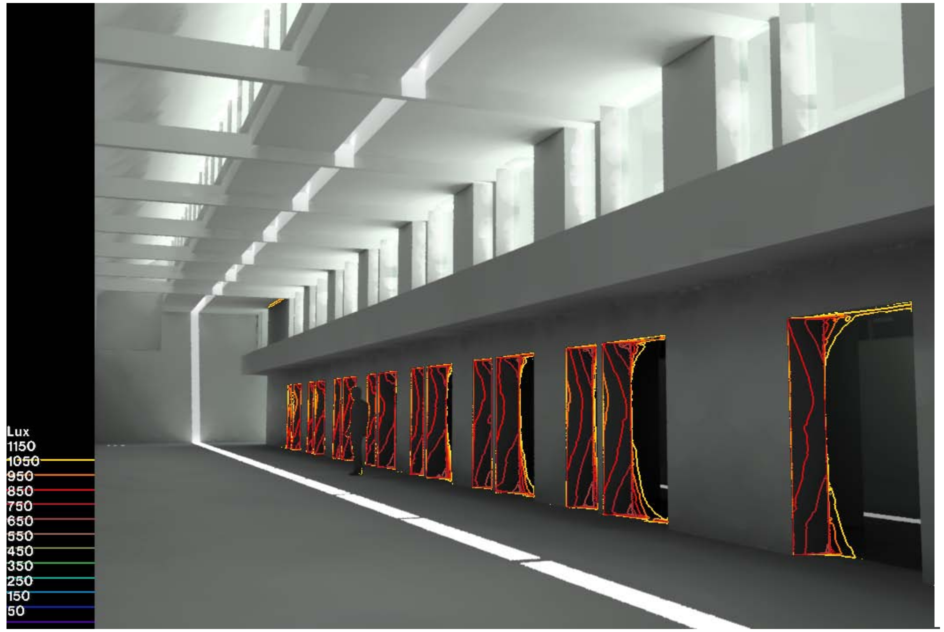
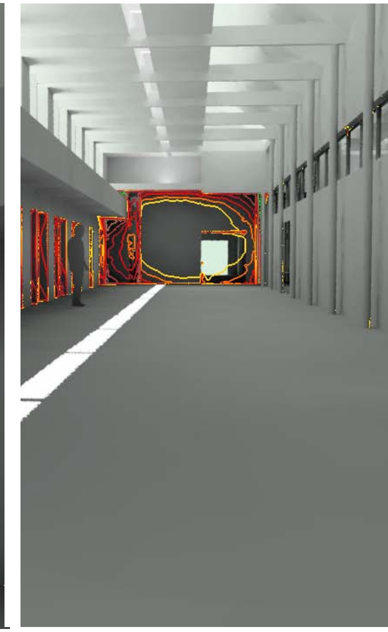
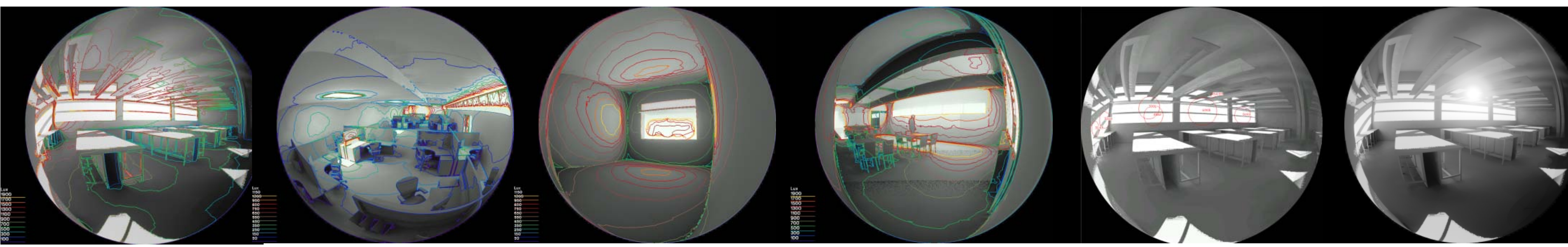
‘Trans’ Materials – Modeling and Specifying a Next Generation







David Mead, Sustainable Building Advisor

Ideas + buildings
that honor the broader
goals of society

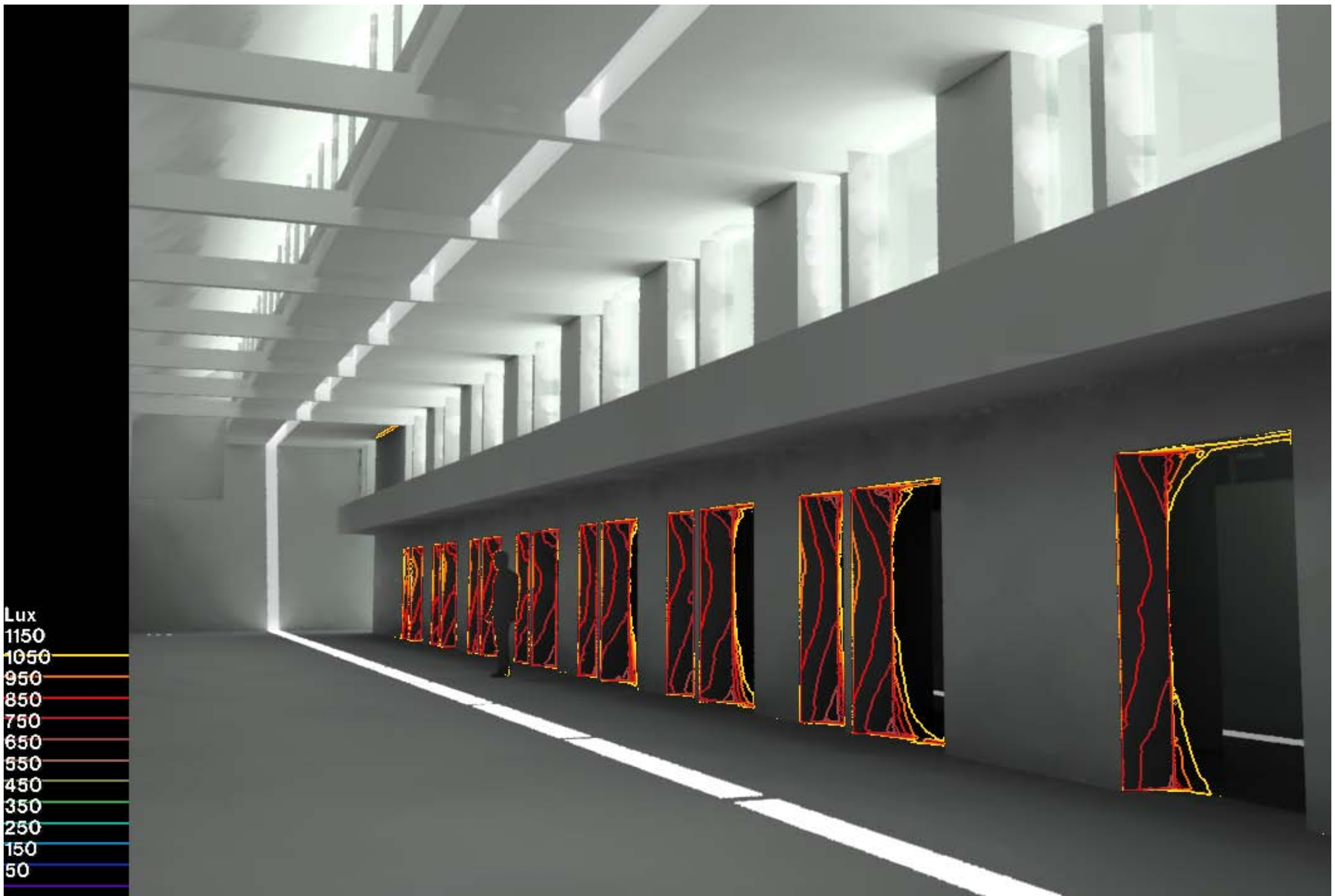
PERKINS+WILL

Why are translucent materials important for building sustainable buildings?

Reasons to use translucent materials:

Roof Monitor & Clerestory glazing:

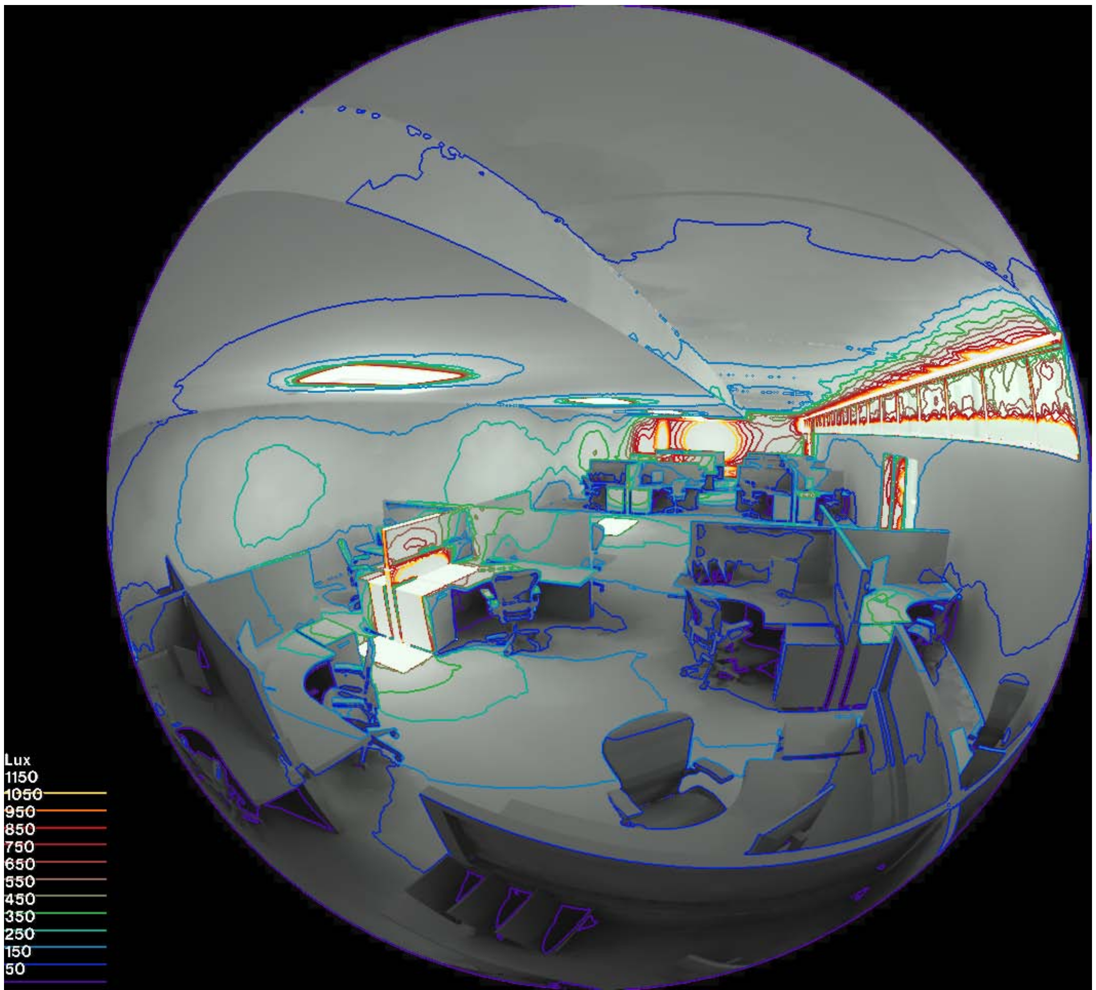
- Avoid expensive initial & long term maintenance options like operable shades & electrochromic glazing
- Avoid options that allow direct sunlight to reach working surfaces through the year like fixed shades and screens



Reasons to use translucent materials:

Skylight glazing:

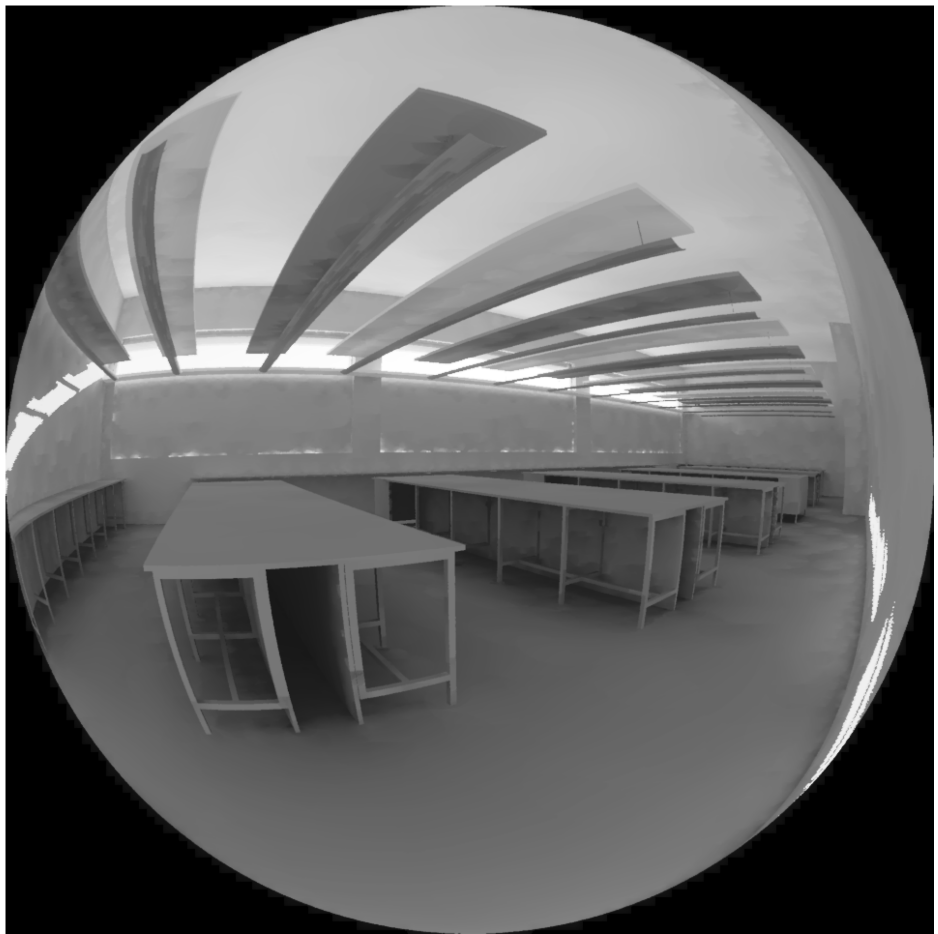
- Doesn't require complex geometry to handle direct sunlight
- Translucent materials better at diffusing light for better spread throughout a space



Reasons to use translucent materials:

Daylight glazing:

- Can be located above vision glazing replacing the need for lightshelfs and operable devices to control direct sunlight
- Translucent materials create diffuse light for a more even distribution of light throughout a space while also limiting views to the parts of the sky that cause relative visual discomfort

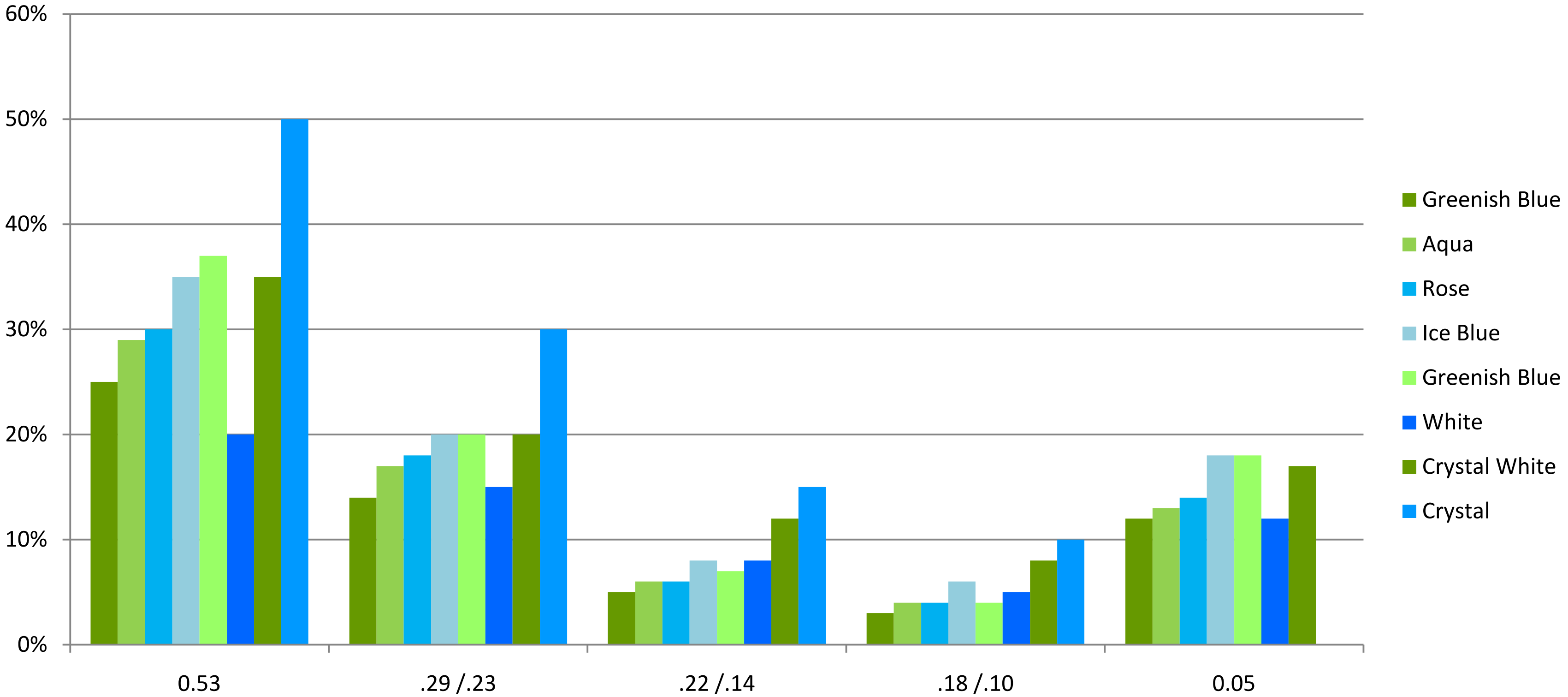


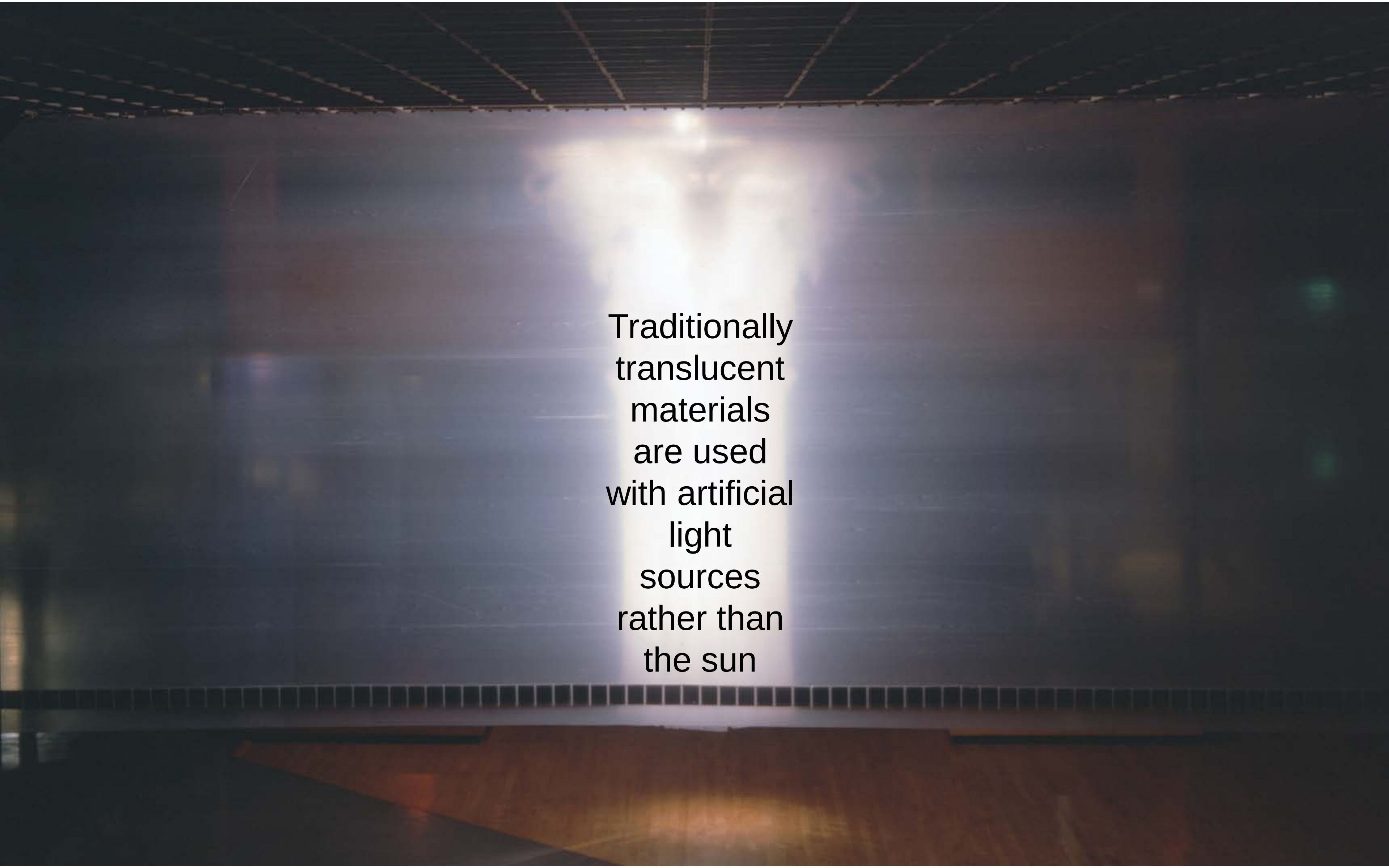
Reasons to be cautious when using translucent materials:

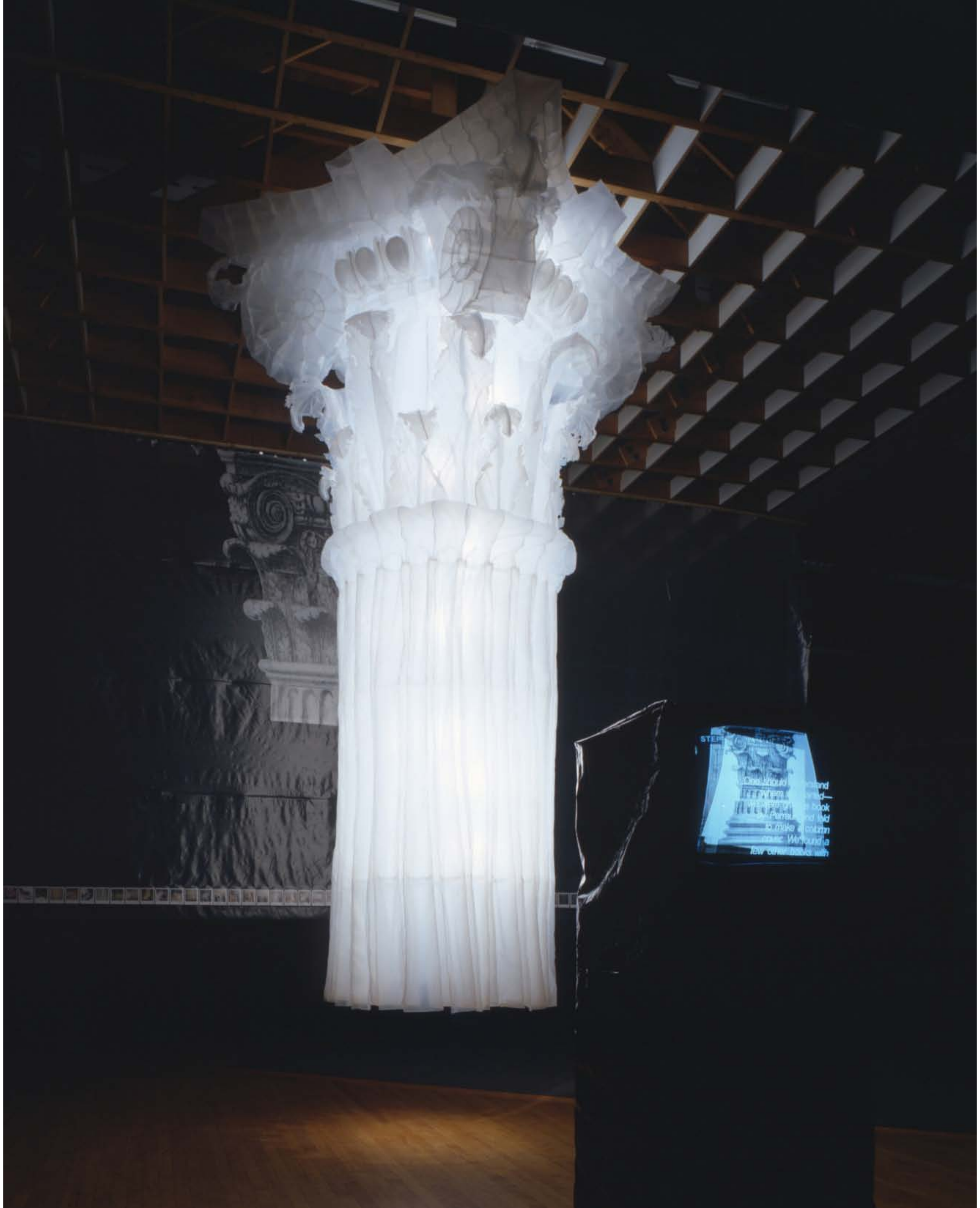
- Good chance there could be relative visual discomfort
- If the project has to use performance based specifications there is no standard performance data to reference so you could get translucent materials that vary from what was modeled

Reasons to be cautious when using translucent materials:

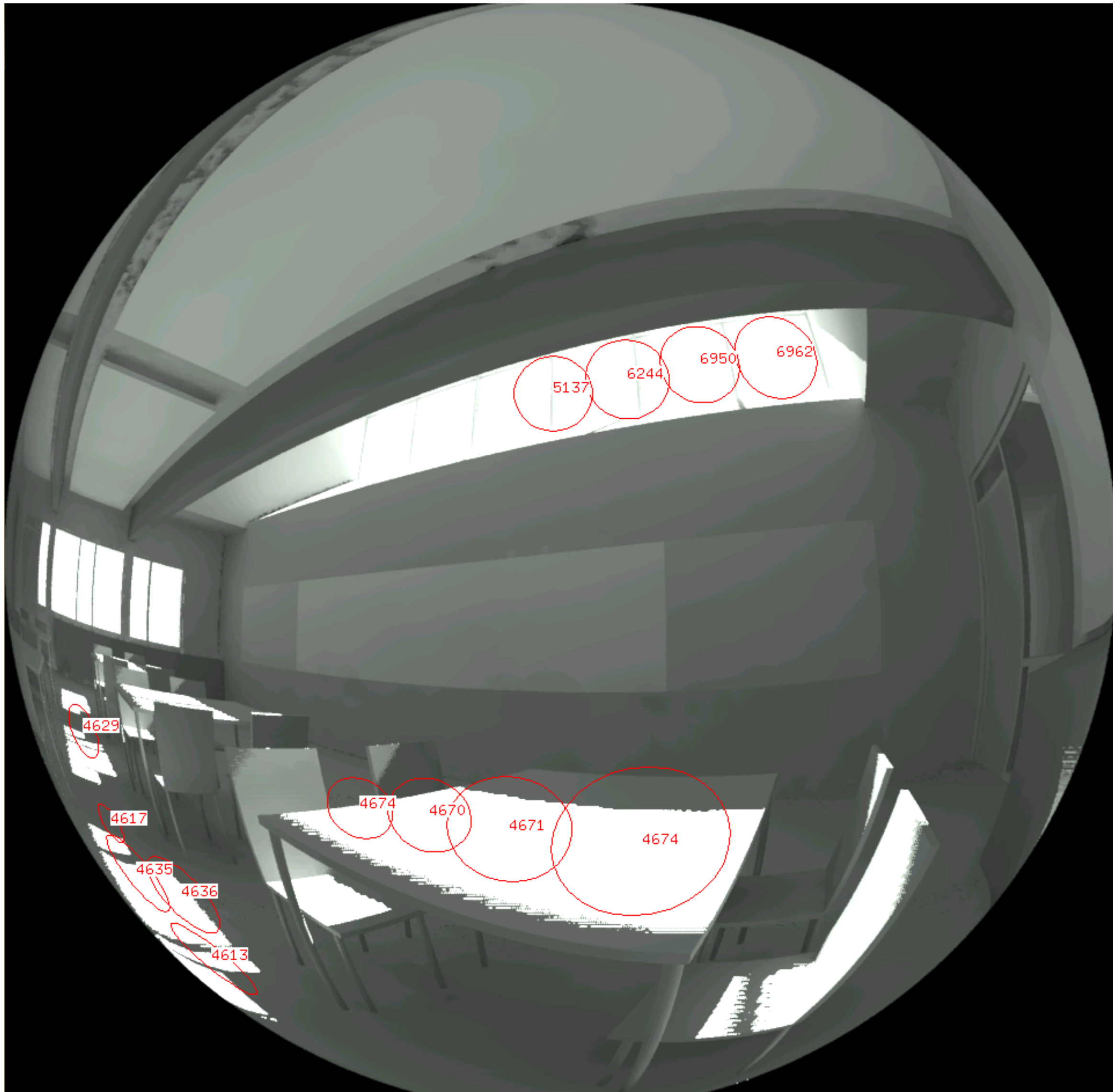
- Due to relative visual comfort issues the VLT of the products may be quite low requiring more area to reach equivalent light levels than with glass



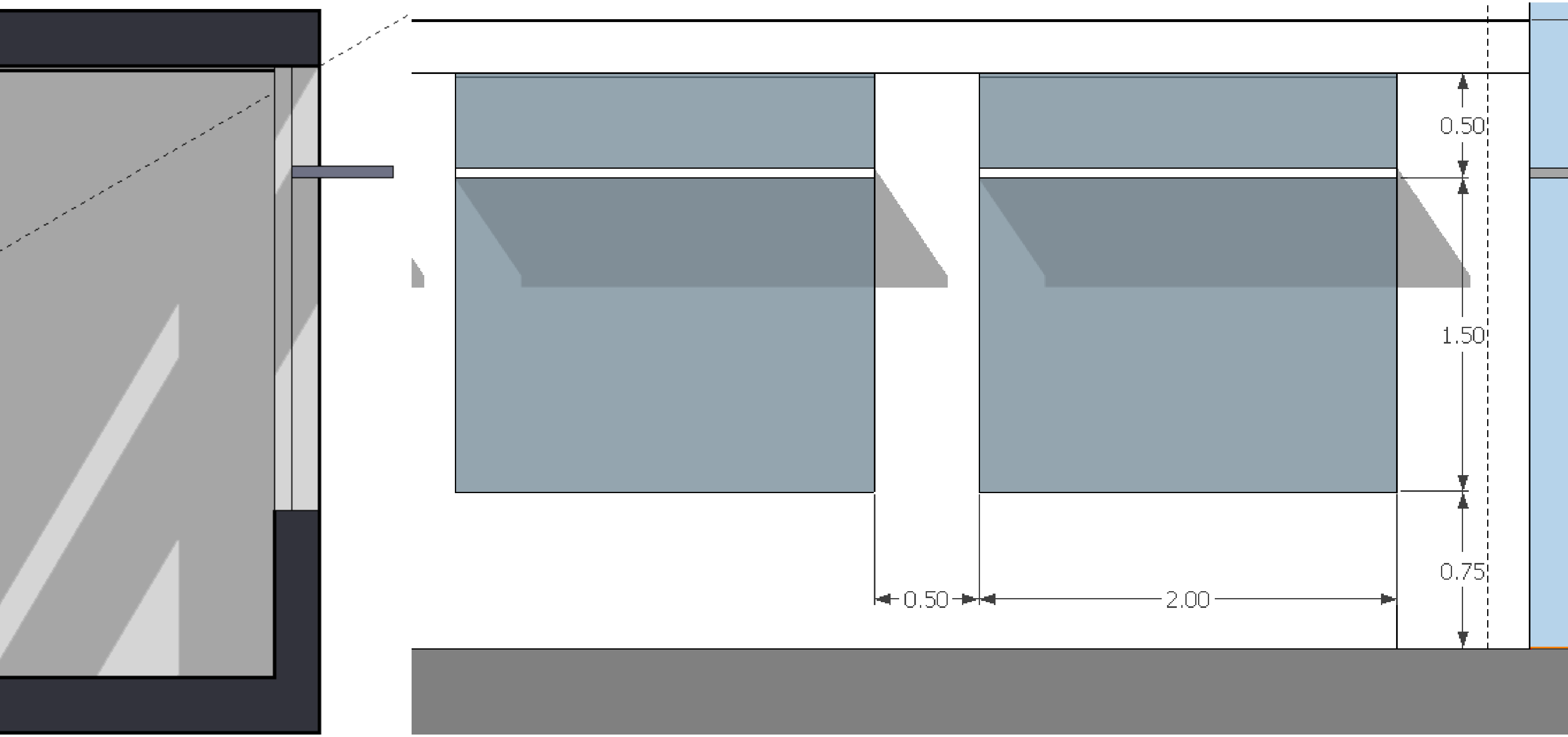

Traditionally translucent materials are used with artificial light sources rather than the sun

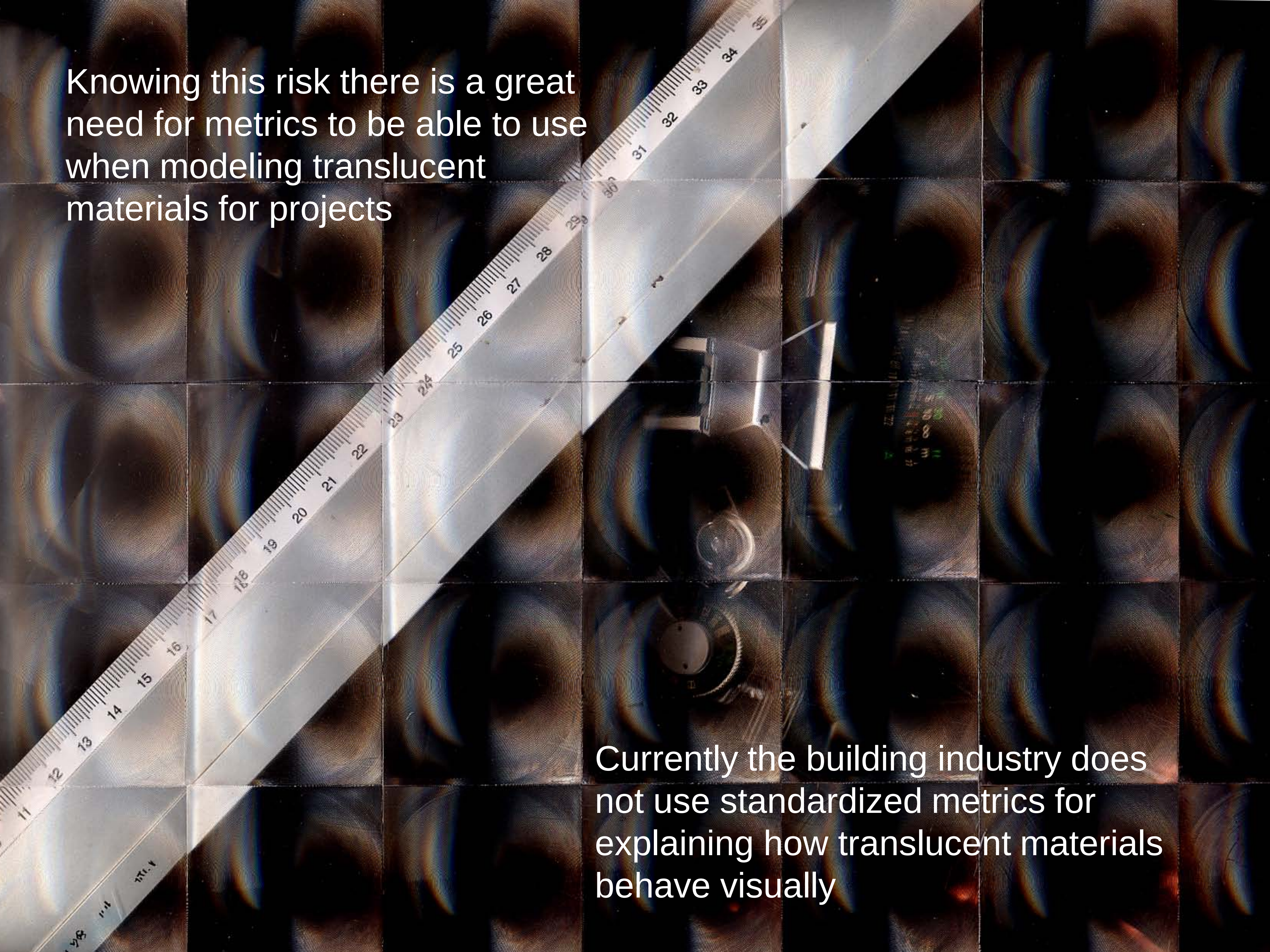


Building envelopes create more challenging design problems as the potential for visual discomfort is very high due to the sun being a far more variable source of light



Currently manufacturers typically only publish visible light transmission and surface reflectance





Knowing this risk there is a great need for metrics to be able to use when modeling translucent materials for projects

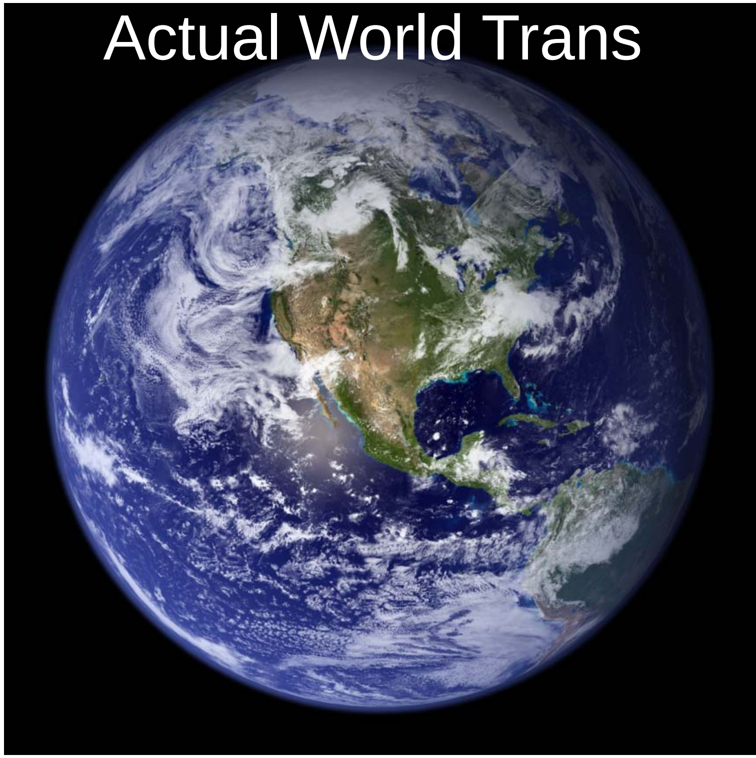
Currently the building industry does not use standardized metrics for explaining how translucent materials behave visually

Transparent Glass has evolved to include standardized measurements that can be obtained from LBNL's Optics programs

Translucent materials are still part of the wild west of modeling

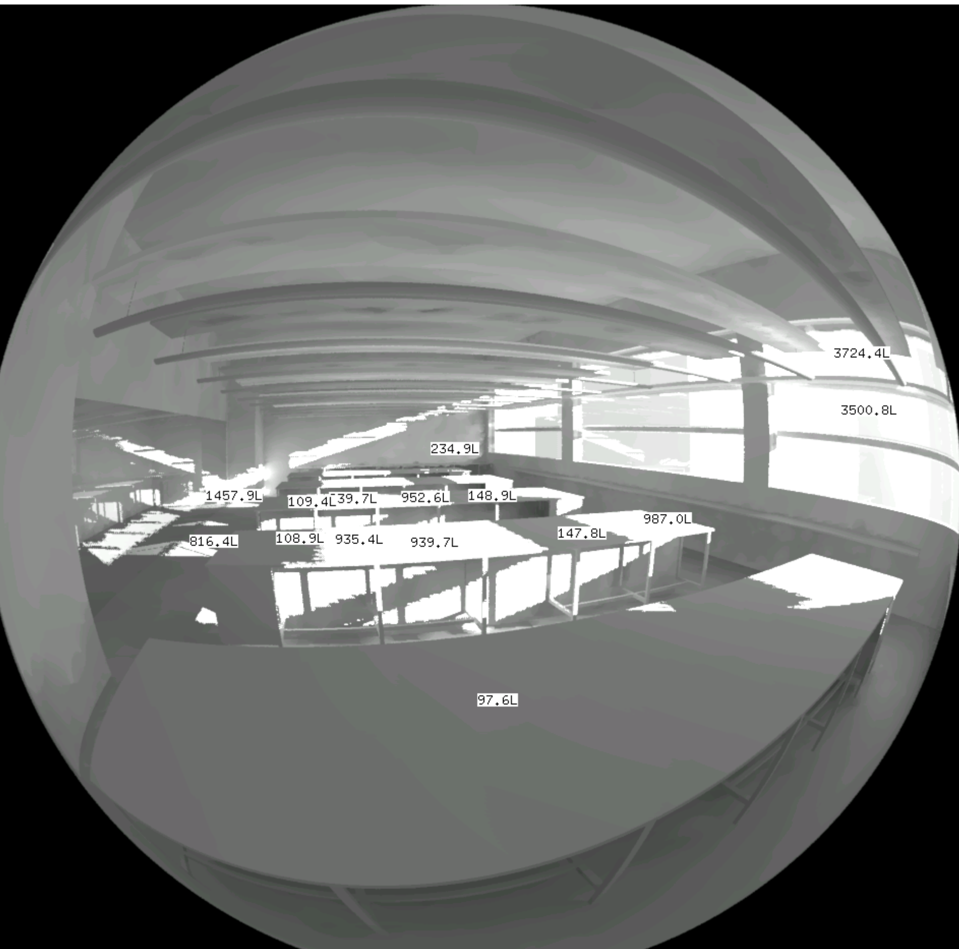
New ISO/ASTM

Standards



This is the case for all translucent materials, there is no common standard for how to measure the Diffuse Reflectance, Reflected Specularity, Surface Roughness, Diffuse Transmission, or Specular Transmission

These can be modeled in Radiance but how does one go about measuring them?



Need special measuring devices to work through this –

gonio-photometers which are currently not in common use in the industry

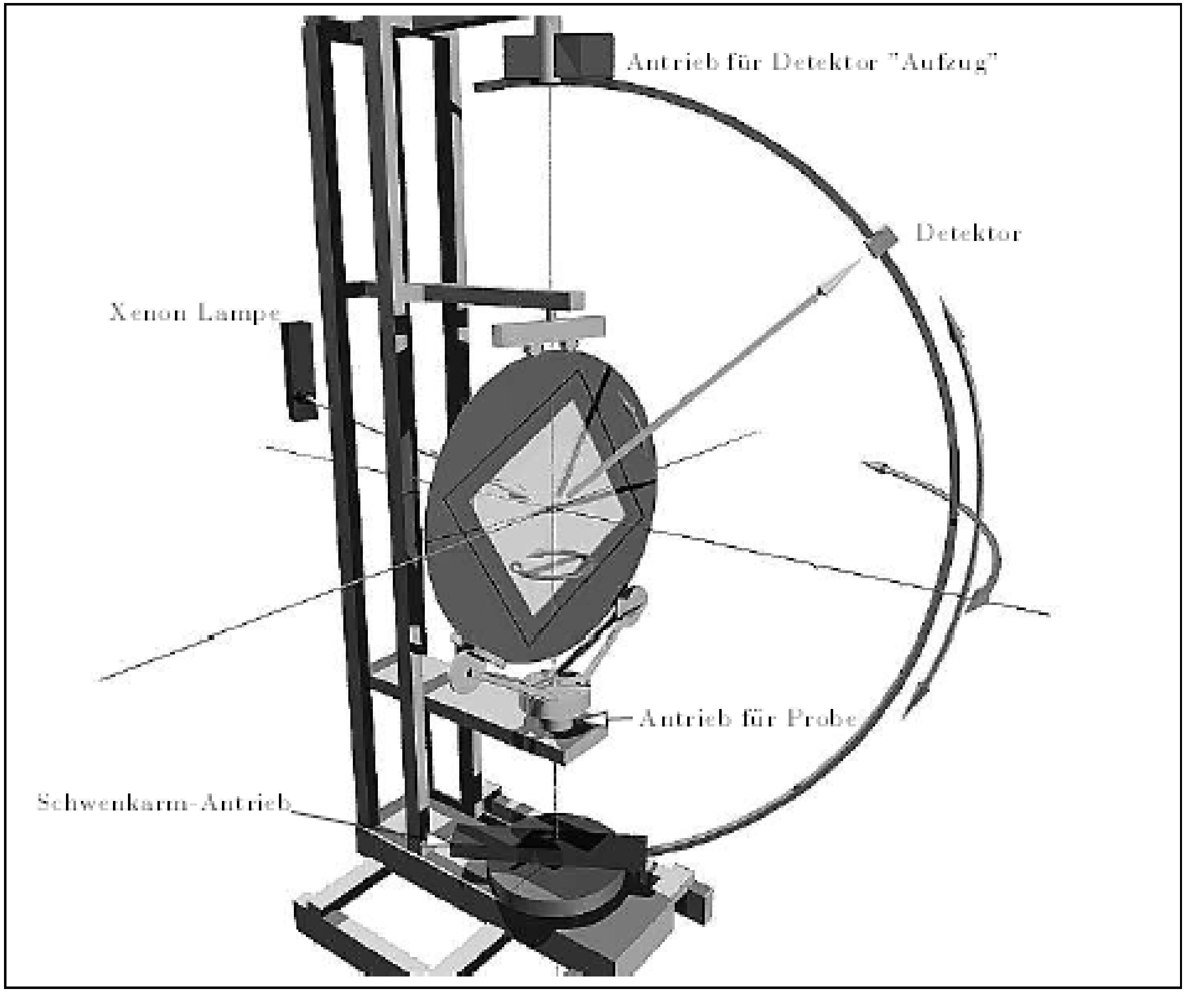
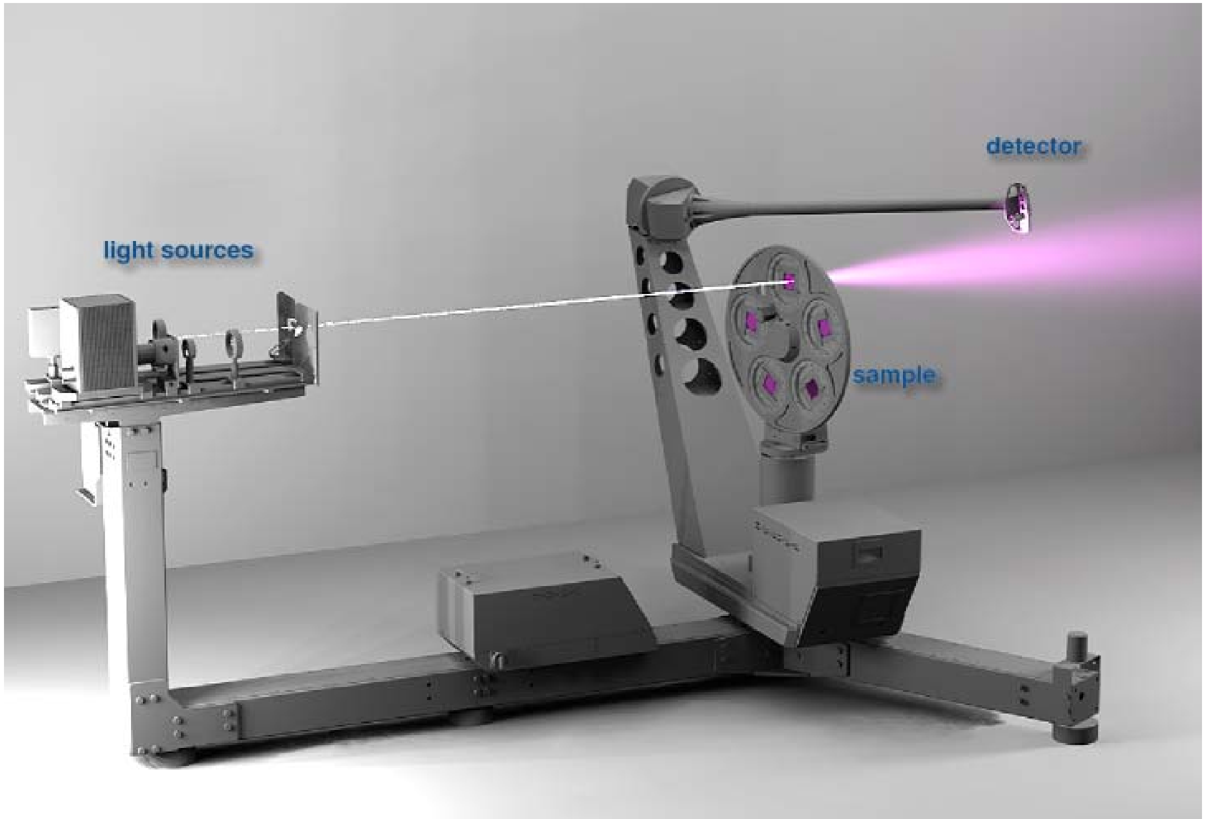


Abbildung 3.4: Perspektivische Ansicht eines Computermodells der Apparatur

This creates risk for designers and engineers as the actual performance is unknown and therefore is hard to specify

For public projects that have performance based specifications for contractors designers cannot reference any applicable standards



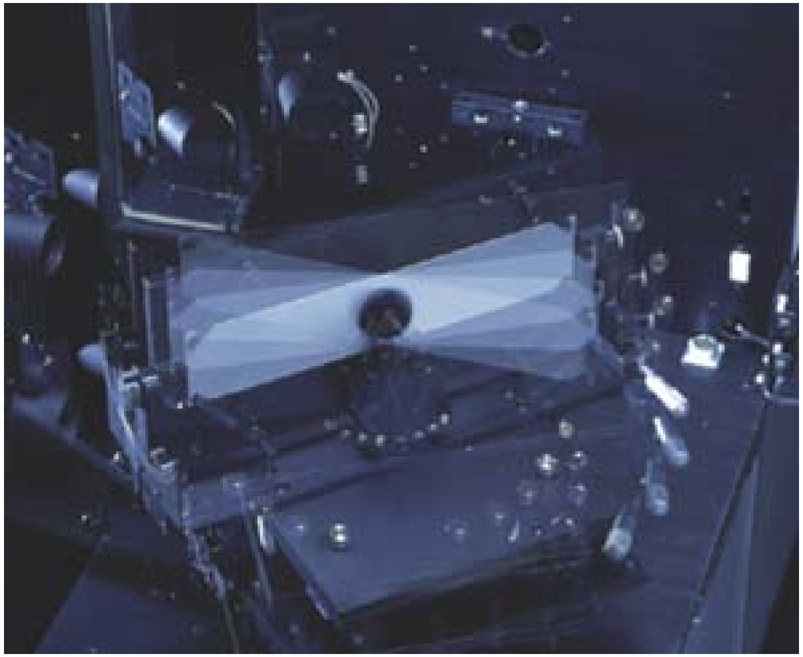
Fritted Glass Performance

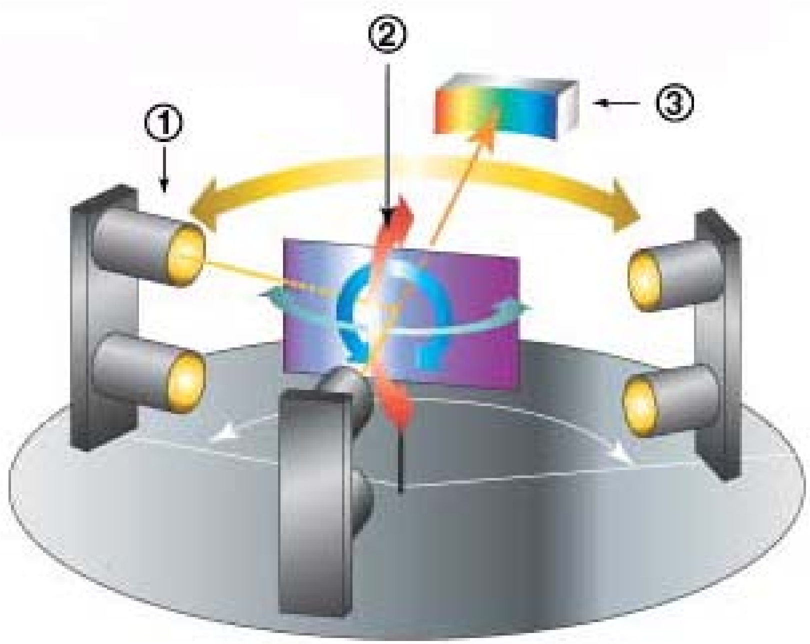
Optics 6 – “Preliminary work has been done to set the stage for a major project to be performed using our new Gonio-spectrophotometer.”

Will be able to measure the BTDF/BRDF

(Bidirectional reflectance distribution function)

(Bi-Directional-Reflectance-Transmission-Function)



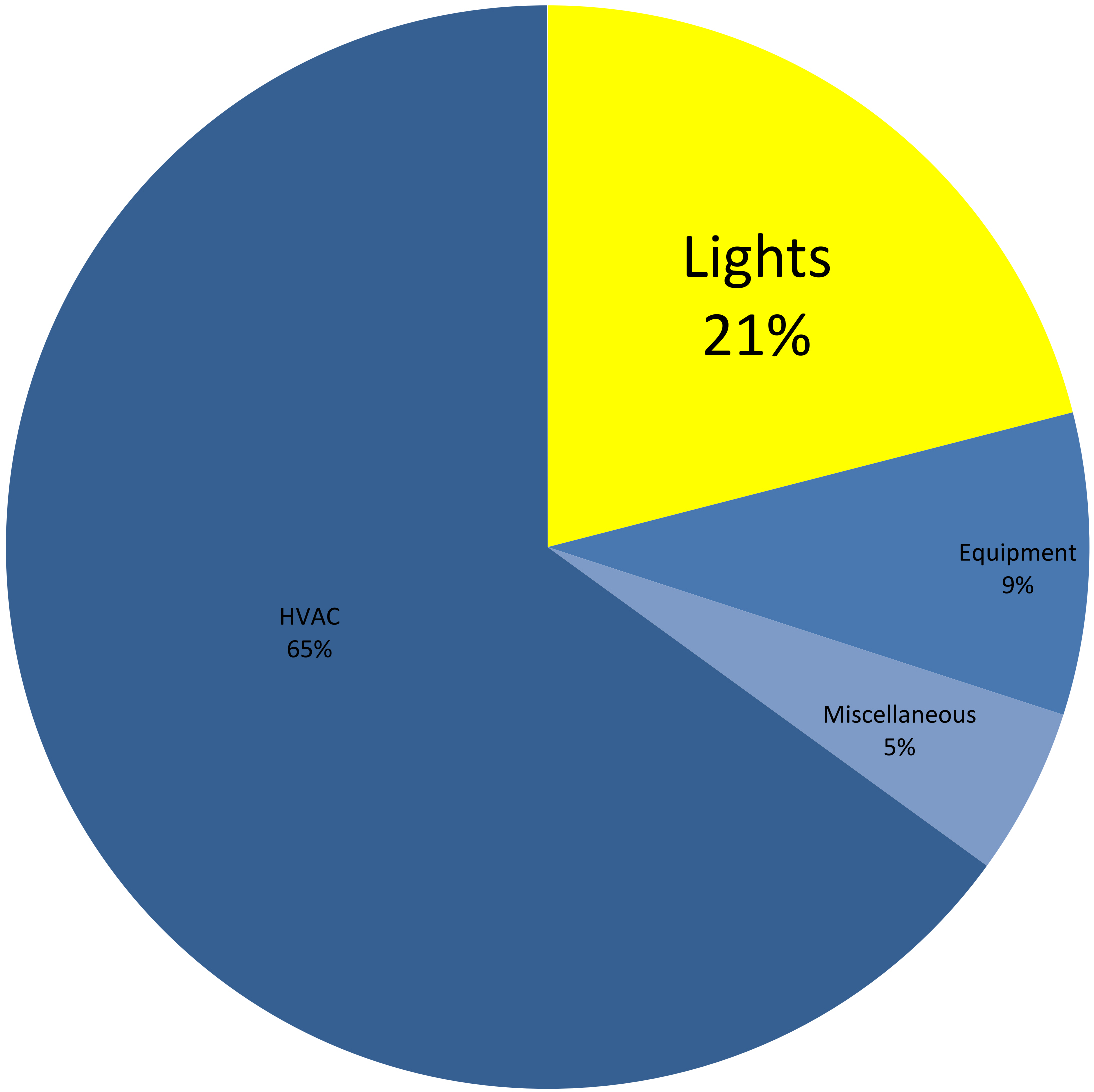


Fritted Glass Performance

Translucent Plastics

“ISO 9050, EN 410, ASTM E903, NFRC 300, are standards for measuring and calculating the properties of specular materials using spectrophotometers. Some of them make vague statements regarding the ability to measure nonspecular materials such as frtted glass, painted slats, etc, but this claim is debatable.”

Performance of nonspecular materials needs to be quantified & verified for architects & engineers to be able to optimize envelopes for daylighting. This in practice could save significant amounts of energy.

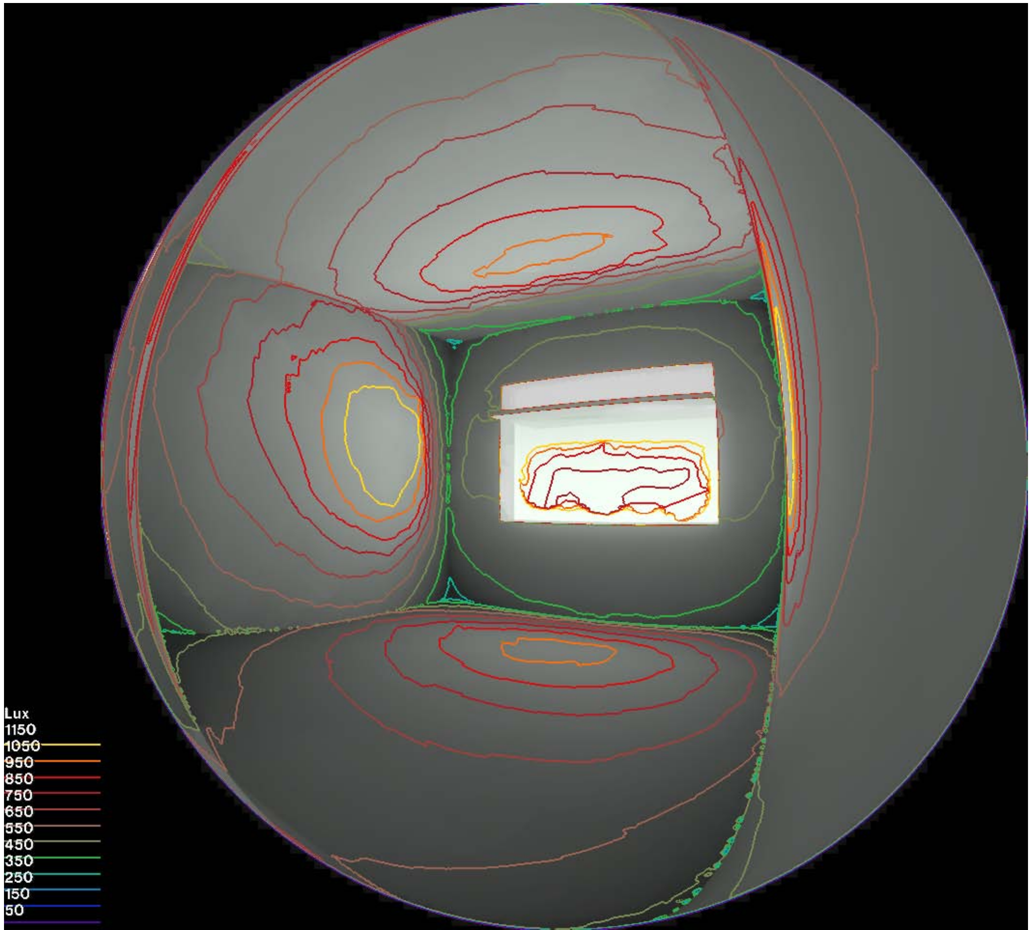


Modeling Radiance ‘trans’ materials as to represent translucent materials that can be specified

1st rule of ‘trans’ materials

According to page 325 of the *Rendering with Radiance2* book the *trans* material is:

"...one of the most confusing material entities in the Radiance repertoire. However, it is the simplest material that will trace direct source rays through a semispecular surface in order to determine diffuse and specular transmitted components…".



Trans

(definition from The RADIANCE 3.5 Synthetic Imaging System Manual)

Trans is a translucent material, similar to plastic. The *diffuse transmittance* is the fraction of penetrating light that travels all the way through the material.

The transmitted specular component is the fraction of transmitted light that is not diffusely scattered. Transmitted and diffusely reflected light is modified by the material color. Translucent objects are infinitely thin.

mod trans id

0

0

7 red green blue spec rough trans tspec

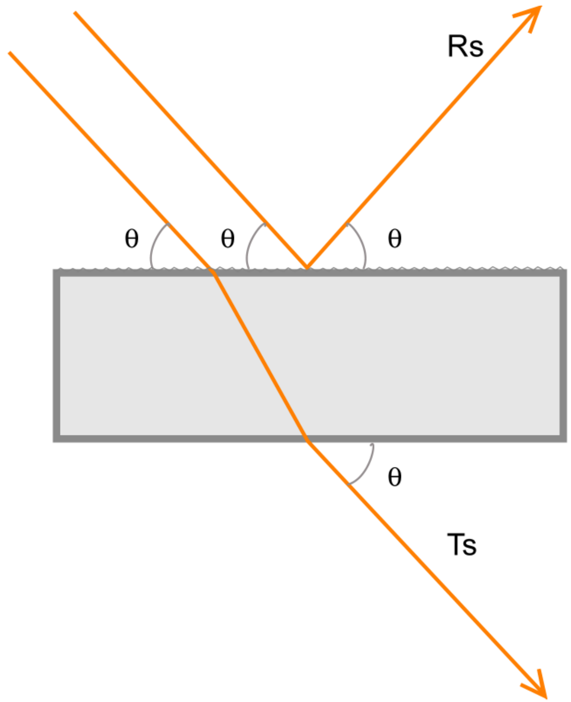
IESNA definitions:

Transmissivity = (transmittance per unit distance)

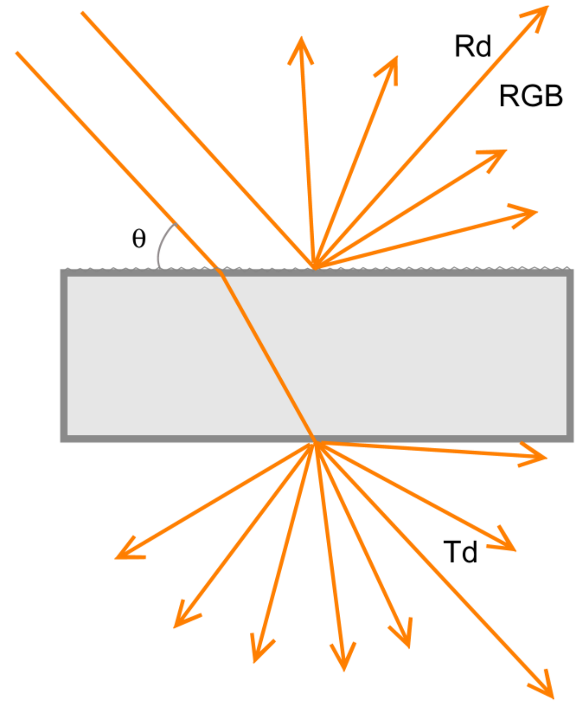
Transmittance: Ratio of the transmitted flux to the incident flux

Function of:

- Geometry
  - of the incident flux
  - of collection for the transmitted flux
- Spectral Distribution
  - characteristic of the incident flux
  - weighting function for the collected flux
- Polarization (*Ignored by Radiance*)
  - of the incident flux
  - component defined for the collected flux



$$E = \frac{I\,\tau^{x}}{x^{2}}$$



Cr,Cg,Cb are the diffuse reflectance in R,G,B channels

Diffuse Transmission (Td) - (fraction transmitted diffusely in a scattering fashion)

Specular Transmission (Ts) - (fraction transmitted as a beam, like through clear glass, not scattered)

Diffuse Reflection (Rd)

Specular Reflectance (Rs)

Absorption

Sr is surface roughness (similar to plastic)

Diffuse Reflectance (Cr)	Color (black = min 0, white = max 1)
Diffuse Reflectance (Cg)	Color (black = min 0, white = max 1)
Diffuse Reflectance (Cb)	Color (black = min 0, white = max 1)
Reflected Specularity (Rs)	Matte = min 0, Satin = suggested max 0.07
Surface Roughness (Sr)	Polished = 0, Low gloss = suggested max 0.02
Diffuse Transmission (Td)	Opaque = 0, Transparent = 1
Specular Transmission (Ts)	Diffuse = 0, Clear = 1

The reflected specularity of common uncoated glass is around .06

void trans material

0

0 *Roughness*

A1	A2	A3	A4	A5	A6	A7
R	*G*	*B*	*Specular Reflectance*	*Roughness*		

A1=Cr / ((1-Rs)*(1-A6))

A2=Cg / ((1-Rs)*(1-A6))

A3=Cb / ((1-Rs)*(1-A6))

A4=Rs

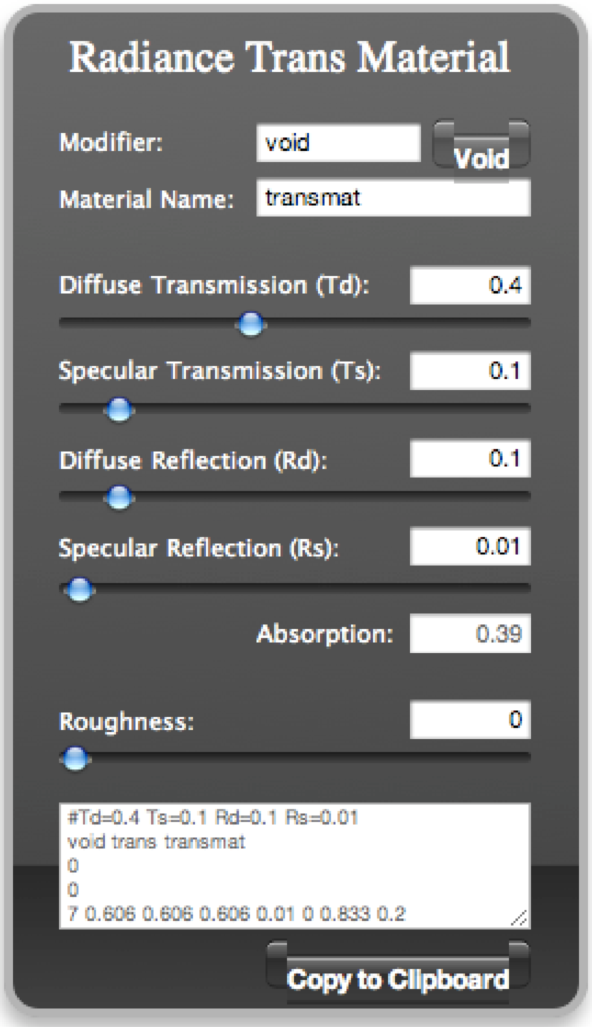
A5=Sr

A6=(Td + Ts) / (Rd + Td + Ts)

A7=Ts / (Td + Ts)

Then the –st setting for rpict or rtrace should be:

St = A6*A7*(1 – photopic average (A1,A2,A3) * A4)




```
# RADIANCE “trans” model of a translucent panel assuming
# only direct normal hemispherical transmittance is available
# Rd = Cr = C = C = 0.21 = diffuse reflectance g b
# Rs = A =0.08 = specular reflectance  4
# Sr = 0.0 = surface roughness
# Td = 0.24 = direct normal diffuse hemispherical transmittance
# Ts = 0 = transmitted specularity (ideal diffuser)
# A7 = T/(Ts s d+T) = 0
# A6 = (T+T)/(Rd+Td+Ts) = 0.5333 d s
# A5 = Sr = 0
# A1 = A2 =A = R3 s
# S = A*A*(1-A)*A4 = 0
d/((1-R)*(1-A6)) = 0.48913
t 6 7 1
# resulting Radiance material:
void trans PANEL
0
0
7 0.48913 0.48913 0.48913 0.08 0  0.5333 0
# A1      A2      A3      A4   A5 A6     A7
```

http://software.mcneilorama.com/Gen_Trans_Widget.html

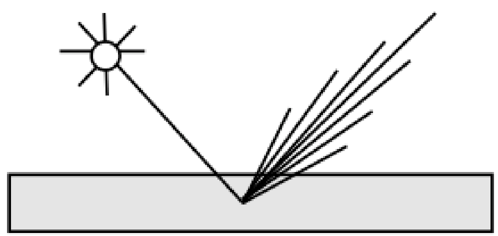
When a ray (and its radiance) hits a surface, it can be reflected, transmitted, or absorbed

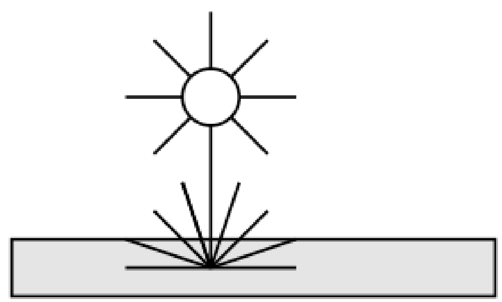
How much is reflected: BRDF (Bidirectional reflectance distribution function)

How much is transmitted: BTDF (Bi-Directional-Reflectance-Transmission-Function)

Most of the time it does the 3 things at the same time, but one component is the most dominant.

(BRDF and BTDF i.e. ratio of the luminance emerging from the sample after either reflection or transmission and incident illuminance on the sample plane)

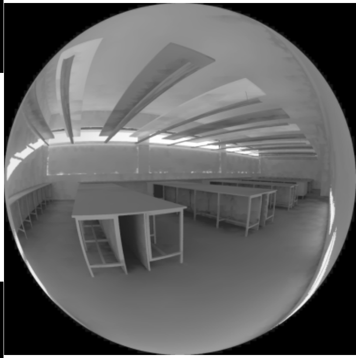




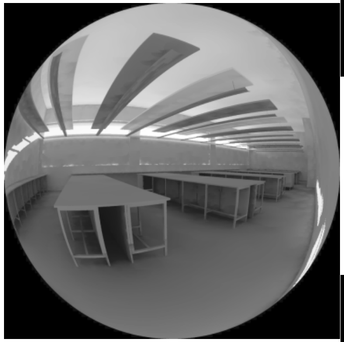
Examples of Radiance ‘trans’ modeling

									Cr,Cg,Cb	0.25
void		trans	trans_01						Rs	0
	0								Sr	0
	0								td	0.15
	7	0.294	0.294	0.294	0	0	0.67	0.7	ts	0.35

									Cr,Cg,Cb	0.25
void		trans	trans_02						Rs	0
	0								Sr	0
	0								td	0
	7	0.250	0.250	0.250	0	0	0.67	1	ts	0.5

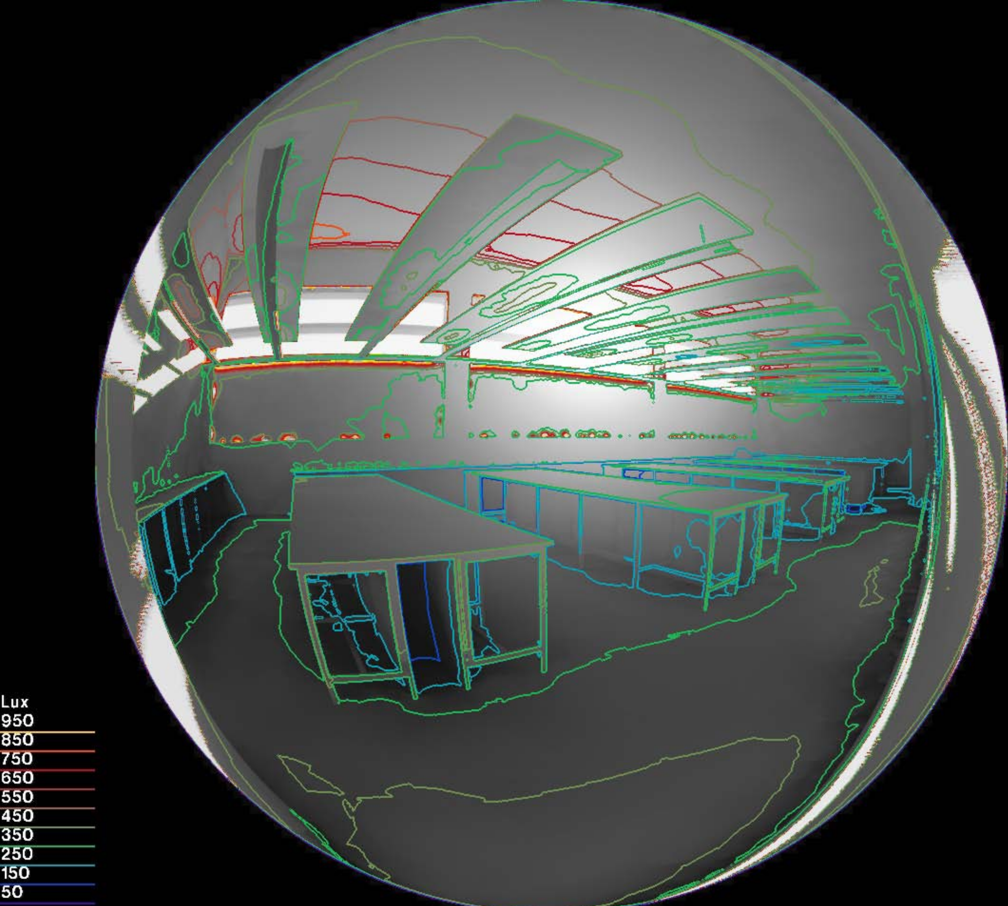


									Cr,Cg,Cb	0.25
void		trans	trans_03						Rs	0
	0								Sr	0
	0								td	0.25
	7	0.333	0.333	0.333	0	0	0.67	0.5	ts	0.25

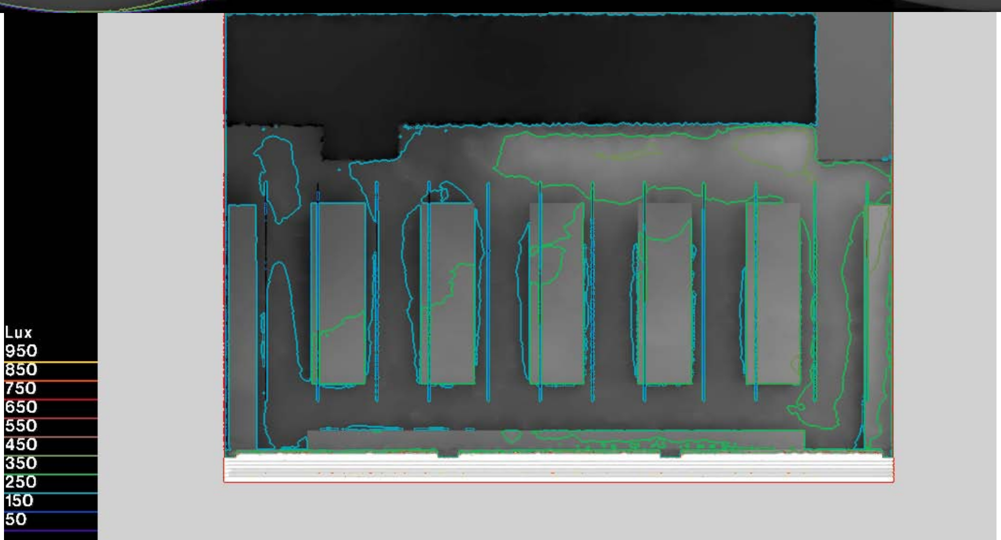


									Cr,Cg,Cb	0.25
void		trans	trans_04						Rs	0
	0								Sr	0
	0								td	0.5
	7	0.5	0.5	0.5	0	0	0.67	0	ts	0

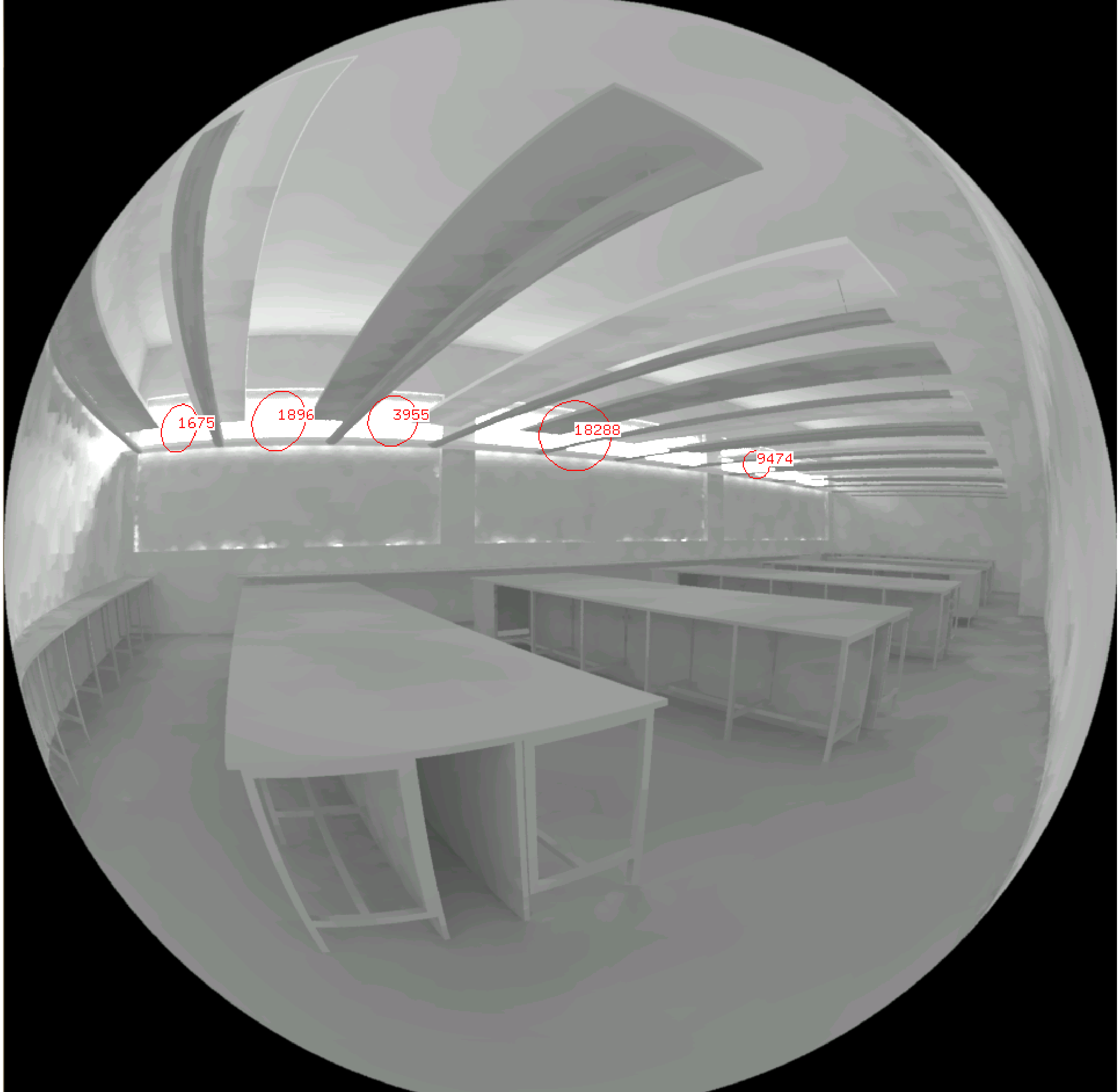
									Cr,Cg,Cb	0.25
void		trans	trans_05						Rs	0
	0								Sr	0.25
	0								td	0.25
	7	0.333	0.333	0.333	0	0.25	0.67	0.5	ts	0.25



Cr,Cg,Cb	0.25
Rs	0
Sr	0
Td	0.15
Ts	0.35



No Vision Glazing
Trans_01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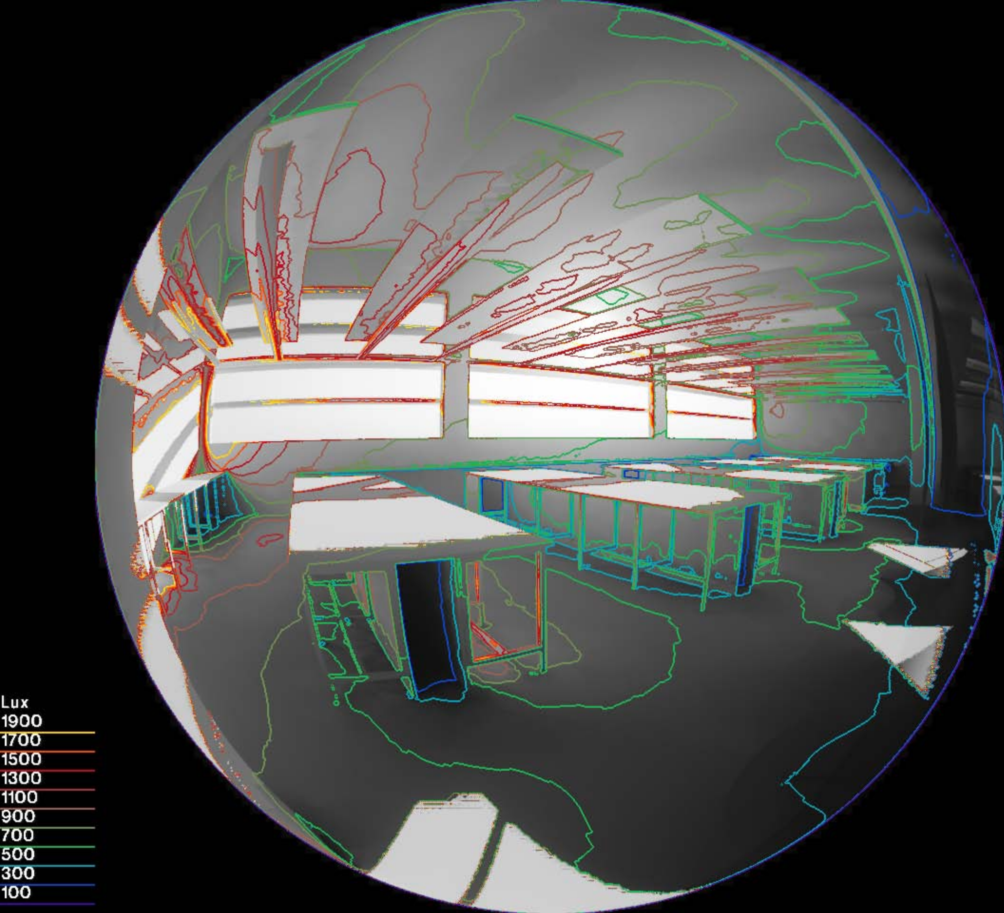
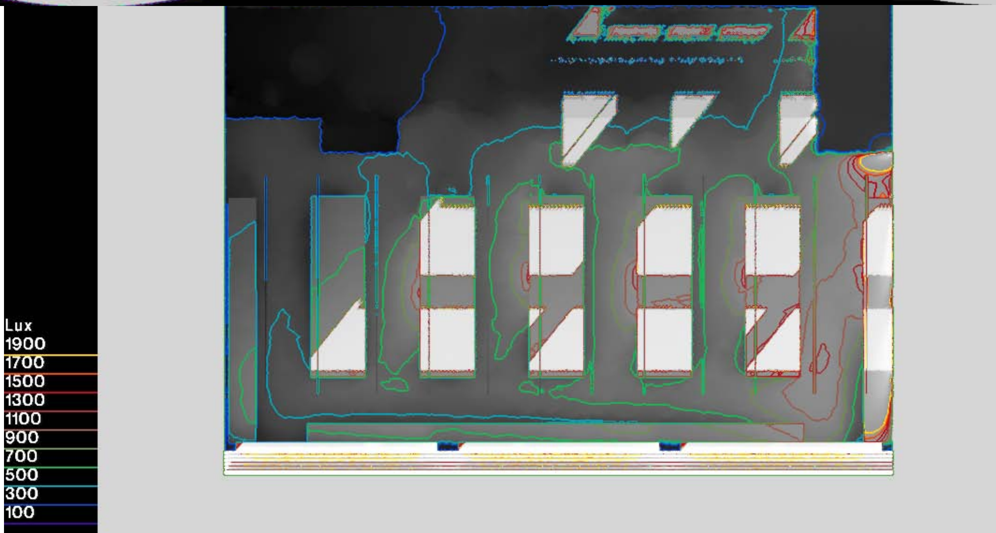
3955
18288
9474





Cr,Cg,Cb	0.25
Rs	0
Sr	0
Td	0.15
Ts	0.35

Vision Glazing
Trans_01

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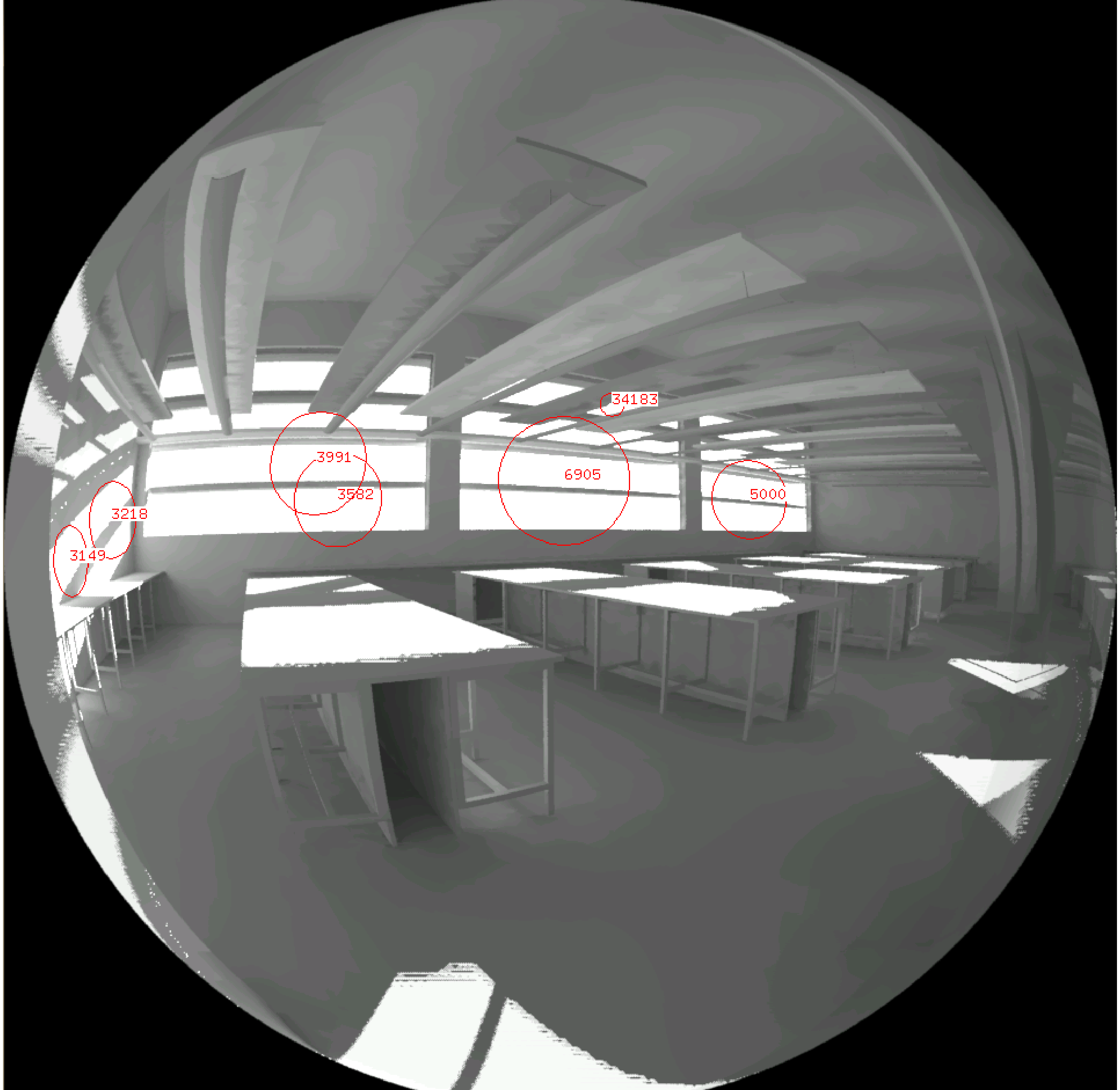
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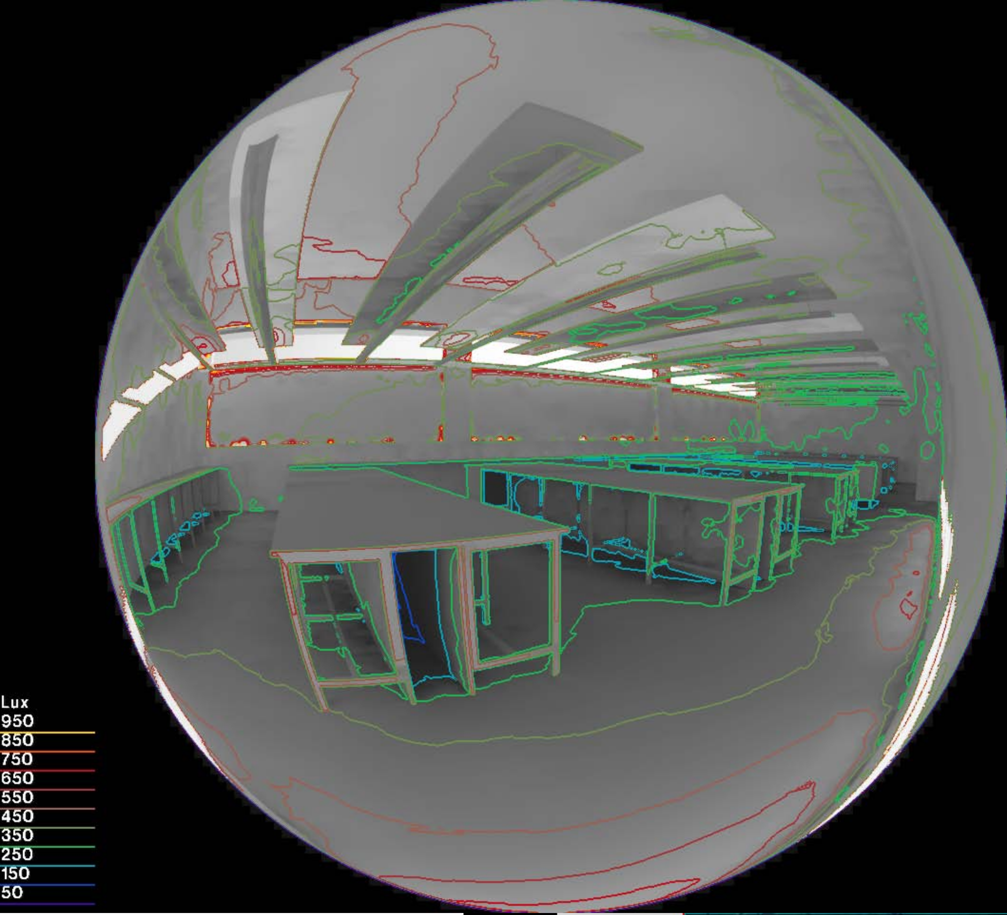
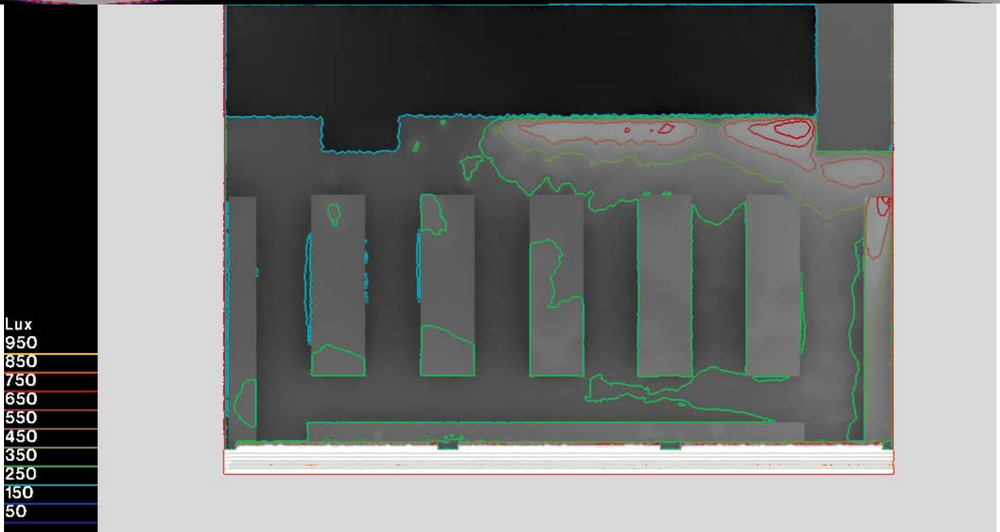
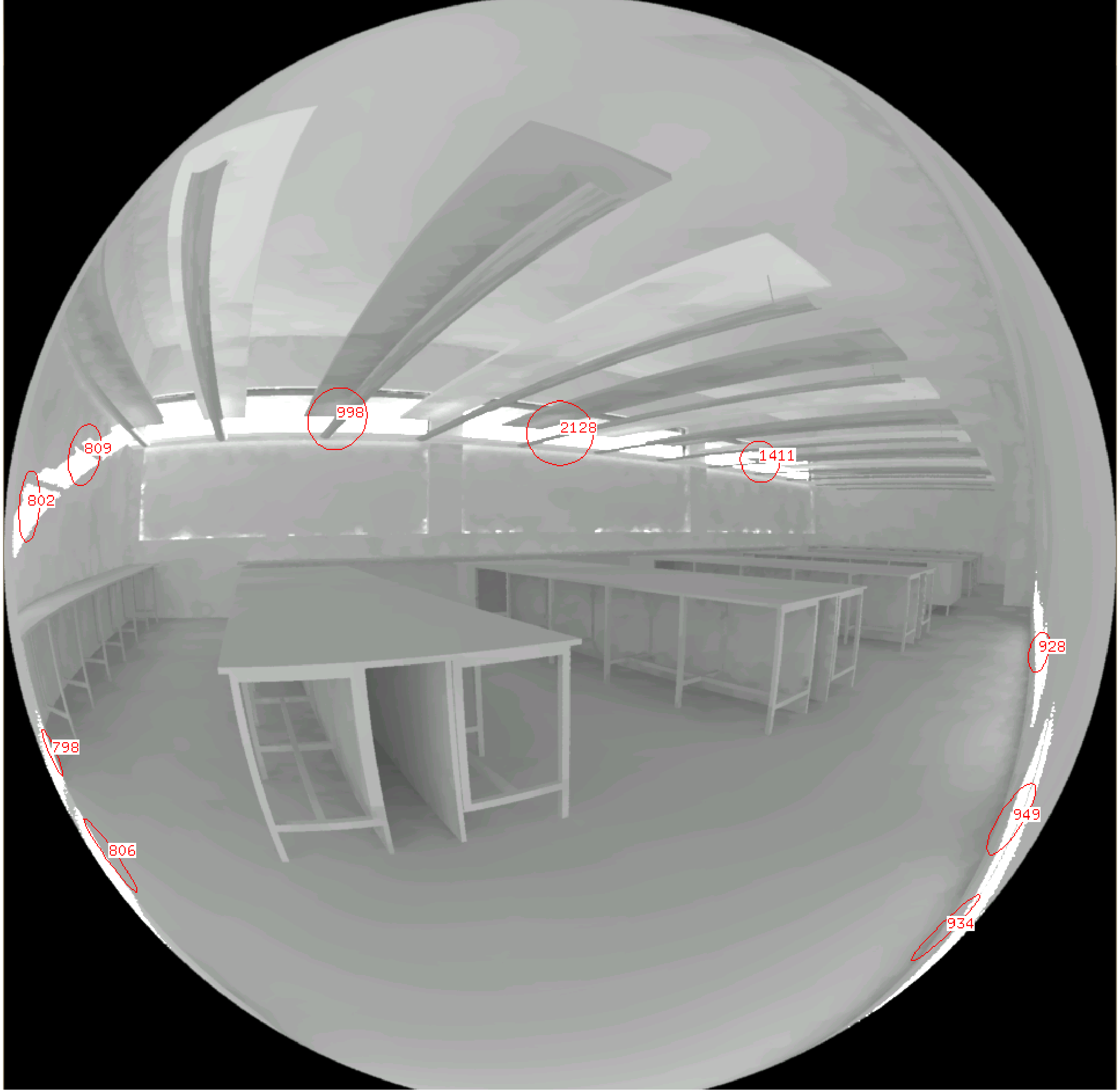


Cr,Cg,Cb	0.25
Rs	0
Sr	0
td	0
ts	0.5



No Vision Glazing
Trans_02

PERKINS+WILL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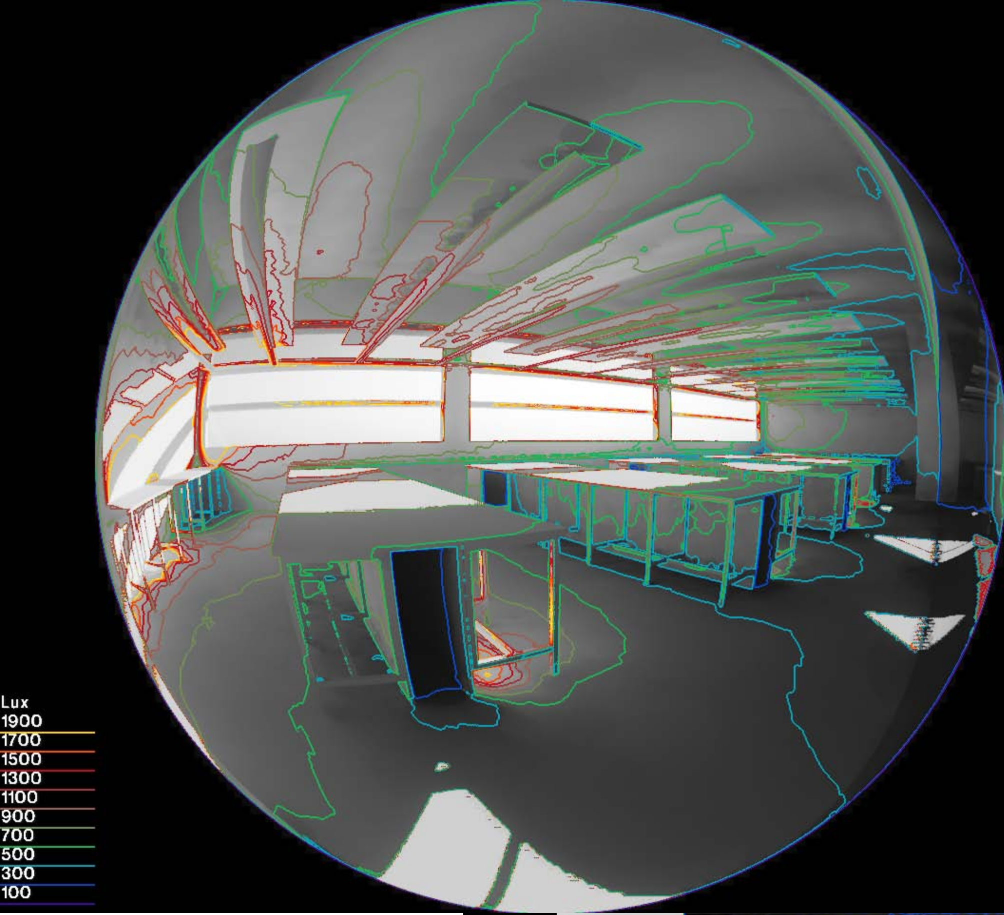
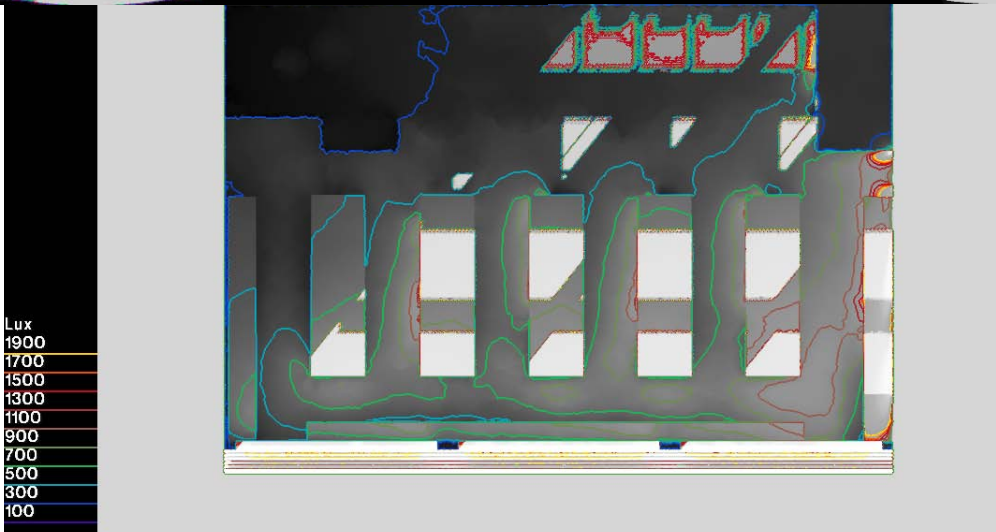
802
928
798
949
806
934

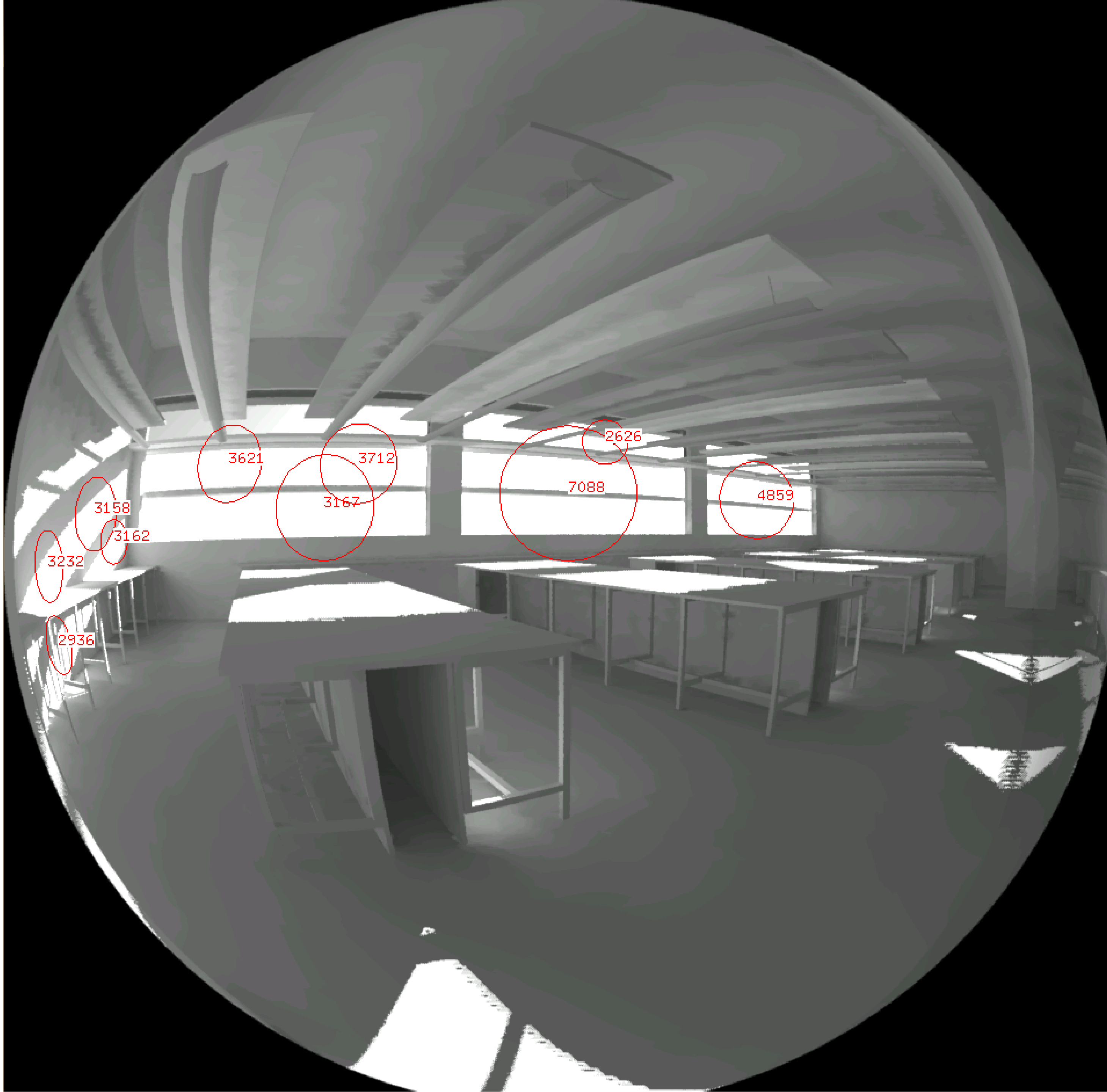




Cr,Cg,Cb	0.25
Rs	0
Sr	0
td	0
ts	0.5

Vision Glazing Trans_02

PERKINS+WILL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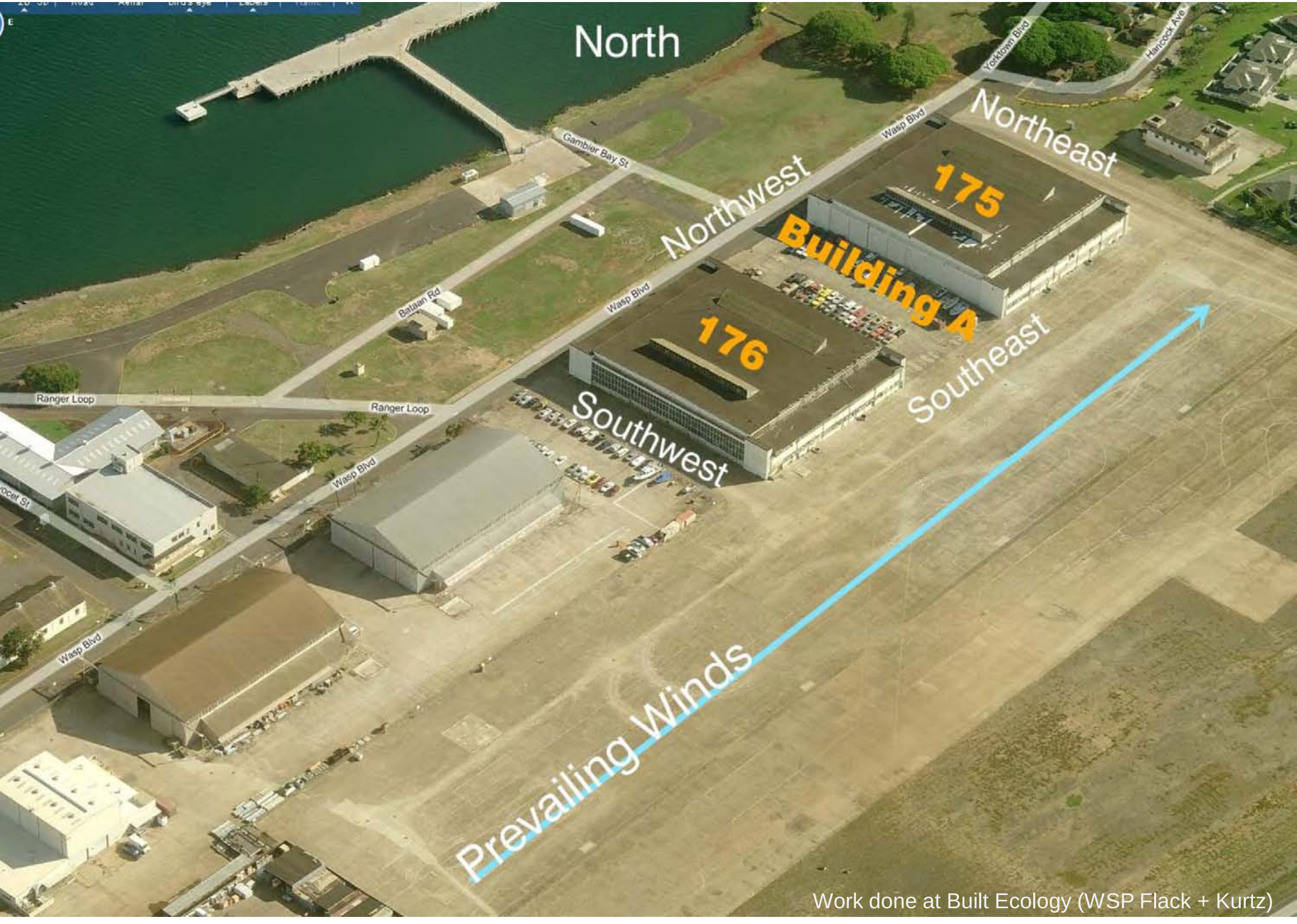
2936


North
Northeast
Northwest
175
Building A
176
Southeast
Southwest
Prevailing Winds
Wasp Blvd
Yorktown Blvd
Hancock Ave
Gambier Bay St
Bataan Rd
Ranger Loop
Work done at Built Ecology (WSP Flack + Kurtz)

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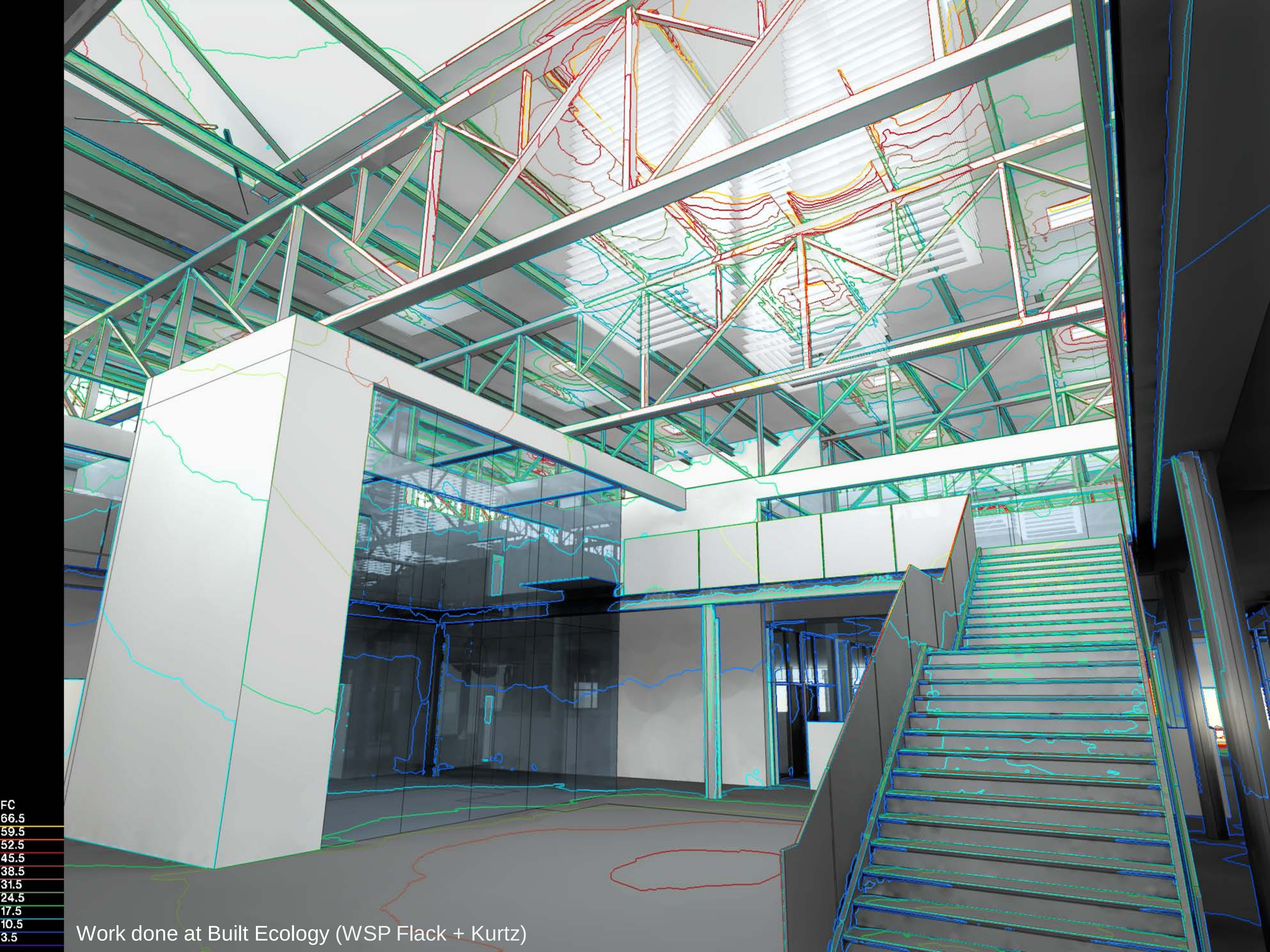

Work done at Built Ecology (WSP Flack + Kurtz)

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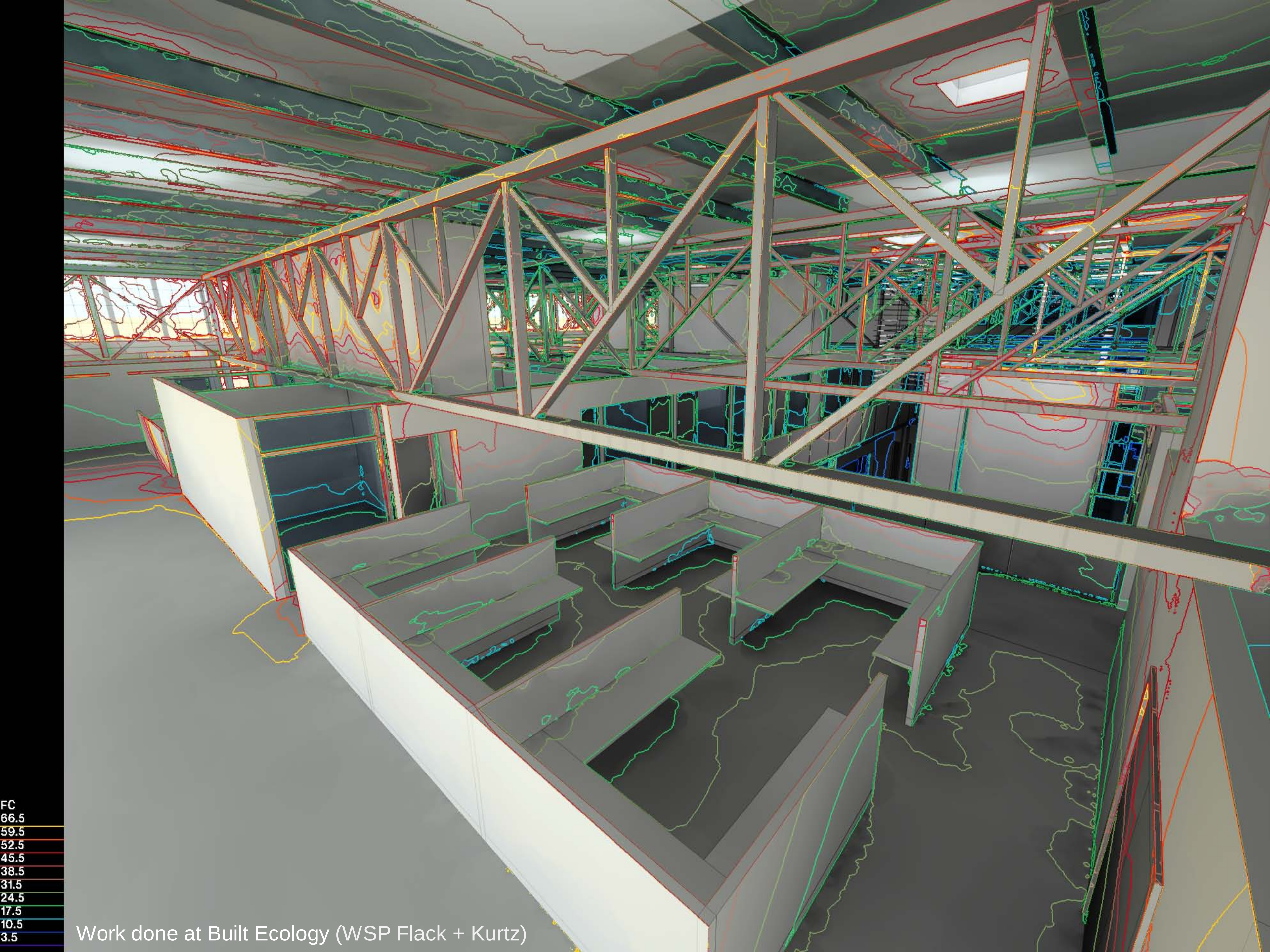


Work done at Built Ecology (WSP Flack + Kurtz)

3-Form Eco Resin Panels – Patent Finish
VLT~70%

There are no published results for:

Direct-hemispherical reflection (rho_{dh})

Direct-hemispherical transmission (tau_{dh})

Diffuse Transmission (Td)

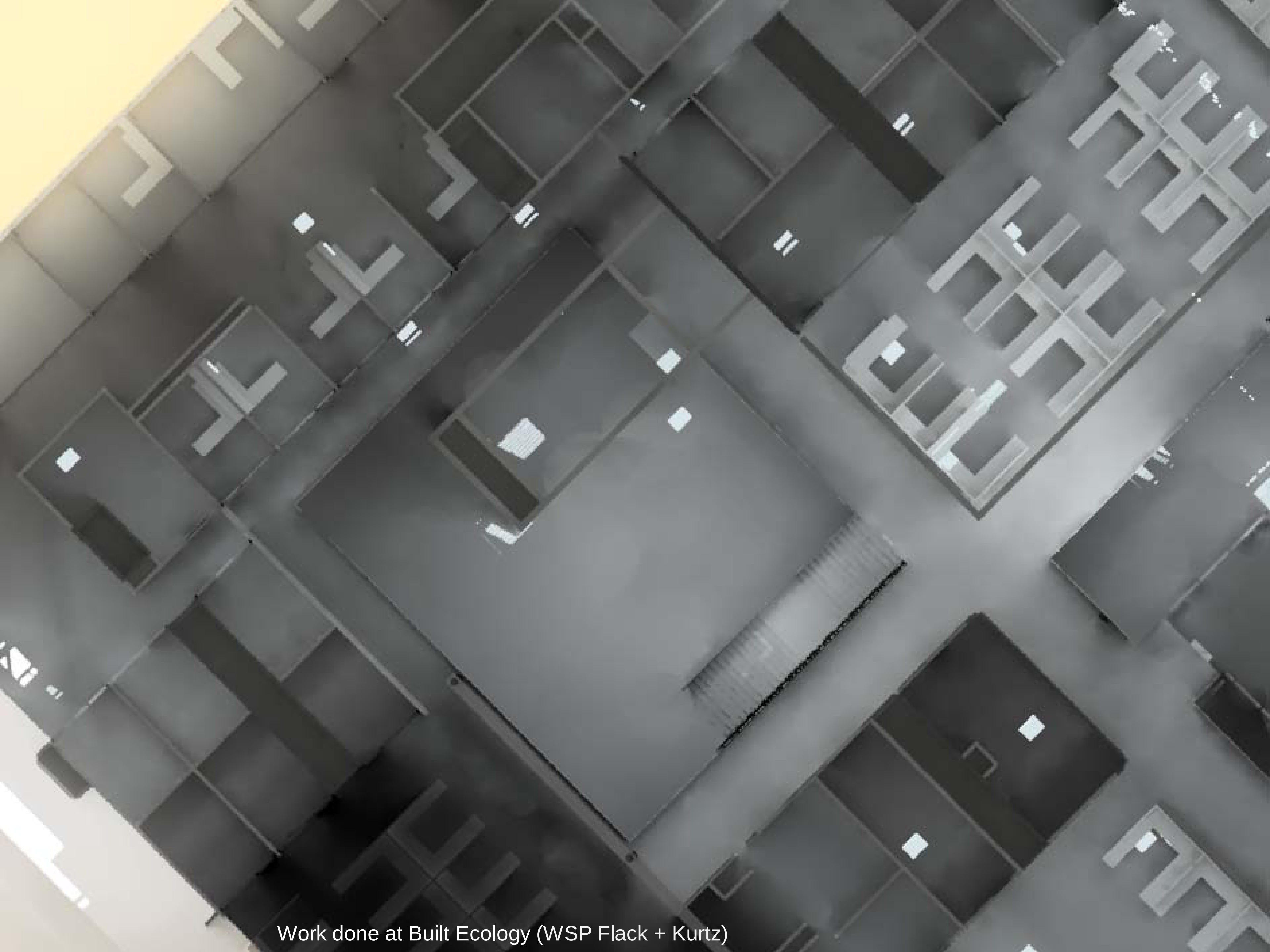
Specular Transmission (Ts)

Diffuse Reflectance (Cb)

Reflected Specularity (Rs)

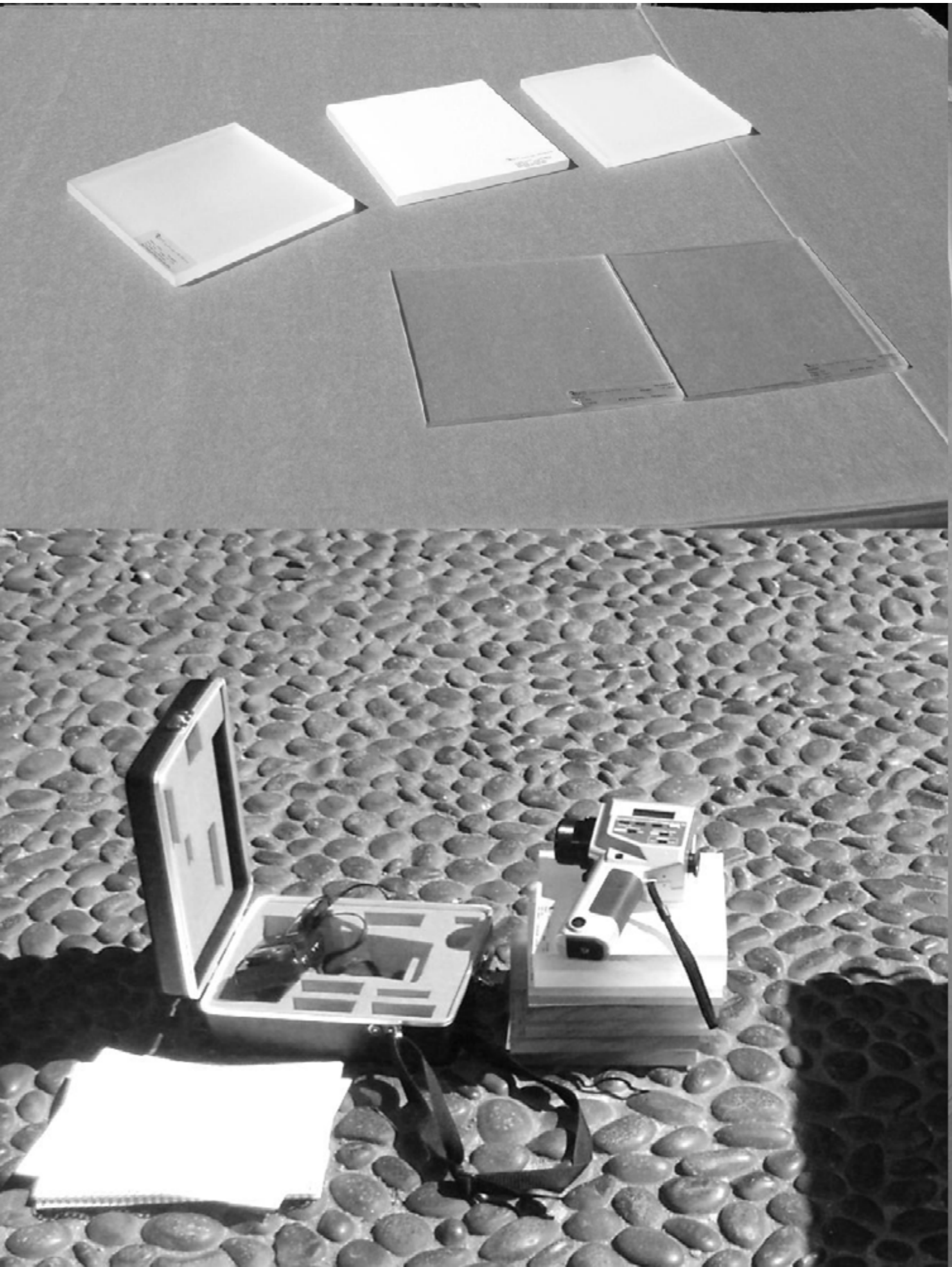
Surface Roughness (Sr)

Work done at Built Ecology (WSP Flack + Kurtz)



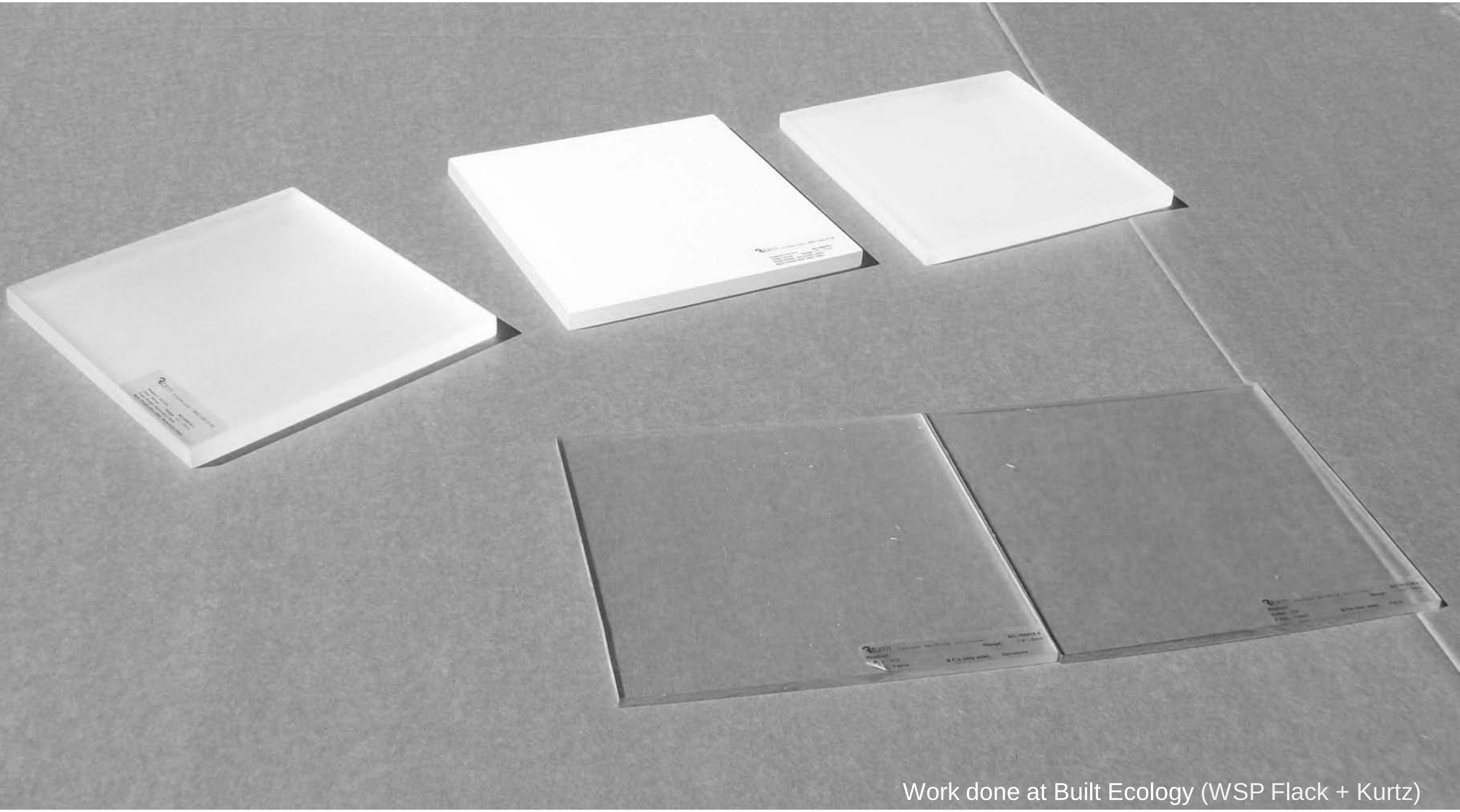
Work done at Built Ecology (WSP Flack + Kurtz)

3-Form Eco Resin Panels – Patent Finish VLT~70%



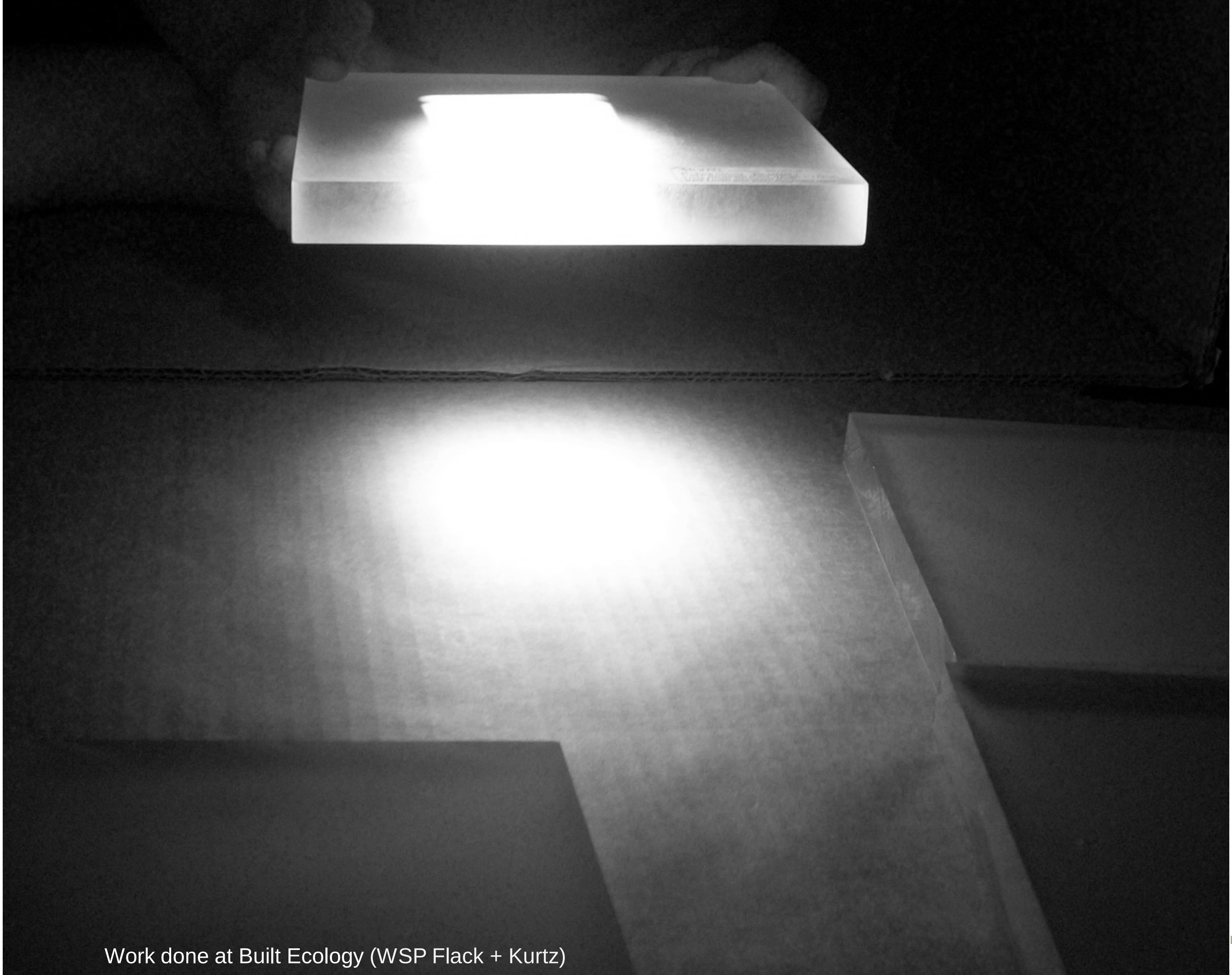
Work done at Built Ecology (WSP Flack + Kurtz)

This is on the transparent side of the translucent material spectrum



Comparing multiple 3-form products made it clear that surface treatments have a huge impact on the performance of panels

Work done at Built Ecology (WSP Flack + Kurtz)



Work done at Built Ecology (WSP Flack + Kurtz)

A light sanded finish can create an extremely diffuse transmission pattern for a material that is almost transparent.

Work done at Built Ecology (WSP Flack + Kurtz)

Most Radiance modeling of trans materials assume a surface roughness of 0

This in reality has a large impact on performance as it directly effects *Diffuse Transmission (Td), Specular Transmission (Ts), Diffuse Reflectance (Cb), & Reflected Specularity (Rs)*

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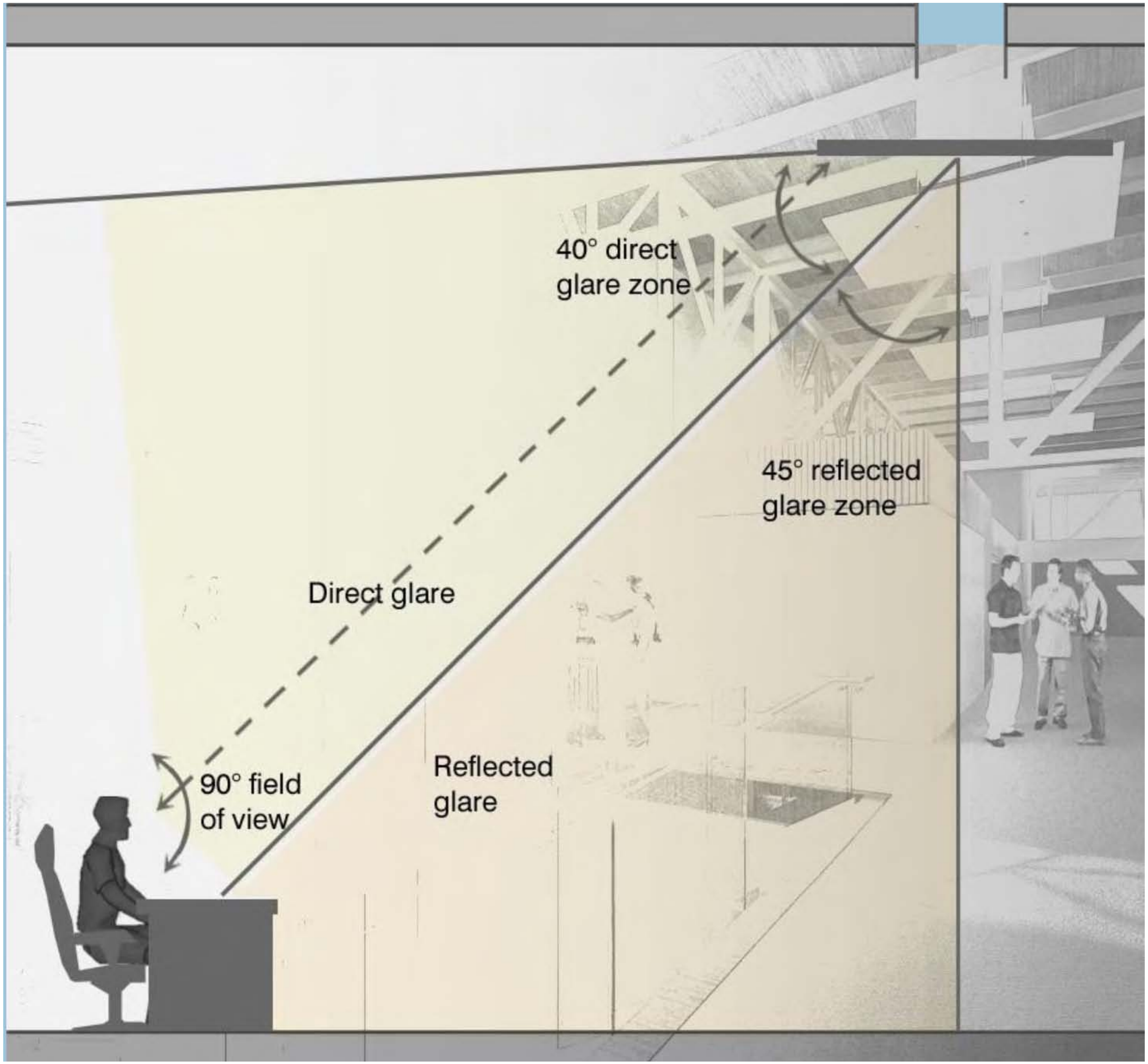

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3-FORM Product Name	Working surface direct light luminance (cd/m²)	Working surface shadow luminance (cd/m²)	Reflector hot spot (cd/m²)	Reflector Hot Spot close to 90° (cd/m²)	Reflector Edge (cd/m²)	Ceiling by reflector (cd/m²)	working surface illuminance - hot spot (FC)	working surface illuminance - indirect light (FC)	Shroud hot spot (cd/m²)	Reflected Light (cd/m²)	Reflected Light (outside) (cd/m²)
SO-101406.1	73	66	40820	26000	100	450	20.8	17	6238	1569	5000
SO-161439.2	4.5	3.9	1750	2100	59	900	1.3	1.2	3050	1731	
SO-161439.5	4.2	3.8	2370	2900	76	390	1.2	1.1	3050	9400	
SO-161439.1	31	30	26000	22000	24	185	9	8	5100	1500	
SO-161439.4									550	25000	
SO-162419.1	54	39	22970	23000	136	226	16.7	14	5300	3500	6400
SO-162419.2	6	5	4000	4600	225	650	1.8	1.8	6350	15300	18140
SO-162419.3	21.7	21.3	15650	17000	266	275	6.4	5.9	8700	4600	9750

Direct sunlight into box	18760	31					5870				
Outside Conditions	15000						6270				

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If there was an ISO/ASTM standard for manufactures to reference it seems the surface roughness could be ignored as long as they can establish the basic guidelines for both diffuse and specular transmission & reflection

How far out is this?

What can the global Radiance community do to encourage this?


Thank You...