What is Daylight: Understanding the Sky as a Source

May 6, 2007; 2:00 to 5:00 p.m.

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Outline

- Part One: Understanding Climate
- Part Two: Modifiers for Sidelighting
- Part Three: Toplighting
Part One Outline

- Introduction
- Climate
- Solar Geometry
- Site Analysis
- Orientation and solar radiation
- Sun charts and diagrams
- Sky Conditions
- Daylight Availability
- Climate & Design Criteria
- Case Studies
- Summary
- Q & A
- References

Government Services and Insurance Systems Headquarters, GSIS, in Manila, Philippines, TAC, Cambridge, MA
Sustainability

• Sustainable design is “meeting the needs of the present without compromising the ability of future generations to meet their own needs.”

• Daylighting strategies should *embrace* sustainable or ecological issues.
Bioclimatic Issues

- Conditions of human comfort.
- Narrow range for human body.
- Person as receptor & generator of heat.
- Radiant & convective gains; convective losses.
Bioclimatic Design

- Psychometric chart
  - Air temperature
  - Humidity
  - Air velocity
  - Mean radiant temperature
- Each affect comfort.
- Comfort zones.

Figure 4.8a The comfort zone and various types of discomfort outside that zone are shown on this psychrometric chart.
Climate

- Explore indigenous architecture to understand response to climate.
- Understand local climatic needs.
- Design that works for all seasons when possible.
- Micro-climate & architectural regionalism.
Climate

• Building envelope is dynamic in nature
  – Acted upon from outside
  – Acted upon from inside

• Outside by the climatic elements:
  – Sun
  – Wind
  – Light

Kimbell Art Museum, Fort Worth, TX, L Kahn, Architect
Climate

- Acted upon from the inside by:
  - Doors
  - Windows
  - Skylights
  - Walls
Climate

- Climate or average weather primarily a function of the sun.
- Distribution of land masses affect winds.
- Temperature changes over water more moderate than over land.
- Moisture in air has a pronounced effect on ambient temperature. Dry climates, little moisture to block solar radiation; humid climates, moisture blocks some radiation (more moderate temperatures compared to dry climates).
- Microclimate important!
Climate of the U.S.

- Use only as a starting point; account for microclimates when possible.
Climate
Sources of Climate Data

- TMY2 data from National Solar Radiation Data Base.
- Solar Radiation Data Manual for Buildings – NREL.
- Secondary sources – e.g. S, W & L by Brown & DeKay; H, C, L by Lechner.
- Radiance, DaySim, Spot, Lumen Designer, AGI32, other programs that use data from TMY2 or similar illuminance data.
Sun Position/Solar Geometry

- Site Analysis
- Orientation
- Elliptical Orbit
- Earth’s Axis
- Sky Dome
- Latitude
- Azimuth
- Latitude & magnetic variation
- Solar Time
- Sun Charts & Sun Path Diagrams
- Shading
Site Analysis

- Process of studying contextual forces that influence:
  - Situating building
  - Orienting spaces
  - Articulating enclosure
  - Linking to landscape
Site Analysis

- Map climatic conditions.
- Sun path.
- Prevailing winds.
- Expected rainfall.
- Impact of landforms & adjacent buildings.
- Location of trees, plants, water features.
Elliptical Orbit

- Earth’s orbit an ellipse, not a circle.
- Distant between earth & sun vary as revolution occurs.
- Earth’s axis is tilted to plane of elliptical orbit \(\rightarrow\) 23.5 degrees.
- Tilt causes seasons.
Earth’s Axis

- Fixed tilt.
- Northern hemisphere faces sun in June.
- Southern hemisphere faces sun in December.
- Summer solstice – longest day; winter solstice – shortest day.
- Spring & fall equinox – equal daytime & nighttime hours.
Sky Dome

- Imaginary “dome” over building site.
- Every hour of day, we can “mark” points where suns rays penetrate sky dome.
- Creates sun path for day.
- Most critical part of day is “solar window”.

Figure 6.8a The sky dome and three sun paths. (From Architectural Graphic Standards, Ramsey/Sleeper 8th ed. John R. Hoke, ed. copyright John Wiley, 1988.)

Figure 6.8b The solar window from about 9 A.M. to about 3 P.M.
Solar Azimuth & Altitude

- Position of sun in sky defined by azimuth angle & altitude angle.
- Functions of: site latitude, day of the year, & solar time of the day.
- Solar azimuth (Y) is angle along the horizon of position of sun, measured to the east or west of true south.
- Solar altitude (X) is the angle measured between the horizon & the position of the sun above the horizon.
Latitude & Magnetic Variation

• Necessary to adjust compass reading for each location.
• Due to earth’s magnetic field.
• Adjustment is degrees east or west. Easterly variation for west of Lake Michigan.
• Necessary to correctly use sun charts!
Solar Time

- Sun always due south at noon solar time but not clock time.
- Clock time varies from sun time.
  - Daylight savings time
  - Deviation in longitude of building site from standard longitude of time zone
  - Earth’s speed in orbit around sun changes during the year
- Calculating correction complex & not of critical importance unless you want sun on a specific spot at an exact time; simply use solar time.
Sun Charts

- Enables you to locate the position of the sun at:
  - any time of day
  - During any month
  - For any location in the U.S. (excluding Alaska).
- Allows you to determine times that sun is blocked on the site by plotting obstructions.
- Done on site with a compass or transit, a hand level, & copy of sun chart for your location.
Sun Path Diagrams

- Use diagram for your latitude.
- Used to plot a profile of all site obstructions at all sun angles.
- Monthly sun paths can be done for 21\textsuperscript{st} of each month.
- Used for:
  - Calculation of illuminance at windows
  - Shading & reflector design
  - Interior illuminance due to sky component
  - Excluding direct sunlight
- When sun will be available on your site!
Sundials

- Used to evaluate existing site conditions.
- Impacts of massing alternatives.
- Sun penetration.
- Shading device effectiveness.
- Must be used on a horizontal model with peg in center using real sun to study penetration & shading.
- Changing position of sun & shade over the day.
Shading

- Horizontal strategies best for south.
- Vertical strategies best for east & west.
- Shading on north can reduce effective daylight.
- Microclimate must be considered.
- Ecotect software good choice of schematic analysis tool ([http://www.squ1.com/](http://www.squ1.com/))
Sky Conditions

- Clear
- Overcast
- Partly Cloudy
Clear Skies

- Direct sun
- Blue sky but less bright than overcast sky.
- 3x Brighter horizon compared to zenith.
- Illumination varies with position of sun, season, water vapor in atmosphere.
- Daylight factor not really useful except when direct sun is blocked from admission.
Overcast Skies

- Diffuse
- May be bright
- May be dim
- Brighter zenith
- Illumination evenly distributed around zenith.
- Daylight factor can be used to predict performance.
Partly Cloudy Skies

- Bright sun, no sun.
- Bright sky.
- Constant changes.
- Too variable to predict in most cases because of varying illumination across sky dome.
Daylight Factor

- Developed in 1920’s for overcast sky locations.
- DF = SC + ERC + IRC
  - DF = daylight factor
  - SC = sky component
  - ERC = externally reflected component
  - IRC = internally reflected component
- Not of practical use in clear sky dominated climates.
- Ratio of light indoors to outdoors.
Source Characteristics

- **Sun**
  - High levels at higher solar altitude.

- **Overcast sky**
  - Higher levels at higher solar altitude.

- **Clear sky**
  - Higher levels at lower solar altitude when compared to overcast skies.
Daylight Availability

- Varies by climate type & cloud conditions.
- Impacted by pollution & emissions.
- Varies by solar altitude & azimuth.
- Varies by season:
  - Horizontal plane more light in summer than vertical.
  - South façade (northern hemisphere; temperate climates) receives most light in winter.
Sun

- Visible, ultraviolet and infrared energy.
- Visible light penetrates all the different levels of atmosphere.
- Ultraviolet & infrared partially absorbed by upper levels of atmosphere.
- Reflection by surface & cloud cover.
Sky Cover Conditions
Direct Sunlight

- Illuminates perpendicular surfaces up to 10000 fc.
- Can contribute favorably to winter heating.
- More efficient than artificial light sources so can reduce cooling loads if proper design used.
- Control or “bounce” or use an optical system or beam daylighting.

Solar Illumination on a Surface Perpendicular to the Sun’s Rays (fc)

<table>
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<th>Latitude</th>
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<th>21 March/21 September</th>
<th>21 June</th>
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<tr>
<td>60° (peak)</td>
<td>—</td>
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<td>1990</td>
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<tr>
<td>60° (average)</td>
<td>—</td>
<td>420</td>
<td>1390</td>
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Reference
Skylight

- Diffuse lighting resulting from refraction & reflection of sunlight through the atmosphere.
- Clear skies $\rightarrow$ blue color from atmospheric particles.
- Overcast skies $\rightarrow$ all wavelengths of light; white colored sky.
- 500 to 2000 fc for overcast sky.
Climate Zones

• Four Climate Zones for Daylighting
  – Hot-Humid (New Orleans)
  – Hot-Arid (Las Vegas)
  – Temperate (Eugene, OR)
  – Cool/Cold (Madison, WI)
Hot-Humid Climate

- Maximum cross ventilation.
- Control of heat.
- Control or avoid direct sunlight.
- Size & locate windows to admit indirect daylight.
- Extensive roof overhangs.
Hot-Humid Climate

• New Orleans, LA
  – Latitude: 29.98° N
  – Longitude: 90.25° W
  – Elevation: 10 feet

<table>
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<th>Orientation</th>
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<th>June</th>
<th>September</th>
<th>December</th>
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<td>11am</td>
<td>1pm</td>
<td>3pm</td>
</tr>
<tr>
<td>Horizontal</td>
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<td>Horizontal</td>
<td>47/26</td>
<td>83/51</td>
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<tr>
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<td>11/10</td>
<td>15/17</td>
<td>16/18</td>
<td>14/15</td>
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<tr>
<td>East</td>
<td>79/28</td>
<td>58/34</td>
<td>16/18</td>
<td>14/15</td>
</tr>
<tr>
<td>South</td>
<td>37/17</td>
<td>64/36</td>
<td>71/42</td>
<td>57/32</td>
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<tr>
<td>West</td>
<td>11/10</td>
<td>15/17</td>
<td>25/22</td>
<td>70/37</td>
</tr>
<tr>
<td>M. Clr (%hrs)</td>
<td>31</td>
<td>31</td>
<td>33</td>
<td>34</td>
</tr>
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</table>
Hot-Arid Climate

- Minimize heat gain
- Control glare.
- Provide relief and protection from intense sunlight.
- Use indirect daylight on south.
- Larger glass areas to the north.
- Solar controls should dominate on east & west
- “Turn your back” to the sun.
Hot-Arid Climate

- Las Vegas, NV
  - Latitude: 36.08° N
  - Longitude: 115.17° W
  - Elevation: 2179 feet

### Average Incident Illuminance (klux-hr) for Mostly Clear/Mostly Cloudy Conditions, Uncertainty ±9%

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<td>1pm</td>
<td>3pm</td>
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<tr>
<td>Horizontal</td>
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<td>83/67</td>
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<td>82/60</td>
<td>61/42</td>
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<tr>
<td>West</td>
<td>11/12</td>
<td>15/17</td>
<td>35/30</td>
<td>78/52</td>
</tr>
<tr>
<td>M. Clr (%hrs)</td>
<td>55</td>
<td>54</td>
<td>49</td>
<td>45</td>
</tr>
</tbody>
</table>
Temperate Climate

- Greater flexibility in design due to modest temperatures and seasonal changes.
- Greater connections between inside & outside.
- Larger glass areas possible.
- Horizontal louvers effective on south during “sun” days for deep penetration of light.
Temperate Climate

- Eugene, OR
  - Latitude: 44.12° N
  - Longitude: 123.22° W
  - Elevation: 358 feet

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<td>11am</td>
<td>1pm</td>
<td>3pm</td>
</tr>
<tr>
<td>Horizontal</td>
<td>32/19</td>
<td>64/38</td>
<td>73/44</td>
<td>61/37</td>
</tr>
<tr>
<td>North</td>
<td>9/8</td>
<td>13/14</td>
<td>14/15</td>
<td>12/13</td>
</tr>
<tr>
<td>East</td>
<td>66/22</td>
<td>57/28</td>
<td>14/15</td>
<td>12/13</td>
</tr>
<tr>
<td>South</td>
<td>35/15</td>
<td>72/33</td>
<td>83/40</td>
<td>69/33</td>
</tr>
<tr>
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<td>9/8</td>
<td>13/14</td>
<td>18/16</td>
<td>62/30</td>
</tr>
<tr>
<td>M. Clr (%hrs)</td>
<td>14</td>
<td>13</td>
<td>16</td>
<td>17</td>
</tr>
</tbody>
</table>
Cool/Cold Climate

- Tremendous seasonal changes especially in cold:
  - Temperature
  - Precipitation
  - Sky conditions
- Combine daylight & passive solar design.
- More daylight openings on east, south, west.
- Decrease glass on north.
- Control glare & contrast from direct gain & bounced light.
Cool/Cold Climate

- Madison, WI
  - Latitude: 43.13° N
  - Longitude: 89.33° W
  - Elevation: 860 feet
Design Criteria

- Avoid direct skylight & sunlight on critical tasks.
- Bounce daylight off surrounding surfaces to diffuse light in more even brightness patterns.
- Bring daylight in from above to obtain deeper penetration into space.
- Filter daylight to avoid harshness of direct sun & sky light.
- Maximize ceiling heights to gain better light distribution.
- Use design strategies that separate view glass from daylight glass.
- Develop appropriate control strategies.
- Building geometry & spatial arrangement should promote, rather than preclude, distribution of daylight.
- Buildings should be massed & configured so maximum # of spaces are near daylight.

Top: Kimbell Art Museum, Fort Worth, TX, L Kahn, Architect
Bottom: Mt. Angel Abbey Library, St. Benedict, OR, A. Aalto, Architect
Six Case Studies
• Plan is asymmetrical
• Wedge shaped basilica
• Stepped longitudinal wall fragments, inclined towards the chancel.

The Riola Parish Church, Bologna Italy, A. Aalto
• Vertical surface of the vaults are glazed white, so that the whole church is bathed in reflected light from the vaults.

• Roof over the supporting arches is composed on the north side as a series of long scalloped light monitors, that decrease in size from the front towards the altar in the rear.

• In spite of the church being closed to the scenery outside, its is completely washed in light, through windows placed high up in the ceiling construction.
A simple and rather small structure. But the masterful orchestration of the elements and the ethereal quality of the white north light, contributing to its organic quality in form and space can be seen as a culmination of certain themes and ideas that Aalto dealt with throughout his career.

As the scalloped light monitors in the north allow only reflected light to penetrate the interior, the white assembly hall is flooded with an illumination, that makes little distinction between the structural and non structural elements, or between spatial and functional divisions between the space.
"The daylighting design is a great success economically and visually.

A typical commercial building uses about 20,000 Btu/sf annually for lighting. Mt. Airy used only 2,691, a reduction of over 86 percent".

"The bottom line is that the daylighted Mt. Airy Public Library is a low-energy-use building that's extremely attractive, aesthetically pleasing and that the people of Mt. Airy have declared, by their enthusiastic utilization of it, a runaway best seller."

Lighting Design + Application magazine

Mt. Airy Library, North Carolina, E. Mazria, Architect

Mt. Airy Public Library won an American Institute of Architects Design Award.
Daylighting Strategies used

- Clerestory and monitor lighting
- Light shelves
- Roof and ceiling reflection
Clerestory and Monitor lighting

The circulation spine separates two day lit zones within the building:

- one zone running north south, contains series of saw toothed skylights that illuminate the circulation desk, reading areas, reference stacks
Recessed windows

- The library has south-facing windows for side lighting and views.
- A typical window unit in the south wall has a light shelf above the viewing frame that reflects sunlight onto the ceiling, thus distributing diffuse light to adjacent areas.
- The light shelf prevents direct-beam illumination of any of the interior areas.
Kimbell Art Museum

- Fort Worth, Texas.
- Louis I. Kahn, Architect.
- Reflected light across concrete vaults.
- Internal reflector suspended below ceiling.
- Much use of bounced light.
- Courts for borrowed light.
- Changing of seasons.
- Linear form.
Kimbell Art Museum
Dayspring Church

- Dayspring United Methodist Church, Tempe, AZ.
- George Christensen, FAIA, Architect.
- Monitors & clerestory.
- Bounced light.
- Difficult site constraints for sun angles.
Mt. Angel Abby Library

- Oregon, USA
- Alvar Aalto, Architect
- Spaces divided into two groups with varying lighting needs
  - Reading (high levels)
  - Book storage (lower levels)
- Reading areas along perimeter wall & under sun scoops.
- Books between reading areas, further from pools of light.
- Centric, linear form
Mt. Angel Abby Library

Library, Mount Angel Abbey, Oregon, Alvar Aalto
Harmony Library

- Fort Collins, CO.
- Davis Partnership, Architects; Lightforms, energy & daylighting consultants.
- Joint use public & community college library.
- 30, 400 sq. ft.
- Clerestories, side lighting, Energy Star labeled lighting fixtures.
- 90-95% daylighted. 40% less energy use than comparable new building in Fort Collins at time of construction.
- “Windows, geometry, reflecting surfaces.”
Harmony Library
Summary

- Follow sustainability design principles & promote daylighting.
- Understand microclimate & use climatic design principles.
- Understand solar geometry.
- Thorough site analysis!
- Understand needs for shading & daylighting.
- Use indirect daylight when possible, especially in sun-dominated climate locations.
- Design for dominate sky condition.
- Mass & configure building so maximum # of spaces are near daylight.
Questions?
References

Web Site References

• **Software**
  http://radsite.lbl.gov/radiance/HOME.html
  http://windows.lbl.gov/materials/optics5/default.htm
  http://windows.lbl.gov/software/window/window.html
  http://irc.nrc-cnrc.gc.ca/ie/lighting/daylight/daysim_e.html
  http://www.archenergy.com/products/spot/l
  http://squ1.com/ecotect

• **Kimbell Art Museum**
  http://www.kimbellart.org/building/Architecture_facts.cfm?id=3

• **Mount Angel Abbey Library**
  http://www.mtangel.edu/library/main/library.htm
  http://www.greatbuildings.com/buildings/Mount_Angel_Library.html
  http://arch.ced.berkeley.edu/vitalsigns/bld/Case_studies/Abstracts/cpslo_mtangel_ab.html

• **Dayspring United Methodist Church**
  http://www.cmgivens.com/dayspring/

• **Harmony Library**
  http://www.fcgov.com/electric/harmonylib/index3.htm

• **Daylight in buildings: a sourcebook on daylighting systems & components:**
  http://gaia.lbl.gov/iea21/
Part Two: Modifiers for Side Lighting
Outline

Modifiers

Single Side Lighting

Bi-lateral Lighting

Multi-lateral Lighting

Clerestory Lighting

Light Shelves

Internal Controls

External Controls

Summary

6-17. Low windows may have a view.
Modifiers

• Building geometry & spatial arrangement should promote, rather than preclude, distribution of daylight
Modifiers

- Buildings should be massed & configured so maximum # of spaces are near daylight.
- Fine-tune strategies based on linear, centric, or clustered forms.
Modifiers

• Create low contrast between the window frame and adjacent walls to reduce glare and improve vision.
• Minimize mullions
• Splay window jambs.
Modifiers

- **Borrowed light**
  - With acceptable depths, light can be shared to hallways & other spaces
  - Interior partitions must have glass or open space to share lighting
  - Noise/security concerns
  - Usually uses clerestories or glass located high in the exterior wall for best distribution.
  - Ceiling is a secondary light source!
Modifiers

• Splayed surfaces are effective at increasing the apparent size of the aperture.
• Splayed surfaces can “temper” brightness variations near the opening.
Modifiers

- External reflection from:
  - Ground
  - Adjacent buildings
  - Roof top
  - Walls
- Reflectance characteristics important
Single Side Lighting

• Performance based on the geometric relationships between:
  – The room
  – Size, shape, location of daylight apertures

• Three proportional relationships:
  – Spatial proportions
  – Aperture proportions
  – Spatial/aperture proportions
Single Side Lighting

- Aperture – rough opening of the window without regard to framing
- High E levels near window; low rear of room
- 1.5 to 2.5 x Ht. To 10%
- Strong directionality of light
- Effective for lighting 2-D horizontal surfaces
- High glass effective for lighting vertical surfaces
Single Side Lighting

- High openings - clerestories

High

High, narrow openings (e.g., ribbon windows) can project light deep into rooms and achieve uniform distribution of daylight, but view of outdoors will be restricted. Ceiling and upper walls should be high-reflectance, matte surfaces.

Light directed toward ceiling will reduce glare from windows

Primary light source (high location can spread and project light deep into room)

High-reflectance wall surfaces (to decrease contrast between glazing and surround)
Single Side Lighting

- Windows with low sills

Central

Openings with low sills project more light onto floor and permit better distribution of reflected ground light.

Wide opening (corresponds to normal horizontal "to-and-fro" eye movements of room occupants)

Secondary light source (reflections from floor can balance reflected light from walls and ceiling)
Single Side Lighting

- Windows at end walls

End

Openings at end of walls can help users understand size and shape of rooms by defining intersections of major surfaces. End openings also can reduce brightness ratios by illuminating adjacent surfaces. However, views of outdoors for time orientation and weather information will be restricted.

Reference

Case Study: Herman Miller SQA Building

- Herman Miller SQA Building, Holland, MI, USA
- William McDonough + Partners, Charlottesville, VA
- 290,000 square feet housing manufacturing, offices & showrooms
- Good energy efficiency
- Indoor air quality
- Daylighting
- Restored wetlands & prairie landscape site.
- Daytime workers rated the building as better for people.
- Linear form
Case Study: Dormitory at M.I.T.

- Steven Holl, Architects, New York City
- 160,000 sq. ft. for 350 students.
- Received 2000 PA Award
- Façade is perforated, prefabricated, concrete panels with large scale openings into view corridors, main entrances & outdoor activity area.
- Linear form
Case Study: Dormitory at M.I.T.
Florida Solar Energy Center

- 1995
- Coco, FL on the University of Central Florida/Brevard Community College Campus.
- Designed to be "the world's most energy efficient building".
- Research labs & Offices.

Architects Design Group, Inc.
Florida Solar Energy Center

- Maximizes usable space on the building perimeter so daylight can illuminate the interior.
- Controls interior air temperatures based on solar exposure (cool south-facing zones without wasting energy cooling the north side, which doesn't need it).
- Exposes the smallest east and west facing building surfaces to hot morning and afternoon sun.

Image from: [http://www.fsec.ucf.edu/about/index.htm](http://www.fsec.ucf.edu/about/index.htm)
Florida Solar Energy Center

- The southeast-facing wall of windows gets lots of solar exposure yet lets in very little heat.
- The window-wall is a system that sandwiches a thin, almost-transparent metallic film between double panes of glass.
- The film is spectrally selective; it lets in almost 70 percent of the sun's visible energy (light), but blocks about 98 percent of the sun's heat-producing infrared energy.
Florida Solar Energy Center

- Exterior/interior light shelf.
- What happens on cloudy days and at sunset?
- A sensor in the ceiling notices as daylight levels dim. It signals an electronic control that brightens the super-energy-efficient lamps in ceiling fixtures.
- Interior illumination stays at a constant, comfortable working level without wasting energy through unnecessary electrical lighting.
Florida Solar Energy Center
Florida Solar Energy Center

- Roof monitors are used since skylights are sensible in a hot, humid climate like Coco.
- Projecting 10 feet above the flat roof, each monitor's north-facing surface is a highly efficient glazing system that lets in cool light from the northern sky but no hot, direct-beam sunlight.
- The light is directed downward into the building's core to offset the need for interior electrical lighting.

Image from: [http://www.fsec.ucf.edu/about/tour/tourstop1.htm](http://www.fsec.ucf.edu/about/tour/tourstop1.htm)
Bi-lateral Lighting
Bi-lateral Lighting

- Better distribution balance
- 15/30 rule
- Less glare than single side lighting
- Glare can still be a problem without filtered or bounced light
- Used to create two or more primary lighting zones in a room
Bi-lateral Lighting

- Illuminance contours are more balanced.
- Horizontal distribution.
- Vertical distribution.
- Reviewing in plan & section useful.
Multi-lateral Lighting

Figure 4.4  Section of the Carmel Mountain Ranch Library.
(M. W. Steele)
Multi-lateral Lighting

- Light from multiple directions
- 15/30/15 proportions
- Better brightness balance
- Glare control still needed
- Less use of artificial lighting during daylight
- Controls by zone
- Can be used to vary the max. to min. illuminance
Clerestory Lighting

- Defined by Robbins (1986, p. 80) as an aperture above the aisle roof of a church nave, transept, or choir acting as a primary light source.
- Any window whose sill height is greater than eye height, usually 7’ or more above the floor.
- If top is above ceiling height, is considered a roof monitor.
Clerestory Lighting

- Usually not used as view glass.
- Open to bright part of sky dome close to zenith.
- Allow deeper daylight penetration.
- Provide excellent horizontal & vertical task illuminance.
- Ground reflections usually not critical; reduces ground-reflected glare.
Case Study: Atlantic Center for the Arts

- Thompson & Rose Architects
- New Smyrna, Florida, USA
- Articulated, clustered site plan
- Boardwalk connects buildings
- Window forms vary among buildings
- Cluster form
- Responsive to micro-climate
Case Study: Atlantic Center for the Arts
Case Study: Seabird Island School

- Salish Indian Reservation, Agassiz, British Columbia, Canada
- Patkau Architects, Vancouver
- Long, linear plan oriented on east-west axis
- Temperate climate with cool, overcast winters
- Large clerestory on south side.
- Low, irregularly shaped windows provide view.
- Complex linear form.
- Building “engages the site.”
Case Study:
Seabird Island School

1. community buildings
2. village common space
3. bridge
4. dry creek bed
5. fire pit
6. Seabird Island School
7. outdoor play areas
8. traditional pit house
9. teaching gardens
10. salmon drying racks
11. bus & passenger drop-off
12. parking

Figure 1.23 Site plan of Seabird Island School.
(Parkeu Architectural)
Light Shelves

2. BOUNCE DAYLIGHT
AGAINST SURFACES TO SPREAD IT OUT AND GET IT DEEP INTO INTERIOR SPACES.
Light Shelves

- Location of shelf affects its exposure to sky.
- Finish of shelf for redirecting light important.
- Diffuse finishes better than shiny due to maintenance & other issues.
- Depth of shelf important relative to sun angle.
- South orientation best.
- Glass below shelf – view glass.
- Glass above shelf – daylight glass.
- Ceiling reflectance impacts interior illuminance.
Light Shelves

- Separate view glass from daylight glass.
- Types:
  - Internal
  - External
  - Combination

6-59. The clerestory portion of a lightshelf should not allow direct penetration of sunlight at any time. The lower window may allow some sunlight penetration as long as it falls below eye level.

6-60. Project lightshelf from facade to capture high-angle sunlight and provide additional shading for low windows.

6-61. With flat facades, most of the lightshelf is in shade at high sun angles.
Light Shelves

- Deep daylighting
- External shelf
- Internal shelf
External Controls

- Louvers
- Eggcrates
- Overhangs
- Screens
Internal Controls

• Two critical issues:
  – Reliability
  – Ease of use

• Categories:
  – Shutters
  – Window shades
  – Drapery
  – Opaque sliding panels
  – Directional glazing & glass block
“Architectural study always involves a moment of art and instinct. Its purpose is still to bring the world of matter into harmony with human life.” (Alvar Aalto)
References

- Kimbell Art Museum
  http://www.kimbellart.org/building/Architecture_facts.cfm?id=3
Part Three: Toplighting Strategies
Toplighting Characteristics

- Of minimal use in tall buildings because you can distribute only a couple of floors.
- Freedom to place “source” where desired.
- Can achieve uniform illumination if needed.
- Solutions have to be different for each building type & location.
- Bring daylight in from above to obtain deeper penetration into space.
Toplighting Characteristics

- Optimizing relationship between lighting & HVAC under wide daily & seasonal variations in sunlight a problem.
- Direct sunlight can be a plus or a minus.
- Can be oriented to sky vault or to horizon, depending on strategy.
- Can distribute daylight over a greater horizontal area than sidelighting.
- Better than sidelighting under overcast skies
Skylights

- Provide a relatively uniform level of illuminance.
- Used to illuminate horizontal work planes.
- Excellent for general illuminance & for lighting 3D artwork or objects.
- Can introduce considerable heat gain in summer.
Skylights

- Need to understand differing effects of clear vs. translucent glazing.
- Splaying the skylight opening can increase horizontal distribution.
- Available in standard & custom sizes from many manufacturers.
- Sound choice for high security & windowless spaces.

Fig. 64: Types of light wells for skylights (adapted from AAMA, 1987).
Skylights

- Basic shapes:
  - Flat
  - Bubble
  - Dormer
  - Pyramid
  - Ridge
- Can be combined with internal modifiers to redirect light which can reduce contrast & glare.
Case Study: Kimbell Art Museum

- Fort Worth, Texas, USA
- Louis I. Kahn, Architect
- Reflected light across concrete vaults
- Internal reflector suspended below ceiling.
- Much use of bounced light.
- Courts for borrowed light.
- Changing of seasons
- Linear form
Case Study: Kimbell Art Museum
Case Study: High Museum of Art
Apple Store Soho

- Bohlin, Cywinski, Jackson, Architects

Images: www.bcj.com
Case Study: Salt Lake City Public Library

- Salt Lake City, UT, USA; 225,000 sq. ft.; 1999-2003.
- Moshe Safdie, Architect with VCBO Architecture, Associate Architects
- Five-story, triangular-shaped main building.
- Houses the stacks, an adjacent rectangular administration facility, & a glass-enclosed Urban Room and public piazza.
- Urban Room open to views of the surrounding Wasatch mountain range.
- Crescent-shaped wall allows visitors to ascend & access a public roof garden.
- At night the glass facade, lit from within, is reflected in a crescent-shaped reflecting pool extending into the outdoor space.
Salt Lake City Public Library
Sawtooth

- Common design strategy for industrial plants during late 19th & early 20th centuries because uniform illuminance possible.
- Can function well with low ceiling heights.
- Sawtooth aperture very complex due to infinite number of design variations.
Sawtooth

- Single & multiple aperture designs do not function in a similar way.
- End aperture differ from center conditions due to sky characteristics & aperture design.
- Pattern of illuminance depends on sky type.
- Three apertures in series required to achieve good pattern of light.
Case Study: Mt: Angel Abby Library

- Oregon, USA
- Alvar Aalto, Architect
- Spaces divided into two groups with varying lighting needs
  - Reading (high levels)
  - Book storage (lower levels)
- Reading areas along perimeter wall & under sun scoops.
- Books between reading areas, further from pools of light.
- Centric, linear form
Case Study: Mt: Angel Abby Library
Case Study: Tampa Art Center

- Largo, Florida, USA.
- Thompson & Rose, Architects, Cambridge, MA
- Museum & administration building.
- Sawtooth monitors for top lighting.
- Galleries are sky lighted.
- Canopy overhang to block direct sun and bounce diffuse light in clerestories.
- Linear, clustered form
Case Study: Tampa Art Center
Roof Monitors

- Utilize vertical or steeply sloped glazing above ceiling line.
- Light scoops face north.
- Sun scoops face south.
- Sun scoops, without modifiers, not appropriate for hot, arid climates.
Roof Monitors

- Overhangs, translucent glass & baffles or heat-reflecting glass can be used to reduce heat gain & improve visual comfort.
- Light scoops use clear glazing to max. transmission.
- Roof surface contributes to ERC.
Roof Monitors

- Light scoops should not be used in cold climates, unless insulating glazing is used.
- Heat loss through a light scoop can be significant in cold climates.
- Light scoops provide most consistent level of illuminance with a min. of glare.
Case Study: Center for Energy & Environmental Education

- University of Northern Iowa.
- Wells Woodson O’Niel, Architects with the Weidt Group, Energy & Environmental Consultants.
- Integrates architecture, ecological design & education.
- Primary goal was to maximize daylighting and reduce electrical energy consumption.
- Combination form
Case Study: Center for Energy & Environmental Education
Lightwells

- A vertical opening through one or more floors of a building.
- Designed to distribute daylight to adjacent spaces.
- Usually located adjacent to vertical circulation.
- Often do not provide view to outdoors.

Fig. 75: Typical lightwell configuration.

Fig. 76: Heliosat used for sun-tracking or beam daylighting.
Lightwells

- Glare not usually a problem when lightwells are tall & narrow.
- Thermal gain usually negligible if interior opening is glazed.
- Exterior opening usually glazed for moisture control.
- Can be used with sun-tracking or beam daylighting devices.
Lightwells

- Canadian National Gallery, Ottawa
- Moshe Safdie, architect
- Opened in 1988
- Granite & glass is the home of Canada's art collection
Atria and Lightcourts

- Atria are central areas that open to the sky in multi-story buildings.
- Often glazed to create a controlled environment.
- Amount of sunlight admitted must be balanced against heating & cooling needs.

Fig. 62: Top lighting can provide deep penetration of daylight if properly designed.
Atria and Lightcourts

- Varying geometries including:
  - Side wall perpendicular to floor
  - Splayed up or down.
- Performance depends on aspect ratio of atria:
  - Tall, narrow
  - Short, wide
- Shape should be determined, in part, based on lighting needs on horizontal vs. vertical surfaces.

Fig. 74: Atria configurations.
Atria and Lightcourts

- Major concern – maintenance of trees & plants.
- Interior wall finishes & wall glazing characteristics will impact distribution.
- Ratios of 1:1 are best (depth to width).
- Vertical wall illuminance is usually less than 20% of exterior horizontal illuminance below 2 or 3 floors from opening.
Case Study: TVA Building

The new TVA building in Tennessee will use tracking-mirrored louvers to reflect sunlight into buildings.
Case Study: Denver Airport
Summary & Discussion

“Architecture is the making of a room; an assembly of rooms. The light is the light of that room. Thoughts exchanged by one and another are not the same in one room as in another.” (Louis Kahn in Buttiker, Urs, Louis I. Kahn Light and Space, New York: Watson-Guptill Publications, 1994, p.178)
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Questions and Reminders
Please remember to complete the course evaluations.

Thank You!

We hope you enjoy the trade show and conference!