Daylight Modeling and Simulation Methods and Standards

8th Velux Daylight Symposium
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Paris, France

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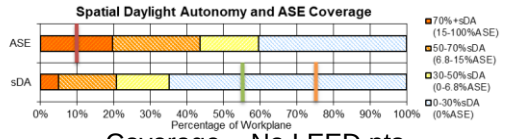
DAYLIGHTING INNOVATIONS

Presentation Outline

- Why? – The case for standards
- What? – IESNA document outline
- Methods and standards development
- ‘Gold Standard’ test cases

Why? – Accuracy and Consistency

- Daylight modelers need consistent standards and software needs annual validation
- Annual, climate-based, daylight modeling uses many assumptions, interpolations, short-cuts to model ~4,400 conditions
- Daylight metrics world need assurance of ‘apples-to-apples’ comparisons using absolute metrics
- Energy modeling world needs sophistication, not such a simple model and ECM switch for savings
- Designers need assurance that renderings are representative and that Daylight Glare Probability (DGP) calculations accurate



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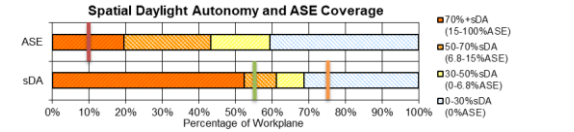

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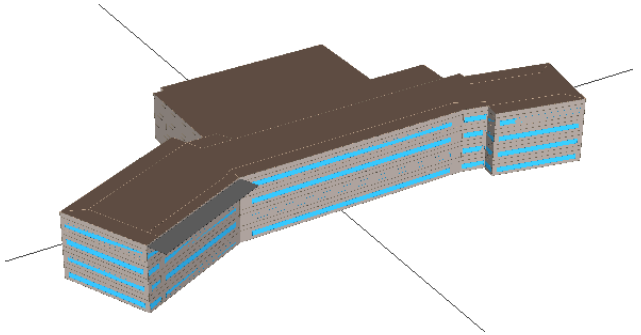
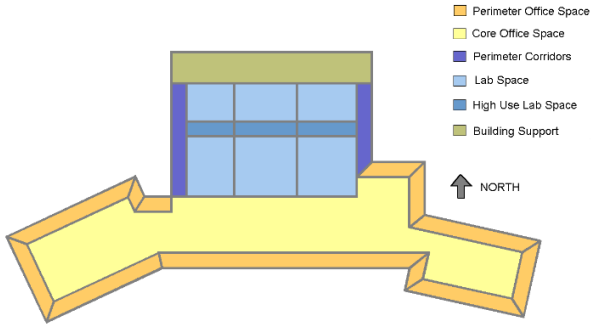
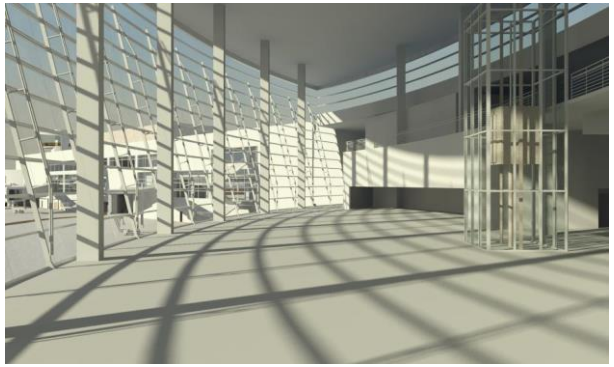
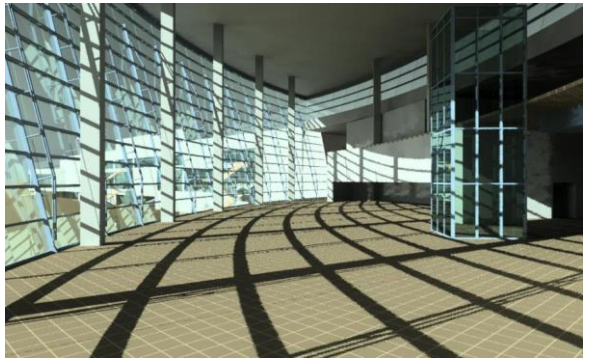


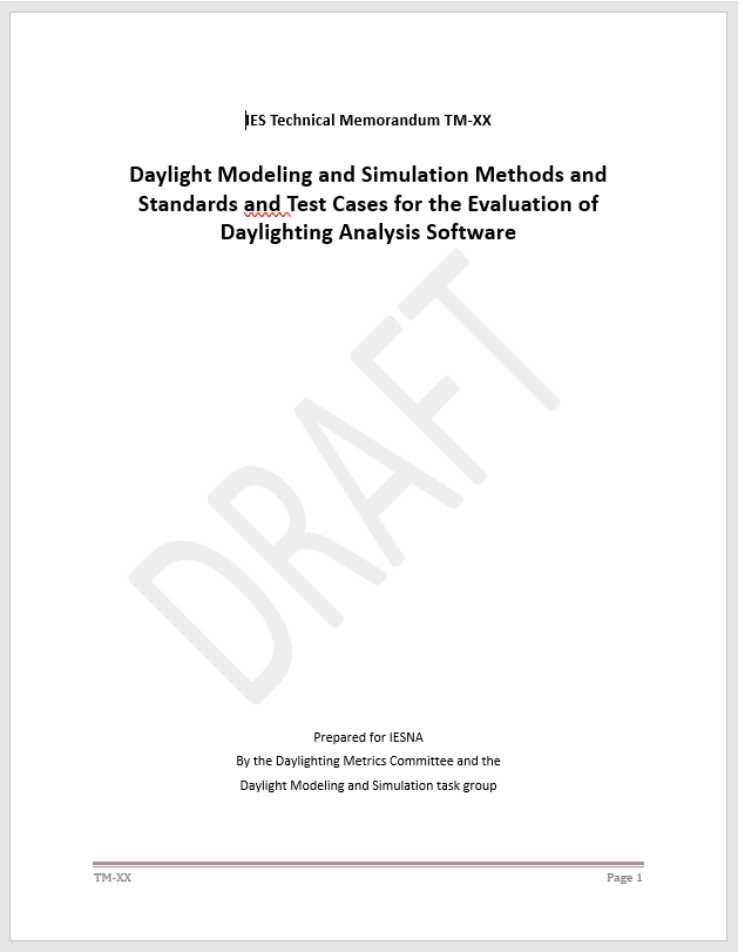






IESNA Daylight Modeling and Simulation Methods and Standards

- Working Title - “Daylighting Modeling and Simulation Methods and Standards: Test Cases for the Evaluation of Daylighting Analysis Software”
  - Similar to ASHRAE Standard 140 “Standard Method of Test for Building Energy Simulation Computer Programs” (BESTEST)
  - Goal to document current knowledge and best practices
  - Highlight areas of assumption – need further development and research
- Daylight Modeling and Simulation Task Group
  - Task subgroup of the IESNA Daylighting Metrics committee
- Initial release as a Technical Memorandum in 2020
  - Continued maintenance with interim Committee Reports (CR)
  - Ultimately a more static IESNA Lighting Practice (LP-XX)


IES Technical Memorandum TM-XX

Daylight Modeling and Simulation Methods and Standards and Test Cases for the Evaluation of Daylighting Analysis Software

DRAFT

Prepared for IESNA
By the Daylighting Metrics Committee and the
Daylight Modeling and Simulation task group

TM-XX Page 1

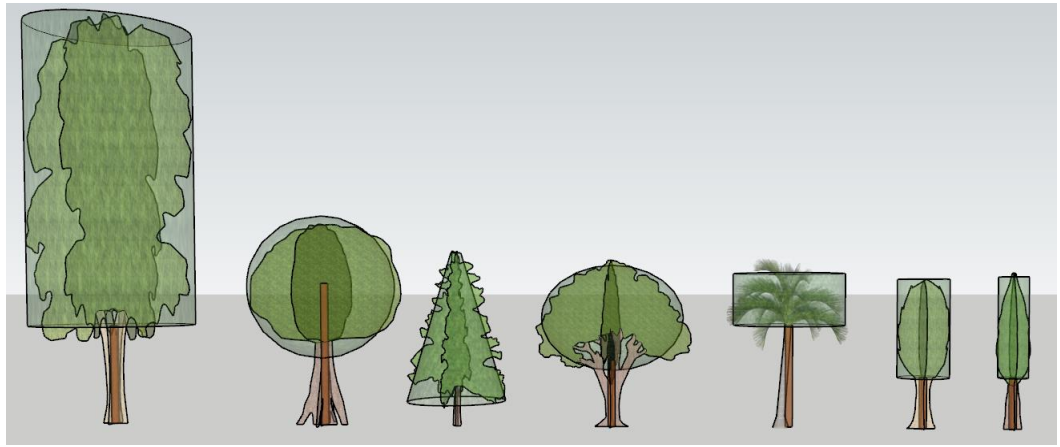
IESNA – Illuminating Engineering Society of North America

Daylight Modeling and Simulation Methods and Standards outline

1. Purpose/Background
2. Daylight Modeling Methods and Standards
   - **i. Sun and Sky Models**
   - **ii. Site and Surroundings**
   - **iii. Surface and Material Modeling**
   - **iv. Fenestration and Window Treatments**
   - v. Interior geometry
3. Simulation for Daylight Sufficiency – Methods and Standards
   - **i. Shading control simulation standards**
   - **ii. Periodic simulation methods**
   - **iii. Simulation settings**
   - iv. Daylight responsive electric lighting control
   - v. Simulation output standards
   - **vi. Daylight sufficiency metrics**
   - **vii. Whole building energy predictions**
   - viii. Plants / animals / artwork preservation
   - ix. Circadian rhythm analysis
4. Simulation for Daylight Quality – Methods and Standards
   - i. Representative time and daylight condition standards
   - ii. Spatial and orientation standards
   - iii. Simulation setting adjustments
   - iv. Color and Surface and Material refinements
   - v. Glare analysis methods and standards
   - vi. Photorealistic visualization methods
5. Gold Standard Test Cases
   - **i. Test Case Geometry**
   - **ii. Sufficiency test cases**
   - iii. Qualitative test cases

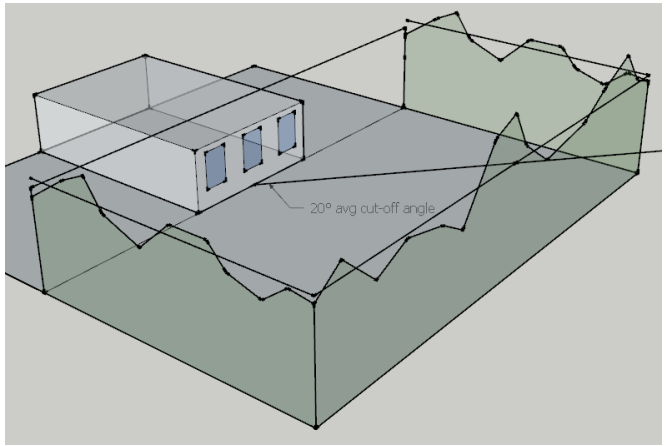
Modeling Standards - Exterior Vegetation

- Trees and forest lines can have a major impact on daylighting performance
  - Methods for modeling individual trees / tree canopies
  - Creating **tree horizons** at the model boundary



- Simulation of seasonal patterns of deciduous trees – encouraging this effective passive strategy

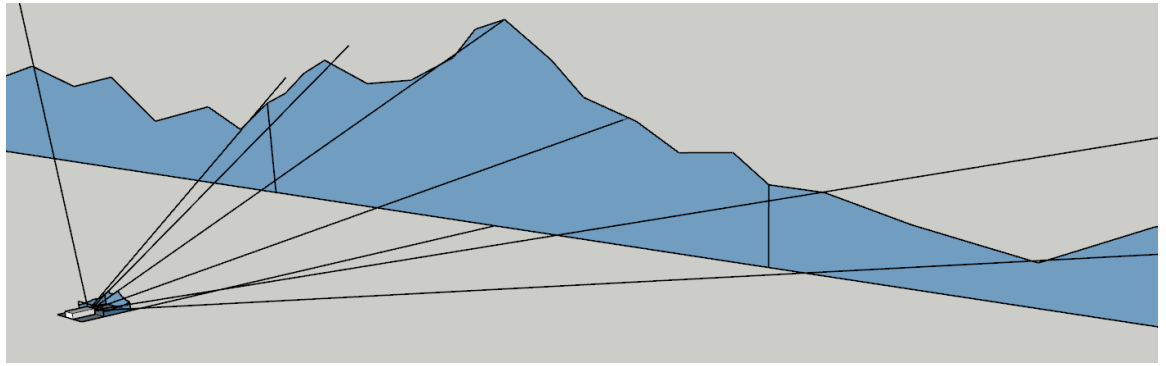
- Starting point - great area for more field research!

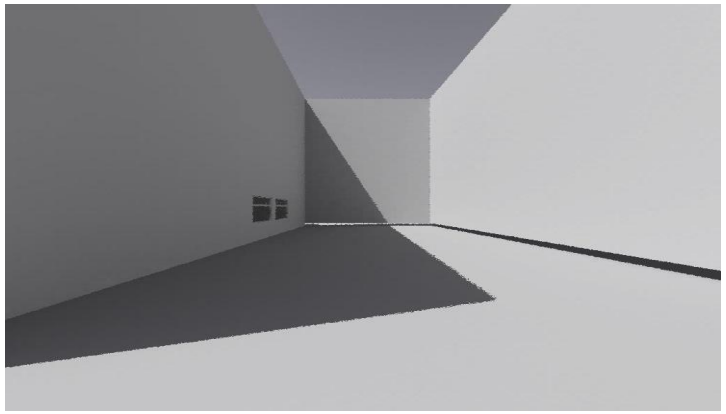


Modeling Standards - Exterior Geometry

- Surrounding opaque objects have a big impact on modeling results

- What to model and how much
  - Ground plane extents – 2x or 3x?
  - Surrounding buildings and opaque structures
  - Translating distant mountains or skylines





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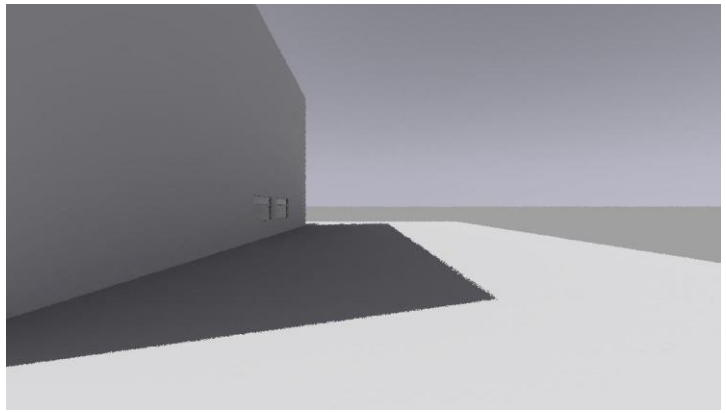

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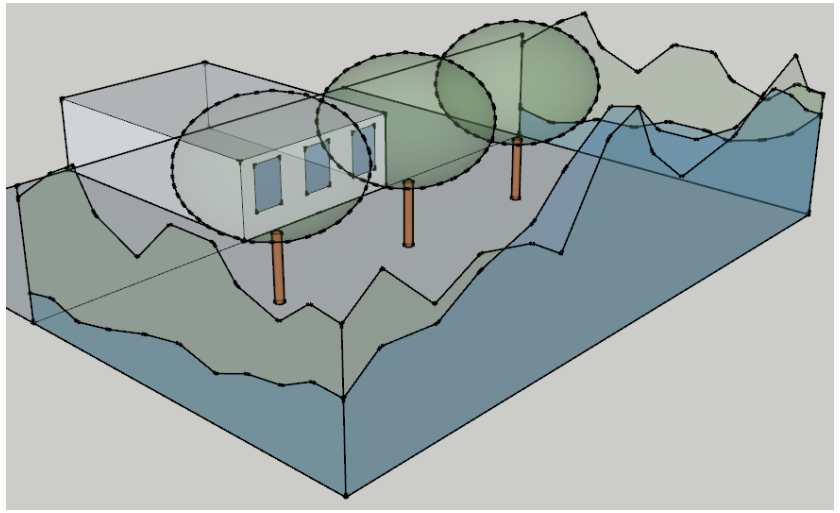
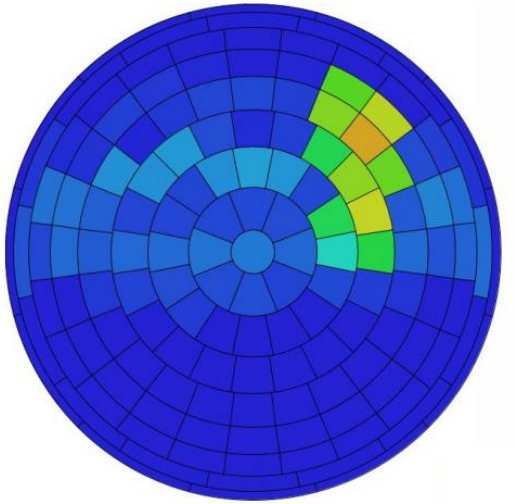
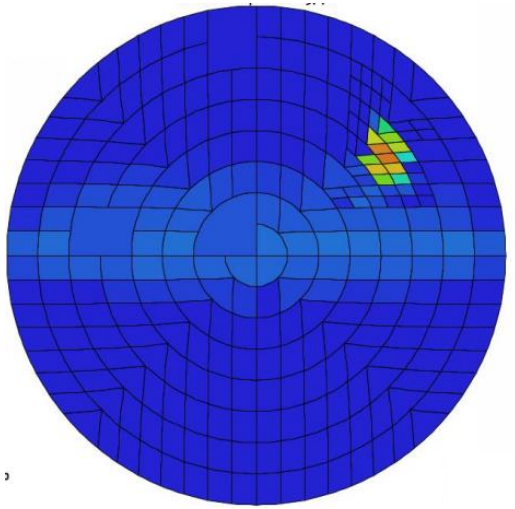


Modeling Standards – Surface materials

- Reflectance and transmittance tables for common architectural surfaces
  - Historically diffuse reflectance standards as base
  - Allowable reflectance ranges to prevent gaming
- Guidelines for specularity and BSDF models
  - High resolution BSDF for qualitative analysis
  - Low resolution for sufficiency
  - Simulation adjustments for BSDF

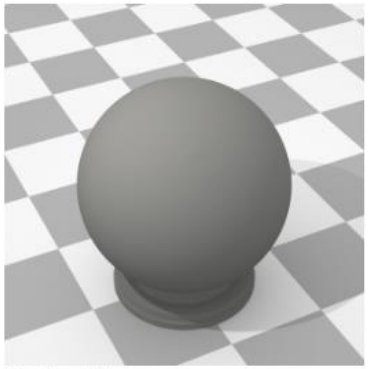


Klems basis – sufficiency analysis

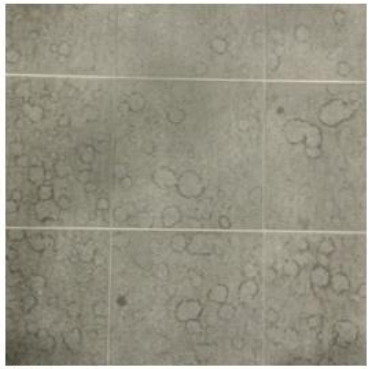


Tensor-tree variable resolution – qualitative analysis

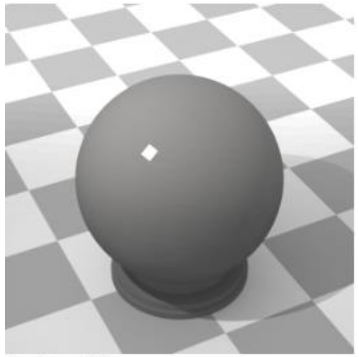
Images from BSDF Viewer tool from LBNL



Rendered View



Photograph



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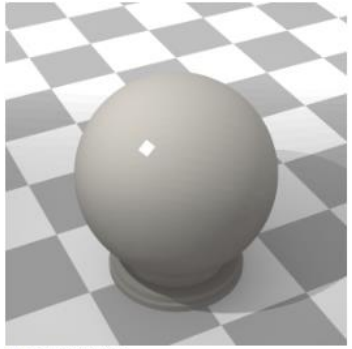


Rendered View

Photograph

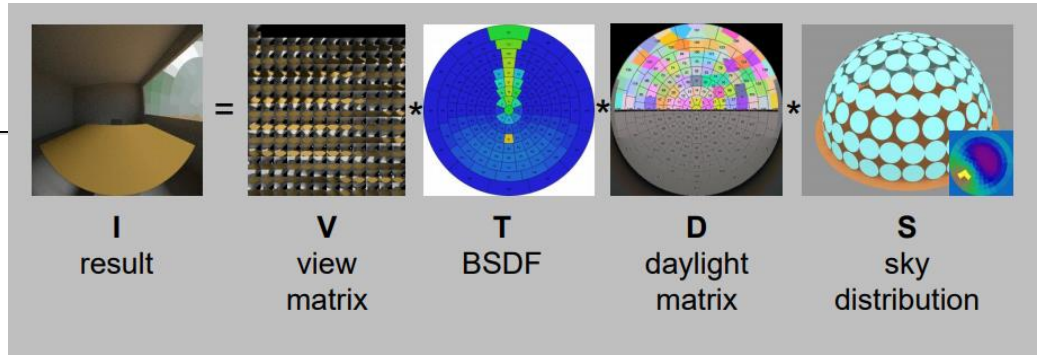
Images courtesy of spectraldb.com (radiance material database)

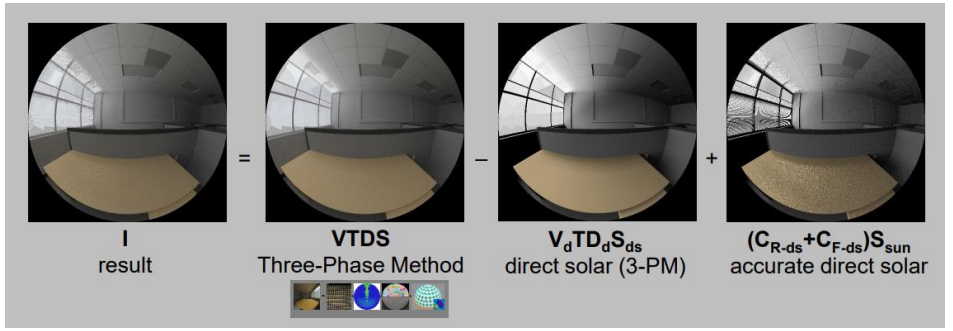
Simulation Standards

- Annual daylighting simulation methods
  - Daylight Coefficient methods – sky patches
    - 2phase, 3phase, 5phase..
  - Annual sky and sunbands – no dynamic elements
  - Design day interpolation methods – fixed orientation
  - Pros and cons to each in different applications

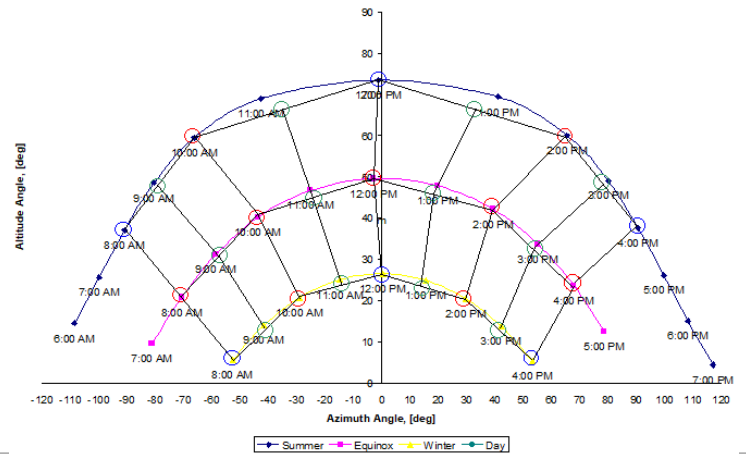
- Simulation settings
  - For both Raytracing and Radiosity
  - Sets of relative accuracy (5%, 10%)
  - Analysis grid and point standards

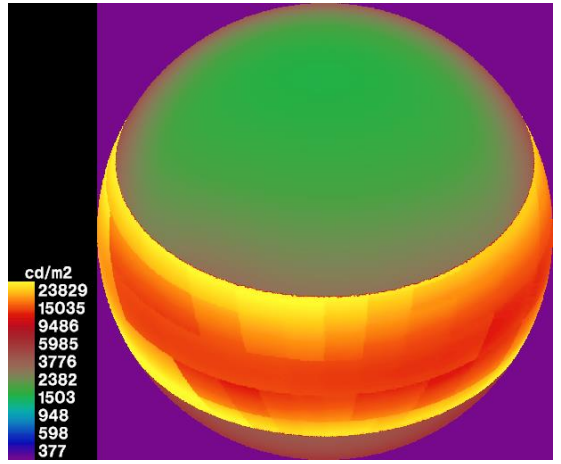
- Shading control simulation
  - Coordinated with LM-83 updates





Images courtesy of David Geisler-Moroder's Radiance 2019 presentation

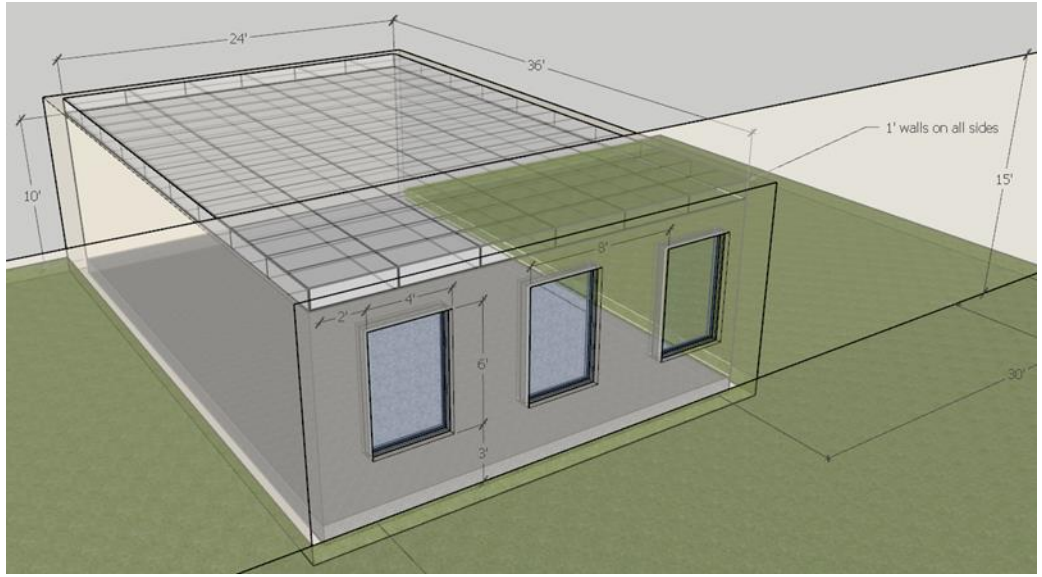




Test Cases

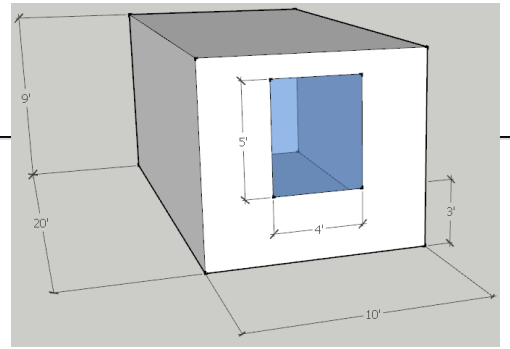
- Creating test case models and results using:
  - The validated Radiance simulation engine
  - Under validated and best practice Perez skies using vetted climate data
  - Based on validated or best available material/surface definitions
  - Using documented modeling and simulation standards

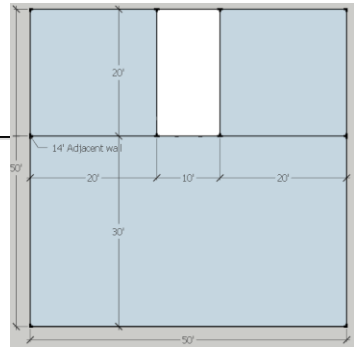
- For evaluating and assessing the overall accuracy
  - Annual daylighting software
  - Software settings
  - Other annual calculation methods

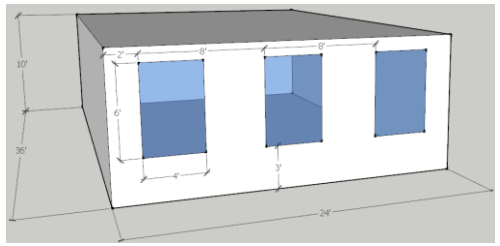


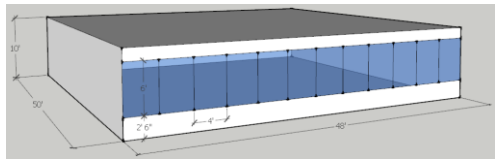
Test Cases – Base Geometry

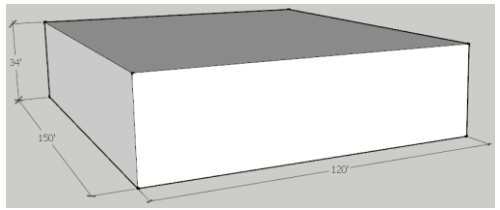
- Small room
  - Represents single office, conf room, dorm room, break room residential spaces…
- Medium room
  - Represents classroom, shared office, mid-size conf rooms, retail space..
- Large room
  - Open offices, restaurants, retail/strip mall storefronts…
- High-bay space
  - Represents gymnasium, commons/atrium, media centers, large conf rooms…
- Warehouse space
  - Represents warehouses, big-box retail, conf floors…
- Atrium space – not shown

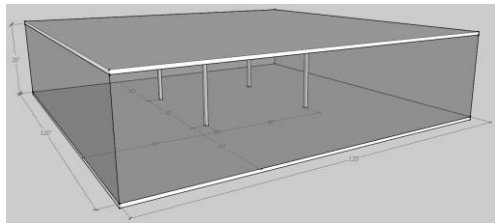






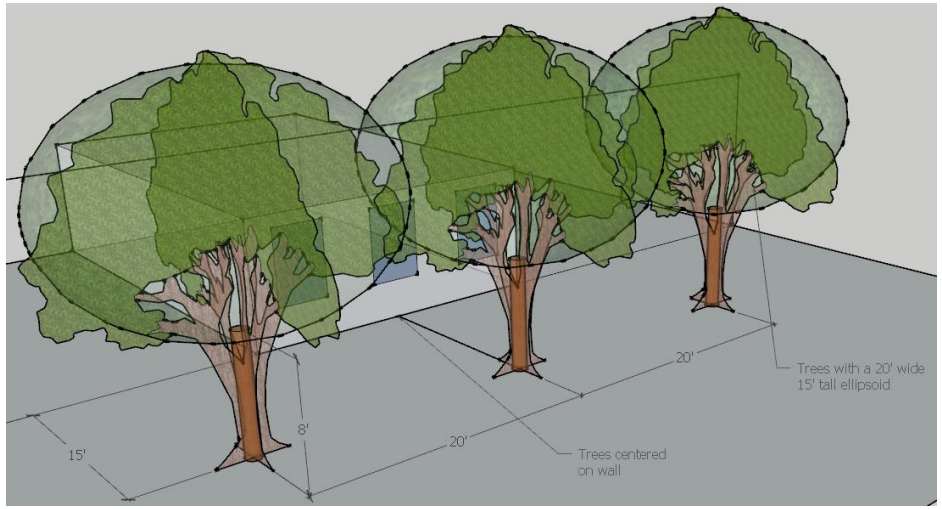


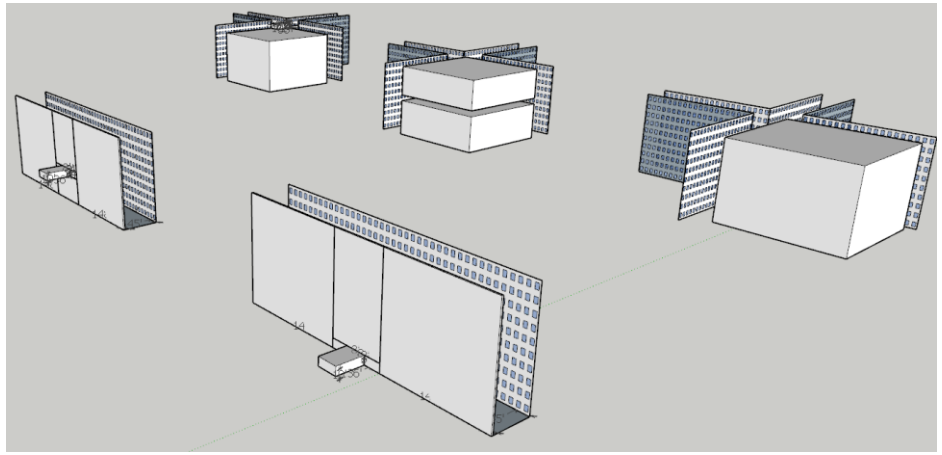




Test Cases – Simple to complex ‘sets’

- Range of simple to complex sets of test cases
  - Distinguish software abilities in handling the various modeling and simulation standards
  - Properly match tools to design problems
- Simple test cases to iron out abilities in software and settings
- Complex test cases to address real world scenarios
  - Adjacent tree and tree horizon sets
  - Urban city scape sets
  - Window treatment sets
  - Climate location and orientation sets…etc.





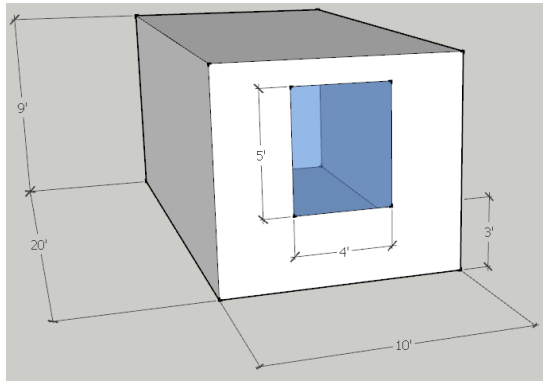
Test Cases - ‘Gold Standard’ or Ground Truth Simulations

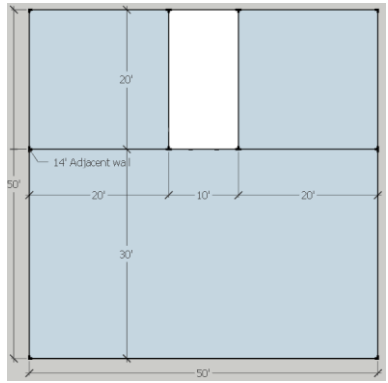
- AnnualBruteForce.py --rad Radfile --wea EPWfile [--wdm W|G|L|E] --opt Optfile [--mat MatFile] --pts PtsFile [--rot RotDeg] [--genc] [--skyc “r g b”] [--grndc “r g b”] [--snow]

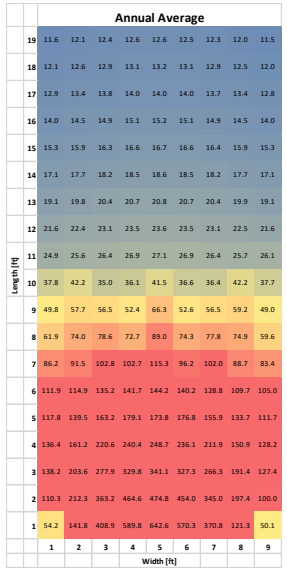
- Simply runs every ~4,400 daylit hours
  - Using Radiance parameters giving <1% error
  - ~16days on a single core-machine
  - Parallel processing built-in (only ~4hrs on 96 cores)

- Simulations with and without window treatments
  - Allows for more straight-forward validation
  - Variable shade control algorithms

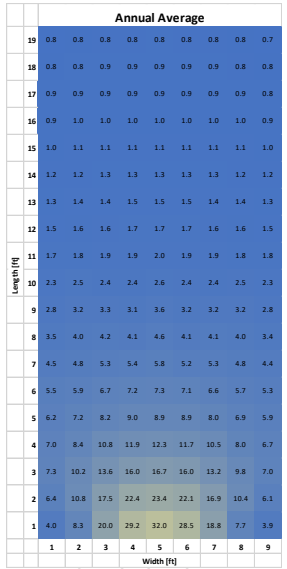
- Data provided in annual summary form (averages and metrics) and as an annual data file



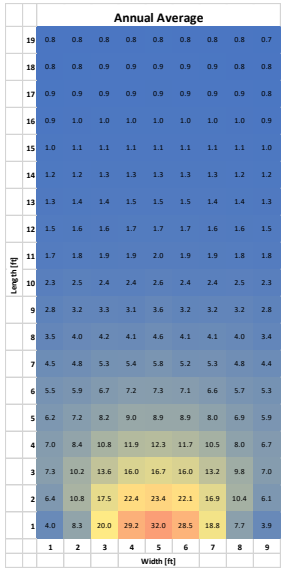




No shades



Fixed shades



Controlled shades

Test Case #1 no shades - Gold Standard Results (16days)

Annual Average

Length [ft] \ Width [ft]	1	2	3	4	5	6	7	8	9
19	11.6	12.1	12.4	12.6	12.6	12.5	12.3	12.0	11.5
18	12.1	12.6	12.9	13.1	13.2	13.1	12.9	12.5	12.0
17	12.9	13.4	13.8	14.0	14.0	14.0	13.7	13.4	12.8
16	14.0	14.5	14.9	15.1	15.2	15.1	14.9	14.5	14.0
15	15.3	15.9	16.3	16.6	16.7	16.6	16.4	15.9	15.3
14	17.1	17.7	18.2	18.5	18.6	18.5	18.2	17.7	17.1
13	19.1	19.8	20.4	20.7	20.8	20.7	20.4	19.9	19.1
12	21.6	22.4	23.1	23.5	23.6	23.5	23.1	22.5	21.6
11	24.9	25.6	26.4	26.9	27.1	26.9	26.4	25.7	26.1
10	37.8	42.2	35.0	36.1	41.5	36.6	36.4	42.2	37.7
9	49.8	57.7	56.5	52.4	66.3	52.6	56.5	59.2	49.0
8	61.9	74.0	78.6	72.7	89.0	74.3	77.8	74.9	59.6
7	86.2	91.5	102.8	102.7	115.3	96.2	102.0	88.7	83.4
6	111.9	114.9	135.2	141.7	144.2	140.2	128.8	109.7	105.0
5	117.8	139.5	163.2	179.1	173.8	176.8	155.9	133.7	111.7
4	136.4	161.2	220.6	240.4	248.7	236.1	211.9	150.9	128.2
3	138.2	203.6	277.9	329.8	341.1	327.3	266.3	191.4	127.4
2	110.3	212.3	363.2	464.6	474.8	454.0	345.0	197.4	100.0
1	54.2	141.8	408.9	589.8	642.6	570.3	370.8	121.3	50.1

Annual Max

Length [ft] \ Width [ft]	1	2	3	4	5	6	7	8	9
19	55	57	59	59	59	59	59	57	55
18	58	60	61	61	62	61	60	60	58
17	61	64	64	65	64	64	66	64	63
16	65	67	69	68	68	70	70	69	68
15	72	73	74	74	74	76	77	76	76
14	79	79	80	80	81	85	85	83	84
13	89	88	89	89	88	92	93	93	91
12	97	98	98	98	98	101	103	103	102
11	1831	195	111	110	109	114	115	114	1915
10	2213	2280	2287	2279	2338	2291	2289	2267	2121
9	2314	2611	2531	2679	2692	2702	2679	2663	2444
8	2735	2701	2931	2918	2906	2914	2797	2820	2475
7	2851	3122	3129	3181	3156	3137	3189	3019	2992
6	3149	3338	3407	3415	3417	3418	3308	3285	3092
5	3380	3435	3615	3631	3646	3621	3528	3483	3205
4	3553	3817	3894	3962	3983	3972	3963	3648	3605
3	3665	3794	4271	4324	4351	4344	4321	3910	3626
2	3064	3820	4299	4370	4401	4390	4351	3900	3027
1	2557	3449	4316	4404	4439	4431	4351	3062	1984

Daylight Saturation

Length [ft] \ Width [ft]	1	2	3	4	5	6	7	8	9
19	0.38	0.40	0.40	0.41	0.41	0.41	0.40	0.39	0.38
18	0.40	0.41	0.42	0.42	0.42	0.42	0.41	0.41	0.40
17	0.42	0.43	0.43	0.44	0.44	0.44	0.43	0.43	0.41
16	0.44	0.45	0.46	0.46	0.47	0.46	0.46	0.45	0.44
15	0.47	0.48	0.49	0.49	0.50	0.50	0.49	0.48	0.47
14	0.50	0.52	0.53	0.53	0.53	0.53	0.53	0.52	0.51
13	0.54	0.55	0.56	0.57	0.57	0.57	0.56	0.56	0.54
12	0.58	0.59	0.60	0.61	0.61	0.61	0.60	0.60	0.58
11	0.62	0.63	0.64	0.65	0.65	0.65	0.64	0.63	0.62
10	0.66	0.67	0.68	0.68	0.69	0.68	0.68	0.67	0.66
9	0.69	0.70	0.71	0.72	0.72	0.72	0.71	0.71	0.69
8	0.72	0.74	0.74	0.75	0.75	0.75	0.75	0.74	0.73
7	0.75	0.76	0.77	0.78	0.78	0.78	0.78	0.77	0.76
6	0.78	0.79	0.80	0.81	0.81	0.81	0.80	0.79	0.78
5	0.80	0.81	0.83	0.83	0.84	0.83	0.83	0.81	0.80
4	0.81	0.83	0.85	0.86	0.86	0.86	0.85	0.83	0.81
3	0.82	0.85	0.87	0.88	0.88	0.88	0.87	0.85	0.82
2	0.80	0.85	0.88	0.89	0.90	0.89	0.88	0.85	0.80
1	0.73	0.82	0.88	0.90	0.91	0.90	0.88	0.82	0.73

Daylight Excess

Length [ft] \ Width [ft]	1	2	3	4	5	6	7	8	9
19	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
18	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
17	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
16	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
15	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
14	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
13	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
12	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
11	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
10	0.01	0.01	0.00	0.00	0.01	0.00	0.00	0.01	0.01
9	0.01	0.02	0.02	0.01	0.02	0.01	0.02	0.02	0.01
8	0.02	0.03	0.03	0.02	0.03	0.02	0.03	0.03	0.02
7	0.04	0.03	0.04	0.04	0.05	0.03	0.04	0.03	0.04
6	0.05	0.05	0.05	0.06	0.06	0.06	0.05	0.05	0.05
5	0.06	0.06	0.06	0.07	0.07	0.07	0.06	0.06	0.06
4	0.07	0.07	0.10	0.10	0.11	0.11	0.10	0.07	0.07
3	0.07	0.10	0.13	0.17	0.18	0.17	0.13	0.10	0.07
2	0.05	0.10	0.20	0.27	0.29	0.27	0.20	0.10	0.05
1	0.01	0.06	0.21	0.35	0.40	0.36	0.21	0.06	0.02

Daylight Autonomy

Length [ft] \ Width [ft]	1	2	3	4	5	6	7	8	9
19	0.11	0.13	0.14	0.14	0.15	0.14	0.14	0.13	0.11
18	0.13	0.14	0.15	0.16	0.16	0.16	0.15	0.14	0.13
17	0.15	0.16	0.17	0.18	0.18	0.17	0.17	0.16	0.15
16	0.18	0.19	0.20	0.20	0.20	0.20	0.19	0.19	0.17
15	0.21	0.22	0.23	0.23	0.23	0.23	0.23	0.22	0.20
14	0.24	0.26	0.27	0.28	0.28	0.28	0.27	0.26	0.24
13	0.29	0.31	0.33	0.34	0.35	0.34	0.33	0.32	0.29
12	0.36	0.39	0.41	0.42	0.43	0.43	0.41	0.39	0.37
11	0.44	0.47	0.50	0.51	0.51	0.51	0.50	0.48	0.45
10	0.53	0.56	0.58	0.59	0.59	0.59	0.58	0.57	0.54
9	0.61	0.63	0.66	0.67	0.68	0.67	0.66	0.64	0.62
8	0.67	0.69	0.71	0.72	0.73	0.73	0.72	0.71	0.68
7	0.72	0.75	0.77	0.78	0.78	0.79	0.78	0.76	0.74
6	0.76	0.78	0.80	0.81	0.82	0.82	0.81	0.81	0.79
5	0.79	0.81	0.84	0.85	0.86	0.85	0.85	0.83	0.82
4	0.80	0.84	0.86	0.88	0.89	0.89	0.88	0.86	0.84
3	0.81	0.85	0.89	0.91	0.91	0.91	0.90	0.88	0.85
2	0.79	0.86	0.91	0.92	0.93	0.93	0.92	0.89	0.84
1	0.67	0.81	0.91	0.93	0.93	0.93	0.92	0.86	0.72

Test Case #1 no shades – Test software results (med quality – 9mins)

Annual Average

Length [ft] \ Width [ft]	1	2	3	4	5	6	7	8	9
19	9.2	9.5	9.8	9.8	9.9	10.0	10.1	10.3	10.6
18	9.4	9.7	10.0	10.0	10.2	10.1	10.2	10.2	10.3
17	10.0	10.1	10.6	10.6	10.8	10.7	10.8	10.5	10.7
16	10.6	11.0	11.3	11.4	11.5	11.6	11.5	11.4	11.3
15	11.6	12.2	12.4	12.6	12.7	12.6	12.6	12.3	12.2
14	13.1	13.4	13.8	13.9	14.0	14.0	13.9	13.6	13.5
13	14.7	14.8	15.6	15.8	15.8	15.8	15.7	15.2	15.0
12	16.5	16.9	17.8	17.7	17.7	17.8	17.8	17.1	16.8
11	19.3	19.5	20.2	20.4	20.3	20.3	20.3	19.9	19.9
10	23.1	22.7	23.2	74.1	23.9	23.7	23.5	23.4	24.6
9	56.2	26.4	27.0	77.4	78.5	78.1	27.5	27.5	68.9
8	60.1	31.2	31.5	82.9	82.9	83.1	32.4	32.4	74.3
7	65.1	64.2	36.6	88.5	88.9	88.8	37.6	76.2	78.6
6	106.3	69.5	71.7	95.9	97.2	96.4	84.1	126.9	127.2
5	110.2	112.2	137.1	161.5	164.9	162.4	137.5	133.3	130.8
4	114.9	119.4	147.8	205.0	178.1	215.8	148.6	141.0	136.0
3	121.3	160.4	288.0	279.8	254.4	336.5	200.1	185.8	111.1
2	58.9	176.0	303.4	454.5	475.0	400.2	214.1	219.4	81.6
1	34.9	122.2	243.6	515.0	501.3	485.1	265.9	146.2	42.7

Annual Max

Length [ft] \ Width [ft]	1	2	3	4	5	6	7	8	9
19	38	40	42	41	41	41	41	39	37
18	40	41	42	43	43	42	42	40	38
17	43	42	44	45	45	45	44	42	40
16	45	47	48	48	48	48	47	45	44
15	50	52	52	53	53	53	52	51	49
14	55	56	57	58	58	58	57	56	55
13	60	60	63	64	64	66	65	63	61
12	65	66	69	69	71	72	73	75	77
11	97	79	76	78	81	82	90	101	129
10	165	105	88	2118	90	94	112	138	226
9	1519	138	103	2104	2133	2119	135	179	1971
8	1561	171	123	2134	2133	2134	158	223	2063
7	1605	1465	137	2149	2149	2150	178	1890	2082
6	2301	1467	1404	2165	2165	2150	1844	2788	2833
5	2380	2266	3008	3217	3246	3214	2801	2807	2846
4	2371	2276	3022	3259	3259	3243	2815	2812	2785
3	2704	2704	3587	3614	3616	3614	3273	3249	3172
2	1917	2700	3587	3912	3912	3642	3283	3240	2556
1	872	2563	2874	3941	3942	3941	3433	2958	1366

Daylight Saturation

Length [ft] \ Width [ft]	1	2	3	4	5	6	7	8	9
19	0.33	0.33	0.34	0.34	0.34	0.35	0.35	0.36	0.37
18	0.33	0.34	0.35	0.35	0.35	0.35	0.36	0.36	0.36
17	0.35	0.35	0.36	0.36	0.37	0.37	0.37	0.36	0.37
16	0.36	0.38	0.38	0.39	0.39	0.39	0.39	0.39	0.39
15	0.39	0.41	0.41	0.42	0.42	0.42	0.42	0.41	0.41
14	0.43	0.44	0.45	0.45	0.45	0.45	0.45	0.44	0.44
13	0.47	0.47	0.49	0.50	0.50	0.49	0.49	0.48	0.48
12	0.51	0.52	0.54	0.54	0.54	0.54	0.54	0.52	0.51
11	0.56	0.57	0.59	0.59	0.59	0.59	0.58	0.57	0.56
10	0.60	0.62	0.64	0.64	0.65	0.64	0.63	0.62	0.61
9	0.66	0.67	0.68	0.69	0.69	0.69	0.68	0.67	0.66
8	0.70	0.72	0.73	0.74	0.74	0.73	0.73	0.71	0.70
7	0.74	0.76	0.77	0.77	0.78	0.77	0.76	0.75	0.74
6	0.77	0.79	0.80	0.81	0.81	0.81	0.80	0.79	0.77
5	0.80	0.82	0.84	0.84	0.85	0.84	0.83	0.81	0.79
4	0.82	0.84	0.86	0.87	0.87	0.87	0.86	0.84	0.81
3	0.83	0.86	0.88	0.89	0.89	0.89	0.88	0.86	0.82
2	0.82	0.87	0.89	0.90	0.91	0.90	0.89	0.86	0.81
1	0.71	0.84	0.90	0.91	0.92	0.91	0.90	0.83	0.72

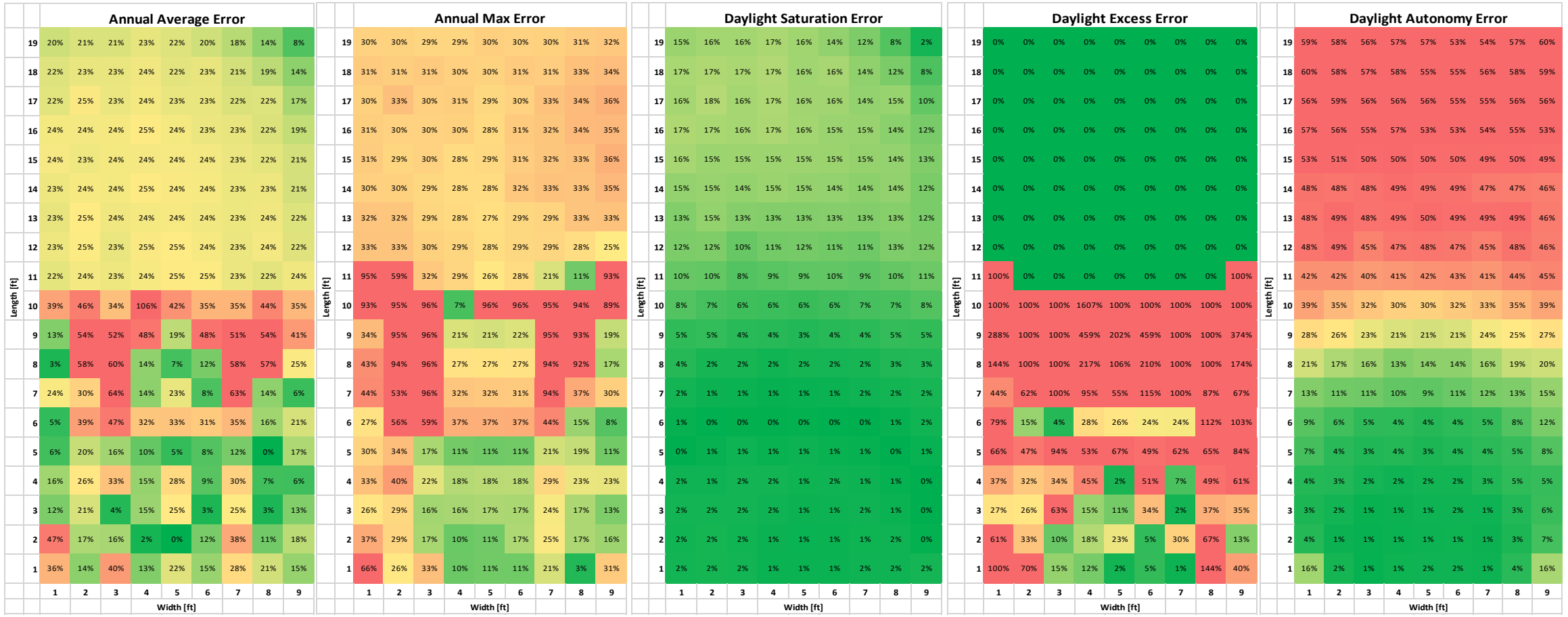
Daylight Excess

Length [ft] \ Width [ft]	1	2	3	4	5	6	7	8	9
19	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
18	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
17	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
16	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
15	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
14	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
13	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
12	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
11	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
10	0.00	0.00	0.00	0.07	0.00	0.00	0.00	0.00	0.00
9	0.05	0.00	0.00	0.07	0.07	0.07	0.00	0.00	0.06
8	0.06	0.00	0.00	0.07	0.07	0.07	0.00	0.00	0.07
7	0.06	0.06	0.00	0.07	0.07	0.07	0.00	0.07	0.07
6	0.10	0.06	0.06	0.07	0.07	0.07	0.07	0.10	0.10
5	0.10	0.10	0.12	0.11	0.11	0.11	0.10	0.10	0.10
4	0.10	0.10	0.13	0.15	0.11	0.16	0.11	0.11	0.11
3	0.09	0.13	0.21	0.20	0.16	0.23	0.14	0.14	0.09
2	0.02	0.14	0.22	0.32	0.36	0.26	0.14	0.17	0.05
1	0.00	0.10	0.18	0.39	0.41	0.37	0.21	0.14	0.02

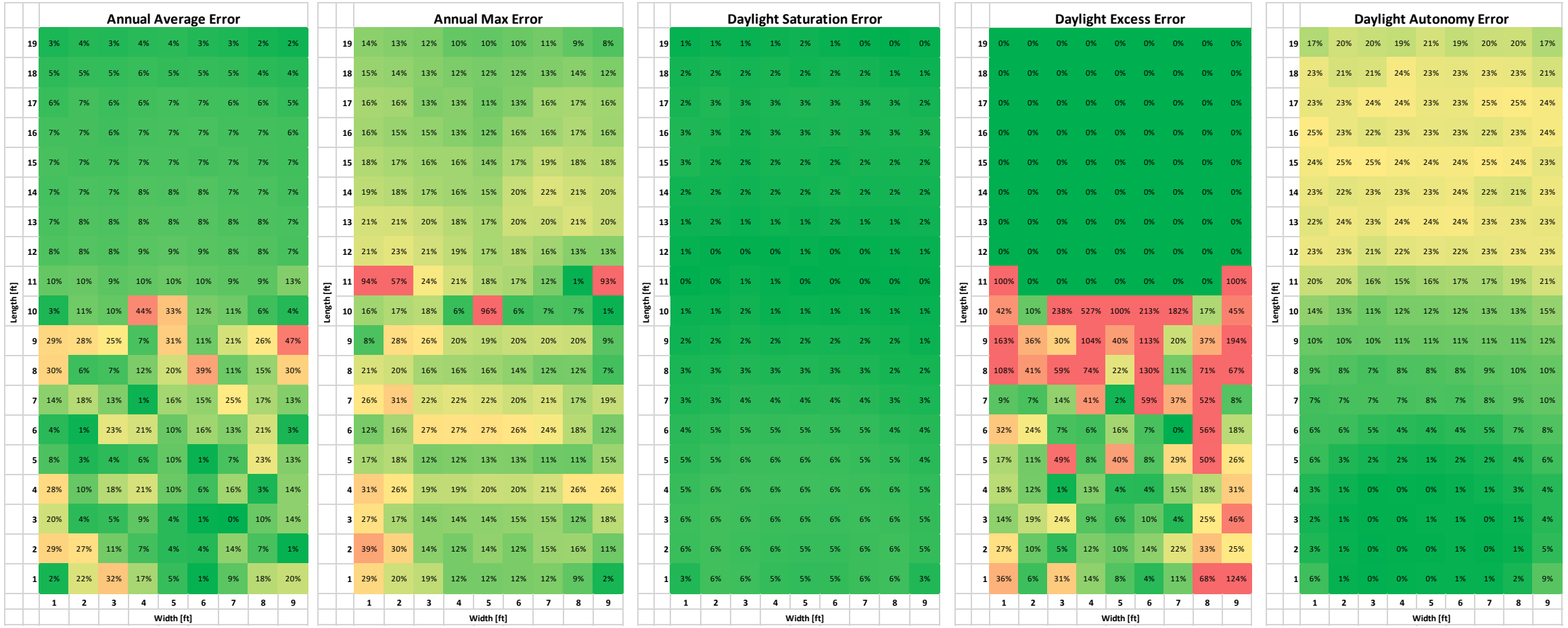
Daylight Autonomy

Length [ft] \ Width [ft]	1	2	3	4	5	6	7	8	9
19	0.11	0.13	0.14	0.14	0.15	0.14	0.14	0.13	0.11
18	0.13	0.14	0.15	0.16	0.16	0.16	0.15	0.14	0.13
17	0.15	0.16	0.17	0.18	0.18	0.17	0.17	0.16	0.15
16	0.18	0.19	0.20	0.20	0.20	0.20	0.19	0.19	0.17
15	0.21	0.22	0.23	0.23	0.23	0.23	0.23	0.22	0.20
14	0.24	0.26	0.27	0.28	0.28	0.28	0.27	0.26	0.24
13	0.29	0.31	0.33	0.34	0.35	0.34	0.33	0.32	0.29
12	0.36	0.39	0.41	0.42	0.43	0.43	0.41	0.39	0.37
11	0.44	0.47	0.50	0.51	0.51	0.51	0.50	0.48	0.45
10	0.53	0.56	0.58	0.59	0.59	0.59	0.58	0.57	0.54
9	0.61	0.63	0.66	0.67	0.68	0.67	0.66	0.64	0.62
8	0.67	0.69	0.71	0.72	0.73	0.73	0.72	0.71	0.68
7	0.72	0.75	0.77	0.78	0.78	0.79	0.78	0.76	0.74
6	0.76	0.78	0.80	0.81	0.82	0.82	0.81	0.81	0.79
5	0.79	0.81	0.84	0.85	0.86	0.85	0.85	0.83	0.82
4	0.80	0.84	0.86	0.88	0.89	0.89	0.88	0.86	0.84
3	0.81	0.85	0.89	0.91	0.91	0.91	0.90	0.88	0.85
2	0.79	0.86	0.91	0.92	0.93	0.93	0.92	0.89	0.84
1	0.67	0.81	0.91	0.93	0.93	0.93	0.92	0.86	0.72

Test Case #1 – Gold Standard vs test software (med quality – 9mins)



Test Case #1 – Gold Standard vs test software (high quality – 7hours)



Next Steps

IESNA

- Finish Daylighting Modeling and Simulation Methods and Standards document and initial release
- Revisit and update other related IESNA documents as necessary (LM-83, RP-5)
- Develop new annual, spatial and temporal daylight metrics document (LM-XX?)

Daylighting colleagues

- More modeling and simulation methods and validation research!
  - Prioritizing critical areas for accuracy and design guidance
  - More field data to help validate annual results
- More field research of the human experience!
  - Improve confidence in sufficiency and glare metrics
  - Gain confidence in shade control and lighting control algorithms!

Questions?

IESNA Daylight Modeling and Simulation Standards

8th Velux Daylight Symposium
October 9th, 2019

Zack Rogers, P.E., IESNA, LEED AP BD+C
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DAYLIGHTING INNOVATIONS