIAL OPPORTUNITY TO REDUCE SKYLIGHT AREA OR DECREASE SURFACE TRANSMISSION VALUES



Anticipated Hourly Annual Illuminance Profile within Gallery 608 based on seasonal louver settings

Control Strategy Analysis

Summer Solstice

Louver position over Gallery 608: 30° open

Louver position over Gallery 607: 30° open

Equinox

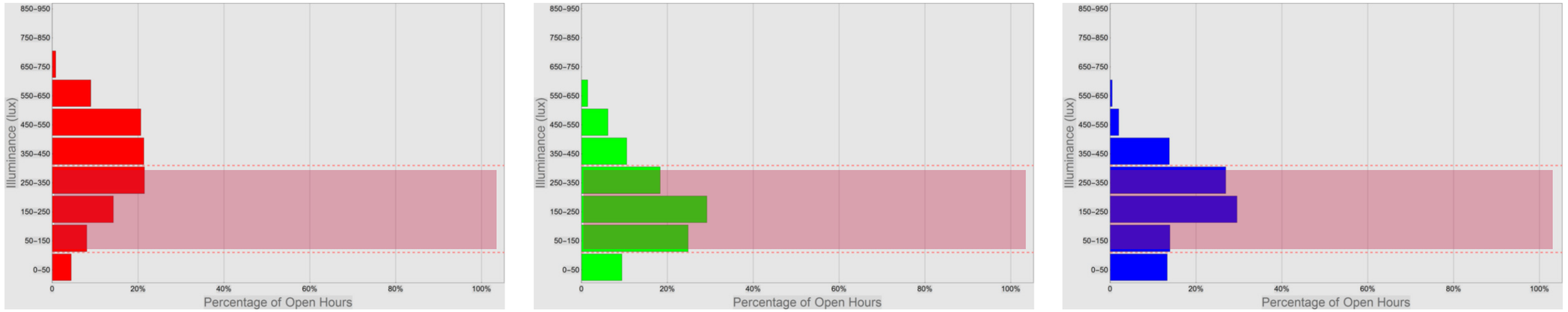
Louver position over Gallery 608: 30° open

Louver position over Gallery 607: 75° open (45° calculated)

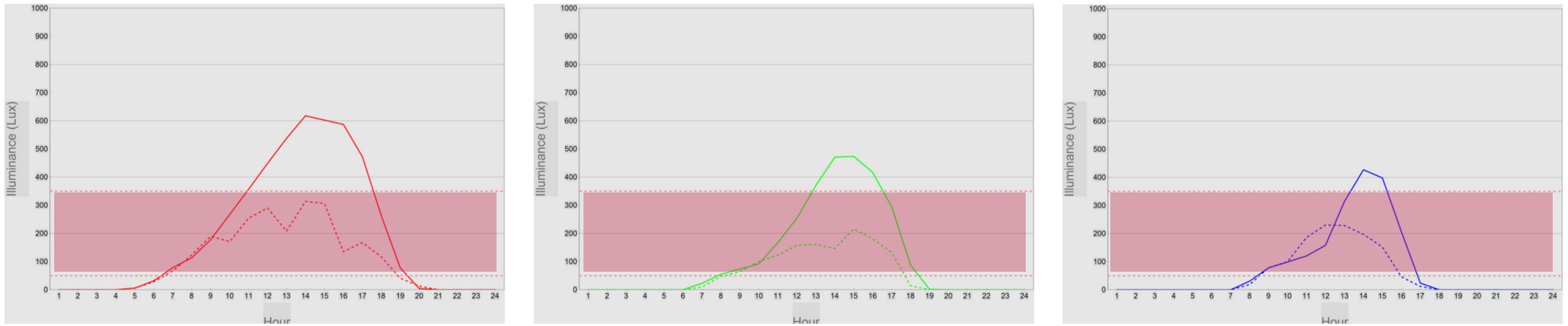
Winter Solstice

Louver position over Gallery 608: 90° open

Louver position over Gallery 607: 90° open

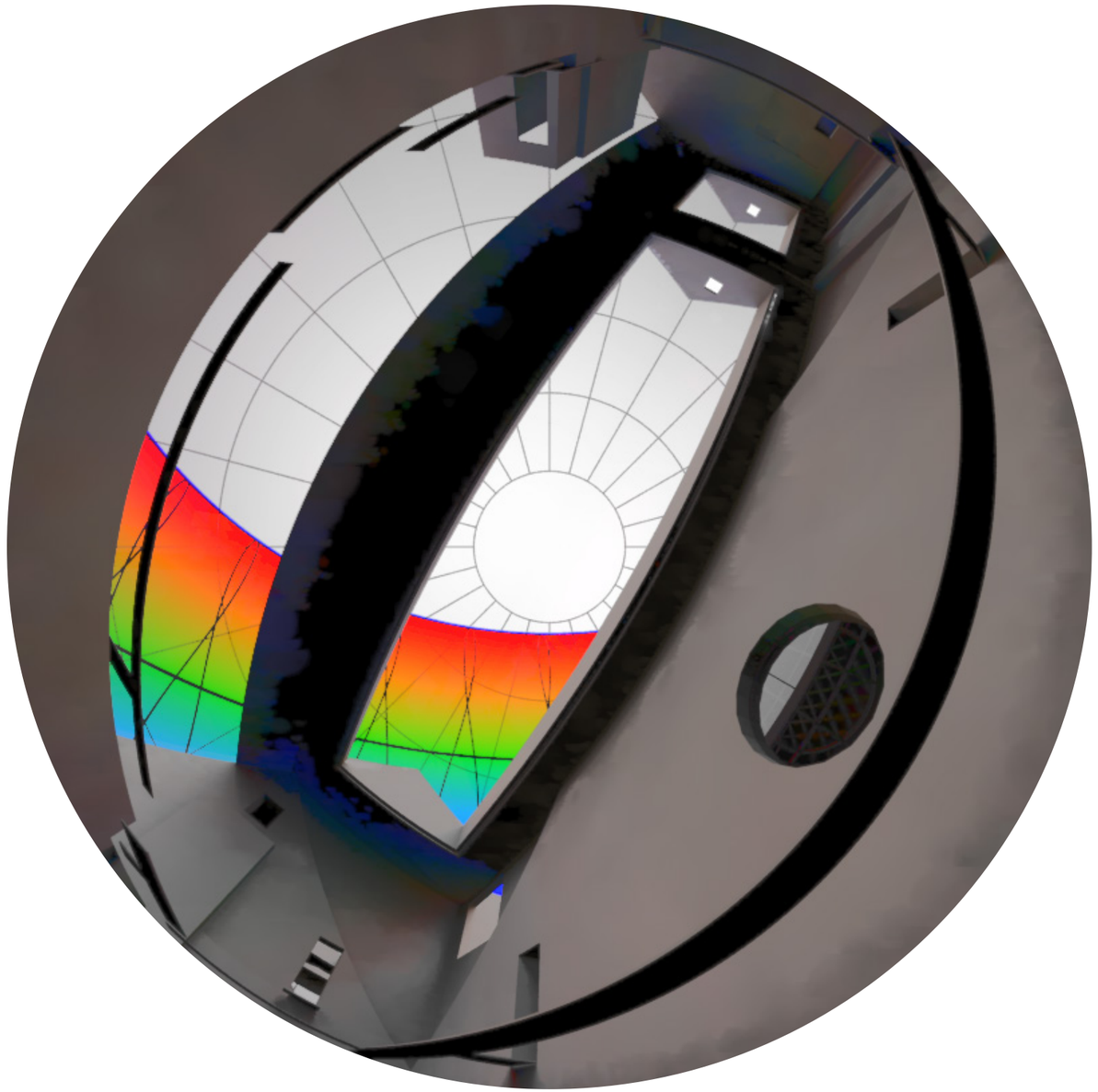


Seasonal Illuminance Distribution Chart

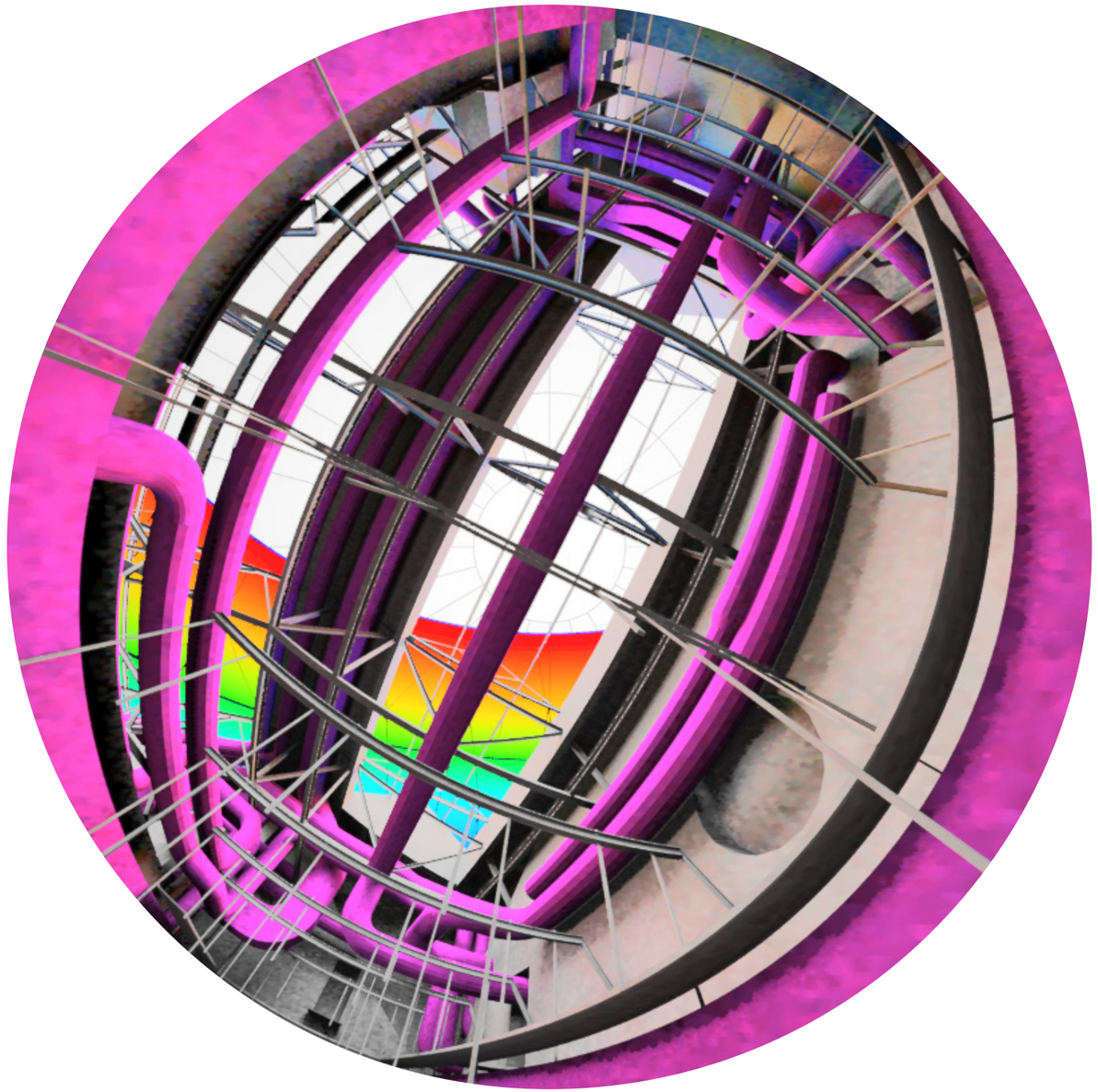


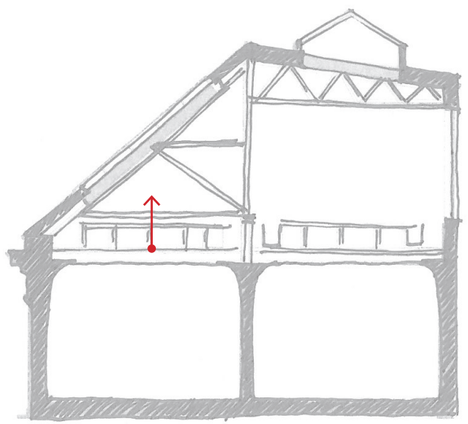
Hourly Illuminance Plots for Sunny and Overcast Sky Conditions

Systems Coordination

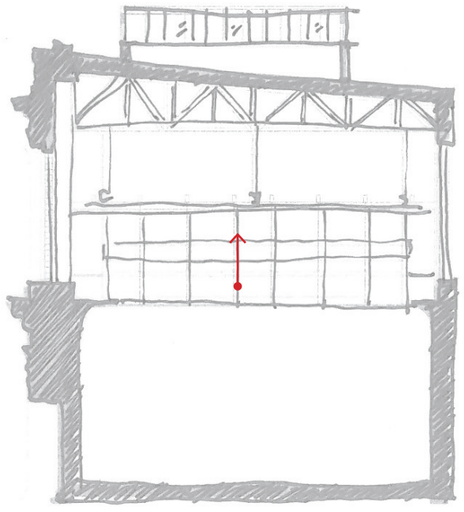


Systems Coordination

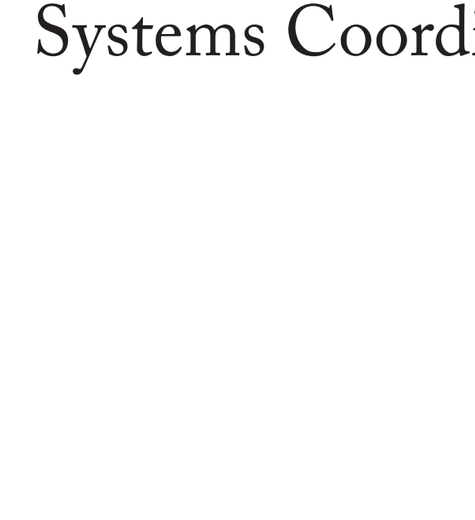




Systems Coordination



Systems Coordination

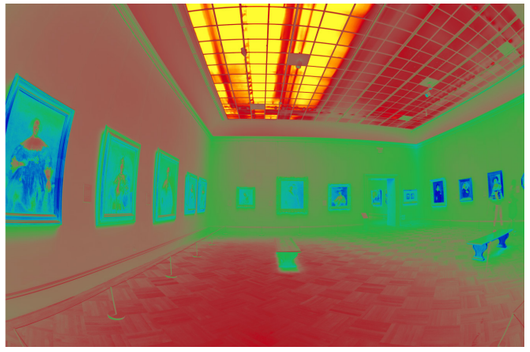


Meanwhile in Secaucus, NJ...

Quarter-scale Daylight Model

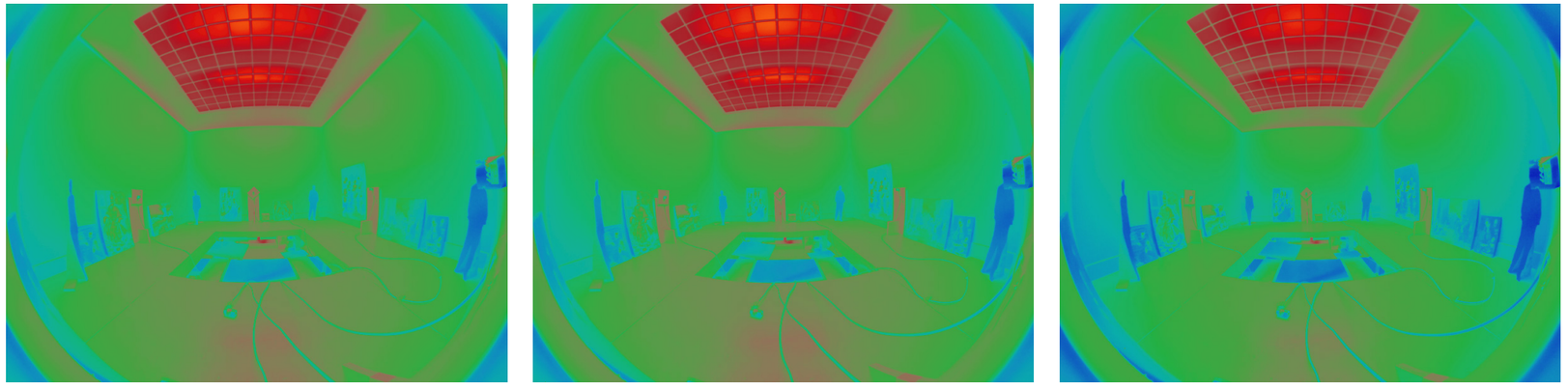
Measured Luminance

GALLERY 637
11 AM
15/06/17
BRIGHT SUNNY DAY

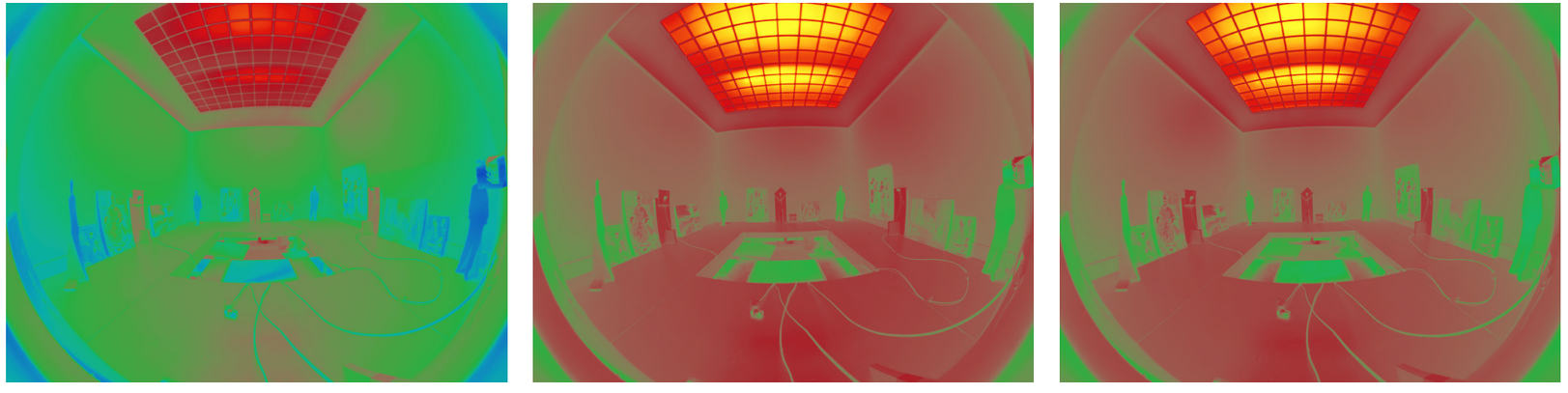


9 AM | 12 PM | 3 PM

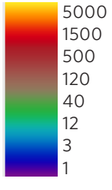
JULY 27, 2017



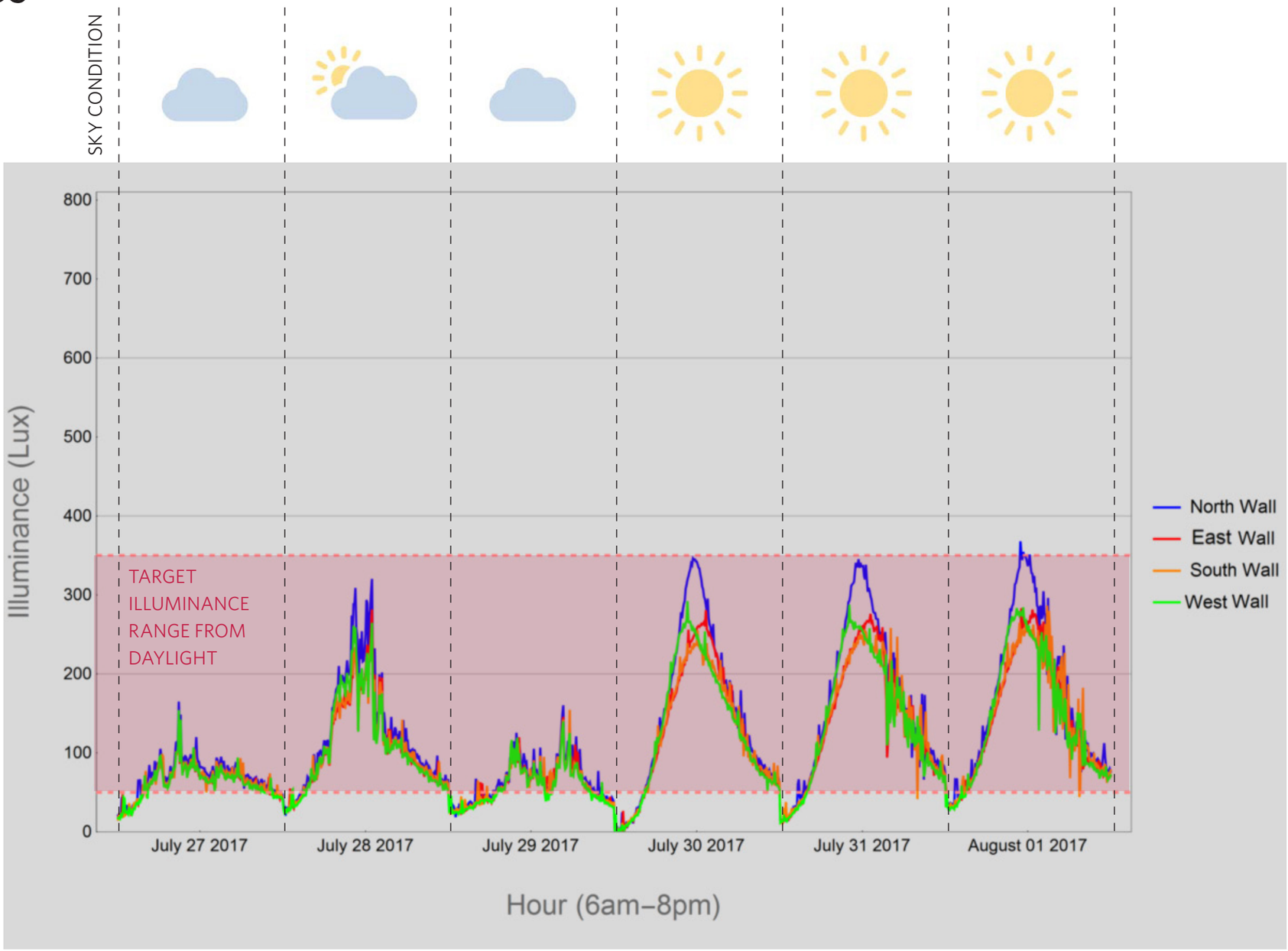
JULY 31, 2017

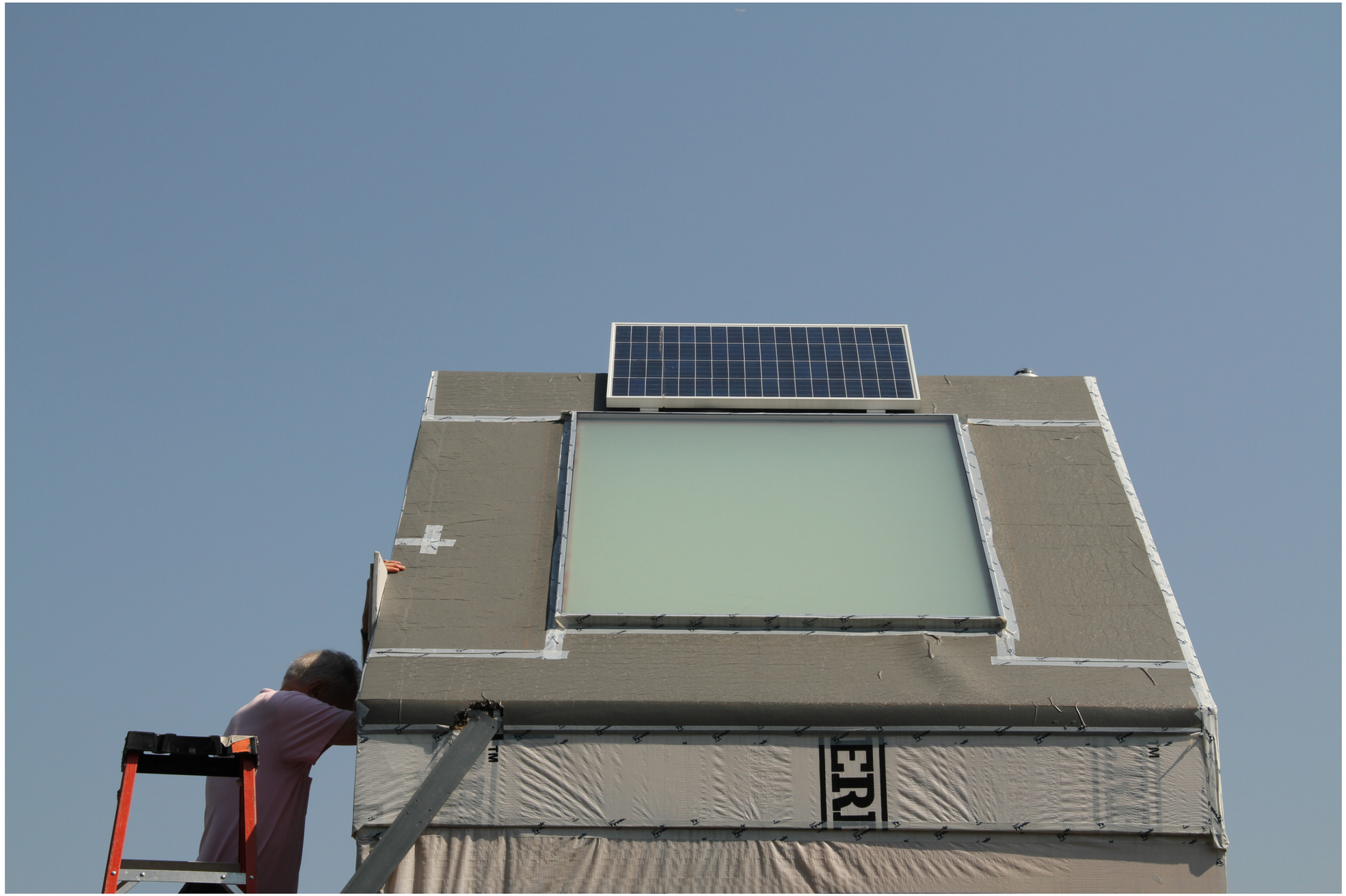


BRIGHTNESS
CD/m²



Measured Illuminance




ERI