RESULTS REPORT:

FACILITY LIGHTING — SUMMER

GENERAL SERVICES ADMINISTRATION
REGIONAL OFFICE BUILDING
301 7TH STREET SW
WASHINGTON, D.C.

Submitted to:

U.S. General Services Administration
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Lighting Research Center
Rensselaer Polytechnic Institute

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301 7TH STREET SW, WASHINGTON, D.C.

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EXECUTIVE SUMMARY

The U.S. General Services Administration (GSA) Regional Office Building (ROB) is a seven-story building located at 301 7th Street SW in Washington, D.C. The building was constructed in the 1930s as a construction supply warehouse. In later years the building was filled with offices. The northwest corner of the 7th floor at ROB was modernized recently, in a style similar to recent renovations at the GSA Central Office Building. Though one part of the 7th floor was modernized in the 21st century, most of the offices have furniture and lighting from the late 20th century.

In June 2015, researchers from the Lighting Research Center (LRC) at Rensselaer Polytechnic Institute, together with GSA staff, visited the site to collect data. LRC made photometric measurements at open-plan deskspaces in the modernized segment of the 7th floor, as well as a few non-modernized open-plan desks without access to daylight. In addition to the field measurements, LRC placed Daysimeter devices on nearby desk-spaces to continously measure photopic and circadian light levels 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[1] 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 one June day with variable weather. Photometric values will vary substantially in many spaces due to daily and seasonal changes in daylight. Some of this variability is shown in the Daysimeter measurements.

[1] Previous LRC/GSA site evaluations also focused on open-plan offices with proximity to daylight.

Below are some of the main findings from the June 2015 site evaluation at ROB:

- The spectroradiometer data showed that all of the deskspaces located on the 7th floor with access to daylight (daylighted area) are at or above the desired CS value of 0.3.
- In the interior offices, the CS values collected using the spectroradiometer varied from 0.1 to 0.36.
- Daysimeter data showed that deskspaces located in the daylighted area (i.e., Deskspaces A and B) varied from 0.28 to 0.49 in the north façade and between 0.15 and 0.29 in the west façade.
- Daysimeter data showed that deskspaces located in the interior offices varied between 0.08 and 0.37 (deskspace located in the large open-plan area that had been renovated). The overhead lighting in this renovated area delivered high amounts of light on the workplane, which may explain the high CS values.
- Most of the deskspaces at ROB had a horizontal illuminance of greater than 30 footcandles (approximately 300 lux). Task lights were not available at most desks. Overall, most (88%) occupants rated the amount of light on their desks as neither too much nor too little. Compared to other office buildings, most occupants (56%) rated the lighting as “better” or “much better” than other buildings.
- When looking separately at the responses between the renovated spaces with access to daylight and the interior offices, 100% of those in daylighted offices and 71% of those in interior offices responded that the amount of light on their desks was neither too much nor too little. 78% of occupants in deskspaces in the renovated spaces stated that their lighting was better or much better than other buildings, while only 29% of occupants in deskspaces in the interior offices agreed with that statement.

INTRODUCTION

The U.S. General Services Administration (GSA) Regional Office Building (ROB) is a seven-story building located at 301 7th Street SW in Washington, D.C. The Lighting Research Center (LRC) collected photometric measurement data at a site visit June 17, 2015.

ROB fills a city block, and no longer has the original 1935 light-well courtyards. Some occupants use flexible desk assignments, in the same manner as at the GSA Central Office Building; like that site, some desks at ROB have low partitions and new furnishings (Figure 2). Most occupants, however, have more permanently-assigned desks, with older equipment and little or no access to daylight because of higher workspace partitions (Figure 3).

Figure 1. ROB 7th floor, northwest corner. Measurement area shown in grey.

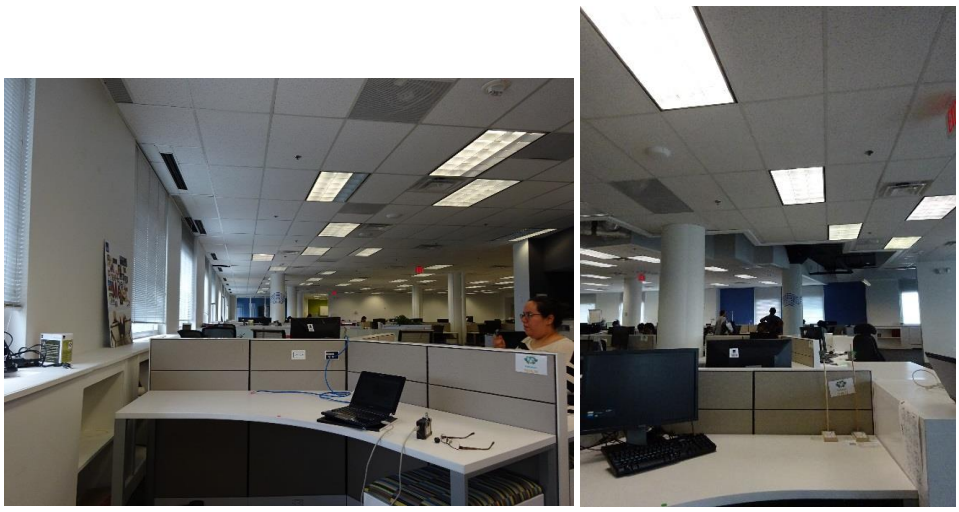

Figure 2. Modernized areas at ROB

Figure 3. Open-plan office areas at ROB, not recently updated

Lighting in the evaluation area consisted of recessed 2’ x 4’ troffers mounted in the conventional ceiling grid. As shown in Figures 2 and 3, most have parabolic louvers with 4’ linear fluorescent lamps.

RESEARCH OBJECTIVES

The LRC collected photometric measurements at ROB in June 2015 at open-plan desks. Some had access to daylight; some were interior open-plan desks with only electric lighting. The goal of the research was to compare seasonal photometric conditions as they relate to occupant comfort, productivity, and circadian health.

Daylighting conditions were representative of summer, as the visit was during daylight savings, and summer solstice occurred the week after the visit. LRC researchers included Dr. Mariana Figueiro (LRC Light and Health Program Director), Jennifer Brons (LRC DELTA Program Director[2]), and research assistant Kassandra Gonzales. The LRC team was escorted and assisted by Bryan Steverson of GSA.

[2] 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.

METHODS

On Day 1 (June 15, 2015), preparations were made for the measurement day (June 17, 2015). Battery-powered measurement equipment was installed and documented. Each member of the research team was responsible for one aspect of data collection (detailed below). Two researchers collected illuminance and luminance measurements while one researcher performed spectral power distribution measurements. Questionnaires were administered on June 17, 2015.

Five types of measurements were completed at ROB:

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. Measurements of 7 additional interior offices used the illuminance function of the spectroradiometer system. (See "SPD" below.)

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^2), 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.

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 well as time of day. SPD was measured at ROB to allow researchers to calculate, using different response functions, measures such as brightness, glare, and circadian stimulus. 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 11 desks and 2 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 ROB. The questions were the same as LRC used at other GSA evaluation sites, and on the previous evaluation of this site.

RESULTS

ILLUMINANCE RESULTS

LRC measured photometric conditions (illuminance and luminance) at ROB. Photometric data were collected for 8 desks over the course of the day and evening. Spot measurements were collected once at an additional 12 interior desks.

Data 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.' Another row of desks was further from windows, but still in eyesight ('C desks'). The skies were primarily overcast/rainy on the measurement day, though there was intermittent sun.

Figure 4 shows an example of typical horizontal illuminance measurement locations at the measurement desks. Because partitions near the windows at ROB are below eye height, LRC did not measure vertical illuminance on partitions. However, LRC did measure vertical illuminance at the eye. Figure 5 is a key plan showing the measurement locations at ROB. Measurement locations were in renovated spaces (with new furniture and overhead lighting) as well as non-renovated spaces (with old furniture and overhead lighting).

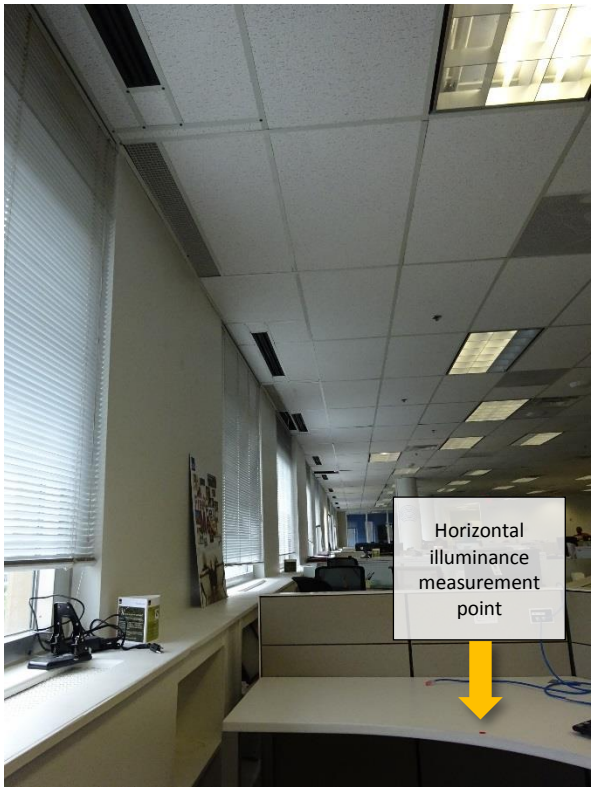

Figure 4. Typical horizontal measurement points at a row A desk.

For those desks with access to daylight, measurements occurred in the morning, midday, in the afternoon (and included additional daylight contribution), as well as after dark. For interior desks with no access to daylight, measurements were collected once, rather than repeatedly throughout the day. The resulting measurements are shown in detail in Appendix A.

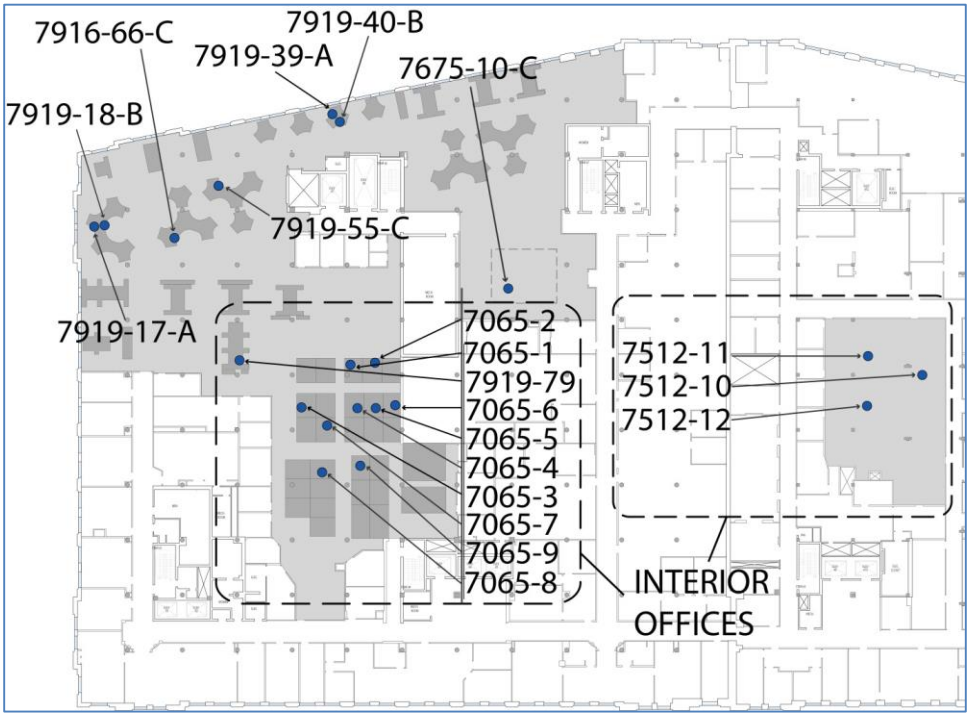

Figure 5. Photometric measurement locations at ROB. Numbering convention: (Room #)-(Desk #)-(Window proximity, if any). Grey color indicates measurement area.

On the north side of ROB, horizontal illuminances were higher (~800 lx) during the day compared to the west side (~600 lx). Both sets of B desks were physically very close to both sets of A desks, thus A and B desks had similar horizontal illuminance measurements.

C desks on both the north and west side did not show much daylight contribution; the majority of the light was generated electrically. One C desk had very high electric light levels on the desk (800 lx) due to two luminaires directly overhead.

The desk with the north-facing skylight overhead had moderate horizontal illuminance during the day (400-500 lx), but low levels at night (200 lx).

LRC also evaluated spaces without daylight ("interior"). These interior offices have high partitions, and no access to daylight. Therefore, horizontal illuminance at interior desks varied depending on whether electric lights were located overhead. Decisions about where to place electric lighting do not seem to have been made based on furniture arrangement, so some interior office cubicles have more light than others; one desk had less than 200 lux, while most had 500-600 lux. It was interesting to observe that the deskspaces with the lowest light levels were generally unoccupied, perhaps because people avoided these deskspaces due to the low light levels.

Vertical illuminances at the eye were mixed as well. A and B desks had similar vertical illuminances at the eye in many cases, and in a few cases, B desks had higher vertical illuminances than A desks.

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. The resulting measurements are shown in detail in Appendix A.

On the north facade, there were a few desks with a view of the sun at multiple times of day, and thus potential window glare; questionnaires, however, showed little concern about sun. (See Appendix B.) As shown in Figure 2, window shades were in use on the north side.

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 luminance 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. The questionnaire results did not suggest that glare was an issue at ROB.

Questionnaire Results

LRC administered a brief questionnaire to 16 people working at ROB in June 2015. Appendix B shows detailed questionnaire results. Where possible, the questionnaire data for this site were compared to results from other office case studies, and to previous GSA site evaluations publications (see References).

All respondents (100%) only work during the day, more than other evaluated GSA sites. Skies were cloudy on the day that the questionnaire was completed, though there was periodic sun. Two window orientations were represented (north: 13%; west: 31%) as well as skylight (13%) and interior (44%). All respondents worked on the 7th floor of ROB, where the other evaluation work was taking place.

Most workers were satisfied by the amount of light provided; 88% reported that the amount of light on their desk was neither too much nor too little (100% of those reporting from offices with daylight vs. 71% of those in interior offices).

Use of task lights was uncommon. Most (50%) reported that they “never” use a task light (33% daylight, 71% interior). Most (44%) did not answer the task light question (67% daylight, 14% interior). LRC noted that a task light was not present at 67% of the desks where people answered the questionnaire.

Many (63%) respondents rated their luminaires as comfortable to look at (89% daylight, 29% interior).

Many (44%) respondents reported from interior offices, without access to daylight, thus any answers they had about windows and blinds are omitted in these results. Most (89%) of the respondents with daylight reported that the windows at ROB are comfortable to look at. For spaces with daylight, venetian blinds are available. One of the nine occupants with daylight (11%) reported that they keep shades up all the time in summer. One (11%) keeps blinds down when sunny, and three (33%) always keep blinds partway down.

As shown in Figure 6, the overall lighting at this building was rated as “better” or “much better” by 56% of the respondents (78% daylight, 29% interior). As shown in Figure 6, these results are slightly more positive than other office lighting case studies, including the GSA Central Office Building, especially those at ROB in the daylighted space.

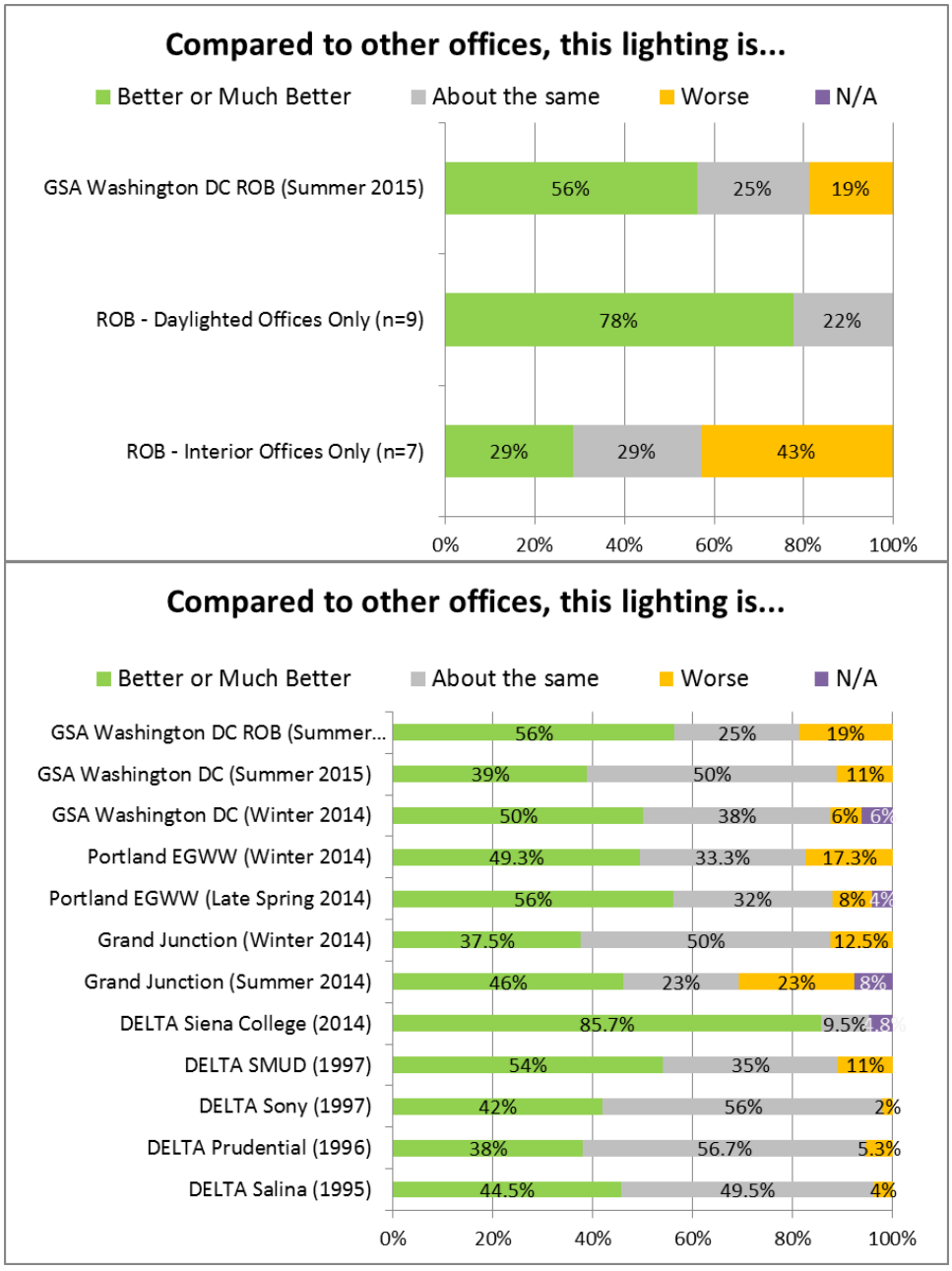

Figure 6. Overall questionnaire results at GSA Central Office Building, daylighted vs. interior (upper), and compared to other office lighting evaluations by the LRC (lower).

Spectral Power Distribution (SPD) Results

Shown below is a photo of the equipment used for measurement of spectral characteristics in summer (Figure 7). 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.)

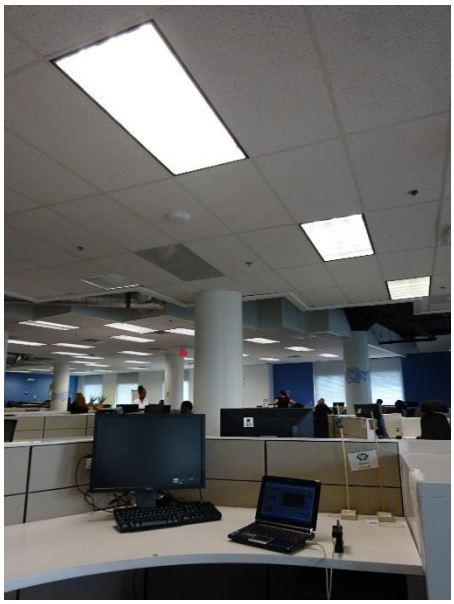

Figure 7. A spectroradiometer taking measurements at ROB desk level.

SPDs were measured at the same desk locations used for hosting other site measurements (see Figure 3).

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 Appendix C and summarized in Appendix D. Table 1 shows average results of summer daytime measurements (excluding evening measurements, since workers were not present after dark). The dataset is small, as shown by the number of desks and number of measurements at each desk; as a result, it is difficult to generalize about the building from these measurements.

Table 1. ROB average daytime measurements using spectroradiometer.

			Illuminance			Color Temp.	Circadian Light		Circadian Stimulus	
Deskspace Locations	# of Desks	Meas./ Desk	Lux	CIEx	CIEy	CCT (K)	Average CL_A	Median CL_A	(up to 0.7) CS	Brightness
A	2	3	529	0.37	0.38	4247	370	362	0.35	369
B	2	3	595	0.37	0.38	4358	456	437	0.39	425
C	2	3	629	0.38	0.38	4062	380	411	0.36	425
Skylight	1	3	281	0.37	0.38	4263	192	187	0.23	194
Interior	1	3	476	0.39	0.40	3861	311	242	0.31	295
Orientation										
W	3	3	553	0.38	0.38	4165	361	342	0.35	381
N	3	3	616	0.37	0.38	4279	443	442	0.38	431
Skylight	1	3	281	0.37	0.38	4263	192	187	0.23	194
Interior	1	3	476	0.39	0.40	3861	311	242	0.31	295

The data from LRC's visit to ROB in June showed moderate overall levels of circadian stimulus at many locations. The desk located under the skylight had lower CS values than the three with windows (A, B, C); this is due to the fact that the skylight is a north-facing roof monitor, with many obstructions to light before it reaches the workplane. Nighttime measurements taken at deskspaces A (closer to windows) were lower than those taken during the daytime, suggesting that these deskspaces had the largest contribution of daylight, while the nighttime measurements taken on deskspaces B and C were not as different as those taken during the day, suggesting that electric lighting was contributing to the measurements. In some locations (such as one of the C desks and the interior desk with distant view of windows) electric light is making most of the contribution to CS. Given that the ceiling in this area is low and that the ceiling luminaires are providing high light levels on the workplane (greater than 500 lux), desired CS was obtained using electric lighting. The one downside of this approach is that the lighting can be perceived as glaring and uncomfortable for some and may not be good lighting for computer work. Our subjective responses, although of limited sample, did not suggest that this was the case, however.

The desks on the north side of ROB had slightly higher average CS values than those on the west side, but most of the deskspaces in this area receive the desired CS value.

These data, however, are snapshots of exposures over the course of one working day in summer. 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

Appendix E shows 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 Figure 8. Below are some of the main findings:

- CS values were close to or above the desired amount of 0.3 in all of the deskspaces located in the daylight area. CS values in deskspaces located in the north façade were higher than those in the west façade.
- CS values in interior spaces were low (ranging from 0.08 to 0.13), except for one deskspace (7919-78) located in the remodeled area, which had a CS value above 0.3; as shown in Appendix E-8, this desk location had a luminaire directly overhead, as well as low partitions.
- Circadian stimulation before 10:00 a.m. is available for the north and west façades, but none of the interior offices in the older part of the building had CS values close to the desired CS value.

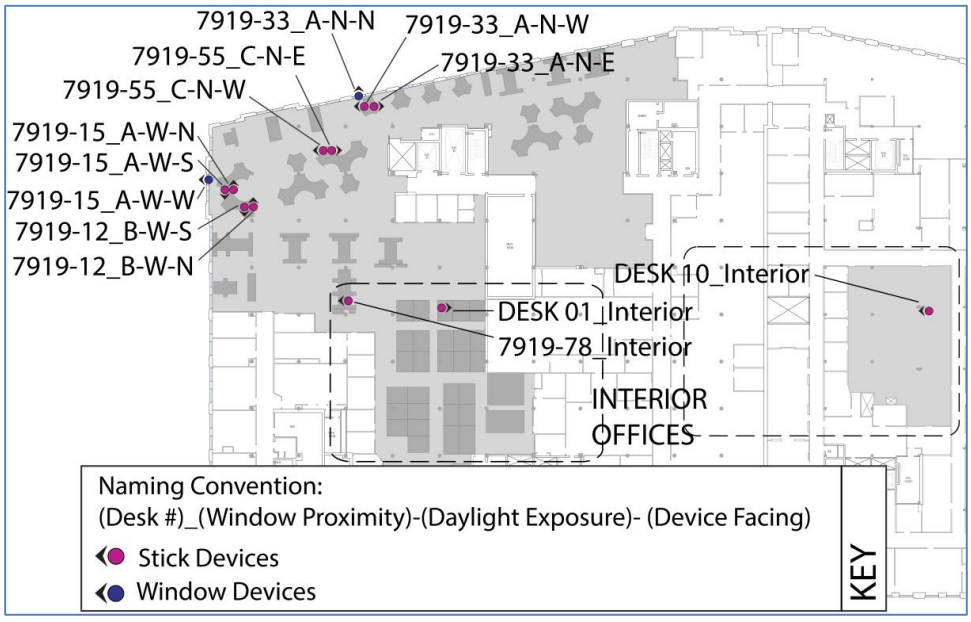

Figure 8. Daysimeters were installed locations in June 2015; 2 were mounted on a window and 11 were mounted on sticks on occupant desks. Window-mounted devices are shown in blue; stick-mounted devices shown in magenta.

DISCUSSION

A summary of the findings is shown in Appendix F. As shown in Figure 9, pink-shaded portions of the figures in Appendix F 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.

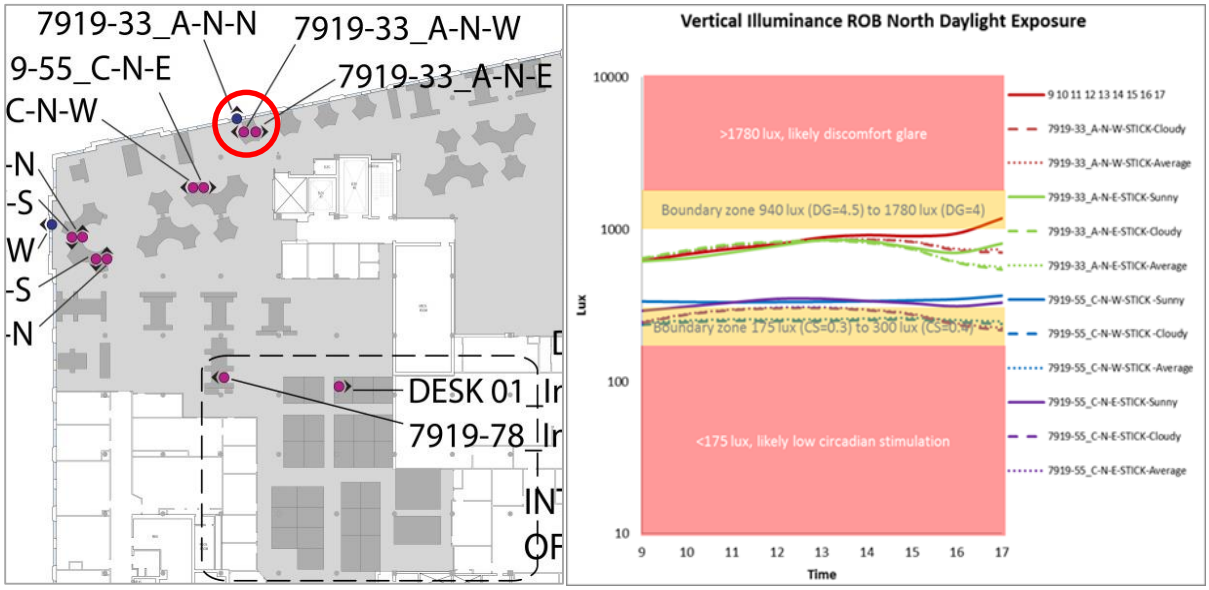

Figure 9. Average vertical illuminance at the eye at two desks at different times of day and sunny vs. cloudy conditions.

The ROB building has two very distinct areas. All of the deskspaces located in the remodeled/daylight area had vertical illuminances close to the desired level for good circadian stimulation and low likelihood for discomfort glare. The contribution of daylight to CS was the greatest in deskspaces close to the windows (deskspaces A).

In the interior offices located in the older parts of the building, the CS values were very low and did not reach the desired amount at any time during the day.

None of the deskspaces we measured had vertical light levels above 1790 lx, which is the boundary for discomfort glare, as discussed in a previous LRC report.

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 to entrain subjects, but estimates of the trade-off between light level and duration are not available. Functionally, CS levels as low as 0.1 may be above threshold 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.

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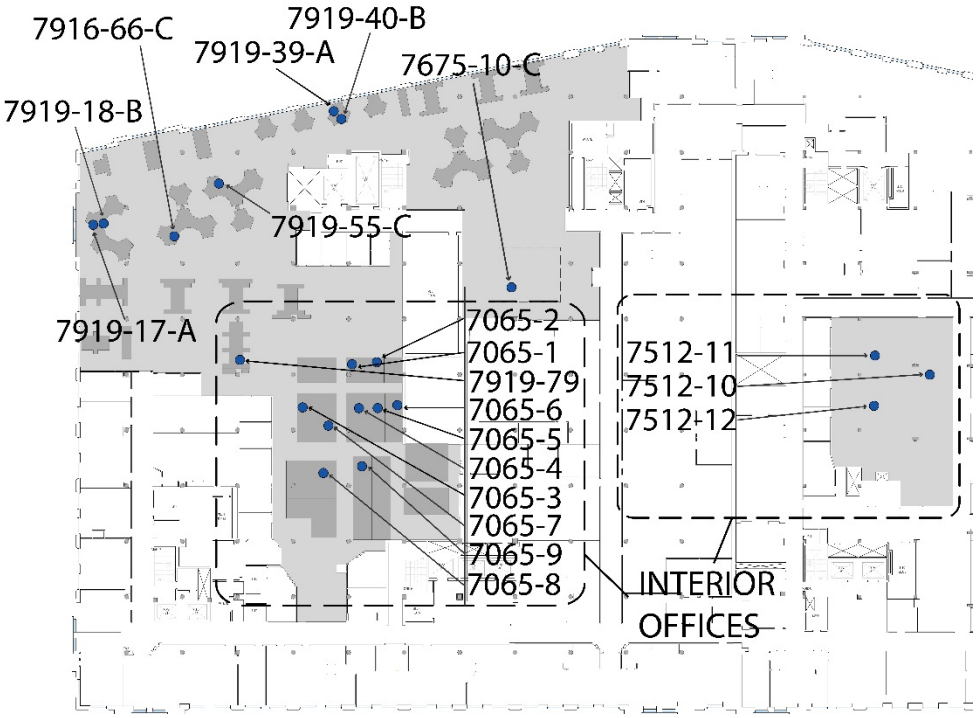
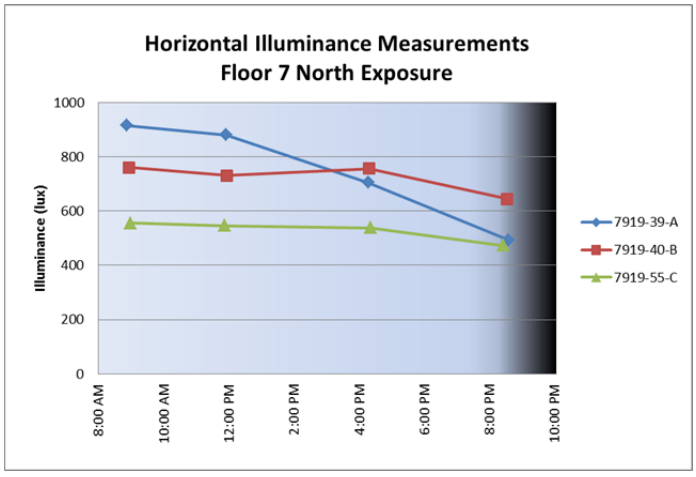
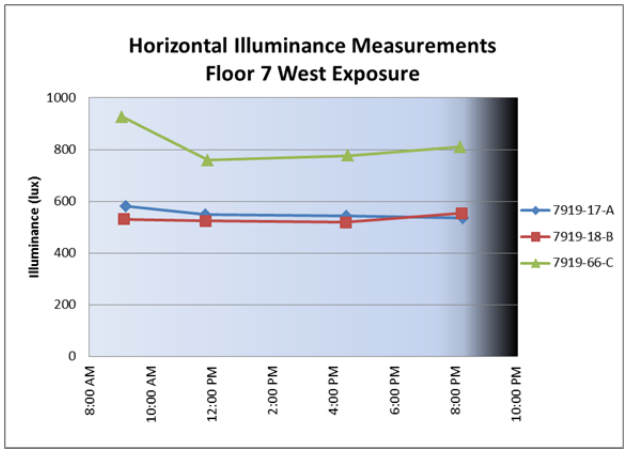
APPENDIX A: PHOTOMETRIC DATA (ILLUMINANCE AND LUMINANCE MEASUREMENTS)



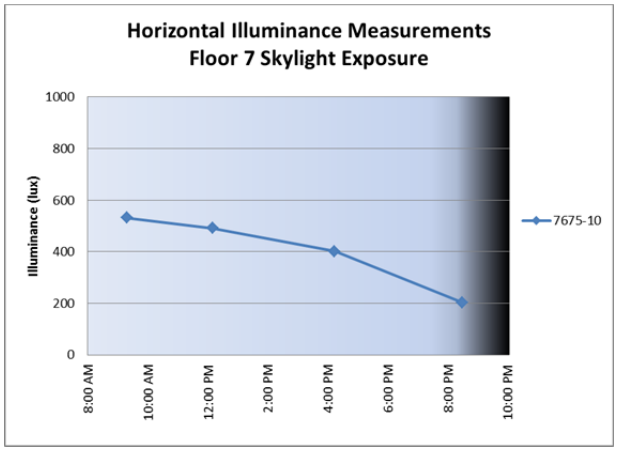
Key plan, showing summer photometric measurement locations on Floor 7. Desks marked "A" are nearest the windows, desks marked "B" are in the adjacent row, and desks marked "C" are deeper in the core of the building. "Interior" desks do not have access to daylight.



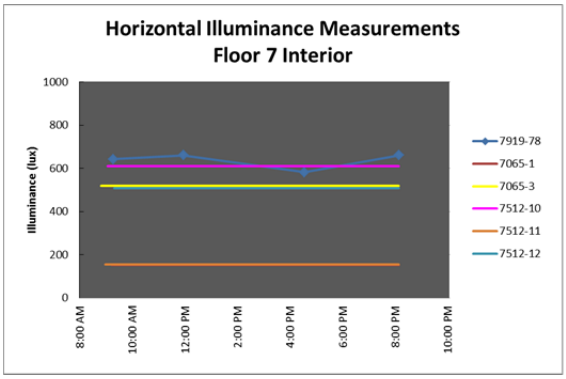
Horizontal illuminance measurements at 3 desks on the north side of the 7th floor, during the day and in the evening.

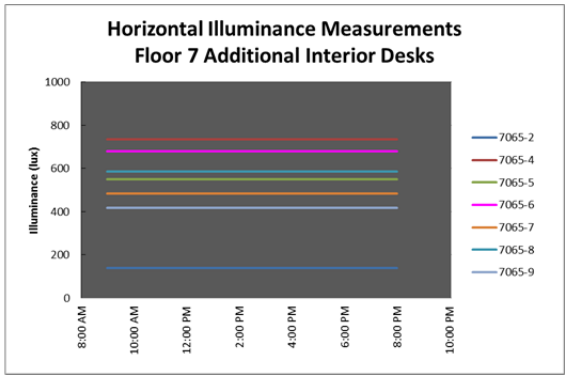


Horizontal illuminance measurements at 3 desks on the west side of the 7th floor, during the day and in the evening.

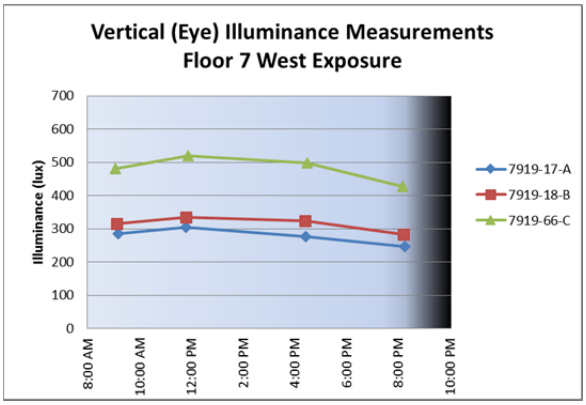


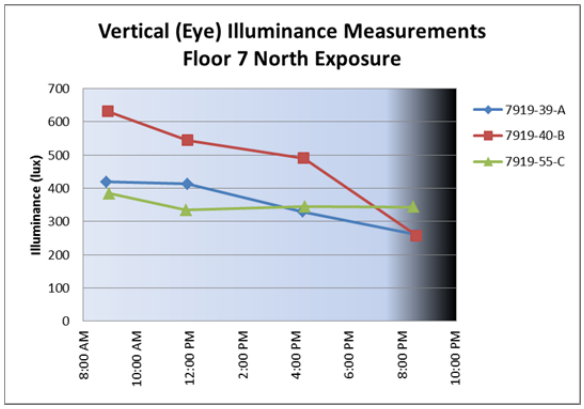
Horizontal illuminance measurements at one desk with skylight exposer on Floor 7, during the day and in the evening.

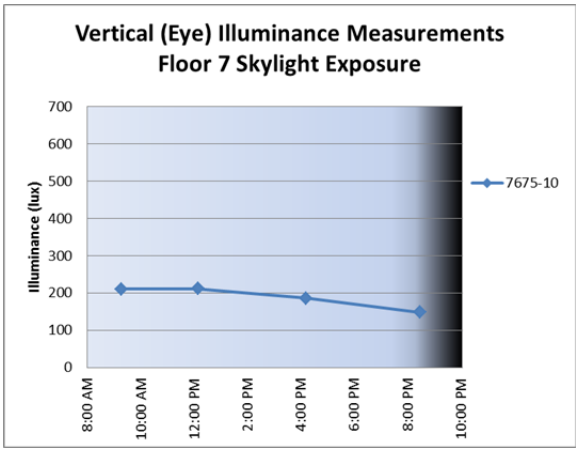


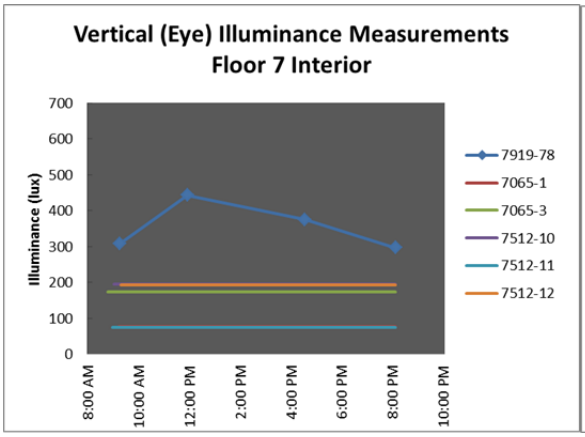


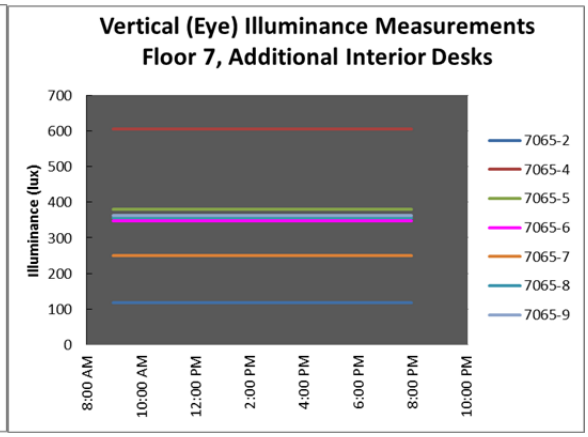
Horizontal illuminance measurements at several interior desks on Floor 7.
(Horizontal line indicates that a single measurement was collected at that desk, due to no daylight exposure)



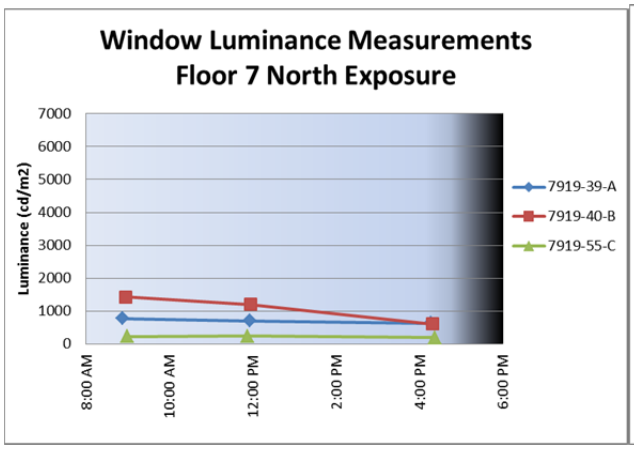


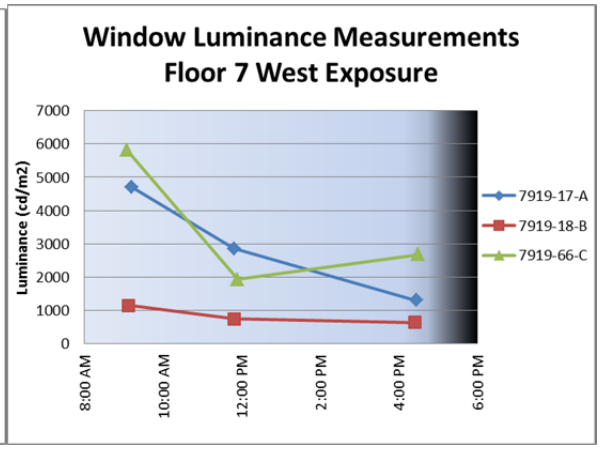




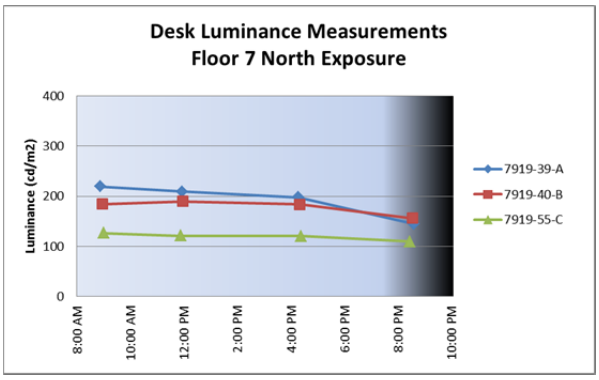


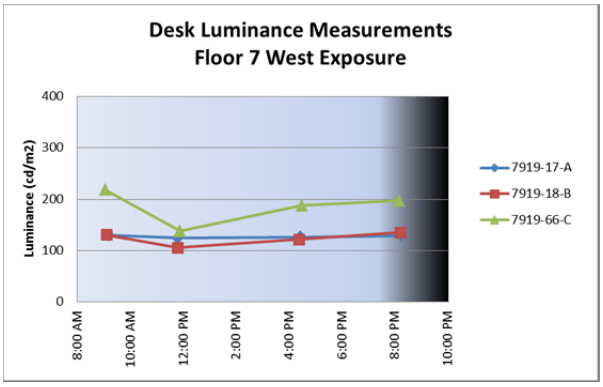
Vertical illuminance (at the eye) at ROB desks, during the day and in the evening. (Horizontal line indicates that a single measurement was collected at that desk, due to no daylight exposure)

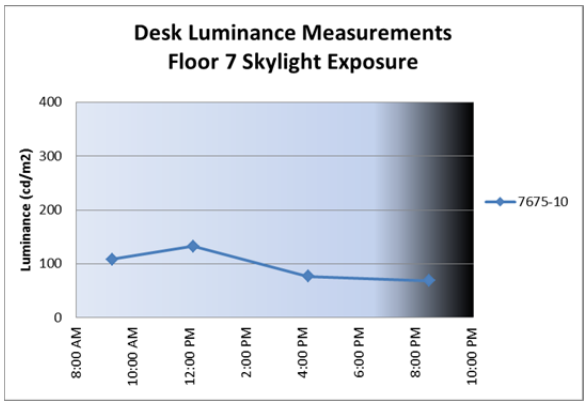


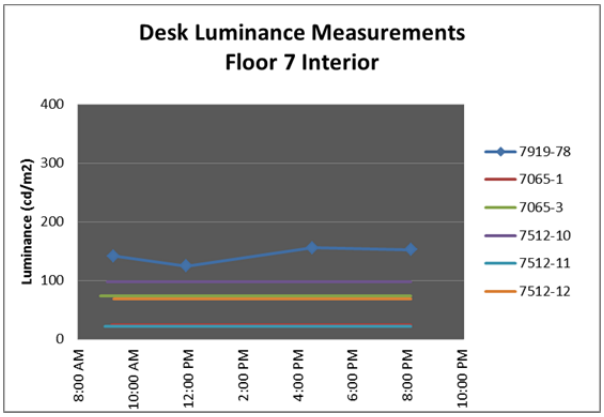


Window luminance at the 6 desks with access to windows, during the daytime measurements.

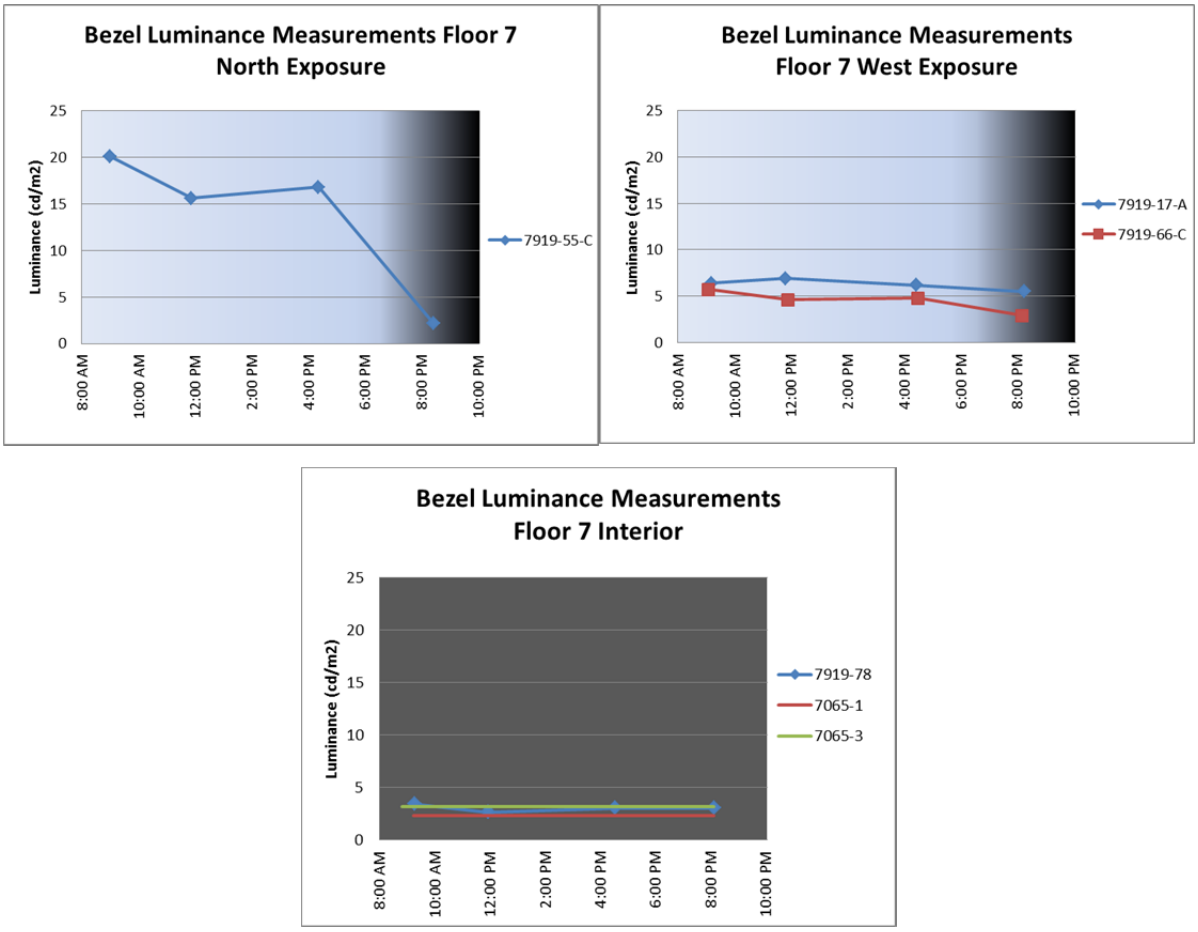






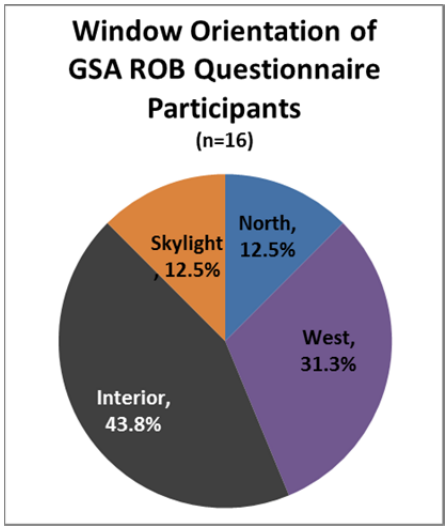


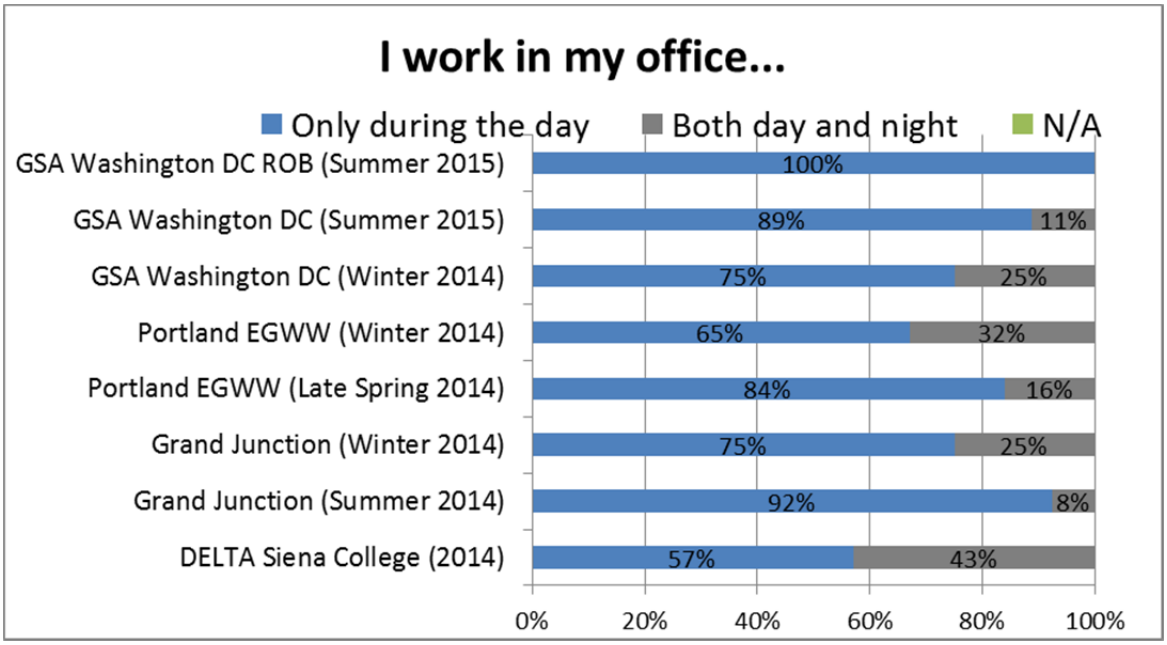
Desk luminance at ROB desks, during the day and in the evening. (Horizontal line indicates that a single measurement was collected at that desk, due to no daylight exposure)

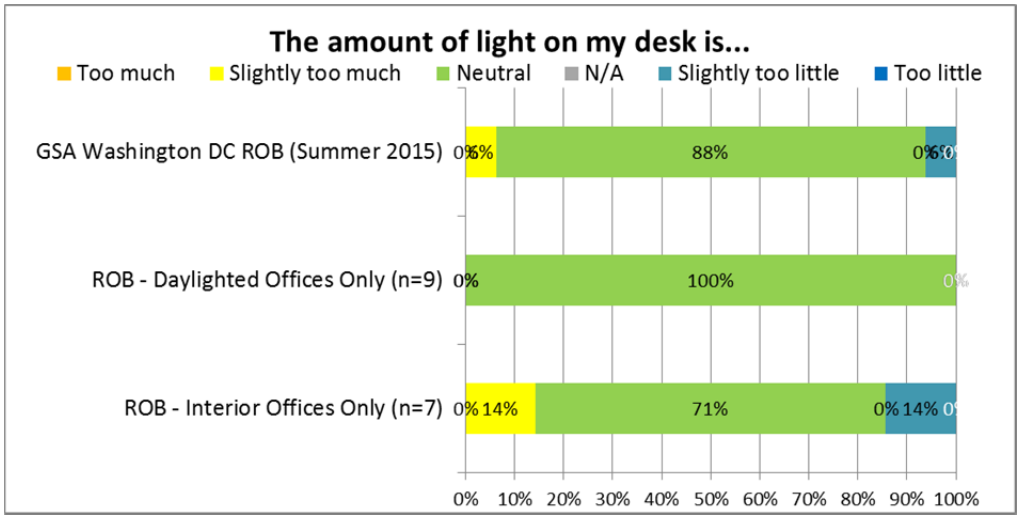


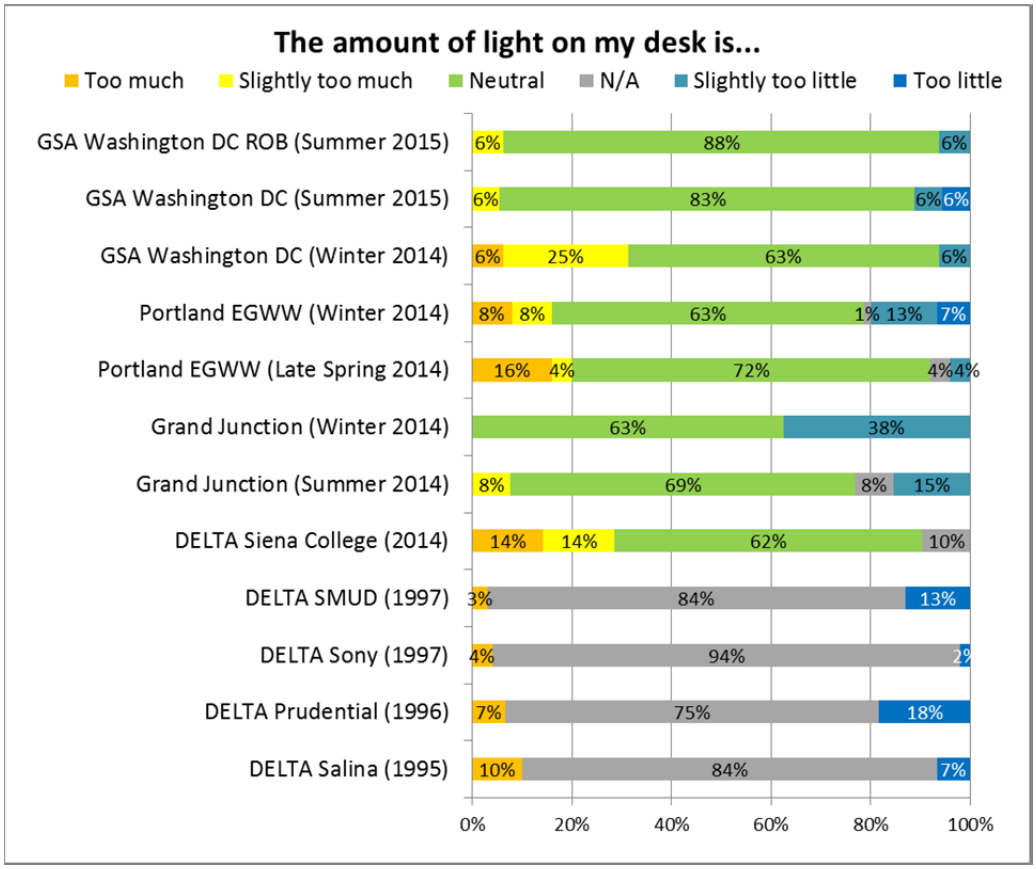
Bezel luminance at ROB desks, during the day and in the evening. (Horizontal line indicates that a single measurement was collected at that desk, due to no daylight exposure)

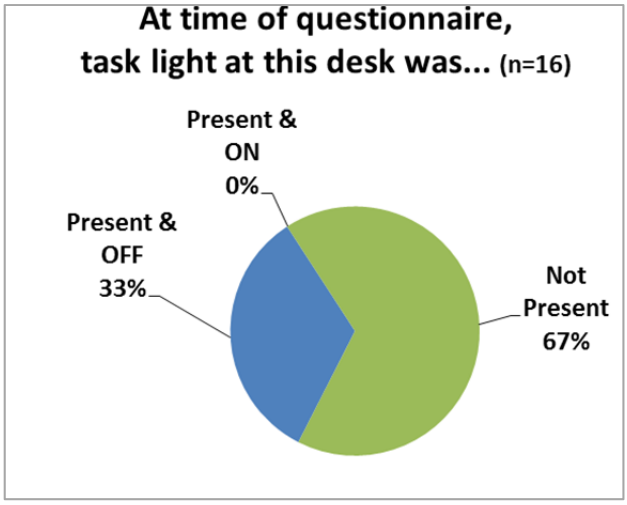
APPENDIX B: QUESTIONNAIRE RESULTS

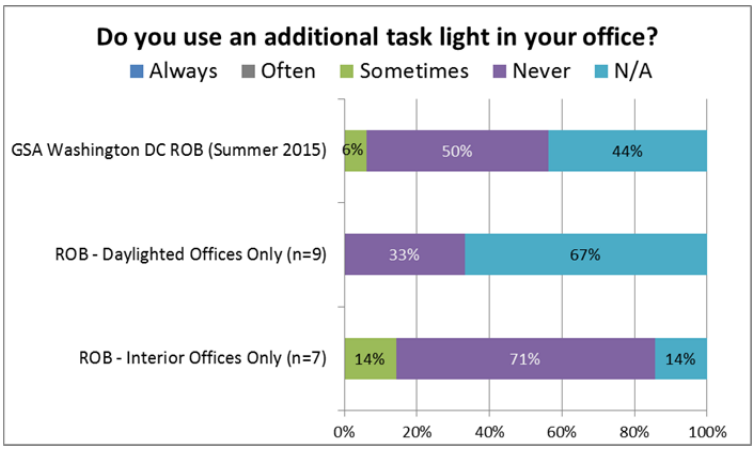


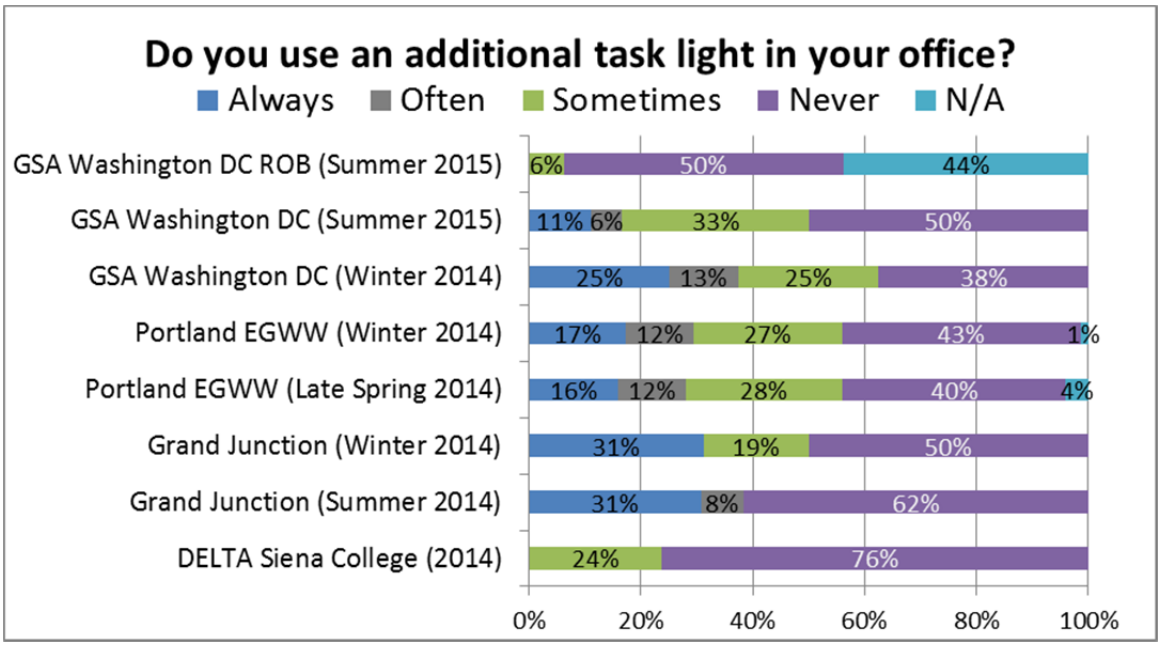


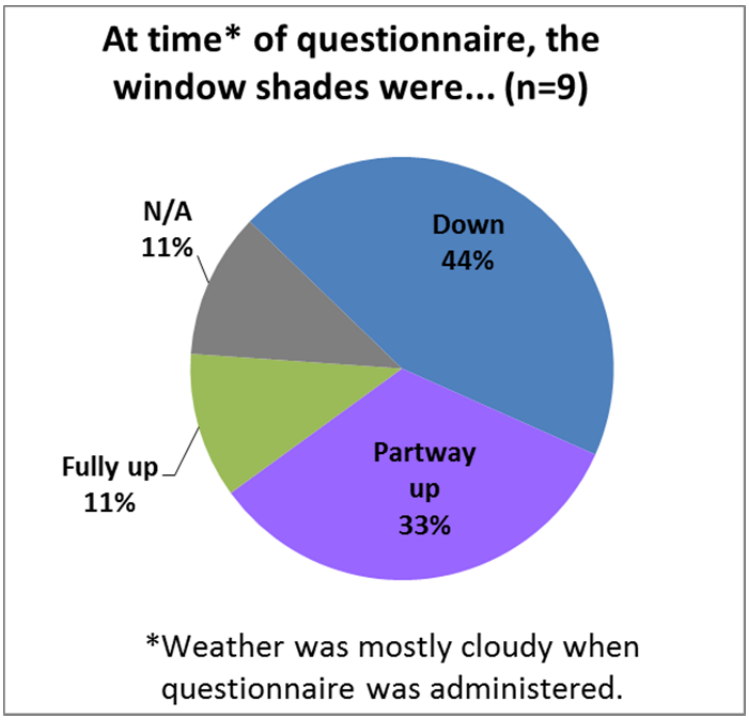

The amount of light on my desk is...
Too much
Slightly too much
Neutral
N/A
Slightly too little
Too little
GSA Washington DC ROB (Summer 2015)
ROB - Daylighted Offices Only (n=9)
ROB - Interior Offices Only (n=7)
0% 10% 20% 30% 40% 50% 60% 70% 80% 90% 100%

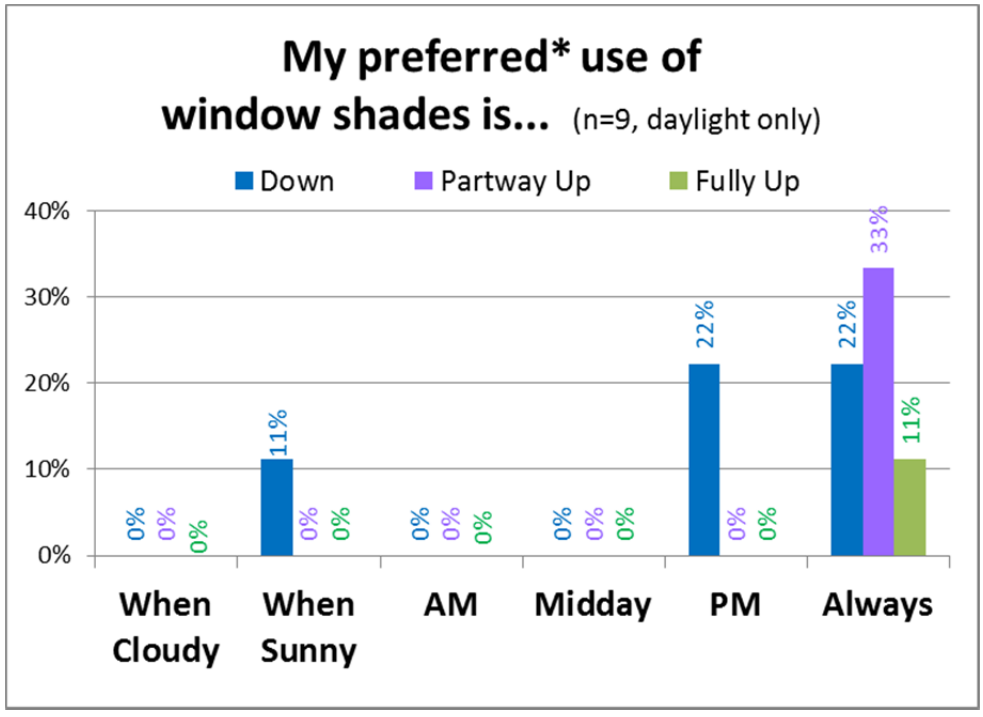

The amount of light on my desk is...
Too much
Slightly too much
Neutral
N/A
Slightly too little
Too little
GSA Washington DC ROB (Summer 2015)
GSA Washington DC (Summer 2015)
GSA Washington DC (Winter 2014)
Portland EGWW (Winter 2014)
Portland EGWW (Late Spring 2014)
Grand Junction (Winter 2014)
Grand Junction (Summer 2014)
DELTA Siena College (2014)
DELTA SMUD (1997)
DELTA Sony (1997)
DELTA Prudential (1996)
DELTA Salina (1995)
0% 20% 40% 60% 80% 100%


At time of questionnaire, task light at this desk was... (n=16)
Present & ON 0%
Present & OFF 33%
Not Present 67%


Do you use an additional task light in your office?
Always
Often
Sometimes
Never
N/A
GSA Washington DC ROB (Summer 2015)
6%
50%
44%
ROB - Daylighted Offices Only (n=9)
33%
67%
ROB - Interior Offices Only (n=7)
14%
71%
14%
0%
20%
40%
60%
80%
100%

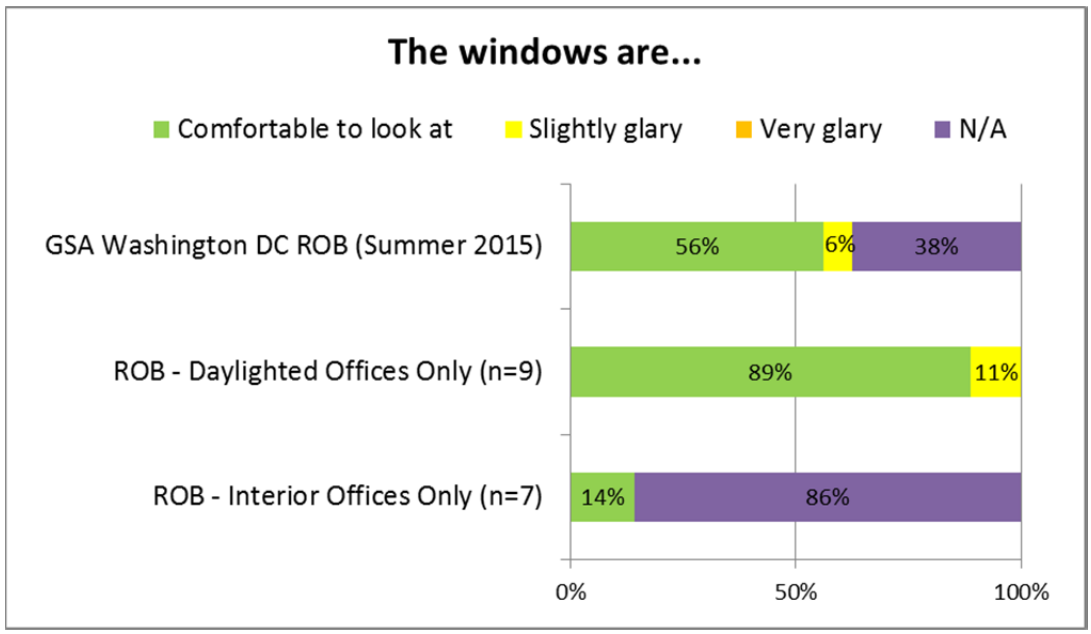

Do you use an additional task light in your office?
Always
Often
Sometimes
Never
N/A
GSA Washington DC ROB (Summer 2015)
6%
50%
44%
GSA Washington DC (Summer 2015)
11%
6%
33%
50%
GSA Washington DC (Winter 2014)
25%
13%
25%
38%
Portland EGWW (Winter 2014)
17%
12%
27%
43%
1%
Portland EGWW (Late Spring 2014)
16%
12%
28%
40%
4%
Grand Junction (Winter 2014)
31%
19%
50%
Grand Junction (Summer 2014)
31%
8%
62%
DELTA Siena College (2014)
24%
76%
0%
20%
40%
60%
80%
100%

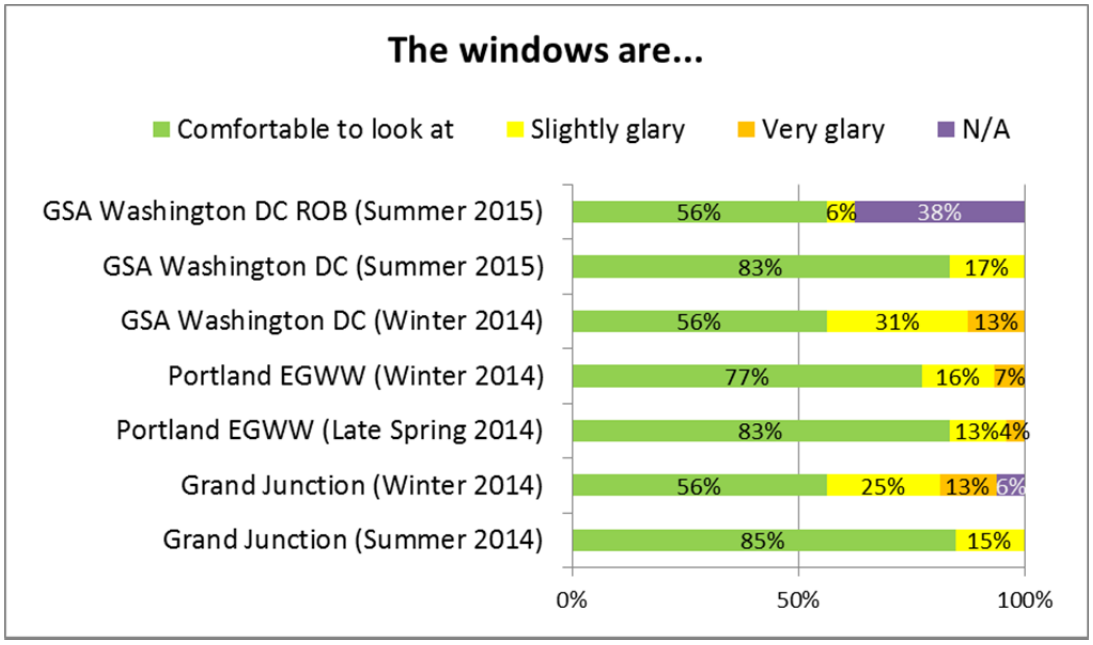


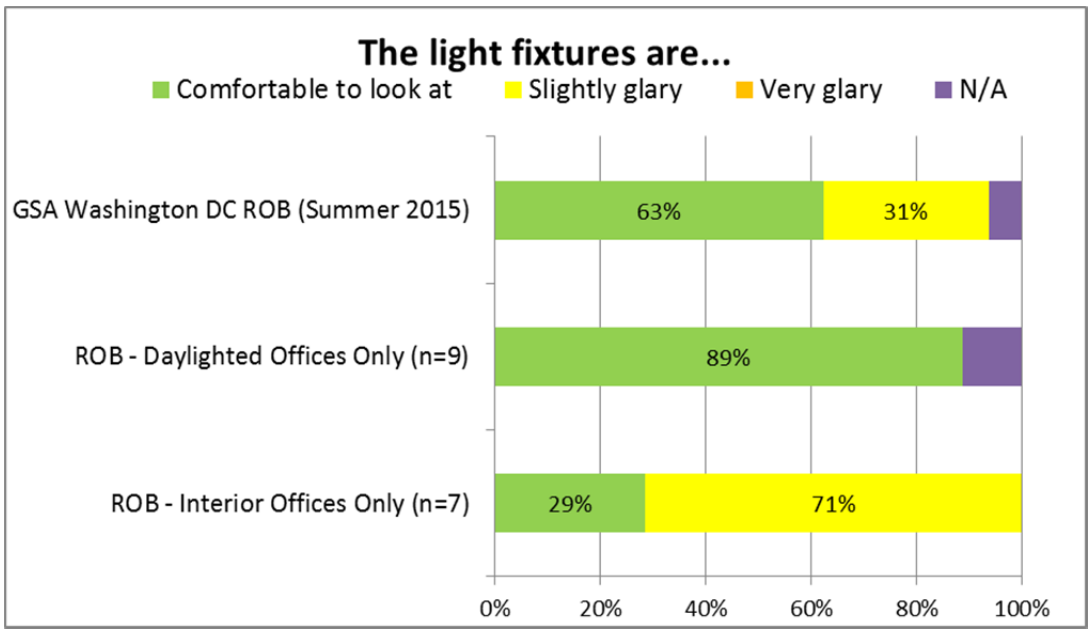


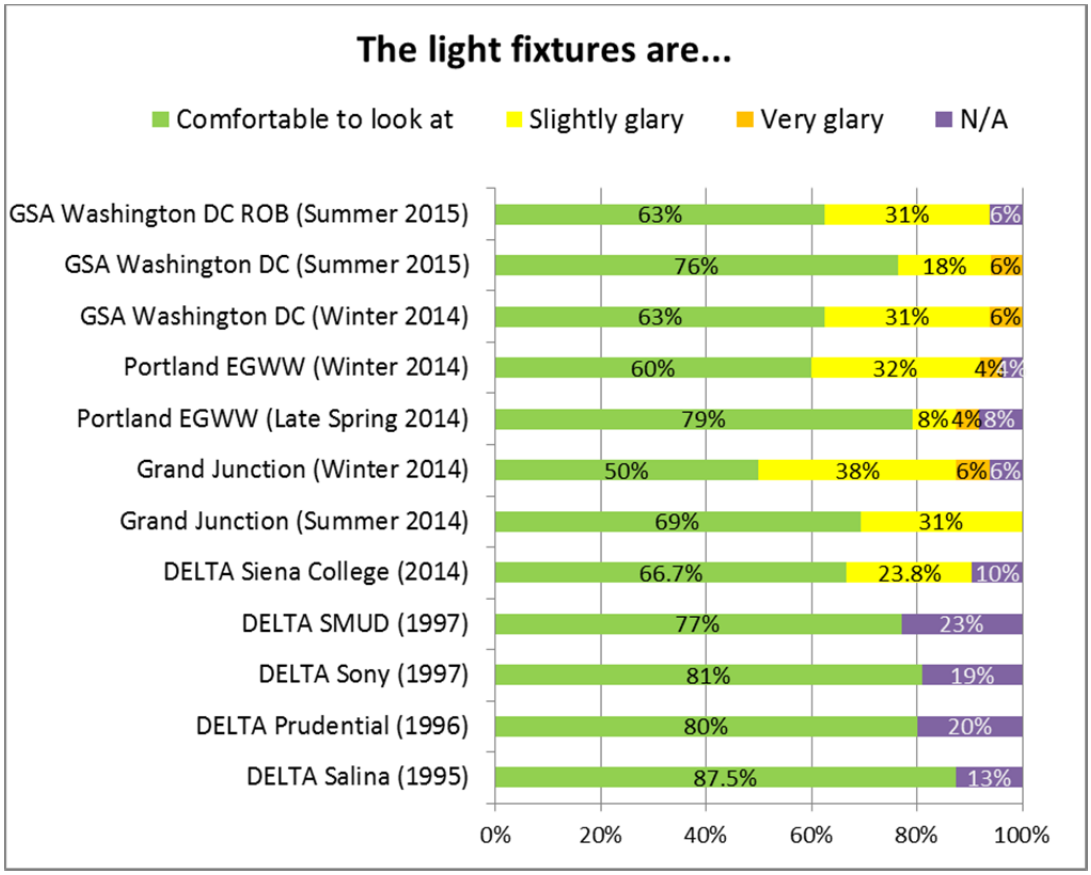
SHADES COMMENTS

- Shades "partway up" because "I like to see the view."
- Windows are "comfortable" because "If too much light, (I can use the) blinds."


The windows are...
Comfortable to look at
Slightly glary
Very glary
N/A
GSA Washington DC ROB (Summer 2015)
56%
6%
38%
ROB - Daylighted Offices Only (n=9)
89%
11%
ROB - Interior Offices Only (n=7)
14%
86%
0%
50%
100%

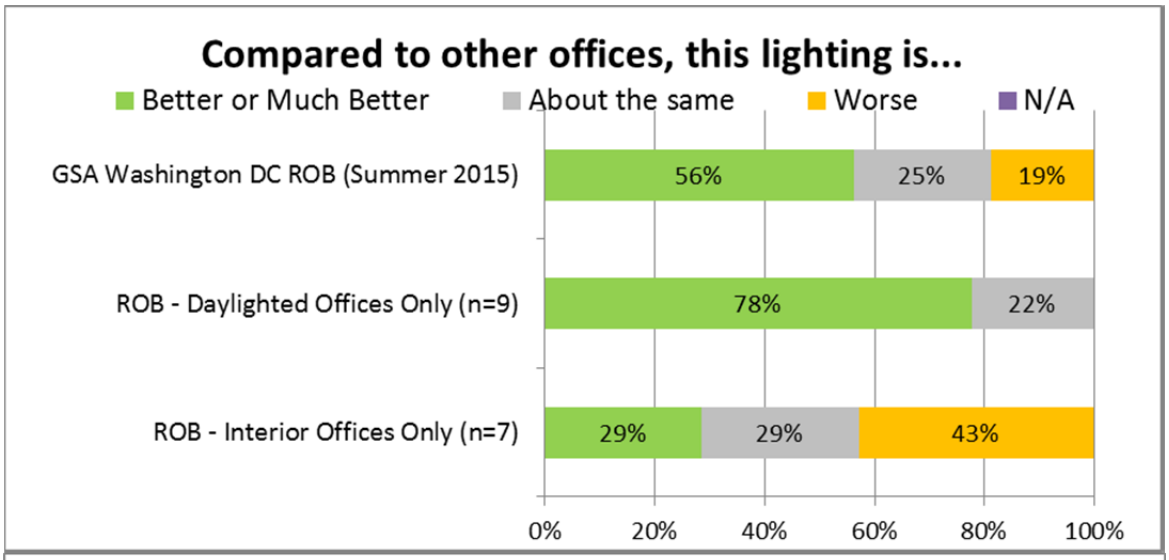

The windows are...
Comfortable to look at
Slightly glary
Very glary
N/A
GSA Washington DC ROB (Summer 2015)
56%
6%
38%
GSA Washington DC (Summer 2015)
83%
17%
GSA Washington DC (Winter 2014)
56%
31%
13%
Portland EGWW (Winter 2014)
77%
16%
7%
Portland EGWW (Late Spring 2014)
83%
13%
4%
Grand Junction (Winter 2014)
56%
25%
13%
6%
Grand Junction (Summer 2014)
85%
15%
0%
50%
100%

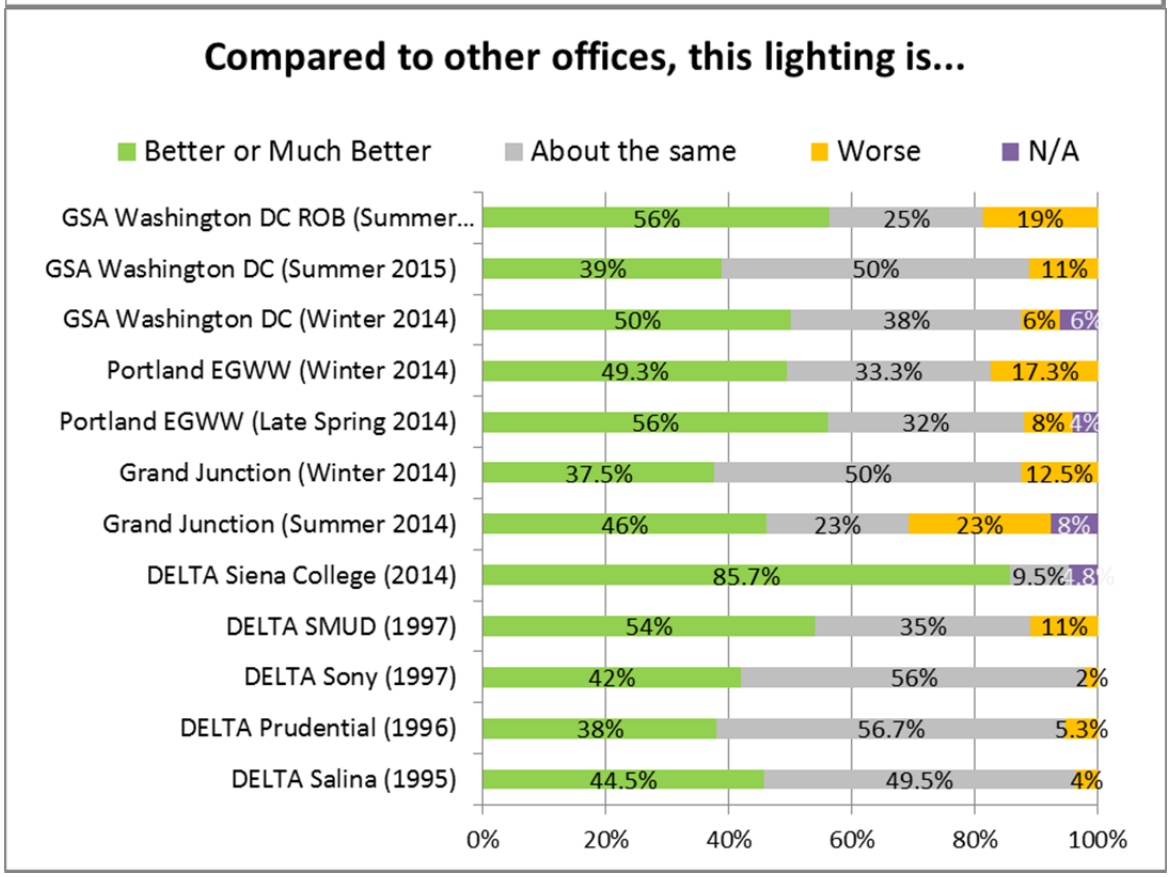




LUMINAIRE COMMENTS

- Regarding interior office "Weird Shadows"
- Regarding interior office "We need new lighting"



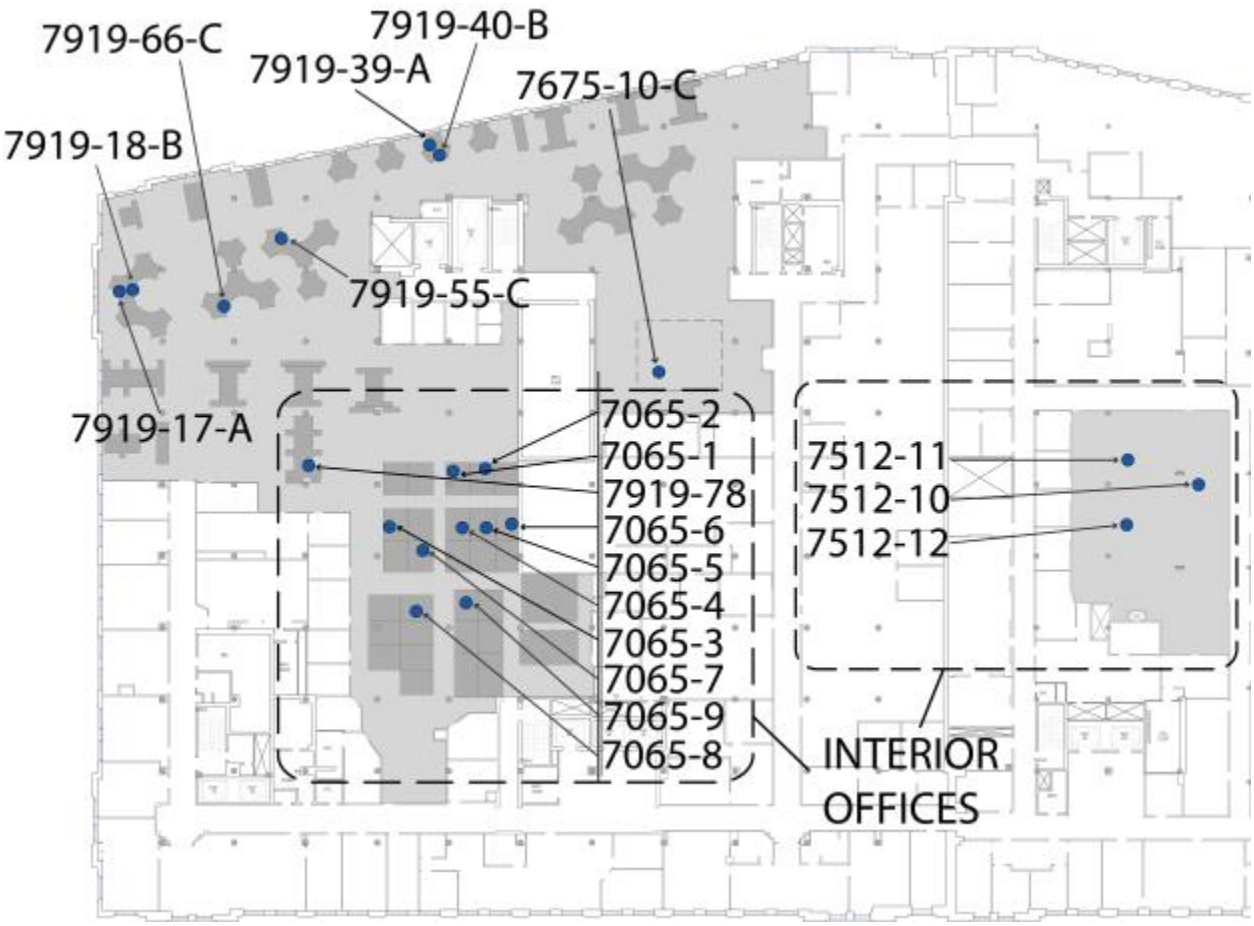


OVERALL COMMENTS

- Overall "Much better… because it's nice and open."
- Overall "better" because "(I) sit very close to window."
- Regarding skylight "I'd like more of those sky domes. That's natural light."

APPENDIX C: SPECTRAL PHOTOMETRIC DATA

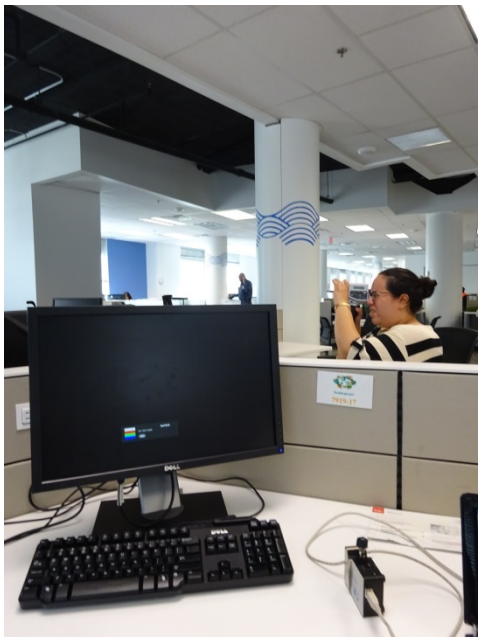
Spectral power distribution (SPD) was measured at ROB desks. Those with access to daylight were measured repeatedly throughout the day and evening, in the same locations and on the same frequency as other measurements (see Appendix A). Desks without access to daylight or view of windows are labeled "interior" and were measured once during the evaluation visit.



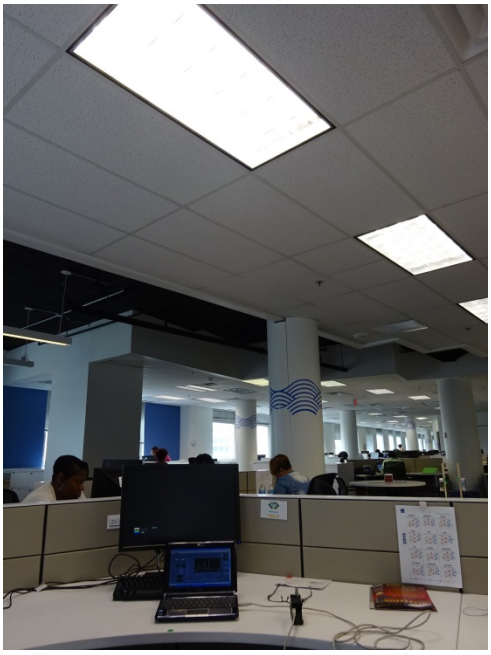
Desks at ROB where SPD measurements were collected

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.

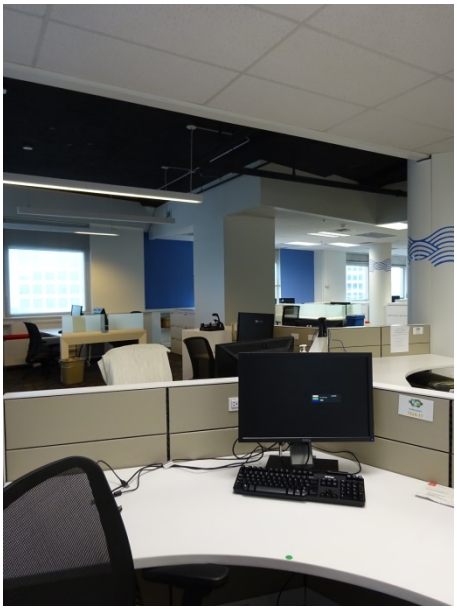
Regional Office Building –Desk 7919-17



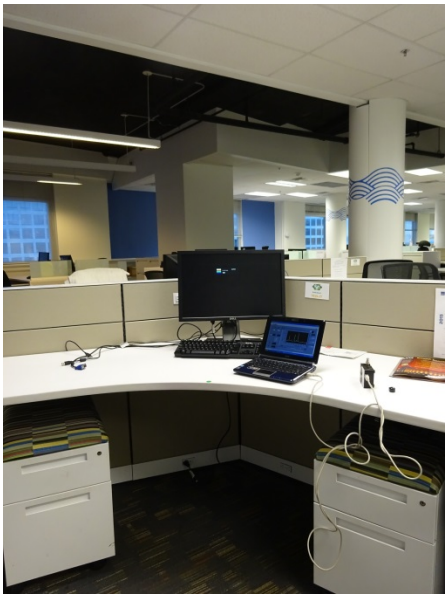
9:10 AM



11:57 AM

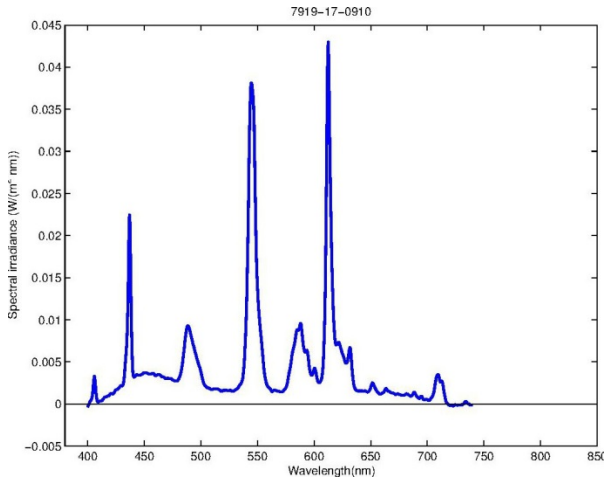


4:31 PM

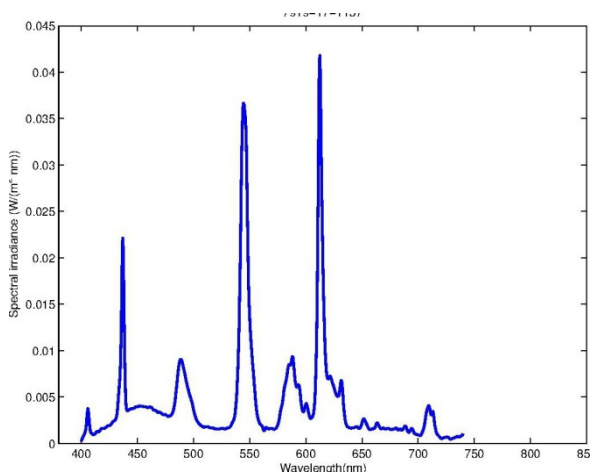


8:12 PM

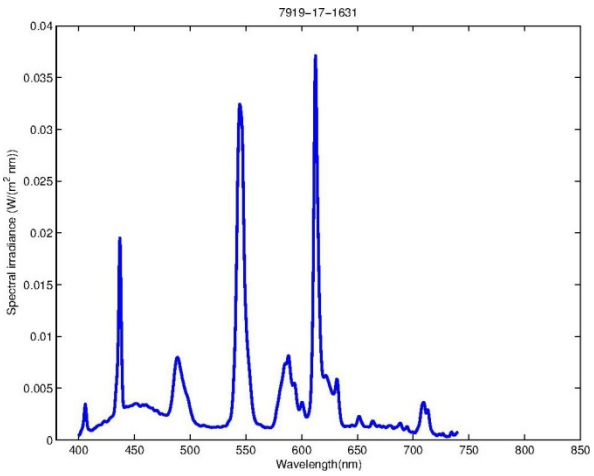
Regional Office Building –Desk 7919-17 (Spectral Power Distribution)



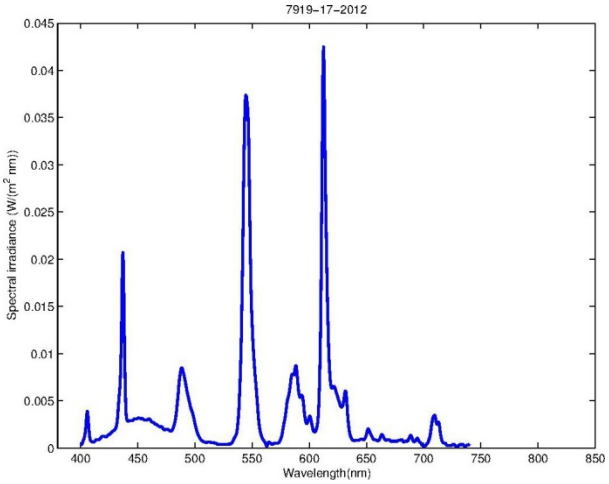
9:10 AM



11:57 AM

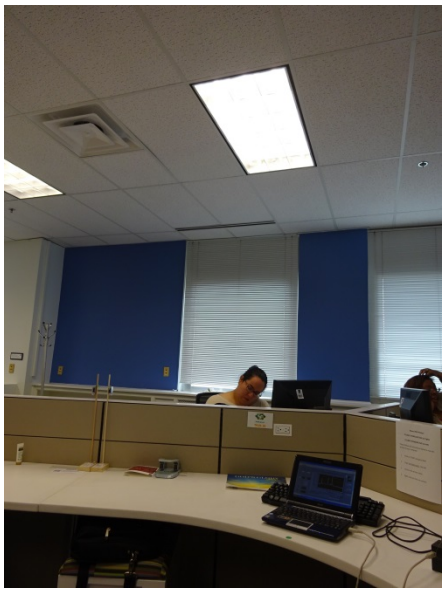


4:31 PM

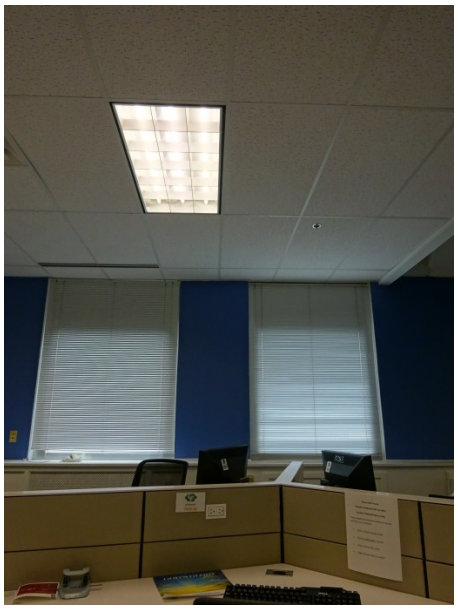


8:12 PM

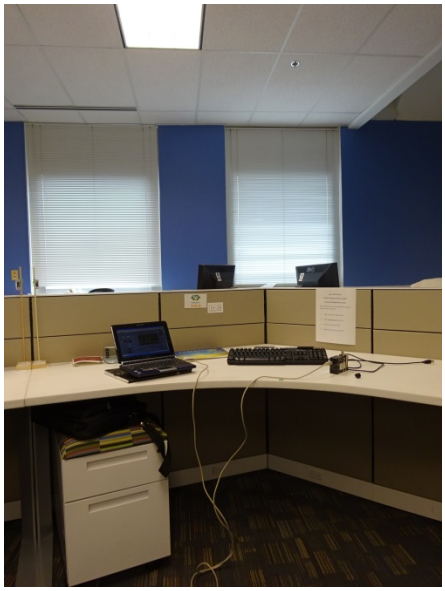
Regional Office Building –Desk 7919-18



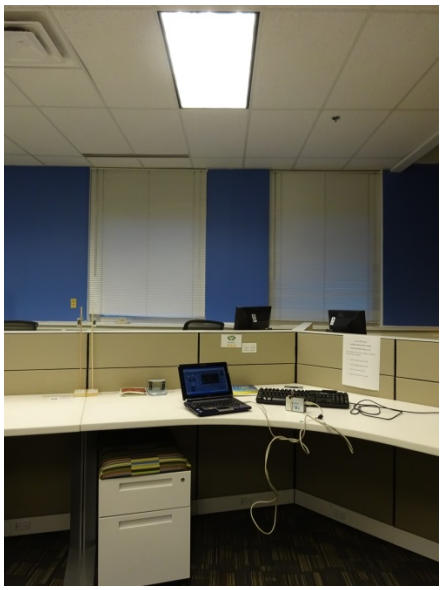
9:14 AM



11:58 AM

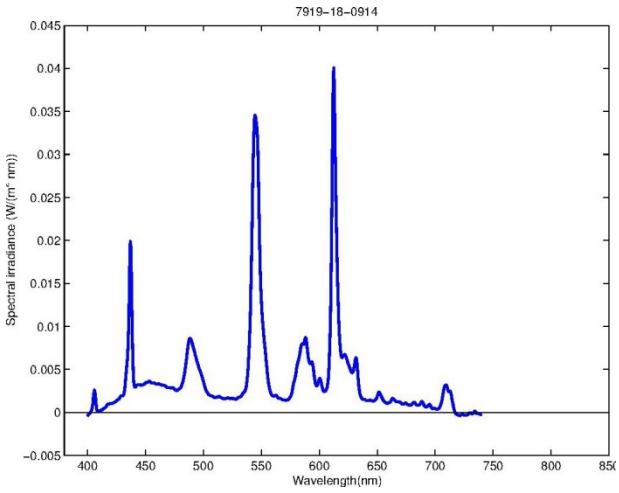


3:56 PM

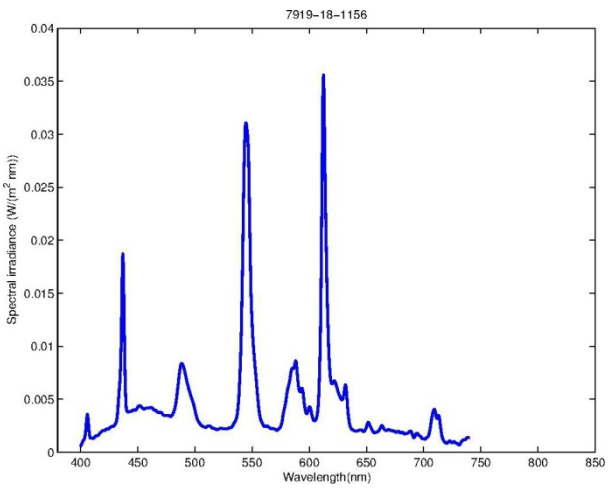


8:10 PM

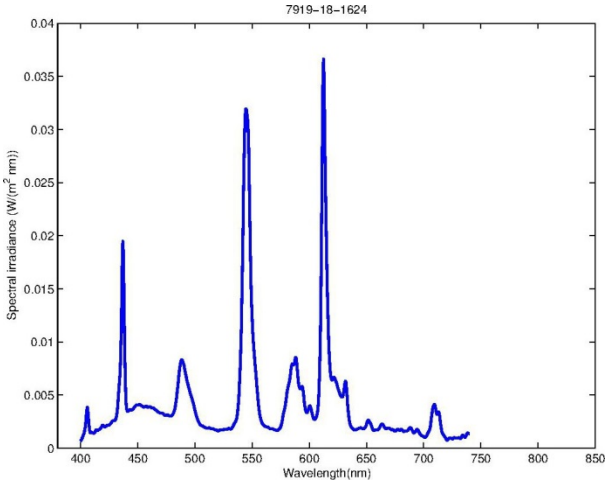
Regional Office Building –Desk 7919-18 (Spectral Power Distribution)



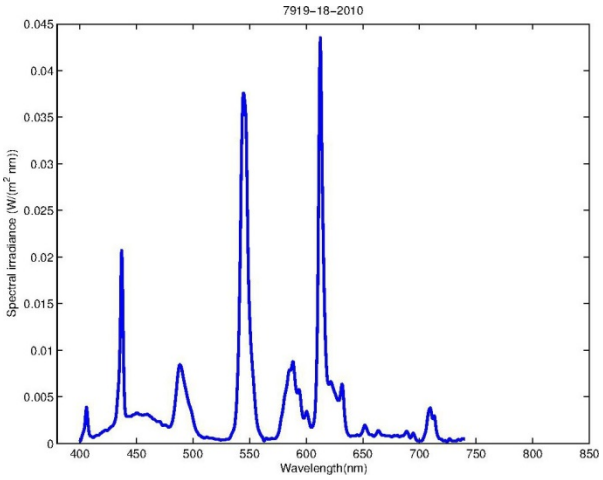
9:14 AM



11:56 AM

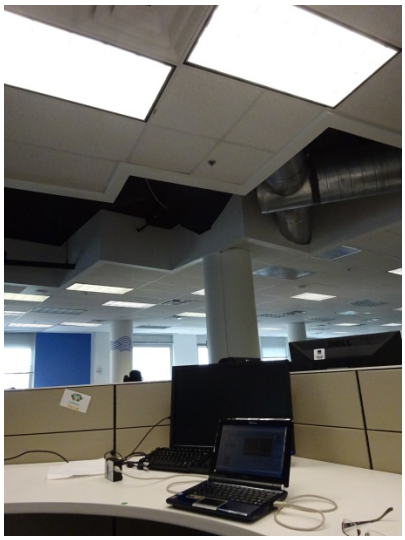


4:24 PM

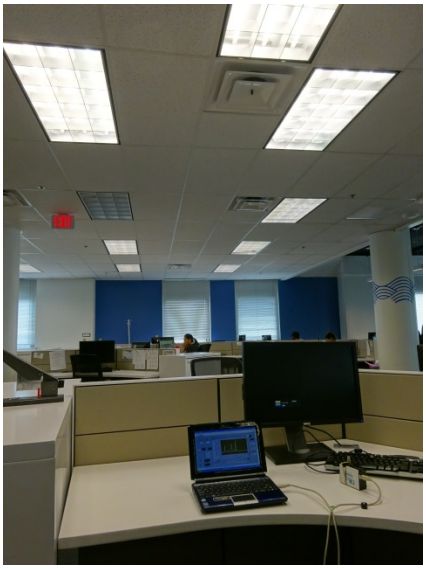


8:10 PM

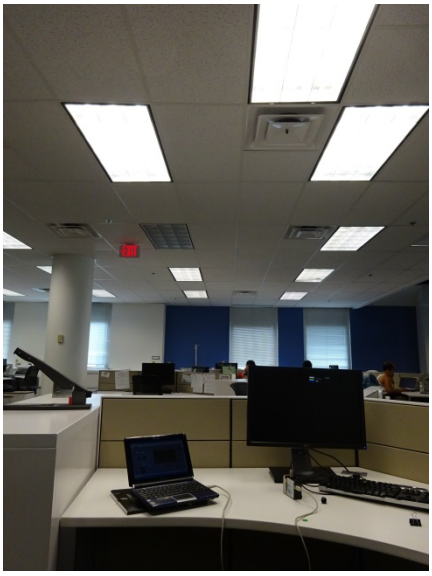
Regional Office Building –Desk 7919-66



9:02 AM



12:01 PM

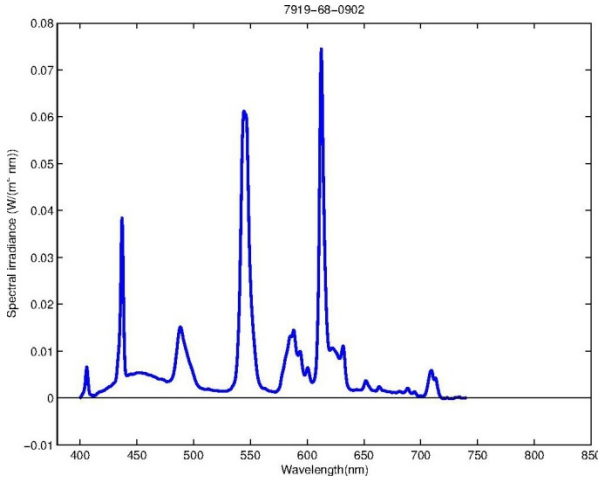


4:26 PM

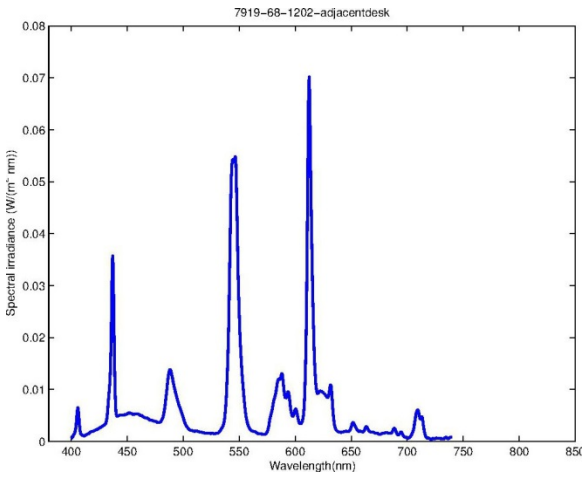
(Photo not available)

8:34 PM

Regional Office Building –Desk 7919-66 (Spectral Power Distribution)



9:02 AM



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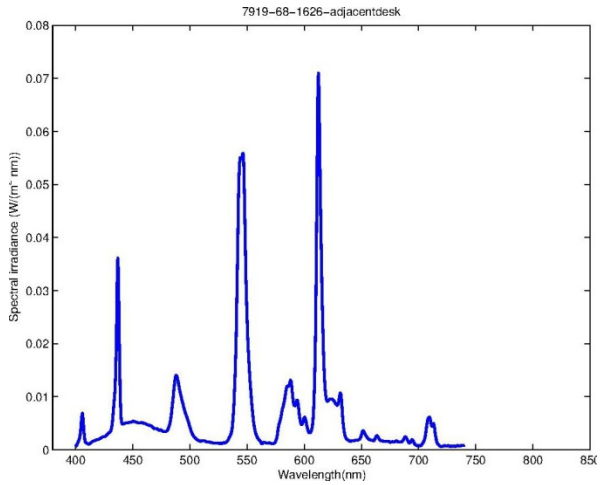
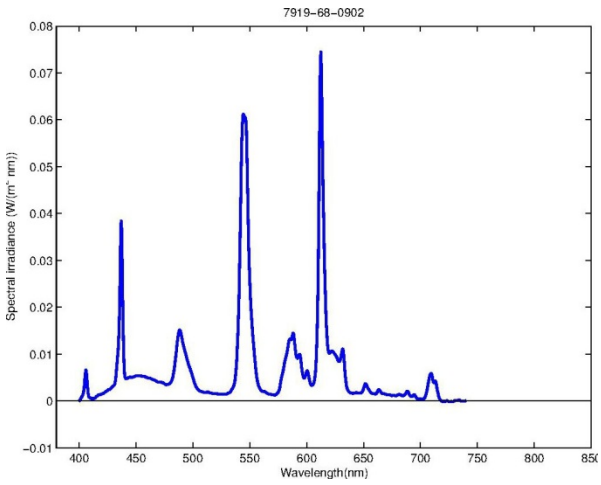
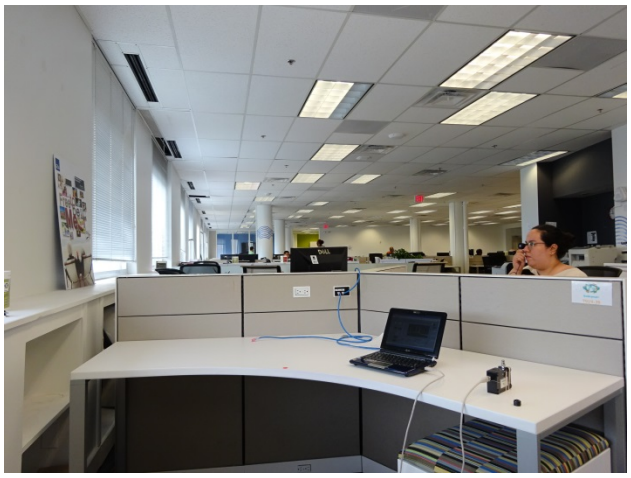


4:26 PM



8:01 PM

REGIONAL OFFICE BUILDING –DESK 7919-39



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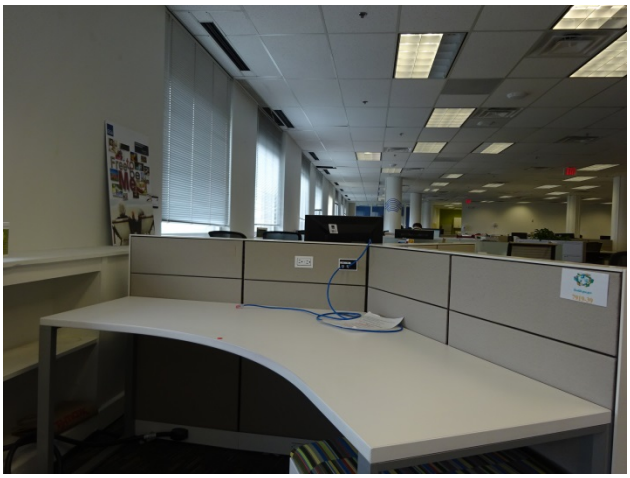

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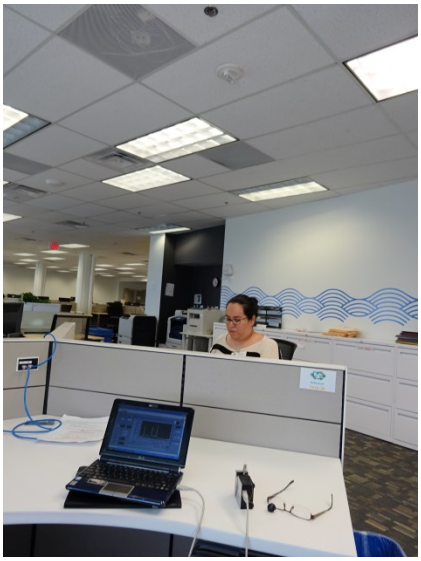

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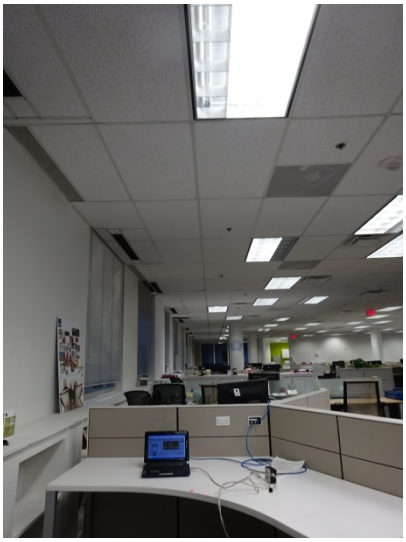
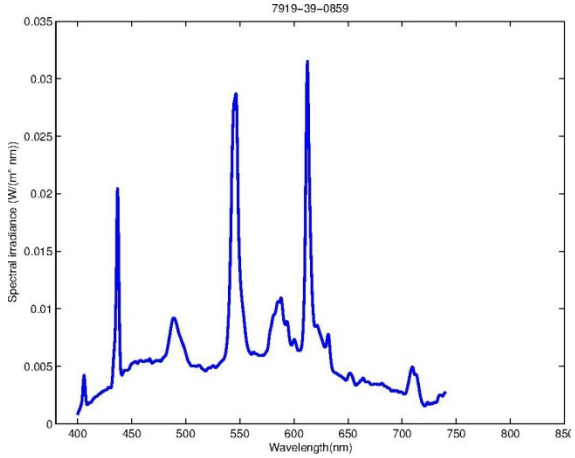


8:30 PM

Regional Office Building –Desk 7919-39 (Spectral Power Distribution)



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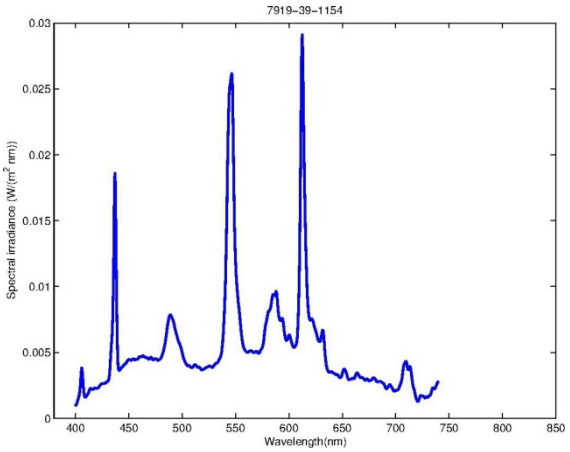

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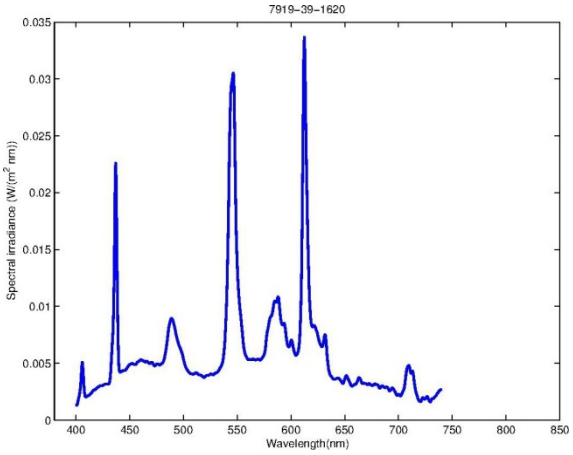

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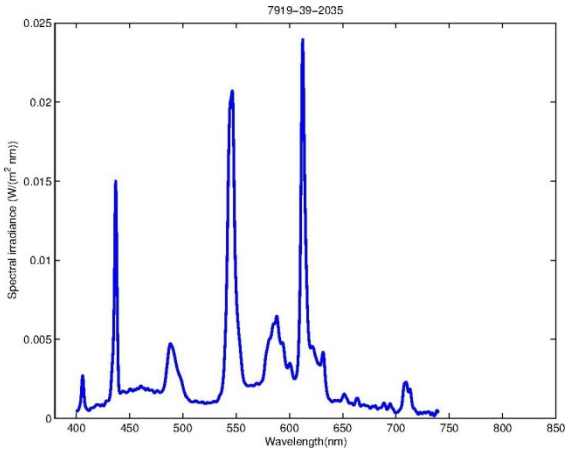

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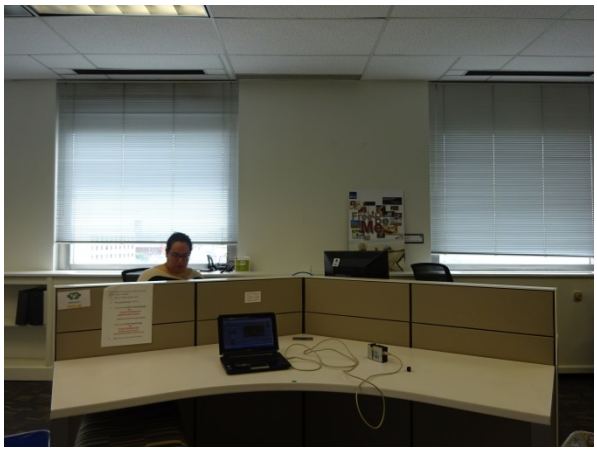
Regional Office Building –Desk 7919-40



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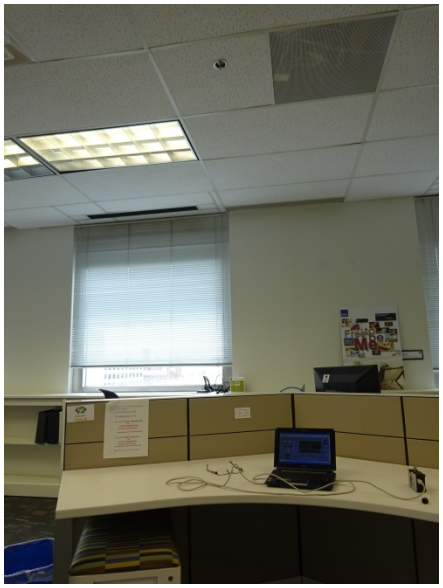

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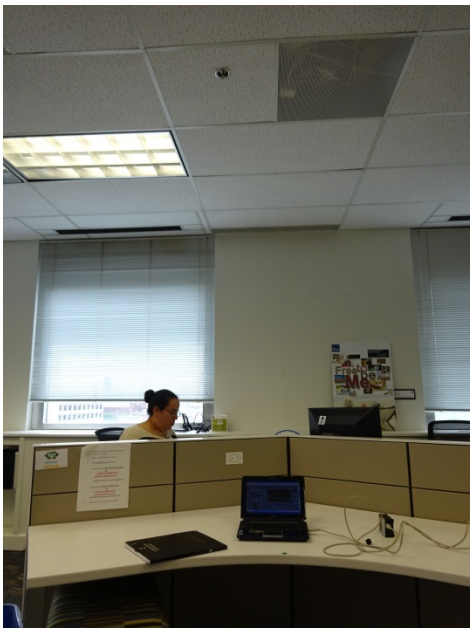
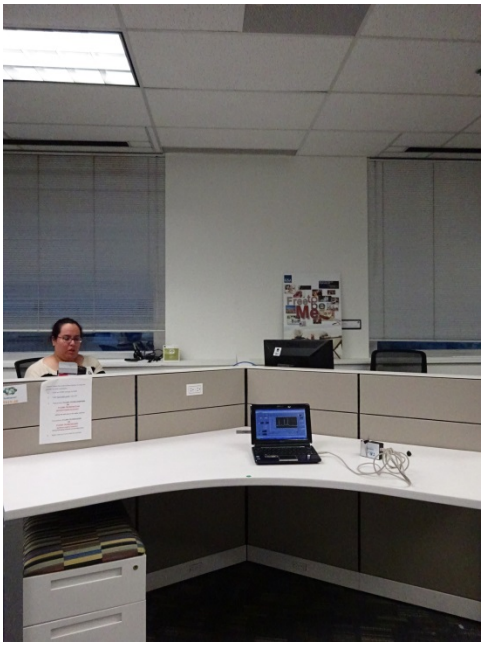
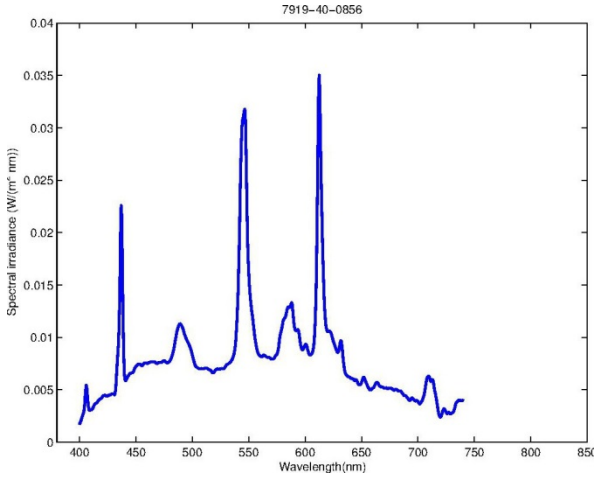


4:18 PM



8:37 PM

Regional Office Building –Desk 7919-40 (Spectral Power Distribution)



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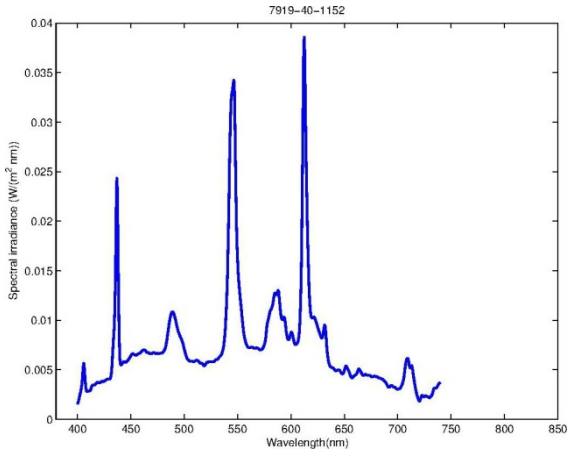
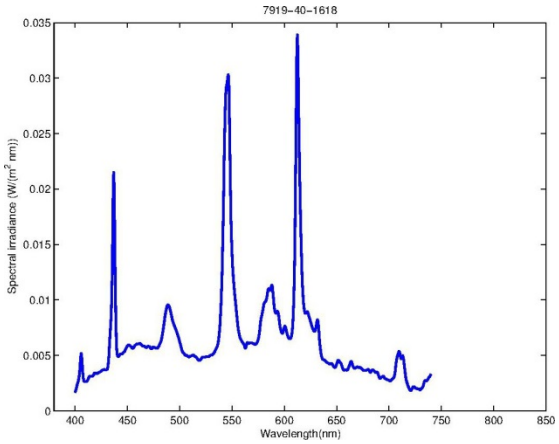


11:52 PM



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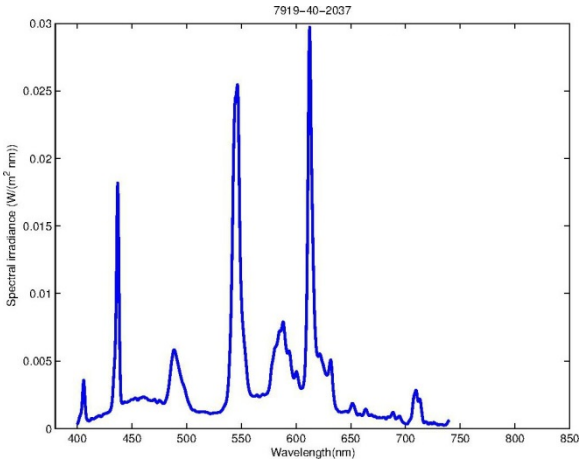
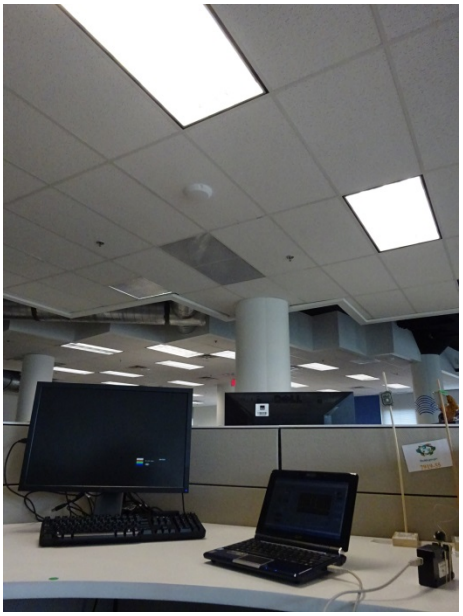
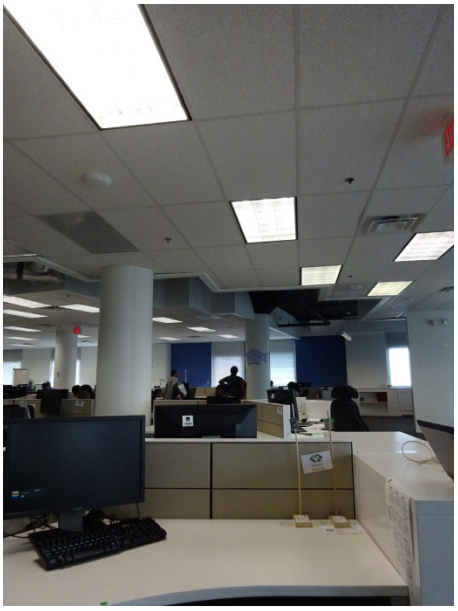


8:37 PM

Regional Office Building –Desk 7919-55



9:06 AM



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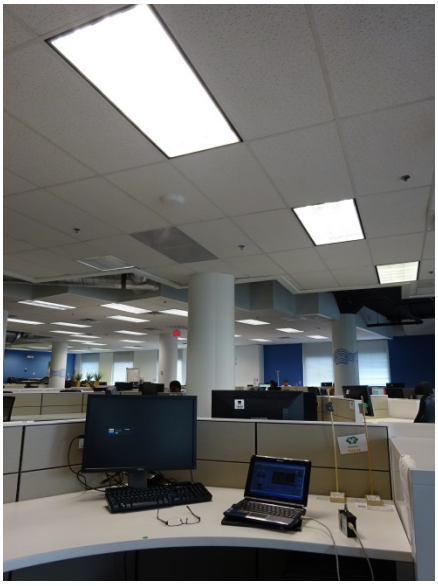
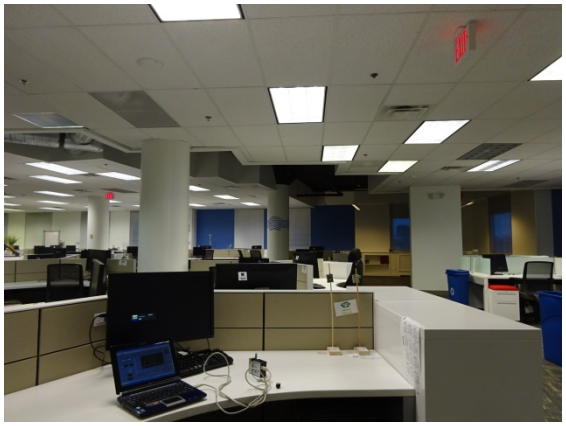
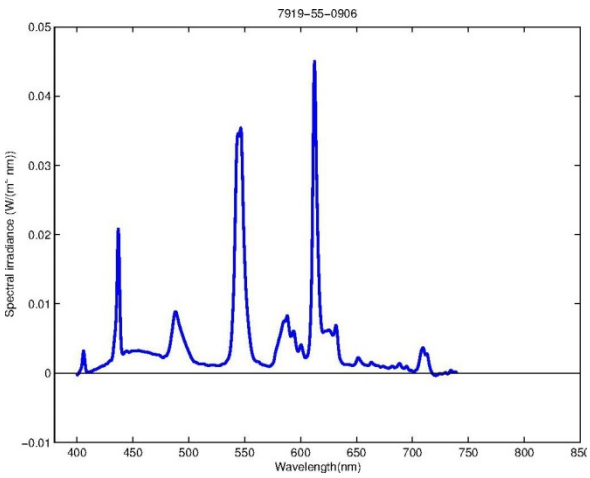


4:22 PM

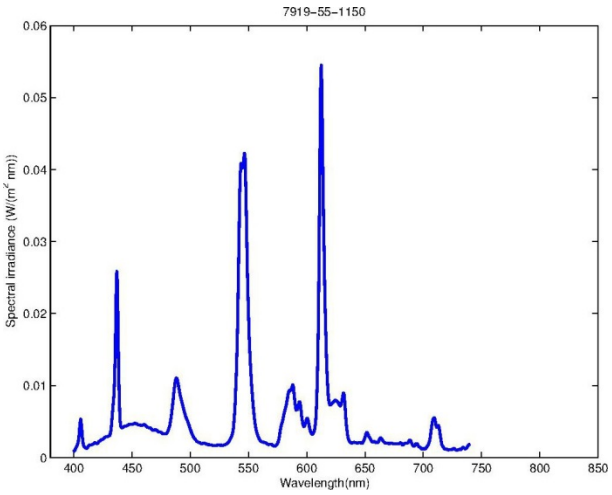


8:29 PM

Regional Office Building –Desk 7919-55 (Spectral Power Distribution)



9:06 AM



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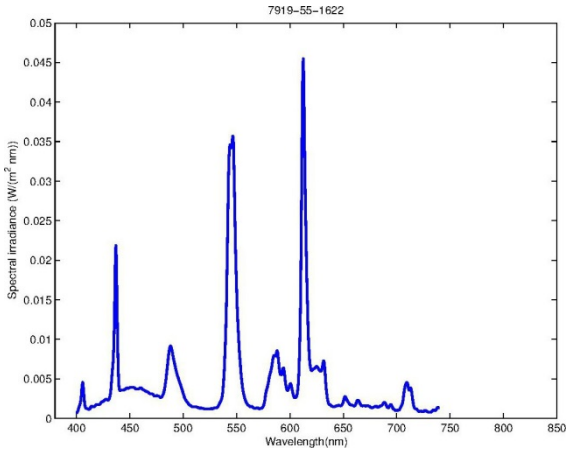

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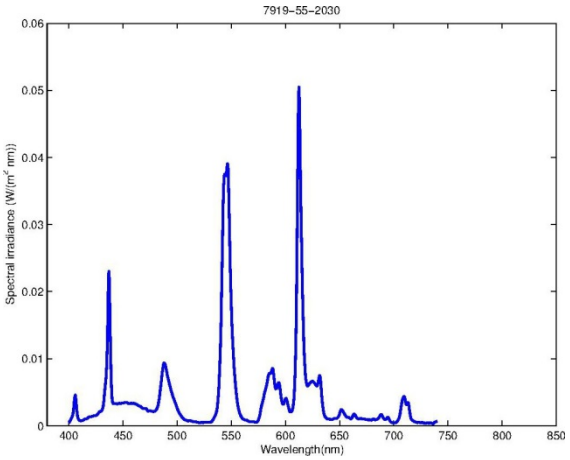
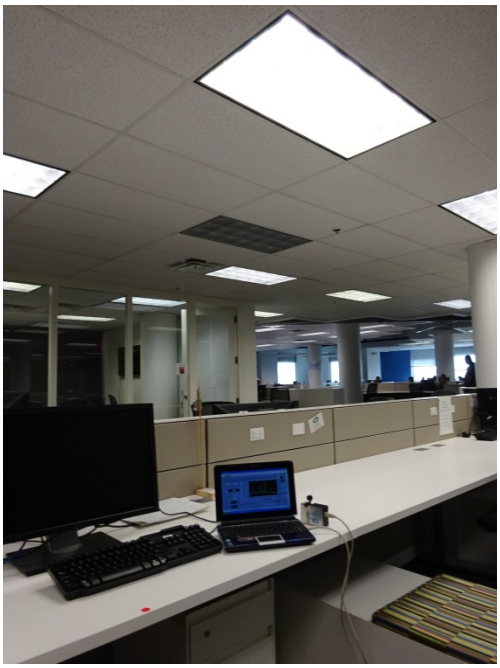
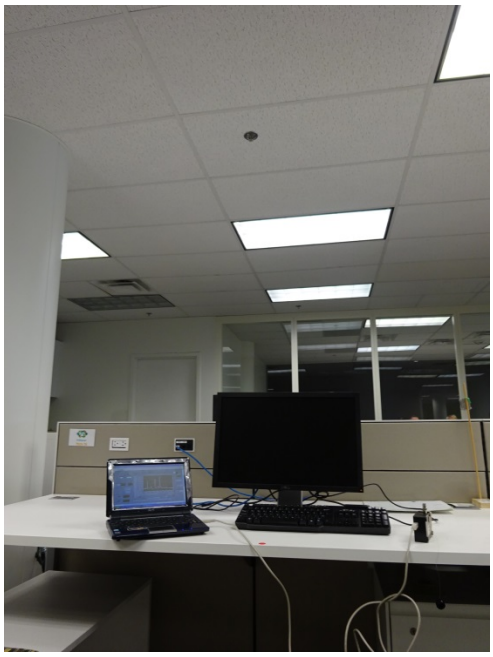


8:30 PM

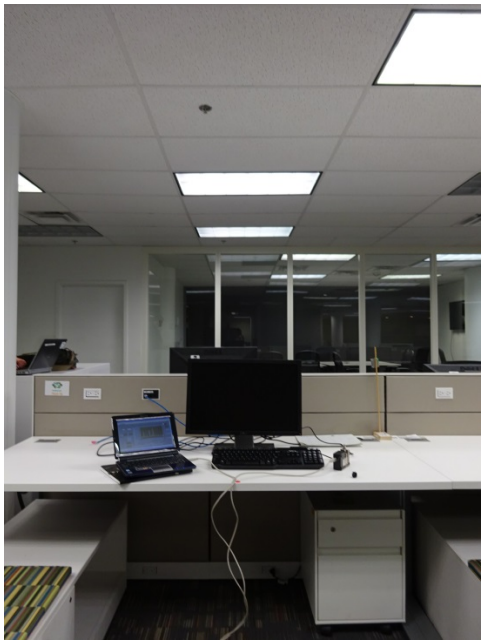
Regional Office Building –Interior Desk 7919-78



9:21 AM



12:07 PM



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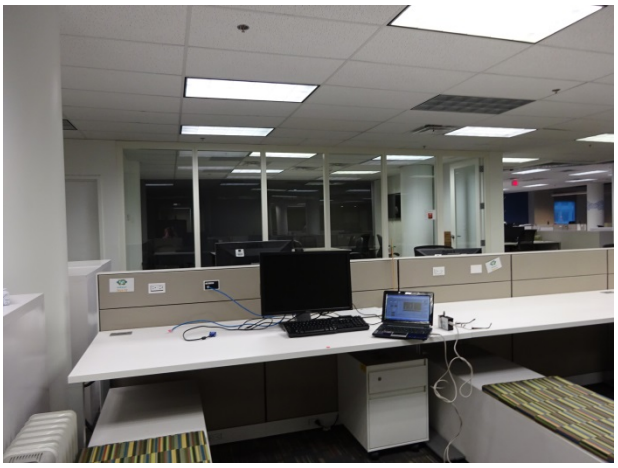
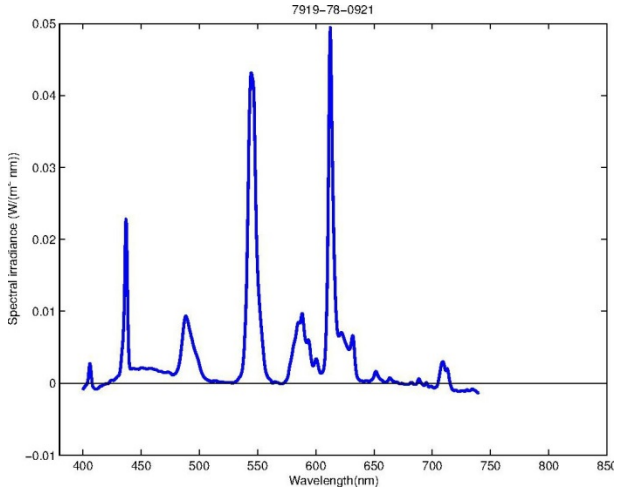


8:07 PM

INTERIOR – DESK 7919-78
(SPECTRAL POWER DISTRIBUTION)



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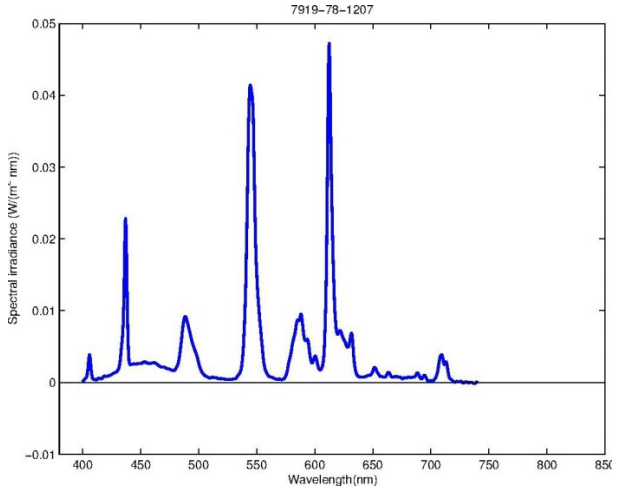

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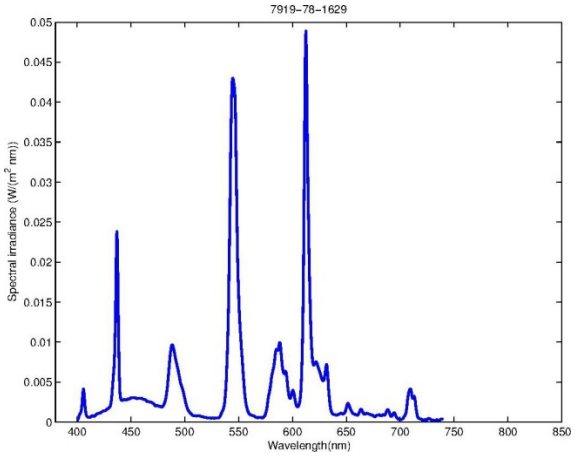

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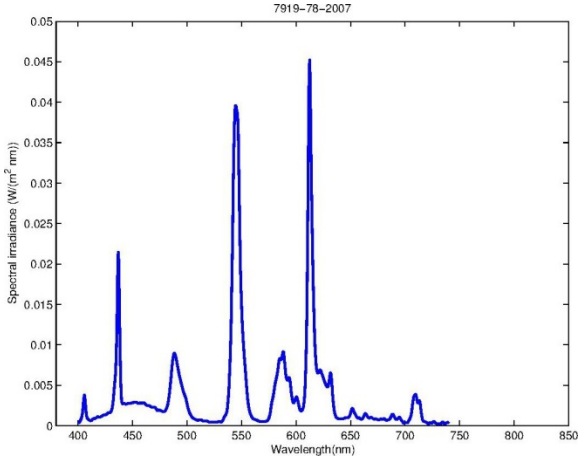
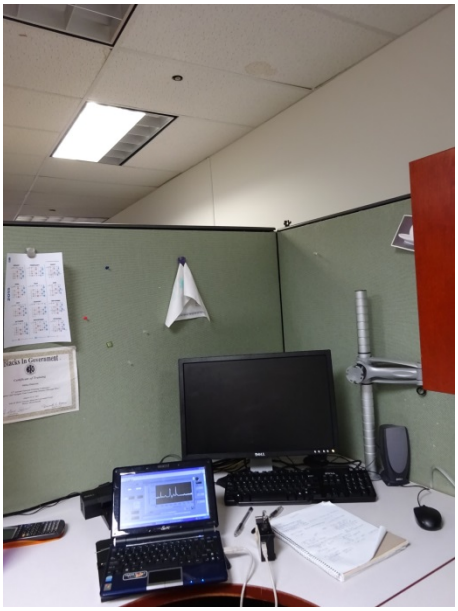


8:07 PM

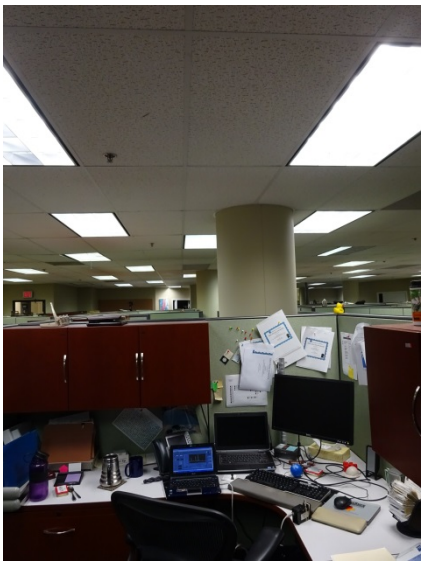
Interior – Desks 1 through 4 (One measurement only)

Desk 7065-1



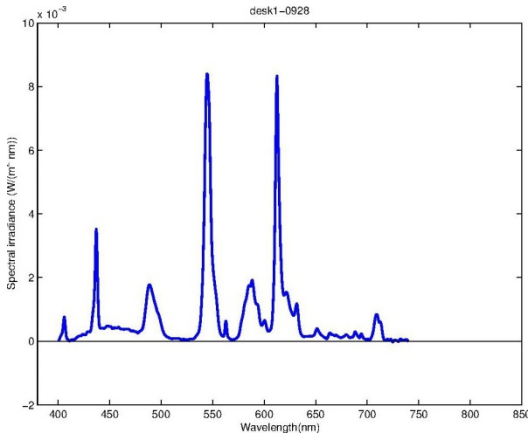
Desk 7065-2

Desk 7065-3

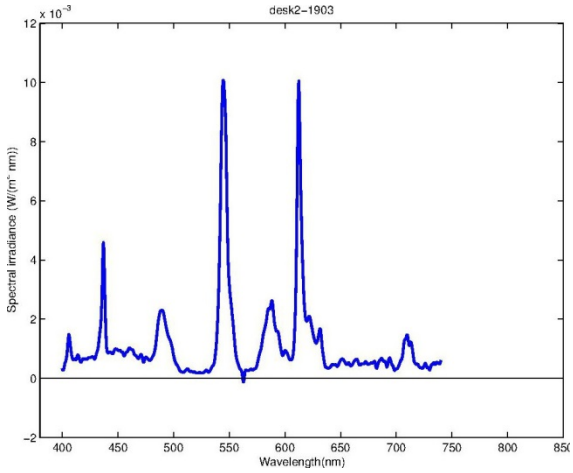


Desk 7065-4

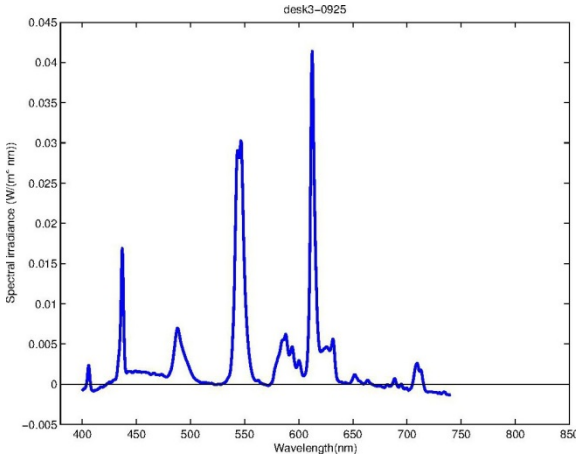
Interior – Desks 1 through 4 (Spectral Power Distribution)



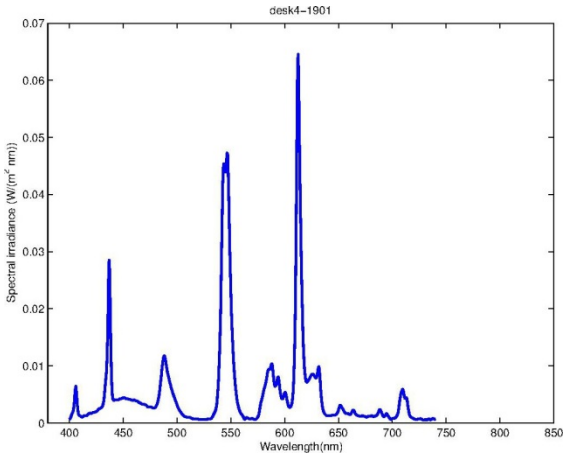
Desk 7065-1



Desk 7065-2

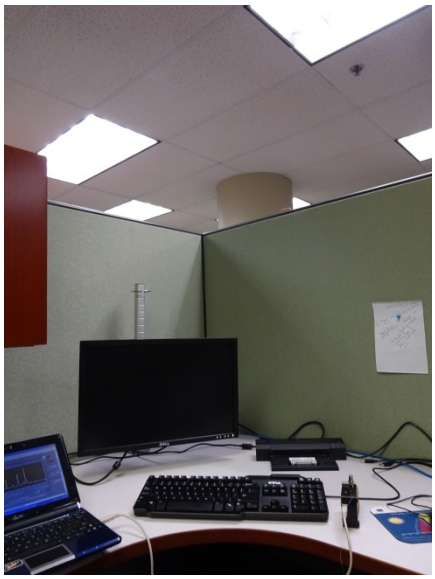


Desk 7065-3

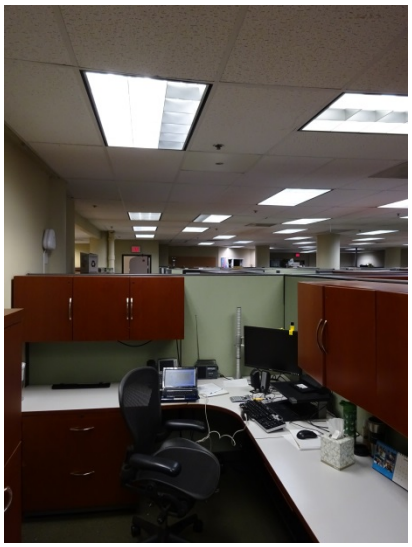


Desk 7055-4

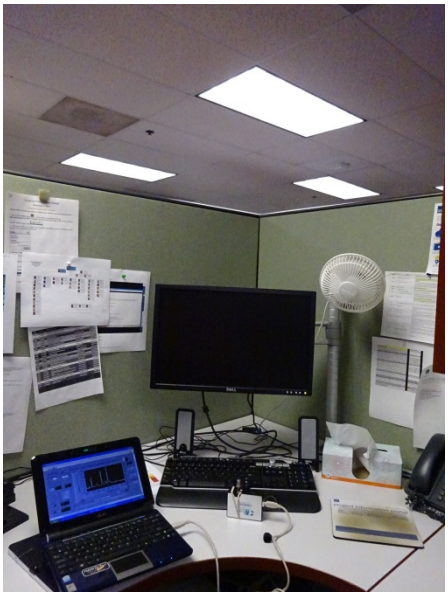
Interior – Desks 5 through 8 (One measurement only)



Desk 7065-5



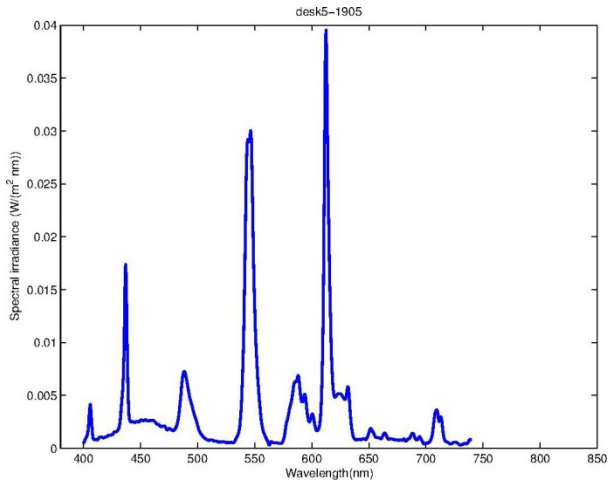
Desk 7065-6



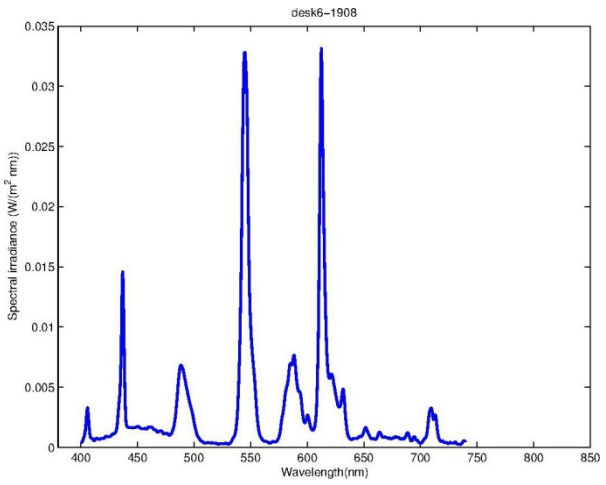
Desk 7065-7

Desk 7065-8

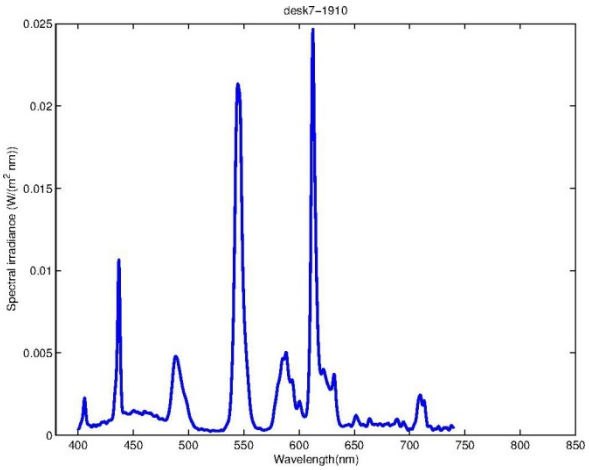
Interior – Desks 5 through 8 (Spectral Power Distribution)



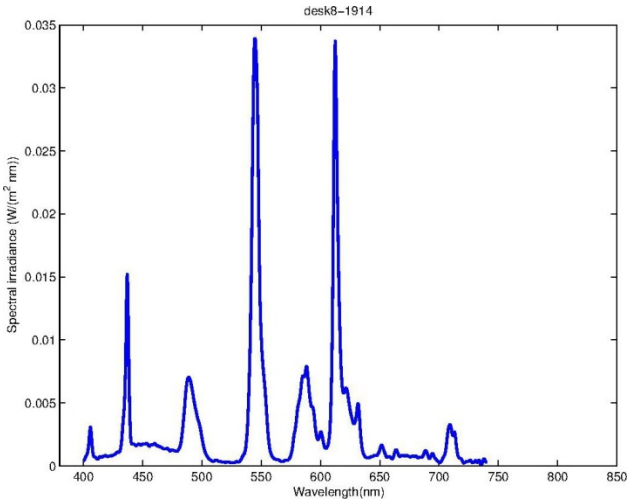
Desk 7065-5



Desk 7065-6



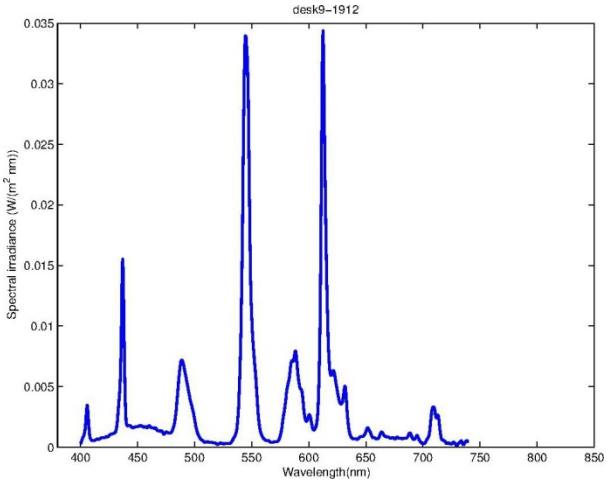
Desk 7065-7



Desk 7065-8

INTERIOR – DESK 9

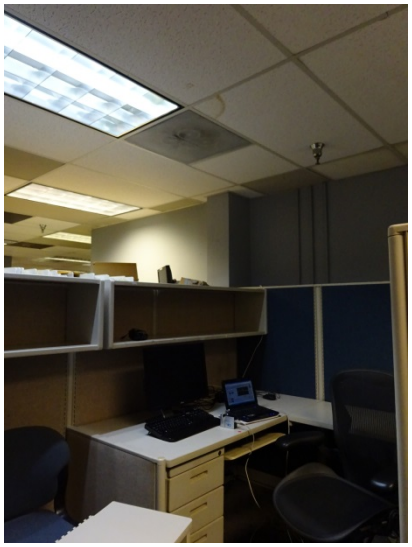
Desk 7065-9



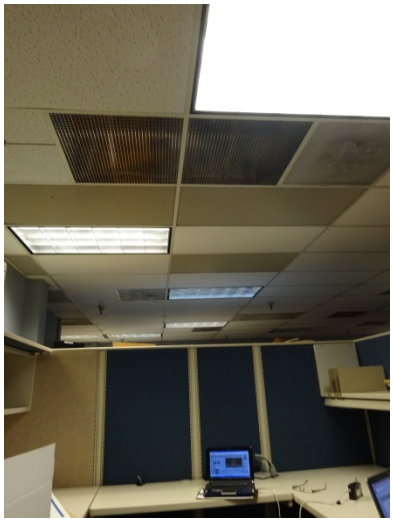
Desk 7065-9

INTERIOR – DESKS 7512-10 THROUGH 7512-12

Desk 7512-10



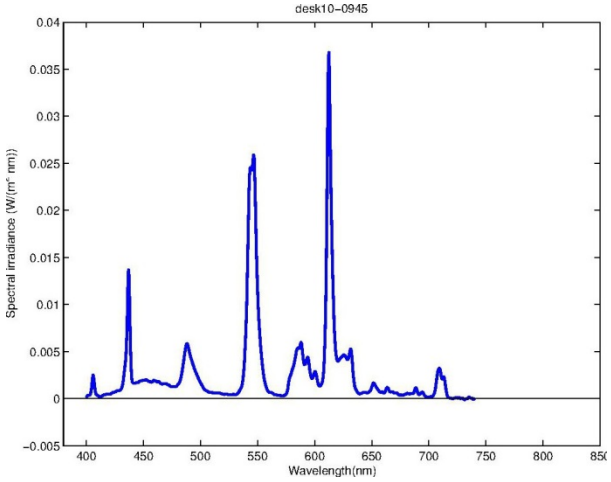
Desk 7512-11 (with LED retrofit tubes)



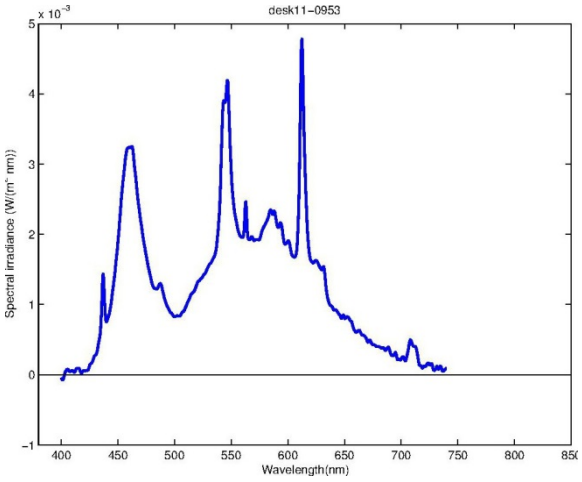
Desk 7512-12

Blank

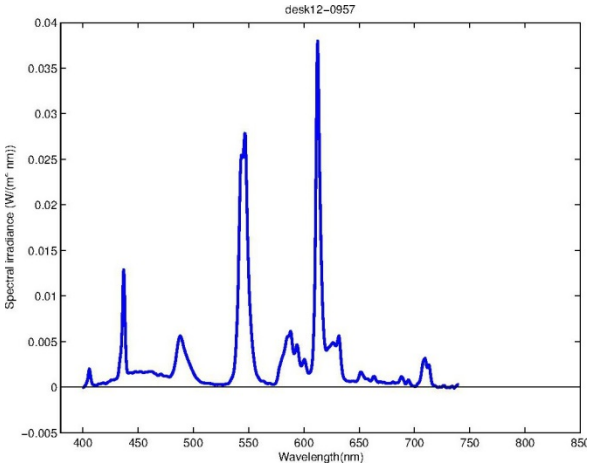
Interior – Desks 7512-10 through 7512-12 (Spectral Power Distribution)



Desk 7512-10



***Desk 7512-11** (with LED retrofit tubes)*



Desk 7512-7

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APPENDIX D: SPECTRORADIOMETRY RESULTS TABLE

					Color Coordinates		Color Temp	Circadian Light	Circadian Stimulus (up to 0.7)	
Desk Number	**Proximity**	**Orientation**	**Time**	**Lux**	**CIEx**	**CIEy**	**CCT(K)**	**CLA**	**CS**	**Brightness**
7919-17	A	West	9:10	490	0.377	0.385	4156	302.6	0.32	331.0
7919-17	A	West	11:57	485	0.373	0.376	4198	337.2	0.34	341.0
7919-17	A	West	16:31	418	0.374	0.375	4165	287.7	0.31	294.9
7919-17	A	West	20:12	423	0.383	0.380	3946	249.3	0.28	286.6
7919-18	B	West	9:14	457	0.376	0.386	4176	280.6	0.30	307.6
7919-18	B	West	11:56	464	0.366	0.372	4379	360.3	0.35	336.7
7919-18	B	West	16:24	448	0.369	0.370	4282	342.3	0.34	325.6
7919-18	B	West	20:10	432	0.384	0.381	3931	250.2	0.28	291.4
7919-66	C	West	9:02	773	0.382	0.387	4046	444.4	0.39	512.5
7919-66	C	West	12:02	726	0.379	0.382	4062	450.7	0.40	494.0
7919-66	C	West	16:26	719	0.381	0.381	4022	439.2	0.39	488.6
7919-66	C	West	20:09	649	0.385	0.384	3946	365.5	0.36	432.5
7919-39	A	North	8:59	633	0.368	0.383	4389	461.6	0.40	439.9
7919-39	A	North	11:54	545	0.371	0.381	4297	386.1	0.37	378.7
7919-39	A	North	16:20	605	0.371	0.378	4278	441.8	0.39	426.2
7919-39	A	North	20:35	316	0.394	0.391	3759	148.8	0.19	201.3
7919-40	B	North	8:56	793	0.362	0.376	4543	659.6	0.46	572.8
7919-40	B	North	11:52	754	0.367	0.378	4384	581.6	0.44	534.9
7919-40	B	North	16:18	654	0.367	0.375	4383	513.9	0.42	469.6
7919-40	B	North	20:37	384	0.395	0.392	3755	179.3	0.22	243.5
7919-55	C	North	9:06	474	0.383	0.392	4047	249.5	0.28	307.3
7919-55	C	North	11:50	595	0.378	0.380	4103	382.2	0.36	409.0
7919-55	C	North	16:22	490	0.378	0.379	4091	314.9	0.33	338.6
7919-55	C	North	20:30	487	0.386	0.384	3909	269.7	0.30	324.8
7675-10	Skylight	Skylight	9:38	324	0.373	0.385	4262	218.7	0.26	221.1
7675-10	Skylight	Skylight	12:15	281	0.372	0.386	4307	187.5	0.23	191.4
7675-10	Skylight	Skylight	16:16	239	0.373	0.377	4219	168.7	0.21	168.4
7675-10	Skylight	Skylight	20:33	153	0.390	0.386	3822	79.5	0.11	100.4
7919-78	Interior*	Interior	9:21	464	0.399	0.411	3793	474.4	0.41	270.6
7919-78	Interior*	Interior	12:07	469	0.390	0.396	3886	217.0	0.26	296.7
7919-78	Interior*	Interior	16:29	494	0.389	0.393	3903	241.5	0.28	316.6
7919-78	Interior*	Interior	20:07	456	0.388	0.392	3903	224.8	0.26	293.7
7065-1	Interior	Interior	9:28	87	0.397	0.407	3801	92.8	0.13	52.2
7065-2	Interior	Interior	19:03	117	0.379	0.374	4010	77.9	0.11	82.8
7065-3	Interior	Interior	9:25	351	0.405	0.413	3682	348.1	0.35	201.2
7065-4	Interior	Interior	19:01	606	0.389	0.383	3830	334.7	0.34	402.8
7065-5	Interior	Interior	19:05	380	0.387	0.384	3884	209.1	0.25	252.8
7065-6	Interior	Interior	19:08	348	0.399	0.405	3743	368.0	0.36	209.7
7065-7	Interior	Interior	19:10	250	0.395	0.396	3765	108.9	0.15	156.7
7065-8	Interior	Interior	19:14	356	0.397	0.405	3783	380.3	0.36	215.0
7065-9	Interior	Interior	19:12	363	0.398	0.405	3776	386.4	0.37	219.1
7512-10	Interior	Interior	9:45	328	0.400	0.398	3664	130.5	0.17	200.7
7512-11**	Interior	Interior	9:53	144	0.353	0.367	4773	123.2	0.17	108.3
7512-12	Interior	Interior	9:57	342	0.409	0.409	3571	337.6	0.34	198.2

* Distant view of windows to one side, thus measures were repeated throughout day

** LED tube retrofit

AVERAGE SPECTRORADIOMETRY RESULTS

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

			Illum-inance			Color Temp	Circadian Light		Circadian Stimulus (up to 0.7)	
Deskspace Locations	**# of desks**	**# of meas. per desk**	**Lux**	**CIEx**	**CIEy**	**CCT(K)**	**Average CL_A**	**Median CL_A**	**CS**	**Bright-ness**
A	2	3	529	0.37	0.38	4247	370	362	0.35	369
B	2	3	595	0.37	0.38	4358	456	437	0.39	425
C	2	3	629	0.38	0.38	4062	380	411	0.36	425
Skylight	1	3	281	0.37	0.38	4263	192	187	0.23	194
Interior	1	3	476	0.39	0.40	3861	311	242	0.31	295
Orientations										
W	3	3	553	0.38	0.38	4165	361	342	0.35	381
N	3	3	616	0.37	0.38	4279	443	442	0.38	431
Skylight	1	3	281	0.37	0.38	4263	192	187	0.23	194
Interior	1	3	476	0.39	0.40	3861	311	242	0.31	295

UNCERTAINTY OF SPECTRORADIOMETRIC MEASUREMENTS

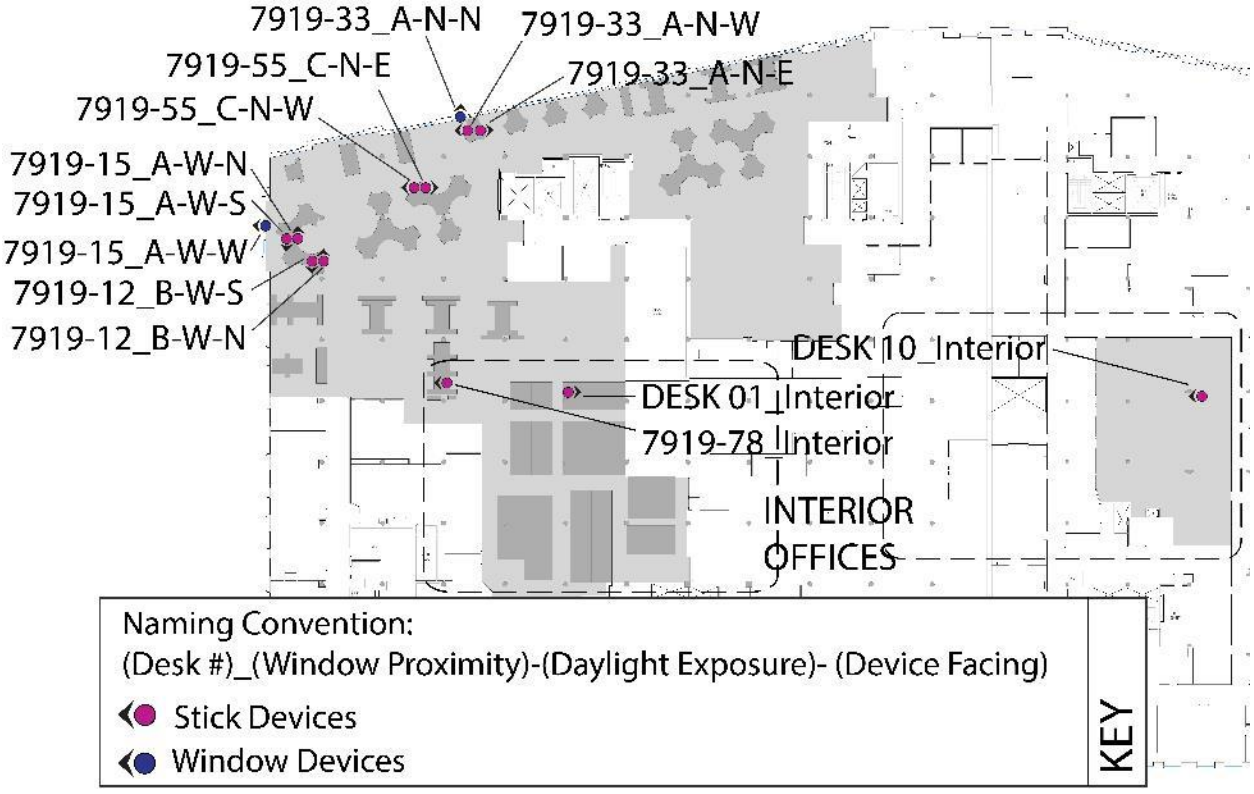
There are three main types of measurement uncertainty associated with the spectrometer used for the spectral measurements: 1) accuracy of the spectral calibration and maintaining it over time, 2) thermal noise due to the nature of the CCD detector employed in the device, and 3) a spatial response that deviates from an ideal cosine response. The accuracy of calibration is estimated to be ± 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 ± 0.004, ± 0.00018, and ± 0.007 W/(m^2 nm) for the spectral ranges $\lambda < 450$ nm; $450 < \lambda < 730$ nm; and $\lambda > 730$ nm, respectively. The corresponding uncertainty (1-sigma) in photopic illuminance is ± 3 lux. Combining these uncertainties leads to an uncertainty of ± (5% of reading + 3 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 E: PHOTOMETRIC DATA FOR ROB 7TH FLOOR STATIONARY DEVICES

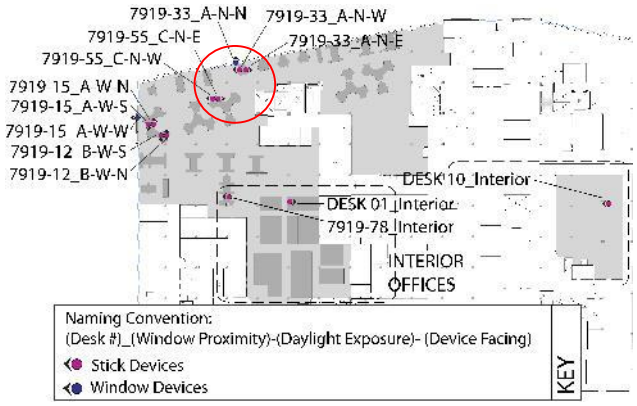
MOUNTED ON STICKS AND IN WINDOWS

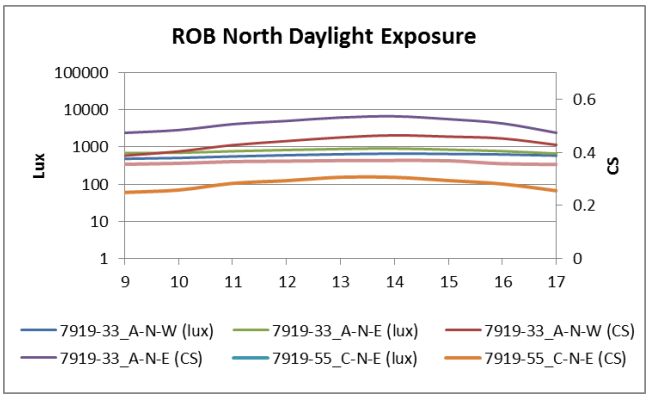
CROPPED TO JUNE 10, 2015 – JUNE 19, 2015 (EXCLUDING JULY 3 HOLIDAY)



Location where measurements were collected.

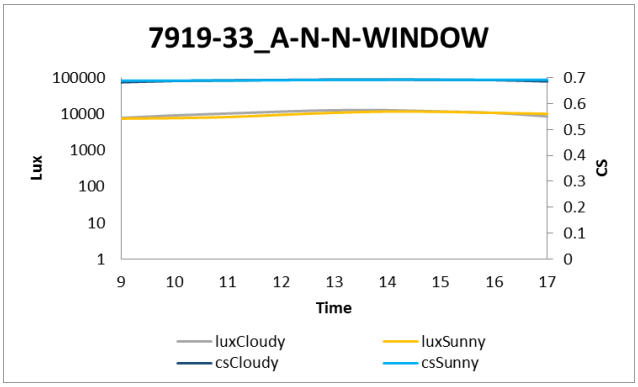
7TH FLOOR NORTH DAYLIGHT EXPOSURE



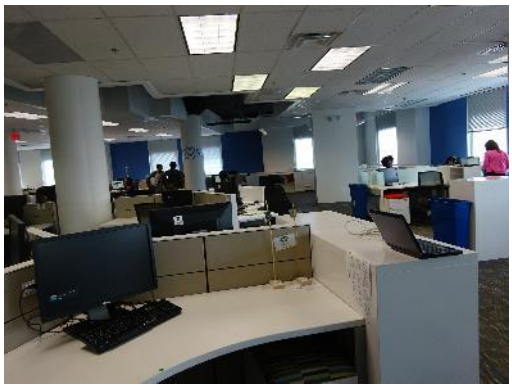


Average Lux and CS

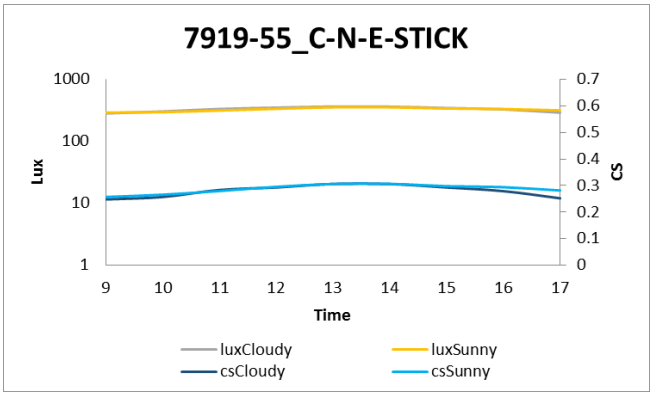
7919-33_A-N-N-WINDOW



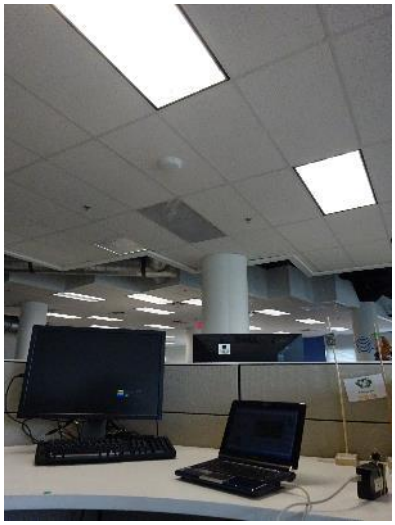
Daysimeter 006 – 7919-33_A-N-N-WINDOW. Mean photopic light level during working hours (08:00 am to 05:00 pm) was 11222 ± 1695 lux on cloudy days. The mean CS value on was 0.69 ± 0.00 on cloudy days. On sunny days mean photopic light level during working hours was 9952 ± 1162 lux. The mean CS value on was 0.69 ± 0.00 on sunny days.



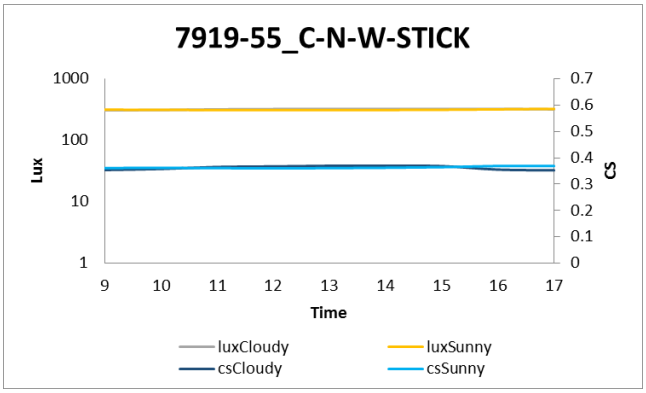
7919-55_C-N-E-STICK



Daysimeter 132 – 7919-55_C-N-E-STICK. Mean photopic light level during working hours (08:00 am to 05:00 pm) was 333 ± 30 lux on cloudy days. The mean CS value on was 0.28 ± 0.02 on cloudy days. On sunny days mean photopic light level during working hours was 328 ± 23 lux. The mean CS value on was 0.29 ± 0.02 on sunny days.

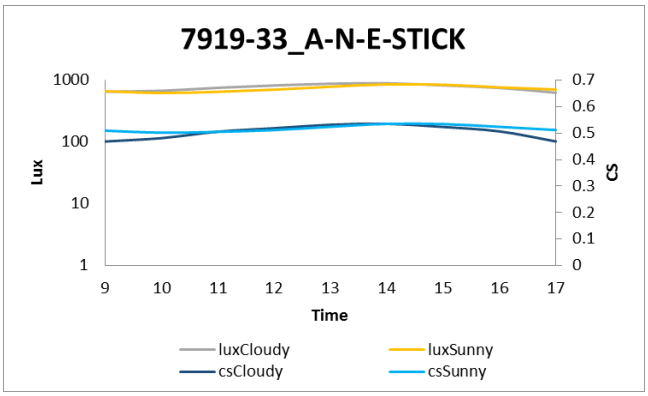


7919-55_C-N-W-STICK



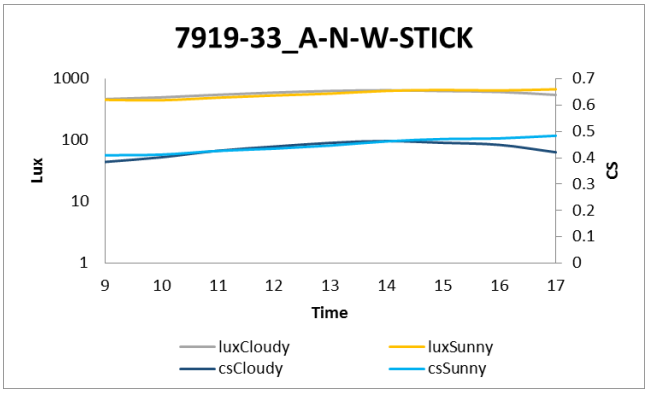
Daysimeter 225 – 7919-55_C-N-W-STICK. Mean photopic light level during working hours (08:00 am to 05:00 pm) was 321 ± 6 lux on cloudy days. The mean CS value on was 0.36 ± 0.01 on cloudy days. On sunny days mean photopic light level during working hours was 315 ± 5 lux. The mean CS value on was 0.36 ± 0.00 on sunny days.

7919-33_A-N-E-STICK



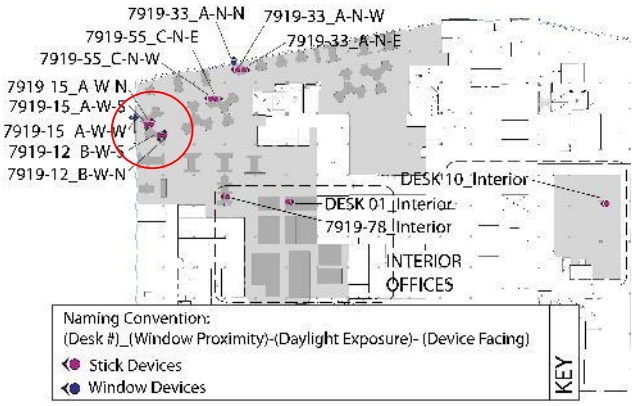
Daysimeter 138 – 7919-33_A-N-E-STICK. Mean photopic light level during working hours (08:00 am to 05:00 pm) was 792 ± 92 lux on cloudy days. The mean CS value on was 0.50 ± 0.03 on cloudy days. On sunny days mean photopic light level during working hours was 741 ± 84 lux. The mean CS value on was 0.52 ± 0.01 on sunny days.

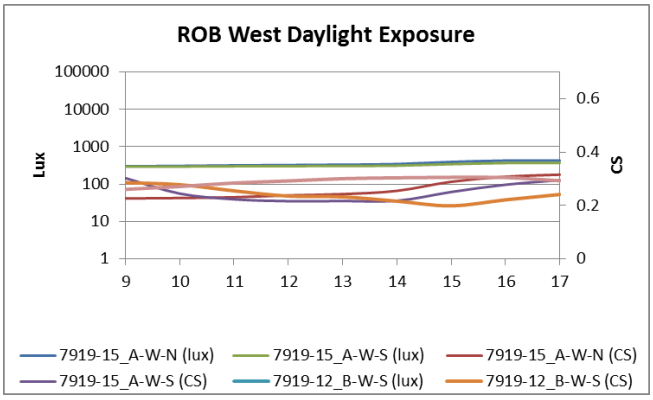
7919-33_A-N-W-STICK



Daysimeter 125 – 7919-33_A-N-W-STICK. Mean photopic light level during working hours (08:00 am to 05:00 pm) was 593 ± 63 lux on cloudy days. The mean CS value on was 0.43 ± 0.03 on cloudy days. On sunny days mean photopic light level during working hours was 574 ± 91 lux. The mean CS value on was 0.45 ± 0.03 on sunny days.

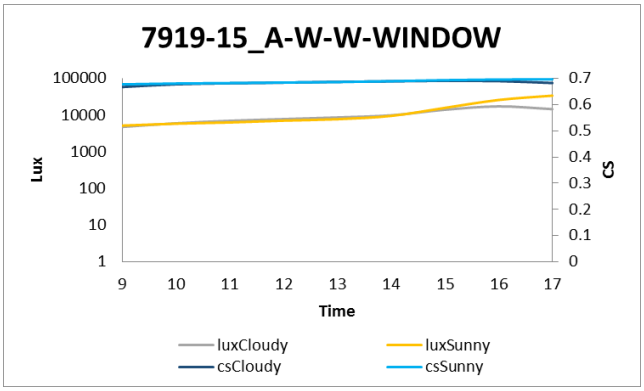
7TH FLOOR WEST DAYLIGHT EXPOSURE



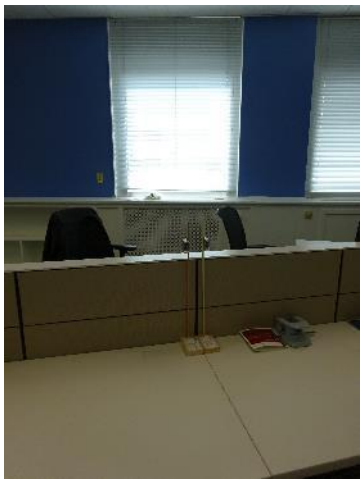


Average Lux and CS

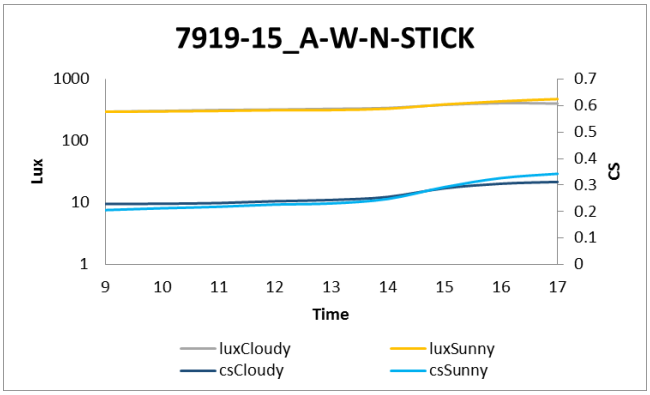
7919-15_A-W-W-WINDOW



Daysimeter 101 – 7919-15_A-W-W-WINDOW. Mean photopic light level during working hours (08:00 am to 05:00 pm) was 12057 ± 6958 lux on cloudy days. The mean CS value on was 0.68 ± 0.01 on cloudy days. On sunny days mean photopic light level during working hours was 13924 ± 11541 lux. The mean CS value on was 0.69 ± 0.01 on sunny days.

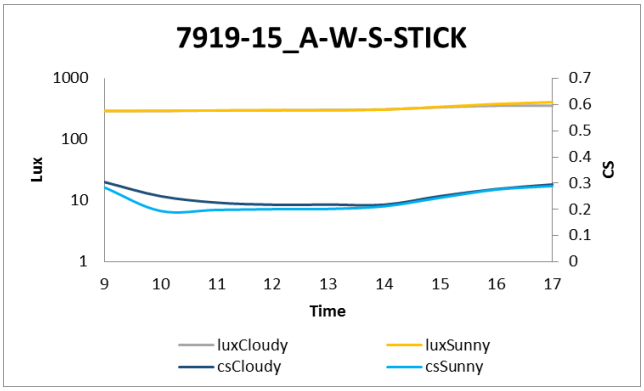


7919-15_A-W-N-STICK

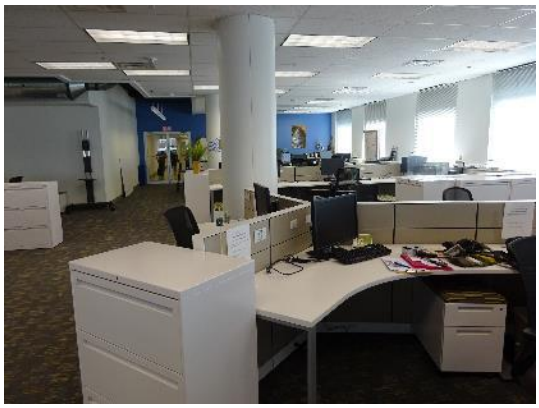


Daysimeter 126 – 7919-15_A-W-N-STICK. Mean photopic light level during working hours (08:00 am to 05:00 pm) was 352 ± 48 lux on cloudy days. The mean CS value on was 0.26 ± 0.03 on cloudy days. On sunny days mean photopic light level during working hours was 356 ± 70 lux. The mean CS value on was 0.26 ± 0.05 on sunny days.

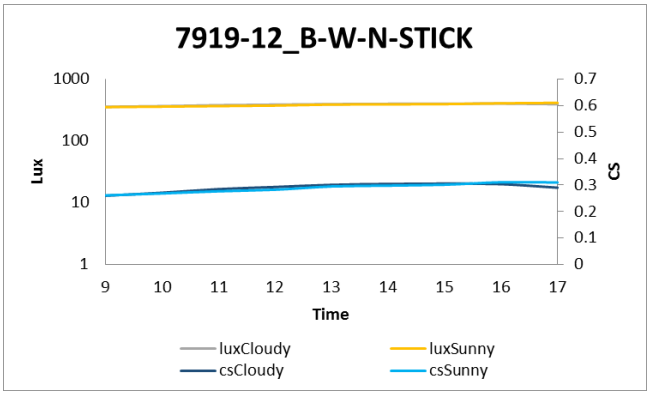
7919-15_A-W-S-STICK



Daysimeter 160 – 7919-15_A-W-S-STICK. Mean photopic light level during working hours (08:00 am to 05:00 pm) was 320 ± 29 lux on cloudy days. The mean CS value on was 0.25 ± 0.03 on cloudy days. On sunny days mean photopic light level during working hours was 328 ± 45 lux. The mean CS value on was 0.23 ± 0.04 on sunny days.

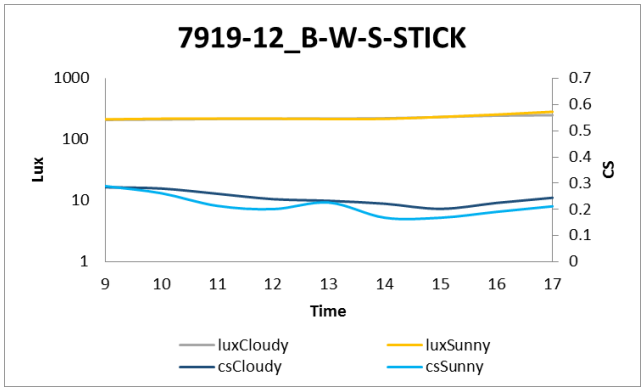


7919-12_B-W-N-STICK



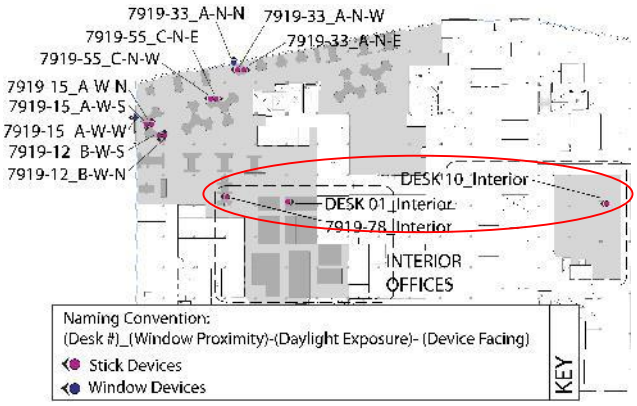
Daysimeter 137 – 7919-12_B-W-N-STICK. Mean photopic light level during working hours (08:00 am to 05:00 pm) was 390 ± 17 lux on cloudy days. The mean CS value on was 0.29 ± 0.02 on cloudy days. On sunny days mean photopic light level during working hours was 385 ± 21 lux. The mean CS value on was 0.29 ± 0.02 on sunny days.

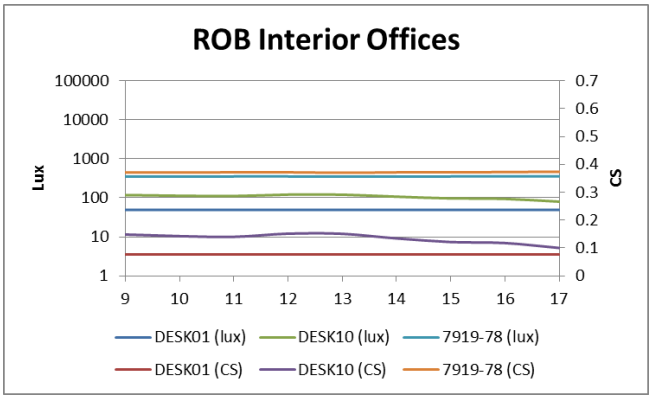
7919-12_B-W-S-STICK



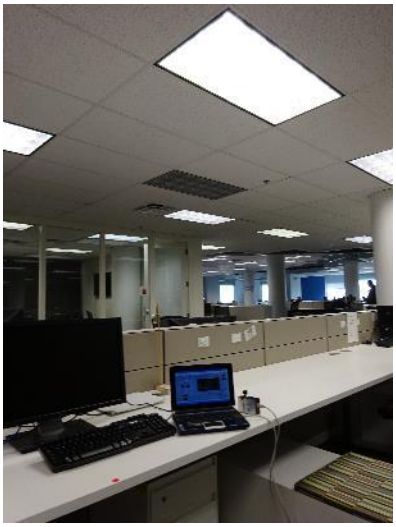
Daysimeter 135 – 7919-12_B-W-S-STICK. Mean photopic light level during working hours (08:00 am to 05:00 pm) was 228 ± 15 lux on cloudy days. The mean CS value on was 0.24 ± 0.03 on cloudy days. On sunny days mean photopic light level during working hours was 233 ± 25 lux. The mean CS value on was 0.21 ± 0.24 on sunny days.

7TH FLOOR INTERIOR EXPOSURE

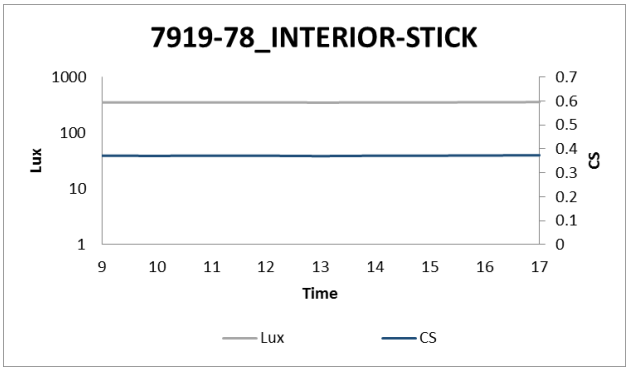




Average Lux and CS



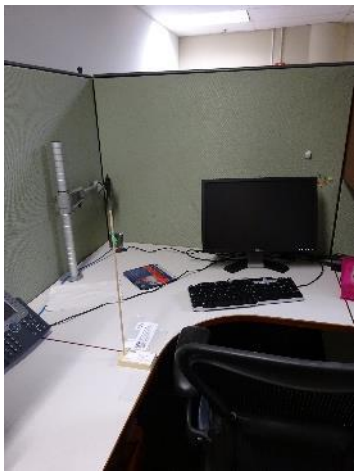
7919-78_INTERIOR-STICK



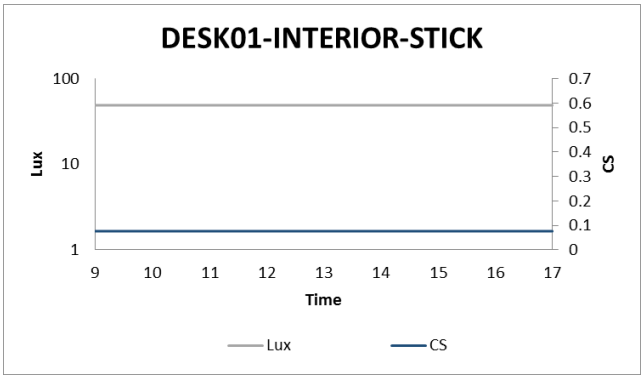
Daysimeter 123 – 7919-78_INTERIOR-STICK.

Mean photopic light level during working hours (08:00 am to 05:00 pm) was 352 ± 2 lux. The mean CS value on was 0.37 ± 0.00.

Sunny/Cloudy analysis excluded for interior desks.



DESK01-INTERIOR-STICK

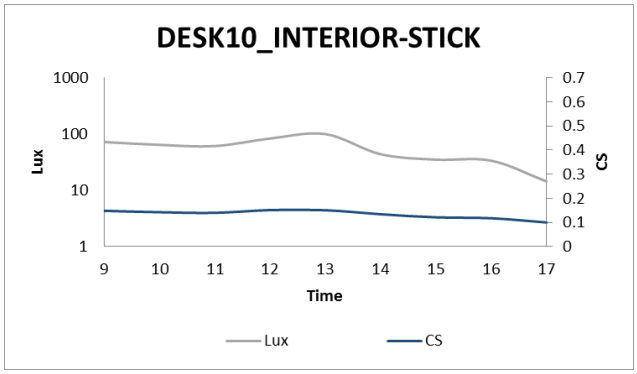


Daysimeter 131 – DESK01-INTERIOR-STICK.

Mean photopic light level during working hours (08:00 am to 05:00 pm) was 49 ± 0 lux. The mean CS value on was 0.08 ± 0.00.

Sunny/Cloudy analysis excluded for interior desks.

DESK10_INTERIOR-STICK



Daysimeter 252 – DESK10_INTERIOR-STICK.*

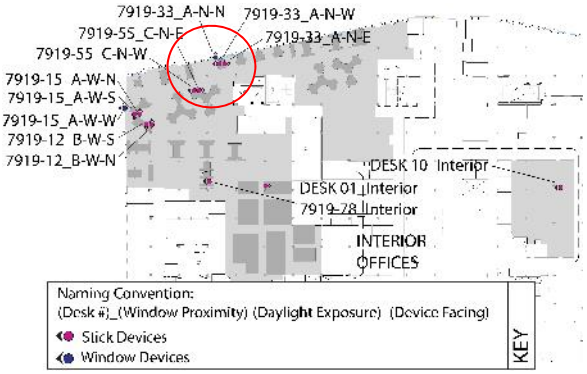
Mean photopic light level during working hours (08:00 am to 05:00 pm) was 56 ± 27 lux. The mean CS value on was 0.13 ± 0.02.

Sunny/Cloudy analysis excluded for interior desks.

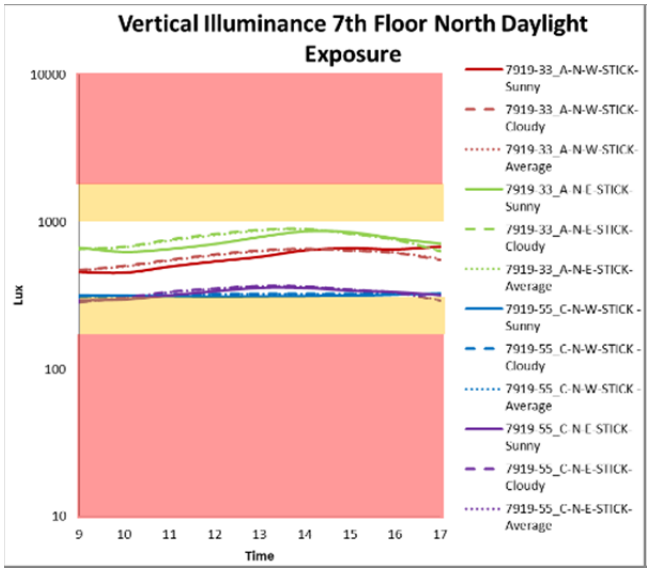
**** Occupants at Desk 10 perform manual switching of adjacent overhead lighting bays; the curving nature of the graphs above indicate manual switching on certain days or times.***

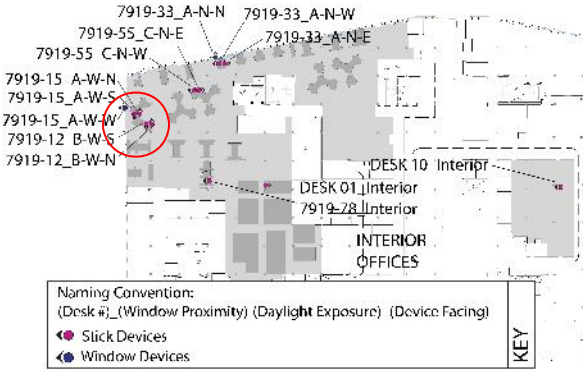
APPENDIX F: VERTICAL ILLUMINANCE FOR STICK DEVICES

ROB 7TH FLOOR

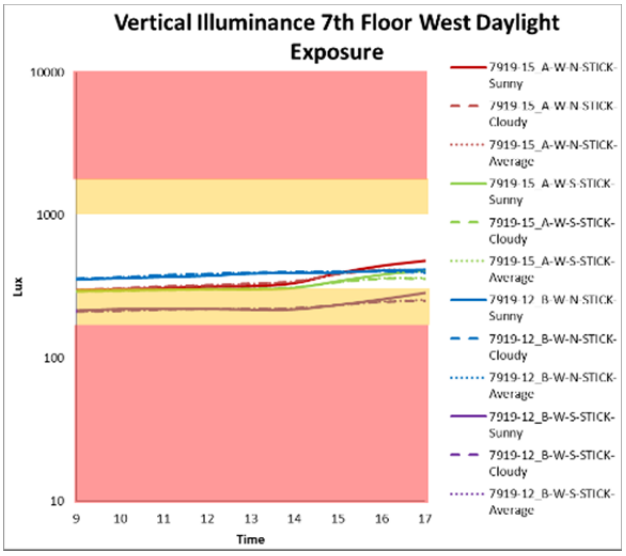


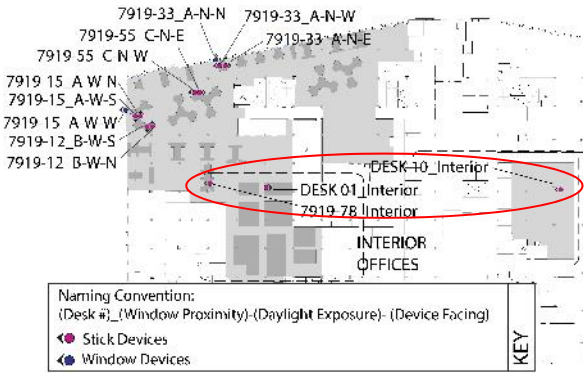
7TH FLOOR NORTH DAYLIGHT EXPOSURE



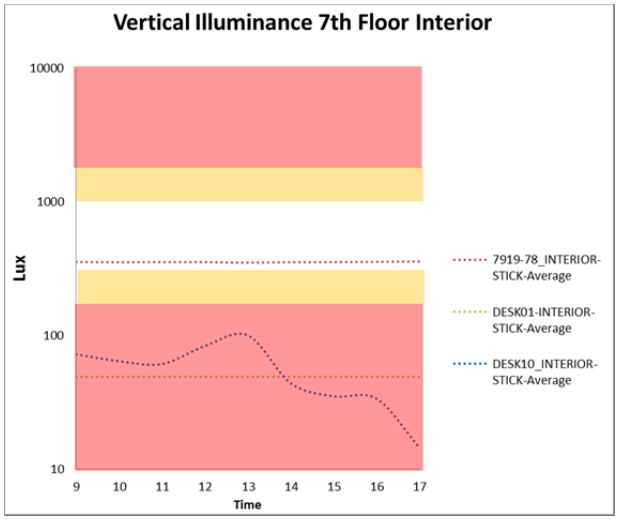


7th Floor West Daylight Exposure





7th Floor Interior



Notes: 1) "Cloudy" and "Sunny" analysis excluded for interior offices without access to daylight. 2) Occupants in area of Desk 10 perform manual switching of adjacent overhead lighting bays; the curving nature of this line above indicates manual switching on certain days or times.