

## RESULTS REPORT:

### **FACILITY LIGHTING — WINTER**

GENERAL SERVICES ADMINISTRATION

CENTRAL OFFICE BUILDING

1800 F STREET NW

WASHINGTON, D.C.

Submitted to:

U.S. General Services Administration

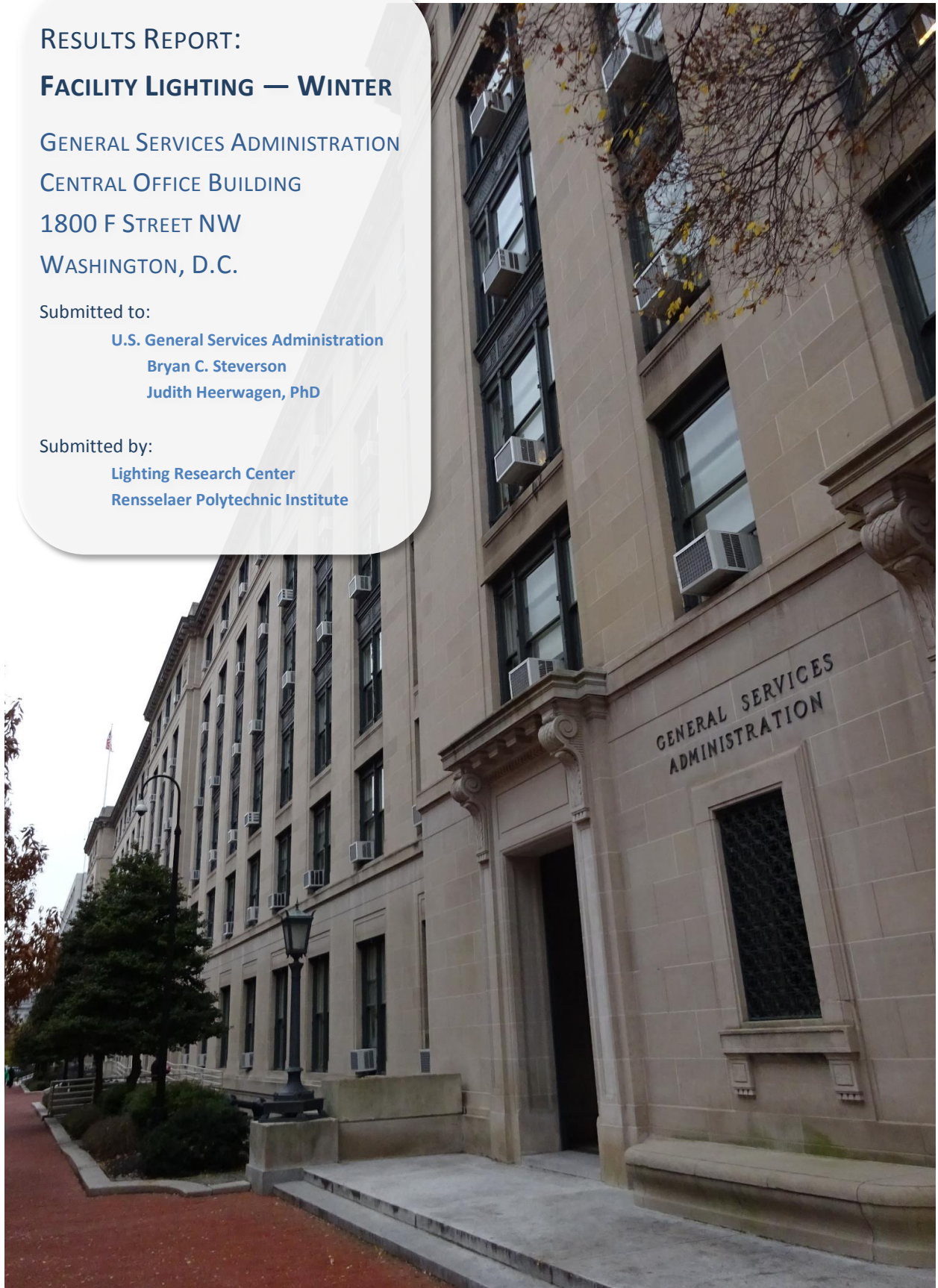
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Submitted by:

Lighting Research Center

Rensselaer Polytechnic Institute



## RESULTS REPORT: FACILITY LIGHTING — WINTER

GENERAL SERVICES ADMINISTRATION CENTRAL OFFICE BUILDING  
1800 F STREET, WASHINGTON, D.C.

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## EXECUTIVE SUMMARY

The U.S. General Services Administration (GSA) Central Office Building is a 9-story building located at 1800 F Street NW in Washington, D.C. The building was originally constructed in 1917; Phase I modernization of about half the building was completed in 2013.<sup>1</sup> Since the renovation, most staff do not permanently use one desk, but rather, they use a “hoteling” strategy, in which different desk locations are temporarily assigned to workers.<sup>2</sup>

In December 2014, researchers from the Lighting Research Center (LRC) at Rensselaer Polytechnic Institute, together with GSA staff, evaluated the site in a manner consistent with other GSA site case studies.<sup>3</sup> LRC researchers made photometric measurements at open-plan deskspaces located on the ground floor (G) and floors 2 and 7. In addition to the field measurements, the LRC placed Daysimeter devices on deskspaces near these desks, as well as desks on floors 4 and 6. These devices were installed to continuously measure photopic lux and circadian light over the course of several days. Daysimeters measure continuous light exposures, allowing researchers to perform calculations of how much light that is effective for the circadian system may be reaching deskspaces (i.e., circadian stimulus, or CS).

Biological rhythms that repeat approximately every 24 hours are called circadian rhythms. Light is the main stimulus that helps the circadian clock, and thus circadian rhythms, synchronize with the 24-hour day. In other words, light tells our body to stay awake during the day and to sleep at night so that our sleep-wake cycle mirrors the earth’s 24-hour cycle of night and day (dark and light). Light of the appropriate quantity, spectrum, timing, duration, and distribution can have a profound effect on sleep, alertness, and performance, along with overall wellbeing. Lack of synchrony between our internal clock and the local environment (such as what happens when travelling across multiple time zones) has been associated with a series of maladies such as diabetes, obesity, cardiovascular disease, and cancer.

Based on the LRC’s previous work, it is hypothesized that CS values above or close to 0.3 should provide enough circadian stimulation to maintain entrainment of circadian rhythms to the local time on Earth. Due to availability of daylight and ease of access, research has continued<sup>4</sup> to focus on open-plan offices. While Daysimeters placed at deskspaces in the building may not be representative of workers’ overall personal light exposures, they give an indication of how much circadian light is available in that part of the building. Another component of this research project, not discussed in this report, is the data collection of personal light exposures by building occupants.

In addition to measuring CS at various deskspaces, this report also documents the measured photometric conditions as they relate to occupant visibility, comfort, as well as occupants’ behavior and acceptance of the lighting in their deskspaces. However, it is important to keep in mind that measurements on this visit were only made on two December days with variable weather. Photometric values will vary substantially in many

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<sup>1</sup> [http://www.thorntontomasetti.com/projects/gsa\\_headquarters\\_renovation/](http://www.thorntontomasetti.com/projects/gsa_headquarters_renovation/)

<sup>2</sup> Successful Hoteling: GSA’s 10 Tips ([http://www.gsa.gov/graphics/admin/Successful-Hoteling-Tips\\_Final.pdf](http://www.gsa.gov/graphics/admin/Successful-Hoteling-Tips_Final.pdf))

<sup>3</sup> See LRC references for Portland, OR, Seattle, WA, and Grand Junction, CO sites.

<sup>4</sup> Previous LRC/GSA site evaluations also focused on open-plan offices with proximity to daylight.

spaces due to daily and seasonal changes in daylight. Some of this variability is shown in the Daysimeter measurements.

Below are some of the main findings from the December site evaluation at the GSA Central Office Building:

- The data from the LRC's visit to the GSA Central Office Building in early December showed low overall levels of circadian stimulus in many spaces.
- As expected, deskspaces on the G floor received circadian stimulation below the desired amount of 0.3, irrespective of wing number and proximity to window. The deskspaces closer to windows had slightly higher CS values, but these values did not reach 0.3, even on sunny days. Deskspaces away from windows had CS values below 0.1, which is possibly very low stimulus for the circadian system.
- Wing 4 received the highest CS values, followed by Wing 2, irrespective of floor height and deskpace orientation. These wings were included in the Phase I building renovations. All of the deskspaces in Wing 4 received a CS of at least 0.3, while only a couple of deskspaces on the 2<sup>nd</sup> floor (Wing 2) received a CS of 0.25. (As no measurements were taken in Wings 2 and 4 on the G floor, we cannot make generalizations about the entire building.) Deskspaces in Wing 1 on the G floor (east facade) had the highest CS values, but still below 0.3 (in general close to 0.2). Deskspaces in Wing 0 were generally lower than 0.3, except for a deskpace near the window on the 7<sup>th</sup> floor on sunny days.
- On the winter visit, most of the deskspaces had a horizontal illuminance of greater than 30 footcandles (approximately 300 lux), especially with the task light on. Most (63%) workers reported that they use their task light, and that the amount of light on their desks was neither too much nor too little.



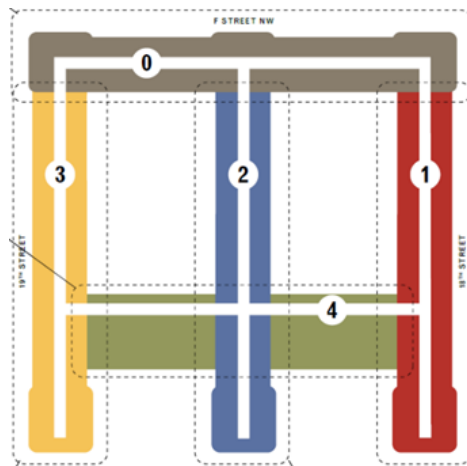
## INTRODUCTION

The U.S. General Services Administration (GSA) Central Office Building is a 9-story building located at 1800 F Street NW in Washington, D.C. The building was originally constructed in 1917. GSA renovated half (Phase 1) of the building in 2013. Since the renovation, most staff do not permanently use one desk, but rather, they use a “hoteling” strategy, in which desk locations are changed from week to week.<sup>5</sup> Partitions are low, and desks have minimal permanent storage. Most desks are open-plan spaces (Figure 1).



**Figure 1. Example of an open-plan office at the GSA Central Office Building.**

The GSA Central Office Building fills a city block. Like many other buildings constructed in the early 1900s, it has light-well courtyards. As shown in Figure 2, each wing bears a number and an assigned color code. Each desk has an alphanumeric address, which is necessary for workers to locate their assigned space from week to week. Over half of the available desks have an east or west window orientation, while the rest have a north or south orientation.



**Figure 2. Generic floor plan at the GSA Central Office Building. Each wing bears a number and assigned color code.**

Overhead lighting ranges in age. Most lighting is comprised of various types of recessed fluorescent troffers, or linear fluorescent pendants (Figure 3). While the overhead lighting

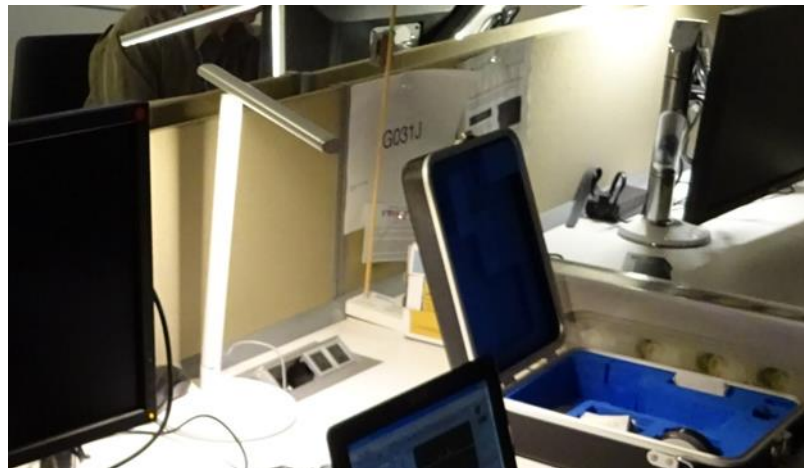
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<sup>5</sup> Successful Hoteling: GSA's 10 Tips ([http://www.gsa.gov/graphics/admin/Successful-Hoteling-Tips\\_Final.pdf](http://www.gsa.gov/graphics/admin/Successful-Hoteling-Tips_Final.pdf))

is diverse, the task lighting throughout the building is newly standardized with the light-emitting diode (LED) task light shown in Figure 4 below.

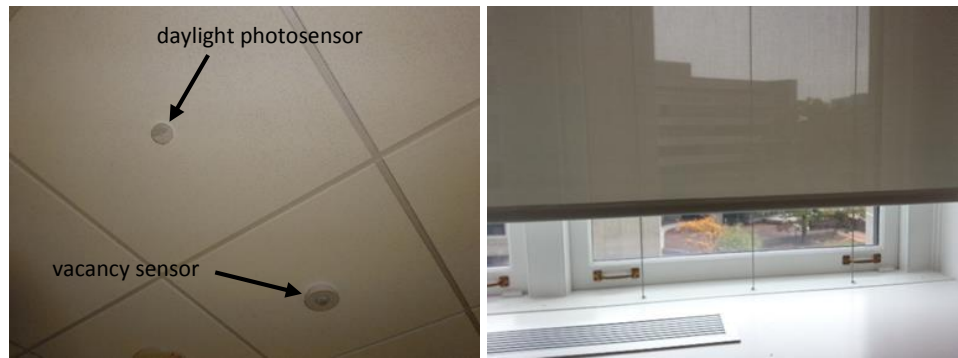


**Figure 3. Diverse types of lighting at the GSA Central Office Building.**



**Figure 4. Standard LED task light.**

There are many lighting controls strategies in use, particularly in the Phase I areas of the GSA Central Office Building. While detailed information was not available, Phase I-renovated spaces clearly employ daylight photosensor-controlled dimming systems and automatically-operated motorized mesh shades (Figure 5). In addition to vacancy sensors, the building management system also prevents lights from being left on when the space is not in use. When “hoteling” workers check in to their desk for the day, the building management system turns on overhead lighting only during hours and in zones in which employees are “checked in.” Task lights have separate local controls, with sensors to turn on when people walk by or are using the deskspaces.



**Figure 5. Daylight photosensor, vacancy sensor, and motorized mesh shades in the Phase I remodel area.**

## RESEARCH OBJECTIVES

The Lighting Research Center (LRC) conducted photometric measurements at the GSA Central Office Building in December 2014. The goal of the research was to compare seasonal photometric conditions as they relate to occupant comfort, productivity, and circadian health.

The evaluation took place on December 3-4, 2014. Daylighting conditions were representative of winter, as the visit was after daylight savings, and winter solstice occurred a few weeks after the visit. The LRC researchers included Dr. Mark Rea (LRC Director), Russ Leslie (LRC Associate Director), Dr. Mariana Figueiro (LRC Light and Health Program Director), and Jennifer Brons (LRC DELTA Program Director<sup>6</sup>). The LRC teams were escorted and assisted by Bryan Steverson of GSA, as well as a GSA contractor (Kelli Canada).

## METHODS

On Day 1 (December 3), measurement locations were set up on five floors with open-plan offices (the ground floor [G], and floors 2, 4, 6 and 7), in both the Phase I-renovated area, as well as spaces with only new furniture. Also on Day 1, battery-powered measurement equipment was installed and documented. Data collection started on the afternoon of Day 1, continued until evening, then resumed on Day 2 (December 4). Each member of the research team was responsible for one aspect of data collection (detailed below). Two researchers collected illuminance and luminance measurements while two researchers performed spectral power distribution measurements. Questionnaires were administered on Days 1-2.

Five types of measurements were completed at the GSA Central Office Building:

**Illuminance:** Illuminance is a measure of the amount of light falling on a surface, in units of lux (lx [SI]) or footcandles (fc [in the U.S.]). Illuminance measurements are important because they are used conventionally as design criteria. LRC measured illuminance multiple times over the measurement day, on horizontal and vertical surfaces, at desks on three floors, and at all window orientations. Two researchers collected these illuminance data using Gigahertz-Optik (model: X91) lux meters. Illuminance data were collected on floors G, 2, and 7, in wings 0, 1, 2, and 3.

**Luminance:** Luminance is a measure of the amount of light emitted or reflected by a surface. Luminance relates to perceptions of brightness and glare. Luminance is measured in units of candela per square meter (cd/m<sup>2</sup>), using a meter device that resembles the viewfinder of a camera aimed at luminous surfaces. Because viewing position impacts luminance, measurements were collected at the desk chair location when facing key surfaces, such as a computer monitor, and the nearest window. Two researchers collected luminance data using Minolta (models: LS-110 and LS-100) luminance meters. Luminance data were collected on floors G, 2, and 7, in wings 0, 1, 2, and 3.

**Spectral power distribution (SPD):** SPD is a measure of the wavelengths of light in the visible spectrum (380-770 nanometers [nm]). SPD will vary between light sources as

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<sup>6</sup> The Demonstration and Evaluation of Lighting Technologies and Applications (DELTA) program is a case study program run by the LRC to design, evaluate, and publicize energy-efficient lighting solutions.

well as time of day. SPD was measured at the GSA Central Office Building to allow researchers to calculate, using different response functions, measures such as brightness, glare, and circadian stimulus. SPD data were collected on floors G, 2, and 7, in wings 0, 1, 2, and 3. Researchers collected these data using a spectroradiometer system consisting of an Ocean Optics (model: USB650) spectrometer and a remote sensor, as well as a laptop. Raw SPD data were collected using the spectroradiometer system, and post-processed using Matlab version R2014a to generate curve functions.

**Daysimeter photopic and circadian light exposure devices:** Daysimeter devices collected continuous light exposures that allowed researchers to perform calculations of how much light that is effective for the circadian system was reaching deskspaces. Briefly, light sensing by the Daysimeter is performed with an integrated circuit (IC) sensor array (Hamamatsu model S11059-78HT) that includes optical filters for four measurement channels: red (R), green (G), blue (B), and infrared (IR). The R, G, B, and IR photo-elements have peak spectral responses at 615 nm, 530 nm, 460 nm, and 855 nm, respectively. The Daysimeter is calibrated in terms of orthodox photopic illuminance (lux) and of circadian illuminance ( $CL_A$ ).  $CL_A$  calibration is based upon the spectral sensitivity of the human circadian system. From the recorded  $CL_A$  values it is then possible to determine the CS magnitude, which represents the input-output operating characteristics of the human circadian system from threshold to saturation. These measurements are representative of light exposures one would receive while sitting at the desk working at a computer. However, it may not represent the person's daily light exposures, such as exposure to outdoor lighting to and from work. Daysimeter devices were installed at 31 desks and 13 windows. These collected data for one month after LRC visited the site. The devices were removed by Mr. Steverson, and were returned by mail to LRC for read-out.

**Questionnaires:** LRC administered questionnaires to 16 employees at the GSA Central Office Building. The questions were the same as LRC used at other GSA evaluation sites.

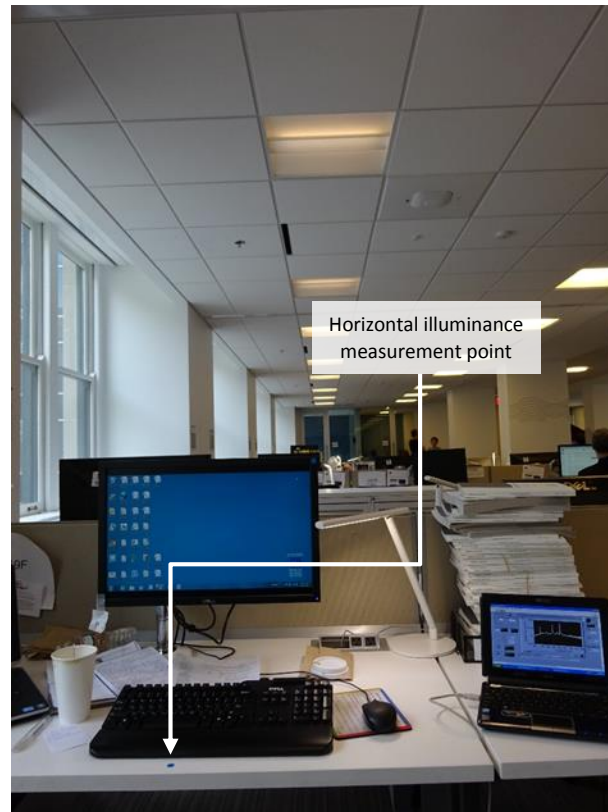
## RESULTS

### ILLUMINANCE RESULTS

LRC measured photometric conditions (illuminance and luminance) at the GSA Central Office Building. Photometric data were collected for 19 desks, and were organized by perimeter proximity, by perimeter window orientation, and by collection time. Desks located on the outer perimeter are referred to as ‘A desks’ while desks not directly next to a window are ‘B desks.’ At a few desks on the ground floor, use of overhead lights (controlled by local switches) changed during the course of measurements; LRC completed the measurements at those desks with overhead lights both on and off. The skies were primarily cloudy on Day 1, but there were shafts of sun on Day 2.

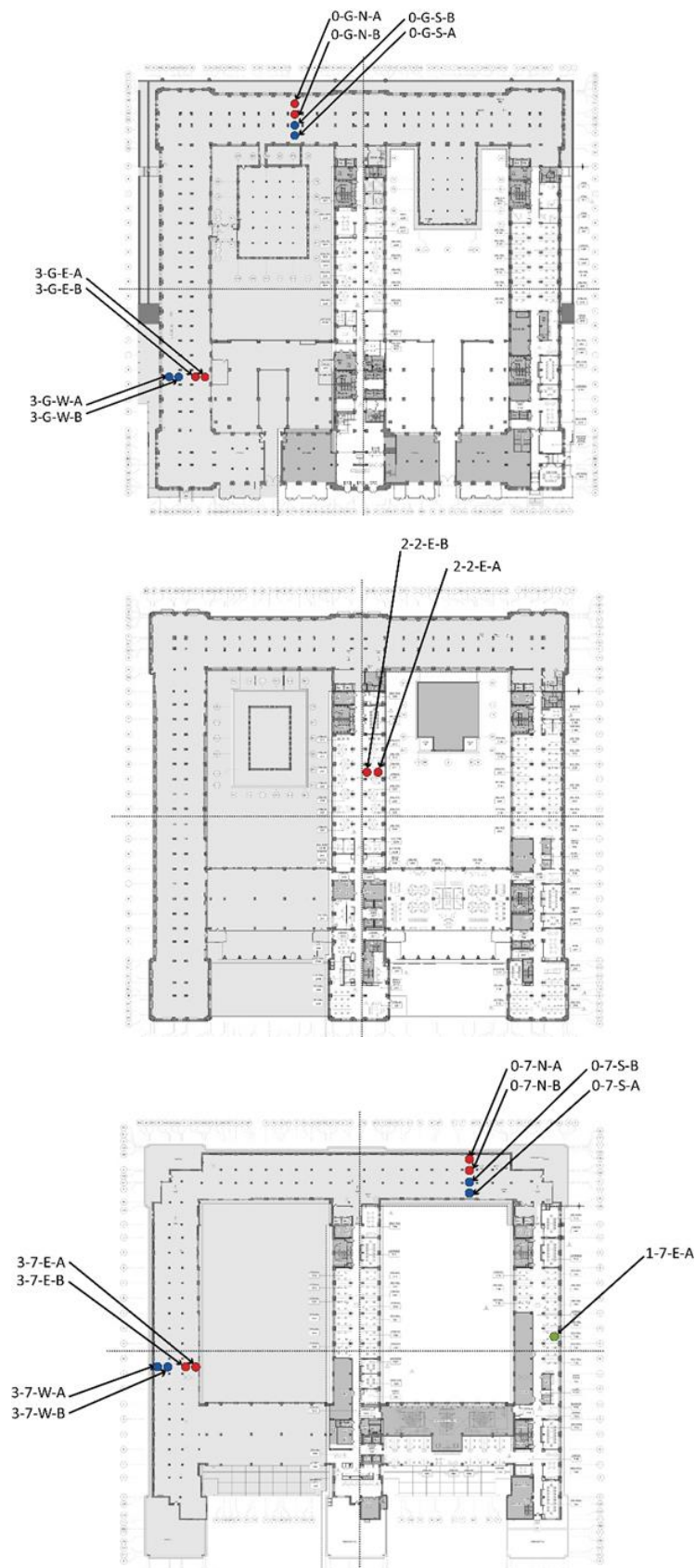
Figure 6 shows an example of typical horizontal illuminance measurement locations at the 19 desks. Because partitions at the GSA Central Office Building are below eye height, LRC did not measure vertical illuminance on partitions. However, LRC did measure vertical illuminance at the eye. Figure 7 is a key plan showing the 19 measurement locations on floors G, 2, and 7. Measurement locations were in both Phase I-renovated spaces as well as non-renovated spaces with new furniture and task lighting.

Measurements occurred in the morning, midday, afternoon, and after dark. Measurements included additional daylight contribution. Some spaces in the Phase I-renovated areas may have seen reduction of electric lighting in response to increased daylighting. The resulting measurements are shown in detail in Appendix A.



**Figure 6. Typical horizontal measurement point at a Row A desk.**

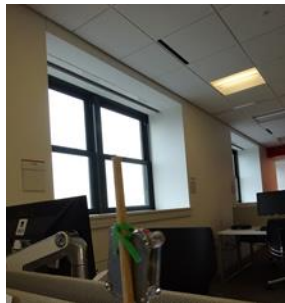




**Figure 7. Photometric measurement locations on floors G, 2, and 7. Numbering convention: (Wing#)-(Floor)-(Window orientation)-(Window proximity). Grey color indicates new furniture/task lights, not full Phase I remodel.**

As shown in Appendix A, horizontal illuminances were high (600-1000 lx) at A desks, especially when all the overhead lighting is on. At B desks, illuminances were often lower than A desks, but a few were still high (500-600 lx) with all overhead lights on. Wing 2 and Wing 1 are in the Phase I renovation area, thus have new overhead lighting that may be controlled by photosensors; desk illuminances in these areas were moderately high (400-750 lx). There were some desks with low illuminances (50-200 lx); these had diverse locations (ground floor west and south, as well as 7<sup>th</sup> floor north) so these low values were not likely exposed to daylight.

Vertical illuminances at the eye were mixed as well. A and B desks had similar vertical illuminances at the eye in many cases. A few desks on the 7<sup>th</sup> floor on the east and west facades had higher light levels near the A desk window. One desk on the east facade of the 7<sup>th</sup> floor had low vertical illuminances all day (150-200 lx), despite being located adjacent to a window; this seating position may face the structural column more than the window (Figure 8).



**Figure 8.** View from A desk that may face column more than window.

## LUMINANCE RESULTS

LRC measured luminance at the same time interval and desk locations used for illuminance measurements. For each of the desks, LRC measured luminance of the nearest window during the daytime measurements, as well as desk surface and computer monitor bezel.



**Figure 9.** To reduce window glare more effectively than mesh window shades, an occupant installed an additional opaque board.

The resulting measurements are shown in detail in Appendix A. On the east facade, there were a few desks with a view of the sun in the morning, both for A desks and B desks. One of the south-facing desks was also exposed to high window luminances, and thus potential window glare. Questionnaires showed a few occupants were concerned about sun, both in terms of light/visibility as well as overheating. (See Appendix B.) The mesh

window shades were not always satisfactory; LRC observed one window with an additional makeshift cardboard shading device installed (Figure 9).

LRC also measured luminance of key surfaces commonly viewed at the desk: on the desk and on the computer monitor bezel. As observed at other GSA evaluation sites (and as shown in Appendix A), the desk typically has higher luminances than the computer bezel, because it is a more reflective (lighter) color and because task lights shine on it. When the eye shifts from these lower luminance surfaces to the window, cubicle occupants may experience glare.

## QUESTIONNAIRE RESULTS

LRC administered a brief questionnaire to 16 people working in the GSA Central Office Building. Appendix B shows detailed questionnaire results. Where possible, the questionnaire data for this site were compared to results from other office case studies and previous GSA site evaluations publications. (See References.)

Most respondents (75%) only work during the day, similar to other sites. Workers answered the questionnaire on both days that LRC evaluated this site. For much of that time, skies were cloudy, though there was some sun on Day 2. All four window orientations were represented (North: 19%; East: 38%; South: 25%; West: 19%). Most respondents (38%) worked on the 7<sup>th</sup> floor, followed by 25% on the 4<sup>th</sup> floor, 31% on the 2<sup>nd</sup> floor, and 6% on the ground floor.

Most workers were satisfied by the amount of light provided; 63% reported that the amount of light on their desk was neither too much nor too little.

Task light use was reported by 62% of occupants. One person commented that he/she did not know how to turn the task light on, partially contributing to the decision not to use it.

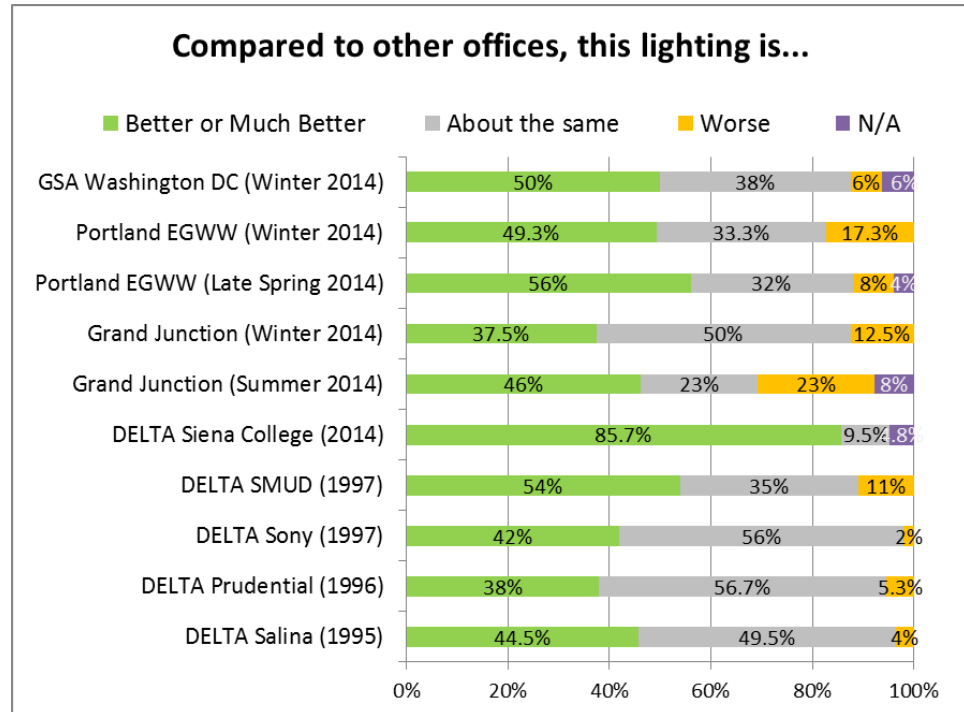
Mesh window shades are often adjusted by the occupants, partly due to changes in weather, and partly due to time-of-day sun position. Sun seemed to be more of a concern at this site in Washington, D.C. than at a previously examined GSA site in the Pacific Northwest.<sup>7</sup> A few people (19%) reported that they keep shades up all the time. More people reported adjusting shades downward due to sunny weather (31%) than reported opening them due to cloudy weather (19%). A quarter of the respondents (25%) reported that they do not have control over the shades, presumably because they were automated/motorized.

About half (56%) reported that the windows at this building are comfortable to look at, and even more respondents (63%) rated their luminaires as comfortable to look at.

As shown in Figure 10, the overall lighting at this building was rated as “better” or “much better” by half (50%) of the respondents. Over a third (38%) considered the lighting to be “about the same” compared to other offices. As shown in Figure 10, these results are similar to other office lighting case studies.

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<sup>7</sup> Edith Green Wendell Wyatt Federal Building, Portland, OR.



**Figure 10. Overall questionnaire results at the GSA Central Office Building, compared to other office lighting evaluations by the LRC.**

## SPECTRAL POWER DISTRIBUTION (SPD) RESULTS

Shown below is a photo of the equipment used for measurement of spectral characteristics (Figure 11). The measurement probe was held at the eye and aimed at the computer screen to simulate the eye position of the person working at each desk. Measurements were collected three times during the day (morning, midday, and afternoon) with both electric light and daylight, as well as after dark (with only electric light, no daylight contribution.)



**Figure 11. A spectroradiometer taking measurements at desk level.**

SPDs were measured at the same desk locations used for hosting other site measurements (see Figure 7).

The SPD measurements were later used to estimate the percentage of daylight and electric light in the space, as well as photopic lux and circadian stimulus (see Table 1).

Relative visual performance (RVP), or the speed and accuracy of reading, are high (RVP > 0.95) for all conditions, because the computer monitors provide high contrast/large font size, and any printed materials are illuminated to at least 30 fc (approximately 300 lx) on the desk surface (horizontal illuminance).

Detailed results are shown in Appendices C-E and summarized in Appendix F. Table 1 shows average results of winter daytime measurements (excluding evening measurements, since workers are not present after dark).

**Table 1. Winter average daytime measurements using spectroradiometer.**

| Deskpace<br>Locations | Illuminance | Approximate Contribution<br>(±15%)* |        |       | Color<br>Temp. | Circadian Light      |                        | Circadian<br>Stimulus | Brightness |
|-----------------------|-------------|-------------------------------------|--------|-------|----------------|----------------------|------------------------|-----------------------|------------|
|                       | Lux         | Fluor %                             | Halo % | Day % | CCT (K)        | Avg. CL <sub>A</sub> | Median CL <sub>A</sub> | CS                    |            |
| A                     | 360         | 39                                  | 23     | 37    | 4029           | 258                  | 221                    | 0.261                 | 244        |
| B                     | 322         | 39                                  | 26     | 35    | 3917           | 215                  | 191                    | 0.233                 | 211        |
| <b>Orientation</b>    |             |                                     |        |       |                |                      |                        |                       |            |
| E                     | 457         | 48                                  | 21     | 31    | 3873           | 319                  | 285                    | 0.310                 | 306        |
| N                     | 336         | 39                                  | 41     | 19    | 3905           | 197                  | 174                    | 0.227                 | 213        |
| S                     | 232         | 38                                  | 16     | 44    | 4138           | 187                  | 174                    | 0.216                 | 160        |
| W                     | 265         | 24                                  | 23     | 52    | 4054           | 181                  | 112                    | 0.193                 | 182        |
| <b>Floor</b>          |             |                                     |        |       |                |                      |                        |                       |            |
| G                     | 279         | 45                                  | 28     | 27    | 3776           | 167                  | 150                    | 0.193                 | 178        |
| 2                     | 378         | 55                                  | 7      | 37    | 3984           | 276                  | 264                    | 0.294                 | 252        |
| 7                     | 391         | 31                                  | 25     | 44    | 4151           | 293                  | 233                    | 0.286                 | 269        |

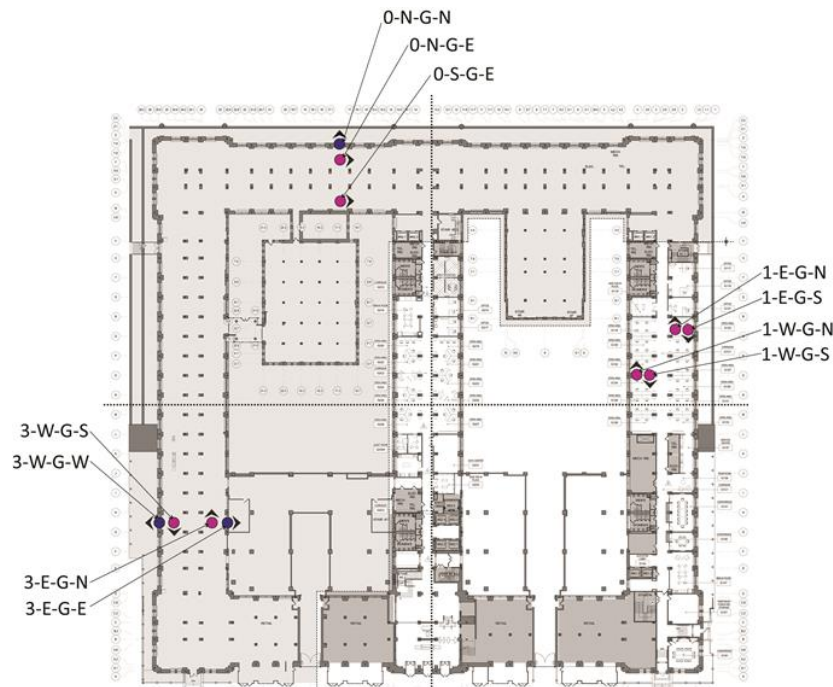
\* Due to measurement uncertainty, some may not add to exactly 100%

The data from LRC's visit to the GSA Central Office Building in early December showed low overall levels of circadian stimulus at many locations. There are some desks with occasional CS values greater than 0.3, which is considered the lower end of the threshold boundary for circadian stimulation. These data, however, are snapshots of exposures over the course of one working day in winter. Daysimeter measurements, discussed below, may be a better representation of the continuous light availability over the course of the working day.

## DAYSIMETER STICK AND WINDOW RESULTS

Appendices G-P show the hourly averages from 8:00 a.m. to 5:00 p.m. of the CS values and the photopic lux values for each Daysimeter. Desk locations are also shown in Figures 12-14. Below are some of the main findings:

- On the G floor, CS values were close to the desired amount of 0.3 in Wing 1 (at the middle of the day). In Wing 0, this was the case only on sunny days. The other wings did not have high CS on any of the deskspaces, regardless of proximity to windows.
- On the 2<sup>nd</sup> floor, deskspaces were located in Wings 2 and 4; except for 2 deskspaces on Wing 2 that had a CS value of 0.28, all other deskspaces had CS values above 0.3. Given that a 0.3 value is defined based on a 1-hour exposure, it is assumed that longer exposure to a CS of 0.28 should be sufficient to stimulate the circadian system.
- On the 4<sup>th</sup> floor, CS values for the most part were at or just below 0.3. The floor's lowest CS values (0.1-0.18) were recorded on the east façade of Wing 3.
- On the 6<sup>th</sup> floor, all measured deskspaces were in Wing 4 and received some of the highest CS values in this building.
- On the 7<sup>th</sup> floor, all of the deskspaces in Wings 0 and 1 were below the target 0.3 CS value. Two deskspaces in Wing 3 had CS exposure above 0.3.
- Circadian stimulation before 10:00 a.m. is available in Wing 4 regardless of floor height. In Wing 1, CS was at a desirable level in the morning on the 4<sup>th</sup> and 7<sup>th</sup> floors.



**Figure 12. Daysimeter locations on the Ground floor. Window-mounted devices are shown in blue; stick-mounted devices shown in magenta. Numbering convention: (Wing#)-(Window Orientation)-(Floor#)-(Device Orientation).**



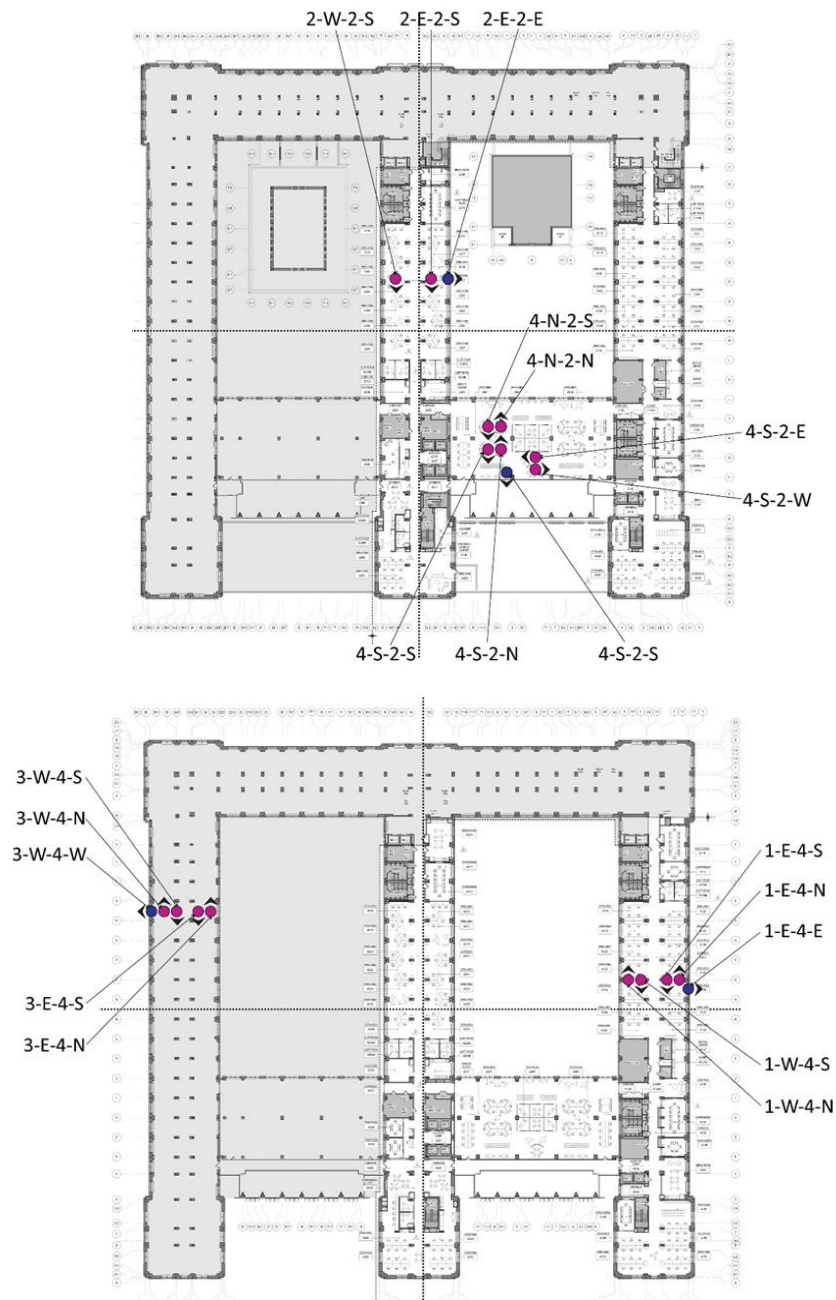


Figure 13. Daysimeter locations on the 2nd floor (upper) and 4th floor (lower).

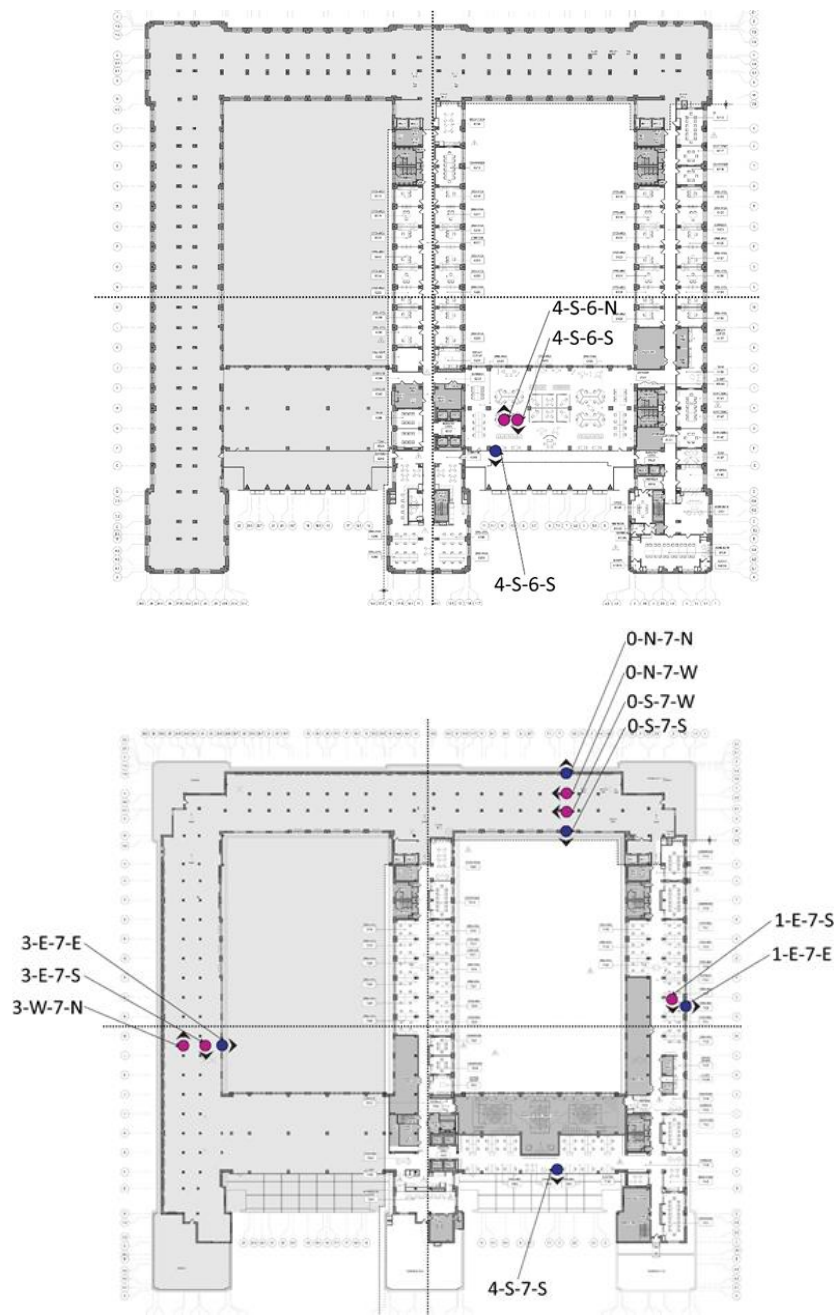
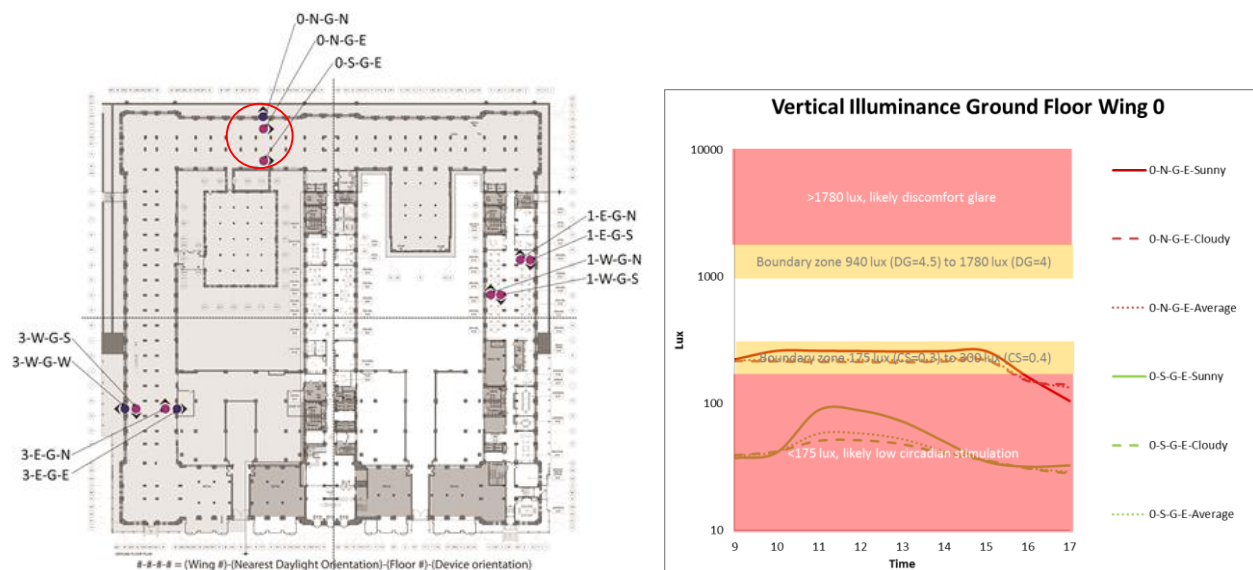


Figure 14. Daysimeter locations on the 6th floor (upper) and 7th floor (lower).

## DISCUSSION

A summary of the findings is shown in Appendix Q. As shown in Figure 15, pink-shaded portions of the figures in Appendix Q reflect areas likely to cause discomfort glare (DG), above 1780 lx, or likely to provide low circadian stimulation (CS), below 175 lx, for a daylight source. The yellow-shaded boundary, between 940 lx and 1780 lx, is considered at or near threshold for evoking a discomfort glare response from occupants. The lower end of the threshold boundary for discomfort glare represents a DG rating of 4.5 whereas the upper boundary represents a DG rating of 4.0. The yellow-shaded boundary, between 175 lx and 300 lx, is considered to be at or near threshold for reliable stimulation of the human circadian system. The lower end of the threshold boundary for circadian stimulation represents a CS value of 0.3, whereas the upper boundary represents a CS value of 0.4. The “ideal” vertical levels of photopic illuminance from daylight, lower than the discomfort glare threshold boundary and above the circadian stimulus threshold boundary, are between 300 lx and 940 lx.



**Figure 15. Average vertical illuminance at the eye at two desks at different times of day and sunny vs. cloudy conditions.**

In general, CS values are above the desired CS value in Wing 4, irrespective of floors and proximity to windows. Deskspace located on the G floor receive the least amount of CS and only a few of the deskspace located in Wing 1 and close to a window received the desired CS value. Otherwise, deskspace in the wings that have not been remodeled and that are located away from windows did not receive a CS above 0.3.

None of the deskspace we measured had vertical light levels above 1790 lx, which is the boundary for discomfort glare, as discussed in a previous LRC report. Some deskspace in Wing 4, a few deskspace had light levels that were bordering discomfort (between 900 lx and 1780 lx). In the winter months, only a few deskspace located on the east facade had light level measurements slightly above the discomfort glare value. No other deskspace reached the boundary for discomfort glare. This may explain light level homogeneity among deskspace located in the different building orientations.

Overall, while these measurements cannot be considered representative of the daily light exposure that office occupants are being exposed to, it gives the researchers an idea of the potential for receiving enough circadian stimulation at these deskspace. In summary,

while deskspaces located in Wings 2 and 4 received good circadian stimulation, many other spaces had low overall levels of circadian stimulus.

Several caveats should be stressed, however:

- CS values are based upon melatonin suppression for a standard observer after 1 hour of light exposure. Longer exposures to light are probably sufficient for entrainment, but estimates of the trade-off between level and duration are not available. Functionally, CS levels as low as 0.1 may be sufficient for circadian entrainment for extended (i.e., 5-8 hours) exposures. More research is needed to determine the relationship between light level and exposure duration as it may affect the circadian system.
- Ideal conditions at work where high levels of CS are provided in the morning hours may be compromised by light exposure after work.
- DG ratings are highly variable among people and for different contexts.

While we were not able to assess many occupants' responses in this building, the photometric measurements and the Daysimeter measurements provided us with some lessons learned that are consistent with other site evaluations performed by the LRC and by other researchers. (See References.) Some of the lessons learned include:

- In locations where there is little daylight availability (e.g., G floor), only the deskspaces located close to windows had circadian stimulation close to the desired level.
- Similar to other buildings (but to a lesser extent), deskspaces in higher floors receive higher CS values.
- None of the Daysimeter measurements suggest that workers are experiencing discomfort glare from excessive sunlight penetration in December. The courtyard between the different wings may have played a role in reducing sunlight penetration in the space, while still allowing for daylight penetration.
- Furniture layout in this building is such that most workers sit perpendicular to windows rather than facing windows; this might also explain why building orientation may not have played a key role on circadian stimulus received on the various deskspaces. Moreover, because this is not a deep core building, even deskspaces that are not located immediately adjacent to a window are still close enough to receive daylight.
- Although most of the measured deskspaces had a horizontal illuminance of greater than 30 footcandles (approximately 300 lx), and most workers reported the amount of light on their desks was neither too much nor too little, some workers still felt the need to use task lights, while others complained about the space being "too bright" for computer use.

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Rea, MS. (2012.) *Value Metrics for Better Lighting*. SPIE Press.

## **CREDITS**

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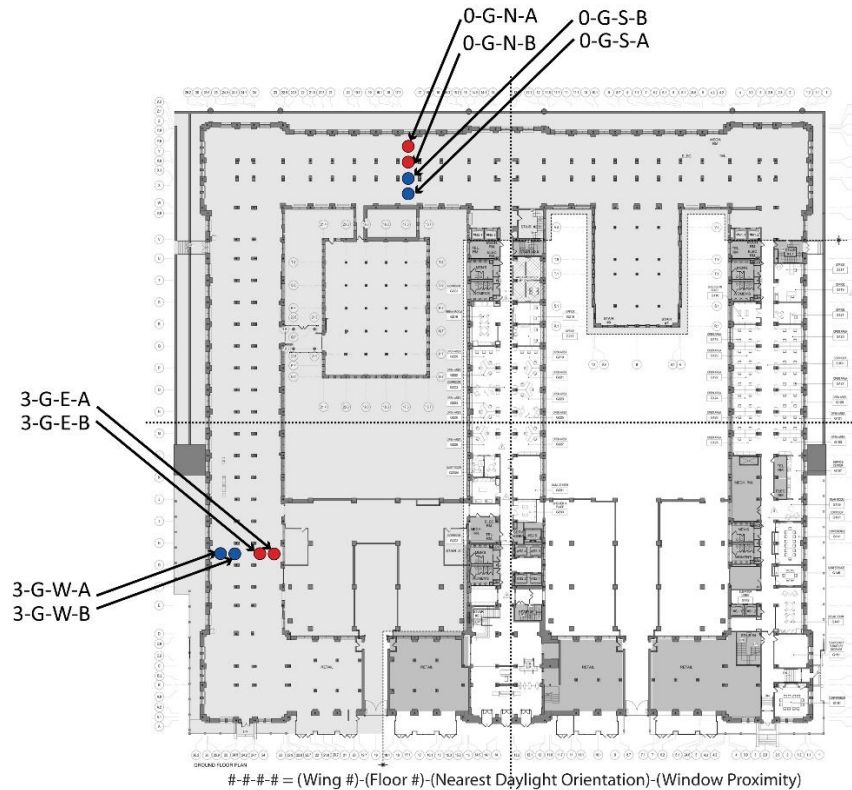
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**Site Evaluation Assistance:** Bryan Steverson, Kelli Canada

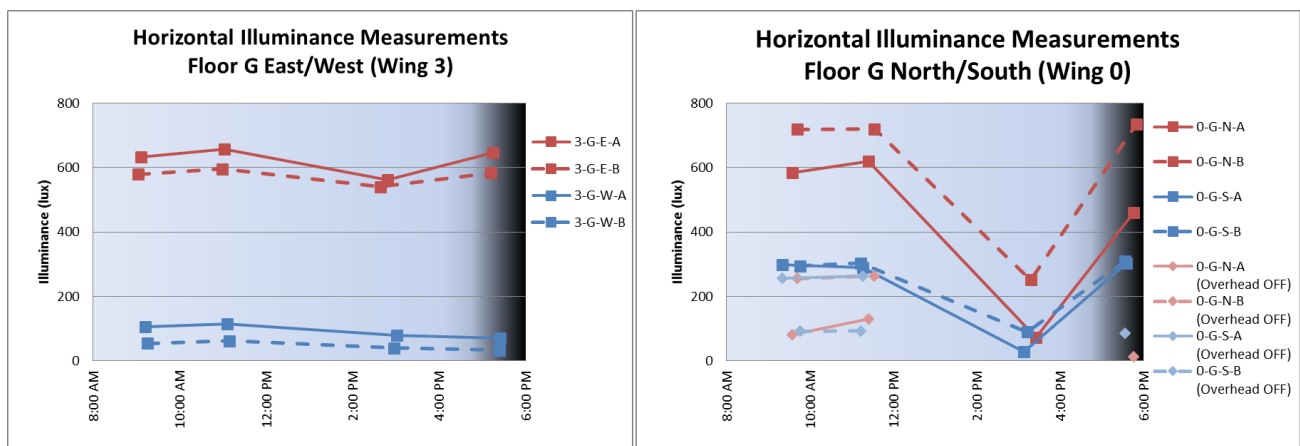
**Graphic Designer:** Dennis Guyon

**Editors:** Rebekah Mullaney, Dennis Guyon, Sarah Hulse

## APPENDIX A: PHOTOMETRIC DATA (ILLUMINANCE AND LUMINANCE MEASUREMENTS)

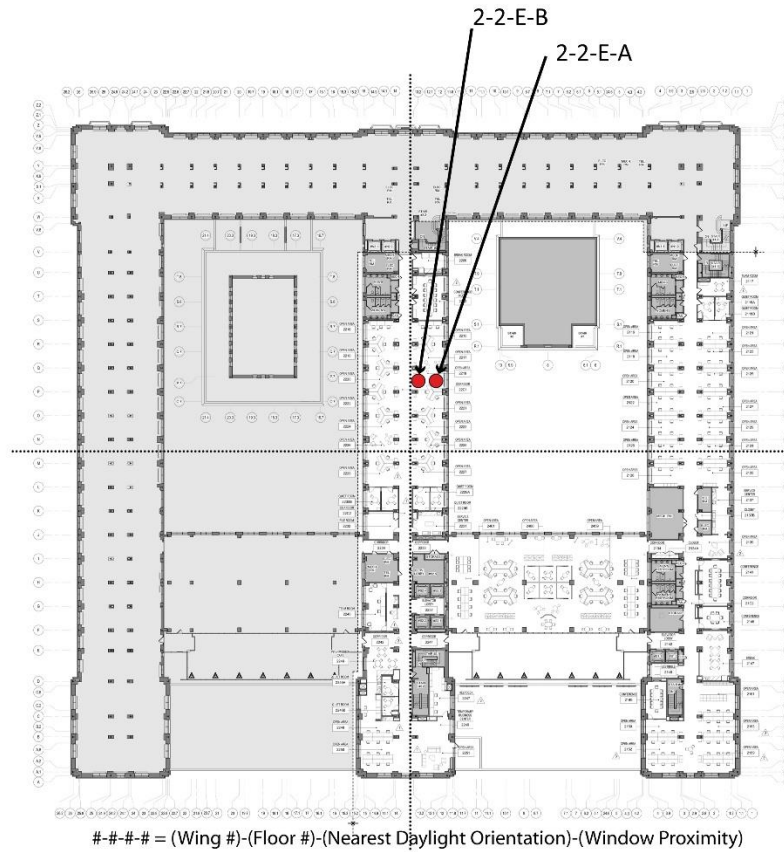


*Key plan, showing photometric measurement locations on Floor G.  
Desks marked "A" are nearest the windows, while desks marked "B" are in the adjacent row.  
Grey shading on the plan indicates that the area was not included in Phase I renovation.*

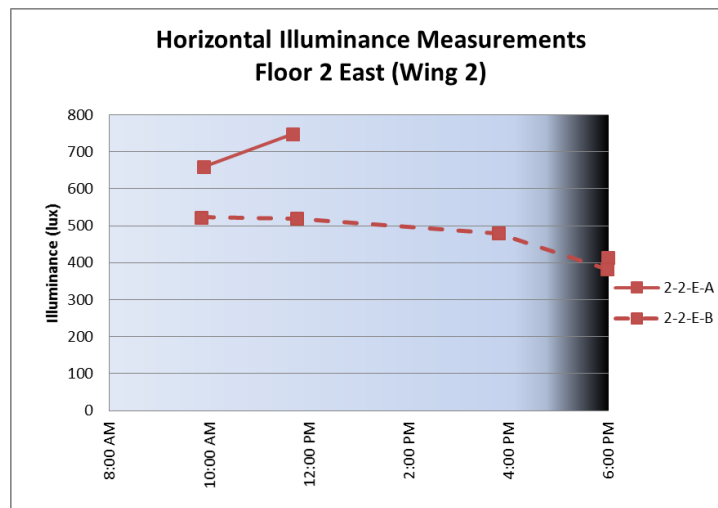


*Horizontal illuminance measurements at 8 desks on Floor G, during the day and in the evening.*

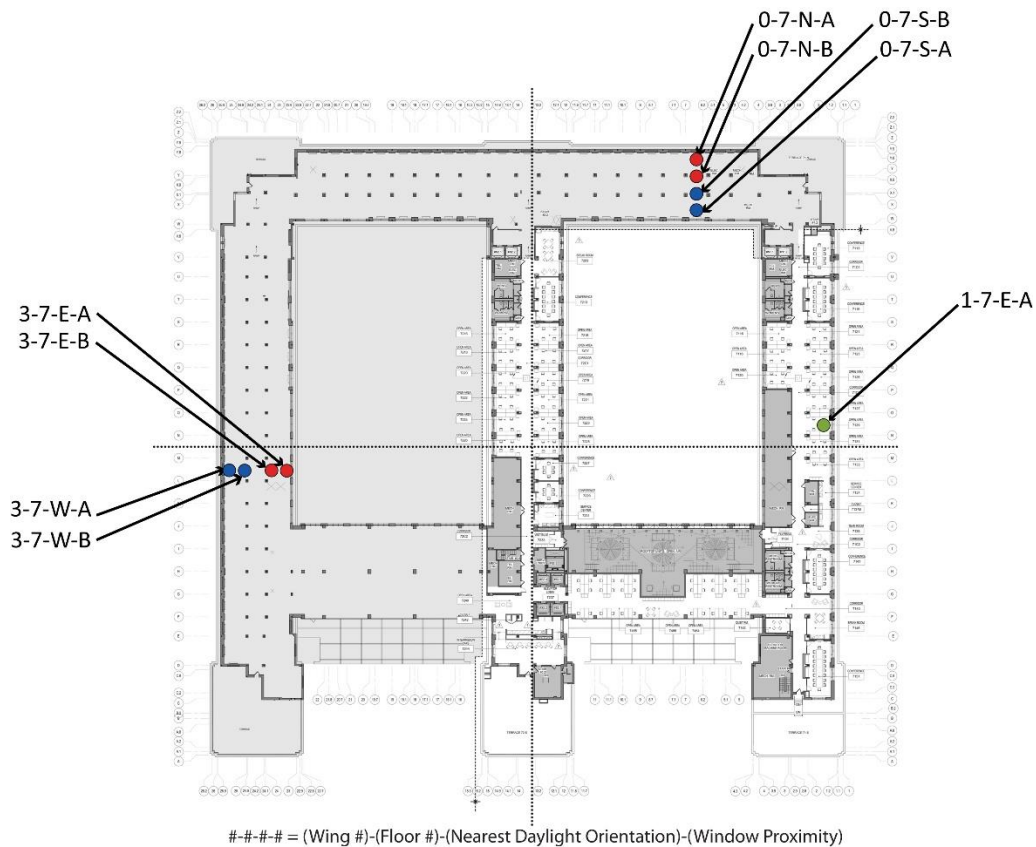




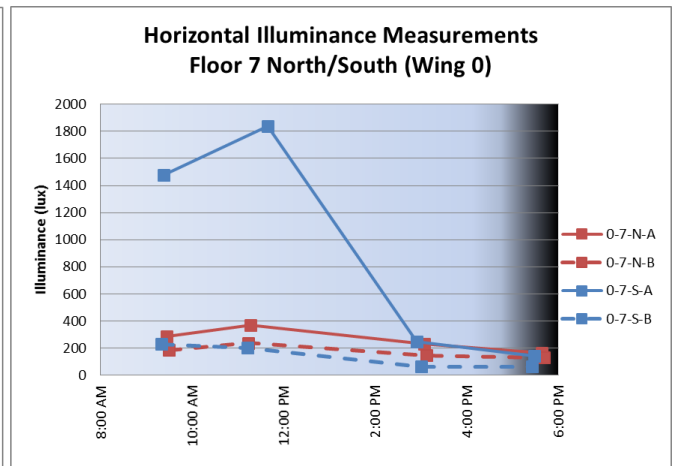
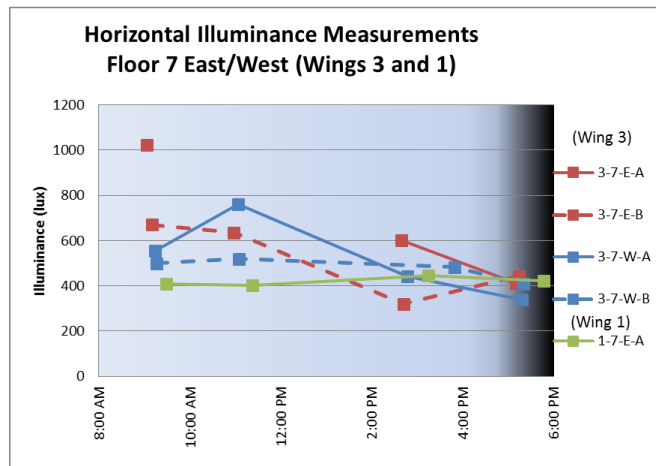
**Key plan, showing photometric measurement locations on Floor 2**  
(Grey shading on the plan indicates that the area was not included in Phase I renovation)



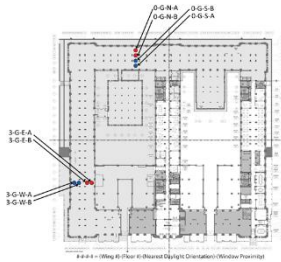
**Horizontal illuminance measurements at 2 desks on Floor 2, during the day and in the evening.**  
(Gaps indicate that desk was not available at that measurement time)



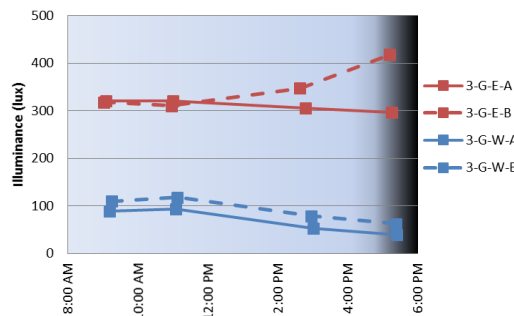
**Key plan, photometric measurement locations on Floor 7**



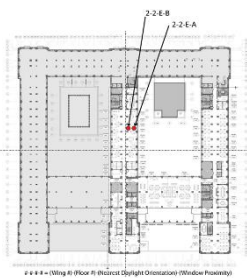
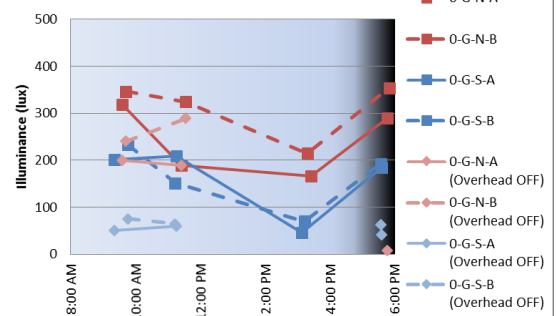
**Horizontal illuminance measurements at 10 desks on Floor 7, during the day and in the evening.  
(Gaps indicate that desk was not available at intermediate measurement time)**



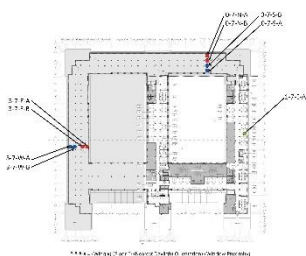
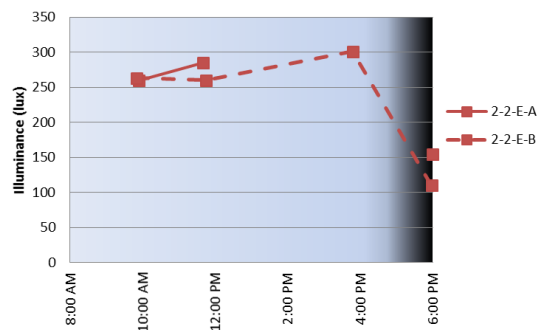
**Vertical (Eye) Illuminance Measurements  
Floor G East/West (Wing 3)**



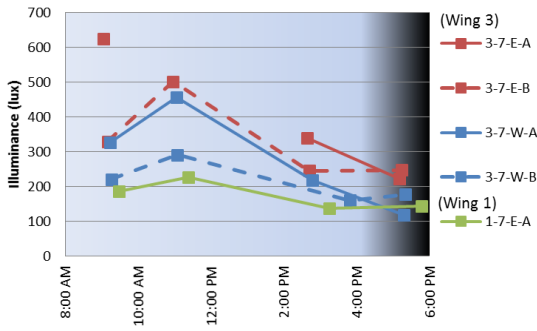
**Vertical (Eye) Illuminance Measurements  
Floor G North/South (Wing 0)**



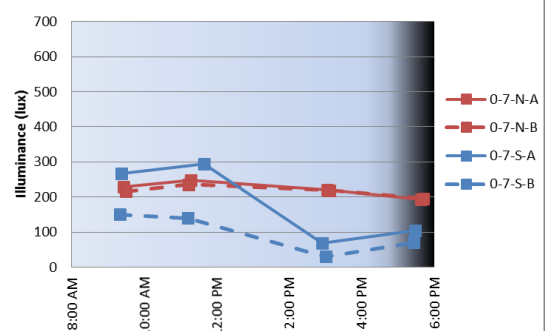
**Vertical (Eye) Illuminance  
Measurements Floor 2 East (Wing 2)**



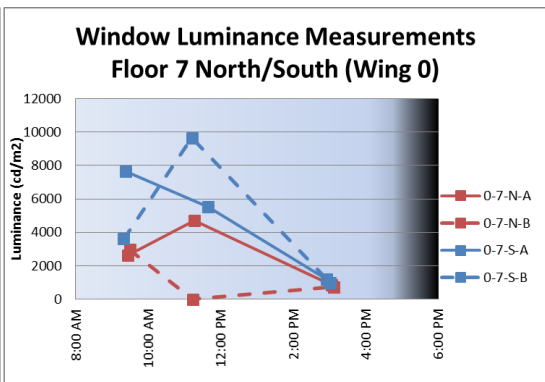
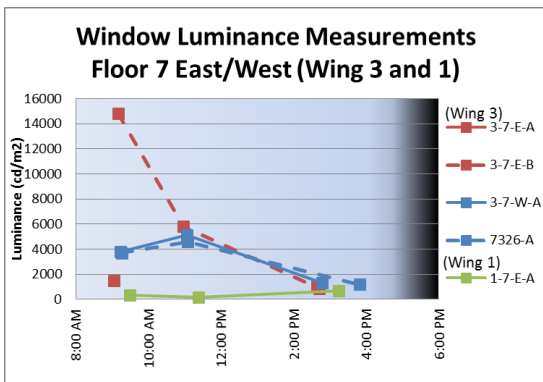
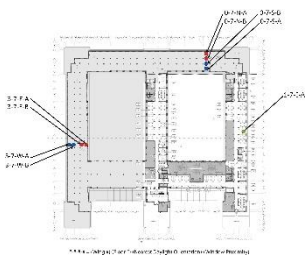
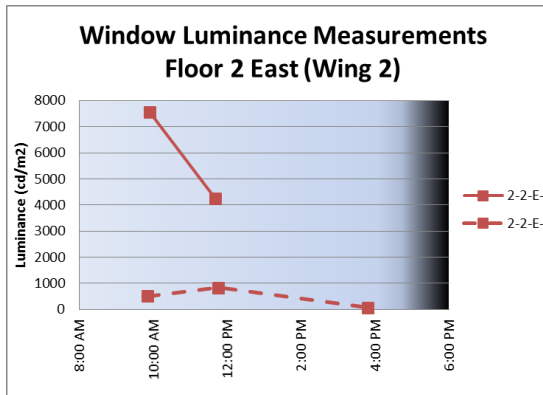
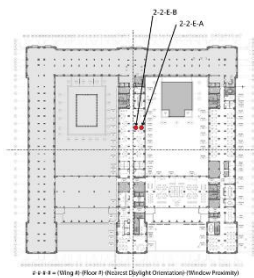
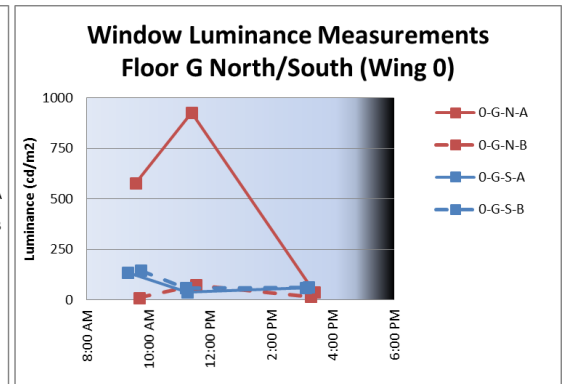
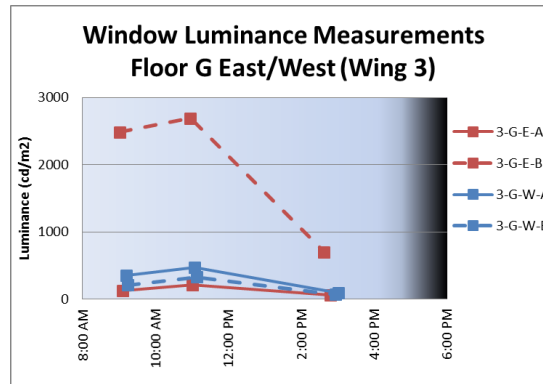
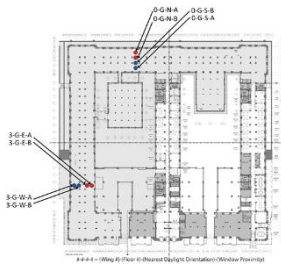
**Vertical (Eye) Illuminance Measurements  
Floor 7 East/West (Wing 3 and 1)**



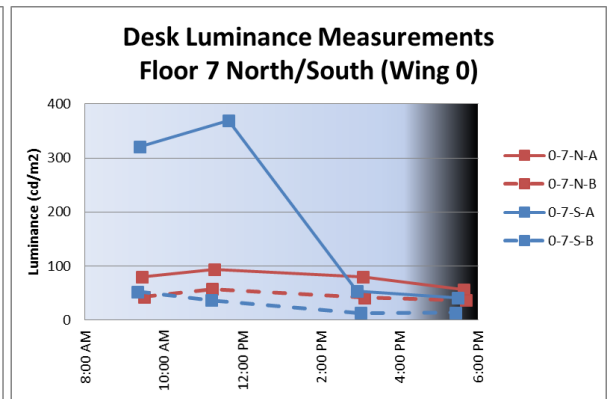
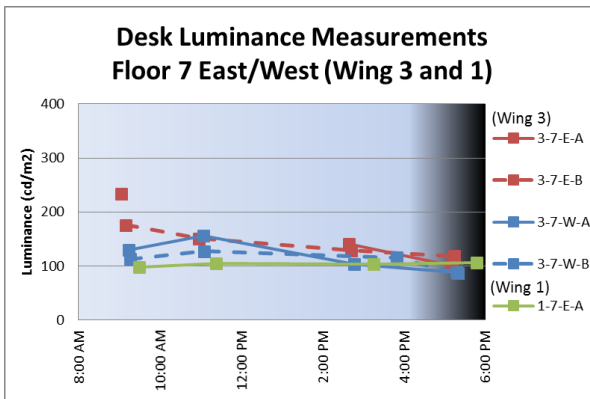
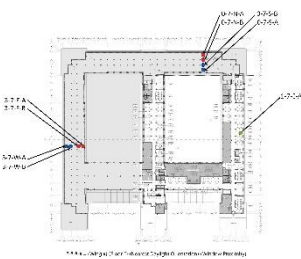
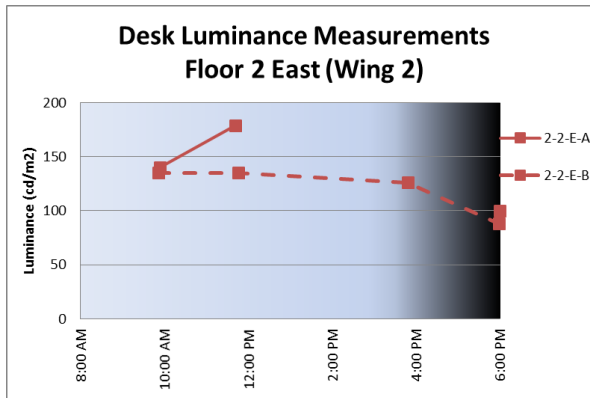
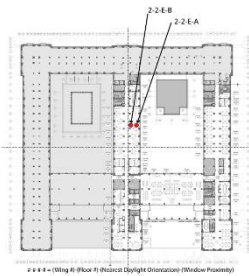
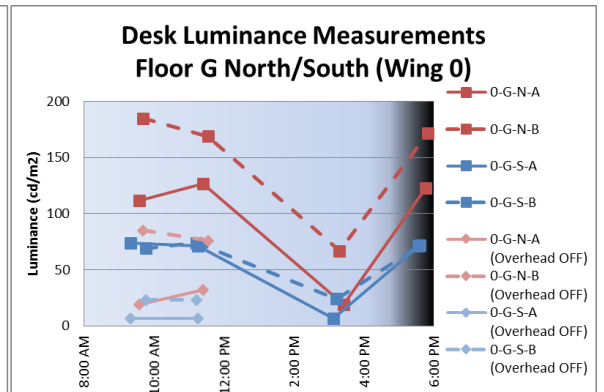
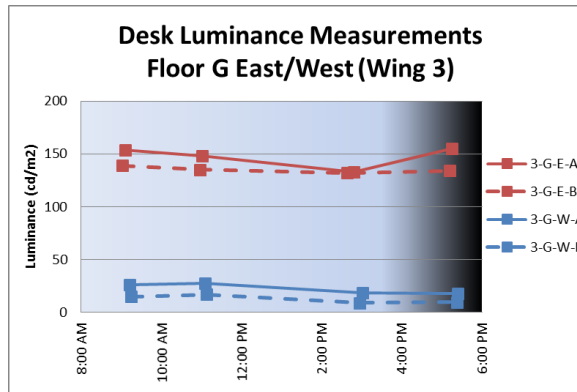
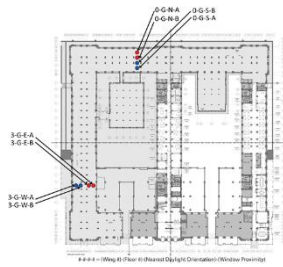
**Vertical (Eye) Illuminance Measurements  
Floor 7 North/South (Wing 0)**



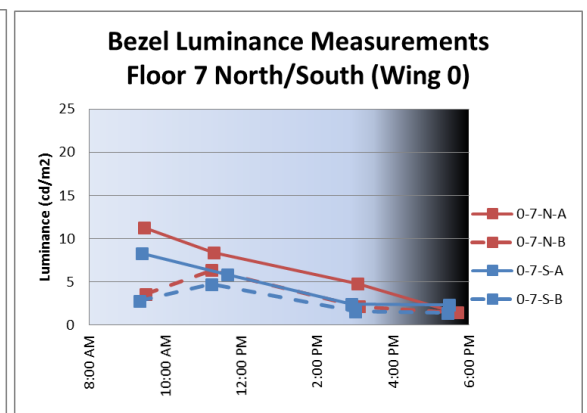
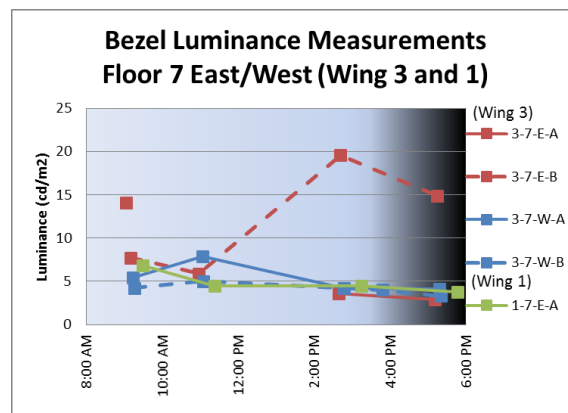
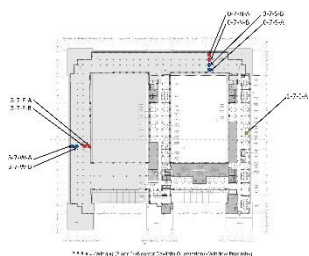
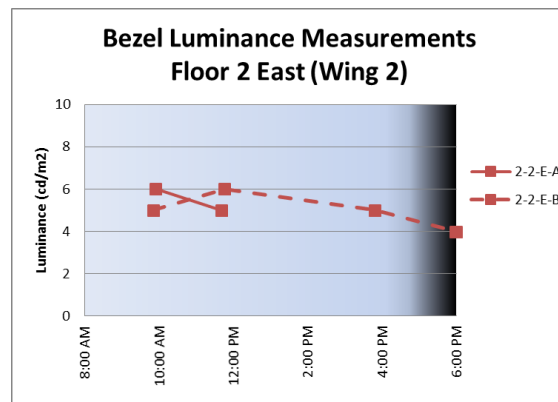
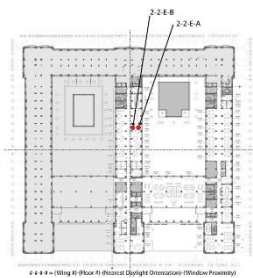
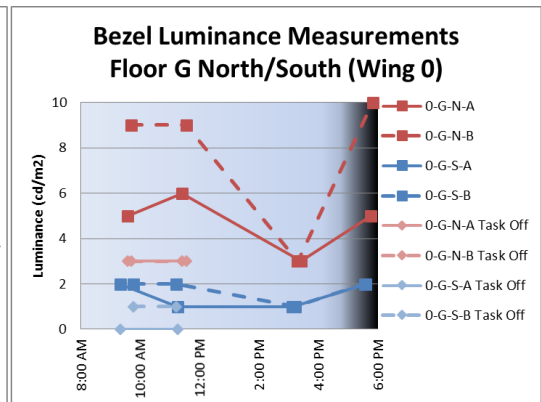
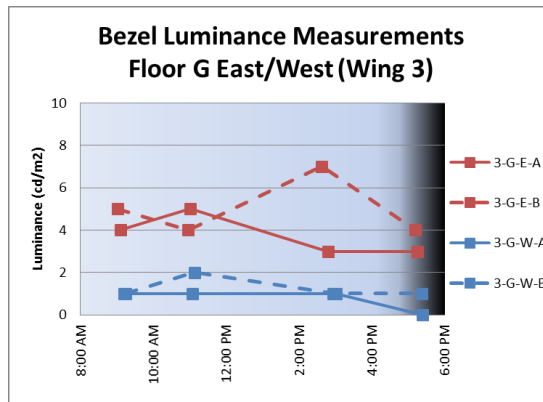
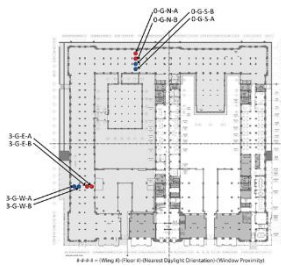
*Vertical illuminance (at the eye) at 19 desks, during the day and in the evening.  
(Gaps indicate that desk was not available at intermediate measurement time)*



*Window luminances at 19 desks, during the day only.  
(Gaps indicate that desk was not available at intermediate measurement time,  
or luminance was too high to measure)*



Desk luminances at 19 desks, during the day and in the evening.  
(Gaps indicate that desk was not available at intermediate measurement time)

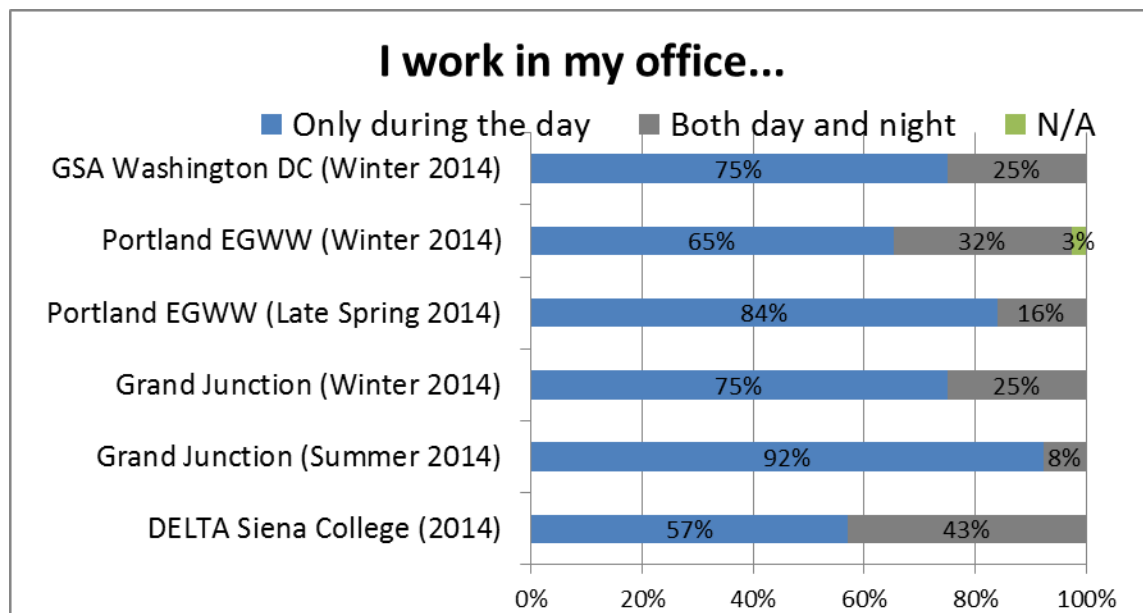
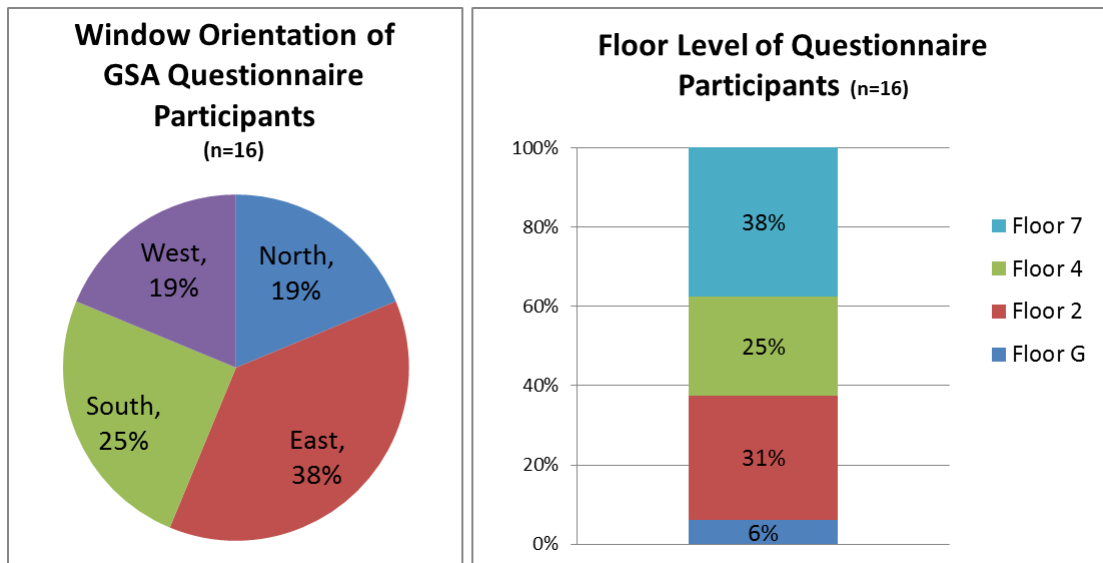


Computer monitor bezel luminances at 19 desks, during the day and in the evening.  
(Gaps indicate that desk was not available at intermediate measurement time)

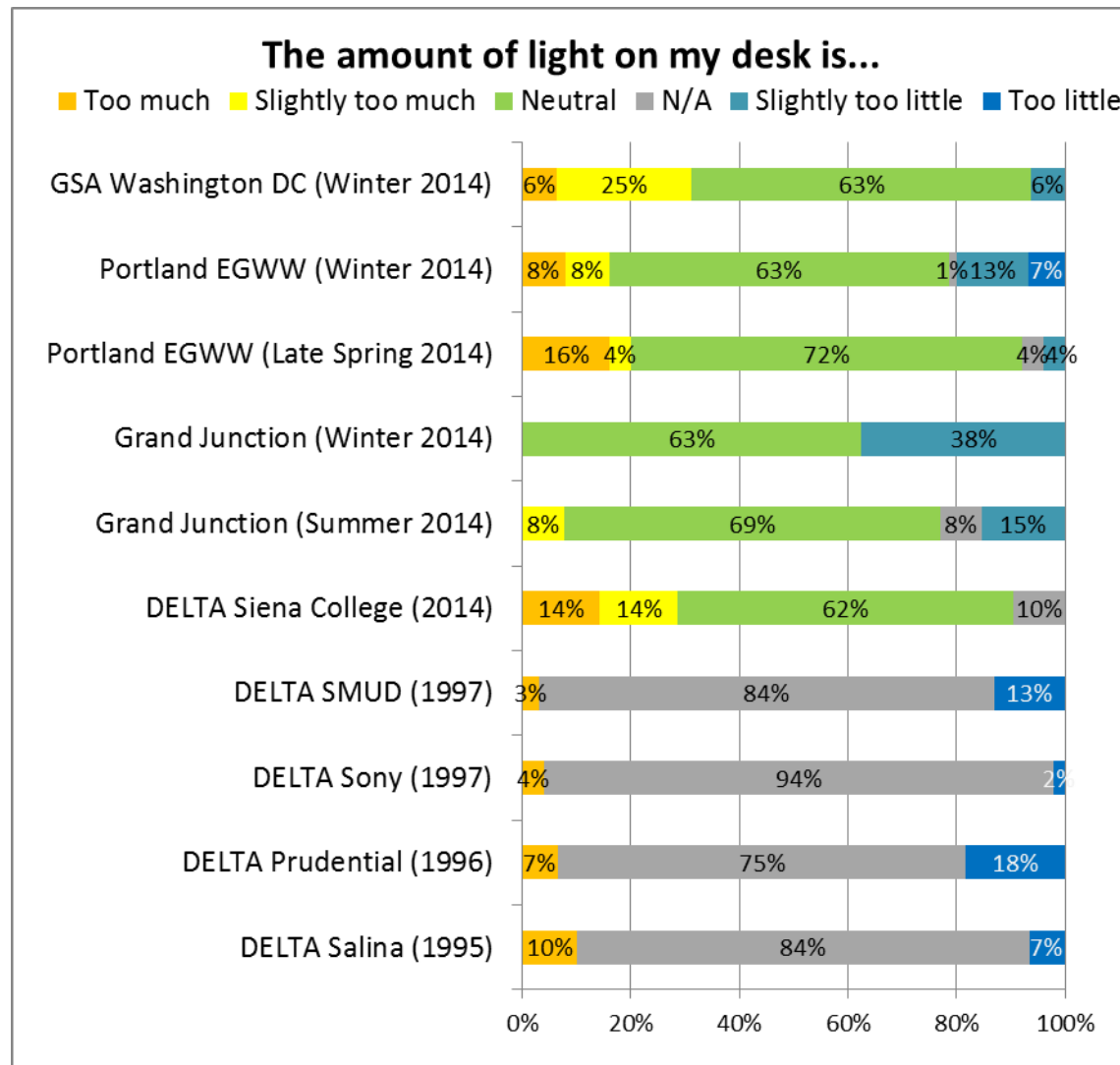


## APPENDIX B: QUESTIONNAIRE RESULTS

### QUESTIONNAIRE DEMOGRAPHICS

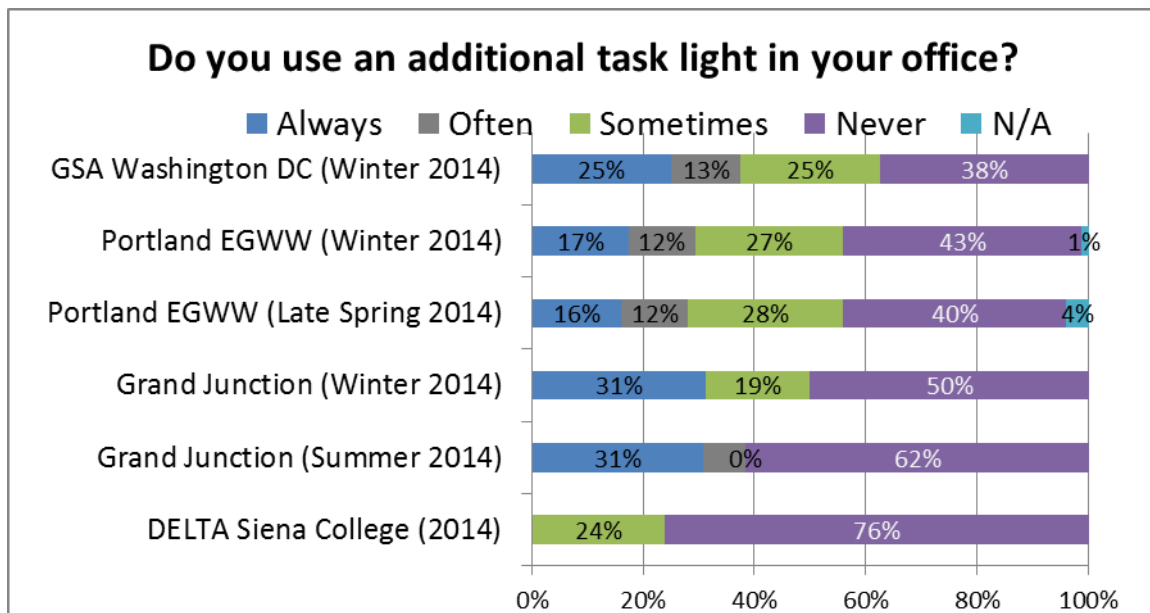
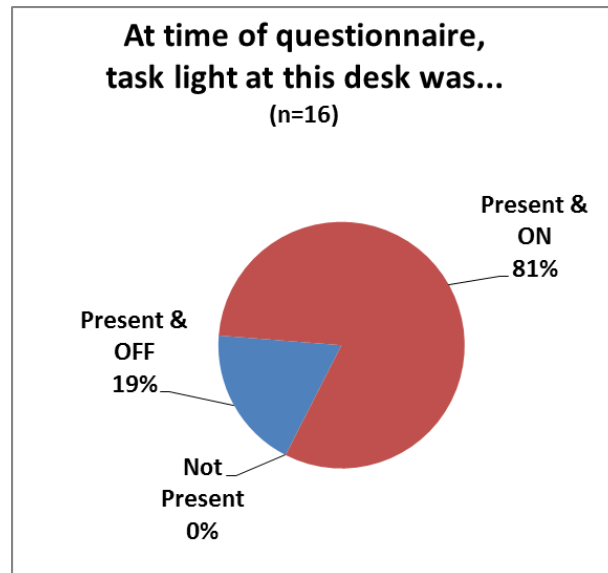


## QUESTIONNAIRE RESULTS (GSA COMPARED TO OTHER SITES, AS AVAILABLE)



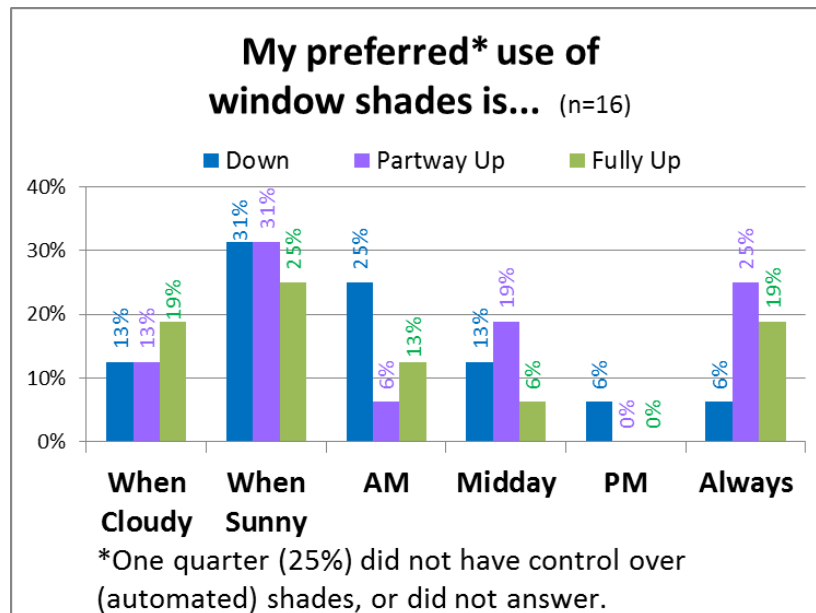
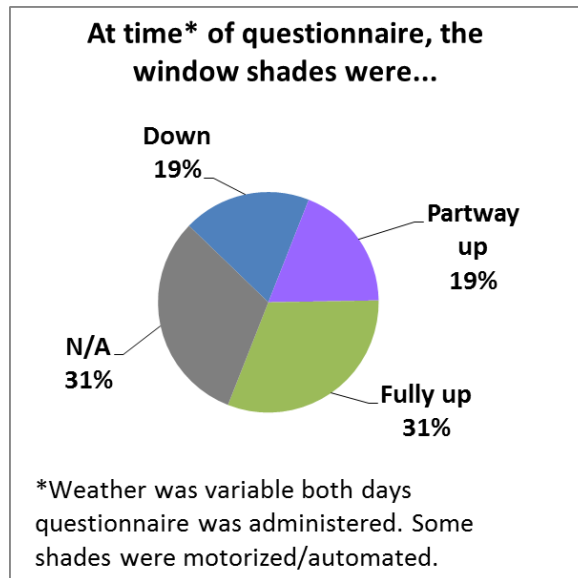
## OTHER COMMENTS (ABOUT AMOUNT OF LIGHT ON THE DESK)

- "I like the openness & lots of light. Though with the sun at certain times of the day it's challenging to see the screen. "
- "The lights don't come on when I first arrive, so it's pretty dark but the task light helps. Once they come on, and if it is sunny, the light gets slightly overwhelming."
- "I like the amount of light I get at (this desk) most of the time. Sometimes there's too much light and I feel like it's hard to shade it."



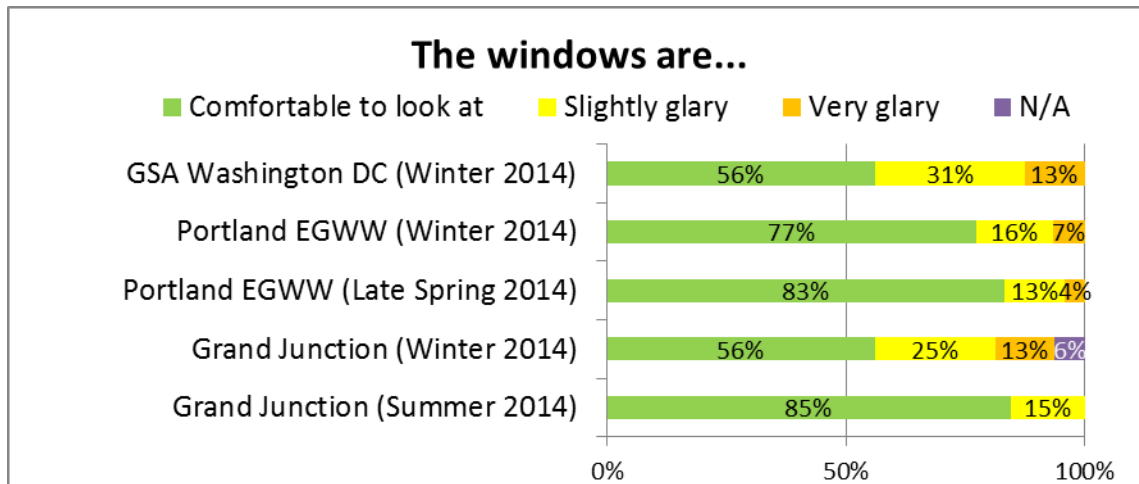
## TASK LIGHT COMMENTS

- "Not sure how to turn on....You really don't need a [task light] if doing computer work."



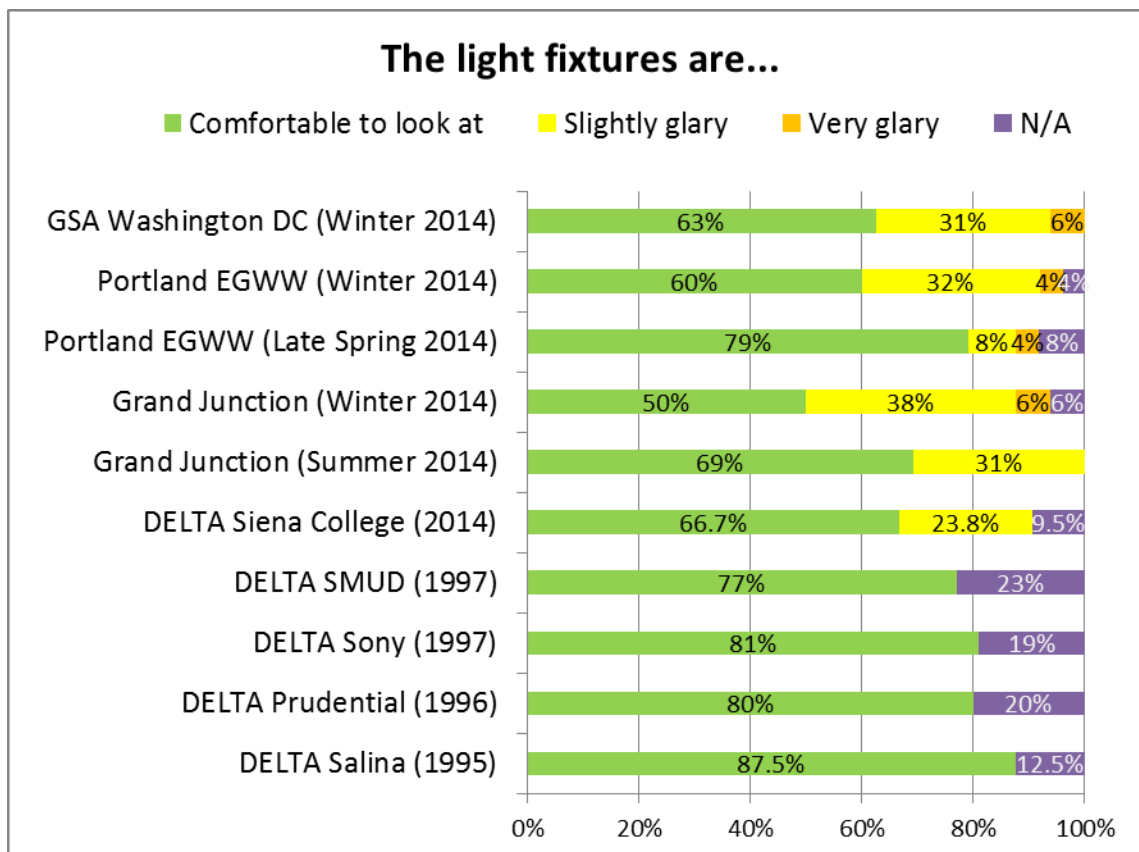
## SHADES COMMENTS

- "West window, other colleagues need it closed sometimes in the afternoon. It gets hot in the summer. I have a permanent office/desk here."



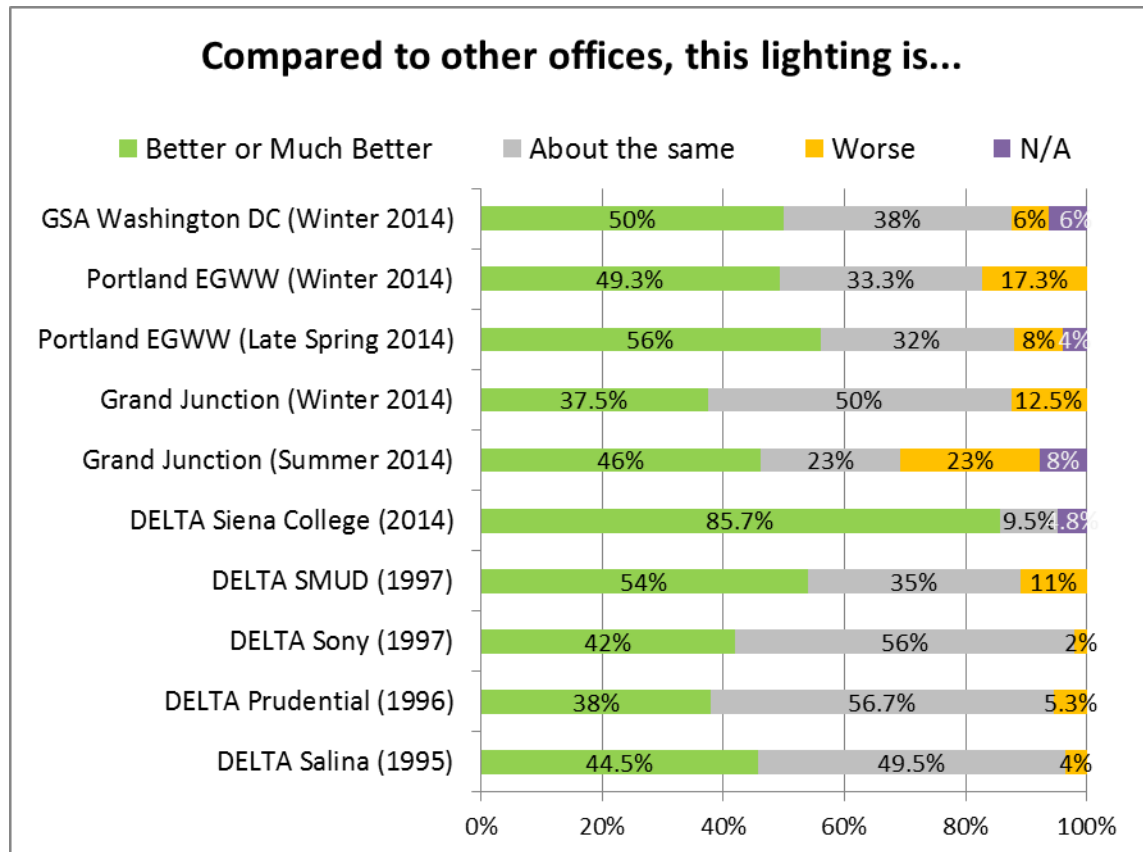
#### WINDOW GLARE COMMENTS

- N/A



#### LUMINAIRE GLARE COMMENTS

- N/A



## OVERALL COMMENTS

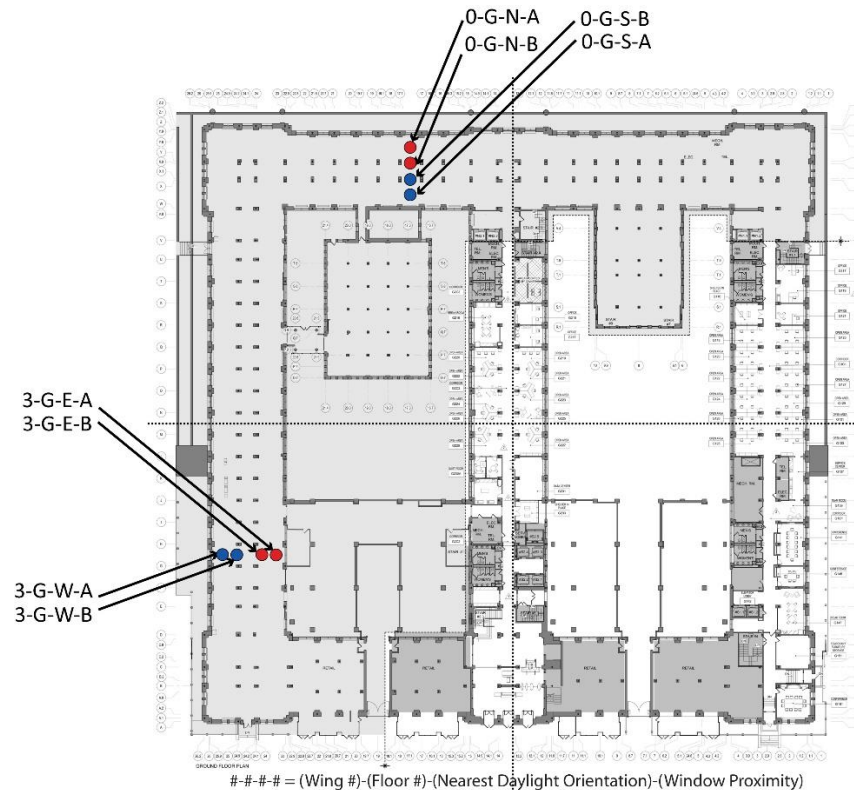
- Overall, "I like it better [here] because in other places, there's sun and glare. I leave the lights however they are."
- "I like the openness [and] lots of light. Though with the sun at certain times of the day it's challenging to see the screen." (See image below for an example of foam core board used to increase shading.)
- "The lights don't come on when I first arrive, so it's pretty dark but the task light helps. Once they come on, and if it is sunny, the light gets slightly overwhelming."
- "I like the amount of light I get at [this desk] most of the time. Sometimes there's too much light and I feel like it's hard to shade it."
- "Some lights behind my desk in row 2217 seem permanently disabled and should be fixed."
- "Lights come on automatically."



*An occupant installed an additional foam core board, clearly dissatisfied with amount of shading from automated mesh shades.*

## APPENDIX C: SPECTRAL PHOTOMETRIC DATA FOR GROUND FLOOR DESKS

Spectral power distribution (SPD) was measured at 8 desks on the Ground floor at GSA during the winter visit. These were the same desks that hosted other measurements (see Appendix A). SPDs were measured repeatedly over the day and after dark.



*Desks on the Ground floor where SPD measurements were collected*

As shown below, the resulting SPD curves change as daylight contribution changes. For reference, a photograph is also presented for most of the measurements, as this represents the scene that the occupant experienced at the time of measurement.



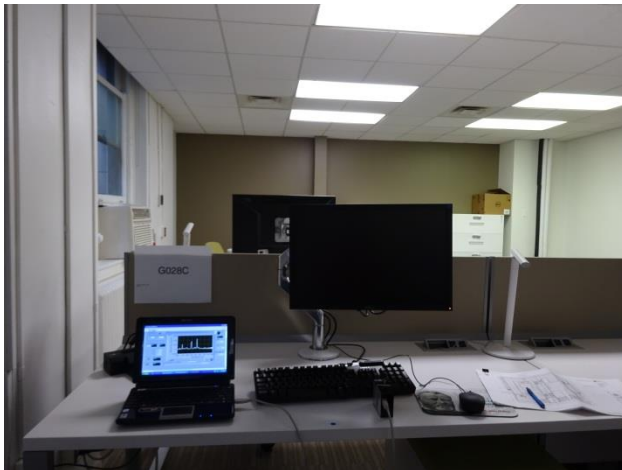
*WING 0-GROUND FLOOR-NORTH-A*



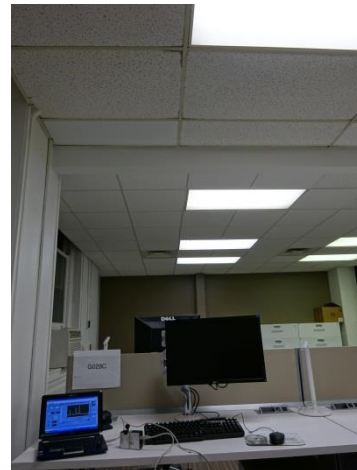
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**11:38 AM**



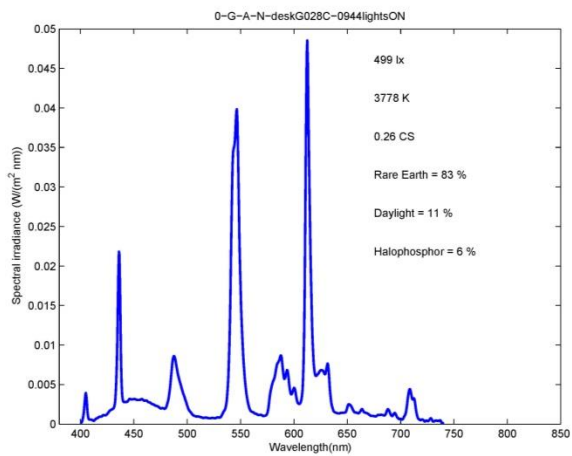
**3:28 PM**



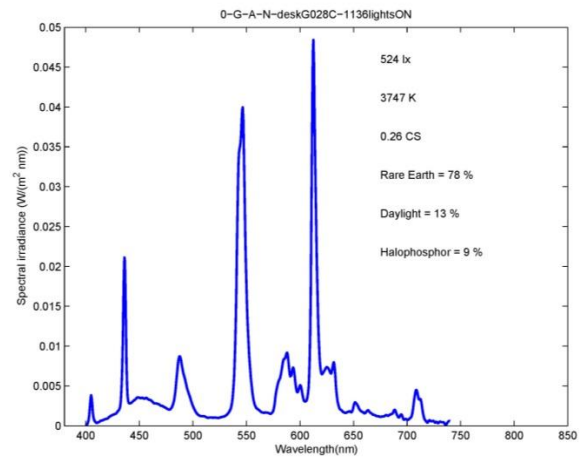
**5:51 PM**

## WING 0-GROUND FLOOR-NORTH-A

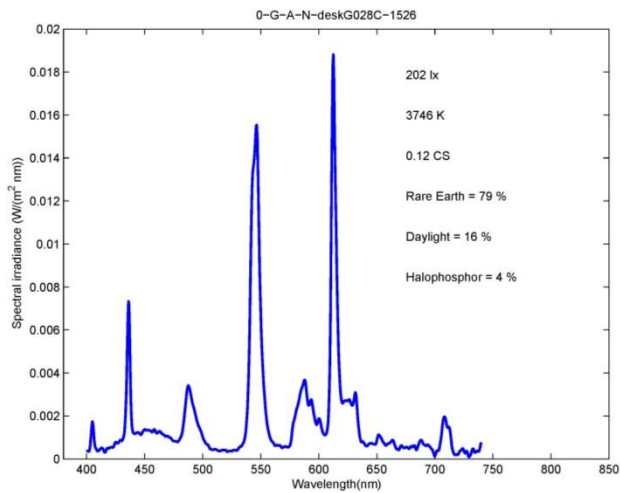
(SPECTRAL POWER DISTRIBUTION)



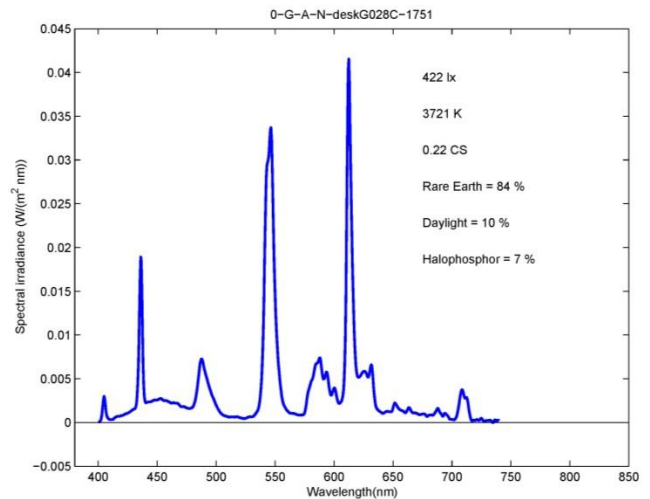
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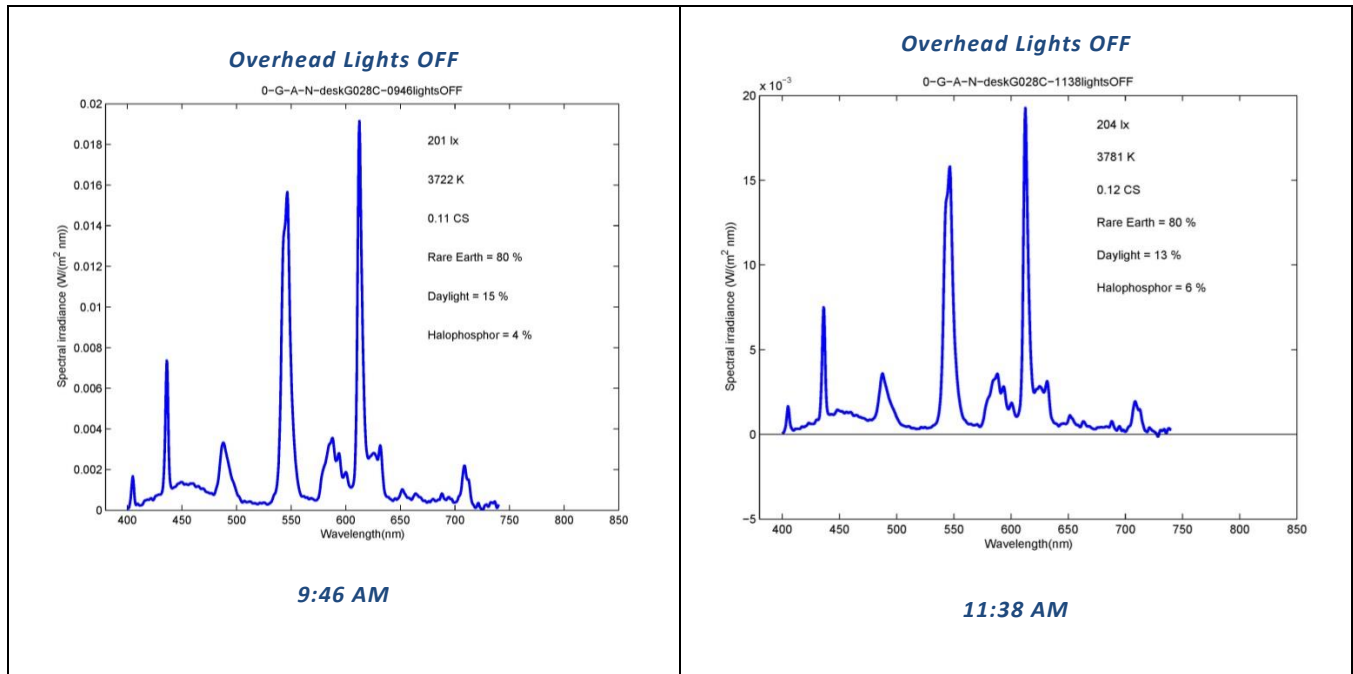
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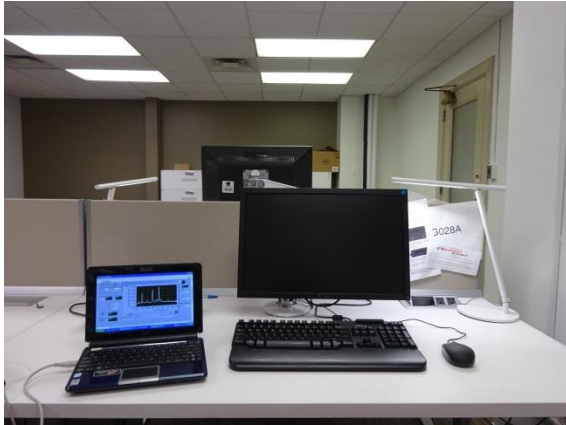
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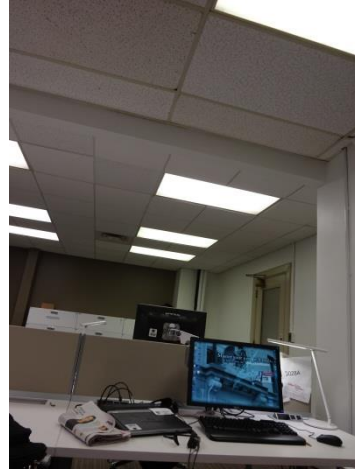
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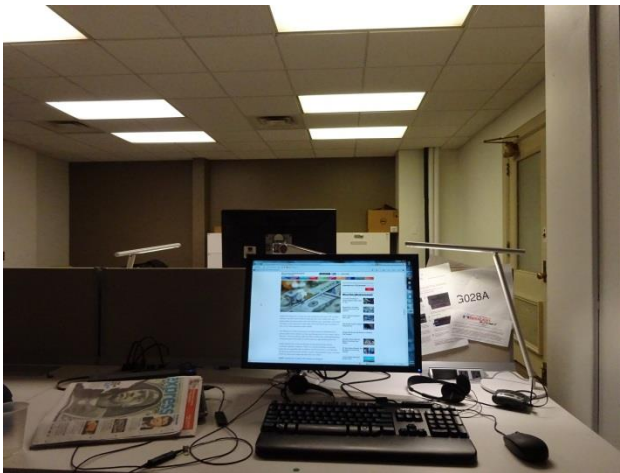
## WING 0-GROUND FLOOR-NORTH-B



**9:41 AM**

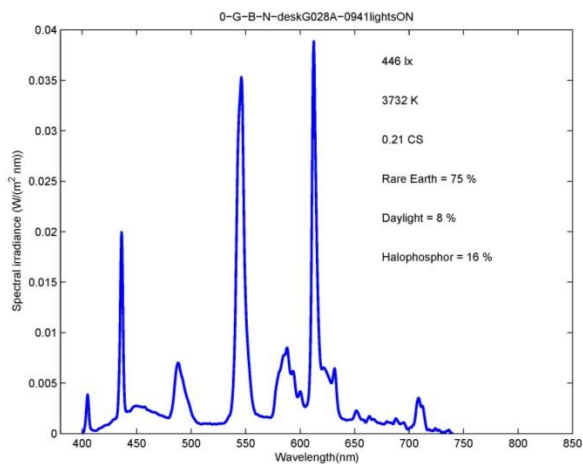


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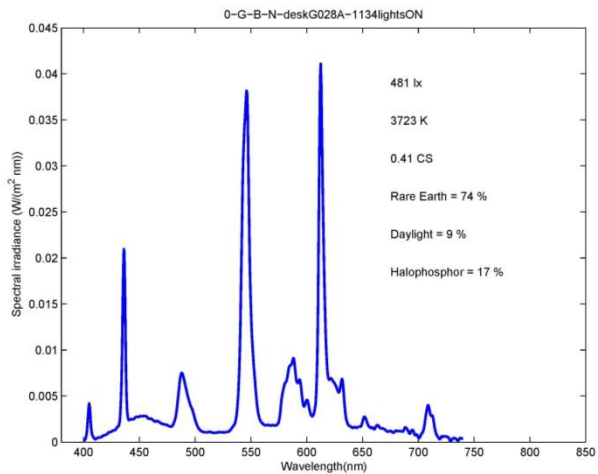


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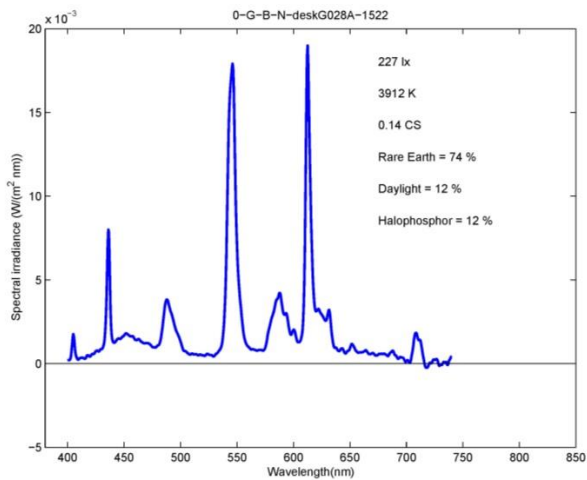
## WING 0-GROUND FLOOR-NORTH-B (SPECTRAL POWER DISTRIBUTION)



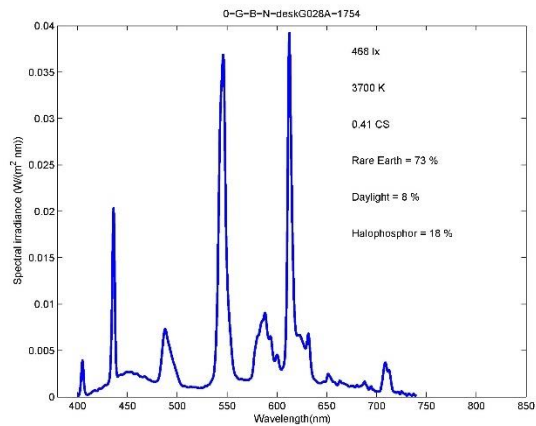
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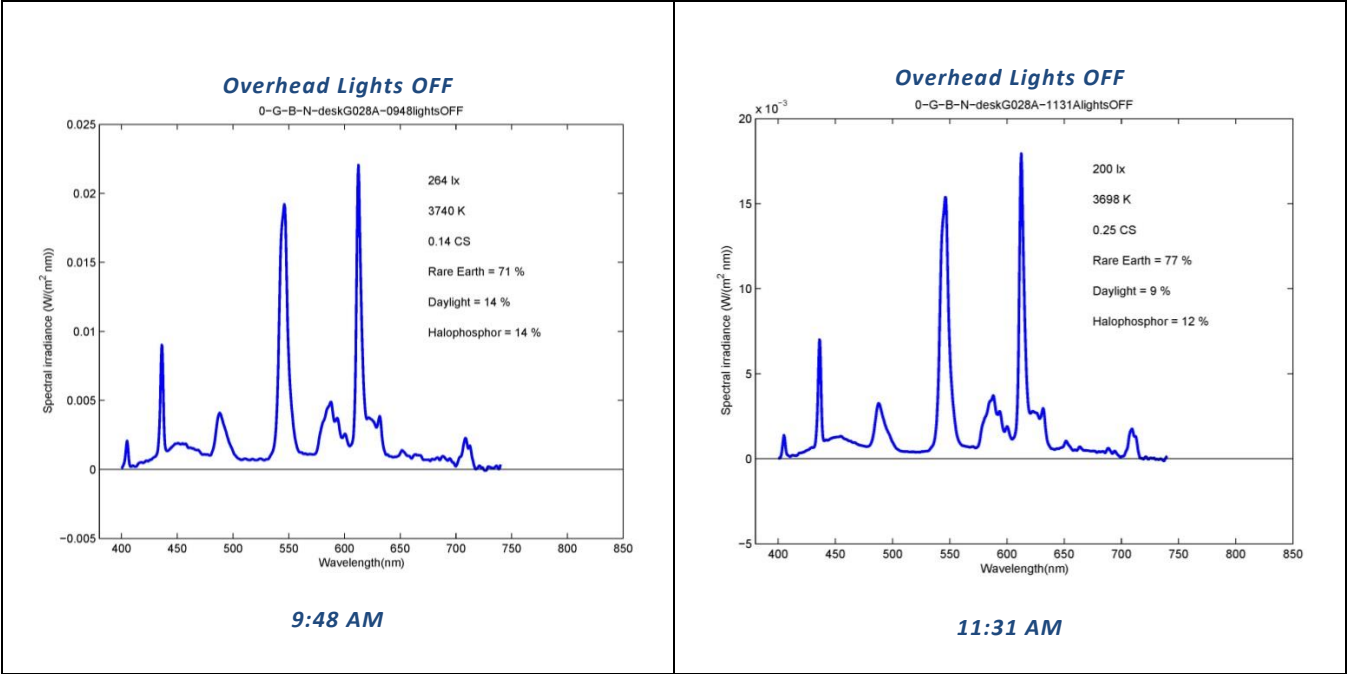
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3:22 PM



5:54 PM

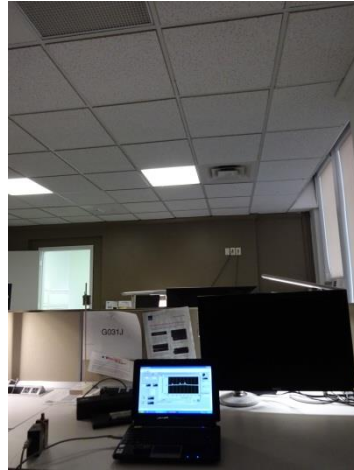




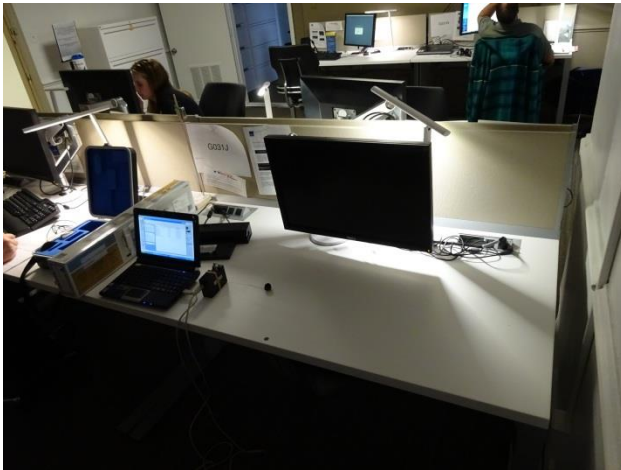
## WING 0-GROUND FLOOR-SOUTH-A



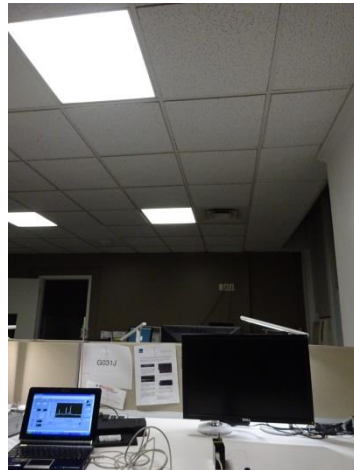
**9:28 AM**



**11:15 AM**

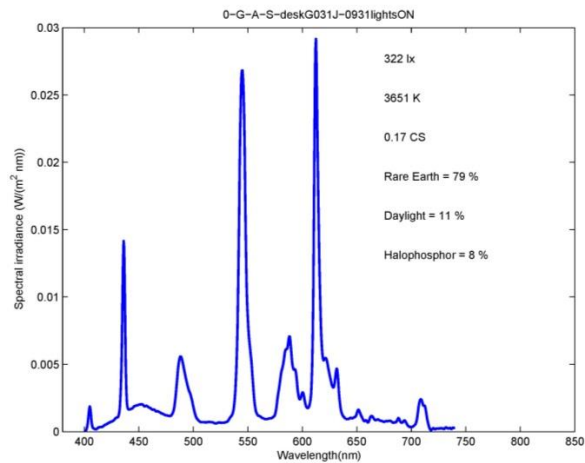


**3:15 PM**

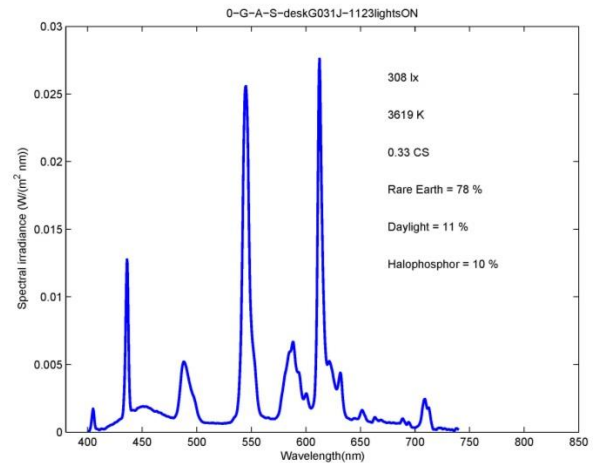


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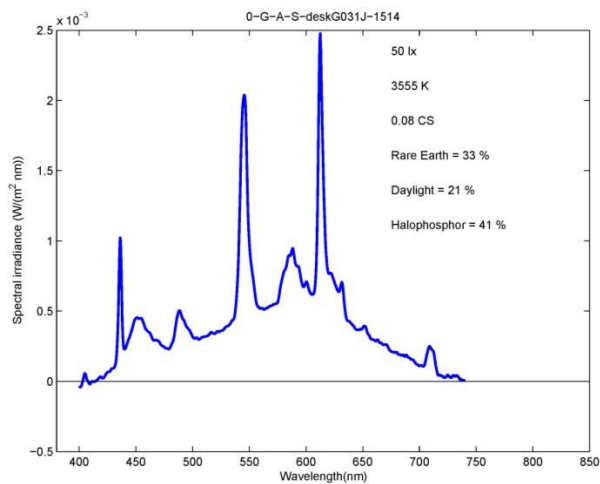
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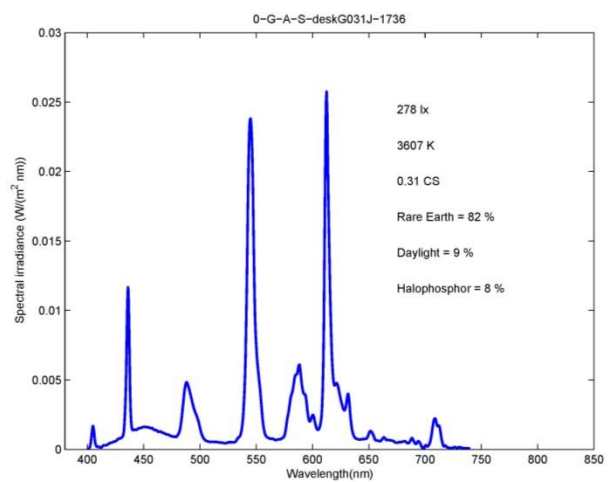
9:31 AM



11:23 AM

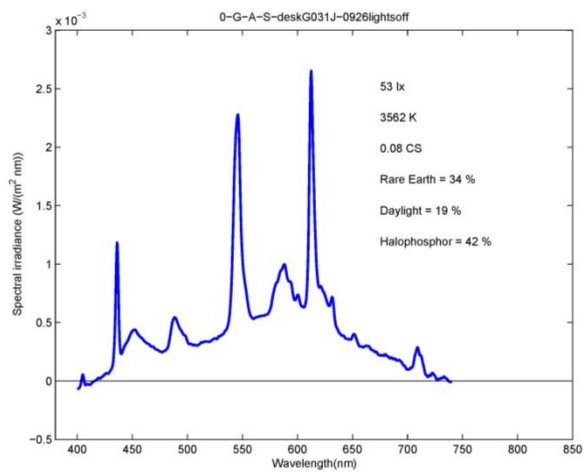


3:14 PM



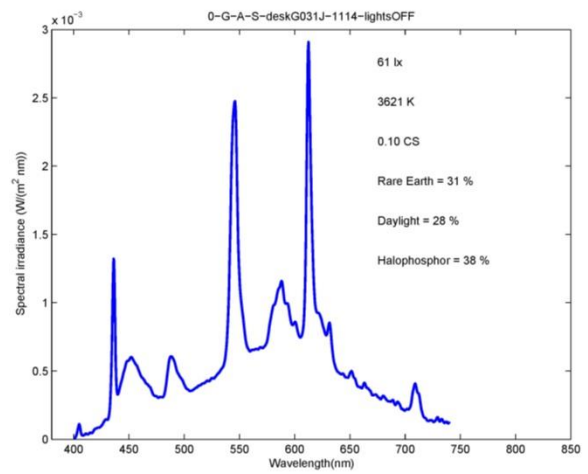
5:51 PM

### Overhead Lights Off



9:26 AM

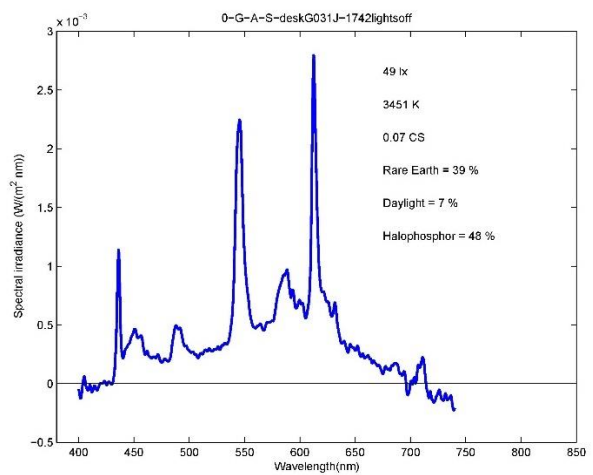
### Overhead Lights Off



11:14 AM

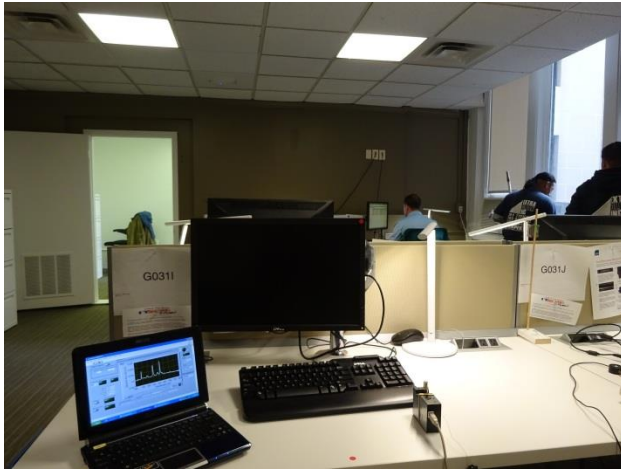
(Overhead lights stayed on in the afternoon)

### Overhead Lights Off



5:42 PM

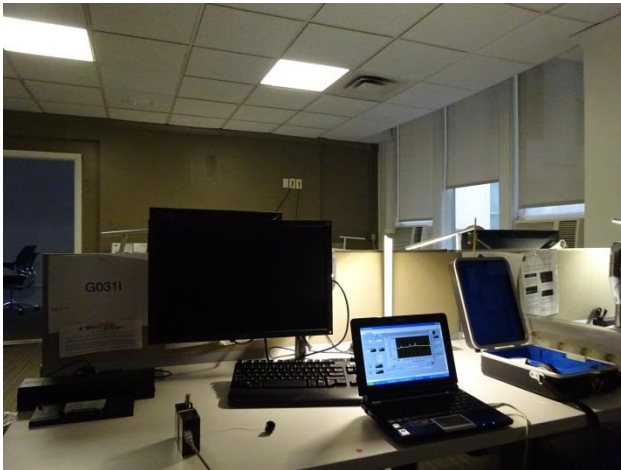
## WING 0-GROUND FLOOR-SOUTH-B



**9:33 AM**



**11:21 AM**



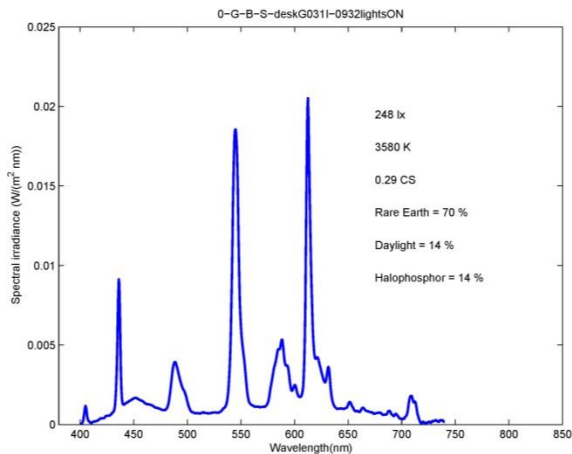
**3:10 PM**



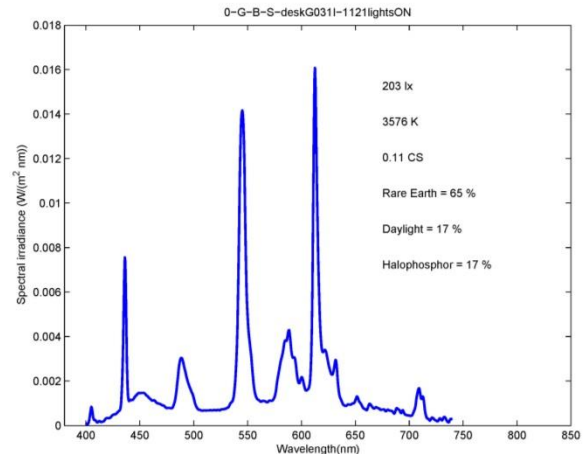
**5:38 PM**

## WING 0-GROUND FLOOR-SOUTH-B

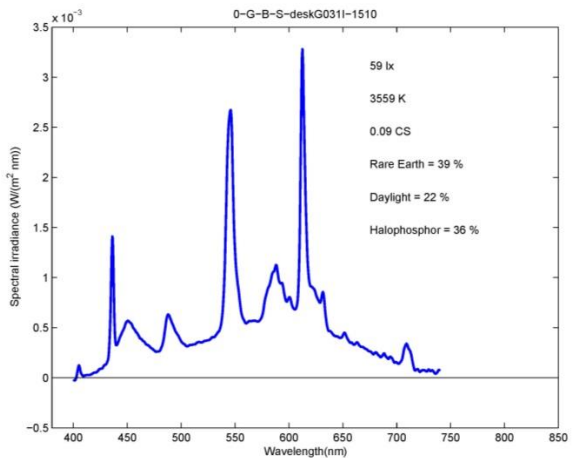
### (SPECTRAL POWER DISTRIBUTION)



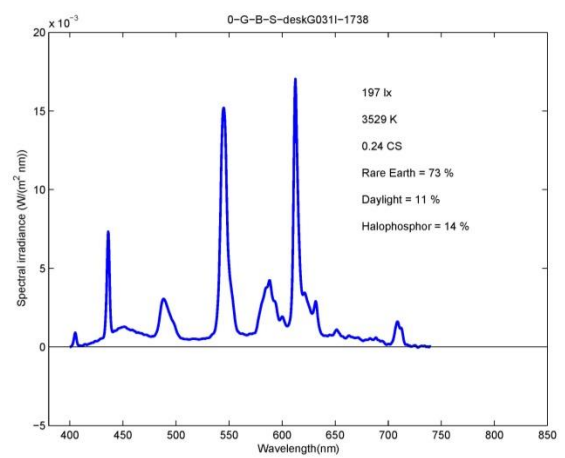
9:32 AM



11:21 AM



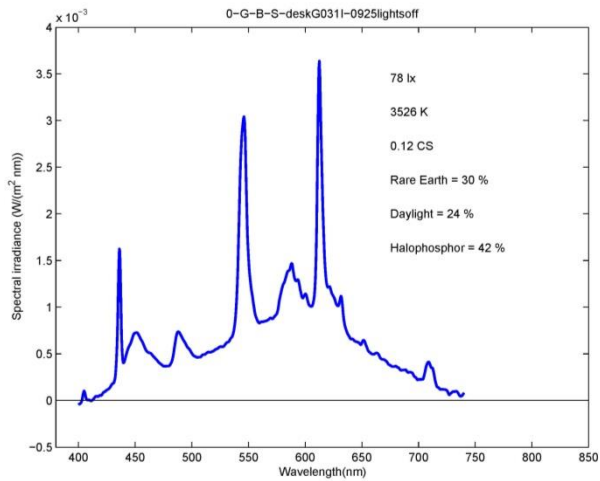
3:10 PM



5:38 PM

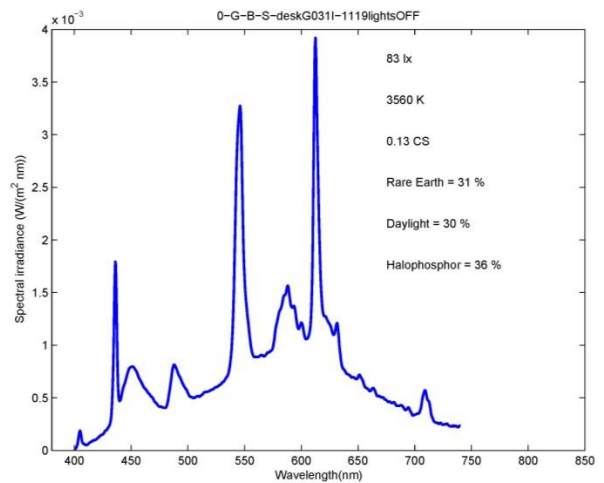
## WING 0-GROUND FLOOR-SOUTH-B (SPECTRAL POWER DISTRIBUTION)

**Overhead Lights Off**



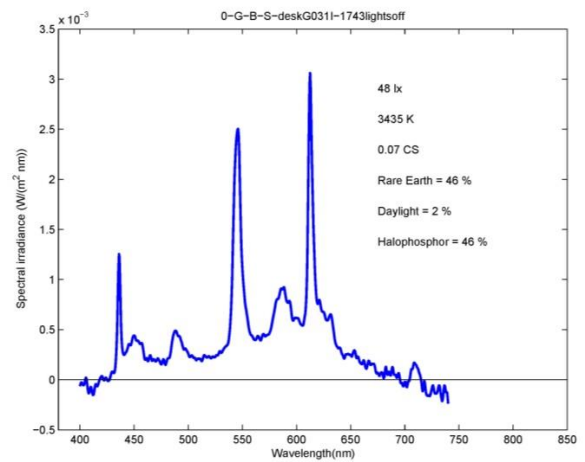
**9:25 AM**

**Overhead Lights Off**



**11:19 AM**

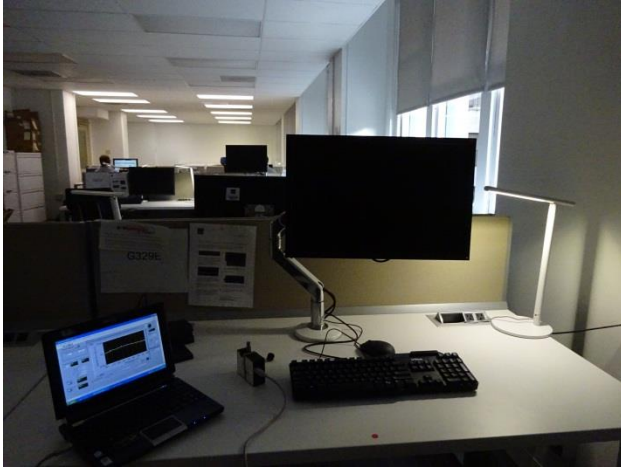
**Overhead Lights Off**



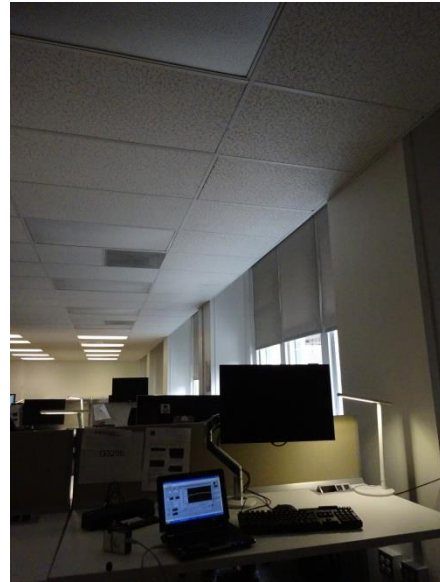
**5:43 PM**



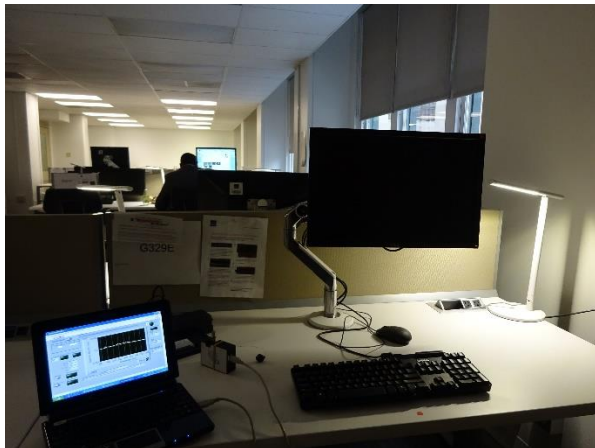
## WING 3-GROUND FLOOR-EAST-A



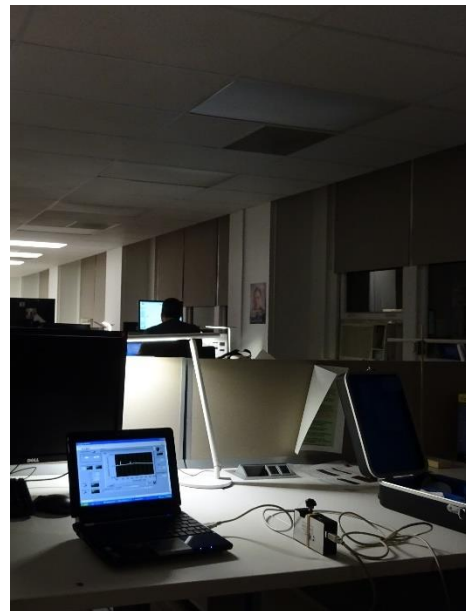
**9:16 AM**



**11:09 AM**

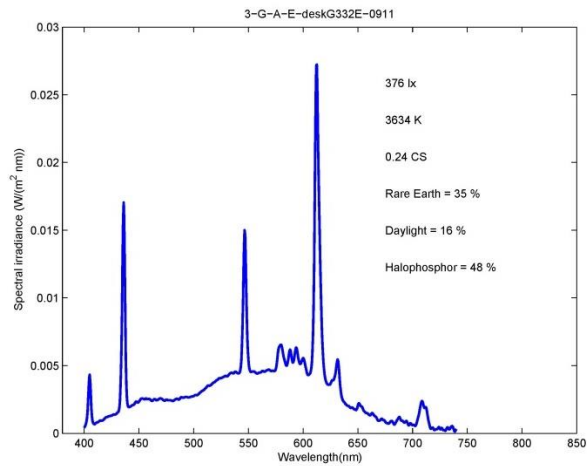


**2:59 PM**

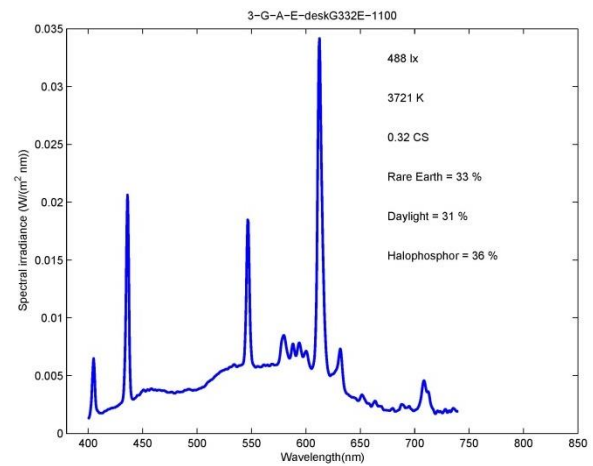


**5:26 PM (in adjacent space)**

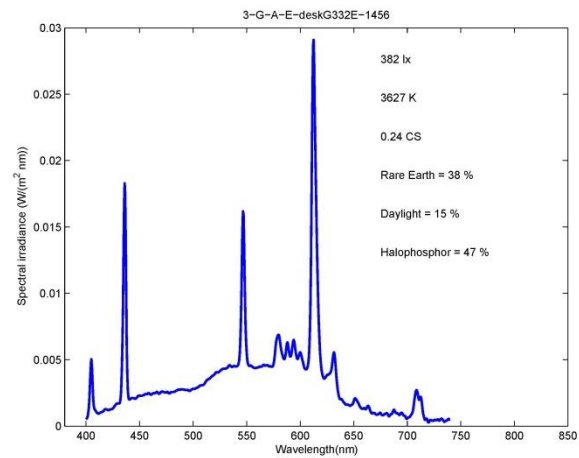
## WING 3-GROUND FLOOR-EAST-A (SPECTRAL POWER DISTRIBUTION)



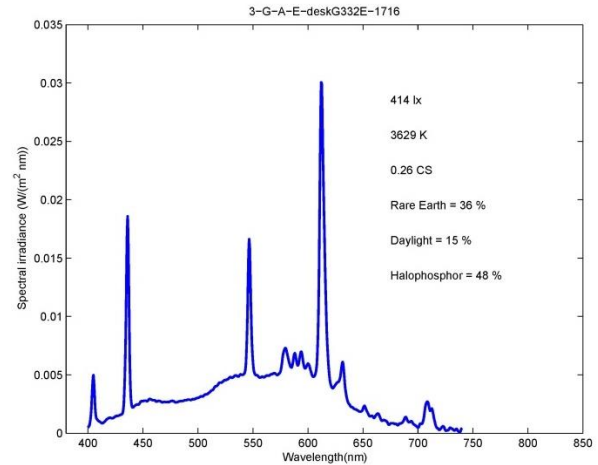
9:11 AM



11:00 AM



2:56 PM

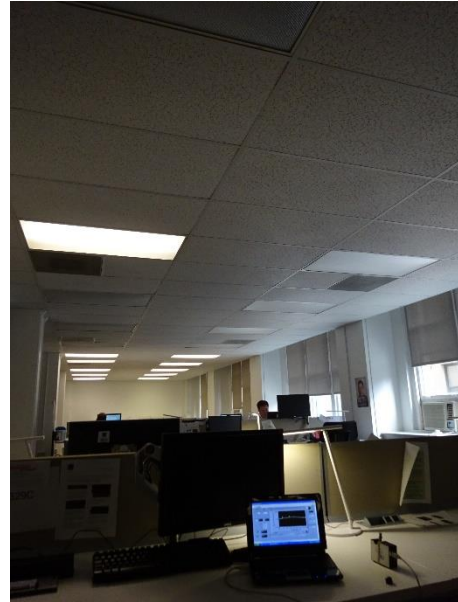


5:16 PM

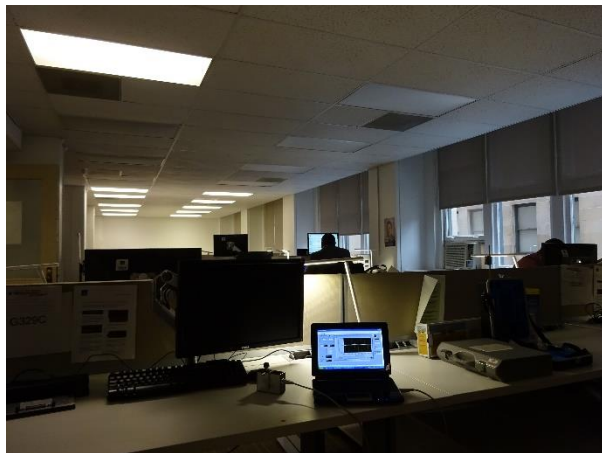
## WING 3-GROUND FLOOR-EAST-B



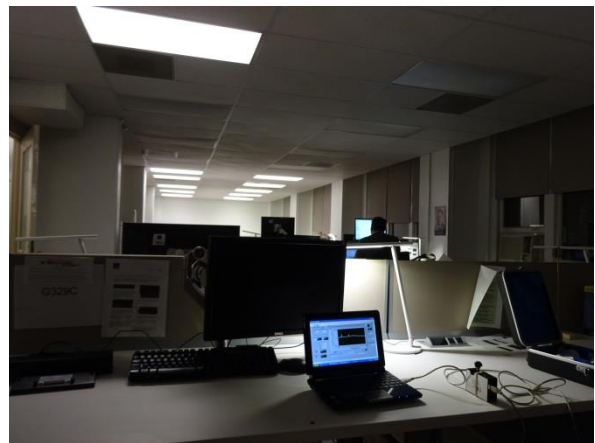
9:07 AM



11:07 AM

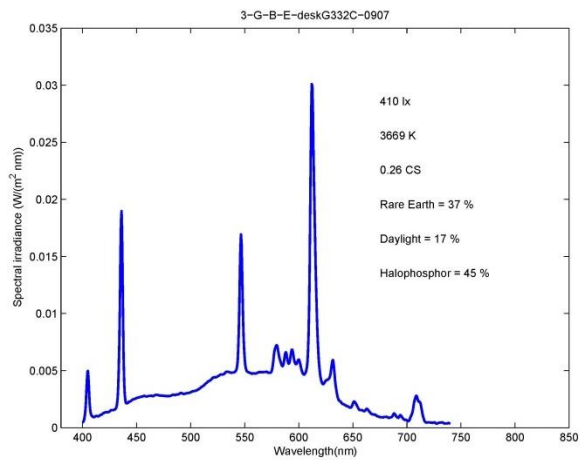


3:05 PM

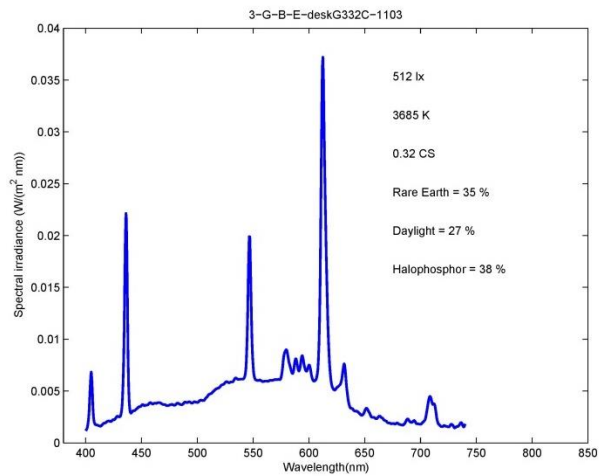


5:19 PM

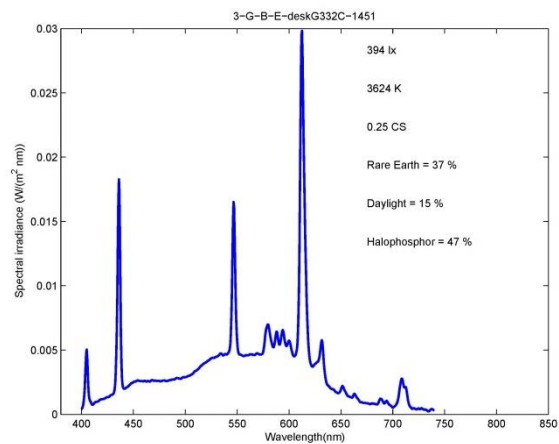
## WING 3-GROUND FLOOR-EAST-B (SPECTRAL POWER DISTRIBUTION)



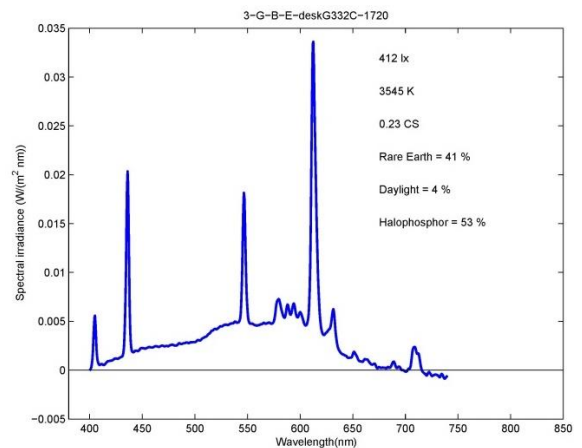
9:07 AM



11:03 AM

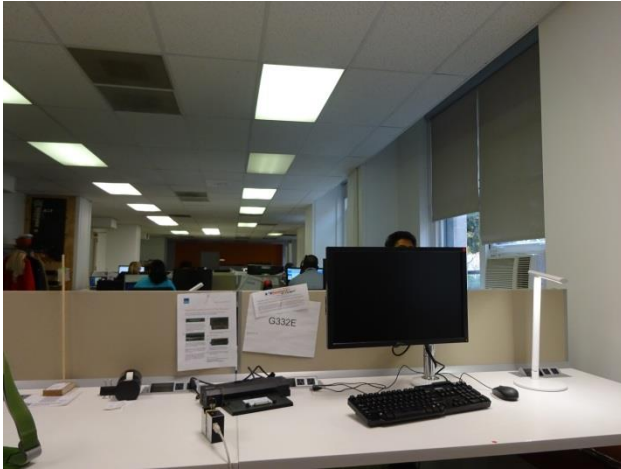


2:51 PM

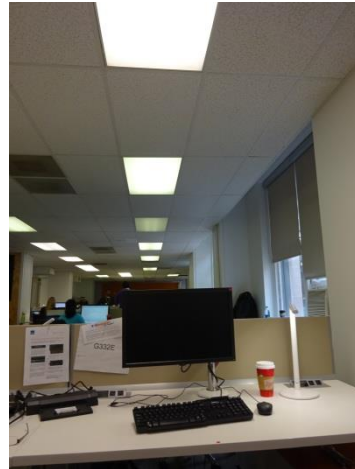


5:20 PM

## WING 3-GROUND FLOOR-WEST-A



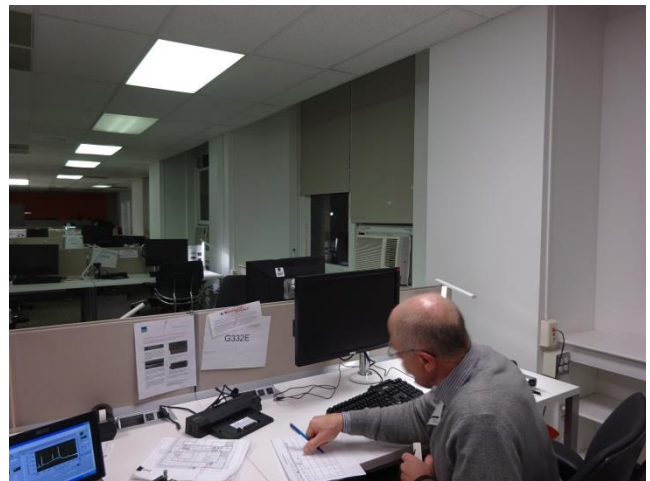
9:11 AM



11:00 AM



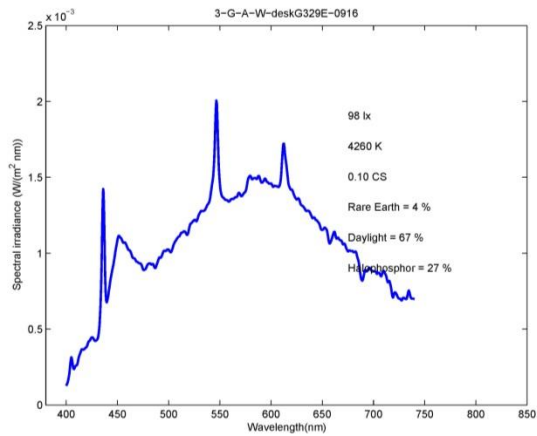
2:53 PM



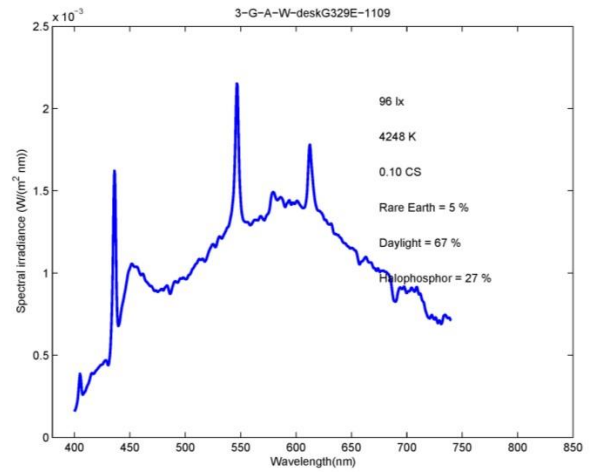
5:17 PM



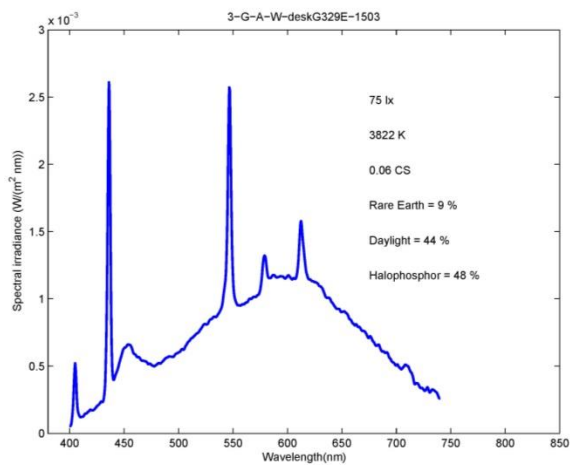
## WING 3-GROUND FLOOR-WEST-A (SPECTRAL POWER DISTRIBUTION)



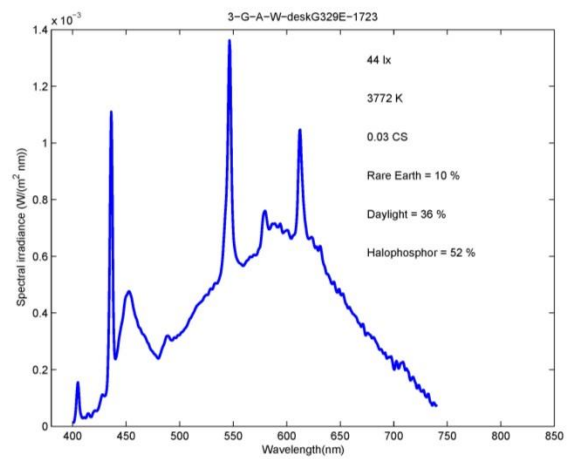
9:16 AM



11:09 AM



3:03 PM



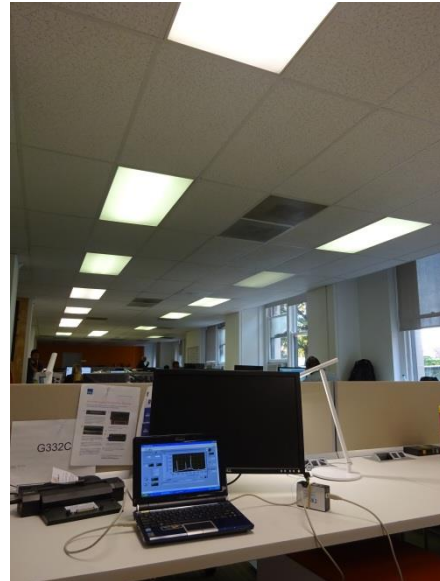
5:23 PM



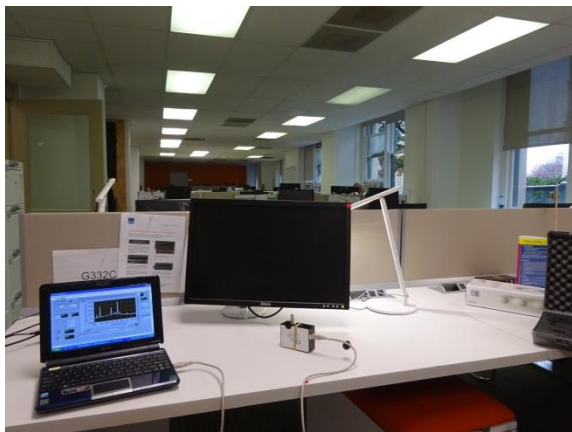
## WING 3-GROUND FLOOR-WEST-B



9:07 AM



11:03 AM

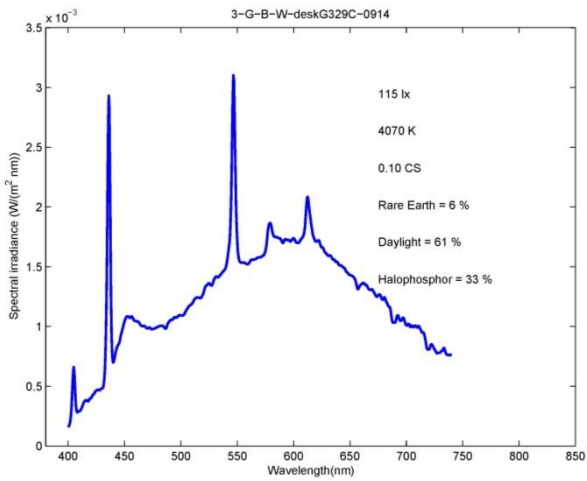


2:52 PM

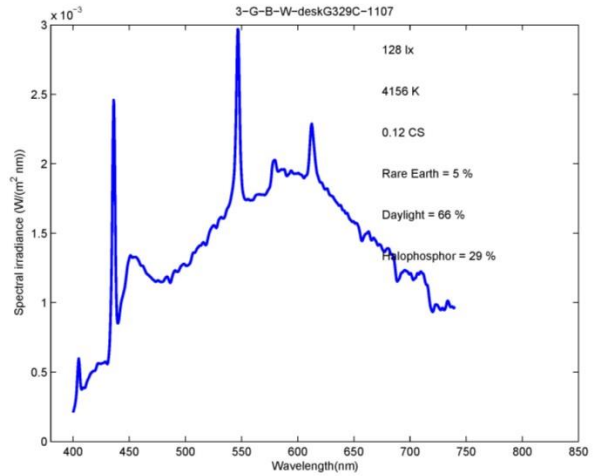


5:19 PM

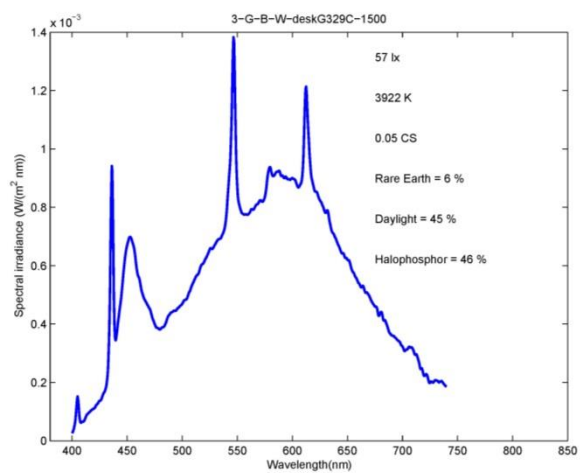
## WING 3-GROUND FLOOR-WEST-B (SPECTRAL POWER DISTRIBUTION)



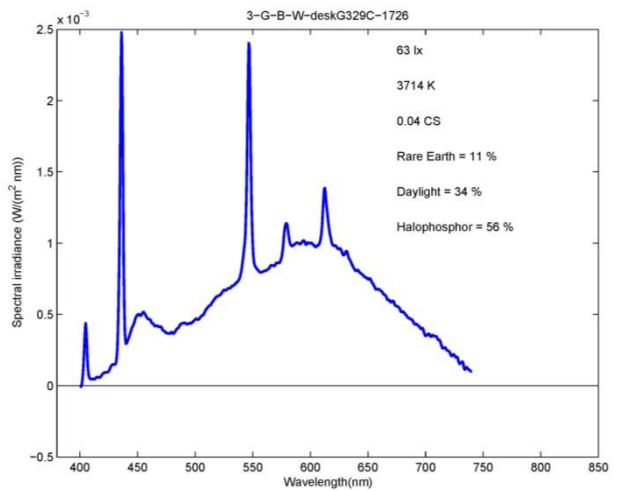
9:14 AM



11:07 AM



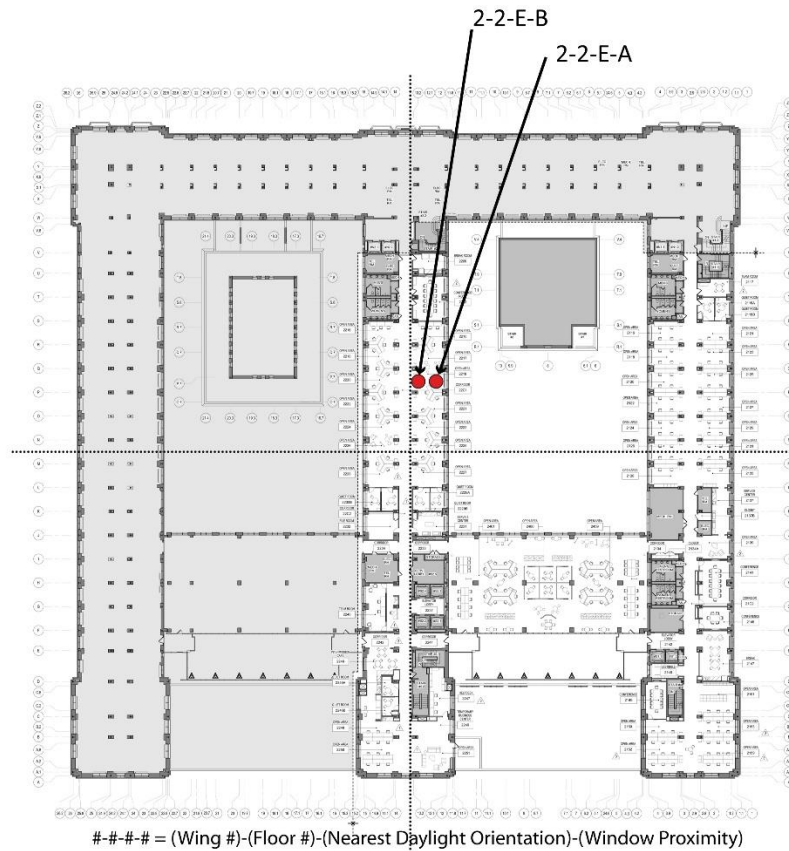
3:00 PM



5:26 PM

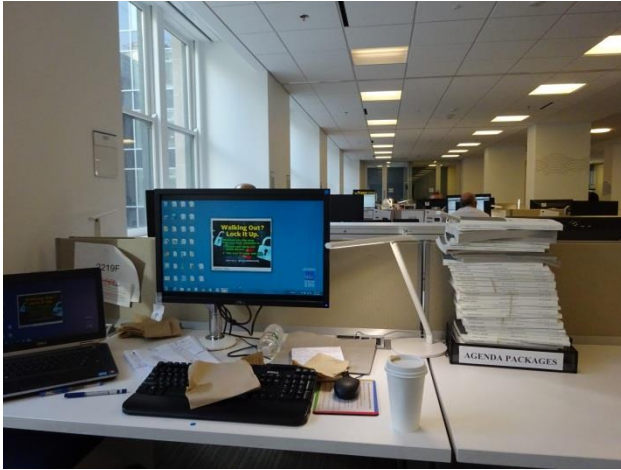
## APPENDIX D: SPECTRAL PHOTOMETRIC DATA FOR 2ND FLOOR DESKS

Spectral power distribution (SPD) was measured at 2 desks on the 2<sup>nd</sup> floor at the GSA headquarters building during the winter visit. These were the same desks that hosted other measurements (see Appendix A). SPDs were measured repeatedly over the day and after dark.

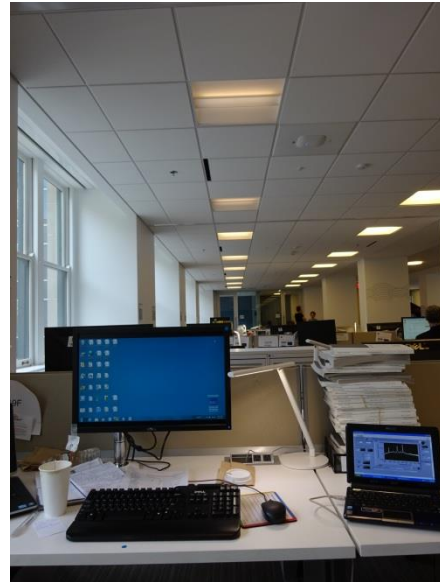


As shown below, the resulting SPD curves change as daylight contribution changes. For reference, a photograph is also presented for most of the measurements, as this represents the scene that the occupant experienced at the time of measurement.

## WING 2 - FLOOR 2 - EAST - A

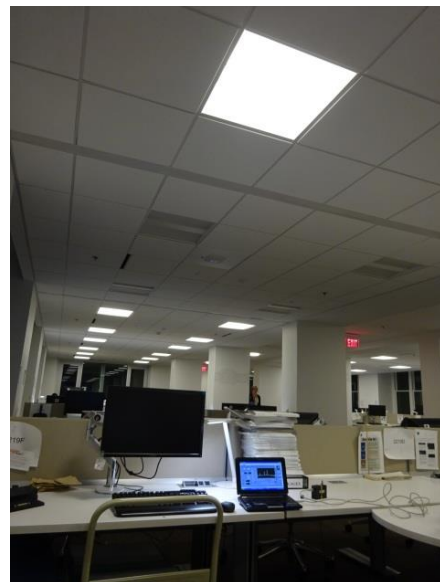


9:57 AM



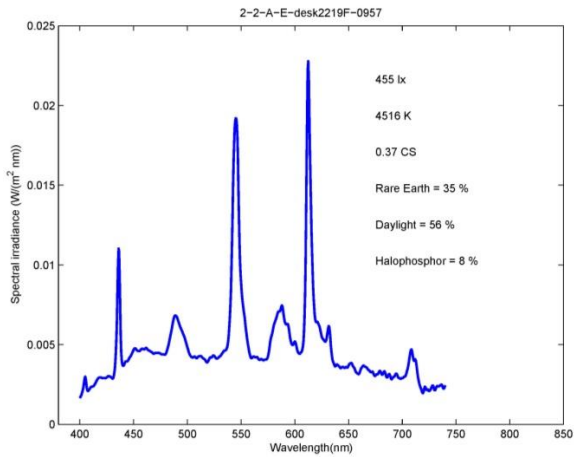
11:46 AM

*Desk not available for afternoon measurement*

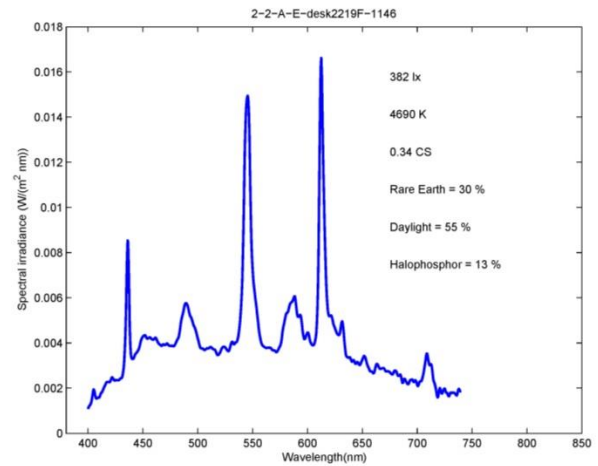


6:00 PM

## WING 2 - FLOOR 2 - EAST - A (SPECTRAL POWER DISTRIBUTION)

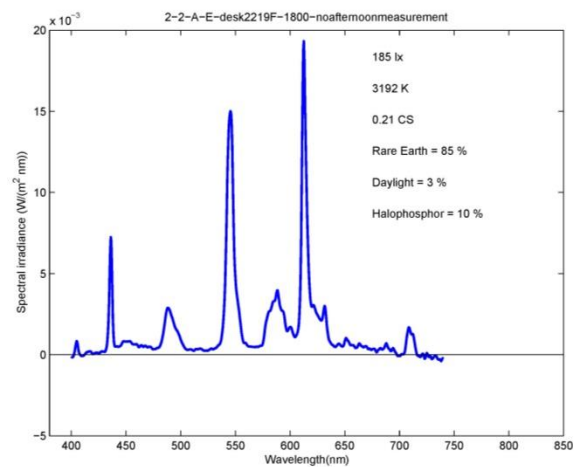


9:57 AM



11:46 AM

Desk not available for afternoon measurement



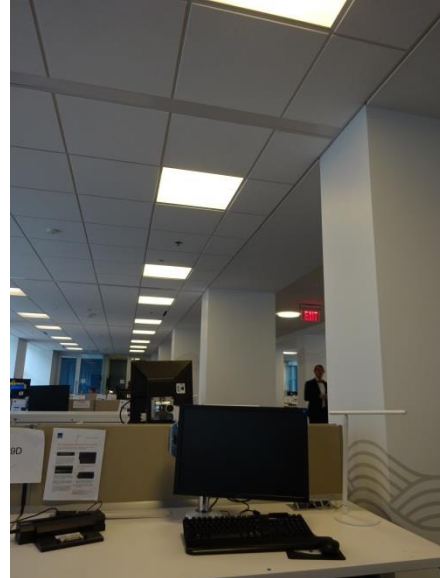
6:00 PM



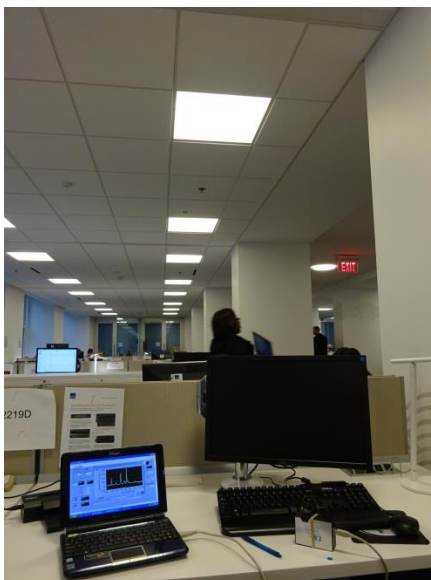
## WING 2 - FLOOR 2 - EAST - B



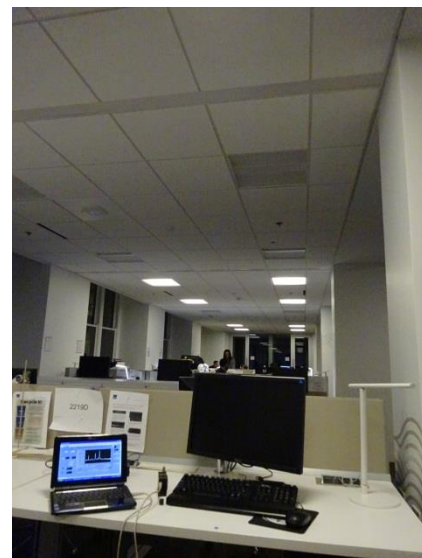
9:55 AM



11:43 AM



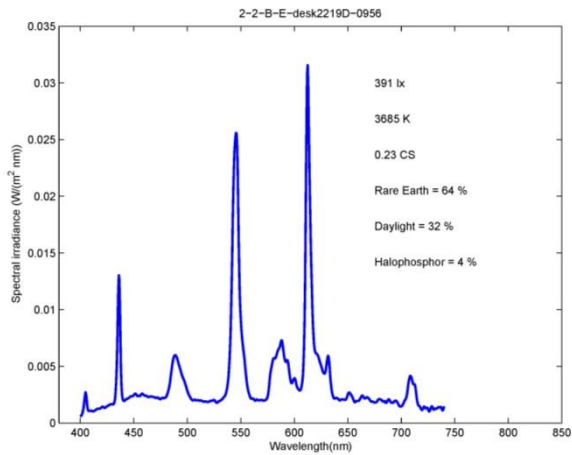
3:53 PM



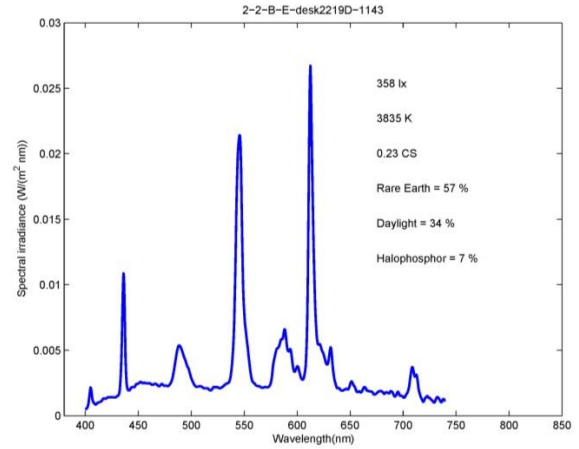
6:02 PM

## WING 2 - FLOOR 2 - EAST - B

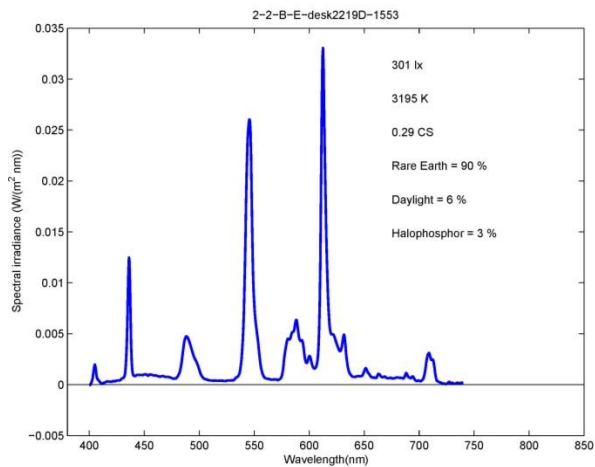
(SPECTRAL POWER DISTRIBUTION)



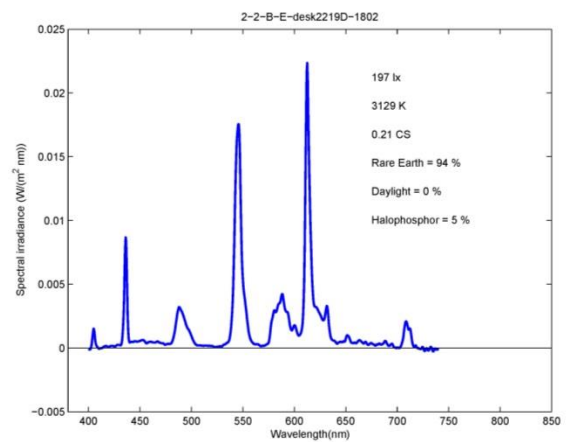
9:56 AM



11:43 AM



3:53 PM

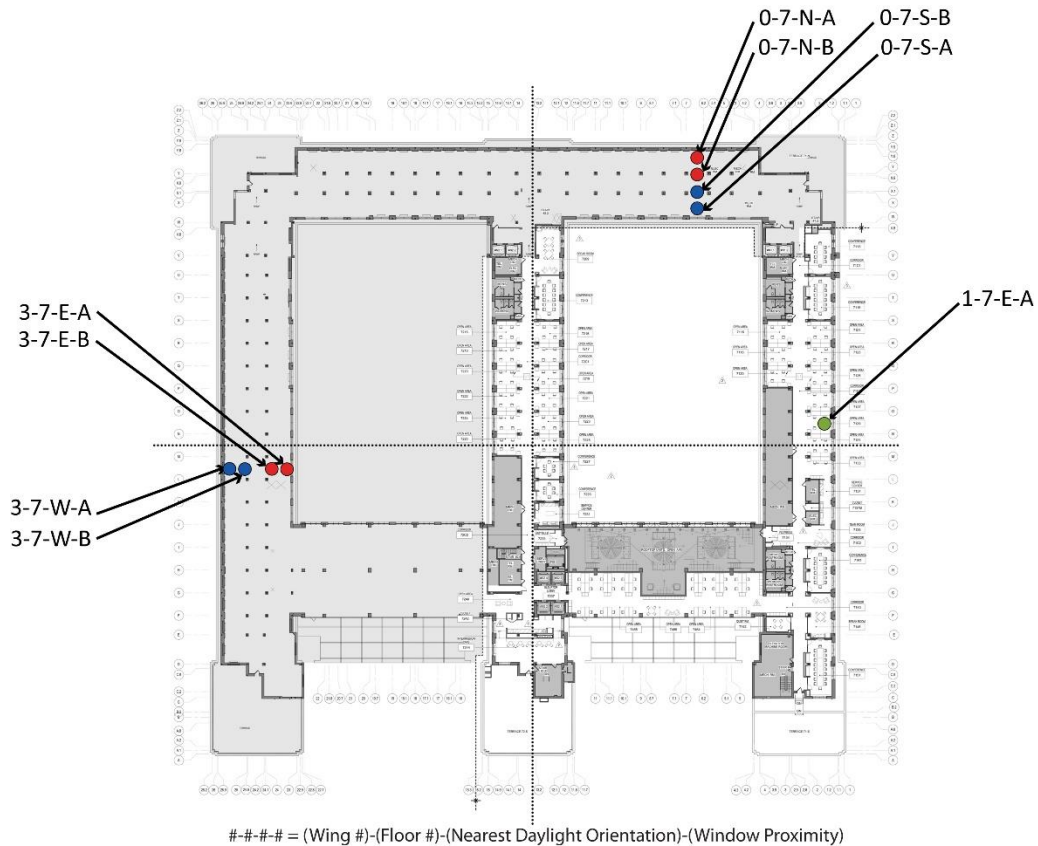


6:02 PM



## APPENDIX E: SPECTRAL PHOTOMETRIC DATA FOR 7TH FLOOR DESKS

Spectral power distribution (SPD) was measured at 9 desks on the 7<sup>th</sup> floor at GSA during the winter visit. These were the same desks that hosted other measurements (see Appendix A). SPDs were measured repeatedly over the day and after dark.



As shown below, the resulting SPD curves change as daylight contribution changes. For reference, a photograph is also presented for most of the measurements, as this represents the scene that the occupant experienced at the time of measurement.

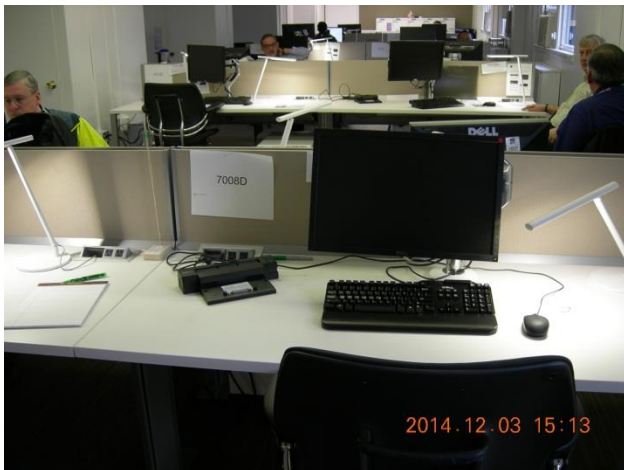
## WING 0 - FLOOR 7 - NORTH - A



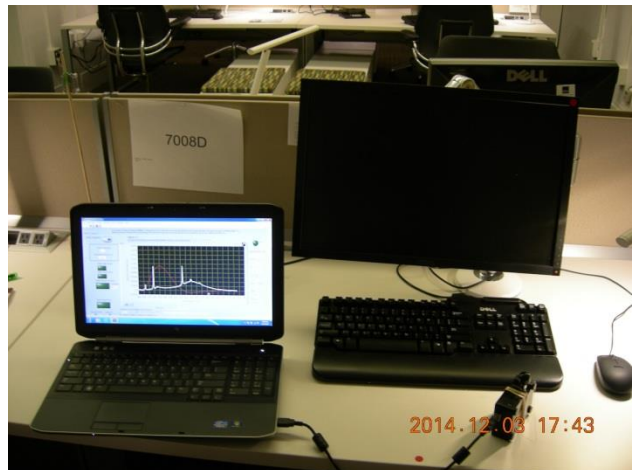
9:32 AM



11:16 AM

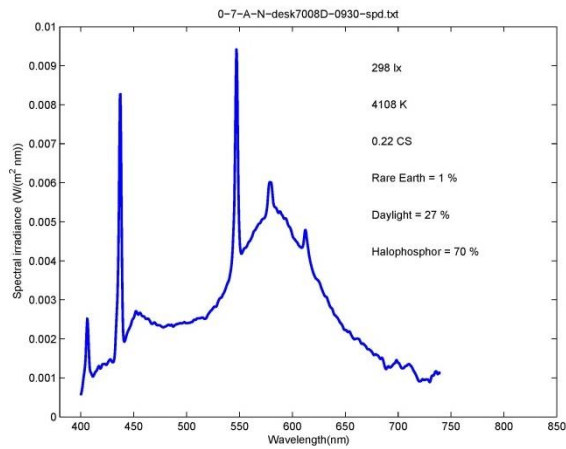


3:13 PM

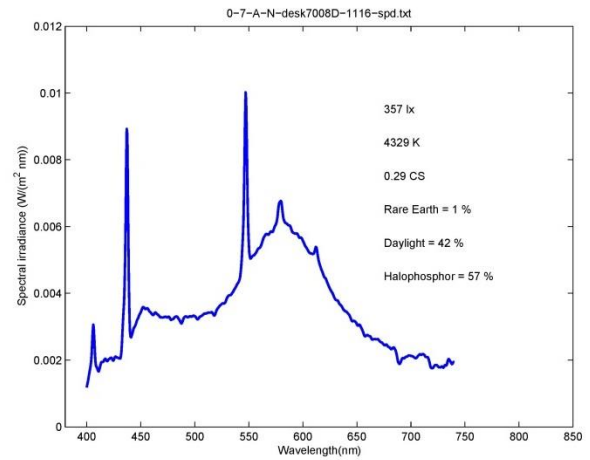


5:43 PM

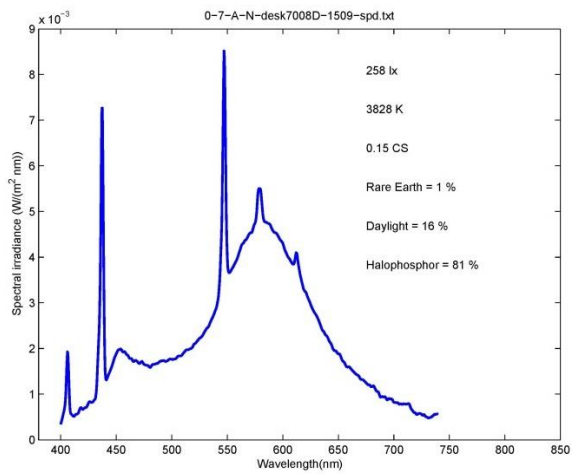
## WING 0 - FLOOR 7 - NORTH - A (SPECTRAL POWER DISTRIBUTION)



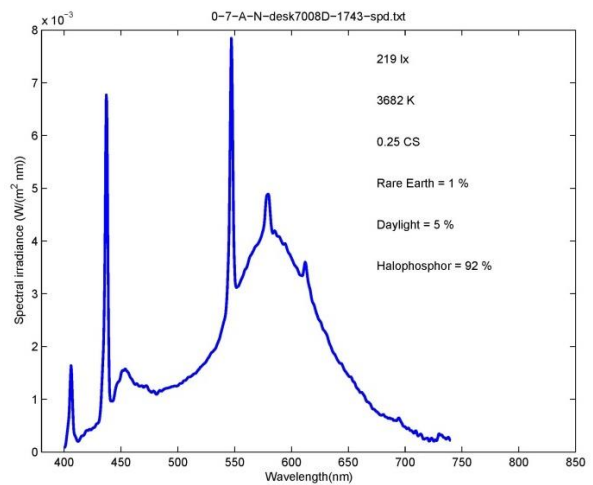
9:30 AM



11:16 AM



3:09 PM

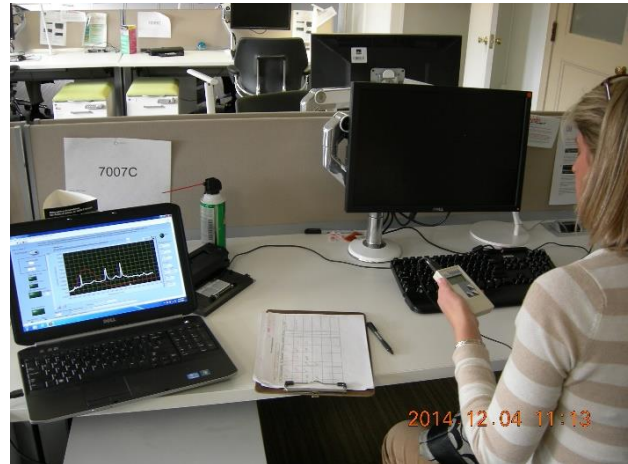


5:43 PM

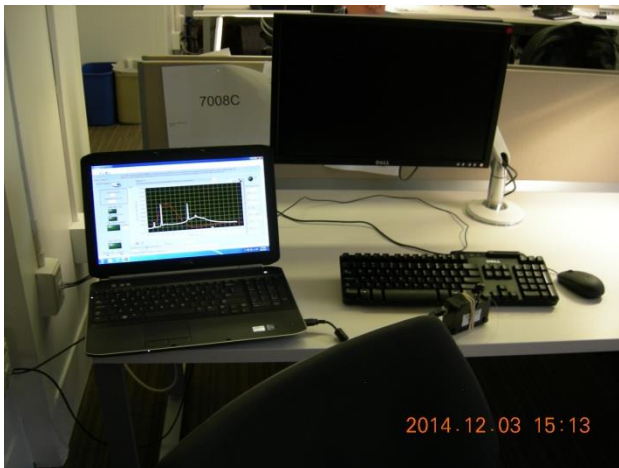
## WING 0 - FLOOR 7 - NORTH - B



9:25 AM



11:13 AM



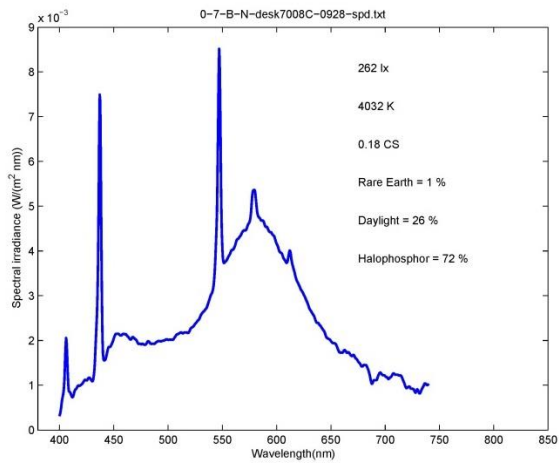
3:13 PM



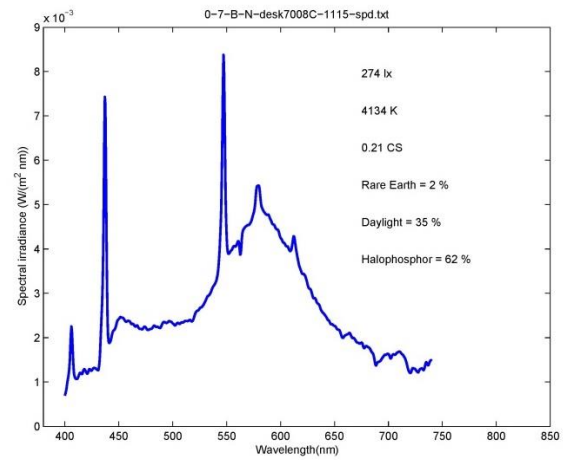
5:43 PM

## WING 0 - FLOOR 7 - NORTH - B

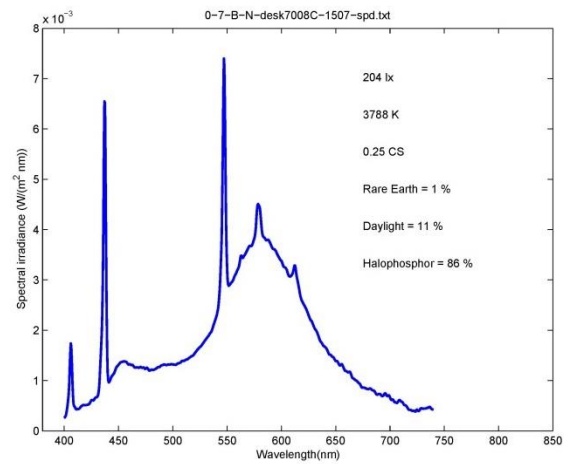
(SPECTRAL POWER DISTRIBUTION)



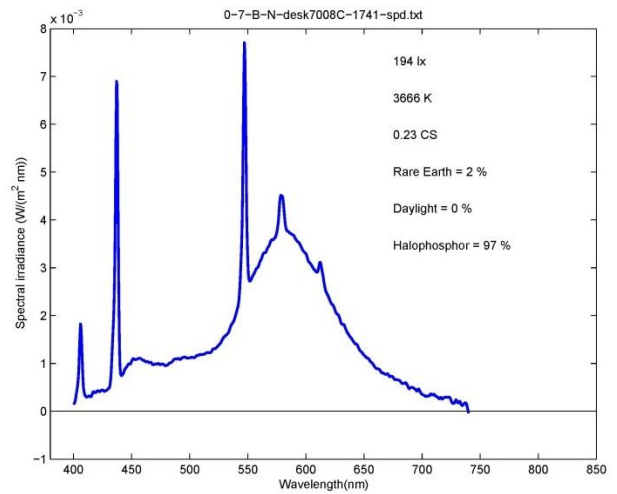
9:28 AM



11:15 AM



3:07 PM



5:41 PM



## WING 0 - FLOOR 7 - SOUTH - A



**9:25 AM**



**11:13 AM**

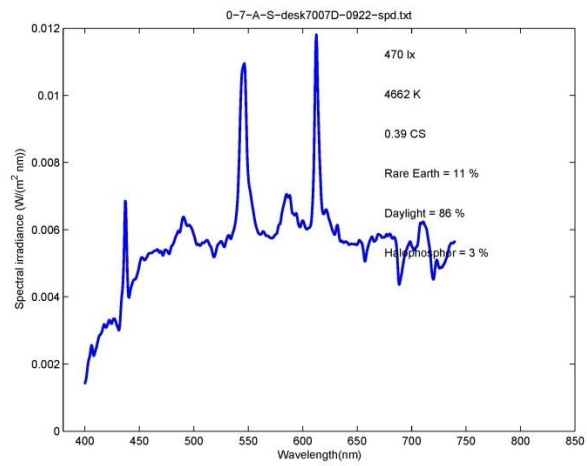


**3:03 PM**

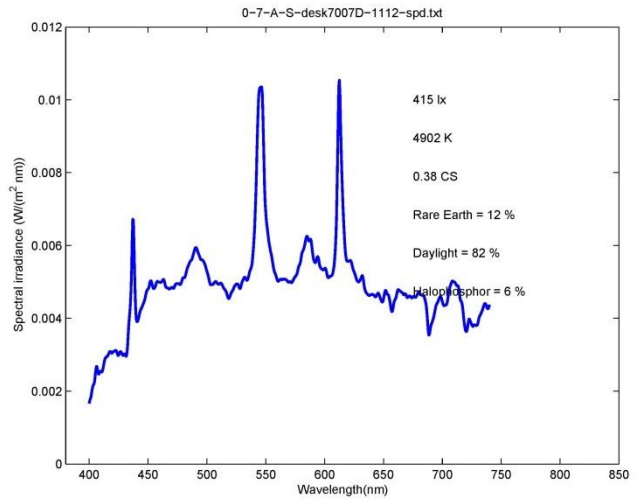


**5:38 PM**

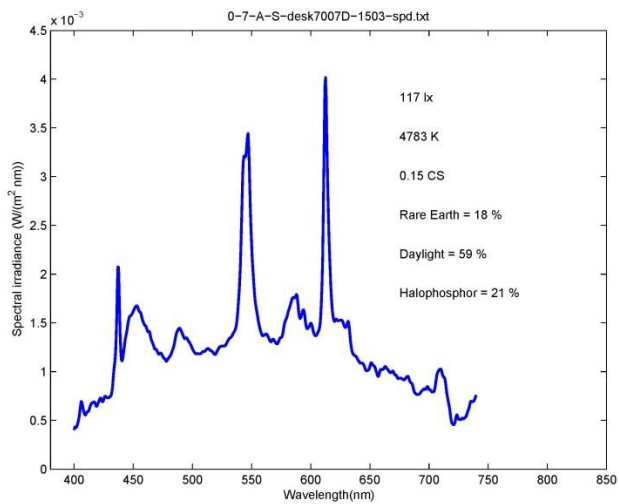
## WING 0 - FLOOR 7 - SOUTH - A (SPECTRAL POWER DISTRIBUTION)



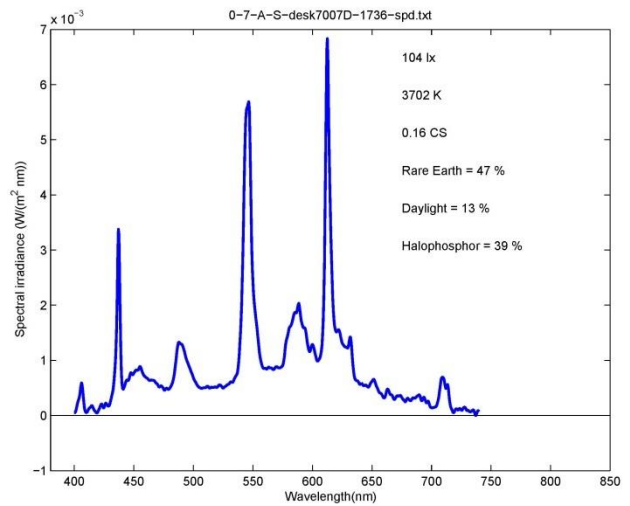
9:22 AM



11:12 AM



3:03 PM



5:36 PM



## WING 0 - FLOOR 7 - SOUTH - B



9:25 AM



11:13 AM



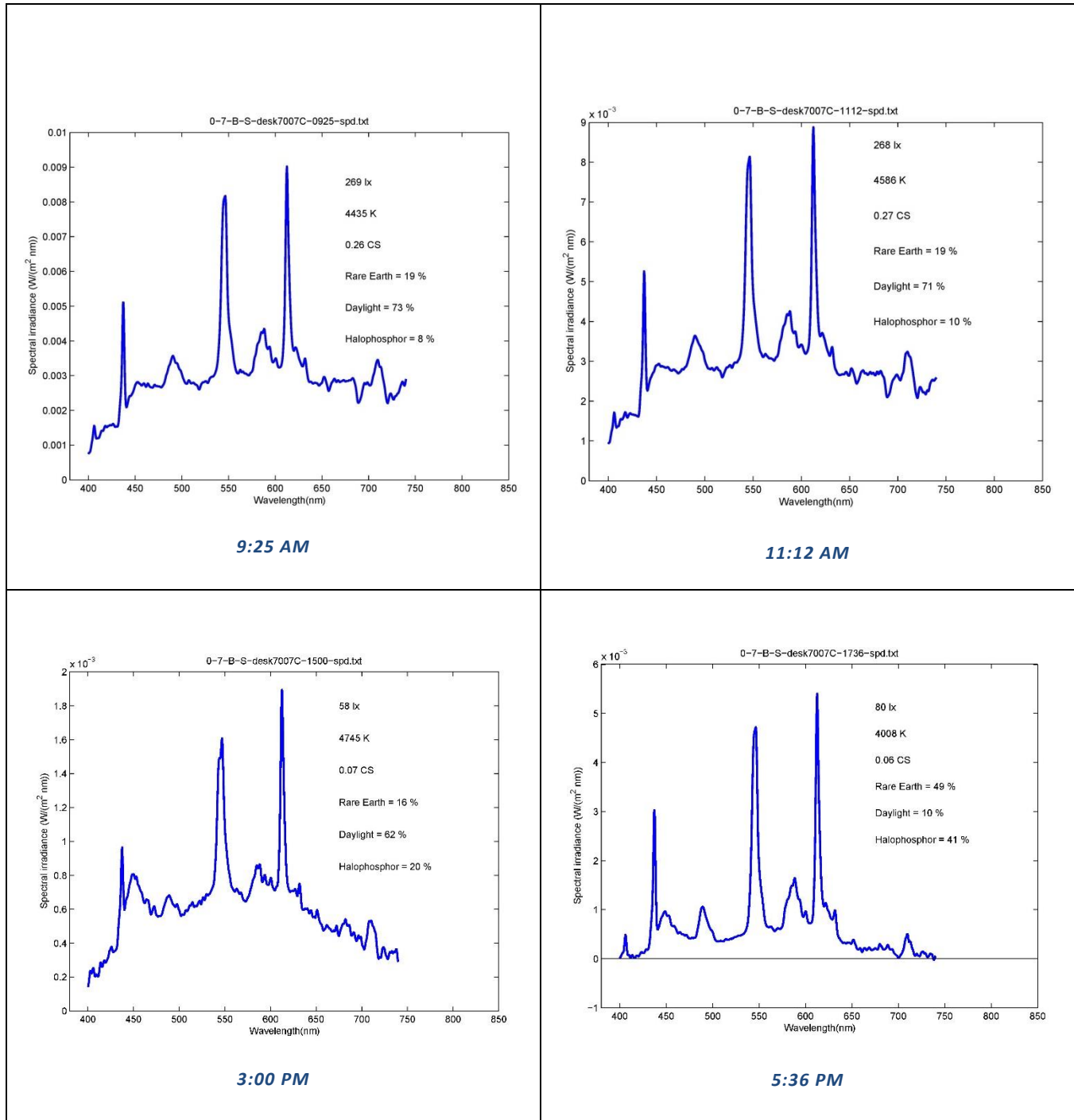
3:03 PM



5:39 PM

## WING 0 - FLOOR 7 - SOUTH - B

(SPECTRAL POWER DISTRIBUTION)



## WING 1 - FLOOR 7 - EAST - A

*(No photo available)*



**11:23 AM**

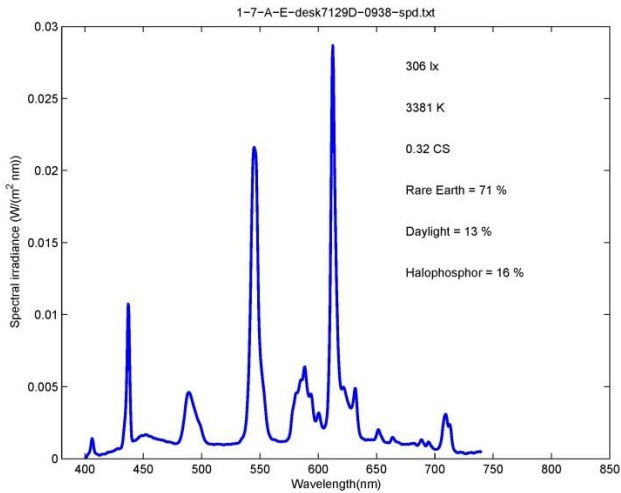


**3:21 PM**

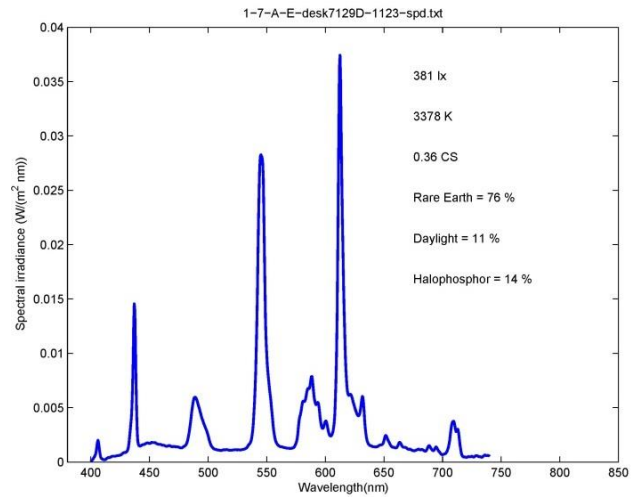


**5:47 PM**

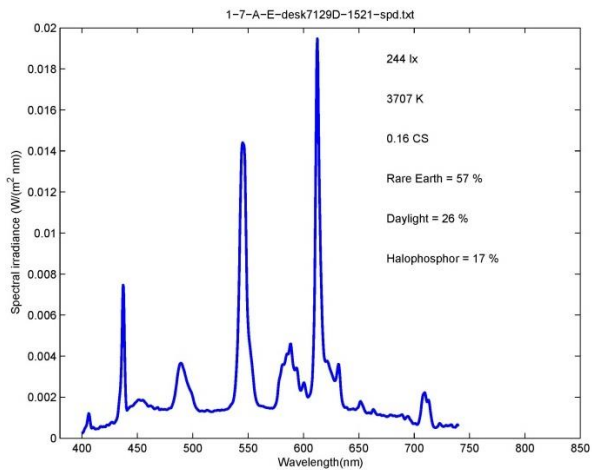
## WING 1 - FLOOR 7 - EAST - A (SPECTRAL POWER DISTRIBUTION)



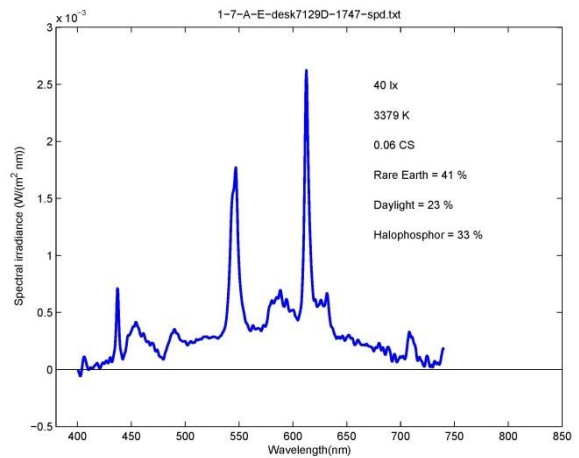
9:38 AM



11:23 AM



3:21 PM

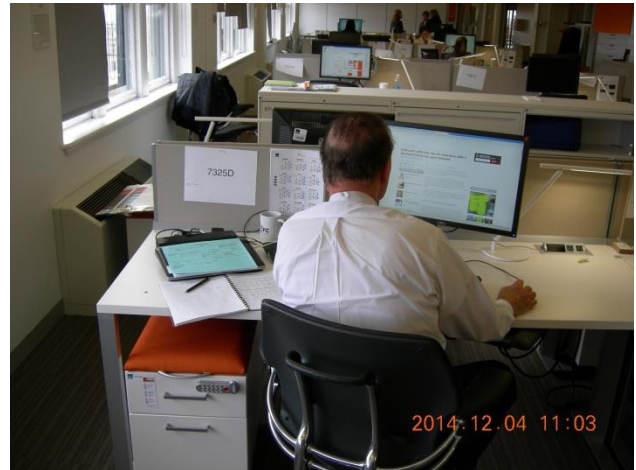


5:47 PM

## WING 3 - FLOOR 7 - EAST - A



**9:10 AM**



**11:03 AM**



**2:47 PM**

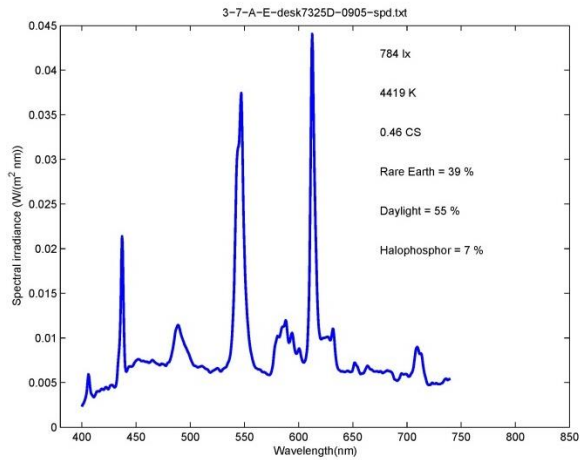


**5:21 PM**

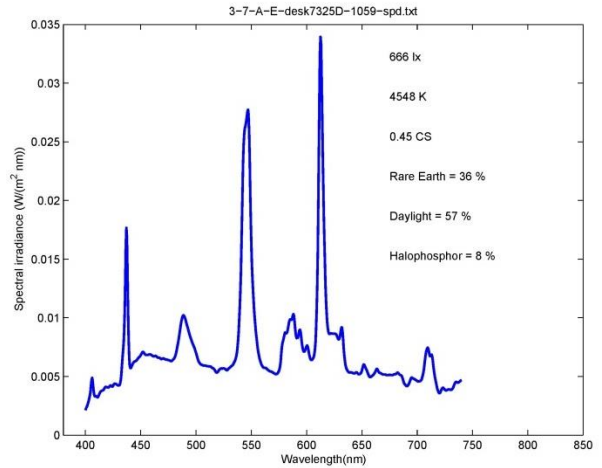


## WING 3 - FLOOR 7 - EAST - A

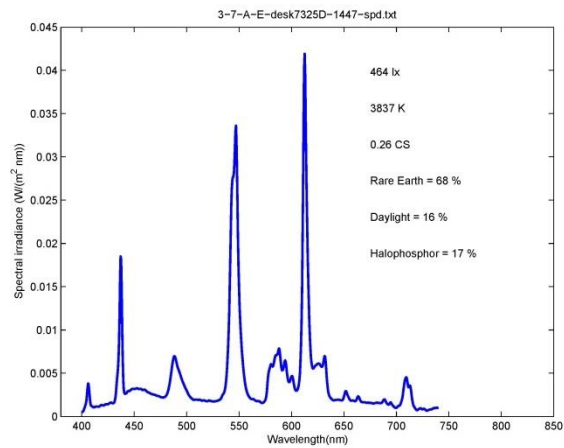
### (SPECTRAL POWER DISTRIBUTION)



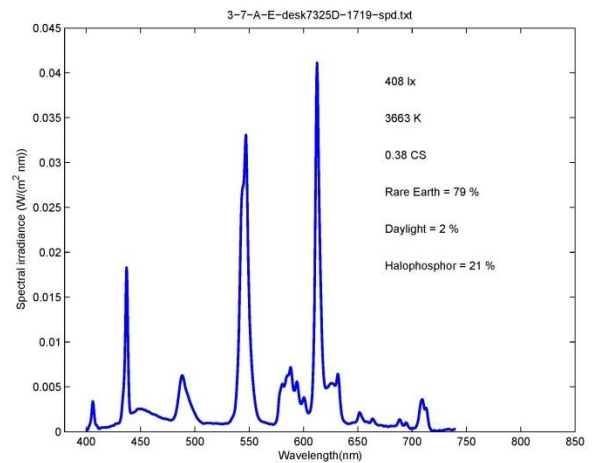
9:05 AM



10:59 AM



2:47 PM



5:19 PM

## WING 3 - FLOOR 7 - EAST - B



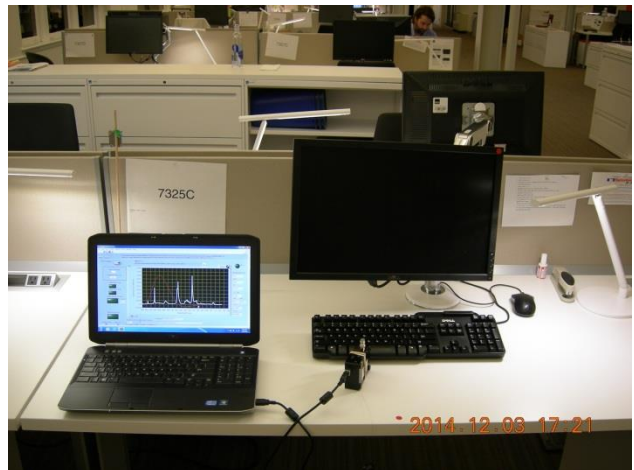
9:11 AM



11:04 AM



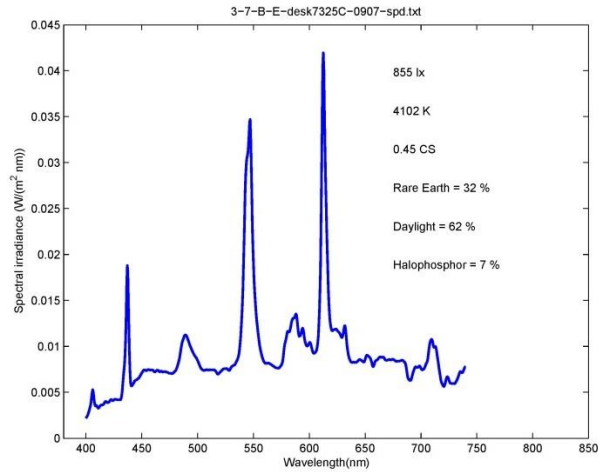
2:46 PM



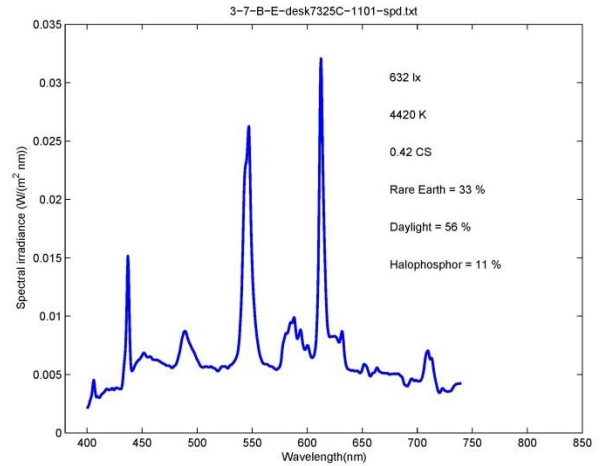
5:21 PM



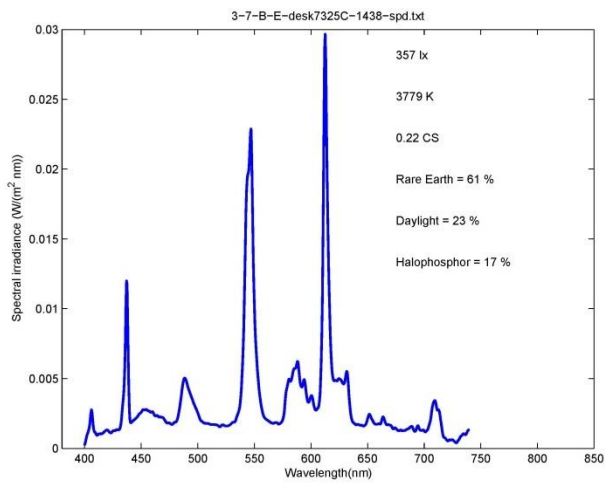
## WING 3 - FLOOR 7 - EAST - B (SPECTRAL POWER DISTRIBUTION)



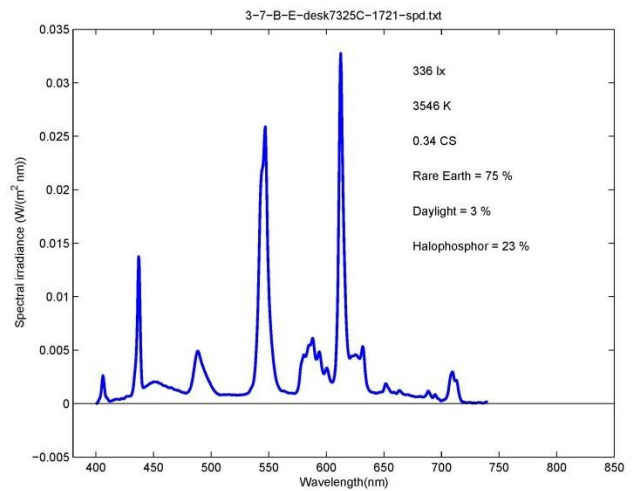
9:07 AM



11:01 AM

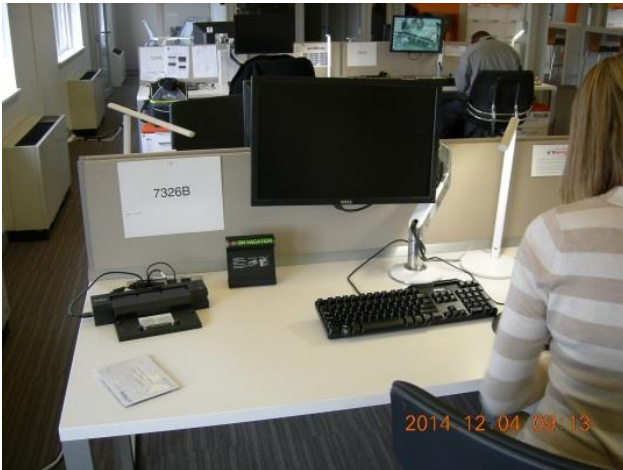


2:38 PM



5:21 PM

## WING 3 - FLOOR 7 - WEST - A



**9:13 AM**



**11:04 AM**

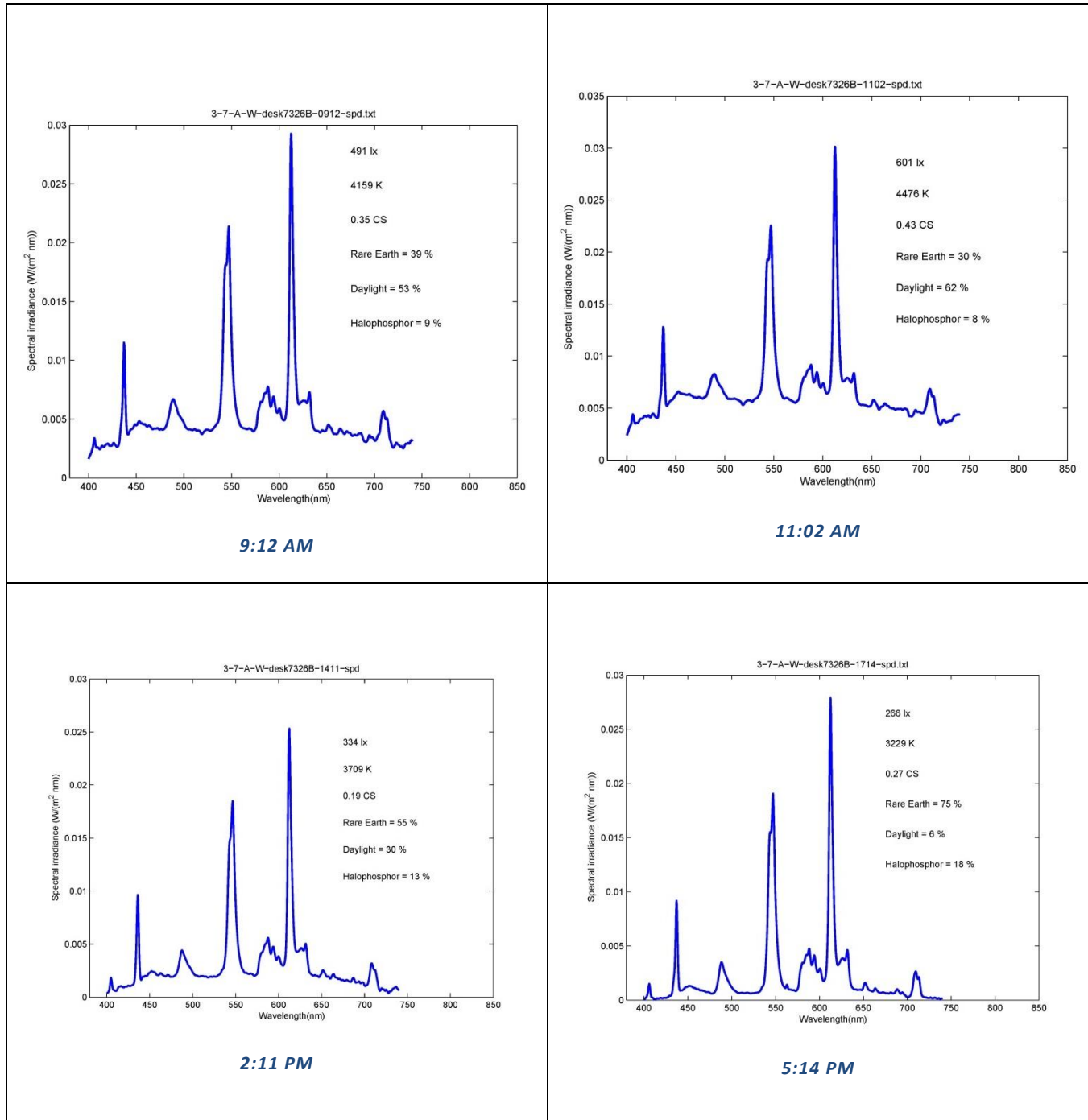


**2:47 PM**



**5:20 PM**

## WING 3 - FLOOR 7 - WEST - A (SPECTRAL POWER DISTRIBUTION)



## WING 3 - FLOOR 7 - WEST - B



9:13 AM



11:04 AM



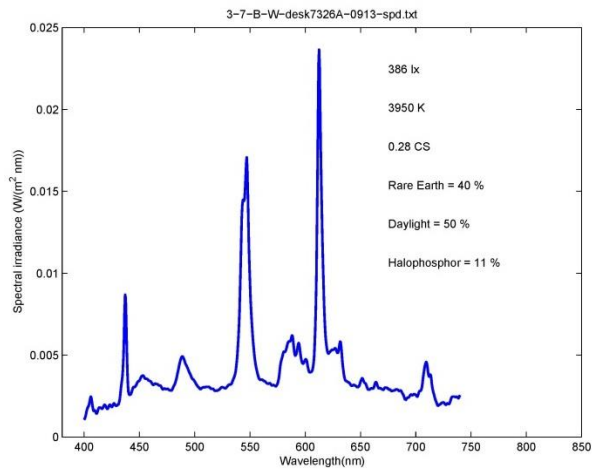
2:47 PM



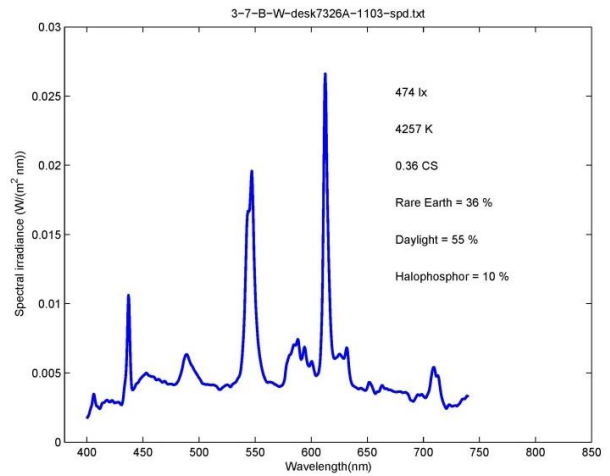
5:20 PM

## WING 3 - FLOOR 7 - WEST - B

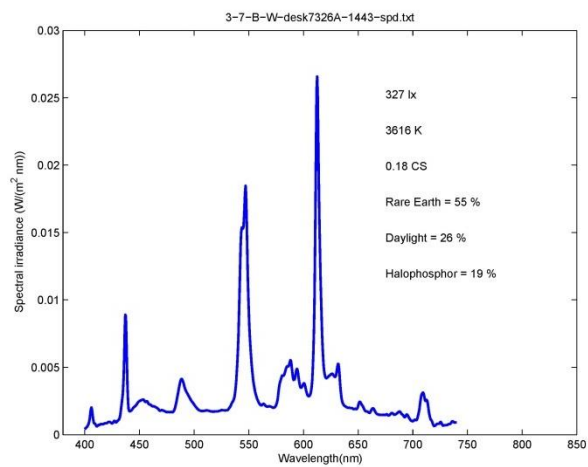
### (SPECTRAL POWER DISTRIBUTION)



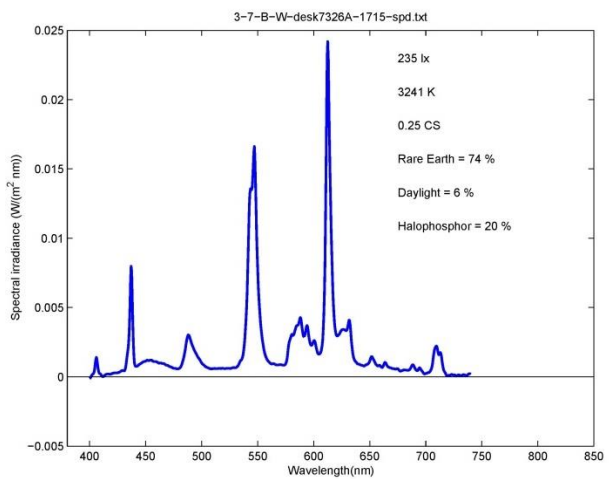
9:13 AM



11:03 AM



2:43 PM



5:15 PM

## APPENDIX F: SPECTRORADIOMETRY RESULTS TABLE

| Wing | Floor | Row | Orientation | Time  | Approximate Contribution<br>(+/- 15%) |     |       |      | Color Coordinates |       | Color Temp | Circadian Light | Circadian Stimulus<br>(up to 0.7) | Brightness |
|------|-------|-----|-------------|-------|---------------------------------------|-----|-------|------|-------------------|-------|------------|-----------------|-----------------------------------|------------|
|      |       |     |             |       | Lux                                   | RE% | Halo% | Day% | CIEx              | CIey  | CCT(K)     | CLA             | CS                                |            |
| 0    | G     | A   | N           | 9:44  | 499                                   | 83% | 6%    | 11%  | 0.395             | 0.395 | 3778       | 217             | 0.257                             | 313        |
| 0    | G     | A   | N           | 11:36 | 524                                   | 78% | 9%    | 13%  | 0.397             | 0.397 | 3747       | 221             | 0.260                             | 325        |
| 0    | G     | A   | N           | 15:26 | 202                                   | 79% | 4%    | 16%  | 0.396             | 0.396 | 3746       | 86              | 0.120                             | 126        |
| 0    | G     | A   | N           | 17:51 | 422                                   | 84% | 7%    | 10%  | 0.397             | 0.396 | 3721       | 175             | 0.219                             | 262        |
| 0    | G     | A   | S           | 9:31  | 322                                   | 79% | 8%    | 11%  | 0.401             | 0.397 | 3651       | 130             | 0.174                             | 198        |
| 0    | G     | A   | S           | 11:23 | 308                                   | 78% | 10%   | 11%  | 0.403             | 0.400 | 3619       | 322             | 0.331                             | 186        |
| 0    | G     | A   | S           | 15:14 | 50                                    | 33% | 41%   | 21%  | 0.408             | 0.405 | 3555       | 53              | 0.076                             | 29         |
| 0    | G     | A   | S           | 17:36 | 278                                   | 82% | 8%    | 9%   | 0.404             | 0.401 | 3607       | 288             | 0.309                             | 167        |
| 0    | G     | B   | N           | 9:41  | 446                                   | 75% | 16%   | 8%   | 0.398             | 0.401 | 3732       | 170             | 0.215                             | 272        |
| 0    | G     | B   | N           | 11:34 | 481                                   | 74% | 17%   | 9%   | 0.399             | 0.402 | 3723       | 496             | 0.414                             | 291        |
| 0    | G     | B   | N           | 15:22 | 227                                   | 74% | 12%   | 12%  | 0.390             | 0.397 | 3912       | 102             | 0.141                             | 143        |
| 0    | G     | B   | N           | 17:54 | 468                                   | 73% | 18%   | 8%   | 0.401             | 0.403 | 3700       | 477             | 0.406                             | 281        |
| 0    | G     | B   | S           | 9:32  | 248                                   | 70% | 14%   | 14%  | 0.405             | 0.400 | 3580       | 259             | 0.290                             | 149        |
| 0    | G     | B   | S           | 11:21 | 203                                   | 65% | 17%   | 17%  | 0.404             | 0.396 | 3576       | 79              | 0.112                             | 124        |
| 0    | G     | B   | S           | 15:10 | 59                                    | 39% | 36%   | 22%  | 0.406             | 0.399 | 3559       | 63              | 0.090                             | 35         |
| 0    | G     | B   | S           | 17:38 | 197                                   | 73% | 14%   | 11%  | 0.409             | 0.403 | 3529       | 200             | 0.243                             | 116        |
| 3    | G     | A   | E           | 9:11  | 376                                   | 35% | 48%   | 16%  | 0.397             | 0.385 | 3634       | 194             | 0.237                             | 242        |
| 3    | G     | A   | E           | 11:00 | 488                                   | 33% | 36%   | 31%  | 0.391             | 0.375 | 3721       | 308             | 0.322                             | 332        |
| 3    | G     | A   | E           | 14:56 | 382                                   | 38% | 47%   | 15%  | 0.397             | 0.383 | 3627       | 202             | 0.244                             | 248        |
| 3    | G     | A   | E           | 17:16 | 414                                   | 36% | 48%   | 15%  | 0.397             | 0.384 | 3629       | 216             | 0.256                             | 268        |
| 3    | G     | B   | E           | 9:07  | 410                                   | 37% | 45%   | 17%  | 0.395             | 0.383 | 3669       | 223             | 0.262                             | 267        |
| 3    | G     | B   | E           | 11:03 | 512                                   | 35% | 38%   | 27%  | 0.393             | 0.378 | 3685       | 309             | 0.323                             | 343        |
| 3    | G     | B   | E           | 14:51 | 394                                   | 37% | 47%   | 15%  | 0.397             | 0.384 | 3624       | 206             | 0.247                             | 255        |
| 3    | G     | B   | E           | 17:20 | 412                                   | 41% | 53%   | 4%   | 0.403             | 0.389 | 3545       | 190             | 0.234                             | 258        |
| 3    | G     | B   | W           | 9:14  | 115                                   | 6%  | 33%   | 61%  | 0.380             | 0.384 | 4070       | 73              | 0.103                             | 77         |
| 3    | G     | B   | W           | 11:07 | 128                                   | 5%  | 29%   | 66%  | 0.376             | 0.381 | 4156       | 87              | 0.122                             | 88         |
| 3    | G     | B   | W           | 15:00 | 57                                    | 6%  | 46%   | 45%  | 0.386             | 0.388 | 3922       | 31              | 0.045                             | 37         |
| 3    | G     | B   | W           | 17:26 | 63                                    | 11% | 56%   | 34%  | 0.397             | 0.393 | 3714       | 28              | 0.040                             | 40         |
| 3    | G     | A   | W           | 9:16  | 98                                    | 4%  | 27%   | 67%  | 0.372             | 0.382 | 4260       | 69              | 0.098                             | 68         |
| 3    | G     | A   | W           | 11:09 | 96                                    | 5%  | 27%   | 67%  | 0.372             | 0.379 | 4248       | 68              | 0.097                             | 67         |
| 3    | G     | A   | W           | 15:03 | 75                                    | 9%  | 48%   | 44%  | 0.391             | 0.388 | 3822       | 39              | 0.056                             | 48         |
| 3    | G     | A   | W           | 17:23 | 44                                    | 10% | 52%   | 36%  | 0.394             | 0.393 | 3772       | 20              | 0.029                             | 28         |
|      |       |     |             |       |                                       |     |       |      |                   |       |            |                 |                                   |            |
| 2    | 2     | A   | E           | 9:57  | 455                                   | 35% | 8%    | 56%  | 0.361             | 0.370 | 4516       | 395             | 0.370                             | 337        |
| 2    | 2     | A   | E           | 11:46 | 382                                   | 30% | 13%   | 55%  | 0.356             | 0.369 | 4690       | 344             | 0.343                             | 287        |
| 2    | 2     | A   | E           | 18:00 | 185                                   | 85% | 10%   | 3%   | 0.432             | 0.417 | 3192       | 161             | 0.206                             | 98         |
| 2    | 2     | B   | E           | 9:56  | 391                                   | 64% | 4%    | 32%  | 0.398             | 0.394 | 3685       | 187             | 0.231                             | 245        |
| 2    | 2     | B   | E           | 11:43 | 358                                   | 57% | 7%    | 34%  | 0.391             | 0.392 | 3835       | 191             | 0.234                             | 229        |
| 2    | 2     | B   | E           | 15:53 | 301                                   | 90% | 3%    | 6%   | 0.431             | 0.415 | 3195       | 264             | 0.293                             | 162        |
| 2    | 2     | B   | E           | 18:02 | 197                                   | 94% | 5%    | 0%   | 0.436             | 0.419 | 3129       | 163             | 0.208                             | 102        |

- “RE%”      Approximate percentage of light generated by rare earth phosphors (newer-generation fluorescent lamps with better color rendering)
- “Halo%”    Approximate percentage of light generated by halophosphors (older-generation fluorescent lamps with poor color rendering)
- “Day%”     Approximate percentage of light generated by daylight



| Wing | Floor | Row | Orientation | Time  | Approximate Contribution<br>(+/- 15%) |     |       |      | Color Coordinates |       | Color Temp | Circadian Light | Circadian Stimulus<br>(up to 0.7) | Brightness |
|------|-------|-----|-------------|-------|---------------------------------------|-----|-------|------|-------------------|-------|------------|-----------------|-----------------------------------|------------|
|      |       |     |             |       | Lux                                   | RE% | Halo% | Day% | CIEx              | CIey  | CCT(K)     | CLA             | CS                                |            |
| 0    | 7     | A   | N           | 9:30  | 298                                   | 1%  | 70%   | 27%  | 0.379             | 0.386 | 4108       | 178             | 0.223                             | 200        |
| 0    | 7     | A   | N           | 11:16 | 357                                   | 1%  | 57%   | 42%  | 0.369             | 0.377 | 4329       | 262             | 0.291                             | 253        |
| 0    | 7     | A   | N           | 15:09 | 258                                   | 1%  | 81%   | 16%  | 0.394             | 0.401 | 3828       | 108             | 0.148                             | 158        |
| 0    | 7     | A   | N           | 17:43 | 219                                   | 1%  | 92%   | 5%   | 0.403             | 0.408 | 3682       | 213             | 0.254                             | 128        |
| 0    | 7     | A   | S           | 9:22  | 470                                   | 11% | 3%    | 86%  | 0.357             | 0.369 | 4662       | 437             | 0.390                             | 352        |
| 0    | 7     | A   | S           | 11:12 | 415                                   | 12% | 6%    | 82%  | 0.349             | 0.363 | 4902       | 421             | 0.383                             | 324        |
| 0    | 7     | A   | S           | 15:03 | 117                                   | 18% | 21%   | 59%  | 0.352             | 0.362 | 4783       | 109             | 0.149                             | 90         |
| 0    | 7     | A   | S           | 17:36 | 104                                   | 47% | 39%   | 13%  | 0.399             | 0.399 | 3702       | 114             | 0.155                             | 63         |
| 0    | 7     | B   | N           | 9:28  | 262                                   | 1%  | 72%   | 26%  | 0.383             | 0.392 | 4032       | 140             | 0.184                             | 170        |
| 0    | 7     | B   | N           | 11:15 | 274                                   | 2%  | 62%   | 35%  | 0.378             | 0.386 | 4134       | 168             | 0.213                             | 185        |
| 0    | 7     | B   | N           | 15:07 | 204                                   | 1%  | 86%   | 11%  | 0.397             | 0.404 | 3788       | 212             | 0.253                             | 124        |
| 0    | 7     | B   | N           | 17:41 | 194                                   | 2%  | 97%   | 0%   | 0.405             | 0.411 | 3666       | 183             | 0.227                             | 112        |
| 0    | 7     | B   | S           | 9:25  | 269                                   | 19% | 8%    | 73%  | 0.365             | 0.375 | 4435       | 217             | 0.257                             | 194        |
| 0    | 7     | B   | S           | 11:12 | 268                                   | 19% | 10%   | 71%  | 0.359             | 0.371 | 4586       | 233             | 0.270                             | 199        |
| 0    | 7     | B   | S           | 15:00 | 58                                    | 16% | 20%   | 62%  | 0.354             | 0.365 | 4745       | 52              | 0.074                             | 44         |
| 0    | 7     | B   | S           | 17:36 | 80                                    | 49% | 41%   | 10%  | 0.382             | 0.384 | 4008       | 44              | 0.063                             | 54         |
| 1    | 7     | A   | E           | 9:38  | 306                                   | 71% | 16%   | 13%  | 0.417             | 0.406 | 3381       | 306             | 0.321                             | 175        |
| 1    | 7     | A   | E           | 11:23 | 381                                   | 76% | 14%   | 11%  | 0.418             | 0.407 | 3378       | 378             | 0.362                             | 217        |
| 1    | 7     | A   | E           | 15:21 | 244                                   | 57% | 17%   | 26%  | 0.397             | 0.393 | 3707       | 117             | 0.159                             | 153        |
| 1    | 7     | A   | E           | 17:47 | 40                                    | 41% | 33%   | 23%  | 0.418             | 0.409 | 3379       | 39              | 0.057                             | 22         |
| 3    | 7     | A   | E           | 9:05  | 784                                   | 39% | 7%    | 55%  | 0.365             | 0.374 | 4419       | 643             | 0.460                             | 566        |
| 3    | 7     | A   | E           | 10:59 | 666                                   | 36% | 8%    | 57%  | 0.360             | 0.368 | 4548       | 596             | 0.447                             | 497        |
| 3    | 7     | A   | E           | 14:47 | 464                                   | 68% | 17%   | 16%  | 0.391             | 0.393 | 3837       | 226             | 0.264                             | 296        |
| 3    | 7     | A   | E           | 17:19 | 408                                   | 79% | 21%   | 2%   | 0.402             | 0.401 | 3663       | 415             | 0.380                             | 246        |
| 3    | 7     | A   | W           | 9:12  | 491                                   | 39% | 9%    | 53%  | 0.375             | 0.377 | 4159       | 363             | 0.354                             | 345        |
| 3    | 7     | A   | W           | 11:02 | 601                                   | 30% | 8%    | 62%  | 0.362             | 0.367 | 4476       | 538             | 0.428                             | 449        |
| 3    | 7     | A   | W           | 14:11 | 334                                   | 55% | 13%   | 30%  | 0.398             | 0.398 | 3709       | 150             | 0.194                             | 206        |
| 3    | 7     | A   | W           | 17:14 | 266                                   | 75% | 18%   | 6%   | 0.429             | 0.416 | 3229       | 230             | 0.268                             | 142        |
| 3    | 7     | B   | E           | 9:07  | 855                                   | 32% | 7%    | 62%  | 0.379             | 0.385 | 4102       | 593             | 0.446                             | 578        |
| 3    | 7     | B   | E           | 11:01 | 632                                   | 33% | 11%   | 56%  | 0.365             | 0.372 | 4420       | 526             | 0.424                             | 461        |
| 3    | 7     | B   | E           | 14:38 | 357                                   | 61% | 17%   | 23%  | 0.394             | 0.393 | 3779       | 173             | 0.218                             | 227        |
| 3    | 7     | B   | E           | 17:21 | 336                                   | 75% | 23%   | 3%   | 0.408             | 0.405 | 3546       | 330             | 0.336                             | 197        |
| 3    | 7     | B   | W           | 9:13  | 386                                   | 40% | 11%   | 50%  | 0.384             | 0.382 | 3950       | 249             | 0.282                             | 261        |
| 3    | 7     | B   | W           | 11:03 | 474                                   | 36% | 10%   | 55%  | 0.371             | 0.373 | 4257       | 373             | 0.359                             | 341        |
| 3    | 7     | B   | W           | 14:43 | 327                                   | 55% | 19%   | 26%  | 0.402             | 0.397 | 3616       | 137             | 0.181                             | 200        |
| 3    | 7     | B   | W           | 17:15 | 235                                   | 74% | 20%   | 6%   | 0.427             | 0.413 | 3241       | 206             | 0.248                             | 128        |

- “RE%” Approximate percentage of light generated by rare earth phosphors (newer-generation fluorescent lamps with better color rendering)
- “Halo%” Approximate percentage of light generated by halophosphors (older-generation fluorescent lamps with poor color rendering)
- “Day%” Approximate percentage of light generated by daylight



## AVERAGE SPECTRORADIOMETRY RESULTS

The following table shows average results during the daytime measurements (excluding evening measurements, since workers are not present after dark).

|                     | Illuminance | Approximate Contribution (+/- 15%)* |       |       | Color Temp | Circadian Light         |                        | Circadian Stimulus (up to 0.7) |            |
|---------------------|-------------|-------------------------------------|-------|-------|------------|-------------------------|------------------------|--------------------------------|------------|
| Deskspace Locations | Lux         | Fluor %                             | Halo% | Day % | CCT(K)     | Average CL <sub>A</sub> | Median CL <sub>A</sub> | CS                             | Brightness |
| A                   | 360         | 39%                                 | 23%   | 37%   | 4029       | 258                     | 221                    | 0.261                          | 244        |
| B                   | 322         | 39%                                 | 26%   | 35%   | 3917       | 215                     | 191                    | 0.233                          | 211        |

| Orientations |     |     |     |     |      |     |     |       |     |
|--------------|-----|-----|-----|-----|------|-----|-----|-------|-----|
| E            | 457 | 48% | 21% | 31% | 3873 | 319 | 285 | 0.310 | 306 |
| N            | 336 | 39% | 41% | 19% | 3905 | 197 | 174 | 0.227 | 213 |
| S            | 232 | 38% | 16% | 44% | 4138 | 198 | 174 | 0.216 | 160 |
| W            | 265 | 24% | 23% | 52% | 4054 | 181 | 112 | 0.193 | 182 |

| Floors |     |     |     |     |      |     |     |       |     |
|--------|-----|-----|-----|-----|------|-----|-----|-------|-----|
| G      | 279 | 45% | 28% | 27% | 3776 | 167 | 150 | 0.193 | 178 |
| 2      | 378 | 55% | 7%  | 37% | 3984 | 276 | 264 | 0.294 | 252 |
| 7      | 391 | 31% | 25% | 44% | 4151 | 293 | 233 | 0.286 | 269 |

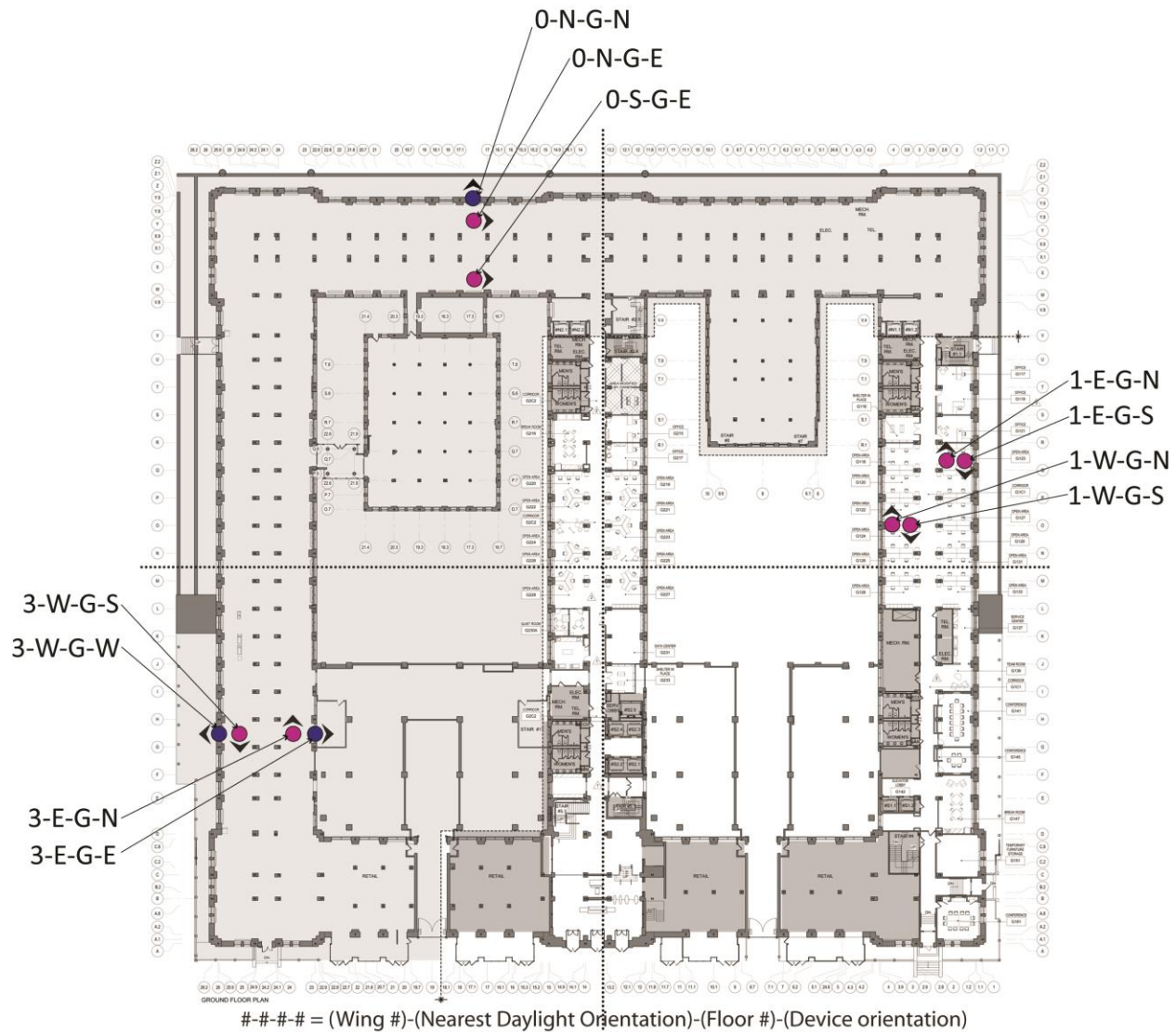
\* Due to measurement uncertainty, some may not add to exactly 100%

## UNCERTAINTY OF SPECTRORADIOMETRIC MEASUREMENTS

There are three main types of measurement uncertainty associated with the spectrometer used for the spectral measurements: 1) accuracy of the spectral calibration and maintaining it over time, 2) thermal noise due to the nature of the CCD detector employed in the device, and 3) a spatial response that deviates from an ideal cosine response. The accuracy of calibration is estimated to be  $\pm 5\%$  of the reading. The effect of thermal detector noise varies with wavelength and from an analysis of the resulting spectra is it estimated to be  $\pm 0.004$ ,  $\pm 0.00018$ , and  $\pm 0.007 \text{ W}/(\text{m}^2 \text{ nm})$  for the spectral ranges  $\lambda < 450 \text{ nm}$ ;  $450 < \lambda < 730 \text{ nm}$ ; and  $\lambda > 730 \text{ nm}$ , respectively. The corresponding uncertainty (1-sigma) in photopic illuminance is  $\pm 3 \text{ lux}$ . Combining these uncertainties leads to an uncertainty of  $\pm (5\% \text{ of reading} + 3 \text{ lux})$ .

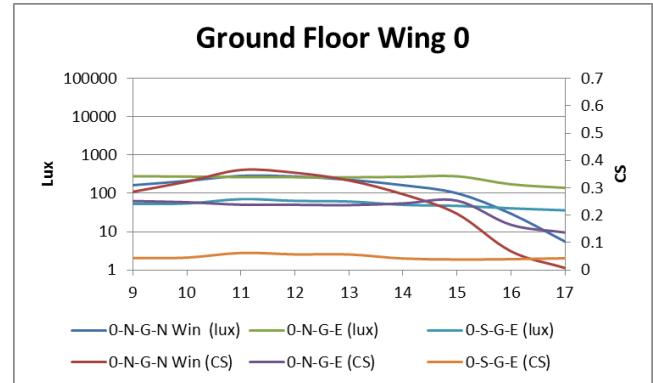
The spatial uncertainty depends greatly on the spatial distribution of light for each measurement; for light of normal incidence the error is near zero, but the error increases significantly, always underreporting the illuminance, for light incident at large angles. An estimate of the spatial uncertainty for the range of diffuse and direct illuminance commonly found in office environments for these measurements is  $+0$ ,  $-5\%$  of the reading.

## APPENDIX G: PHOTOMETRIC DATA FOR GROUND FLOOR STATIONARY DEVICES MOUNTED ON STICKS AND IN WINDOWS CROPPED TO DECEMBER 4, 2014 – DECEMBER 19, 2014



*Location where measurements were collected.*

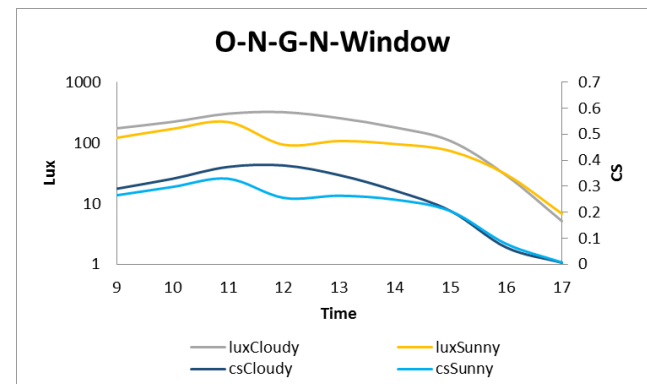
## GROUND FLOOR WING 0



**Average Lux and CS**



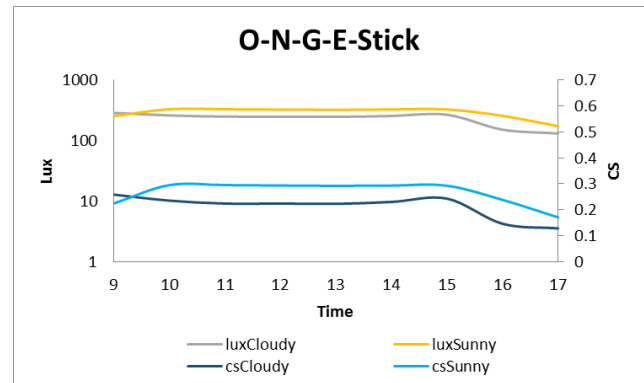
**O-N-G-N-Window**



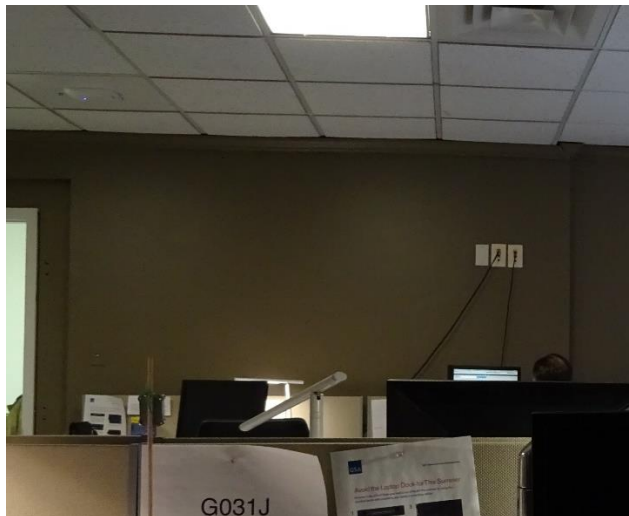
Daysimeter 207 – O-N-G-N-Window. Mean photopic light level during working hours (08:00 am to 05:00 pm) was  $177 \pm 112$  lux on cloudy days. The mean CS value on was  $0.25 \pm 0.13$  on cloudy days. On sunny days mean photopic light level during working hours was  $102 \pm 66$  lux. The mean CS value on was  $0.22 \pm 0.11$  on sunny days.



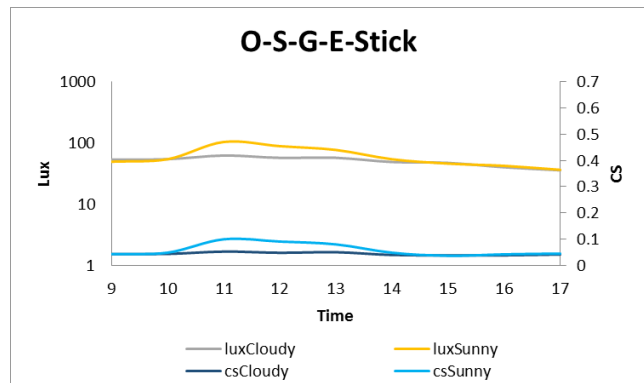
**O-N-G-E-Stick**



Daysimeter 172 – O-N-G-E-Stick. Mean photopic light level during working hours (08:00 am to 05:00 pm) was  $233 \pm 53$  lux on cloudy days. The mean CS value on was  $0.21 \pm 0.04$  on cloudy days. On sunny days mean photopic light level during working hours was  $293 \pm 55$  lux. The mean CS value on was  $0.27 \pm 0.04$  on sunny days.

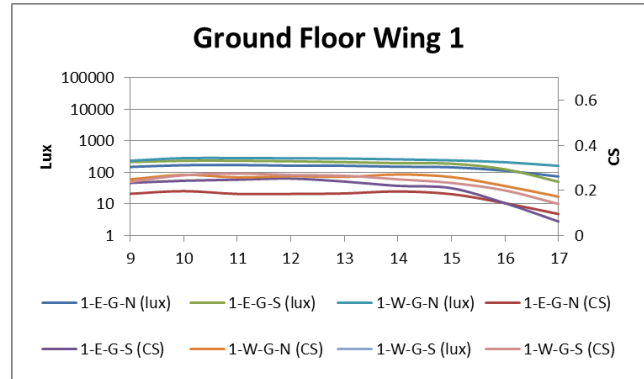


**O-S-G-E-Stick**



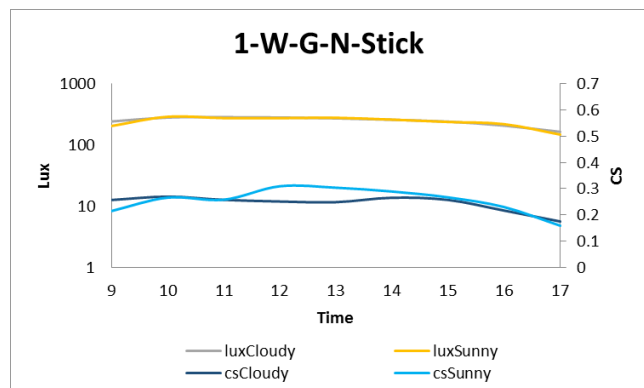
Daysimeter 177 – O-S-G-E-Stick. Mean photopic light level during working hours (08:00 am to 05:00 pm) was  $51 \pm 9$  lux on cloudy days. The mean CS value on was  $0.04 \pm 0.01$  on cloudy days. On sunny days mean photopic light level during working hours was  $61 \pm 23$  lux. The mean CS value on was  $0.06 \pm 0.02$  on sunny days.

## GROUND FLOOR WING 1



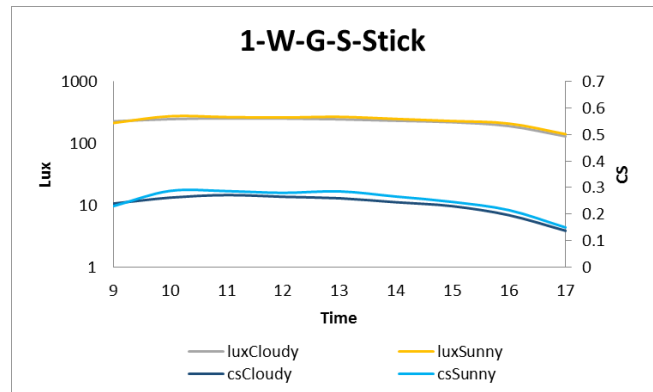
Average Lux and CS

(Photo not taken)



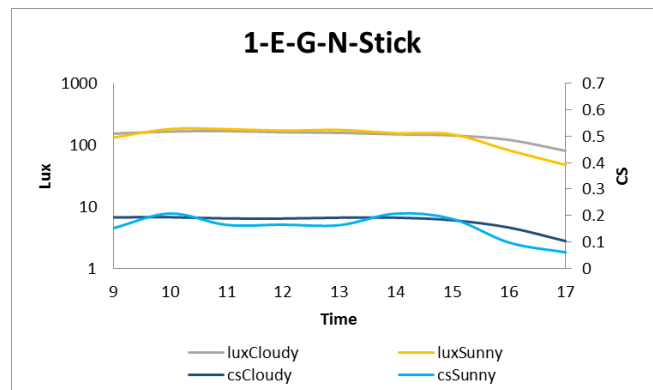
Daysimeter 010 – 1-W-G-N-Stick. Mean photopic light level during working hours (08:00 am to 05:00 pm) was  $248 \pm 40$  lux on cloudy days. The mean CS value on was  $0.24 \pm 0.03$  on cloudy days. On sunny days mean photopic light level during working hours was  $243 \pm 46$  lux. The mean CS value on was  $0.26 \pm 0.05$  on sunny days.

(Photo not taken)



Daysimeter 190 – 1-W-G-S-Stick. Mean photopic light level during working hours (08:00 am to 05:00 pm) was  $222 \pm 40$  lux on cloudy days. The mean CS value on was  $0.23 \pm 0.04$  on cloudy days. On sunny days mean photopic light level during working hours was  $235 \pm 43$  lux. The mean CS value on was  $0.25 \pm 0.05$  on sunny days.

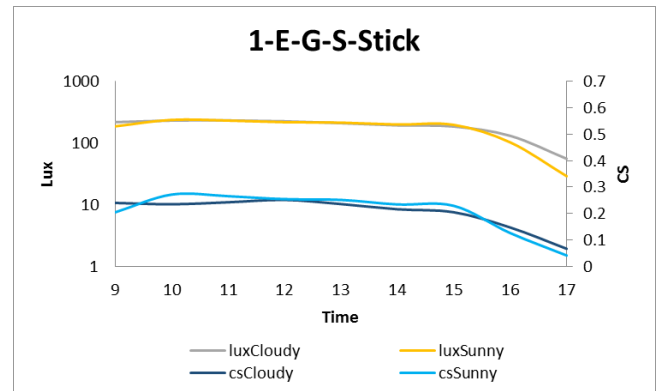
(Photo not taken)



Daysimeter 024 – 1-E-G-N-Stick. Mean photopic light level during working hours (08:00 am to 05:00 pm) was  $145 \pm 28$  lux on cloudy days. The mean CS value on was  $0.18 \pm 0.03$  on cloudy days. On sunny days mean photopic light level during working hours was  $142 \pm 47$  lux. The mean CS value on was  $0.16 \pm 0.05$  on sunny days.

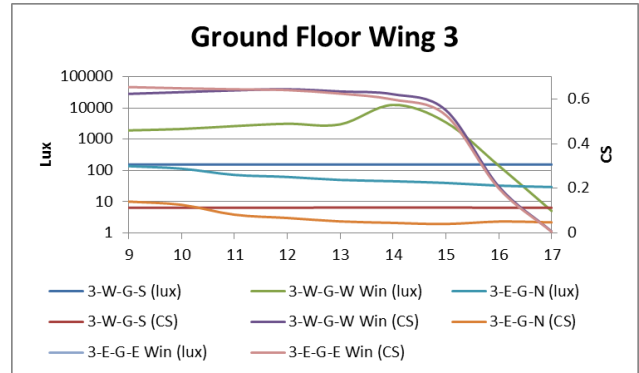


*(Photo not taken)*



Daysimeter 028 – 1-E-G-S-Stick. Mean photopic light level during working hours (08:00 am to 05:00 pm) was  $187 \pm 59$  lux on cloudy days. The mean CS value on was  $0.20 \pm 0.06$  on cloudy days. On sunny days mean photopic light level during working hours was  $180 \pm 69$  lux. The mean CS value on was  $0.21 \pm 0.08$  on sunny days.

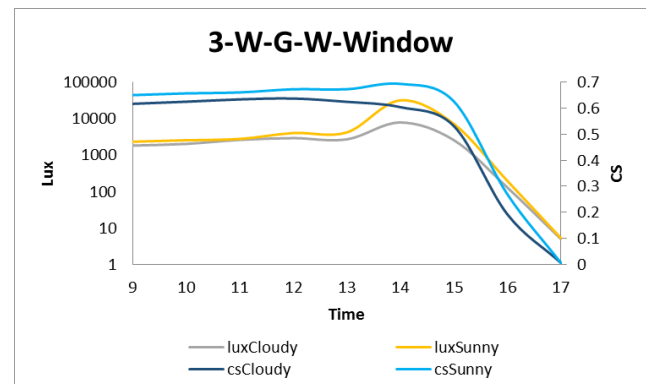
## GROUND FLOOR WING 3



Average Lux and CS



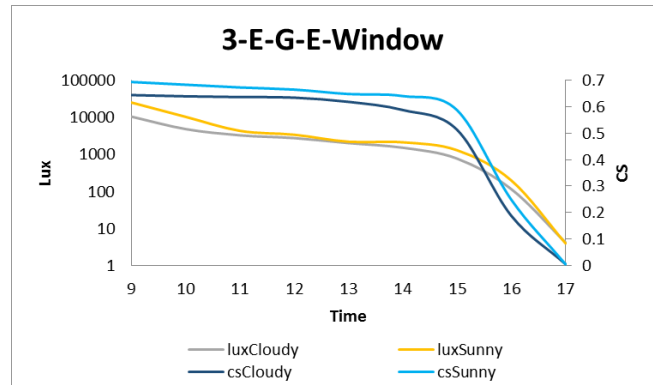
3-W-G-W-Window



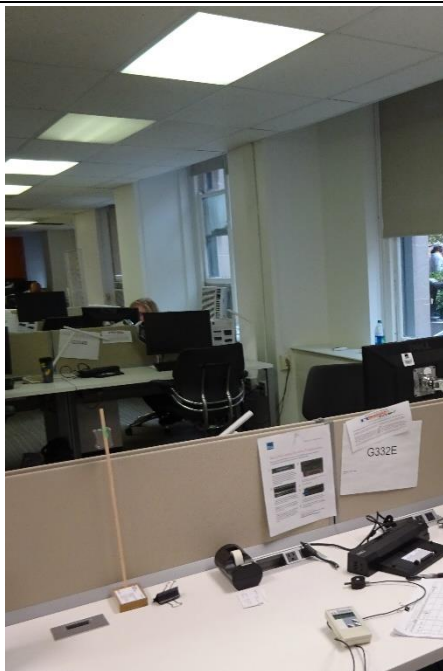
Daysimeter 210 – 3-W-G-W-Window. Mean photopic light level during working hours (08:00 am to 05:00 pm) was  $2517 \pm 2274$  lux on cloudy days. The mean CS value on was  $0.50 \pm 0.23$  on cloudy days. On sunny days mean photopic light level during working hours was  $6113 \pm 9863$  lux. The mean CS value on was  $0.55 \pm 0.24$  on sunny days.



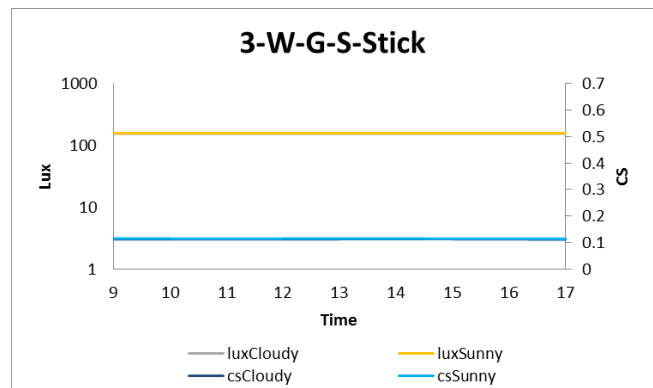
**3-E-G-E-Window**



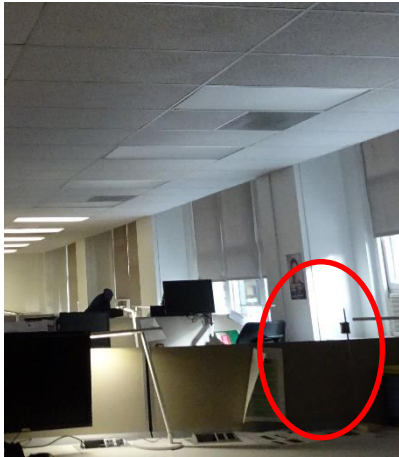
Daysimeter 208 – 3-E-G-E-Window. Mean photopic light level during working hours (08:00 am to 05:00 pm) was  $2864 \pm 3252$  lux on cloudy days. The mean CS value on was  $0.50 \pm 0.23$  on cloudy days. On sunny days mean photopic light level during working hours was  $5450 \pm 8017$  lux. The mean CS value on was  $0.54 \pm 0.24$  on sunny days.



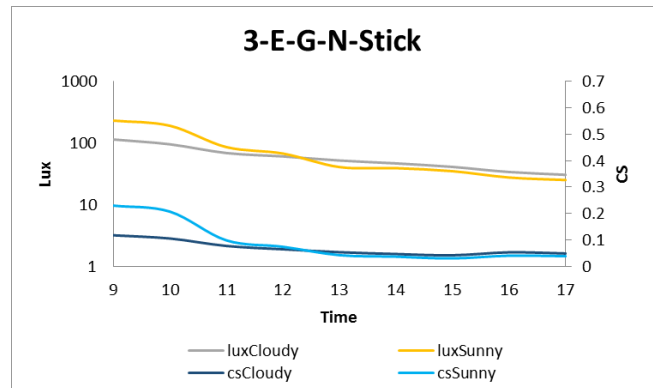
**3-W-G-S-Stick**



Daysimeter 170 – 3-W-G-S-Stick. Mean photopic light level during working hours (08:00 am to 05:00 pm) was  $155 \pm 0$  lux on cloudy days. The mean CS value on was  $0.11 \pm 0.00$  on cloudy days. On sunny days mean photopic light level during working hours was  $158 \pm 0$  lux. The mean CS value on was  $0.11 \pm 0.00$  on sunny days.

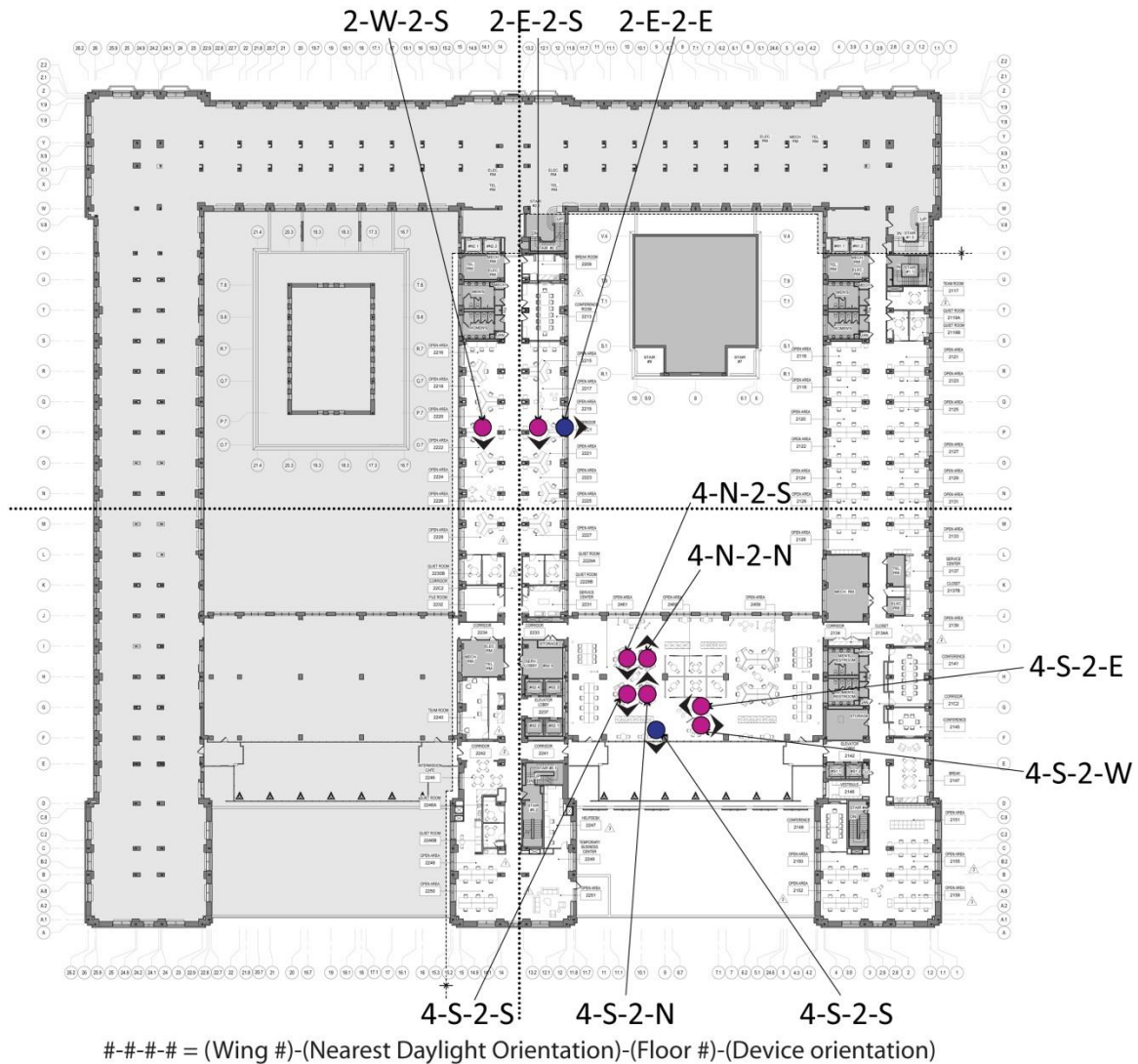


**3-E-G-N-Stick**



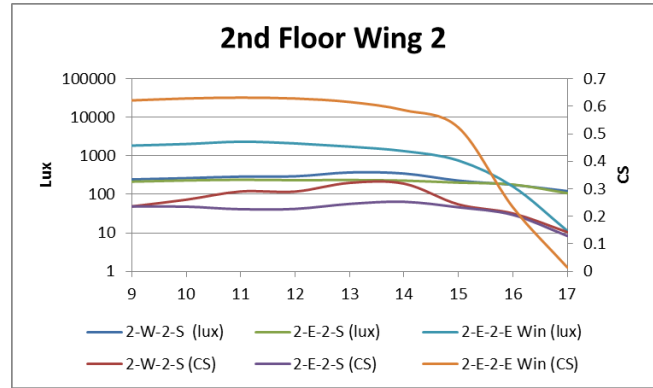
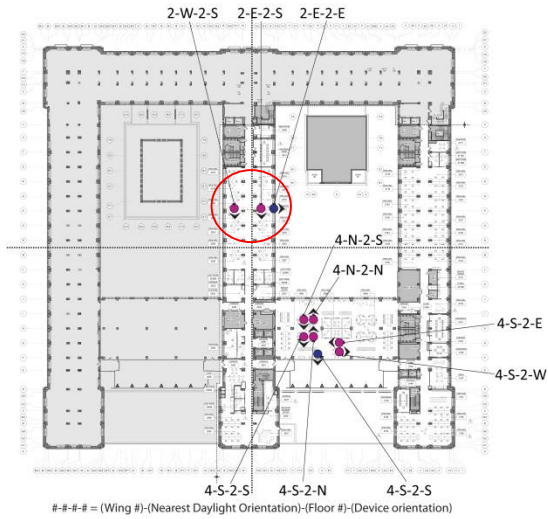
Daysimeter 179 – 3-E-G-N-Stick. Mean photopic light level during working hours (08:00 am to 05:00 pm) was  $60 \pm 28$  lux on cloudy days. The mean CS value on was  $0.07 \pm 0.03$  on cloudy days. On sunny days mean photopic light level during working hours was  $83 \pm 76$  lux. The mean CS value on was  $0.09 \pm 0.08$  on sunny days.

## APPENDIX H: PHOTOMETRIC DATA FOR 2<sup>ND</sup> FLOOR STATIONARY DEVICES MOUNTED ON STICKS AND IN WINDOWS CROPPED TO DECEMBER 4, 2014 – DECEMBER 19, 2014



*Location where measurements were collected.*

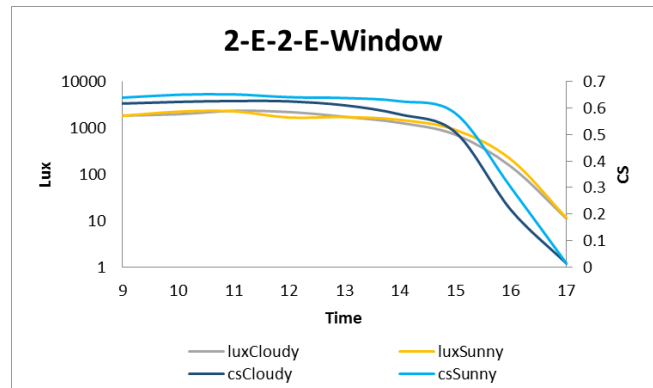
## 2<sup>ND</sup> FLOOR WING 2



**Average Lux and CS**



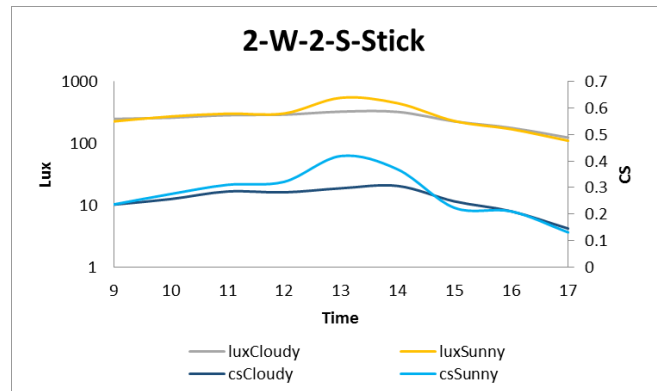
**2-E-2-E-Window**



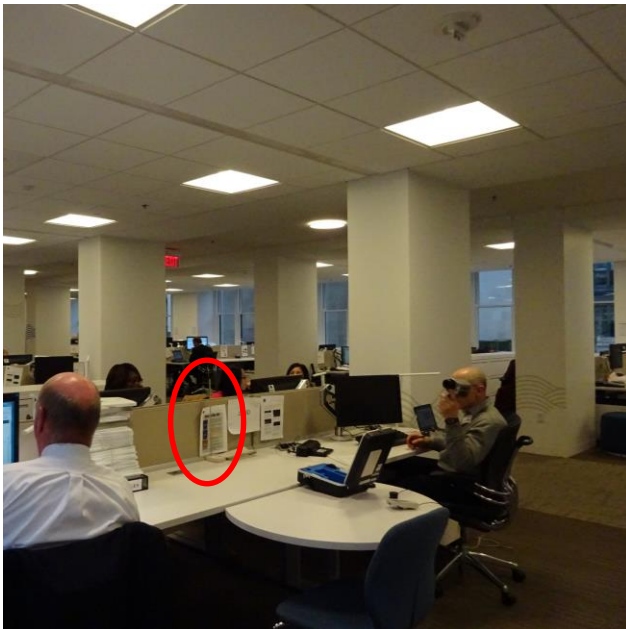
Daysimeter 200 – 2-E-2-E-Window. Mean photopic light level during working hours (08:00 am to 05:00 pm) was  $1363 \pm 876$  lux on cloudy days. The mean CS value on was  $0.49 \pm 0.22$  on cloudy days. On sunny days mean photopic light level during working hours was  $1374 \pm 824$  lux. The mean CS value on was  $0.53 \pm 0.22$  on sunny days.



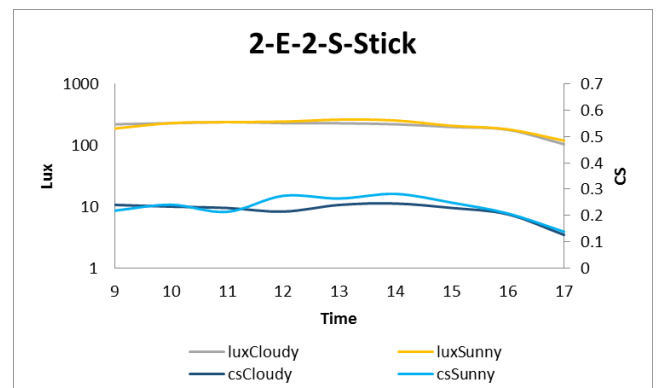
(No photo taken)



Daysimeter 173 – 2-W-2-S-Stick. Mean photopic light level during working hours (08:00 am to 05:00 pm) was  $252 \pm 67$  lux on cloudy days. The mean CS value on was  $0.25 \pm 0.05$  on cloudy days. On sunny days mean photopic light level during working hours was  $290 \pm 135$  lux. The mean CS value on was  $0.28 \pm 0.09$  on sunny days.

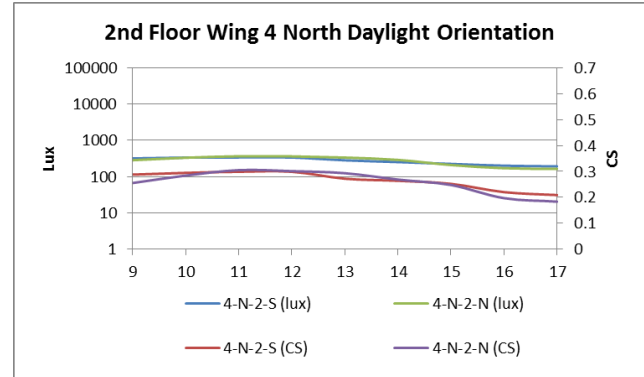
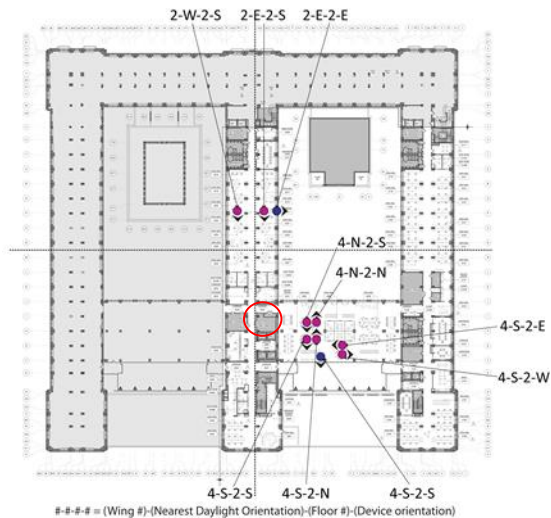


2-E-2-S-Stick



Daysimeter 171 – 2-E-2-S-Stick. Mean photopic light level during working hours (08:00 am to 05:00 pm) was  $206 \pm 42$  lux on cloudy days. The mean CS value on was  $0.22 \pm 0.04$  on cloudy days. On sunny days mean photopic light level during working hours was  $214 \pm 45$  lux. The mean CS value on was  $0.23 \pm 0.04$  on sunny days.

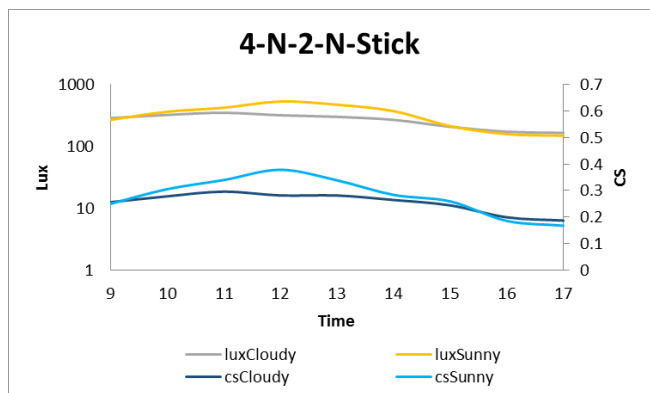
## 2<sup>ND</sup> FLOOR WING 4



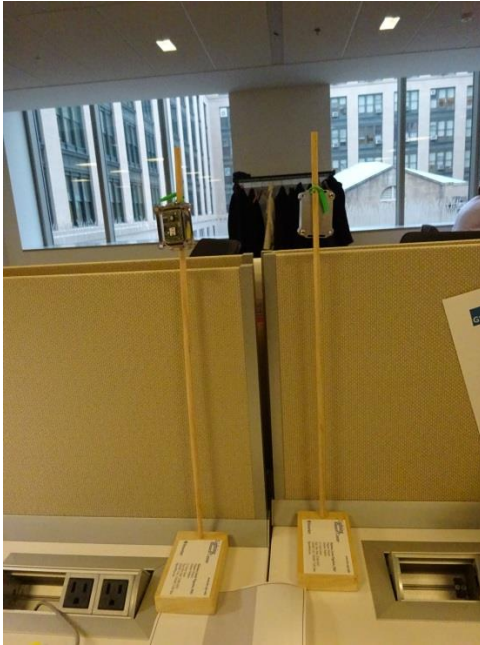
**Average Lux and CS**



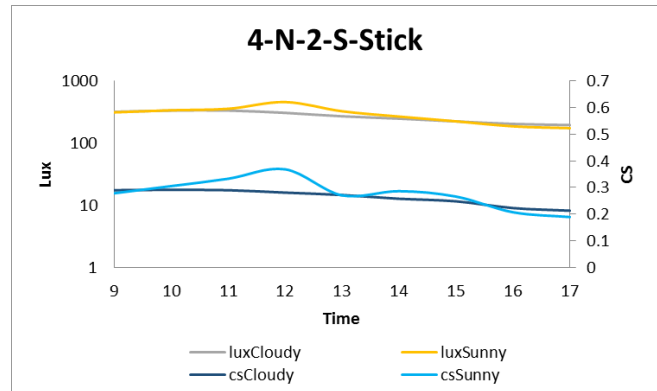
**4-N-2-N-Stick**



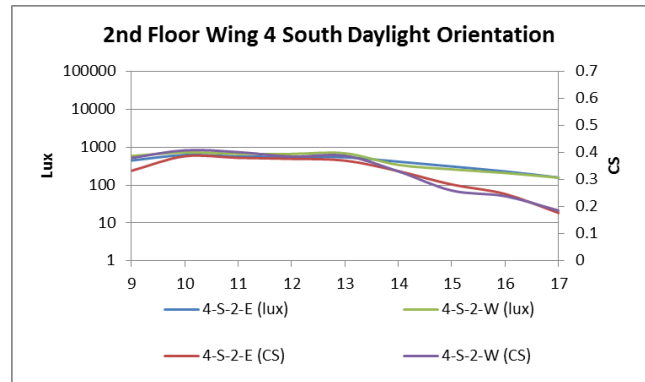
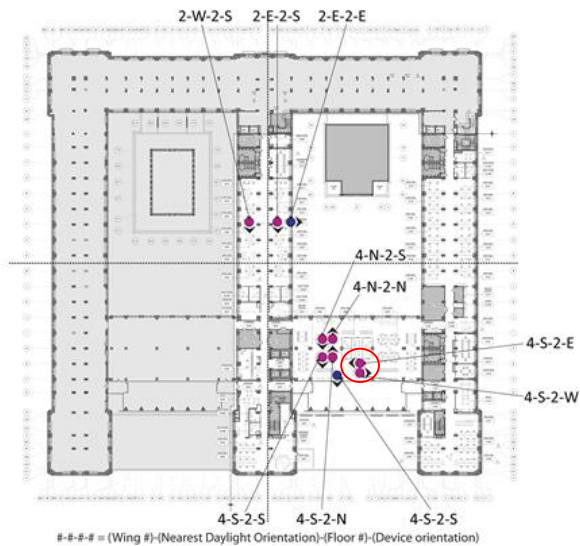
Daysimeter 176 – 4-N-2-N-Stick. Mean photopic light level during working hours (08:00 am to 05:00 pm) was  $266 \pm 68$  lux on cloudy days. The mean CS value on was  $0.25 \pm 0.04$  on cloudy days. On sunny days mean photopic light level during working hours was  $328 \pm 138$  lux. The mean CS value on was  $0.28 \pm 0.07$  on sunny days.



**4-N-2-S-Stick**

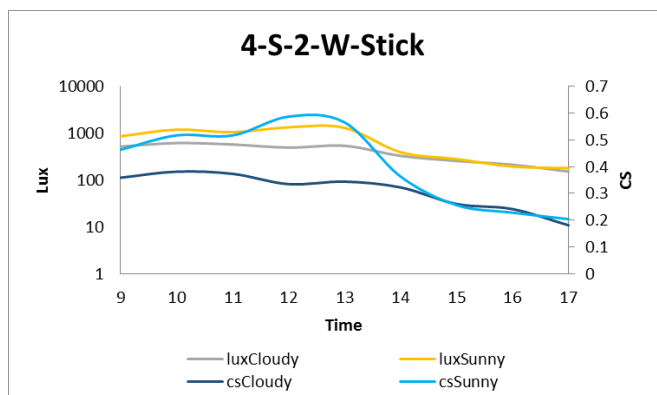


Daysimeter 174 – 4-N-2-S-Stick. Mean photopic light level during working hours (08:00 am to 05:00 pm) was  $270 \pm 55$  lux on cloudy days. The mean CS value on was  $0.26 \pm 0.03$  on cloudy days. On sunny days mean photopic light level during working hours was  $293 \pm 90$  lux. The mean CS value on was  $0.28 \pm 0.06$  on sunny days.



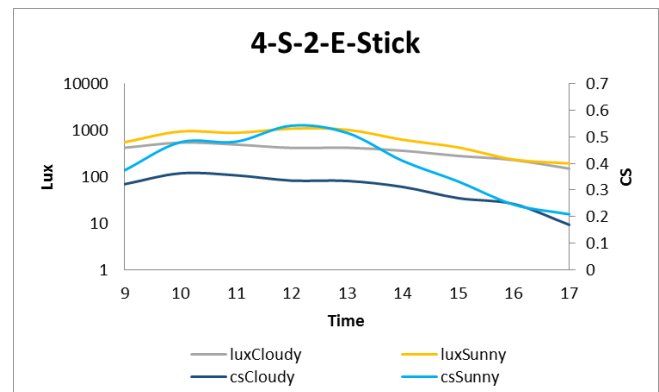
Average Lux and CS

(Photo not taken)

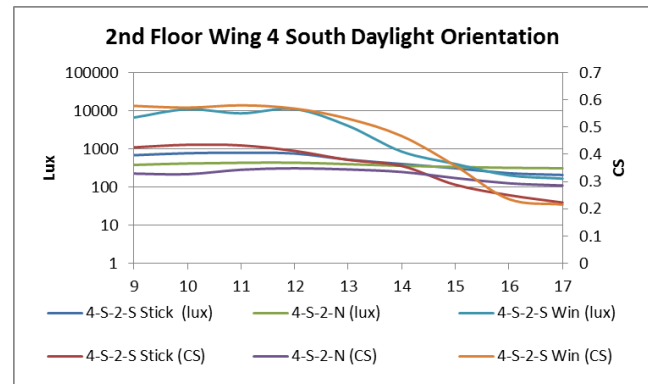


Daysimeter 181 – 4-S-2-W-Stick. Mean photopic light level during working hours (08:00 am to 05:00 pm) was  $410 \pm 173$  lux on cloudy days. The mean CS value on was  $0.31 \pm 0.07$  on cloudy days. On sunny days mean photopic light level during working hours was  $755 \pm 491$  lux. The mean CS value on was  $0.41 \pm 0.15$  on sunny days.

(Photo not available)



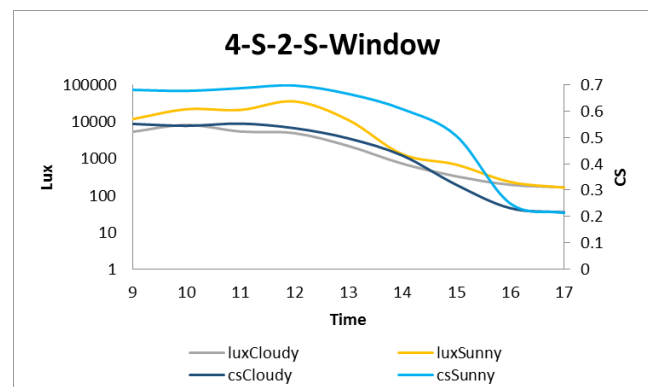
Daysimeter 169 – 4-S-2-E-Stick. Mean photopic light level during working hours (08:00 am to 05:00 pm) was  $369 \pm 127$  lux on cloudy days. The mean CS value on was  $0.30 \pm 0.06$  on cloudy days. On sunny days mean photopic light level during working hours was  $663 \pm 336$  lux. The mean CS value on was  $0.40 \pm 0.12$  on sunny days.



Average Lux and CS

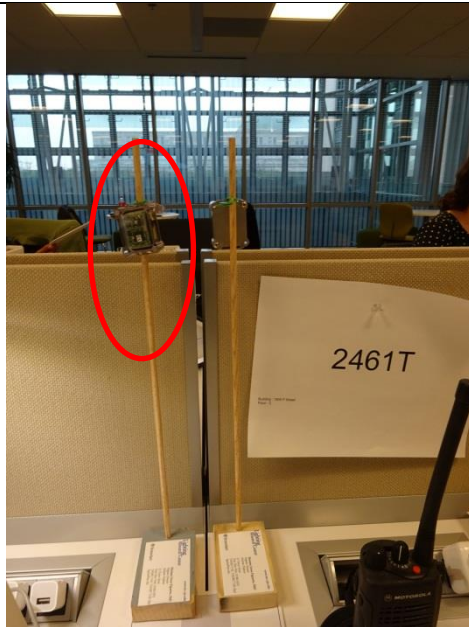


4-S-2-S-Window

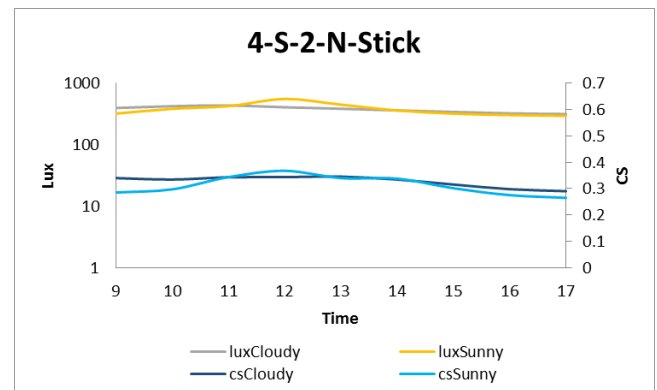


Daysimeter 206 - 4-S-2-S-Window. Mean photopic light level during working hours (08:00 am to 05:00 pm) was  $3060 \pm 2978$  lux on cloudy days. The mean CS value on was  $0.43 \pm 0.14$  on cloudy days. On sunny days mean photopic light level during working hours was  $11558 \pm 12548$  lux. The mean CS value on was  $0.55 \pm 0.19$  on sunny days.

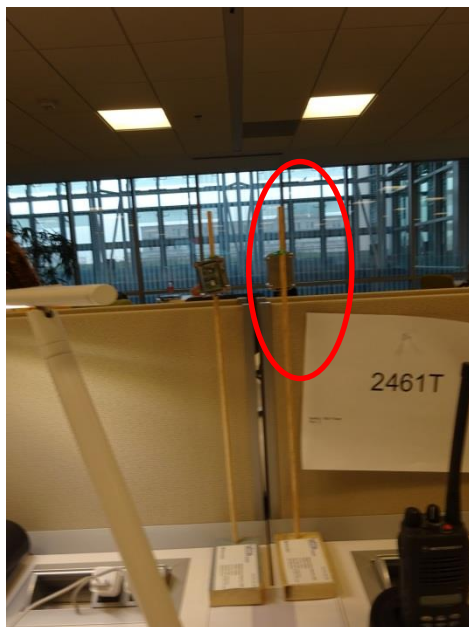




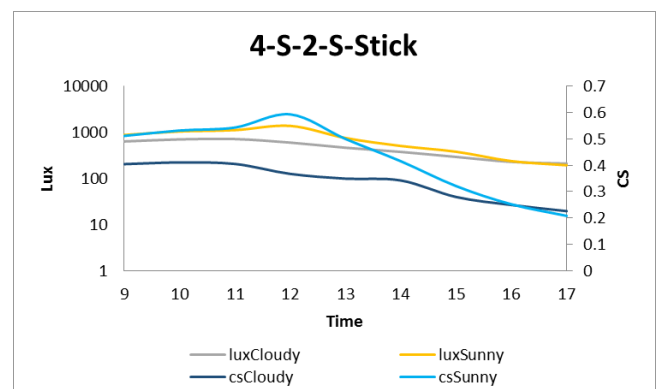
4-S-2-N-Stick



Daysimeter 013 – 4-S-2-N-Stick. Mean photopic light level during working hours (08:00 am to 05:00 pm) was  $375 \pm 43$  lux on cloudy days. The mean CS value on was  $0.33 \pm 0.02$  on cloudy days. On sunny days mean photopic light level during working hours was  $378 \pm 85$  lux. The mean CS value on was  $0.31 \pm 0.04$  on sunny days.

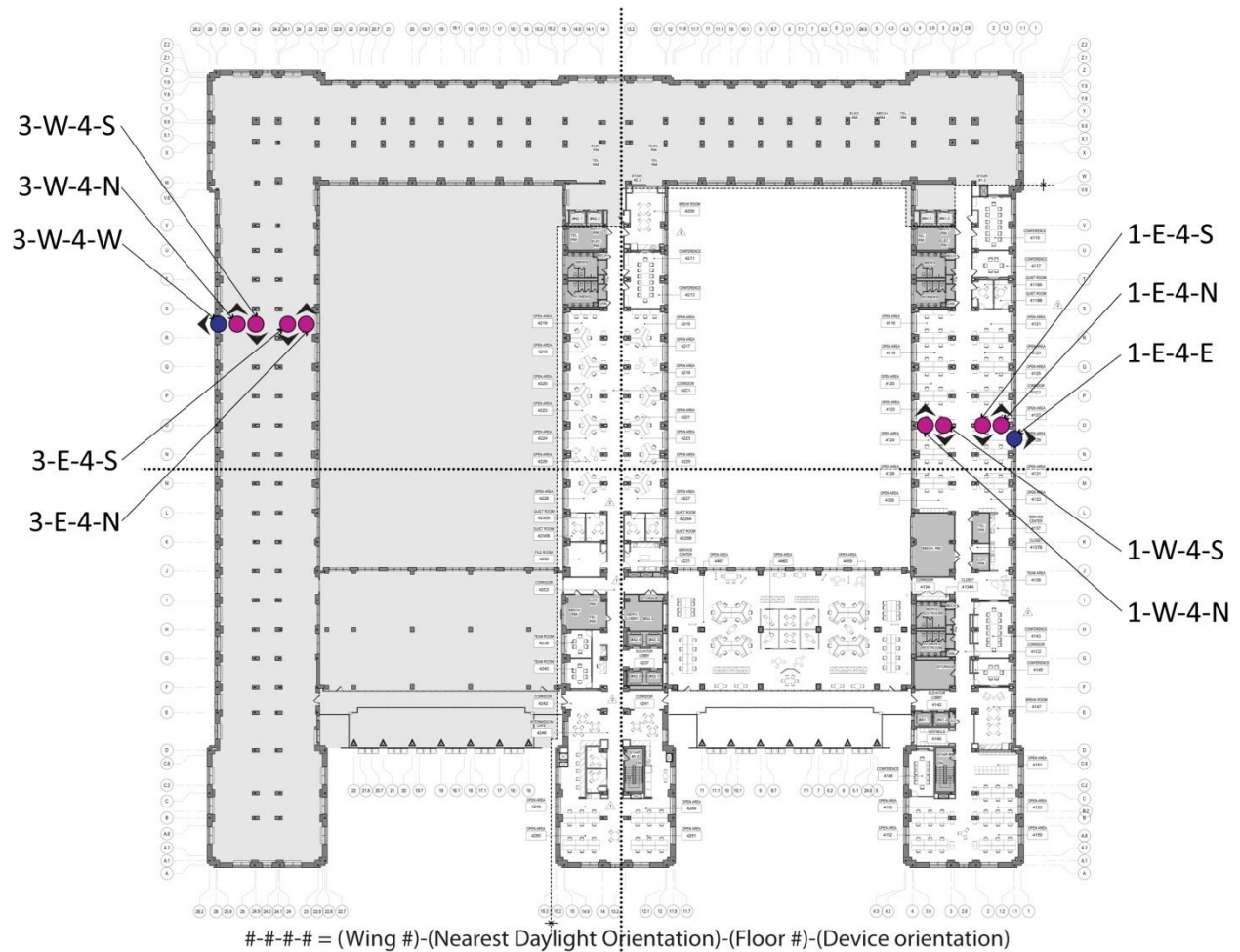


4-S-2-S-Stick



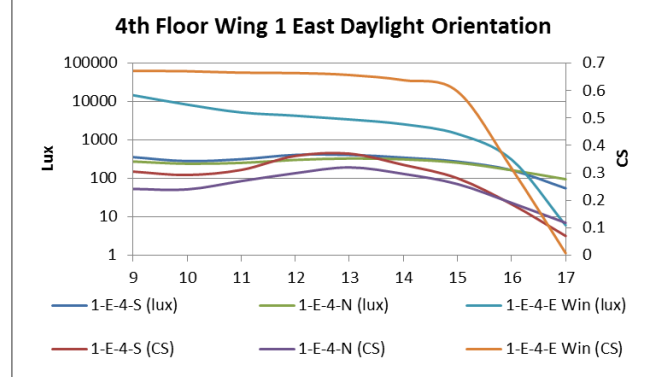
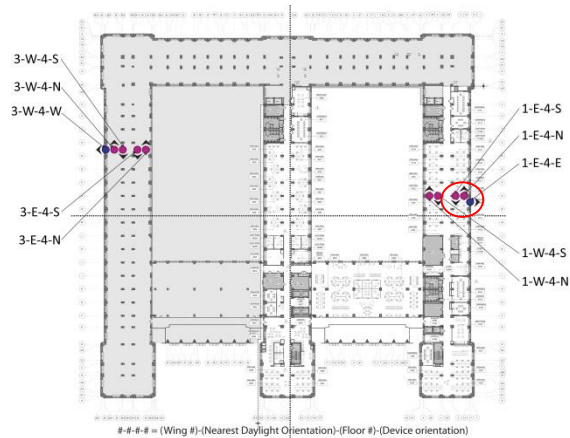
Daysimeter 182 – 4-S-2-S-Stick. Mean photopic light level during working hours (08:00 am to 05:00 pm) was  $470 \pm 201$  lux on cloudy days. The mean CS value on was  $0.34 \pm 0.07$  on cloudy days. On sunny days mean photopic light level during working hours was  $721 \pm 417$  lux. The mean CS value on was  $0.43 \pm 0.14$  on sunny days.

## APPENDIX I: PHOTOMETRIC DATA FOR 4<sup>TH</sup> FLOOR STATIONARY DEVICES MOUNTED ON STICKS AND IN WINDOWS CROPPED TO DECEMBER 4, 2014 – DECEMBER 19, 2014



*Location where measurements were collected.*

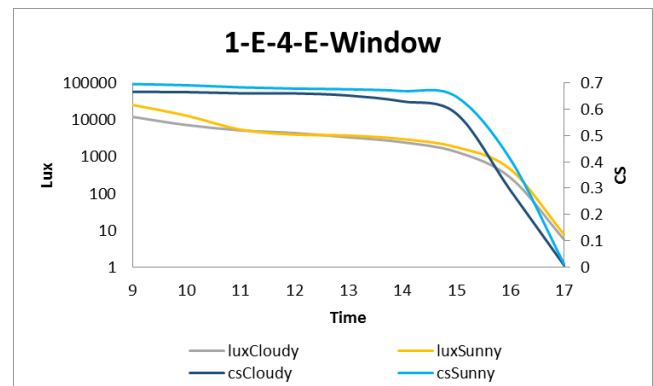
## 4<sup>TH</sup> FLOOR WING 1



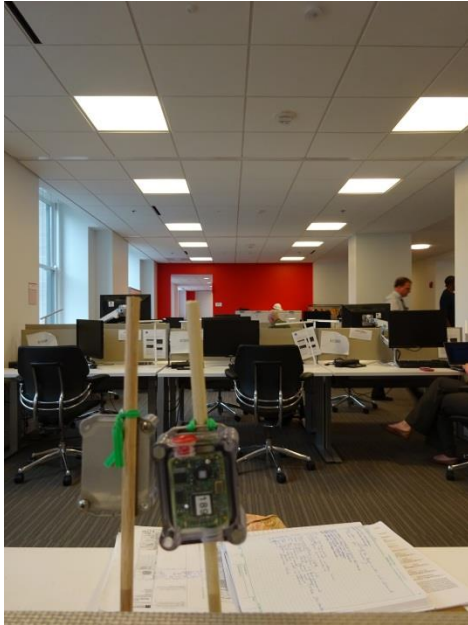
**Average Lux and CS**



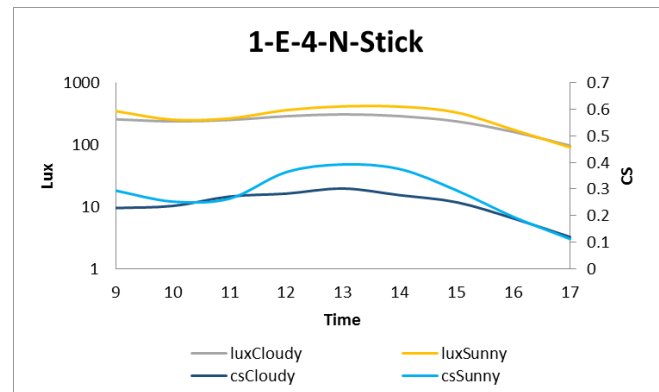
**1-E-4-E-Window**



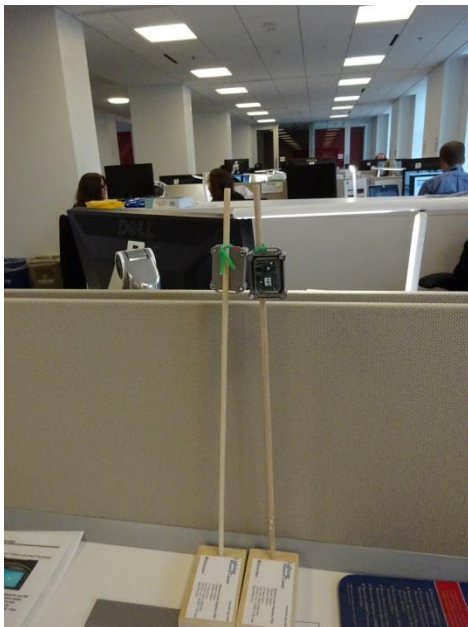
Daysimeter 203 – 1-E-4-E-Window. Mean photopic light level during working hours (08:00 am to 05:00 pm) was  $4018 \pm 3796$  lux on cloudy days. The mean CS value on was  $0.54 \pm 0.23$  on cloudy days. On sunny days mean photopic light level during working hours was  $6296 \pm 8092$  lux. The mean CS value on was  $0.57 \pm 0.23$  on sunny days.



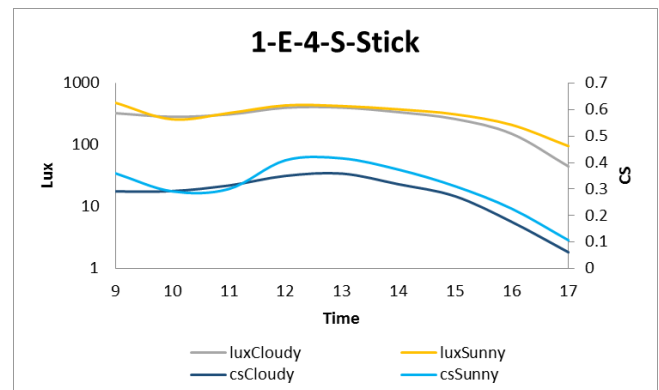
**1-E-4-N-Stick**



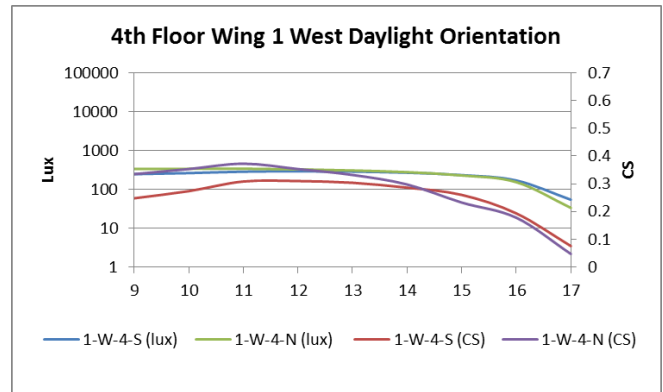
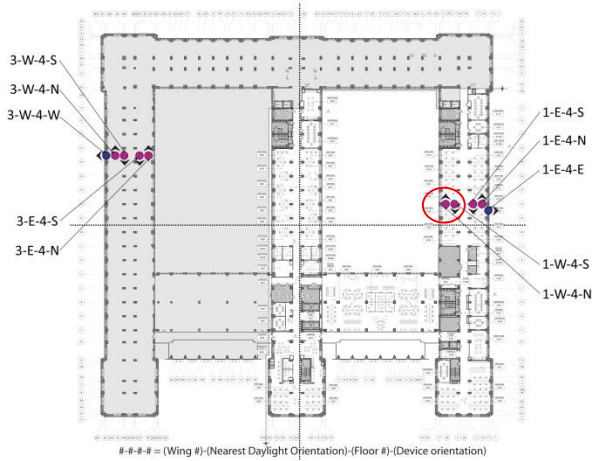
Daysimeter 189 – 1-E-4-N-Stick. Mean photopic light level during working hours (08:00 am to 05:00 pm) was  $237 \pm 68$  lux on cloudy days. The mean CS value on was  $0.24 \pm 0.06$  on cloudy days. On sunny days mean photopic light level during working hours was  $295 \pm 109$  lux. The mean CS value on was  $0.28 \pm 0.09$  on sunny days.



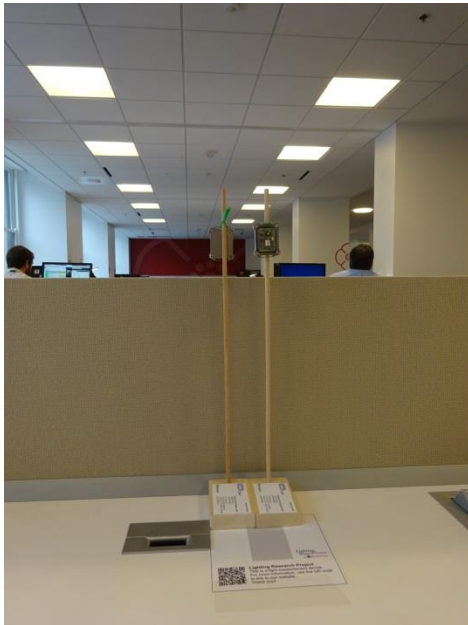
**1-E-4-S-Stick**



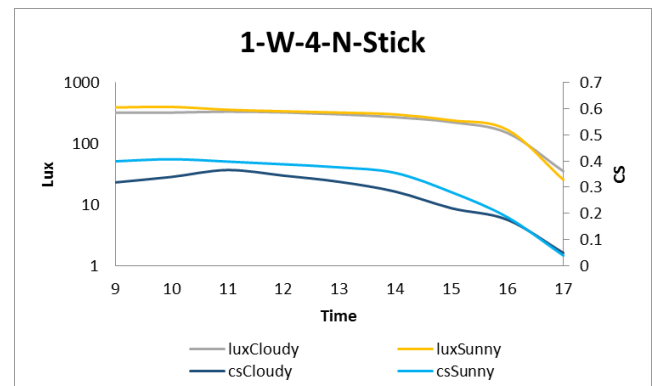
Daysimeter 167 – 1-E-4-S-Stick. Mean photopic light level during working hours (08:00 am to 05:00 pm) was  $282 \pm 117$  lux on cloudy days. The mean CS value on was  $0.27 \pm 0.09$  on cloudy days. On sunny days mean photopic light level during working hours was  $327 \pm 123$  lux. The mean CS value on was  $0.31 \pm 0.10$  on sunny days.



Average Lux and CS

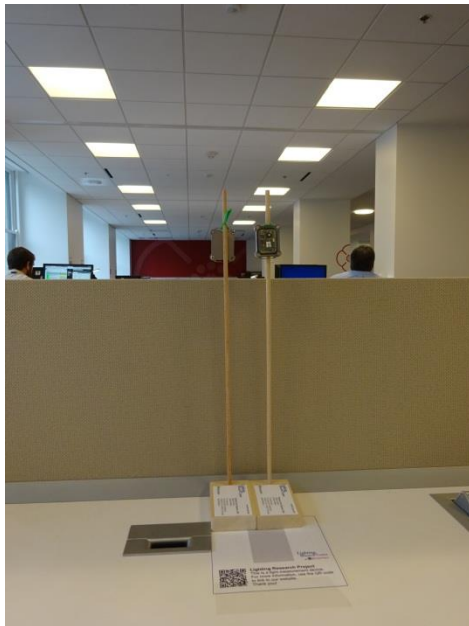


1-W-4-N-Stick

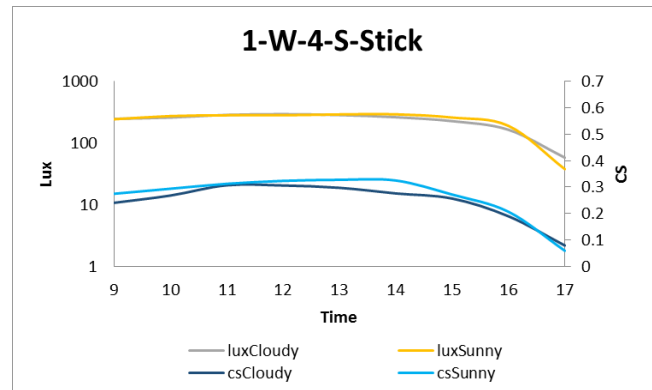


Daysimeter 184 – 1-W-4-N-Stick. Mean photopic light level during working hours (08:00 am to 05:00 pm) was  $254 \pm 102$  lux on cloudy days. The mean CS value on was  $0.27 \pm 0.10$  on cloudy days. On sunny days mean photopic light level during working hours was  $283 \pm 121$  lux. The mean CS value on was  $0.31 \pm 0.13$  on sunny days.





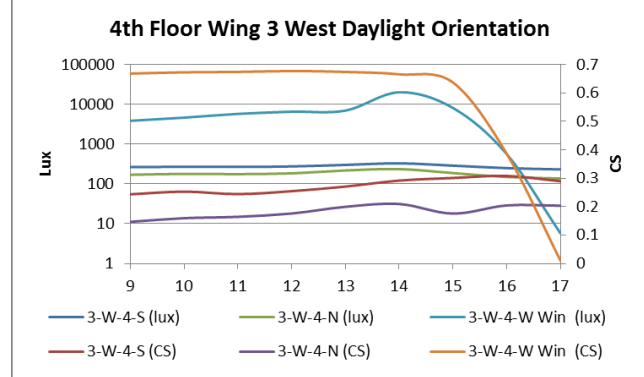
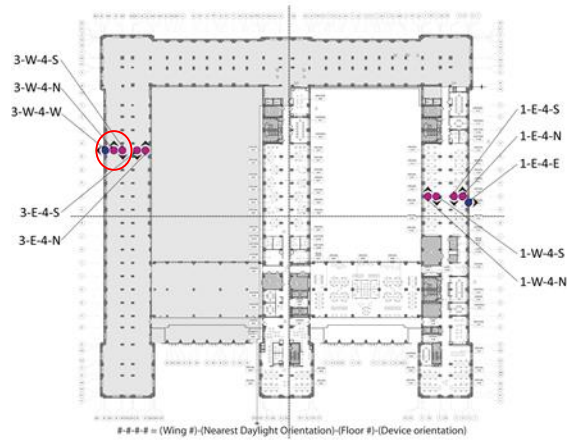
**1-W-4-S-Stick**



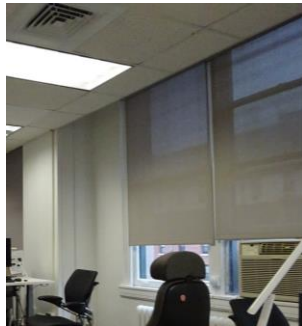
Daysimeter 196 – 1-W-4-S-Stick. Mean photopic light level during working hours (08:00 am to 05:00 pm) was  $231 \pm 76$  lux on cloudy days. The mean CS value on was  $0.25 \pm 0.07$  on cloudy days. On sunny days mean photopic light level during working hours was  $239 \pm 82$  lux. The mean CS value on was  $0.27 \pm 0.09$  on sunny days.



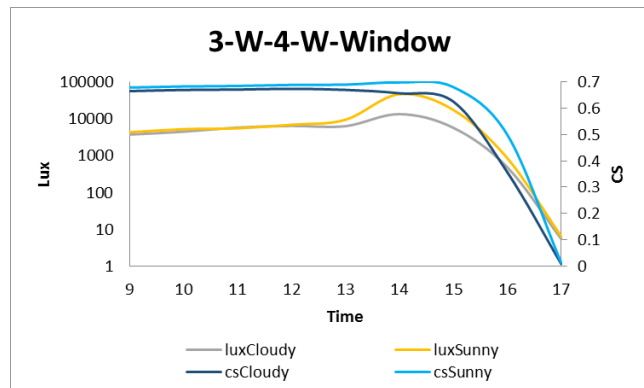
## 4<sup>TH</sup> FLOOR WING 3



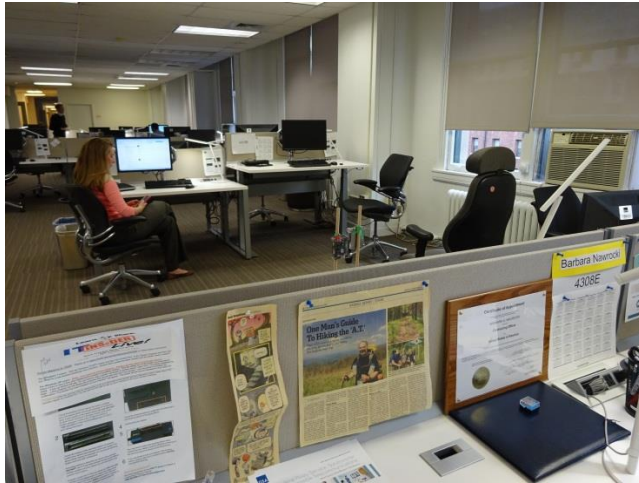
**Average Lux and CS**



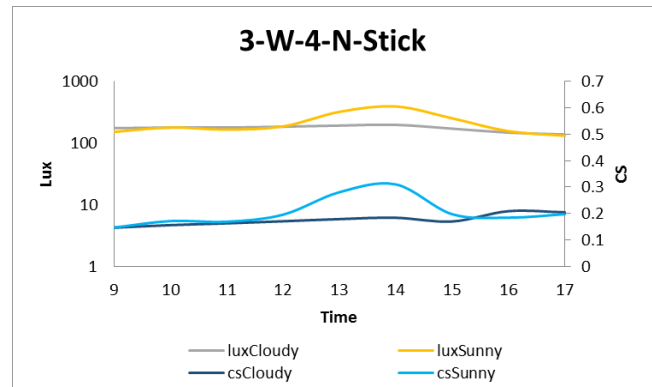
**3-W-4-W-Window**



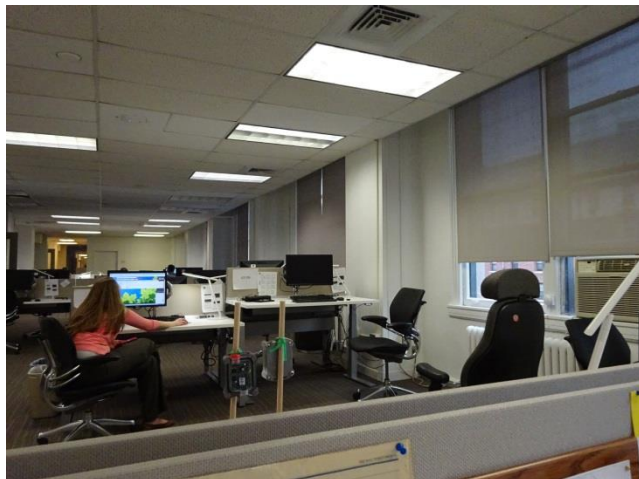
Daysimeter 204 – 3-W-4-W-Window. Mean photopic light level during working hours (08:00 am to 05:00 pm) was  $5145 \pm 3908$  lux on cloudy days. The mean CS value on was  $0.56 \pm 0.23$  on cloudy days. On sunny days mean photopic light level during working hours was  $10692 \pm 14366$  lux. The mean CS value on was  $0.59 \pm 0.23$  on sunny days.



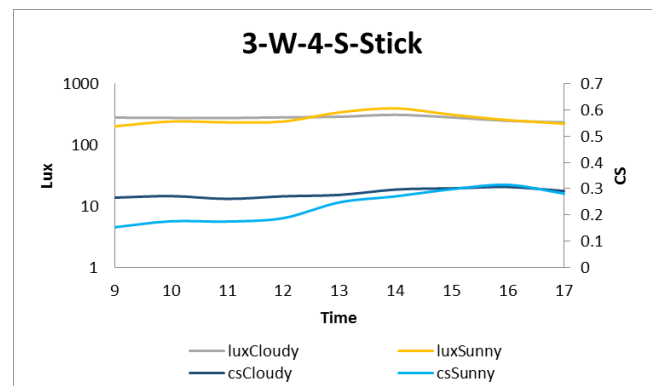
**3-W-4-N-Stick**



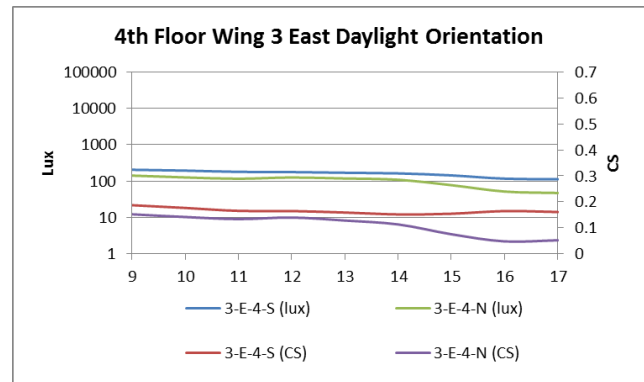
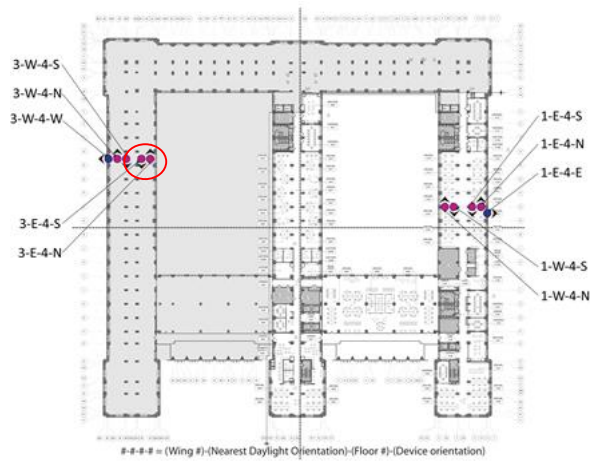
Daysimeter 185 – 3-W-4-N-Stick. Mean photopic light level during working hours (08:00 am to 05:00 pm) was  $173 \pm 19$  lux on cloudy days. The mean CS value on was  $0.18 \pm 0.02$  on cloudy days. On sunny days mean photopic light level during working hours was  $215 \pm 88$  lux. The mean CS value on was  $0.21 \pm 0.05$  on sunny days.



**3-W-4-S-Stick**

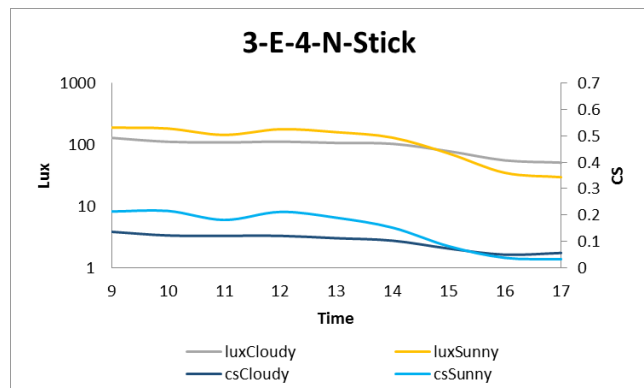


Daysimeter 192 – 3-W-4-S-Stick. Mean photopic light level during working hours (08:00 am to 05:00 pm) was  $276 \pm 23$  lux on cloudy days. The mean CS value on was  $0.28 \pm 0.02$  on cloudy days. On sunny days mean photopic light level during working hours was  $272 \pm 64$  lux. The mean CS value on was  $0.23 \pm 0.06$  on sunny days.



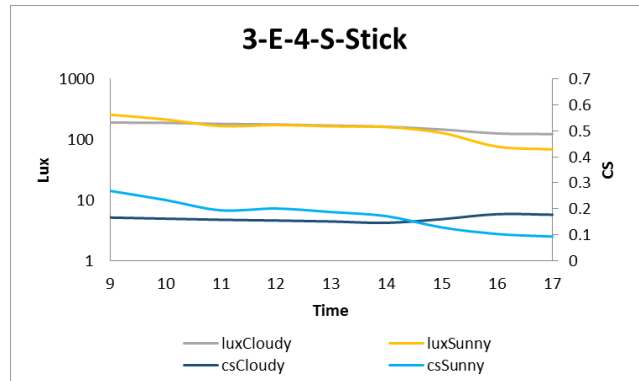
*Average Lux and CS*

*(No photo taken)*



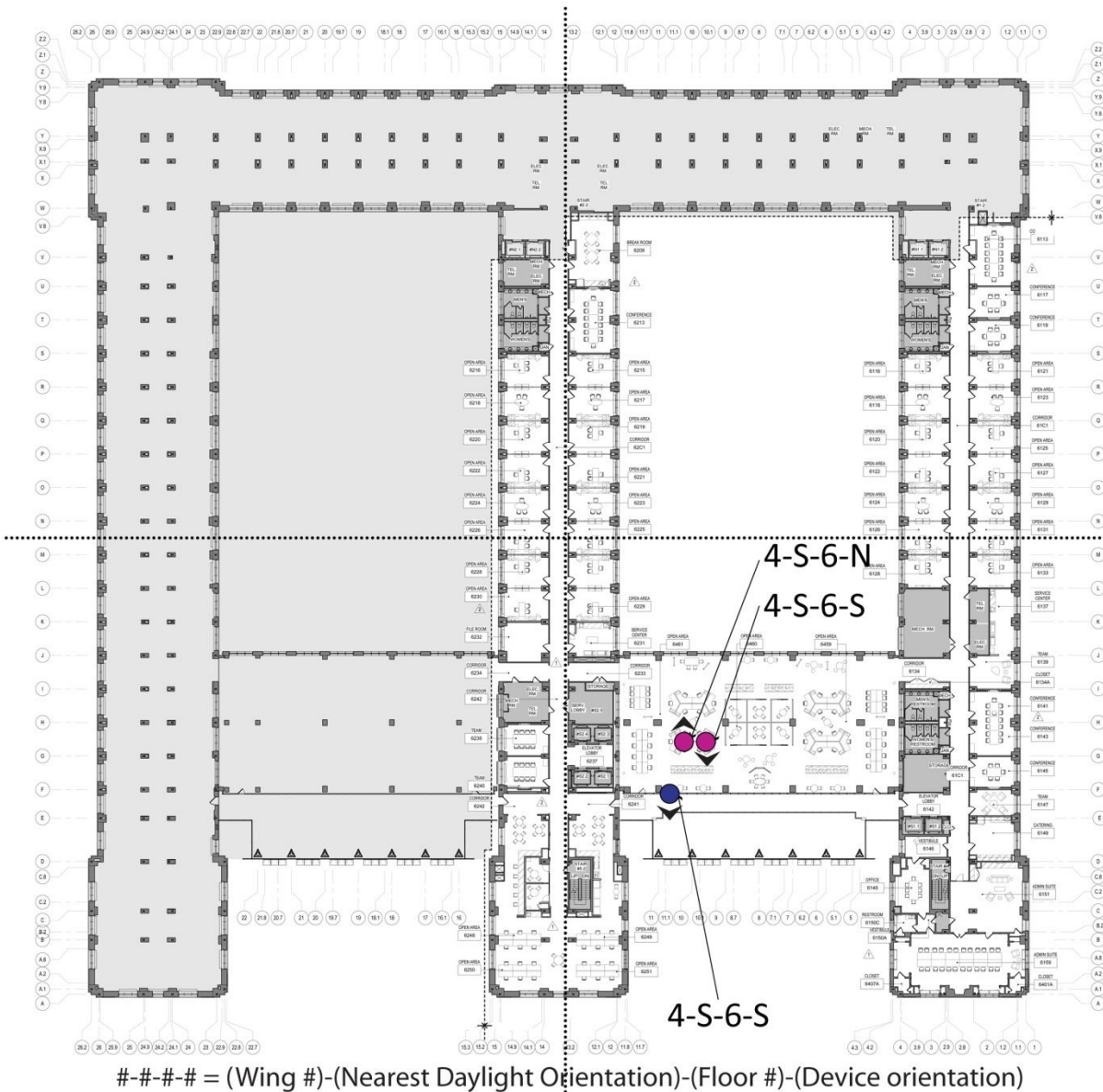
Daysimeter 191 – 3-E-4-N-Stick. Mean photopic light level during working hours (08:00 am to 05:00 pm) was  $95 \pm 27$  lux on cloudy days. The mean CS value on was  $0.10 \pm 0.03$  on cloudy days. On sunny days mean photopic light level during working hours was  $125 \pm 63$  lux. The mean CS value on was  $0.15 \pm 0.08$  on sunny days.

(No photo taken)



Daysimeter 195 – 3-E-4-S-Stick. Mean photopic light level during working hours (08:00 am to 05:00 pm) was  $163 \pm 26$  lux on cloudy days. The mean CS value on was  $0.16 \pm 0.01$  on cloudy days. On sunny days mean photopic light level during working hours was  $157 \pm 60$  lux. The mean CS value on was  $0.18 \pm 0.06$  on sunny days.

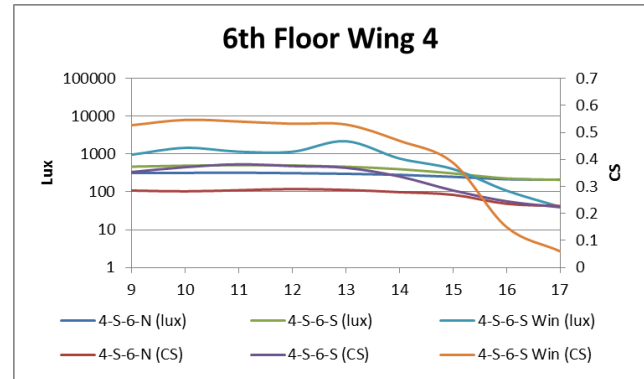
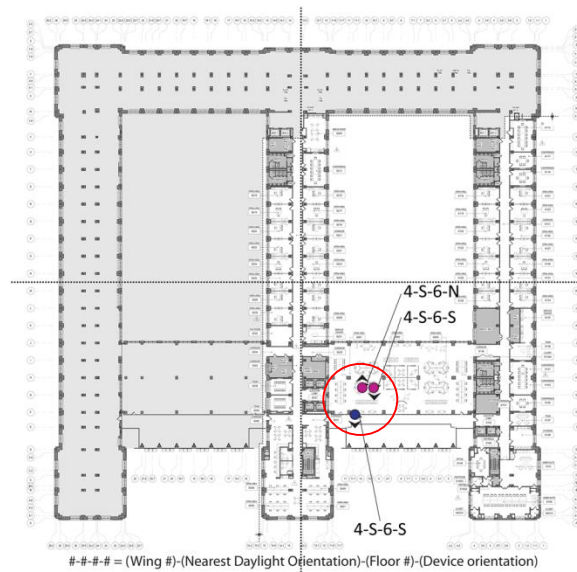
## APPENDIX J: PHOTOMETRIC DATA FOR 6<sup>TH</sup> FLOOR STATIONARY DEVICES MOUNTED ON STICKS AND IN WINDOWS CROPPED TO DECEMBER 4, 2014 – DECEMBER 19, 2014



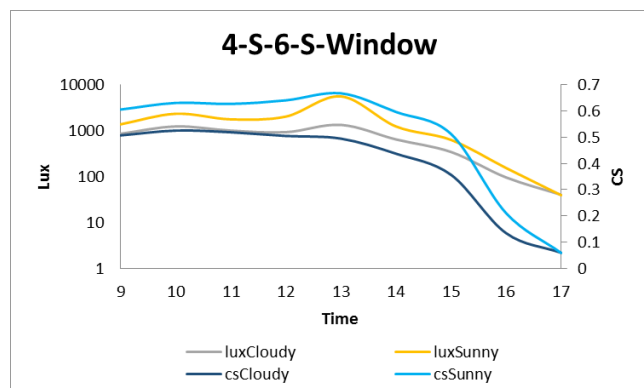
*Location where measurements were collected.*



## 6<sup>TH</sup> FLOOR NORTH WING 4



4-S-6-S-Window

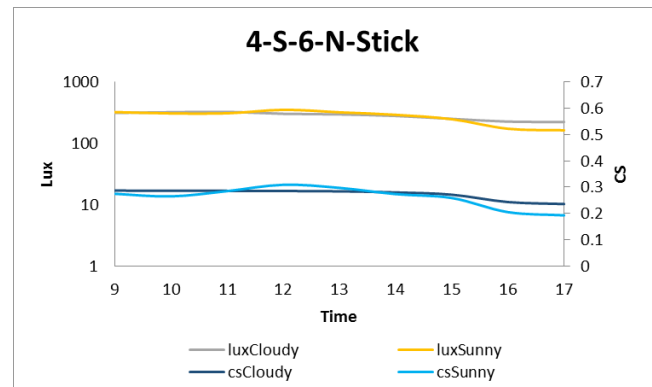


Daysimeter 199 – 4-S-6-S-Window. Mean photopic light level during working hours (08:00 am to 05:00 pm) was  $722 \pm 474$  lux on cloudy days. The mean CS value on was  $0.39 \pm 0.18$  on cloudy days. On sunny days mean photopic light level during working hours was  $1683 \pm 1665$  lux. The mean CS value on was  $0.51 \pm 0.22$  on sunny days.





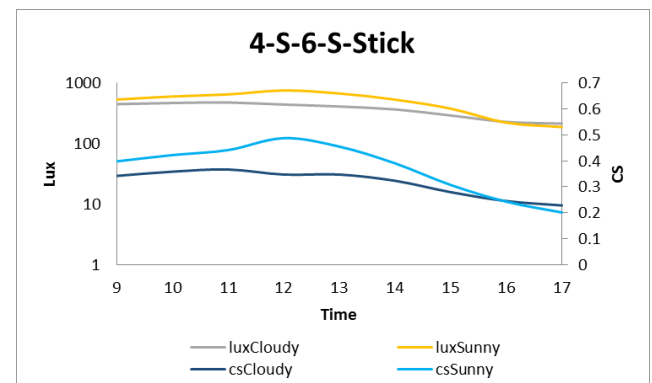
**4-S-6-N-Stick**



Daysimeter 168 – 4-S-6-S-Stick. Mean photopic light level during working hours (08:00 am to 05:00 pm) was  $282 \pm 40$  lux on cloudy days. The mean CS value on was  $0.27 \pm 0.02$  on cloudy days. On sunny days mean photopic light level during working hours was  $276 \pm 67$  lux. The mean CS value on was  $0.26 \pm 0.04$  on sunny days.

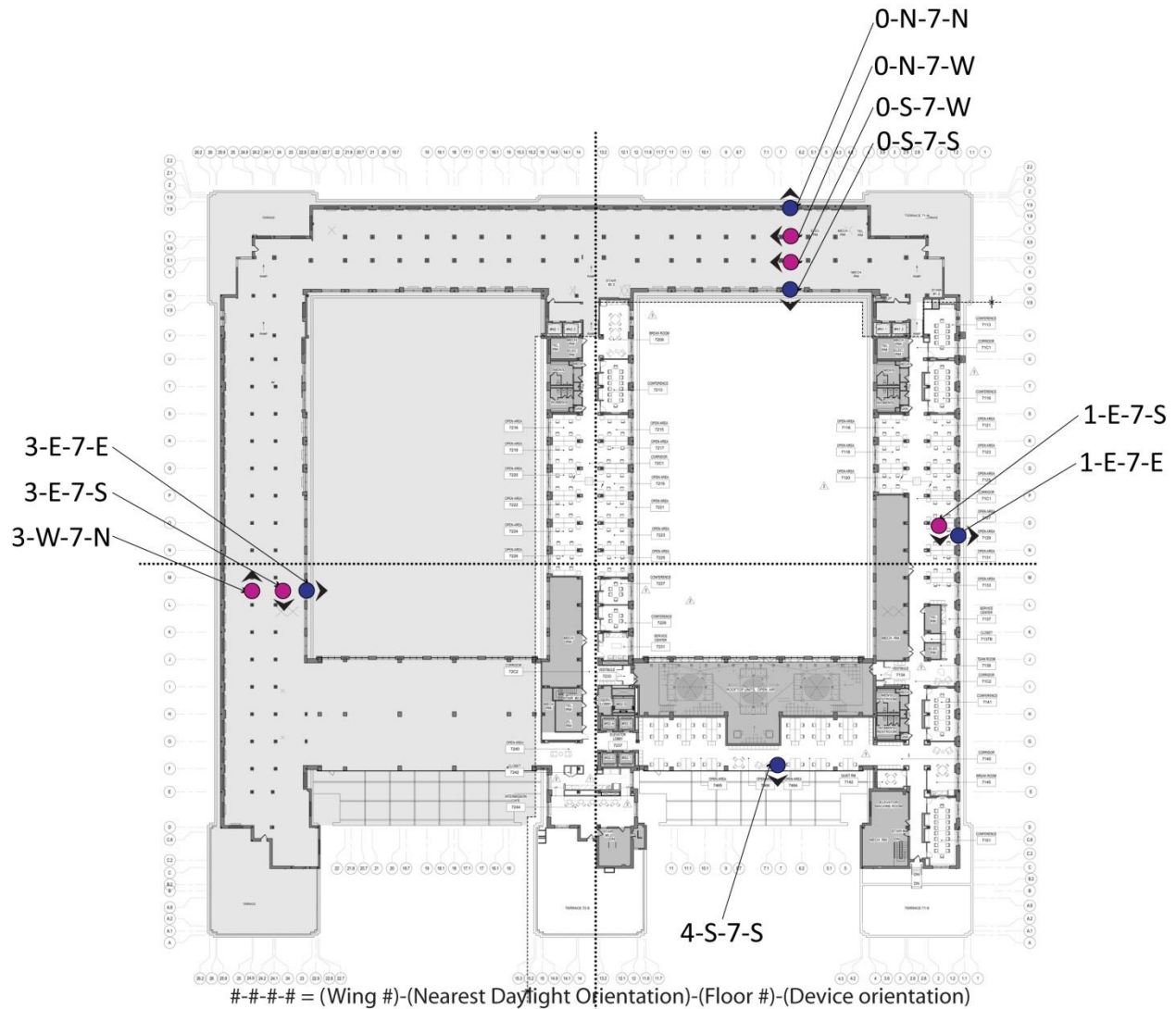


**4-S-6-S-Stick**



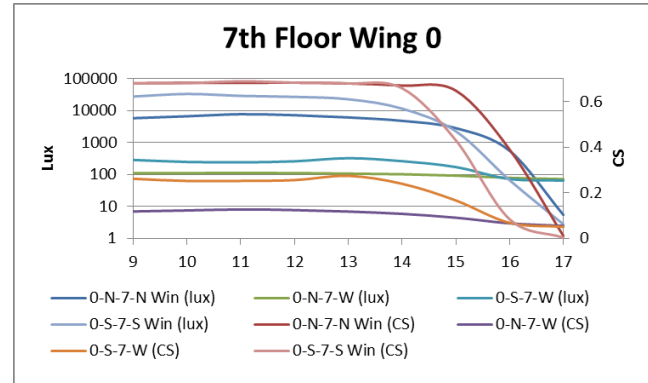
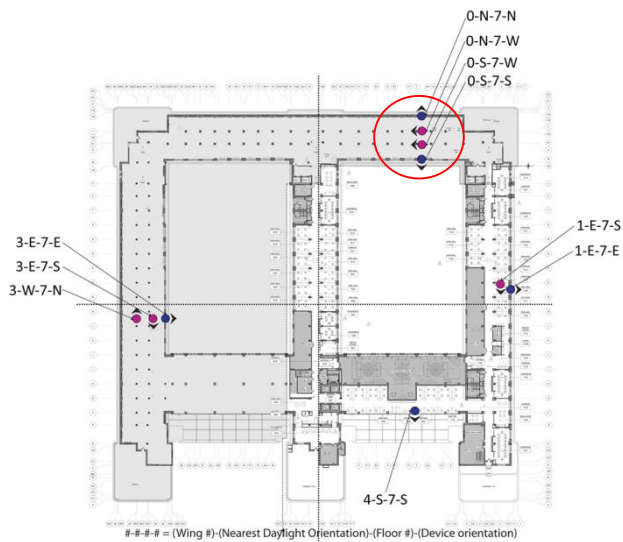
Daysimeter 175 – 4-S-6-S-Stick. Mean photopic light level during working hours (08:00 am to 05:00 pm) was  $371 \pm 103$  lux on cloudy days. The mean CS value on was  $0.32 \pm 0.05$  on cloudy days. On sunny days mean photopic light level during working hours was  $502 \pm 199$  lux. The mean CS value on was  $0.37 \pm 0.10$  on sunny days.

## APPENDIX K: PHOTOMETRIC DATA FOR 7<sup>TH</sup> FLOOR STATIONARY DEVICES MOUNTED ON STICKS AND IN WINDOWS CROPPED TO DECEMBER 4, 2014 – DECEMBER 19, 2014



*Location where measurements were collected.*

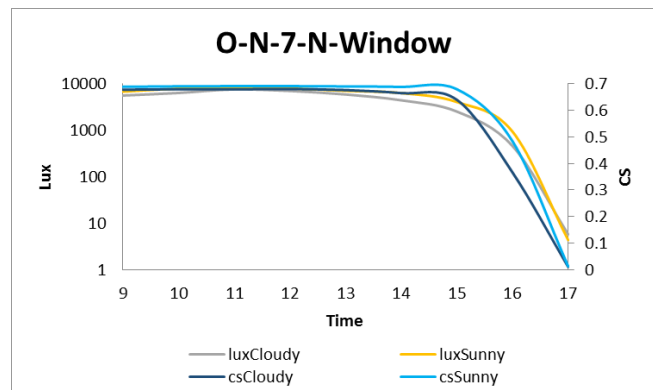
## 7<sup>TH</sup> FLOOR WING 0



Average Lux and CS



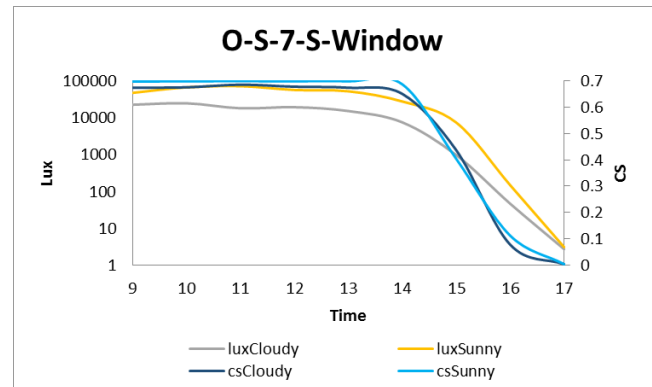
O-N-7-N-Window



Daysimeter 202 – O-N-7-N-Window. Mean photopic light level during working hours (08:00 am to 05:00 pm) was  $4418 \pm 2793$  lux on cloudy days. The mean CS value on was  $0.56 \pm 0.23$  on cloudy days. On sunny days mean photopic light level during working hours was  $5474 \pm 3111$  lux. The mean CS value on was  $0.59 \pm 0.23$  on sunny days.



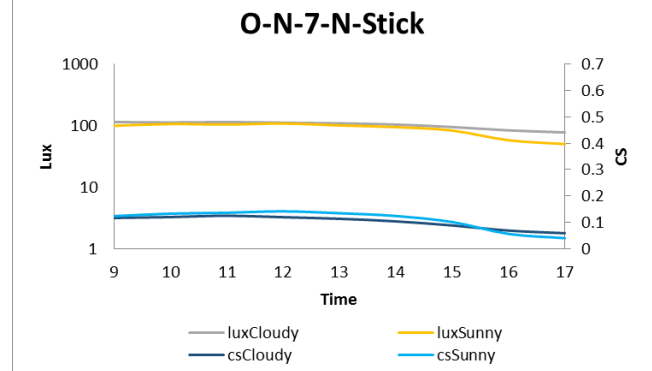
**O-S-7-S-Window**



Daysimeter 209 – O-S-7-S-Window. Mean photopic light level during working hours (08:00 am to 05:00 pm) was  $12075 \pm 10039$  lux on cloudy days. The mean CS value on was  $0.51 \pm 0.28$  on cloudy days. On sunny days mean photopic light level during working hours was  $36814 \pm 28654$  lux. The mean CS value on was  $0.52 \pm 0.28$  on sunny days.



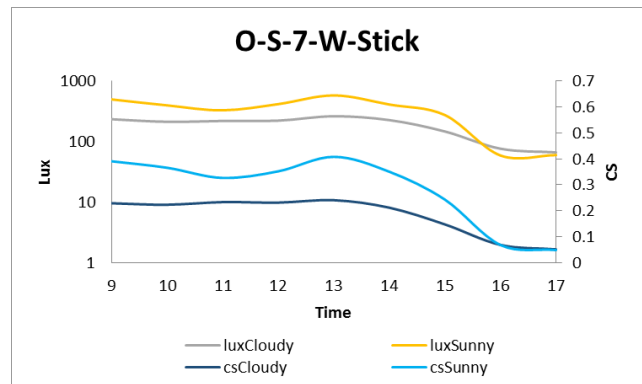
**O-N-7-W-Stick**



Daysimeter 198 – O-N-7-W-Stick. Mean photopic light level during working hours (08:00 am to 05:00 pm) was  $103 \pm 14$  lux on cloudy days. The mean CS value on was  $0.10 \pm 0.02$  on cloudy days. On sunny days mean photopic light level during working hours was  $90 \pm 21$  lux. The mean CS value on was  $0.11 \pm 0.04$  on sunny days.



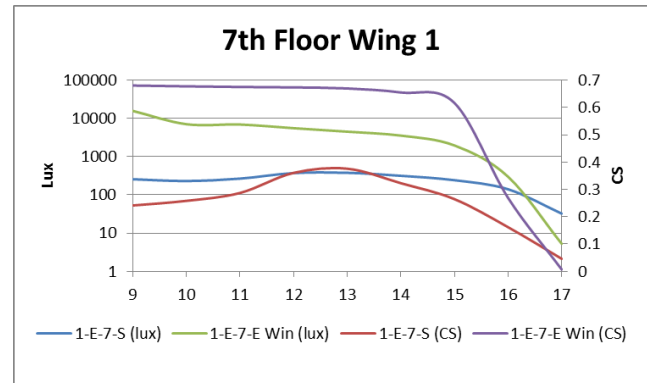
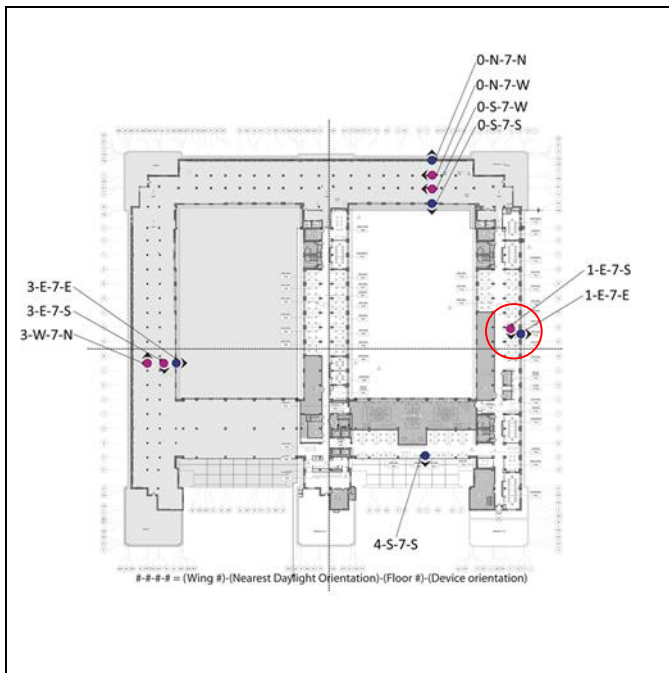
**0-S-7-W-Stick**



Daysimeter 186 – 0-S-7-W-Stick. Mean photopic light level during working hours (08:00 am to 05:00 pm) was  $185 \pm 71$  lux on cloudy days. The mean CS value on was  $0.18 \pm 0.07$  on cloudy days. On sunny days mean photopic light level during working hours was  $335 \pm 179$  lux. The mean CS value on was  $0.28 \pm 0.14$  on sunny days.



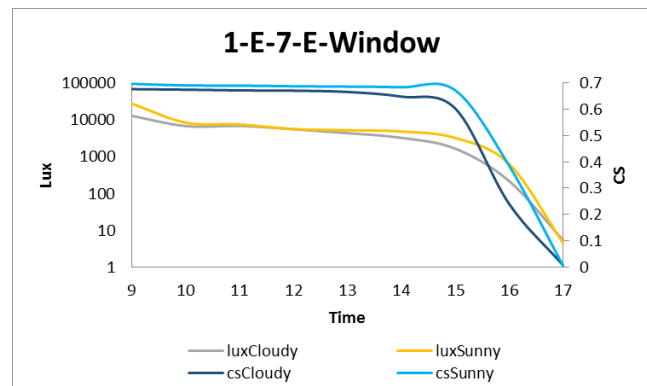
## 7<sup>TH</sup> FLOOR WING 1



Average Lux and CS

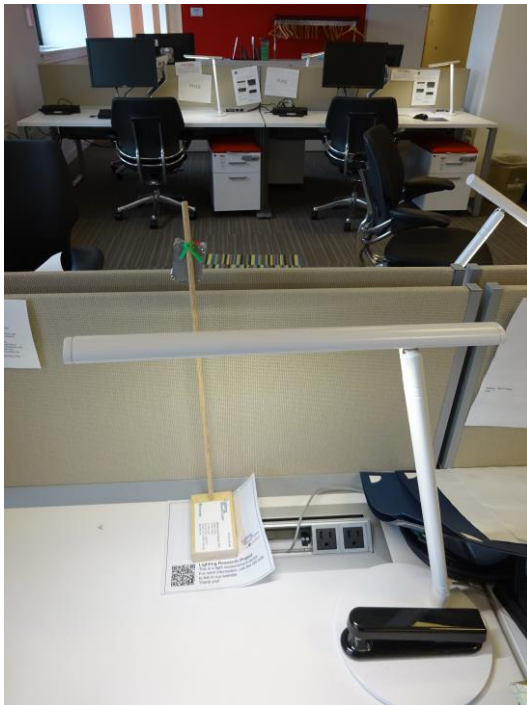


1-E-7-E-Window

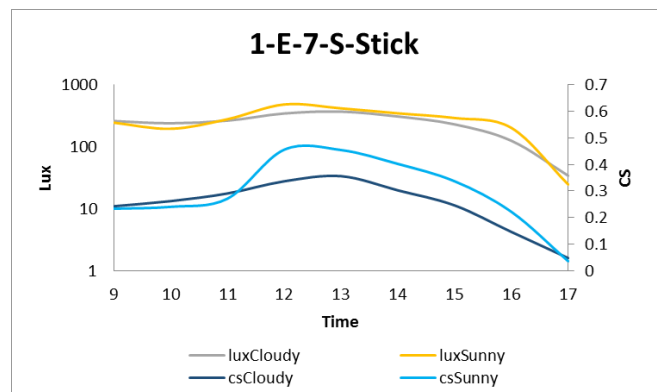


Daysimeter 205 – 1-E-7-E-Window. Mean photopic light level during working hours (08:00 am to 05:00 pm) was  $4596 \pm 4010$  lux on cloudy days. The mean CS value on was  $0.54 \pm 0.24$  on cloudy days. On sunny days mean photopic light level during working hours was  $6995 \pm 8232$  lux. The mean CS value on was  $0.58 \pm 0.24$  on sunny days.



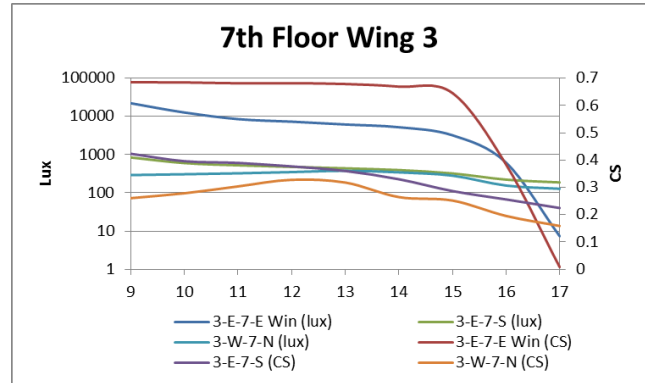
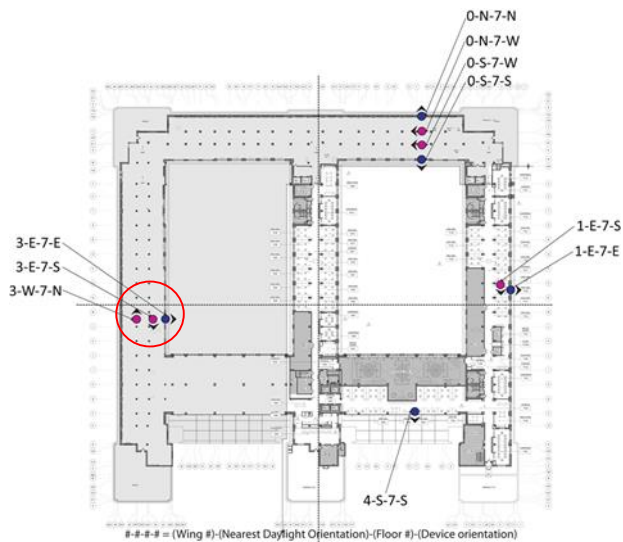


**1-E-7-S-Stick**



Daysimeter 187 – 1-E-7-S-Stick. Mean photopic light level during working hours (08:00 am to 05:00 pm) was  $241 \pm 105$  lux on cloudy days. The mean CS value on was  $0.25 \pm 0.10$  on cloudy days. On sunny days mean photopic light level during working hours was  $275 \pm 134$  lux. The mean CS value on was  $0.29 \pm 0.13$  on sunny days.

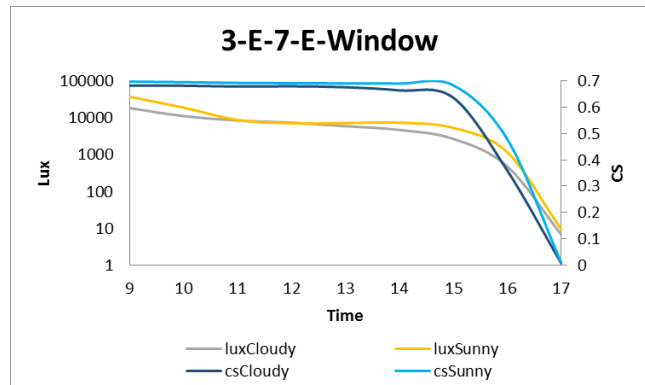
## 7<sup>TH</sup> FLOOR WING 3



Average Lux and CS



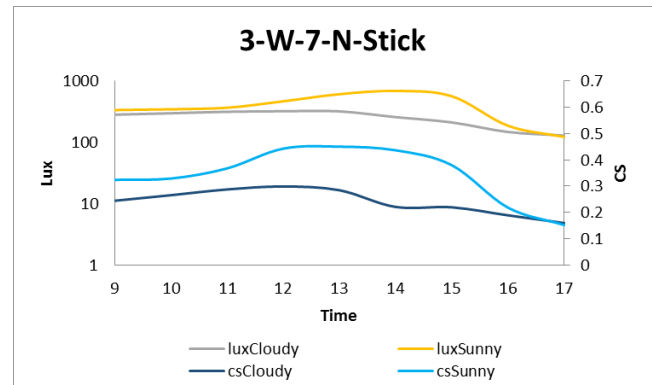
3-E-7-E-Window



Daysimeter 201 – 3-E-7-E-Window. Mean photopic light level during working hours (08:00 am to 05:00 pm) was  $6573 \pm 5755$  lux on cloudy days. The mean CS value on was  $0.56 \pm 0.23$  on cloudy days. On sunny days mean photopic light level during working hours was  $10323 \pm 11403$  lux. The mean CS value on was  $0.59 \pm 0.23$  on sunny days.



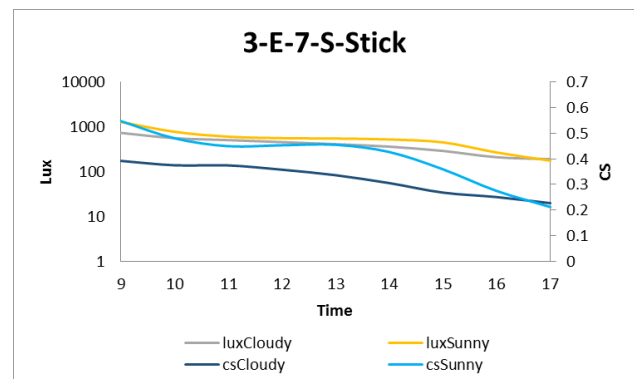
**3-W-7-N-Stick**



Daysimeter 197 – 3-W-7-N-Stick. Mean photopic light level during working hours (08:00 am to 05:00 pm) was  $254 \pm 74$  lux on cloudy days. The mean CS value on was  $0.24 \pm 0.05$  on cloudy days. On sunny days mean photopic light level during working hours was  $409 \pm 190$  lux. The mean CS value on was  $0.34 \pm 0.10$  on sunny days.

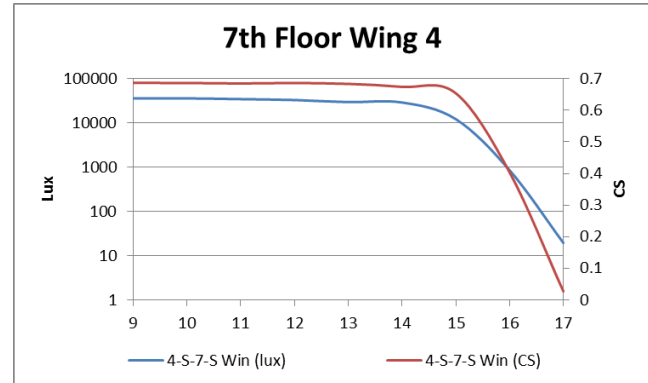
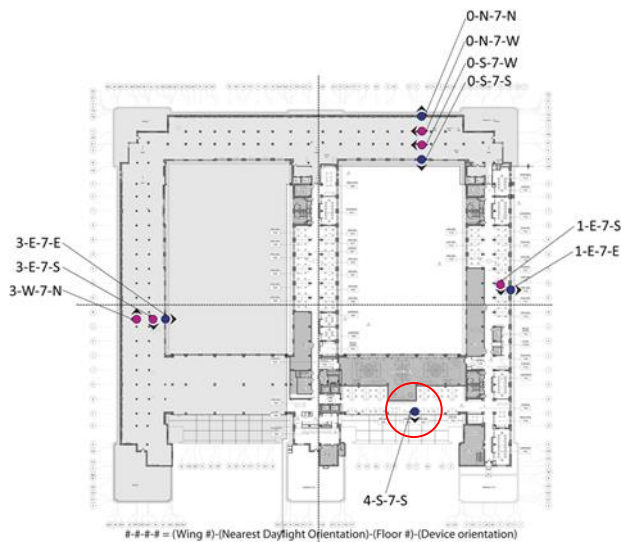


**3-E-7-S-Stick**



Daysimeter 188 – 3-E-7-S-Stick. Mean photopic light level during working hours (08:00 am to 05:00 pm) was  $413 \pm 174$  lux on cloudy days. The mean CS value on was  $0.32 \pm 0.06$  on cloudy days. On sunny days mean photopic light level during working hours was  $577 \pm 320$  lux. The mean CS value on was  $0.41 \pm 0.11$  on sunny days.

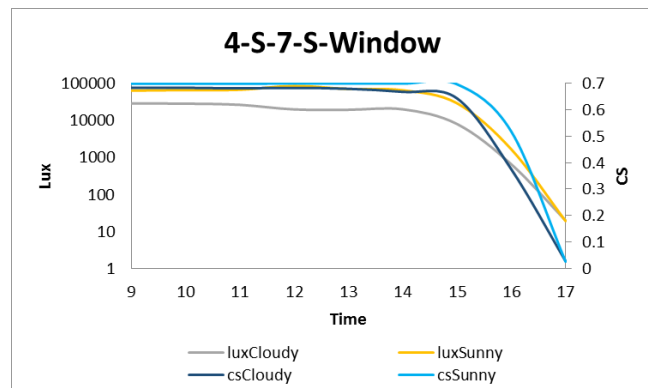
## 7<sup>TH</sup> FLOOR WING 4



Average Lux and CS

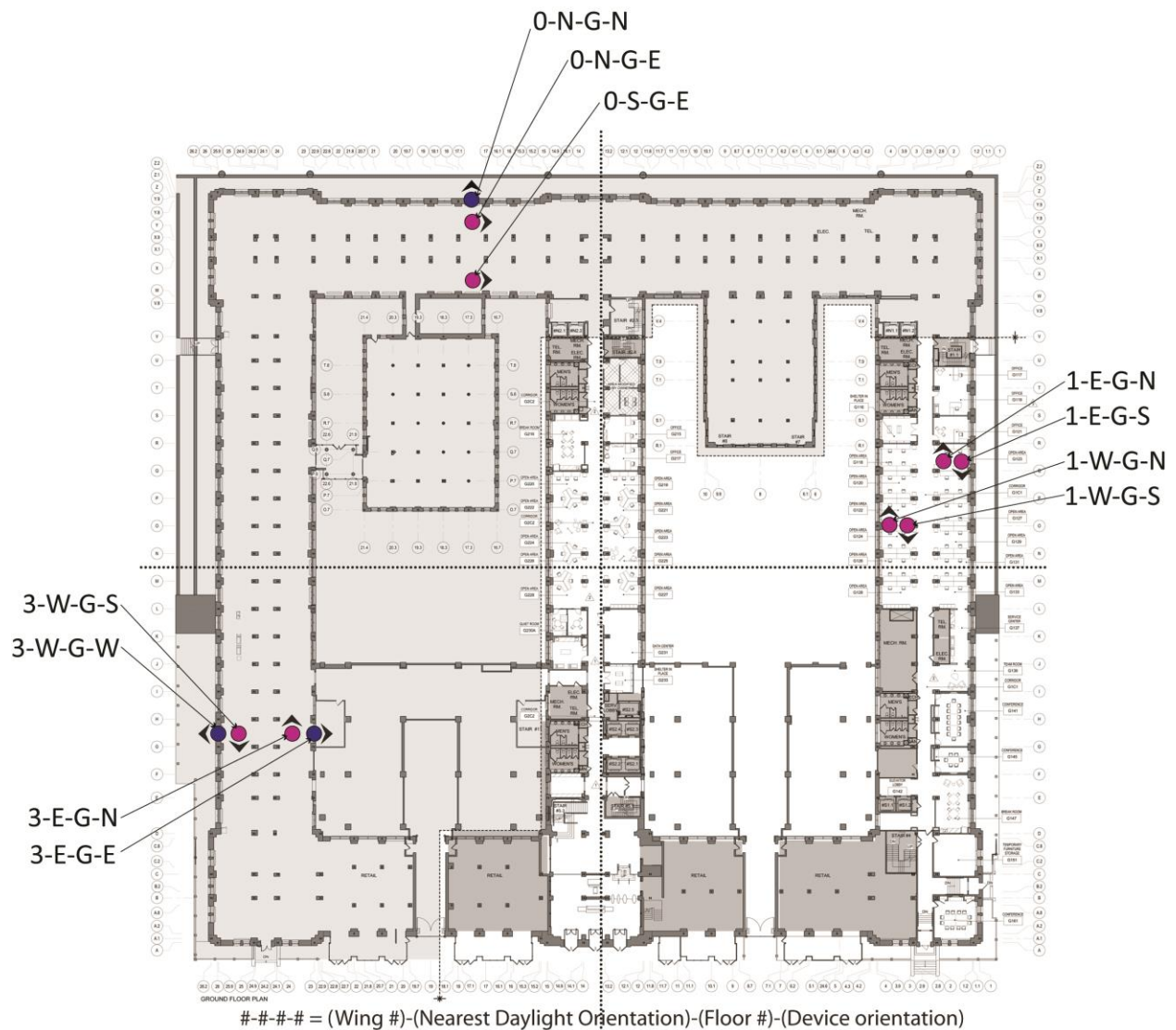


4-S-7-S-Window



Daysimeter 183 – 4-S-7-S-Window. Mean photopic light level during working hours (08:00 am to 05:00 pm) was  $16748 \pm 11205$  lux on cloudy days. The mean CS value on was  $0.57 \pm 0.23$  on cloudy days. On sunny days mean photopic light level during working hours was  $49751 \pm 31387$  lux. The mean CS value on was  $0.60 \pm 0.22$  on sunny days.

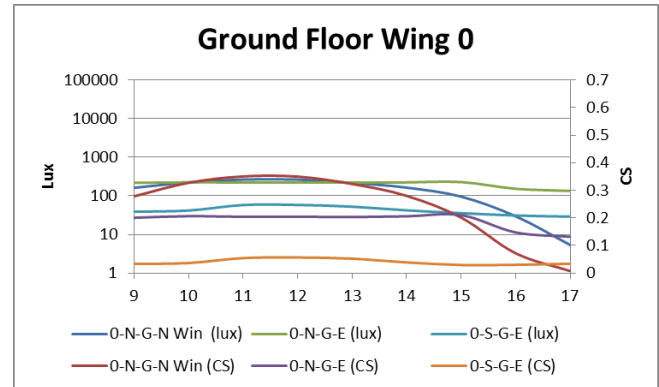
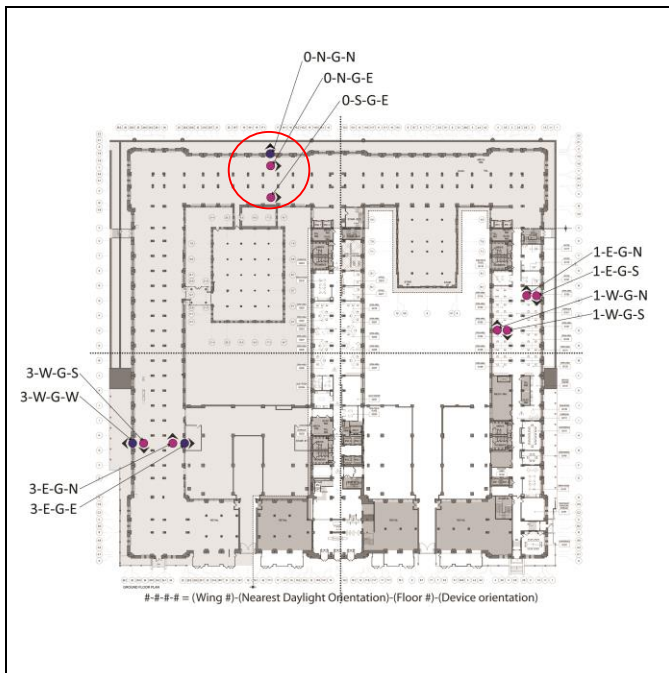
## APPENDIX L: PHOTOMETRIC DATA FOR GROUND FLOOR STATIONARY DEVICES MOUNTED ON STICKS AND IN WINDOWS HOLIDAYS INCLUDED (DECEMBER 4, 2014 – JANUARY 4, 2015)



*Location where measurements were collected.*



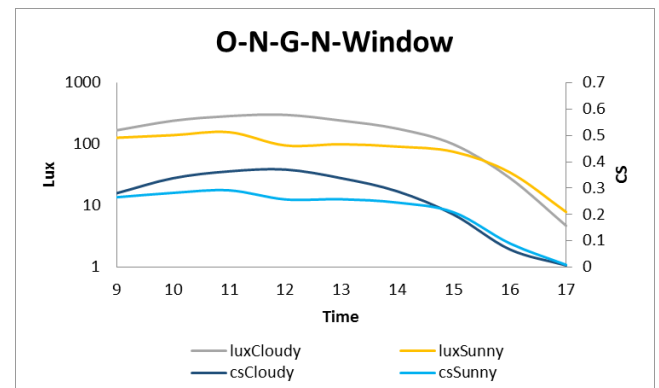
## GROUND FLOOR WING 0



Average Lux and CS



O-N-G-N-Window

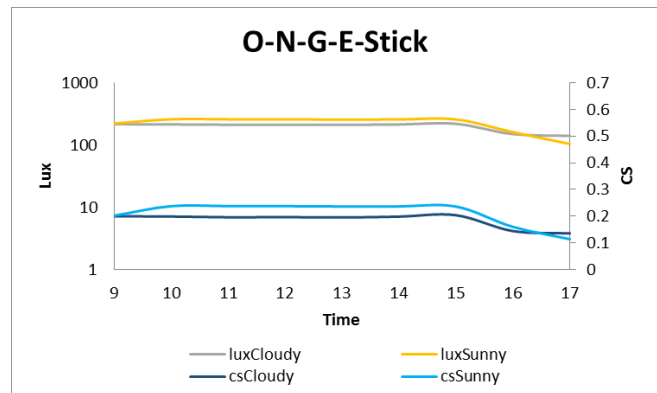


Daysimeter 207 – O-N-G-N-Window. Mean photopic light level during working hours (08:00 am to 05:00 pm) was  $173 \pm 109$  lux on cloudy days. The mean CS value on was  $0.25 \pm 0.13$  on cloudy days. On sunny days mean photopic light level during working hours was  $93 \pm 48$  lux. The mean CS value on was  $0.21 \pm 0.10$  on sunny days.

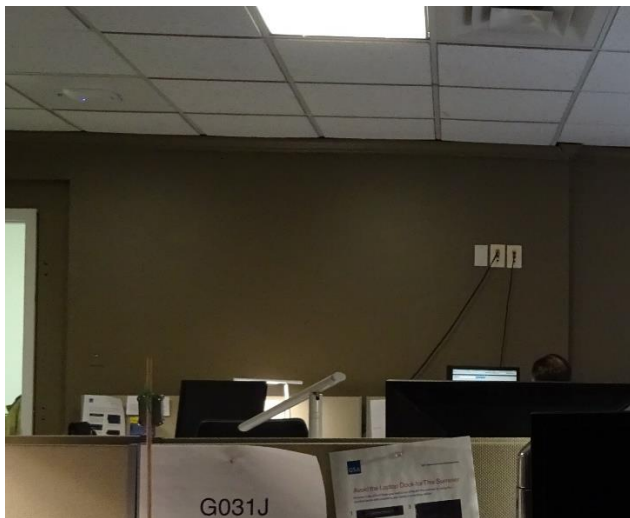




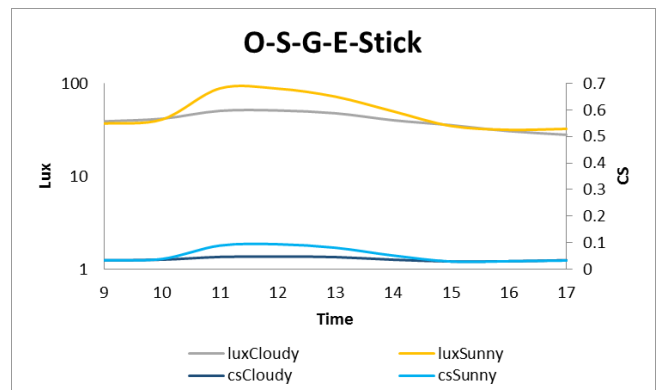
**O-N-G-E-Stick**



Daysimeter 172 – O-N-G-E-Stick. Mean photopic light level during working hours (08:00 am to 05:00 pm) was  $199 \pm 31$  lux on cloudy days. The mean CS value on was  $0.19 \pm 0.03$  on cloudy days. On sunny days mean photopic light level during working hours was  $227 \pm 56$  lux. The mean CS value on was  $0.21 \pm 0.05$  on sunny days.

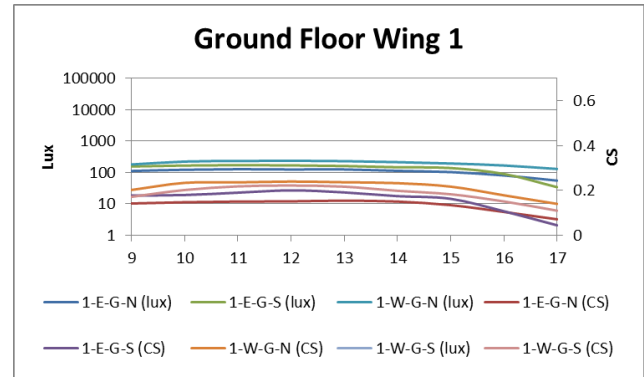


**O-S-G-E-Stick**



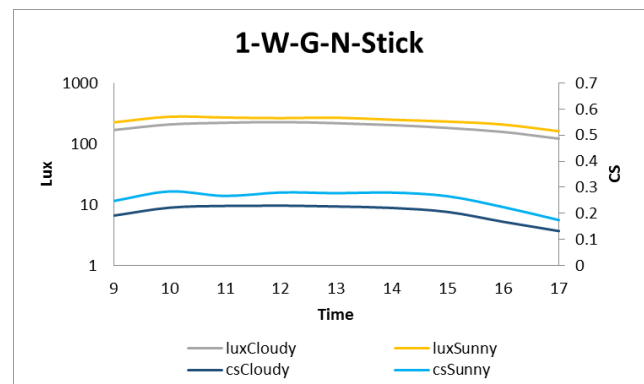
Daysimeter 177 – O-S-G-E-Stick. Mean photopic light level during working hours (08:00 am to 05:00 pm) was  $41 \pm 8$  lux on cloudy days. The mean CS value on was  $0.04 \pm 0.01$  on cloudy days. On sunny days mean photopic light level during working hours was  $53 \pm 24$  lux. The mean CS value on was  $0.05 \pm 0.03$  on sunny days.

## GROUND FLOOR WING 1



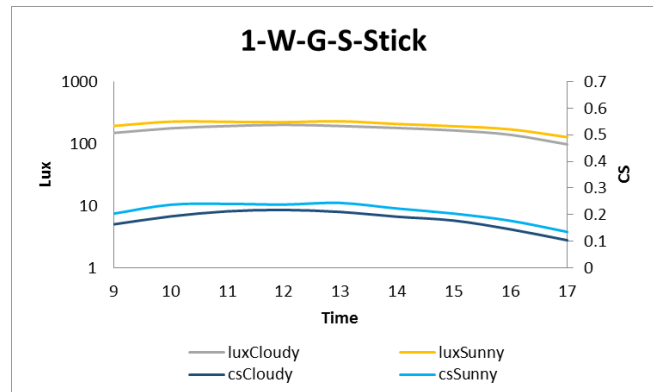
Average Lux and CS

(Photo not taken)



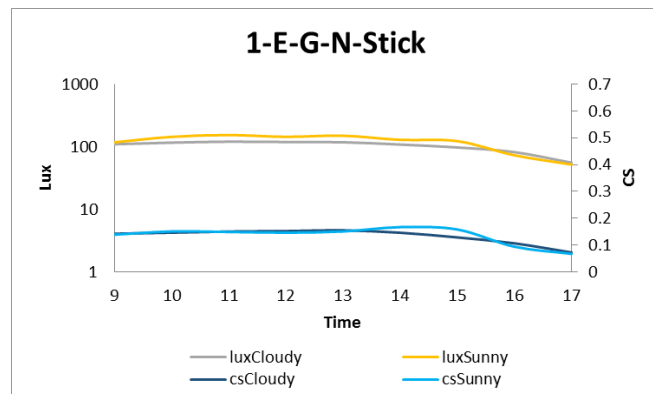
Daysimeter 010 – 1-W-G-N-Stick. Mean photopic light level during working hours (08:00 am to 05:00 pm) was  $191 \pm 36$  lux on cloudy days. The mean CS value on was  $0.20 \pm 0.03$  on cloudy days. On sunny days mean photopic light level during working hours was  $241 \pm 38$  lux. The mean CS value on was  $0.26 \pm 0.04$  on sunny days.

(Photo not taken)



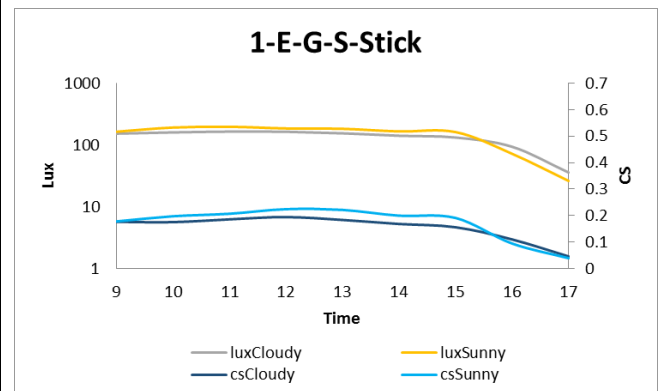
Daysimeter 190 – 1-W-G-S-Stick. Mean photopic light level during working hours (08:00 am to 05:00 pm) was  $166 \pm 33$  lux on cloudy days. The mean CS value on was  $0.18 \pm 0.04$  on cloudy days. On sunny days mean photopic light level during working hours was  $200 \pm 34$  lux. The mean CS value on was  $0.21 \pm 0.04$  on sunny days.

(Photo not taken)



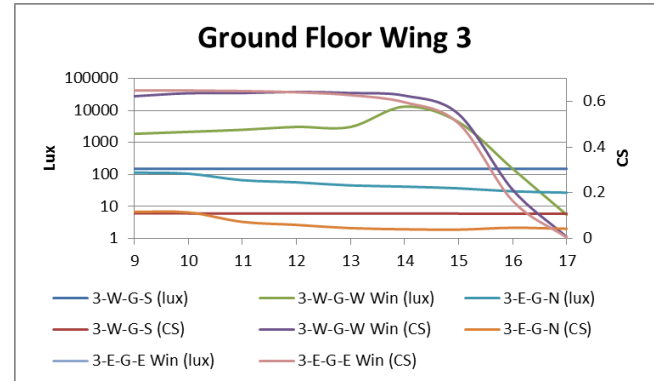
Daysimeter 024 – 1-E-G-N-Stick. Mean photopic light level during working hours (08:00 am to 05:00 pm) was  $103 \pm 22$  lux on cloudy days. The mean CS value on was  $0.13 \pm 0.03$  on cloudy days. On sunny days mean photopic light level during working hours was  $121 \pm 36$  lux. The mean CS value on was  $0.14 \pm 0.03$  on sunny days.

*(Photo not taken)*



Daysimeter 028 – 1-E-G-S-Stick. Mean photopic light level during working hours (08:00 am to 05:00 pm) was  $134 \pm 43$  lux on cloudy days. The mean CS value on was  $0.16 \pm 0.05$  on cloudy days. On sunny days mean photopic light level during working hours was  $150 \pm 60$  lux. The mean CS value on was  $0.17 \pm 0.06$  on sunny days.

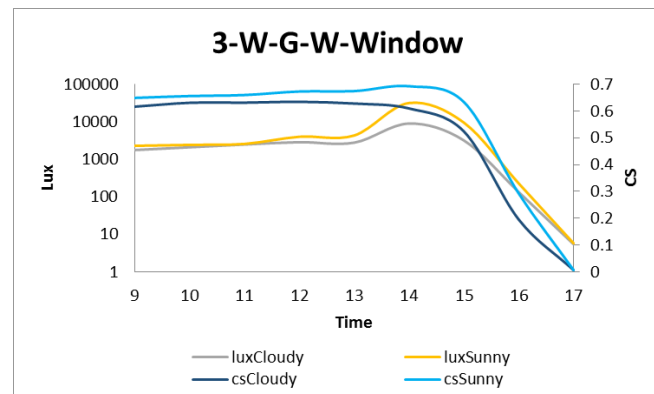
## GROUND FLOOR WING 3



Average Lux and CS



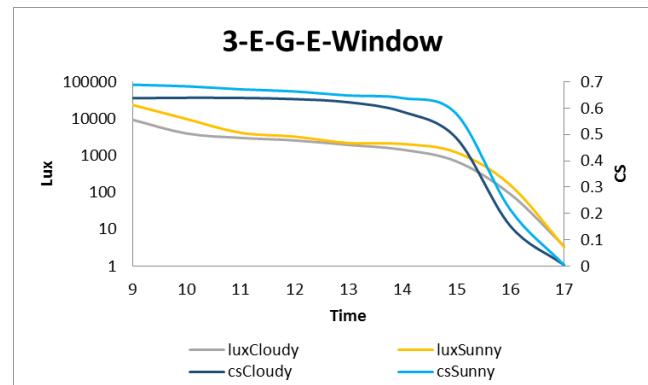
3-W-G-W-Window



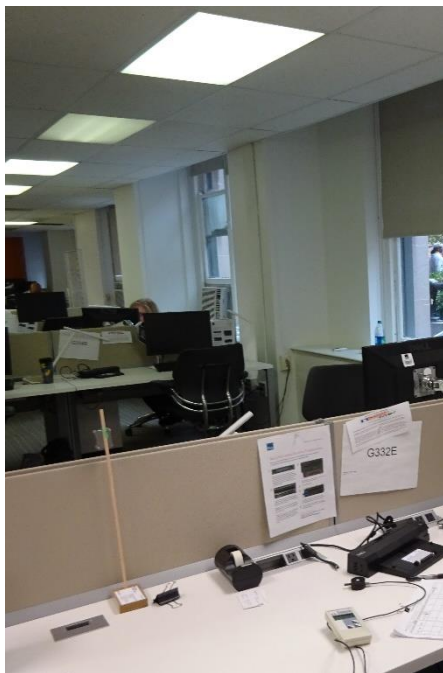
Daysimeter 210 – 3-W-G-W-Window. Mean photopic light level during working hours (08:00 am to 05:00 pm) was  $2705 \pm 2628$  lux on cloudy days. The mean CS value on was  $0.50 \pm 0.23$  on cloudy days. On sunny days mean photopic light level during working hours was  $6348 \pm 9922$  lux. The mean CS value on was  $0.55 \pm 0.24$  on sunny days.



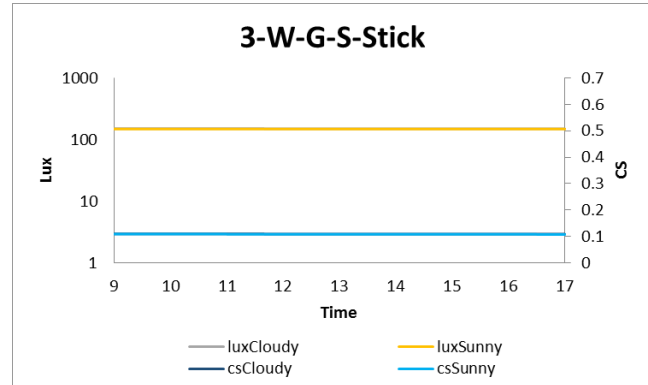
**3-E-G-E-Window**



Daysimeter 208 – 3-E-G-E-Window. Mean photopic light level during working hours (08:00 am to 05:00 pm) was  $2574 \pm 2876$  lux on cloudy days. The mean CS value on was  $0.49 \pm 0.24$  on cloudy days. On sunny days mean photopic light level during working hours was  $5189 \pm 7550$  lux. The mean CS value on was  $0.53 \pm 0.25$  on sunny days.

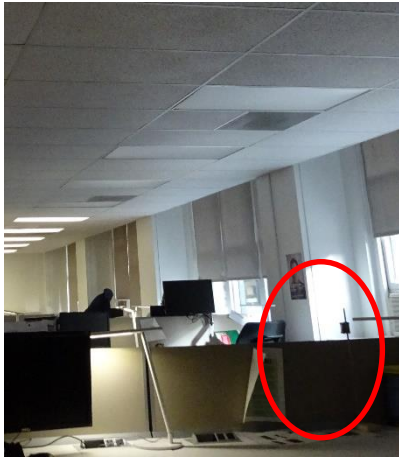


**3-W-G-S-Stick**

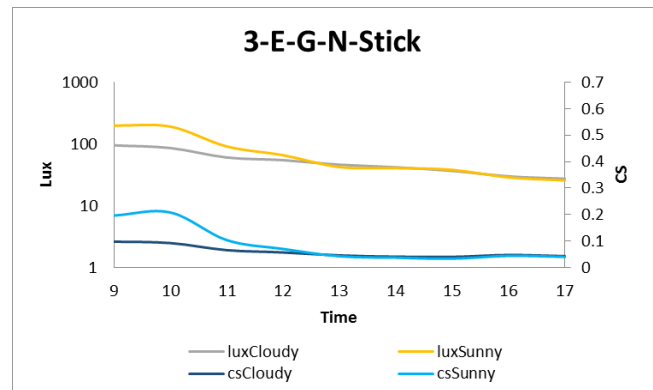


Daysimeter 170 – 3-W-G-S-Stick. Mean photopic light level during working hours (08:00 am to 05:00 pm) was  $151 \pm 0.5$  lux on cloudy days. The mean CS value on was  $0.11 \pm 0.0005$  on cloudy days. On sunny days mean photopic light level during working hours was  $149 \pm 0.1$  lux. The mean CS value on was  $0.11 \pm 0.0005$  on sunny days.





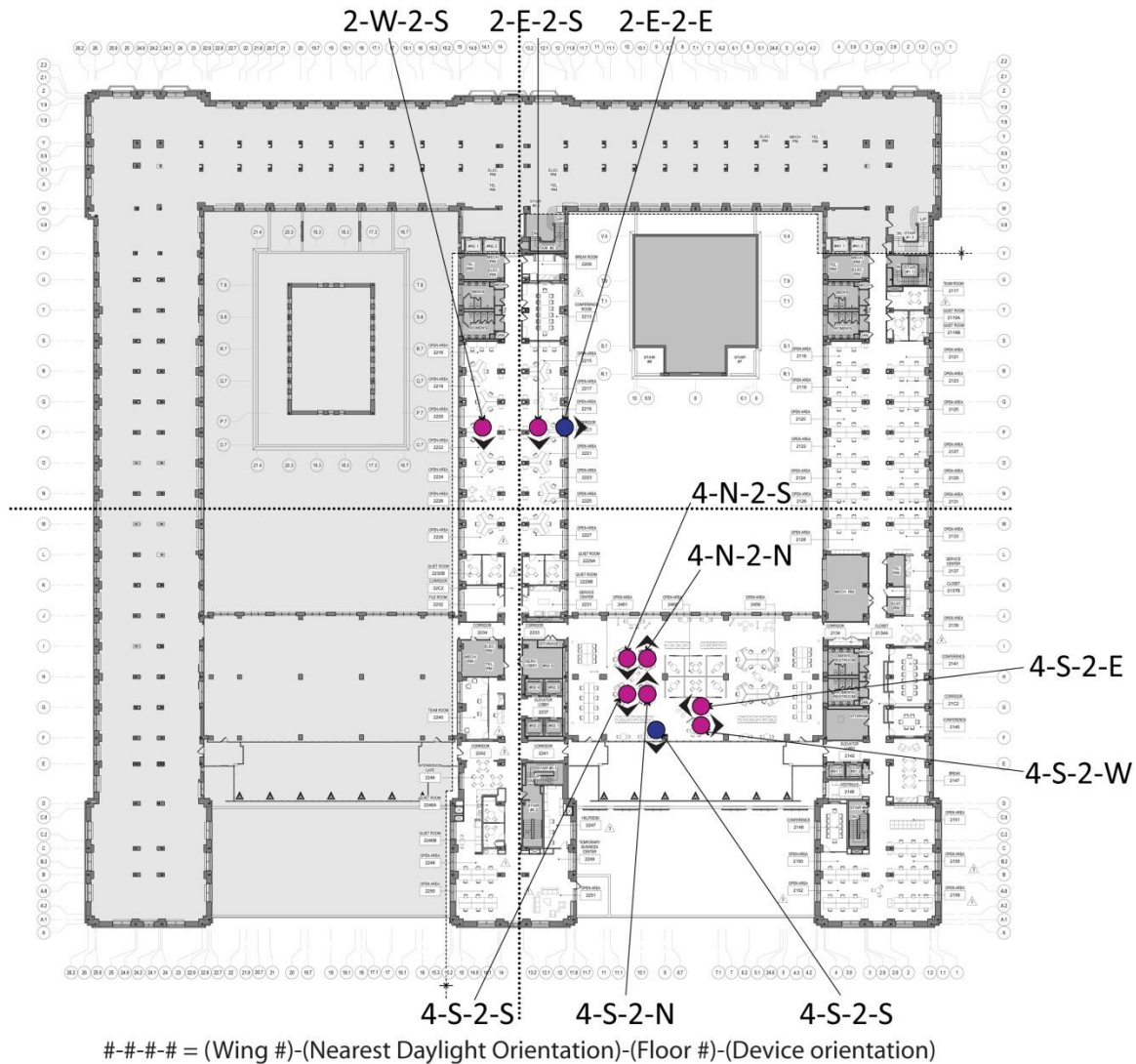
**3-E-G-N-Stick**



Daysimeter 179 – 3-E-G-N-Stick. Mean photopic light level during working hours (08:00 am to 05:00 pm) was  $53 \pm 24$  lux on cloudy days. The mean CS value on was  $0.06 \pm 0.02$  on cloudy days. On sunny days mean photopic light level during working hours was  $81 \pm 68$  lux. The mean CS value on was  $0.09 \pm 0.07$  on sunny days.

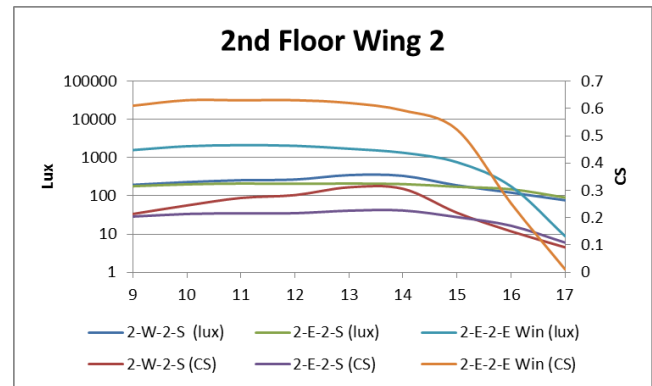
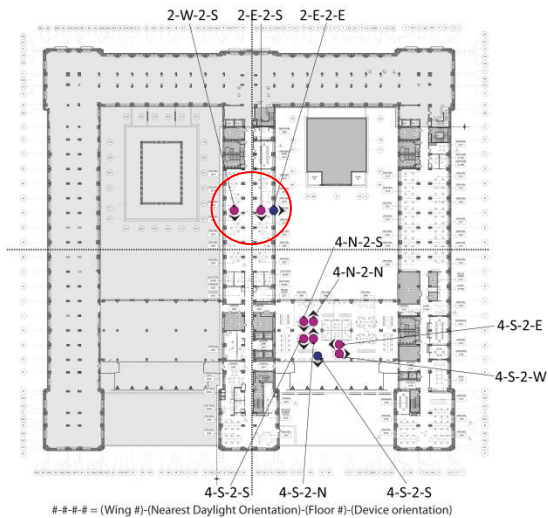
## APPENDIX M: PHOTOMETRIC DATA FOR 2<sup>ND</sup> FLOOR STATIONARY DEVICES MOUNTED ON STICKS AND IN WINDOWS

HOLIDAYS INCLUDED (DECEMBER 4, 2014 – JANUARY 4, 2015)

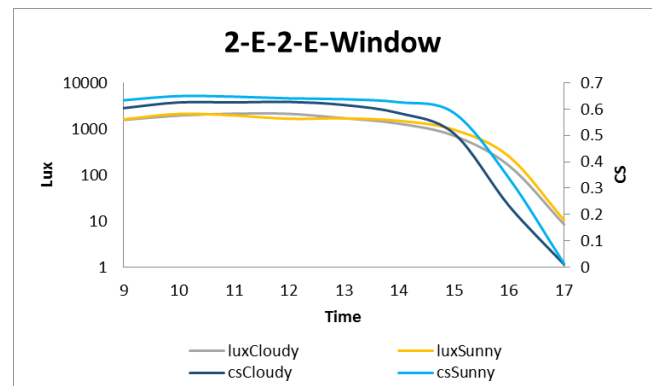


*Location where measurements were collected.*

## 2<sup>ND</sup> FLOOR WING 2

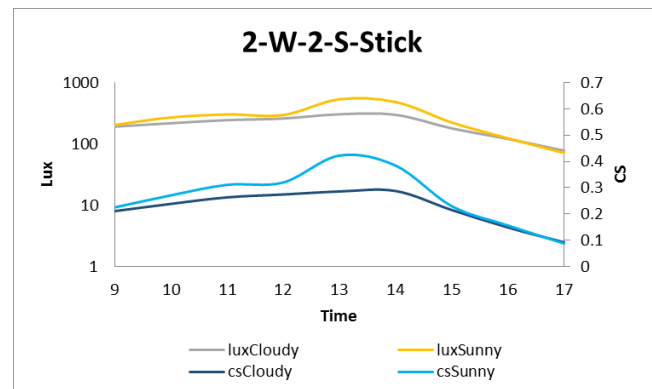


**2-E-2-E-Window**



Daysimeter 200 – 2-E-2-E-Window. Mean photopic light level during working hours (08:00 am to 05:00 pm) was  $1303 \pm 823$  lux on cloudy days. The mean CS value on was  $0.49 \pm 0.22$  on cloudy days. On sunny days mean photopic light level during working hours was  $1314 \pm 746$  lux. The mean CS value on was  $0.53 \pm 0.22$  on sunny days.

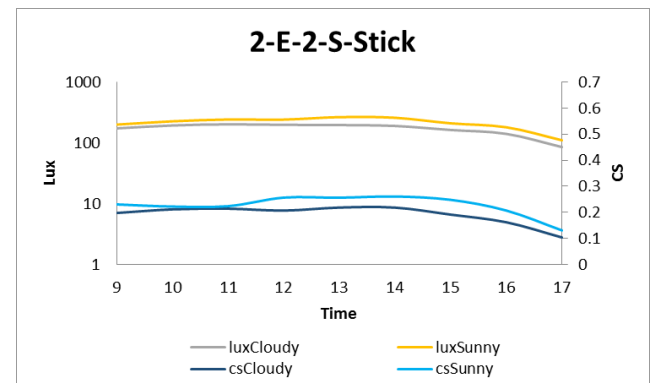
(No photo taken)



Daysimeter 173 – 2-W-2-S-Stick. Mean photopic light level during working hours (08:00 am to 05:00 pm) was  $211 \pm 77$  lux on cloudy days. The mean CS value on was  $0.22 \pm 0.07$  on cloudy days. On sunny days mean photopic light level during working hours was  $280 \pm 153$  lux. The mean CS value on was  $0.27 \pm 0.11$  on sunny days.

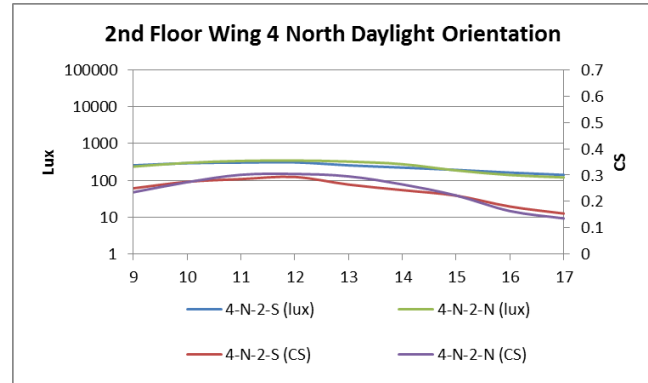
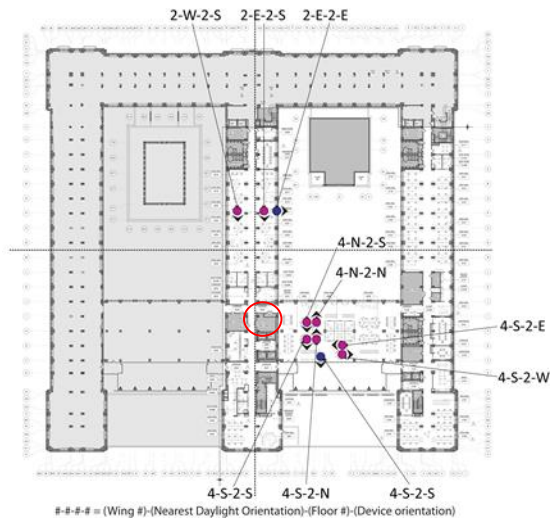


2-E-2-S-Stick



Daysimeter 171 – 2-E-2-S-Stick. Mean photopic light level during working hours (08:00 am to 05:00 pm) was  $172 \pm 38$  lux on cloudy days. The mean CS value on was  $0.19 \pm 0.04$  on cloudy days. On sunny days mean photopic light level during working hours was  $216 \pm 48$  lux. The mean CS value on was  $0.23 \pm 0.04$  on sunny days.

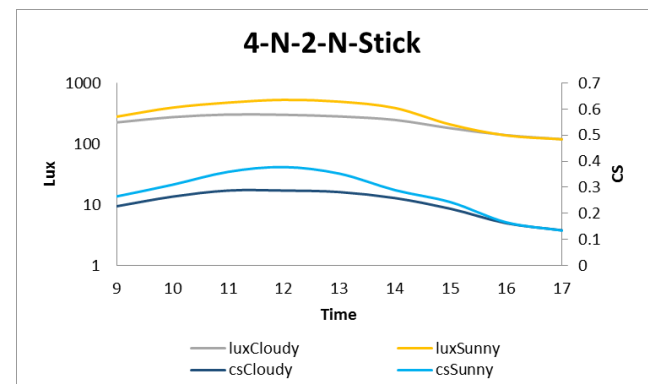
## 2<sup>ND</sup> FLOOR WING 4



**Average Lux and CS**



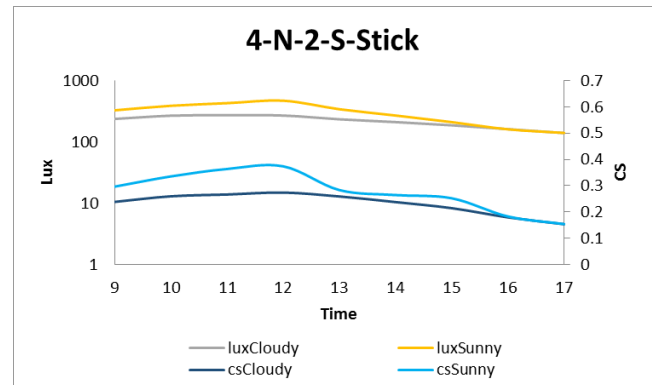
**4-N-2-N-Stick**



Daysimeter 176 – 4-N-2-N-Stick. Mean photopic light level during working hours (08:00 am to 05:00 pm) was  $231 \pm 70$  lux on cloudy days. The mean CS value on was  $0.24 \pm 0.06$  on cloudy days. On sunny days mean photopic light level during working hours was  $338 \pm 157$  lux. The mean CS value on was  $0.28 \pm 0.09$  on sunny days.

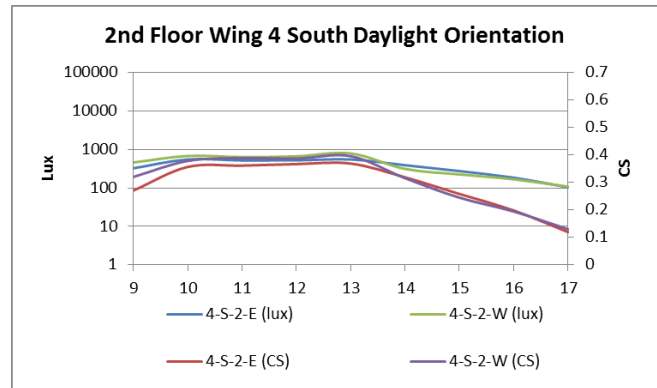
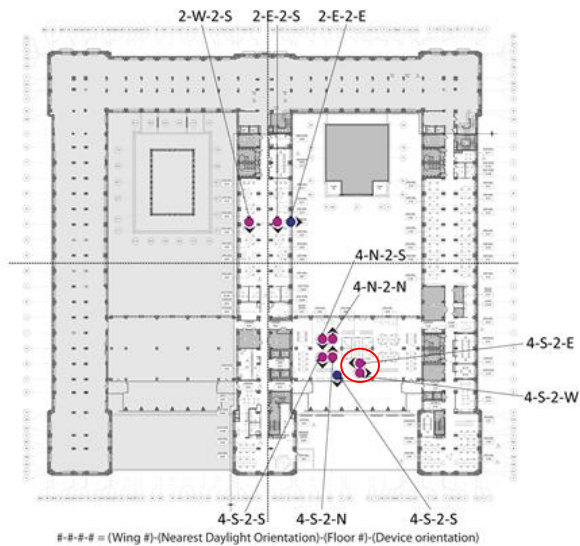


**4-N-2-S-Stick**



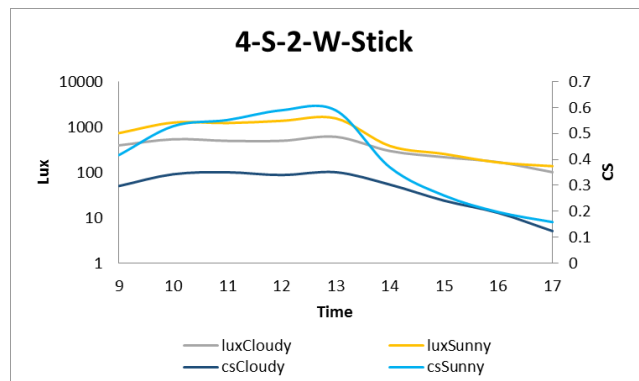
Daysimeter 174 – 4-N-2-S-Stick. Mean photopic light level during working hours (08:00 am to 05:00 pm) was  $221 \pm 49$  lux on cloudy days. The mean CS value on was  $0.23 \pm 0.04$  on cloudy days. On sunny days mean photopic light level during working hours was  $306 \pm 118$  lux. The mean CS value on was  $0.28 \pm 0.08$  on sunny days.





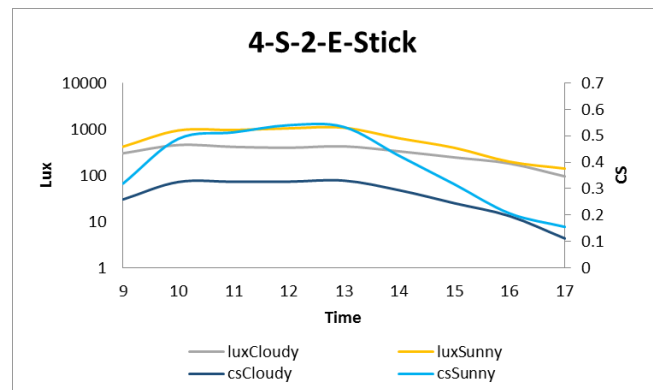
Average Lux and CS

(Photo not taken)

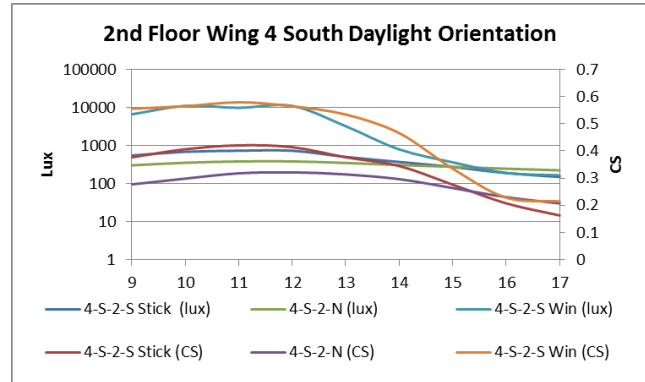
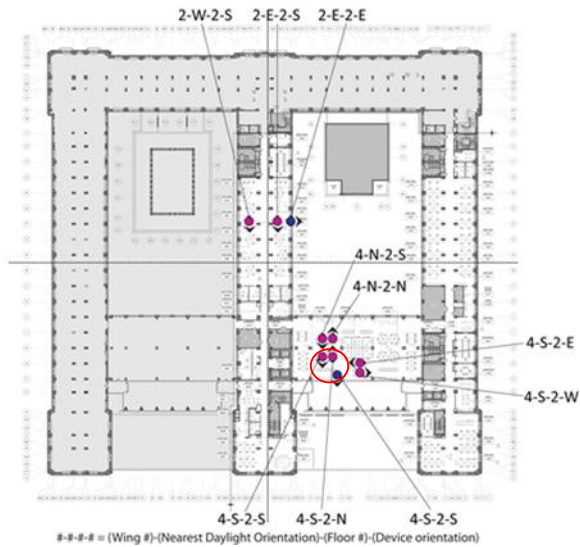


Daysimeter 181 – 4-S-2-W-Stick. Mean photopic light level during working hours (08:00 am to 05:00 pm) was  $370 \pm 181$  lux on cloudy days. The mean CS value on was  $0.28 \pm 0.08$  on cloudy days. On sunny days mean photopic light level during working hours was  $789 \pm 571$  lux. The mean CS value on was  $0.41 \pm 0.17$  on sunny days.

(Photo not taken)



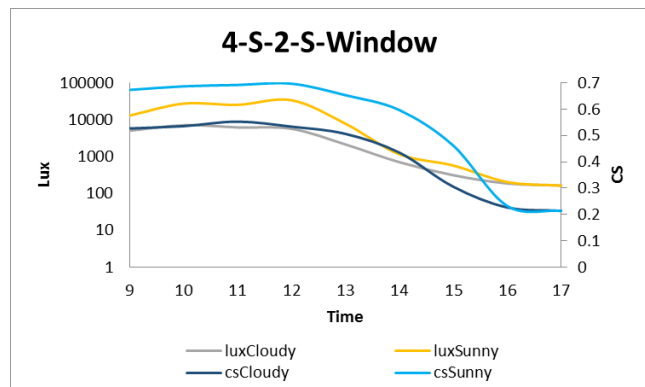
Daysimeter 169 – 4-S-2-E-Stick. Mean photopic light level during working hours (08:00 am to 05:00 pm) was  $318 \pm 123$  lux on cloudy days. The mean CS value on was  $0.27 \pm 0.07$  on cloudy days. On sunny days mean photopic light level during working hours was  $649 \pm 373$  lux. The mean CS value on was  $0.39 \pm 0.15$  on sunny days.



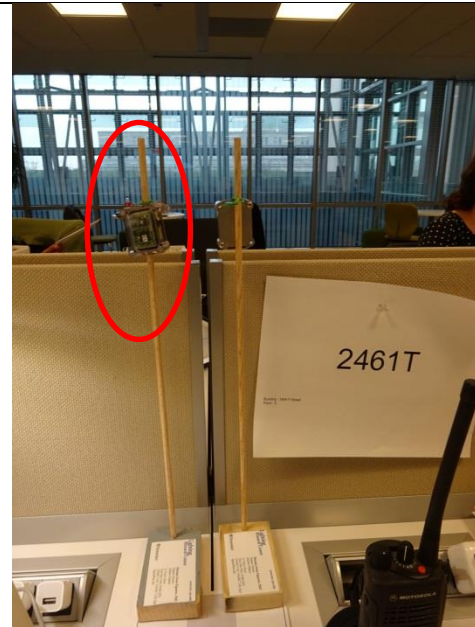
Average Lux and CS



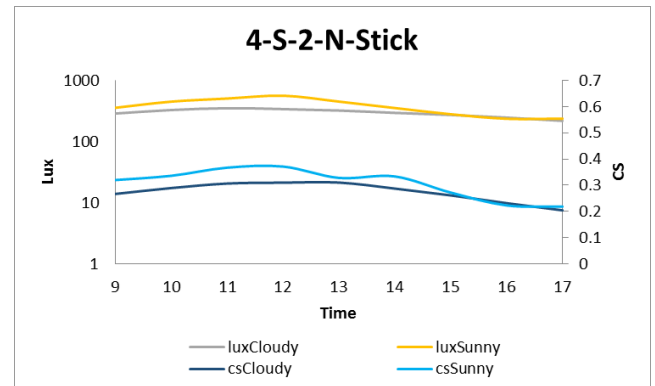
4-S-2-S-Window



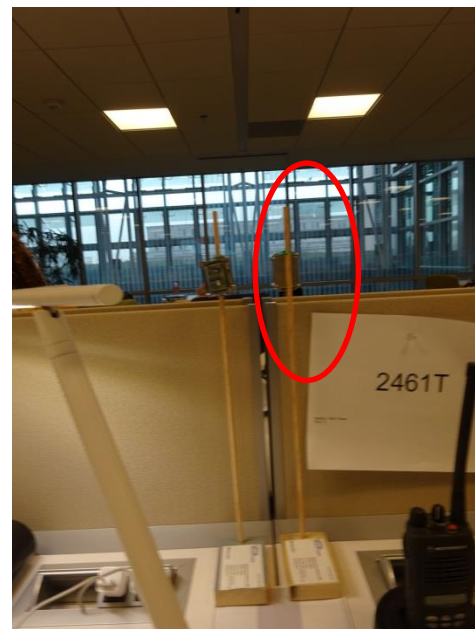
Daysimeter 206 - 4-S-2-S-Window. Mean photopic light level during working hours (08:00 am to 05:00 pm) was  $3070 \pm 2917$  lux on cloudy days. The mean CS value on was  $0.43 \pm 0.14$  on cloudy days. On sunny days mean photopic light level during working hours was  $12220 \pm 13465$  lux. The mean CS value on was  $0.55 \pm 0.20$  on sunny days.



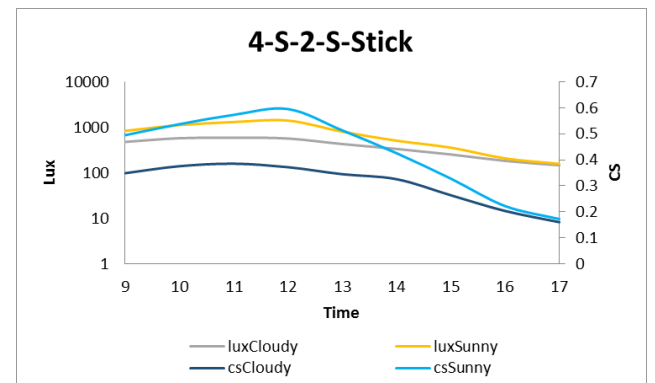
4-S-2-N-Stick



Daysimeter 013 – 4-S-2-N-Stick. Mean photopic light level during working hours (08:00 am to 05:00 pm) was  $297 \pm 45$  lux on cloudy days. The mean CS value on was  $0.27 \pm 0.04$  on cloudy days. On sunny days mean photopic light level during working hours was  $383 \pm 119$  lux. The mean CS value on was  $0.31 \pm 0.06$  on sunny days.



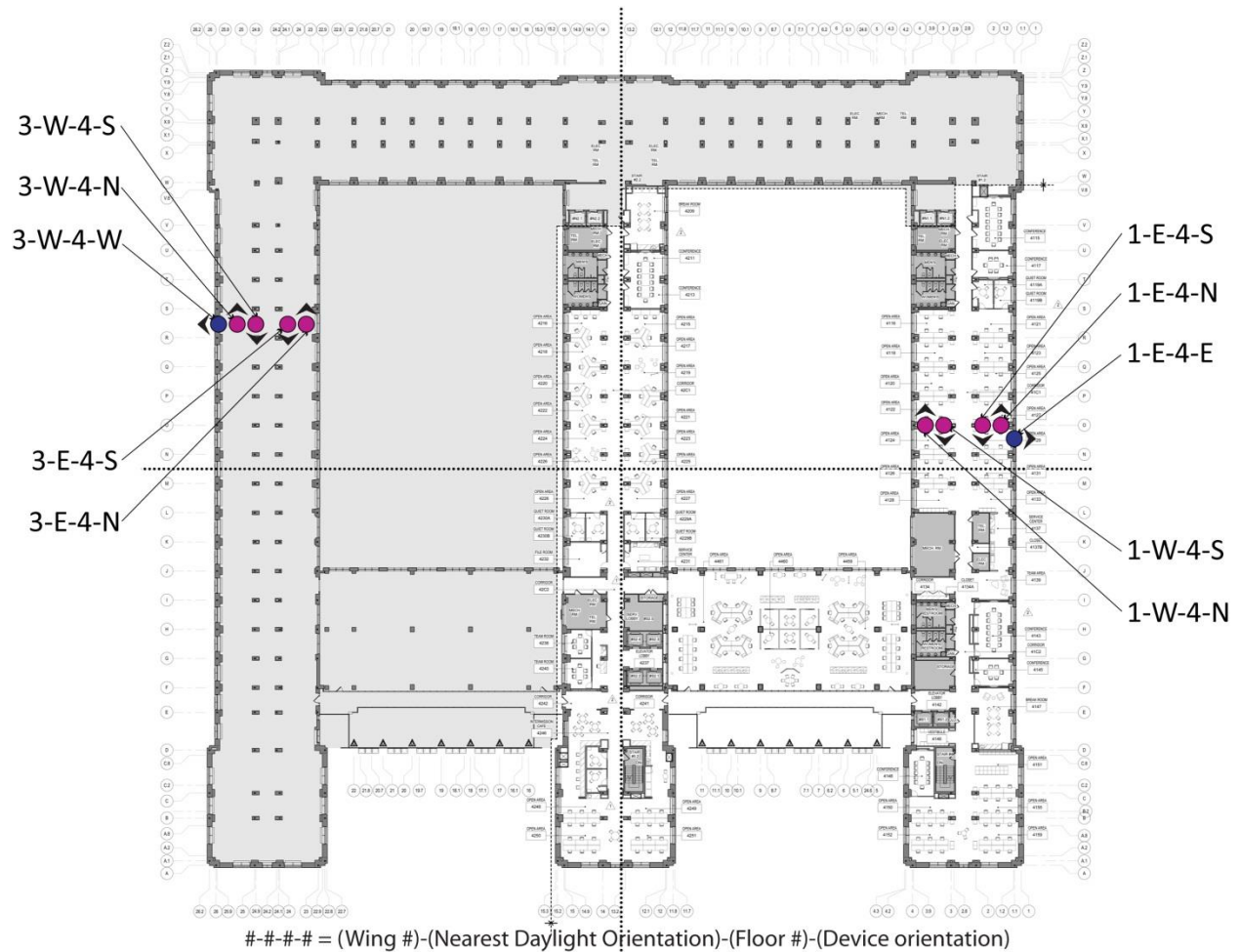
4-S-2-S-Stick



Daysimeter 182 – 4-S-2-S-Stick. Mean photopic light level during working hours (08:00 am to 05:00 pm) was  $398 \pm 174$  lux on cloudy days. The mean CS value on was  $0.31 \pm 0.08$  on cloudy days. On sunny days mean photopic light level during working hours was  $749 \pm 470$  lux. The mean CS value on was  $0.43 \pm 0.15$  on sunny days.

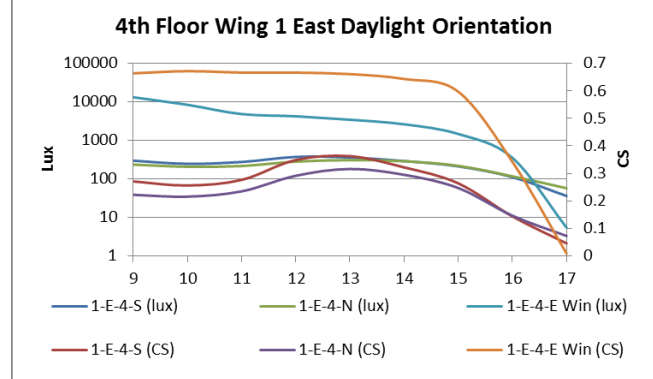
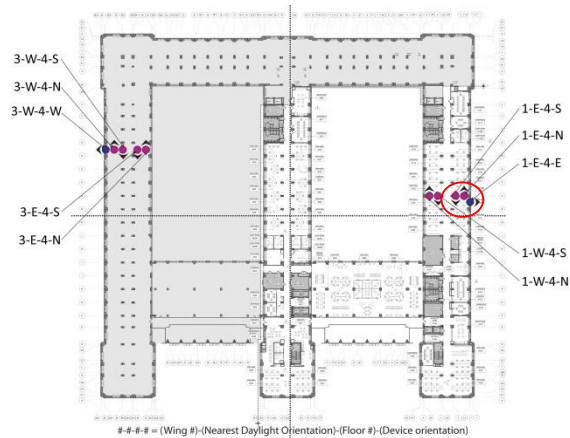
## APPENDIX N: PHOTOMETRIC DATA FOR 4<sup>TH</sup> FLOOR STATIONARY DEVICES MOUNTED ON STICKS AND IN WINDOWS

HOLIDAYS INCLUDED (DECEMBER 4, 2014 – JANUARY 4, 2015)



*Location where measurements were collected.*

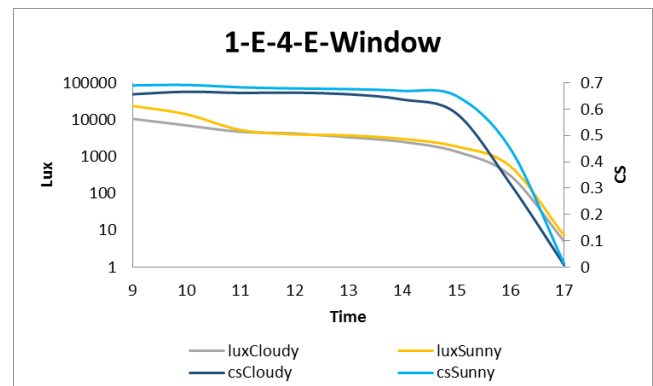
## 4<sup>TH</sup> FLOOR WING 1



**Average Lux and CS**

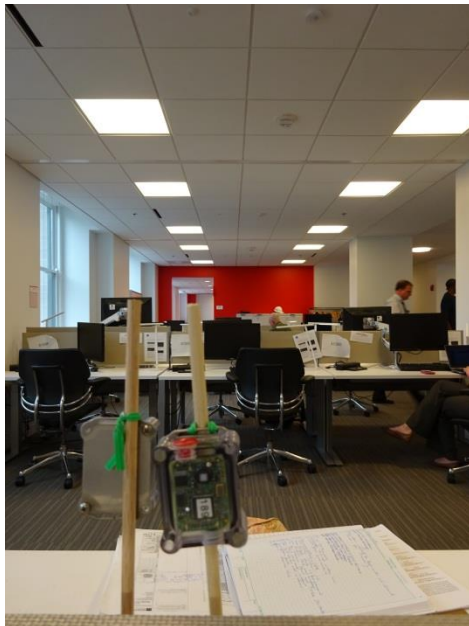


**1-E-4-E-Window**

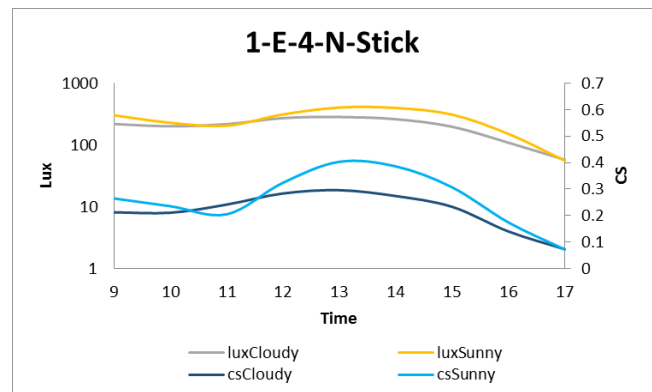


Daysimeter 203 – 1-E-4-E-Window. Mean photopic light level during working hours (08:00 am to 05:00 pm) was  $3797 \pm 3391$  lux on cloudy days. The mean CS value on was  $0.54 \pm 0.23$  on cloudy days. On sunny days mean photopic light level during working hours was  $6279 \pm 7790$  lux. The mean CS value on was  $0.58 \pm 0.23$  on sunny days.

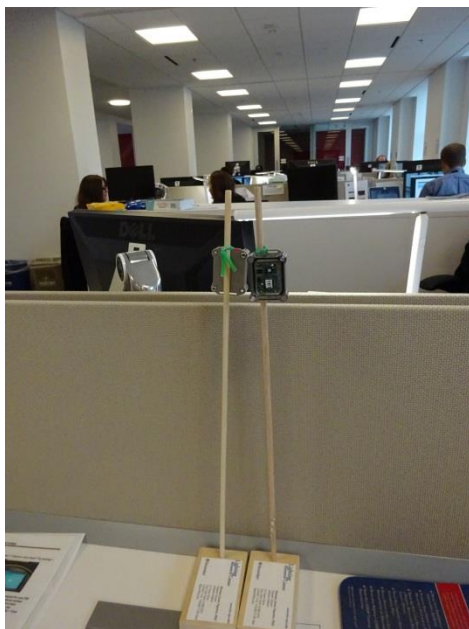




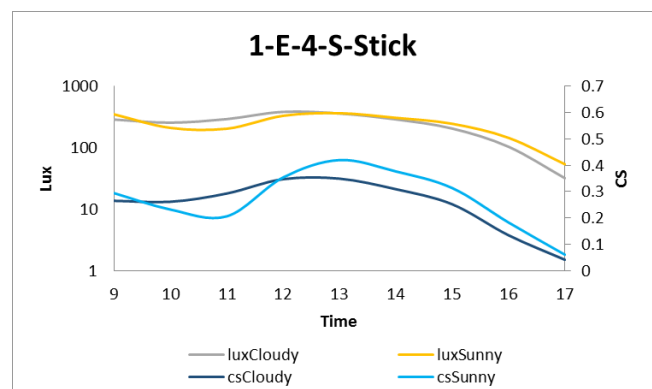
**1-E-4-N-Stick**



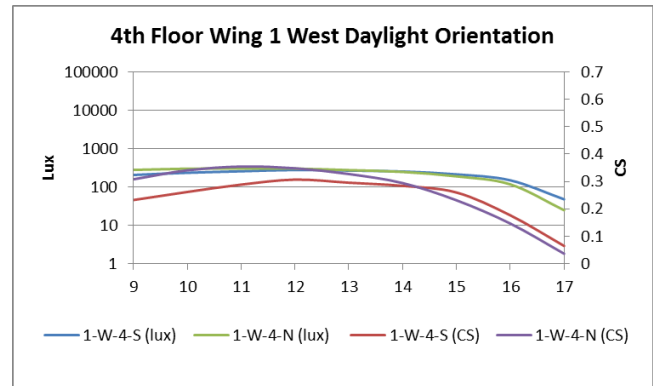
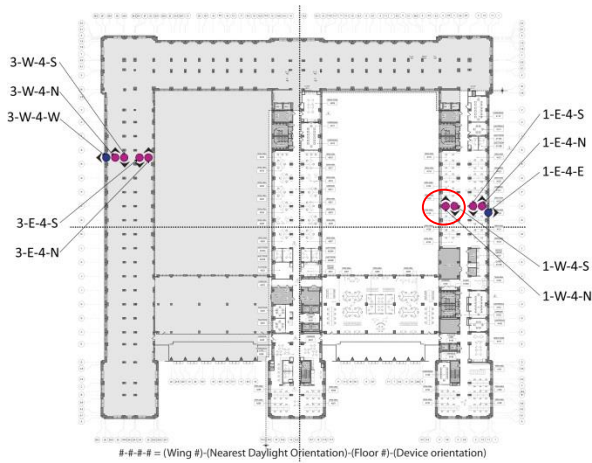
Daysimeter 189 – 1-E-4-N-Stick. Mean photopic light level during working hours (08:00 am to 05:00 pm) was  $203 \pm 76$  lux on cloudy days. The mean CS value on was  $0.22 \pm 0.07$  on cloudy days. On sunny days mean photopic light level during working hours was  $264 \pm 115$  lux. The mean CS value on was  $0.26 \pm 0.11$  on sunny days.



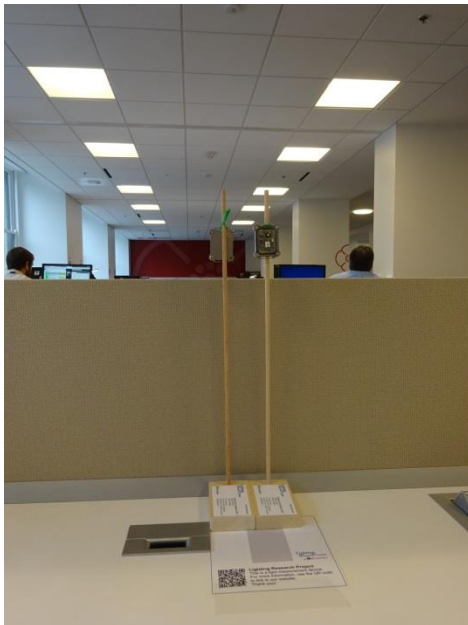
**1-E-4-S-Stick**



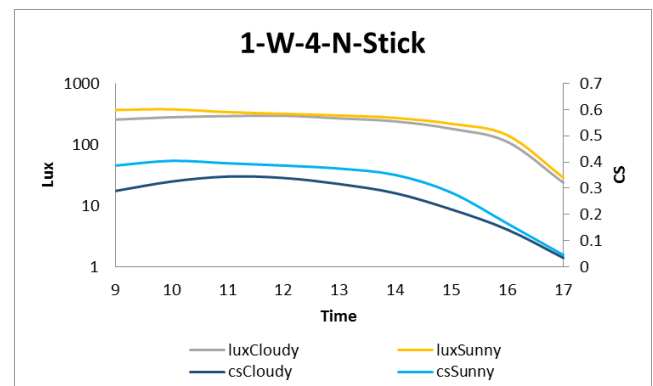
Daysimeter 167 – 1-E-4-S-Stick. Mean photopic light level during working hours (08:00 am to 05:00 pm) was  $245 \pm 114$  lux on cloudy days. The mean CS value on was  $0.25 \pm 0.10$  on cloudy days. On sunny days mean photopic light level during working hours was  $245 \pm 103$  lux. The mean CS value on was  $0.27 \pm 0.11$  on sunny days.



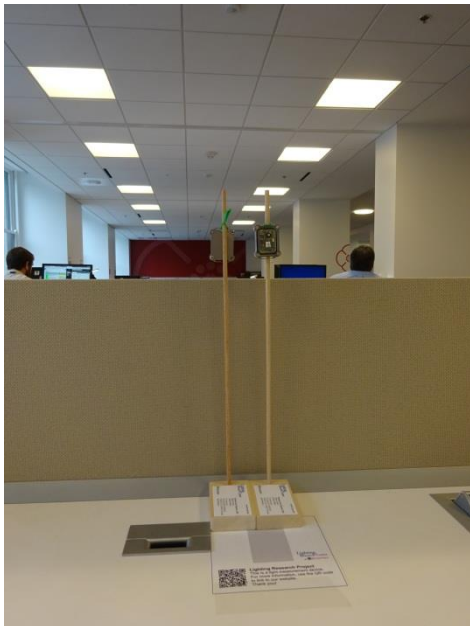
Average Lux and CS



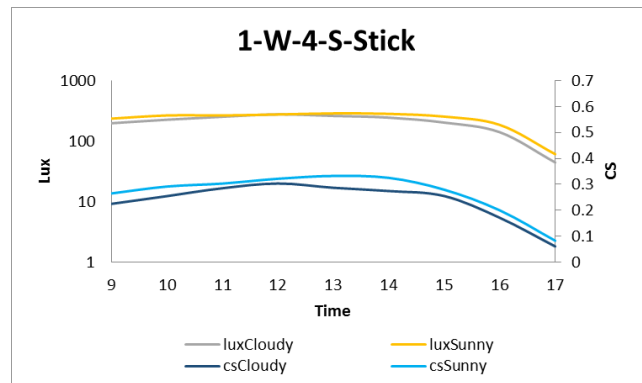
1-W-4-N-Stick



Daysimeter 184 – 1-W-4-N-Stick. Mean photopic light level during working hours (08:00 am to 05:00 pm) was  $217 \pm 94$  lux on cloudy days. The mean CS value on was  $0.25 \pm 0.11$  on cloudy days. On sunny days mean photopic light level during working hours was  $264 \pm 115$  lux. The mean CS value on was  $0.31 \pm 0.13$  on sunny days.

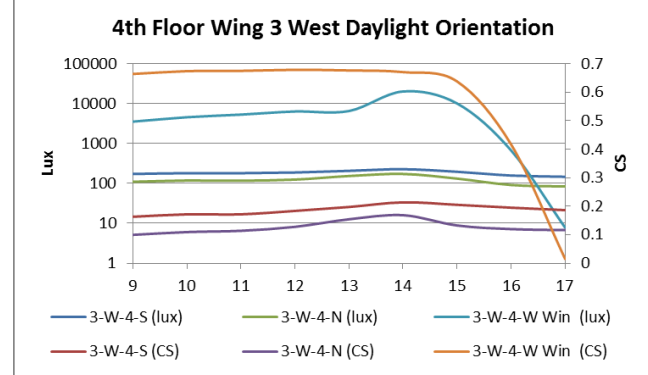
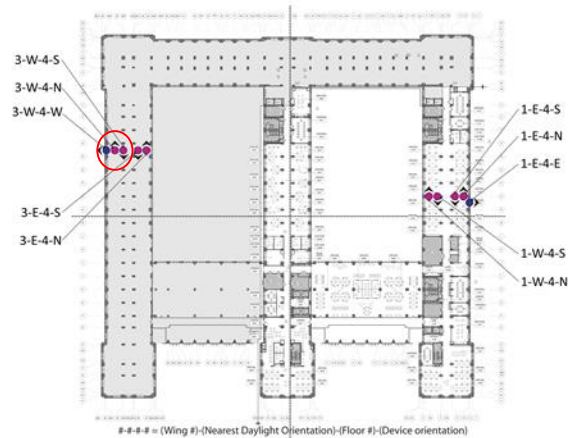


**1-W-4-S-Stick**

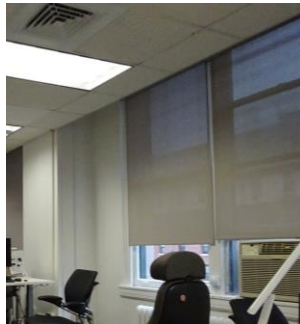


Daysimeter 196 – 1-W-4-S-Stick. Mean photopic light level during working hours (08:00 am to 05:00 pm) was  $206 \pm 73$  lux on cloudy days. The mean CS value on was  $0.24 \pm 0.08$  on cloudy days. On sunny days mean photopic light level during working hours was  $236 \pm 73$  lux. The mean CS value on was  $0.27 \pm 0.08$  on sunny days.

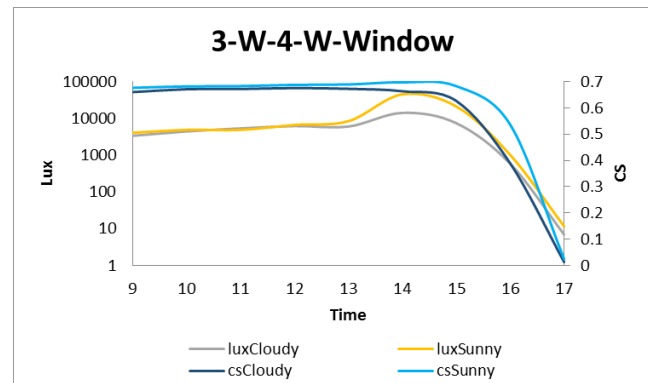
## 4<sup>TH</sup> FLOOR WING 3



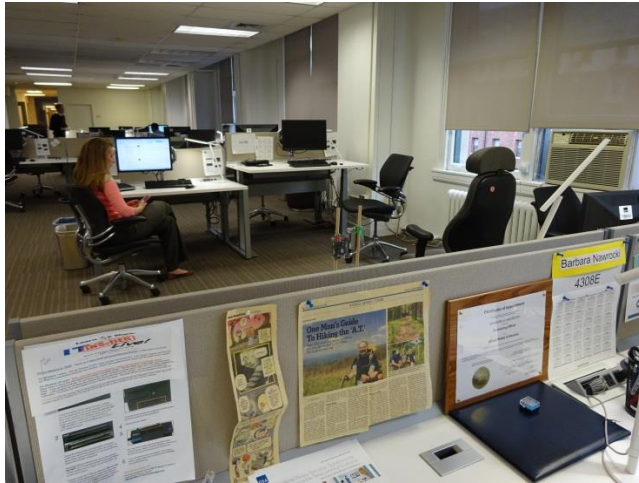
**Average Lux and CS**



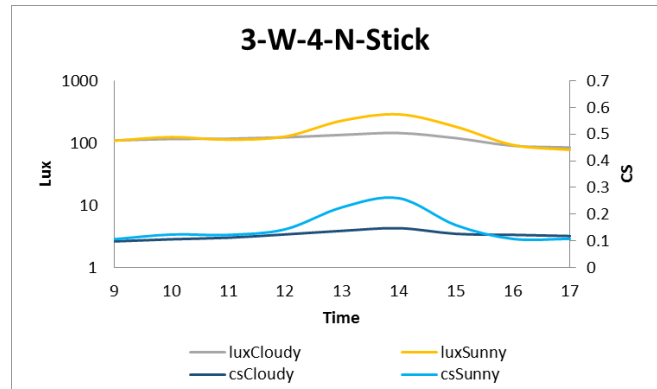
**3-W-4-W-Window**



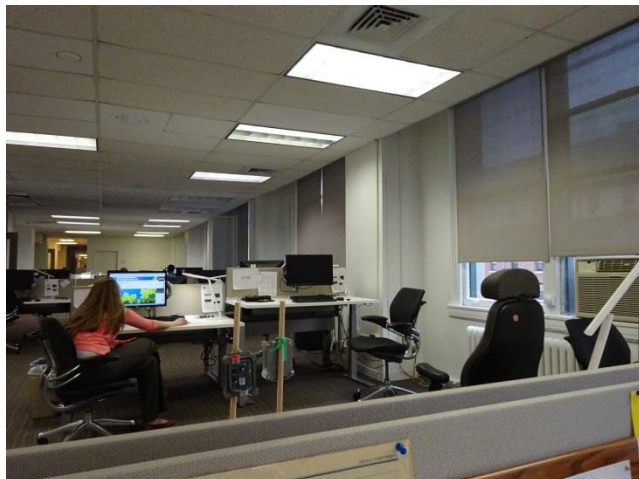
Daysimeter 204 – 3-W-4-W-Window. Mean photopic light level during working hours (08:00 am to 05:00 pm) was  $5313 \pm 4187$  lux on cloudy days. The mean CS value on was  $0.56 \pm 0.22$  on cloudy days. On sunny days mean photopic light level during working hours was  $10750 \pm 14378$  lux. The mean CS value on was  $0.60 \pm 0.22$  on sunny days.



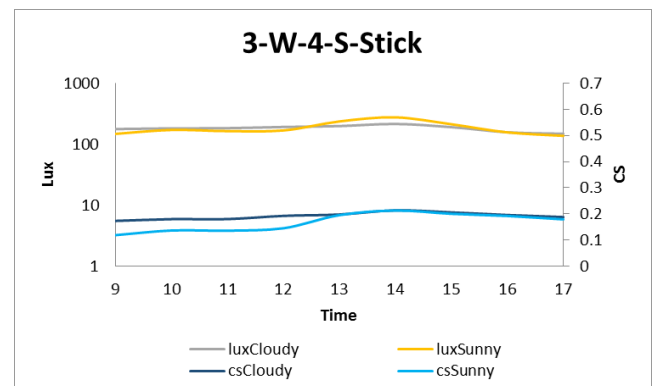
**3-W-4-N-Stick**



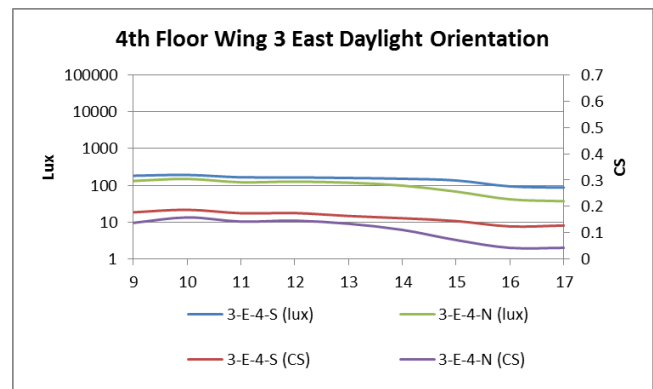
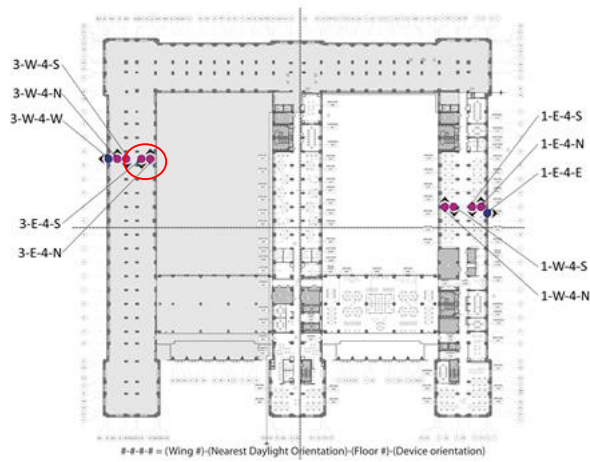
Daysimeter 185 – 3-W-4-N-Stick. Mean photopic light level during working hours (08:00 am to 05:00 pm) was  $116 \pm 19$  lux on cloudy days. The mean CS value on was  $0.12 \pm 0.02$  on cloudy days. On sunny days mean photopic light level during working hours was  $150 \pm 70$  lux. The mean CS value on was  $0.15 \pm 0.06$  on sunny days.



**3-W-4-S-Stick**

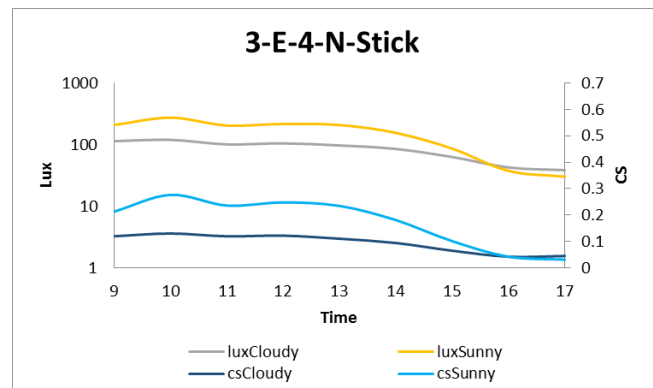


Daysimeter 192 – 3-W-4-S-Stick. Mean photopic light level during working hours (08:00 am to 05:00 pm) was  $183 \pm 20$  lux on cloudy days. The mean CS value on was  $0.19 \pm 0.01$  on cloudy days. On sunny days mean photopic light level during working hours was  $186 \pm 46$  lux. The mean CS value on was  $0.17 \pm 0.03$  on sunny days.



Average Lux and CS

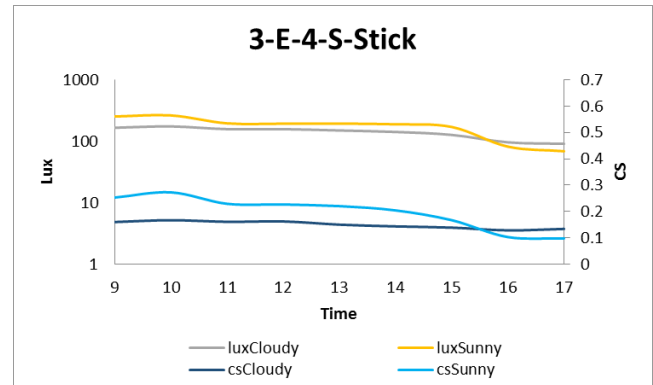
(No photo taken)



Daysimeter 191 – 3-E-4-N-Stick. Mean photopic light level during working hours (08:00 am to 05:00 pm) was  $85 \pm 30$  lux on cloudy days. The mean CS value on was  $0.09 \pm 0.03$  on cloudy days. On sunny days mean photopic light level during working hours was  $158 \pm 87$  lux. The mean CS value on was  $0.17 \pm 0.09$  on sunny days.

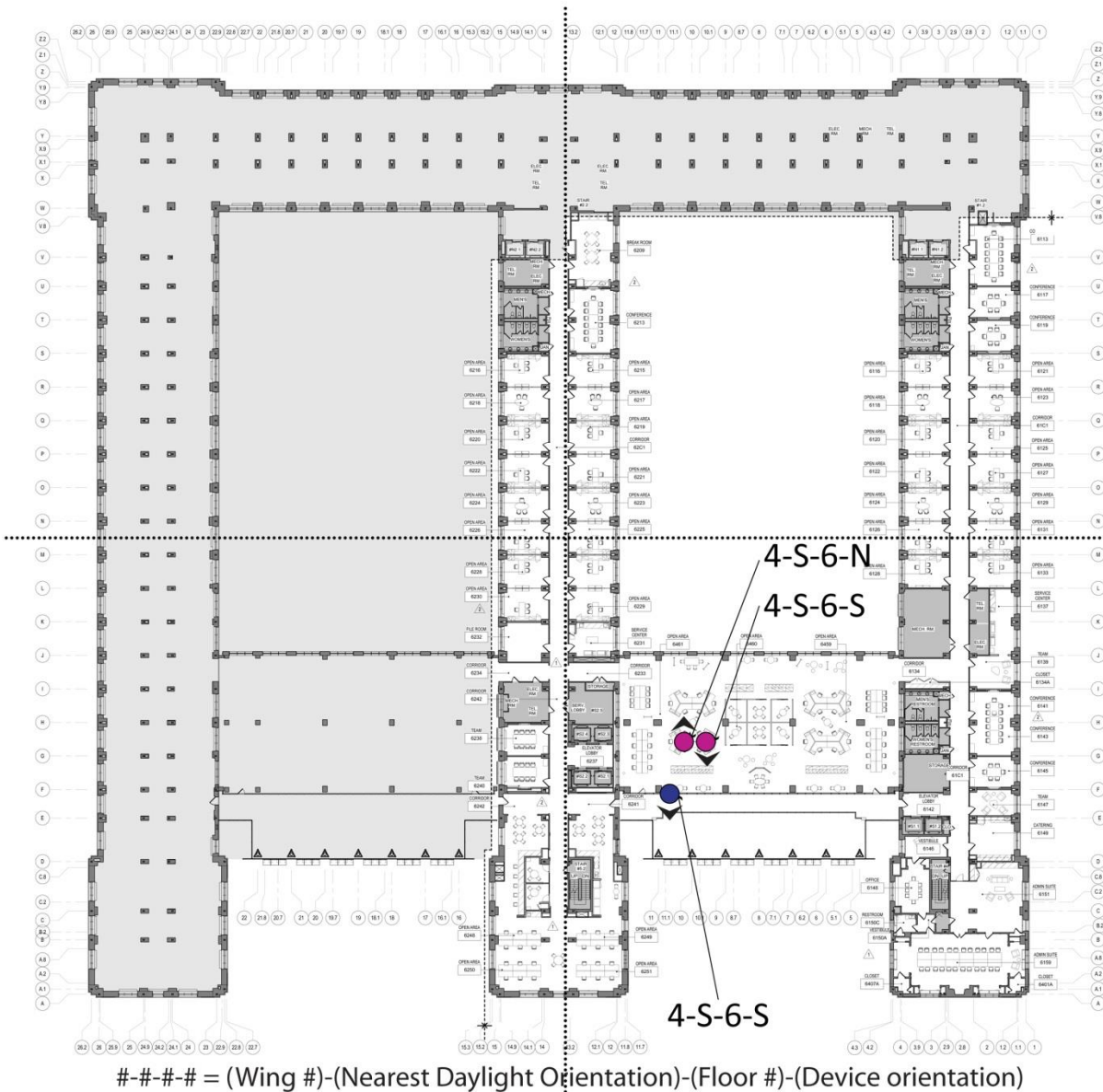


(No photo taken)



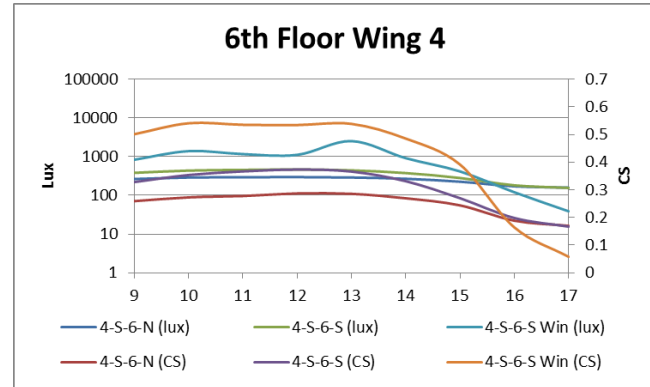
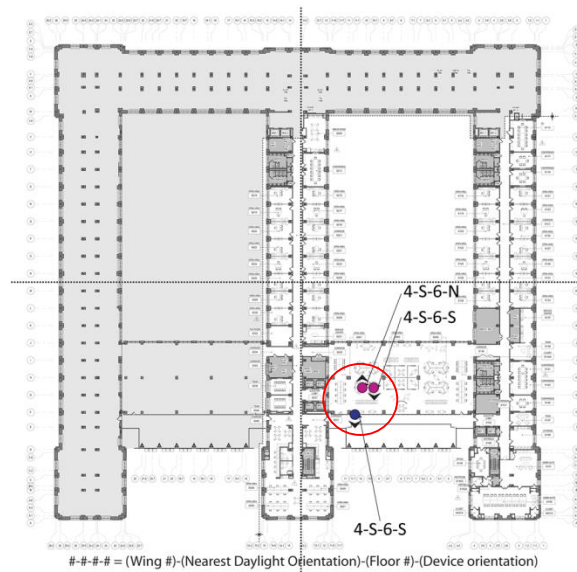
Daysimeter 195 – 3-E-4-S-Stick. Mean photopic light level during working hours (08:00 am to 05:00 pm) was  $141 \pm 30$  lux on cloudy days. The mean CS value on was  $0.15 \pm 0.01$  on cloudy days. On sunny days mean photopic light level during working hours was  $180 \pm 66$  lux. The mean CS value on was  $0.20 \pm 0.06$  on sunny days.

## APPENDIX O: PHOTOMETRIC DATA FOR 6<sup>TH</sup> FLOOR STATIONARY DEVICES MOUNTED ON STICKS AND IN WINDOWS HOLIDAYS INCLUDED (DECEMBER 4, 2014 – JANUARY 4, 2015)

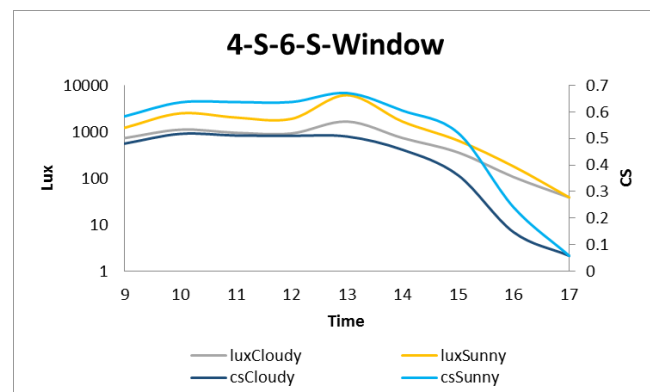


*Location where measurements were collected.*

## 6<sup>TH</sup> FLOOR NORTH WING 4



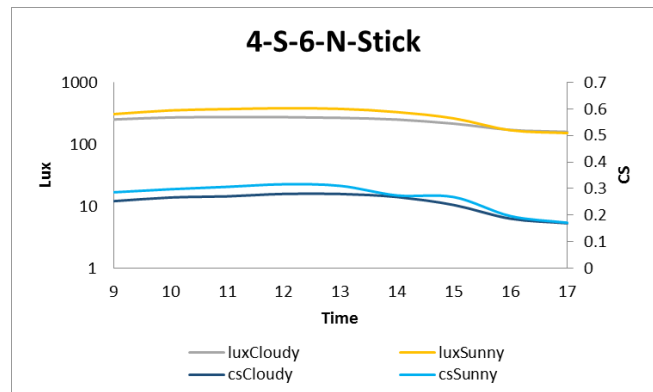
4-S-6-S-Window



Daysimeter 199 – 4-S-6-S-Window. Mean photopic light level during working hours (08:00 am to 05:00 pm) was  $741 \pm 517$  lux on cloudy days. The mean CS value on was  $0.39 \pm 0.17$  on cloudy days. On sunny days mean photopic light level during working hours was  $1827 \pm 1847$  lux. The mean CS value on was  $0.51 \pm 0.21$  on sunny days.



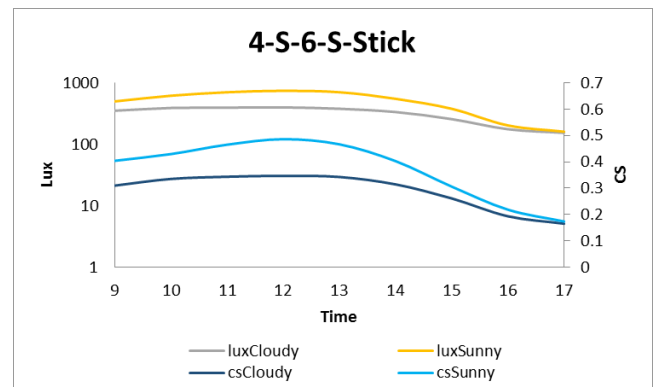
**4-S-6-N-Stick**



Daysimeter 168 – 4-S-6-S-Stick. Mean photopic light level during working hours (08:00 am to 05:00 pm) was  $238 \pm 45$  lux on cloudy days. The mean CS value on was  $0.25 \pm 0.04$  on cloudy days. On sunny days mean photopic light level during working hours was  $302 \pm 88$  lux. The mean CS value on was  $0.27 \pm 0.05$  on sunny days.

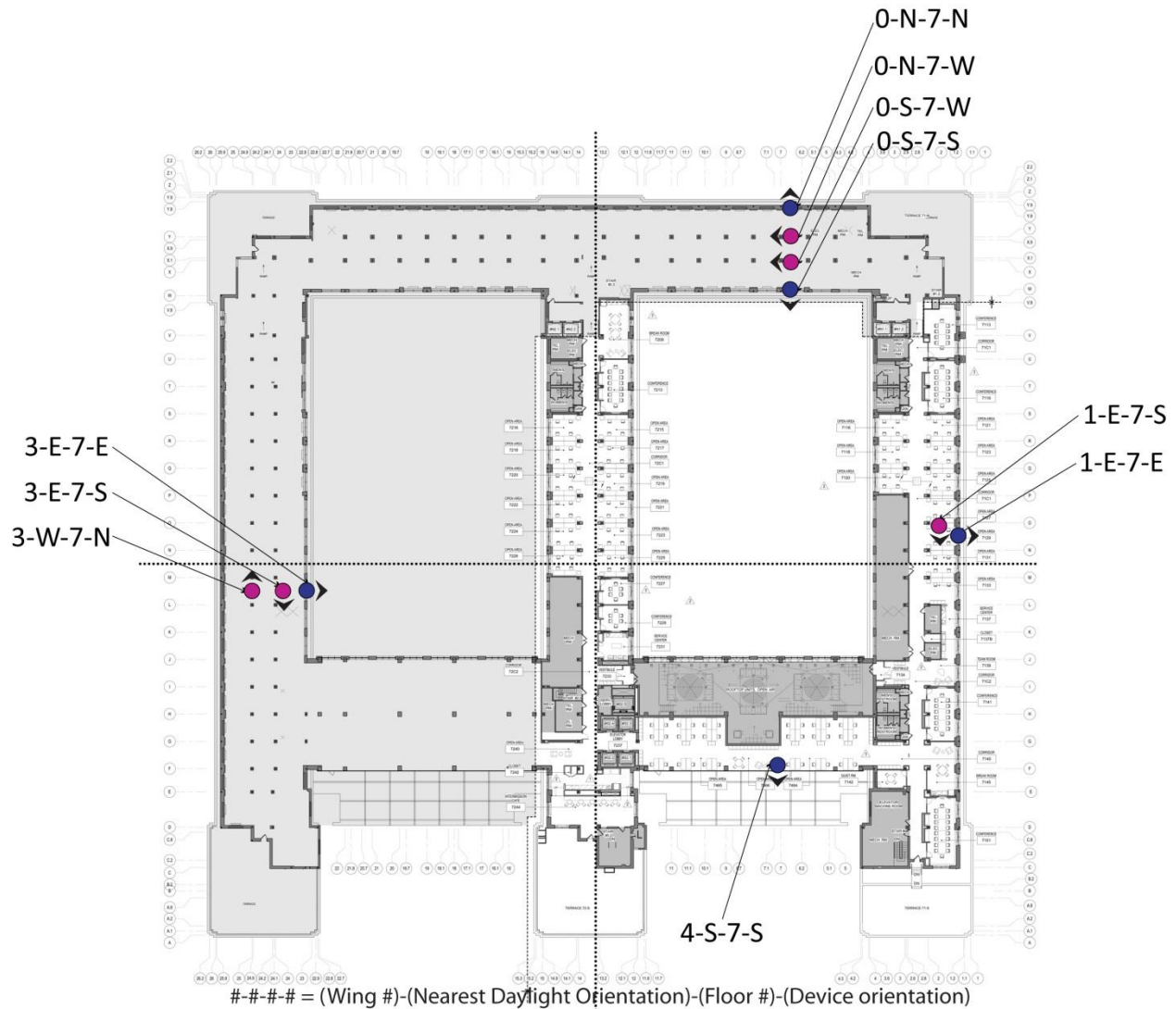


**4-S-6-S-Stick**



Daysimeter 175 – 4-S-6-S-Stick. Mean photopic light level during working hours (08:00 am to 05:00 pm) was  $316 \pm 96$  lux on cloudy days. The mean CS value on was  $0.29 \pm 0.07$  on cloudy days. On sunny days mean photopic light level during working hours was  $508 \pm 218$  lux. The mean CS value on was  $0.37 \pm 0.11$  on sunny days.

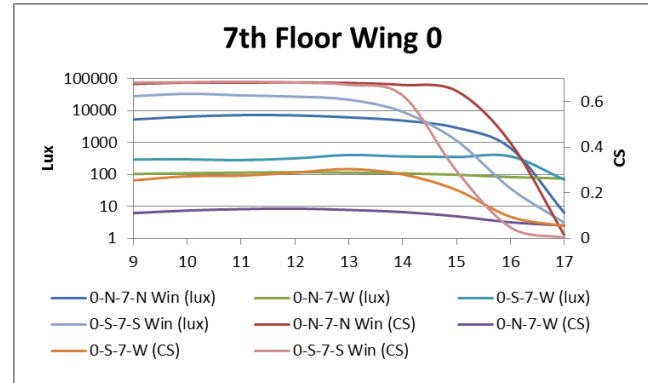
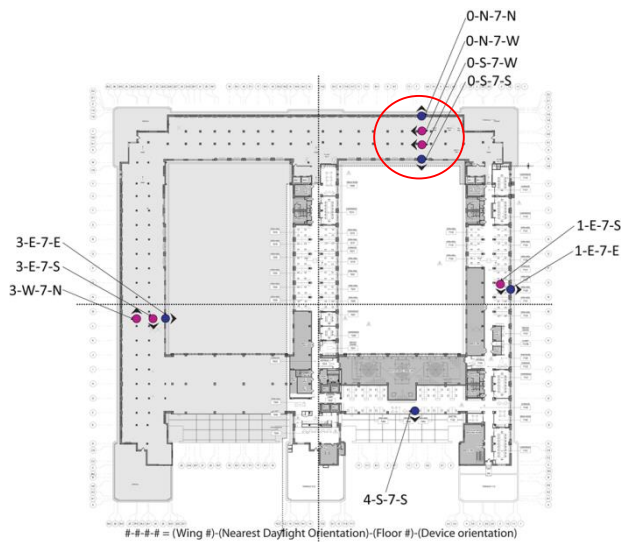
## APPENDIX P: PHOTOMETRIC DATA FOR 7<sup>TH</sup> FLOOR STATIONARY DEVICES MOUNTED ON STICKS AND IN WINDOWS HOLIDAYS INCLUDED (DECEMBER 4, 2014 – JANUARY 4, 2015)



*Location where measurements were collected.*



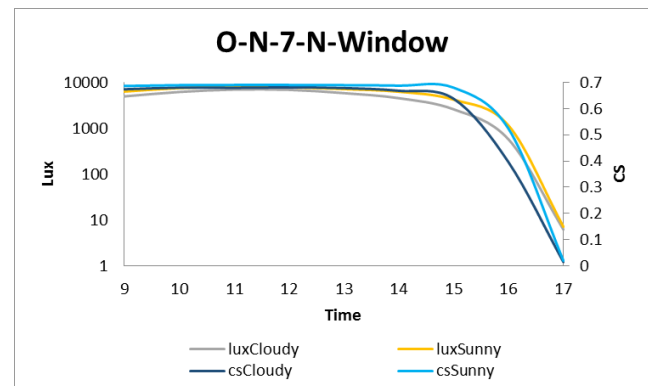
## 7<sup>TH</sup> FLOOR WING 0



Average Lux and CS



O-N-7-N-Window

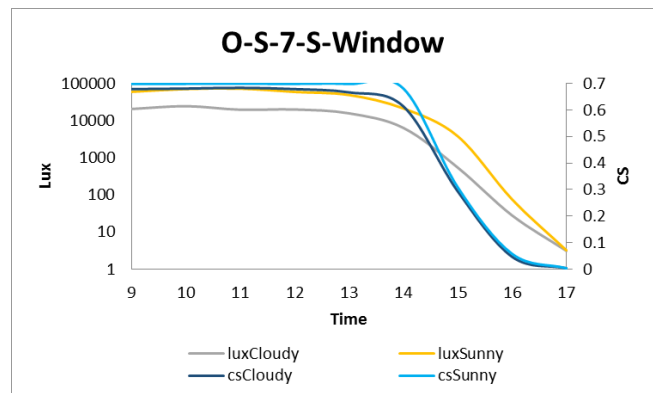


Daysimeter 202 – O-N-7-N-Window. Mean photopic light level during working hours (08:00 am to 05:00 pm) was  $4315 \pm 2655$  lux on cloudy days. The mean CS value on was  $0.57 \pm 0.23$  on cloudy days. On sunny days mean photopic light level during working hours was  $5432 \pm 2998$  lux. The mean CS value on was  $0.60 \pm 0.22$  on sunny days.





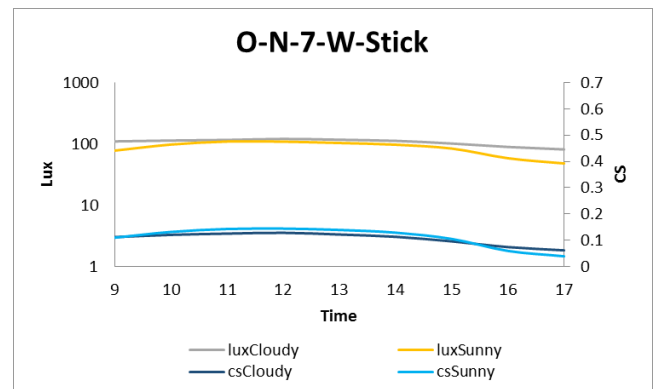
**O-S-7-S-Window**



Daysimeter 209 – O-S-7-S-Window. Mean photopic light level during working hours (08:00 am to 05:00 pm) was  $11962 \pm 10123$  lux on cloudy days. The mean CS value on was  $0.48 \pm 0.29$  on cloudy days. On sunny days mean photopic light level during working hours was  $37518 \pm 31026$  lux. The mean CS value on was  $0.51 \pm 0.30$  on sunny days.



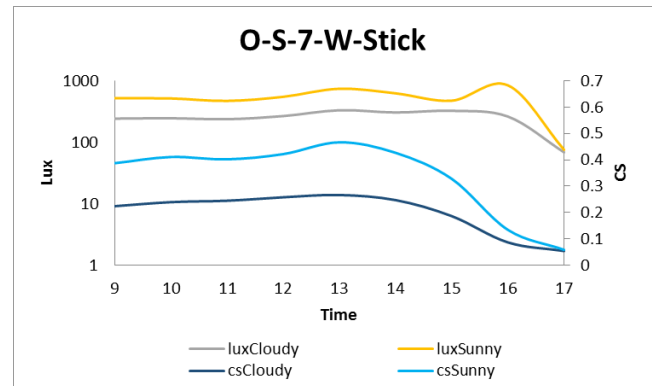
**O-N-7-W-Stick**



Daysimeter 198 – O-N-7-W-Stick. Mean photopic light level during working hours (08:00 am to 05:00 pm) was  $107 \pm 13$  lux on cloudy days. The mean CS value on was  $0.11 \pm 0.02$  on cloudy days. On sunny days mean photopic light level during working hours was  $87 \pm 22$  lux. The mean CS value on was  $0.11 \pm 0.04$  on sunny days.

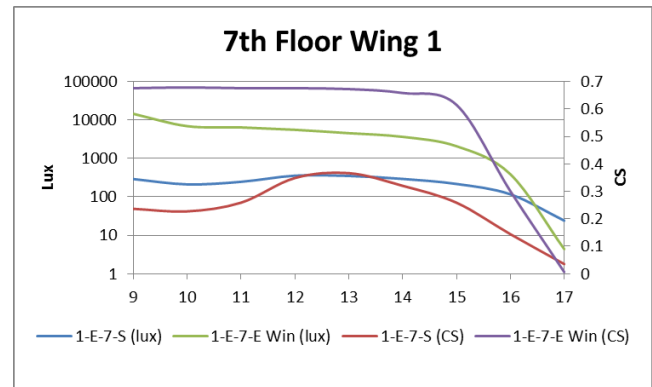
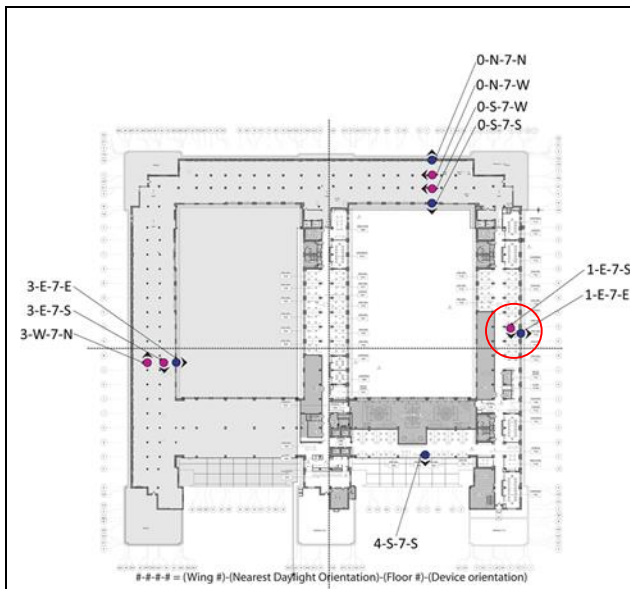


*0-S-7-W-Stick*



Daysimeter 186 – 0-S-7-W-Stick. Mean photopic light level during working hours (08:00 am to 05:00 pm) was  $255 \pm 78$  lux on cloudy days. The mean CS value on was  $0.20 \pm 0.08$  on cloudy days. On sunny days mean photopic light level during working hours was  $538 \pm 215$  lux. The mean CS value on was  $0.34 \pm 0.14$  on sunny days.

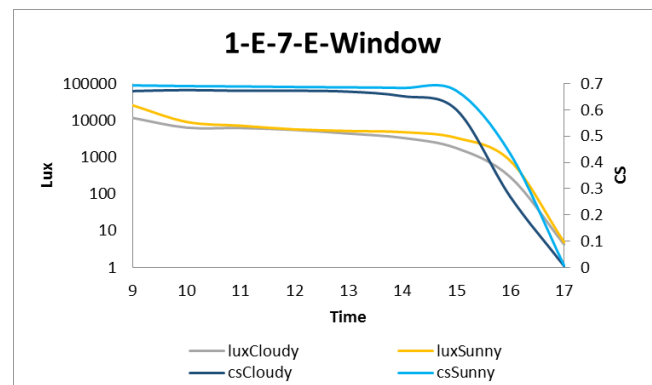
## 7<sup>TH</sup> FLOOR WING 1



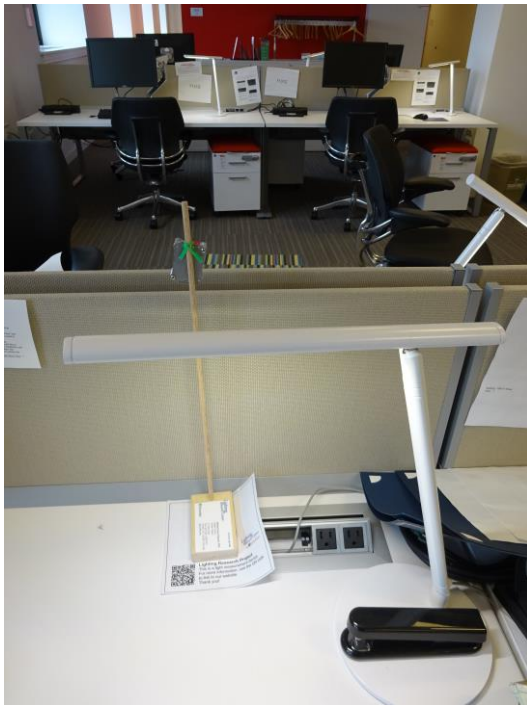
**Average Lux and CS**



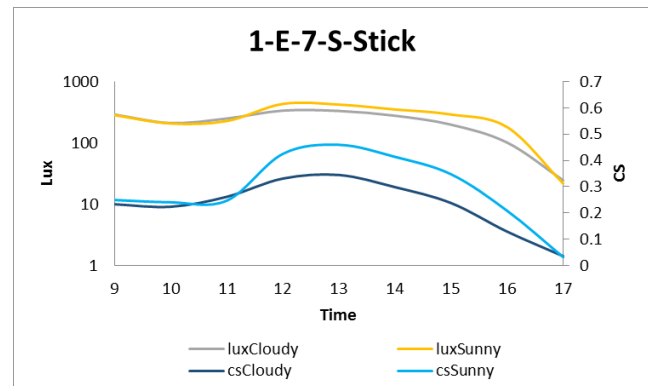
**1-E-7-E-Window**



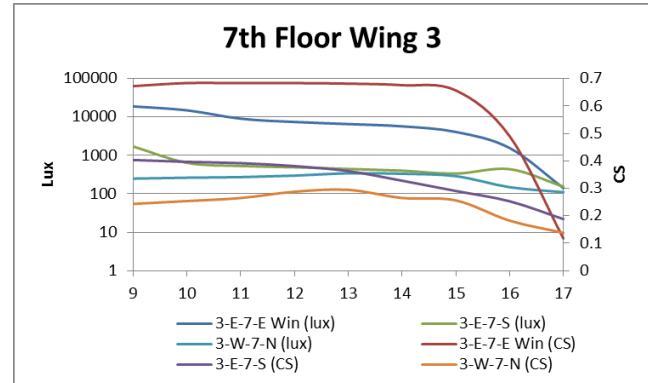
Daysimeter 205 – 1-E-7-E-Window. Mean photopic light level during working hours (08:00 am to 05:00 pm) was  $4421 \pm 3653$  lux on cloudy days. The mean CS value on was  $0.54 \pm 0.24$  on cloudy days. On sunny days mean photopic light level during working hours was  $6911 \pm 7676$  lux. The mean CS value on was  $0.58 \pm 0.23$  on sunny days.



**1-E-7-S-Stick**



Daysimeter 187 – 1-E-7-S-Stick. Mean photopic light level during working hours (08:00 am to 05:00 pm) was  $226 \pm 105$  lux on cloudy days. The mean CS value on was  $0.23 \pm 0.10$  on cloudy days. On sunny days mean photopic light level during working hours was  $270 \pm 129$  lux. The mean CS value on was  $0.29 \pm 0.13$  on sunny days.

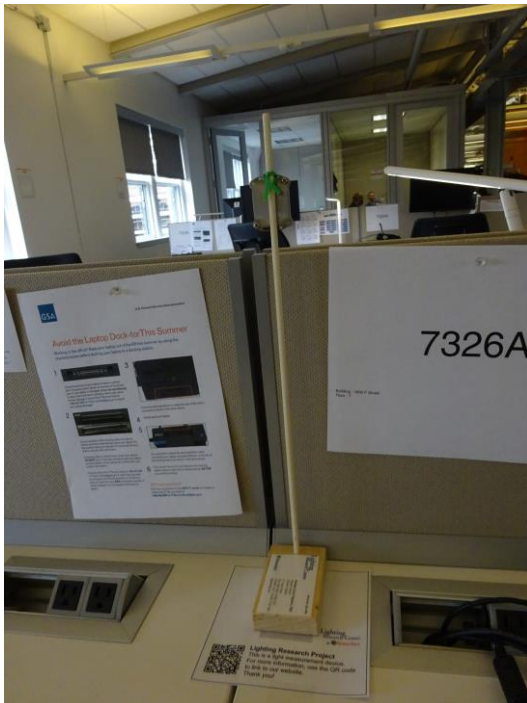


**3-E-7-E-Window**

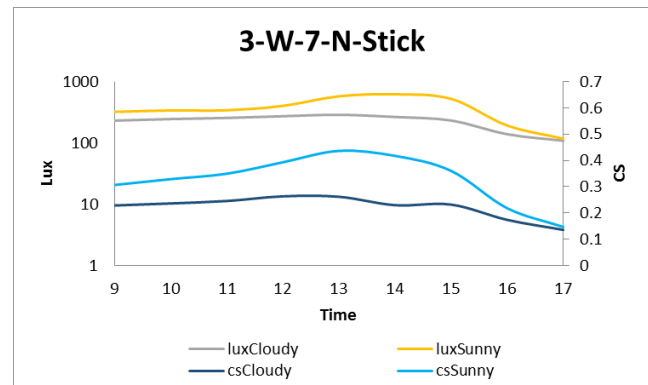
| Time | luxCloudy | luxSunny | csCloudy | csSunny |
|------|-----------|----------|----------|---------|
| 9    | ~10,000   | ~30,000  | ~90,000  | ~95,000 |
| 10   | ~8,000    | ~20,000  | ~90,000  | ~95,000 |
| 11   | ~6,000    | ~15,000  | ~90,000  | ~95,000 |
| 12   | ~5,000    | ~10,000  | ~90,000  | ~95,000 |
| 13   | ~4,500    | ~8,000   | ~90,000  | ~95,000 |
| 14   | ~4,000    | ~8,000   | ~90,000  | ~95,000 |
| 15   | ~3,500    | ~6,000   | ~80,000  | ~90,000 |
| 16   | ~2,000    | ~3,000   | ~1,000   | ~10,000 |
| 17   | ~1,000    | ~1,000   | ~10      | ~10     |

P-7





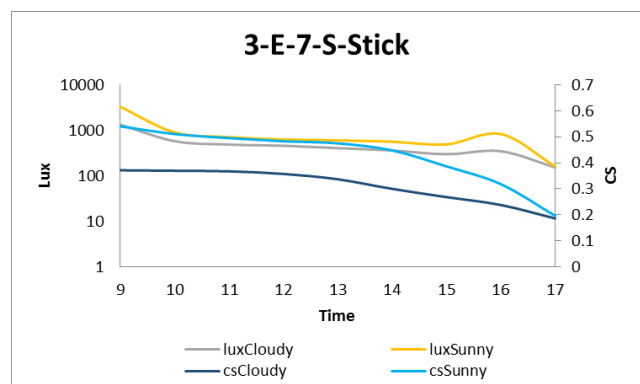
**3-W-7-N-Stick**



Datalogger 197 – 3-W-7-N-Stick. Mean photopic light level during working hours (08:00 am to 05:00 pm) was  $227 \pm 62$  lux on cloudy days. The mean CS value on was  $0.22 \pm 0.04$  on cloudy days. On sunny days mean photopic light level during working hours was  $383 \pm 170$  lux. The mean CS value on was  $0.33 \pm 0.09$  on sunny days.



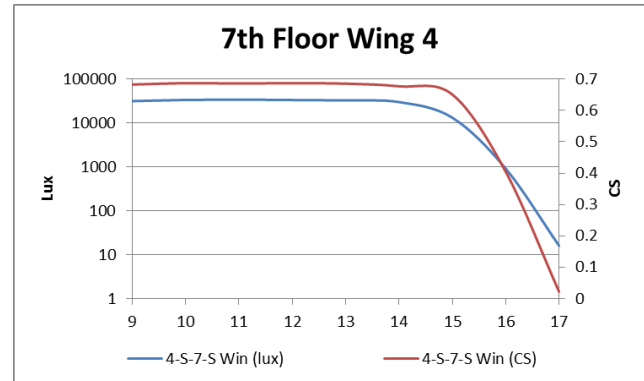
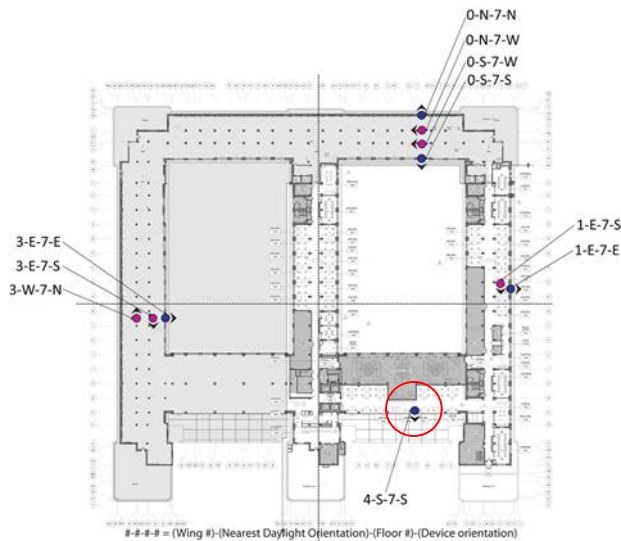
**3-E-7-S-Stick**



Datalogger 188 – 3-E-7-S-Stick. Mean photopic light level during working hours (08:00 am to 05:00 pm) was  $494 \pm 340$  lux on cloudy days. The mean CS value on was  $0.31 \pm 0.07$  on cloudy days. On sunny days mean photopic light level during working hours was  $913 \pm 923$  lux. The mean CS value on was  $0.43 \pm 0.11$  on sunny days.



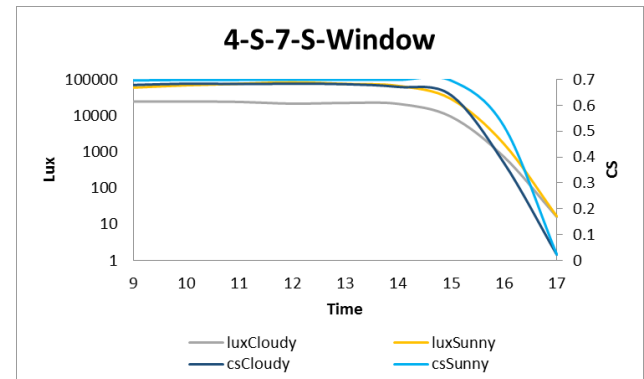
## 7<sup>TH</sup> FLOOR WING 4



Average Lux and CS



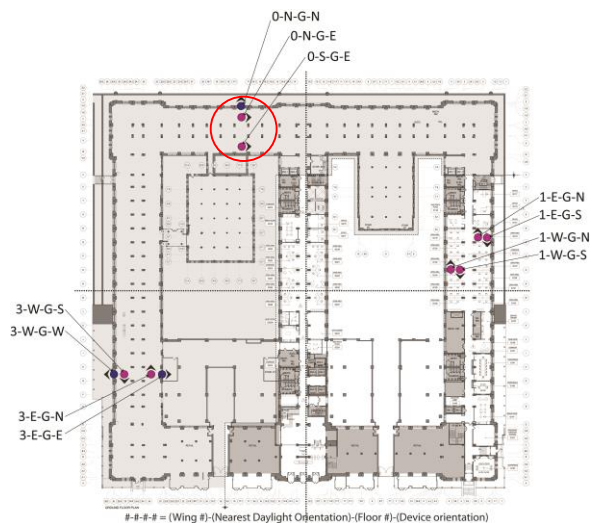
4-S-7-S-Window



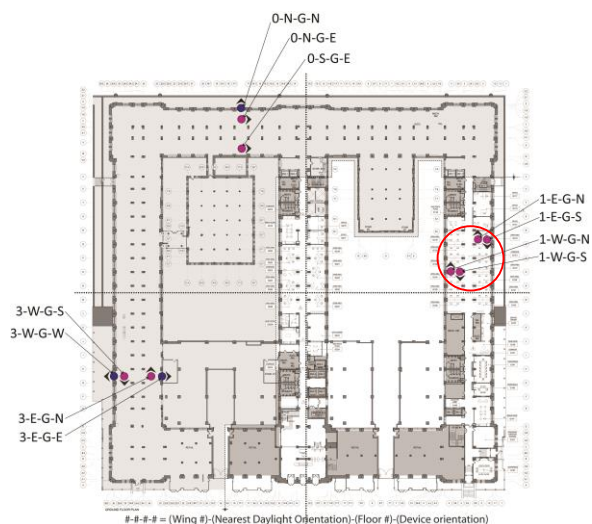
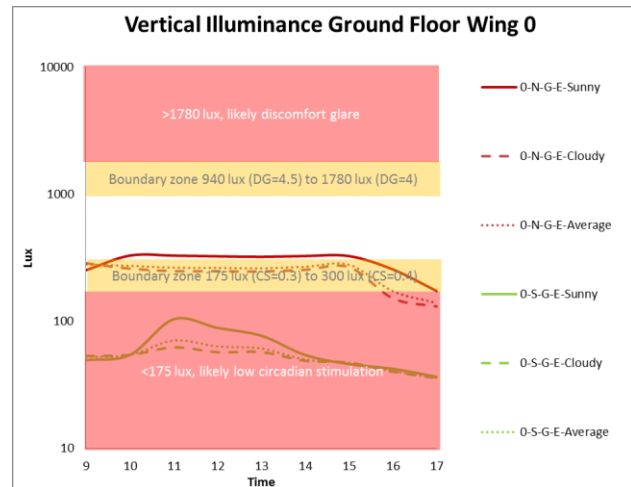
Daysimeter 183 – 4-S-7-S-Window. Mean photopic light level during working hours (08:00 am to 05:00 pm) was  $16609 \pm 10320$  lux on cloudy days. The mean CS value on was  $0.57 \pm 0.23$  on cloudy days. On sunny days mean photopic light level during working hours was  $51587 \pm 32715$  lux. The mean CS value on was  $0.60 \pm 0.23$  on sunny days.

## APPENDIX Q: VERTICAL ILLUMINANCE FOR STICK DEVICES CROPPED TO DECEMBER 4, 2014 – DECEMBER 19, 2014

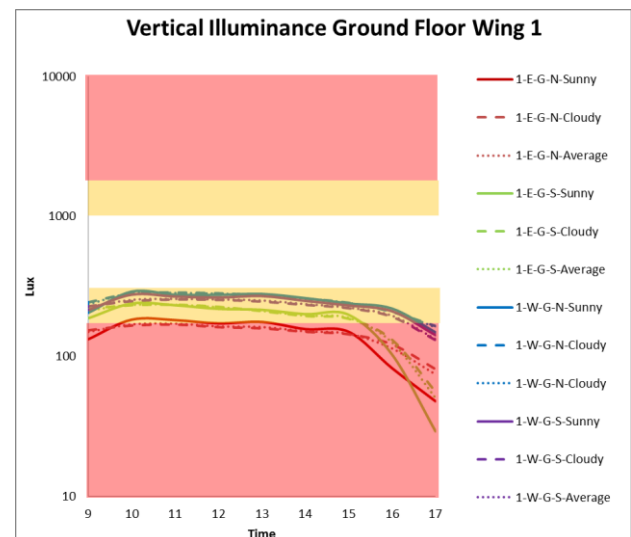
### GROUND FLOOR

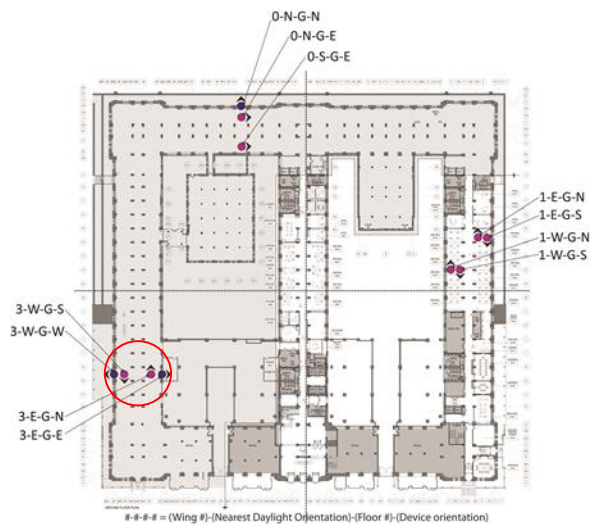


GROUND FLOOR WING 0

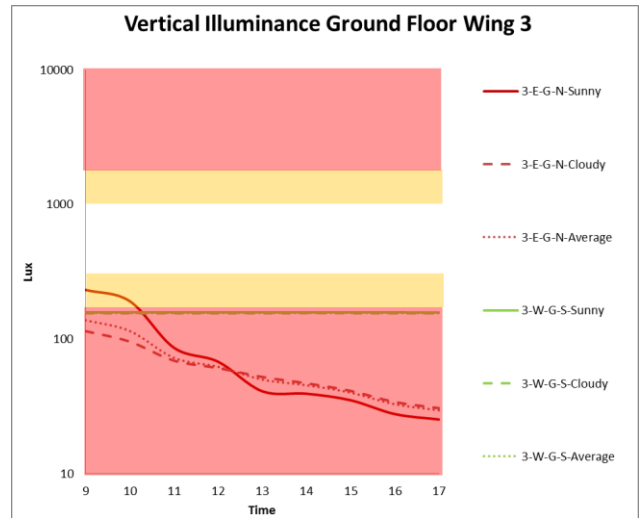


Ground Floor Wing 1

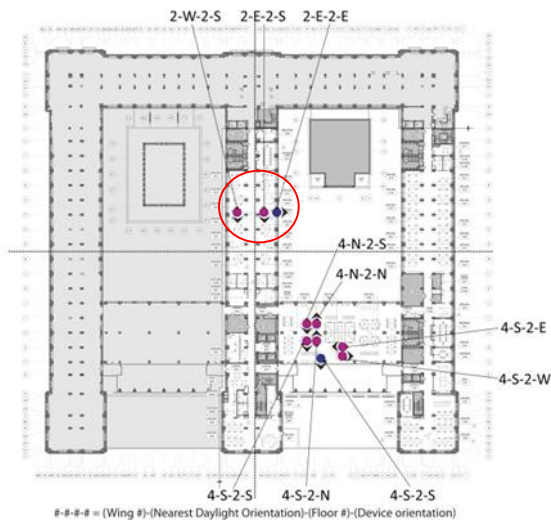




**Ground Floor Wing 3**

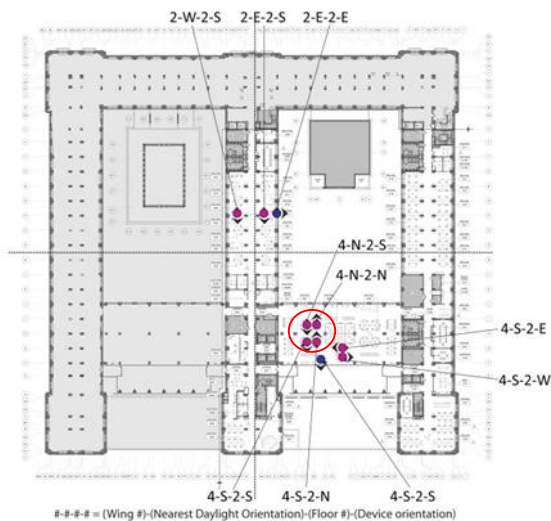
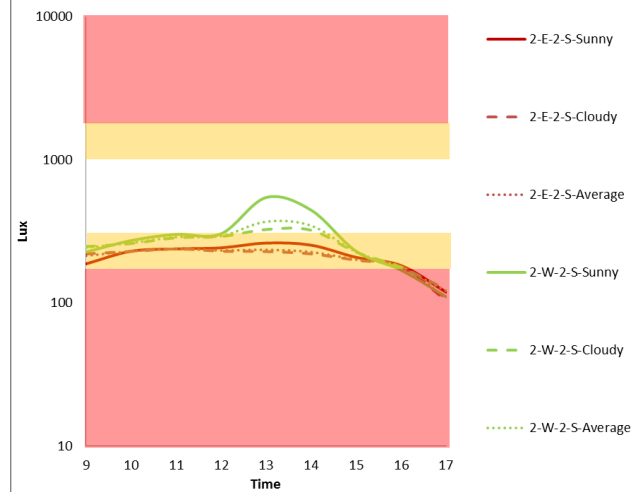


## 2ND FLOOR



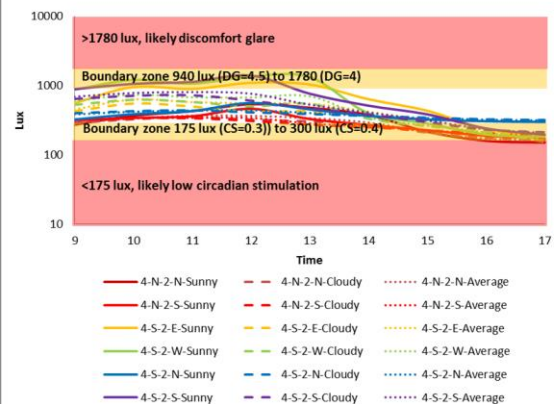
**2<sup>nd</sup> Floor Wing 2**

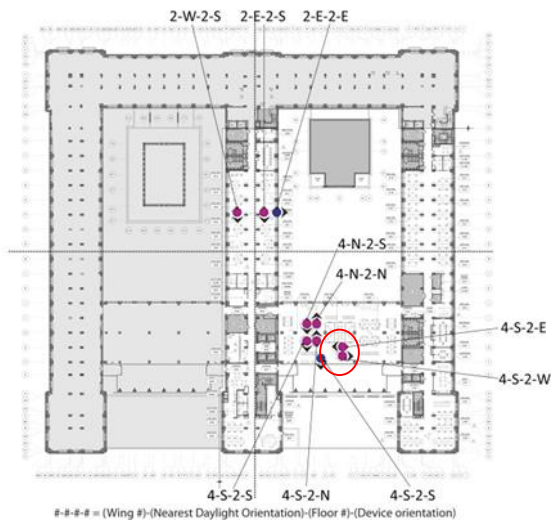
### Vertical Illuminance 2nd Floor Wing 2



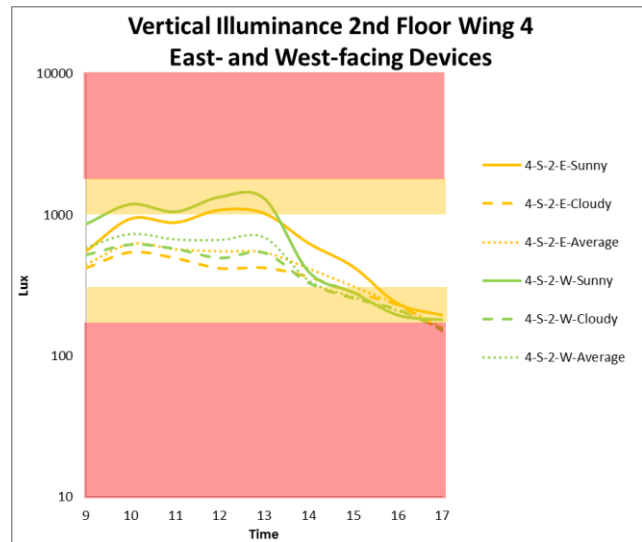
**2<sup>nd</sup> Floor Wing 4 North- and South-facing Devices**

### Vertical Illuminance 2nd Floor Wing 4

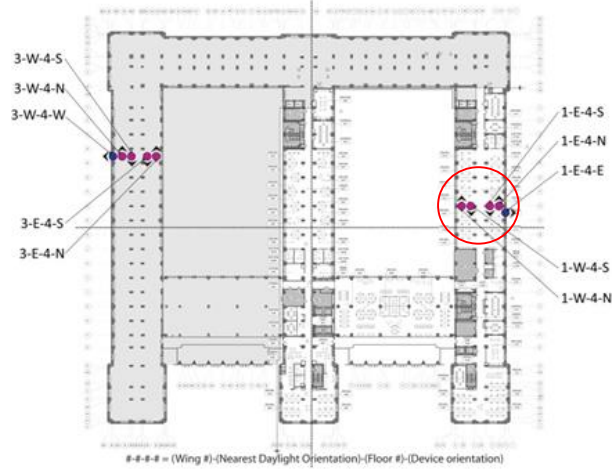




**2<sup>nd</sup> Floor Wing 4 East- and West-facing Devices**

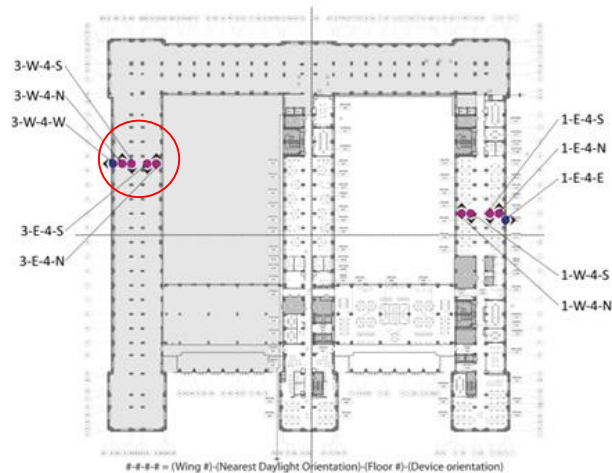
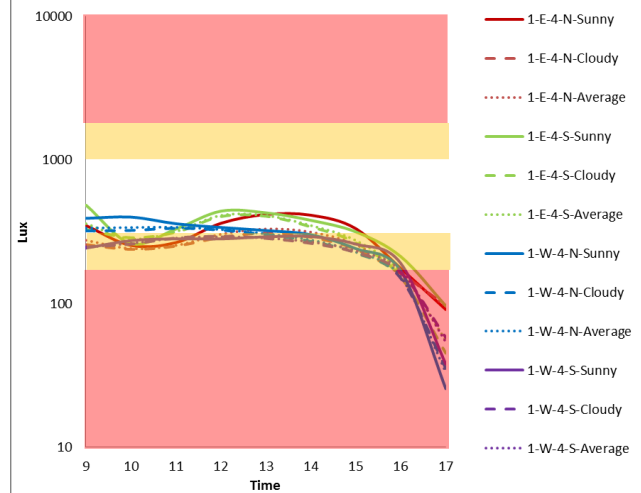


## 4TH FLOOR



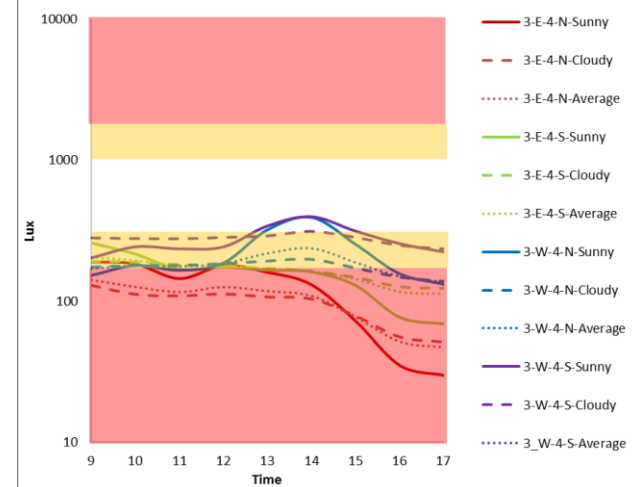
4<sup>th</sup> Floor Wing 1

Vertical Illuminance 4th Floor Wing 1



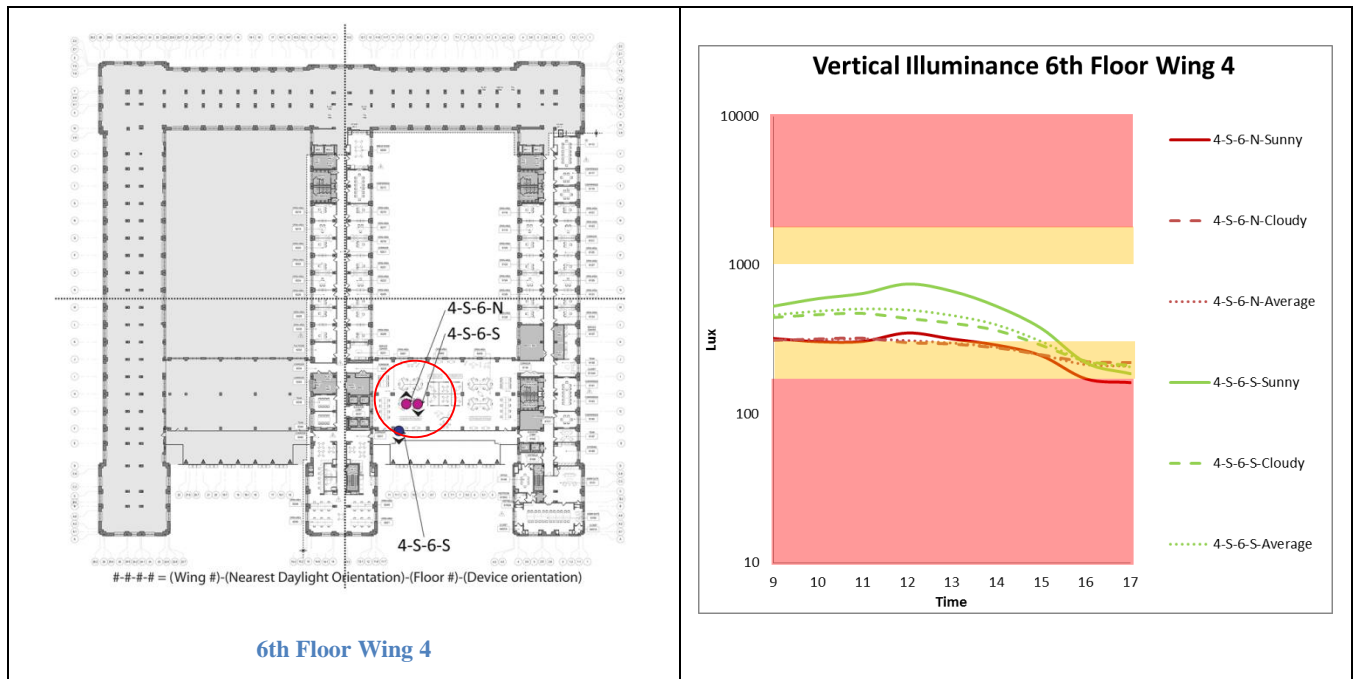
4<sup>th</sup> Floor Wing 3

Vertical Illuminance 4th Floor Wing 3

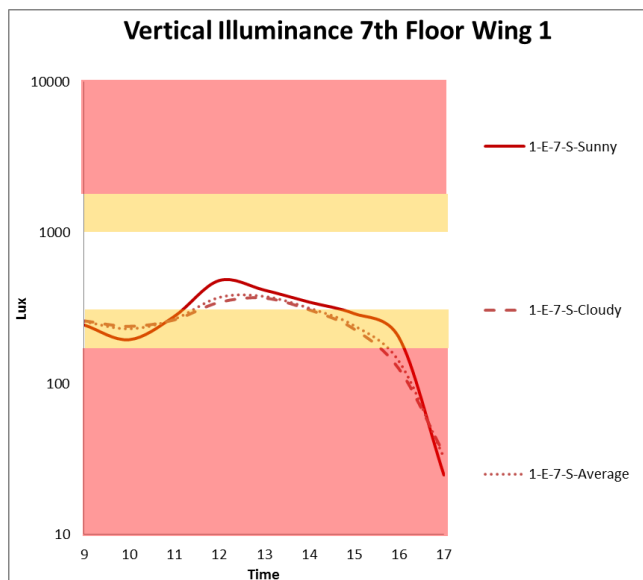
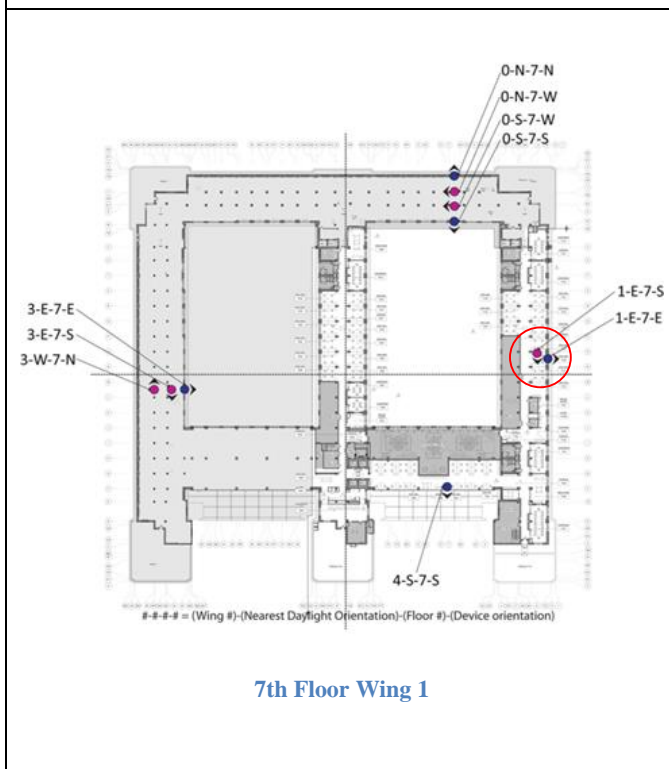
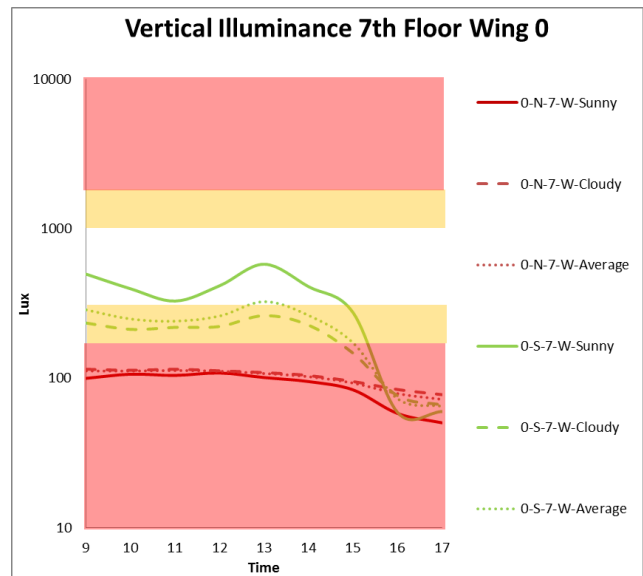
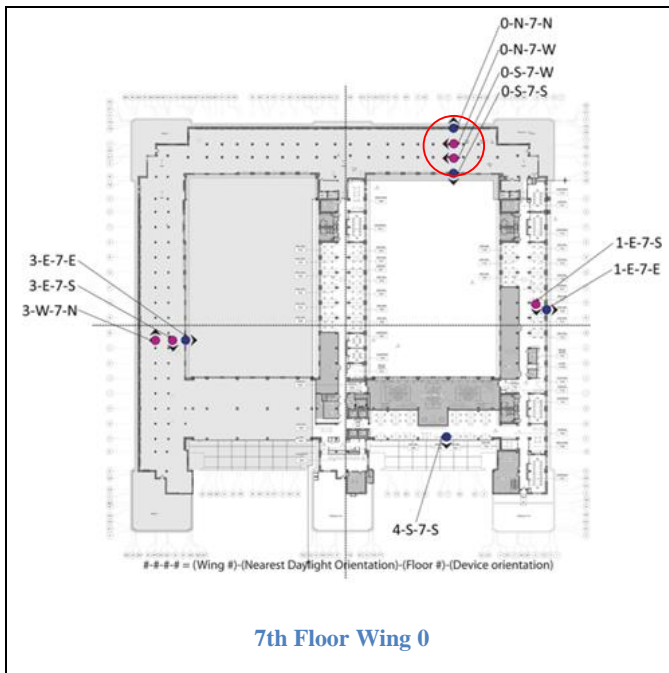


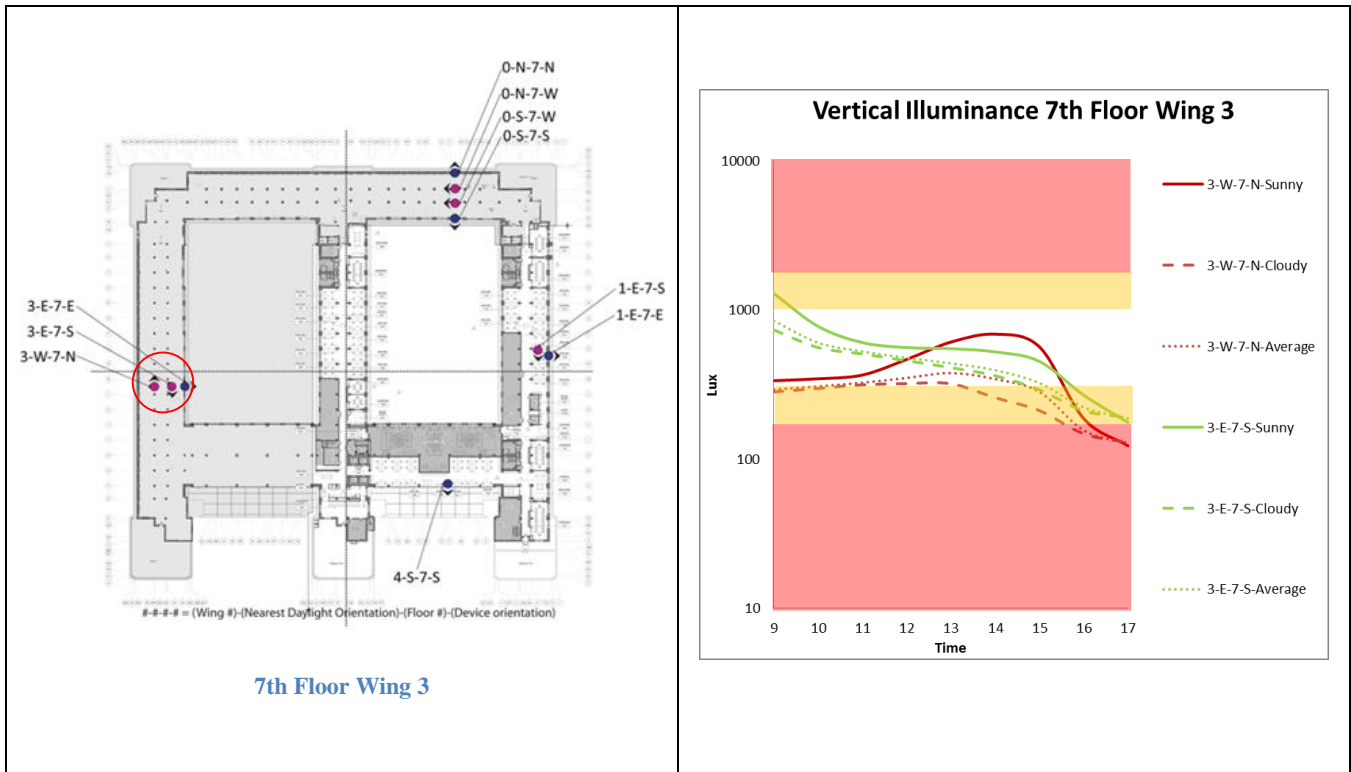


## 6TH FLOOR



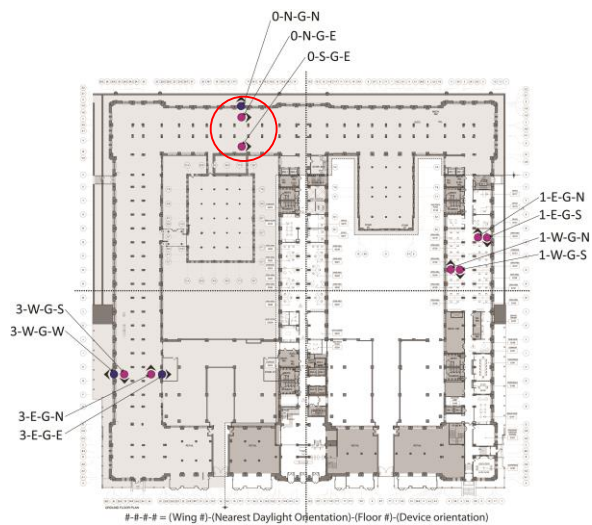
## 7TH FLOOR



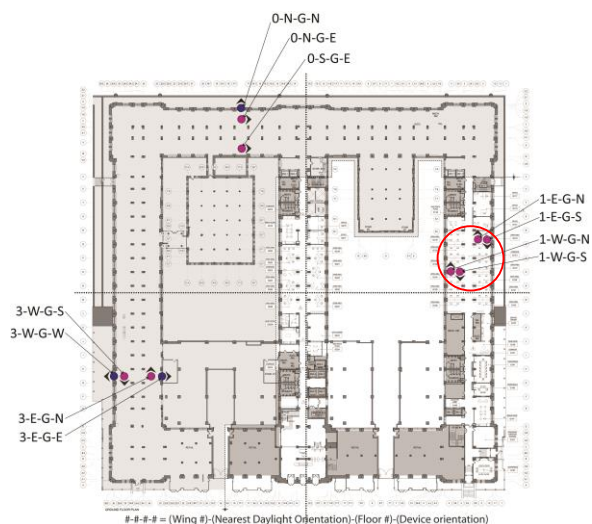
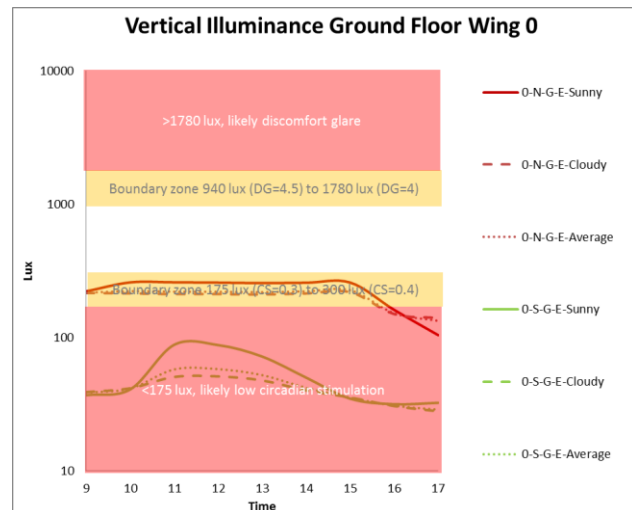


## APPENDIX R: VERTICAL ILLUMINANCE FOR STICK DEVICES HOLIDAYS INCLUDED (DECEMBER 4, 2014 – JANUARY 4, 2015)

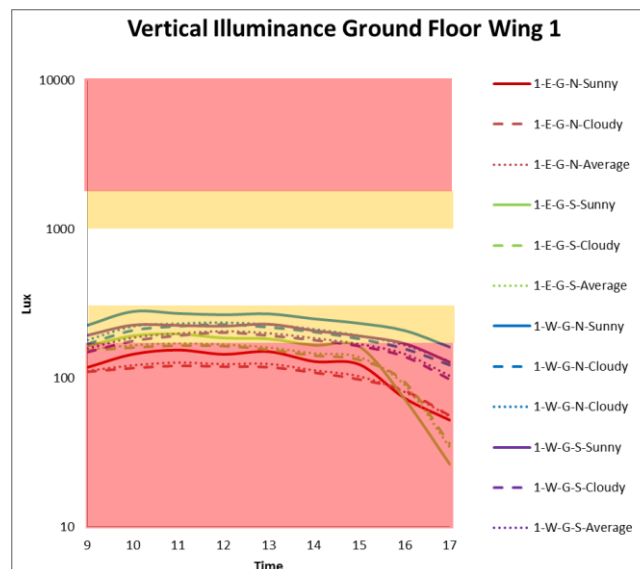
### GROUND FLOOR

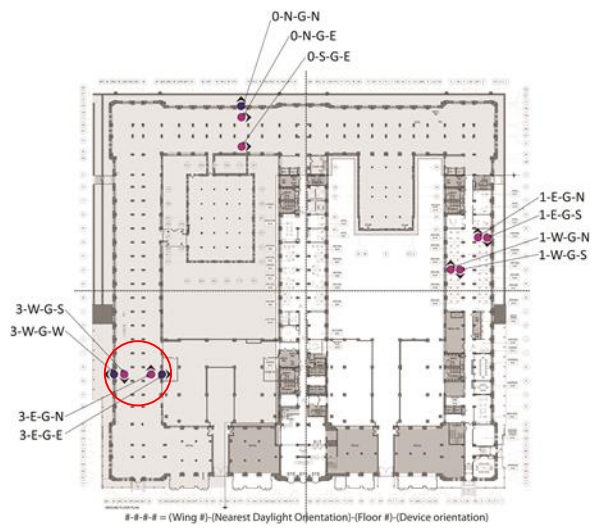


GROUND FLOOR WING 0

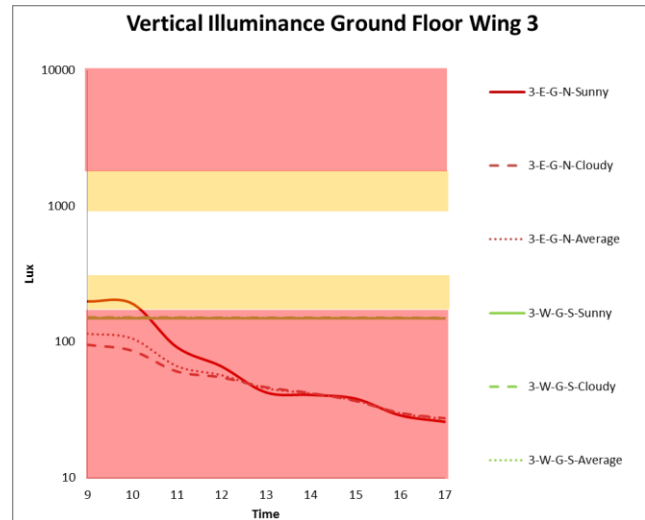


Ground Floor Wing 1

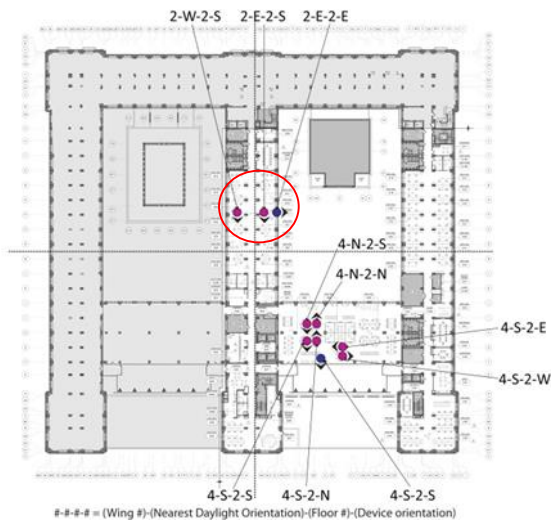




**Ground Floor Wing 3**

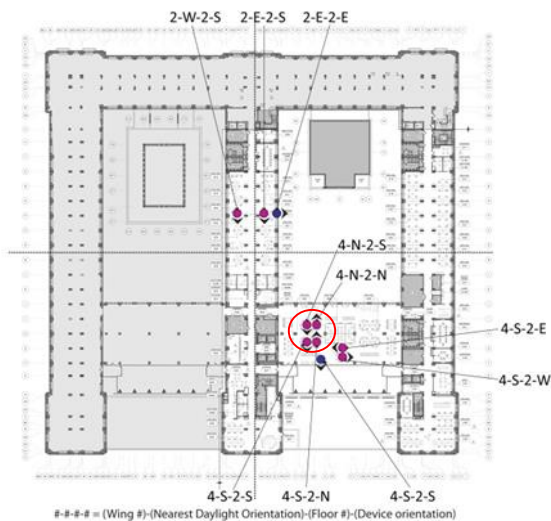
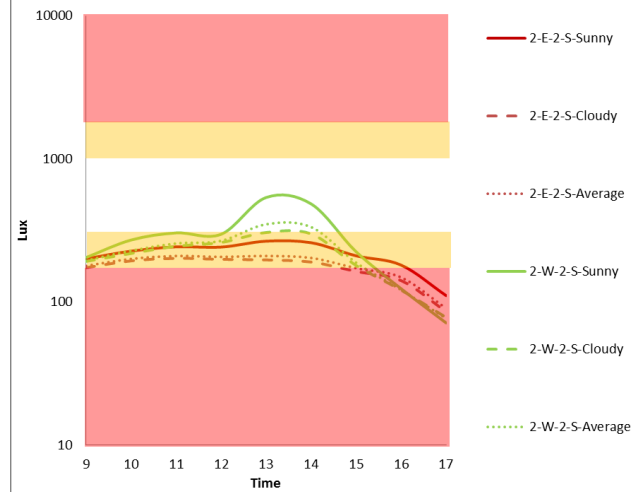


## 2ND FLOOR



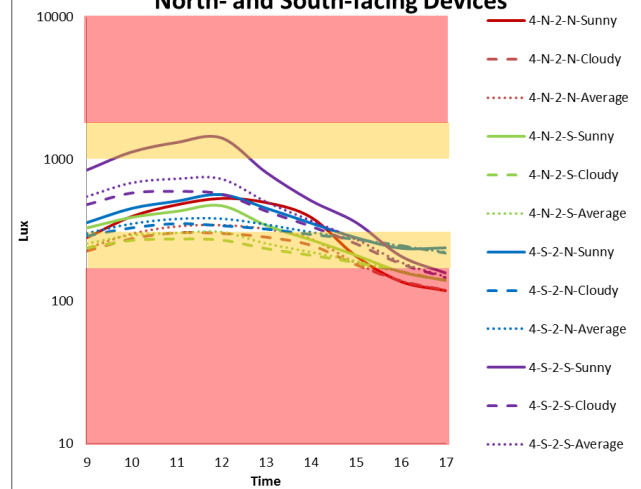
**2<sup>nd</sup> Floor Wing 2**

### Vertical Illuminance 2nd Floor Wing 2

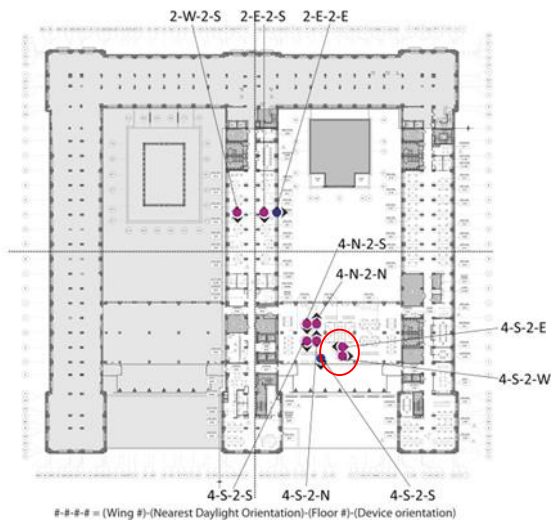


**2<sup>nd</sup> Floor Wing 4 North- and South-facing Devices**

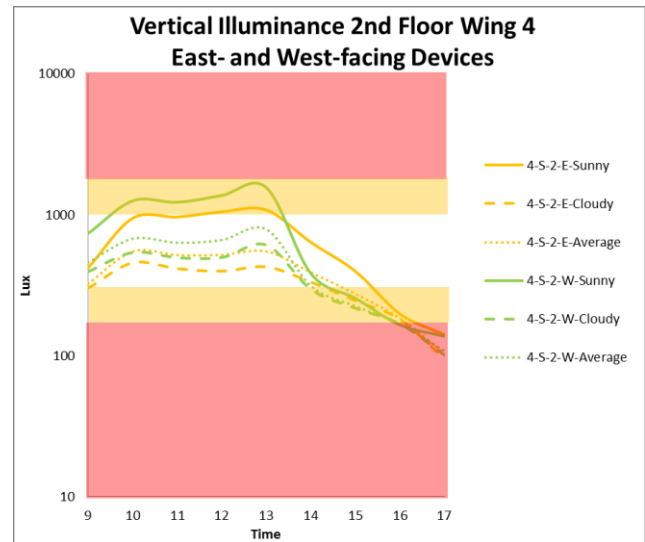
### Vertical Illuminance 2nd Floor Wing 4 North- and South-facing Devices



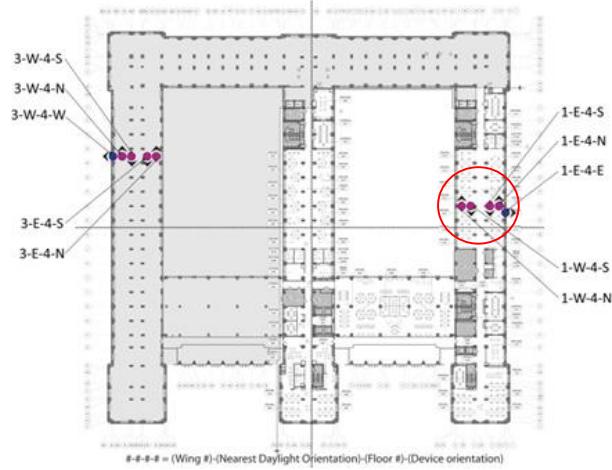




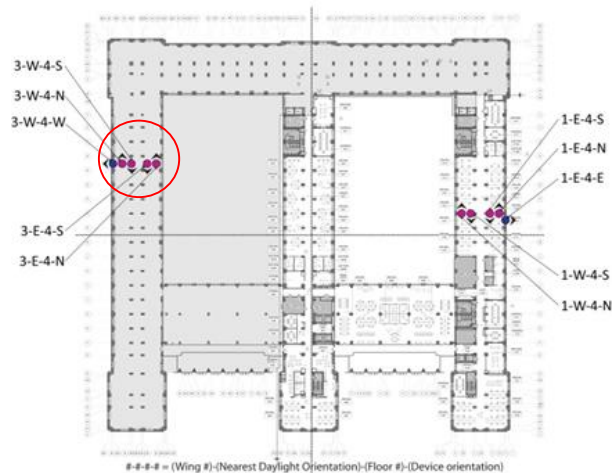
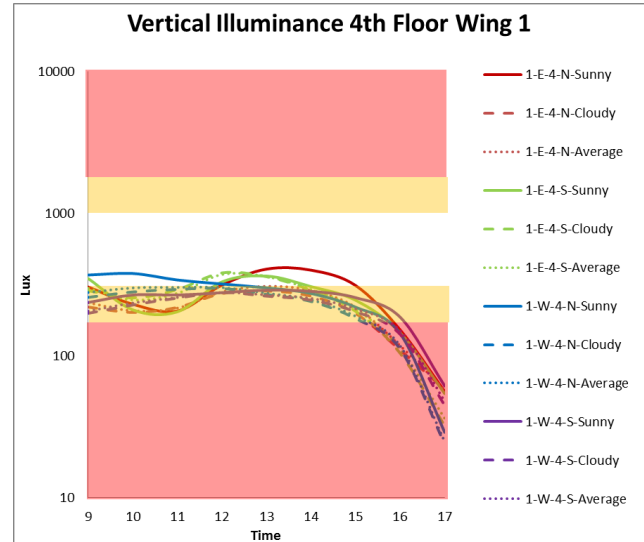
**2<sup>nd</sup> Floor Wing 4 East- and West-facing Devices**



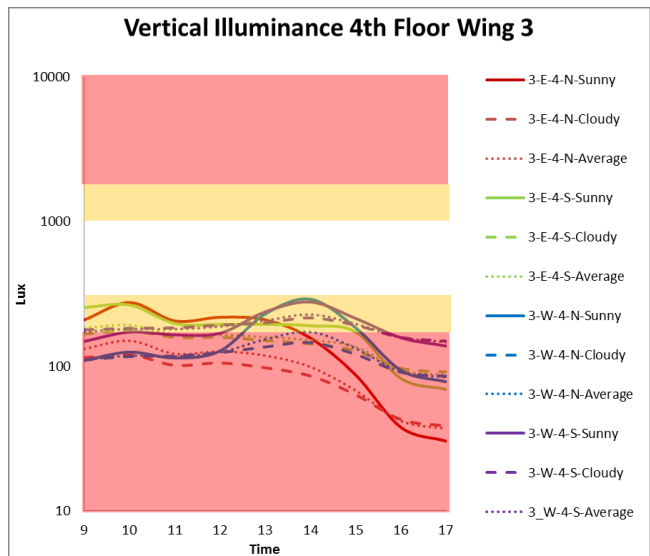
## 4TH FLOOR



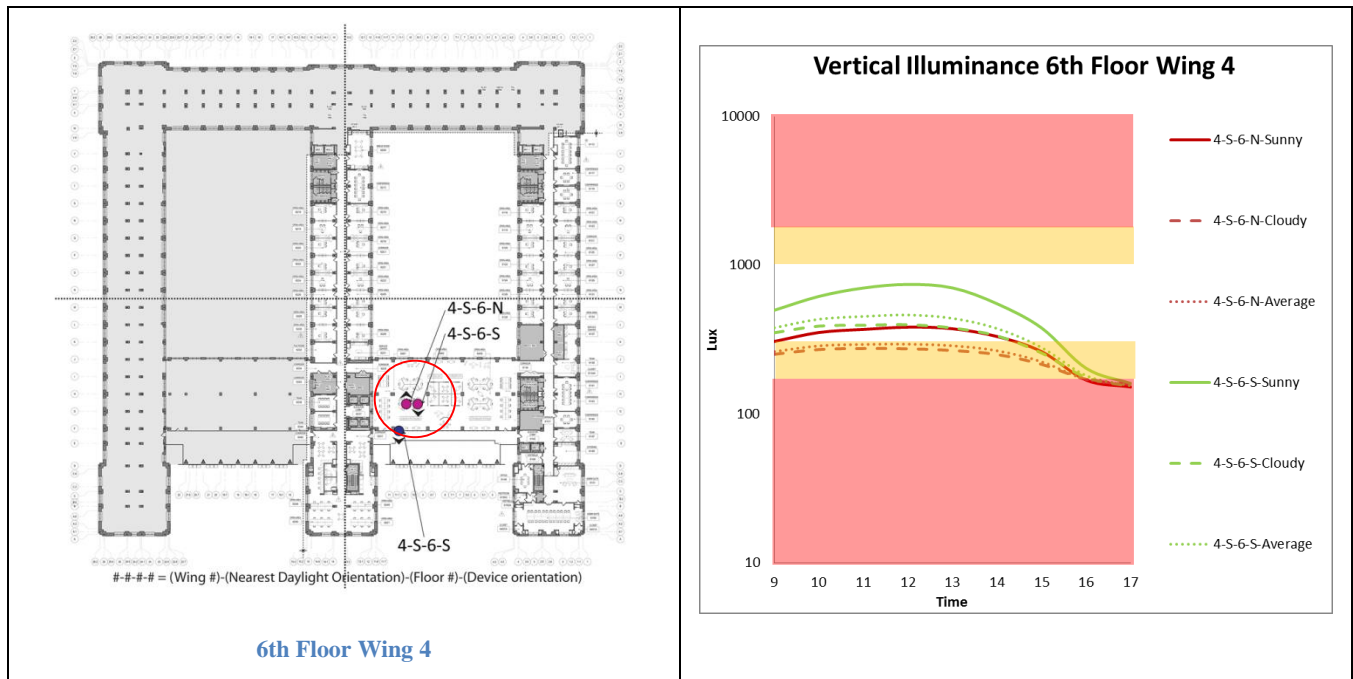
4<sup>th</sup> Floor Wing 1



4<sup>th</sup> Floor Wing 3



## 6TH FLOOR



## 7TH FLOOR

