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UGR – A Misunderstood Glare Metric with Limited Usefulness

Naomi J Miller, FIES, FIALD
Retired Lighting Nerd
Oberlin OH
naomimiller135@gmail.com
Also, Senior Scientist, Emerita, Pacific Northwest National Laboratory

UGR – A Misunderstood Glare Metric with Limited Usefulness

Abstract

Unified Glare Rating is the best indoor glare metric available, and it has serious shortcomings: poor documentation and instructions, confusing routes for implementation, wide misunderstanding by design professionals and regulators, and published product values by manufacturers that mislead specifiers and compliance programs. Plus, it doesn't apply to most luminaires and spaces for which it is used. This will be a brief introduction to why this metric should be applied sparingly, and what needs to be done to improve it.

Principal Flavors of Glare

Disability Glare

- Really not sensory glare, but visibility reduction for interior or exterior
- Light source close to axis of view that creates scatter (the “veil”) that obscures the visual image on the retina
- Eye/brain mechanism fairly well understood
- Can be calculated (L_v is veiling luminance, E= illuminance at eye, θ = angular displacement from axis of view)

$$L_v(\theta) = [10E/\theta^2] \text{ for } 1^\circ < \theta < 30^\circ$$

Images courtesy of The International Dark-Sky Association

Principal Flavors of Glare

Discomfort Glare

- Light source in the field of view brighter than the luminance to which the observer is adapted
- Causes discomfort
- Mechanism poorly understood
- Many mediocre discomfort glare metrics exist
- Unified Glare Rating (UGR) works for lensed troffers, linear diffuser products, and other diffuse apertures. It is NOT predictive of glare response for small sources, indirect lighting, or non-uniform sources such as louvers or visible LED arrays.

Discomfort Glare Metric Landscape

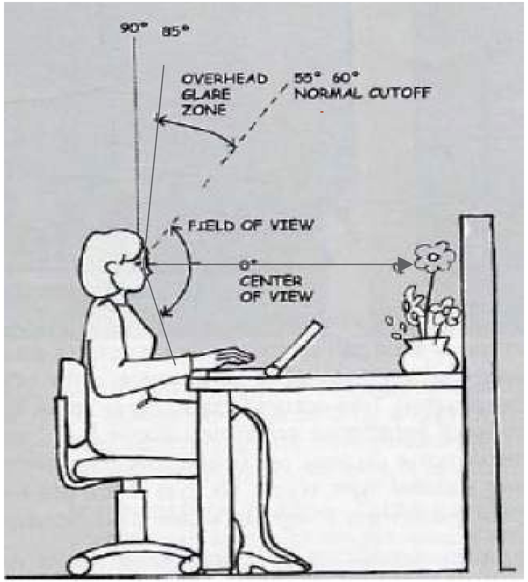
Metric/Index	Year	Research or Standard	Note
British Glare Index (BGI)	1950	Research	
Visual Comfort Probability (VCP)	1963	IES	Interior
Discomfort Glare Index (DGI)	1972	Research	
European Glare Limiting Method	1972	Research	
CIE Glare Index (CGI)	1979	Research	
Glare Rating (GR)	1994	CIE 112-1994	Exterior
Unified Glare Rating (UGR)	1995	CIE 117-1995	
UGR for small sources (UGR_{small})	2002	CIE 147-2002	
Max. luminance above 53° FOV	2003	IES	
Discomfort Glare Probability (DGP)	2005	Research	
Discomfort Glare	2008	Research	
BUG Rating	2011	IES	Exterior

Table courtesy of Design Lights Consortium

Discomfort Glare - Background

Reasons glare metrics don't work very well

- Position index assumes horizontal view, and assumes discomfort disappears as luminaire image vanishes from visual field (approx. 55° above axis of view).
- Position index is based average of 10 observers. Turns out facial features affect glare response.
- UGR assumes that observer has fixed gaze, never looking above horizontal when experiencing a room.
- (Think of a place where occupants regularly look around a room, and frequently above horizontal…)
- No consideration of SPD of source in glare perception.

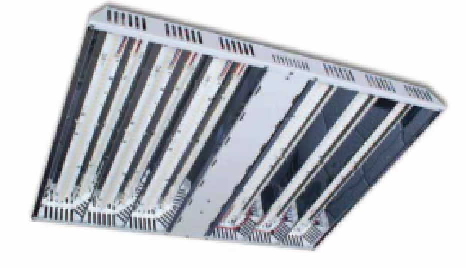
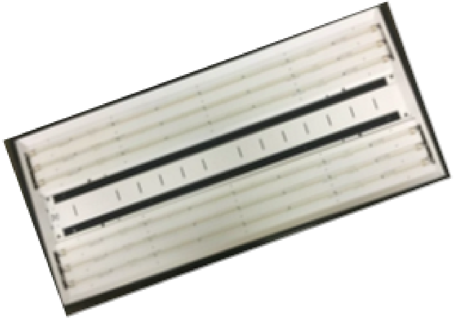
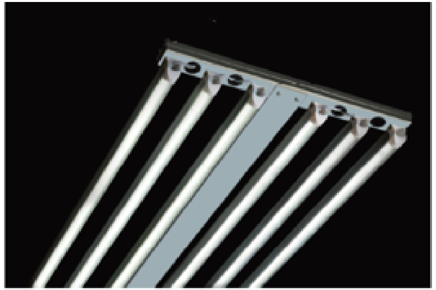


Source picture: IES DG-18-08

What products were glare metrics developed for?

Diffuser and lensed products, seldom exceeding 12,000 cd/m²

What are LED luminances really like?

		
17-S1B and C	17-S2A and B	17-S3A and B
		
17-S4A and B	17-S5A and B	17-S6A and B
		
	17-S7A and B	

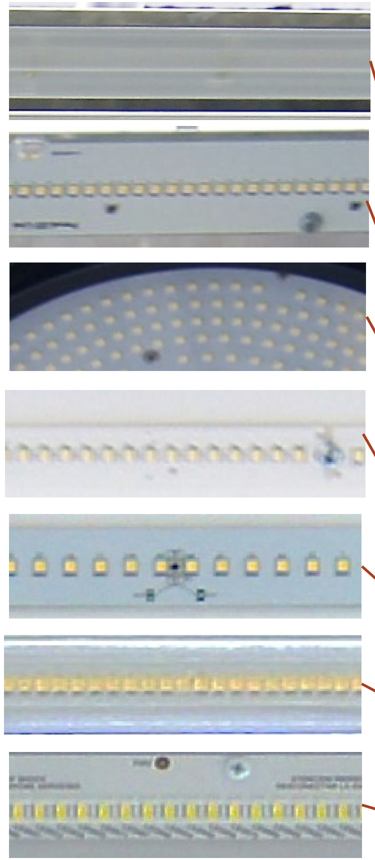


Table 4. Measured max luminances of luminaires at mockup site.

System ID	Area measured	Avg. LED package or lens luminance (cd/m^2)	No. of LED packages or diffusers
17-S1B	LEDs behind diffuse tubular cover	41,523	4
17-S2A	Bare LED	661,024	1080
17-S3A	Bare LED behind clear cover glass	767,160	536
17-S4A	Bare LED	1,150,543	756
17-S5A	Bare LED	1,069,857	672
17-S6A	Bare LED, behind clear acrylic cover	625,695	2862
17-S7A	Bare LED	1,066,823	576

Unified Glare Rating (UGR)

$$UGR = 8 \cdot \log\left(\frac{0.25}{L_{Background}}\right)\sum_{n}\left(\frac{L^2\omega}{p^2}\right)$$

where

L = *Luminance of the luminous area*

ω = *size of the luminous area*

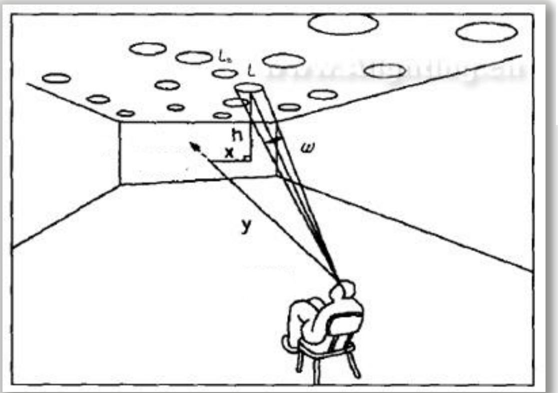
p = *Guth position index*

$L_{Background}$ = *Background Luminance*

n = *number of luminaires*

Formula & Common Use

- The best of the competing metrics, although it has limited applicability. Used for interior lighting
- UGR evaluates glare sensation of a space from a particular observer position
- Based on ~10-30 scale
  - Designed to be a glare metric for a **specific room and lighting layout**
  - Or a glare metric for a **typical room size and regular lighting layout**
  - Not originally a **luminaire** glare metric, but it's being used that way (it's an oversimplification)
- UGR difference <3 is meaningless



UGR	Hopkinson's Glare Rating Scale
<10	Imperceptible
<13	Just Perceptible
<16	Perceptible
<19	Acceptable
>22	Unacceptable
>25	Just Uncomfortable
>28	Uncomfortable

3	Offices			
Ref. no.	Type of interior, task or activity	$\bar{E}_m$ lx	UGR_L -	R_a -
3.1	Filing, copying, etc.	300	19	80
3.2	Writing, typing, reading, data processing	500	19	80
3.3	Technical drawing	750	16	80
3.4	CAD work stations	500	19	80
3.5	Conference and meeting rooms	500	19	80
3.6	Reception desk	300	22	80
3.7	Archives	200	25	80

Indoor Discomfort Glare – UGR table for a regular layout

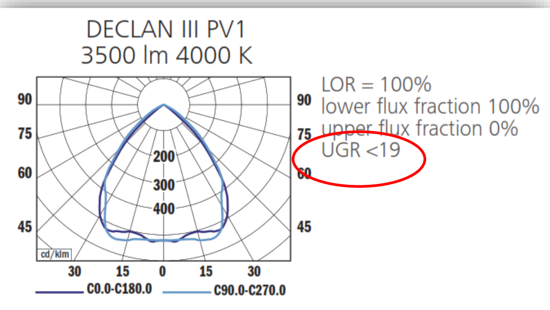
Table of the corrected unified glare ratings (UGR)

Luminaire distance / suspension height above observer's eye: $s/H = 0,25$

Reflectance values											
Ceiling		**0,70**	0,70	0,50	0,50	0,30	**0,70**	0,70	0,50	0,50	0,30
Walls		**0,50**	0,30	0,50	0,30	0,30	**0,50**	0,30	0,50	0,30	0,30
Floor		**0,20**	0,20	0,20	0,20	0,20	**0,20**	0,20	0,20	0,20	0,20
Room dimensions		**Corrected glare assessments – Luminous flux 3,300 lm**									
X	Y	Viewing direction: oblique					Viewing direction: longitudinal				
$2H$	$2H$	19,8	21,4	20,3	21,9	22,5	16,6	18,2	17,1	18,7	19,3
	$3H$	22,3	23,8	22,8	24,4	25,0	17,8	19,3	18,4	19,9	20,5
	$4H$	23,7	25,1	24,2	25,7	26,3	18,2	19,7	18,8	20,2	20,9
	$6H$	25,2	26,5	25,7	27,1	27,7	18,5	19,8	19,1	20,4	21,1
	$8H$	25,9	27,2	26,5	27,8	28,4	18,6	19,8	19,1	20,4	21,1
	$12H$	26,6	27,9	27,2	28,5	29,1	18,6	19,8	19,2	20,4	21,1
$4H$	$2H$	20,2	21,7	20,8	22,2	22,9	17,9	19,3	18,4	19,9	20,5
	$3H$	23,0	24,3	23,6	24,9	25,5	19,4	20,7	20,0	21,2	21,9
	$4H$	24,6	25,7	25,2	26,3	27,0	20,0	21,1	20,6	21,7	22,4
	$6H$	26,2	27,3	26,8	27,9	28,6	20,4	21,4	21,0	22,0	22,7
	$8H$	|27,1|	28,0	27,7	28,7	29,4	20,5	21,5	21,1	22,1	22,8
	$12H$	27,9	28,8	28,6	29,5	30,2	20,6	21,4	21,2	22,1	22,8
$8H$	**$4H$**	**24,8**	25,8	25,4	26,4	27,1	**|20,9|**	21,9	21,6	22,5	23,3
	$6H$	26,7	27,5	27,3	28,2	28,9	21,7	22,5	22,3	23,2	23,9
	$8H$	27,7	28,4	28,4	29,1	29,8	22,0	22,7	22,6	23,4	24,1
	$12H$	28,7	29,4	29,4	30,0	30,8	22,1	22,8	22,8	23,5	24,3
$12H$	$4H$	24,8	25,7	25,4	26,3	27,1	21,2	22,1	21,8	22,7	23,5
	$6H$	26,8	27,5	27,4	28,2	28,9	22,1	22,9	22,8	23,5	24,3
	$8H$	27,8	28,5	28,5	29,1	29,9	22,5	23,2	23,2	23,9	24,6

And….

- In the EU (and now NA), a luminaire UGR can be listed on product spec sheets, for
  - One standardized room size and height
  - One standardized set of reflectances

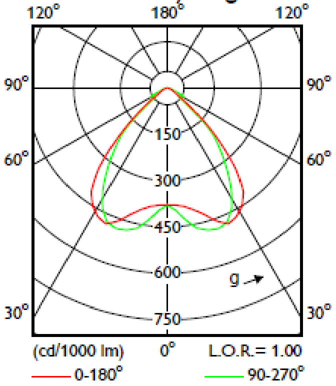


UGR on a luminaire cut sheet

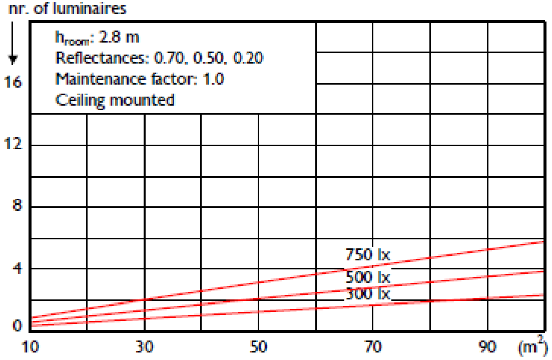
BY470P 1 xGRN130S/840 WB GC

1 x 13000 lm

Polar intensity diagram



Quantity estimation diagram



Light output ratio 1.00
Service upward 0.00
Service downward 1.00

CIE flux code 70 96 100 100 100

S/H ratio crosswise max. 1.5
lengthwise max. 1.7

UGRcen (4Hx8H, 0.25H) 23
UTE71-121: 1.00AS + 0.00T

Utilisation factor table

Room Index k	Reflectances for ceiling, walls and working plane (CIE)										
	0.80 0.50 0.30	0.80 0.50 0.10	0.70 0.50 0.30	0.70 0.50 0.20	0.70 0.50 0.10	0.70 0.30 0.10	0.50 0.30 0.10	0.50 0.10 0.10	0.30 0.30 0.10	0.30 0.10 0.10	0.00 0.00 0.00
0.60	0.62	0.59	0.62	0.60	0.59	0.53	0.53	0.49	0.52	0.49	0.47
0.80	0.73	0.69	0.72	0.70	0.68	0.62	0.62	0.58	0.61	0.58	0.56
1.00	0.82	0.76	0.80	0.78	0.75	0.70	0.69	0.66	0.69	0.65	0.63
1.25	0.90	0.82	0.88	0.85	0.81	0.77	0.76	0.72	0.75	0.72	0.70
1.50	0.95	0.86	0.93	0.89	0.86	0.81	0.80	0.77	0.79	0.77	0.75
2.00	1.04	0.93	1.01	0.96	0.92	0.88	0.87	0.85	0.86	0.84	0.82
2.50	1.09	0.96	1.06	1.01	0.95	0.93	0.91	0.89	0.90	0.88	0.86
3.00	1.13	0.99	1.10	1.03	0.98	0.95	0.94	0.92	0.93	0.91	0.89
4.00	1.17	1.01	1.14	1.07	1.00	0.98	0.97	0.95	0.95	0.94	0.92
5.00	1.20	1.03	1.16	1.08	1.02	1.00	0.98	0.97	0.97	0.96	0.93

Ceiling mounted

Luminance Table

Plane / Cone	0.0	45.0	90.0
45.0	40200	72449	35583
50.0	21386	53339	14700
55.0	10051	30152	10335
60.0	7226	13031	13348
65.0	5924	6458	14050
70.0	5226	5219	7761
75.0	4335	4439	8265
80.0	3331	3142	5226
85.0	1610	1377	2077
90.0	-	-	-

(cd/m2)

UGR = 23

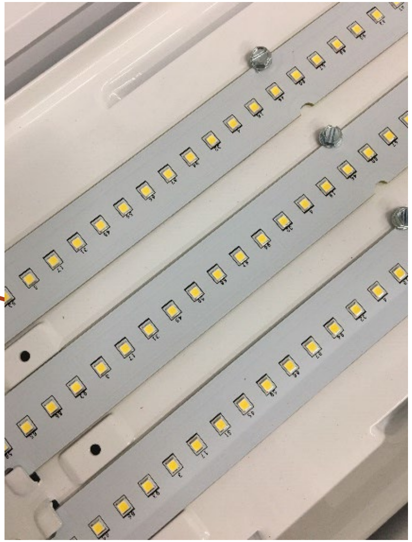
LVP0050300

2017-02-08

UGR Glare Metric Limitations

UGR calculations

- Generally rely on the .ies file defined aperture for luminaire “luminous area”
- Larger luminous areas = lower UGR values (= more comfortable)
- What do we do about LED “size”????
- Bare LEDs can be 1.5 million cd/m^2 or higher (compare to T5HO fluorescent lamps at 25-30,000 cd/m^2)



More Limitations of UGR….

- UGR does NOT work for….
    - Indirect lighting or luminous ceilings
    - Wall washers aimed away from viewer
    - Large light sources >0.1 steradian
    - Small light sources <0.0003 steradian
    - Daylight
    - Non-uniform light sources (LED arrays, louvers, baffles, decorative shapes)
- UGR cannot be measured in the field because no meter is able to measure luminance and area of each source, or a value that relates to the discomfort sensation.

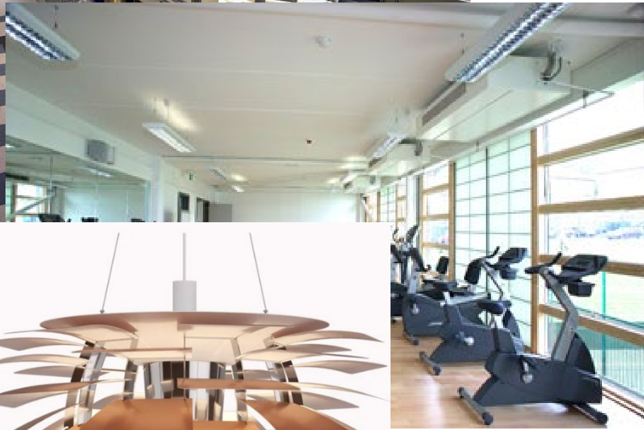


Photo: Louis Poulsen

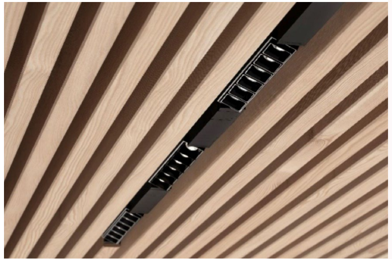


Photo: Zumtobel

CIE 232-2019 approach to dealing with luminaires with non-uniform luminances

Revise UGR luminous area assumption:

- Take HDRi image of luminaire from 50° and 65° from luminaire nadir, and filter image for blur. Sum areas with luminance >500 cd/m² into effective luminous area. Calculate effective solid angle.

Step 1
2 or 4 High resolution luminance images (50° and 65° from normal, cross and lengthwise)

Step 2
Filter image to correct for eye resolution (Gaussian with 12 mm FWHM at luminaire)

Step 3
Remove pixels below luminance threshold (500 cd/m²)

Step 4
Calculate total area and average luminance of pixels above threshold luminance

Step 5
Group all sources within a luminaire into one source with an effective projected area and effective luminance

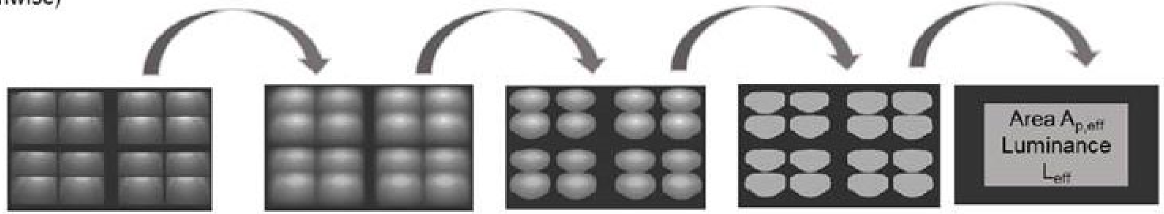
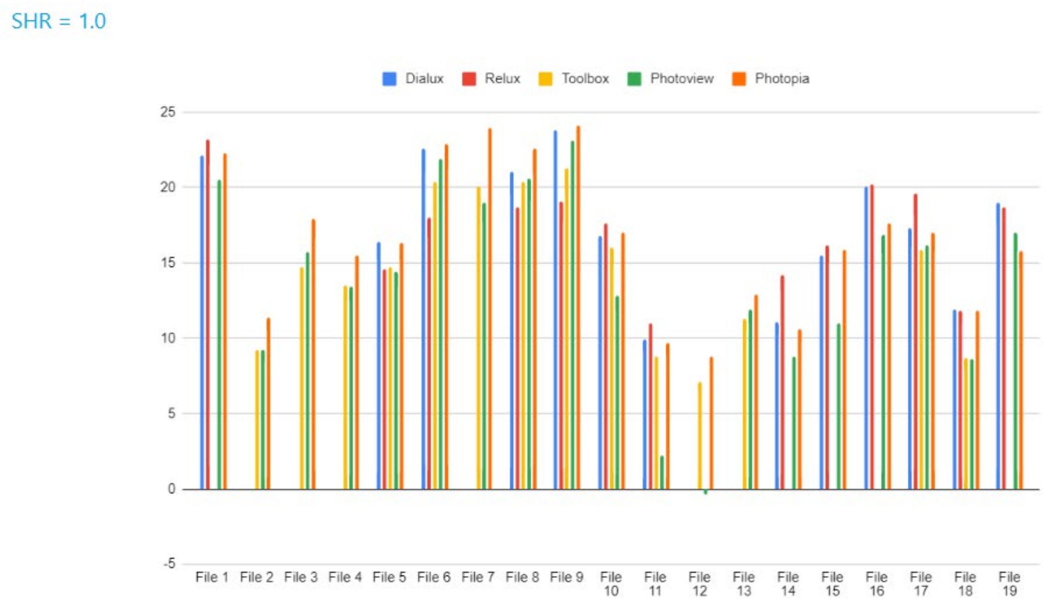


Figure 2 – Overview of the measurement and image processing steps that are required to obtain the effective projected area and effective luminance. Note that the effective solid angle of the source ω_{eff} is equal to the effective projected area $A_{p,eff}$ divided by the measurement distance squared.

More UGR limitations from Mark Jongewaard…

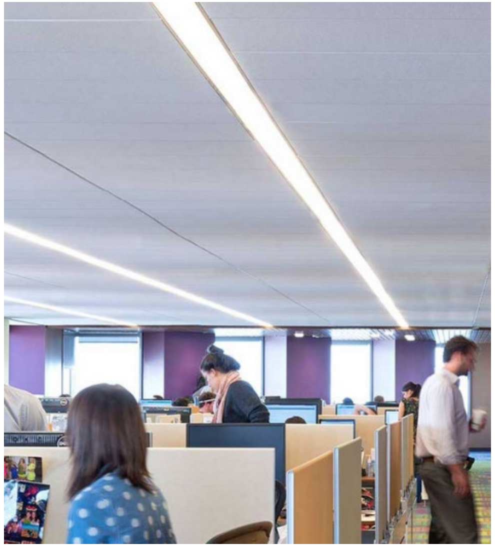
- UGR calculations are not well defined in the CIE documents
  - Different photometric reporting software packages produce different UGR values, resulting in differences up to 30% from a single luminaire.
  - The root cause is that the CIE standard is really only half of a standard since it doesn't define the entire calculation.



https://www.ltioptics.com/en/ugr-unified-glare-rating

Conclusions

- UGR calculations have limited usefulness (they work for diffuse recessed luminaires, but not much else)
- Today's LED luminaires are so varied in appearance and optics that the UGR calculations no longer apply widely.
- There is inconsistency in calculation software and their results.
- UGR for luminaires is a highly oversimplified application of the UGR concepts and should NOT be used for comparing luminaires for specification.
- Improved glare metrics, possibly using HDR photometry techniques, need to be researched and developed.



Glad you were here to hear!

Hurl those nerdly questions….

Naomi J Miller

Naomimiller135@gmail.com

Oberlin OH