# Architectural Research Planning

Bruce Haglund, Distinguished Professor of Architecture

Research types:

- ❖ Original research
- ❖ Applied research
- ❖ Design as inquiry

*Your project's concept is not the form, shape, or floor-plan; it is much better to frame it as a question that you are trying to answer.—Jeanne Gang, Studio Gang*

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# Research Components

- Research Question
- Background/Inspiration
- Rationale
- Literature Search
- Methodology
- Testing
- Results
- Lessons Learned
- Conclusion

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**Feasibility and Design of a Daylighted Artificial Sky**
Bruce Haglund, Professor of Architecture

## Question: Is it possible to create an artificial sky for daylighting design testing that is daylighted?

**All current skies are electrically lighted**

My students in the new artificial sky at the Bartlett School's Here East facility in London.

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**Feasibility and Design of a Daylighted Artificial Sky**
Bruce Haglund, Professor of Architecture, Associate AIA, FASES

## Three reasons/sub questions:

- **Philosophical:** Is there a passive tool that could encourage this mindset and be used to test daylighting models?
- **Qualitative:** Could natural light be used for model testing?
- **Environmental:** Is there a zero-energy alternative to electrically lighted artificial skies?

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Bruce Haglund, Professor of Architecture, Associate AIA, FASES

Daylighted space vs. Electrically lighted space in the Great Court of the British Museum shows the vast difference between natural and electric light sources.

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## Background.

To achieve highly successful results, daylighting schemes for both new and existing buildings must be tested for light levels, light distribution, and glare, as well as be visually assessed for architectural quality before the building is actually built or remodeled. This type of testing is also valuable in architectural education where students can verify the fitness of their proposals for building designs. The design, testing, and re-design of their projects provide opportunities to gain practical skills applicable in their professional careers as well as experience with research methodology.

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## Models in the Design Process.

Testing physical scale models of architectural spaces is an accurate means to evaluate daylighting schemes for buildings. An effective daylighting model allows the designer to record and compare daylight aperture design options quickly and reliably. Useful comparisons can be achieved only under reliably consistent sky conditions.

The natural sky poses a problem: Natural skies are dynamically variable, not only from day-to-day, but minute-to-minute, defeating the principle of consistency required for accurate comparisons.

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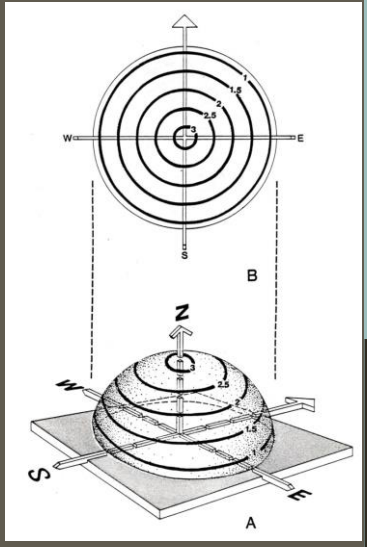
Criteria:

Artificial skies must be able to simulate a standard uniform overcast sky condition where the zenith is about three times brighter than the horizon with gradual darkening from zenith to horizon.

To achieve this goal two basic types of electrically lighted skies have been used—mirror box and hemispheric skies.

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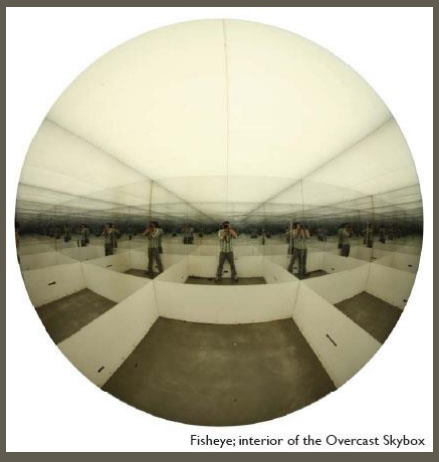
**Two common types of artificial skies—hemispheric and mirror box.**



Fisheye; interior of the Overcast Skybox

Inside Hemispheric Sky (Michigan) vs. Mirror Box Sky (Seattle IDL)

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**Actual Overcast Sky**

You cannot see the sun's position in the sky.

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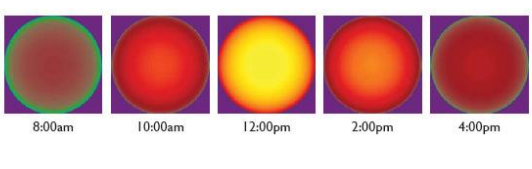
As a point of reference, the following images are a series of hemispherical fisheye images simulated in Radiance. The simulation was run on September 21 under overcast conditions.




Integrated Design Lab | University of Washington | Seattle, WA

The brightness of even ideal overcast skies varies significantly during each day.

However, the distribution of light is constant—3x brighter at the apex.

So our goal is to provide proper distribution, not specific luminance.

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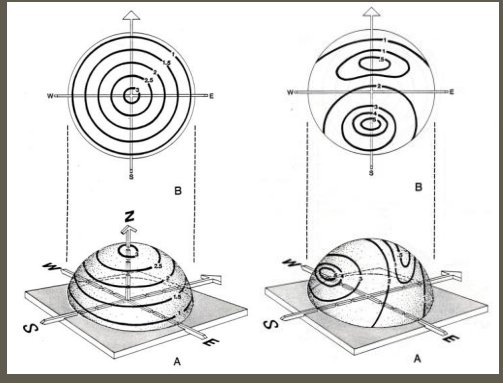
## Literature search:

In this case, we explored the physical presence of artificial skies in use world-wide.

We found some hemispheric skies simulate both clear and cloudy skies.

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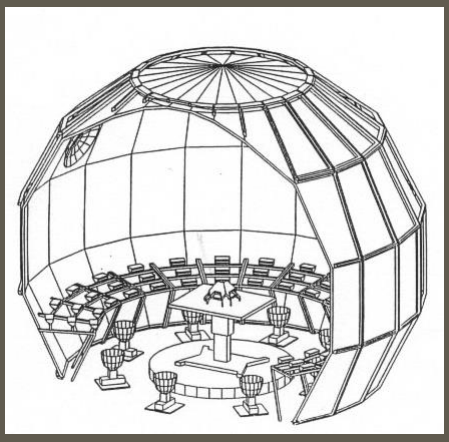

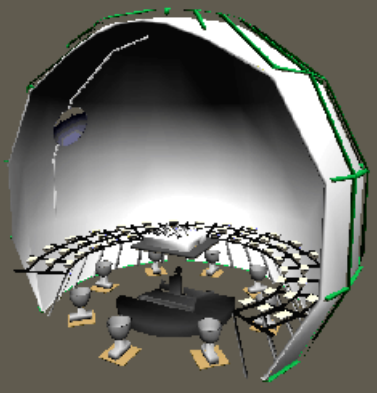

University of Michigan Hemispheric Sky

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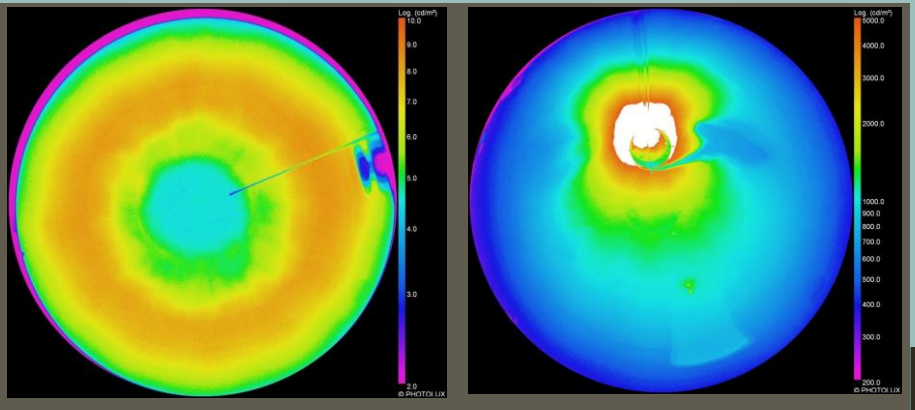


University of Michigan Sky: Overcast vs. Clear Sky Conditions

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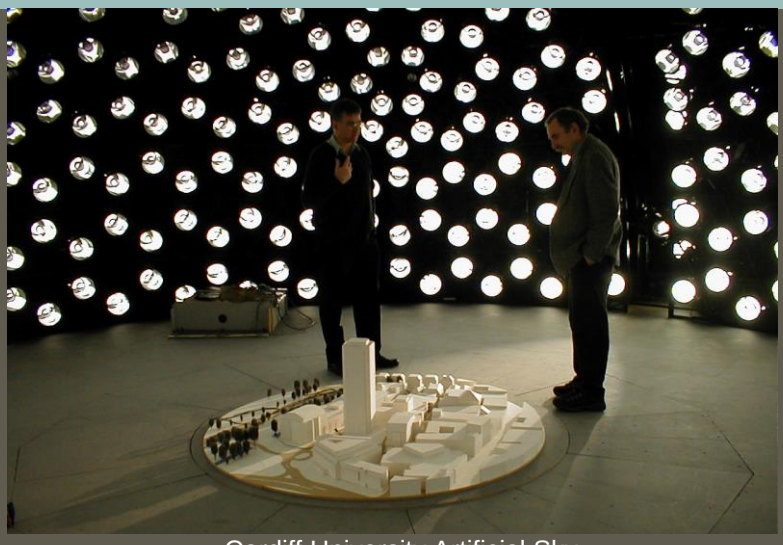

Cardiff University Artificial Sky

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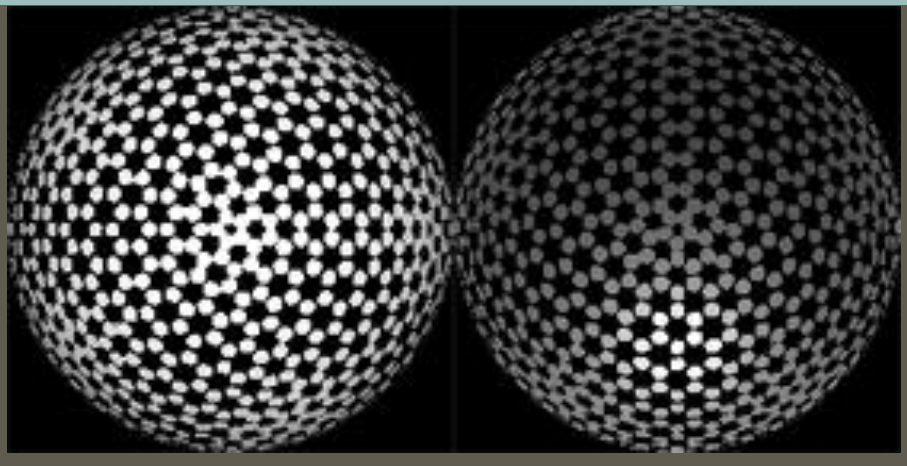

University of Cardiff Sky: Overcast vs. Clear Sky Conditions

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**Cardiff Sky 8m diameter:** 640 luminaires (20-watt Philips CL 4500K) CFLs (12,800 watts total)

**Old Bartlett Sky 5.2m diameter:** 270 CFLs (5,400 watts total).

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Mirror-Box Artificial Sky at IDL, Boise, ID
uses twenty-two 59-watt fluorescent lamps (1,298 watts total)

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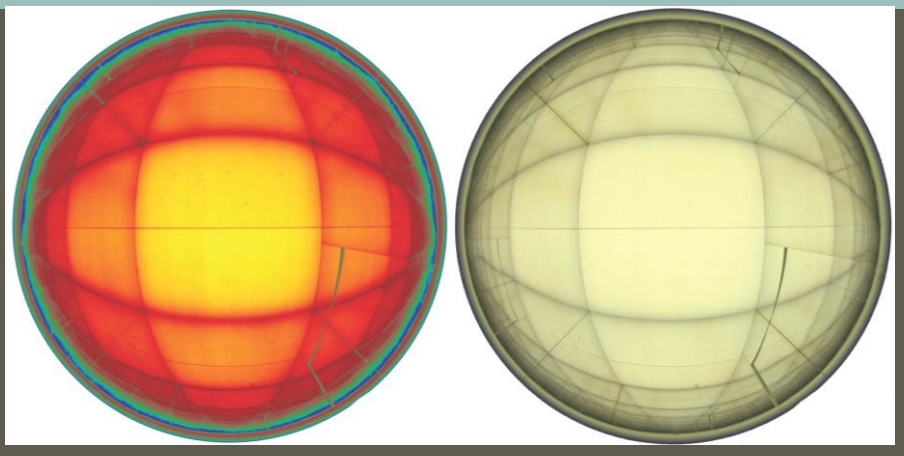

Mirror Box Sky: False Color Fisheye vs. HDR Fisheye

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Computer-driven Heliodon for Sun Simulation at IDL, Boise, ID

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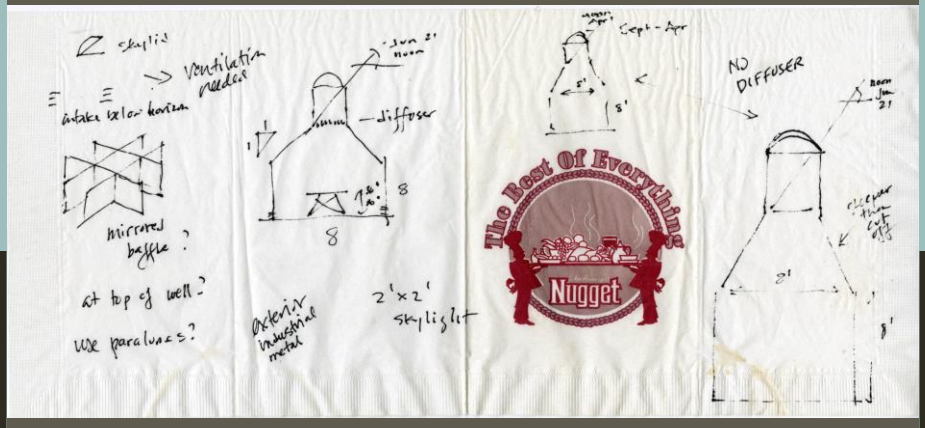
Bruce Haglund, Professor of Architecture

## **Methodology**…
from napkin sketch to realization?

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## **Inspiration**.

We were inspired to begin this project by two precedents—

- University of Oregon's cutting-edge classroom for the Mt. Angel Abbey School in Mt. Angel, OR
- Ball State University's use of digital cameras to analyze glare by charting relative brightness in the field of view.

Our sky will be similar to a mirror-box sky in that it will simulate overcast sky conditions and feature no heliodon.

Our heliodon, which uses a tilt table, sun peg, and the actual sun, will continue to be used to test sun penetration for daylighting models.

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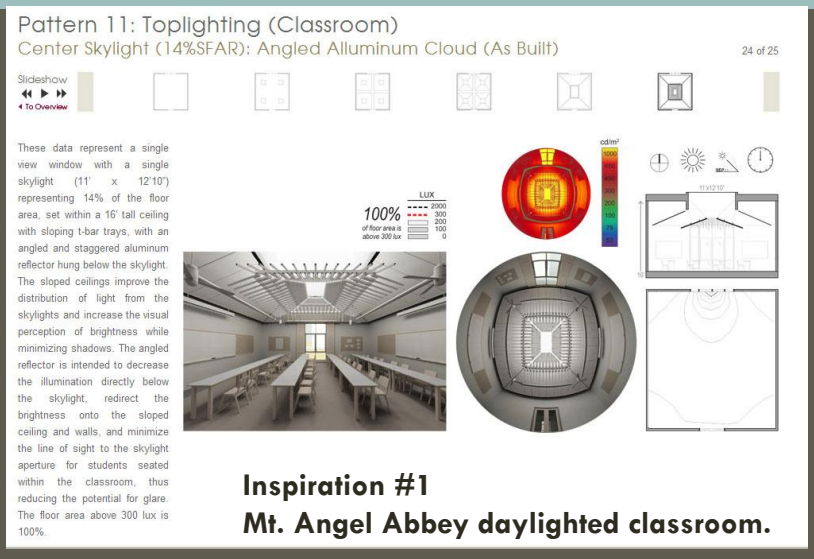


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## Inspiration #2:

Model testing under the translucent barrel vault at PUCE.

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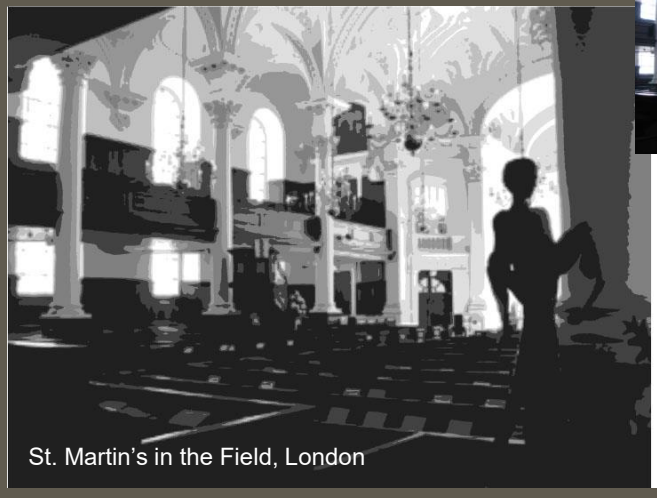
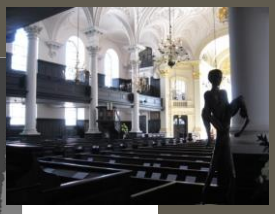
## Inspiration #3--Culplite analyses



St. Martin's in the Field, London




RAW format of the image is used.

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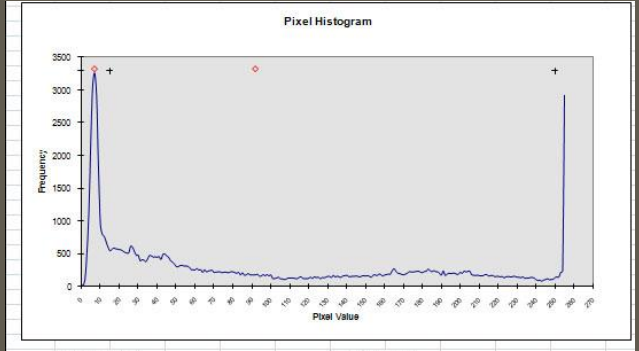


| | | | | |
|---|---|---|---|---|
| **Overall Image** | | **Indiviual Pixel** | | |
| Weighted Ave Pixel Intensity | 105.12 | Individual Pixel Value | 40 | |
| Total Number of Pixels | 76800 | Corresponding Luminance | 58.12 | footlamberts |
| **Background Bell Curve** | | **Spike** | | |
| Low End Pixel Value | 15 | Low End Pixel Value | 0 | |
| High End Pixel Value | 250 | High End Pixel Value | 15 | |
| Background Median Value | 92 | Spike Median Value | 7 | |
| Number of Background Pixels | 53915 | Number of Spike Pixels | 19753 | |
| Background Percentage of View | 70.20 % | Spike Percentage of View | 25.72 % | |

"When a digital camera makes an exposure the imaging chip records the amount of light that has hit each pixel, or photo site."

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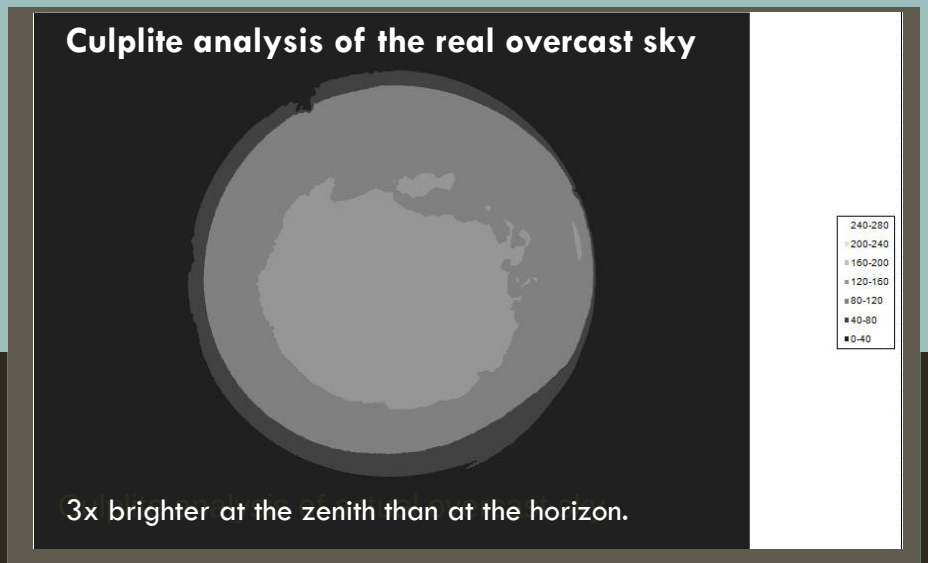


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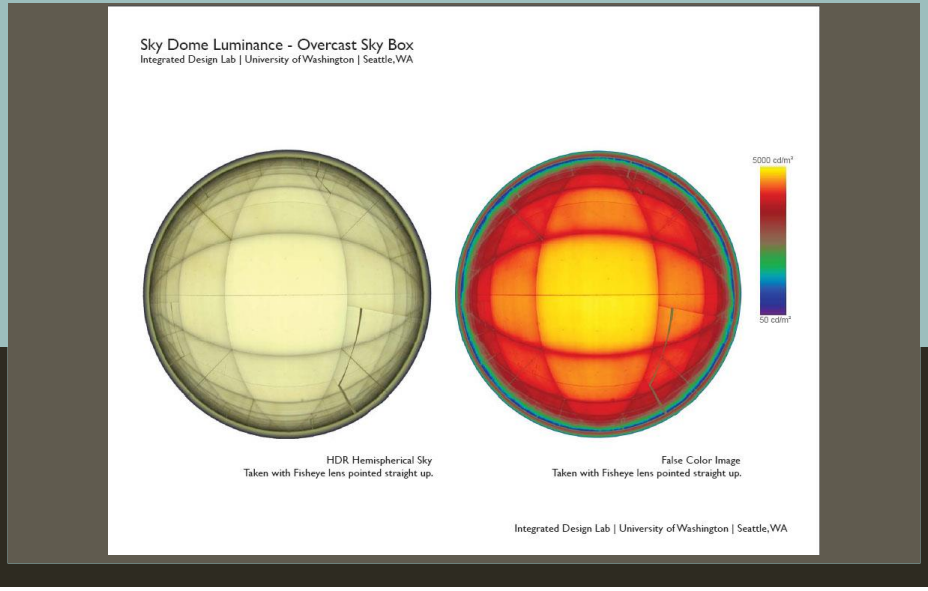


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## Methodology
## Preliminary model testing.

| | Rectilinear | Cylindrical |
|---|---|---|
| Matte white surfaces | Model A | Model C |
| Mirrored surfaces | Model B | Model D |


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Early days test of one model before circular fisheye lens was available.

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Sigma 4.5mm f/2.8 EX DC HSM circular fisheye lens mounted on a Nikon D-5000 Digital SLR camera

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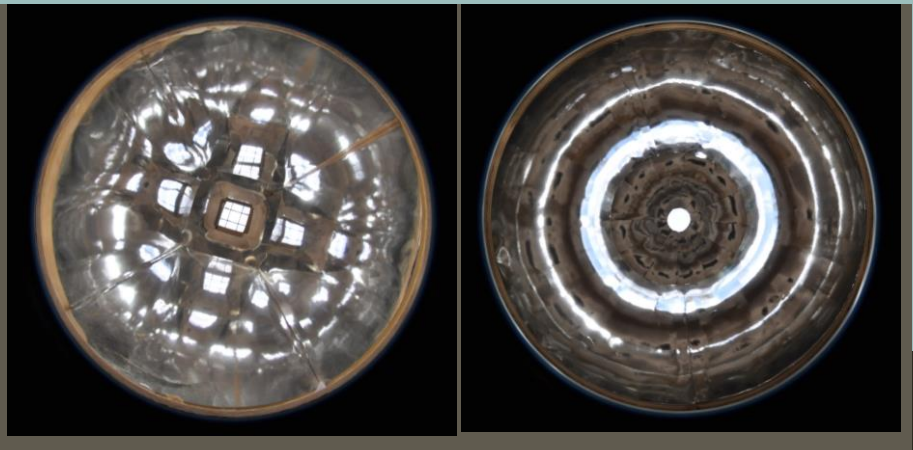

Preliminary Test: Mirrored Rectilinear vs. Cylindrical

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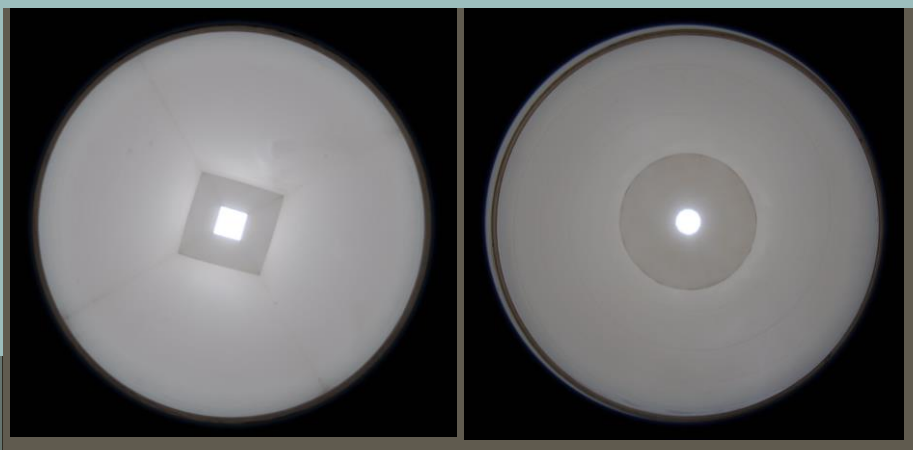

Preliminary Test: Matte White Rectilinear vs. Cylindrical

The preliminary models were not correct!

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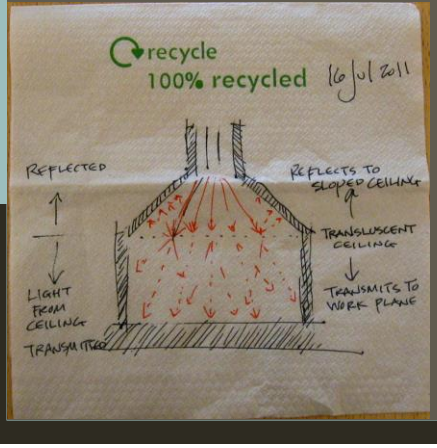
## Redesign:

Test new designs





Experimenting with translucent ceiling and neutral floor materials. And, ultimately with different shapes.

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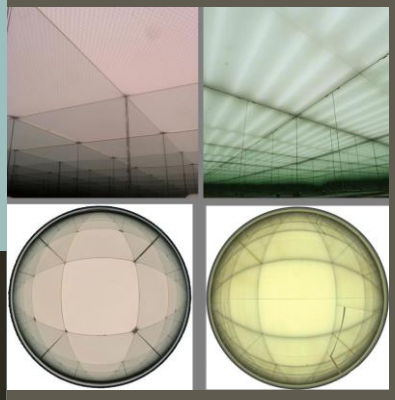
## First Feasible Option:



**Two teams proposed Mirror-Box Sky w/Kalwall Skylight.**

**Daylighted vs. Electrically Lighted**

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## Second Feasible Option:

**Two teams proposed Conical Sky w/matte white interior.**

**Culplight analysis image**

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**Methodology**
**Prototype daylighted sky.**
We built a full-scale prototype (~10 ft x 10 ft) adjacent to the advanced architecture studios.

The design and construction of the prototype was a hands-on research project for a group of students from both architecture and interior design.

The team of student researchers constructed, instrumented, tested, and analyzed the results of this prototype in a non-thesis research class. (30 students over 5 years!)

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**Seed Grant for construction and instrumentation awarded for $12,000.**

Funding: 1 July 2012 - 31 July 2014.

**We've built option #2.**

SketchUp model

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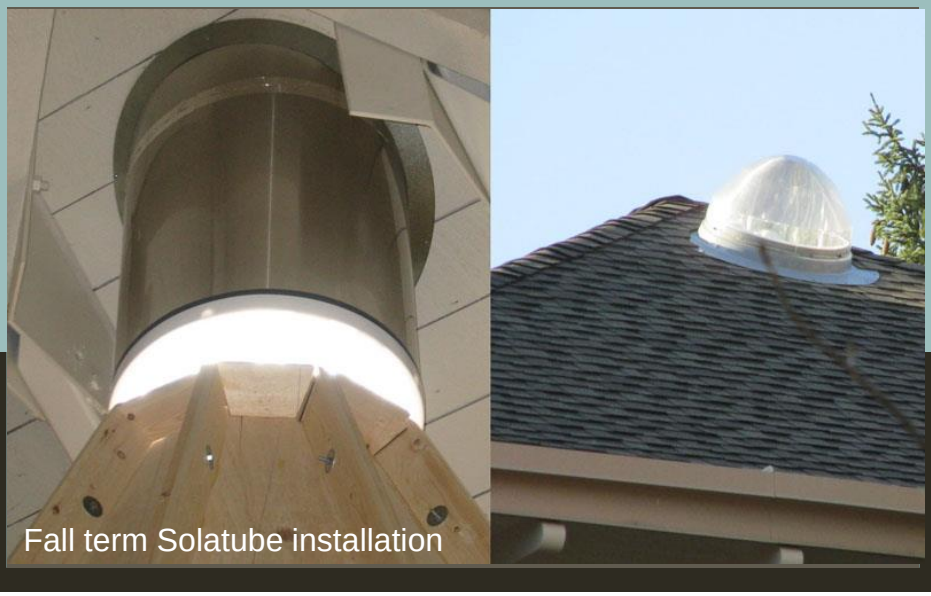


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## Using Photography for Testing and Calibration:

Pro

Photography can collect luminance data for all points simultaneously and act as a per pixel luminance meter when calibrated properly, resulting in extremely high-resolution measurements.

Con

All lenses exhibit vignetting, or the darkening of pixels at the corners of the photos. This phenomena must be accurately corrected for in order to be used for analysis.

http://upload.wikimedia.org/wikipedia/commons/1/1f/Example_of_vignetting_and_du

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## Fisheye Lens Calibration Success:

Before with vignetting

After—no vignetting

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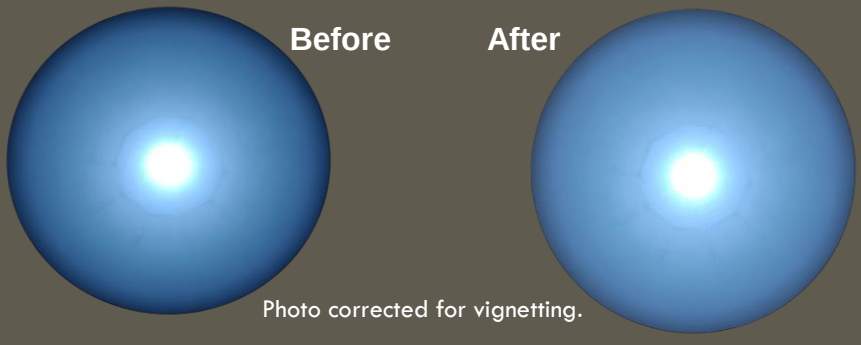
## Testing the Sky Using Photography

Photo taken using fisheye lens inside artificial sky on Oct 14th 2013 at 2:20PM; Clear sky conditions.

Lens pointed directly at zenith and positioned at the height of the horizon.

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## Field Test: Lighting Seminar Designs for 1912 Center

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## Comparing physical model in sky vs. outdoors:

In Sky

In the dome 1

In the dome 2

Outdoors

Outside Cloudy Day 1

Outside Cloudy Day 1

Tom Kearns,
Ryan Ivie,
Ben Ferry,
Clay Cravea

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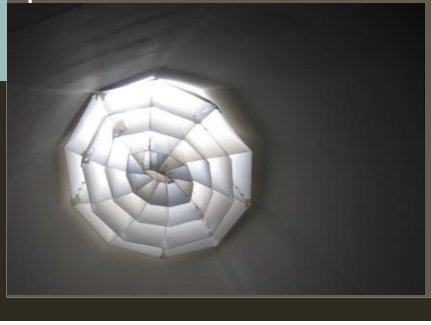
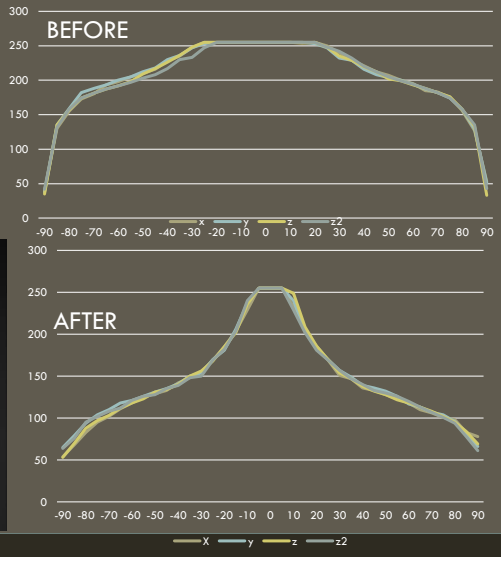
Before and after installation of temporary baffle.

So we installed a permanent baffle.



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## Conclusion

We have a working zero-energy sky.
Students discovered it is also ideal for model photographs

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## Heliodon with sunpeg

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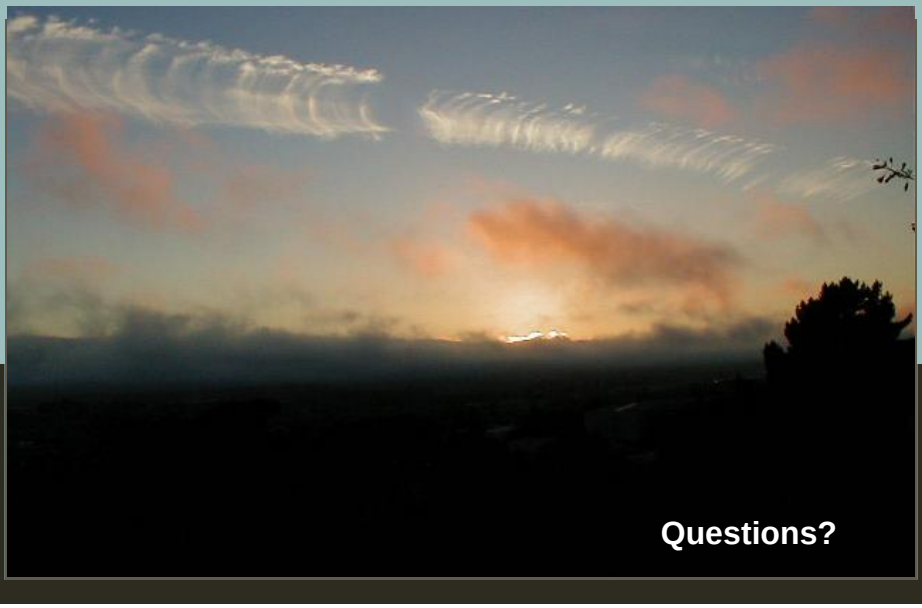


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