LIGHTING RESEARCH PROGRAM

Project 6.2 SPOT Technical Manual

FINAL REPORT

SPOT

SENSOR PLACEMENT + ORIENTATION TOOL

Consultant Report

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Beta 2.0 Release

Technical Manual

SPOT™

SENSOR PLACEMENT + ORIENTATION TOOL

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Sensor Placement and Orientation Tool (SPOT™) Technical Manual

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1.0 Introduction

The Sensor Placement and Orientation Tool or SPOT™ is intended to assist a designer quantify existing or intended electric lighting performance, evaluate annual daylighting characteristics and help establish the optimal photosensor placement in a given space relative to annual performance and annual energy savings. SPOT™ was developed with classroom daylighting in mind, but can be used for all types of spaces. SPOT™ handles top and side daylight sources and can model any electric lighting source from existing IES files[1]. This technical manual summarizes the various user interface screens of SPOT™ and describes the available inputs and outputs.

1.1 Overview of SPOT™

SPOT™ consists of a series of screens that the user navigates sequentially, as illustrated in Figure 1-1 with a flow diagram for the program. The progressive staging of inputs and results is designed to minimize user wait time. Wait time is reduced by running required calculations behind the scenes before they are needed. Hence, much of the calculation time in the program occurs while the user is interacting with another input screen or reviewing a results screen. The sequential staging of the interface screens also provides a coherent structure to the process of designing a daylighting and photosensor control system. The program has two main sections: a Design Tool followed by an AnalysisTool. The Design Tool consists of all geometric and site inputs and calculates electric lighting performance and preliminary annual daylighting results. The final stage of the Design Tool provides recommended photosensor placements for the analyzed space. These recommended placements provide good starting points for analysis but do not necessarily represent the optimal photosensor placement. Further iteration with the Analysis Tool is required to fine tune the photosensor system design. The Analysis Tool is the final phase of SPOT™ and consists of two screens. The first screen allows the user to mix and match defined photosensor scenarios with luminaire zones and analyze resulting correlations and estimated annual performance. The second screen takes the set photosensor scenarios and analyzes their performance throughout the year using annual hour-by-hour weather data.

[1] IES files are numeric text files provided by lighting manufacturers which define luminaire light distribution patterns.

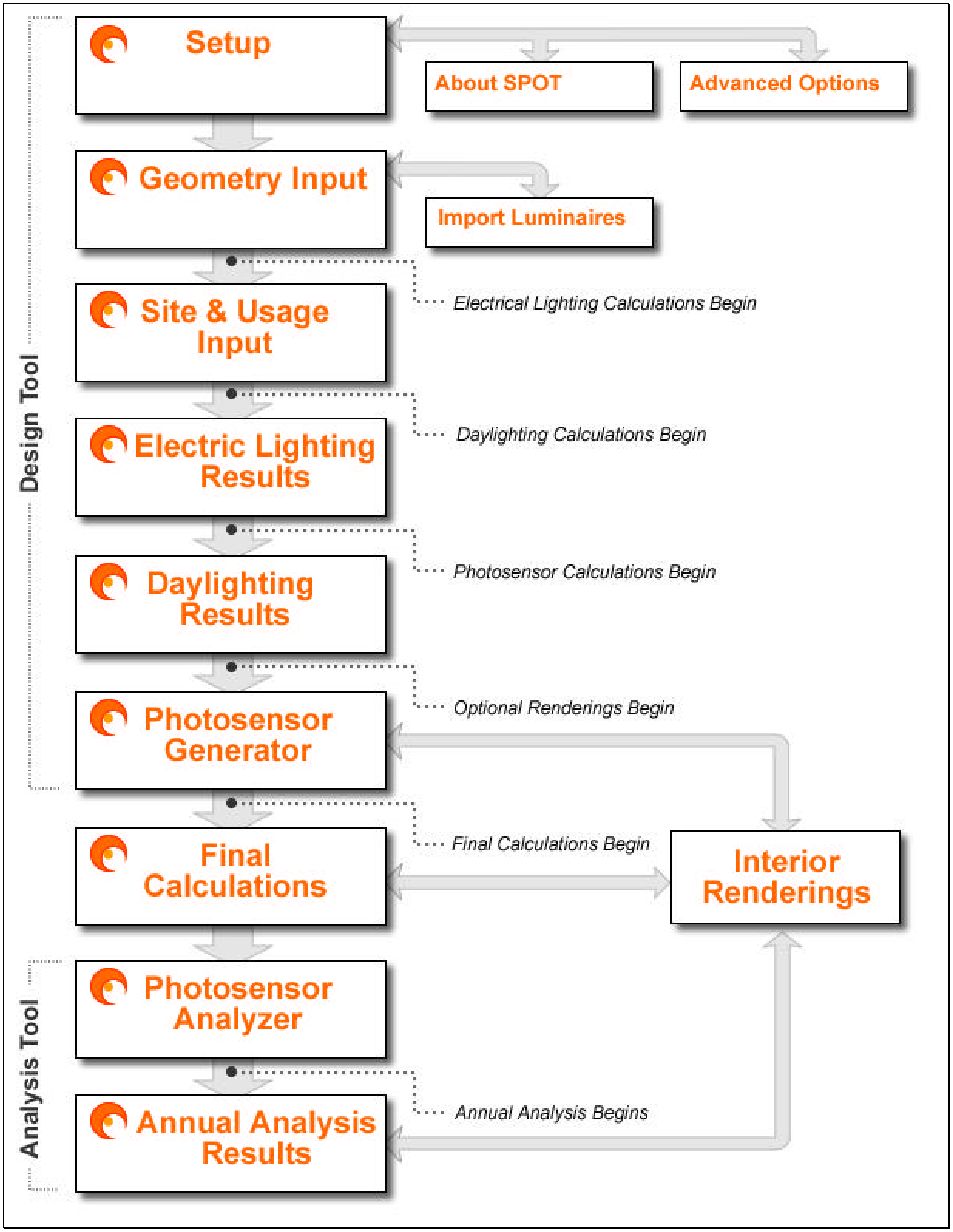


Figure 1-1: SPOT™ Flow Diagram

1.2 General SPOT™ Notes

Several important concepts, assumptions and caveats to note before beginning the program are as follows:

- The SPOT™ Interface Program is essentially an Excel™ template file. This means that anytime a fAnresh interface file is saved, it will be saved as a regular Excel spreadsheet file under a different name. The main template will always be accessible through the Start Menu link or found in c:\Program Files\SPOT™. To revisit an already existing model, open the Excel spreadsheet file under the corresponding name and in the corresponding directory.

- Upon opening SPOT™, some versions of Excel may ask whether to enable macros -- always choose to enable macros when SPOT™ opens. Certain versions of Excel, Excel 2000 and newer, have an option that either always enables or disables macros. In these cases, the user may have to go into Excel beforehand and choose to always enable, or always ask to enable macros.

- It is important to navigate through the program with the [NEXT >>] and [<< BACK] buttons. The Excel sheet tabs are not displayed automatically when starting the program. The program is intended to be navigated exclusively using the [NEXT >>] and [<< BACK] buttons. If the tabs are displayed and used to jump from screen to screen out of order errors will result.

- Upon entering in the initial project information, SPOT™ will automatically save and create a directory in the location selected. It is up to the user to save their work throughout the rest of the program as SPOT™ does not do it automatically.

- In some cases, upon hitting [NEXT >>] the user may see several other screens flicker on the screen before the next screen is actually shown. Don't worry about seeing these; it indicates certain calculations are occurring. Also, it is important to wait until the hourglass disappears indicating that the program has finished any calculations before continuing with the program.

- SPOT™ engine calculations are run in the background in a "SPOT™ Calculations" window, shown in Figure 1-2. When calculations start which occurs upon hitting [NEXT >>], this window will open and come to the forefront of the screen. This window can then be minimized and will continue to run in the background until the calculations are finished. Refer to this window for progress of the current calculation set. Note that sometimes there are two or three sets of calculations, the current calculation set is indicated in the title of the SPOT™ Calculations window.

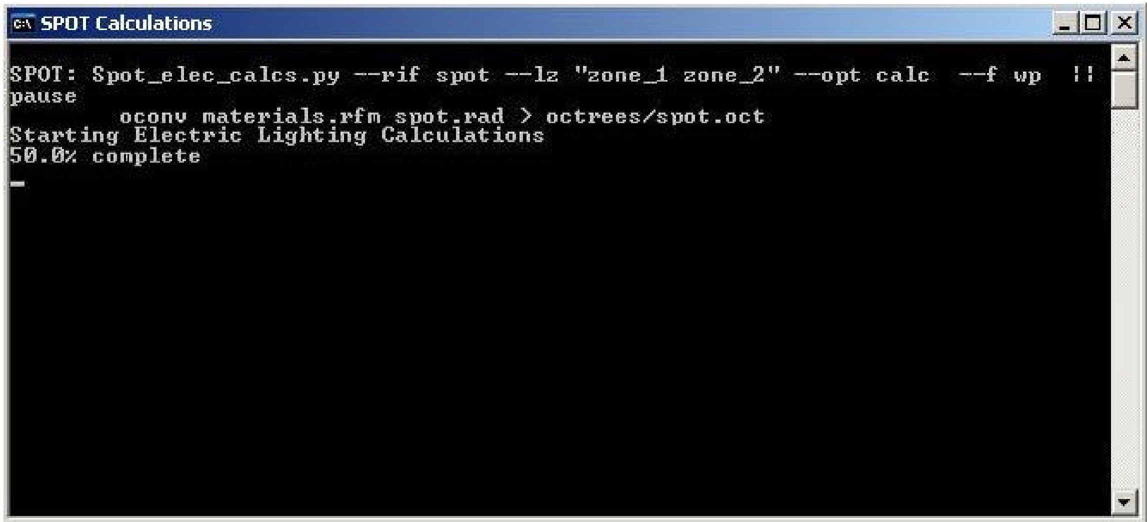


Figure 1-2: SPOT™ Calculations Window Screen Shot

- No results or calculations in the Beta release have been thoroughly validated. Basic validation studies have been performed, but detailed validation studies using actual field measurements were not completed for the Beta release. Nevertheless, the results provide very useful information, but should not be relied on as completely accurate.

- The SPOT™ Development Report, referred to throughout the report, provides technical background information on the software program. This report can be downloaded from the SPOT™ website: www.archenergy.com/SPOT

- Some of the SPOT™ Excel sheets are not protected, it is important to not make any changes other than the apparent input fields required.

- The << BACK button is only activated if the current SPOT™ Calculation window is finished. If the calculations do not need to finish, if a change is going to be made in the design, the user can manually close the SPOT™ Calculation window before it is finished by hitting the “X” in the upper right corner. Then the user can go back to a previous page and make any desired changes.

- Throughout the program, a red triangle tag on the screen indicates a help message. Move the mouse over the red triangle to see the help message.

2.0 SPOT™ Setup

The project set-up screen is displayed upon opening SPOT™, shown in Figure 2-1. This screen allows the user to set up initial project information and access the Advanced Options and About screens.

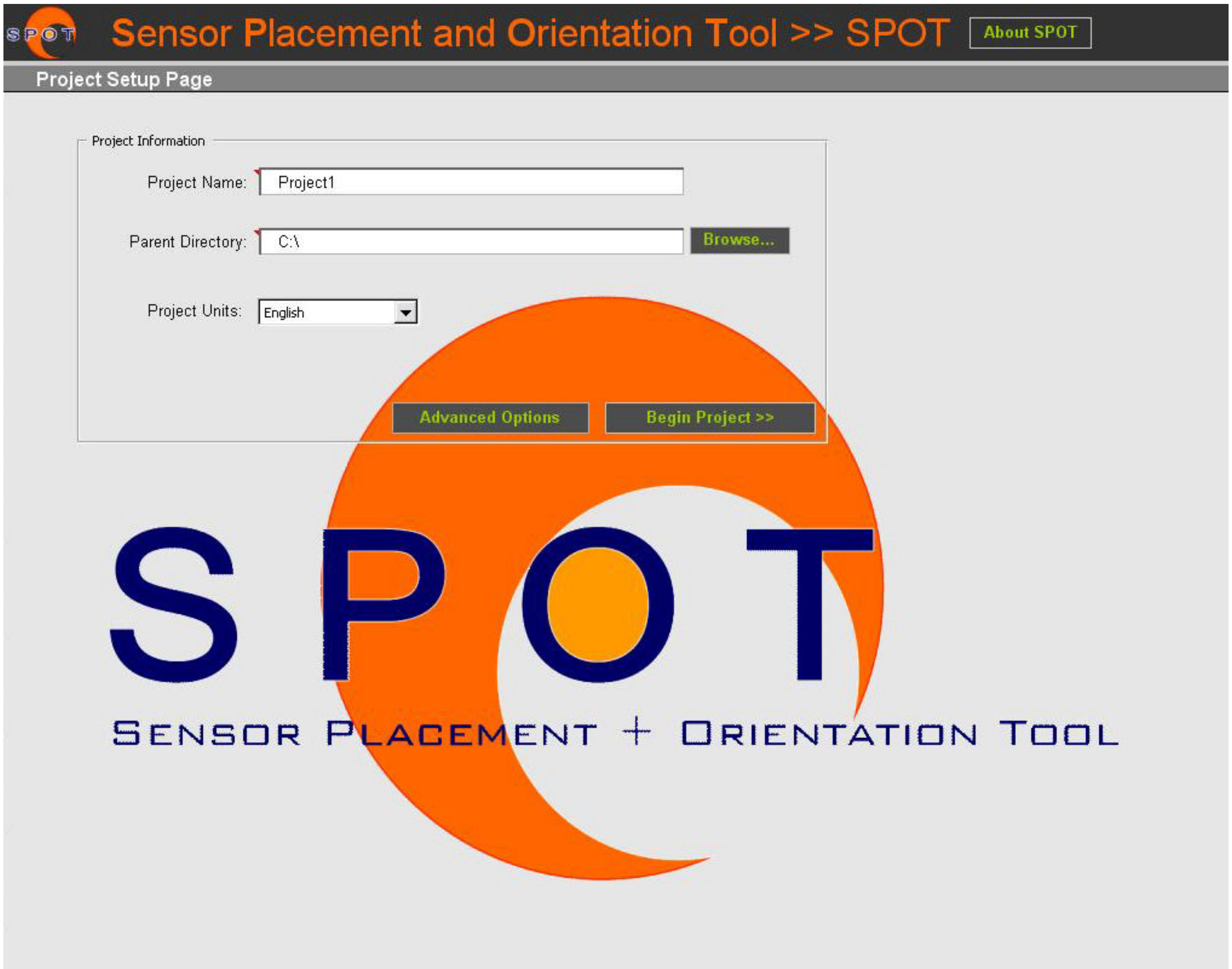


Figure 2-1: Project Setup Screen Shot

2.1 Project Information

Project information sets the name of the current project, the parent directory for the current project, and the units to use for the project.

Project Name – This sets a name associated with the current project. A sub-directory within the parent directory will be created with this name to contain all the data files associated with the current project.

Parent Directory – This sets a directory location selected by the user that will contain the project sub-directory. Selecting the Browse... button allows the user to navigate the computer's directory structure to find the desired parent directory.

Project Units – This field allows the user to choose between SI (metric) and English units.

Begin Project - The Begin Project >> button takes you to the first screen, Geometry Input, and saves the file. The file will automatically be saved to the specified directory and will be named according to the project name. If at a later time you would like to revisit the project, find the project in the directory specified and open the Excel file with the project name. <u>It is up to the user to save any changes in their project from this point forward.</u>

About SPOT™ - The About SPOT button displays SPOT™ version and development information and copyright information.

2.2 Advanced Options

The Advanced Options button activates the advanced options screen, shown in Figure 2-2, which allows the user to change some of the program calculation settings. The program's default values for these settings are listed. An input field allows the user to override each setting.

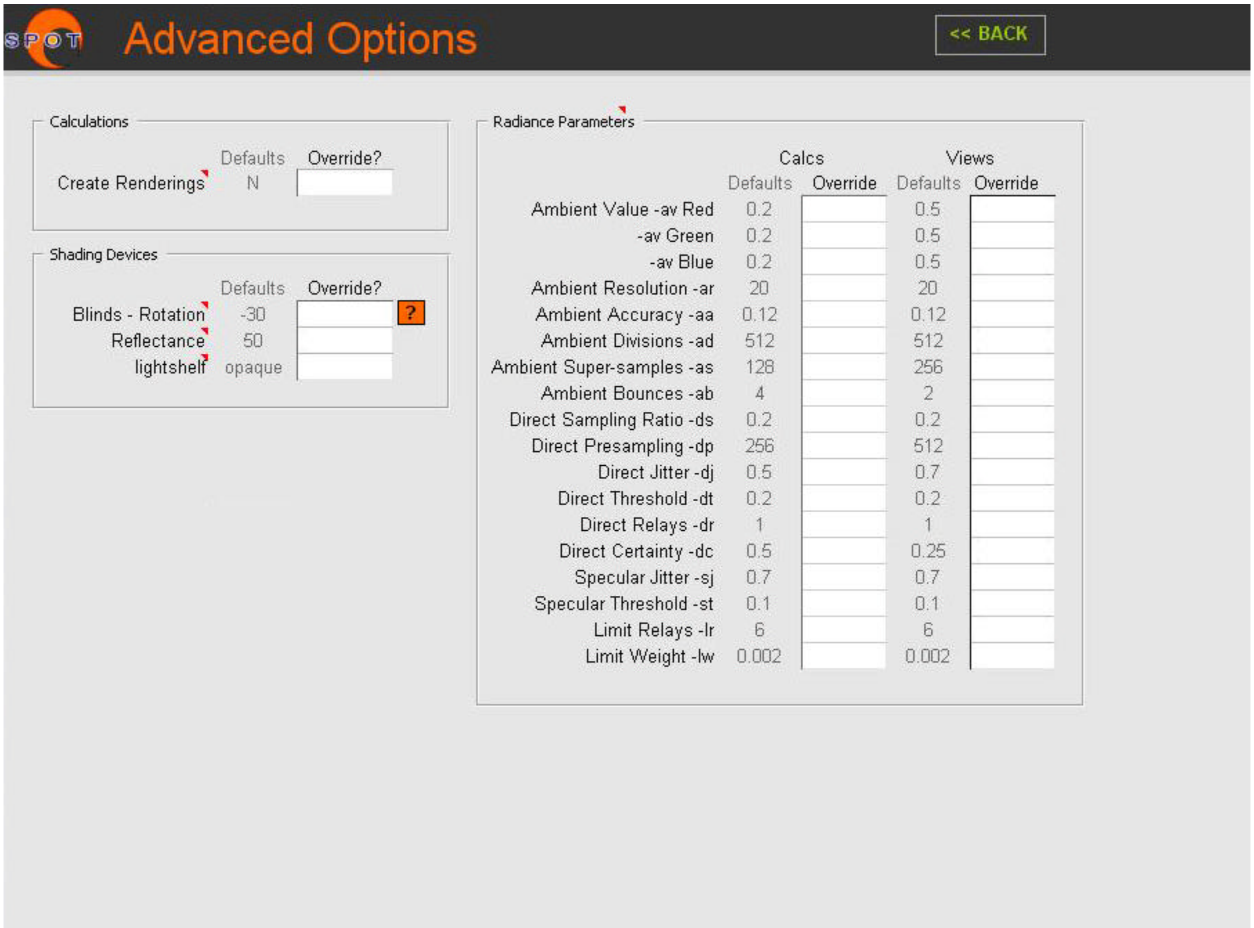


Figure 2-2: Advanced Options Screen Shot

Calculations – These fields allow the user to override basic calculation settings.

Create Renderings – This field requires either Yes (Y) or No (N) and tells SPOT™ whether or not to perform renderings of the space. If this option is selected, the Radiance view parameters chosen will be used to create these renderings and they will be viewable after the photosensor generator screen.

Shading Devices – These fields allow the user to override the shading device settings.

Blinds Rotation – This field sets the rotation angle of any mini-blinds used in your model. Selecting the ? button provides an illustration showing how this angle relates to the geometry of the blinds.

Blinds Reflectance – This field sets the reflectance of any mini-blinds used in your model.

Lightshelf Type – This field sets the type of Lightshelf to use. The user can choose between an opaque and a translucent shelf. If an opaque lightshelf is selected, the user will set the lightshelf reflectance on the Geometry Input page. If a translucent shelf is selected, the user will set the lightshelf transmittance on the Geometry Input page.

Radiance Parameters – These fields allow the user to override the default Radiance parameters used for calculations and for renderings. **WARNING –** These are advanced options that should only be changed by an experienced Radiance user. In most cases, the default settings are appropriate. Please refer to Radiance references[2] for a description of these parameters on the Radiance program in general.

[2] http://radsite.lbl.gov/radiance/HOME.html

3.0 Geometry Input

On the Geometry Input screen the user defines the room geometry and electric lighting layout of the space to be analyzed. SPOT™'s geometric modeling capabilities are limited to relatively simple, orthogonal, spaces with a limited number of elements. Future versions will allow more complex geometry to be modeled in other CAD packages and imported to the program, bypassing SPOT™'s intrinsic geometry modeler.

At anytime while defining the model geometry, the View Renderings button can be used to display a quick interactive rendering of the current model in a viewing program called "rview". This is helpful to ensure the space has been modeled as intended. The image starts very crude and pixelated, but continually refines its resolution until a recognizable image is obtained. From this interactive viewer, other Radiance views can be defined and implemented behind the scenes. Please refer to Radiance documentation for further information regarding the use of "rview".

3.1 Spatial Characteristics

Spatial Characteristics define the geometric dimensions of the space as well as the solar orientation, and surface characteristics. While only orthogonal walls are allowed, the definition of room orientation allows for accurate modeling of the solar position. Figure 3-1 presents a screen shot of Spatial Characteristics input. The "Compass" window and the "Space Isometric" window are updated in real-time to give the user visual feedback of the geometry they are defining.

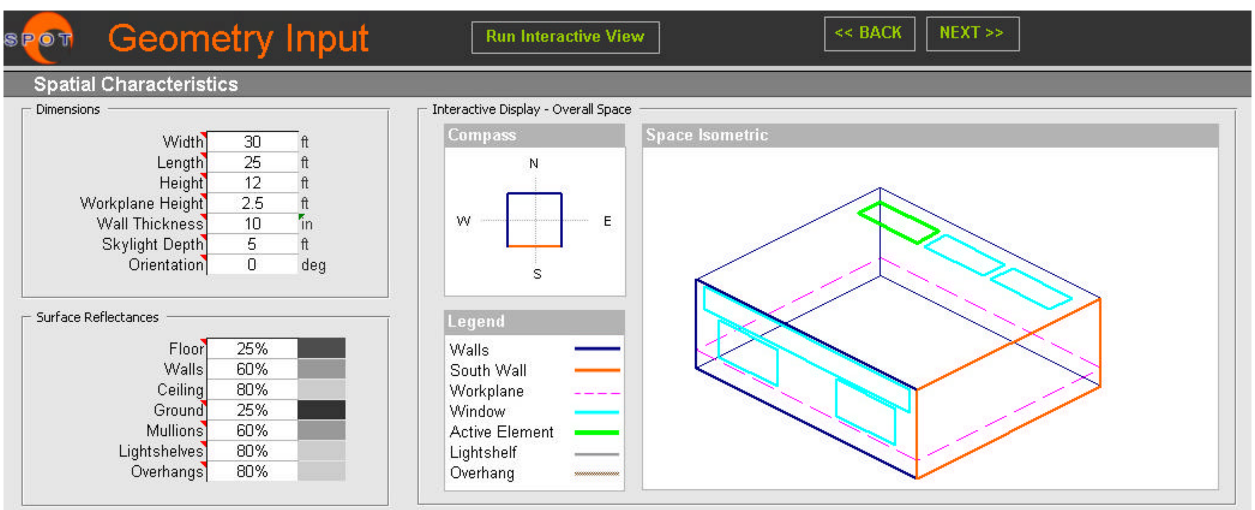


Figure 3-1: Spatial Characteristics Screen Shot

Dimensions – These fields represent the room's overall dimensions and orientation.

Width – This field sets the overall width or North-South dimension of the space. The dimension measures from interior wall to interior wall.

Length – This field sets the overall length or East-West dimension of the space. The dimension measures from interior wall to interior wall.

Height – This field sets the overall height of the space from finished floor to finished ceiling.

Workplane Height – This field sets the location of the illuminance calculation grid above the finished floor. This can be any height within the limits of the space, but is typically used to represent a workplane, 30 – 36" above the finished floor.

Wall Thickness – This field sets the thickness of the exterior walls, and essentially defines the thickness of any window sills and/or mullions in the model.

Skylight Depth – This field sets the depth of any skylight shafts, essentially the distance between the finished ceiling and the skylight opening. The shafts are assumed to be orthogonal. Splayed skylight shafts are not currently supported with the SPOT™ geometry modeler.

Orientation – This field sets the space's orientation relative to true south. This input must be between -45^{o} and 45^{o}, since any rotation greater than 45^{o} simply changes which façade is referred to as "South". The "Compass" window shows the user the orientation of the footprint of the space relative to the true cardinal directions. Throughout the program, the south façade is denoted as the orange façade, while all other facades are shown as blue.

Surface Reflectances – These fields represent the reflectance of the various surfaces in the model. All reflectances in SPOT™ are modeled as monochromatic -- or shades of gray.

Floor, Walls, Ceiling – Sets the reflectance of the floor, walls, and ceiling surfaces, respectively.

Ground – Sets the reflectance of the ground outside the building.

Mullions – Sets the reflectance of any surfaces representing the thickness of the walls. This applies to window sills and window mullions.

Lightshelves – Sets the reflectance of opaque lightshelves or the transmittance of translucent lightshelves. The lightshelves are opaque by default, but can be modeled as translucent if selected on the Advanced Options screen.

Overhangs – Sets the reflectance of any overhangs used in the model.

3.2 Walls and Apertures

The wall and aperture inputs, shown in Figure 3-2, allow the user to define three architectural features per each façade of the space: windows, interior lightshelves, and overhangs. The program allows for 10 window inputs per façade, 2 lightshelf inputs, and 2 overhang inputs. The user selects which façade to add architectural features to using the "Architectural Element" pull-down menu. This menu contains an option for each of the four walls (east, south, west, and north) and the ceiling. Once a façade is selected, the user chooses which architectural feature to define using the "Architectural Feature" pull-down menu. The red "delete" button removes the selected architectural feature.

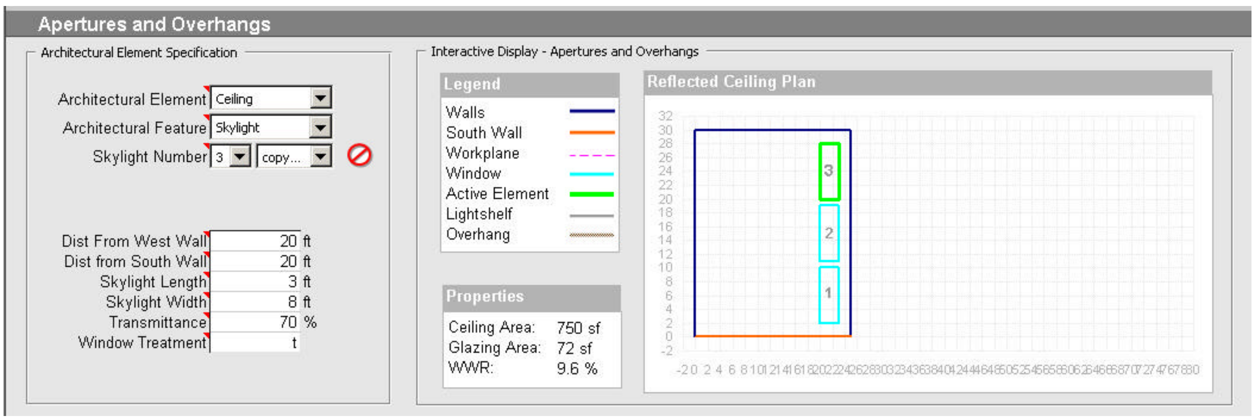


Figure 3-2: Walls and Apertures Input Screen Shot

The "Interactive Display" box, located to the right of the inputs, is updated in real-time to give the user visual feedback of the layout of the façade. The window farthest to the right displays an interior elevation of the element selected. The Properties window displays current information on the selected architectural element. Displayed in this window is the area of the element, the area of glazing on the element, and its window-to-wall ratio (WWR).

Windows – This architectural feature sets the apertures in the space. Window number 1 is selected for definition first, followed by Window number 2, 3, and so on. Up to 10 windows can be defined for each façade. The "copy…" pull-down menu allows the user to copy a window definition from a previously defined window. The copied window appears directly on top of the original and needs to be moved to an available (non-overlapping) position.

Location – This field sets the window's distance from the left wall when viewed as an interior elevation. The scale on the interior elevation plot illustrates this dimension.

Sill Height – This field sets the height of the bottom of the window above the floor.

Window Height – This field sets the height of the window.

Window Width – This field sets the width of the window.

Transmittance – This field sets the visible transmittance of the window. All glazing transmittances are modeled as monochromatic and use typical double pane clear glass front and back reflection characteristics.

Window Treatment – This field sets solar control option to be applied to the window selected. The user can choose **n** for no treatment, **b** for mini-blinds, **s** for fabric shades, or **t** for translucent glass. The blinds and the shade treatments can then be controlled using either manual, timer, or automatic photosensor controls. Only automatic shade control is available in the Beta release. Also note that all shades or blinds entered for the space will be controlled together, ie. south and east blinds cannot be controlled separately.

Interior Lightshelves – This architectural feature creates interior lightshelves in the space. These elements are modeled as infinitely thin surfaces that are either opaque or translucent depending on the setting made on the Advanced Options screen. Opaque lightshelves are the default.

Distance from Left Wall – This field sets the lightshelf's distance from the left wall when viewed as an interior elevation.

Height above floor – This field sets the height of the lightshelf above the finished floor.

Width - This field sets the width of the lightshelf or the dimension perpendicular to the window.

Length – This field sets the length of the lightshelf or the dimension parallel to the window.

Overhangs – This architectural feature creates exterior overhangs on the selected façade. These elements are modeled as a 3-dimensional parallelepiped (as a box). Although these elements are intended for the exterior, the adventurous user can use them to model other exterior objects or interior objects as well.

Distance from Left Wall – This field sets the exterior overhang's distance from the left wall when viewed as an interior elevation.

Height above ground – This field sets the exterior overhang's height above the ground, which is the same plane as the floor.

Thickness – This field sets the thickness (height) of the exterior overhang.

Width – This field sets the width or the dimension perpendicular to the window of the exterior overhang.

Length – This field sets the length or the dimension parallel to the window of the exterior overhang.

3.3 Electric Lighting

The electric lighting inputs, Figure 3-3, allow the user to select luminaire types and layout for up to 3 luminaire zones. The user can select a luminaire type from the SPOT™ fixture library, or add a new luminaire type by importing a new IES file. The "Reflected Ceiling Plan" view is updated in real-time and provides visual feedback for the current luminaire zone. Each luminaire zone represents a set of luminaires that are controlled together. Often luminaires are grouped together together relative to daylight availability. Luminaire zones may also be defined keeping physical or electrical constraints in mind. For example, in reality a row of connected fixtures is easiest controlled together rather than being split into two or more different luminaire zones. If, upon receiving the annual daylighting illuminance results, the user feels the luminaires should be rezoned and it is deemed reasonable from a physical and electrical standpoint, this screen can be revisited and updated.

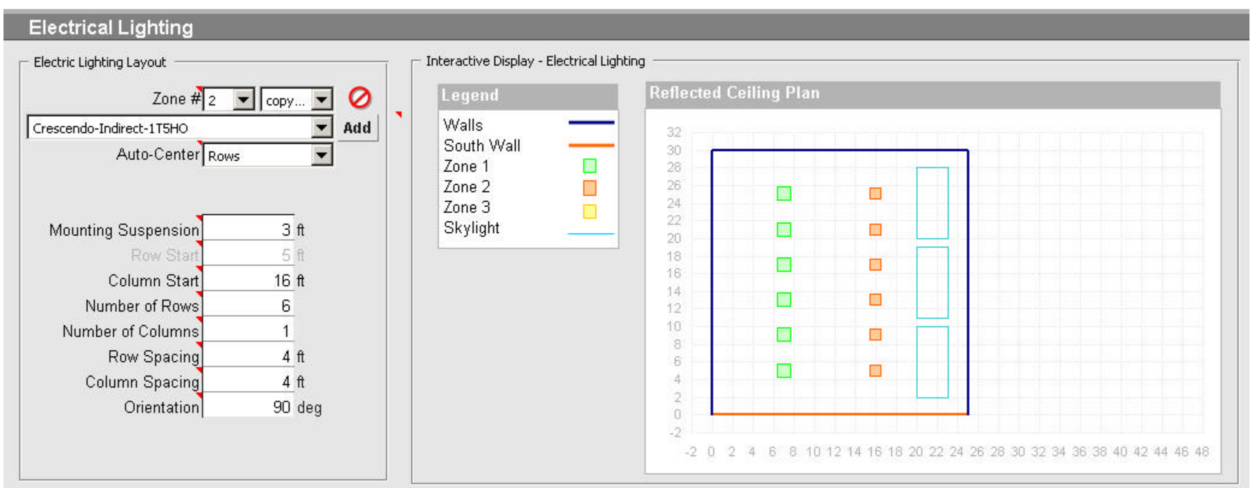


Figure 3-3: Electrical Lighting Input Screen Shot

Import Luminaires – Selecting the Add button will bring up the Import Luminaires screen, shown in Figure 3-4. This screen displays the available Luminaire Library in the pull-down menu and lists the luminaires currently in the project in the box below. To add a luminaire to the project, select a luminaire from the available Luminaire Library in the pull-down list. The luminaire will then be automatically added to the "Luminaires Currently in Project" box. To remove a luminaire from the project, simply delete it from this list by highlighting and using the computers delete key.

To add single or multiple luminaires to the Luminaire Library from existing IES file(s), hit the **Select File(s)** button, navigate to the desired file directory, and choose the desired IES file(s) to import. To add a directory of IES files to the Luminaire Library, hit the **Select Folder** button and navigate to the directory to be imported. This will import all IES files located in the specified directory. Use the **Edit Library** button to edit and organize the names and files in the Luminaire Library. The **Repopulate List** button updates the list of luminaires in the pull-down menu after new luminaires have been added.

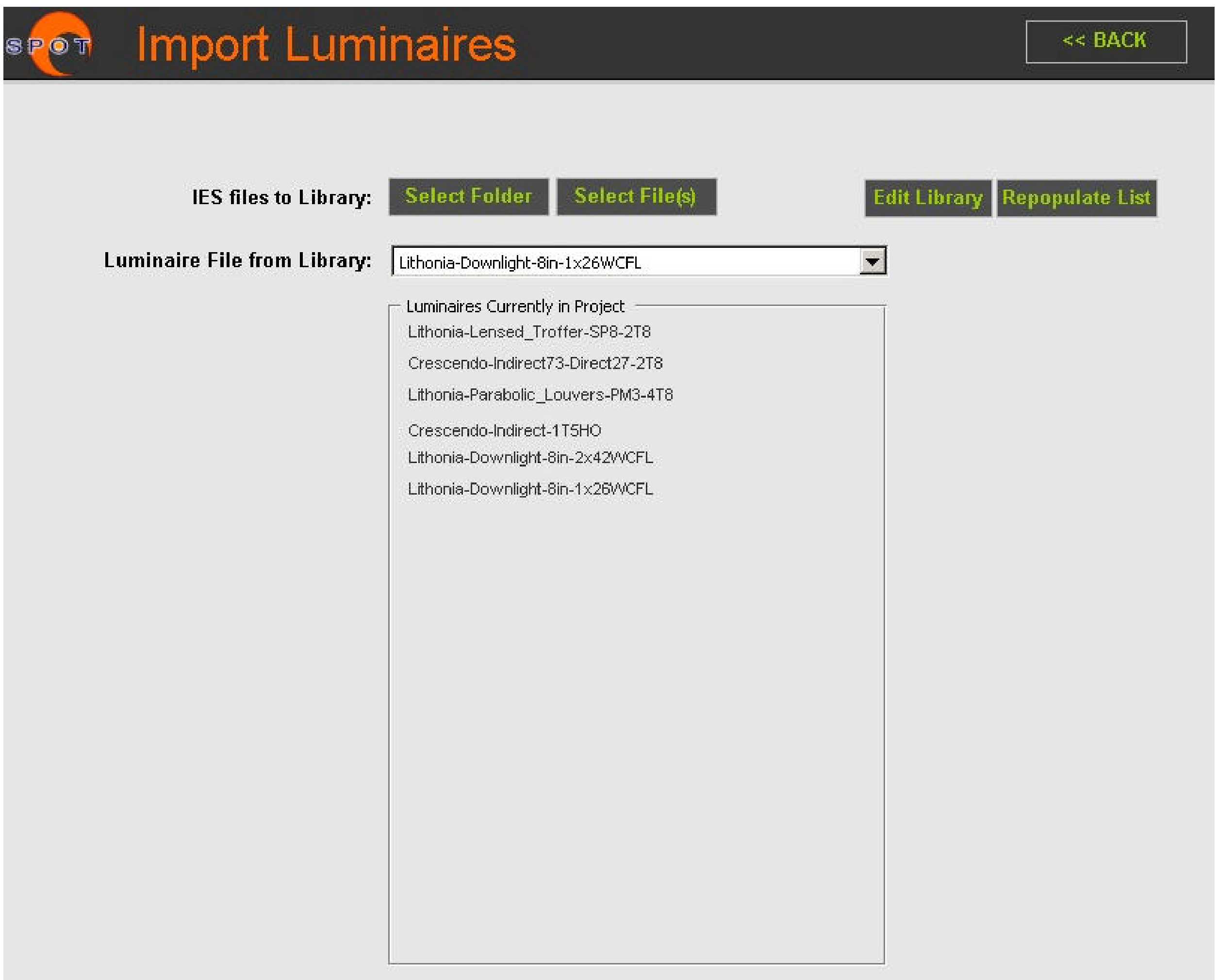


Figure 3-4: Import Luminaires Screen Shot

Electric Lighting Layout – These fields define the dimensional characteristics of the selected luminaire zone. All the characteristics apply to the luminaire zone, selected in the "Zone #" pull-down menu. The red ⊘ button deletes the selected zone. The "Auto-Center" pull-down menu provides the choice of auto-centering rows, columns, or both. When one of these options is selected, the corresponding inputs for row start and/or column start will be greyed out and set automatically.

Mounting Suspension – This field sets the suspension height of the luminaires, which is the distance from the center of the luminaires to the ceiling height. This should be zero for surface mounted or recessed luminaires.

Row Start – This field sets the distance of the first row from the south façade.

Column Start – This field sets the distance of the first column from the west (or left hand) façade.

Number of Rows – This field sets the total number of rows.

Number of Columns – This field sets the total number of columns.

Row Spacing – This field sets the distance between adjacent rows.

Column Spacing – This field sets the distance between adjacent columns.

Orientation – This field sets the orientation of the luminaire. An orientation of 0^o aligns the x-axis of the luminaire (defined in the IES file) with the x-axis (length) of the space. A positive rotation rotates the luminaire counter clockwise.

Upon selecting the NEXT >> button, electric lighting calculations will begin. These calculations will be running in the SPOT™ Calculations window, which appears. This window can be minimized and the calculations will continue in the background while the user provides information on the next input screen – the Site and Usage Input screen. The electric lighting calculations can take several minutes depending on the number of zones and the speed of the computer’s processor.

4.0 Site and Usage Input

The Site and Usage Input screen allows the user to define the location of the building, occupancy and shade device schedules, and set the desired shade device control strategy. The electric lighting calculations will continue run in the background while inputs are entered and the NEXT >> button will not be activated until these calculations have finished. Figure 4-1 presents a screen shot of the Site and Usage Input screen.

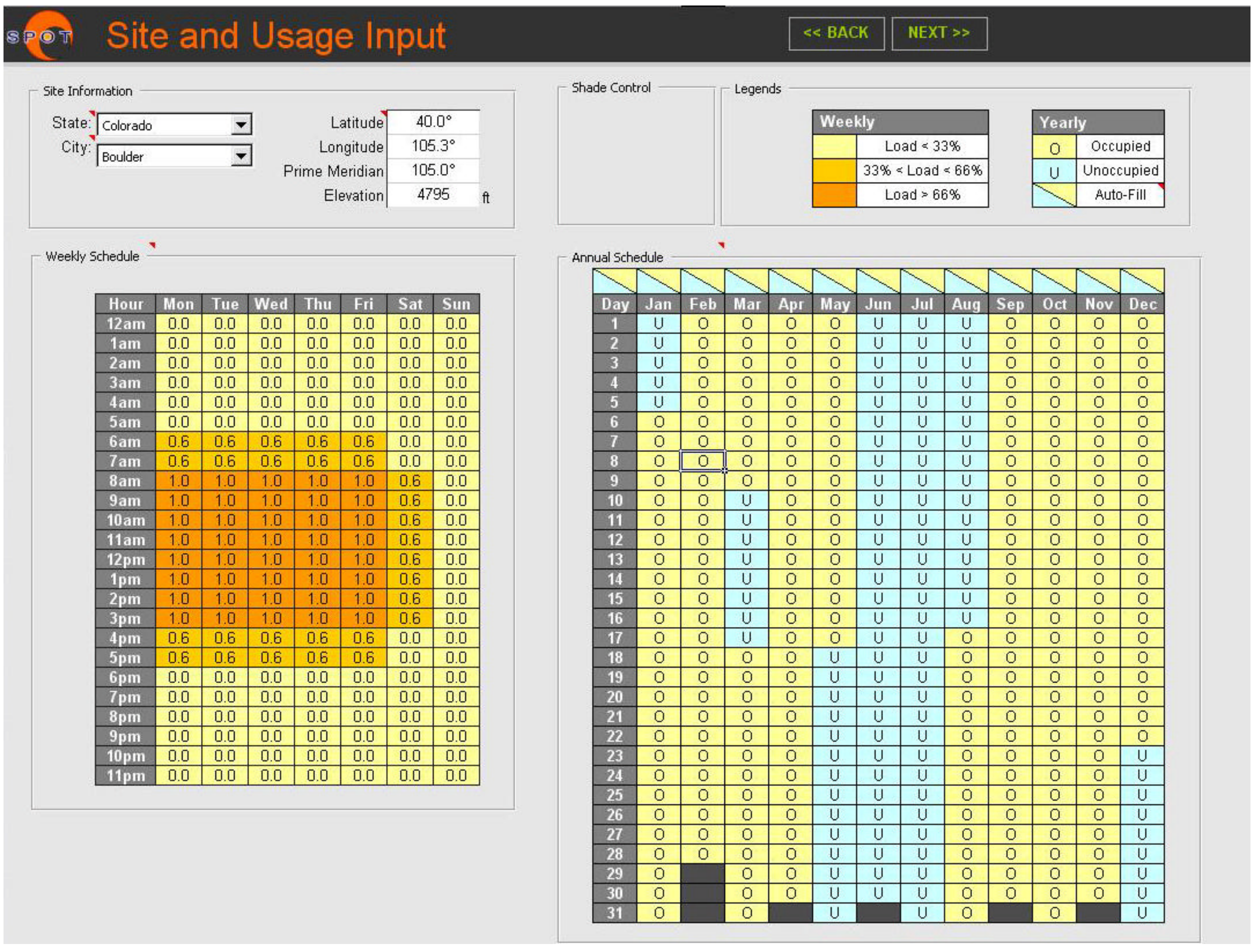


Figure 4-1: Site and Usage Input Screen Shot

4.1 Site Information

These fields allow the user to select the most climatically representative city for their project from a library of cities for which TMY2 data is available. This database of cities is organized and accessible to the user through the "State" and "City" pull-down menus. Default latitude, longitude, prime meridian, and elevation values are provided based on the city selected. The user can then override the default values with more precise latitude and longitude values if the

TMY2 city's location is too far away to predict the accurate solar position. Typically, if the building is within 1^{o} of the latitude or longitude of the representative TMY2 city, the solar angles are sufficiently similar.

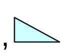
4.2 Shade Control

These fields are only visible if blinds or shades have been input. If present, the user can choose between manual, timer-based, or automatic shade control. Only automatic shade control is supported in the Beta release. When using automatic shade control, the user selects which façade to place the photosensor. The four walls or the roof can be selected for placement of this shade controlling photosensor. This photosensor is then used to raise and lower the blinds or shades as necessary. The setting of this sensor is automatic and such that the blinds will always be open under overcast sky conditions and open under sunny conditions when the photosensor signal drops to overcast levels. Note that in the Beta version it is only possible to place a single sensor on one orientation. As a result, if blinds are on two orientations the user must select a single orientation's solar conditions to raise and lower the blinds.

4.3 Weekly Schedule

The weekly schedule table defines 7 building occupancy schedules, one for each day of the week. The unoccupied times selected are not included in the annual analysis calculations. A value of one means the space is fully occupied and the lights would be fully on if not controlled with a photosensor system. A value of 0.5 means the space is 50% occupied, or occupied 50% of the time. A value of 0 means the space in not occupied.

4.4 Annual Schedule

The annual schedule table defines an annual daily occupancy schedule for the space. The table is a grid of cells, which represent each day of the year with the months listed along the top and the day along the side. "O" for occupied and "U" for unoccupied are used in each cell to indicate which days are and which are not occupied. Note that an Unoccupied "U" input in the annual schedule means the entire day is absolutely unoccupied and the weekly schedule is unused. An Occupied "O" input in the annual schedule means that the space abides by the weekly schedule for that day. January 1st is chosen arbitrarily to be a Monday. The diagonal yellow and blue buttons at the top of this table allows the user to fill an entire month or the entire year as either occupied or unoccupied. Clicking the blue portion, , of the button will fill in Unoccupied "U" values and clicking the yellow portion, , of the button will fill in Occupied "O" values.

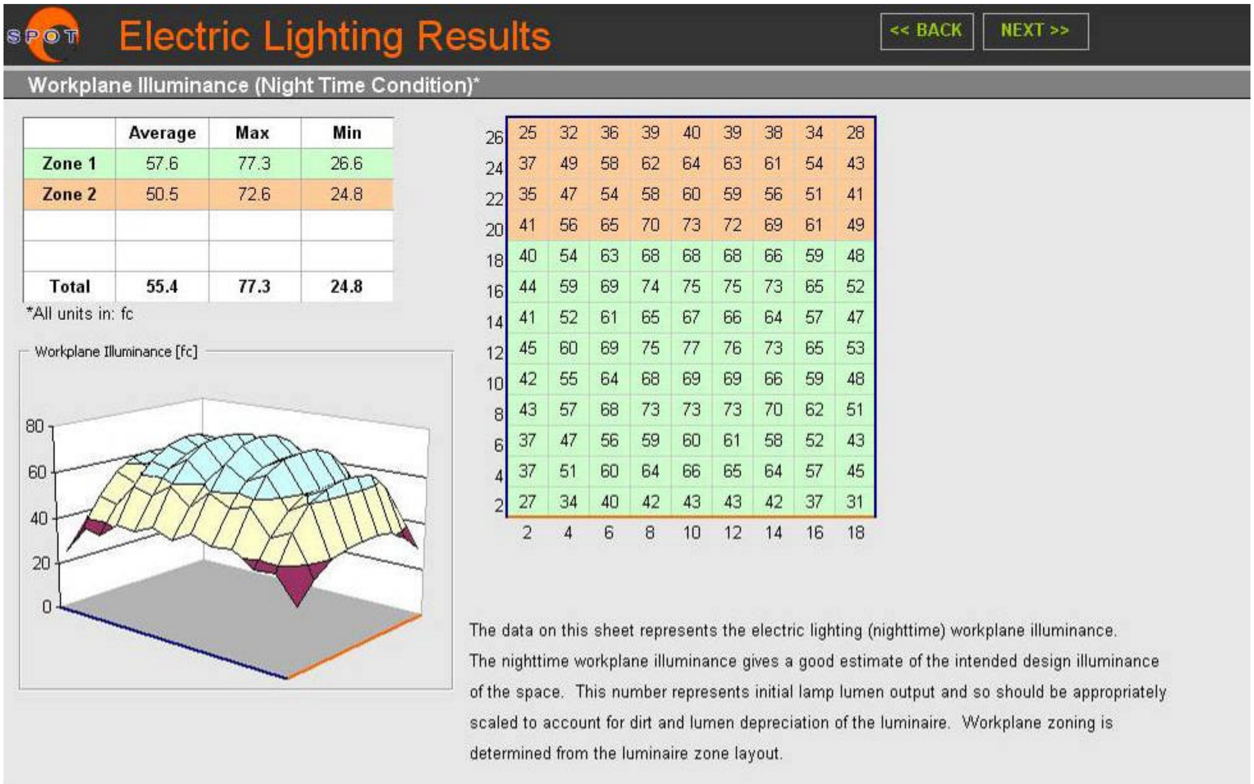
Selecting the NEXT >> button from this screen executes the daylighting calculations. These will run in a SPOT™ calculation window, which can be minimized while reviewing the next screen, Electric Lighting Results. The user will be limited to this screen until the calculations are finished.

5.0 SPOT™ Design Tools

The next three screens of the software are related to the design portion of SPOT™. The design portion of SPOT™ uses the geometry and site information provided and reports three main sets of information back to the user: 1) Electric lighting performance under nighttime conditions, 2) Annual daylighting performance under a sampling of conditions and 3) Photosensor placement recommendations for each luminaire zone. These design-related results are described in the following sections.

5.1 Electric Lighting Results

The Electric Lighting Results screen presents nighttime workplane illuminance with the electric lighting on at 100%. This screen, shown in Figure 5-1, is viewable once the electric lighting calculations have finished. The intent of this screen is to inform the user of the nighttime illuminance of the space, which often is the design illuminance of the space and a reasonable starting setpoint for the photosensor control system. In the case shown in Figure 5-1, the average nighttime workplane illuminance is 44.5 fc, which is a good indication of the intended design illuminance. Or, if this is higher or lower than desired, the user may go back and redesign the lighting layout. Note that this calculation represents an initial nighttime illuminance, Light Loss Factors such as dirt and lumen depreciation should be accounted for by the user.



	Average	Max	Min
Zone 1	57.6	77.3	26.6
Zone 2	50.5	72.6	24.8
Total	55.4	77.3	24.8

	2	4	6	8	10	12	14	16	18
26	25	32	36	39	40	39	38	34	28
24	37	49	58	62	64	63	61	54	43
22	35	47	54	58	60	59	56	51	41
20	41	56	65	70	73	72	69	61	49
18	40	54	63	68	68	68	66	59	48
16	44	59	69	74	75	75	73	65	52
14	41	52	61	65	67	66	64	57	47
12	45	60	69	75	77	76	73	65	53
10	42	55	64	68	69	69	66	59	48
8	43	57	68	73	73	73	70	62	51
6	37	47	56	59	60	61	58	52	43
4	37	51	60	64	66	65	64	57	45
2	27	34	40	42	43	43	42	37	31

Figure 5-1: Electric Lighting Results Screen Shot

A table in the upper left corner reports the average, maximum, and minimum workplane illuminances for each zone and overall. A 3-D contour plot located below this table displays the distribution of the electric lighting workplane illuminance. A plot located to the right of this table provides similar distribution information displaying in plan detailed point-by-point illuminance values at the height previously specified. SPOT™ automatically determines the workplane points that correspond to each luminaire zone, which is indicated by the color-coding seen on this plot. The workplane zoning corresponds to the luminaire zoning provided and is determined by which luminaire zone provides the highest illuminance to each point. This method provides the most accurate zoning information. For example, if a point falls below design illuminance and is of concern, then it reports the zone which has the greatest impact on that point as the zone that should be adjusted. The user should not be alarmed if the automatic zoning calculation returns zones with jagged boundaries. This happens when a row or set of points straddles between two luminaire zones, both of which contribute equally.

The NEXT >> button on the electric lighting screen will not be activated until the daylighting calculations have finished, which are running in the background while viewing this screen. Once they are finished, the NEXT >> button will activate the photosensor generation calculations window, which will run in the background while the Daylighting Results screen is viewed.

5.2 Daylighting Results

The Daylighting Results screen presents annual daytime workplane illuminances, shown in Figure 5-2. By this point in the program, SPOT™ has calculated a sampling of 10 representative sky conditions. The chosen sampling of sky conditions is discussed in the SPOT™ Development Report. The intent of this screen is to inform the user of overall annual daylight illuminance levels in the space. With this information, albeit generated using only a sampling of design day sky conditions, the user can start making decisions regarding refinements in the luminaire zoning, which zones should be controlled (and how aggressively).

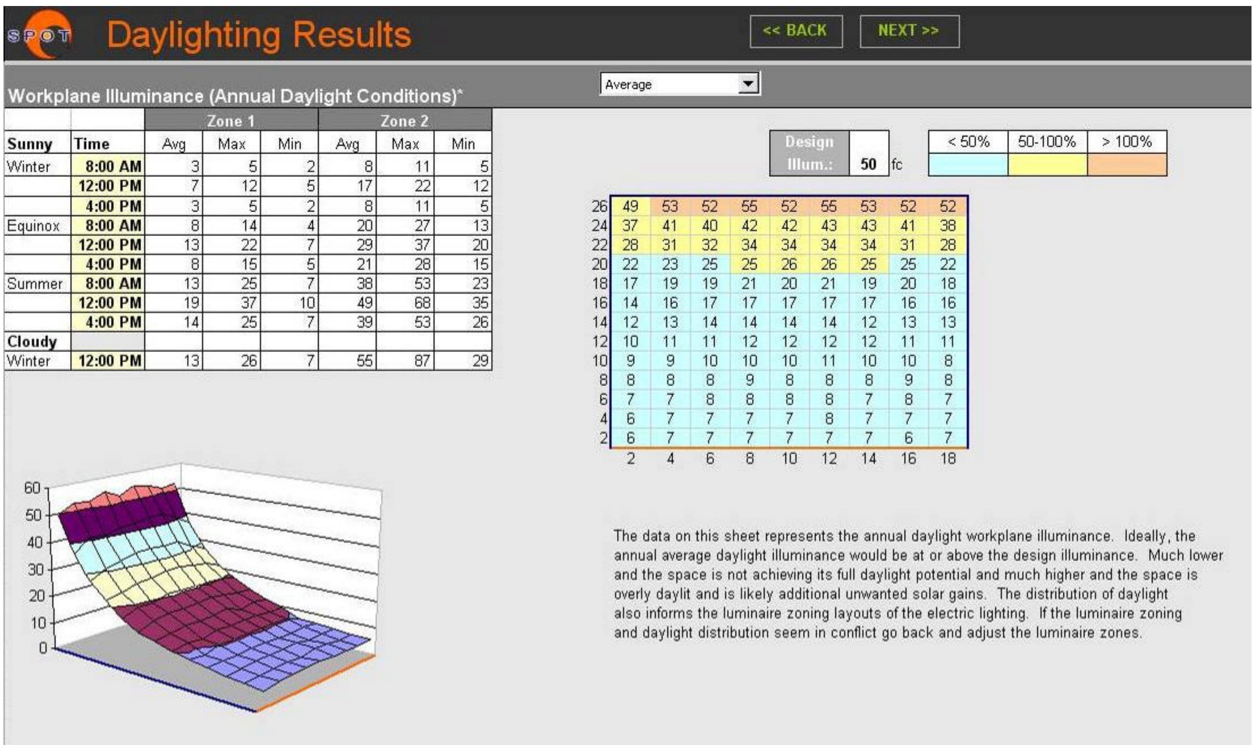


Figure 5-2: Daylighting Results Screen Shot

The table in the upper left corner reports the average, minimum, and maximum illuminance for each luminaire zone at the 10 representative design days and times. A workplane illuminance plot is shown just to the right of the table displaying point-by-point illuminance distribution in the space. When “Average” is selected in the adjacent pull-down menu, this plot displays the average of the 9 representative clear sky conditions and weights them according to the average cloudiness of the city selected with the 1 cloudy sky condition. Each representative day can also be selected in the pull-down menu, and the plot will display workplane illuminance distribution for that given sky condition.

The design illuminance is displayed directly above this plot. Upon arriving on this screen, the design illuminance defaults to the nighttime average electric lighting illuminance rounded up.

This value can be overridden by the user if a different design illuminance is desired. The value entered for the design illuminance on this screen will be used as the intended target illuminance throughout the rest of the program.

The illuminance plot is color-coded to indicate which portions of the workplane meet or exceed the design illuminance. Portions of the workplane that, on average, exceed the design illuminance (color coded orange) are the best zones to control with a photosensor system. Those that fall between 50% and 100% (color coded yellow) of the design illuminance are second priority zones to control. Portions that fall below 50% (color coded blue) of the design illuminance are the least effective zones to control.

At this point, if the daylighting results do not correspond well with the defined luminaire zones and if other luminaire zoning options are available, the user can click the << BACK button twice and redefine the luminaire zones. However, the electric lighting calculations will have to be recalculated.

Like the previous screens, the NEXT >> button will not be activated until the photosensor generator calculations have finished. Once these are ready, the NEXT >> button will initiate renderings of the space if the user chose this option on the Advanced Options screen.

5.3 Photosensor Generator

The last portion of the design tool provides photosensor location recommendations and allows the user to define other photosensor scenarios for further analysis. Figure 5-3 shows a screen shot of the Photosensor Generator screen.

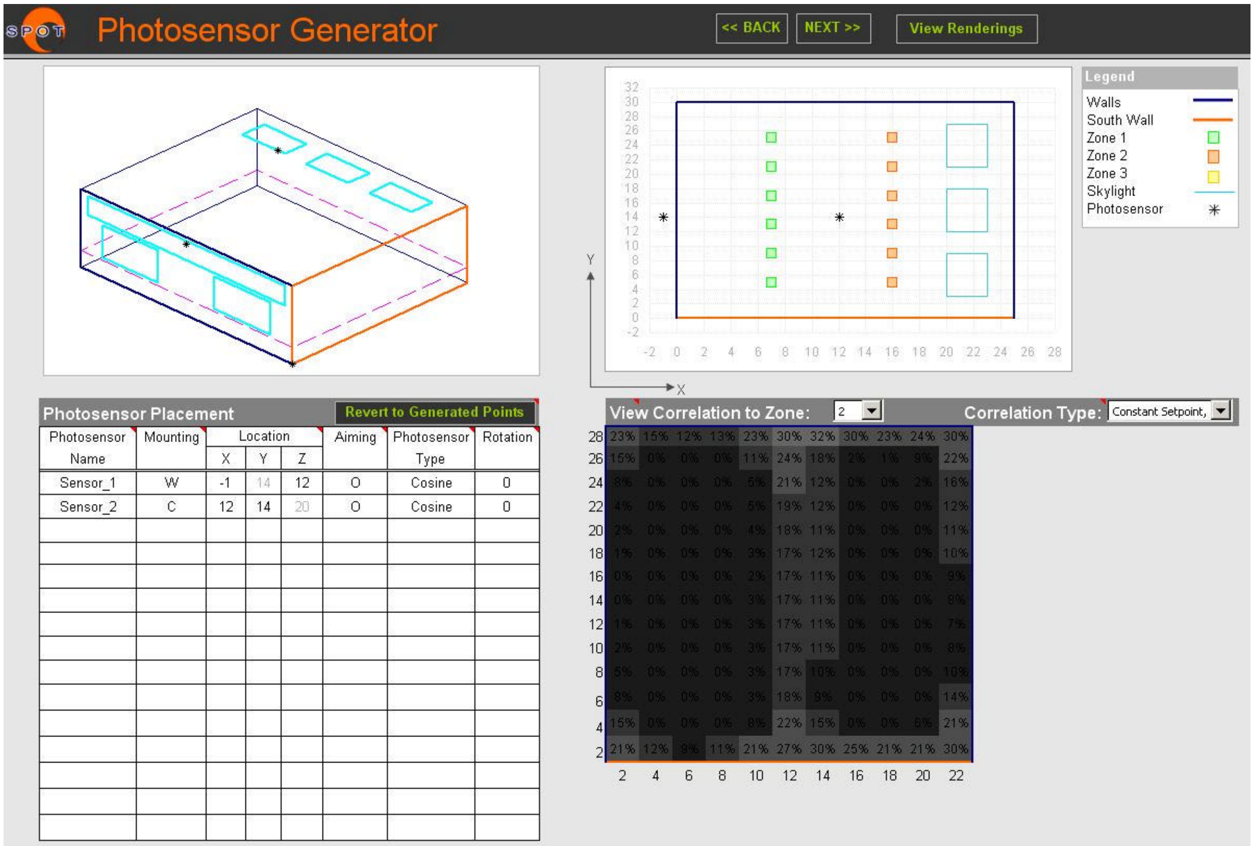


Figure 5-3: Photosensor Generator Screen Shot

For each luminaire zone, a recommended default photosensor scenario is provided in the Photosensor table in the lower left of this screen. The default photosensor locations represent the points on the ceiling that provide the best correlation with the average workplane illuminance for each zone. The are two types of correlation plots available, and can be selected for viewing from the “Correlation Type” pull-down menu; one that is more relevant to constant setpoint systems and one that is more relevant to sliding setpoint systems. The corresponding correlation plots are shown in the lower right corner of this screen. These plots represent a grid of ceiling points and each value is the correlation between the illuminance at that point and the workplane illuminance. The correlation values in this plot are color-coded so that a lower correlation is represented by darker colors and a better correlation is represented by lighter colors. Correlation values for other zones can be displayed by choosing the zone of interest in the pull-down menu located in the header of this plot. The correlation values are accurate for photosensors with a cosine spatial distribution response. The “Revert to Generated Points” button reverts the table to the original photosensor placements, if they have been manually changed by the user.

The photosensor scenarios listed in the table are shown as black dots graphically on the 3-D isometric of the space and on a reflected ceiling plan in the upper right corner. To add a photosensor, simply type in the name and mounting information into the next blank row in the table. To remove a photosensor, delete all the photosensor's information from the row. Blank rows in the middle of this table are acceptable and will be removed upon going to the next screen. The inputs for each column in the Photosensor definition table are as follows:

Photosensor Name - This field defines a name for the photosensor scenario defined on the corresponding line. This can be any name that makes sense to the user, although no blank spaces are allowed in the name. If a space is desired, use an underscore.

Mounting - This field sets the general mounting location for the photosensor. The user can choose from a list of mounting locations. The location fields, the next three columns of the table, specify the photosensor's X, Y, and Z coordinates. Fixed dimensions are greyed out. The following mounting locations are allowed:

> *Ceiling* - A ceiling mount is the default mounting location and is designated by entering a "C" into this field.
>
> *South (S), East (E), North (N), West (W)* - An "S", "E", "N", or "W" designates a wall mounting on either the south, east, north, or west wall, respectively.
>
> *Free (F)* - A free-standing mount can be used to place the photosensor someplace other than the ceiling or walls of the space. This may be useful for placing photosensors beneath luminaries or on top of furniture systems.

Location - These three fields set the specific location of the photosensor in X, Y, and Z coordinates. The coordinate system used is illustrated in the reflected ceiling plan in the upper right corner of the screen. The X values represent the length (or E-W dimension) of the space. The Y values represent the width (or N-S dimension) of the space. The Z values represent the height of the space. One of the fields may be greyed out depending on the mounting location entered. For example, with a ceiling mounted sensor, the Z dimension must equal the height of the space, which is automatically entered and greyed out.

Aiming - This field sets which direction the photosensor is pointing. The default aiming is always perpendicular to the mounting surface chosen. A free standing mounting always defaults with a downward aiming. The user is given six options for aiming; up, down, north, east, south, and west. Diagonal aiming is not currently supported with the SPOT™ interface; the underlying SPOT™ Radiance engine however can handle any aiming. The adventurous user can go behind the scenes and define any desired aiming angles. Choose "Open Loop" for aiming when using an open loop systems with exterior mounted photocells. This will place the photosensor on the surface chosen in the "Mounting" inputs but moved to the exterior of the surface and aimed perpendicular to the surface.

Photocell Type - This field is specified with a pull-down menu showing the current list of defined photocell types. SPOT™ comes with a small library of only a handful of photocell types; however, additional photocell definitions can be imported and saved within the library on the Advanced Options screen (not currently available in Beta release). The following generic photocell types currently are found in the SPOT™ library:

> Cosine - This is a perfectly hemispherical distribution that gives a signal that is linear to photometric illuminance. Many photosensor products on the market attempt to achieve this type of spatial distribution response.
>
> 45^{o}, 55^{o}, and 65^{o} cosine - These spatial distributions are the same as the cosine distribution, but limited in overall scope to a cone with the specified angle. These sensors respond to a cone of luminance centered on the axis line of the sensor.
>
> TWS1 - This is an older sensor distribution from The Watt Stopper with a fairly narrow band of distribution. It is no longer in production.

Rotation - This field sets how the photocell is oriented relative to the room. This field is only relevant for asymmetric photocell responses. For photocells with response functions that are symmetrical around the central axis, the rotation angle does not apply. A value of 0^{o} means the 0^{o} angle of the data is oriented to the north.

The user can choose to view and/or generate renderings at any time from this screen on to the end of the program by selecting any of the View Renderings buttons. If renderings have not been run (if they were not selected initially on the Advanced Options screen), this button will ask if you want to start renderings, sometimes at the expense of a longer final calculation time. If Create Renderings was selected as yes on the Advanced Options screen, this button will activate the Interior Renderings screen, once the calculations are finished.

If renderings have been selected on the Advanced Options screen, clicking the NEXT >> button before they are finished gives the user two options: 1) Let the renderings finish and increase the final calculation time or 2) Choose to terminate the renderings and start the final calculations. Upon clicking the NEXT >> button, all the photosensor scenarios listed in the table will be calculated under each electric lighting zone and more complete representative daylighting conditions. This also starts a set of calculations that will update the workplane illuminances with a complete set of representative daylighting conditions.

5.4 Final Calculations Running

After the Photosensor Generator and other design tool screens, the most extensive set of calculations begin. A transition screen is displayed during this process, shown in Figure 5-4.

The user can select to view renderings, if they are complete, or to start renderings while waiting on this screen. If renderings are started, they may slow down the final calculations.

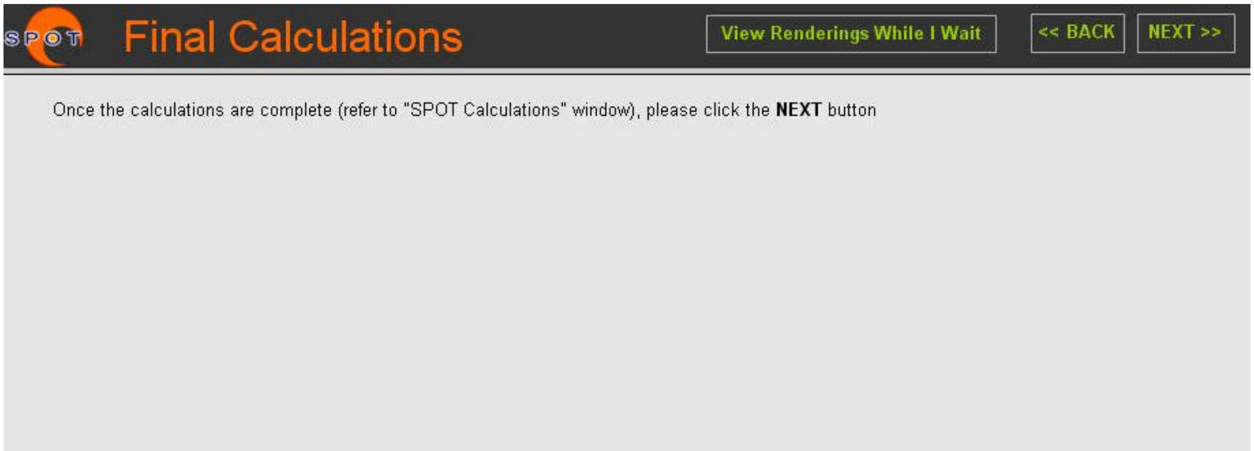


Figure 5-4: Final Calculations Screen Shot

5.5 Interior Renderings

The Interior Renderings screen can be displayed from the Photosensor Generator screen, the Final Calculation screen, or from the Annual Analysis screen by clicking the View Renderings button. If renderings were not selected initially on the Advanced Options screen, this button will ask if the user would like to initiate renderings. Once the renderings have completed, the View Renderings button will be activated and take the user to the Interior Renderings screen, shown in Figure 5-5.

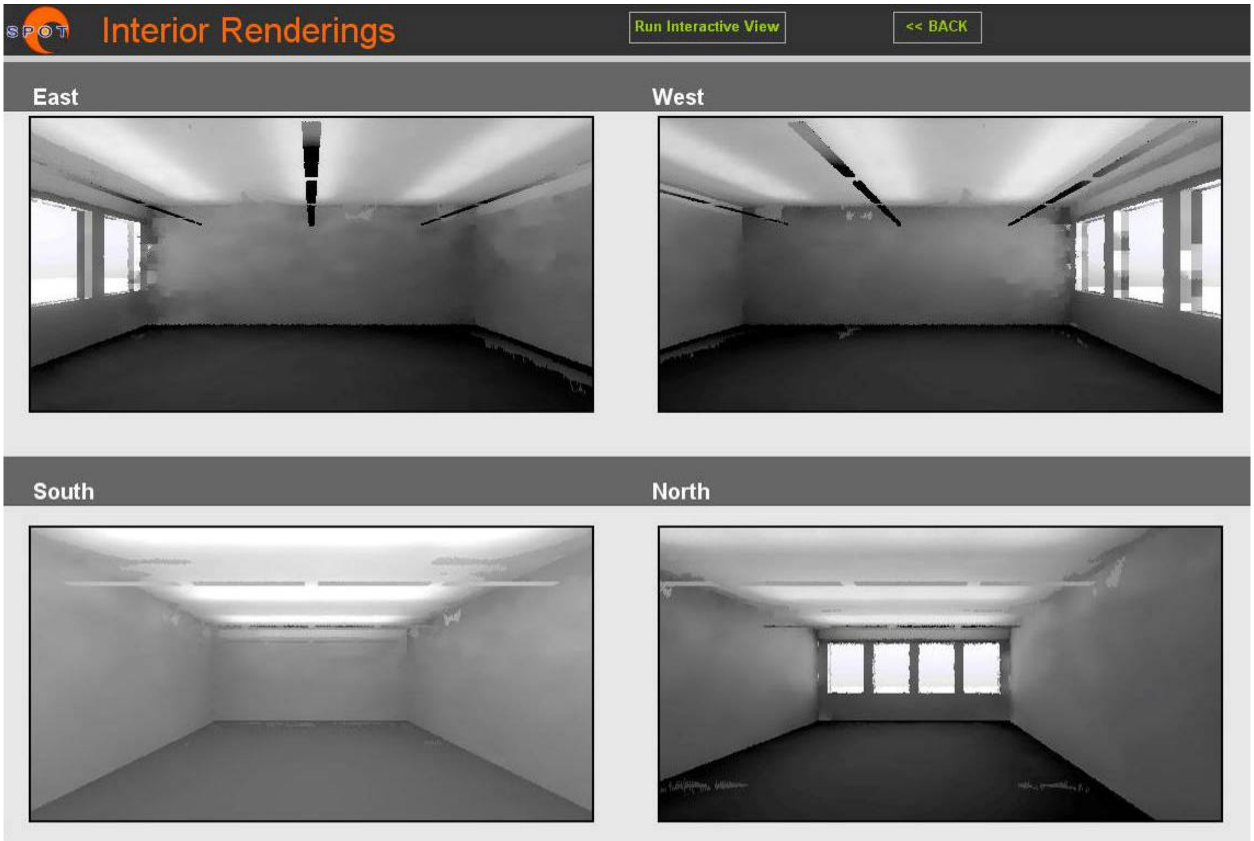


Figure 5-5: Interior Renderings Screen Shot

Four cross-sectional renderings of the modeled space are displayed on this screen, one for each cardinal direction; North, East, South, and West. These images can be copied from this screen onto the clipboard for use in other programs or reports. These images are created based on the Radiance "View Parameter" values on the Advanced Options screen. An inexperienced user of Radiance should beware when adjusting these parameters as they can have a significant effect on the accuracy and quality of these renderings. For the novice, these Radiance parameters affect the overall quality and accuracy of the Radiance simulations.

Selecting the Run Interactive View button will open an interactive viewing program called "rview". This will bring up a new window with a corner perspective view of the space. The image starts very crude and pixelated, but continually refines its resolution until a recognizable image is obtained. From this interactive viewer, other Radiance views can be defined and implemented behind the scenes. Please refer to Radiance documentation for further information regarding the use of "rview".

6.0 SPOT™ Analysis Tools

The final two screens of the software tool are related to the analysis portion of SPOT™. The analysis portion of the tool allows the user to apply various photosensor scenarios to the luminaire zones, adjust the photosensor system settings, and perform annual performance calculations. The analysis portion consists of two screens, the Photosensor Analyzer screen and the Annual Analysis screen, both of which are described in the following sections.

6.1 Photosensor Analyzer

The Photosensor Analyzer is the first screen in the analysis portion of the tool, shown in Figure 6-1. This screen allows you to mix and match the various photosensor scenarios defined on the previous screen and analyze how they will perform under a larger set of representative days and sky conditions. The months and days for these final calculations can be set on the Advanced Options screen; however, the default of equinox and solstice with a two-hour time step is recommended for most applications.

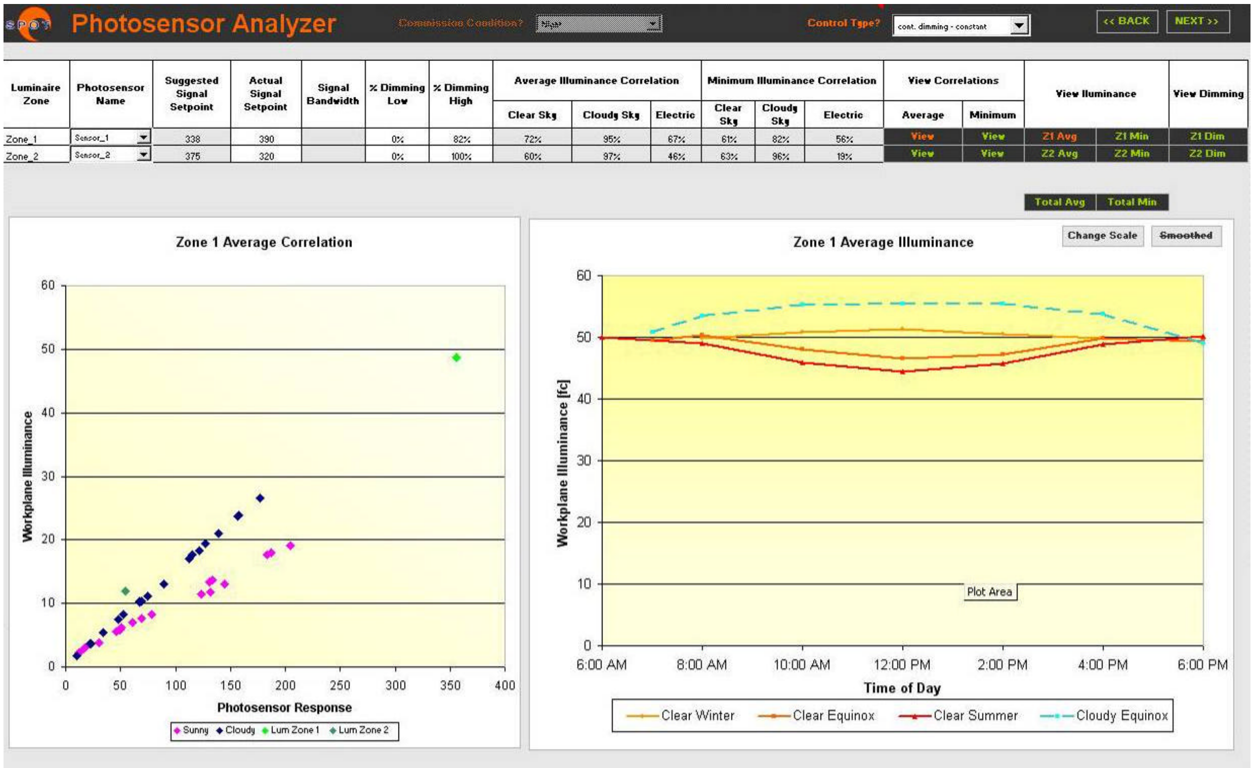


Figure 6-1: Photosensor Analyzer Screen Shot

At the top of the screen, use the pull-down menus to select the condition under which the photosensor system will be calibrated as well as the type of control algorithm that the photosensor system will use.

The photosensor **signal** discussed throughout these sections refers to the response received from the actual photocell. This response is actually in units of mA/Watt and is typically linear to the resulting 0-10V signal received from the photosensor system. This response is then put through signal amplification to receive a 0 - 10V signal.

Control Type - This field sets the type of control algorithm that the photosensor system will use. A pull-down menu is provided with a list of the supported control algorithms. Currently, these are all generalized and ideal control algorithms, explained in greater depth in the SPOT™ Development Report. For analysis of real-world control algorithms refer to Andy Bierman's photosensor studies[3]. The control types supported are as follows:

> *Continuous Dimming, Constant Setpoint* - This control type for continuously dimmable fixtures allows a single input signal to be set, then tries to maintain that signal at all times. If the signal is lower than this setpoint, the luminaires will be on at maximum output, and if it is greater, they will be on at their minimum output. The times between these end conditions, the luminaires will be dimmed accordingly to maintain the single signal setpoint with a combination of electric light and daylight. Figure 6-2 illustrates the relationship between the luminous dimming of the electric lighting system and the sensor response for this type of system.

[3] Refer to Appendix E - References

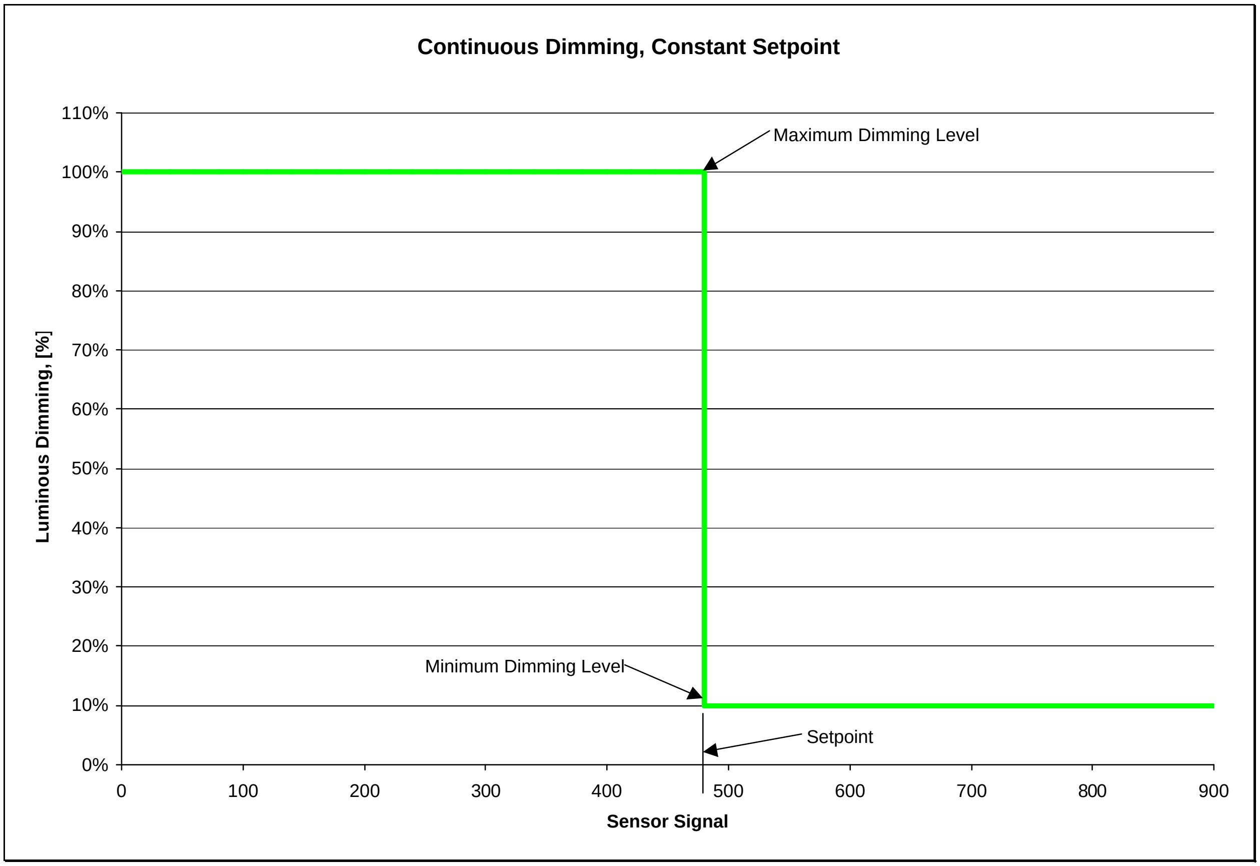


Figure 6-2: General Continuous Dimming, Constant Setpoint Control Algorithm

Continuous Dimming, Sliding Setpoint - This control type for continuously dimmable fixtures allows two input signal to be set as a high setpoint and a low setpoint. The low setpoint gives the point at which the luminous dimming will begin to occur and it will occur linearly with the sensor signal until the high setpoint is reached and the system reaches its maximum luminous dimming. Figure 6-3 illustrates this control type showing the relationship between the luminous dimming of the system and the sensor response.

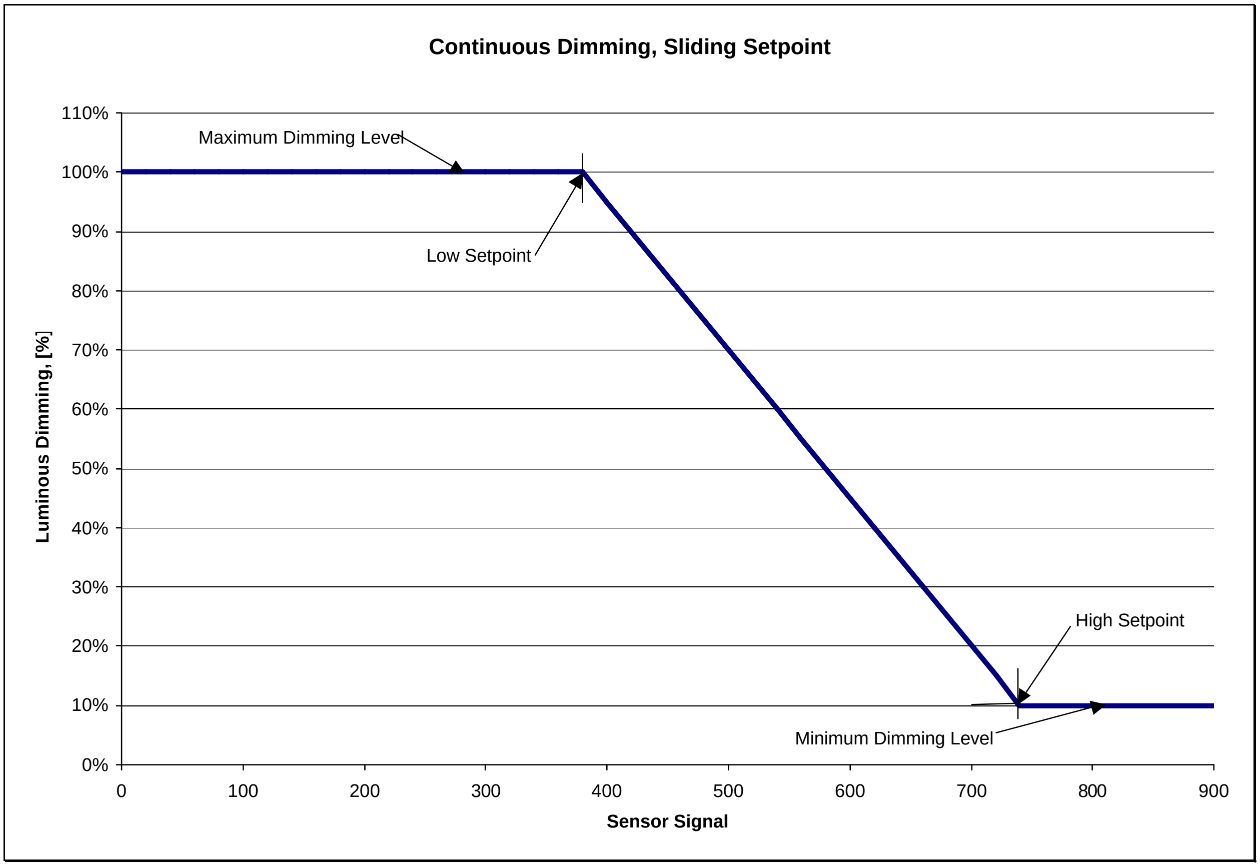


Figure 6-3: General Continuous Dimming, Sliding Setpoint Control Algorithm

On/Off - This control type for non-dimmable systems requires two input signal setpoints. This is sometimes provided with a high and low setpoint and sometimes with a setpoint plus bandwidth setting. Sometimes, the bandwidth is set as a percentage of the low setpoint. The high setpoint is the photosensor signal at which the lighting system will be turned off and the low setpoint is the photosensor signal at which the lighting system will be turned back on. The range between the low and high setpoints is the bandwidth of the system. This bandwidth must be sufficiently larger than the photosensor signal received from the controlled electric lighting zone by itself. If this is not the case, than the system will flicker under certain daylighting and electric lighting conditions, cycling between on and off. SPOT™ will give a warning if such a setting occurs. Figure 6-4 illustrates the luminous dimming versus photosensor signal characteristics of this control type.

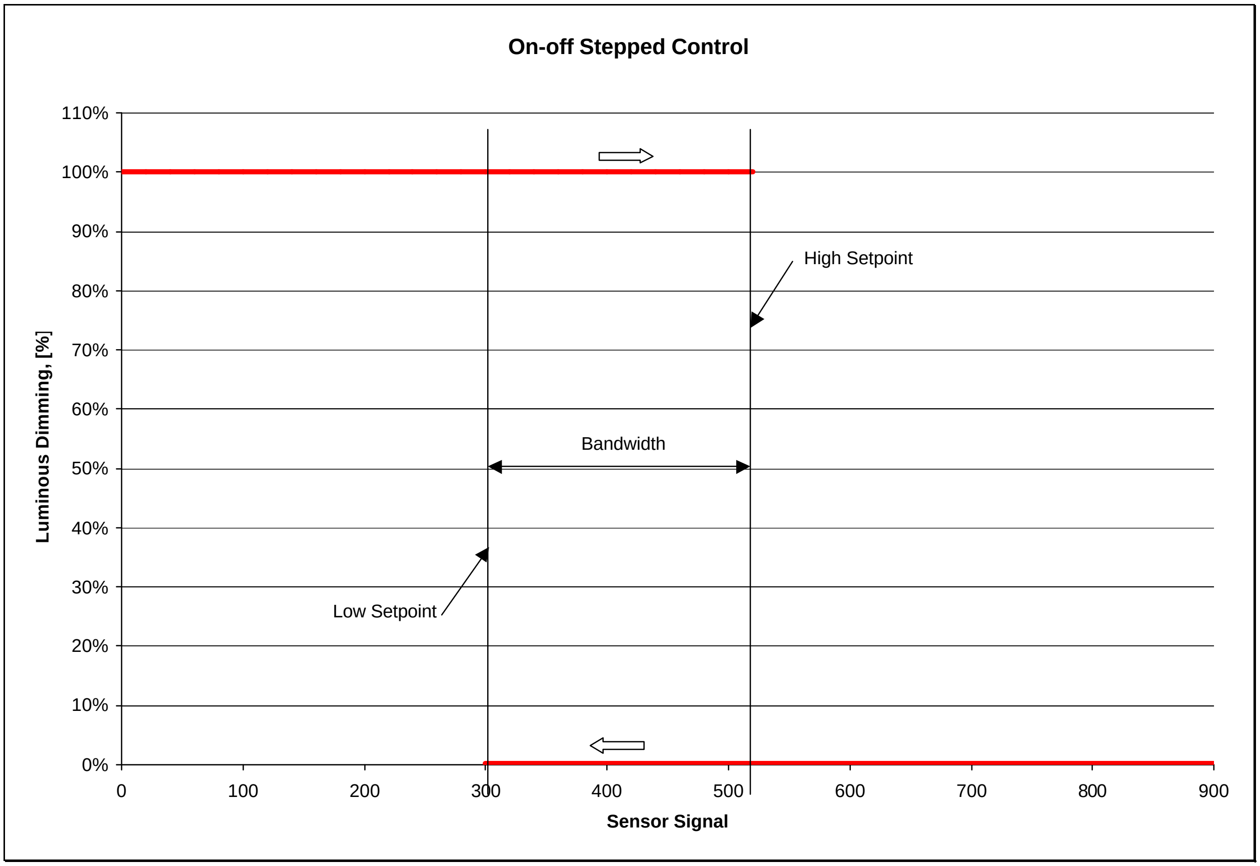


Figure 6-4: General On-Off Control Algorithm

Bi-Level - This control type is for electric lighting systems capable of two distinct light levels including completely off. Four signal setpoints are required for this type of system, or two setpoints and a bandwidth. Two setpoints determine when the lighting system will go from maximum light output to a mid-level light output and back. These are the first high and low setpoints. An additional two setpoints determine when the lighting system will go from a mid-level light output to off and back. These are the second high and low setpoints. Similar to on/off control, the bandwidth of the system is the difference between the high and low setpoints. Also, the bandwidth has to be sufficiently larger than the photosensor signal received from the controlled zone. Figure 6-5 illustrates the bi-level photosensor control type. This control system is popular with 2 lamp fixtures where the lamps can be controlled separately.

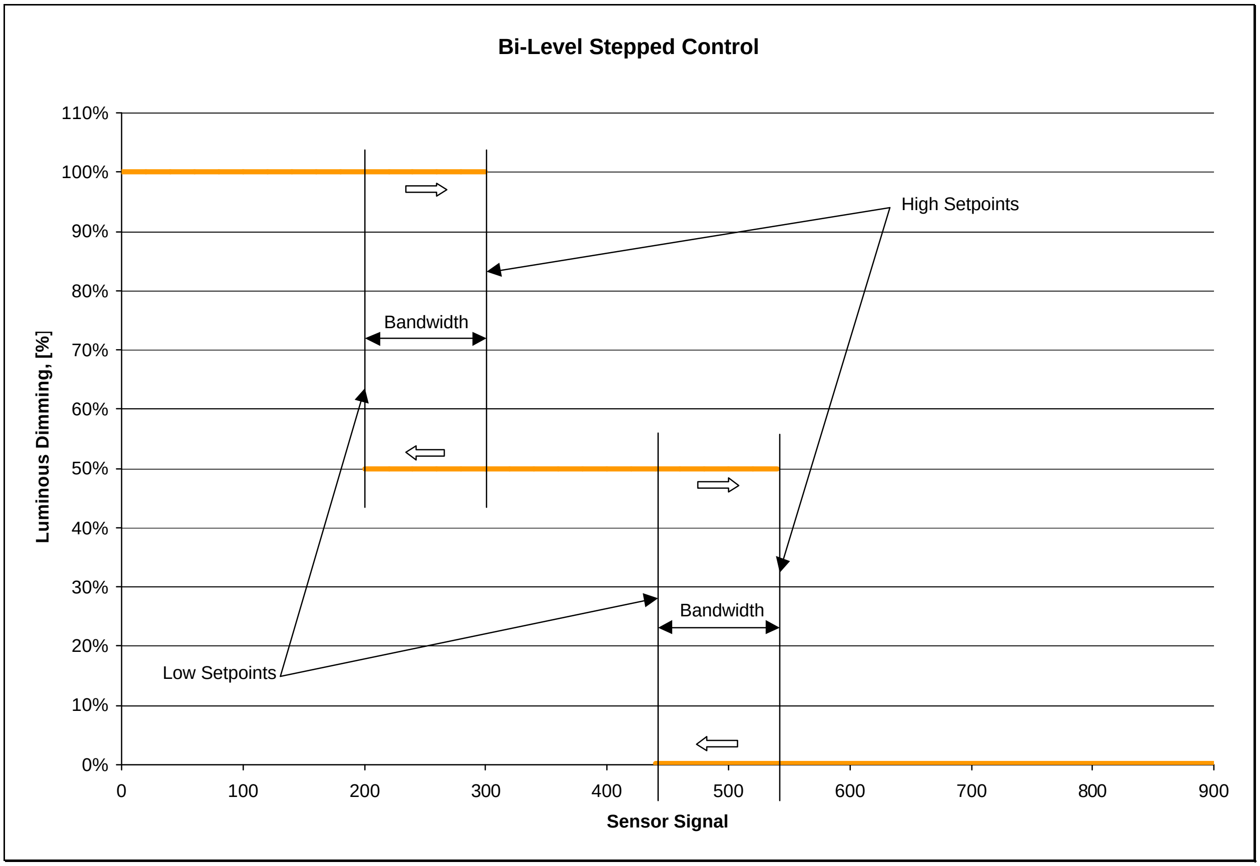


Figure 6-5: General Bi-Level Control Algorithm

Tri-Level - Tri-level control is similar to bi-level and on/off control, but it is used for electric lighting systems capable of three distinct light outputs and off. Three setpoints and a bandwidth, or three high and three low setpoints are required for this type of system. This control system is popular with three lamp systems where each lamp can be controlled individually.

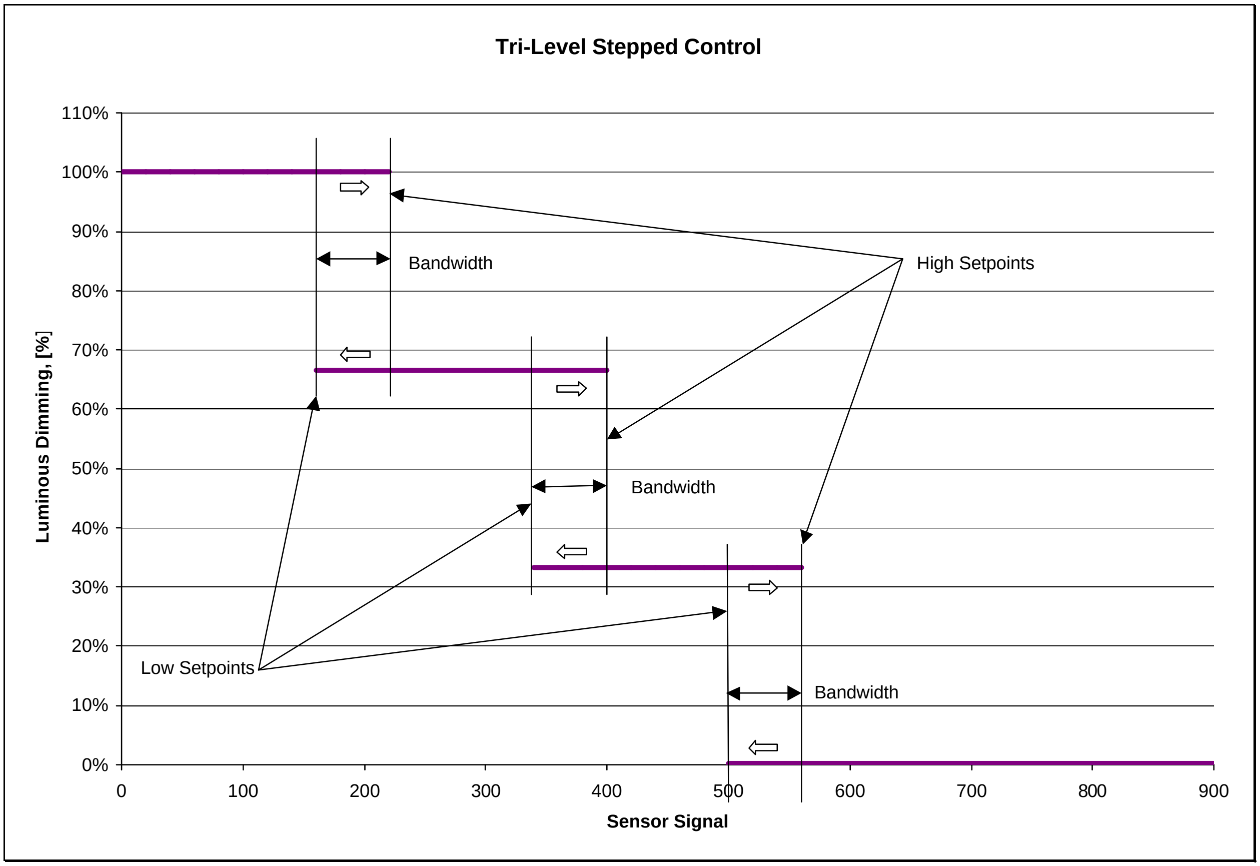


Figure 6-6: General Tri-Level Control Algorithm

Open Loop - In ideal open loop control systems, the photosensor does not receive any signal from the controlled electric lights.

Open loop dimming system characteristics are essentially the same as sliding setpoint, continuous dimming systems. Although, instead of a settable lower setpoint, the origin or a neutral “0” response is assumed to be the low setpoint. This makes sense intuitively since the lower setpoint in a sliding setpoint system is typically set at night and is meant to represent the electric lighting contribution to the photosensor’s signal. Since an ideal open loop system has no electric lighting contribution to the photosensor, it has a low setpoint of “0”.

Open loop on/off, bi-level, and tri-level systems are essentially the same as the closed loop counter parts except little bandwidth is needed.

Calibration Condition - This field sets the time and sky condition under which the photosensor system will be calibrated. A pull-down menu is provided for the user to choose the final calculation times and sky conditions. Night is also given as an option as many photosensor systems rely on a night-time calibration. Currently, only nighttime calibration for constant setpoint is supported in the Beta Release. After selecting the calibration condition, the suggested setpoint will be updated, providing the signal that the system would receive if calibrated under the selected conditions given the selected control type. The maximum dimming value is also adjusted, if necessary, given the calibration condition selected. Additional research and development will be performed to better relate the photosensor system settings to useable instructions to the installing contractor.

The table located in the upper left corner contains a row for each luminaire zone defined, named in the first field of each row. The white fields in this table require user input and the grey fields provide calculated data to the user, the grey fields. The fields in the table include:

Photosensor Name - This field provides a pull-down menu containing the previously defined photosensor scenarios. Select the photosensor to assign to each luminaire zone.

Suggested Signal Setpoint - This field provides a suggested signal setpoint for the given photosensor and luminaire zone combination. These setpoints are calculated based on the system type and the calibration condition settings discussed above.

Actual Setpoint - This field is the actual signal setpoint to use. It allows the user to explore tweaking the setting above and below the suggested signal setpoint. This could be used to mimick field commissioning tricks of temporarily increasing or decreasing the signal of a photosensor by shading or reflecting more light towards it.

Signal Bandwidth - This field gives the signal bandwidth to use if the control system selected requires a high and low setpoint. The bandwidth represents the difference between the two setpoints. The bandwidth is added to the actual setpoint provided earlier to calculate the high setpoint.

Dimming Low - This field sets the lowest level of light output that the electric lighting system can produce. Often, for non-continuous control systems, this will be completely off, or 0%. For continuous dimming systems, there is often a minimum dimming level imposed or desired for psychological reasons and the low dimming level will be between 1 and 10%.

Dimming High - This field sets the highest level of light output that the electric lighting system can produce. Often, for non-continuous control systems, the lights will go to completely on, or 100%. For continuous dimming systems, it is often desired, in the case of an overlit space, to set this below 100% to better meet design illuminance and further improve energy savings. When a continuous control system type and nighttime calibration is selected, if the calculated nighttime level is greater than the design illuminance level, the high dimming level will be calculated automatically giving the dimming level that provides an average equal to the design illuminance.

Average Illuminance Correlation - These fields provide crude correlations calculations between the average workplane illuminance and the photosensor response under clear sky, cloudy sky, and electric lighting conditions. A 100% correlation is ideal and means that the ratio between the average workplane illuminance and the photosensor signal is always the same.

Minimum Illuminance Correlation - These fields provide crude correlations calculations between the minimum workplane illuminance and the photosensor response under clear sky, cloudy sky, and electric lighting conditions. Like the average correlations, the higher the correlation the better, with a 100% correlation meaning that the ratio between the minimum workplane illuminance and the photosensor signal is always the same. Minimum correlations are important to consider if the system needs to ensure that all areas of the workplane receive adequate light.

View Correlations - The View buttons allow the user to select which correlation graph to view. The red View button indicates the correlation graph currently displayed. The correlation graph is shown in Figure 6-7 and represents the variation in sensor readings that the selected photosensor / luminaire zone combination experiences throughout a year for sunny and cloudy conditions. The ideal correlation graph will be very linear between the cloudy, sunny, and electric lighting conditions. In other words, the blue, pink, and green dots should be linearly aligned.

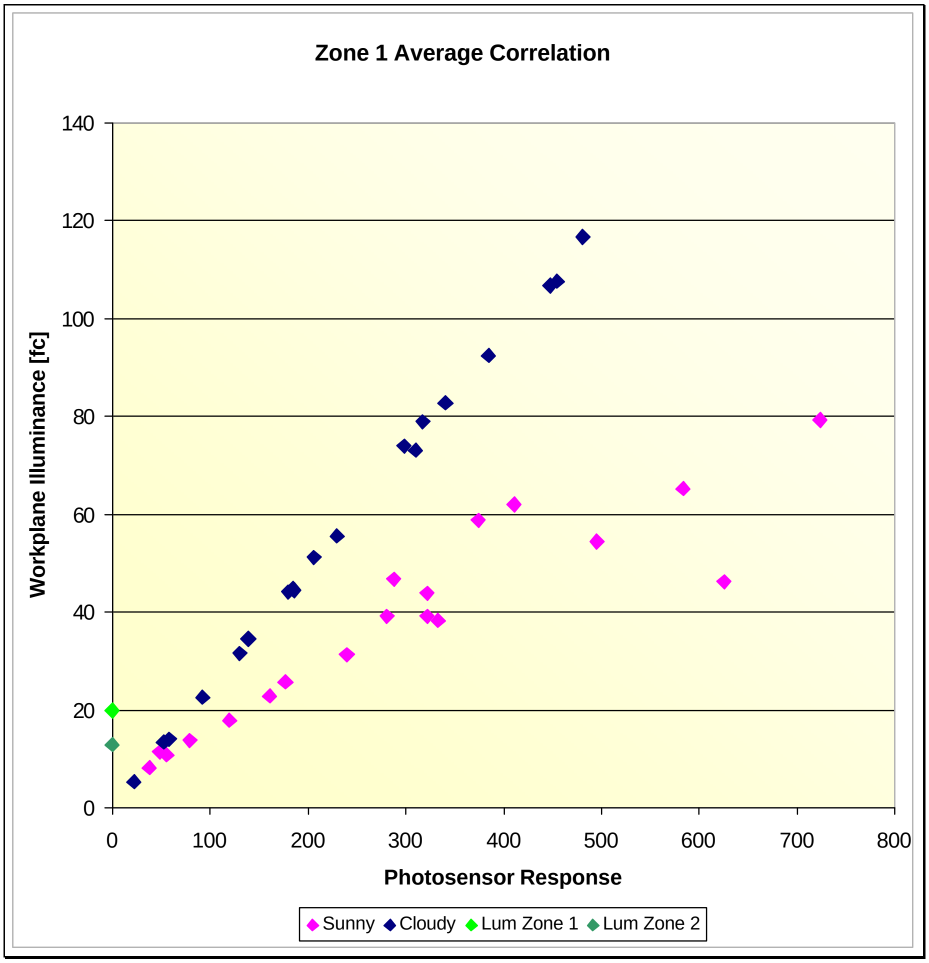


Figure 6-7: Average Correlation Graph

View Illuminance - Upon assigning a photosensor scenario for each luminaire zone, the graph and the last couple of columns of the table are updated to reflect the current settings. The graph, shown in Figure 6-8, presents the resulting workplane illuminances for each day that has been calculated. The target design workplane illuminance is indicated with a green horizontal line. From this graph, it is easy to see which days, if any, will have lower than desired average or minimum illuminance. The user can then interactively adjust the photosensor combinations and settings until they are satisfied with the performance on the given set of sample days.

The “Change Scale” button on this graph allow the user to change the Y-axis scale of this graph for better readability. The “Smoothed” button allows the user to change the plot type from a linear point-to-point to a spline fitted curve.

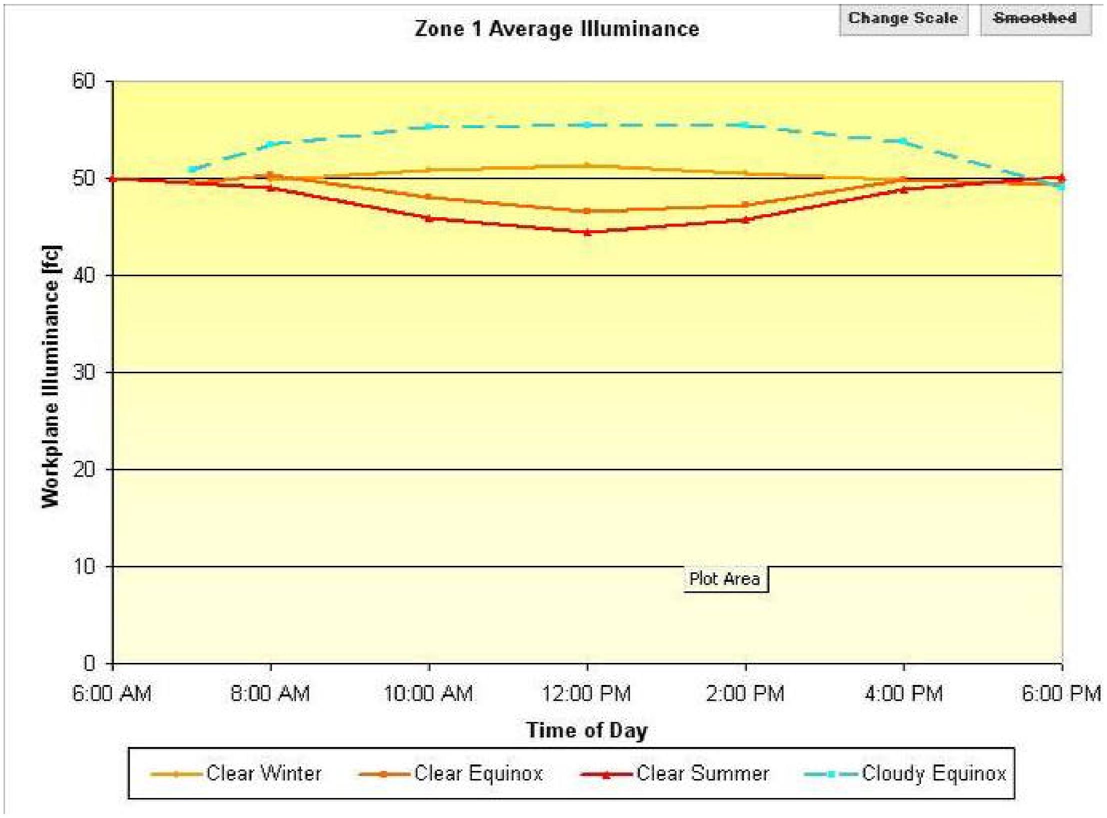


Figure 6-8: Average Workplane Illuminance Graph

6.2 Annual Results

The analysis portion of the tool provides annual performance calculations. Some of the calculations are essentially the same as those performed on earlier screens for the representative days except now they are run using the expanded interpolated Daylight Factor matrices, as discussed in the SPOT™ Development Report, for each 8760 hours of weather data. This provides a more accurate analysis of the photosensor system since it now takes the climate conditions, schedules, and time of the day into account - ie. coincident load type issues. Several sets of results are displayed on the Annual Analysis screen. The user can utilize Excel's print functionality to print any reports desired.

At the top of the Annual Analysis screen is a table of the annual results as shown in Figure 6-9. The table to the left lists the average light output, electric savings, heating load, cooling load, and average, minimum, and maximum illuminance for each zone individually and all zones together.

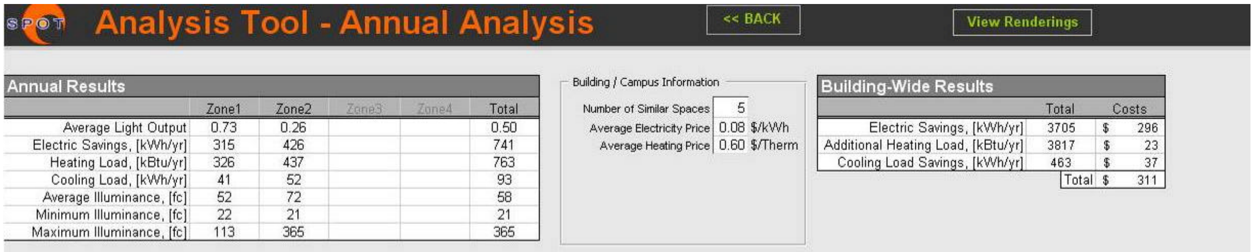


Figure 6-9: Annual Results Table - Screen Shot

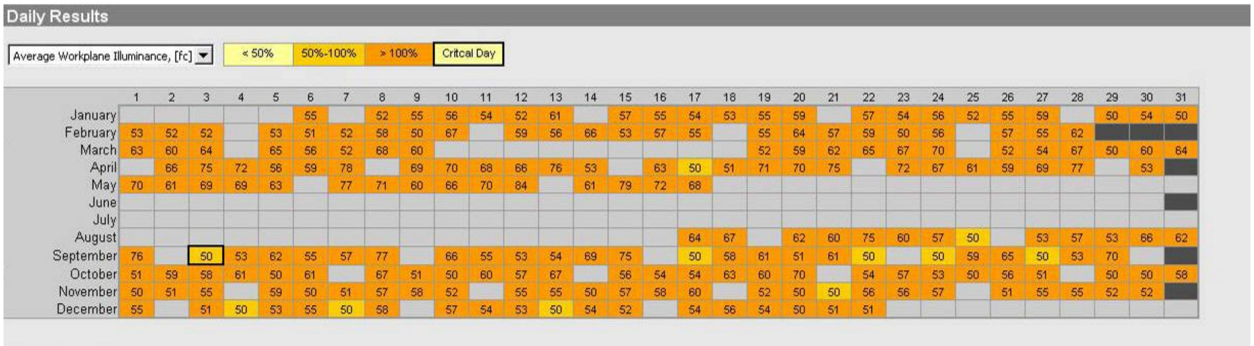
Next to this table are some additional *Building / Campus Information* inputs. Here, the user specifies a multiplier that is used to calculate savings for a group of similar spaces and the annual average utility rates for electricity and gas.

The table to the right provides building wide results for overall energy and energy cost savings. The total building wide energy related cost savings are provided at the bottom of this table. Remember, energy savings is only part of the equation for daylighting. Benefits related to productivity, well-being, health, enhanced learning environments and increased retail sales should be considered and completely outweigh the energy saving benefits of daylighting.

6.3 Daily Results

The next section of the Annual Analysis screen consists of a table showing results for each day of the year, as illustrated in Figure 6-10, and a pull-down menu that selects the data displayed in the table. These results can be used to identify certain days of the year that may be under performing. Each day of the month represents the columns and each month represents the rows in this table.

A color-coding system is provided for this table when illuminance numbers are displayed to help show daily performance relative to the set design illuminance. The **Critical Day** is represented on the graph as the cell with the thick black outline and represents the day that had the lowest average workplane illuminance. If minimum or maximum illuminance is selected in the pull-down menu, then the lowest minimum or highest maximum illuminance is highlighted as the **Critical Day**.



	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
January						55		52	55	56	54	52	61		57	55
February	53	52	52		53	51	52	58	50	67		59	56	66	53	57
March	63	60	64		65	56	52	68	60							
April		66	75	72	56	59	78		69	70	68	66	76	53		63
May	70	61	69	69	63		77	71	60	66	70	84		61	79	72
June																
July																
August																
September	76		50	53	62	55	57	77		66	55	53	54	69	75	
October	51	59	58	61	50	61		67	51	50	60	57	67		56	54
November	50	51	55		59	50	51	57	58	52		55	55	50	57	58
December	55		51	50	53	55	50	58		57	54	53	50	54	52	

	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31
January	54	53	55	59		57	54	56	52	55	59		50	54	50
February	55		55	64	57	59	50	56		57	55	62			
March			52	59	62	65	67	70		52	54	67	50	60	64
April	50	51	71	70	75		72	67	61	59	69	77		53	
May	68														
June															
July															
August	64	67		62	60	75	60	57	50		53	57	53	66	62
September	50	58	61	51	61	50		50	59	65	50	53	70		
October	54	63	60	70		54	57	53	50	56	51		50	50	58
November	60		52	50	50	56	56	57		51	55	55	52	52	
December	54	56	54	50	51	51									

Figure 6-10: Daily Results Table - Screen Shot

The options to display on the table are selected in the pull-down menu and include:

Average Light Output [%] - This option displays the daily average light output for all luminaire zones, weighted according to the overall lighting power.

Average Illuminance [fc or lux] - This option displays the daily average workplane illuminance under electric light and daylight.

Maximum Illuminance [fc or lux] - This option displays the daily maximum workplane illuminance under electric light and daylight.

Time of Maximum Illuminance [hour] - This option displays the time of day, in military decimal form, when the maximum illuminance occurred.

Minimum Illuminance [fc or lux] - This option displays the daily minimum workplane illuminance under electric light and daylight.

Time of Minimum Illuminance [hour] - This option displays the time of day, in military decimal form, when the minimum illuminance occurred.

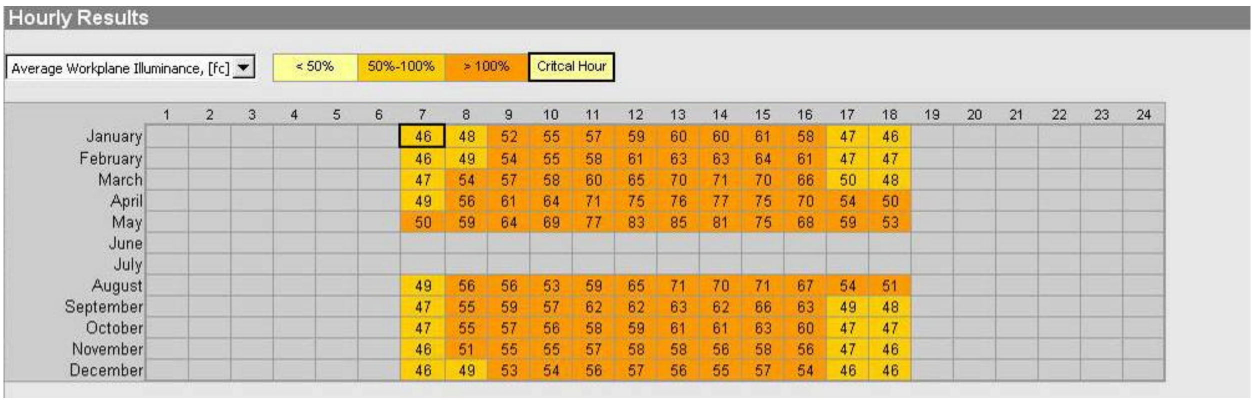
Electric Savings [kWh/day] - This option displays the daily electric savings achieved. This represents the electric savings due to the electric lighting system only and not other indirect electric savings due to reduced fan power and cooling electricity requirements.

Additional Heating Load [kBtu/day or kWh/day] - This option displays the additional heating load imposed on the space due to the lack of heat gain from turned off electric lighting.

Cooling Load Savings [kBtu/day or kWh/day] - This option displays the reduced cooling load provided to the space due to the lack of heat gain from turned off electric lighting.

6.4 Hourly Results

The next set of results consists of a color-coded hourly results table and a pull-down menu to choose the data to be displayed as shown in Figure 6-11. The hourly results table has a row for each month of the year, January through December, and a column for each hour, 1 through 24. The data displayed represents the monthly average for that particular hour. This can inform the user of which times of day are and are not performing well. Similar to the daily results, the **Critical Hour** is highlighted. This represents the hour with the lowest average monthly illuminance in a typical year. If minimum or maximum illuminance is selected in the pull-down menu, the **Critical Hour** highlighted is either the lowest minimum illuminance or higher maximum illuminance.



	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
January							46	48	52	55	57	59	60	60	61	58	47	46						
February							46	49	54	55	58	61	63	63	64	61	47	47						
March							47	54	57	58	60	65	70	71	70	66	50	48						
April							49	56	61	64	71	75	76	77	75	70	54	50						
May							50	59	64	69	77	83	85	81	75	68	59	53						
June																								
July																								
August							49	56	56	53	59	65	71	70	71	67	54	51						
September							47	55	59	57	62	62	63	62	66	63	49	48						
October							47	55	57	56	58	59	61	61	63	60	47	47						
November							46	51	55	55	57	58	58	56	58	56	47	46						
December							46	49	53	54	56	57	56	55	57	54	46	46						

Figure 6-11: Hourly Results Table - Screen Shot

The options to display on the table are selected in the pull-down menu and include:

Average Light Output [%] - This option displays the monthly average light output for all luminaire zones for each hour of the day, weighted according to the overall lighting power.

Average Illuminance [fc or lux] - This option displays the monthly average workplane illuminance under both electric light and daylight.

Maximum Illuminance [fc or lux] - This option displays the monthly maximum workplane illuminance under both electric light and daylight.

Day of Maximum Illuminance [day] - This option displays the day of the month when the maximum illuminance occurred.

Minimum Illuminance [fc or lux] - This option displays the monthly minimum workplane illuminance under electric light and daylight.

Day of Minimum Illuminance [day] - This option displays the day of the month when the minimum illuminance occurred.

Electric Savings [kWh/month] - This option displays the electric savings achieved for the given hour over the entire month. This represents the electric savings due only to the electric lighting system and not other indirect electric savings due to reduced fan power and cooling electricity requirements.

Additional Heating Load [kBtu/month or kWh/month] - This option displays the additional heating load imposed on the space due to the lack of heat gain from turned off electric lighting.

Cooling Load Savings [kBtu/month or kWh/month] - This option displays the reduced cooling load provided to the space due to the lack of heat gain from turned off electric lighting.

6.5 Detailed Results

The last table on the Annual Analysis screen is similar to the table shown on the Design Tool - Daylight Calculations screen except it now represents true annual data rather than an approximation from the given representative days. Similar to the tables discussed above, the table is color-coded to show the relative performance when illuminance values are selected in the pull-down menu, as illustrated in Figure 6-12. The **Critical Point** in the room is also highlighted for average, minimum, and maximum illuminance selections. When average illuminance is selected, the point highlighted is the point in the room that receives the lowest annual average illuminance. When minimum illuminance is selected, the true **Critical Point** is highlighted, which is the point that received the lowest illuminance throughout the year. When maximum illuminance is selected, the point with the highest illuminance throughout the year is selected.

26	81	88	88	92	88	90	89	87	86
24	64	74	79	81	81	82	80	77	69
22	52	60	65	67	68	67	66	62	55
20	46	54	59	61	63	62	60	56	49
18	44	53	58	61	62	61	60	56	48
16	45	57	64	67	69	68	67	61	51
14	41	49	57	60	61	60	58	54	45
12	42	53	61	65	67	66	63	58	48
10	39	49	55	58	60	59	57	52	43
8	38	49	57	61	61	61	59	53	44
6	34	41	48	50	52	51	50	45	38
4	34	44	51	54	55	55	54	48	40
2	25	32	36	38	38	38	37	34	29
	2	4	6	8	10	12	14	16	18

Figure 6-12: Detailed Results Table - Screen Shot

The data to display on the table is selected in the pull-down menu and includes:

Average Illuminance [fc or lux] - This option displays the annual average workplane illuminance under both electric light and daylight.

Maximum Illuminance [fc or lux] - This option displays the annual maximum workplane illuminance under both electric light and daylight.

Time of Maximum Illuminance [h.m] - This option displays the hour and month the maximum illuminance occurred for each point on the workplane.

Minimum Illuminance [fc or lux] - This option displays the annual minimum workplane illuminance under electric light and daylight. This is the absolute critical point of the space. **Error! Reference source not found.** shows the minimum illuminance for this example and shows the critical point illuminance of 5fc highlighted.

Time of Minimum Illuminance [h.m] - This option displays the hour and month the minimum illuminance occurred for each point on the workplane.

Appendix A - Frequently Asked Questions

1.) What is SPOT™?

SPOT™ stands for Sensor Placement Orientation Tool. It is a software package that helps architects, engineers, lighting designers and electrical contractors establish the correct photosensor placement relative to the proposed daylighting and electric lighting design and to analyze overall lighting design performance.

SPOT™ was developed for designers, design engineers, building scientists, contractors, facilities managers, and commissioning agents to provide a relatively simple way to test and evaluate the selection and placement of a photosensor(s) during design in order to promote optimal daylight harvesting, increased energy savings, and higher occupant satisfaction in the built space.

2.) What are the computer system requirements for SPOT™?

Windows 2000, Windows NT, or Windows XP
Excel ’97 (or higher)
400 MegaHertz
128 MegaBytes

3.) How does SPOT™ work and what programs will be installed on my computer with the install package?

SPOT™ basically runs as an Excel interface on top of a Radiance engine using Python as the scripting language. SPOT™’s install package includes:

SPOT™ Excel Template
An abridged version of Radiance for Windows
Python v 2.3
Numarray (a matrix module to Python)

4.) Do I need to know Excel or Radiance to use SPOT™?

No. A working familiarity with Excel may be helpful, but it is not necessary. Radiance will be largely invisible to the majority of users, and only runs behind the Excel interface. Advanced Radiance users may use the “Advanced Options” screen to interact with Radiance through the Excel interface or directly by manipulating the Radiance files, but this is NOT required in the execution of SPOT™ and is not recommended unless you are a skilled Radiance user.

5.) Where does SPOT™ save my work?

SPOT™ automatically creates a file with your project information when you advance the project with the **Begin Project >>** button. It saves the project information in a folder automatically named with the Project Name. This folder is located in the "Parent Directory" that the user establishes on the opening screen of SPOT™. After launching SPOT™ it is necessary, as with most programs, for the user to periodically (frequently) save his or her work using the save icon, or "save" from the pull down menu to insure no information is lost.

6.) What are all the numerous files created by SPOT™ and do I need to save them?

These files are support files created by Radiance. They store the inputs used by SPOT™ to run the calculations. Should you delete these files you will need to re-start a project from the beginning so that these files are recreated.

7.) What are "Radiance Advanced Options" and should I use them?

The default SPOT™ settings have been optimized to minimize the run-time (calculation time) of the program. The Advanced Radiance Options allows the experienced Radiance user to manipulate the default settings in Radiance if he or she desires to refine a particular setting for advanced study. This screen is intended for people familiar with Radiance and its methodology. However, others are welcome to experiment with the settings to learn more about the influence of various inputs on the results. Be aware, that changing the settings may increase run-time and decrease the accuracy of the results.

8.) What are average run-times for SPOT™?

This depends upon on the computer system on which SPOT™ is running. On newer machines, typical run-time may be 20 to 30 minutes, the majority of which will occur for the final calculations performed between the Photosensor Generator screen and the Photosensor Analyzer screen.

9.) What geometrical inputs are allowable for my space?

SPOT™ builds the geometry for the user based on the numeric information input into the Excel interface. Currently, the interface creates orthogonal geometries and can accommodate windows, skylights, and interior and exterior lightselves.

10.) Can I input a geometry directly from Autocad?

No, SPOT™ cannot currently perform this function.

11.) How will the results be presented and will SPOT™ create an image of my space?

Results will be created in Excel tables and graphs formats, which the user can either print or copy and paste into other reports. A Radiance image will be created of the space modeled and will be saved as a .jpeg in the project directory.

12.) Can I model more than one space at a time?

No SPOT™ is designed to analyze a single space in isolation.

13.) Is there any technical support provided for SPOT™?

Send an e-mail to spotsupport@archenergy.com.

Appendix B - SPOT™ Case Studies (to be added)

Test Classroom #1 - Vary Location

Test Classroom #2 - Vary Orientation

Test Classroom #3 - Vary Electric Lighting, Indirect, Semi-Indirect, Direct

Test Classroom #4 - Vary Photosensor Types

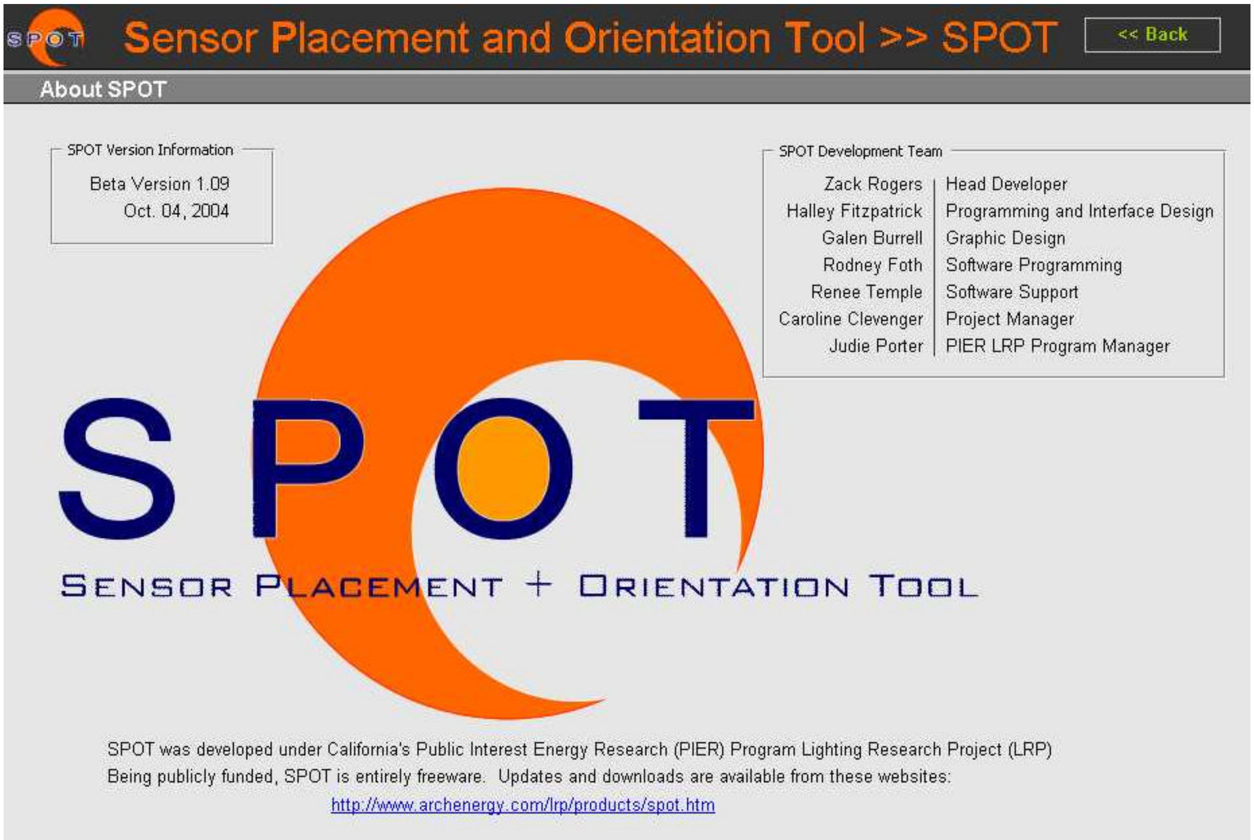
Test Classroom #5 - Vary Photosensor Location

Test Classroom #6 - Vary Photosensor Orientation

Elementary #30 - Compare to Measurements

Test Classroom #7 - Vary Control System Type - Sliding vs. Constant Setpoint

Appendix C - About SPOT™



Appendix D – Copyright Information

This software requires access to the Radiance lighting analysis software, please see license agreement information below, and to the Excel spreadsheet application version 97 and/or above, which are copyrighted by Microsoft Corporation.

SPOT™ is a trademark of Architectural Energy Corporation. All other trademarks are owned by their respective owners.

The Radiance Software License, Version 3.5

Numarray Copyright (C) 2003, 2004 Peter J. Verveer

Appendix E – References

Bierman, A and Conway, K. 2000. Characterizing Daylight Photosensor System Performance to Help Overcome Market Barriers. *Journal of the IESNA* Vol. 29(no.1): 101-115

Ehrlich, C; Papamichael, K; Lai, J and Revzan, K 2001. A Method for Simulating the Performance of Photosensor-based Lighting Controls. *Energy and Buildings.*

Mistrick, R; Chen, C.; Bierman, A. and Felts, D. 2000. "A Comparison of Photosensor-Controlled Electronic Dimming Systems in a Small Office." *Journal of the IESNA* Vol. 28(no.1):59-73

SPOT Version 3.1

Users Manual

SPOT™

Sensor Placement + Optimization Tool

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December 29th, 2006

The SPOT™ software and Users Manual were developed by Architectural Energy Corporation.

The beta version was prepared with support from the California Energy Commission. The Commission, the state of California, its employees, contractors, and subcontractors make no warranty, express or implied, and assume no legal liability for the information in this manual; nor does any party represent that the use of this information will not infringe upon privately owned rights. This manual has not been approved or disapproved by the Commission nor has the Commission passed upon the accuracy or adequacy of the information in this manual.

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Sensor Placement + Optimization Tool (SPOT™) Users Manual

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Table of Figures

1.0 Introduction

The Sensor Placement + Optimization Tool, or SPOT™, is intended to help designers quantify existing or intended electric lighting performance, evaluate annual daylighting characteristics and help establish the optimal photosensor placement and photosensor system settings for a given space relative to annual performance and annual energy savings. SPOT was developed with classroom daylighting in mind, but can be used for all types of spaces. SPOT handles top and side daylight sources and can model any electric lighting source from existing IES files[1]. This technical manual summarizes the various user interface screens of SPOT and describes the available inputs and outputs.

1.1 Overview of SPOT

SPOT consists of a series of screens that the user navigates sequentially, as illustrated in Figure 1-1 with a flow diagram for the program. The sequence of input and result screens is designed to minimize user wait time. Wait time is reduced by running required calculations behind the scenes before they are needed. Hence, much of the calculation time in the program occurs while the user is interacting with another input screen or reviewing a results screen. Re-calculation of results occurs only when necessary depending on user changes of input parameters. This sequential staging of the interface screens also provides a coherent structure to the process of designing a daylighting and photosensor control system. The program has two main sections: a Design Tool followed by an Analysis Tool. The Design Tool consists of all geometric and site inputs, and calculates electric lighting performance and annual daylighting results and performance. The final stage of the Design Tool provides recommended photosensor placements for the analyzed space. These recommended placements provide good starting points for analysis, but do not necessarily represent the absolute optimal photosensor placement. Further iteration with the Analysis Tool is required to fine tune the photosensor system design. The Analysis Tool is the final phase of a SPOT analysis session and consists of two screens. The first screen allows the user to mix and match photosensor placement and setting scenarios with the defined luminaire zones and analyze the resulting correlations and estimated annual performance. The second screen takes the set photosensor scenarios, analyzes their performance throughout the year using annual hour-by-hour weather data, and provides a variety of annual results allowing for an in-depth review of the system from both a qualitative (light levels) and quantitative (energy savings) standpoint.

[1] IES files are numeric text files provided by lighting manufacturers which define luminaire light distribution patterns.

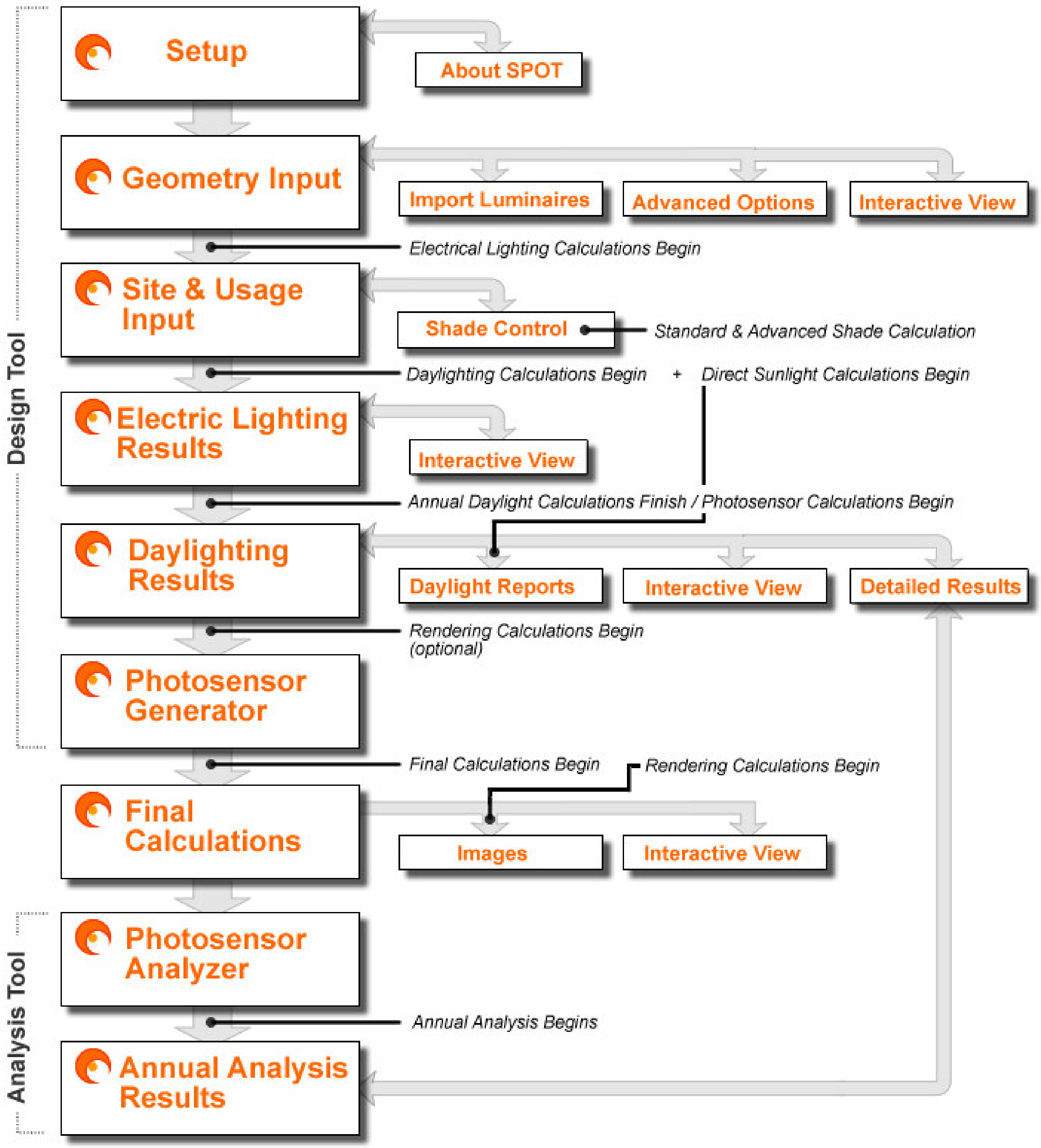


Figure 1-1: SPOT Flow Diagram

1.2 General SPOT Notes

Several important concepts, assumptions and caveats to note before using SPOT are as follows:

- The SPOT Interface Program is essentially an Excel™ template file. This means that anytime a new interface file is saved (ie. Creating a new project name and selecting "Begin Project"), it will be saved as a regular Excel spreadsheet file, titled as the project name. The main template will always be accessible through the Start Menu link or found in c:\Program Files\SPOT. To revisit an already existing model, open the Excel spreadsheet file under the corresponding name and in the corresponding directory.

- Upon opening SPOT, some versions of Excel may ask whether to enable macros -- always choose to enable macros when SPOT opens. Certain versions of Excel, Excel 2000, and newer, have an option that either always enables or disables macros. In these cases, the user may have to go into Excel beforehand and choose to always enable, or always ask to enable macros.

- It is important to navigate through the program with the NEXT >> and << BACK buttons, not by using the worksheet tabs. Excel worksheet tabs are not displayed automatically when starting the program for this reason. The program is intended to be navigated exclusively using the NEXT >> and << BACK buttons. If the tabs are displayed and used to jump from screen to screen, out of order errors will result.

- Upon entering the initial project information, SPOT will automatically save and create a directory in the location selected. It is up to the user to save their work throughout the rest of the program as SPOT does not do this automatically.

- In some cases, upon hitting NEXT >> the user may see several other screens briefly flicker on the screen before the next screen is actually shown. Don't worry about seeing these; it indicates certain calculations are occurring. Also, it is important to wait until the hourglass disappears indicating that the program has finished any calculations before continuing with the program.

- SPOT engine calculations are run in the background in a "SPOT Calculations" window, shown in Figure 1-2. When calculations begin -- which occurs upon hitting NEXT >> -- this window will open and come to the forefront of the screen. In most cases, this window can then be minimized and will continue to run in the background until the calculations are finished. Refer to this window for progress of the current calculation set. Note that sometimes there are two or three sets of calculations; the current calculation set is indicated in the title of the SPOT Calculations window.

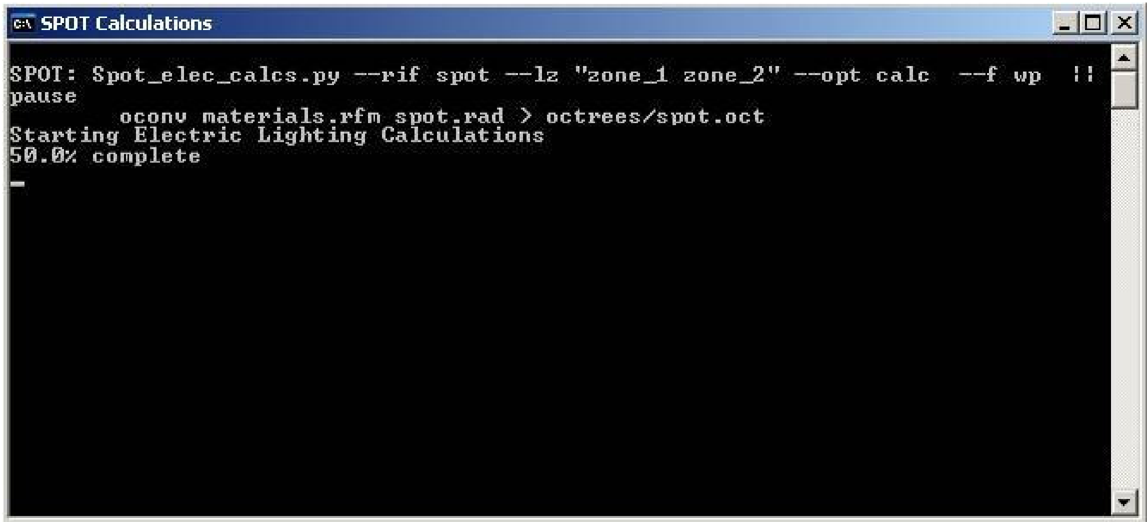


Figure 1-2: SPOT Calculations Window Screen Shot

In some cases, the SPOT Calculations window has to finish before you can continue in the program. You will not be able to do anything in Excel until the calculation finishes. These calculation windows will have an estimated time (ie. “please wait….30sec”) in their title. The calculation time for these windows is relatively short: 30sec – 10 min.

- The electric lighting and design daylight calculations in this release have been validated, but do depend on the Radiance parameter selected on the “Advanced Options” page. The default parameters will give fairly accurate results (+/-10%) for most scenes, however, the experienced user can override these parameters for varying levels of accuracy.

- The annual calculations are based on IESNA recommended CIE sky models that are applied to annual climate (TMY2) data. The calculation method uses the direct illuminance (illuminance from a 5^{o} circumsolar region) and diffuse illuminance (sky illuminance) to weight cloudy and sunny conditions. The method provides annual accuracy similar to the daylight coefficient approach of the DAYSIM software. Note, that while annual averages with this method will be fairly accurate, specific day illuminances (particularly under partly cloudy skies) are close estimates but will never accurately represent a future partly cloudy sky condition.

- The SPOT Development Report and the SPOT Daylight Autonomy Report, both referred to throughout this manual, provide technical background information. See Appendix F for more information. These reports can be downloaded from the SPOT website: www.archenergy.com/SPOT

- The SPOT Excel sheets are protected so that accidental changes to fields other than the apparent input fields do not occur. Protecting the sheets prevent the user from selecting certain cells. If copying of any tables or cells is desired, select Tools -> Protection -> Unprotect Sheet. Be careful not to change any non-input cells while the sheet in unprotected. If you do re-protect, after copying information, check “Select Unlocked Cells” only.

- The << BACK button is only activated if the current SPOT Calculation window is finished. If the calculations do not need to finish, ie, if a change is going to be made in the design, the user can manually close the SPOT Calculation window before it is finished by clicking on the “X” in the upper right corner. Then the user can go back to a previous page and make any desired changes. It is important that after manually closing a calculation window, you hit the << BACK button. Trying to continue on after manually stopping a calculation window before it finishes will result in program errors.

- Throughout the program, a red triangle tag on the screen indicates a help message. Move the mouse over the red triangle to see the help message. A help menu has been added to the program and is available at any time by hitting Ctrl + H.

2.0 SPOT Setup

The project set-up screen is displayed upon opening SPOT, shown in Figure 2-1. This screen allows the user to set up initial project information and access the About screen.

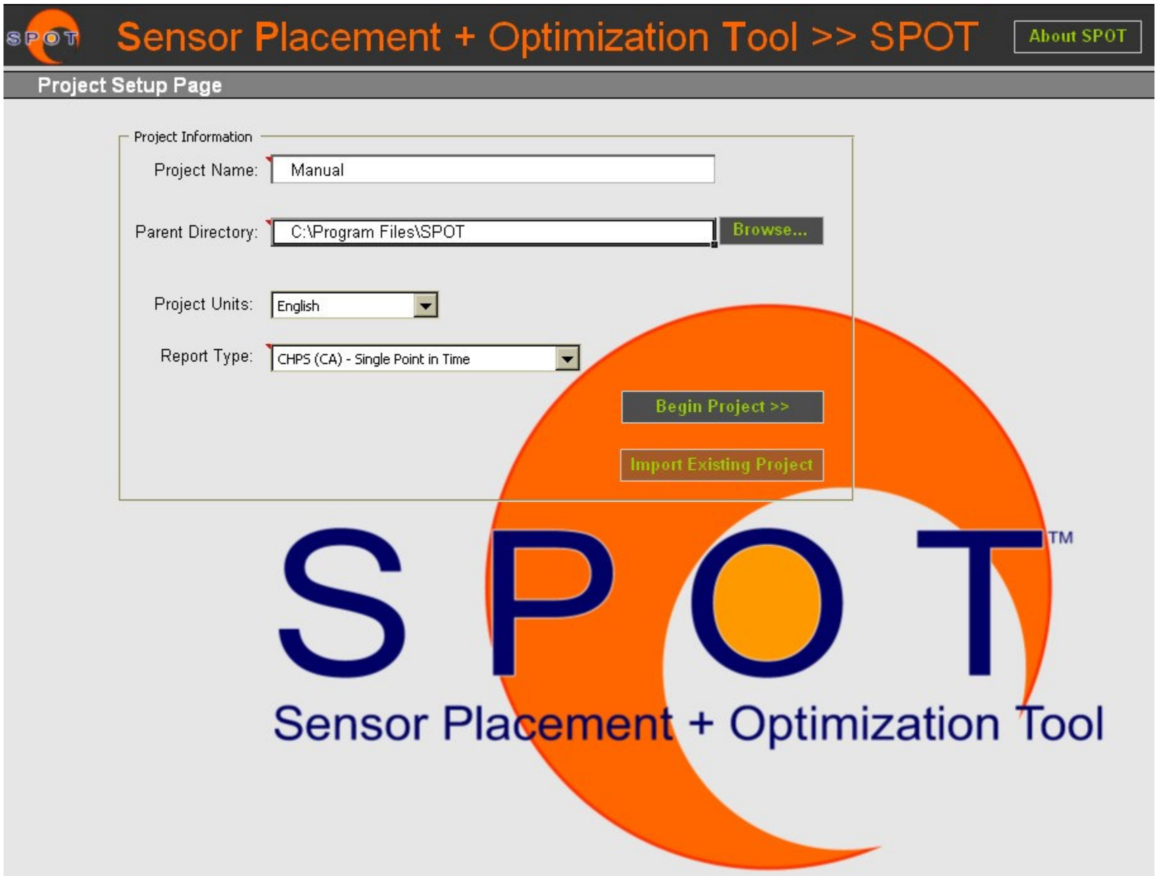


Figure 2-1: Project Setup Screen Shot

2.1 Project Information

The first thing a user sees when starting a new SPOT project is the Project Information Screen, where several key pieces of information get entered.

Project Name – This sets a name associated with the current project. A sub-directory within the parent directory will be created with this name to contain all the data files associated with the current project.

Parent Directory – This sets a directory location selected by the user that will contain the project sub-directory. Selecting the Browse... button allows the user to navigate the computer's directory structure to find the desired parent directory.

Project Units – This pull-down menu allows the user to choose between SI (metric) and English units.

Report Type – This pull-down menu allows the user to pre-select a daylighting metric report that will be generated for the space being analyzed. Refer to Section 5.2.2 for more information on the various daylighting performance metric reports available. The report to view can be selected later, and multiple reports can be viewed for any SPOT model. However, by pre-selecting a report the necessary setup parameters will get automatically set, as noted by the notification window shown in Figure 2-2, and various prerequisite checks will get enabled that provide an immediate warning if a given daylight model does not pass the selected daylighting metric prerequisites.

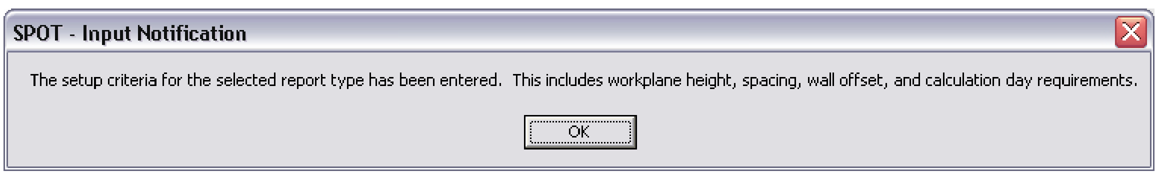


Figure 2-2: Report Type Setup Adjustment Notification

Begin Project - The Begin Project >> button takes you to the first screen, Geometry Input, and saves the file. The file will automatically be saved to the specified directory and will be named according to the project name. If at a later time you would like to revisit the project, find the project in the directory specified and open the Excel file with the project name. <u>It is up to the user to save any changes in their project from this point forward.</u> Whatever page is active when the program is saved will be the active page upon re-opening the program. Be sure to save before closing down the program.

About SPOT - The About SPOT button displays SPOT version and development information and copyright information.

3.0 Geometry Input

On the Geometry Input screen, the user defines the room geometry and electric lighting layout of the space to be analyzed. SPOT's geometric modeling capabilities are limited to relatively simple, orthogonal, spaces with a limited number of elements. Future versions will allow more complex geometry to be modeled in other CAD packages and imported to the program, bypassing SPOT's internal geometry modeler.

At anytime while defining the model geometry, the Run Interactive View button can be used to display a quick interactive nighttime rendering of the current model in a viewing program called "rview". This is helpful to ensure the space has been modeled as intended. Note that before electric lighting has been defined, the scene will be viewable but 'lit' purely with a false ambient brightness. The image starts very crude and pixelated, but continually refines its resolution until a recognizable image is obtained. From this interactive viewer, other Radiance views can be defined and implemented behind the scenes. Please refer to Radiance documentation for further information regarding the use of "rview".

3.1 Advanced Options

The Advanced Options button activates the advanced options screen, shown in Figure 3-1, which allows the user to change some of the program calculation settings. The program's default values for these settings are listed. An input field allows the user to override each setting.

Figure 3-1: Advanced Options Screen Shot

Calculations – These fields allow the user to override basic calculation settings.

Months – This field allows the user to specify which months of the year to use for the design daylighting calculations. This field must include the solstices: December (12) for winter solstice and June (6) for the summer solstice and it must only contain months between December and June (ie. 12 1 2 3 4 5 6). If design results for a fall month are desired, choose the corresponding spring month. The months should be entered without quotes and separated by a space.

Design Start Time – This field indicates the first time that will be calculated for each day selected. The time must be an integer and input in 24 hour clock form. This start time is only used in the design calculations, the annual calculations will be performed for hours between sunrise and sunset.

Design Stop Times – This field is the last time that will be calculated for each day selected. The time must be an integer and input in 24 hour clock form. This stop time is only used in the design calculations, the annual calculations will be performed for hours between sunrise and sunset.

Design Time Step – This field is the time step between calculation times for the design calculations only. The times calculated will always include noon, 12:00PM, and will vary off noon by this time step. The start and stop times will always be calculated.

Analysis Time Step – This field is the time step between calculation times for the analysis calculation matrix. The times calculated will always include noon, 12:00PM, and will vary off noon by this time step. The start and stop times are sunrise and sunset times for the analysis calculation matrix. Note that every time specified on the "Site and Usage Input" sheet are still calculated for the annual simulations, interpolated as necessary from the analysis calculation matrix.

Create Renderings – This field requires either Yes (Y) or No (N) and tells SPOT whether or not to perform renderings of the space. If this option is selected the renderings will begin simulating upon getting to the Photosensor Generator page and they will be viewable while on the Calculating page. The rendering can be viewed on the Calculating page even if not selected to pre-calculate on the Advanced Options page

Field Point Spacing – This field allows the user to specify the spacing distance to use for the calculation grids. If left empty, the program will auto-size the calculation grid to fit the defined geometry width and length. WARNING – A small grid size for a large space will result in a large calculation grid and long calculation times.

Field Wall Spacing – This field defines the offset the calculation grid will have from the walls of the space. The default offset is 2 feet or 0.5 meters.

Shading Devices – These fields allow the user to override the shading device settings.

Blinds Rotation – This field sets the rotation angle of any mini-blinds used in your model. Selecting the ? button provides an illustration showing how this angle relates to the geometry of the blinds.

Blinds Reflectance – This field sets the reflectance of any mini-blinds used in your model.

Lightshelf Characteristics – This field sets the type of Lightshelf to use. The user can choose between an opaque and a translucent shelf. If an opaque lightshelf is selected, the user will set the lightshelf reflectance on the Geometry Input page. If a translucent shelf is selected, the user will set the lightshelf transmittance on the Geometry Input page.

Shade Transmittance - This field defines the openness of any roller shades used in the model. The shade is assumed to be light in color and the openness cannot exceed 25%.

Radiance Parameters – These fields allow the user to override the default Radiance parameters used for calculations and for renderings. **WARNING:** These are advanced options that should only be changed by an experienced Radiance user. For most cases, the default settings will give results accurate to +/-5%. Please refer to Radiance references[2] for a description of these parameters and the Radiance program in general.

3.2 Spatial Characteristics

The Spatial Characteristics screen is used to define the geometric dimensions of the space as well as the solar orientation and surface characteristics. While only orthogonal walls are allowed, the definition of room orientation allows for accurate modeling of the solar position. Figure 3-2 presents a screen shot of Spatial Characteristics input. The "Compass" window and the "Space Isometric" window are updated in real-time to give the user visual feedback of the geometry they are defining.

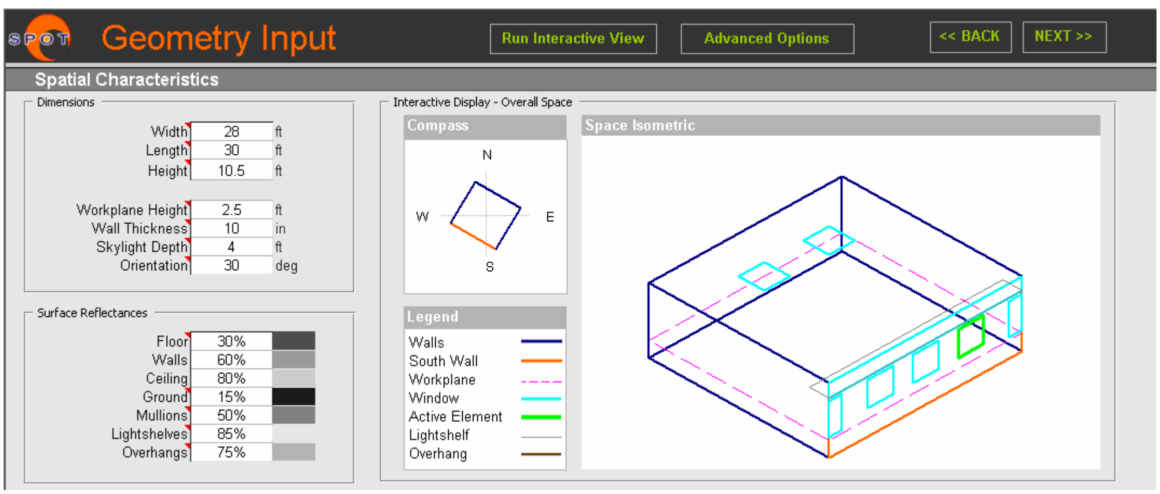


Figure 3-2: Spatial Characteristics Screen Shot

Dimensions – These fields represent the room's overall dimensions and orientation.

Width – This field sets the overall width, or North-South dimension of the space. The dimension measures from interior wall to interior wall.

[2] http://radsite.lbl.gov/radiance/HOME.html

Length – This field sets the overall length, or East-West dimension of the space. The dimension measures from interior wall to interior wall.

Height – This field sets the overall height of the space from finished floor to finished ceiling.

Workplane Height – This field sets the location of the illuminance calculation grid above the finished floor. This can be any height within the limits of the space, but is typically used to represent a workplane, 30 – 36" above the finished floor.

Wall Thickness – This field sets the thickness of the exterior walls, and essentially defines the thickness of any window sills and/or mullions in the model.

Skylight Depth – This field sets the depth of any skylight shafts, essentially the distance between the finished ceiling and the skylight opening. The shafts are assumed to be orthogonal. Splayed skylight shafts are not currently supported with the SPOT geometry modeler.

Orientation – This field sets the space's orientation relative to true south. This input must be between -45^{o} and 45^{o}, since any rotation greater than 45^{o} simply changes which façade is referred to as "South". The "Compass" window shows the user the orientation of the footprint of the space relative to the true cardinal directions. Throughout the program, the south façade is denoted as the orange façade, while all other facades are shown as blue.

Surface Reflectances – These fields represent the reflectance of the various surfaces in the model. All reflectances in SPOT are modeled as monochromatic -- or shades of gray.

Floor, Walls, Ceiling – Sets the reflectance of the floor, walls, and ceiling surfaces, respectively.

Ground – Sets the reflectance of the ground outside the building.

Mullions – Sets the reflectance of any surfaces representing the thickness of the walls. This applies to window sills and window mullions.

Lightshelves – Sets the reflectance of opaque lightshelves or the transmittance of translucent lightshelves. The lightshelves are opaque by default, but can be modeled as translucent if selected on the Advanced Options screen.

Overhangs – Sets the reflectance of any overhangs used in the model.

3.3 Walls and Apertures

The wall and aperture inputs, shown in Figure 3-3, allow the user to define three architectural features per each façade of the space: windows, interior lightshelves, and overhangs. The program allows for up to 10 window inputs per façade, 2 lightshelf inputs, and 2 overhang inputs. The user selects which façade to add architectural features to using the “Architectural Element” pull-down menu. This menu contains an option for each of the four walls (east, south, west, and north) and the ceiling. Once a façade is selected, the user chooses which element type to define using the “Element Type” pull-down menu. The red “delete” button removes the selected architectural feature.

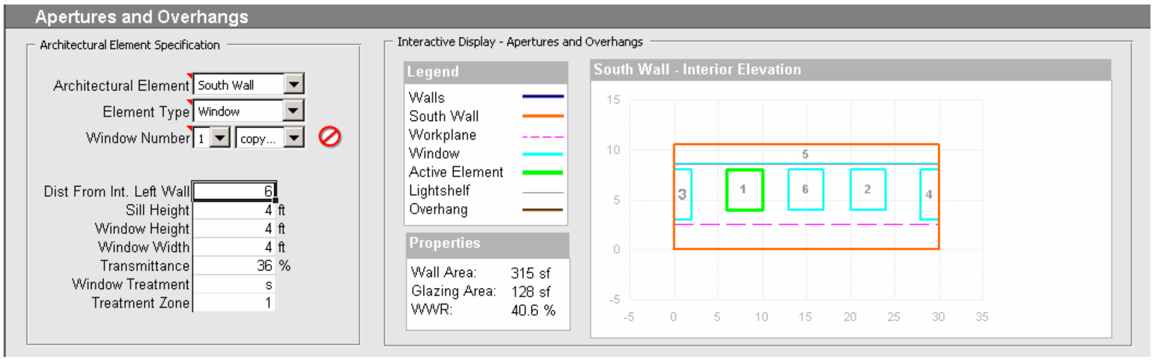


Figure 3-3: Walls and Apertures Input Screen Shot

The “Interactive Display” box, located to the right of the inputs, is updated in real-time to give the user visual feedback of the layout of the façade. The window farthest to the right displays an interior elevation of the architectural element selected, unless the ceiling is selected upon which this window will display a reflected ceiling plan. The Properties window displays current information on the selected architectural element. Displayed in this window is the area of the element, the area of glazing on the element, and its window-to-wall ratio (WWR).

Windows – This element type sets the apertures in the space. Window number 1 is selected first, followed by Window number 2, 3, and so on. Up to 10 windows can be defined for each façade. The “copy…” pull-down menu allows the user to copy a window definition from a previously defined window. The copied window appears directly on top of the original and needs to be moved to an available (non-overlapping) position.

> *Distance from West Wall* – This field sets the window’s distance from the left wall when viewed as an interior elevation. The scale on the interior elevation plot illustrates this dimension.

Sill Height / Distance from South Wall – This field sets the height of the bottom of the window above the floor, or in the case of a ceiling element, sets the distance from the south wall.

Window Height / Skylight Length – This field sets the height of the window or the length of a skylight.

Window Width / Skylight Width – This field sets the width of the window or the width of a skylight.

Transmittance – This field sets the visible transmittance of the window. All glazing transmittances are modeled as monochromatic and use typical double pane clear glass front and back reflection characteristics.

Window Treatment – This field sets solar control option to be applied to the window selected. The user can choose **n** for no treatment, **b** for mini-blinds, **s** for fabric shades, or **t** for translucent glass. The blinds and the shade treatments can then be controlled using manual, timer, or automatic photosensor controls. Settings for the blinds and fabric shades can be found on the advanced options page. Timer based or “active” manual controlled shades are not available in this release.

Treatment Zone – Multiple shade control “zones” can be defined. These zones represent sets of shades or blinds that will be controlled, raised, and lowered, together. The Treatment Zone field assigns the given window treatment (shades or blinds) to that Treatment Zone number. The zone number counts up from 1. The user will specify the control settings for each treatment zone later in the program on the “Shade Control” page.

Interior Lightshelves – This architectural feature creates interior lightshelves in the space. These elements are modeled as infinitely thin surfaces that are either opaque or translucent depending on the setting made on the Advanced Options screen. Opaque lightshelves are the default.

Distance from Left Wall – This field sets the distance between the lightshelf and the left wall when viewed as an interior elevation.

Height above floor – This field sets the height of the lightshelf above the finished floor.

Width - This field sets the width of the lightshelf or the dimension perpendicular to the window.

Length – This field sets the length of the lightshelf or the dimension parallel to the window.

Overhangs – This architectural feature creates exterior overhangs on the selected façade. These elements are modeled as a 3-dimensional parallelepiped (box). Although these elements are intended for the exterior, the adventurous user can use them to model other exterior objects or interior objects as well.

Distance from Left Wall – This field sets the distance between the exterior overhang and the left wall when viewed as an interior elevation.

Height above ground – This field sets the height of the exterior overhang above the ground, which is the same plane as the floor.

Thickness – This field sets the thickness (height) of the exterior overhang.

Width – This field sets the width or the dimension perpendicular to the window of the exterior overhang.

Length – This field sets the length or the dimension parallel to the window of the exterior overhang.

3.4 Electric Lighting

The electric lighting inputs, shown in Figure 3-4, allow the user to select luminaire types and create layouts for up to 4 luminaire zones. The user can select a luminaire type from the SPOT fixture library, or add a new luminaire type by importing a new IES file. The Reflected Ceiling Plan view is updated in real-time and provides visual feedback for the defined luminaire zoning. Each luminaire zone represents a set of luminaires that are controlled together. Often luminaires are grouped together relative to daylight availability. Luminaire zones may also be defined with physical or electrical constraints in mind. For example, in reality a row of connected fixtures is easiest controlled together rather than being split into two or more different luminaire zones. If, upon receiving the annual daylighting illuminance results, the user feels the luminaires should be rezoned and it is deemed reasonable from a physical and electrical standpoint, this screen can be revisited and updated.

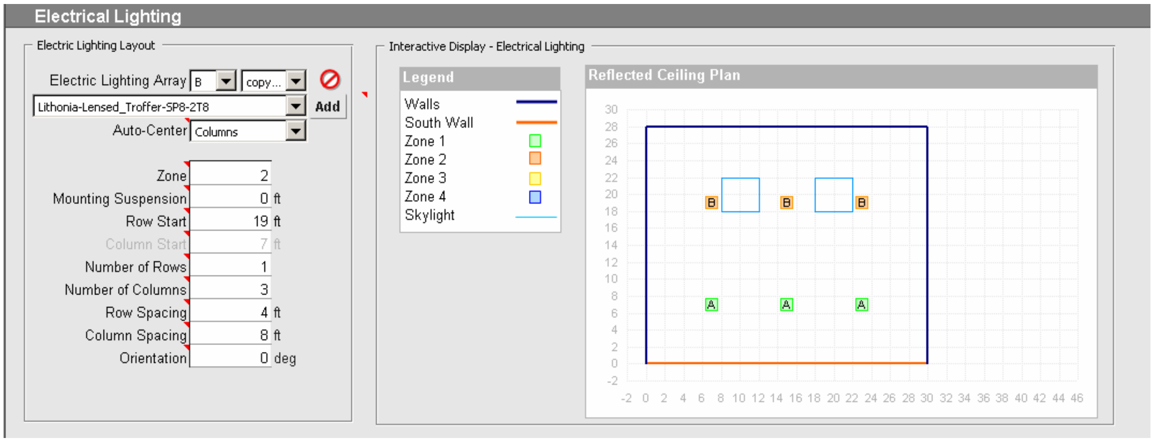


Figure 3-4: Electrical Lighting Input Screen Shot

Import Luminaires – Selecting the Add button will display the Import Luminaires screen, shown in Figure 3-5. This screen displays the available Luminaire Libraries in the three pull-down menus and lists the luminaires currently in the project in the box below. The Luminaire Libraries can be organized with two levels of categories; a first category will typically be used to indicate the luminaire manufacturer, 'SPOT Generic', or other main level of categorization, and the second category will typically be used to indicate a luminaire family, fixture type, or other. The final pull-down menu lists the individual luminaire (IES) files that are found under the first two categories.

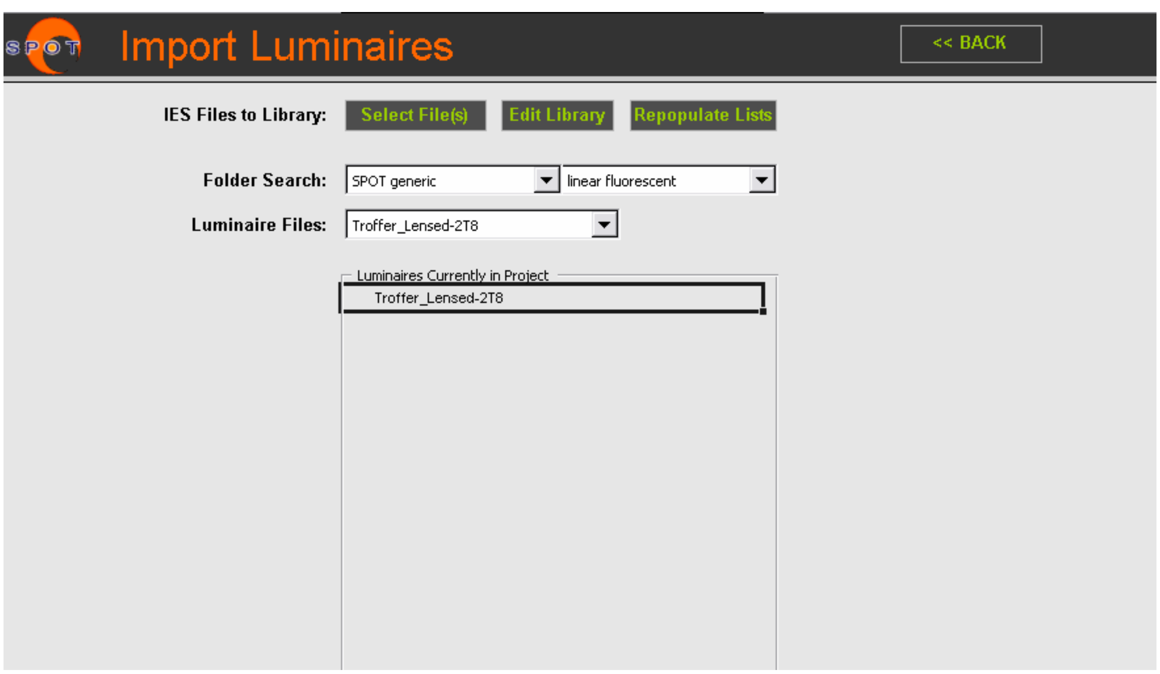


Figure 3-5: Import Luminaires Screen Shot

To add a luminaire to the project, select the desired first and second level luminaire categories and then select a luminaire from the list under the 'Luminaire Files' pull-down menu. The luminaire will then be automatically added to the 'Luminaires Currently in Project' box. To remove a luminaire from the project, simply delete it from this list by highlighting and using the computer's delete key.

To add single or multiple luminaires to the Luminaire Library from existing IES file(s), hit the **Select File(s)** button, navigate to the desired file directory, and choose the desired IES file(s) to import. This will import all IES files selected into the main and sub categories chosen in the pop-up window shown below in Figure 3-6. IES files can either be added to existing directories or new directories can be created.

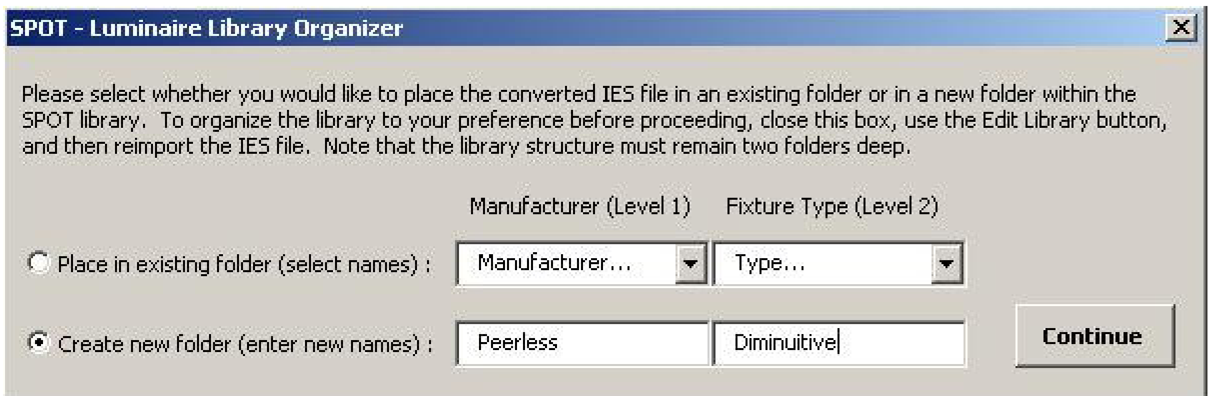


Figure 3-6: SPOT Luminaire Library Organizer Window

Use the **Edit Library** button to edit and organize the names and files in the Luminaire Library, refer to Figure 3-7. The Luminaire Library consists of a (*.rad) and a (*.dat) file for every luminaire in your library. To organize your Luminaire Library, the name of all (*.rad) and (*.dat) files needs to remain the same as the IES file derived from, but the directories in which these files reside can change. All luminaire files have to reside in a two-level deep directory under the c:\Program Files\SPOT\luminaire\ installation directory. The name of the first directory level becomes the name seen in the 1st pull-down menu for 'Manufacturer (Level 1)'. Similarly, the name of the second directory level becomes the name seen in the 2nd pull-down menu. The **Repopulate List** button updates the list of manufacturers, luminaire families or fixture types, and luminaire types in the pull-down menus after new luminaires have been added.

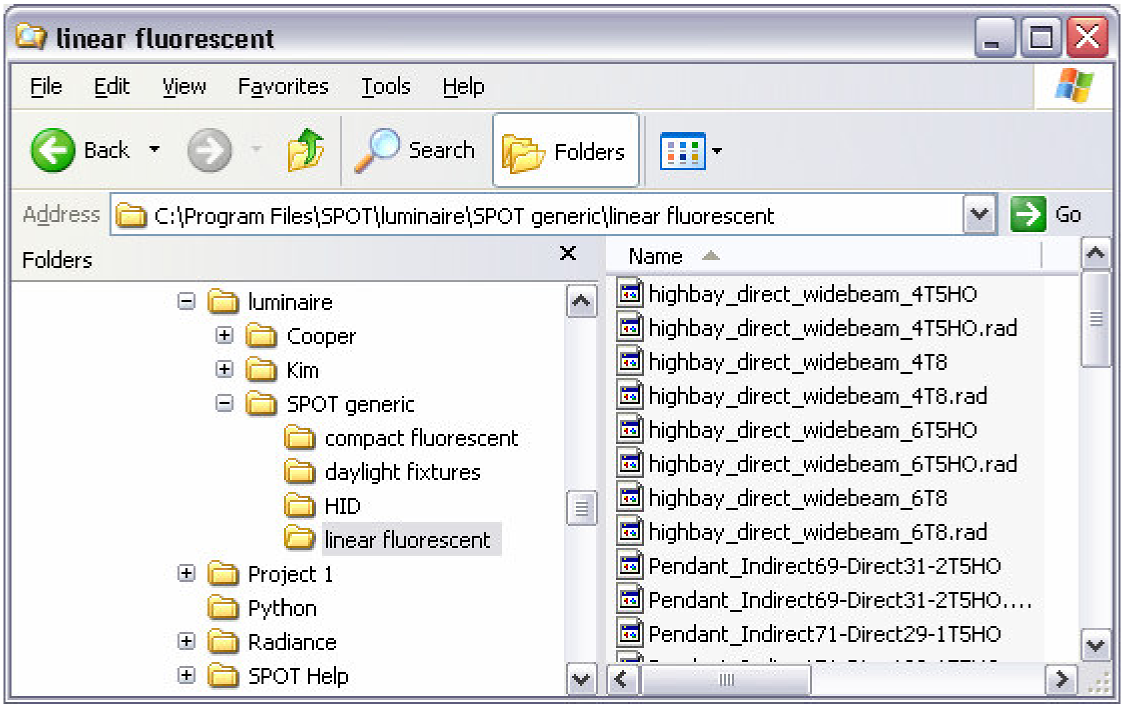


Figure 3-7: Luminaire Library Editing Window

Electric Lighting Layout – These fields define the characteristics of a particular luminaire array. Lighting layouts are created from one or more arrays of luminaires, and these layouts are in turn assigned to one or more zones. The red button deletes the selected array. The "Auto-Center" pull-down menu provides the choice of auto-centering rows, columns, or both. When one of these options is selected, the corresponding inputs for row start and/or column start will be grayed out and set automatically.

Electric Lighting Array – This pull-down menu selects the current electric lighting array for editing. Up to 10 electric lighting arrays can be defined and assigned to up to 4 electric lighting zones. The lighting zones represent sets of fixtures that will be controlled together; electric lighting arrays just provide a way to make ‘zones’ that do not have to be orthogonal in shape.

Zone – This field defines which lighting zone to assign the current electric lighting array to. Up to 4 zones can be defined from the 10 possible electric lighting arrays.

Mounting Suspension – This field sets the suspension height of the luminaires, which is the distance from the center of the luminaires to the ceiling height. This should be zero for surface mounted or recessed luminaires.

Row Start – This field sets the distance of the first row from the south façade.

Column Start – This field sets the distance of the first column from the west (or left hand) façade.

Number of Rows – This field sets the total number of rows.

Number of Columns – This field sets the total number of columns.

Row Spacing – This field sets the distance between adjacent rows.

Column Spacing – This field sets the distance between adjacent columns.

Orientation – This field sets the orientation of the luminaire. An orientation of 0^o aligns the x-axis of the luminaire (defined in the IES file) with the x-axis (length) of the space. A positive rotation rotates the luminaire counter clockwise.

Upon selecting the 

button, prerequisite checks will occur (depending on the daylight reports option chosen on the setup screen) and the electric lighting calculations will begin. If any of the current inputs do not meet the selected daylighting report's prerequisites, a warning window will appear as shown in Figure 3-8 and will allow for either the given inputs to be used or for them to be changed so that they comply with the given daylight metric.

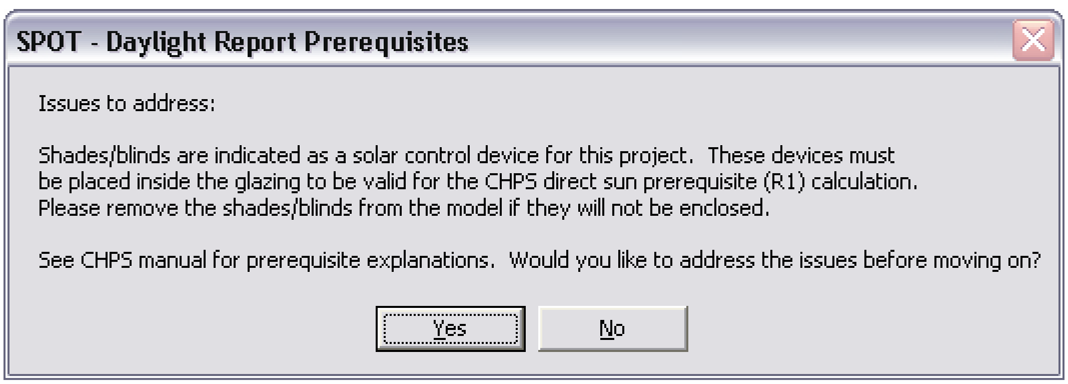


Figure 3-8: Daylight Report Prerequisites Warning Window

Once the prerequisite checks are done, the electric lighting calculations will begin. These calculations will be running in the SPOT Calculations window, which will appear in the foreground. This window can be minimized and the calculations will continue in the background while the user provides information on the next input screen – the Site and Usage Input screen. The electric lighting calculations can take several minutes depending on the number of zones and the speed of the computer's processor.

4.0 Site and Usage Input

The Site and Usage Input screen allows the user to define the location of the building, occupancy, and shade device schedules, and set the desired shade device control strategy. The electric lighting calculations will continue to run in the background while inputs are entered and the NEXT >> button will not be activated until these calculations have finished. Figure 4-1 presents a screen shot of the Site and Usage Input screen.

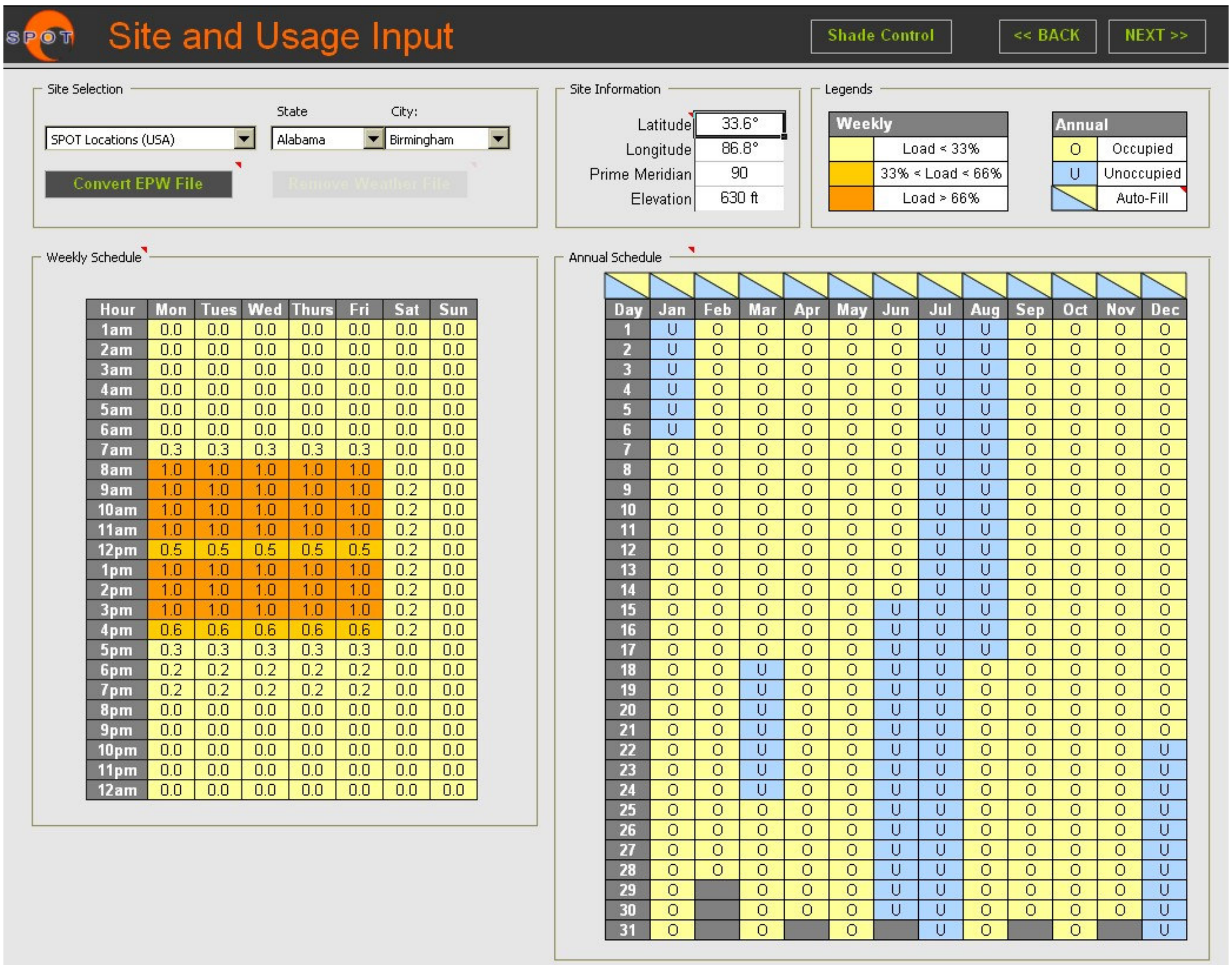


Figure 4-1: Site and Usage Input Screen Shot

4.1 Site Selection and Site Information

These fields allow the user to select the most climatically representative city for their project. SPOT comes with a library of cities for which Typical Meteorological Year (TMY2) data is available (most US locations). This database of cities is organized and accessible to the user through the “State” and “City” pull-down menus. Default latitude, longitude, prime meridian, and elevation values are provided based on the city selected. The user can override the default values with more precise latitude and longitude values if the TMY2 city's location is too far away to predict the accurate solar position. Typically, if the building is within 1° of the latitude or longitude of the representative TMY2 city, the solar angles are sufficiently similar.

Other TMY2 climate files or EnergyPlus weather files (*.epw) can be imported into SPOT by pressing the **Convert EPW File** button which allows for an EPW or TMY2 (*.tm2) file to be selected for importing. The newly imported locations will be added to the base climate library for use on future SPOT projects and will be named according to the original weather file name. The **Remove Weather File** button can be used to remove a weather file from the SPOT location library.

4.2 Shade Control

If any blinds or shades have been added on the geometry input page, the user will see the **Shade Control** button on the Site and Usage page. This button allows advanced shade control settings to be made. If these settings are not made manually, the following window shown in Figure 4-2, will appear upon hitting the **NEXT >>** button. This window will either take the user to the 'Shade Control' page to make more advanced shade control setting or allow the automatic and default shade settings to be accepted. The default shade setting is automatic shade control with the sensor placement and setpoint set in the same as discussed in the following section.

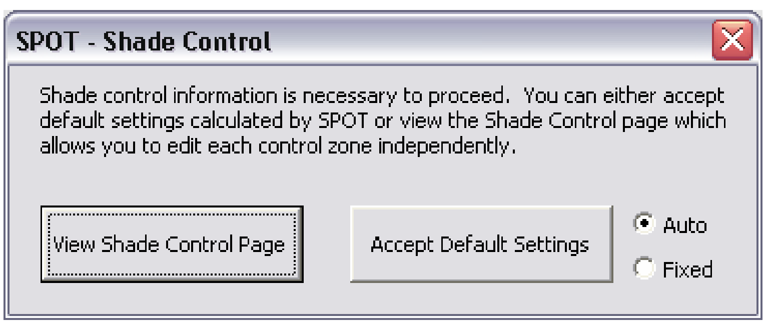


Figure 4-2: Shade Control Notification and Auto Setting Window

Selecting the **Shade Control** button or the "View Shade Control Page" button above will activate the Shade Control page, shown in Figure 4-3. This page allows the user to specify the type of shade control for each window/skylight shade zone (numbered from 1) previously defined on the Geometry Input page. A shade zone is a group of window/skylight shades or blinds that will be controlled together. Each zone can either be assigned an 'auto' or 'fixed' shade control. An automatic control ties the shades to a defined photosensor location and setpoint which determines when the shades will be drawn or retracted. Auto-generating the shade position, by pressing the **Position** button, will place the photosensor on the exterior of the wall or roof that contains the shades for the given zone. Auto-generating the shade sensor setpoint, by pressing the **Setpoint** button, will set the setpoint just above the brightest cloudy day, ensuring that the shades will be retracted under overcast conditions but drawn during most instances of direct sunlight. To simulate passive manual control of the shade zone, select the 'fixed' option. This will keep the shades drawn at all times, representing the typical 'passive' user behavior when manual control of shades is given.

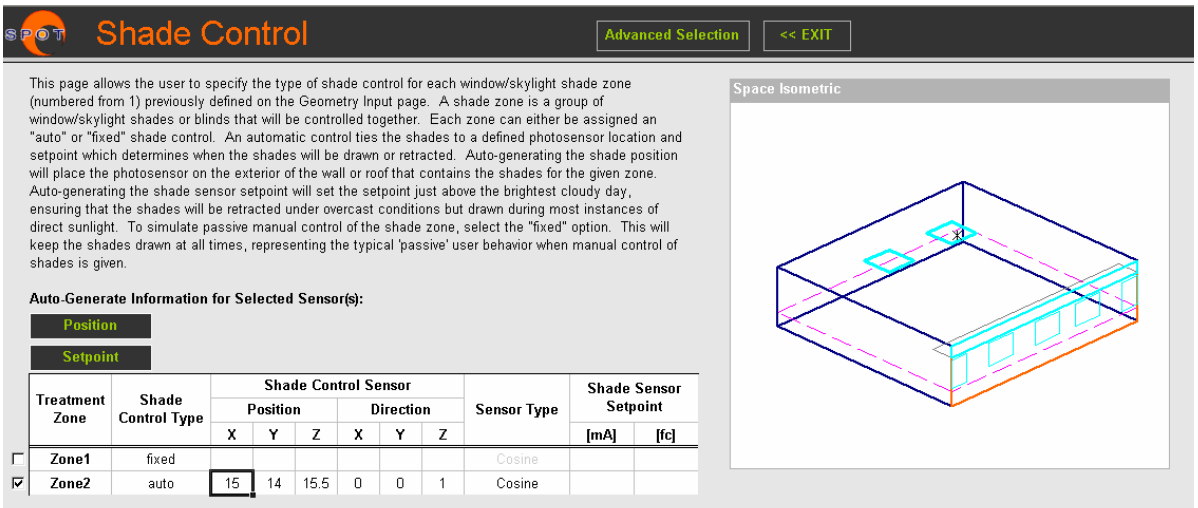


Figure 4-3: Shade Control – Manually Changing Sensor Position

4.2.1 Treatment Zone Control Definition Table

The main element on this page is the table that is used to define the control settings for each treatment zone. This table consists of the following components:

Treatment Zone – There is one row in the table for each treatment zone defined on the geometry input page. The first column indicates which treatment zone each row represents. The radio buttons next to the treatment zone column are used to select a given treatment zone for the automatic generation buttons described in the next section.

Shade Control Type – This column sets the control type for each treatment zone. Currently two control types can be selected: 'fixed' or 'auto'. The fixed control simply keeps the blinds or shades shut for all the calculations. This control type can be used to simulate manual control for a 'passive' occupant. The automatic control type simulates the treatment zone being controlled by a defined photosensor position, type, and setting. The rest of the fields in the definition table relate to the sensor settings and do not apply with 'fixed' shade control. Automatic shade control also assumes an 'open-loop' sensor placement where the photosensor does not change depending on whether shades are drawn or retracted.

Shade Control Sensor Position – These three fields define the X, Y, and Z sensor position for the current treatment zone. The X values represent the length (or E-W dimension) of the space. The Y values represent the width (or N-S dimension) of the space. The Z values represent the height of the space. The user will have to ensure the sensor does not get placed within a wall, overhang, or lightshelf element as this will result in inaccurate results.

Shade Control Sensor Direction – These three fields define the aiming direction for the current sensor. The X, Y, and Z fields allow a direction vector to be defined. The sensor will be aimed according to this direction vector. The **Position** button, discussed above, will automatically input the sensor position and direction fields for the selected Treatment Zones.

Sensor Type – This field designates the type of photosensor to use. The current database of photosensor types is limited to five generic sensor spatial sensitivity distributions: a cosine distribution, 45^{o} cone cosine, 55^{o} cone cosine, 65^{o} cone cosine, and an old Watt Stopper coned distribution; refer to Section 5.3 for more information on the sensors available. Most sensors will have a spatial sensitivity similar to that of a cosine distribution. The generic cone distributions mimic this type of sensor with shielding that limit the sensor's view.

Shade Sensor Setpoint – These fields define the sensor set-point in both milliamps and in terms of illuminance at the sensor. The milliamp setting relates to the milliamp signal generated by the given sensor distribution file. In most cases, the user will not have access to the milliamp signal coming from the sensor as it most often is wired straight to a 0 – 10V converter. The illuminance field indicates the illuminance on the sensor that would produce the given milliamp signal. Both these fields will be automatically filled out if the **Setpoint** button is selected. After this button has been selected, the corresponding illuminance field will automatically be updated. The milliamp signal is all that matters for SPOT, but the corresponding illuminance field can give useful information for commissioning.

4.2.2 Advanced Automatic Shade Control Settings

The **Advanced Selection** button will bring an advanced shade control setting graph to the forefront. This graph shows the sensor signal for the selected treatment zone for the 'design day' set of daylight conditions defined on the 'Advanced Options' page. It also displays the default sensor setpoint setting. A good setpoint will often lie right above the brightest overcast sky condition ensuring the shades are open under overcast conditions but drawn for most sunny conditions. The default setpoint calculation finds the brightest overcast condition and sets the setpoint just above this condition. The treatment zone to view in this window is selected with the pull-down menu located on the graph. To adjust the sensor setpoint, remember the milliamp signal you want to use for the setting and press 'Hide Chart' to enter the new setpoint in the Treatment Zone table. The 'Get Defaults' button will revert the setpoint back to the default level.

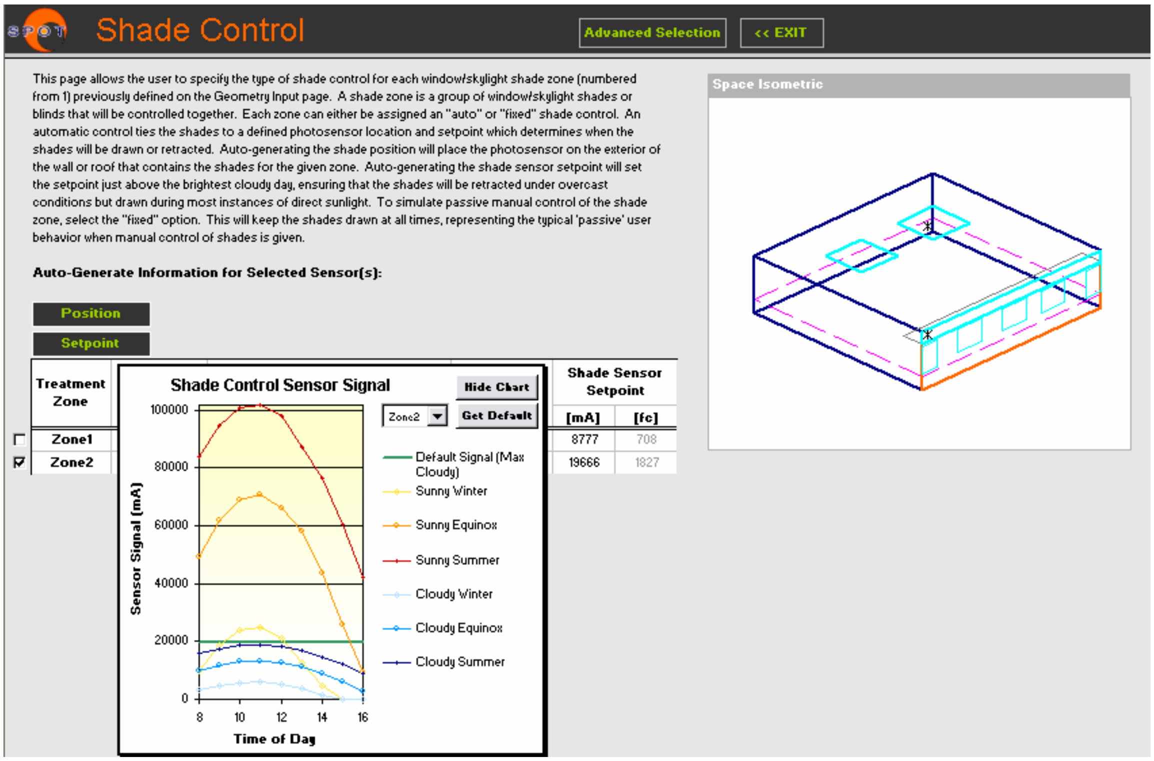


Figure 4-4: Shade Control –Auto- Generating Selected Sensor Setpoint

4.3 Weekly Schedule

The weekly schedule table defines 7 building occupancy schedules, one for each day of the week. The unoccupied times are not included in the annual analysis calculations. A value of one means the space is fully occupied and the lights would be fully on if not controlled with a photosensor system. A value of 0.5 indicates that 50% of the spaces are occupied (when using a space multiplier in the annual calculations) or a single space is occupied during that hour 50% of the time. A value of 0 means the space is not occupied.

4.4 Annual Schedule

The annual schedule table defines an annual daily occupancy schedule for the space. The table is a grid of cells, which represent each day of the year with the months listed along the top and the day along the side. "O" for occupied and "U" for unoccupied are used in each cell to indicate which days are and which are not occupied. Note that an Unoccupied “U” input in the annual schedule means the entire day is absolutely unoccupied and the weekly schedule is unused. An Occupied “O” input in the annual schedule means that the space abides by the weekly schedule for that day. January 1st is chosen arbitrarily to be a Monday. The diagonal yellow and blue buttons at the top of this table allows the user to fill an entire month or the entire year as either occupied or unoccupied. Clicking the blue portion, , of the button will fill in Unoccupied “U” values and clicking the yellow portion, , of the button will fill in Occupied “O” values.

Selecting the NEXT >> button from this screen will initiate some prerequisite checks (if a daylight metric report has been pre-selected) and then executes the daylighting calculations. These will run in a SPOT calculation window, which can be minimized while reviewing the next screen, Electric Lighting Results. The user will be limited to this next screen until the calculations are finished.

5.0 SPOT Design Tools

The next three screens of the program provide various design output and comprise the design portion of SPOT. The design portion of SPOT uses the geometry and site information provided and reports three main sets of information back to the user: 1) Electric lighting performance under nighttime conditions, 2) Annual daylighting performance under a specified sampling of conditions and 3) Photosensor placement recommendations for each luminaire zone. These design-related results are described in the following sections.

5.1 Electric Lighting Results

The Electric Lighting Results screen presents nighttime workplane illuminance with the electric lighting on at the specified Light Loss Factor (LLF) percentage. This screen, shown in Figure 5-1, is viewable once the electric lighting calculations have finished. The intent of this screen is to inform the user of the nighttime illuminance of the space, which can inform the design illuminance of the space and a reasonable starting set-point for the photosensor control system. The average nighttime workplane illuminance should be close to the intended design illuminance. If this is higher or lower than desired, the user may go back and redesign the lighting layout.

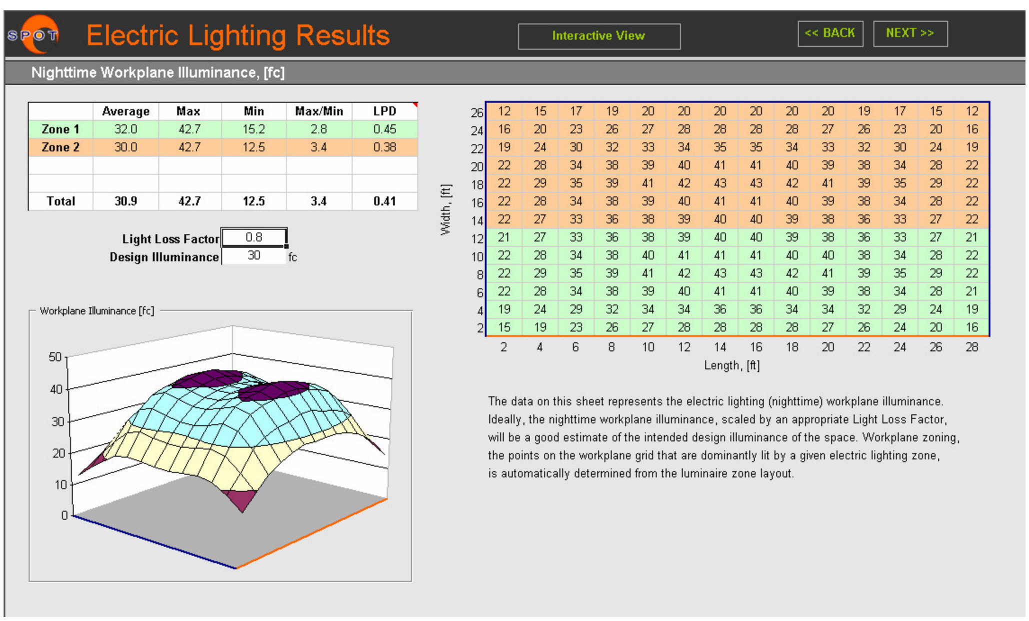


Figure 5-1: Electric Lighting Results Screen Shot

A table in the upper left corner reports the average, maximum, and minimum workplane illuminances, a maximum to minimum ratio and the calculated Lighting Power Density [W/area] (LPD) for each zone and for the overall space. Note the LPD calculation is only valid if the IES files used contain accurate power use information. The Max/Min ratios represent the percent difference between the highest and lowest illuminance in the data set.

Light Loss Factor – This field defines a Light Loss Factor to apply to the illuminance calculations. The Light Loss Factor is used to define an average fixture light output efficiency accounting for light reducing conditions such as dirt buildup and lumen depreciation.

Design Illuminance – This field defines the design illuminance for the space. Upon arriving on this screen, the design illuminance defaults to the nighttime average electric lighting illuminance, rounded down. This value can be overridden by the user if a different design illuminance is desired. The value entered for the design illuminance on this screen will be used as the intended target illuminance throughout the rest of the program (though it can be adjusted again on the Photosensor Analyzer page).

A 3-D contour plot located below this table displays the distribution of the electric lighting workplane illuminance. A plot located to the right of this table provides similar distribution information displaying in plan detailed point-by-point illuminance values at the height previously specified. SPOT automatically determines the workplane points that correspond to each luminaire zone, which is indicated by the color-coding seen on this plot. The workplane zoning corresponds to the luminaire zoning provided and is determined by which luminaire zone provides the highest illuminance to each point. This method provides the most accurate zoning information. For example, if a point falls below design illuminance and is of concern, then it should signal to the zone which has the greatest impact on that point as the zone that should be adjusted. The user should not be alarmed if the automatic zoning calculation returns zones with jagged boundaries. This happens when a row or set of points straddles between two luminaire zones, both of which contribute equally.

The NEXT >> button on the electric lighting screen will not be activated until the daylighting calculations have finished, which are running in the background while viewing this screen. Once they are finished, the NEXT >> button will activate the photosensor generation calculations window, which will run in the background while the Daylighting Results screen is viewed.

5.2 Daylighting Results

The Daylighting Results screen presents annual daytime workplane illuminances, shown in Figure 5-2. By this point in the program, SPOT has calculated a sampling of 'design day' representative sky conditions as specified on the Advanced Options page. Refer to the SPOT Development Report (Appendix F) for more information on the simulation approach. The intent of this screen is to inform the user of overall annual daylight illuminance levels in the space. With this information, albeit generated using only a sampling of design day sky conditions, the user can start making decisions regarding refinements in the luminaire zoning including which zones should be controlled (and how aggressively). At this point, the user can get a daylighting report, view daylight illuminance for any day and time of the year (relative to the typical climate data file), and create renderings of any of the simulated daylight conditions.

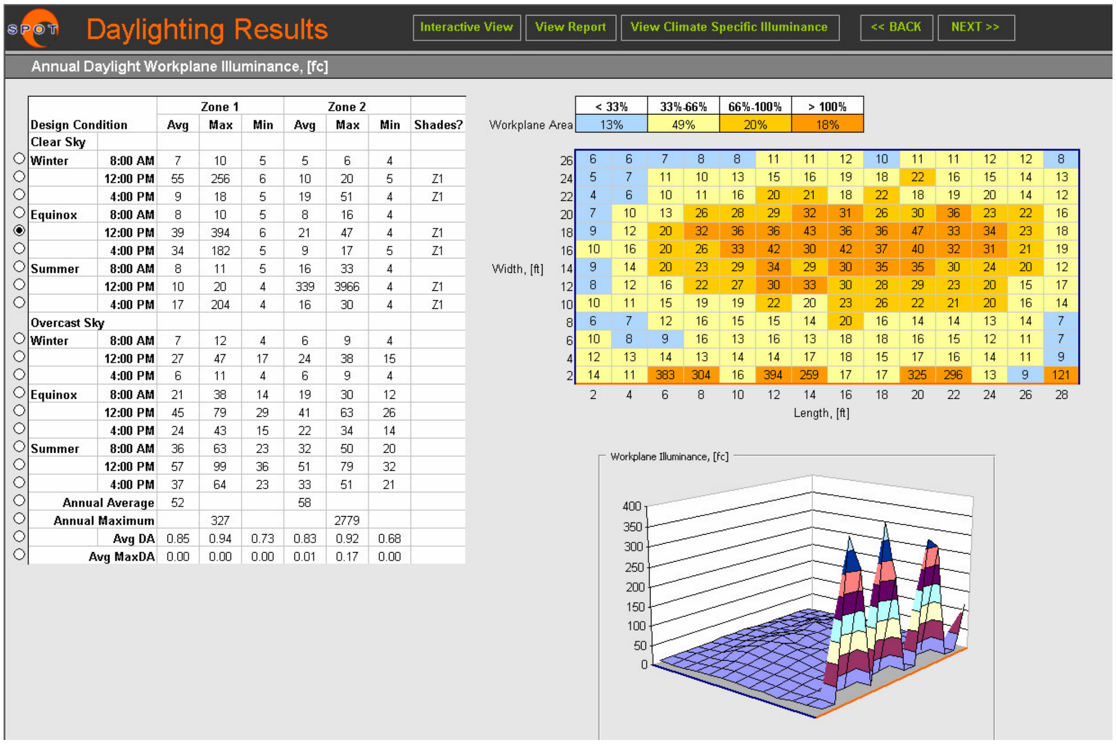


Figure 5-2: Daylighting Results Screen Shot

The table in the upper left corner reports the average, minimum, and maximum illuminance for each luminaire zone for each of the representative design days and times. A workplane illuminance plot is shown just to the right of the table displaying point-by-point illuminance distribution in the space.

Each representative day can be selected for viewing by selecting the radio button adjacent to the day of interest. The illuminance grid and the isometric plot will display workplane illuminance distribution for that given sky condition. When “Annual Average” or “Annual Maximum” is selected, the grid and plot will display annual average illuminance or the annual maximum illuminances, respectively.

The bottom two rows of the daylight results table display the Average Daylight Autonomy (DA) and Average Maximum Daylight Autonomy (MaxDA) factors for the daylit space. These factors relate to the percentage of time a given point contributes to the design illuminance for a space. When these radio buttons are selected, the grid and plot display the corresponding DA information for each point on the workplane grid.

The illuminance plot is color-coded to indicate which portions of the workplane meet or exceed the design illuminance. Portions of the workplane that, on average, exceed the design illuminance (color coded orange) are the best zones to control with a photosensor system. Those that fall between 50% and 100% (color coded yellow) of the design illuminance are second priority zones to control. Portions that fall below 50% (color coded blue) of the design illuminance are the least effective zones to control.

Selecting the **Interactive View** button at any time will launch an interactive viewing (rview) window for the current daylight condition selected in the table.

5.2.1 Climate Specific Results

Selecting the **View Climate Specific Illuminance** button will activate a detailed daylighting results page. This page will display the simulated daylight illuminance, based on the given weather data, for any occupied day and time throughout the year. This page consists of several pull-down menus, several informational fields, and a workplane illuminance plot (see Figure 5-9).

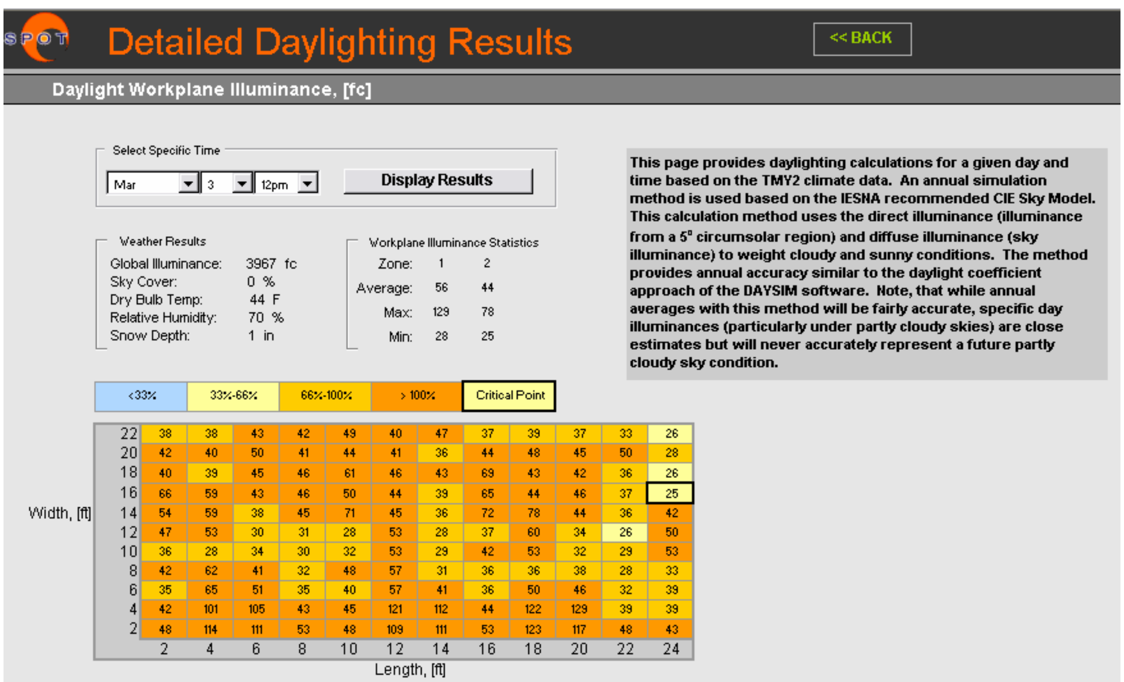


Figure 5-3: Climate Specific Results Screen Shot

Using the pull-down menus, the user selects a specific month, day and time of interest – only days that were simulated based on the annual and weekly occupancy schedule will be available for viewing. Pressing the **Display Results** button will display the daylight illuminance for the selected day and time in the workplane grid. The illuminance values will be color-coded according to where they fall compared to the design illuminance for the space.

The “weather results” fields display relevant weather information from the weather file for the specified day and time. The global illuminance, percentage of opaque sky cover, dry bulb temperature, relative humidity, and snow depth are displayed.

The “workplane illuminance statistics” fields display average, maximum, and minimum illuminance information for the various electric lighting zones.

This page provides daylighting calculations for a given day and time based on the TMY2 or other climate data. An annual simulation method is used based on the IESNA recommended CIE Sky Model. This calculation method uses the direct illuminance (illuminance from a 5^{o} circumsolar region) and diffuse illuminance (sky illuminance) to weight cloudy and sunny conditions. The method provides annual accuracy similar to the daylight coefficient approach of the DAYSIM software. Note, that while annual averages with this method will be fairly accurate, specific day illuminances (particularly under partly cloudy skies) are close estimates but will never accurately represent a future partly cloudy sky condition.

5.2.2 Daylighting Report

Selecting the View Report button will activate the Daylighting Report page. This page provides a printable report that gives information relevant to the daylight design and an indication of the annual daylighting performance for the given space relative to the selected daylight metric. When initially arriving on the report page and if a metric report was not pre-selected on the Setup Page, you will see a blank report. Choose which report you would like to view by selecting it in the pull-down menu located at the top of the page. Some of the metrics will require additional calculations before the results can be displayed. Several different daylighting performance metrics have been implemented within SPOT, the daylight metrics implemented include:

- **Collaborative for High Performance Schools (CHPS) – New York**. The Continuous Daylight Autonomy (Ratio) metric presented in the SPOT Daylight Autonomy report have been adopted in various forms for CHPS-NY. This method uses a continuous Daylight Autonomy (DA), a Maximum Daylight Autonomy (DA_{max}) and a uniformity calculation.

- **Collaborative for High Performance Schools (CHPS) – California**. This daylighting metric has several prescriptive and performance based prerequisites along with the option of three different compliance paths. The paths include a

Single Point-in-time method, a Daylight Factor method, and a Daylight Saturation Percentage method (similar to the Daylight Autonomy metric)

- **LEED Single Point-in-time.** This is a report for one of the compliance paths currently accepted in LEED v2.2. The main method is a 'Glazing Factor' approach using a Excel template provided by the USGBC. Another compliance method requires achieving a certain level of daylight on a given day and time which is the method calculated by SPOT. A third method exists that depends on taking actual measurements of the space once built.

Continuous Daylight Autonomy (CHPS MA/NY)

This report uses a newly developed dynamic daylighting metric; refer to the Daylight Autonomy report (see Appendix F) for more information on this daylighting metric. In summary, this method is the combination of three daylighting metrics based on an annual simulation that uses typical weather data. The metric considers the annual quantity of daylight as well as the quality of the introduced daylight. The quality metrics look for both incidences of high contrast ratios and for general uniformity of the daylight throughout the space.

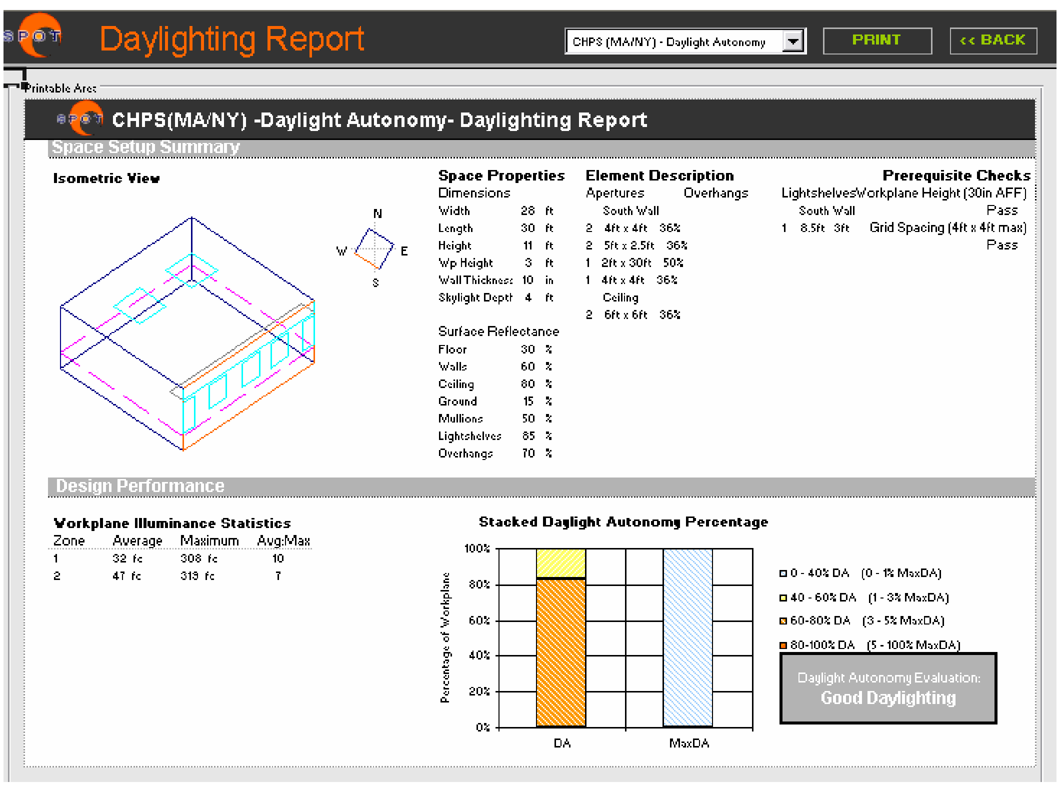


Figure 5-3: SPOT Daylight Report Screen Shot

The upper half of the report page, shown in Figure 5-3, provides an isometric of the space and other general geometric information about the space. The upper right corner lists the status of the prerequisites that are required for this metric. The lower half of the report provides daylighting performance information for the space. The table on the lower left provides average annual illuminance. The graph in the middle of the page presents the annual Daylight Autonomy (DA) and maximum Daylight Autonomy (maxDA) for the space. The color coding indicates the threshold of DA or maxDA achieved. Refer to the report mentioned above for more explanation of this metric. The grey box in the lower right of the report gives a general rating for the daylit space and the grey note box below the printable area provides daylighting suggestions, if warranted.

CHPS CA Report

The CHPS CA daylighting performance metric includes a variety of both performance and prescriptive based prerequisites with three different compliance paths for measuring daylighting quantity. When you select one of the CHPS compliance paths, several calculations will start and several questions will come up, see Figure 5-4. The main calculation that will be performed is one that determines if the design meets the direct sunlight prerequisite. The questions cover the prescriptive prerequisites of the CHPS metric.

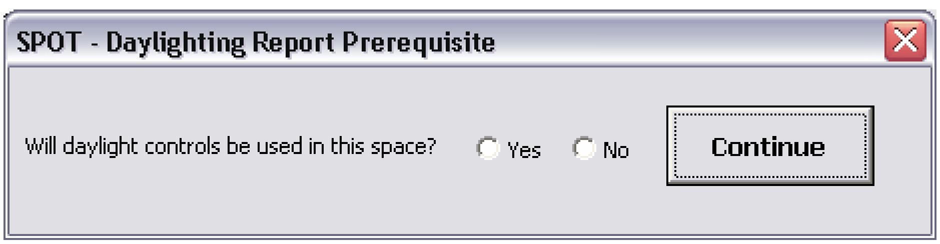


Figure 5-4: Daylight Report Prerequisite Question

Once the calculations have finished and all the questions answered, the daylight report should be complete and look similar to the SPOT daylighting report, see Figure 5-5 for a daylight report example of the Single Point-in-time compliance path. The upper half of the report remains mostly the same – listing the relevant geometrical information and the status of the various prerequisites.

The lower half of this report presents a table showing averaged illuminance information along with a workplane plot showing the illuminance distribution in the space for the required day and time of Equinox at 12:00PM. This compliance path requires an average of 25fc at this time. The box in the lower right corner gives the final status of the daylighting design relative to this metric compliance path. Note, that not all the compliance paths are equal and a design may pass under some and not under others.

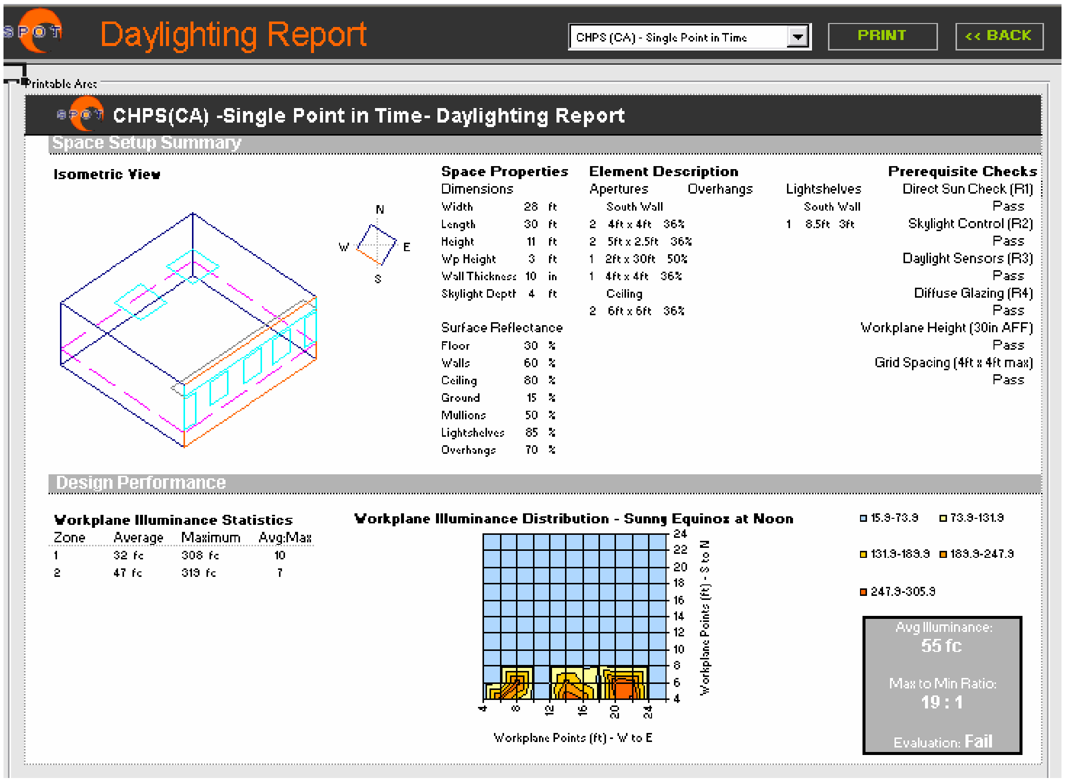


Figure 5-5: CHPS(CA) Single Point-in-time – Daylighting Report

Figure 5-6 shows a daylighting report for the CHPS-CA Daylight Saturation Percentage (DSP) compliance path. This metric was derived from the Continuous Daylight Autonomy work presented above and requires an annual simulation over a given set of annual school hours to determine. The lower half of this report gives a table summarizing the annual daylighting performance with a chart showing the DSP calculated for space. The box in the lower right presents the status of the daylit space; whether it passes the metric and how many points it achieves.

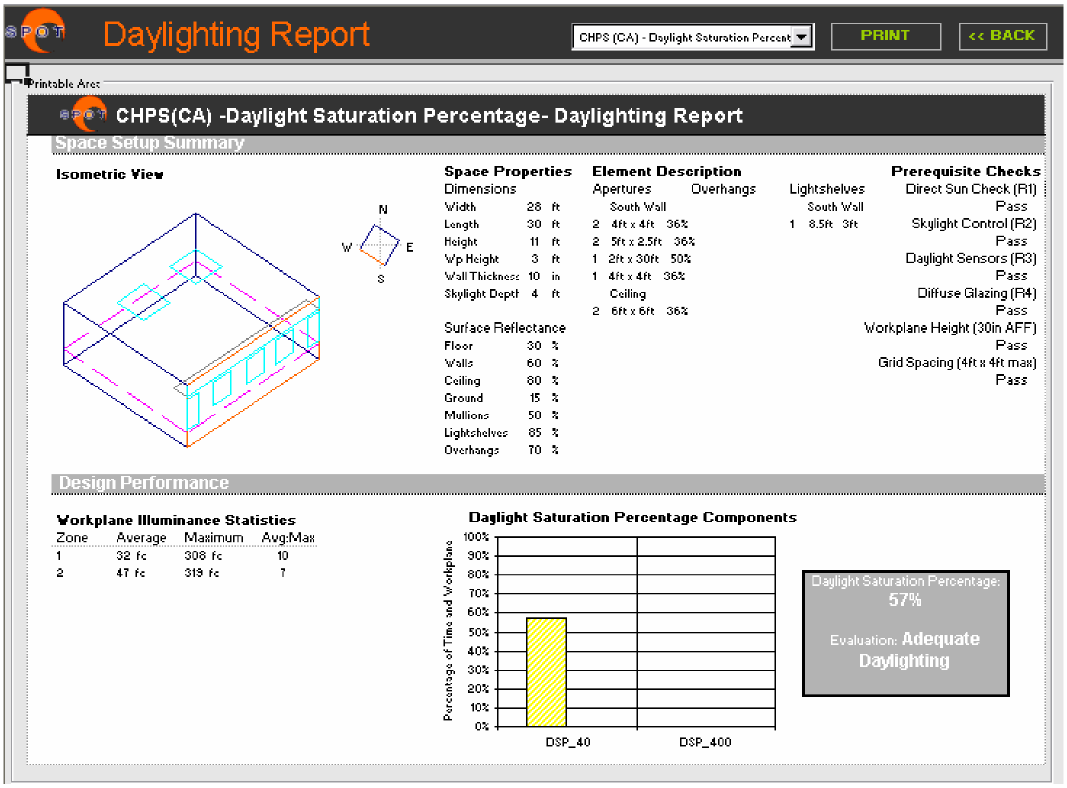


Figure 5-6: CHPS(CA) Daylight Saturation Percentage – Daylighting Report

The final compliance path for the CHPS CA daylight metric is based on the Daylight Factor (DF) approach used in previous LEED versions (2.1 and older). The graph in the bottom half of the report shows the DF for the entire workplane grid. The box in the lower right corner gives the status of the daylit space relative to this compliance path.

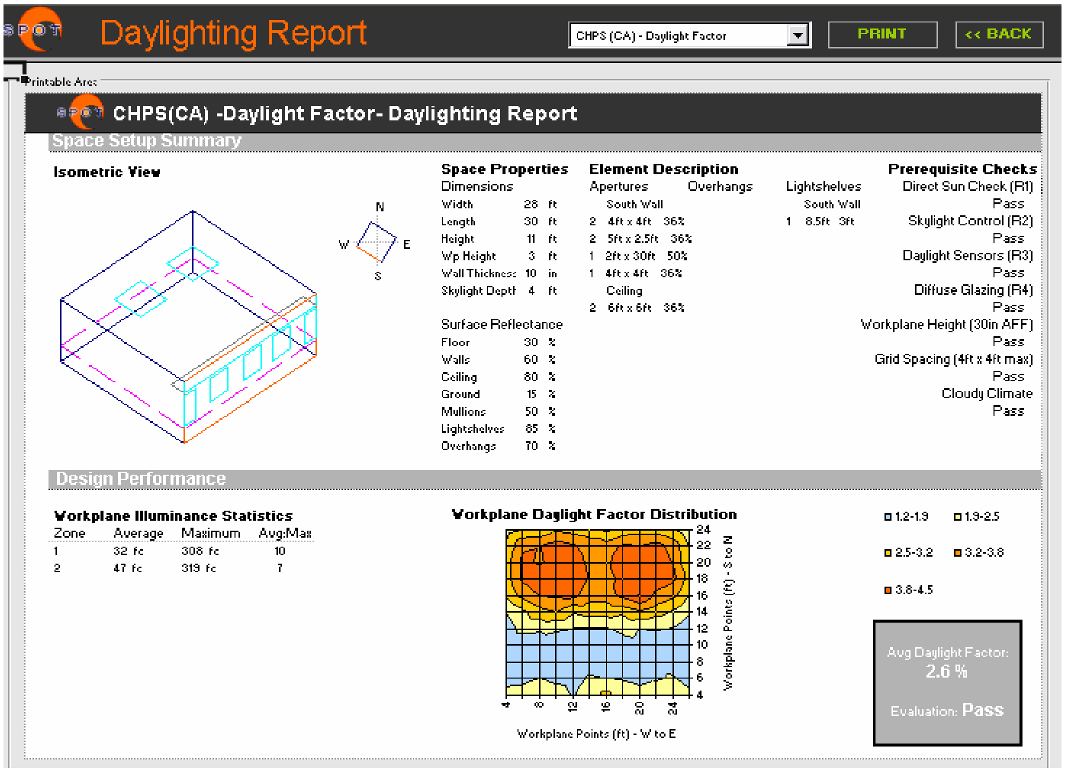


Figure 5-7: CHPS(CA) Daylight Factor – Daylighting Report

LEED Single Point-in-time Report

The LEED report only covers one of the compliance paths for this metric. The two compliance paths for this popular daylight metric: a **Glazing Factor** (used to be a Daylight Factor) calculation and a Single Point-in-time daylight illuminance calculation. The Glazing Factor can be calculated with a spreadsheet provided by USGBC and is not calculated by SPOT. The Single Point-in-time metric is similar to the one adopted by CHPS-CA and requires a 25fc average illuminance be achieved on Equinox at noon. Figure 5-8 shows the LEED report for this compliance path. Like the other reports, the workplane grid displays illuminance for the given day and the box in the lower right corner gives the status of the daylit space relative to this metric.

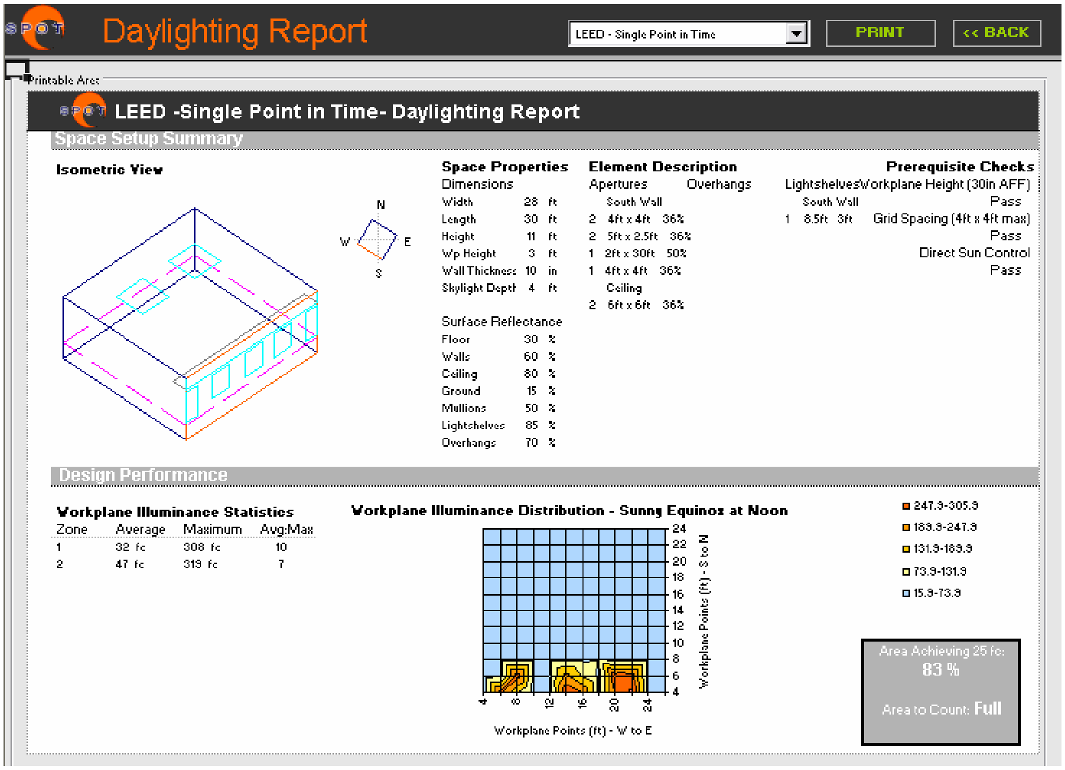


Figure 5-8: LEED Single Point-in-time – Daylighting Report

At this point, if the daylighting results do not correspond well with the defined luminaire zones and given that other luminaire zoning options are available, the user can click the << BACK button twice and redefine the luminaire zones. However, the electric lighting calculations will have to be recalculated.

Like the previous screens, the NEXT >> button will not be activated until the photosensor generator calculations have finished. Once these are ready, the NEXT >> button will initiate sectional renderings of the space (if selected on the Advanced Options screen) and will activate the Photosensor Generator page.

5.3 Photosensor Generator

The last portion of the design tool provides photosensor location recommendations and allows the user to define other photosensor scenarios for further analysis. Figure 5-9 shows a screen shot of the Photosensor Generator screen.

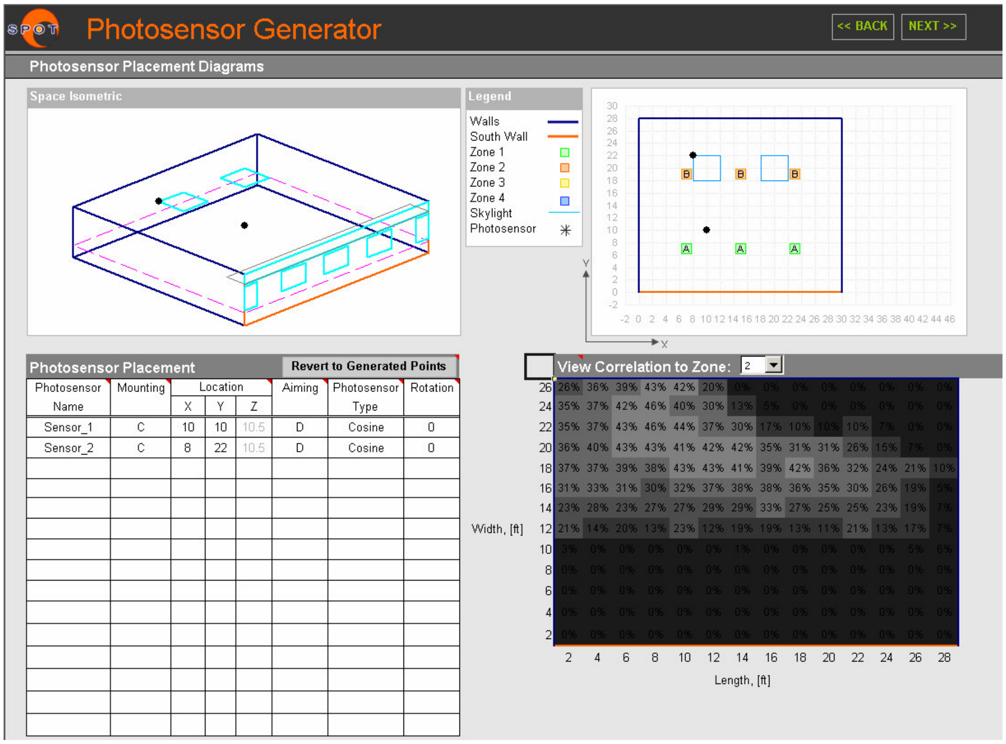


Figure 5-9: Photosensor Generator Screen Shot

For each luminaire zone, a recommended default photosensor scenario is provided in the Photosensor table in the lower left of this screen. The default photosensor locations represent the points on the ceiling that provide the best correlation with the average workplane illuminance for each zone. The correlation plots are shown in the lower right corner of this screen. These plots represent a grid of ceiling points and each value is the correlation between the illuminance at that point and the workplane illuminance. The correlation values in this plot are color-coded so that a lower correlation is represented by darker colors and a better correlation is represented by lighter colors. Correlation values for other zones can be displayed by choosing the zone of interest in the pull-down menu located in the header of this plot. The correlation values are accurate for photosensors with a cosine spatial distribution response. The “Revert to Generated Points” button will revert the table to the original photosensor placements, if they have been manually changed by the user.

The photosensor scenarios listed in the table are shown as black dots graphically on the 3-D isometric of the space and on a reflected ceiling plan in the upper right corner. To add a photosensor, simply type the name and mounting information into the next blank row in the table. To remove a photosensor, delete all the photosensor’s information from the row. Blank rows in the middle of this table are acceptable and will be removed upon going to the next screen. The inputs for each column in the Photosensor definition table are as follows:

Photosensor Name - This field defines a name for the photosensor scenario defined on the corresponding line. This can be any name that makes sense to the user, although no blank spaces are allowed in the name. If a space is desired, use an underscore.

Mounting - This field sets the general mounting location for the photosensor. The user can choose from a list of mounting locations. The location fields, the next three columns of the table, specify the photosensor's X, Y, and Z coordinates. Fixed dimensions are greyed out. The following mounting locations are allowed:

> *Ceiling* - A ceiling mount is the default mounting location and is designated by entering a "C" into this field.
>
> *South (S), East (E), North (N), West (W)* - An "S", "E", "N", or "W" designates a wall mounting on either the south, east, north, or west wall, respectively.
>
> *Free (F)* - A free-standing mount can be used to place the photosensor someplace other than the ceiling or walls of the space. This may be useful for placing photosensors beneath luminaries or on top of furniture systems.

Location - These three fields set the specific location of the photosensor in X, Y, and Z coordinates. The coordinate system used is illustrated in the reflected ceiling plan in the upper right corner of the screen. The X values represent the length (or E-W dimension) of the space. The Y values represent the width (or N-S dimension) of the space. The Z values represent the height of the space. One of the fields may be greyed out depending on the mounting location entered. For example, with a ceiling mounted sensor, the Z dimension must equal the height of the space, which is automatically entered and greyed out.

Aiming - This field sets which direction the photosensor is pointing. The default aiming is always perpendicular to the mounting surface chosen. A free standing mounting always defaults with a downward aiming. The user is given six options for aiming; up, down, north, east, south, and west. Diagonal aiming is not currently supported with the SPOT interface; the underlying SPOT Radiance engine however can handle any aiming. The adventurous user can go behind the scenes and define any desired aiming angles. Choose "Open Loop" for aiming when using an open loop system with exterior mounted photocells. This will place the photosensor on the surface chosen in the "Mounting" inputs, but moved to the exterior of the surface and aimed perpendicular to the surface.

Photocell Type - This field is specified with a pull-down menu showing the current list of defined photocell types. SPOT comes with a small library of only a handful of photocell types; however, additional photocell definitions can be imported and saved within the library on the

Advanced Options screen (not currently available in this release). The following generic photocell types currently are found in the SPOT library:

Cosine - This is a perfectly hemispherical distribution that gives a signal that is linear to photometric illuminance. Many photosensor products on the market attempt to achieve this type of spatial distribution response.

45°, 55°, and 65° cosine - These spatial distributions are the same as the cosine distribution, but limited in overall scope to a cone with the specified angle. These sensors respond to a cone of luminance centered on the axis line of the sensor.

TWS1 - This is an older sensor distribution from The Watt Stopper with a fairly narrow band of distribution. It is no longer in production.

Rotation - This field sets how the photocell is oriented relative to the room. This field is only relevant for asymmetric photocell responses. For photocells with response functions that are symmetrical around the central axis, the rotation angle does not apply. A value of 0° means the 0° angle of the data is oriented to the north.

Upon clicking the NEXT >> button, all the photosensor scenarios listed in the table will be calculated under each electric lighting zone and more complete representative daylighting conditions. This also starts a set of calculations that will update the workplane illuminances under the same set of daylighting conditions.

5.4 Final Calculations Running

After the Photosensor Generator and other design tool screens, the most extensive set of calculations begin. A transition screen is displayed during this process, shown in Figure 5-10.

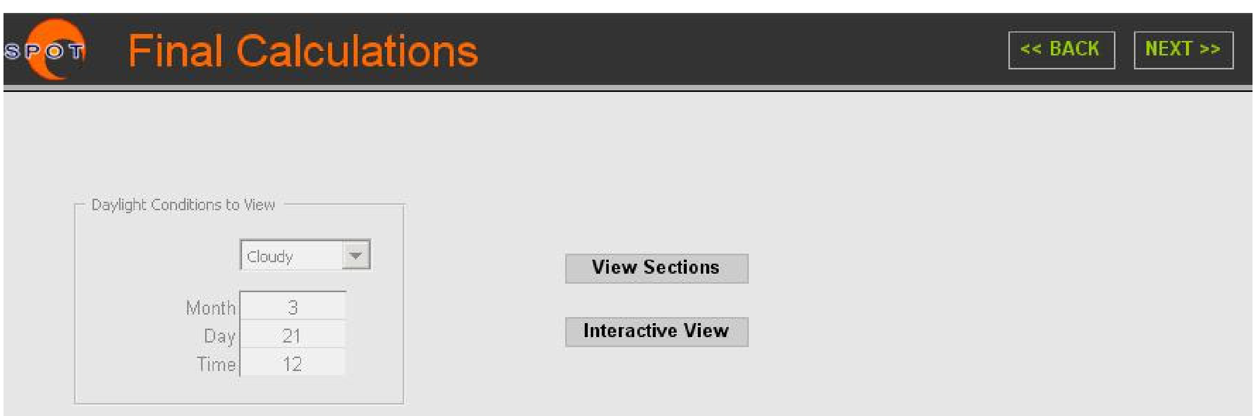


Figure 5-10: Final Calculations Screen Shot

While waiting for the final set of calculations to finish, the user can look at both an interactive view and a view of four space cross-sections. The day condition shown in the interactive view is the same as the last condition selected on the Daylight Results page. The **View Sections** button will initiate the calculation of several renderings, if the renderings option was not set to yes on the Advanced Options page, and then take the user to an images page, shown in Figure 5-11. These renderings represent four cross-sectional views of the space from each cardinal direction. The renderings are done for a sunny equinox day at noon.

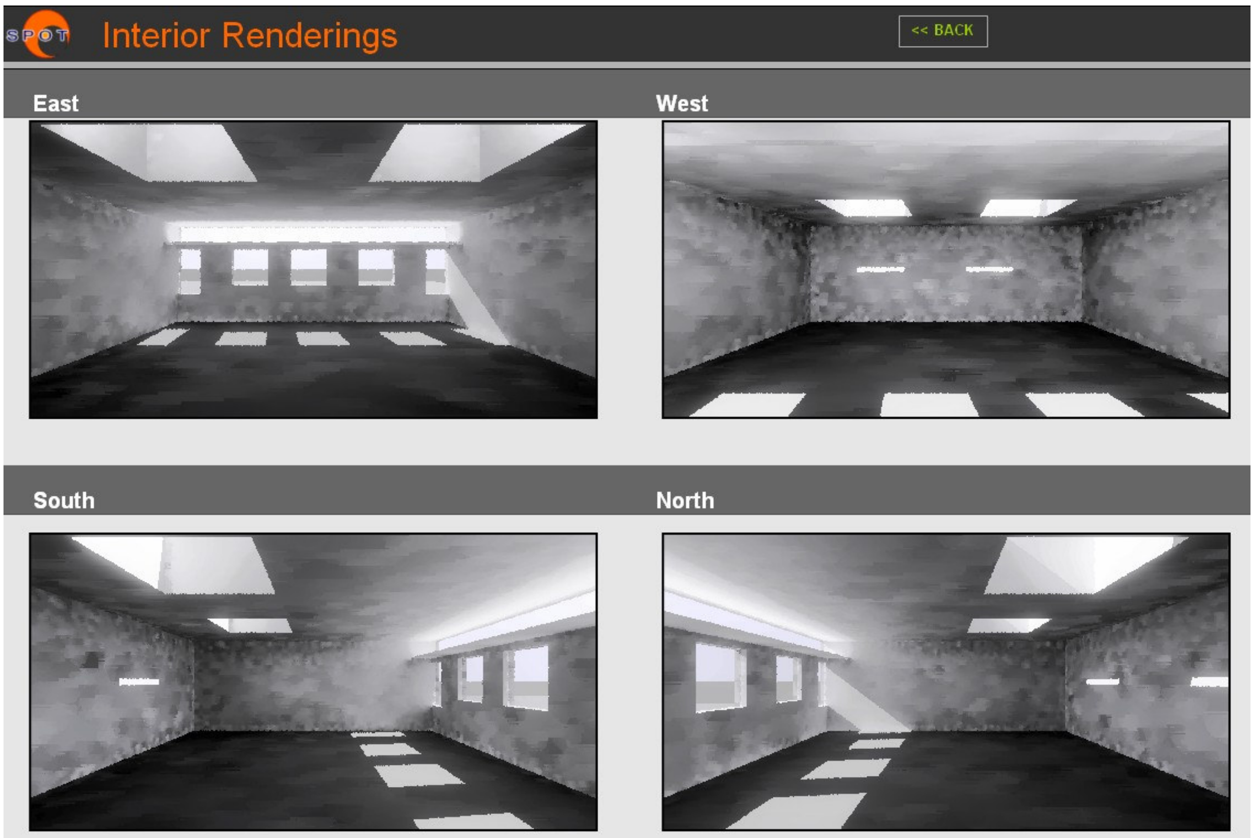


Figure 5-11: Interior Renderings Screen Shot

6.0 SPOT Analysis Tools

The final two screens of the software tool are related to the analysis portion of SPOT. The analysis portion of the tool allows the user to apply various photosensor scenarios to the luminaire zones, adjust the photosensor system settings, and perform annual performance calculations. The analysis portion consists of two screens, the Photosensor Analyzer screen and the Annual Analysis screen, both of which are described in the following sections.

6.1 Photosensor Analyzer

The Photosensor Analyzer is the first screen in the analysis portion of the tool, shown in Figure 6-1. This screen allows you to mix and match the various photosensor scenarios defined on the previous screen and analyze how they will perform under a larger set of representative days and sky conditions.

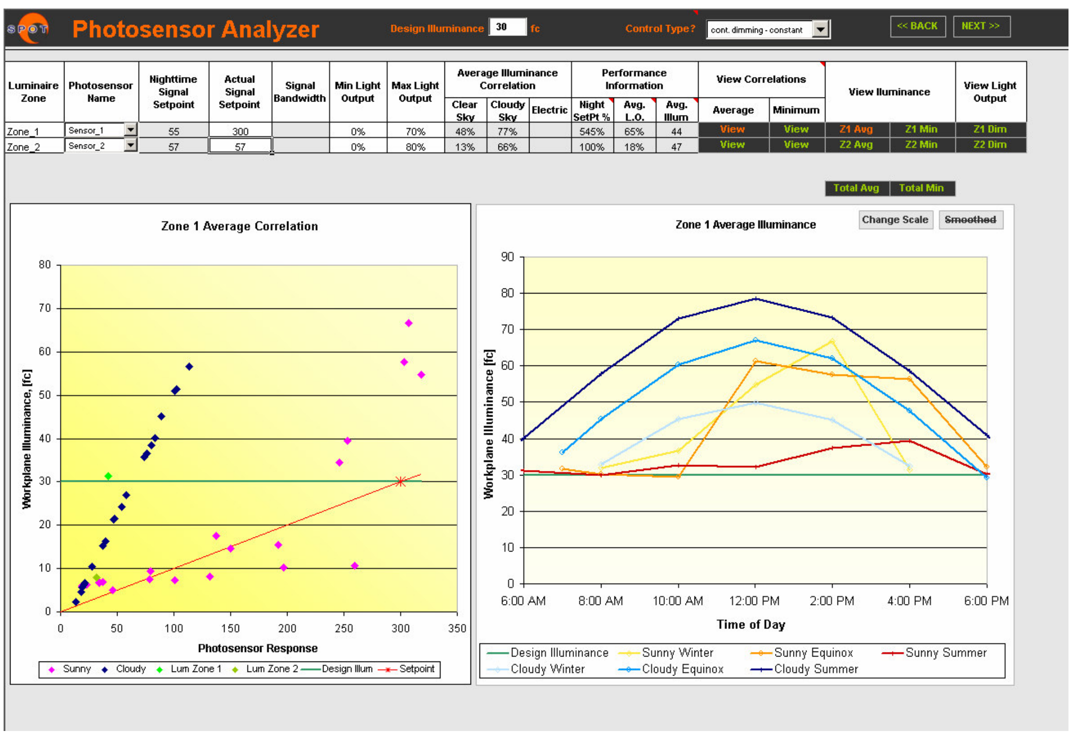


Figure 6-1: Photosensor Analyzer Screen Shot

The photosensor **signal** discussed throughout these sections refers to the response received from the actual photocell. This response is actually in units of mA/Watt and is typically linear to the resulting 0-10V signal received from the photosensor system. This response is then put through signal amplification to receive a 0 - 10V signal.

Many of the updates that will be implemented in SPOT version 4.0 (due mid-2007) will involve this page and its relevance to equipment in the field. Refer to the SPOT Development Report for more information on the methods and algorithms currently used on this page and for the new approaches that will be implemented in the next SPOT release. Future SPOT work includes allowing the user to define photosensor settings given a selected photosensor system, easing the transition from a SPOT photosensor analysis and actual field commissioning practices.

Control Type - This field sets the type of control algorithm that the photosensor system will use. A pull-down menu is provided with a list of the supported control algorithms. Currently, these are all generalized and ideal control algorithms, explained in greater depth in the SPOT Development Report. For analysis of real-world control algorithms, refer to Andy Bierman's photosensor studies in Appendix F. The control types supported are as follows (bi-level and tri-level control algorithms are not supported in this release):

Continuous Dimming, Constant Setpoint - This control type for continuously dimmable fixtures allows a single input signal to be set, then tries to maintain that signal at all times. If the signal is lower than this setpoint, the luminaires will be on at maximum output, and if it is greater, they will be on at their minimum output. During times between these end conditions, the luminaires will be dimmed accordingly to maintain the single signal setpoint with a combination of electric light and daylight. Figure 6-2 illustrates the relationship between the luminous dimming of the electric lighting system and the sensor response for this type of system.

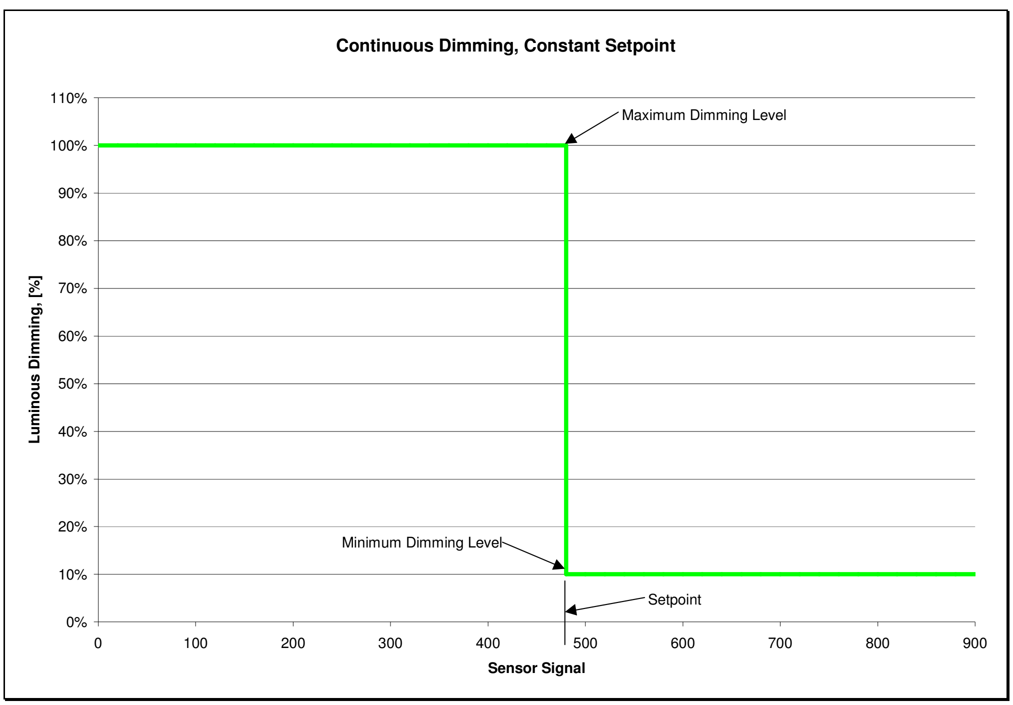


Figure 6-2: General Continuous Dimming, Constant Setpoint Control Algorithm

Continuous Dimming, Sliding Setpoint - This control type for continuously dimmable fixtures allows two input signal to be set as a high setpoint and a low setpoint. The low setpoint gives the point at which the luminous dimming will begin to occur and it will occur linearly with the sensor signal until the high setpoint is reached and the system reaches its maximum luminous dimming. Figure 6-3 illustrates this control type showing the relationship between the luminous dimming of the system and the sensor response.

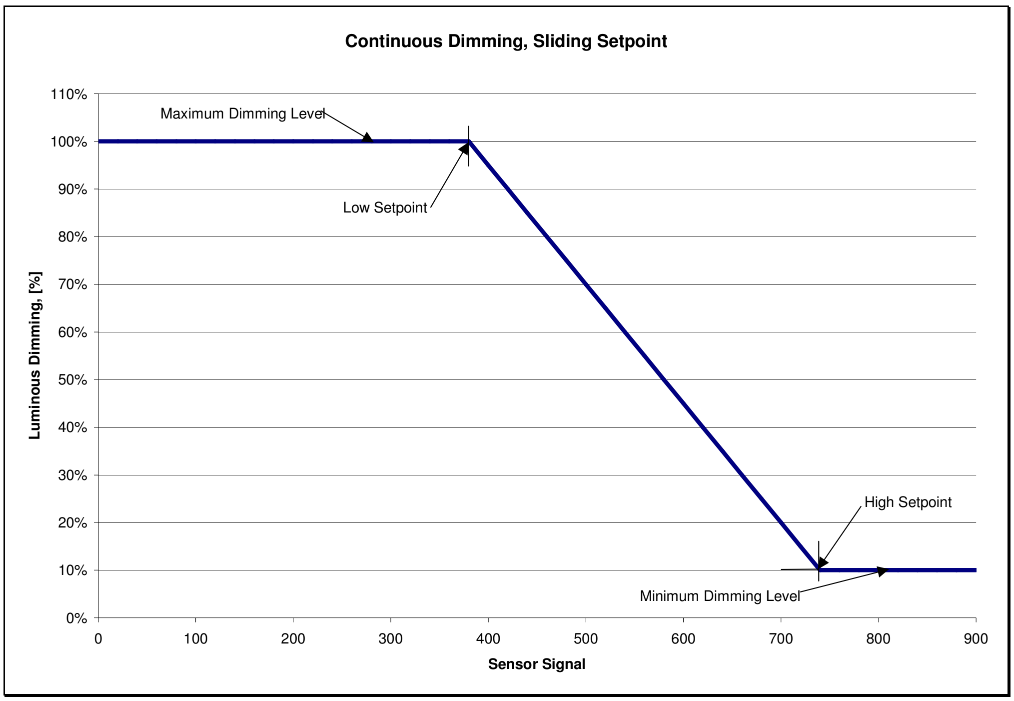


Figure 6-3: General Continuous Dimming, Sliding Setpoint Control Algorithm

On/Off - This control type for non-dimmable systems requires two input signal setpoints. This is sometimes provided with a high and low setpoint and sometimes with a setpoint plus bandwidth setting. Sometimes, the bandwidth is set as a percentage of the low setpoint. The high setpoint is the photosensor signal at which the lighting system will be turned off and the low setpoint is the photosensor signal at which the lighting system will be turned back on. The range between the low and high setpoints is the bandwidth of the system. This bandwidth must be sufficiently larger than the photosensor signal received from the controlled electric lighting zone by itself. If this is not the case, then the system will flicker under certain daylighting and electric lighting conditions, cycling between on and off. SPOT will give a warning if such a setting occurs. Figure 6-4 illustrates the luminous dimming versus photosensor signal characteristics of this control type.

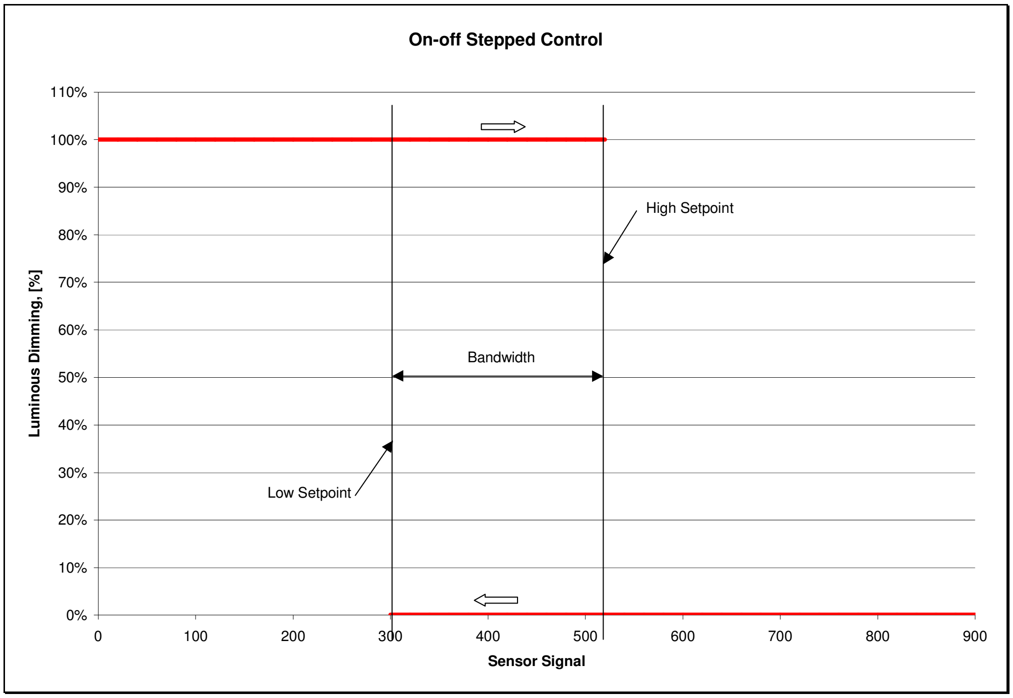


Figure 6-4: General On-Off Control Algorithm

Bi-Level - This control type is for electric lighting systems capable of two distinct light levels including completely off. Four signal setpoints are required for this type of system, or two setpoints and a bandwidth. Two setpoints determine when the lighting system will go from maximum light output to a mid-level light output and back. These are the first high and low setpoints. An additional two setpoints determine when the lighting system will go from a mid-level light output to off and back. These are the second high and low setpoints. Similar to on/off control, the bandwidth of the system is the difference between the high and low setpoints. Also, the bandwidth has to be sufficiently larger than the photosensor signal received from the controlled zone. Figure 6-5 illustrates the bi-level photosensor control type. This control system is popular with two-lamp fixtures where the lamps can be controlled separately. Bi-level control algorithms are not supported in this release.

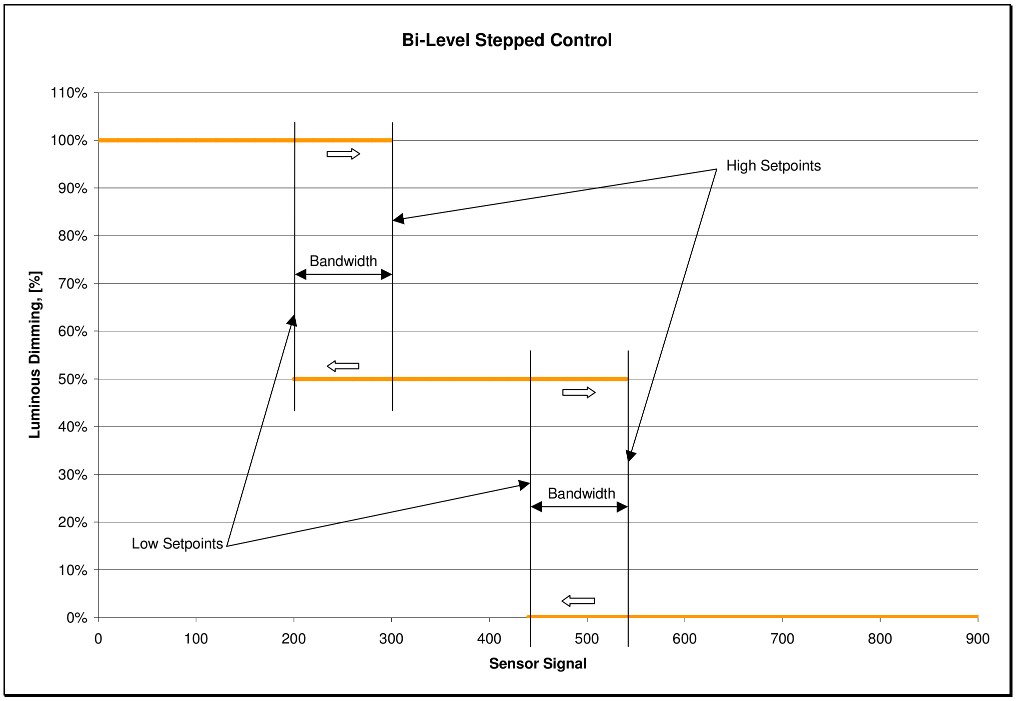


Figure 6-5: General Bi-Level Control Algorithm

Tri-Level - Tri-level control is similar to bi-level and on/off control, but it is used for electric lighting systems capable of three distinct light outputs and off. Three setpoints and a bandwidth, or three high and three low setpoints are required for this type of system. This control system is popular with three lamp systems where each lamp can be controlled individually. Tri-level control algorithms are not supported in this release.

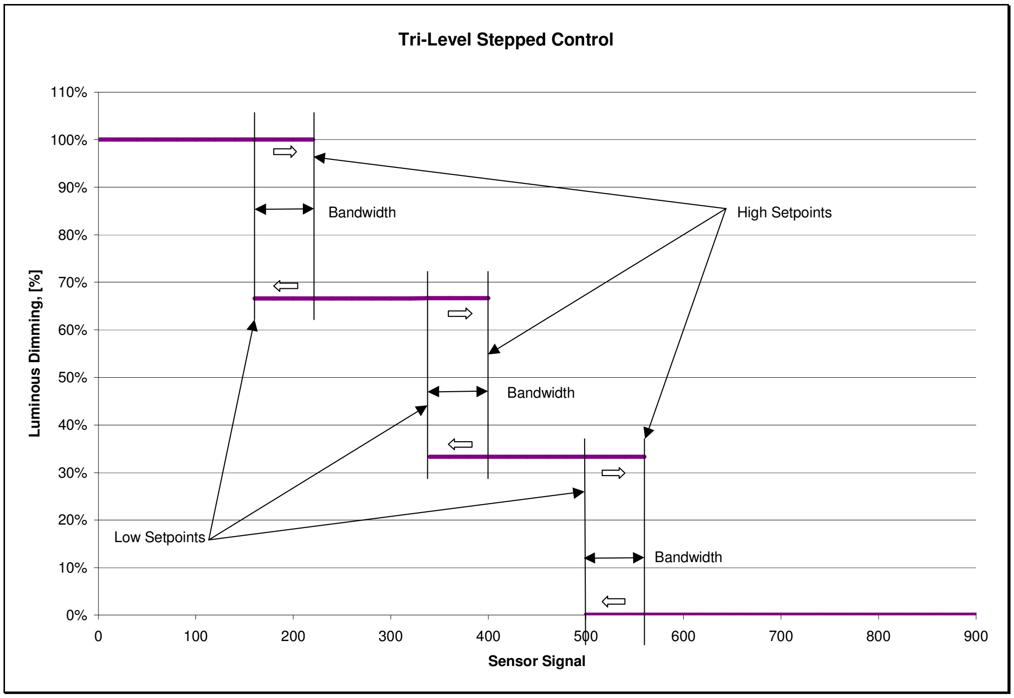


Figure 6-6: General Tri-Level Control Algorithm

Open Loop - In ideal open loop control systems, the photosensor does not receive any signal from the controlled electric lights.

Open loop dimming system characteristics are essentially the same as sliding setpoint, continuous dimming systems, although instead of a settable lower setpoint, the origin or a neutral "0" response is assumed to be the low setpoint. This makes sense intuitively since the lower setpoint in a sliding setpoint system is typically set at night and is meant to represent the electric lighting contribution to the photosensor's signal. Since an ideal open loop system has no electric lighting contribution to the photosensor, it has a low setpoint of "0".

Open loop on/off, bi-level, and tri-level systems are essentially the same as the closed loop counter parts except little bandwidth is needed.

The table located in the upper left corner contains a row for each luminaire zone defined, named in the first field of each row. The white fields in this table require user input and the grey fields provide calculated data to the user, the grey fields. The fields in the table include:

Photosensor Name - This field provides a pull-down menu containing the previously defined photosensor scenarios. Select the photosensor to assign to each luminaire zone.

Suggested Signal Setpoint - This field provides a suggested signal setpoint for the given photosensor and luminaire zone combination. These setpoints are calculated based on the system type and a nighttime calibration condition setting.

Actual Setpoint - This field is the actual signal setpoint to use. It allows the user to explore tweaking the setting above and below the suggested signal setpoint. This could be used to mimic a field commissioning trick of temporarily increasing or decreasing the signal of a photosensor by shading or reflecting more light towards it. Each zone can also be set to stay "on". This would be done if the zone is not receiving significant daylight and controlling the zone is not resulting in significant lighting savings. Also, setting low daylight saturation zones to "on" can make the calibration of the control settings for the other zones less complex.

Signal Bandwidth - This field gives the signal bandwidth to use if the control system selected requires a high and low setpoint. The bandwidth represents the difference between the two setpoints. The bandwidth is added to the actual setpoint provided earlier to calculate the high setpoint.

Dimming Low - This field sets the lowest level of light output that the electric lighting system can produce. Often, for non-continuous control systems, this will be completely off (0%). For continuous dimming systems, there is often a minimum dimming level imposed or desired for psychological reasons and the low dimming level will be between 1 and 10%.

Dimming High - This field sets the highest level of light output that the electric lighting system can produce. Often, for non-continuous control systems, the lights will go to completely on (100%). For continuous dimming systems, it is often desired, in the case of an overlit space, to set this below 100% to better meet design illuminance and further improve energy savings. When a continuous control system type and nighttime calibration is selected, if the calculated nighttime level is greater than the design illuminance level, the high dimming level will be calculated automatically giving the dimming level that provides an average equal to the design illuminance.

Average Illuminance Correlation - These fields provide crude correlations calculations between the average workplane illuminance and the photosensor response under clear sky, cloudy sky, and electric lighting conditions. A 100% correlation is ideal and means that the ratio between the average workplane illuminance and the photosensor signal is always the same.

Minimum Illuminance Correlation - These fields provide crude correlation calculations between the minimum workplane illuminance and the photosensor response under clear sky, cloudy sky, and electric lighting conditions. Like the average correlations, the higher the correlation the better, with a 100% correlation meaning that the ratio between the minimum workplane illuminance and the photosensor signal is always the same. Minimum correlations are important to consider if the system needs to ensure that all areas of the workplane receive adequate light.

View Correlations - The View buttons allow the user to select which correlation graph to view. The red View button indicates the correlation graph currently displayed. The correlation graph is shown in Figure 6-7 and represents the variation in sensor readings that the selected photosensor / luminaire zone combination experiences throughout a year for sunny and cloudy conditions. The ideal correlation graph will be very linear between the cloudy, sunny, and electric lighting conditions. In other words, the blue, pink, and green dots should be linearly aligned. The green horizontal line represents the current target design illuminance.

The red line or lines (if you have a high and a low setpoint) appear on this graph and indicate the current setpoint relative to the array of sky condition data. The point the red line crosses the green design illuminance line is the current signal setpoint. This line will default to a nighttime condition, so it will initially be lined up with the average electric lighting conditions plotted. This correlation graph can be used to determine the best sensor signal setting. Essentially, any sky condition data point that falls below the green design illuminance line and below the red signal setpoint line will be sky conditions that may have a less than adequate resulting illuminance. Therefore, the setpoint setting should be made such that all points fall above the red line or green design illuminance line. It's up to the user to find their desired balance between energy savings and resulting illuminance.

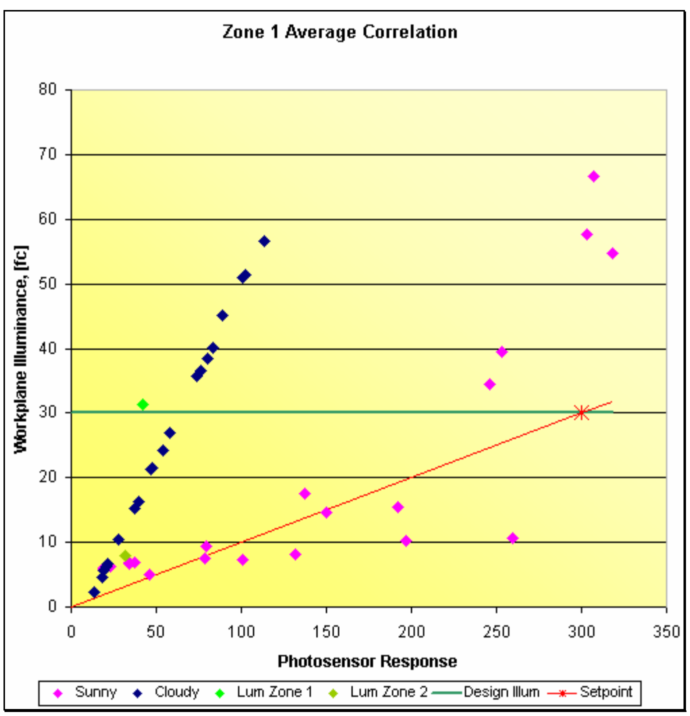


Figure 6-7: Average Correlation Graph

View Illuminance - Upon assigning a photosensor scenario for each luminaire zone, the graph and the last couple of columns of the table are updated to reflect the current settings. The graph, shown in Figure 6-8, presents the resulting workplane illuminances for each day that has been calculated. The target design workplane illuminance is indicated with a green horizontal line. From this graph, it is easy to see which days, if any, will have lower than desired average or minimum illuminance. The user can then interactively adjust the photosensor combinations and settings until they are satisfied with the performance on the given set of sample days.

The "Change Scale" button on this graph allows the user to change the Y-axis scale of this graph for better readability. The "Smoothed" button allows the user to change the plot type from a linear point-to-point to a spline fitted curve.

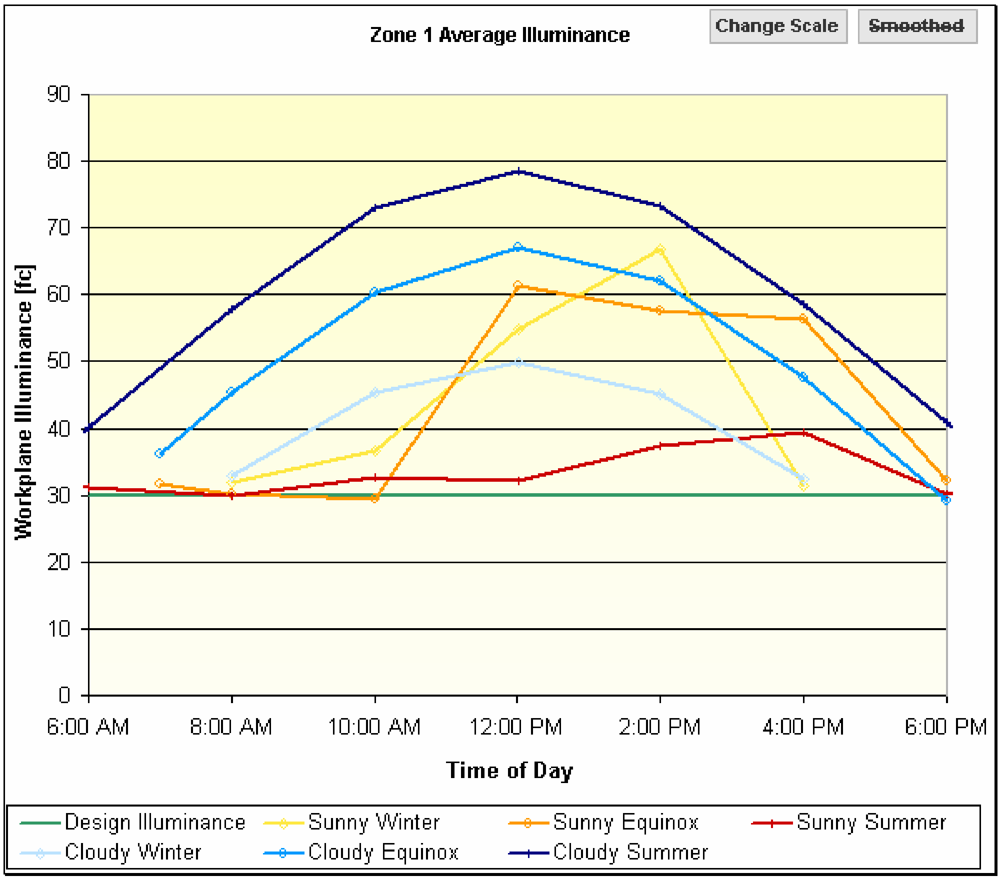


Figure 6-8: Average Workplane Illuminance Graph

6.2 Annual Results

The analysis portion of the tool provides annual performance calculations. Some of the calculations are essentially the same as those performed on earlier screens for the representative days except now they are run using the expanded Daylight Factor matrices, as discussed in the SPOT Development Report, for each 8760 hours of weather data. This provides a more accurate analysis of the photosensor system since it now takes the climate conditions, schedules, and time of the day into account – i.e. coincident load type issues. Several sets of results are displayed on the Annual Analysis screen. The user can utilize Excel's print functionality to print any reports desired.

At the top of the Annual Analysis screen is a table of the annual results as shown in Figure 6-9. The table to the left lists the average light output, electric savings, heating load, cooling load, and average, minimum, and maximum illuminance for each zone individually and all zones together.

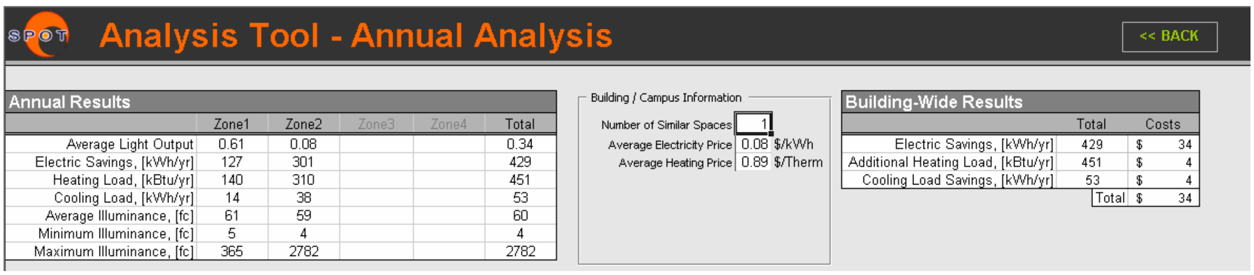


Figure 6-9: Annual Results Table - Screen Shot

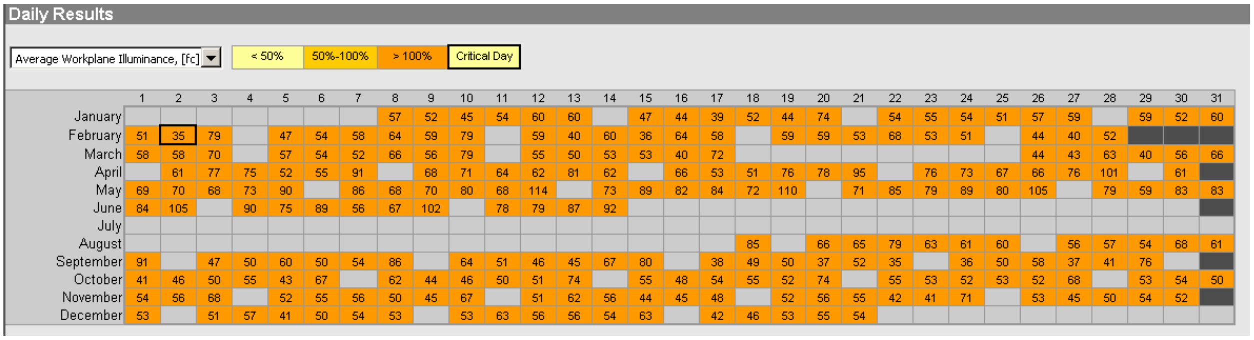
Next to this table are some additional *Building / Campus Information* inputs. Here, the user specifies a multiplier that is used to calculate savings for a group of similar spaces and the blended utility rates for electricity and gas.

The table to the right provides building wide results for overall energy and energy cost savings. The total building wide energy related cost savings are provided at the bottom of this table. Remember, energy savings is only part of the equation for daylighting. Benefits related to productivity, well-being, health, enhanced learning environments, and increased retail sales should be considered and completely outweigh the energy saving benefits of daylighting.

6.3 Daily Results

The next section of the Annual Analysis screen consists of a table showing results for each day of the year, as illustrated in Figure 6-10, and a pull-down menu that selects the data displayed in the table. These results can be used to identify certain days of the year that may be under performing. Each day of the month represents the columns and each month represents the rows in this table.

A color-coding system is provided for this table when illuminance numbers are displayed to help show daily performance relative to the set design illuminance. The **Critical Day** is represented on the graph as the cell with the thick black outline and represents the day that had the lowest average workplane illuminance. If minimum or maximum illuminance is selected in the pull-down menu, then the lowest minimum or highest maximum illuminance is highlighted as the **Critical Day**.



	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31
January								57	52	45	54	60	60		47	44	39	52	44	74		54	55	54	51	57	59		59	52	60
February	51	35	79		47	54	58	64	59	79		59	40	60	36	64	58		59	59	53	68	53	51		44	40	52			
March	58	58	70		57	54	52	66	56	79		55	50	53	53	40	72									44	43	63	40	56	66
April		61	77	75	52	55	91		68	71	64	62	81	62		66	53	51	76	78	95		76	73	67	66	76	101		61	
May	69	70	68	73	90		86	68	70	80	68	114		73	89	82	84	72	110		71	85	79	89	80	105		79	59	83	83
June	84	105		90	75	89	56	67	102		78	79	87	92																	
July																															
August																		85		66	65	79	63	61	60		56	57	54	68	61
September	91		47	50	60	50	54	86		64	51	46	45	67	80		38	49	50	37	52	35		36	50	58	37	41	76		
October	41	46	50	55	43	67		62	44	46	50	51	74		55	48	54	55	52	74		55	53	52	53	52	68		53	54	50
November	54	56	68		52	55	56	50	45	67		51	62	56	44	45	48		52	56	55	42	41	71		53	45	50	54	52	
December	53		51	57	41	50	54	53		53	63	56	56	54	63		42	46	53	55	54										

Figure 6-10: Daily Results Table - Screen Shot

The options to display on the table are selected in the pull-down menu and include:

Average Light Output [%] - This option displays the daily average light output for all luminaire zones, weighted according to the overall lighting power.

Average Illuminance [fc or lux] - This option displays the daily average workplane illuminance under electric light and daylight.

Maximum Illuminance [fc or lux] - This option displays the daily maximum workplane illuminance under electric light and daylight.

Time of Maximum Illuminance [hour] - This option displays the time of day, in military decimal form, when the maximum illuminance occurred.

Minimum Illuminance [fc or lux] - This option displays the daily minimum workplane illuminance under electric light and daylight.

Time of Minimum Illuminance [hour] - This option displays the time of day, in military decimal form, when the minimum illuminance occurred.

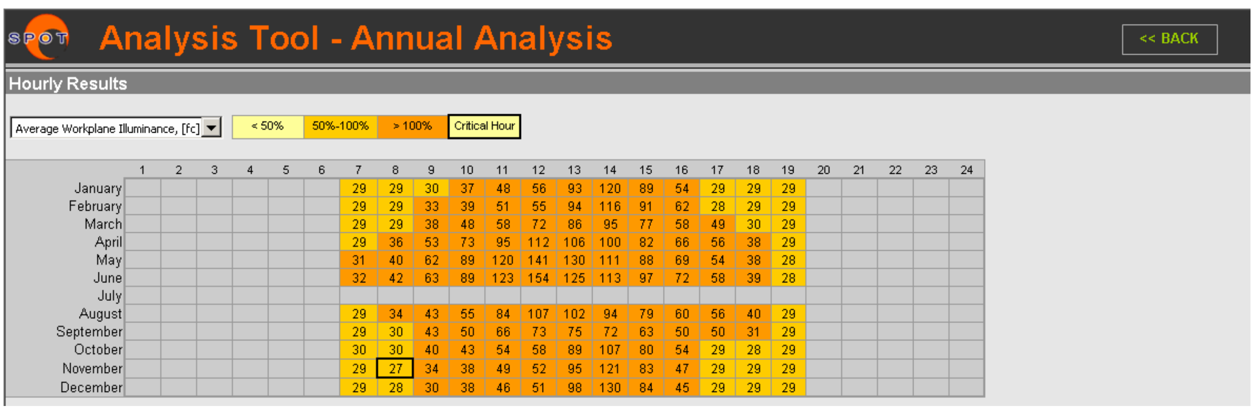
Electric Savings [kWh/day] - This option displays the daily electric savings achieved. This represents the electric savings due to the electric lighting system only and not other indirect electric savings due to reduced fan power and cooling electricity requirements.

Additional Heating Load [kBtu/day or kWh/day] - This option displays the additional heating load imposed on the space due to the lack of heat gain from turned off electric lighting.

Cooling Load Savings [kBtu/day or kWh/day] - This option displays the reduced cooling load provided to the space due to the lack of heat gain from turned off electric lighting.

6.4 Hourly Results

The next set of results consists of a color-coded hourly results table and a pull-down menu to choose the data to be displayed as shown in Figure 6-11. The hourly results table has a row for each month of the year, January through December, and a column for each hour, 1 through 24. The data displayed represents the monthly average for that particular hour. This can inform the user of which times of day are and are not performing well. Similar to the daily results, the **Critical Hour** is highlighted. This represents the hour with the lowest average monthly illuminance in a typical year. If minimum or maximum illuminance is selected in the pull-down menu, the **Critical Hour** highlighted is either the lowest minimum illuminance or higher maximum illuminance.



	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
January							29	29	30	37	48	56	93	120	89	54	29	29	29					
February							29	29	33	39	51	55	94	116	91	62	28	29	29					
March							29	29	38	48	58	72	86	95	77	58	49	30	29					
April							29	36	53	73	95	112	106	100	82	66	56	38	29					
May							31	40	62	89	120	141	130	111	88	69	54	38	28					
June							32	42	63	89	123	154	125	113	97	72	58	39	28					
July																								
August							29	34	43	55	84	107	102	94	79	60	56	40	29					
September							29	30	43	50	66	73	75	72	63	50	50	31	29					
October							30	30	40	43	54	58	89	107	80	54	29	28	29					
November							29	27	34	38	49	52	95	121	83	47	29	29	29					
December							29	28	30	38	46	51	98	130	84	45	29	29	29					

Figure 6-11: Hourly Results Table - Screen Shot

The options to display on the table are selected in the pull-down menu and include:

Average Light Output [%] - This option displays the monthly average light output for all luminaire zones for each hour of the day, weighted according to the overall lighting power.

Average Illuminance [fc or lux] - This option displays the monthly average workplane illuminance under both electric light and daylight.

Maximum Illuminance [fc or lux] - This option displays the monthly maximum workplane illuminance under both electric light and daylight.

Day of Maximum Illuminance [day] - This option displays the day of the month when the maximum illuminance occurred.

Minimum Illuminance [fc or lux] - This option displays the monthly minimum workplane illuminance under electric light and daylight.

Day of Minimum Illuminance [day] - This option displays the day of the month when the minimum illuminance occurred.

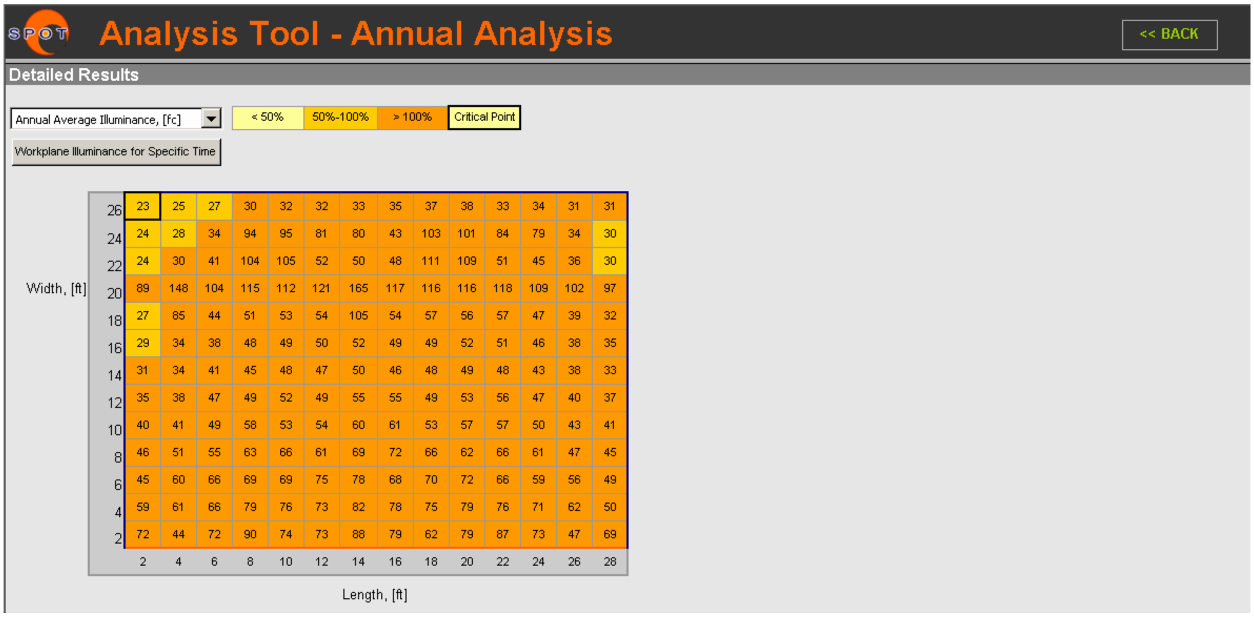
Electric Savings [kWh/month] - This option displays the electric savings achieved for the given hour over the entire month. This represents the electric savings due only to the electric lighting system and not other indirect electric savings due to reduced fan power and cooling electricity requirements.

Additional Heating Load [kBtu/month or kWh/month] - This option displays the additional heating load imposed on the space due to the lack of heat gain from turned off electric lighting.

Cooling Load Savings [kBtu/month or kWh/month] - This option displays the reduced cooling load provided to the space due to the lack of heat gain from turned off electric lighting.

6.5 Detailed Results

The last table on the Annual Analysis screen is similar to the table shown on the Design Tool - Daylight Calculations screen except it now represents true annual data rather than an approximation from the given representative days. Similar to the tables discussed above, the table is color-coded to show the relative performance when illuminance values are selected in the pull-down menu, as illustrated in Figure 6-12. The **Critical Point** in the room is also highlighted for average, minimum, and maximum illuminance selections. When average illuminance is selected, the point highlighted is the point in the room that receives the lowest annual average illuminance. When minimum illuminance is selected, the true **Critical Point** is highlighted, which is the point that received the lowest illuminance throughout the year. When maximum illuminance is selected, the point with the highest illuminance throughout the year is selected.



Width, [ft] \ Length, [ft]	2	4	6	8	10	12	14	16	18	20	22	24	26	28
26	23	25	27	30	32	32	33	35	37	38	33	34	31	31
24	24	28	34	94	95	81	80	43	103	101	84	79	34	30
22	24	30	41	104	105	52	50	48	111	109	51	45	36	30
20	89	148	104	115	112	121	165	117	116	116	118	109	102	97
18	27	85	44	51	53	54	105	54	57	56	57	47	39	32
16	29	34	38	48	49	50	52	49	49	52	51	46	38	35
14	31	34	41	45	48	47	50	46	48	49	48	43	38	33
12	35	38	47	49	52	49	55	55	49	53	56	47	40	37
10	40	41	49	58	53	54	60	61	53	57	57	50	43	41
8	46	51	55	63	66	61	69	72	66	62	66	61	47	45
6	45	60	66	69	69	75	78	68	70	72	66	59	56	49
4	59	61	66	79	76	73	82	78	75	79	76	71	62	50
2	72	44	72	90	74	73	88	79	62	79	87	73	47	69

Figure 6-12: Detailed Results Table - Screen Shot

The data to display on the table is selected in the pull-down menu and includes:

Average Illuminance [fc or lux] - This option displays the annual average workplane illuminance under both electric light and daylight.

Maximum Illuminance [fc or lux] - This option displays the annual maximum workplane illuminance under both electric light and daylight.

Time of Maximum Illuminance [h.m] - This option displays the hour and month the maximum illuminance occurred for each point on the workplane.

Minimum Illuminance [fc or lux] - This option displays the annual minimum workplane illuminance under electric light and daylight. This is the absolute critical point of the space.

Time of Minimum Illuminance [h.m] - This option displays the hour and month the minimum illuminance occurred for each point on the workplane.

The Workplane Illuminance for Specific Time button below the pull-down menu, takes the user to the Climate Specific Results page previously accessible in the program. At this point, the results displayed on this page will be more accurate than before as they will be based on the denser analysis mode sample days.

Appendix A – Frequent Frequently Asked Questions

1.) What is SPOT?

SPOT stands for Sensor Placement + Optimization Tool. It is a software package that helps architects, engineers, lighting designers and electrical contractors establish the correct photosensor placement relative to the proposed daylighting and electric lighting design and to analyze overall lighting design performance.

SPOT was developed for designers, design engineers, building scientists, contractors, facilities managers, and commissioning agents to provide a relatively simple way to test and evaluate the selection and placement of a photosensor(s) during design in order to promote optimal daylight harvesting, increased energy savings, and higher occupant satisfaction in the built space.

2.) What are the computer system requirements for SPOT?

Windows 2000, Windows NT, or Windows XP
Excel 2000 (or higher)
800 MegaHertz CPU
128 Megabytes RAM

3.) How does SPOT work and what programs will be installed on my computer with the install package?

SPOT basically runs as an Excel interface on top of a Radiance engine using Python as the scripting language. SPOT's install package includes:

SPOT Excel Template
An abridged version of Radiance for Windows
Python v 2.3
Numarray (a matrix module for Python)

4.) Do I need to know Excel or Radiance to use SPOT?

No. A working familiarity with Excel may be helpful, but it is not necessary. Radiance will be largely invisible to the majority of users, and only runs behind the Excel interface. Advanced Radiance users may use the "Advanced Options" screen to interact with Radiance through the Excel interface or directly by manipulating the Radiance files, but this is NOT required in the execution of SPOT and is not recommended unless you are a skilled Radiance user.

5.) Where does SPOT save my work?

SPOT automatically creates a file with your project information when you advance the project with the Begin Project >> button. It saves the project information in a folder automatically named with the Project Name. This folder is located in the "Parent Directory" that the user establishes on the opening screen of SPOT. After launching SPOT it is necessary, as with most programs, for the user to periodically (frequently) save his or her work using the save icon, or "save" from the pull down menu to insure no information is lost.

6.) What are all the numerous files created by SPOT and do I need to save them?

These files are support files created by Radiance. They store the inputs used by SPOT to run the calculations. Should you delete these files you will need to re-start a project from the beginning so that these files are recreated.

7.) What are "Advanced Radiance Options" and should I use them?

The default SPOT settings have been optimized to minimize the run-time (calculation time) of the program. The Advanced Radiance Options allows the experienced Radiance user to manipulate the default settings in Radiance if he or she desires to refine a particular setting for advanced study. This screen is intended for people familiar with Radiance and its methodology. However, others are welcome to experiment with the settings to learn more about the influence of various inputs on the results. Be aware, that changing the settings may increase run-time and decrease the accuracy of the results.

8.) What is the average run-time for SPOT?

This depends upon on the computer system on which SPOT is running. On newer machines, typical run-time may be 60 to 90 minutes, the majority of which will occur for the final calculations performed between the Photosensor Generator screen and the Photosensor Analyzer screen.

9.) What geometrical inputs are allowable for my space?

SPOT builds the geometry for the user based on the numeric information input into the Excel interface. Currently, the interface creates orthogonal geometries and can accommodate windows, skylights, and interior and exterior lightshelves.

10.) Can I input geometry directly from Autocad?

No, SPOT cannot currently perform this function. However, this capability is planned for a future release.

11.) How will the results be presented and will SPOT create an image of my space?

Results will be created in Excel tables and graphs formats, which the user can either print or copy and paste into other reports. A Radiance image will be created of the space modeled and will be saved as a .jpeg in the project directory.

12.) Can I model more than one space at a time?

No, SPOT is designed to analyze a single space in isolation.

13.) Is there any technical support provided for SPOT?

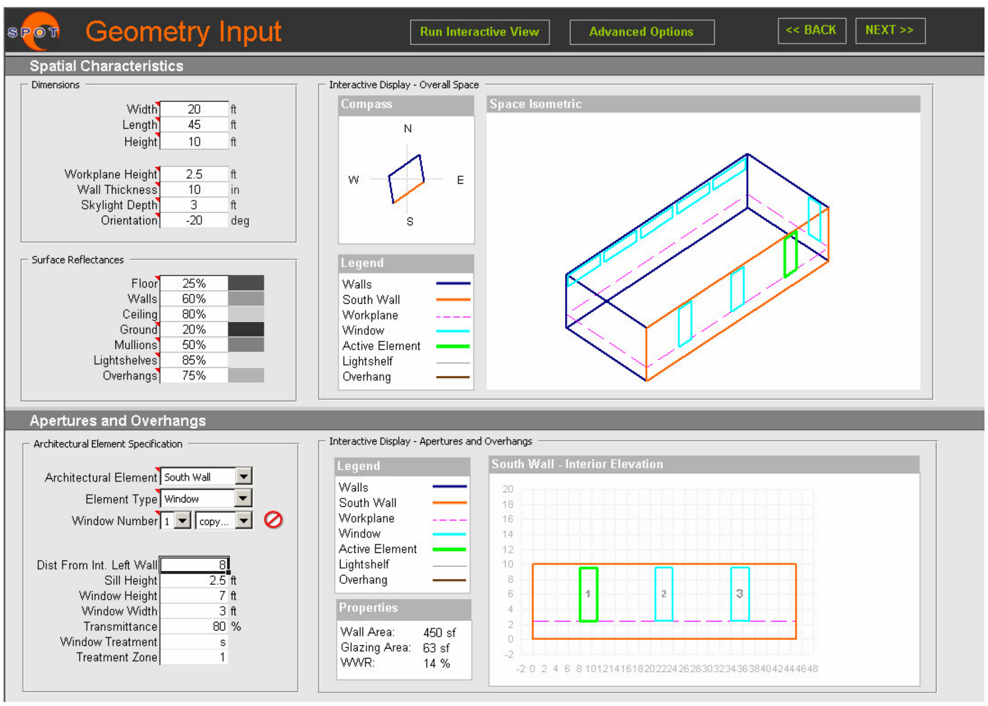
Send an e-mail to spotsupport@archenergy.com. In addition, there is an internet mailing list for all issues related to SPOT. To sign up for the list go to http://www.archenergy.com/mailman/listinfo/SPOT

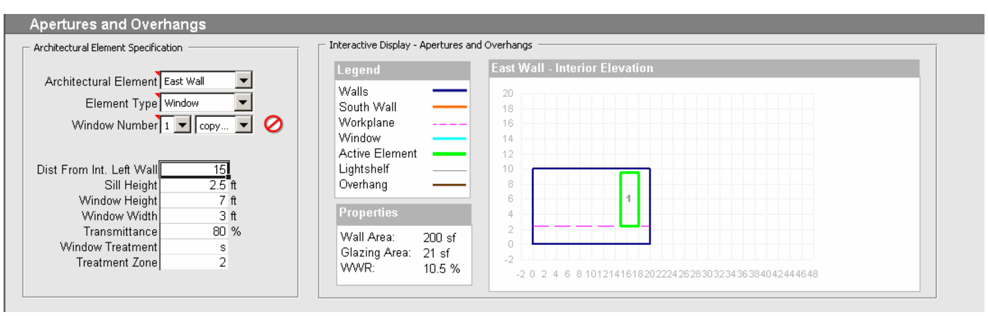
Appendix B – SPOT Case Studies

The following two case studies step through the user input process outlined in previous sections, and additionally, show iterations with the analysis portion of SPOT.

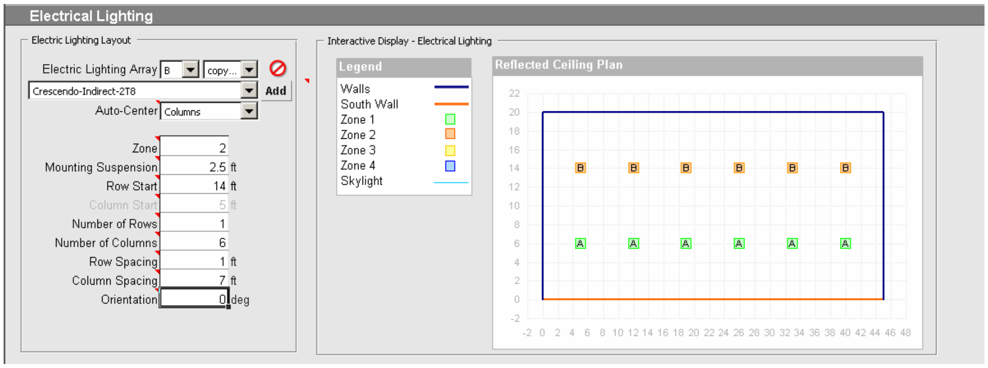
Test Classroom #1 – South and East windows w/ shades, and North windows (2 lighting zones)

Test Classroom #1 is a narrow space, oriented 20° East of South. Windows on the south wall are associated with shade control zone 1, while the window on the East wall is associated with shade control zone 2. The translucent windows on the North side of the building do not have any additional solar control devices.

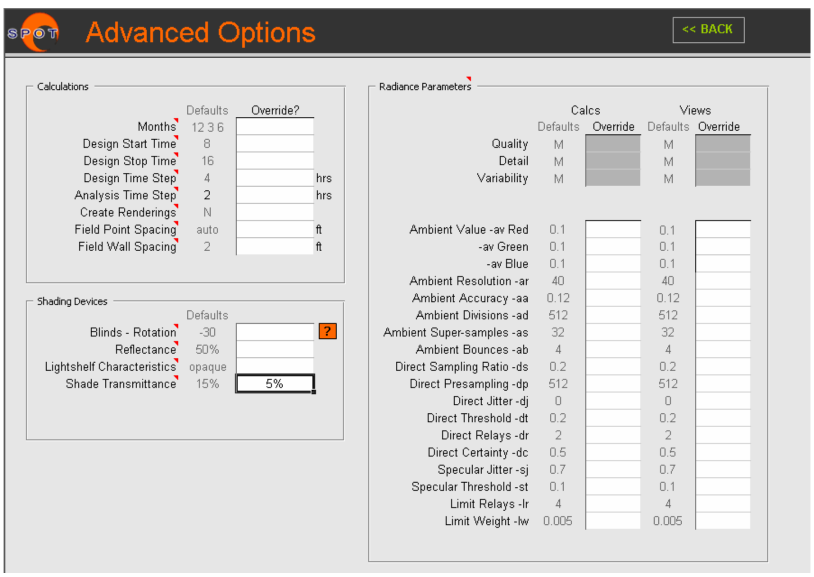


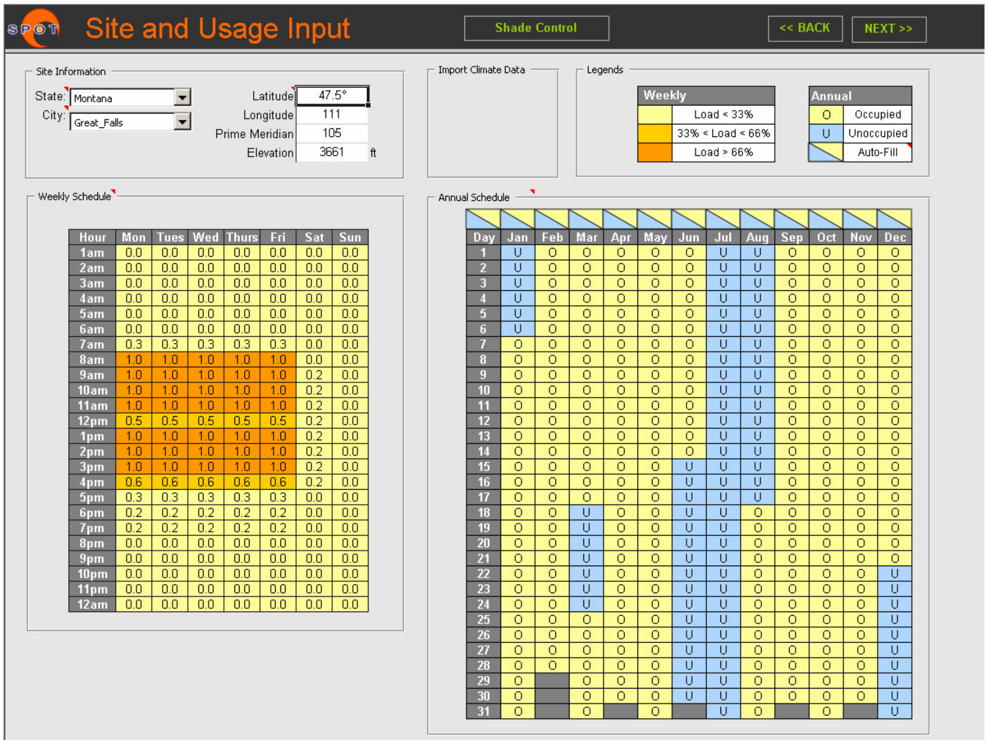


Two electric lighting zones are defined for separate photosensor control.

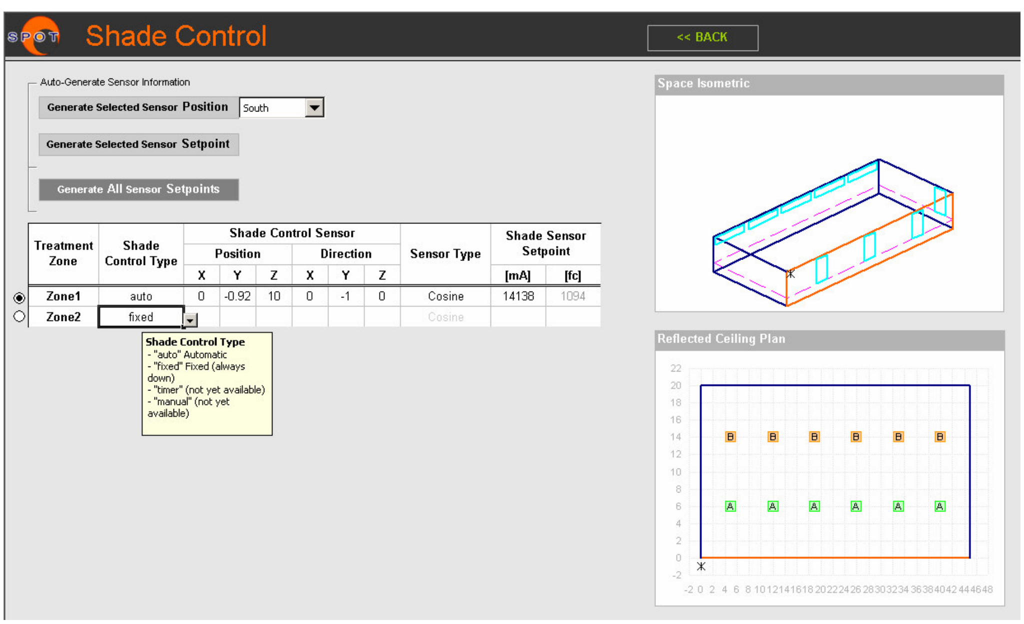


All variables remain as default values except for the shade transmittance, which is lowered to 5%.

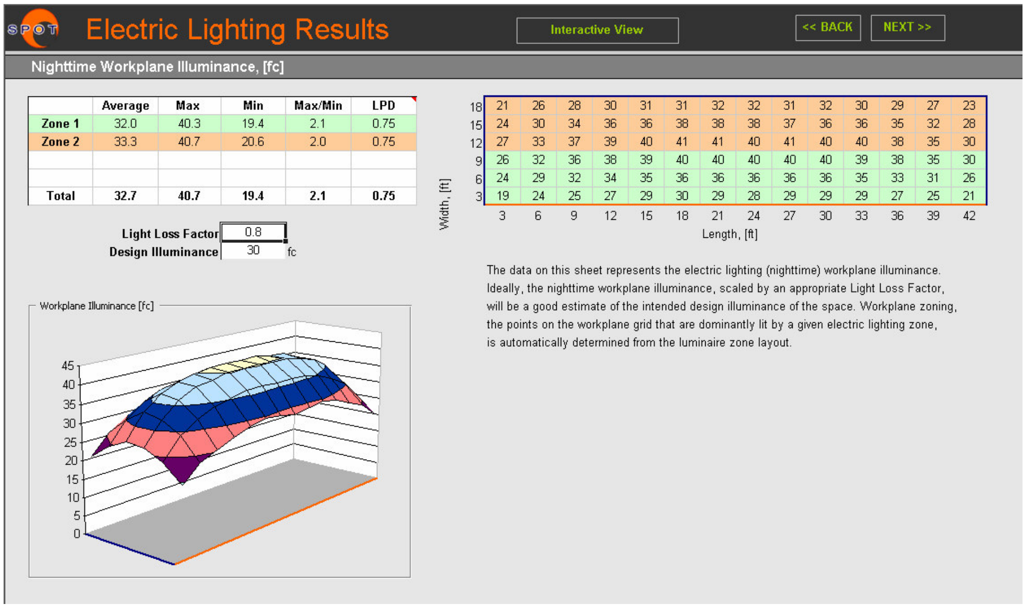




The shades for the South windows (Zone 1, as previously defined) are given automatic controls. The sensor position can be entered manually, but in this instance, the position is determined by first selecting the South wall from the drop down menu and then clicking on the "Generate Selected Sensor Position" button. The setpoint is also generated automatically. Since it is difficult to provide solar control on the East façade of a building, the East window (Zone 2) is given fixed shades, which will be considered down for all calculations.



With the Light Loss Factor set to 0.8, the design illuminance of 30 footcandles is met over a majority of the workplane.



SPOT Electric Lighting Results

Interactive View | << BACK | NEXT >>

Nighttime Workplane Illuminance, [fc]

	Average	Max	Min	Max/Min	LPD
Zone 1	32.0	40.3	19.4	2.1	0.75
Zone 2	33.3	40.7	20.6	2.0	0.75
Total	32.7	40.7	19.4	2.1	0.75

Light Loss Factor 0.8

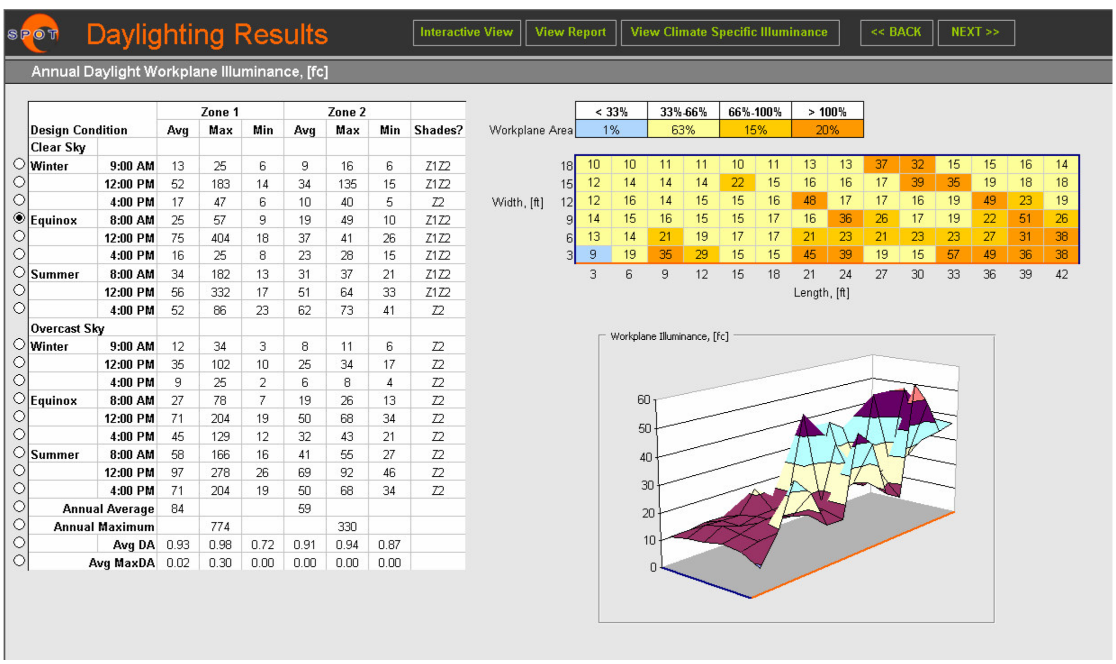
Design Illuminance 30 fc

Width, [ft] \ Length, [ft]	3	6	9	12	15	18	21	24	27	30	33	36	39	42
18	21	26	28	30	31	31	32	32	31	32	30	29	27	23
15	24	30	34	36	36	38	38	38	37	36	36	35	32	28
12	27	33	37	39	40	41	41	40	41	40	40	38	35	30
9	26	32	36	38	39	40	40	40	40	40	39	38	35	30
6	24	29	32	34	35	36	36	36	36	36	35	33	31	26
3	19	24	25	27	29	30	29	28	29	29	29	27	25	21

The data on this sheet represents the electric lighting (nighttime) workplane illuminance. Ideally, the nighttime workplane illuminance, scaled by an appropriate Light Loss Factor, will be a good estimate of the intended design illuminance of the space. Workplane zoning, the points on the workplane grid that are dominantly lit by a given electric lighting zone, is automatically determined from the luminaire zone layout.

Workplane Illuminance [fc]

As expected, the low transmittance shades block a great deal of the low morning sun entering through the South and East windows. The translucent North windows help provide a low level of ambient daylight throughout the space.



SPOT Daylighting Results

Interactive View | View Report | View Climate Specific Illuminance | << BACK | NEXT >>

Annual Daylight Workplane Illuminance, [fc]

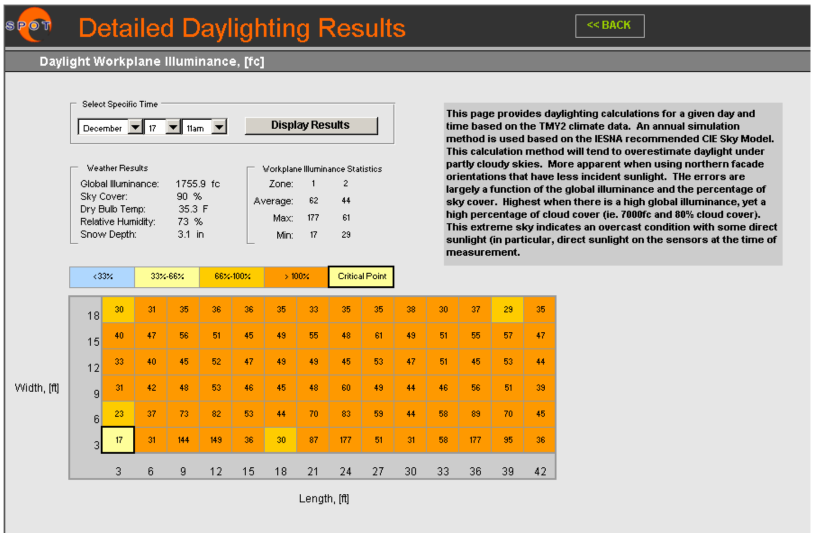
Design Condition		Zone 1 Avg	Zone 1 Max	Zone 1 Min	Zone 2 Avg	Zone 2 Max	Zone 2 Min	Shades?
Clear Sky								
Winter	9:00 AM	13	25	6	9	16	6	Z1Z2
	12:00 PM	52	183	14	34	135	15	Z1Z2
	4:00 PM	17	47	6	10	40	5	Z2
Equinox	8:00 AM	25	57	9	19	49	10	Z1Z2
	12:00 PM	75	404	18	37	41	26	Z1Z2
	4:00 PM	16	25	8	23	28	15	Z1Z2
Summer	8:00 AM	34	182	13	31	37	21	Z1Z2
	12:00 PM	56	332	17	51	64	33	Z1Z2
	4:00 PM	52	86	23	62	73	41	Z2
Overcast Sky								
Winter	9:00 AM	12	34	3	8	11	6	Z2
	12:00 PM	35	102	10	25	34	17	Z2
	4:00 PM	9	25	2	6	8	4	Z2
Equinox	8:00 AM	27	78	7	19	26	13	Z2
	12:00 PM	71	204	19	50	68	34	Z2
	4:00 PM	45	129	12	32	43	21	Z2
Summer	8:00 AM	58	166	16	41	55	27	Z2
	12:00 PM	97	278	26	69	92	46	Z2
	4:00 PM	71	204	19	50	68	34	Z2
Annual Average		84			59			
Annual Maximum			774			330		
	Avg DA	0.93	0.98	0.72	0.91	0.94	0.87	
	Avg MaxDA	0.02	0.30	0.00	0.00	0.00	0.00	

	< 33%	33%-66%	66%-100%	> 100%
Workplane Area	1%	63%	15%	20%

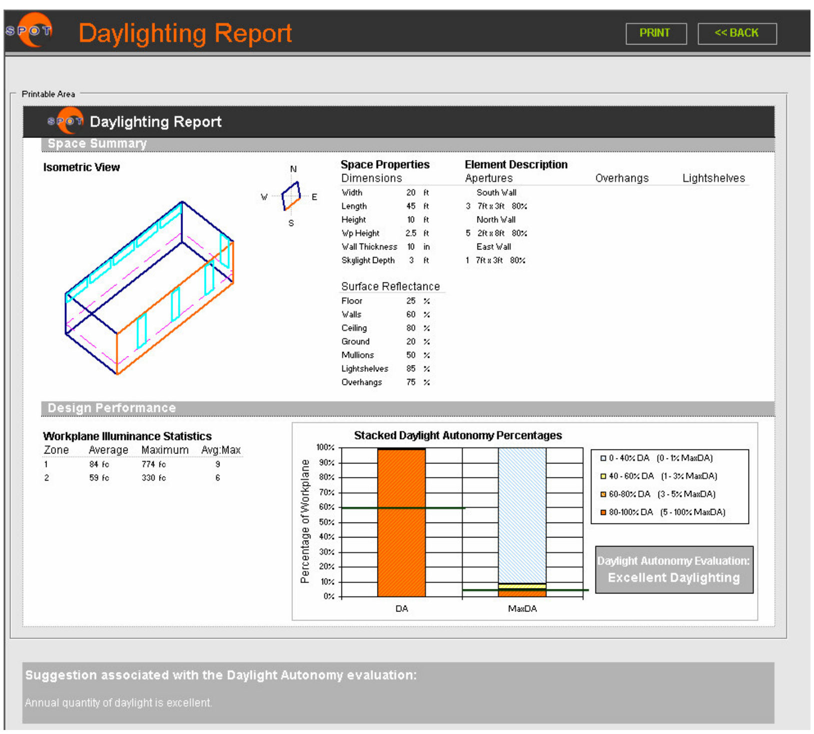
Width, [ft] \ Length, [ft]	3	6	9	12	15	18	21	24	27	30	33	36	39	42
18	10	10	11	11	10	11	13	13	37	32	15	15	16	14
15	12	14	14	14	22	15	16	16	17	39	35	19	18	18
12	12	16	14	15	15	16	48	17	17	16	19	49	23	19
9	14	15	16	15	15	17	16	36	26	17	19	22	51	26
6	13	14	21	19	17	17	21	23	21	23	23	27	31	38
3	9	19	35	29	15	15	45	39	19	15	57	49	36	38

Workplane Illuminance, [fc]

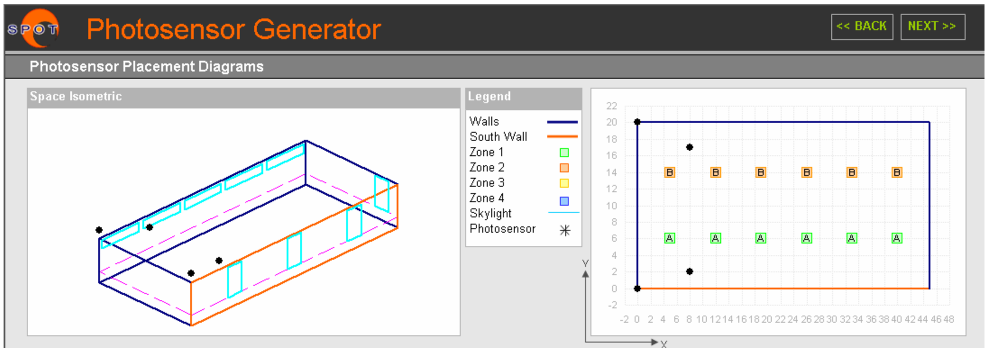
Due to the building orientation and fenestration selection, it can be seen that the Southwest corner of the room will receive the least daylight contribution during most hours and days of the year. This page also proves a reminder and/or connection between the selected location in terms of latitude (which is displayed on the Site and Usage page) and the location's climate.



Test Classroom #1 provides copious amounts of diffuse daylight, without allowing direct sun to penetrate the façade. This circumstance awards the space with a Daylight Autonomy evaluation of "Excellent Daylighting".



Sensor_1 and Sensor_2 placements are the recommendations given by SPOT. As can be seen by the lighter colored regions in each Correlation to Zone plot, SPOT shows optimal placement in the annular region surrounding the electric lights. Additional sensors are placed by the user in each zone to test the affects of 45-degree Cosine sensors and Open Loop sensors on energy and cost savings. Sensors 1b and 2b are defined as free standing (F) so that they can be placed on the exterior of the building for Open Loop control.



Photosensor Placement — Revert to Generated Points

Photosensor Name	Mounting	Location X	Y	Z	Aiming	Photosensor Type	Rotation
Sensor_1	C	8	2	10	D	Cosine	0
Sensor_2	C	8	17	10	D	Cosine	0
Sensor_1a	C	8	2	10	D	45cos	0
Sensor_2a	C	8	17	10	D	45cos	0
Sensor_1b	F	0	0	12	S	Cosine	0
Sensor_2b	F	0	20	12	N	Cosine	0

View Correlation to Zone: 1

Width, [ft] \ Length, [ft]	2	5	8	11	14	17	20	23	26	29	32	35	38	41
17	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
14	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
11	30%	0%	18%	17%	14%	15%	12%	26%	5%	25%	9%	18%	13%	5%
8	54%	26%	29%	35%	40%	33%	28%	42%	27%	38%	32%	39%	31%	25%
5	33%	41%	34%	22%	38%	27%	21%	38%	19%	35%	23%	35%	28%	22%
2	44%	62%	69%	66%	62%	56%	66%	59%	60%	61%	62%	68%	65%	57%

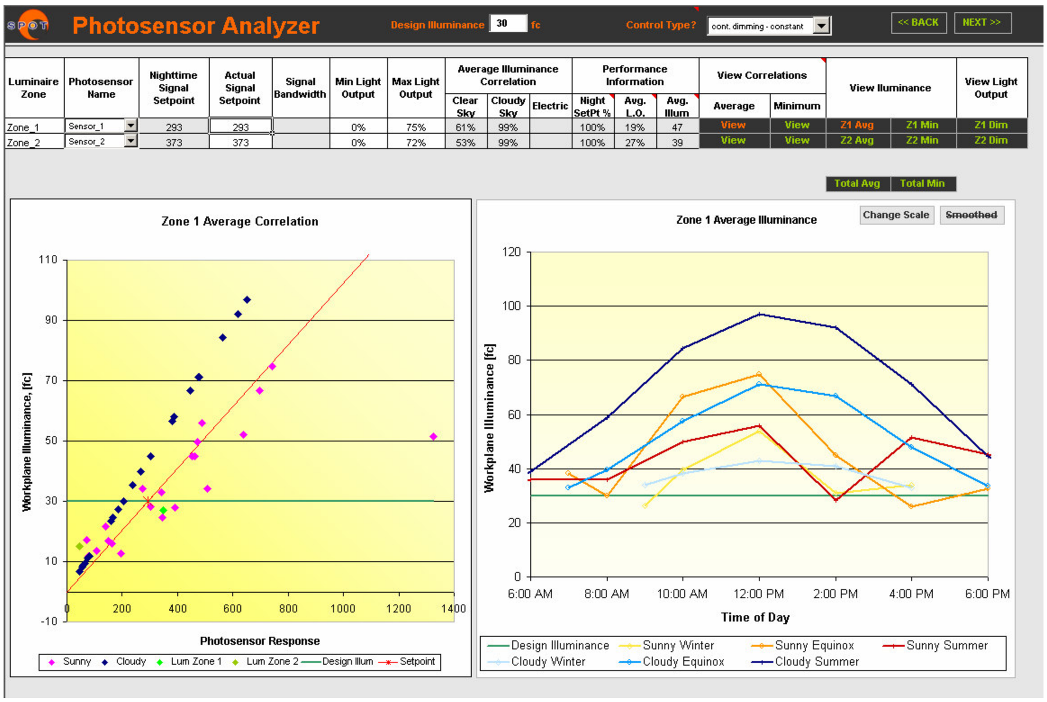
Photosensor Placement — Revert to Generated Points

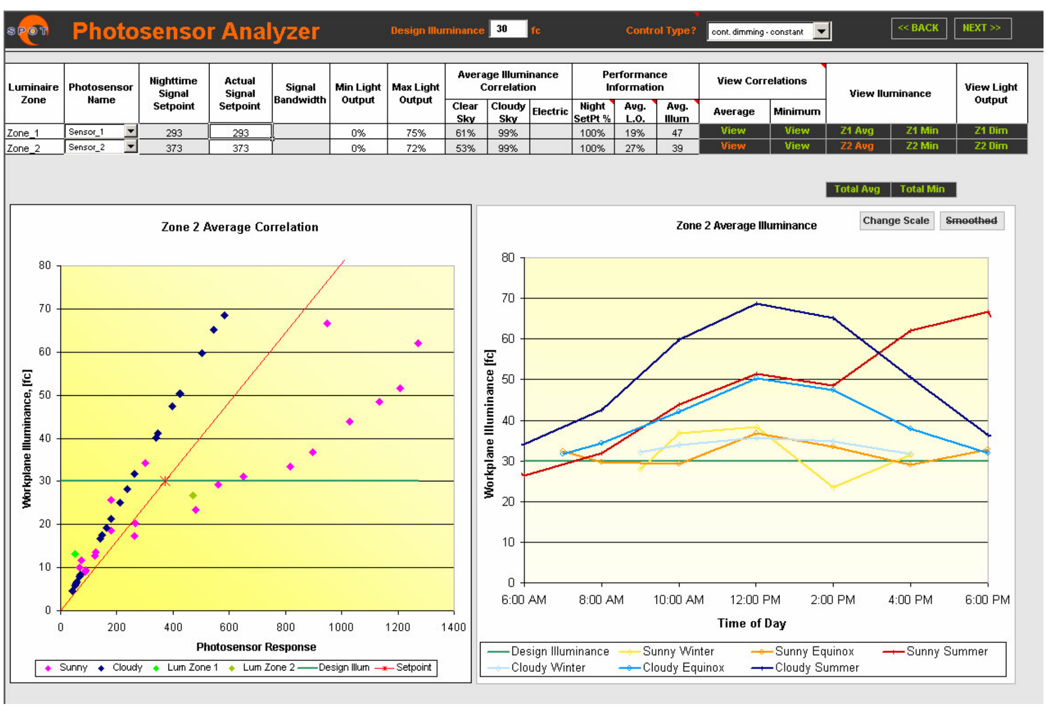
Photosensor Name	Mounting	Location X	Y	Z	Aiming	Photosensor Type	Rotation
Sensor_1	C	8	2	10	D	Cosine	0
Sensor_2	C	8	17	10	D	Cosine	0
Sensor_1a	C	8	2	10	D	45cos	0
Sensor_2a	C	8	17	10	D	45cos	0
Sensor_1b	F	0	0	12	S	Cosine	0
Sensor_2b	F	0	20	12	N	Cosine	0

View Correlation to Zone: 2

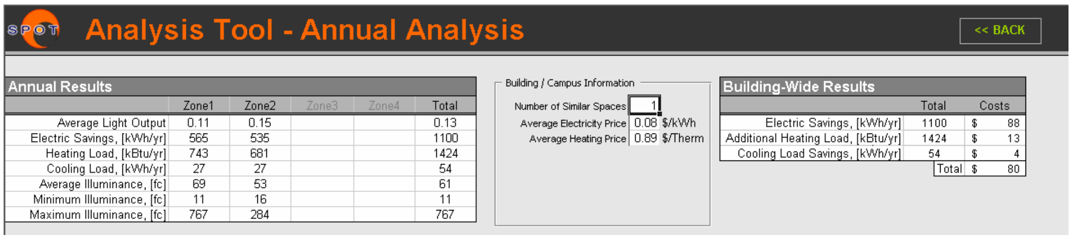
Width, [ft] \ Length, [ft]	2	5	8	11	14	17	20	23	26	29	32	35	38	41
17	63%	61%	71%	60%	62%	69%	58%	66%	59%	69%	63%	57%	60%	57%
14	55%	28%	59%	31%	30%	38%	28%	52%	27%	55%	32%	30%	32%	22%
11	53%	45%	60%	68%	59%	60%	61%	69%	54%	67%	58%	64%	58%	55%
8	7%	0%	0%	0%	0%	0%	0%	6%	0%	1%	0%	0%	0%	0%
5	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
2	0%	0%	10%	9%	5%	1%	10%	8%	4%	6%	7%	11%	9%	1%

The positive feedback given in the Daylighting Report is reinforced in the Photosensor Analyzer page by the strong linear correlation between photosensor response and workplane illuminance during sunny conditions, for both zones. With the SPOT photosensor placements of Sensor_1 and Sensor_2, the average workplane illuminance will range from about 30 to 100 footcandles, and occasionally drop below the 30 footcandle criterion.





The energy and cost savings for one similar space, with the Cosine sensor and Continuous Dimming control system are given in the Annual Results charts.



Annual Results

	Zone1	Zone2	Zone3	Zone4	Total
Average Light Output	0.11	0.15			0.13
Electric Savings, [kWh/yr]	565	535			1100
Heating Load, [kBtu/yr]	743	681			1424
Cooling Load, [kWh/yr]	27	27			54
Average Illuminance, [fc]	69	53			61
Minimum Illuminance, [fc]	11	16			11
Maximum Illuminance, [fc]	767	284			767

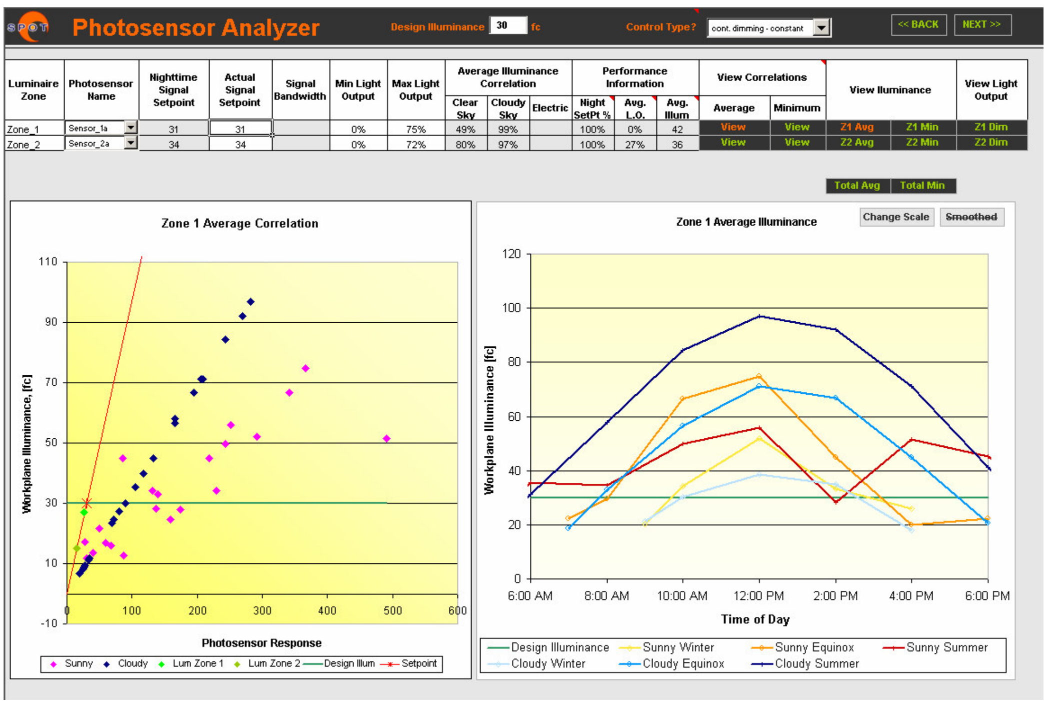
Building / Campus Information

Number of Similar Spaces	1	
Average Electricity Price	0.08	$/kWh
Average Heating Price	0.89	$/Therm

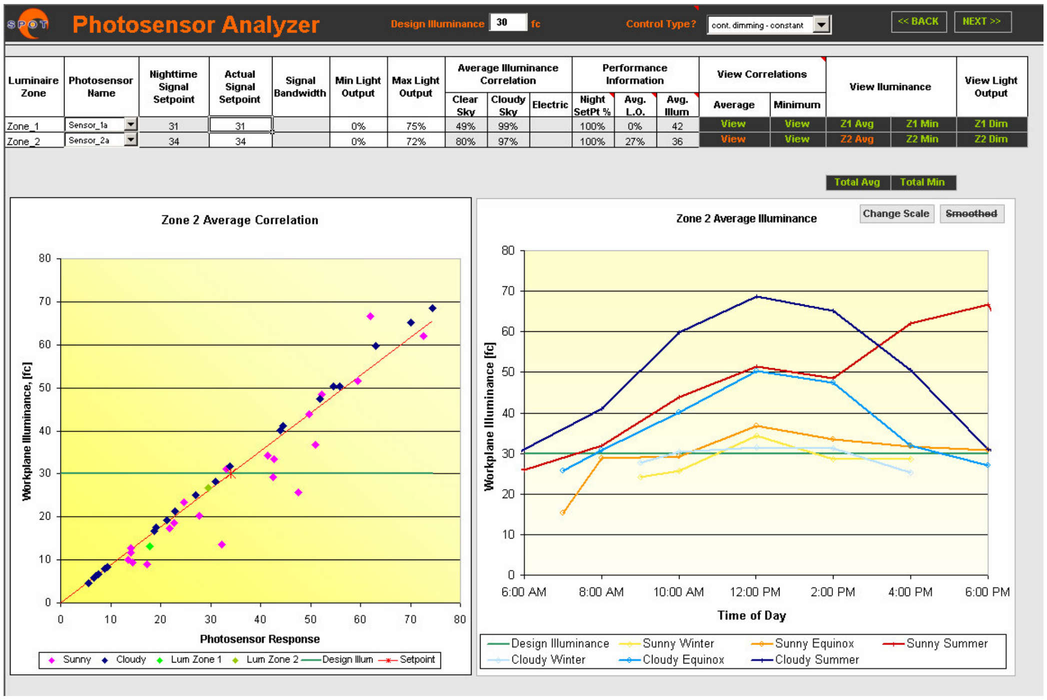
Building-Wide Results

	Total	Costs
Electric Savings, [kWh/yr]	1100	$ 88
Additional Heating Load, [kBtu/yr]	1424	$ 13
Cooling Load Savings, [kWh/yr]	54	$ 4
	Total	$ 80

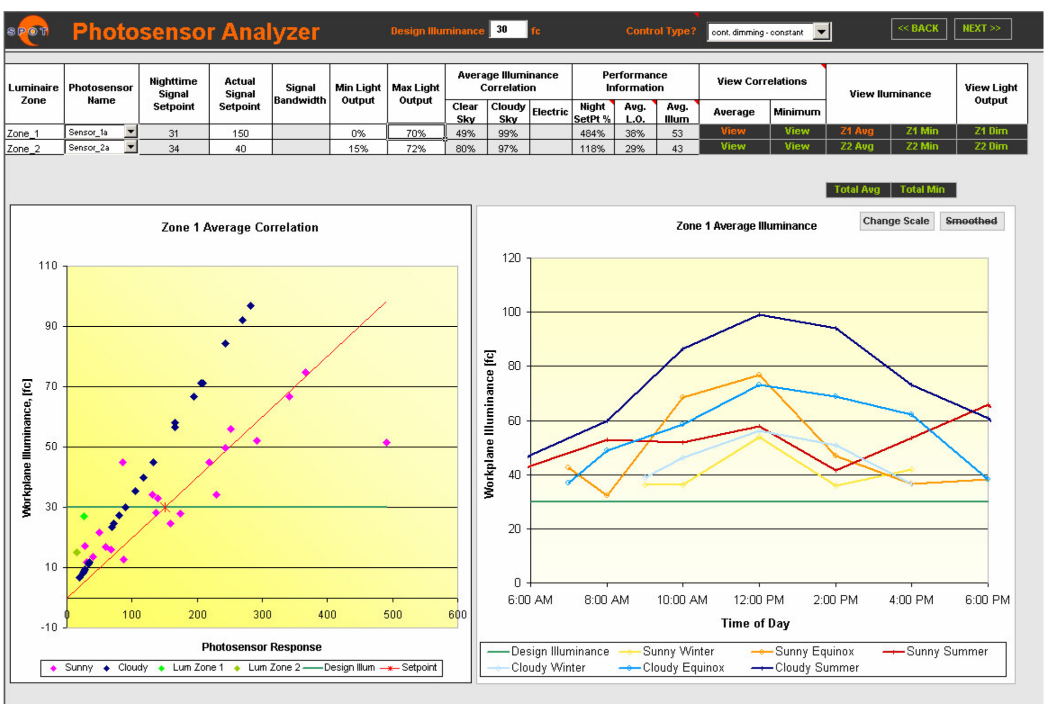
The following plots show the SPOT defaults given for the 45-degree Cosine sensors (Sensor_1a and Sensor_2a) added by the user. With these SPOT default values, the average workplane illuminance will often fall below the criterion.



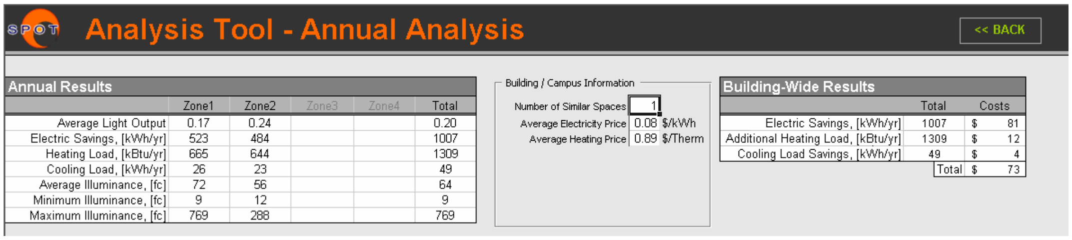
Luminaire Zone	Photosensor Name	Nighttime Signal Setpoint	Actual Signal Setpoint	Signal Bandwidth	Min Light Output	Max Light Output	Average Illuminance Correlation: Clear Sky	Cloudy Sky	Electric	Performance Information: Night SetPt %	Avg. L.O.	Avg. Illum	View Correlations: Average	Minimum	View Iluminance		View Light Output
Zone_1	Sensor_1a	31	31		0%	75%	49%	99%		100%	0%	42	View	View	Z1 Avg	Z1 Min	Z1 Dim
Zone_2	Sensor_2a	34	34		0%	72%	80%	97%		100%	27%	36	View	View	Z2 Avg	Z2 Min	Z2 Dim



Since the linear correlation for the previous plot appears very strong, the photosensor variables are adjusted for the 45-degree Cosine sensors to determine if greater savings can be achieved. For Sensor_1a and Sensor_2a, the setpoints are increased, and the minimum light output for Sensor_2a is increased. The minimum of 30 footcandles is now met for both zones during all times of day and year, but the range of workplane illuminance does not appear much different than with the use of Cosine sensors.



The energy and cost savings prove to be slightly lower than with the use of Cosine sensors, although this difference could be due to user adjustment of the default values, and not necessarily functionality of the 45-degree Cosine sensor in this application.



Analysis Tool - Annual Analysis

Annual Results

	Zone1	Zone2	Zone3	Zone4	Total
Average Light Output	0.17	0.24			0.20
Electric Savings, [kWh/yr]	523	484			1007
Heating Load, [kBtu/yr]	665	644			1309
Cooling Load, [kWh/yr]	26	23			49
Average Illuminance, [fc]	72	56			64
Minimum Illuminance, [fc]	9	12			9
Maximum Illuminance, [fc]	769	288			769

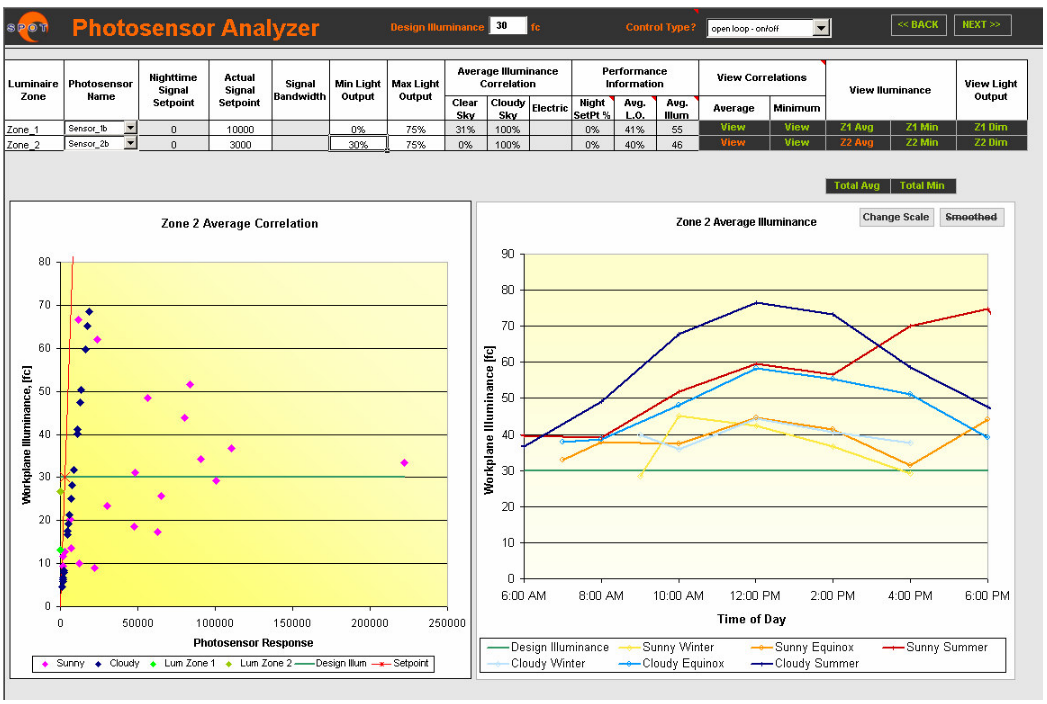
Building / Campus Information

Number of Similar Spaces	1
Average Electricity Price	0.08 $/kWh
Average Heating Price	0.89 $/Therm

Building-Wide Results

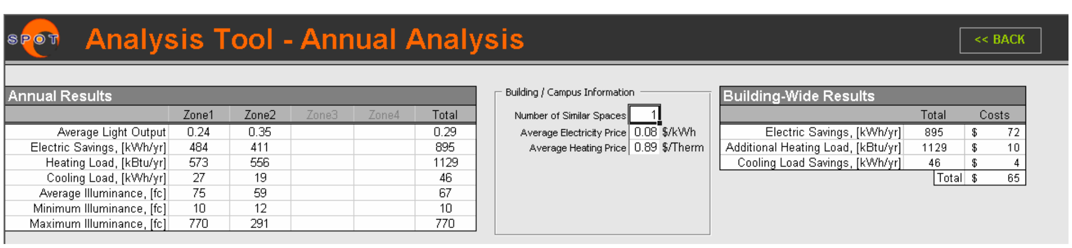
	Total	Costs
Electric Savings, [kWh/yr]	1007	$ 81
Additional Heating Load, [kBtu/yr]	1309	$ 12
Cooling Load Savings, [kWh/yr]	49	$ 4
	Total	$ 73

In order to test one more sensor type, the following plots show the selection of Open Loop control type paired with the exterior sensors 1b and 2b. The SPOT default values for setpoint and minimum light output are adjusted by the user in an iterative process in an attempt to shrink the workplane illuminance range while keeping the minimum illuminance above the criterion.



Luminaire Zone	Photosensor Name	Nighttime Signal Setpoint	Actual Signal Setpoint	Signal Bandwidth	Min Light Output	Max Light Output	Average Illuminance Correlation: Clear Sky	Cloudy Sky	Electric	Performance Information: Night SetPt %	Avg. L.O.	Avg. Illum	View Correlations: Average	Minimum	View Iluminance		View Light Output
Zone_1	Sensor_1b	0	10000		0%	75%	31%	100%		0%	41%	55	View	View	Z1 Avg	Z1 Min	Z1 Dim
Zone_2	Sensor_2b	0	3000		30%	75%	0%	100%		0%	40%	46	View	View	Z2 Avg	Z2 Min	Z2 Dim

The savings provided by the open loop sensors are the lowest of the three options presented.



Analysis Tool - Annual Analysis

Annual Results

	Zone1	Zone2	Zone3	Zone4	Total
Average Light Output	0.24	0.35			0.29
Electric Savings, [kWh/yr]	484	411			895
Heating Load, [kBtu/yr]	573	556			1129
Cooling Load, [kWh/yr]	27	19			46
Average Illuminance, [fc]	75	59			67
Minimum Illuminance, [fc]	10	12			10
Maximum Illuminance, [fc]	770	291			770

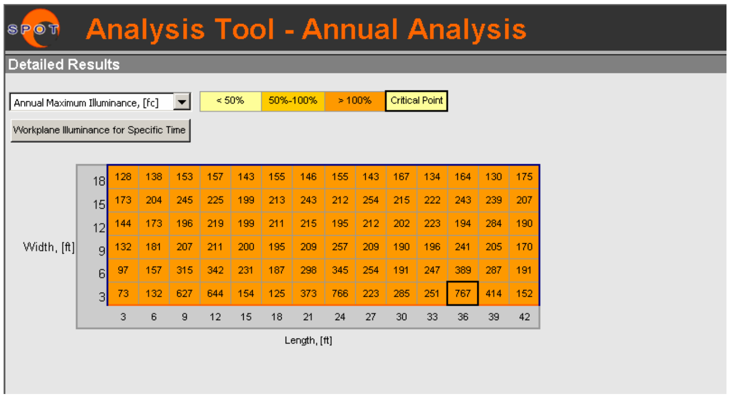
Building / Campus Information

Number of Similar Spaces	1
Average Electricity Price	0.08 $/kWh
Average Heating Price	0.89 $/Therm

Building-Wide Results

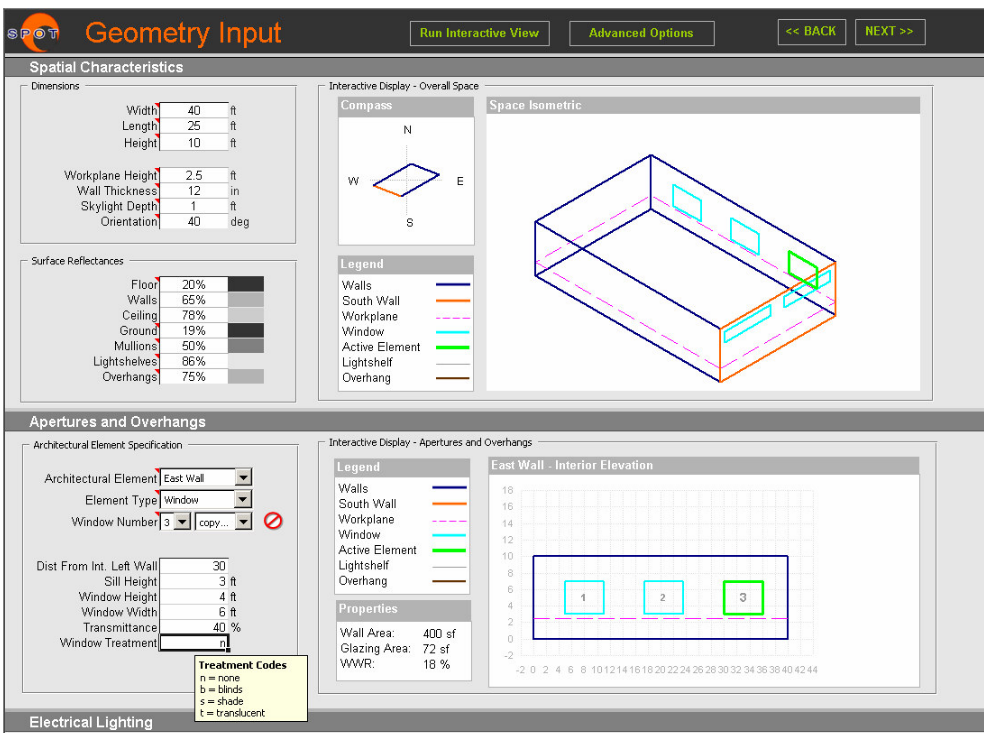
	Total	Costs
Electric Savings, [kWh/yr]	895	$ 72
Additional Heating Load, [kBtu/yr]	1129	$ 10
Cooling Load Savings, [kWh/yr]	46	$ 4
	Total	$ 65

In addition to comparing the energy and cost savings tables, Daily, Hourly, and Detailed Results for the workplane should be reviewed on the Annual Analysis page to ensure an overall acceptable daylighting design.

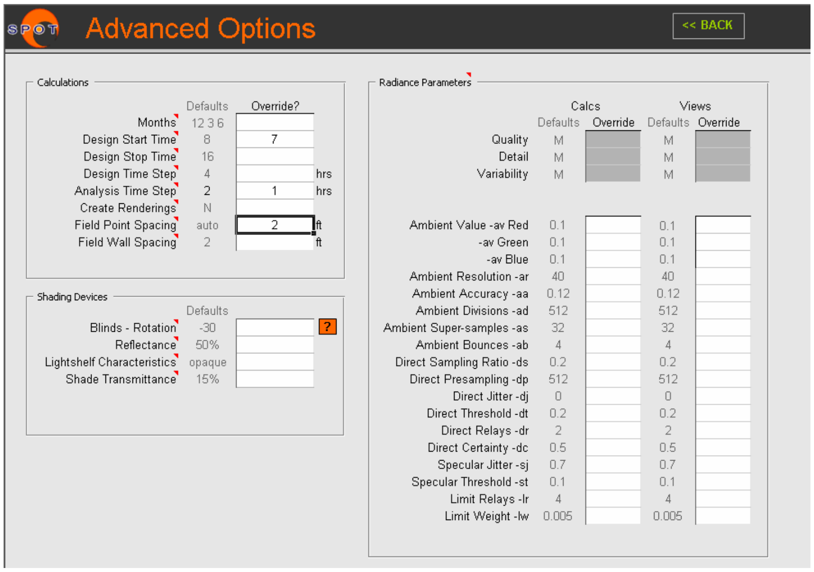


Test Classroom #2 – South and East windows w/out solar control devices (3 lighting zones)

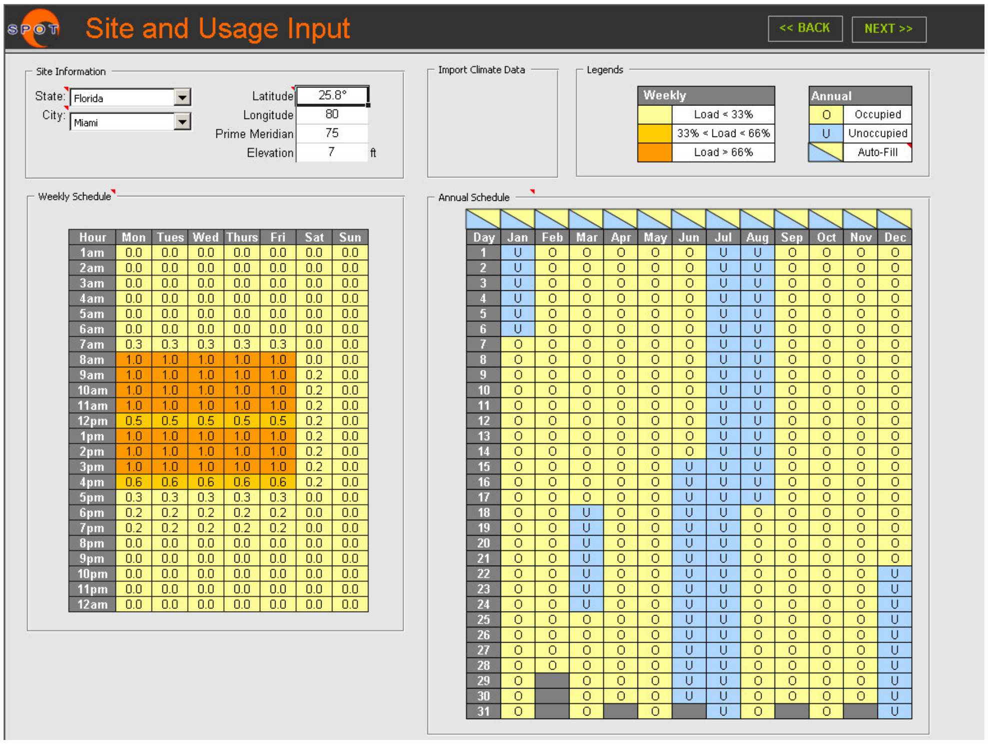
Unlike the previous test classroom, this space is not given solar control devices for the fenestration. Three electric lighting zones are used with the thought of seeing some energy and cost savings with dimming control.



Electrical Lighting
Electric Lighting Layout
Electric Lighting Array D copy...
Crescendo-Indirect-2T8
Add
Auto-Center Off
Zone 3
Mounting Suspension 2.5 ft
Row Start 16.75 ft
Column Start 7 ft
Number of Rows 4
Number of Columns 1
Row Spacing 6.5 ft
Column Spacing 10 ft
Orientation 90 deg
Interactive Display - Electrical Lighting
Legend
Walls
South Wall
Zone 1
Zone 2
Zone 3
Zone 4
Skylight
Reflected Ceiling Plan



Advanced Options
<< BACK
Calculations
Defaults Override?
Months 12 3 6
Design Start Time 8 7
Design Stop Time 16
Design Time Step 4 hrs
Analysis Time Step 2 1 hrs
Create Renderings N
Field Point Spacing auto 2 ft
Field Wall Spacing 2 ft
Shading Devices
Defaults
Blinds - Rotation -30
Reflectance 50%
Lightshelf Characteristics opaque
Shade Transmittance 15%
Radiance Parameters
Calcs Views
Defaults Override Defaults Override
Quality M M
Detail M M
Variability M M
Ambient Value -av Red 0.1 0.1
-av Green 0.1 0.1
-av Blue 0.1 0.1
Ambient Resolution -ar 40 40
Ambient Accuracy -aa 0.12 0.12
Ambient Divisions -ad 512 512
Ambient Super-samples -as 32 32
Ambient Bounces -ab 4 4
Direct Sampling Ratio -ds 0.2 0.2
Direct Presampling -dp 512 512
Direct Jitter -dj 0 0
Direct Threshold -dt 0.2 0.2
Direct Relays -dr 2 2
Direct Certainty -dc 0.5 0.5
Specular Jitter -sj 0.7 0.7
Specular Threshold -st 0.1 0.1
Limit Relays -lr 4 4
Limit Weight -lw 0.005 0.005


Site and Usage Input
<< BACK
NEXT >>
Site Information
State: Florida
City: Miami
Latitude 25.8°
Longitude 80
Prime Meridian 75
Elevation 7 ft
Import Climate Data
Legends
Weekly
Load < 33%
33% < Load < 66%
Load > 66%
Annual
O Occupied
U Unoccupied
Auto-Fill
Weekly Schedule
Hour Mon Tues Wed Thurs Fri Sat Sun
1am 0.0 0.0 0.0 0.0 0.0 0.0 0.0
2am 0.0 0.0 0.0 0.0 0.0 0.0 0.0
3am 0.0 0.0 0.0 0.0 0.0 0.0 0.0
4am 0.0 0.0 0.0 0.0 0.0 0.0 0.0
5am 0.0 0.0 0.0 0.0 0.0 0.0 0.0
6am 0.0 0.0 0.0 0.0 0.0 0.0 0.0
7am 0.3 0.3 0.3 0.3 0.3 0.0 0.0
8am 1.0 1.0 1.0 1.0 1.0 0.0 0.0
9am 1.0 1.0 1.0 1.0 1.0 0.2 0.0
10am 1.0 1.0 1.0 1.0 1.0 0.2 0.0
11am 1.0 1.0 1.0 1.0 1.0 0.2 0.0
12pm 0.5 0.5 0.5 0.5 0.5 0.2 0.0
1pm 1.0 1.0 1.0 1.0 1.0 0.2 0.0
2pm 1.0 1.0 1.0 1.0 1.0 0.2 0.0
3pm 1.0 1.0 1.0 1.0 1.0 0.2 0.0
4pm 0.6 0.6 0.6 0.6 0.6 0.2 0.0
5pm 0.3 0.3 0.3 0.3 0.3 0.0 0.0
6pm 0.2 0.2 0.2 0.2 0.2 0.0 0.0
7pm 0.2 0.2 0.2 0.2 0.2 0.0 0.0
8pm 0.0 0.0 0.0 0.0 0.0 0.0 0.0
9pm 0.0 0.0 0.0 0.0 0.0 0.0 0.0
10pm 0.0 0.0 0.0 0.0 0.0 0.0 0.0
11pm 0.0 0.0 0.0 0.0 0.0 0.0 0.0
12am 0.0 0.0 0.0 0.0 0.0 0.0 0.0
Annual Schedule
Day Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec
1 U O O O O O U U O O O O
2 U O O O O O U U O O O O
3 U O O O O O U U O O O O
4 U O O O O O U U O O O O
5 U O O O O O U U O O O O
6 U O O O O O U U O O O O
7 O O O O O O U U O O O O
8 O O O O O O U U O O O O
9 O O O O O O U U O O O O
10 O O O O O O U U O O O O
11 O O O O O O U U O O O O
12 O O O O O O U U O O O O
13 O O O O O O U U O O O O
14 O O O O O O U U O O O O
15 O O O O O U U U O O O O
16 O O O O O U U U O O O O
17 O O O O O U U U O O O O
18 O O U O O U U O O O O O
19 O O U O O U U O O O O O
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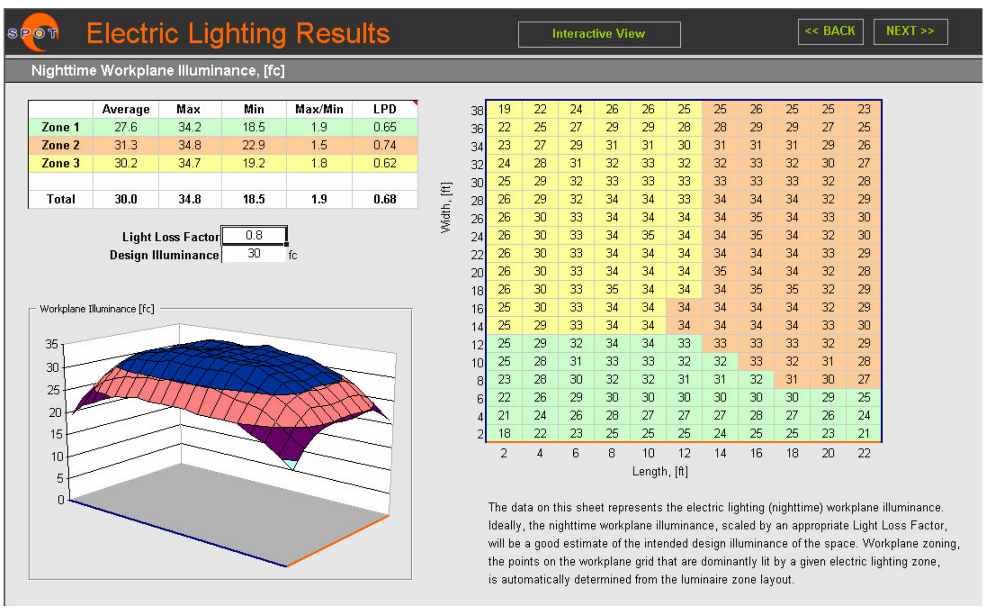
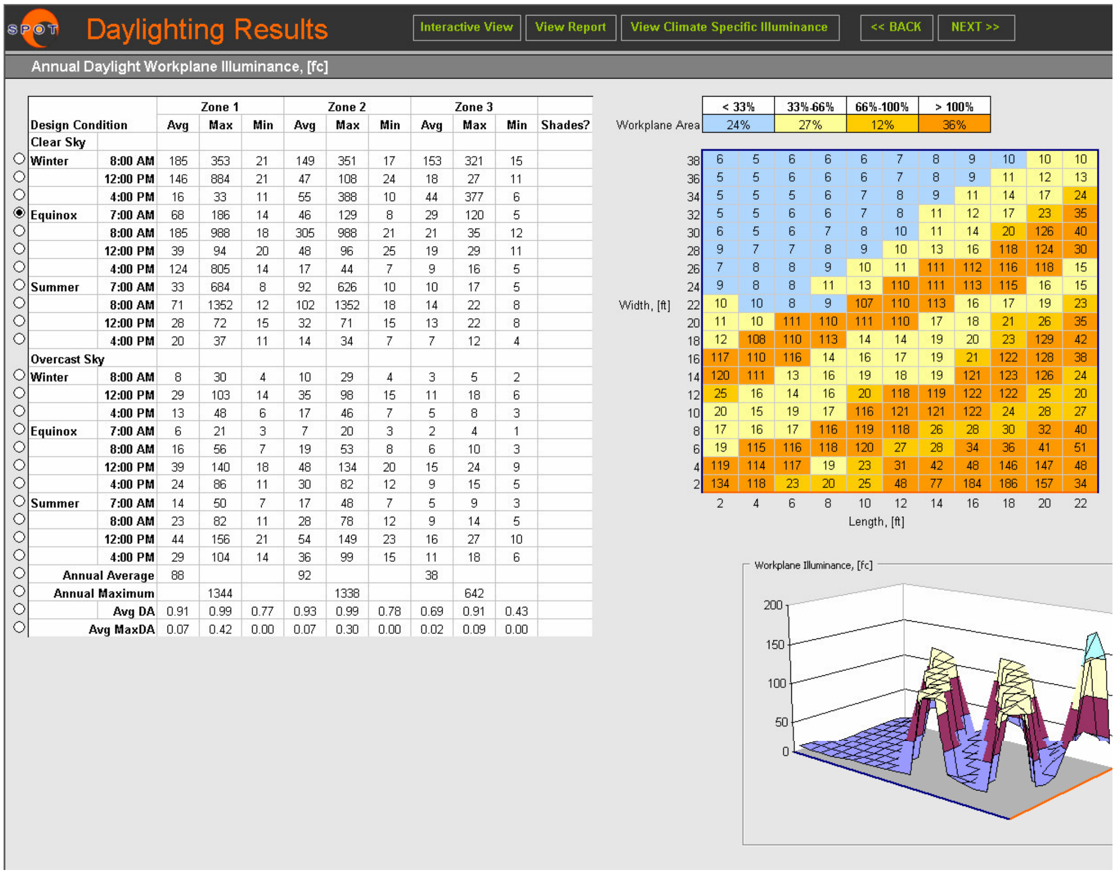
21 O O U O O U U O O O O O
22 O O U O O U U O O O O U
23 O O U O O U U O O O O U
24 O O U O O U U O O O O U
25 O O O O O U U O O O O U
26 O O O O O U U O O O O U
27 O O O O O U U O O O O U
28 O O O O O U U O O O O U
29 O O O O U U O O O O U
30 O O O O U U O O O O U
31 O O O U O O U


Electric Lighting Results
Interactive View
<< BACK
NEXT >>
Nighttime Workplane Illuminance, [fc]
Average Max Min Max/Min LPD
Zone 1 27.6 34.2 18.5 1.9 0.65
Zone 2 31.3 34.8 22.9 1.5 0.74
Zone 3 30.2 34.7 19.2 1.8 0.62
Total 30.0 34.8 18.5 1.9 0.68
Light Loss Factor 0.8
Design Illuminance 30 fc
Workplane Illuminance [fc]
35
30
25
20
15
10
5
0
Width, [ft]
38 19 22 24 26 26 25 25 26 25 25 23
36 22 25 27 29 29 28 28 29 29 27 25
34 23 27 29 31 31 30 31 31 31 29 26
32 24 28 31 32 33 32 32 33 32 30 27
30 25 29 32 33 33 33 33 33 33 32 28
28 26 29 32 34 34 33 34 34 34 32 29
26 26 30 33 34 34 34 34 35 34 33 30
24 26 30 33 34 35 34 34 35 34 32 30
22 26 30 33 34 34 34 34 34 34 33 29
20 26 30 33 34 34 34 35 34 34 32 28
18 26 30 33 35 34 34 34 35 35 32 29
16 25 30 33 34 34 34 34 34 34 32 29
14 25 29 33 34 34 34 34 34 34 33 30
12 25 29 32 34 34 33 33 33 33 32 29
10 25 28 31 33 33 32 32 33 32 31 28
8 23 28 30 32 32 31 31 32 31 30 27
6 22 26 29 30 30 30 30 30 30 29 25
4 21 24 26 28 27 27 27 28 27 26 24
2 18 22 23 25 25 25 24 25 25 23 21
2 4 6 8 10 12 14 16 18 20 22
Length, [ft]
The data on this sheet represents the electric lighting (nighttime) workplane illuminance.
Ideally, the nighttime workplane illuminance, scaled by an appropriate Light Loss Factor,
will be a good estimate of the intended design illuminance of the space. Workplane zoning,
the points on the workplane grid that are dominantly lit by a given electric lighting zone,
is automatically determined from the luminaire zone layout.

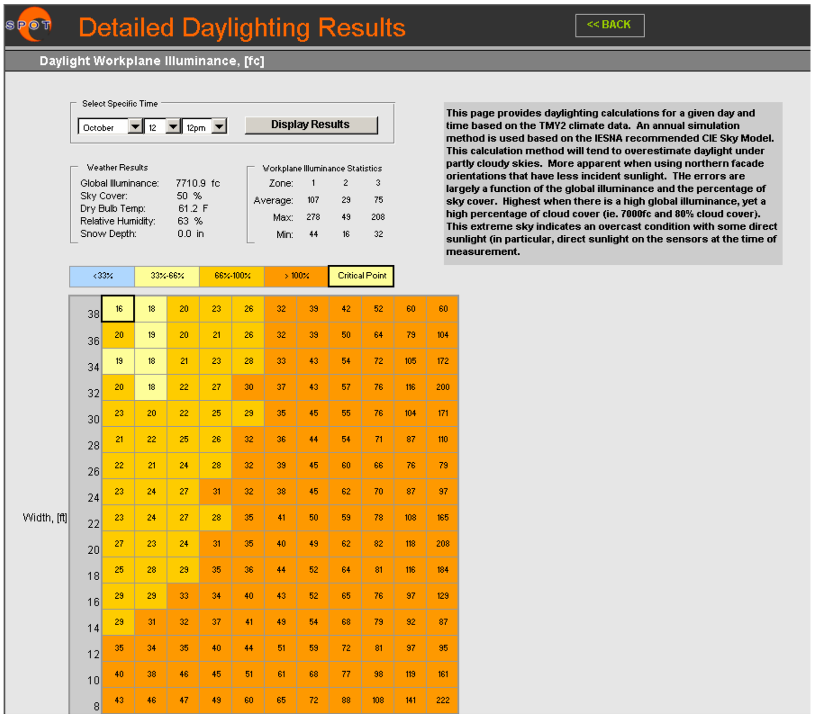
As requested on the Advanced Options page, the daylight distribution at 7:00 AM is calculated for the times of year when the sun is above the horizon at that hour.



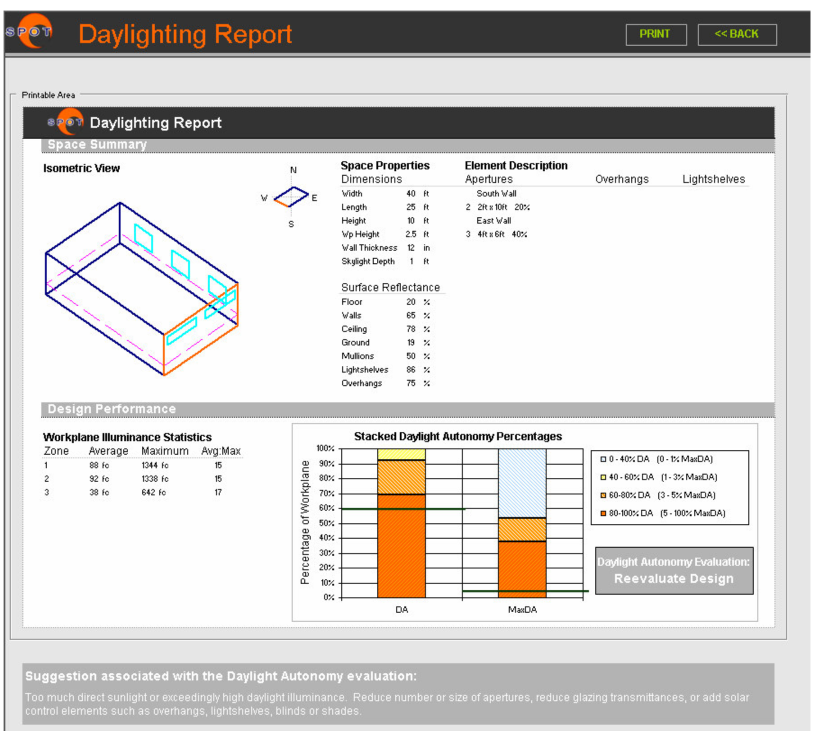
Design Condition		Zone 1 Avg	Zone 1 Max	Zone 1 Min	Zone 2 Avg	Zone 2 Max	Zone 2 Min	Zone 3 Avg	Zone 3 Max	Zone 3 Min	Shades?
Clear Sky											
Winter	8:00 AM	185	353	21	149	351	17	153	321	15	
	12:00 PM	146	884	21	47	108	24	18	27	11	
	4:00 PM	16	33	11	55	388	10	44	377	6	
Equinox	7:00 AM	68	186	14	46	129	8	29	120	5	
	8:00 AM	185	988	18	305	988	21	21	35	12	
	12:00 PM	39	94	20	48	96	25	19	29	11	
	4:00 PM	124	805	14	17	44	7	9	16	5	
Summer	7:00 AM	33	684	8	92	626	10	10	17	5	
	8:00 AM	71	1352	12	102	1352	18	14	22	8	
	12:00 PM	28	72	15	32	71	15	13	22	8	
	4:00 PM	20	37	11	14	34	7	7	12	4	
Overcast Sky											
Winter	8:00 AM	8	30	4	10	29	4	3	5	2	
	12:00 PM	29	103	14	35	98	15	11	18	6	
	4:00 PM	13	48	6	17	46	7	5	8	3	
Equinox	7:00 AM	6	21	3	7	20	3	2	4	1	
	8:00 AM	16	56	7	19	53	8	6	10	3	
	12:00 PM	39	140	18	48	134	20	15	24	9	
	4:00 PM	24	86	11	30	82	12	9	15	5	
Summer	7:00 AM	14	50	7	17	48	7	5	9	3	
	8:00 AM	23	82	11	28	78	12	9	14	5	
	12:00 PM	44	156	21	54	149	23	16	27	10	
	4:00 PM	29	104	14	36	99	15	11	18	6	
Annual Average		88			92			38			
Annual Maximum			1344			1338			642		
Avg DA		0.91	0.99	0.77	0.93	0.99	0.78	0.69	0.91	0.43	
Avg MaxDA		0.07	0.42	0.00	0.07	0.30	0.00	0.02	0.09	0.00	

	< 33%	33%-66%	66%-100%	> 100%
Workplane Area	24%	27%	12%	36%

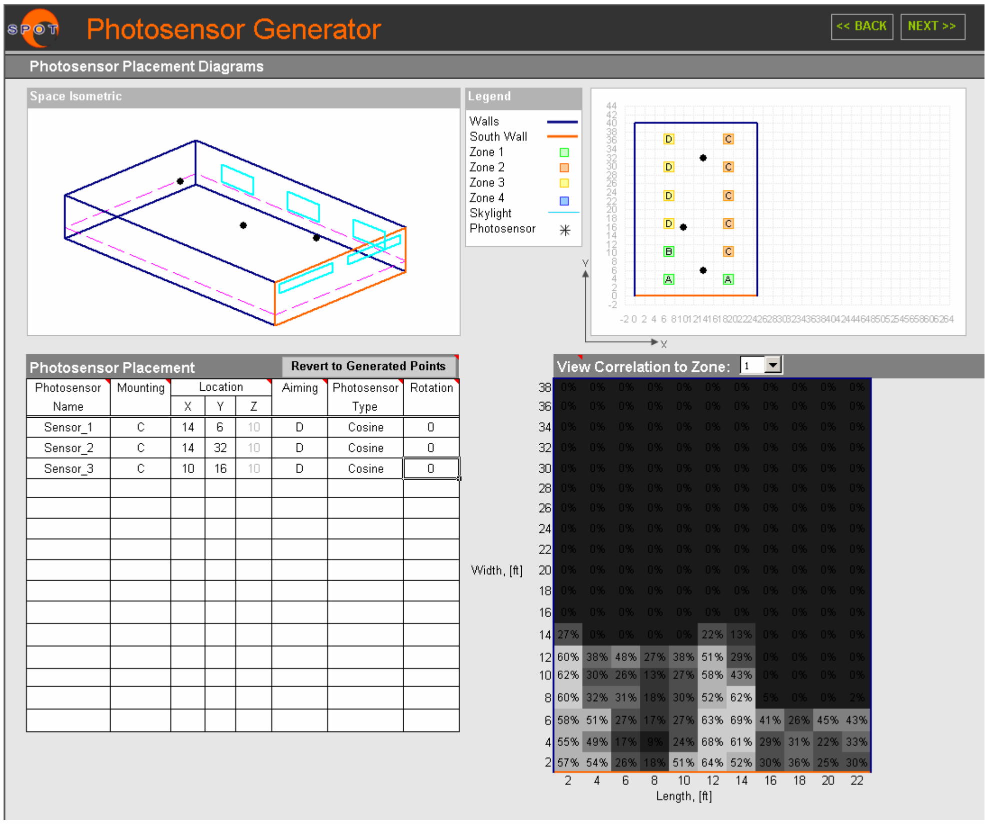
Width, [ft] \ Length, [ft]	2	4	6	8	10	12	14	16	18	20	22
38	6	5	6	6	6	7	8	9	10	10	10
36	5	5	6	6	6	7	8	9	11	12	13
34	5	5	5	6	7	8	9	11	14	17	24
32	5	5	6	6	7	8	11	12	17	23	35
30	6	5	6	7	8	10	11	14	20	126	40
28	9	7	7	8	9	10	13	16	118	124	30
26	7	8	8	9	10	11	111	112	116	118	15
24	9	8	8	11	13	110	111	113	115	16	15
22	10	10	8	9	107	110	113	16	17	19	23
20	11	10	111	110	111	110	17	18	21	26	35
18	12	108	110	113	14	14	19	20	23	129	42
16	117	110	116	14	16	17	19	21	122	128	38
14	120	111	13	16	19	18	19	121	123	126	24
12	25	16	14	16	20	118	119	122	122	25	20
10	20	15	19	17	116	121	121	122	24	28	27
8	17	16	17	116	119	118	26	28	30	32	40
6	19	115	116	118	120	27	28	34	36	41	51
4	119	114	117	19	23	31	42	48	146	147	48
2	134	118	23	20	25	48	77	184	186	157	34



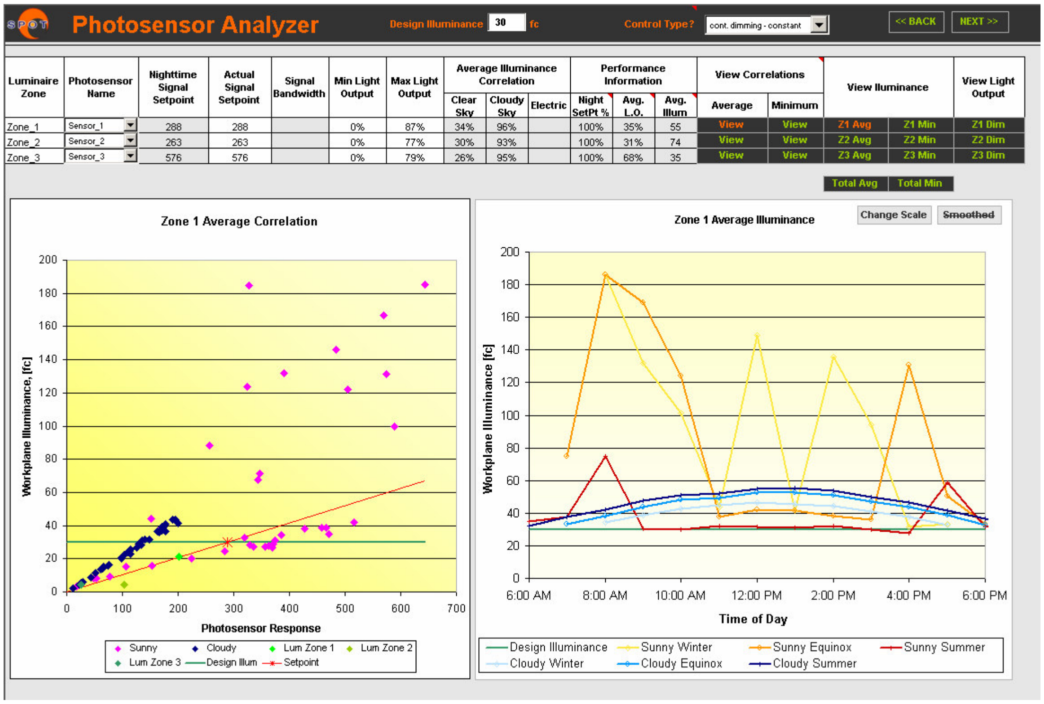
Generally, an appropriate amount of daylight exists in the space, but there are too many times when over 300 footcandles is calculated on the workplane – the suggestion is then to reevaluate the design using more or different solar control strategies. It is recommended that at this point, the user backs up to the geometry page to take another look at the design, although for this test case the project is run to the end.

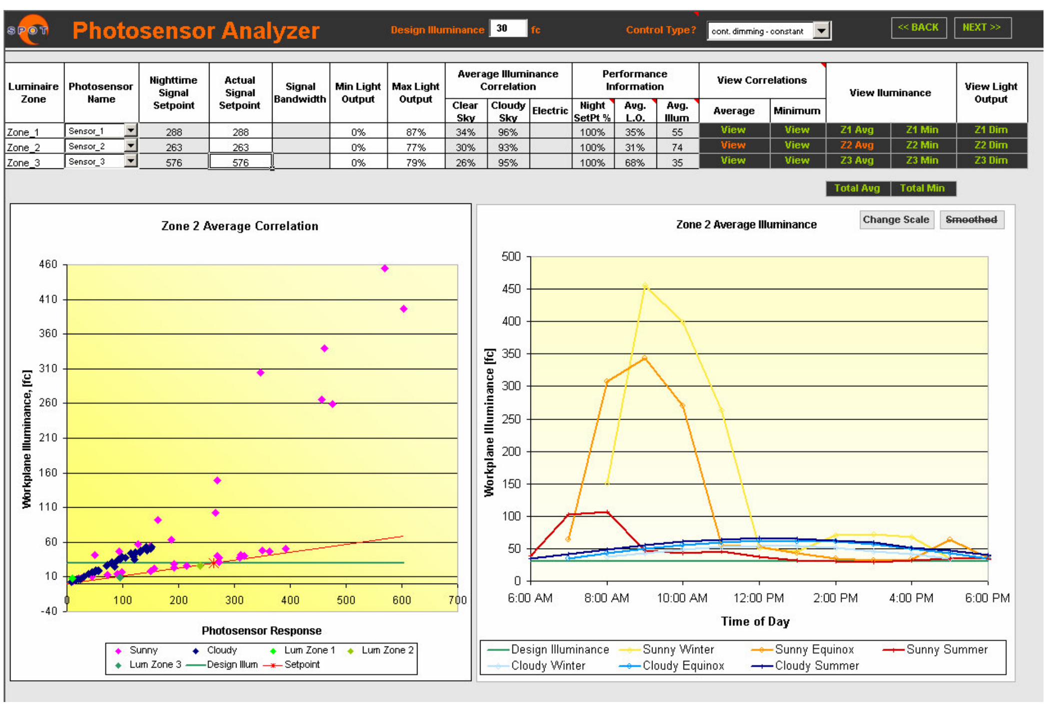


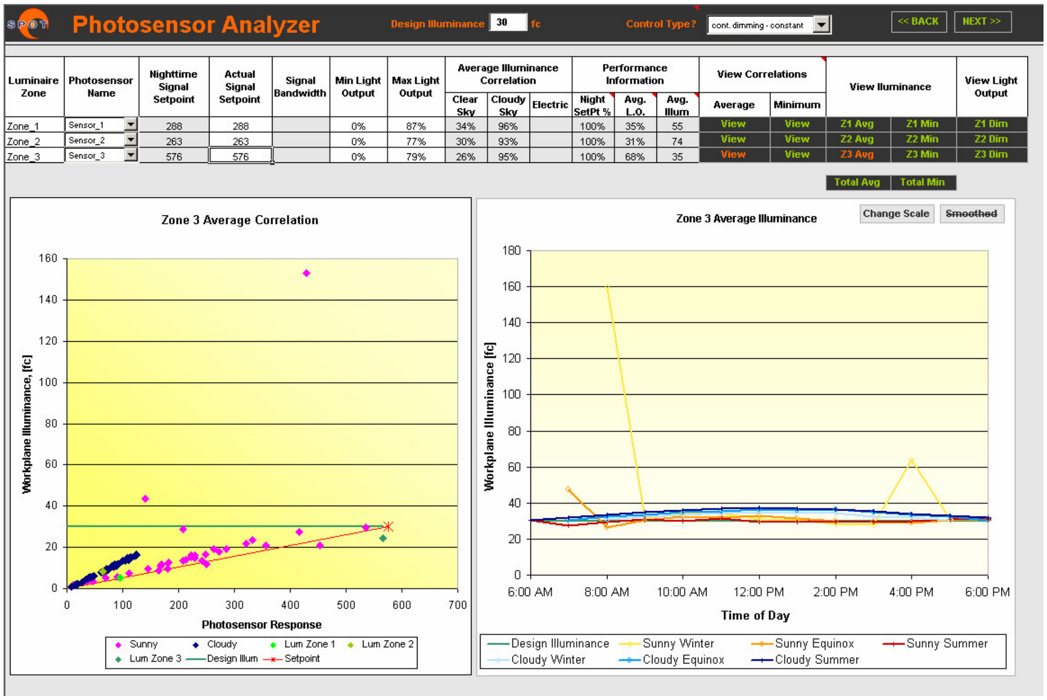
Similar to the first test case, SPOT places the sensor for each zone at the spot on the ceiling which receives illuminance values most closely paralleled with the average zone workplane illuminance throughout the year.



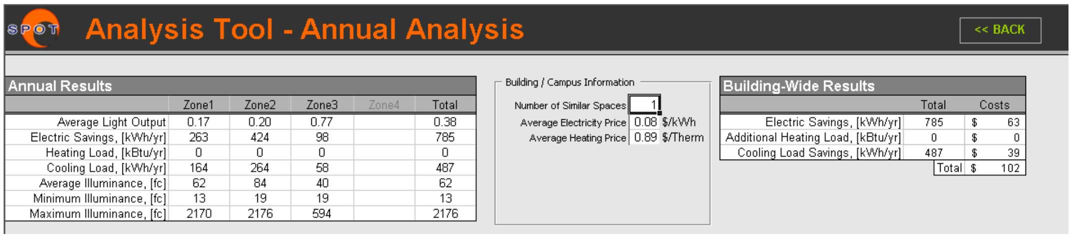
In comparison to Test Classroom #1, this case shows a much greater scatter in the photosensor response to workplane illuminance relationship, reinforcing the lack of solar control in the space.



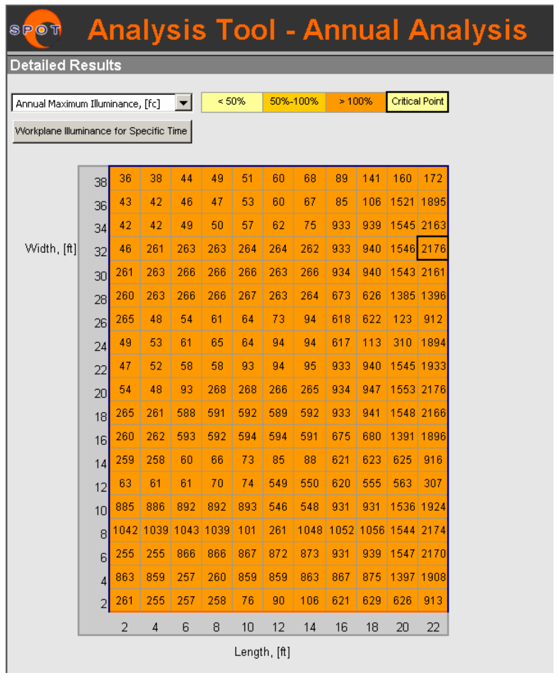




Adjusting the photosensor variables results in little reduction of the light level range on the workplane (30 to 450 footcandles - maximum range). This is a product of the space/fenestration design, not the photosensor type or placement. The energy and cost savings are given in the following table.



Although the dollar amount in savings is greater than in the previous case, the average light output for the space is less and the maximum light levels shown over the workplane in the following plot, create undesirable work zones for much of the year.



Width, [ft] \ Length, [ft]	2	4	6	8	10	12	14	16	18	20	22
38	36	38	44	49	51	60	68	89	141	160	172
36	43	42	46	47	53	60	67	85	106	1521	1895
34	42	42	49	50	57	62	75	933	939	1545	2163
32	46	261	263	263	264	264	262	933	940	1546	2176
30	261	263	266	266	266	263	266	934	940	1543	2161
28	260	263	266	266	267	263	264	673	626	1385	1396
26	265	48	54	61	64	73	94	618	622	123	912
24	49	53	61	65	64	94	94	617	113	310	1894
22	47	52	58	58	93	94	95	933	940	1545	1933
20	54	48	93	268	268	266	265	934	947	1553	2176
18	265	261	588	591	592	589	592	933	941	1548	2166
16	260	262	593	592	594	594	591	675	680	1391	1896
14	259	258	60	66	73	85	88	621	623	625	916
12	63	61	61	70	74	549	550	620	555	563	307
10	885	886	892	892	893	546	548	931	931	1536	1924
8	1042	1039	1043	1039	101	261	1048	1052	1056	1544	2174
6	255	255	866	866	867	872	873	931	939	1547	2170
4	863	859	257	260	859	859	863	867	875	1397	1908
2	261	255	257	258	76	90	106	621	629	626	913

Appendix C – Photosensor Analyzer Tutorial

Coming soon in mid 2007 is the v4.0 release, which will include a much improved Photosensor Analyzer page.

Appendix D – About SPOT

Appendix E – Copyright Information

The Radiance Software License, Version 3.5

Appendix F – References

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