A Guide to Daylighting Success

A study of spaces around the U.S. offers both proof of concept and valuable ammunition when making the daylighting case to architects and owners

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The Integrated Design Labs at the University of Washington in Seattle and University of Idaho in Boise in partnership with New Buildings Institute have developed a free web-based design resource for the implementation of proven daylighting design strategies in commercial buildings. The *Daylighting Pattern Guide* (*http://patternguide.advancedbuildings.net/*) provides building designers, owners and students a platform to explore the relationships between sky, site, building aperture and space planning. This interactive resource uses a combination of real-world built examples, including offices, schools, libraries, laboratories, museums and industrial facilities (**Figure 1**), and advanced simulation to set the stage for substantial reductions in lighting power density and overall building energy use.

Over the past decade the Integrated Design Labs have provided daylighting design and technical assistance to architects, engineers and lighting designers in the Pacific Northwest and nationally. Much of this work has been funded by the Northwest Energy Efficiency Alliance as part of a commercial building conservation program. This practice has revealed recurrent themes, key variables and architectural principles, which were demonstrated by daylit spaces that had proven to be successful over time. Building upon this knowledge, we have built a series of daylighting patterns that identify and visually represent these successes and lessons-learned in an intuitive and visually oriented online resource. The *Guide* illustrates successful daylighting design patterns by placing an emphasis on creating visually comfortable spaces because our experience suggests this will help ensure that that occupants accept energy-efficiency measures associated with daylight such as automated electric lighting controls.

A recent study by the Heschong Mahone Group revealed that less than 25 percent of the predicted energy savings are realized in spaces with daylight delivered from the side (Heschong et al., 2005). Even more revealing is that more than 70 percent of the reasons identified for failure relate directly to a lack of human satisfaction with the overall daylight performance, with less than 30 percent explained by failures due to hardware components. This follows our experience, which suggests that poor daylighting performance stems primarily from the fact that many spaces with daylight fail to meet the visual satisfaction expectations of occupants either due to insufficient daylight, imbalanced distribution of daylight, or challenges maintaining visual comfort with such a highly variable light source.

As a starting point, we developed a list of daylighting design strategies and principles and prioritized the most critical

Figure 1. Selected building interiors used in the *Daylight Pattern Guide*.

variables to overall daylighting success. We then developed a matrix including daylighting design variables and possible design approaches or "daylighting patterns." We contacted daylighting experts from around the country to supply candidate buildings for site visits and inclusion in the *Guide*. Site visits consisted of collecting illuminance and luminance data of the spaces of interest. High Dynamic Range (HDR) photography techniques were used to document the luminous conditions of the spaces and were later used to create luminance maps of the scenes.

Next, digital models were created using site measurements, photography and architectural drawings. These models were processed in the Radiance simulation program where detailed rendering parameters and material properties were input. Rendering cameras were specified to match the field of view of the photographed space. Then a simplified accuracy check was conducted on the Radiance simulations using the HDR photographs of the built spaces to fine tune material properties and simulation parameters.

After the as-built simulations were finalized, a series of test conditions were developed in order to explore successful and unsuccessful compositions of daylight distribution. These test conditions were choreographed into a series of "pattern steps" (**Figure 2**) that combine to make up an individual pattern sequence illustrating an important daylighting design variable. This allows us to demonstrate the relationships between good built examples of daylit space, the information generated by design tools and the kind of "rule of thumb" guidelines that designers commonly apply. We felt that beginning with successful built spaces was critical to support meaningful interpretation and increase confidence in the results. Our highest priority was given to qualitative data, essentially via color renderings, with supporting quantitative data such as luminance distribution diagrams.

In order to support navigation, an instrumented dashboard indicates simulation parameters for time of day, time of year and sky condition. A consistent key was made for illumination plots, and the percent of floor area that achieved a specified illumination criterion is called out for each pattern step. A "filmstrip" reveals the different geometric variables explored throughout a given pattern and is commonly illustrated with architectural section icons and occasionally other widgets.

Four of the 19 patterns in the *Guide* are outlined here to provide an introduction to the content available in the online resource.

EXHIBITS A-D

Pattern A-Work Station Partitions: This pattern sequence (**Figure 3**) is based on the Banner Bank Building in Boise, ID. It includes a 40 percent window-to-exterior wall ratio with a window head height at 9 ft, 6 in., a sill height at 3 ft and a ceiling height at 10 ft. Interior reflectances are roughly 80 percent-50 percent-20 percent for ceiling, walls and floors, respectively. The pattern reveals the significant interaction between daylight penetration from perimeter glazing and interior office furniture design. The selection and design of open office furniture, especially workstation partitions, requires care to ensure the preservation of daylight and views. Even in the most carefully considered daylighting solutions, effective workstation design can be the difference between realizing daylighting goals and unintentionally compromising design intentions. This pattern illustrates the challenges associated with providing

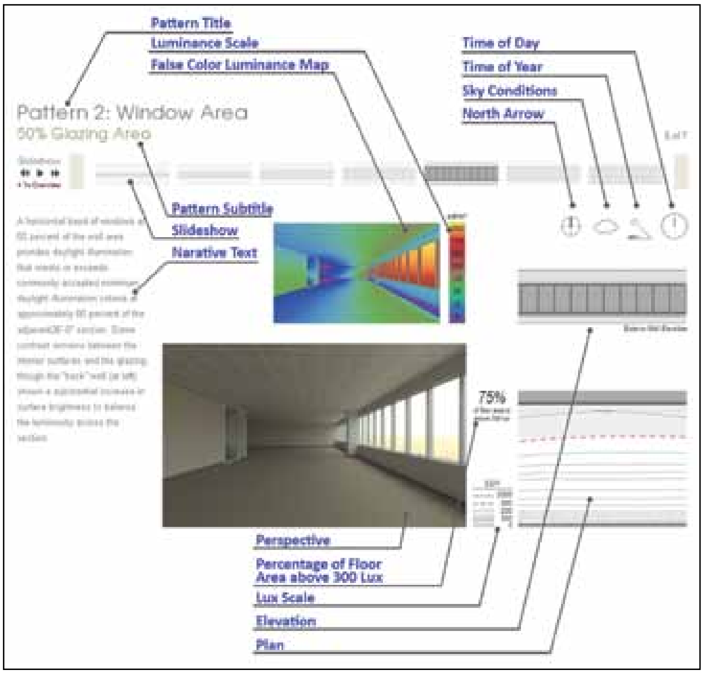

Figure 2. Layout of an example "pattern step."

daylight from one side when interior furniture partitions exceed 42 in. parallel to daylight glazing.

Pattern B-Glass Area Ratios: This pattern (**Figure 4**) is based upon NBBJ Architects' New York City office space at 2 Rector Street. The pattern sequence highlights the implications of different degrees of glass-to-wall area ratios (20 percent, 26 percent, and 30 percent) while also revealing the effect of glazing located on one, two and three sides. The pattern demonstrates how important it is to have daylight from multiple sides and how one can provide substantial daylight using a 30 percent glazing-to-wall area ratio as long as windows are provided on multiple sides.

Pattern C-Blinds and Shades: Blinds and shades provide a range of methods to control direct sunlight and redirect diffuse daylight (**Figure 5**). Assuming a reasonable relationship between section depth and window head height (does not exceed 2:1), sufficient daylight can be provided by windows on just one side of a space. However, blind systems and their use (or lack of use) by occupants can be the single largest determinate of realized daylight performance in many building types. This pattern examines multiple blind types and positions given various weather conditions to illustrate an often overlooked, but absolutely critical aspect of effective daylighting design. While fixed external shading can provide significant benefits, it is rare that glare control can be entirely solved without some form of blinds or internal shades.

Poor design that results in blind closure for long periods can make an otherwise well-daylit space virtually non-daylit. Specifically, this pattern illustrates that inadvertently leaving blinds deployed during an overcast day results in only 21 percent of the space as "daylit" whereas on a sunny day, 89 percent of the space is "daylit" with the blinds deployed at the same position. To solve this problem, some buildings incorporate automated roller shades or louver blinds. This allows blinds to be adjusted based on time of day or sky condition or simply repositioned open after a preset time.

The case study example used here is the Genzyme Building at 500 Kendall Street in Cambridge, MA, designed by Behnisch Architekten. It is important to note that the Genzyme building uses automated motorized daylight enhancing blinds with weather station and astronomic time clock control and allows for user overrides of the system. However, to illustrate important points about blinds use, several other types of blinds and blind control assumptions are included.

Pattern D-Toplighting (Small Building): This pattern provides a model for effective daylighting design in small-scale, single-story commercial construction. This building type constitutes the vast majority of new and existing buildings in North America. These buildings represent a tremendous daylighting opportunity—which is applicable to retail, office, light industrial and other small-scale building

Figure 3. Excerpts from the pattern sequence showing daylight renderings with different furniture. At the left with no furniture, then desks, then 42-in. partitions, and at the far right with 60-in. partitions.

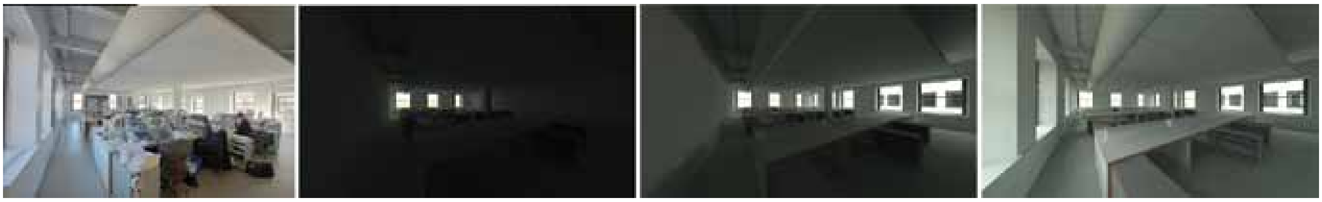

Figure 4. Excerpts from the pattern sequence showing the as-built condition (far left) and daylight renderings of the space with a 30 percent glass-to-wall area on one, two and three sides (far right).

typologies—through the use of skylights and vertical glazing. This is primarily because the entire floor plate, regardless of orientation or section depth, has daylight access from overhead. In this case (**Figure 6**), we explore a range of skylight distributions, transparent vs. diffusing skylight glazing, the inclusion of view windows and the role of wall-washing skylights.

This case study example is the IDeAs Office Building in San Jose, CA, designed by the EHDD Architecture and Integrated Design Associates (IDeAs). The building is a renovation of an existing single-story retail bank building. Through the use of daylighting, along with an innovative mechanical system and rooftop photovoltaic panels, the IDeAs office building achieves net-zero energy use on an annual basis.

THE GUIDE'S GOOD INTENTIONS

Our intention with the *Daylighting Pattern Guide* is to provide a resource that designers can consult to generate ideas for initial concept design and to showcase the range of critical considerations inherent in a broad range of daylighting designs. By beginning with existing highly regarded daylighting projects we provide both a level of "proof of concept" and a measure of real-world feasibility. We hope that the *Guide* will be informative to design teams as they work with owners and users in making the case for daylight illuminated buildings. The *Guide* can also be useful in promoting collaboration and discussion about possible design alternatives among architects, engineers, lighting designers and interior designers. We also think the *Guide* will be useful to students exploring daylighting alternatives in architectural studios.

The *Guide* cannot be a replacement for the rigorous testing of specific design ideas—in fact we consider the appropriate use of simulation tools to be critical to effective daylighting design. We do however feel that by illustrating high-performance daylit buildings and the design iterations possible within their typological context, that designers might begin at a point closer to a successful daylighting outcome and that any simulation time and effort will be applied toward the most meaningful lines of design inquiry. ■

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Figure 5. Excerpts from the pattern sequence showing the as-built condition (far left) and daylight renderings of the space with blinds retracted under a sunny sky, with light redirecting blinds deployed under a sunny sky, and with the same blind position under an overcast sky (far right).

Figure 6. Excerpts from the pattern sequence showing the as-built condition (far left) and daylight renderings of the space with several different toplighting strategies.