Daylighting design with climate

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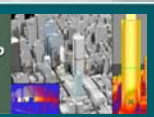
5th International
Radiance and HDR Scientific Workshop
13-14 September 2006
De Montfort University, Leicester, UK



ARUP

Summary

- Current daylighting design practice
- Limitations of the DF approach
- Climate based dynamic lighting simulation
- New daylighting metrics
- Radiance based dynamic daylighting software
- A design application: evaluation of the performance of different types of shading devices

Daylight

- Sun / direct
- Sky / diffuse

- Dynamic
  - Magnitude
  - Directionality
  - Spectrum / Colour
- High variability
  - Daily / Seasonal

- Climate to the eye

Climate, Daylight, Buildings







Climate, Daylight, Windows

Daylighting in buildings: design problems

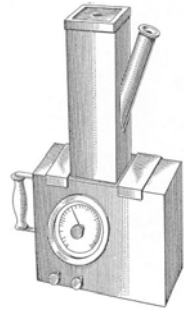
- Concept/development stage: shape of building
  - "Architecture is the masterly, correct, and magnificent play of masses brought together in light. Our eyes are made to see forms in light; light and shade reveal these forms." *Le Corbusier*
- Windows dimensioning / design / view out
- Shading and glazing design / thermal implications
- Maximisation of daylight / Energy and CO_2 emissions reduction
- Urban planning

Current daylighting design practice

- Separate evaluation of:

Climate ?

A short history of daylighting



- 1832: Right to light (UK Prescription Act)
- ~1900: Trotter lux meter.....
- 1907 ... : Waldram: (sky/**daylight factor**, uniform sky, 0.2% *grumble point*)
- 1929 ... : Commission Internationale de l'Eclairage
- 1942: Moon & Spencer overcast sky, in 1955 *CIE overcast sky*
- 1962: Dresler: “Availability of daylight at various latitudes”
- 1970: Publication CIE 16-1970: Daylight

DF

- 1983: Tregenza: Daylight coefficients
- 1990 ... : Ward: ***Radiance***
- 1999: Mardaljevic: (*Radiance* daylight validation, DCs, ...)
- 2003: CIE Standard General Sky

- AND NOW?

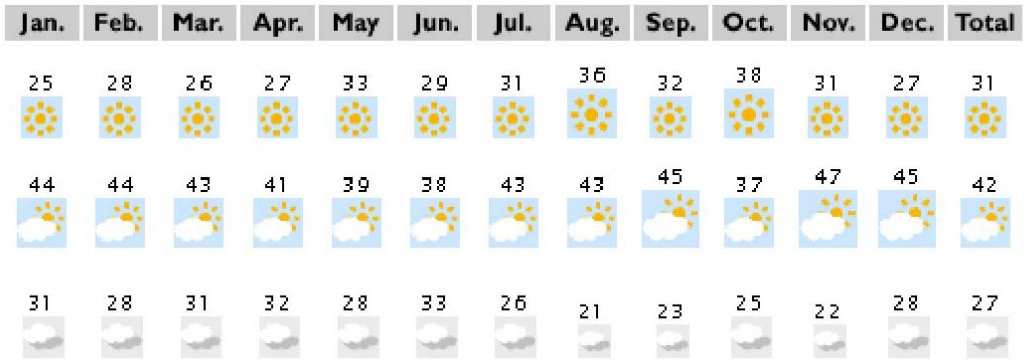
Thermal modelling
Climate based, dynamic thermal analysis and CFD
already used since early 1980s

The Daylight Factor approach

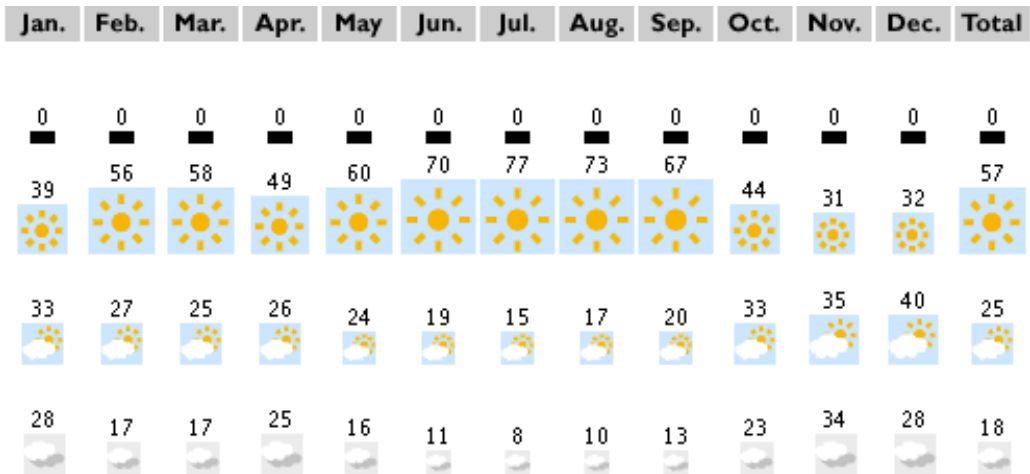
- The DF is the standard recognised daylighting metric in any place in the World where there is an interest in daylighting.
- Reasons for the success of the DF approach:
  - If the natural lighting is sufficient on an overcast day, it is likely to be more than adequate when the sun is shining.
  - But ... a daylight factor optimised building admits as much light as possible, therefore the ideally daylit building would be fully glazed! This is clearly in contrast with comfort requirements.
  - A densely overcast sky looks the same whichever direction one faces - North, South, East or West. Therefore the effect of the orientation vanishes from the calculation.
  - But ... the simplification introduced with the use of the daylight factor does not account for building location and orientation, season, time of day, direct solar penetration, variability of sky conditions. It is not possible to predict glare.

Luminous Climate

- London, UK



- Rimini, Italy

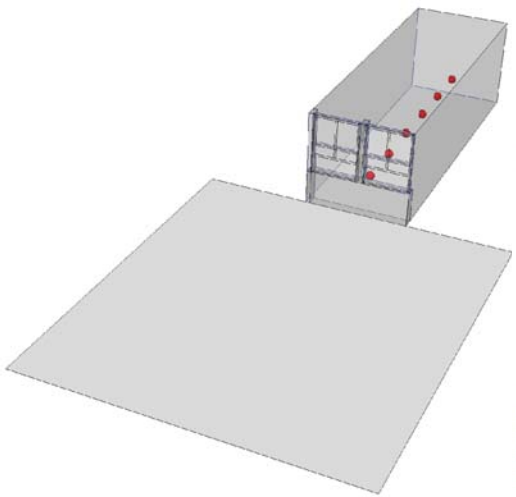


Bad daylighting design with DFs

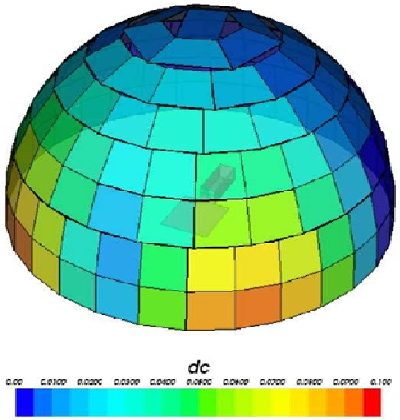
Climate based dynamic lighting simulation

- Input: 1) weather data, 2) 3D model, 3) sensor points
- Pre-process: calculation of daylight coefficients to save time. If dynamic daylighting systems are used, such as movable blinds, sun tracking systems, electrochromic glazing, etc., different sets of daylight coefficients need to be calculated.
- Simulation: coupling of daylight coefficients with climate data over the chosen time basis and occupancy profile. For dynamic systems, a control algorithm triggers the use of the different set of daylight coefficients.
- Results: time series of illuminance and/or luminance (annual, seasonal, daily, etc ...)
- Post-process: time series can be plotted, and other indicators can be calculated (daylight autonomy, continuous daylight autonomy, useful daylight illuminance, annual light exposure).

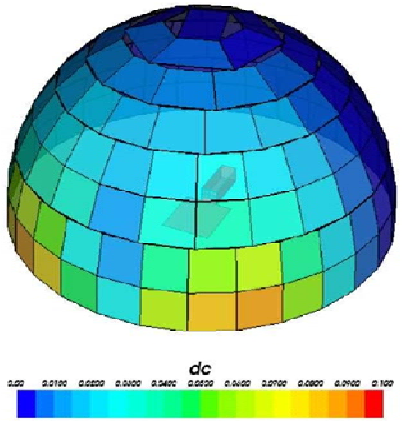
Daylight Coefficients



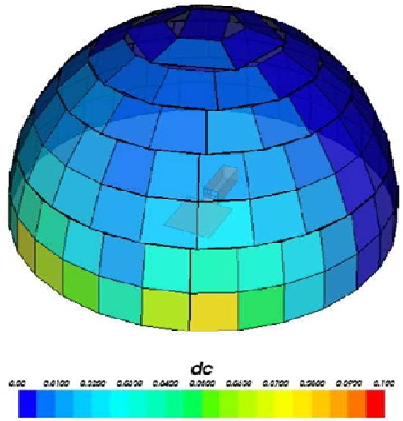
measurement point n. 1



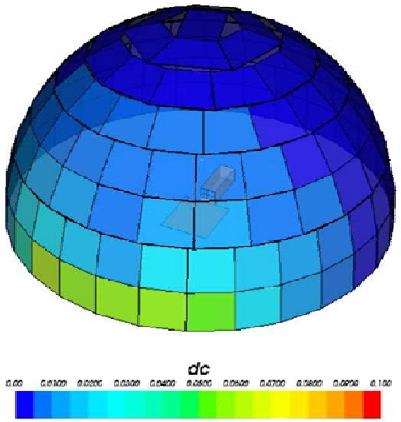
measurement point n. 2



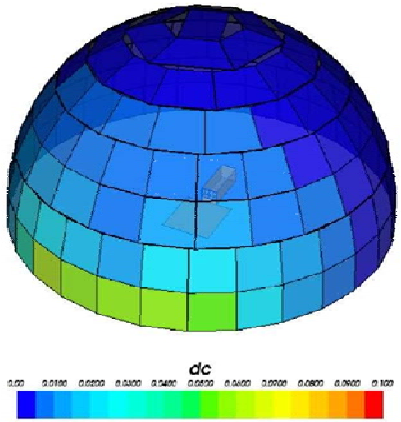
measurement point n. 3



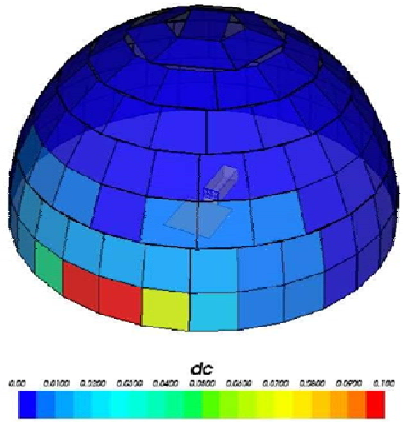
measurement point n. 4



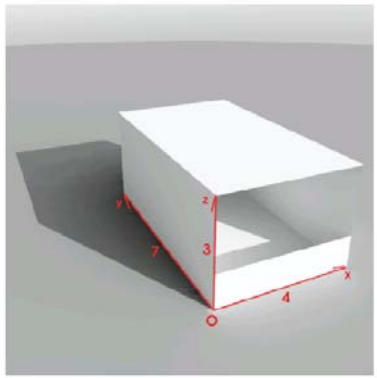
measurement point n. 5

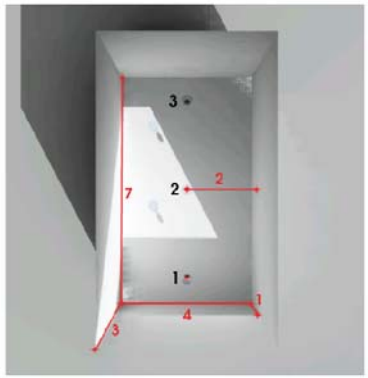


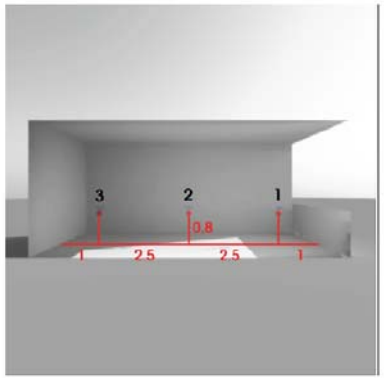
measurement point n. 6

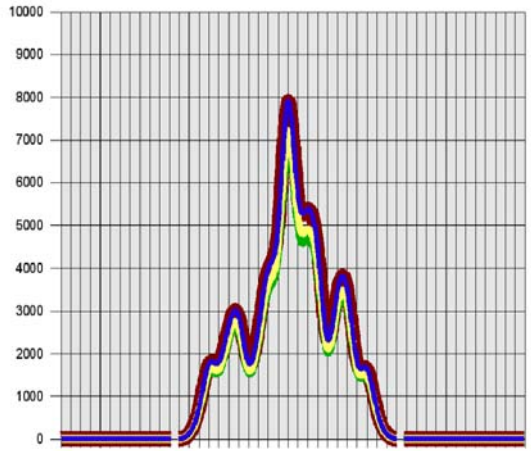


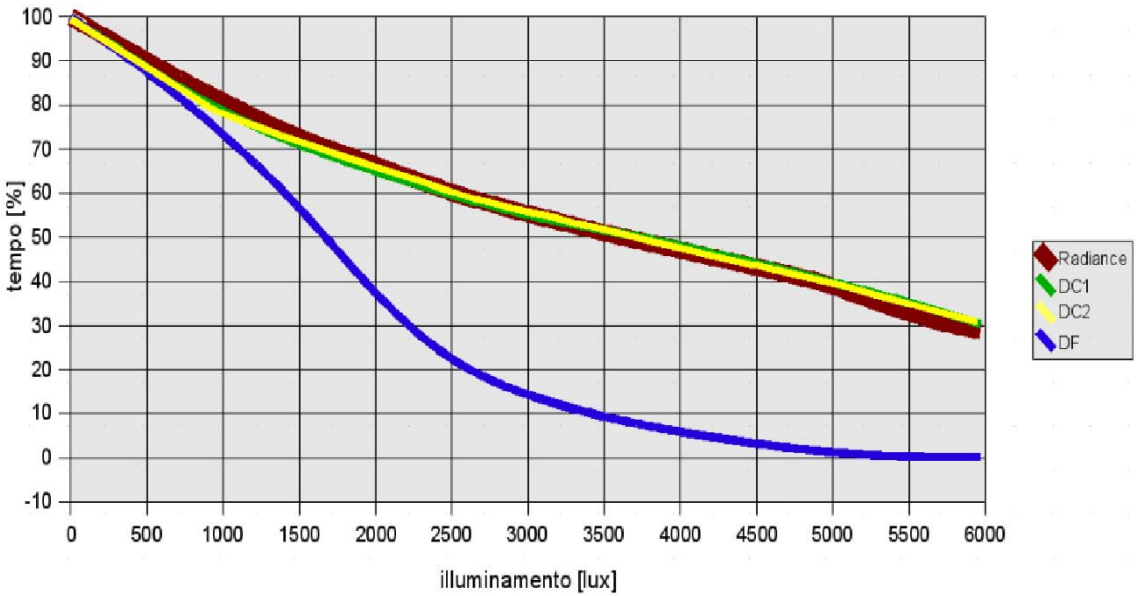
Daylight Coefficients: accuracy

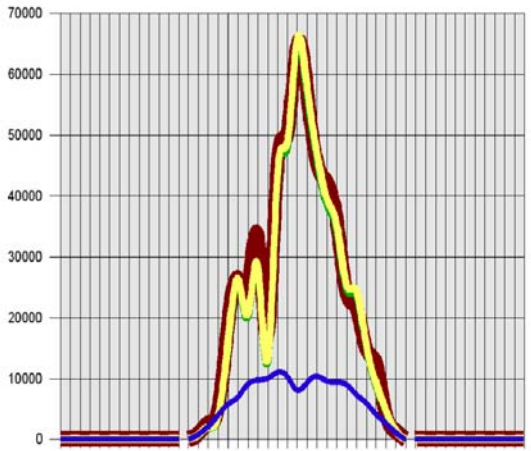








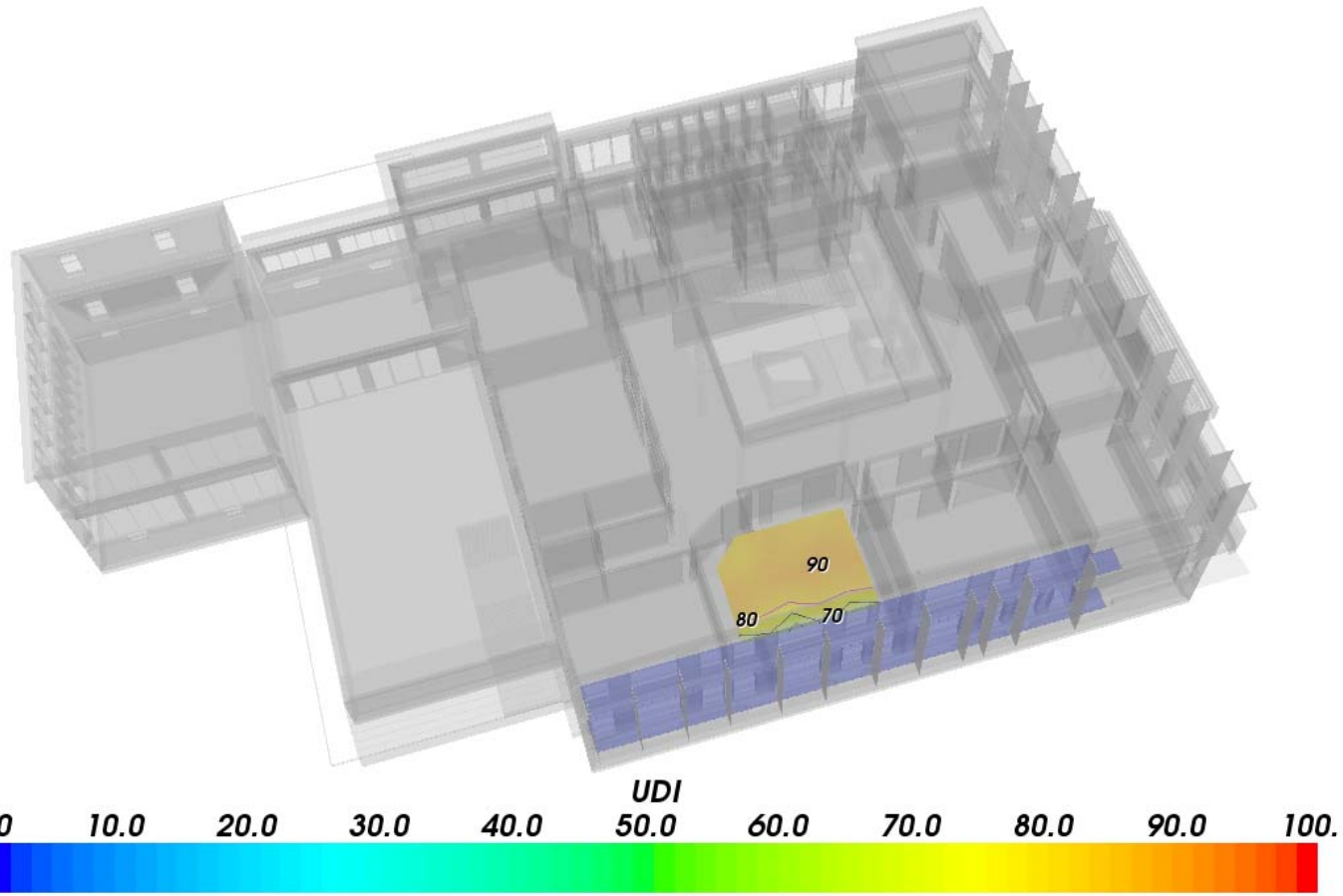




New daylighting metrics, based on annual work-plane illuminance series

- **Daylight Autonomy**: percentage of year when a minimum illuminance threshold is met by daylight alone.
- **Continuous Daylight Autonomy**: same as above, but partial credit is attributed to time steps when the daylight illuminance is below the minimum illuminance level (Z. Rogers).
- **Useful Daylight Illuminance**: occurrence of annual illuminances across the work plane that are within a range considered “useful” by occupants – this range has been based on a survey of reports of occupance preferences and is currently 100-2000 lux (J. Mardaljevic).
- **Annual Light Exposure**: cumulative amount of visible light incident on a point of interest over a year – used for museum environment containing light sensitive exhibits.

Useful Daylight Illuminance



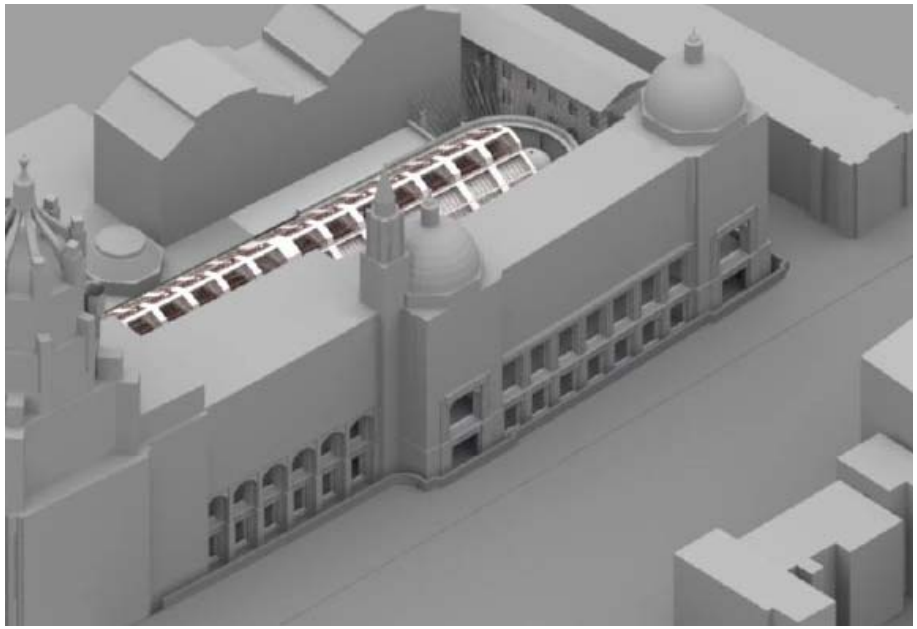
Radiance based dynamic daylighting simulation software

- **ESP-r** (Energy Systems Research Unit at the University of Strathclyde)
  - “all-in-one” building simulation software
- **Adeline (IEA Task 21)**
  - commercial software
  - doesn't use the DC approach, but the Szerman's statistical sky
- **eXtensible DAylight Prediction System (XDAPS)** (John Mardaljevic)
  - not publicly available
  - toolkit of data analysis/visualisation procedures written in the IDL programming language and the UNIX C-shell
- **DAYSIM + Lightswitch Wizard** (Christoph Reinhart, Oliver Walkenhorst)
  - patched Radiance source code and additional command line programs
  - new Java user interface
- **DLS** (Paul Cropper)
  - Java user interface
- New *dynamic lighting simulation* support in **`radmap`** (Francesco Anselmo)

Climate based daylighting design application

- Museum environment

  (V&A Museum – new Medieval & Renaissance Galleries)
- Windows design: different shading systems
- Performance indicator: light exposure

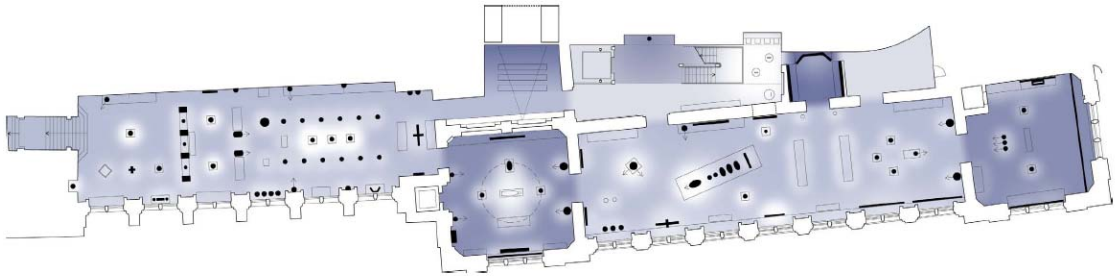


Design credits:

Architect:
MUMA
(McInnes Usher
McKnight Architects)

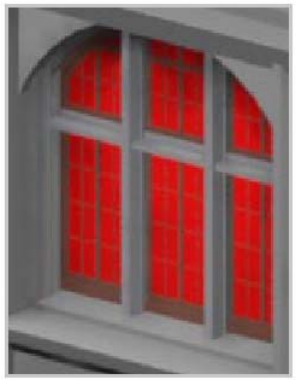
Daylighting consultant:
Arup
Andy Sedgwick
Steve Walker
Francesco Anselmo

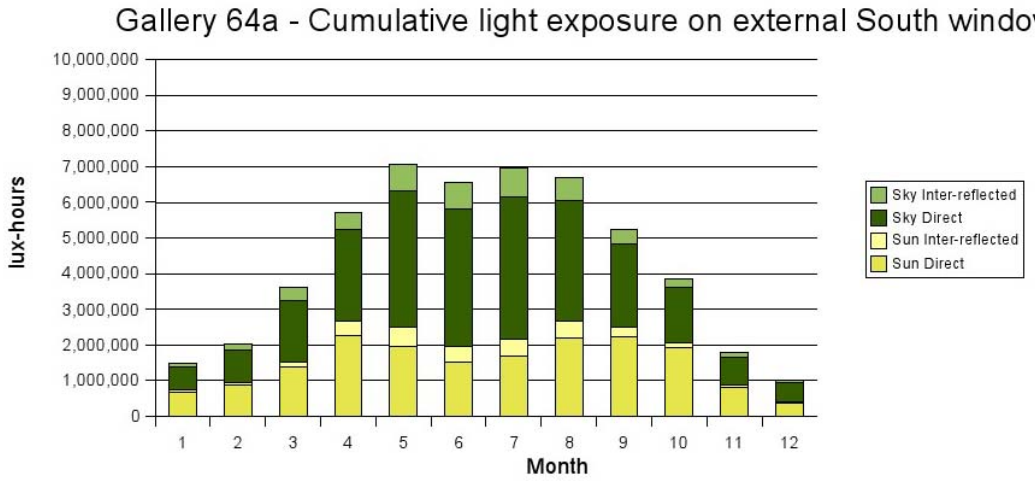
Architect's intentions

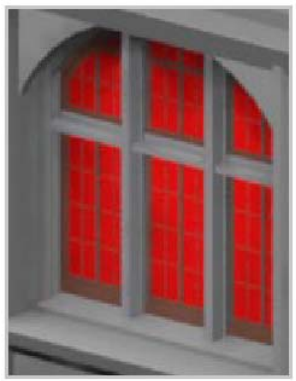


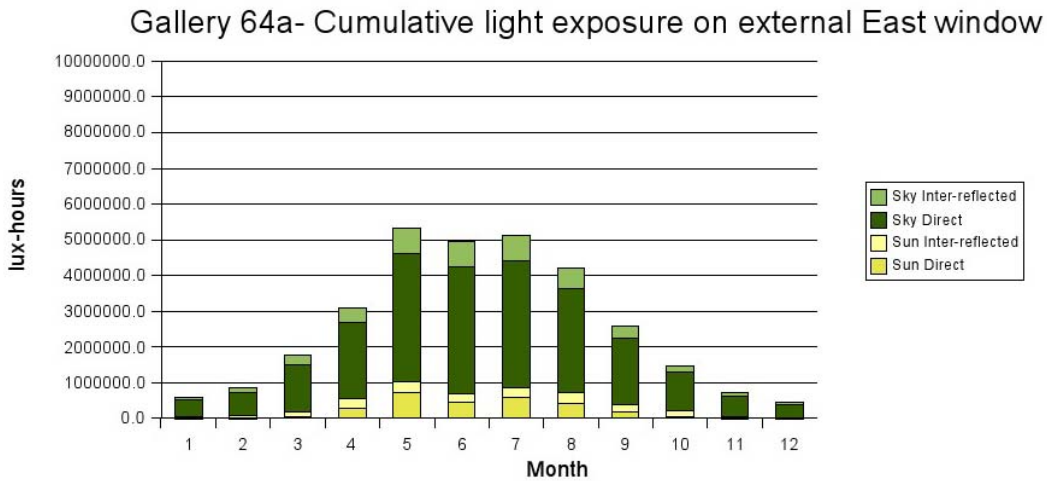
- Let daylight in
- Modulate daylight through translucent materials (alabaster, paper)

Lighting exposure on windows

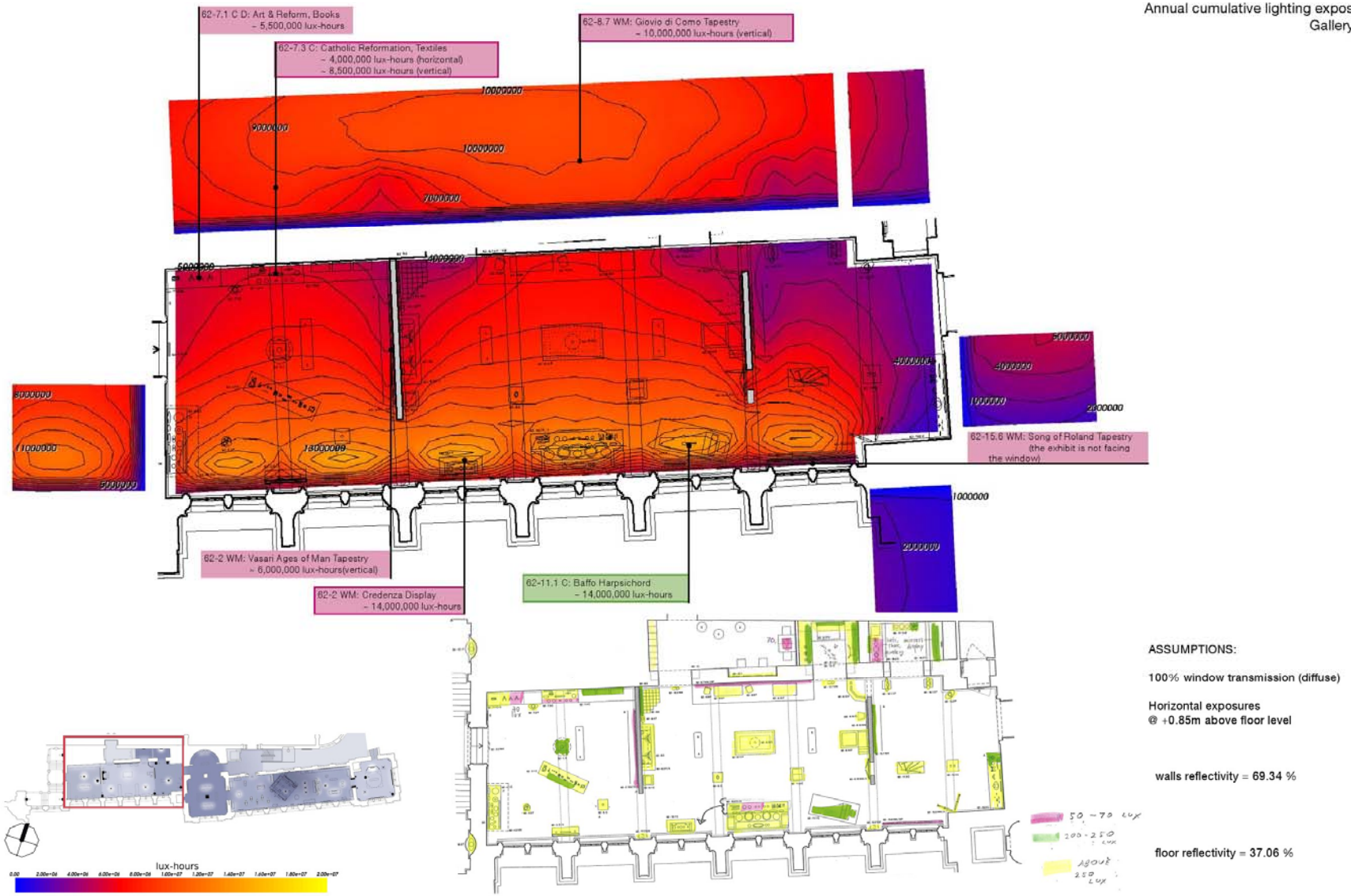






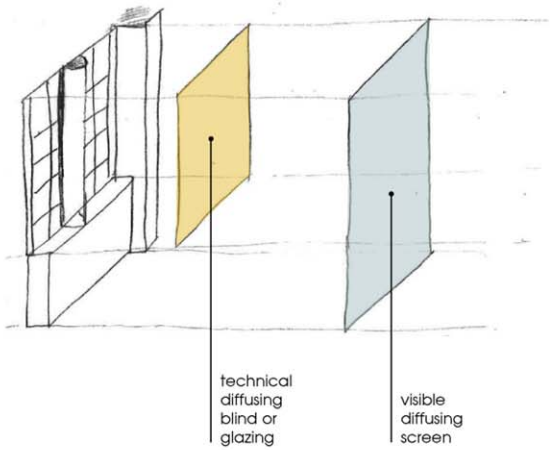


Annual lighting exposure: 100% diffuse transmission

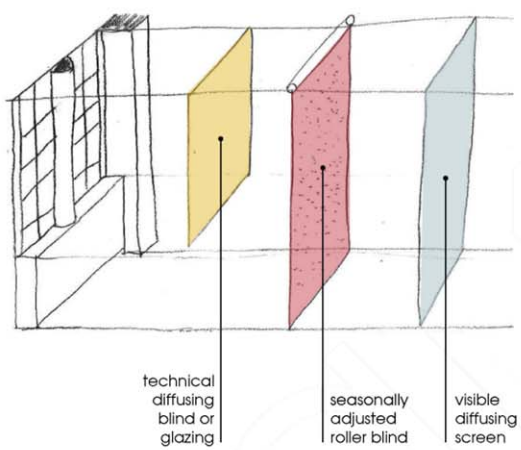


Windows options

Option 1: Static Diffusing Fabric Blinds

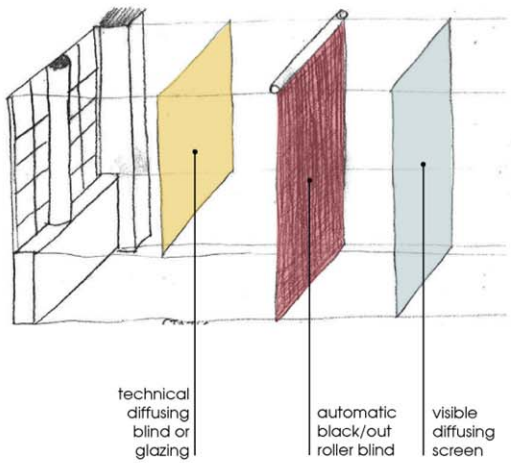


Option 2: Seasonally Adjusted Blinds, Manual Control

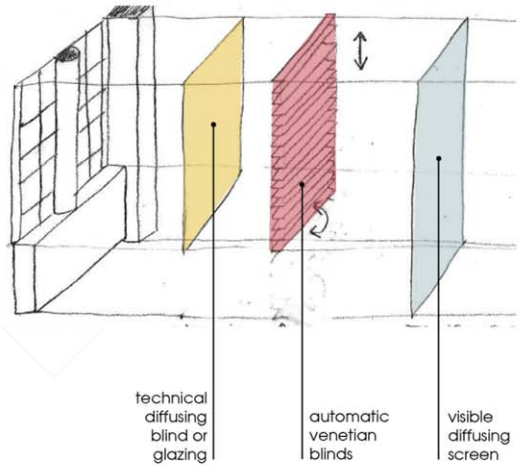


Light level control - three lux level control that allows the slats to adjust to maintain light levels within a selected band width.

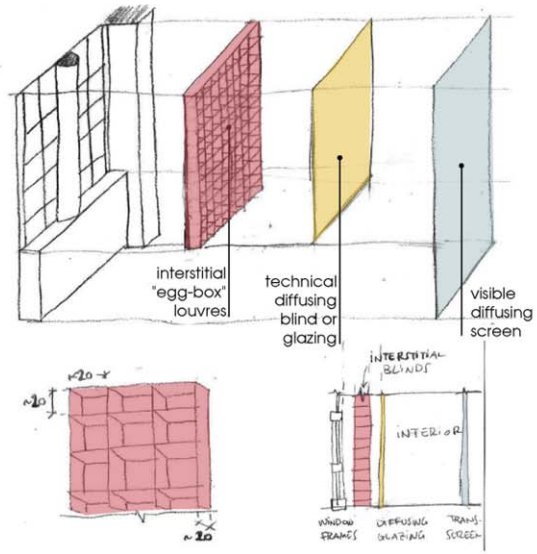
Option 3: Automatic Open/Close Roller Blinds (9-18)



Option 4: Automatic Venetian Blinds



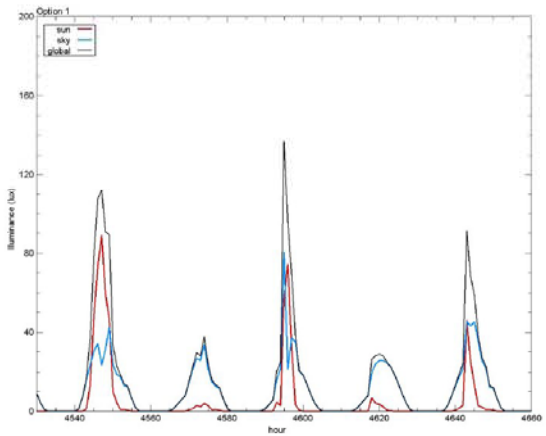
Option 5: Fixed Interstitial Louvres (1 to 1 Ratio)



Annual illuminance profiles on most sensitive exhibit

Summer Instantaneous Daily Illuminance Profiles
Gallery 8, Most Sensitive Exhibit

Option 1: Static Diffusing Fabric Blinds



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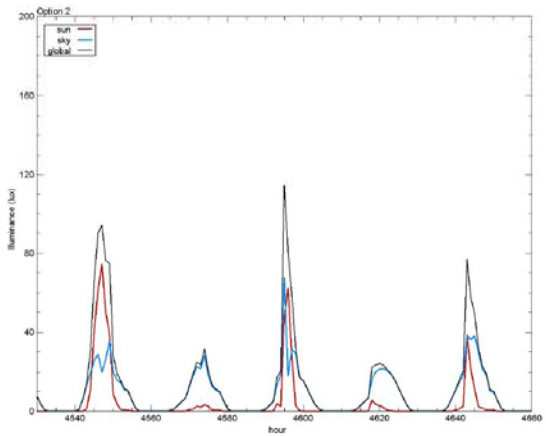

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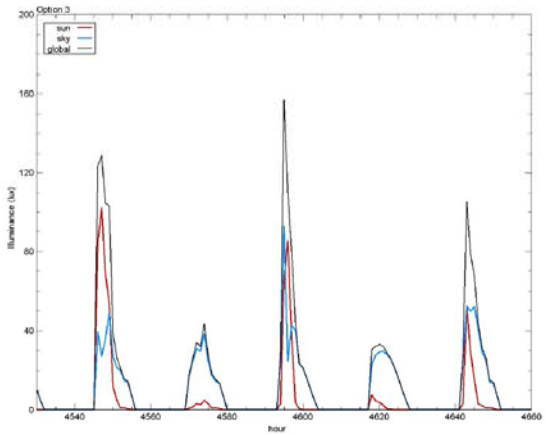

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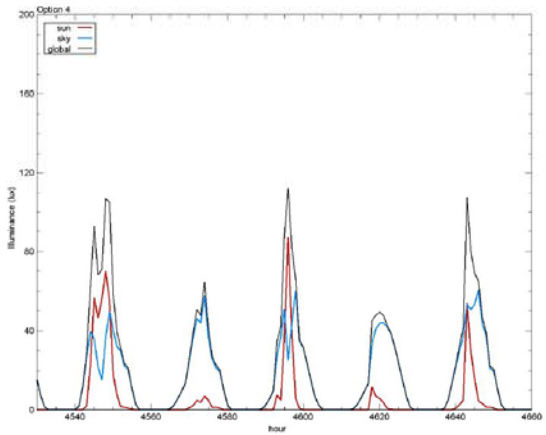

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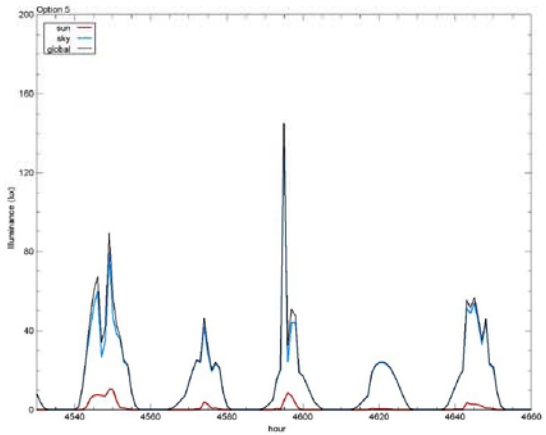
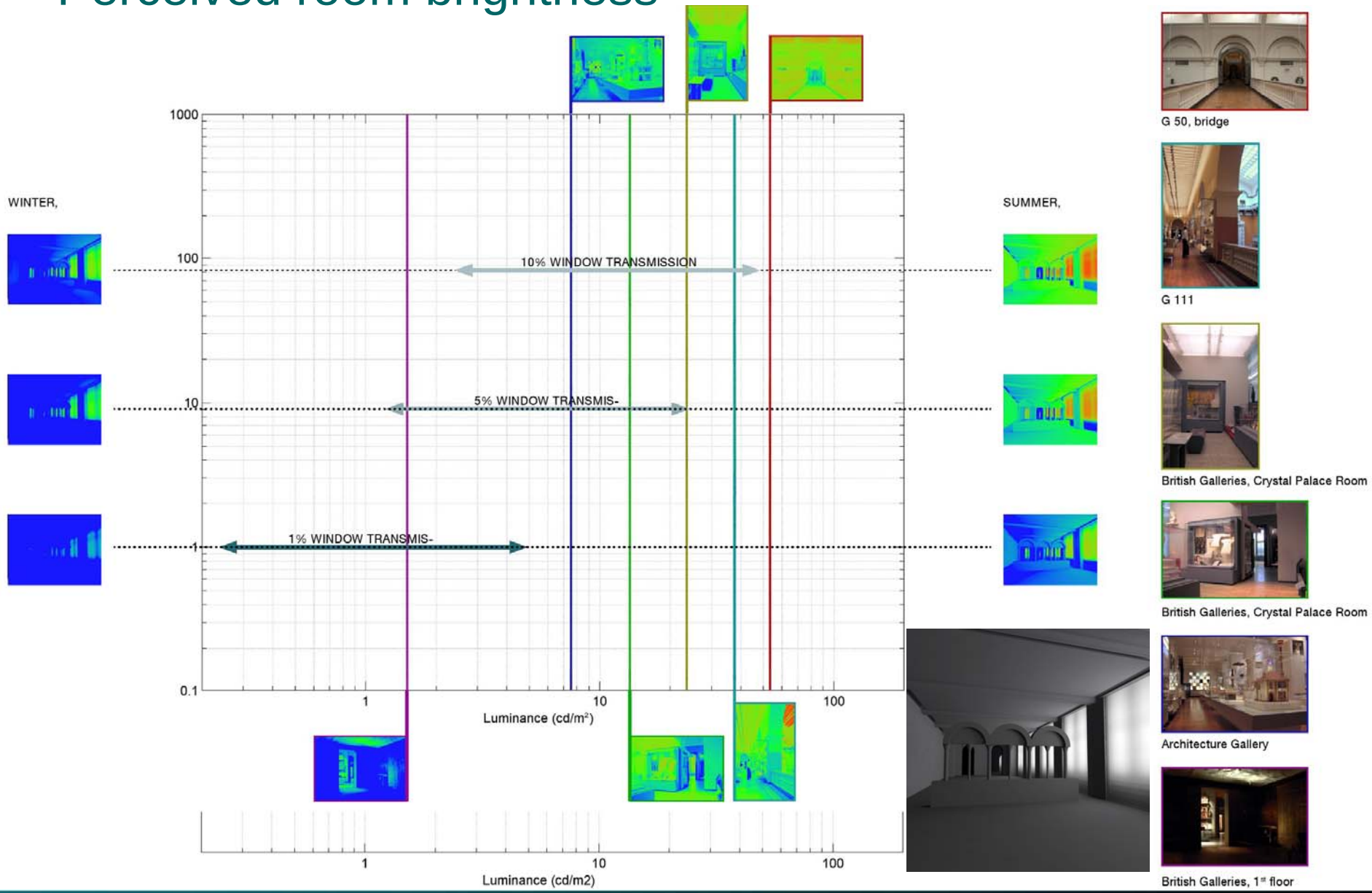


Perceived room brightness



G 50, bridge

G 111

British Galleries, Crystal Palace Room

British Galleries, Crystal Palace Room

Architecture Gallery

British Galleries, 1st floor

Thanks for your attention!