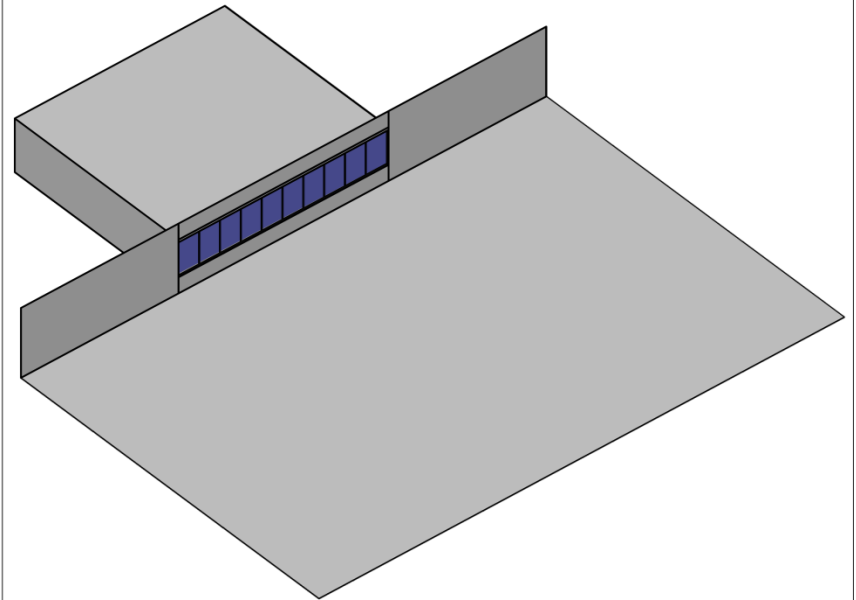
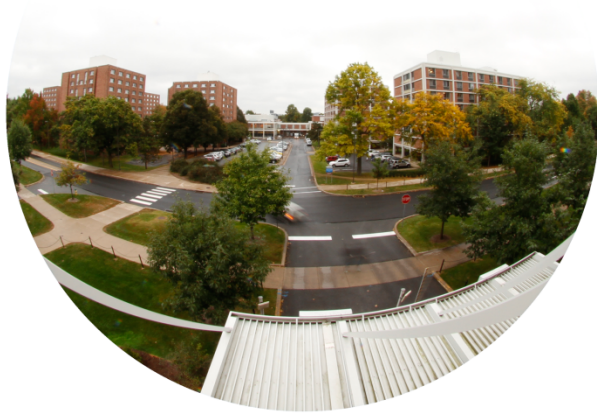


2015 International Radiance Workshop  
Wednesday August 19<sup>th</sup>, 2015

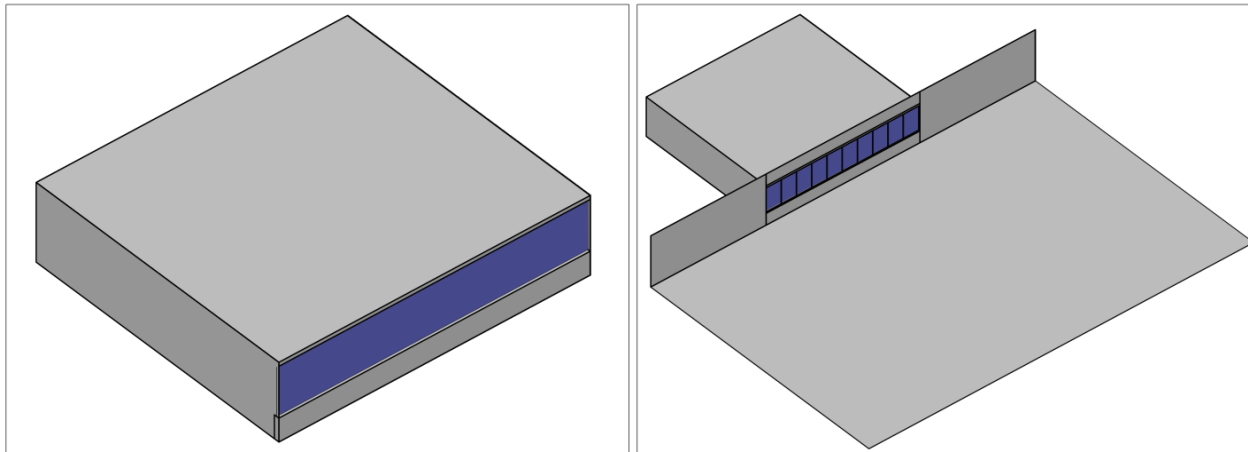
# **MODELING THE EXTERIOR SURROUND - HOW MUCH DETAIL IS NECESSARY?**

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Penn State University  
Department of Architectural Engineering



# Introduction: The Problem

- Daylighting is affected by the surrounding exterior
- The exterior surround both reflects and blocks daylight
- Occupants are more tolerant of glare when the view is appealing to them
- Current daylight modeling practice considers minimal or no exterior elements
- Very little information is available on modeling the exterior daylighting environment



# Introduction:

## LM83: Exterior Surround Modeling Instructions

---

- Buildings and opaque structures are to be modeled within at least 100' (with resolution of at least a 10' increment)
- Actual reflectance is to be used (or 30% if unknown)
- Exterior surround of equal height and setback of space under study(if unknown)
- Ground reflectance of 10% (if the actual value is unknown)
- Trees are modeled as cones, spheres or cylinders with a 20% reflectance





# Methodology

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- Part 1: Case study
  - HDR images of actual buildings in a real life setting (HDR of the window view)
- Part2: Radiance simulations
  - Modeling of the environment conditions in part 1 using common practice methods and tools

# Methodology

## Data Collection : Selected location



Loc-A-01



Loc-A-02



Loc-A-03



Loc-A-04



Loc-A-05



Loc-A-06

# Methodology

## Data Collection : Selected location



Loc-B-01



Loc-B-02



Loc-B-03



Loc-B-04



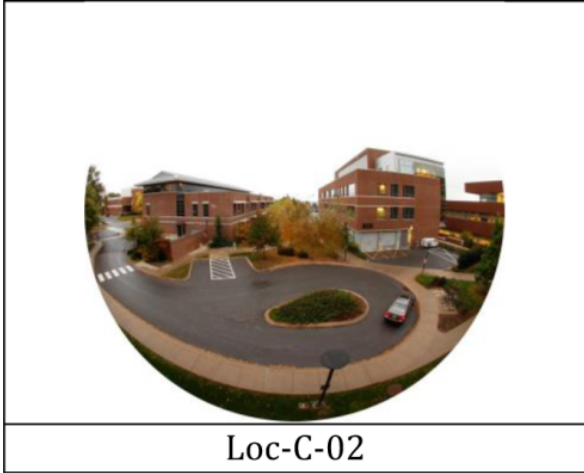
Loc-B-05



Loc-C-01

# Methodology

## Data Collection : Selected location



# Methodology

## Data Collection : Seasonal Variations

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Summer



Fall



Winter



# Methodology

## Data Collection : Sky conditions



10:00 AM



12:00 AM



3:00 PM



Overcast

# Methodology

## Data Collection

---

- Sky: Irradiance (Direct & Diffuse) and Horizontal Illuminance (Direct & Diffuse). These values are used in the simulations.
- 9 LDR images are fused to create the HDR of the window view)
- Vertical Illuminance at the camera lens (To verify  $E_v$  as computed from the HDR)
- Luminance measured at few points in the view (for calibration)
- Date, Time (saved automatically by camera and Pyranometer system)

# Methodology

## Data analysis: Luminance map

- Photosphere (HDR)
- Calibration process (Luminance, Vignetting effect)
- HDR: RGB plus luminance information



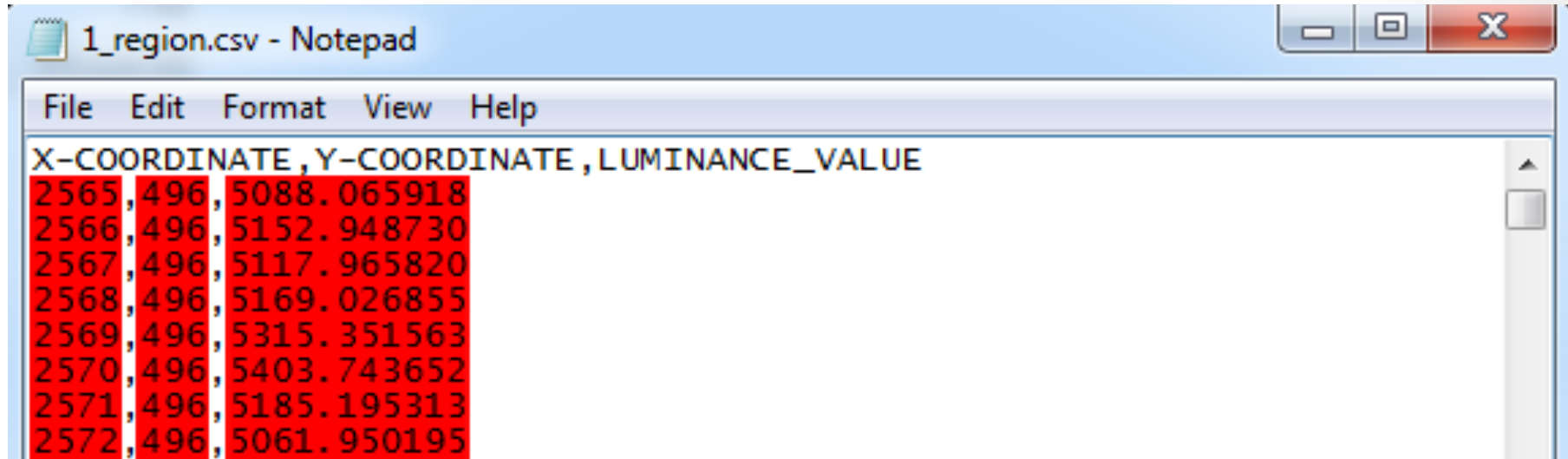
X=3062  
Y=1826  
R=168  
G=143  
B=74  
L=83.9



# Methodology

## Data analysis: Luminance map

- Data: x-y pixel coordinate, Luminance



```
1_region.csv - Notepad
File Edit Format View Help
X-COORDINATE,Y-COORDINATE,LUMINANCE_VALUE
2565,496,5088.065918
2566,496,5152.948730
2567,496,5117.965820
2568,496,5169.026855
2569,496,5315.351563
2570,496,5403.743652
2571,496,5185.195313
2572,496,5061.950195
```

# Methodology

## Exterior luminous environment

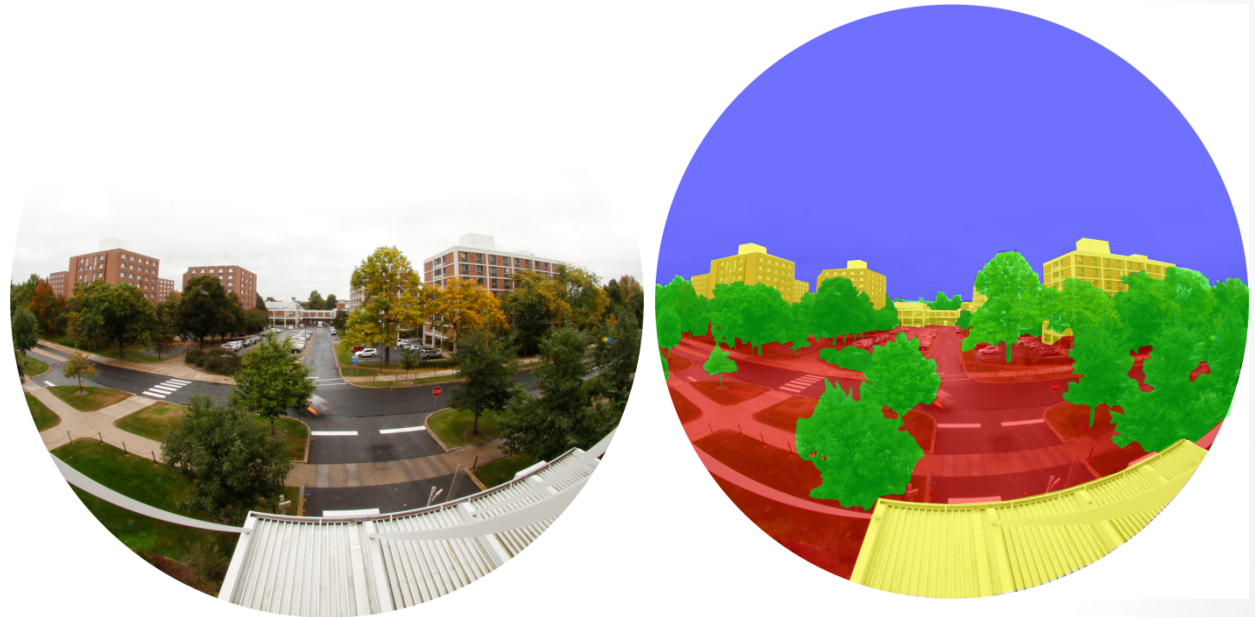
- Contribution to architectural opening:

1- Sky

2- Architectural Elements

3- Vegetation (3D)

4- Ground



# Methodology

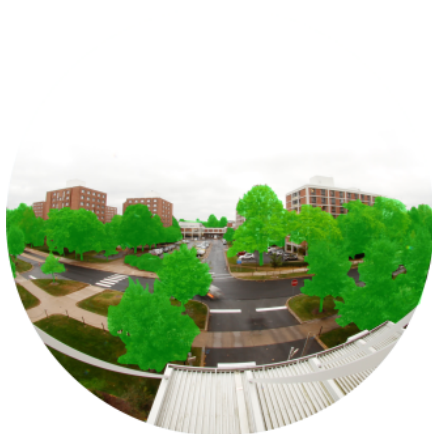
## Data analysis: Luminance map

- An appropriate mask is applied



# Methodology

## Data analysis: Luminance map



# Methodology

## Data analysis: Vertical illuminance

- Fish eye lens: equidistance projection (Miyamoto, 1964)
- Solid angle computation from pixel's xy coordinates

$$d\Omega(i,j) = \pi / l_{ij}^2 \cdot D \cdot \sin(\pi \cdot l_{ij} / D) \cdot dA$$

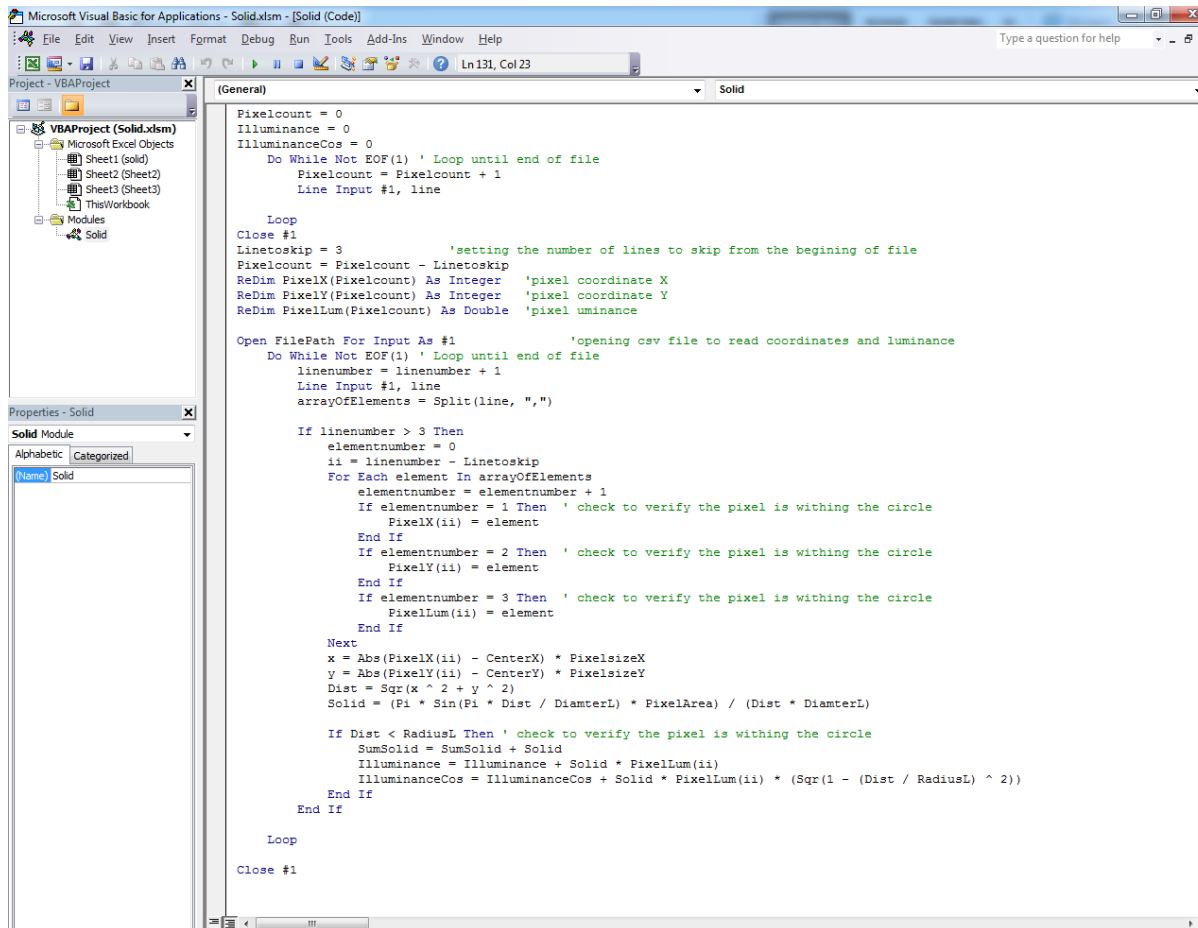
(Wei, Van Dommelen, Lewis, McLean, & Voss, 2012)

( $\Omega$  = Solid angle in steradian,  $l_{ij}$  = distance of pixel from the center of image,  
 $D$  = diameter of image,  $i$  &  $j$  = pixel row and column,  $dA$  = pixel area)

# Methodology

## Data analysis: Vertical illuminance

- VBA code was developed (Vertical illuminance)



The screenshot displays the Microsoft Visual Basic for Applications (VBA) editor interface. The title bar reads "Microsoft Visual Basic for Applications - Solid.xlsm - [Solid (Code)]". The menu bar includes File, Edit, View, Insert, Format, Debug, Run, Tools, Add-Ins, Window, and Help. The status bar at the bottom indicates "Ln131, Col23".

The left sidebar shows the "Project - VBAPProject" tree with the following structure:

- VBAPProject (Solid.xlsm)
  - Microsoft Excel Objects
    - Sheet1 (solid)
    - Sheet2 (Sheet2)
    - Sheet3 (Sheet3)
  - Modules
    - Solid

The "Properties - Solid" window is open, showing the "Solid Module" with tabs for "Alphabetic" and "Categorized". The "Alphabetic" tab is selected, showing a list of modules with "Solid" selected.

The main code window displays the following VBA code:

```
Pixelcount = 0
Illuminance = 0
IlluminanceCos = 0
Do While Not EOF(1) ' Loop until end of file
    Pixelcount = Pixelcount + 1
    Line Input #1, line

    Loop
Close #1
Linetoskip = 3 'setting the number of lines to skip from the beginning of file
Pixelcount = Pixelcount - Linetoskip
ReDim PixelX(Pixelcount) As Integer 'pixel coordinate X
ReDim PixelY(Pixelcount) As Integer 'pixel coordinate Y
ReDim PixelLum(Pixelcount) As Double 'pixel uminance

Open FilePath For Input As #1 'opening csv file to read coordinates and luminance
Do While Not EOF(1) ' Loop until end of file
    linenumber = linenumber + 1
    Line Input #1, line
    arrayofElements = Split(line, ",")

    If linenumber > 3 Then
        elementnumber = 0
        ii = linenumber - Linetoskip
        For Each element In arrayofElements
            elementnumber = elementnumber + 1
            If elementnumber = 1 Then ' check to verify the pixel is withing the circle
                PixelX(ii) = element
            End If
            If elementnumber = 2 Then ' check to verify the pixel is withing the circle
                PixelY(ii) = element
            End If
            If elementnumber = 3 Then ' check to verify the pixel is withing the circle
                PixelLum(ii) = element
            End If
        Next
        x = Abs(PixelX(ii) - CenterX) * PixelsizeX
        y = Abs(PixelY(ii) - CenterY) * PixelsizeY
        Dist = Sqr(x ^ 2 + y ^ 2)
        Solid = (Pi * Sin(Pi * Dist / DiamterL) * PixelArea) / (Dist * DiamterL)

        If Dist < RadiusL Then ' check to verify the pixel is withing the circle
            SumSolid = SumSolid + Solid
            Illuminance = Illuminance + Solid * PixelLum(ii)
            IlluminanceCos = IlluminanceCos + Solid * PixelLum(ii) * (Sqr(1 - (Dist / RadiusL) ^ 2))
        End If
    End If
Loop
Close #1
```

# Hypothesis

## Data analysis: Luminance map

---

Descriptive Statistics: Building, Ground, Sky, Vegetation (Ratio)						
Variable	Mean	SE Mean	StDev	Minimum	Maximum	
Building	13.70	8.09	16.18	3.52	37.65	
Ground	11.97	4.39	8.78	4.49	22.65	
Sky	62.69	9.05	18.09	46.38	87.62	
Vegetation	12.01	2.74	5.48	4.53	16.74	

# Methodology

## Modeling : Level of Details

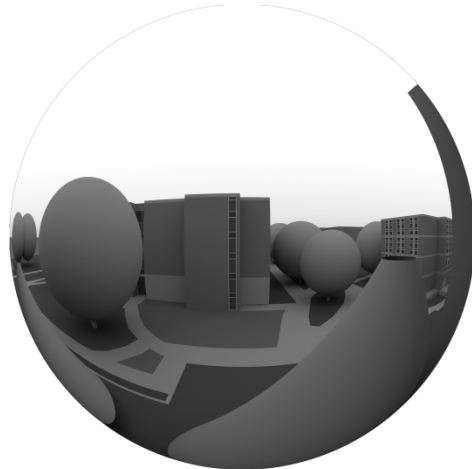
---



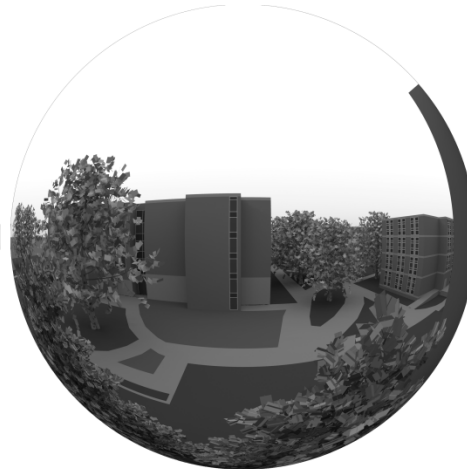


# Methodology

## Modeling : Level of Details



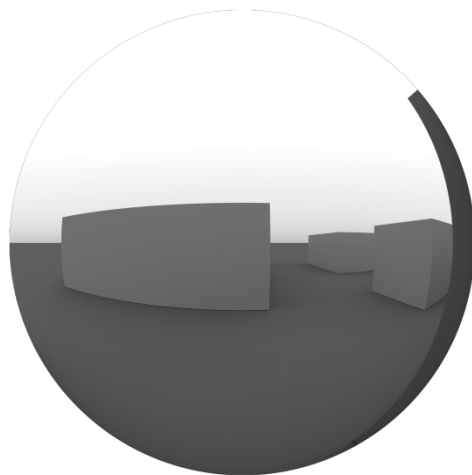
LM-83



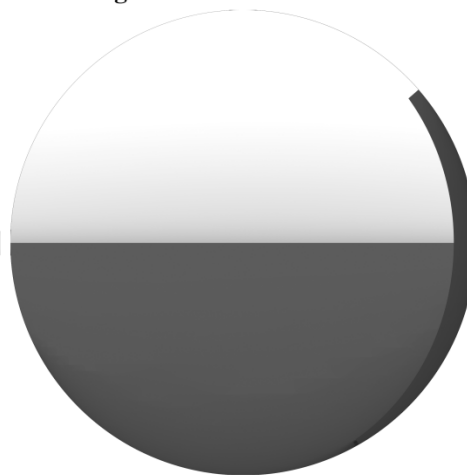
High Detailed Surround + Trees



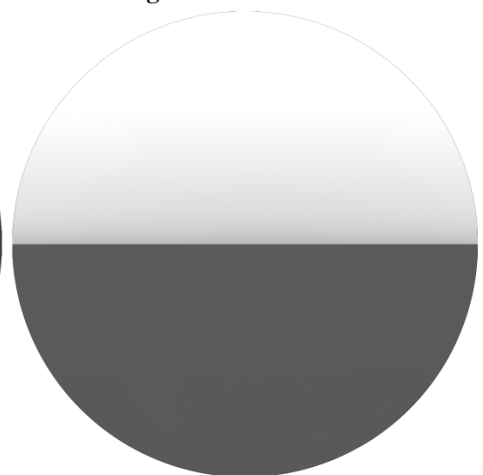
High Detailed Surround



Low Detailed Surround



Building itself



No Surround

# Methodology

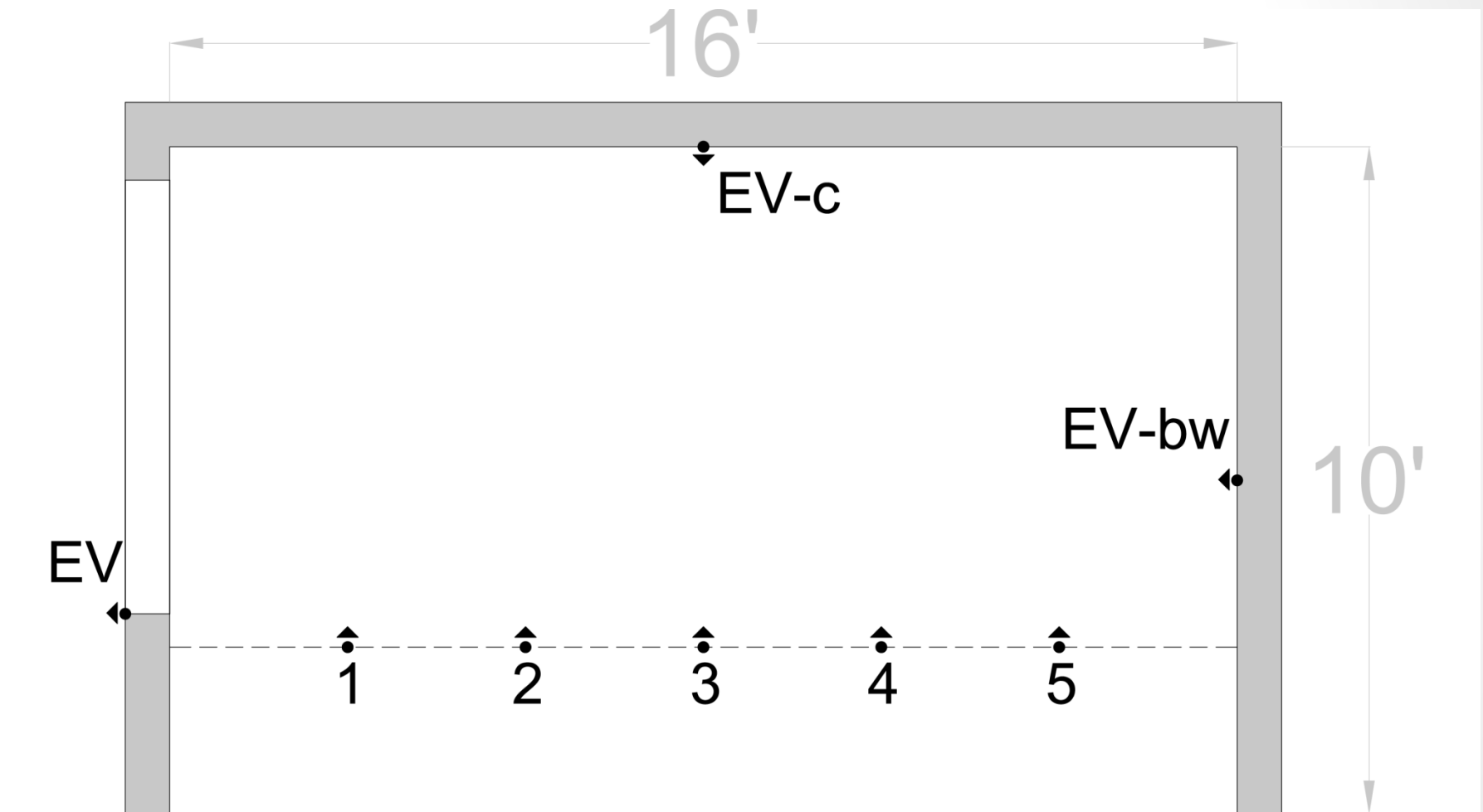
## Modeling

---

- Small office (10' x 16' x 10')
- Reflectance (Floor=0.2, Walls=0.6 , Ceiling=0.9)
- Workplane at 2.5 ft.

# Methodology

## Modeling



# Methodology

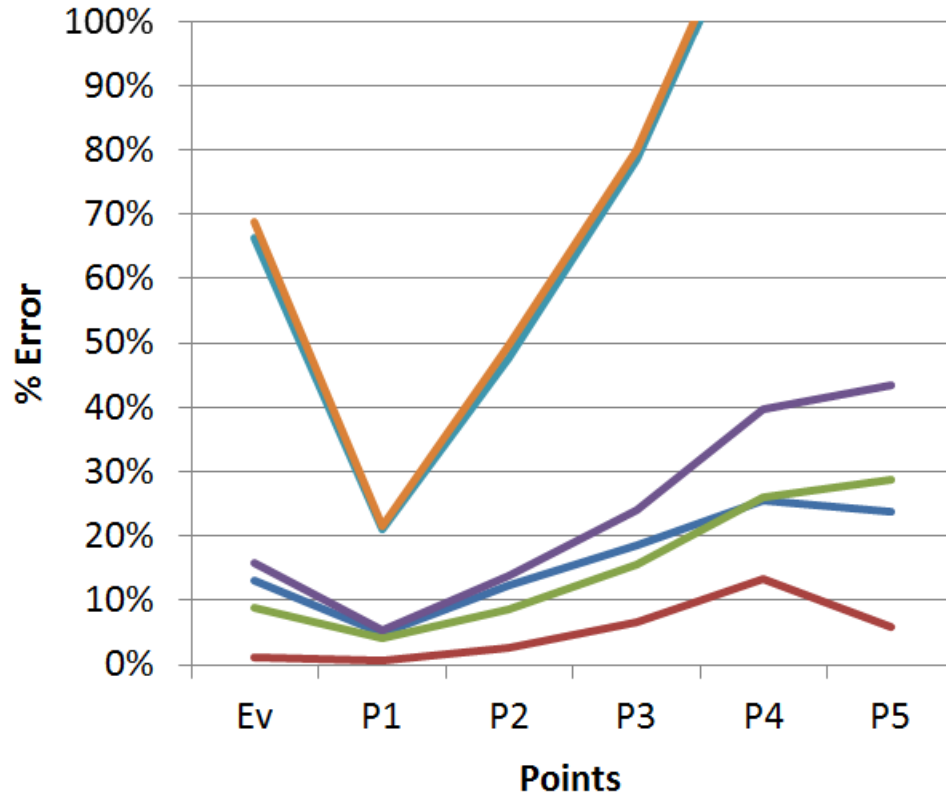
## Simulation

---

- Radiance (dxf2rad, oconv, rpict, rtrace)
- Image-based lighting was used in Radiance to compute illuminance in the interior from the HDR image
- 6 levels of detail were modeled using irradiance values as input to Perez sky to models

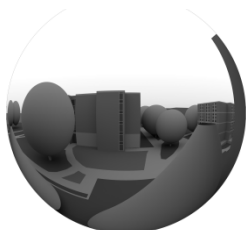
# Results

## Summer

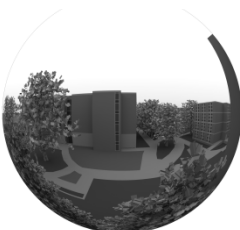


- No Surround
- Building itself
- Low Detailed Surround
- LM-83
- High Detailed Surround
- High Detailed Surround & Trees

Season: Summer  
Sky: Clear  
Time: Morning



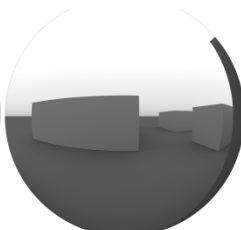
LM-83



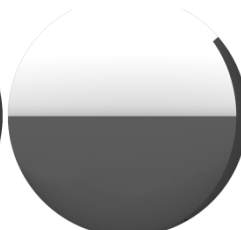
High Detailed Surround + Trees



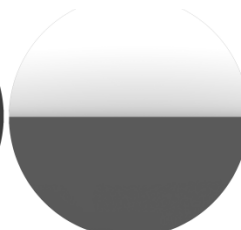
High Detailed Surround



Low Detailed Surround



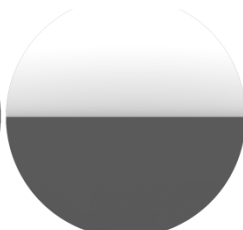
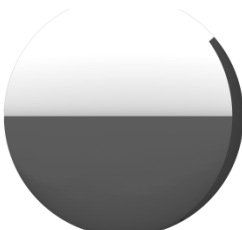
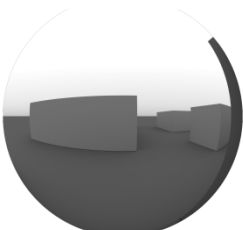
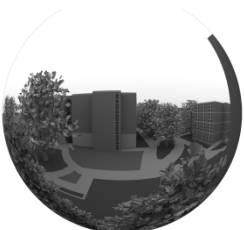
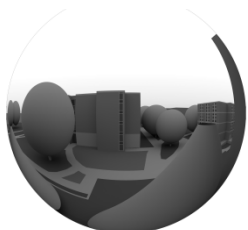
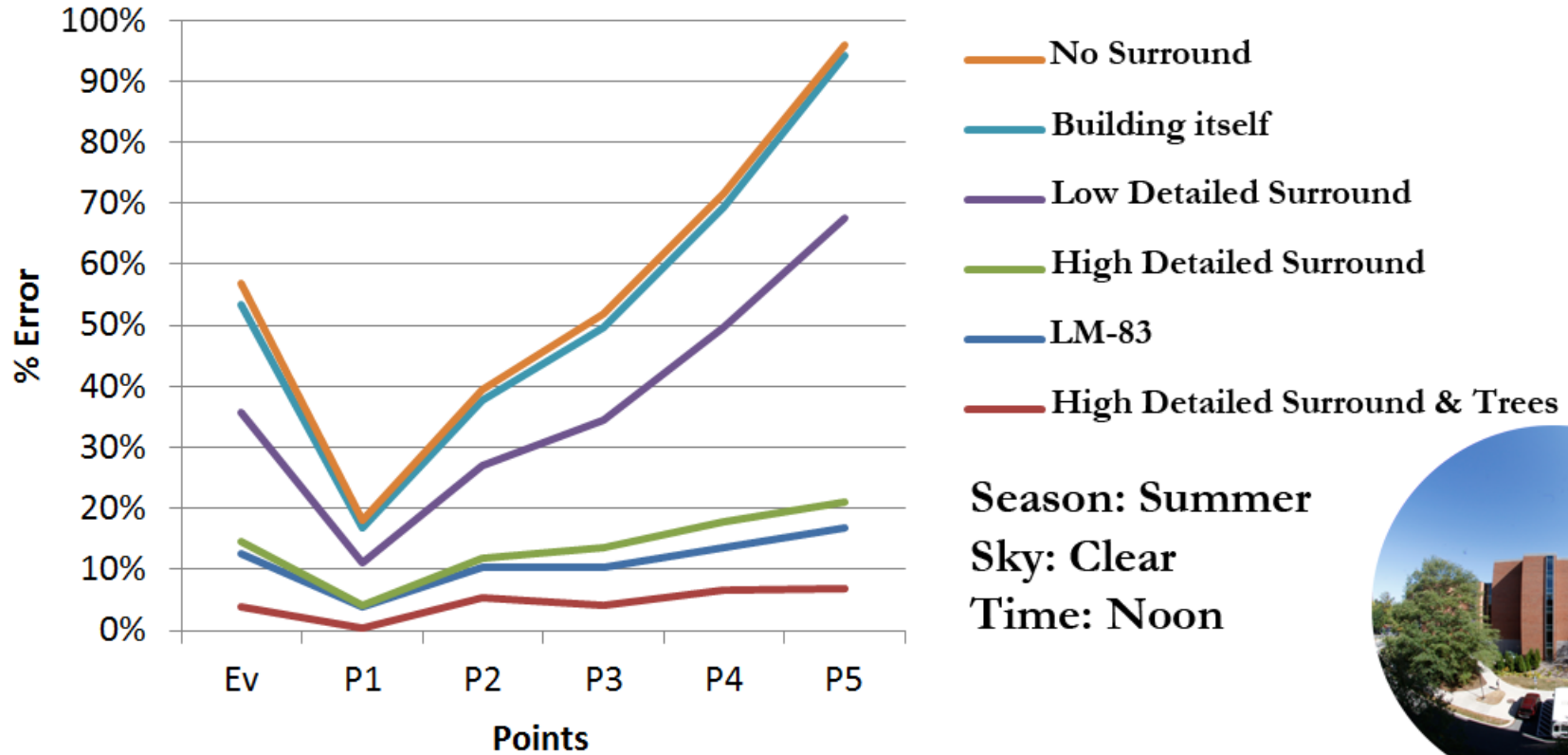
Building itself



No Surround

# Results

## Summer



LM-83

High Detailed Surround + Trees

High Detailed Surround

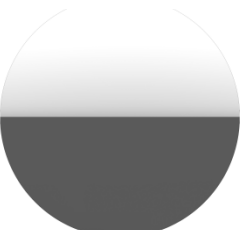
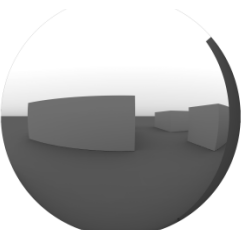
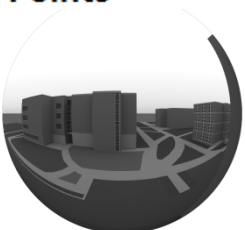
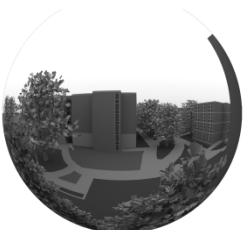
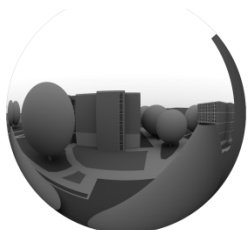
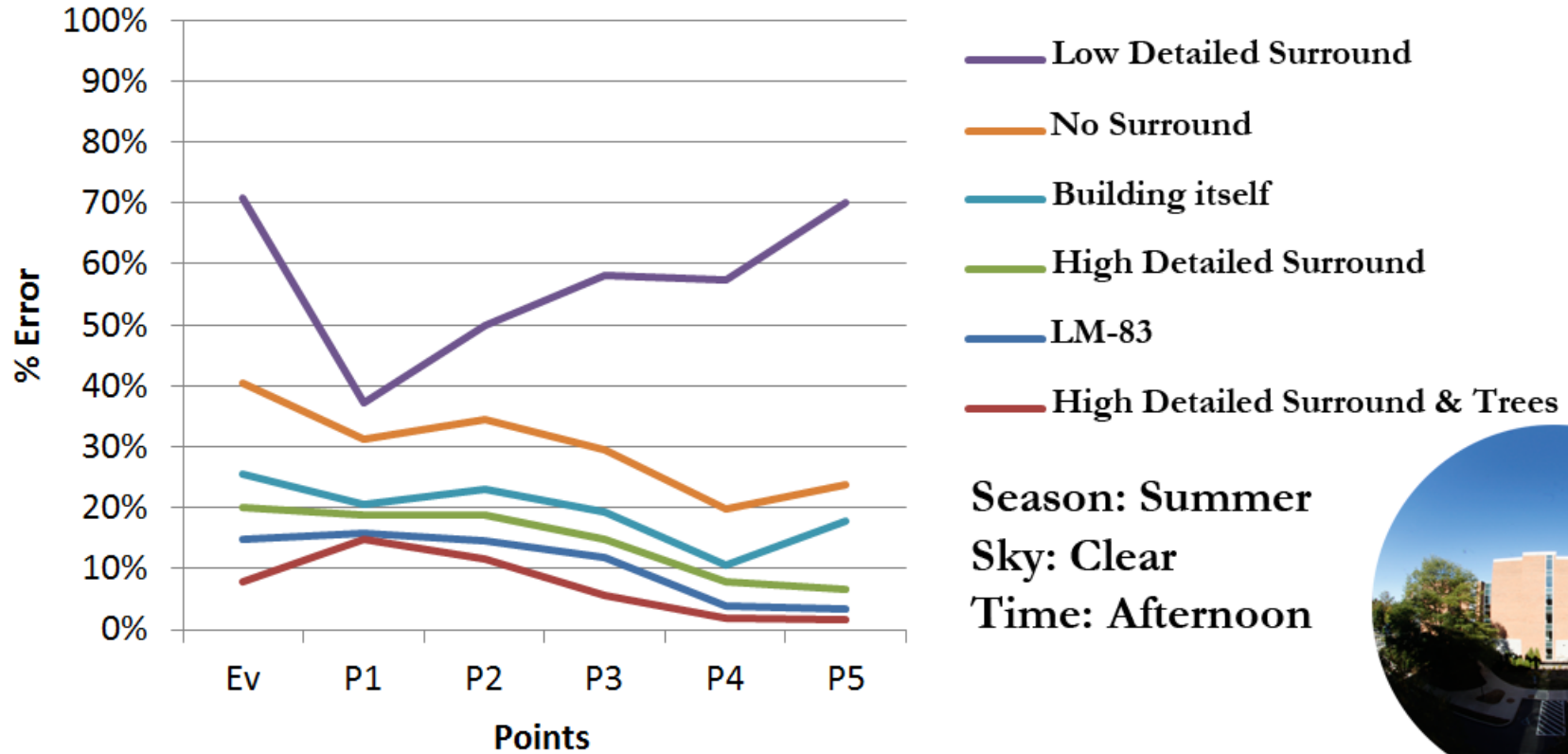
Low Detailed Surround

Building itself

No Surround

# Results

## Summer



LM-83

High Detailed Surround + Trees

High Detailed Surround

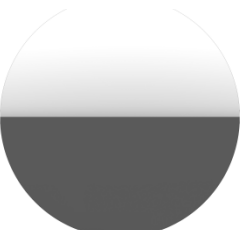
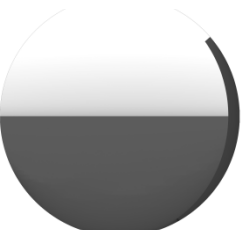
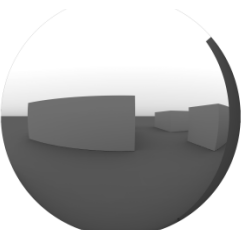
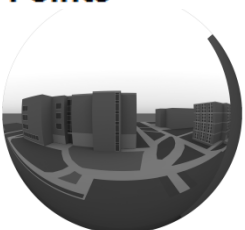
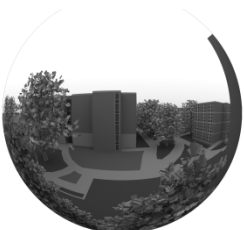
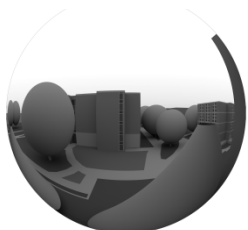
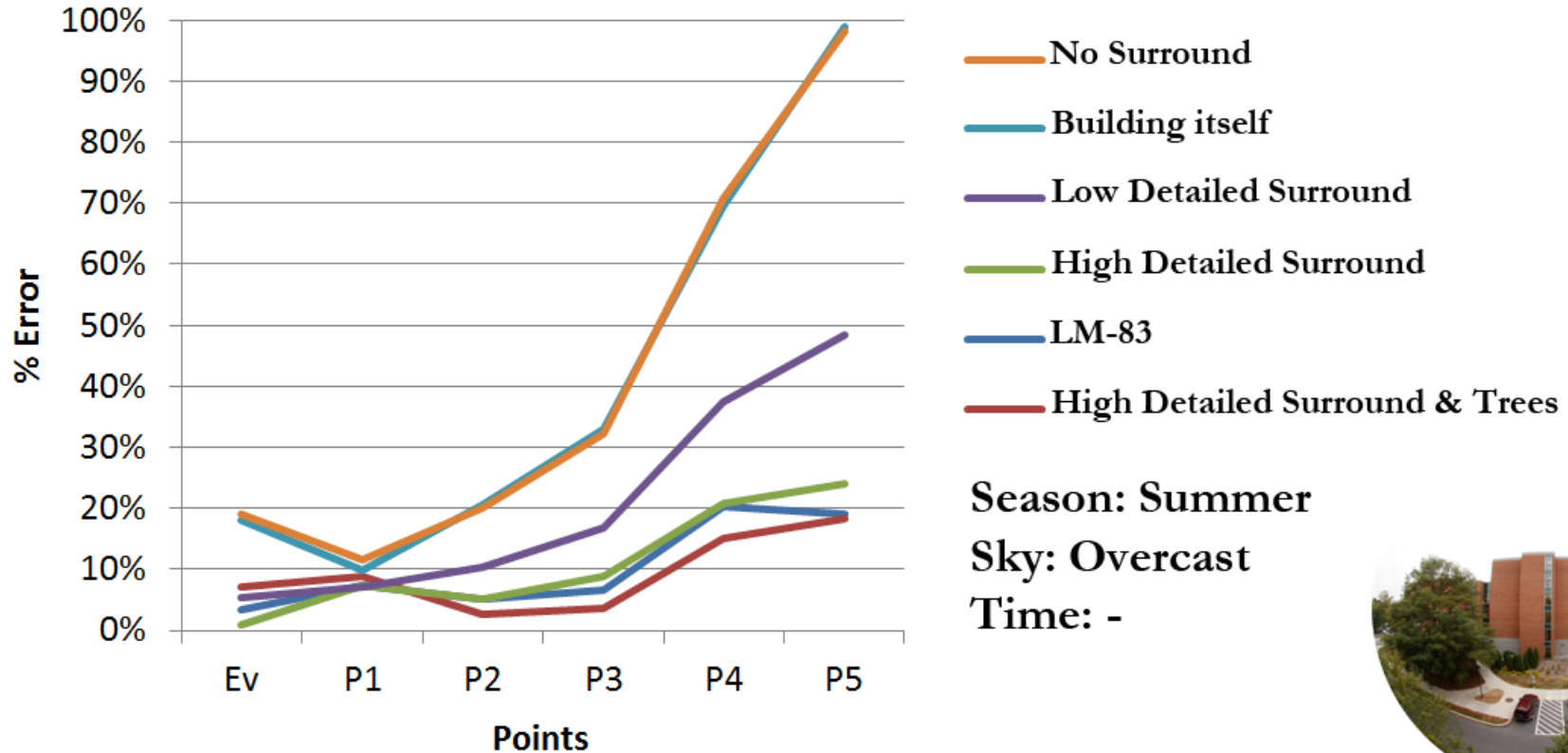
Low Detailed Surround

Building itself

No Surround

# Results

## Summer



LM-83

High Detailed Surround + Trees

High Detailed Surround

Low Detailed Surround

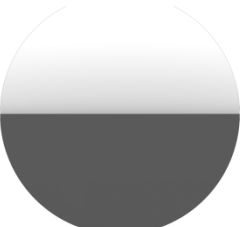
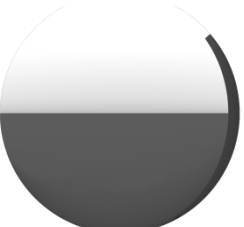
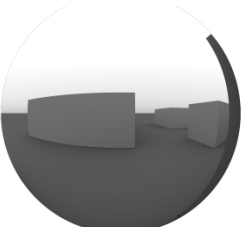
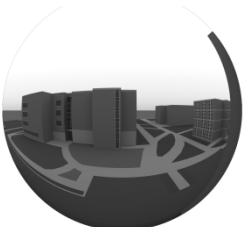
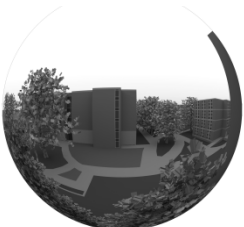
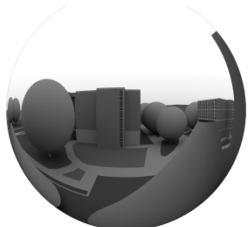
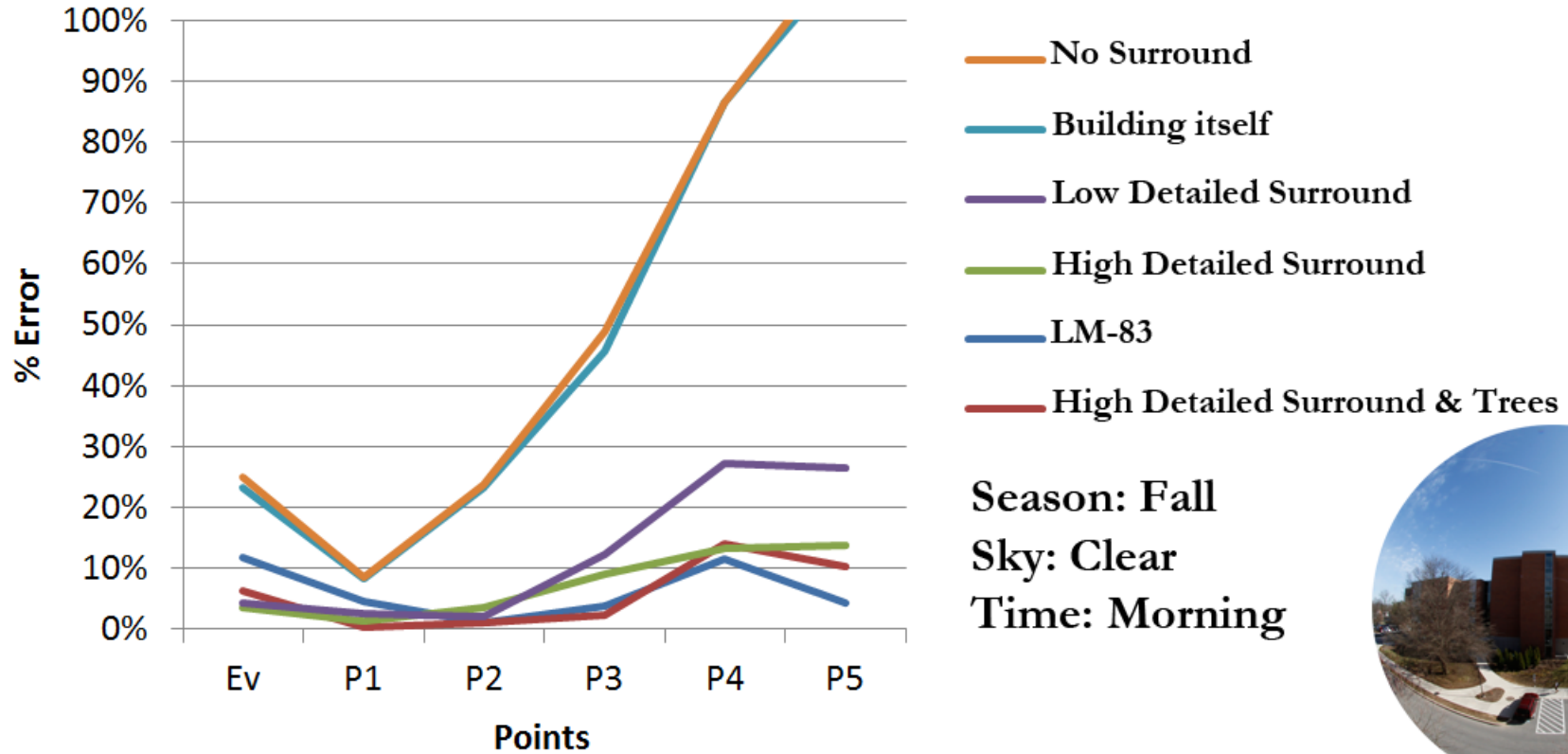
Building itself

No Surround



# Results

## Fall



LM-83

High Detailed Surround + Trees

High Detailed Surround

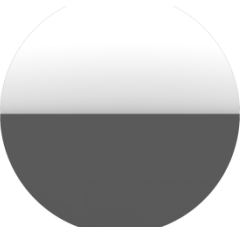
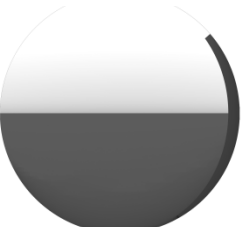
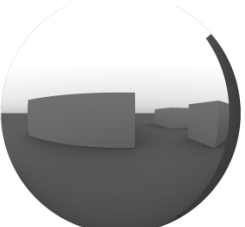
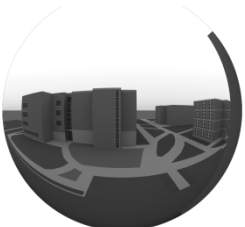
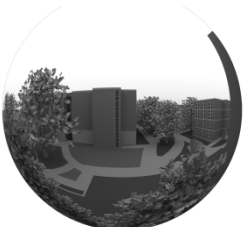
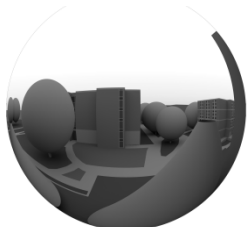
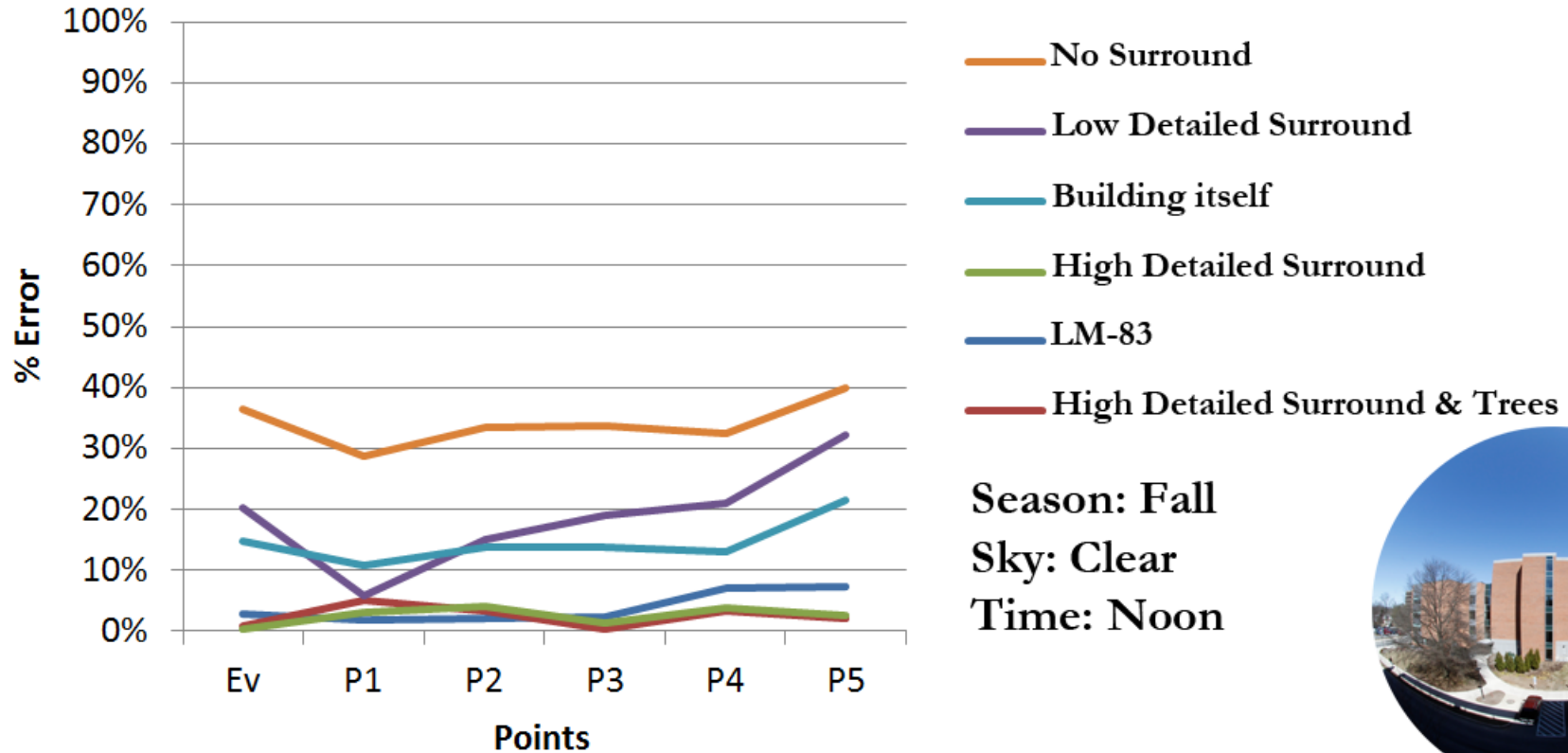
Low Detailed Surround

Building itself

No Surround

# Results

## Fall



LM-83

High Detailed Surround + Trees

High Detailed Surround

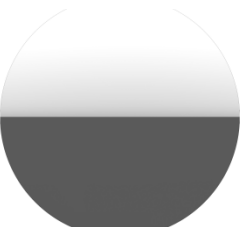
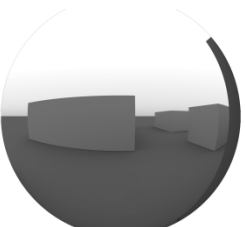
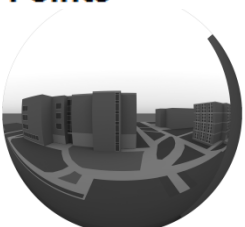
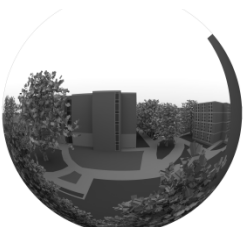
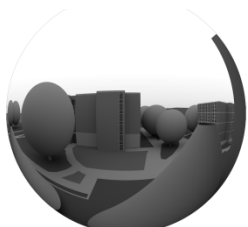
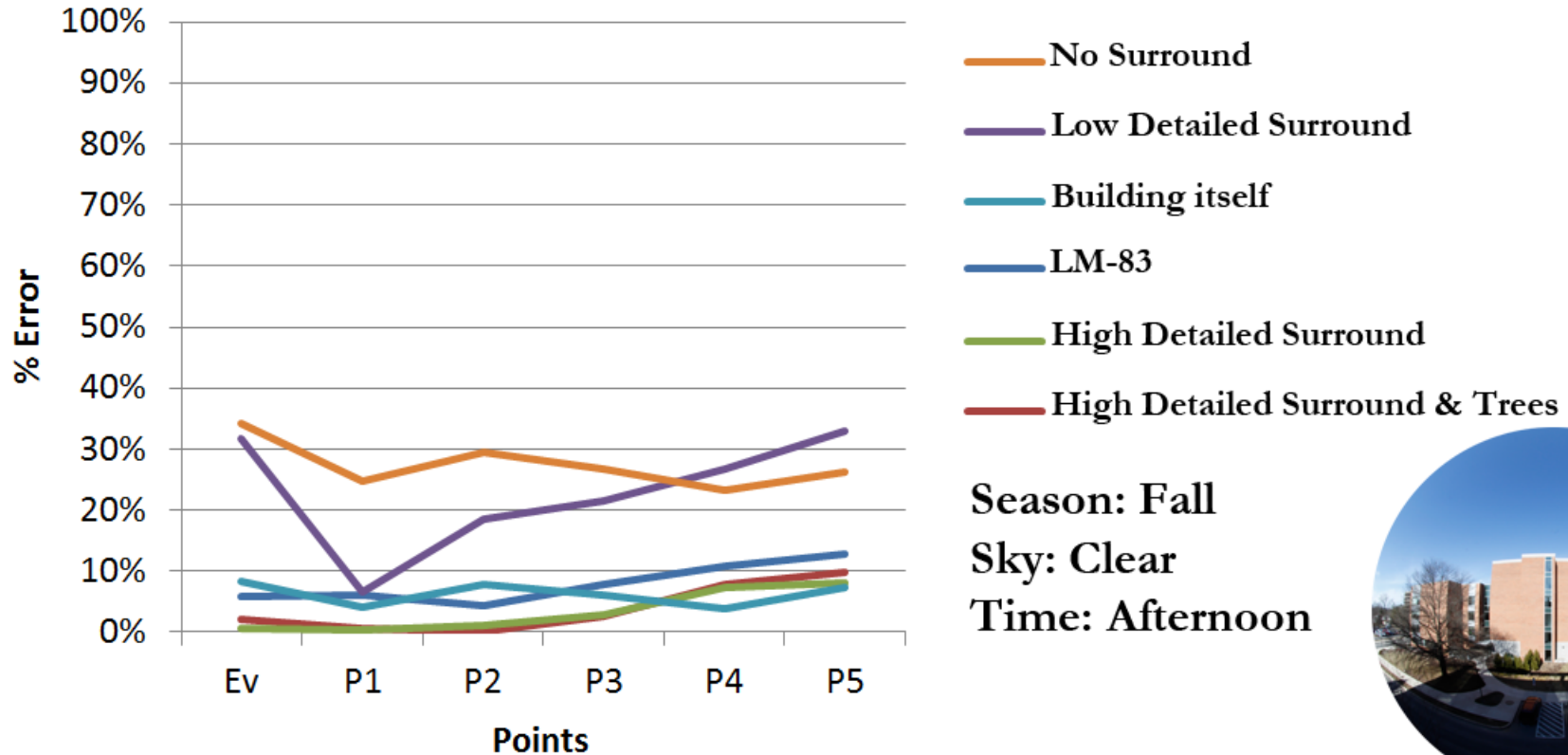
Low Detailed Surround

Building itself

No Surround

# Results

## Fall



LM-83

High Detailed Surround + Trees

High Detailed Surround

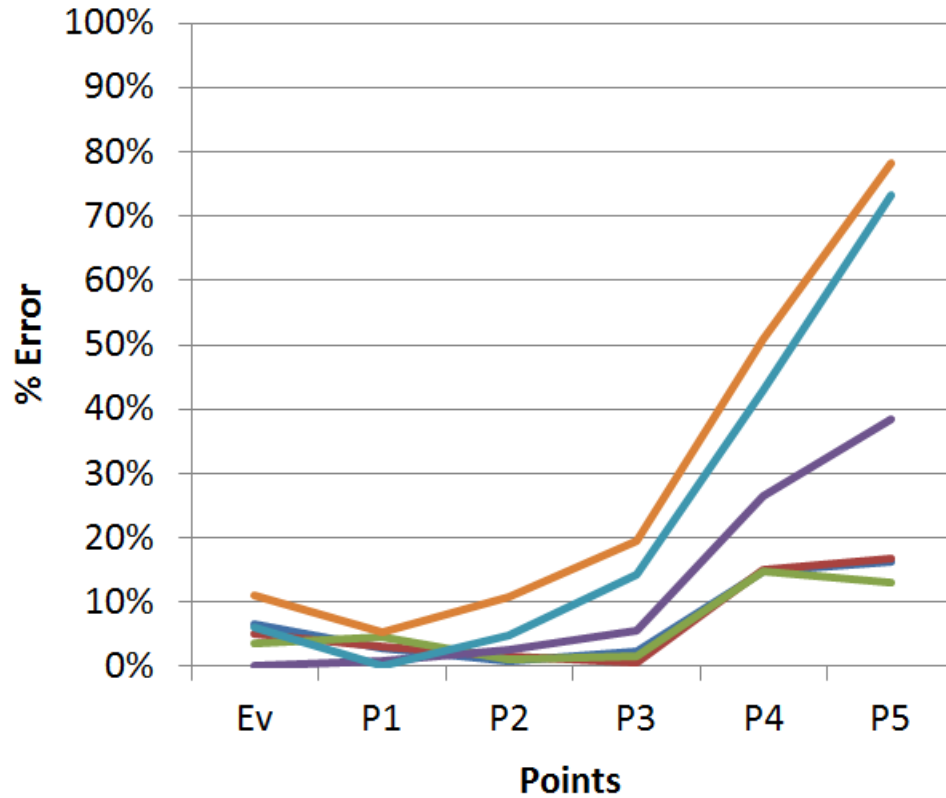
Low Detailed Surround

Building itself

No Surround

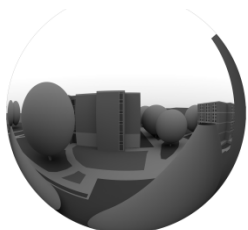
# Results

## Fall

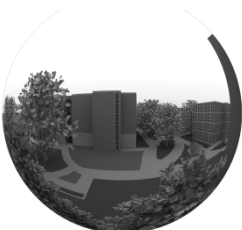


- No Surround
- Building itself
- Low Detailed Surround
- LM-83
- High Detailed Surround
- High Detailed Surround & Trees

Season: Fall  
Sky: Overcast  
Time: -



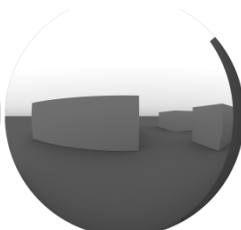
LM-83



High Detailed Surround + Trees



High Detailed Surround



Low Detailed Surround



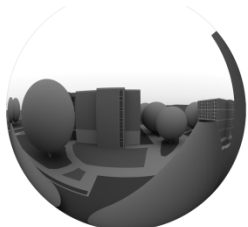
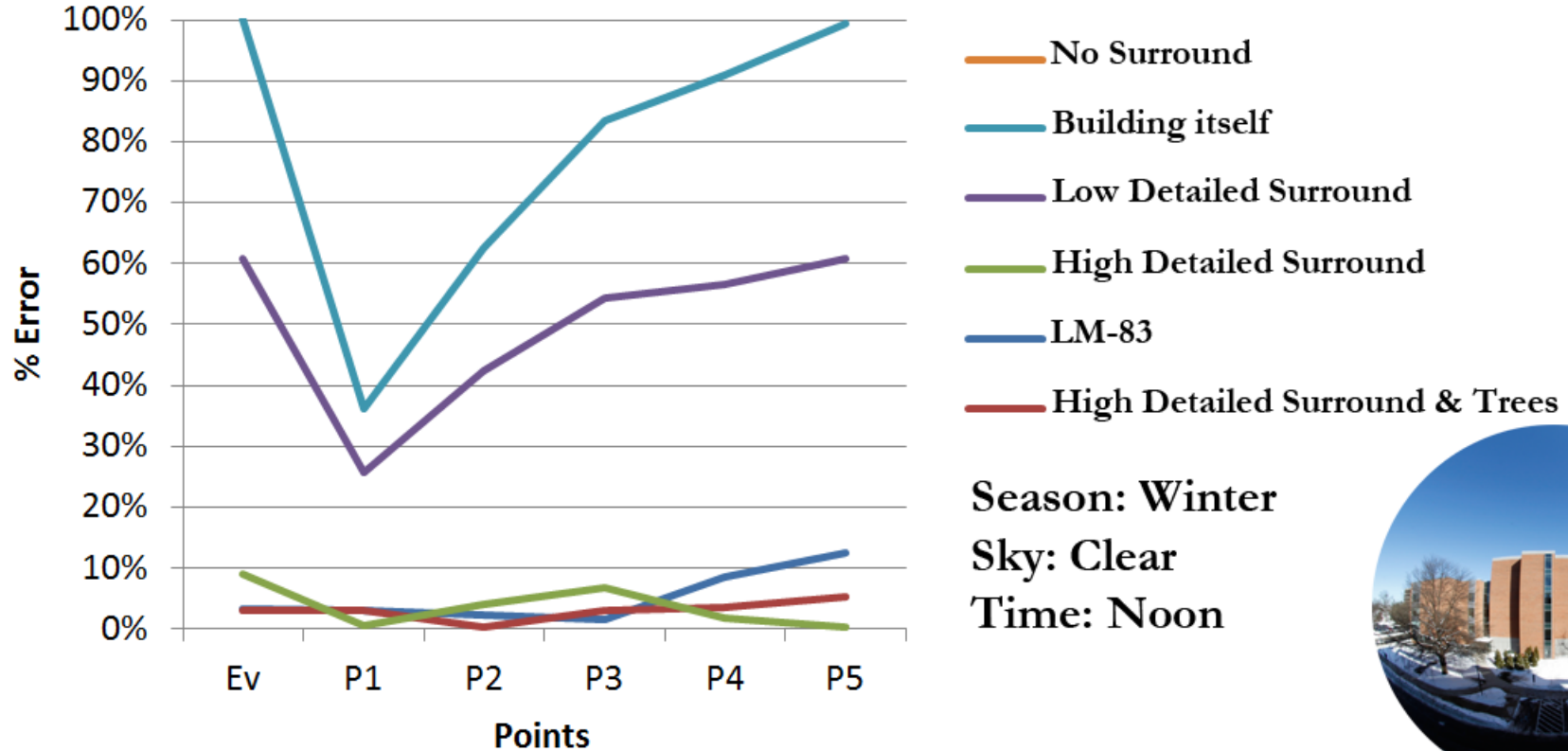
Building itself



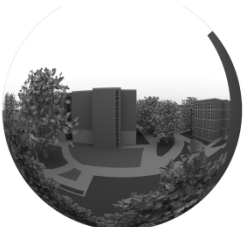
No Surround

# Results

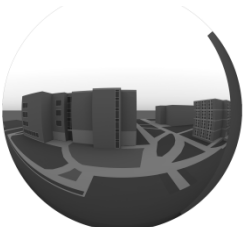
## Winter



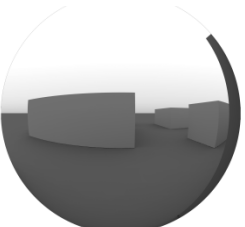
LM-83



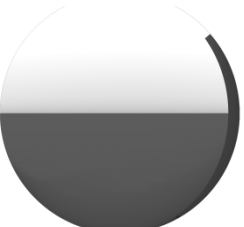
High Detailed Surround + Trees



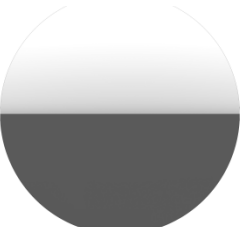
High Detailed Surround



Low Detailed Surround



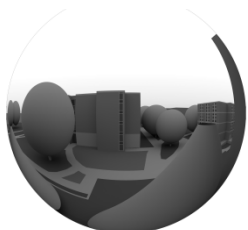
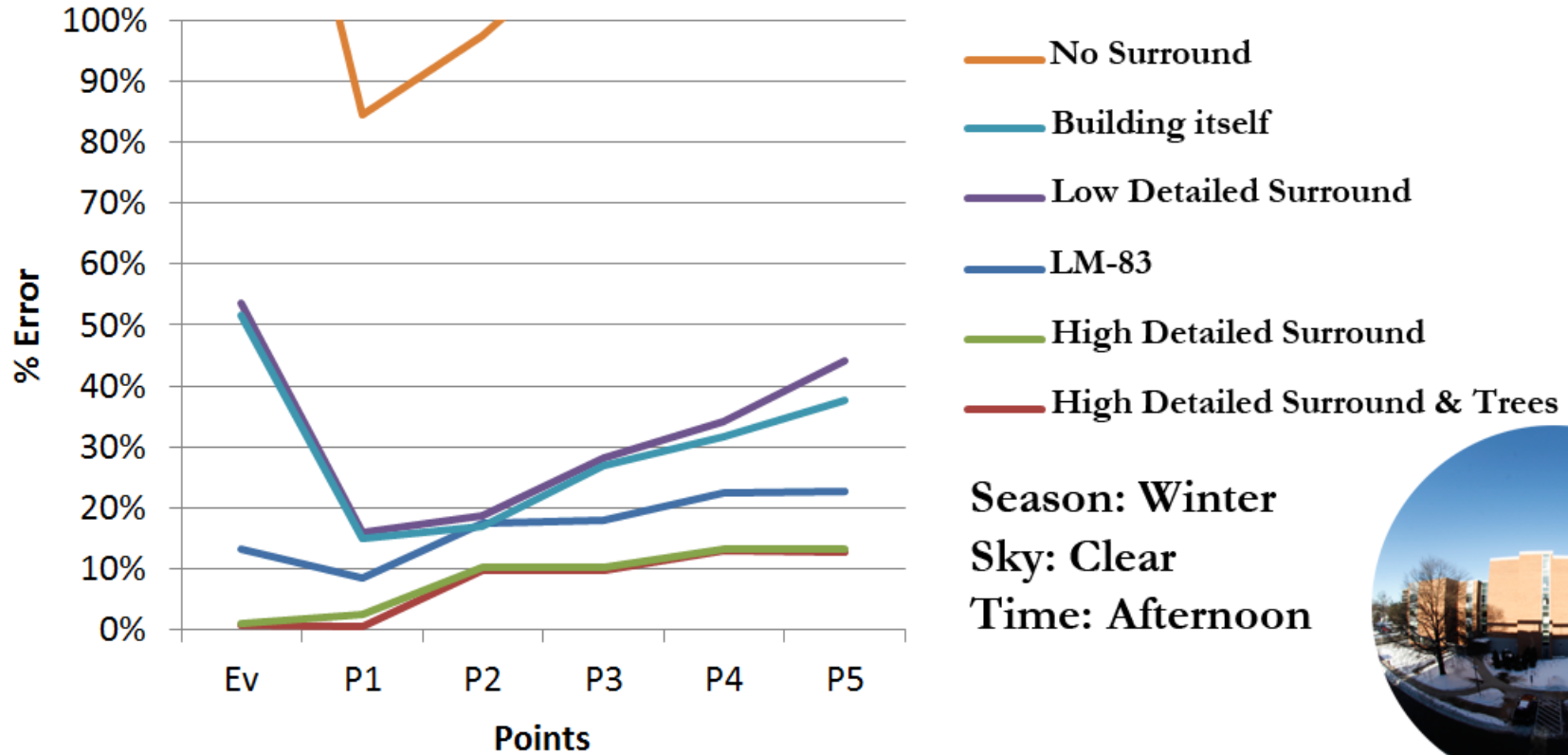
Building itself



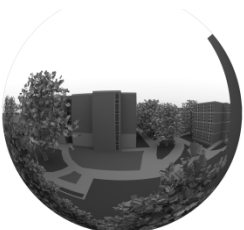
No Surround

# Results

## Winter



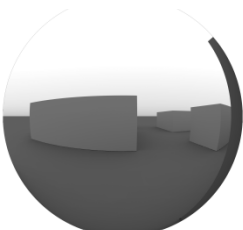
LM-83



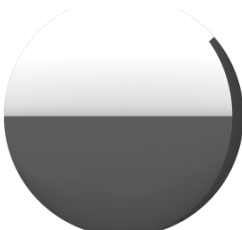
High Detailed Surround + Trees



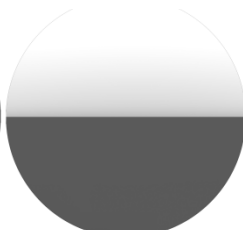
High Detailed Surround



Low Detailed Surround



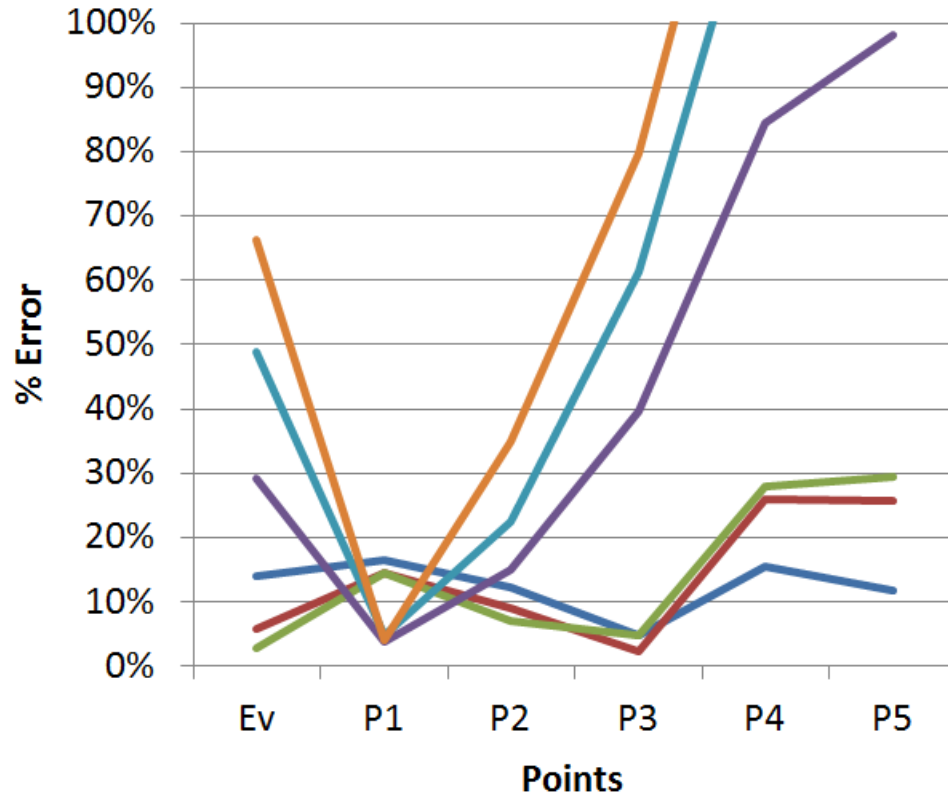
Building itself



No Surround

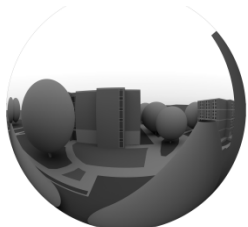
# Results

## Winter

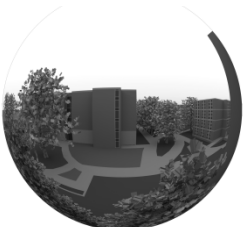


- No Surround
- Building itself
- Low Detailed Surround
- LM-83
- High Detailed Surround
- High Detailed Surround & Trees

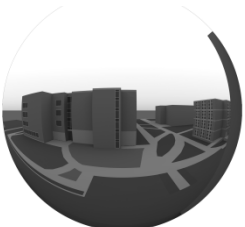
Season: Winter  
Sky: Overcast  
Time: -



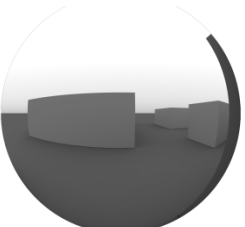
LM-83



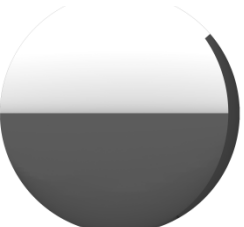
High Detailed Surround + Trees



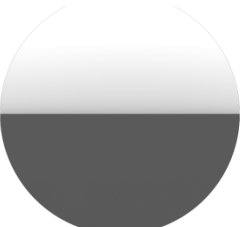
High Detailed Surround



Low Detailed Surround



Building itself



No Surround

# Conclusion

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- Not including exterior elements results in significant error (overestimating the available daylight)
- A high level of detail, including detailed trees, generated the lowest error
- The level of error of LM-83 model was generally acceptable
- Seasonal effects need to be considered



# Comments/Questions

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