Annual Simulation Error Analysis

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Anyhere Software

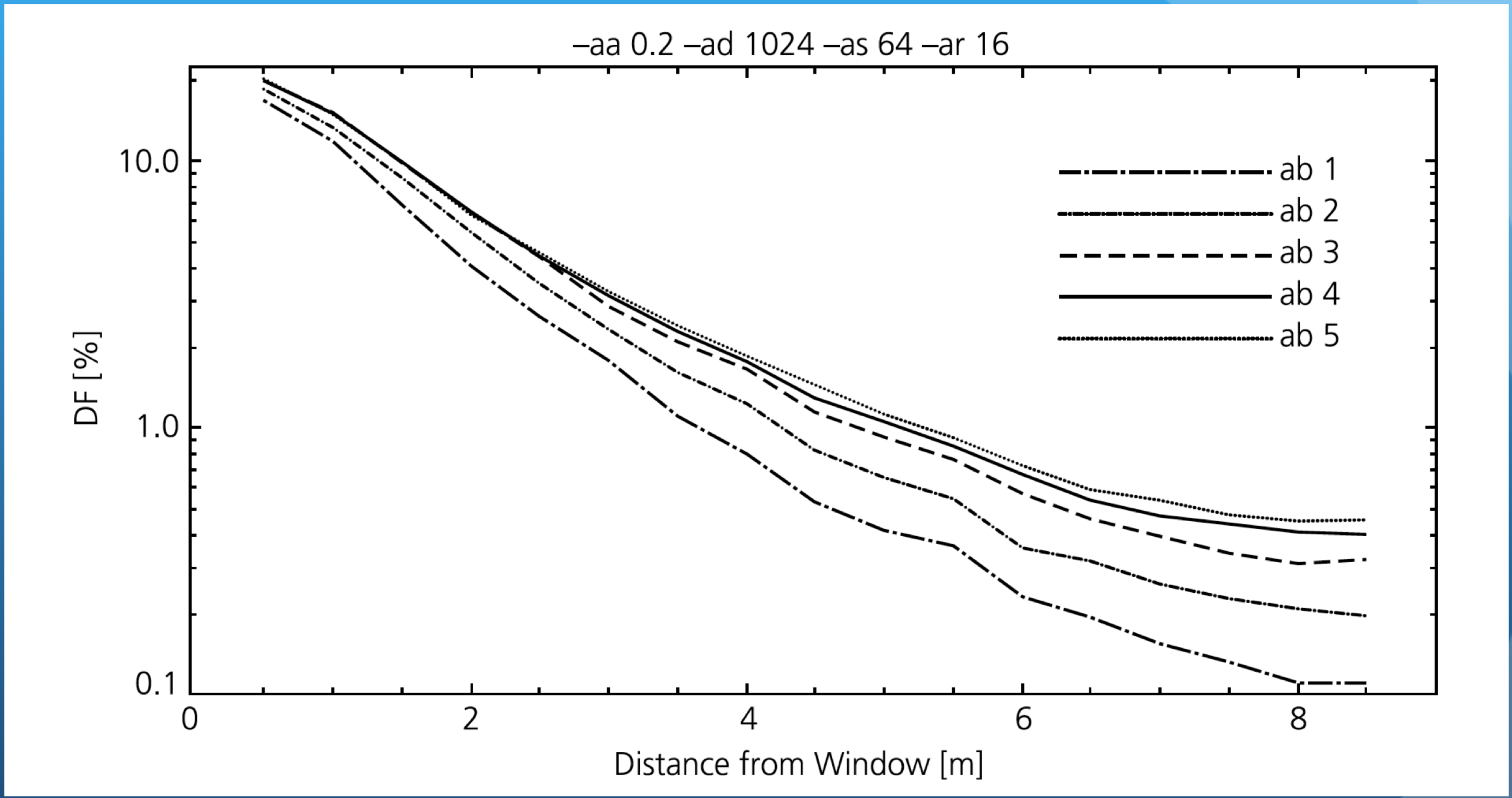
Problem Statement

- Setting up annual simulations is complex
  - Abundant modeling and calculation parameters
- We want to know relationship between parameters and simulation accuracy
- Can we estimate parameter sensitivity?
  - Estimated accuracy is good enough
  - Is convergence testing a viable approach?

Convergence Testing

- Test parameter setting by steadily moving towards higher accuracy, stopping when changes are below acceptance threshold
- Challenges:
  - May not be obvious if result has desired accuracy
  - Takes as much time as most costly simulation plus all others that led up to it
    - particularly bad for ray-tracing portion of annual simulation, as much dependent analysis follows

Convergence Testing

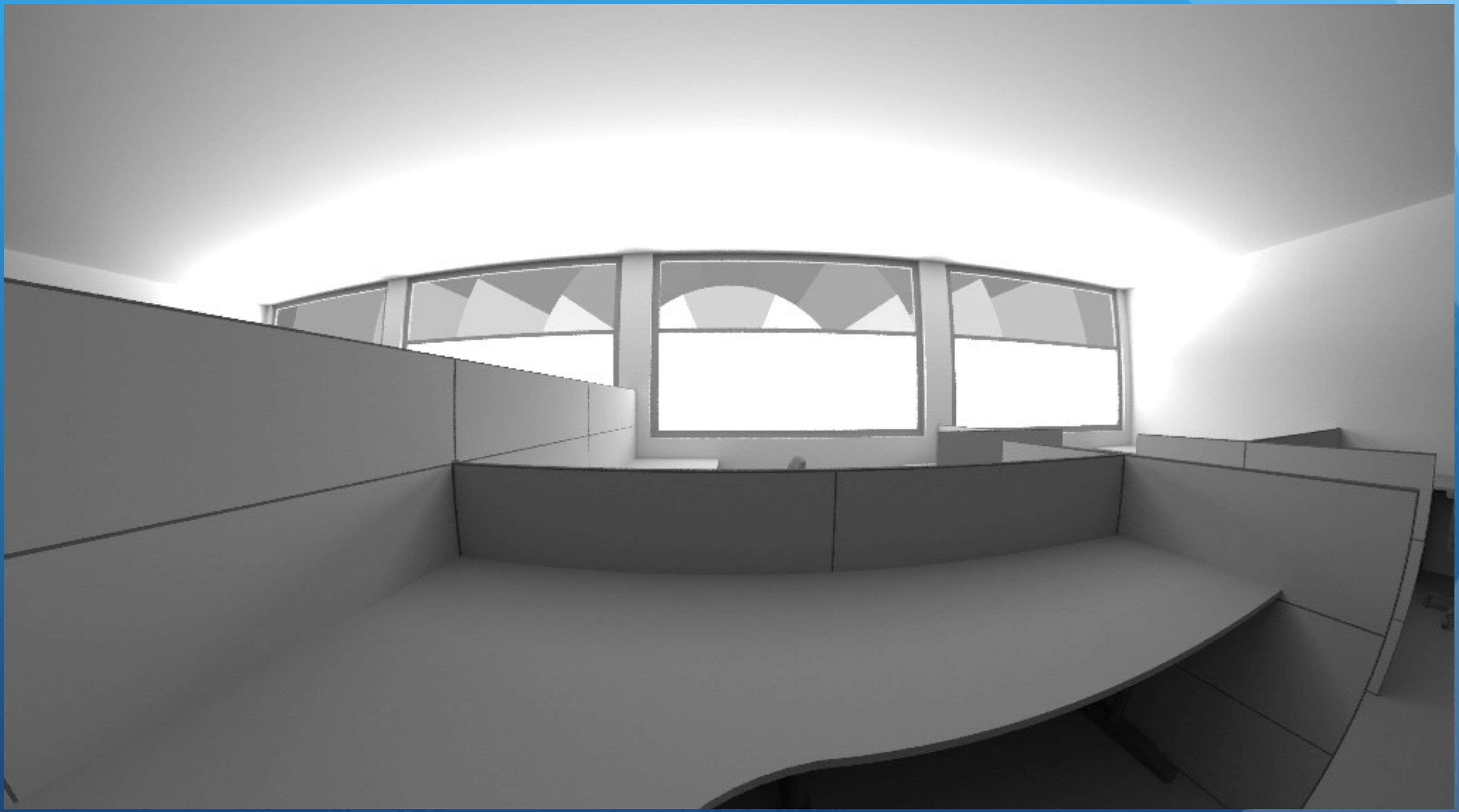


From John Mardaljevic's Daylighting chapter in RwR

Annual Simulation Subproblem

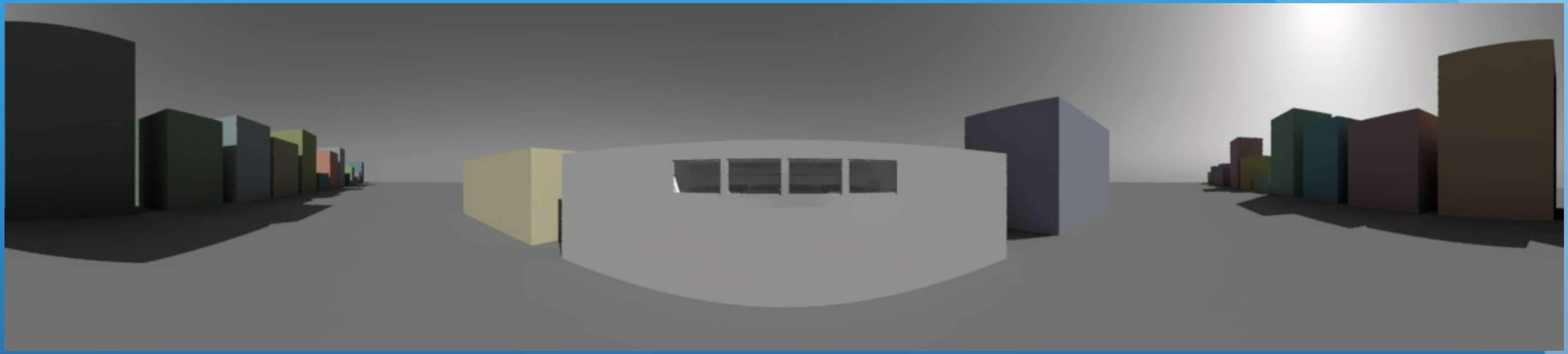
- Too much to tackle everything at once, so…
- Examine the sensitivity of window subdivision for the 3-phase method
- Analysis is mostly independent of other simulation parameters

Our Test Model

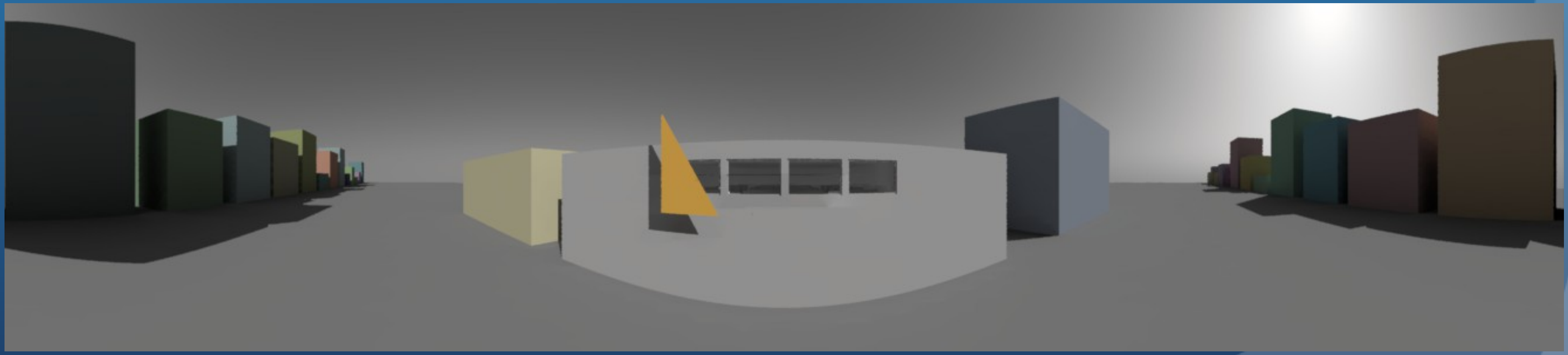


Interior view - clerestory uses LightLouver™

Our Test Model



without blocker

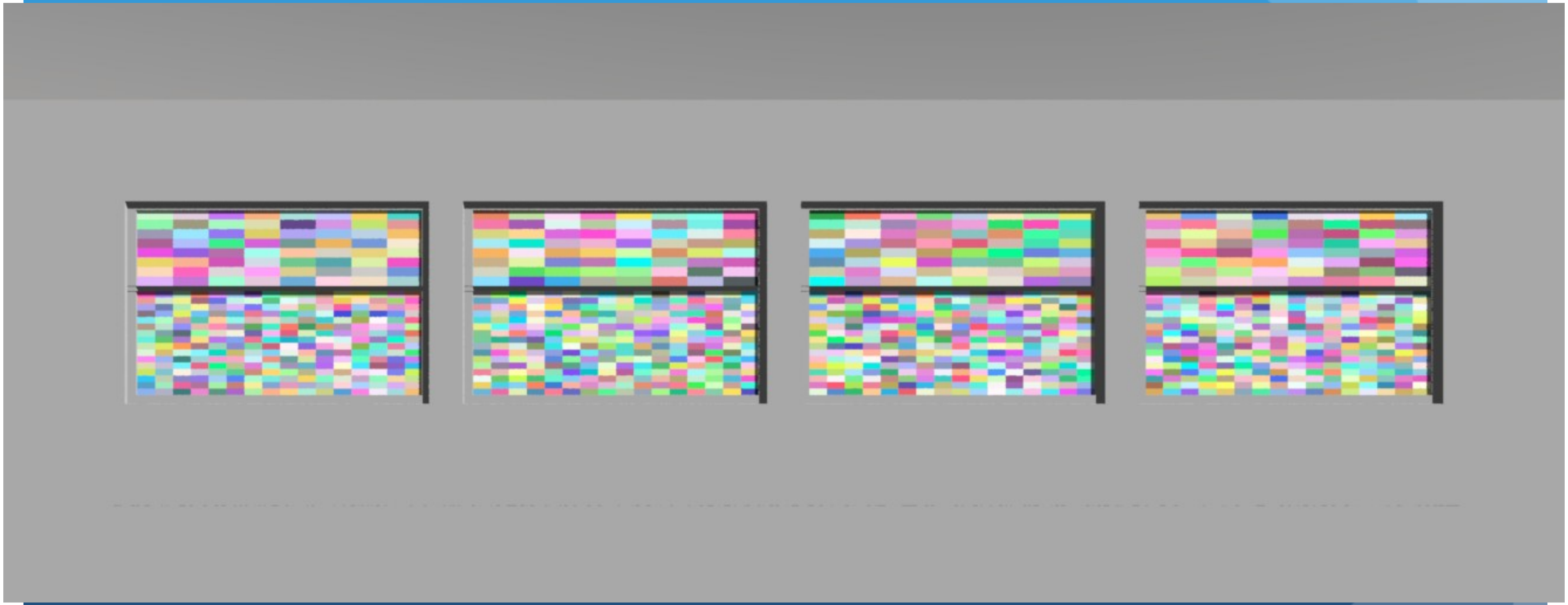


with blocker

What Inputs Do We Require?

- Complete building and exterior model
- Window/skylight rectangles
- Minimum subdivision size
- Work plane positions for analysis
- Weather file with locale
- BSDF file(s) for window shading systems

Two Subdivisions

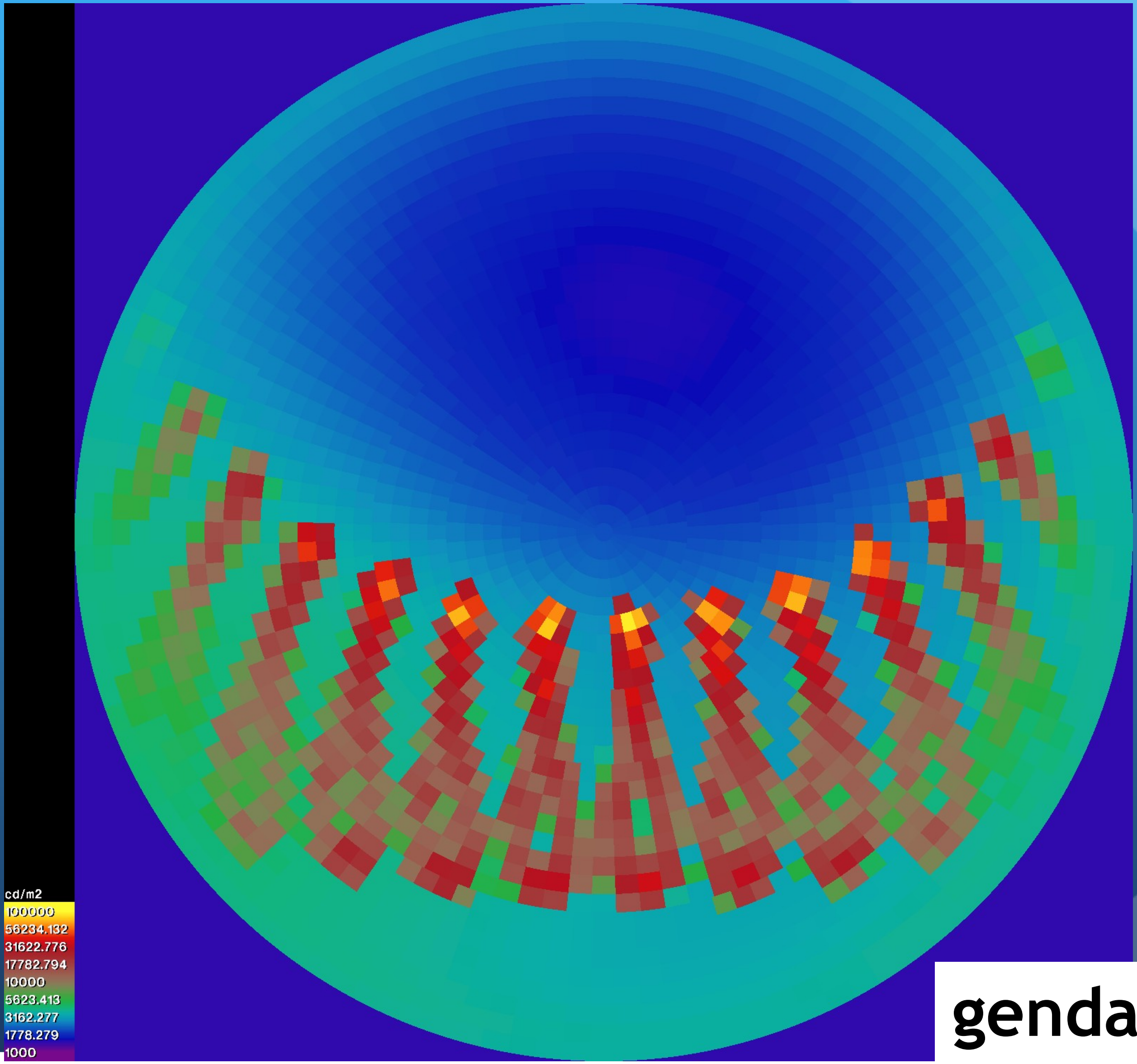


Maximum subdivision shown for clerestory and view windows

What Do We Measure?

- Estimate variance due to cruder subdivision
  - Assume finest subdivision is “gold standard”
    - similar to convergence testing in this respect
- Simulate average daytime illuminance at design work plane positions
  - Can use average sky rather than entire year
  - Sample sun positions to detect exterior shading

Average Sky



gendaymtx -A

What Will We Estimate?

- For each window rectangle:
  - Mean illuminance contribution, and
  - For each candidate decimation level (factors of 2):
    - For each work plane analysis point:
      - Expected absolute error contribution
- The above are all “average case” estimates
- Having mean illuminance estimate with RMS error allows us to interpret error contribution in context of overall simulation

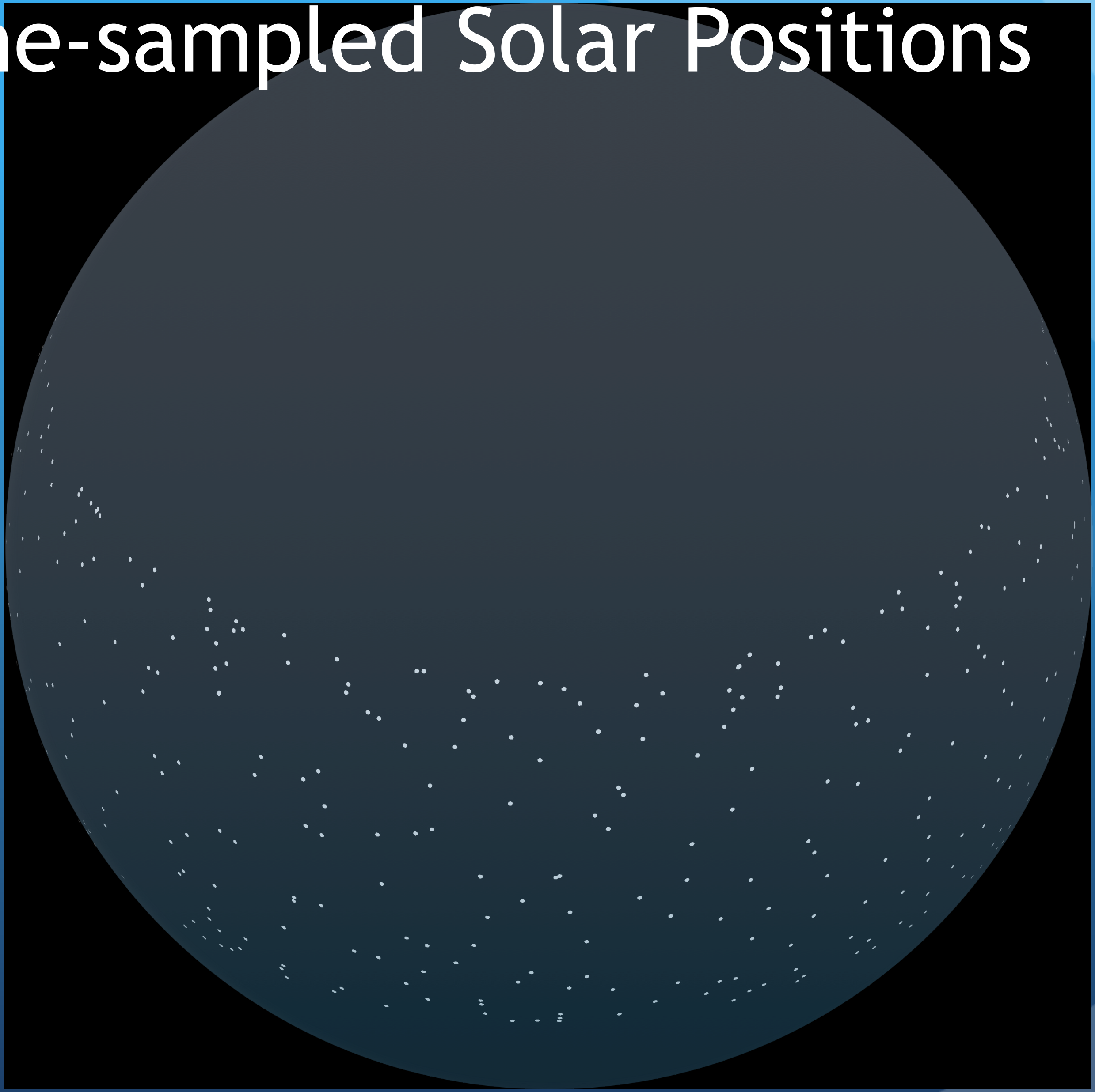
(Inadequate) Subdivision Errors

- Two multiplicative sources of error:
  1. Interior obstructions and wall effects
  2. Exterior obstructions/shading
- Interior error influence through view matrix calculation (**rfluxmtx**)
- Exterior obstructions measured with aid of special solar shading test
  - Assumes indirect lighting plays a minor role

What Do We Need to Calculate?

1. Average sky contrib. through shading system(s)
   a. Exterior **D** matrix: flux from window to sky+ground
   b. **TDs** gets converted to window source distribution using "average sky" vector **s**
      - controllable shading may require partitioned weather files
2. Interior **V** matrix: flux between work plane points and subdivided window sources, **rcontrib -V+**
   - Yields mean subwindow illuminance contributions
3. Solar shading coefficients from sampled sun positions (target = 200 suns, cosine dist.)

Cosine-sampled Solar Positions



Relative Solar Shading Probability

- Fraction of time a given subrectangle of window is in shadow while at least 15% of other points access the sun
- Samples sent from centroid of each minimal subrectangle
- Use **rcontrib -I+ -V+** (as for **V** matrix)

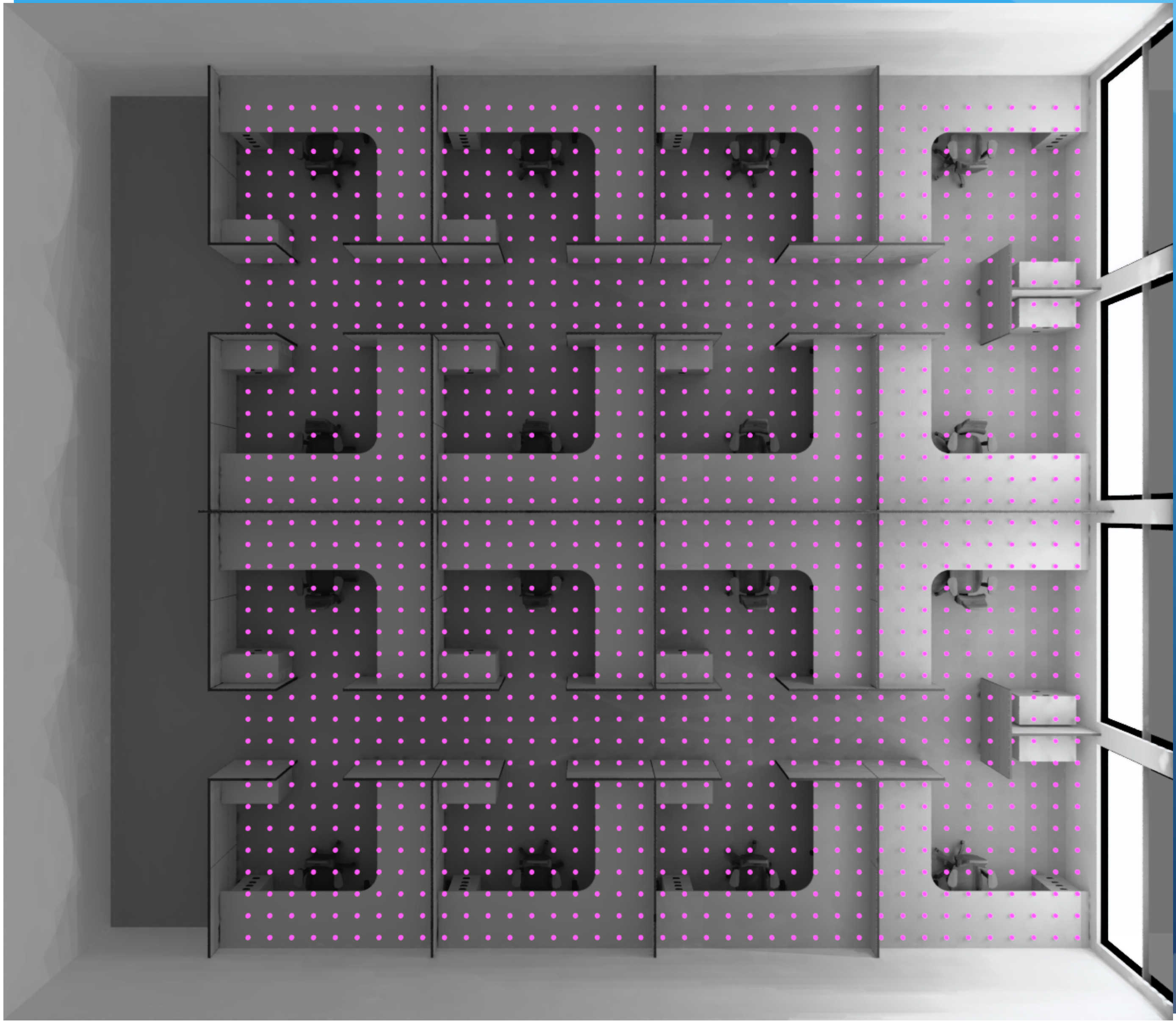
1 - Relative Shading Probability

model with blocker

Final Error Estimation

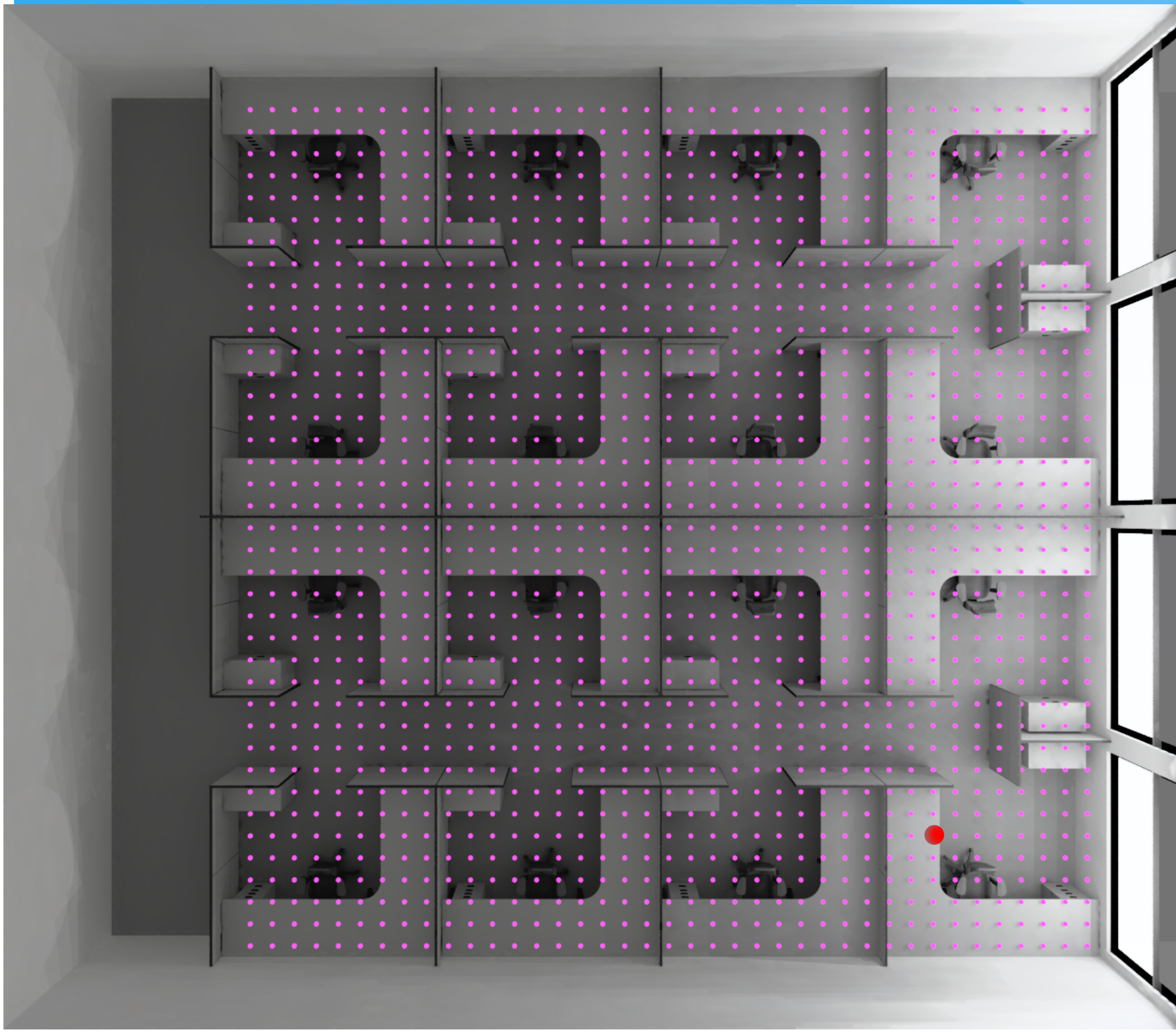
- For each window rectangle and subdivision:
  - Compute average over each trial subdivision
  - Using minimal subdivided regions, subtract partial contribution from the above average
  - Multiply these absolute differences by relative shading probability for each minimal region & sum
- This gives estimate of error from using a given subdivision compared to max.

Work Plane Analysis Points



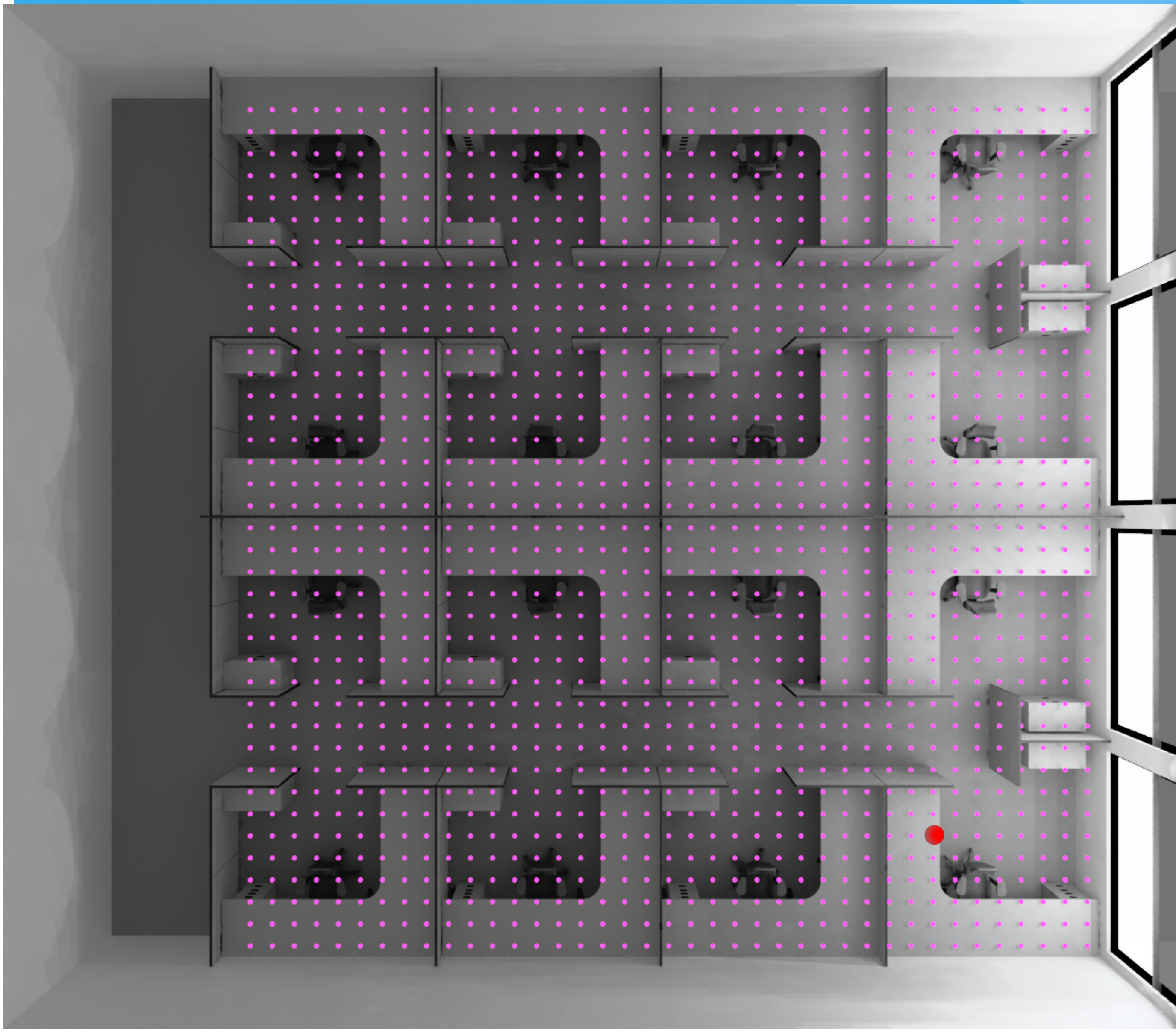
Obstructed Case

Work Plane Point 279@div=1



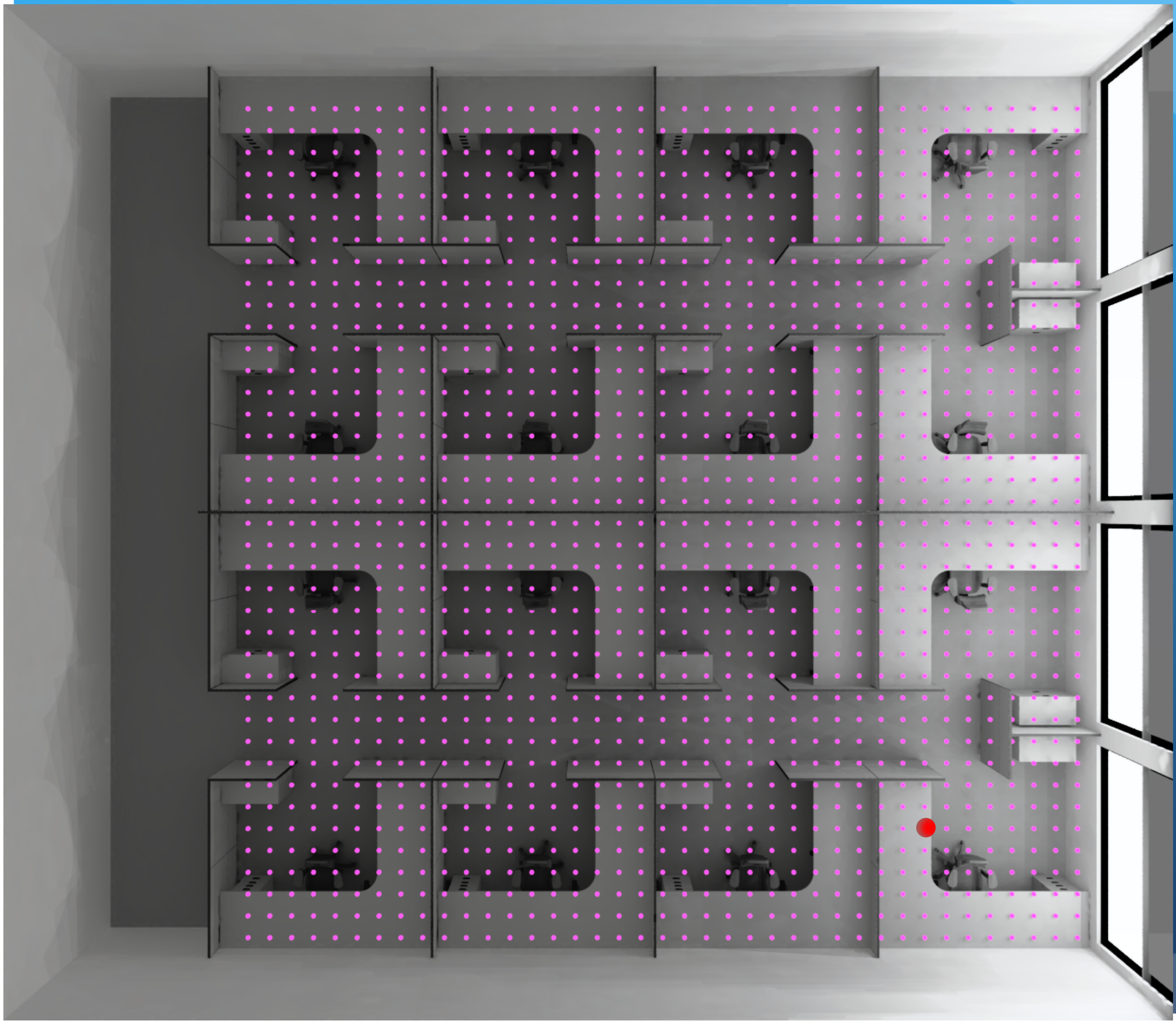
View err (lux, %)	Clerestory err (lux, %)
0.047 2.1%	0.057 3.5%
0.30 2.2%	0.35 2.9%
3.0 3.0%	3.6 3.3%
22. 7.2%	15. 4.9%

Work Plane Point 279@div=2



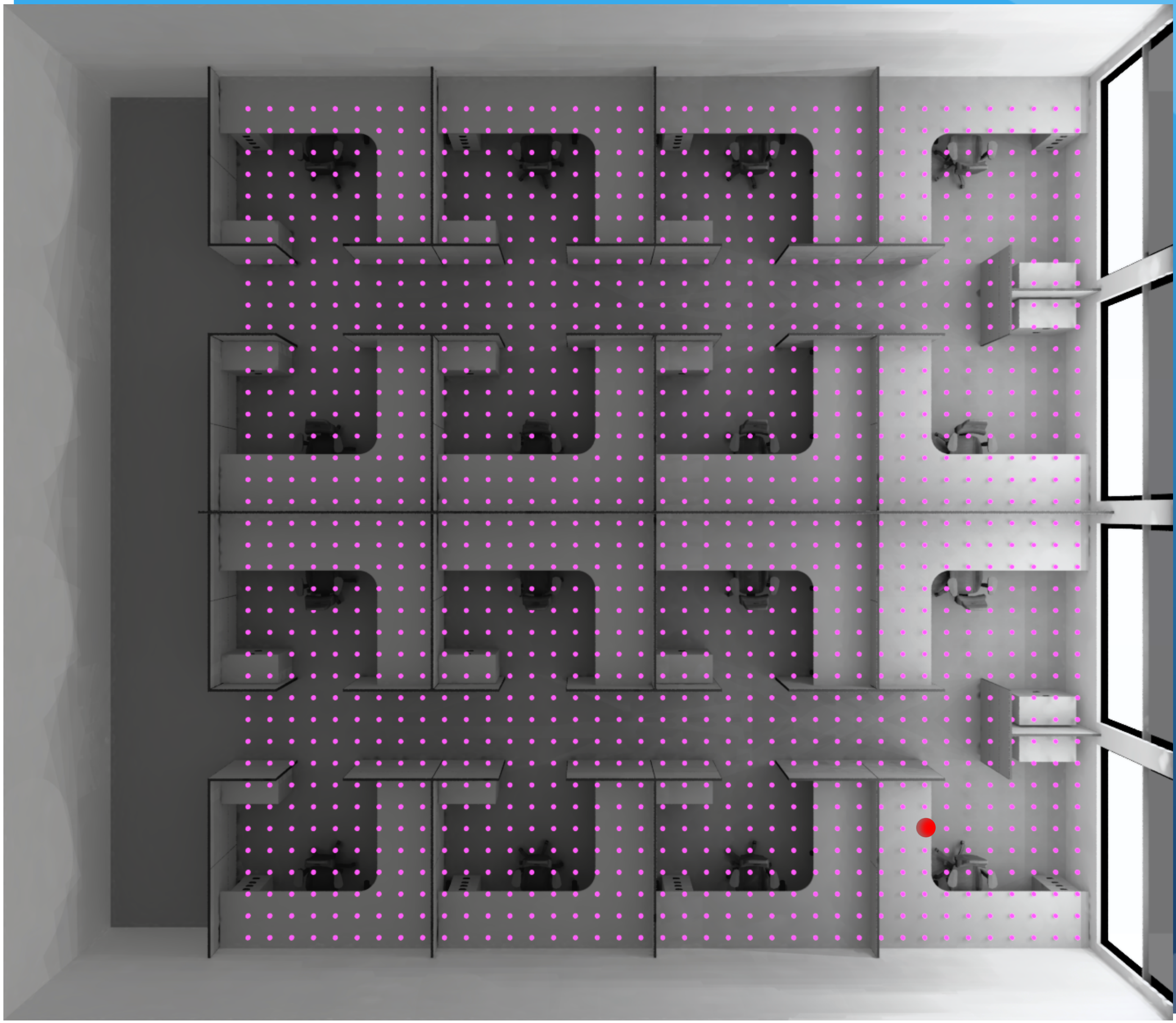
View err (lux, %)	Clerestory err (lux, %)
0.039 1.7%	0.037 2.3%
0.25 1.8%	0.23 1.9%
2.0 2.0%	2.2 2.0%
15. 5.0%	12. 4.0%

Work Plane Point 279@div=4



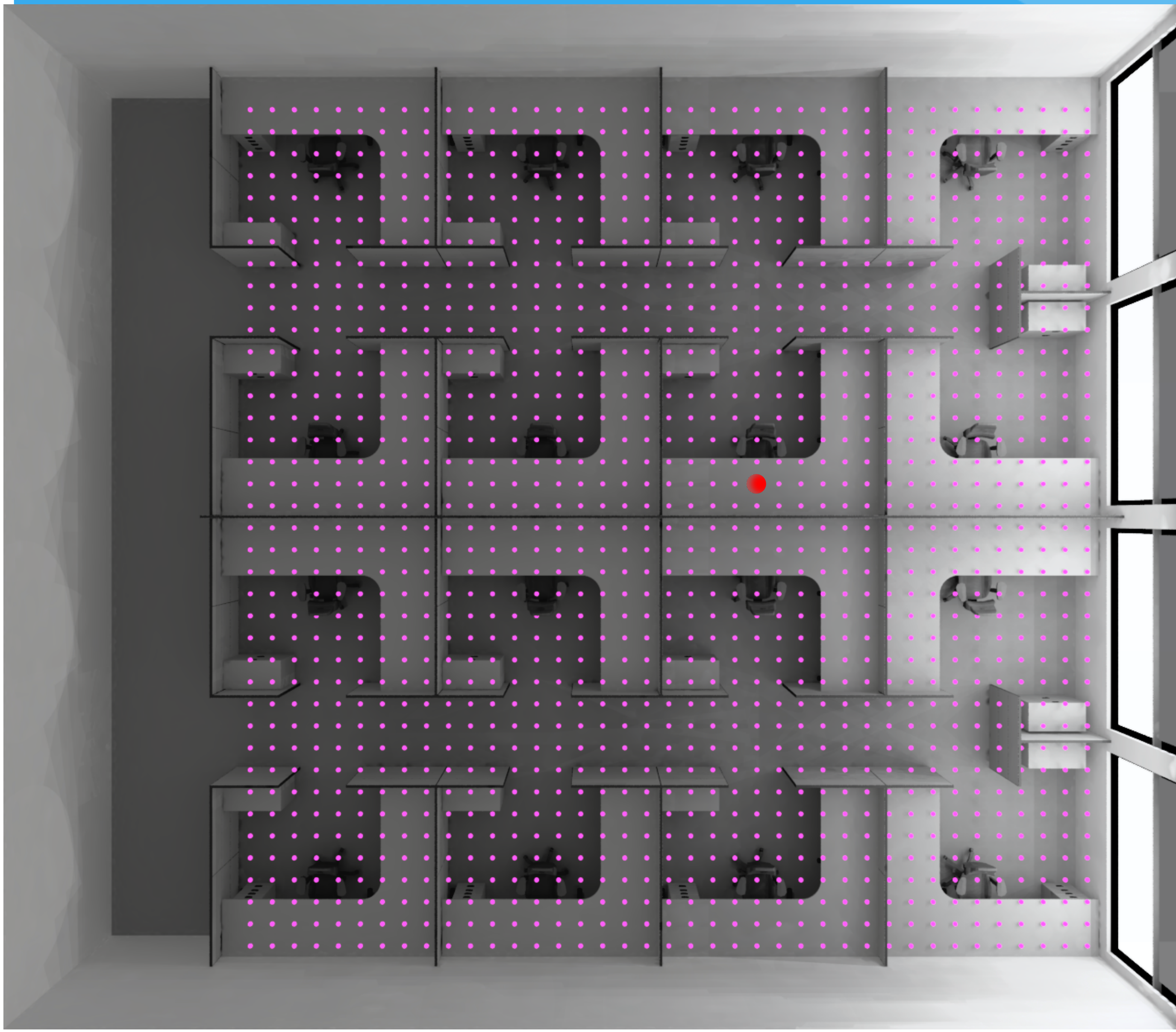
View err (lux, %)	Clerestory err (lux, %)
0.031 1.4%	0.025 1.5%
0.23 1.7%	0.15 1.3%
1.5 1.5%	1.5 1.4%
12. 3.9%	9.1 3.0%

Work Plane Point 279@div=8



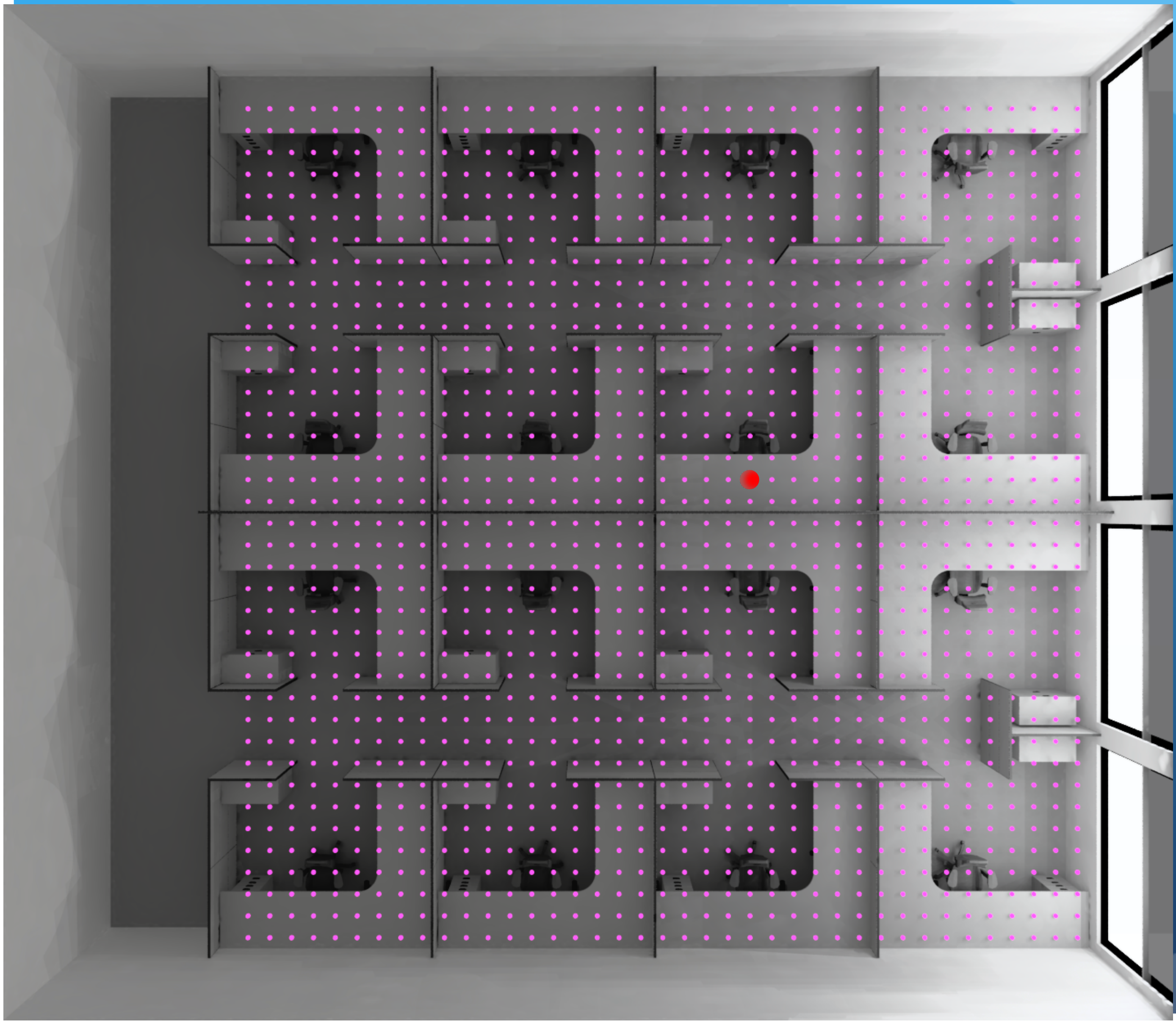
View err (lux, %)	Clerestory err (lux, %)
0.021 0.94%	n/a
0.21 1.6%	n/a
1.4 1.4%	n/a
8.6 2.9%	n/a

Work Plane Point 607@div=1



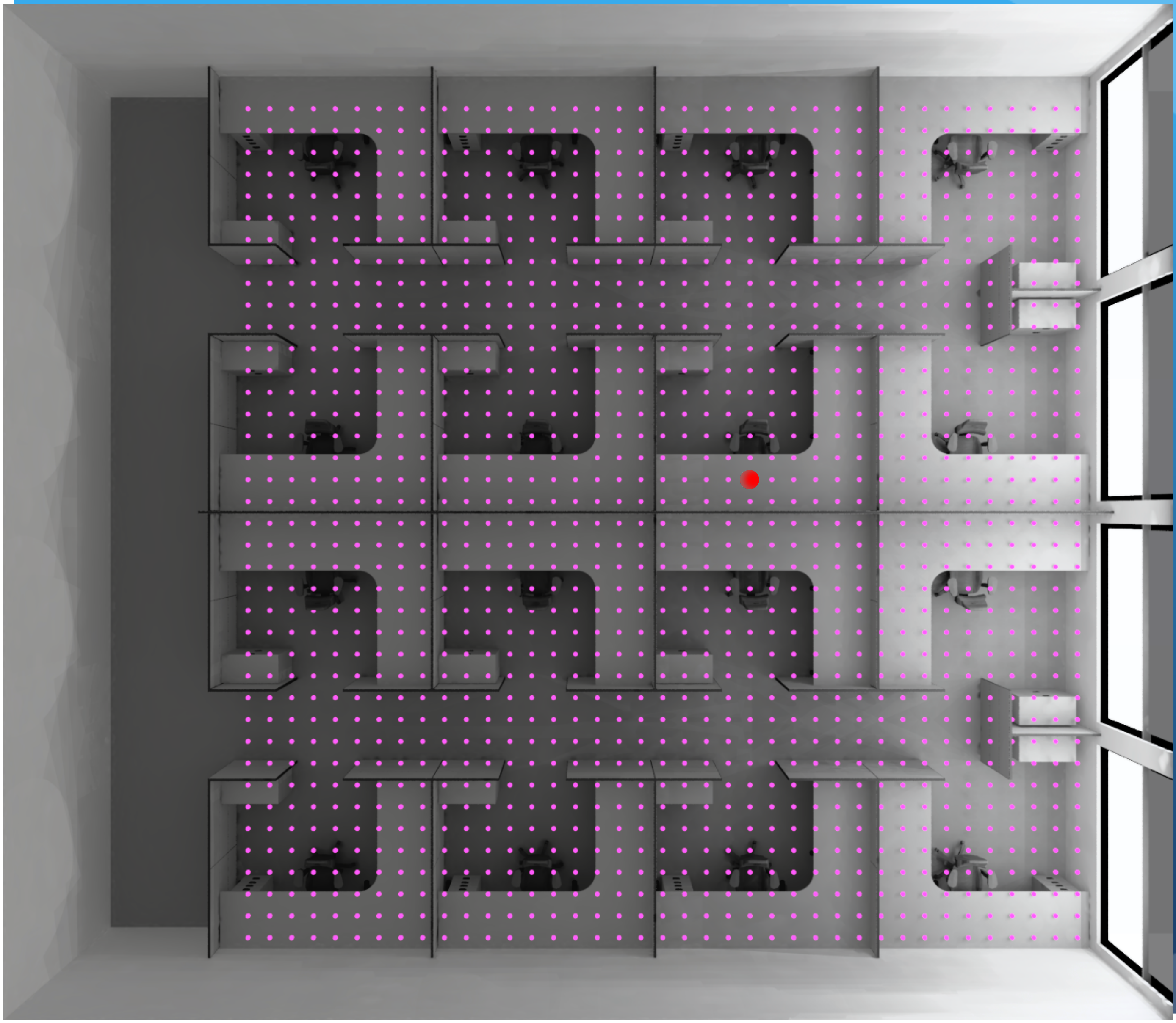
View err (lux, %)	Clerestory err (lux, %)
0.37 1.5%	1.3 4.2%
0.42 0.95%	3.8 4.9%
0.54 3.0%	1.5 4.9%
0.48 10%	0.78 18%

Work Plane Point 607@div=2



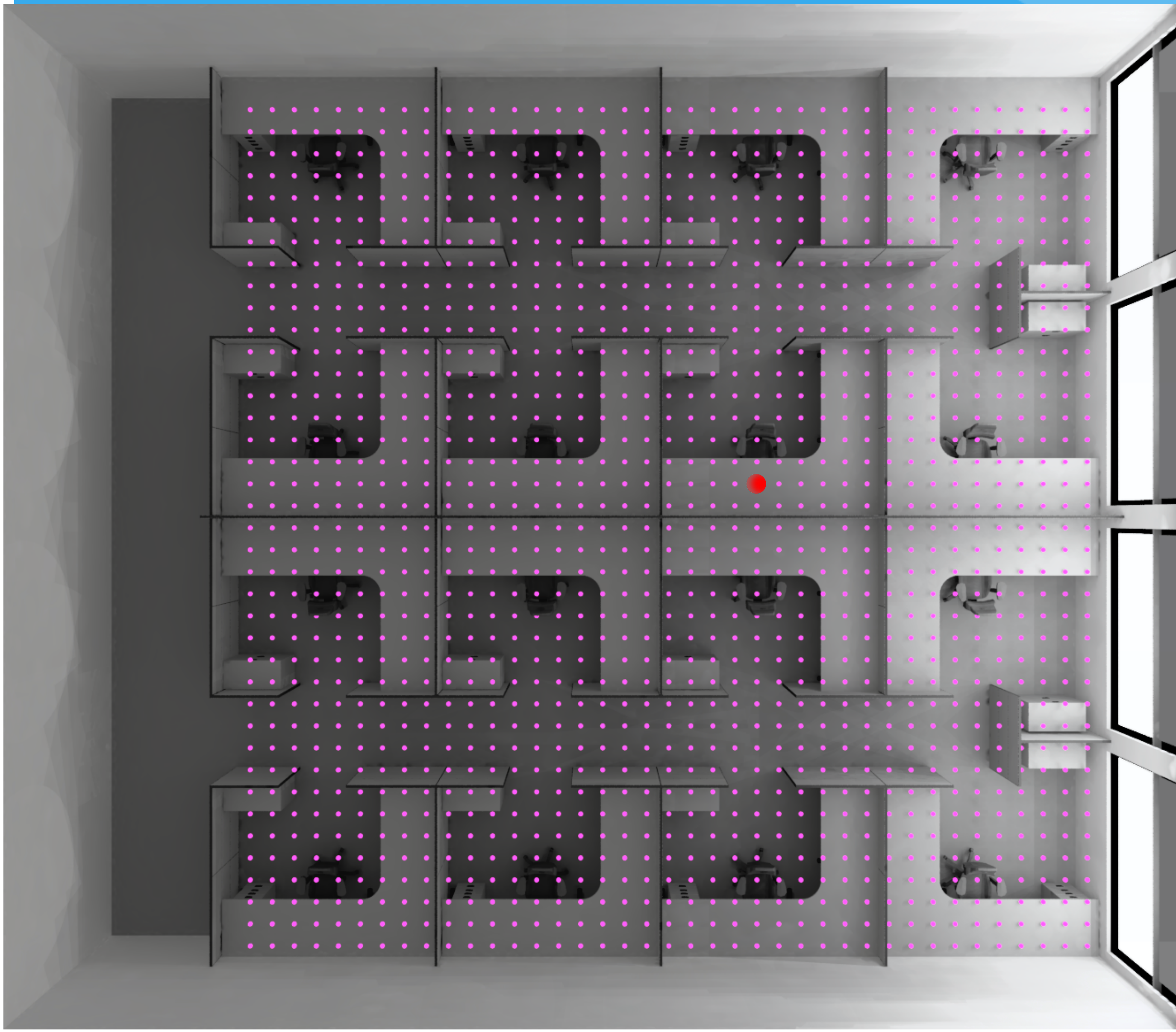
View err (lux, %)	Clerestory err (lux, %)
0.22 0.92%	0.76 2.5%
0.34 0.76%	3.1 4.0%
0.31 1.7%	0.62 2.0%
0.26 5.8%	0.36 8.4%

Work Plane Point 607@div=4



View err (lux, %)	Clerestory err (lux, %)
0.22 0.93%	0.68 2.2%
0.37 0.84%	3.3 4.2%
0.22 1.2%	0.29 0.93%
0.17 3.7%	0.19 4.4%

Work Plane Point 607@div=8



View err (lux, %)	Clerestory err (lux, %)
0.19 0.77%	n/a
0.32 0.71%	n/a
0.19 1.0%	n/a
0.12 2.7%	n/a

Calculation Time

7.4 CPU hours : **D** matrix calculation

15 CPU hours : **V** matrix calculation

1.9 hours : Total wall-time on 12-core Mac Pro

Generalization of Method

1. Simulate with average sky at highest subdivision or parameter setting
2. Compute absolute average error for lower subdivision or parameter settings
   - Modulate local errors by any factors known to reduce parameter influence
3. Select time/accuracy trade-off for final simulation

Future Work

- How to best use information to decide window subdivision
  - Better visualizations
- Extension to other parameters, such as matrix subdivision
- Applications to 5-phase method (possible?)
- Integrate into Taoning Wang's **frad** utility