Lighting and Daylighting for The 21st Century School

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BENYA LIGHTING DESIGN

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Thank you!

Goals

Learn:

- What is a 21st century school?
- What is AV lighting science?
- How do I perform basic daylighting?

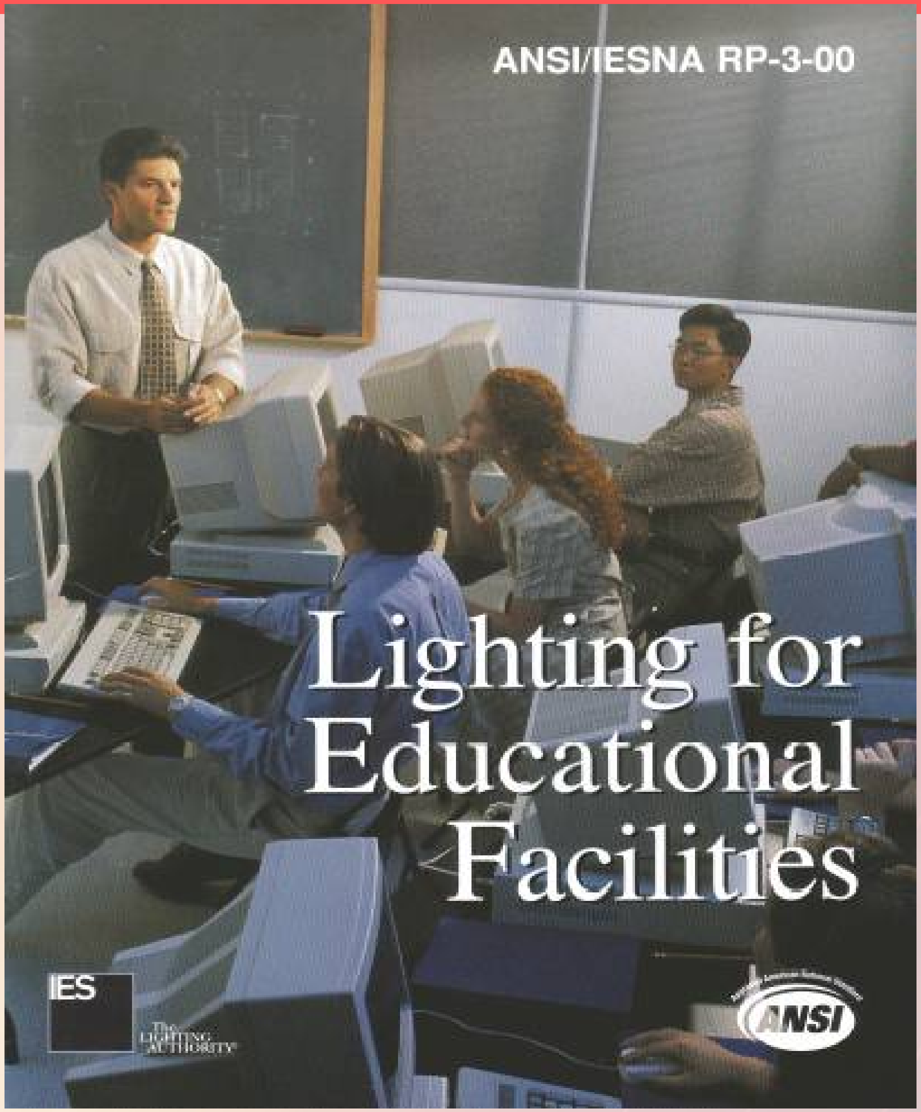
Issues We'll Face

- Changes in lighting requirements
- Energy costs
- Energy codes
- LEED
- Rebates and tax credits

The 21st Century School

Hint: This is not the school YOU attended.

Basic Reference



Latest Research

- California Public Interest Energy-efficiency Research (PIER) Report 4.5
  - The evolving electronic classroom
  - An integrated approach to lighting
- California Collaborative for High Performance Schools (CHPS) and PIER
  - The educational benefits of classroom daylight

Latest Research

The Questions

- What trends in teaching can we predict?
- Are these trends “fads” or cost effective enough to spread broadly?
- Is there a viable alternative just around the corner?

Predictable Teaching Technologies

WAXING
- White Boards
- Computer Projections
- Object cameras
- Individual Computers

CONSTANT
- Paper and pencil or ink
- Posters and Art

WANING
- Overhead projectors
- Slide projectors
- Film projectors
- Opaque projectors
- Chalkboards

The Force of Change

Streaming video now playing in classrooms

Area districts, if they have the high-speed capacity, are switching to the versatile digital technology

By LUCIANA LOPEZ
THE OREGONIAN

The video of a hydrogen bomb safety drill, generated from an aging film, played fuzzily on Jeanette Ryan's computer at the Tualatin High School library.

With a few mouse clicks, the school librarian returned to a computerized archive containing similar footage, along with films about the Cold War, checking for other options.

In the past, Ryan would have had to switch tapes or DVDs or even filmstrips to show the images. These days, Tualatin High and many schools throughout the metro area are tapping into a new resource: streaming video, a sequence of images sent over the Internet that can be displayed on a user's computer as they arrive.

School districts are increasingly using digital video files in the classroom, because teachers can download them to show classes, and students can watch and use the files on their own.

Streaming video files, accessed through subscriptions that local education service districts buy, are more versatile than tapes or DVDs, although school officials acknowledge that the high-speed Internet connections streaming video requires

Please see **STREAMING,** Page 4

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Image Considerations

Principal Types

- Front projection
- Rear projection
  - Projector and screen
  - Self contained
- Self Illuminated
  - CRT
  - Plasma
  - LCD

The practical choice: front projection

- Most sensitive to room ambient light
- White board ≠ screen

Image (screen) size

Most A/V experts know how big an image should be.

Image height = ½ x closest seat and 1/6 x furthest seat

- (16’/2 = 8’ H)
- (48’/6 = 8’ H)
- 8’ is perfect screen height

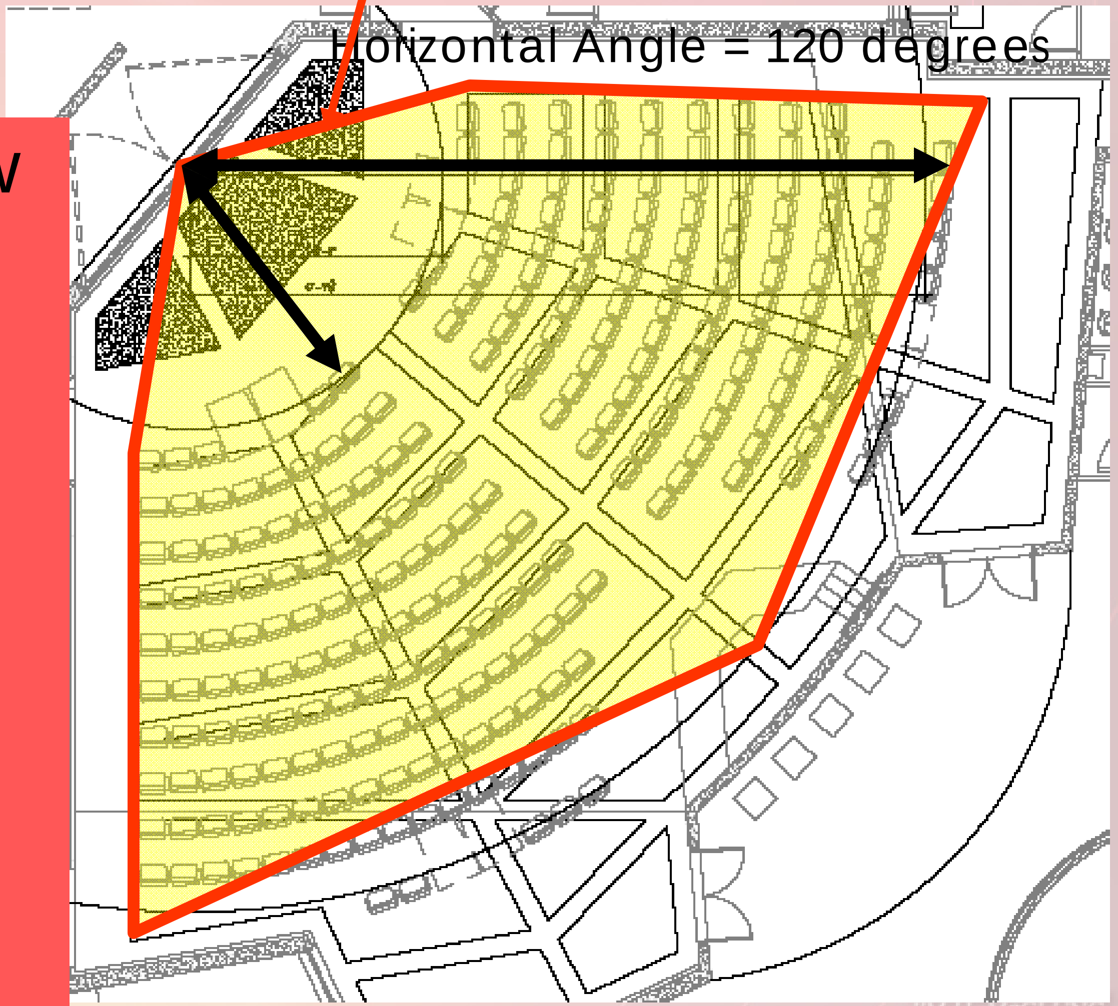


Image (screen) size

Image height = ½ x closest seat and 1/6 x furthest seat

- (16'/2 = 8' H)
- (48'/6 = 8' H)

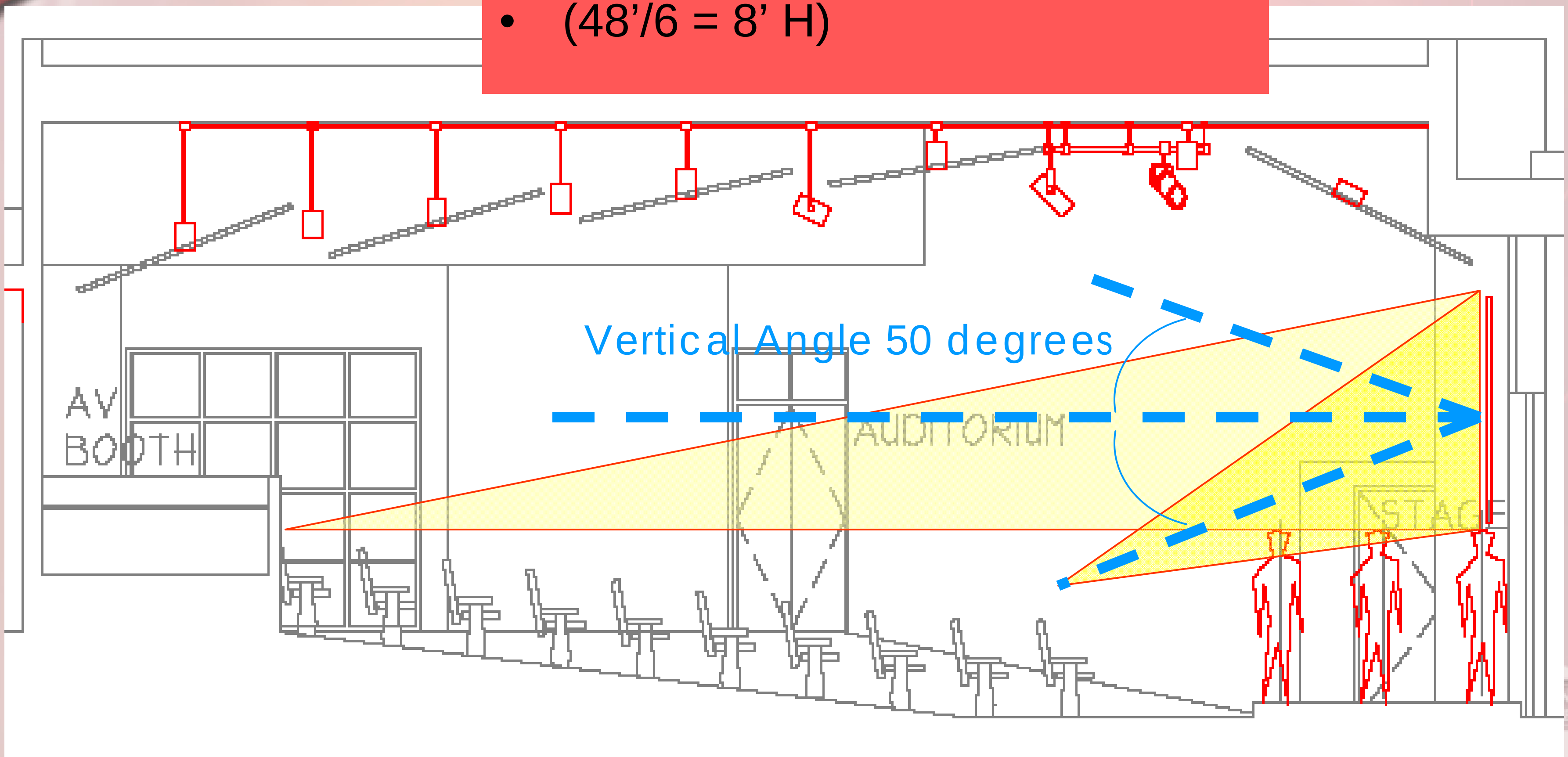


Image (screen) size

Widescreen 16:9

16:9 = x:8

9x = 128

x = 14’

Standard 4:3

4:3 = x:8

3x = 32

x = 11’

Image (screen) size

Using the 8’ x 11’ screen:

- Screen area is 8’ x 11’ = 88 square feet (SF) or about 8.8 m^2

Using the 8’ x 14’ screen

- Screen area is 8’ x 14’ = 112 square feet (SF) or about 11.2 m^2

Projection Calculations

White Level

Rules of Thumb

- Maximum useful white level = 50 fc
- Acceptable contrast for PowerPoint 10:1
- Desirable contrast for TV >25:1
- Feature film: 50:1

Front Projection Calculations

White Level

White Level = (projector light + ambient footcandles on screen) x screen gain (SG)

Projector light = ANSI lumens/screen area x LLF

Black Level = ambient footcandles on screen x screen gain

Front Projection Calculations

White Level

Projector light = ANSI lumens/screen area = 4000/80 = 50 footcandles or 500 lux initial and 30 fc maintained

For a 4000 lumen projector and an 80 sf image

For a room with 5 footcandles at the screen

White level = (50 fc +5 fc) x SG

Black level = 5 fc x SG

CONTRAST = 55 SG / 5 SG = 11 initial

White level = (30 fc +5 fc) x SG

Black level = 5 fc x SG

CONTRAST 35 SG / 5 SG = 7 maintained

Rear Projection Calculations

White Level

White Level = projector light + (0.15 x ambient footcandles on screen) x screen gain (SG) x LLF

Projector light = (ANSI lumens/screen area) x LLF

Black Level = 0.15 x ambient footcandles on screen x screen gain

Rear Projection Calculations

White Level

Projector light = ANSI lumens/screen area = 4000/80 = 50 footcandles or 500 lux initial and 30 fc maintained

For a 4000 lumen projector and an 80 sf image

For a room with 5 footcandles at the screen

White level = (50 fc +(.15 x5 fc)) x SG

Black level = (.15 x 5) fc x SG

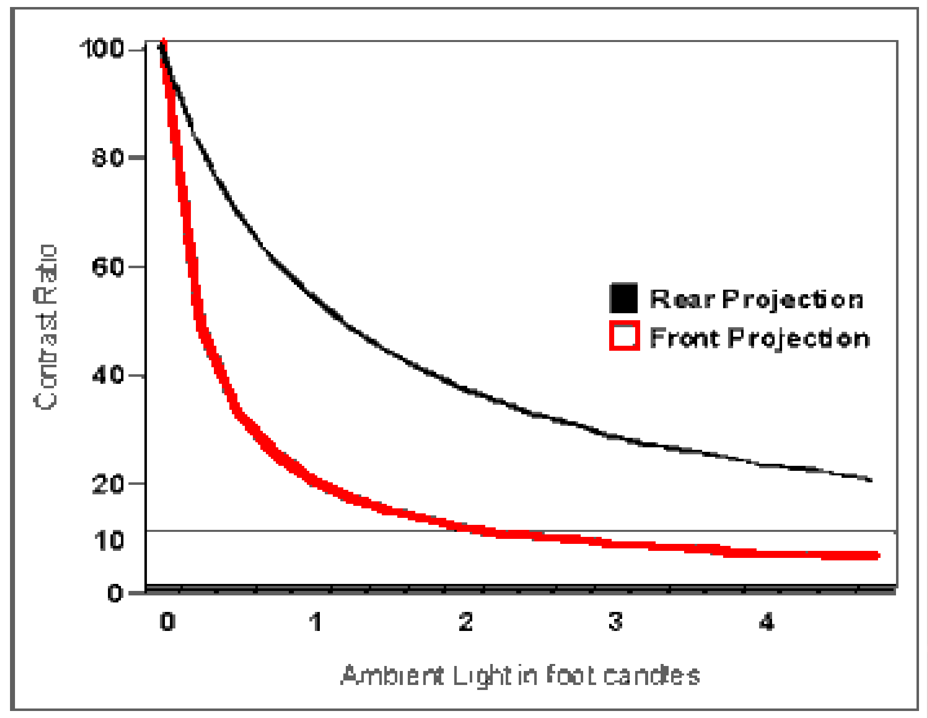
CONTRAST = 50.75 SG / .75 SG = 67 initial

White level = (30 fc +(.15 x5 fc)) x SG

Black level = (.15 x 5) fc x SG

CONTRAST = 30.75 SG / .75 SG = 41 maintained

Methods Compared



Advantages of Front Screen

- Brighter image
- Sharper image
- Wider angle audience
- Cheaper

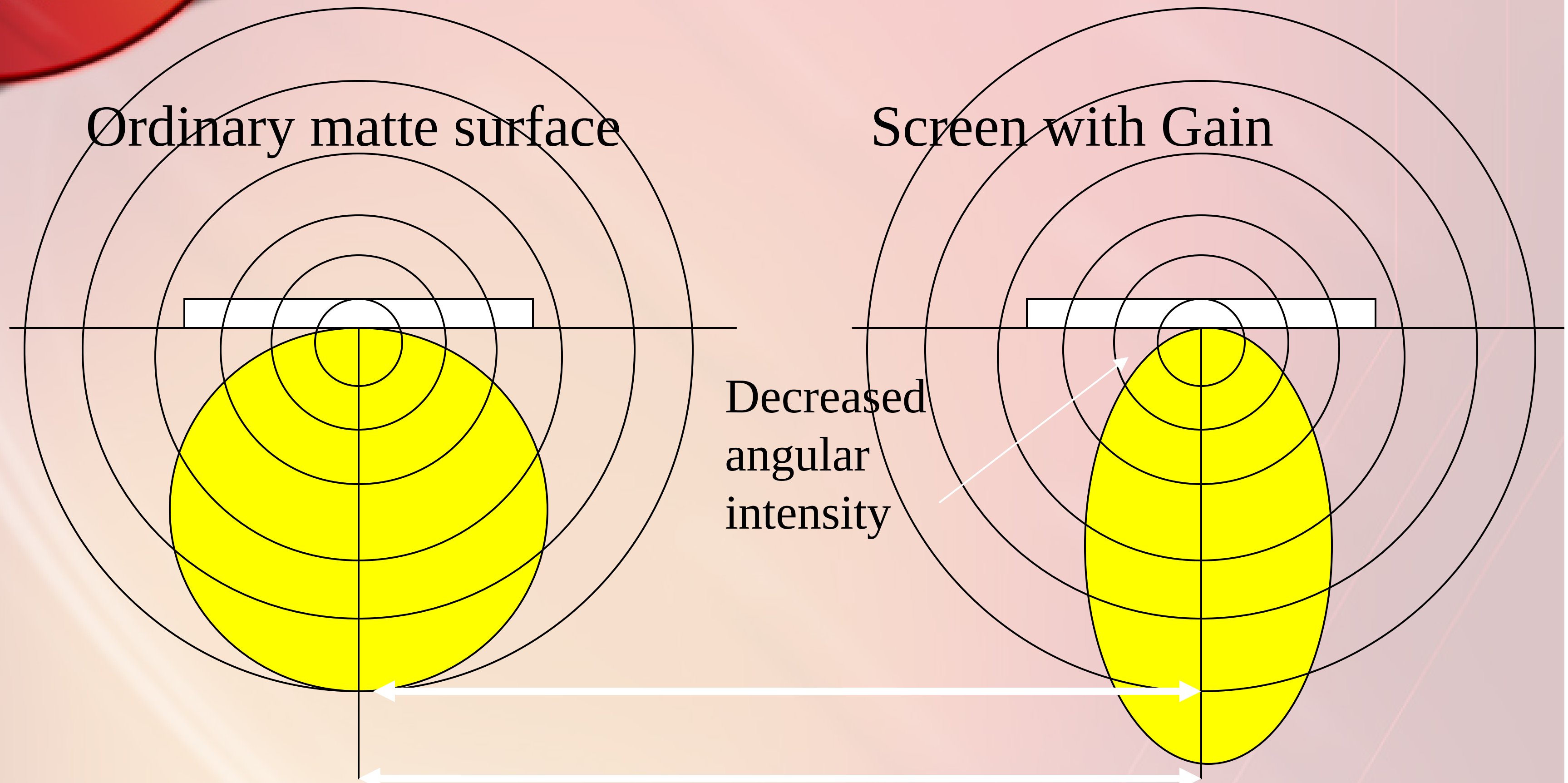
Advantages of Rear Screen

- Greater contrast
- Reduced sensitivity to room light

Using ANSI Lumens

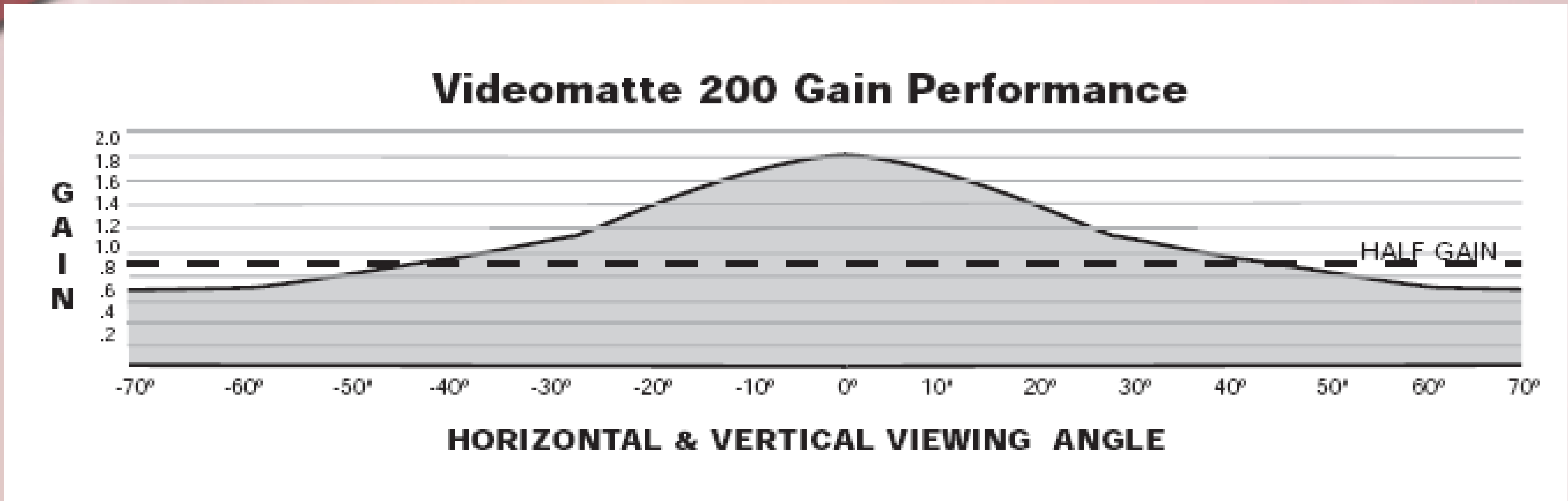
- The projected image lumens (white)
- Assumes reasonably even, flat field (uniform distribution)
- Permits image illuminance calculations
- Permits image exitance calculations
- Does NOT include lamp lumen depreciation

Screen Gain



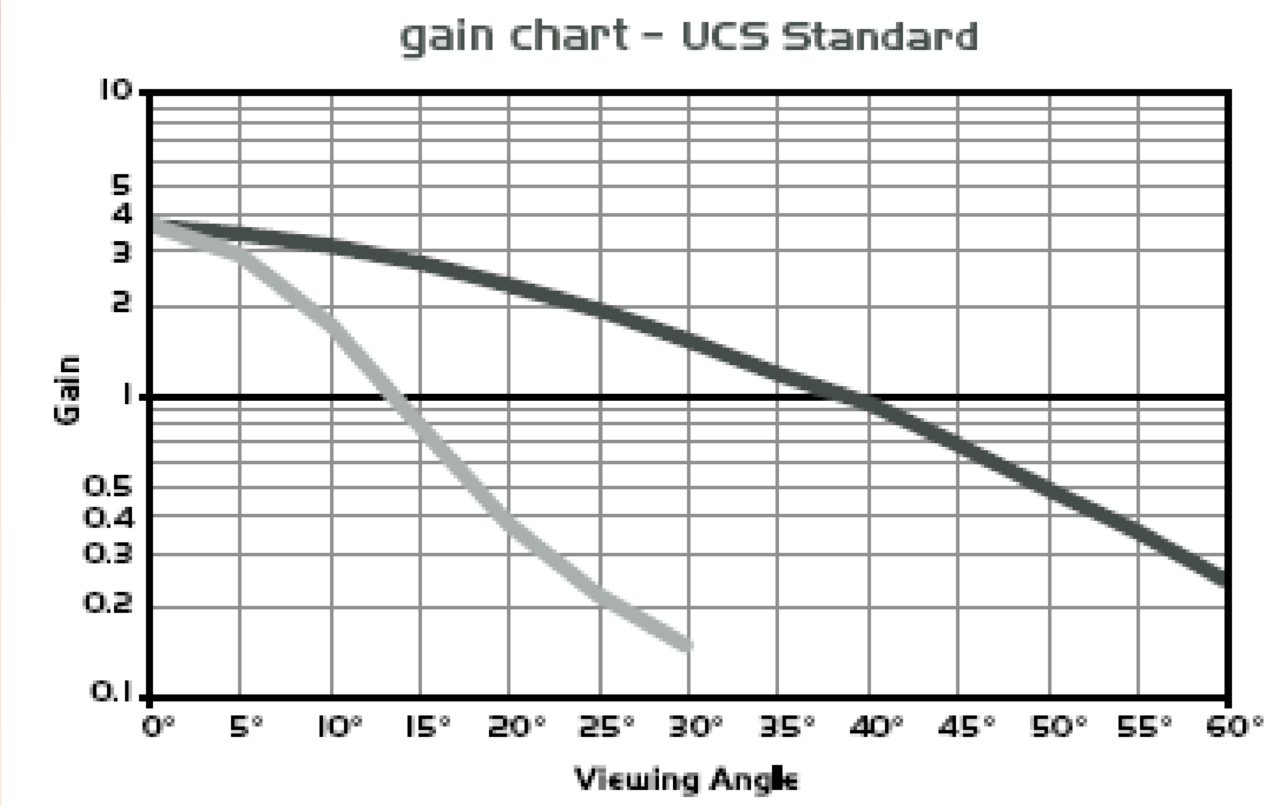
Ordinary matte surface
Screen with Gain
Decreased
angular
intensity

Screen Gain and Angle



Stewart Matte Front Screen

Screen Gain and Angle



DNP Rear UCS lenticular screen

Maximizing contrast

- The objective is to maximize the screen white:black ratio.
- Black is the ambient screen illumination.
- White is the *sum of ambient screen illumination and projected white illumination*.
- **To improve contrast best reduce room ambient light.**

The importance of contrast

- Most video material has a contrast ratio of over 100:1
- If the screen is too bright, it will reduce the image contrast
- Also, the ambient light will affect color balance
  - Typical video, 5500-9000K
  - Typical lighting, 2200-3000K

Classroom Sized Screens

- Standard classroom is about 30’ x 32’
- Maximum viewer distance is about 24’
- Minimum screen height is about 4’
- Typical screen widths
  - 5’4” for a standard single image 4:3 aspect ratio
  - 7’1” for a widescreen 16:9 image
  - 10’8” for dual side by side standard images

Classroom Video Planning

For rear projection:

- Minimum White Level: 25 fc
  - The projector should be at least 1000 ANSI lumens
  - For 10:1 contrast, the maximum ambient screen level is about 14 fc
- Desirable White Level: 50 fc
  - For 10:1 contrast, the maximum ambient screen level is about 25 fc
  - The projector should be at least 2000 ANSI lumens

Classroom Video Planning

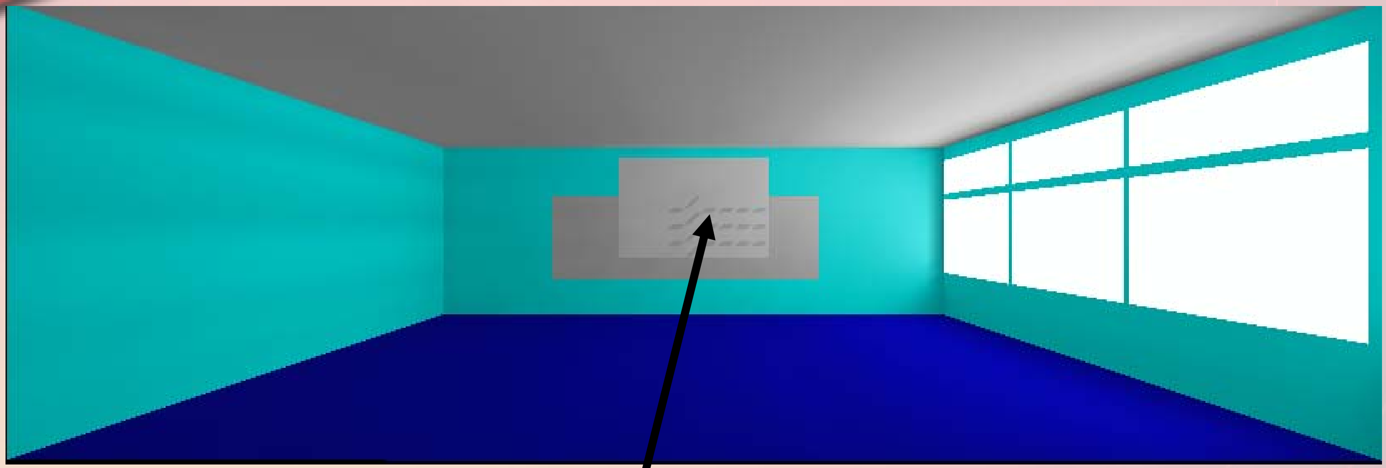
For front projection:

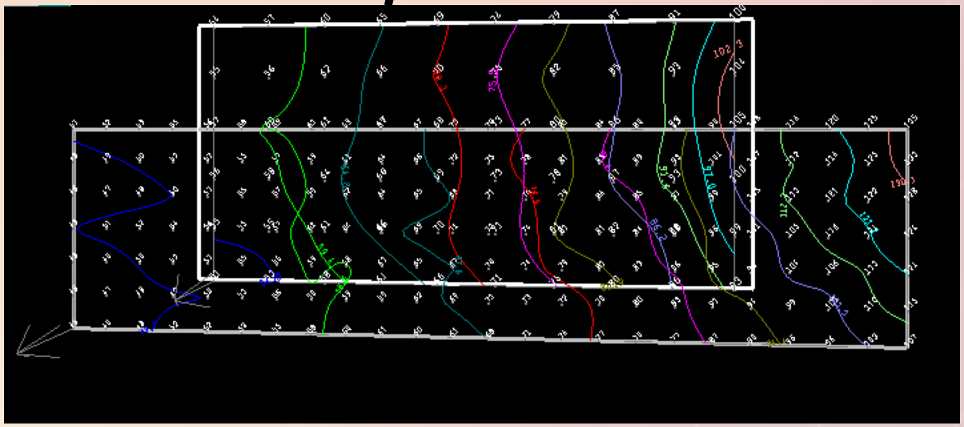
- Minimum White Level: 25 fc
  - The projector should be at least 1000 ANSI lumens
  - For 10:1 contrast, the maximum ambient screen level is about 2.5 fc
- Desirable White Level: 50 fc
  - For 10:1 contrast, the maximum ambient screen level is about 5 fc
  - The projector should be at least 2000 ANSI lumens

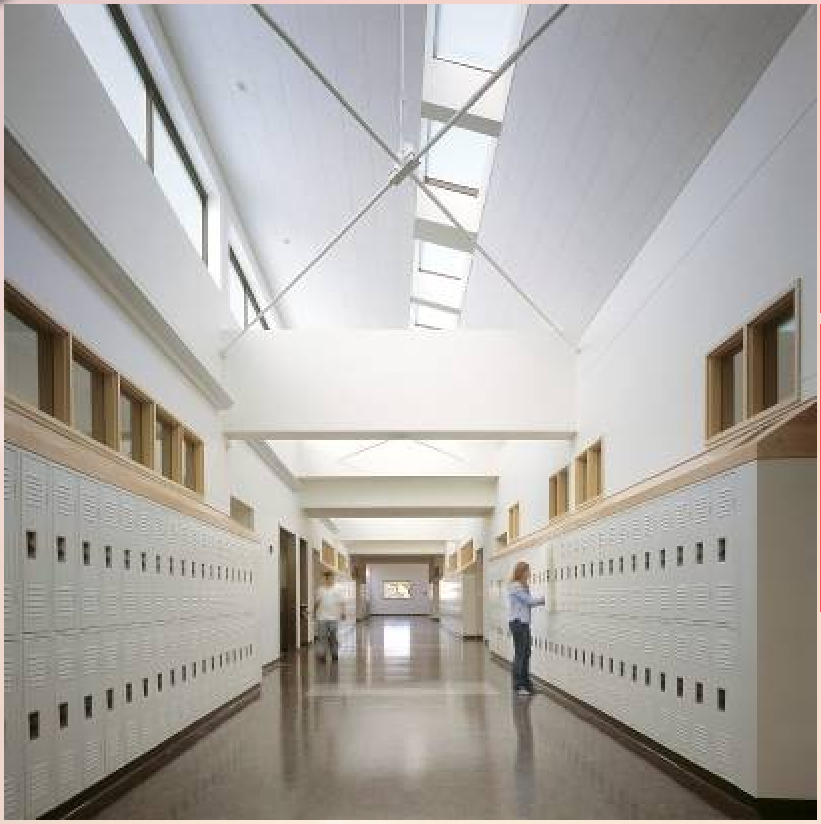
Recommendations: How to Do It

1. Insist on properly sized screen
   - For a 1000 sf classroom, the screen is about 4-5’ high
2. Insist on capability of at least 50 initial ANSI lumens per SF of screen area
3. Design lighting and daylighting to a maximum of 5 vertical footcandles at the screen

Set Analysis Grids for the Screen and White Board







Daylighting in Schools

No need for physical models, artificial skies or black magic

North Clackamas High School

BOORA, Architects

A Renewed Interest in Daylighting: The Next Major Design Challenge

- Makes interior spaces more pleasant and appealing
- Recognized as a significant aid in academic performance.
- Can provide significant energy cost savings.
  - Peak savings tend to occur at peak demand and peak rates
- A very large percentage of American schools are in decent climates for daylighting
  - Minimum temperature differential indoors to outdoors
  - Very high daylight availability

What is “Daylighting Design”?

- Designing spaces to use diffuse light from the sky.
- Use daylighting to provide the PRIMARY illumination within a space.
- Design the electric lighting system to SUPPLEMENT the daylight.
  - Make sure it is turned off when not needed.
  - Provide adequate light when no daylight is available.
- Includes the design of architectural and interior elements such as light shelves and shades to control daylight quantity and quality.

What is NOT Daylighting?

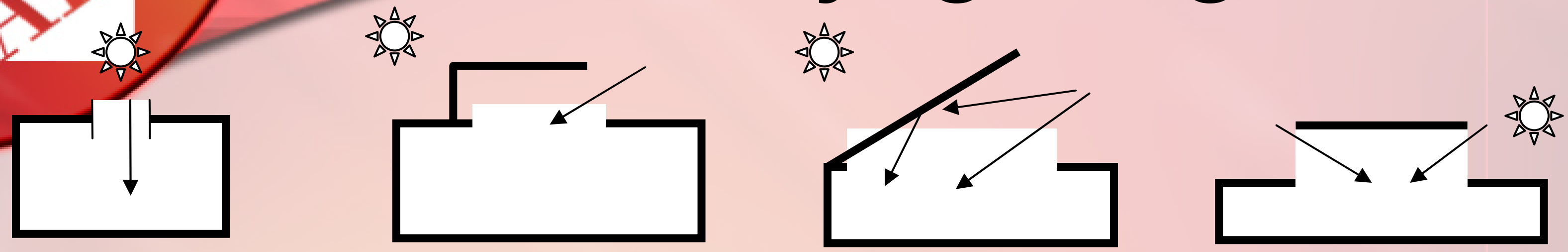
- Too much daylight – a solar oven
- Incorrectly massed and oriented buildings
- A building with good daylight illumination BUT the electric lights burning away.

Direct sunlight is usually not good daylight

- Too bright, causing contrast and visual comfort problems.
- Significant infrared radiation causes local thermal discomfort
- Does not diffuse the light, making use of electric lighting necessary and increasing the cooling load

Basic Types of Daylighting

Toplighting



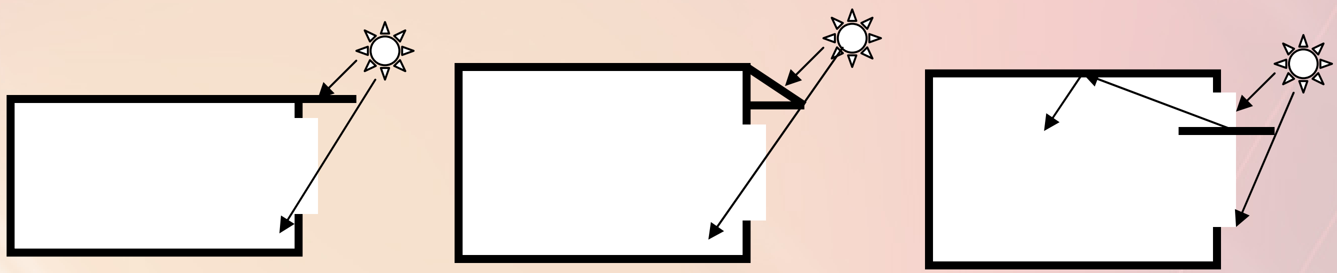
Skylight

Clerestory

Sawtooth or angled clerestory

Monitor

Sidelighting

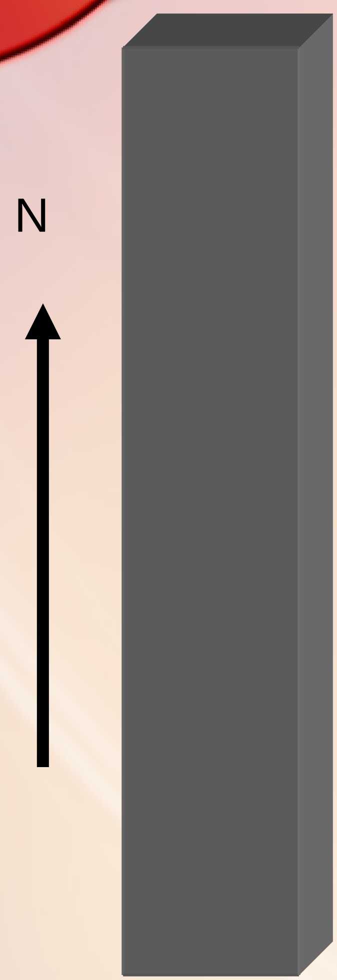


Window with Overhang

Window with shading

Window with light shelf

Basic Principles of Solar Orientation



Worst Exposure

•North and south ends provide minimum interior light

•East and west sides tend to introduce too much light and heat

•East and west sides require complex shading systems

•Shading often requires blocking view glazing

Ideal Exposure

•North side can introduce a maximum of diffuse daylight

•South side can be passively shaded most of the year without blocking view glazing

•East and West sides can have minimal fenestration

Daylighting Design Principles

- Allow NO direct sun penetration,except in circulation spaces.
- Diffuse the light broadly through diffusing glazing and/or shading.
- Introduce daylight as high as possible,
- Use light colored surfaces.
- Keep brightest surfaces out of line of sight.
- Provide blinds or louvers where there is potential for glare or for audio-visual control.

Daylighting Criteria

COOLING SEASON

- The issue is solar gain
- Shade to prevent E>150 fc

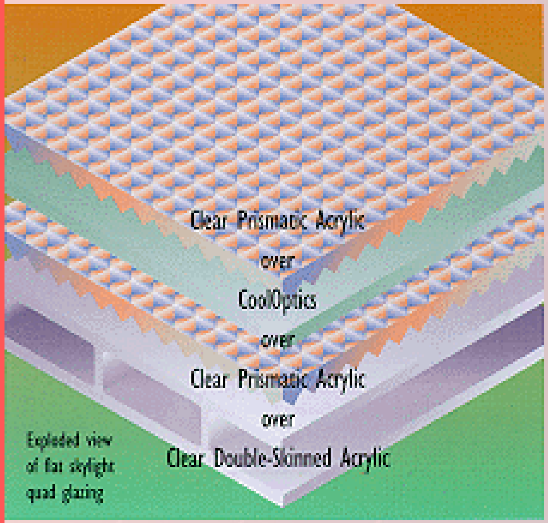
HEATING SEASON

- The issue is glare
- Shade to limit glare

Skylights – Simple and Reliable Daylight

Consider skylights whenever possible in single story buildings and the upper level of multi story buildings. Use diffuse or prismatic skylights in most cases. Skylights with internal louvers are an excellent option for light level control but add cost.

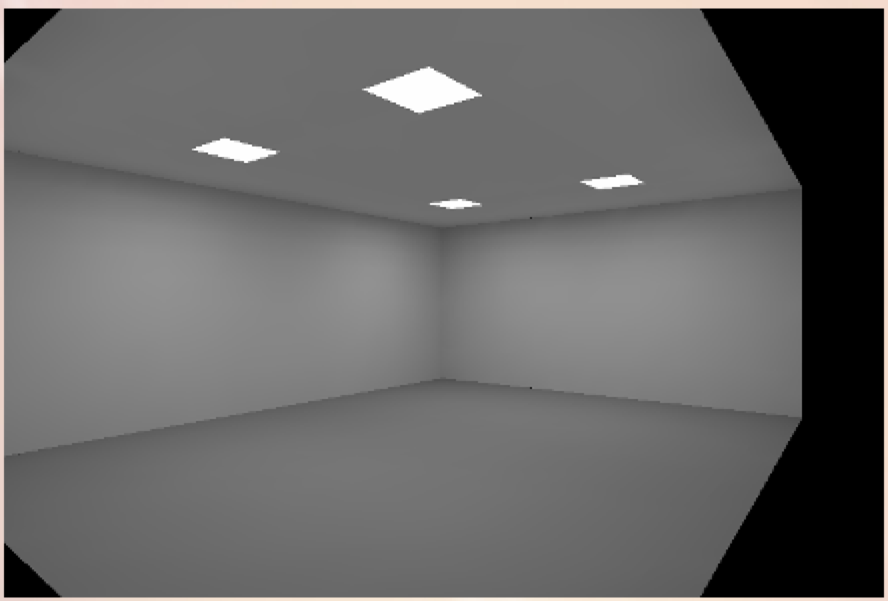
- Proper sizing needed. Use SkyCalc or equivalent.
- Consider modern skylights using prismatic refractors, specular throats and other technologies to increase efficiency, allow smaller skylight to floor ratio (SFR).
- “Cool” skylights with low-e type filtering now available – check them out.
- Skylights are:
  - Effective all day long.
  - Effective under sunlight or cloudy skies.
  - Comparatively inexpensive.
  - Relatively independent of building orientation.



New Design Tool - SkyCalc

- Skylight design tool
- Standard Excel Spreadsheet Template (www.savingsbydesign.com)
- Readily available data for most of California Climate Zones
- Built-in basic lighting calculations, energy cost analysis, and other useful information
- Makes skylight sizing quick and easy
- Accounts for
  - Heating
  - Cooling
  - Lighting
  - Energy Rates
  - Occupancy/use

Design Using SkyCalc



PROJECT: Washington School for the Deaf

Typical small classroom 20 x 25, 10’ ceiling

Original Daylight Concept

Single Center Skylight 8’ x 8’ clear. Total of 64 SF (12.8% SFR) with VLT =50%

Average light level: 604 fc (equinox clear)

Peak light level: 3928 fc

Typical light level: 80-100 fc

Minimum light level: 63 fc

Recommended Daylighting Revision

4 diffuse skylights, 2’ x 2’ , total of 16 SF (3.2% SFR) with VLT=50%

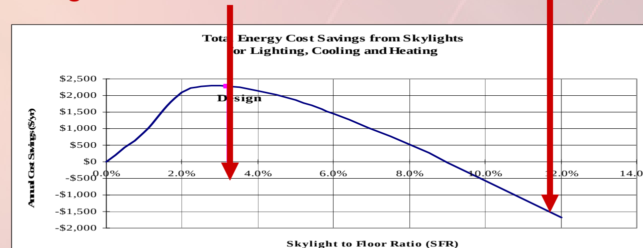
Average light level: 121 fc (equinox clear)

Peak light level: 172 fc

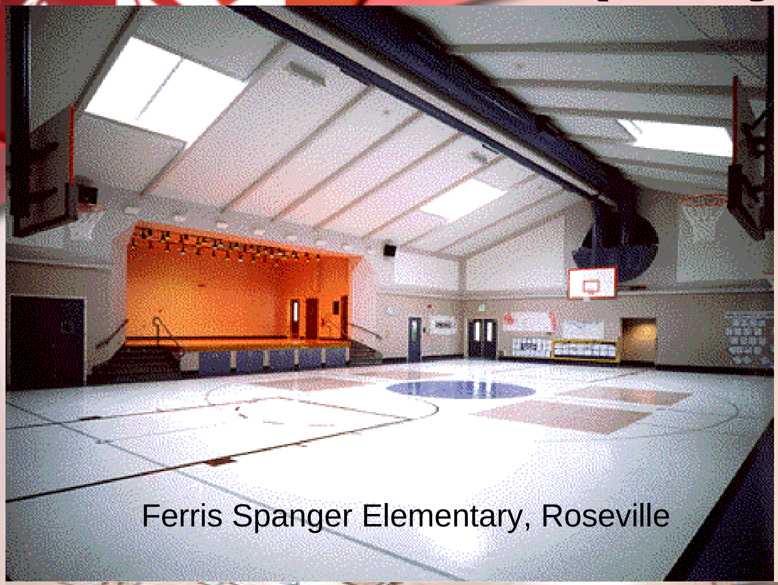
Typical light level: 80-100 fc

Minimum light level: 72 fc

12.8% SFR



Two Gymnasiums (SkyCalc ~ 4% SFR)



Ferris Spanger Elementary, Roseville

Four large (8’ x 16’) skylights 50% VLT
4% SFR

Average light level 200 fc (equinox clear)

Maximum light level 335 fc

Minimum light level 83 fc

Twenty small (4’ x 4’) skylights 60% VLT
3.33% SFR

Average light level 142 fc (equinox clear)

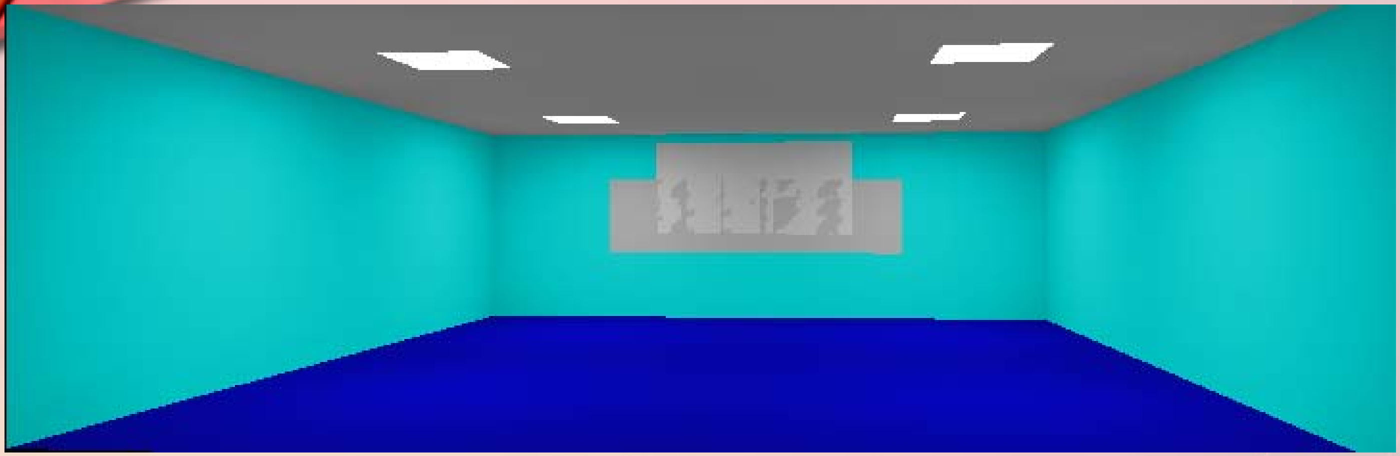
Maximum light level 172 fc

Minimum light level 80 fc

(Calculations for Sacramento)

Designing Skylights

- 960 sf classroom
- Start at 4% SFR, tweak according to plan and other details
- 960*.04 = 38 sf of skylight
- Try (4) skylights each 9 sf (3’ x 3’)
- Be sure to use diffuse or refracting skylights



Sunny	***Cloudy***
6/21 1200 223 fc	6/21 1200 44 fc
9/21 1200 193 fc	9/21 1200 37 fc
12/21 1200 120 fc	12/21 1200 24 fc
9/21 0900 150 fc	9/21 0900 30 fc

Skylights with Louvers

1440 SF Large Classroom.

Demonstrating "daylight dimming" using internal louvers in skylighting system.

BENEFITS

Higher light levels on gray days

Necessary for AV integration

DRAWBACKS

Louvers are not perfect reflectors, can cause increased solar gain when closed.

Salida Middle School, Vella Campus

Ken Kaestner, Architect.

Sidelighting
Daylight with a View – and complexity

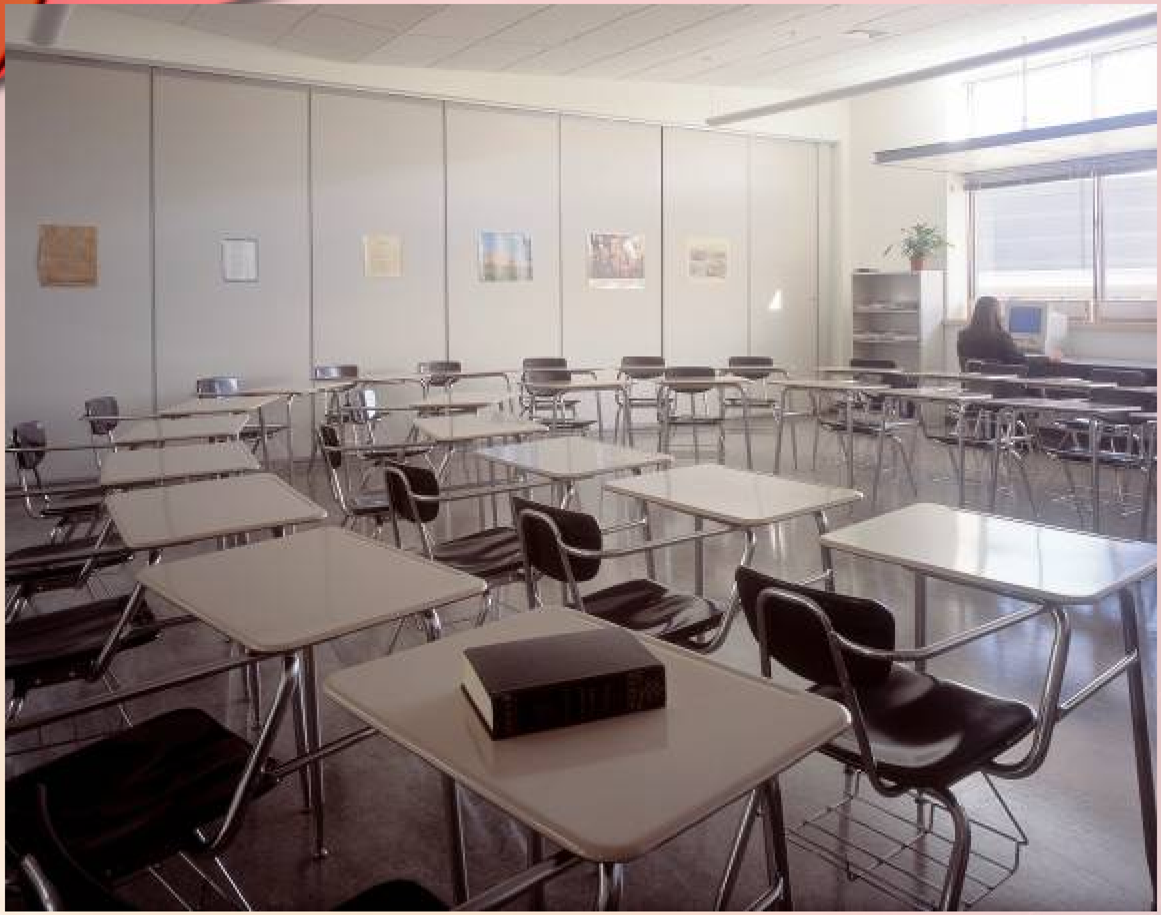
- Consider using windows and clerestories to provide daylight when toplighting is not practical.
- Solar orientation is critical. Windows must be shaded on the south, east and west faces. Light shelves with combination clerestory/view windows can be used on the south face. Window walls and high clerestory windows can be clear on the north face – on the east, south and west faces, diffusion and shading is needed.
- Two side lighting is much better than one side.
- Shaped ceilings can improve the performance of sidelighting.

Sidelighting is Hard

- During the cooling season, direct sunlight is absolutely unwanted
  - North exposure is fine
  - South exposure can be shaded
  - East and West exposures are vulnerable
- During the heating season, direct sunlight is conditionally unwanted
  - May be desirable for psychological benefit
  - May contribute to heating of building
  - Low solar angles will create glare and screen washout

The Three Lines of Defense Against Solar Gain

- External Shading (best)
  - Never let direct sunlight even hit the glass. Use shades and light shelves
  - Allows best daylighting
- Self shading (next)
  - Use windows that reflect and/or absorb solar energy, or windows with internal shading elements
  - Allows pretty good daylighting
- Interior Shading (least)
  - Last line of defense for solar gain
  - Probably the worst daylighting



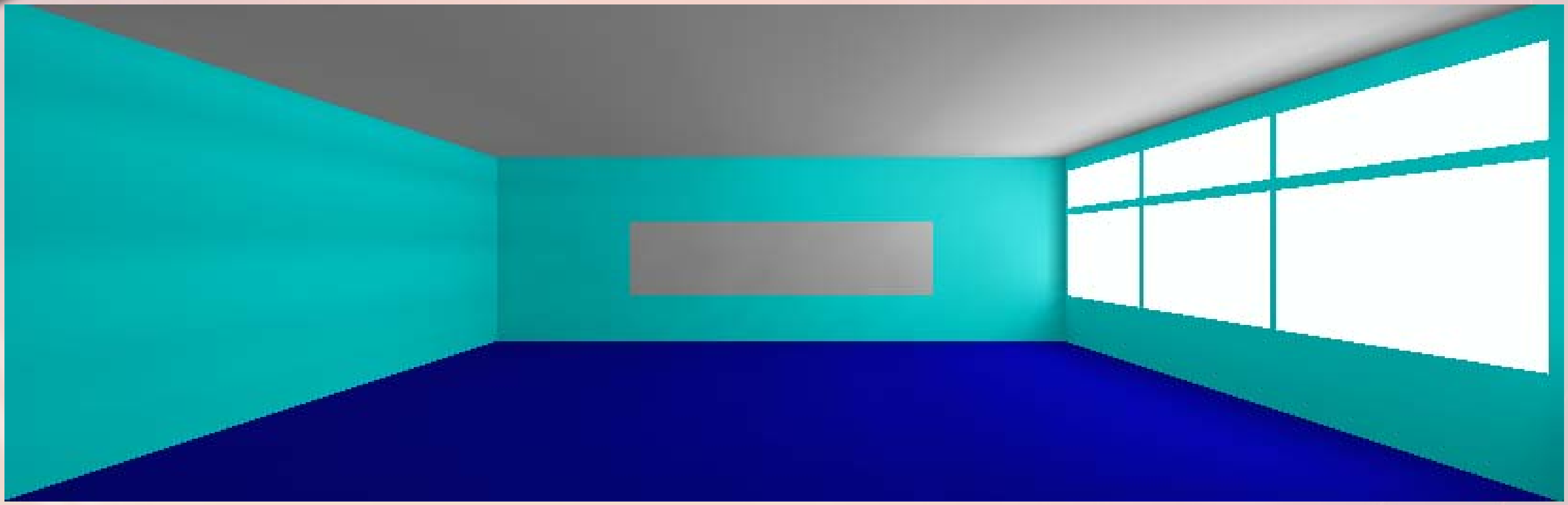
Carefully Integrated Sidelighting with Interior and Exterior Shelf and Angled Ceiling

North Clackamas High School

Light shelf plus eyelid shield for clerestory

SCE CTAC

The 3 Lines of Defense South Noon on Sept 21



- Light shelf and eyelid: 112 fc (46-361)
- High Performance Glazing 460 fc (81-2960)
- High Performance Glazing + Interior Shades (25% open) 118fc (21-730 fc)

Top Lighting + Side Lighting South Noon on Sept 21

- Side Light only: 112 fc (46-361)
- Top Light added: 172 fc (97-340)

North Sidelighting for the Library

North Clackamas High School

Related Daylighting Design Considerations

Structural Issues

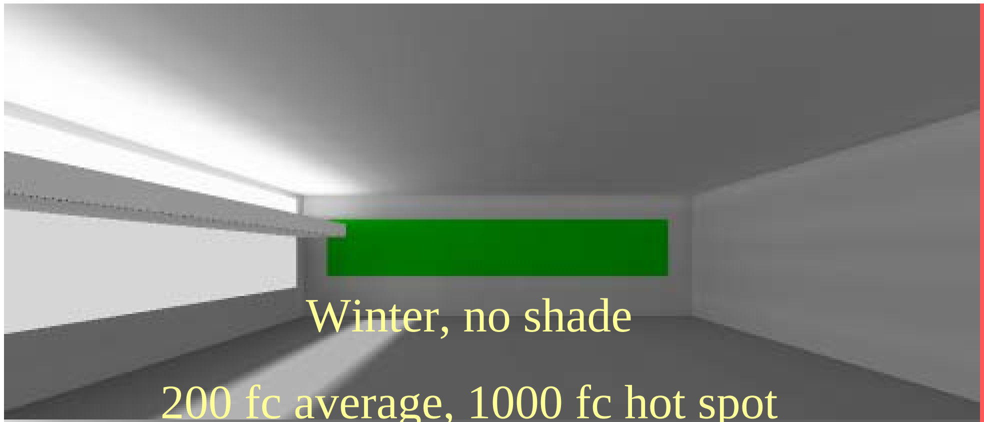
- Roof penetrations
- Additional reinforcing

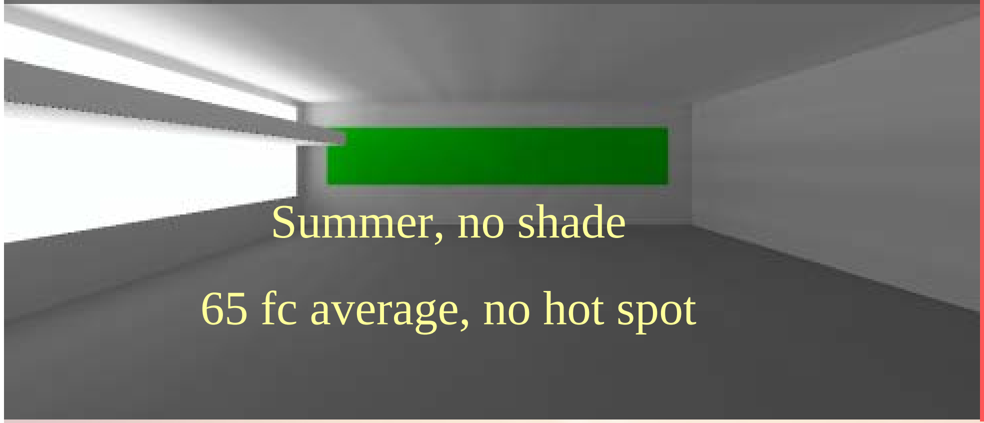
Classic Concerns

- Noise Control.
- Safety and Security.
- Air and Water Leakage.
- Condensation.
- Fire Protection.
- Visual Privacy.
- Maintenance and Replacement.

Modern Daylighting Analysis Using Models

- Daylight Factor Calculations
- Use of Scale Models
  - Best studied under both an artificial sky (diffuse light) and heliodon (direct solar radiation)
  - Can also be studied outdoors
- Benefits of Model Methods
  - Hands on three dimensional study
  - Daylight scales perfectly
  - May allow reconfiguration
  - Allows understanding of what works and why





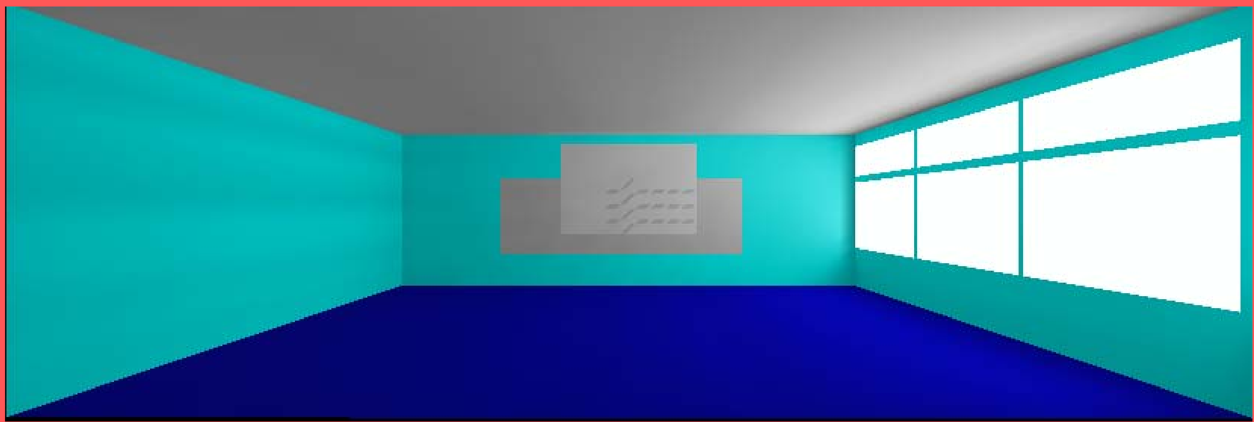
Modern Daylighting Analysis Using Radiosity

Modern lighting software permits daylighting analysis in lighting terms.

- Rapid 3-D modeling using simple primitive models
- Rapid calculation time allows analysis under many conditions
  - Time of day
  - Time of year
  - Weather condition
  - Different glazing conditions

Room Ambient for AV

- Vary the transmission of the (glass VLT * shading VLT) until acceptable results are obtained.
- Example: Sept 21, side lighting, 1% total transmission gives 1-2 fc on the screen.



End of Session

www.benyalighting.com