Feasibility and Design of a Daylighted Artificial Sky

Bruce Haglund, Professor of Architecture, Associate AIA, FASES

…from napkin sketch to realization?
Introduction.
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.

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.
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.
The brightness of even the ideal overcast sky 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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Inside Hemispheric Sky (Michigan) vs. Mirror Box Sky (Seattle IDL)

University of Michigan Hemispheric Sky
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University of Michigan Sky: Overcast vs. Clear Sky Conditions

Cardiff University Artificial Sky
**University of Cardiff Sky: Overcast vs. Clear Sky Conditions**

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

Bartlett Sky 5.2m diameter: 
270 CFLs (5,400 watts total).
Mirror-Box Artificial Sky at IDL, Boise, ID uses twenty-two 59-watt fluorescent lamps (1,298 watts total)

Mirror Box Sky: False Color Fisheye vs. HDR Fisheye
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Three reasons.
- **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?
Methodology. We were inspired to begin this project by two precedents—

- University of Oregon’s cutting edge classroom for the Mt. Angel Abbey School in Eugene, 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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Pattern 1: Toplighting (Classroom)
Center Skylight (14%FAR); Angled Aluminum Cloud (As Built)

Model testing under the translucent barrel vault at PUCE.
When a digital camera makes an exposure the imaging chip records the amount of light that has hit each pixel, or photo site.
Culplite analysis of actual overcast sky.

More sophisticated camera systems can be calibrated to cd/m² or footlamberts.
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Sky Dome Luminance - Overcast Sky Box
Integrated Design Lab | University of Washington | Seattle, WA

Rectilinear
Matte white surfaces  Model A
Mirrored surfaces  Model B

Cylindrical
Model C
Model D
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Early days test of one model before circular fisheye lens was available.

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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Heliodon with sunpeg.

Preliminary Test: Matte White Rectilinear vs. Cylindrical
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Preliminary Test: Mirrored Rectilinear vs. Cylindrical
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Culplite analysis of matte white rectilinear model.
Prototype daylighted sky.
If our research and testing proves the naturally lighted artificial sky viable, we intend to build a full-scale prototype (~10 ft x 10 ft) for eventual installation at our new interdisciplinary design laboratory on campus in Moscow, Idaho. The design and construction of the prototype will be a hands-on research project for a group of students from both architecture and interior design. The team of student researchers will construct, instrument, test, and analyze the results of the prototype in a non-thesis research class.

Questions?