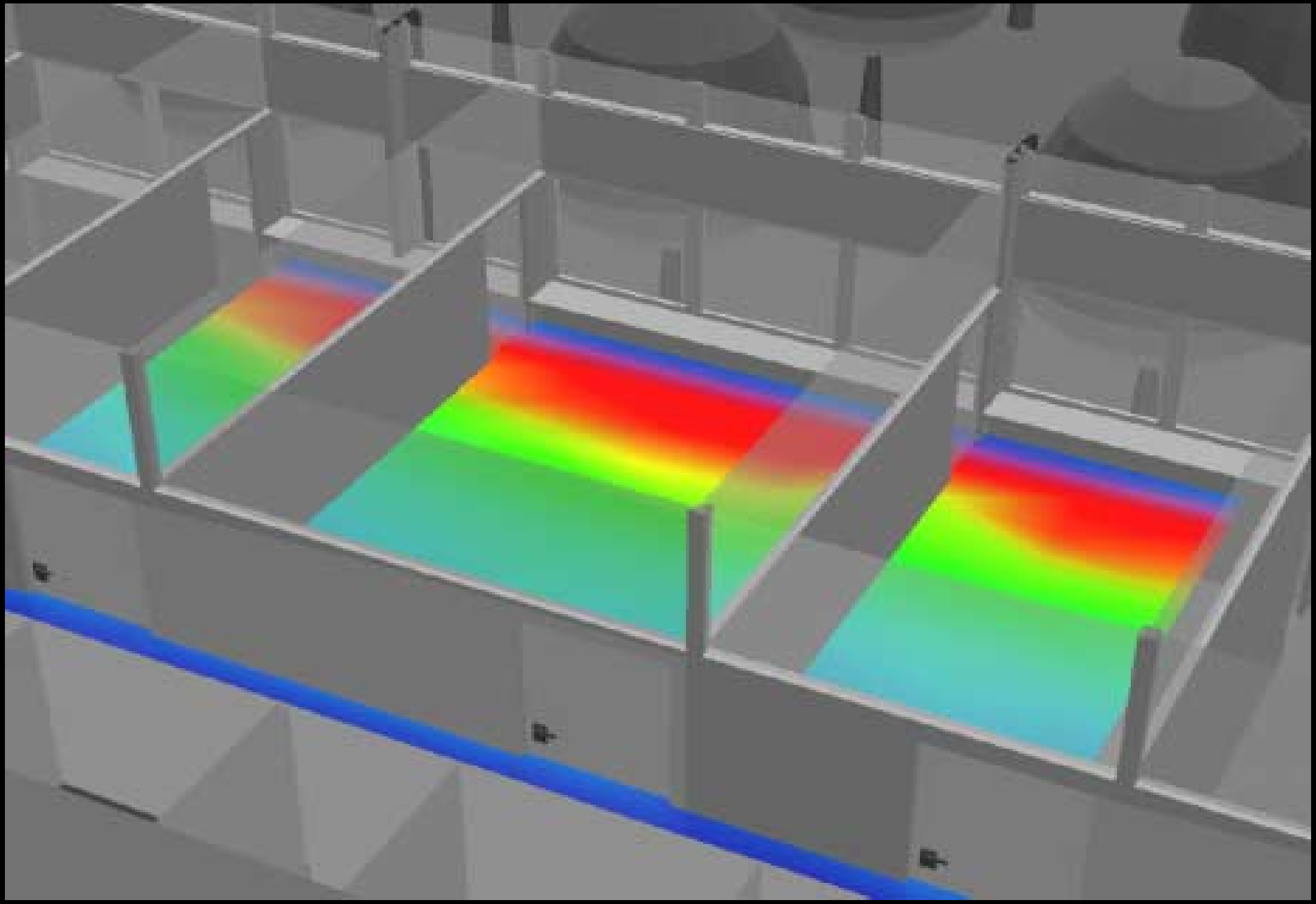
A File Format for Dynamic Daylight Simulations



Dr. Christoph Reinhart – Aug 11 2005

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Objective

- ❑ promote the use of dynamic daylight performance metrics for sustainable building design
- ❑ promote common format for inter-program data exchange (e.g. for integrated thermal/lighting simulations)

Content

- ❑ provide an overview of dynamic daylight simulations
- ❑ propose a Daylight Coefficient Format (individual sensors)
- ❑ propose a Dynamic Daylight Simulation Format (building level)

Details are presented in the accompanying paper.

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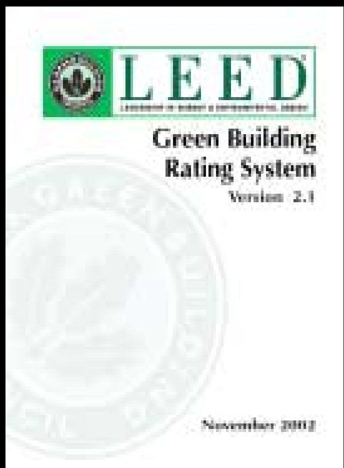
Context I



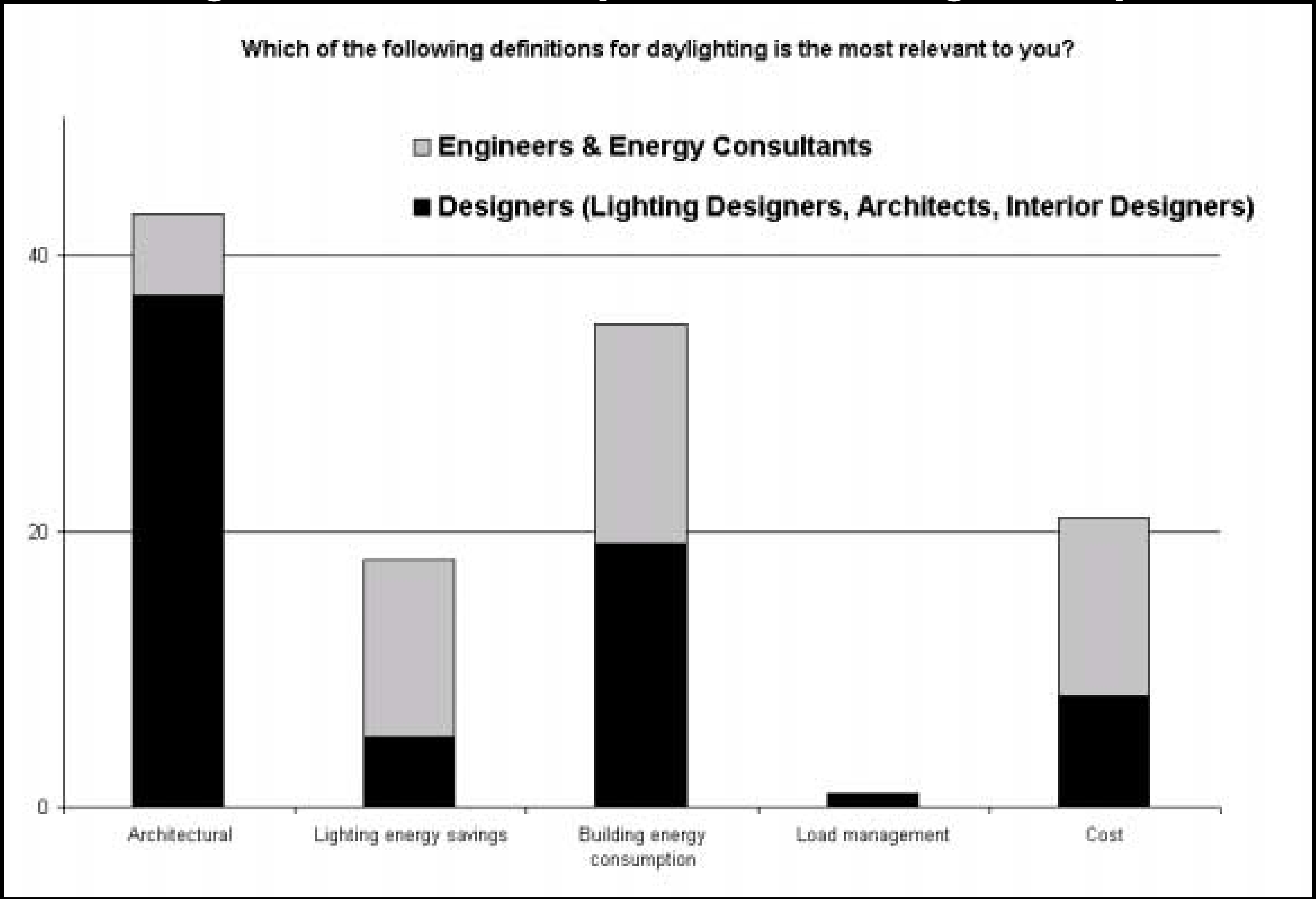
LEED and Green Globe provide daylight credits for:

- **daylight factor**
- **view to the outside**
- **specification of shading devices (Green Globe only)**

Compliance is verified via spreadsheet method.

Context II- What is Daylighting?

173 Design Practitioners (over 80% using LEED) choose



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Context III- What is Daylighting?

**	*Architectural definition:* the interplay of natural light and building form to provide a visually stimulating, healthful, and productive interior environment
	Lighting Energy Savings definition: the replacement of indoor electric illumination needs by daylight, resulting in reduced annual energy consumption for lighting
*	*Building Energy Consumption definition:* the use of fenestration systems and responsive electric lighting controls to reduce overall building energy requirements (heating, cooling, lighting)
	Load Management definition: dynamic control of fenestration and lighting to manage and control building peak electric demand and load shape
	Cost definition: the use of daylighting strategies to minimize operating costs and maximize output, sales, or productivity

Do daylight factor & view LEED to good daylighting?

What about:

- local climate data (Vancouver vs. Regina)
- building use (occupancy patterns, lighting requirements)
- movable shading devices (venetian blinds)

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Dynamic Daylight Simulations (DDS)

- As opposed to static DL simulations that only consider one sky condition at a time, dynamic daylight simulations generate annual time series of interior illuminances and/or luminances.

- Radiance combined with daylight coefficients and Perez sky model can efficiently and reliable calculate DDS. (validated approach – several independent studies – resulting accuracy ~20% rel. error – comparable to static simulations)

Relevant literature cited in paper.

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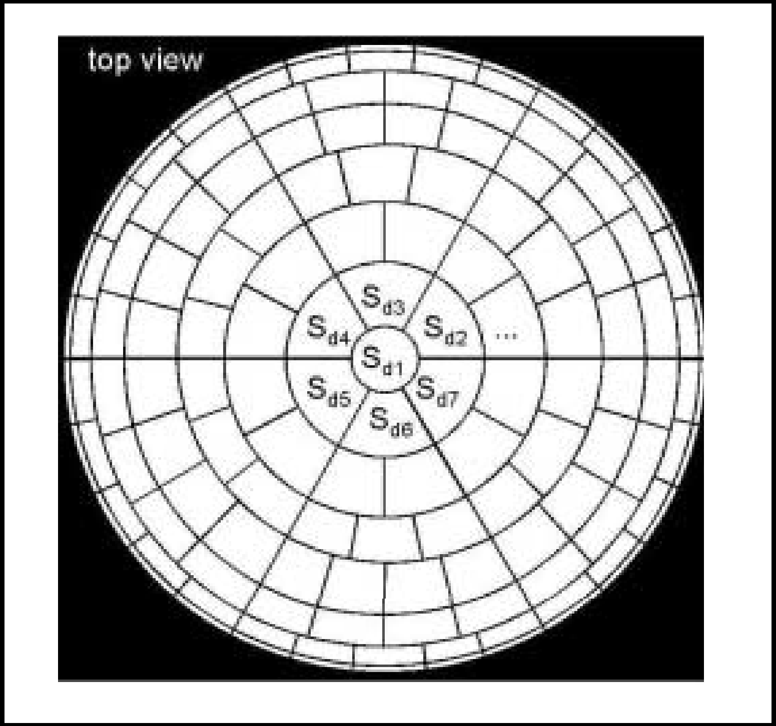
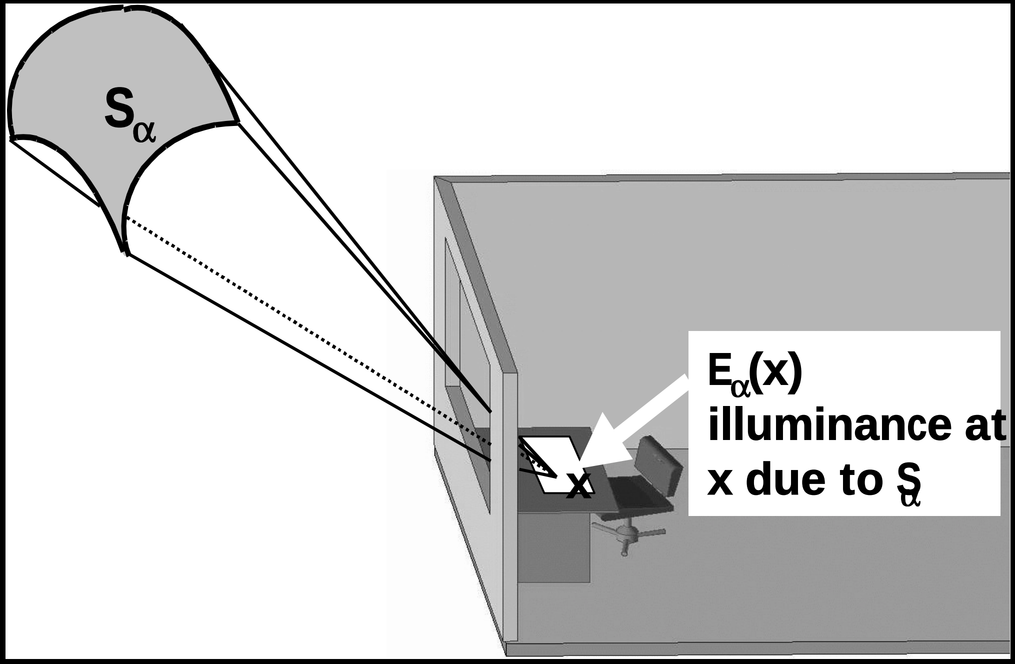
Daylight Coefficients

(1) Division of the Celestial Hemisphere



(2)Calculate Daylight Coefficients



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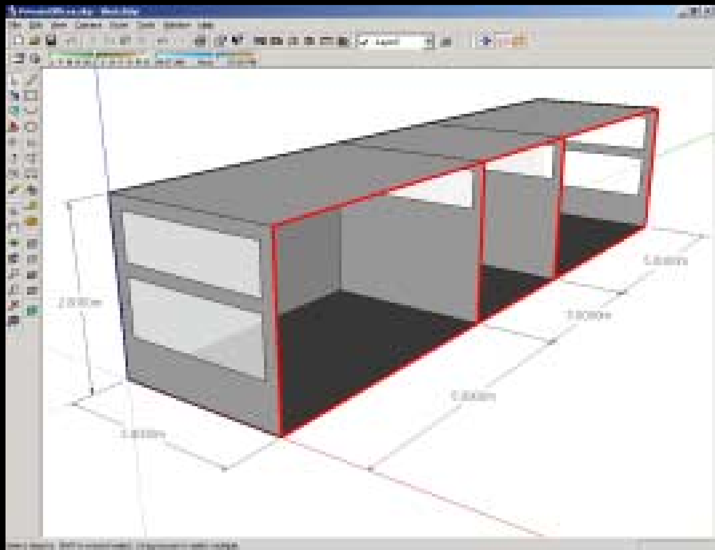
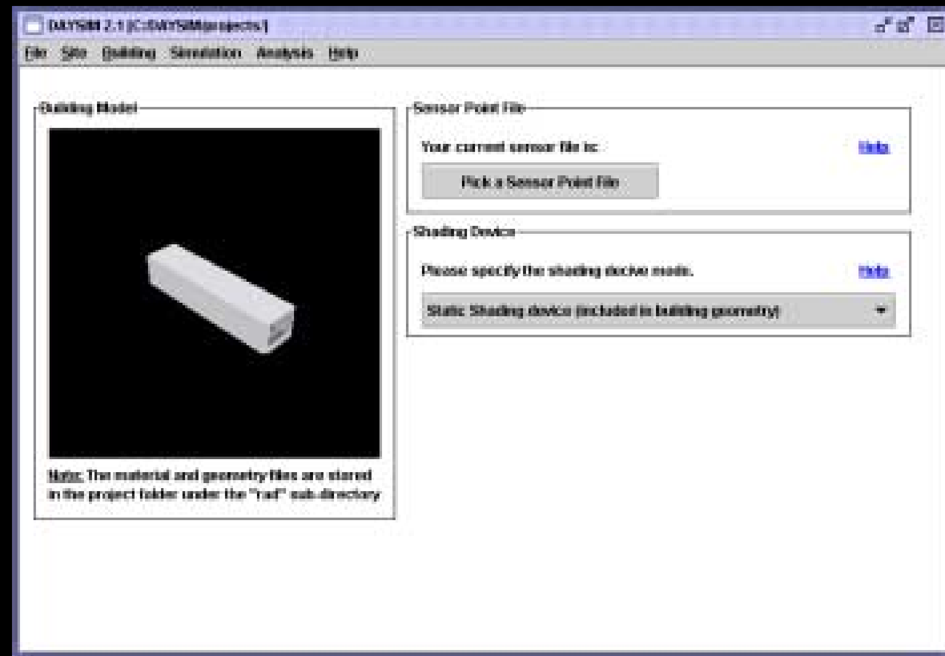
Required Work Flow

SketchUp/ AutoCAD/ Ecotect/ …

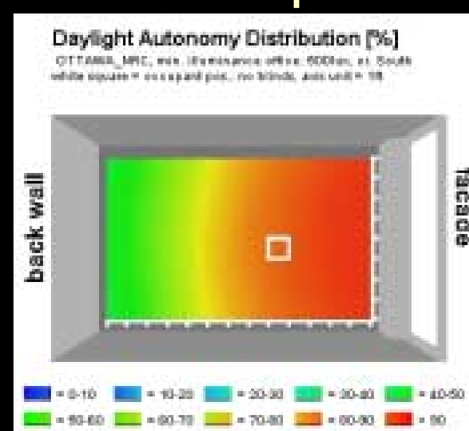


Daysim Analysis

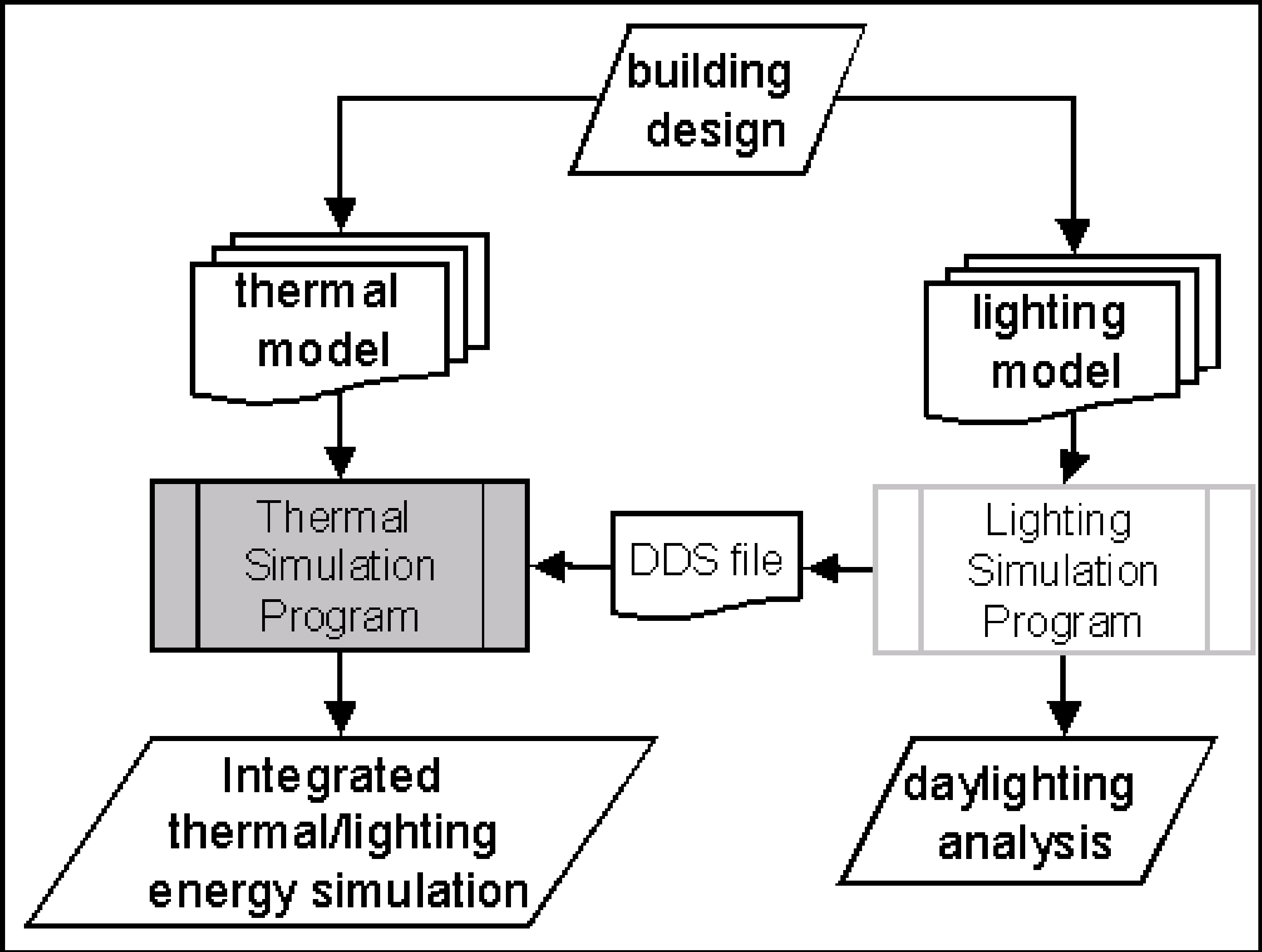


Daysim Simulation Report

falsecolor maps



Dynamic Daylight Simulation (DDS) File format



Elements of a DDS file

DDS file

```
<?xml version="1.0" encoding="UTF-8"?>
<scene>
   <description>string</description>
   <radsettings>-ab 0 -ad 1500 ...</radsettings>
   <radscene>
        <textfile>file type (*.rad)</textfile>
   </radscene>
</scene>

<sensors>
   <textfile>file type (*.pts)</textfile>
</sensors>

<daylightcoefficients>
   <textfile>file type (*.dc)</textfile>
</daylightcoefficients>
```

PTS file

Type | thermal-zone | light zone | x | y | z | or_x | or_x | or_x
Ill office1 near_window 0 2 0.85 0 0 1
…

DC file

DC_1 DC_2… DC_{291}
…

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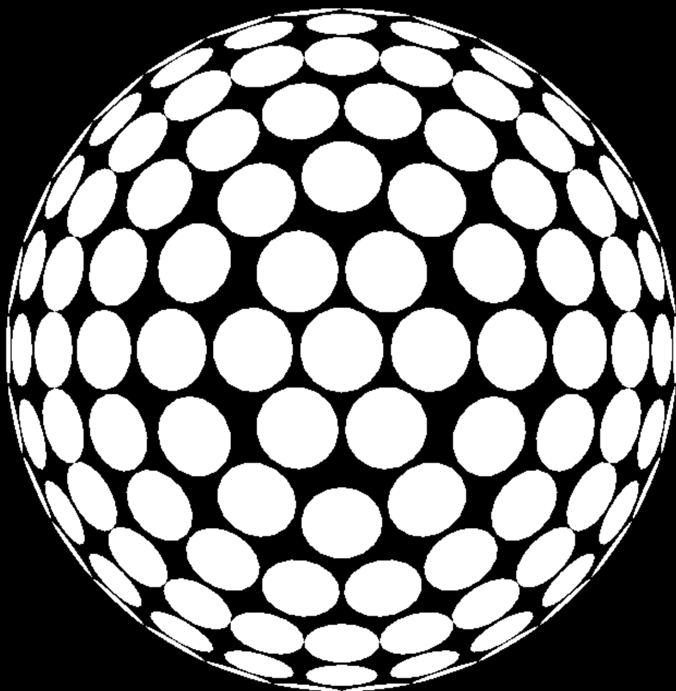
Daylight Coefficient File Format

- three types of daylight coefficients:
  - diffuse (145)
  - ground (1)
  - direct (145)

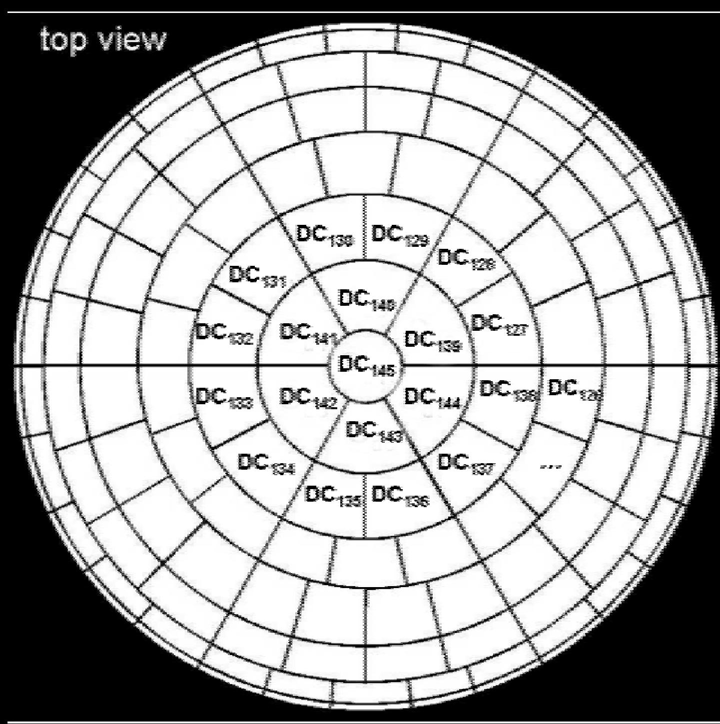
$$E(x) = \underbrace{\sum_{\alpha=1}^{145} DC_{\alpha}^{diffuse}(x) L_{\alpha}^{diffuse} \Delta S_{\alpha}^{diffuse}}_{\text{diffuse daylight}} + \underbrace{DC^{ground}(x) L^{ground} \Delta S^{ground}}_{\text{ground reflection}} + \underbrace{\sum_{\alpha=1}^{145} DC_{\alpha}^{direct}(x) L_{\alpha}^{direct} \Delta S_{\alpha}^{direct}}_{\text{direct sunlight}}$$

Diffuse & Ground Daylight Coefficients

Tregenza division

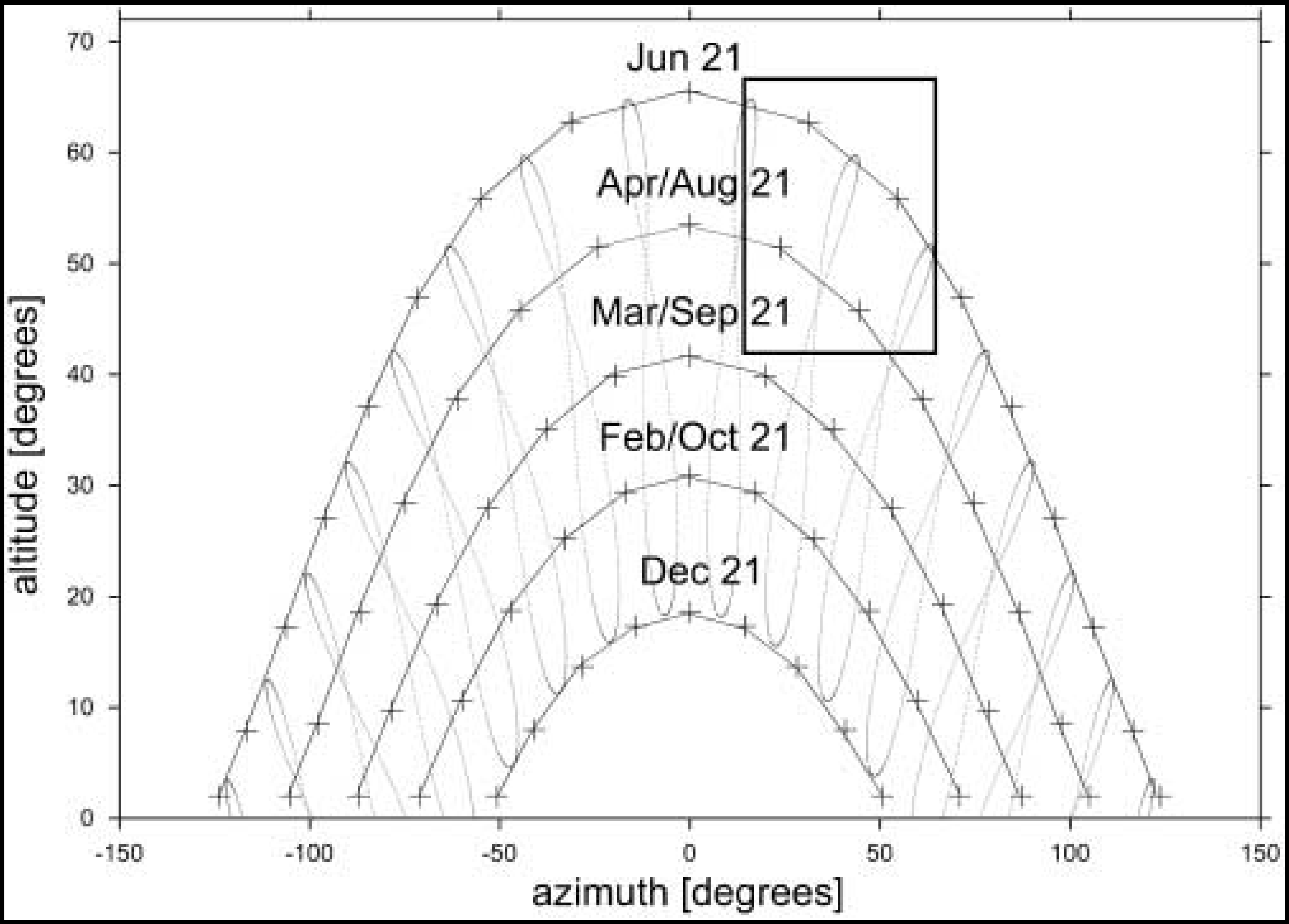


continuous division



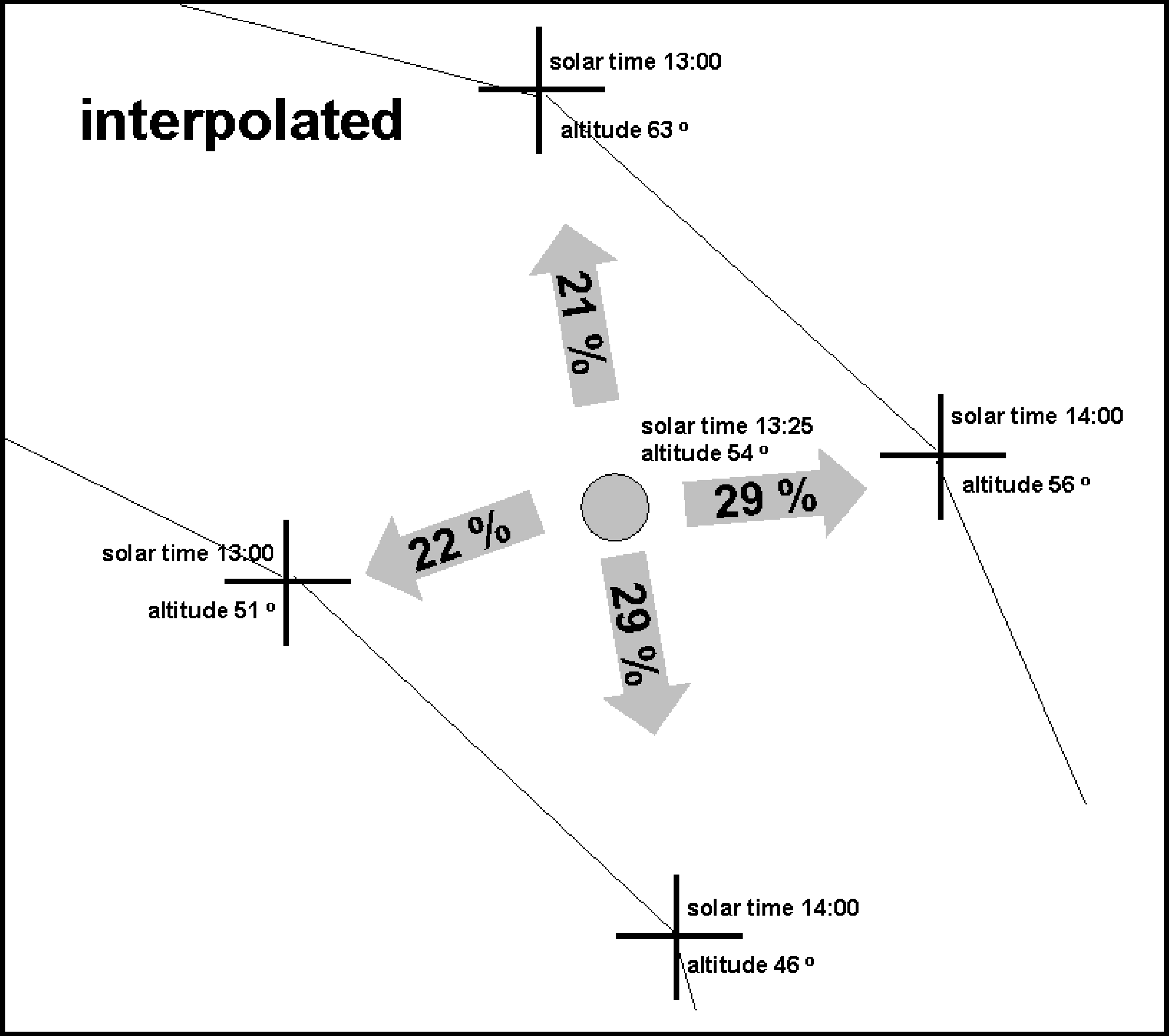
Direct Daylight Coefficients

Daysim division (along solar swath)



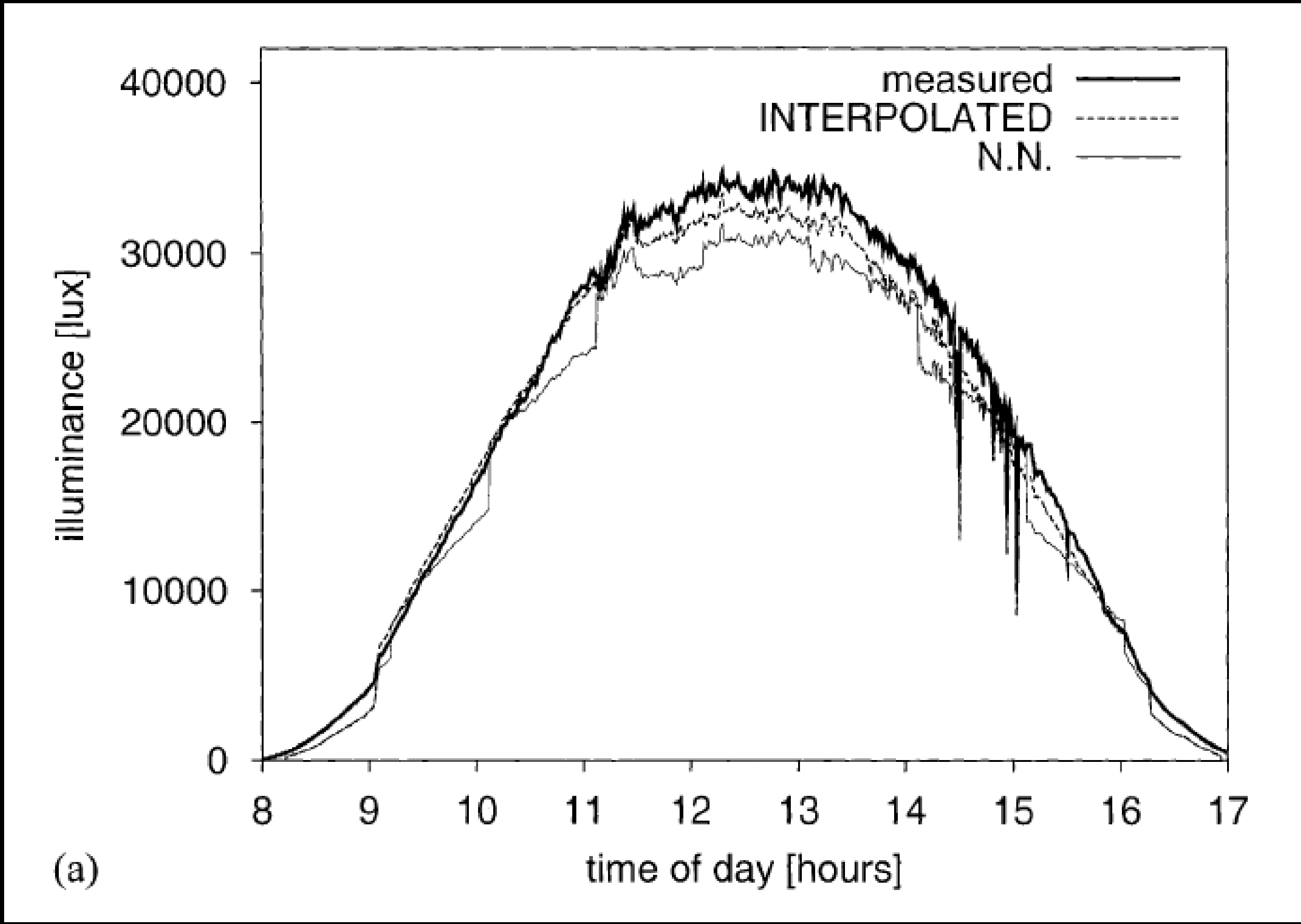
Direct Daylight Coefficients

Interpolated mode



Direct Daylight Coefficients

Interpolated mode



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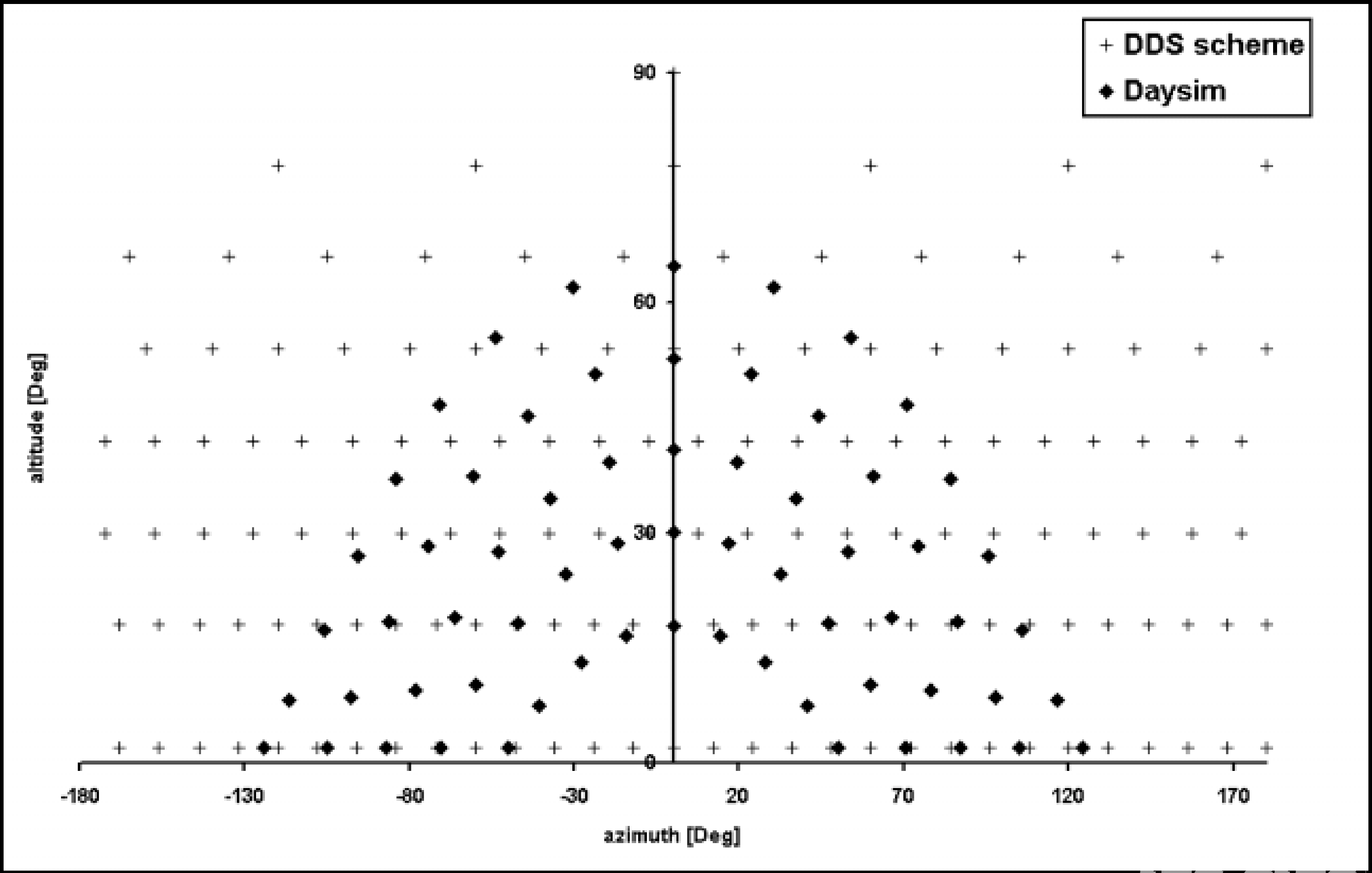
New Direct Daylight Coefficient Division

DDS division



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Pros and Cons

(-) longer simulation times

(+) proposed format is independent of building site and orientation
(+) simple matrix rotation if the building scene is turned
(+) number of coefficients always the same
(+) less room of error on behalf of the software user
(+) more flexible for parameter studies (one DC set for 4 façade orientations)
(+) DCs become a property of a building independent of surrounding climate

Note: ability to go to 4x145 = 580 direct DCs

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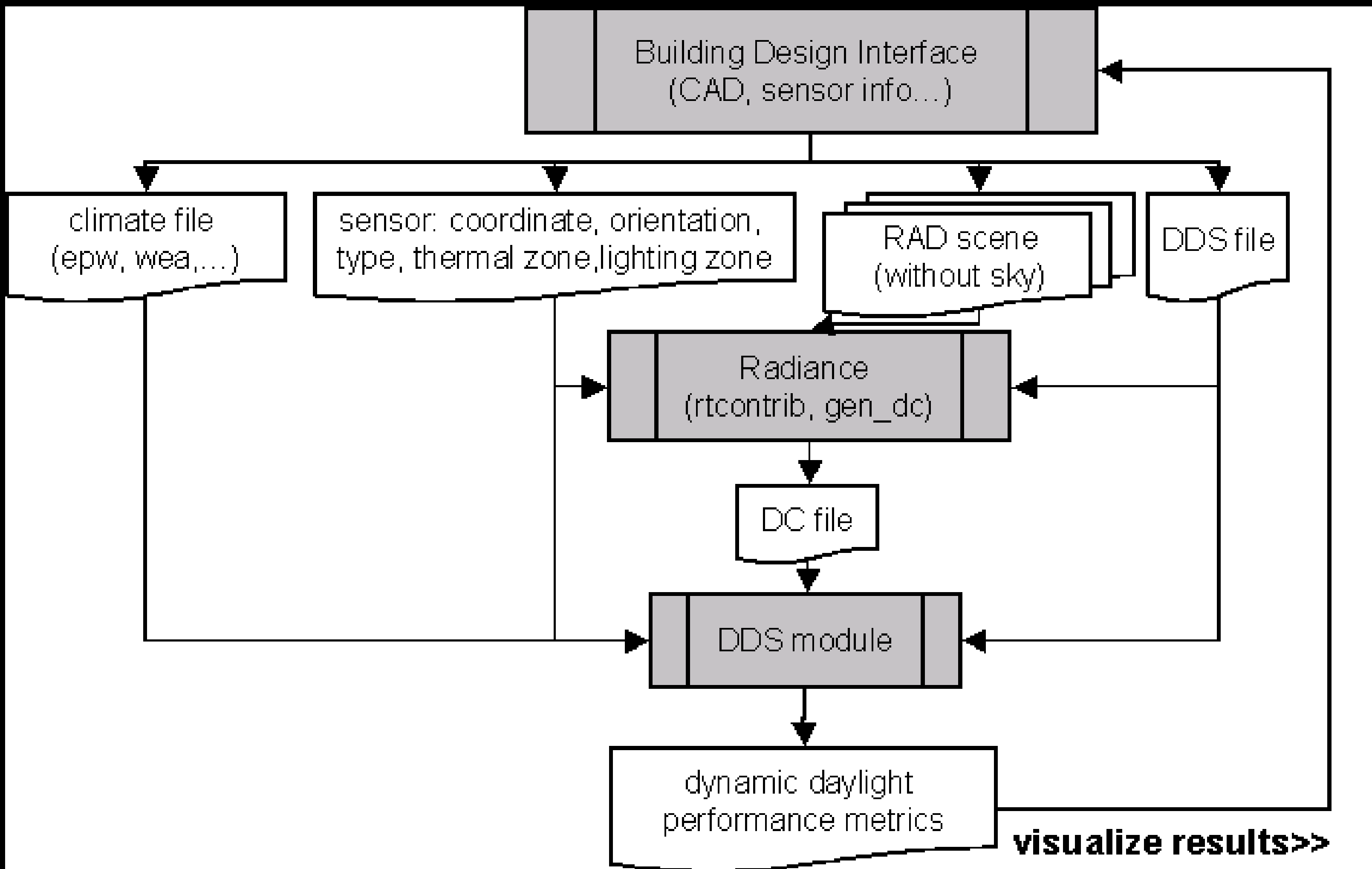
DDS file implementation for Lighting Visualizations (Daylight Autonomy, UDI…)



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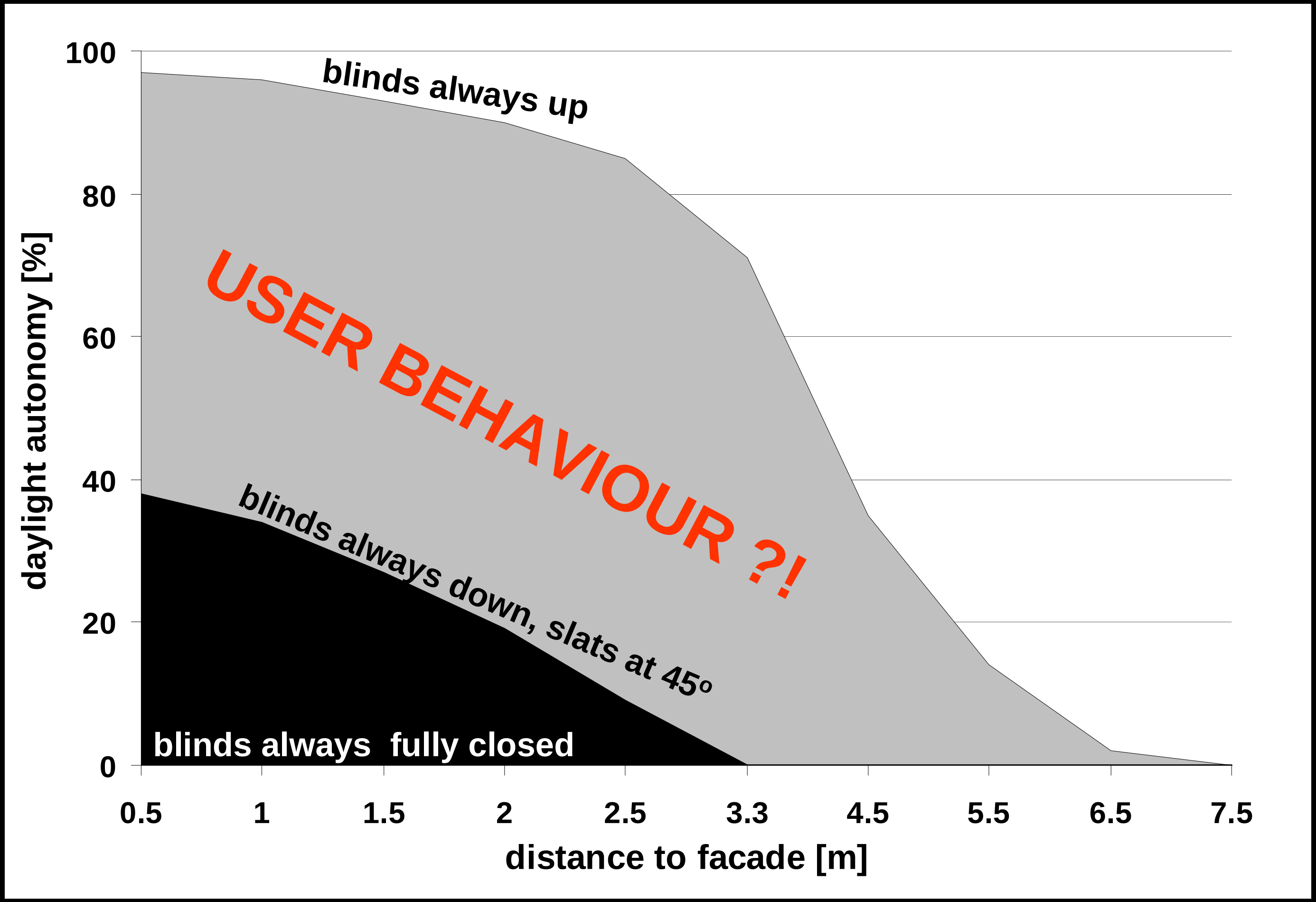
Movable Shading Devices



- venetian blinds should be treated as the reference case

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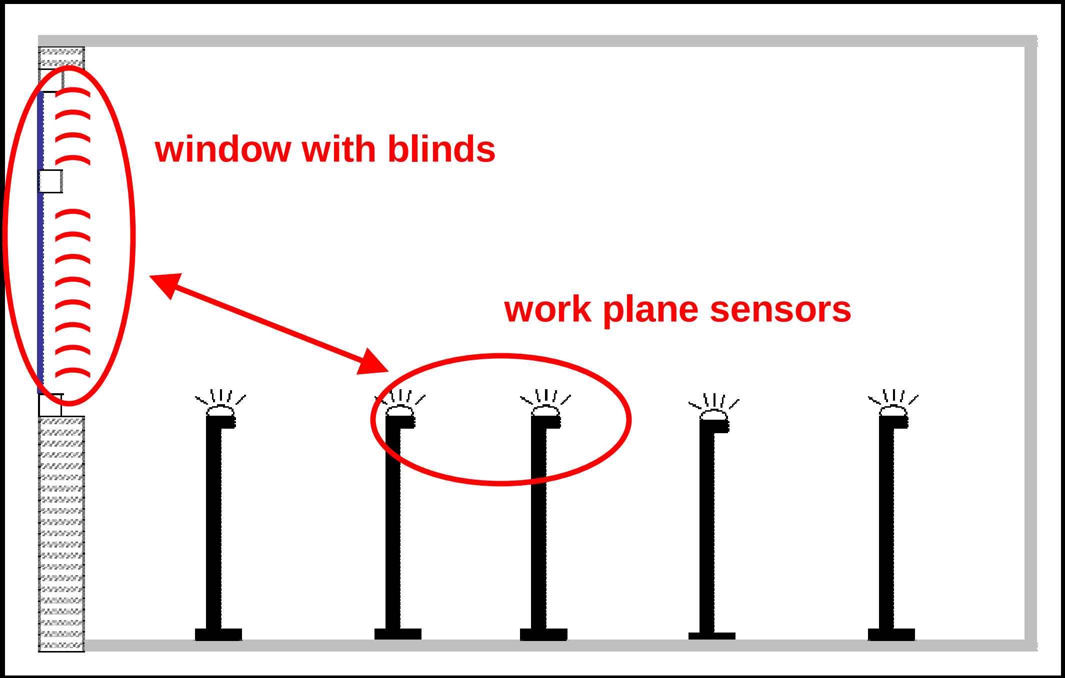
Manual blind control model



- Daysim: active (energy conscious) or passive user
- Associate work plan sensor with window
- Note: this act couple individual sensors together.
- Benefit: Direct comparison between daylighting concepts with and without movable and/or fixed shading devices

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Movable Shading Devices

- to model movable shading devices, several sets of DCs are required

- DDS file to provide "hooks" for thermal programs to control shading devices. These hooks are control values associated with the setting of a shading device. E.g.

(1) Venetian Blinds (three settings)

control = 90 : Slats horizontal

control = 45 : Slats under a 45 Deg angle facing downwards

control = 30 : Slats under a 60 Deg angle facing downwards

(2) Electrochromic Glazing (two extreme settings)

control = 0.05 : Electrochromic Glazing at 5% transmittance

control = 0.60 : Electrochromic Glazing at 60% transmittance

- conscious separation of physical description of shading devices and the control of shading devices (modular approach)

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DDS file including shading

DDS file

<?xml version="1.0" encoding="UTF-8"?>
<scene>
<description>string</description>
<radsettings>-ab 0 -ad 1500 ...</radsettings>
<radscene>
<textfile>**file type (*.rad)**</textfile>
</radscene>
</scene>

<sensors>
<textfile>**file type (*.pts)**</textfile>
</sensors>

<daylightcoefficients>
<textfile>**file type (*.dc)**</textfile>
</daylightcoefficients>

Plus shading systems

PTS file

Type | thermal-zone | light zone | x | y | z | or$_x$ | or$_x$ | or$_x$
Ill office1 near_window 0 2 0.85 0 0 1
…

DC file

DC$_1$ DC$_2$… DC$_{291}$
…

Open debate for workshop…

DDS file including shading

DDS file

```
…
<shading_system>
   <name>façade opening descriptor</name>
   <description>string</description>
  <list>
        <control>
            <name>string</name>
            <base_control_value>float</base_control_value>

            <control value>float</control value>
            <radscene>
                 <textfile>file type (*.rad)</textfile>
            </radscene>

            <control value>float</control value>
            <radscene>
                 <textfile>file type (*.rad)</textfile>
            </radscene>
        </control>
  </list>
</shading_system>
```

Window1

Window with venetian (blinds 3 settings)

Venetian Blinds

0 (blinds opened)

0.5 (blinds lowered, slats horizontal)

Radiance model of blinds

1.0 (blinds lowered, slats closed)

Radiance model of blinds

DC file

DC_1 DC_2… DC_{291} (Sen1blinds opened **base**)
DC_1 DC_2… DC_{291} (Sen1blinds lowered, slats hor.)
DC_1 DC_2… DC_{291} (Sen1blinds lowered, slats closed)
…

DDS file including shading

DDS file

```
…
<shading_system>
  <name>façade opening descriptor</name>
  <description>string</description>
  <list>
     <control>
        <name>string</name>
        <base_control_value>float</base_control_value>

        <control value>float</control value>
        <radscene>
           <textfile>file type (*.rad)</textfile>
        </radscene>

        <control value>float</control value>
        <radscene>
           <textfile>file type (*.rad)</textfile>
        </radscene>
     </control>
  </list>
</shading_system>
```

- **DDS file would be generated by Ecotect, ESP-r …**
- **shading device name would coincide with a thermal zone in simulation program**
- **control name would coincide with shading control strategy in simulation program. The control would assign the control value at any given simulation time step**

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Other aspect: differential daylight coefficients

- the daylight coefficient for a sensor for a point in time would correspond to the sum of the base daylight coefficients and the differential daylight coefficients for the different shading device settings.

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Your turn

- ❑ **your comments: now or via email**
  - ***Is this useful?***
  - ***Should the DDS file be binary and include DC and PTS entries?***
  - ***Did we forget an input required for thermal simulations?***

- ❑ **NRC/NRCan will use a DDS file approach for the Lightswitch Wizard project in the fall. Large database of daylight coefficients used for integrated thermal/lighting and daylight autonomy visualizations.**

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