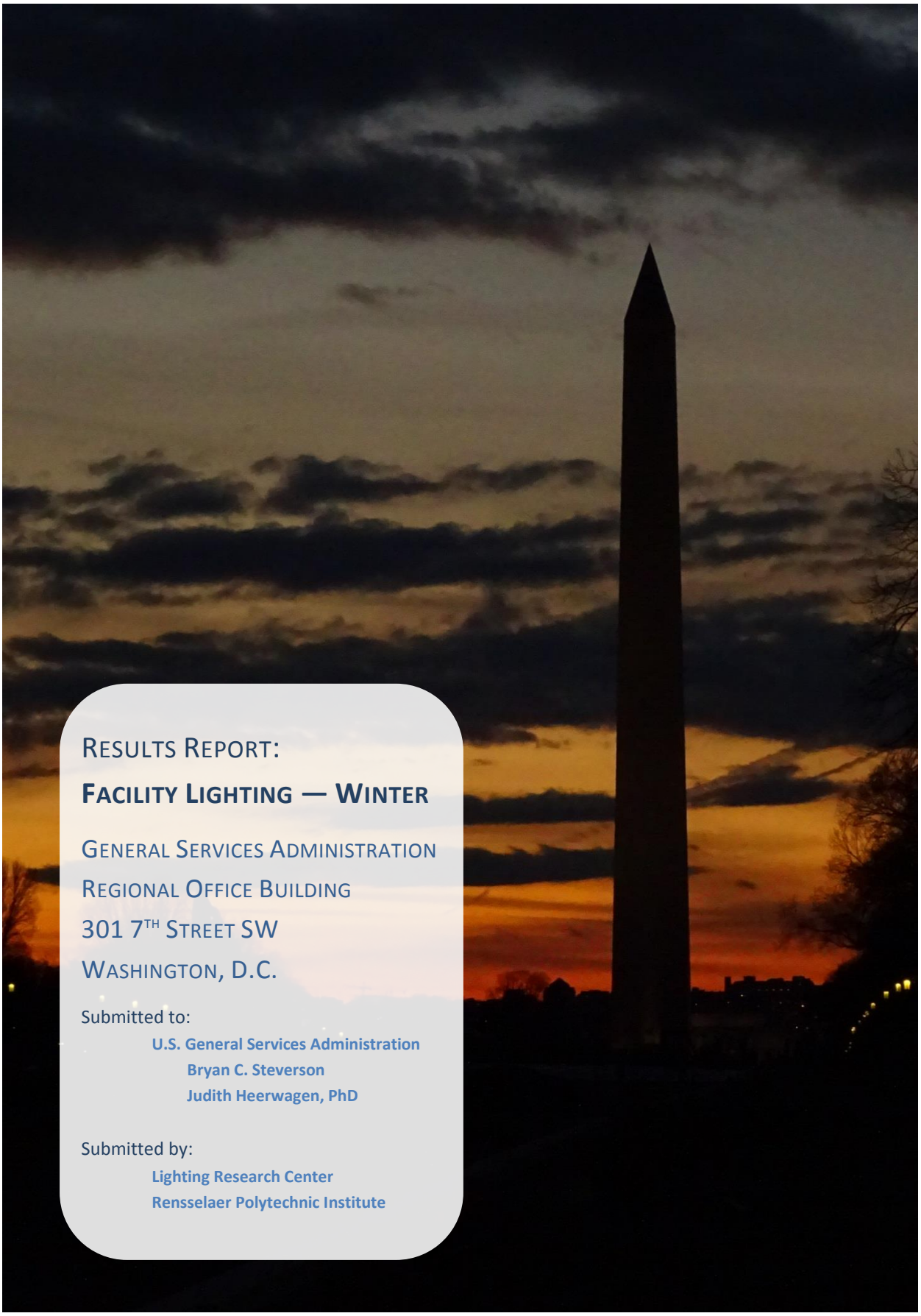

RESULTS REPORT:

FACILITY LIGHTING — WINTER

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

Submitted to:

U.S. General Services Administration
Bryan C. Steverson
Judith Heerwagen, PhD

Submitted by:

Lighting Research Center
Rensselaer Polytechnic Institute

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

SUBMITTED DATE: MARCH 31, 2016

V2: REVISED/UPDATED MAY 18, 2016

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Executive Summary

The U.S. General Services Administration (GSA) National Capital Region (NCR) Regional Office Building (ROB) is a 7-story building located at 301 7th Street SW in Washington, DC. The building was constructed in the 1930s as a construction supply warehouse. In later years, the building was converted into offices. The northwest corner of the 7th floor at ROB was recently modernized in a style similar to the workspace design at the GSA Central Office Building. Though one part of the 7th floor has been modernized in the twenty-first century, most of the offices have furniture and lighting dating to the late twentieth century.

In January 2016, a researcher from the Lighting Research Center (LRC) at Rensselaer Polytechnic Institute, together with GSA staff, returned to the site to repeat the seasonal data collection originally performed in June 2015. LRC made photometric measurements at open-plan deskspaces in the modernized segment of the 7th floor which had access to daylight. In addition to the one-time field measurements, LRC placed Daysimeter devices on nearby deskspaces to continously measure photopic and circadian light levels over the course of several days.

Daysimeters measure continuous light exposures, allowing researchers to calculate how much light that is effective for the circadian system may be reaching deskspaces (i.e., circadian stimulus [CS]). Circadian rhythms are biological rhythms that repeat approximately every 24 hours. 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 that which 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 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 the 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 nonetheless provide 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[2], is the data collection of personal light exposures by building occupants.

In addition to reporting the CS values measured at various deskspaces, this report also documents measured photometric conditions as they relate to occupant visibility and comfort, as well as the occupants' behavior and acceptance of the lighting in their deskspaces. It is important to bear in mind, however, that measurements from this visit were made on a single day in January with variable weather. Photometric values will vary

[1] Previous LRC–GSA site evaluations also focused on open-plan offices with proximity to daylight.
[2] See "References" for August 2015.

substantially in many spaces due to daily and seasonal changes in daylight, and some degree of this variability is apparent in this study's Daysimeter measurements.

The main findings from the January 2016 site evaluation at ROB are:

- The spectroradiometer data showed most 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, particularly in the middle of the day. Similar results were found in the previous summer measurements.
- Daysimeter data showed that CS values for the deskspaces located in the daylighted area varied from 0.19 to 0.50 in the north facade and from 0.18 and 0.32 in the west facade. (Previous [summer] Daysimeter data showed that CS values for deskspaces located in the daylighted area varied from 0.28 to 0.69 in the north facade and from 0.21 and 0.69 in the west facade.)
- These data show that proximity to a window is not the only option for achieving high CS values. In one case a desk was further from a window but faced the window, while its neighbor was immediately adjacent to the window, but faced perpendicular to the window; in that case the desk facing the window had higher CS values at the eye. Some positions were far from windows but had high electric light levels.
- Most of the deskspaces at ROB had a winter horizontal illuminance of greater than 30 footcandles (approximately 300 lux). Task lights were not available at any of the desks.

Introduction

The U.S. General Services Administration (GSA) National Capital Region (NCR) Regional Office Building (ROB) is a 7-story building located at 301 7th Street SW in Washington, DC. The Lighting Research Center (LRC) collected photometric measurement data during a site visit on January 15, 2016.

ROB fills a city block and no longer has the original 1935 light-well courtyards (Figure 1). 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).

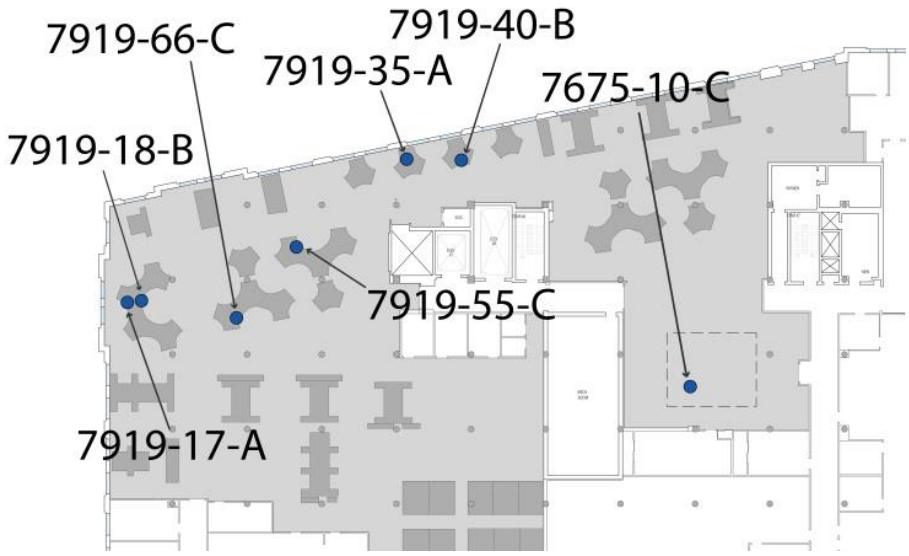

Figure 1. ROB 7th floor, northwest corner. Winter measurement area shown in gray.

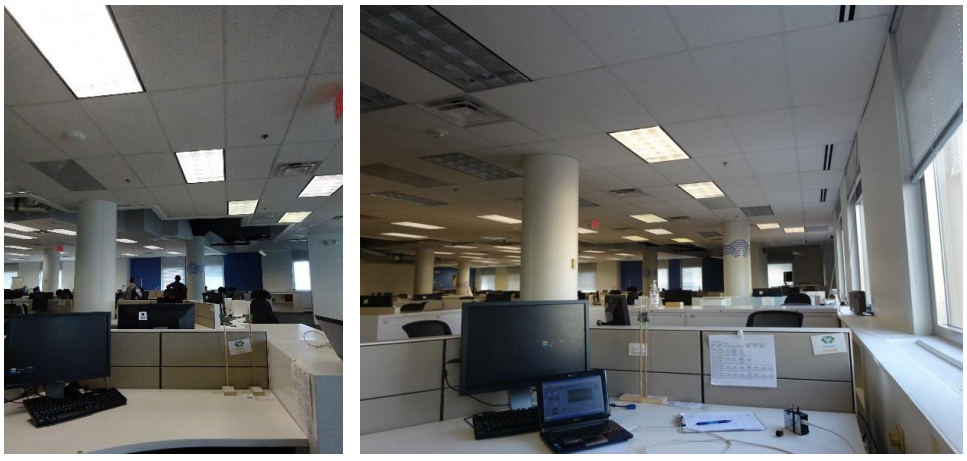

Figure 2. Modernized areas at ROB.

Figure 1. Open-plan offices areas at ROB, not recently updated.

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

Research Objectives

LRC repeated photometric measurements at ROB in January 2016 at the same open-plan desks with access to daylight as were measured in June 2015. The goal of the research was to compare seasonal photometric conditions as they relate to occupant comfort and circadian health.

The follow-up evaluation took place on January 14–15, 2016, and daylighting conditions were representative of winter. The LRC researcher was Jennifer Brons (LRC DELTA Program Director[3]), escorted and assisted by Bryan Steverson of GSA.

[3] 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 (January 14, 2016), preparations were made for the measurement day (June 15, 2016). Battery-powered measurement equipment was installed and documented. The LRC researcher performed all aspects of data collection (detailed below). This included illuminance and luminance measurements as well as spectral power distribution measurements. Questionnaires were administered on January 14–15, 2015.

Five categories of measurements were completed at ROB:

Illuminance: Illuminance is a measure of the amount of light falling on a surface, in units of lux (SI) or footcandles (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, and at all window orientations. Illuminance data were collected using Gigahertz-Optik (model: X91) lux meter.

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. The researcher collected luminance data using Minolta (model: LS-110) luminance meter.

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 (CS). The researcher collected these data using a spectroradiometer system consisting of an Ocean Optics (model: USB2000) 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 a desk working at a computer. However, it may not represent a given person's daily light exposures, such as those received from outdoor lighting while going to and from work or indoor lighting in different building locations. Daysimeter devices were installed at 6

desks and 2 windows. These devices collected data for one month after LRC visited the site, and were then removed and returned by mail to LRC for read-out.

Questionnaires: LRC administered questionnaires to 11 employees at ROB adjacent to the vacant desks used for evaluation. 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 7 desks over the course of the day and evening.

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, situated further from (but still in eyesight of) windows, are designated "C desks." The sky was primarily sunny on the measurement day (January 15), though sky cover increased in the afternoon.

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. As in the summer visit, winter measurement locations were sited in renovated spaces (with new furniture and overhead lighting) because these spaces had access to daylight and were expected to have seasonal light changes. One previously-evaluated desk ("7919-39-A") was substituted with an adjacent one ("7919-35-A") that was not occupied. The remaining 6 desks were the same ones that had been evaluated during the summer visit.

Measurements were collected in the morning, midday, in the afternoon (and included additional daylight contribution), as well as after dark. The resulting measurements are shown in detail in Appendix A.

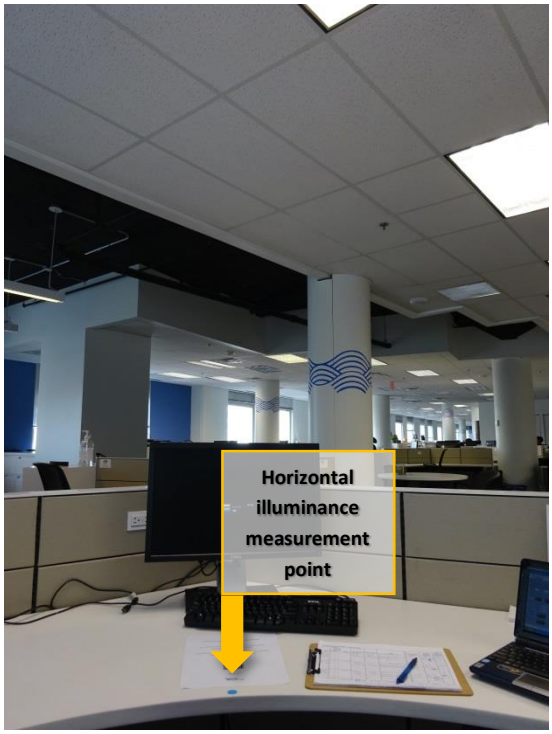

Figure 2. Typical horizontal measurement points at a row A desk.

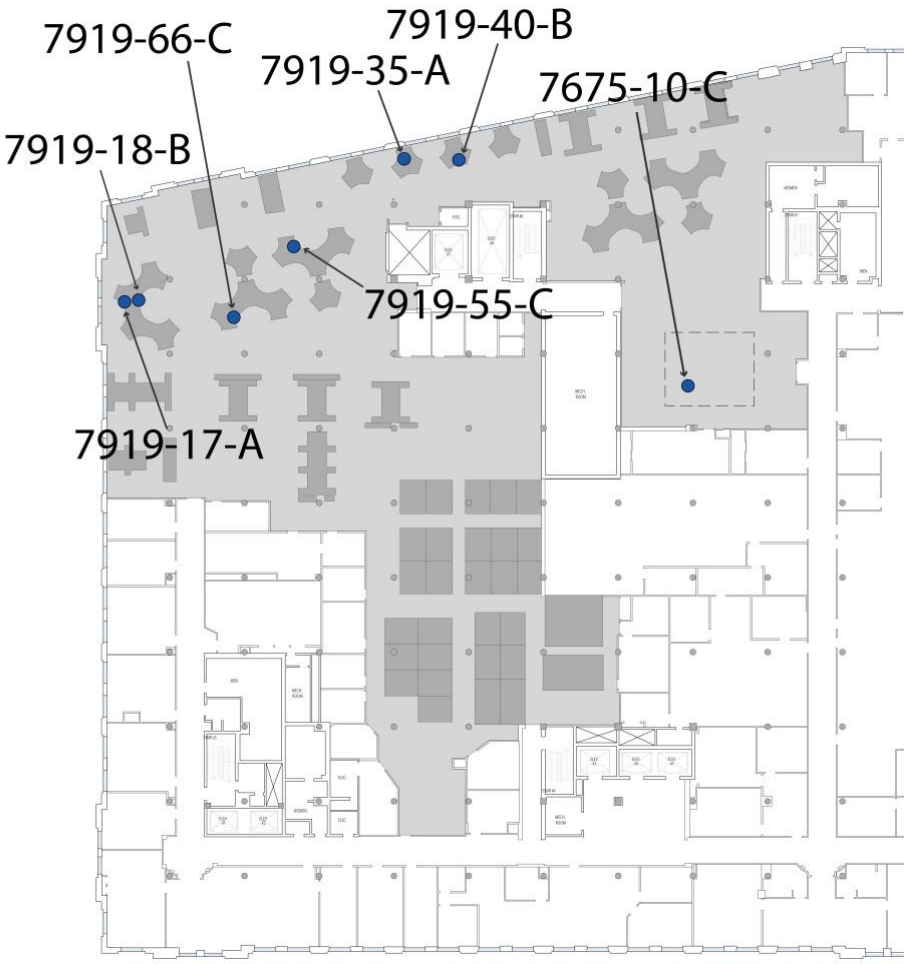

Figure 3. Winter photometric measurement locations at ROB. Numbering convention: (Room #)-(Desk #)-(Window proximity, if any) Gray shading indicates measurement area.

During the winter visit, daytime horizontal illuminances were approximately the same for desks on both north and west sides (approximately 600 lux). In the summer, horizontal illuminances were higher (approximately 800 lux) on the north side of the building compared to the west side (approximately 600 lux), probably due to the need to use shades in the afternoon on the west side. As both sets of B desks were physically very close to both sets of A desks, those desks had similar horizontal illuminance measurements.

As in the summer visit, C desks on both the north and west sides of ROB did not show much daylight contribution; the majority of the light was generated electrically. One C desk (7919-66-C) had very high electric light levels (800 lux) on the desk due to the presence of two luminaires directly overhead.

The desk with the north-facing skylight overhead had lower horizontal illuminance during the day (250–400 lux) compared to summer (400–500 lux). After dark, light levels were low (200 lux).

On the north side of the building, A and B desks had lower daytime light levels at the eye in the winter (250–500 lux) than the summer (400–600 lux). At the A and B desks on the western side, vertical illuminances at the eye were actually higher in the mornings (400–600 lux) compared to summer measurements (300-500 lux); this may be due to differing weather conditions on the specific summer/winter measurement days. This may also be due to low angle sunlight reflected off adjacent, light-colored buildings, or changes in the tilt of window blinds. Window blinds are typically down on the west side of the building,

Figure 4. Blinds are typically down on the west side, creating a filtered view of adjacent buildings.

thus creating a filtered view of adjacent buildings (Figure 6).

Luminance Results

As with the summer measurements, LRC measured wintertime 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 that of the desk surface and computer monitor bezel. The resulting measurements are shown in detail in Appendix A.

On the north facade, a few desks had a view of the sun in the mornings, and thus potential window glare; however, questionnaires showed little concern about sun (Appendix B.)

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 (42–237 cd/m^2) than the computer bezel (2–44 cd/m^2) because the desk 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.

Spectral Power Distribution (SPD) Results

The equipment used for the measurement of spectral characteristics in winter is shown in 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.)

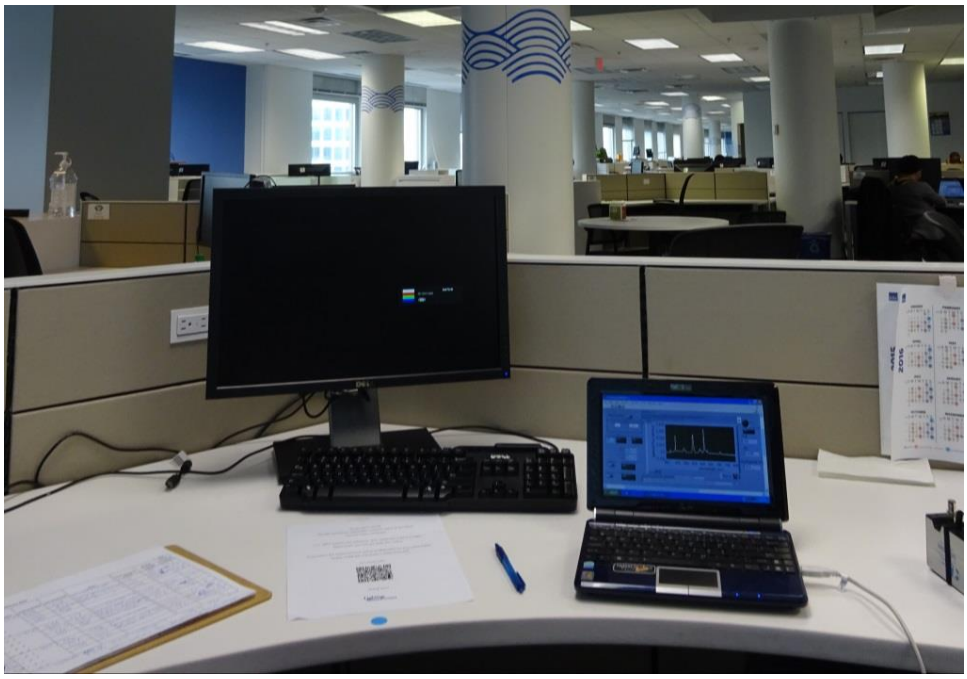

Figure 5. A spectroradiometer taking measurements at ROB.

SPDs were measured at the same desk locations used for other site measurements (see Figure 4). The SPD measurements were later used to estimate photopic lux and circadian stimulus (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 footcandles (approximately 300 lux) on the desk surface (horizontal illuminance).

Detailed results are shown in Appendix C and summarized in Appendix D. Table 1 shows average results of winter daytime measurements (excluding evening measurements, since workers are 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 based on these measurements.

The data from LRC's visit to ROB in winter (see Table 1) were similar to those in summer (Table 2). These both showed moderate overall levels of circadian stimulus at many locations. The desk located under the skylight had lower CS values than those 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 task plane.

Table 1. Winter ROB average daytime measurements using spectroradiometer.

Deskspace	Desks (n)	Measurem./ Desk (n)	Illuminance (lux)	Chromaticity CIEx	Chromaticity CIEy	Color Temp (CCT [K])	Circadian Light (CL_A) Avg.	Circadian Light (CL_A) Median	Circadian Stimulus (CS) Avg.	Circadian Stimulus (CS) Median	Brightness
Location											
A	2	3	370	0.36	0.37	4591	308	281	0.31	0.30	272
B	2	3	418	0.37	0.38	4368	318	275	0.32	0.30	298
C	2	3	524	0.38	0.39	3981	292	290	0.31	0.31	347
Skylight	1	3	201	0.38	0.40	4040	104	96	0.14	0.39	129
Orientation											
W	3	3	467	0.38	0.38	4118	294	320	0.31	0.33	319
N	3	3	408	0.36	0.38	4509	318	260	0.32	0.29	293
Skylight	1	3	201	0.38	0.40	4040	104	96	0.14	0.13	129

Table 2. Summer ROB average daytime measurements using spectroradiometer.

Deskspace	Desks (n)	Measurem./ Desk (n)	Illuminance (lux)	Chromaticity CIEx	Chromaticity CIEy	Color Temp (CCT [K])	Circadian Light (CL_A) Avg.	Circadian Light (CL_A) Median	Circadian Stimulus (CS) Avg.	Circadian Stimulus (CS) Median	Brightness
Location											
A	2	3	529	0.37	0.38	4247	370	362	0.35	0.35	369
B	2	3	595	0.37	0.38	4358	456	437	0.39	0.39	425
C	2	3	629	0.38	0.38	4062	380	411	0.36	0.38	425
Skylight	1	3	281	0.37	0.38	4263	192	187	0.23	0.55	194
Interior	1	3	476	0.39	0.40	3861	311	242	0.31	0.28	295
Orientation											
W	3	3	553	0.38	0.38	4165	361	342	0.35	0.34	381
N	3	3	616	0.37	0.38	4279	443	442	0.38	0.39	431
Skylight	1	3	281	0.37	0.38	4263	192	187	0.23	0.23	194
Interior	1	3	476	0.39	0.40	3861	311	242	0.31	0.28	295

Unlike in summer, the desks on the north side of ROB had similar winter average CS values to those on the west side. Most of the deskspaces in this area receive the desired CS value even in winter.[4]

[4] LRC. (2014). Lighting Research Report, Federal Center South, Seattle, WA. Submitted to U.S. General Services Administration, March 2014.

These data show that proximity to the window (A) is not the only option for achieving high CS values. In one case, the B desk (7919-40-B) faced the window while the A desk (7919-39-A) was perpendicular to the window wall; hence, the B-desk had higher CS values at the eye. Some positions were far from windows (7919-66-CC or interior desks) but had high electric light levels.

These data are, however, but snapshots of what the exposures are 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 08:00 am to 05:00 pm, of the CS values and the photopic lux values for each Daysimeter. Table 3 shows average CS for each pair of desk-mounted devices. Desk locations are also shown in Figure 8.

The data show:

- As in summer, the winter CS values were close to or above the desired amount of 0.3 in most of the deskspaces located in the daylight area. As in summer, the winter CS values in deskspaces located in the north facade were higher than those in the west facade. (These spaces had the same ceiling heights and reflectances, so the difference is likely due to daylight exposure and blind use.) After sunset in winter, CS values for all of the devices dropped below 0.3.
- Before 10:00 am in winter, some desks had CS values close to or above the desired amount of 0.3.

Table 3. Average winter CS values for four pairs of desk-mounted Daysimeter devices at ROB.

	North Windows				West Windows			
	Desk 35 (A-desk), Facing		Desk 55 (C-desk), Facing		Desk 15 (A-desk), facing		Desk 12 (B-desk), Facing	
Time of Day	east	west	east	west	north	south	north	south
08:00–09:00 am	0.39	0.44	0.36	0.25	0.22	0.31	0.23	0.26
09:00–10:00 am	0.44	0.48	0.40	0.28	0.25	0.32	0.26	0.27
10:00–11:00 am	0.46	0.50	0.42	0.29	0.25	0.29	0.27	0.27
11:00 am-12:00 pm	0.47	0.50	0.42	0.29	0.25	0.28	0.27	0.27
12:00–01:00 pm	0.45	0.49	0.40	0.28	0.27	0.29	0.27	0.24
01:00–02:00 pm	0.42	0.46	0.37	0.26	0.29	0.32	0.27	0.25
02:00–03:00 pm	0.37	0.41	0.33	0.24	0.29	0.32	0.26	0.25
03:00–04:00 pm	0.27	0.31	0.25	0.19	0.20	0.29	0.18	0.24
04:00–05:00 pm[a]	0.15	0.16	0.14	0.15	0.21	0.28	0.13	0.24

Note: a, after sunset.

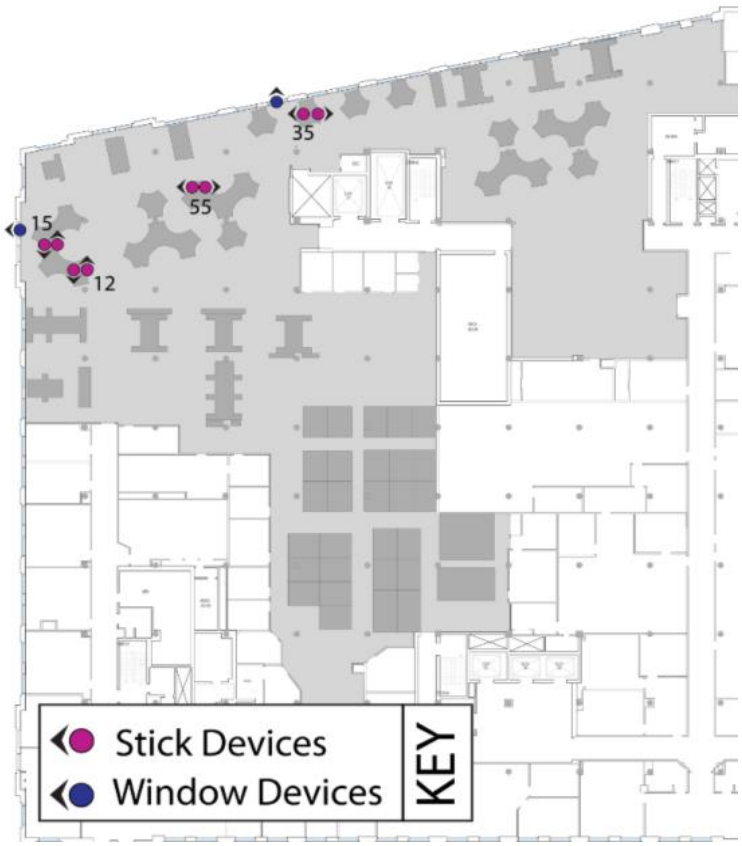

Figure 6. Daysimeters locations January-February 2016; 2 were mounted on windows, and 8 were mounted on sticks on occupant desks. Window-mounted devices are shown in blue; stick-mounted devices shown in magenta.

QUESTIONNAIRE RESULTS

LRC administered a brief questionnaire to 11 people working at ROB in January 2016; few, if any, of the respondents answered the previous, summer questionnaire. 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 evaluation publications (see References).

Most of the winter respondents (n = 8) reported that they only work during the day, which is sensible considering that most of these occupants leave the building at around 4:00 pm, when it starts to get dark in winter. All questionnaire respondents during the summer evaluation said they only work during the day. Skies were mostly sunny on the days that the winter questionnaire was completed. Two window orientations were represented (north: 27%; west: 46%) as well as a skylight (27%). All respondents worked on the 7th floor of ROB, where the winter measurements took place.

In the winter visit, all workers were satisfied by the amount of light provided; 100% reported that the amount of light on their desk was neither too much nor too little. This was also the case for desks with daylight on the summer visit. During the summer and winter measurements, respondents said they did not use task lights. LRC noted that a task light was not present at any of the desks where people answered the winter questionnaire.

Many (n = 8 [73%]) of the winter respondents rated their luminaires as comfortable to look at (compared to 89% of summer respondents with access to daylight).

In the winter visit, all respondents had access to daylight. In winter, 10 (91%) of the respondents reported that the windows were comfortable to look at (compared 89% of summer respondents with access to daylight.)

As shown in Figure 9, the overall lighting at this building was rated as "better" or "much better" by 6 (55%) of the winter respondents. This is about the same acceptance rate as all 16 summer respondents (56%), though not quite as positive as the 9 summer respondents with daylight (78% of which rated the lighting positively). These winter results are similar to other office lighting case studies (see Figure 9).

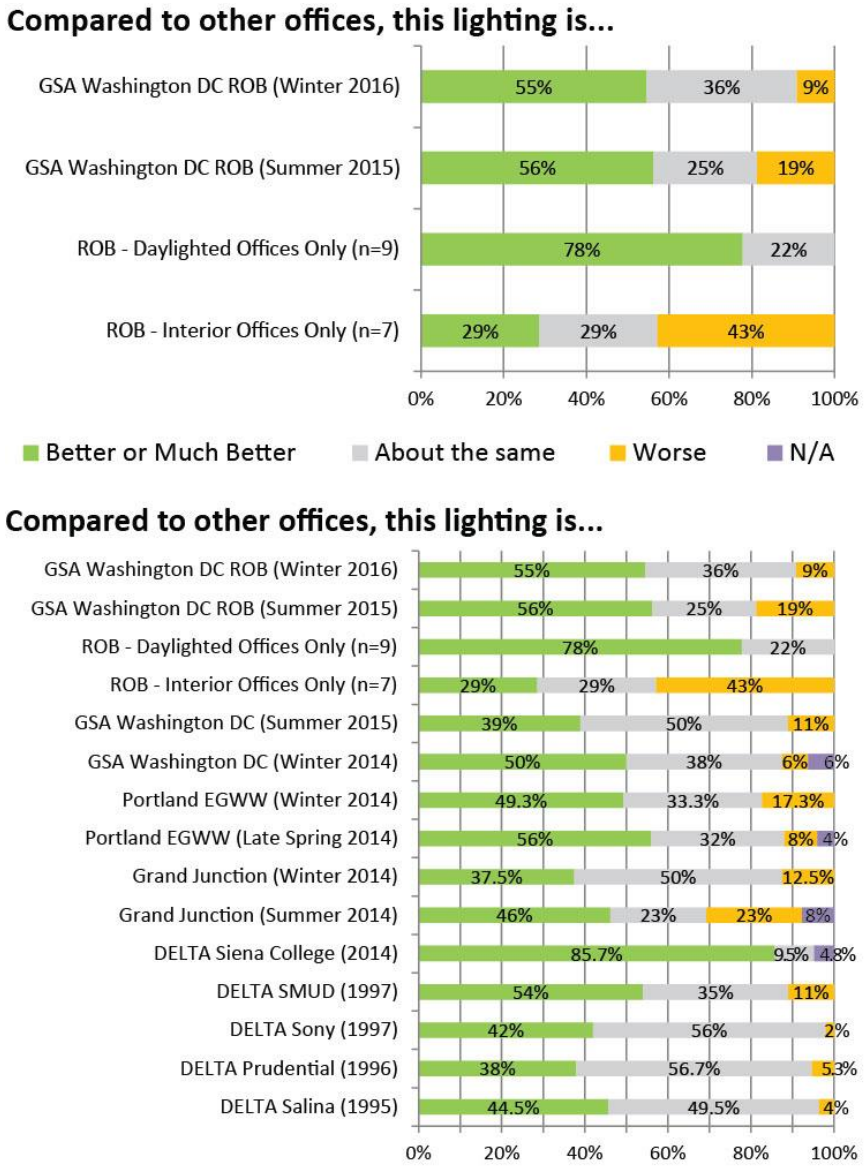

Figure 7. Overall winter and summer questionnaire results at GSA Central Office Building, daylighted vs. interior (upper), and compared to other office lighting evaluations by the LRC (lower).

Discussion

A summary of the vertical illuminance findings is provided in Appendix F. As shown in Figure 10, the pink-shaded portions of the figures in Appendix F reflect areas likely to cause discomfort glare (DG), above 1780 lux, or likely to provide low circadian stimulation (CS), below 175 lux, for a daylight-like source (e.g., 6500 K). The yellow-shaded boundary, between 940 lux and 1780 lux, is considered at or near the 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 lux and 300 lux, 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 is between 300 lux and 940 lux, which is lower than the discomfort glare threshold boundary and above the circadian stimulus threshold boundary.

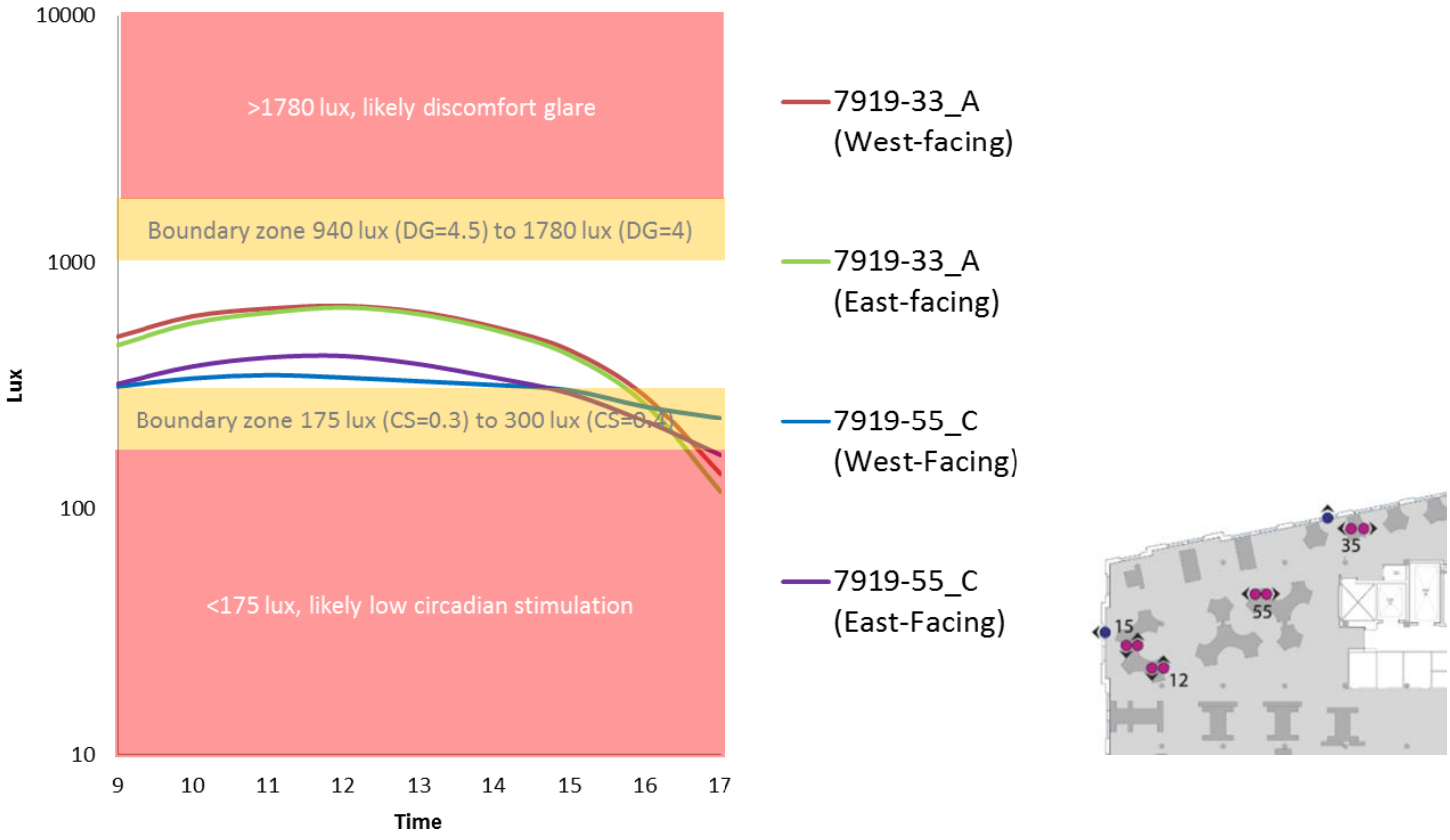

Figure 8. Winter average vertical illuminance at the eye at two desks with northern daylight exposure, at different times of day.

Based on the Daysimeter measurements, 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 Daysimeter measurements over the course of several days suggest that the both electric light and contribution of daylight both affect CS values. Deskspaces closest to the windows, however, tend to show higher CS values during the daytime hours, especially in the morning and midday (see Table 3). It is also interesting to observe that some of photometric measurements, which are spot measurements and simply provide a snapshot of the potential for circadian stimulation, do not suggest that deskspaces close to windows have greater potential for higher CS. These discrepancies underscore the importance of monitoring the building for some period to assure that desired CS is achieved.

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

Two 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.
- Discomfort glare ratings are highly variable among people and for different contexts.

References

Konis, K. (2013). Evaluating daylighting effectiveness and occupant visual comfort in a side-lit open plan office building in San Francisco, California. *Building and Environment,* 59:662-677.

LRC. (1995). DELTA Portfolio: 450 South Salina Street, Office Building.

LRC. (1996). DELTA Portfolio: Prudential Healthcare, Office Building.

LRC. (1997). DELTA Portfolio: SONY Disc Manufacturing, Administration and Support Spaces.

LRC. (1997). DELTA Portfolio: Sacramento Municipal Utility District (SMUD), Office Building.

LRC. (2014). DELTA Portfolio: LED Lighting in a Campus Building.

LRC. (2014). Results Report: Facility Lighting – Winter, Wayne N. Aspinall Federal Building, Grand Junction, CO.

LRC. (2014). Results Report: Facility Lighting – Winter, Federal Center South, Seattle, WA..

LRC. (2014). Results Report: Facility Lighting – Late Spring, Edith Green Wendell Wyatt Federal Building Federal Building, Portland, OR.

LRC. (2014). Results Report: Facility Lighting – Summer, Wayne N. Aspinall Federal Building, Grand Junction, CO.

LRC. (2015). Results Report: Facility Lighting – Winter, GSA Central Office Building, Washington, DC.

LRC. (2015). Measuring Personal Light Exposures, Mood, and Wellbeing Outcomes, Edith Green Wendell Wyatt Federal Building Federal Building, Portland, OR.

LRC. (2015). Results Report: Facility – Summer, GSA Regional Office Building, Washington, DC.

LRC. (2015). Results Report: Facility – Summer, GSA Central Office Building, Washington, DC.

LRC. (2015). Results Report: Facility Lighting – Winter, Edith Green Wendell Wyatt Federal Building Federal Building, Portland, OR.

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

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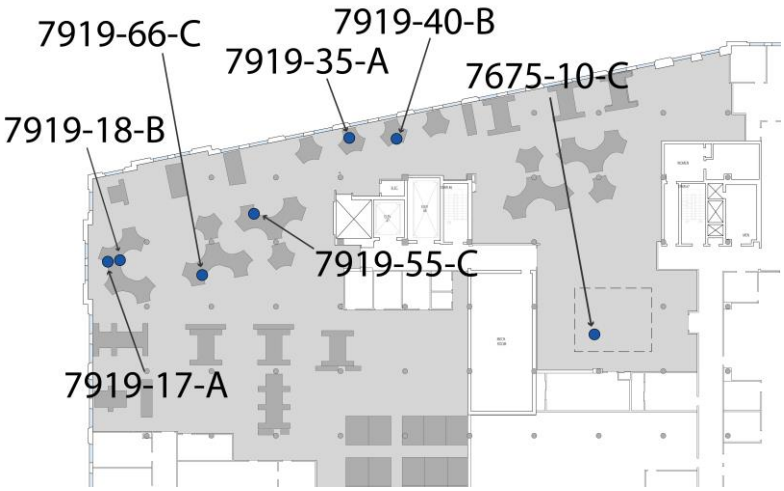
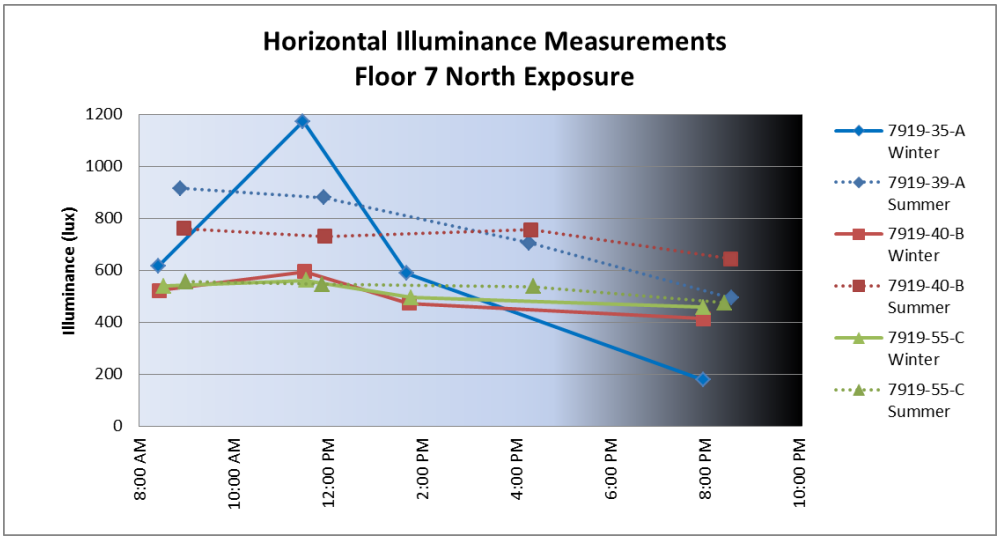
Editors: Rebekah Mullaney, David Pedler

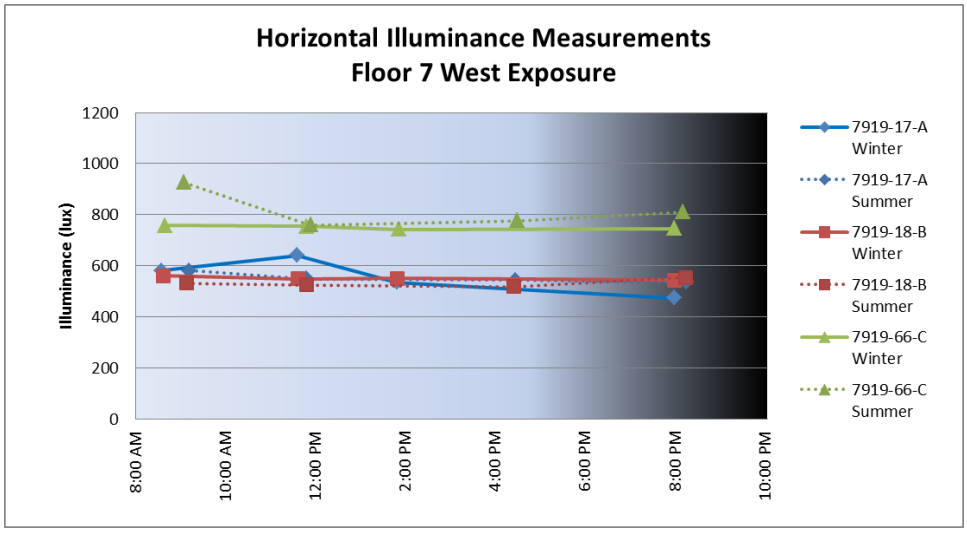
APPENDIX A: PHOTOMETRIC DATA (ILLUMINANCE AND LUMINANCE MEASUREMENTS)



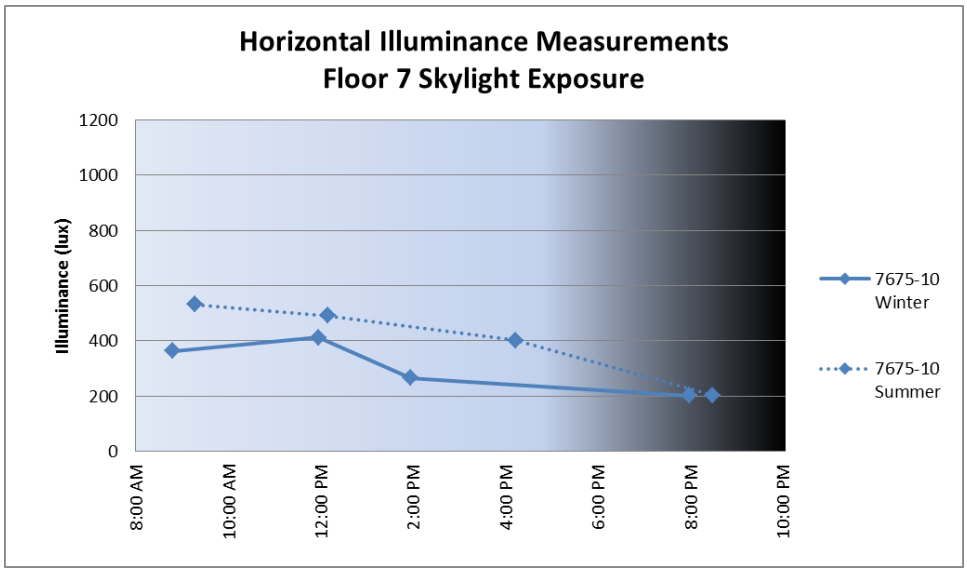
Key plan, showing summer photometric measurement locations on Floor 7. Desks marked "A" are nearest the windows, desks marked "B" are in the adjacent row, and desks marked "C" are deeper in the core of the building. "Interior" desks do not have access to daylight.



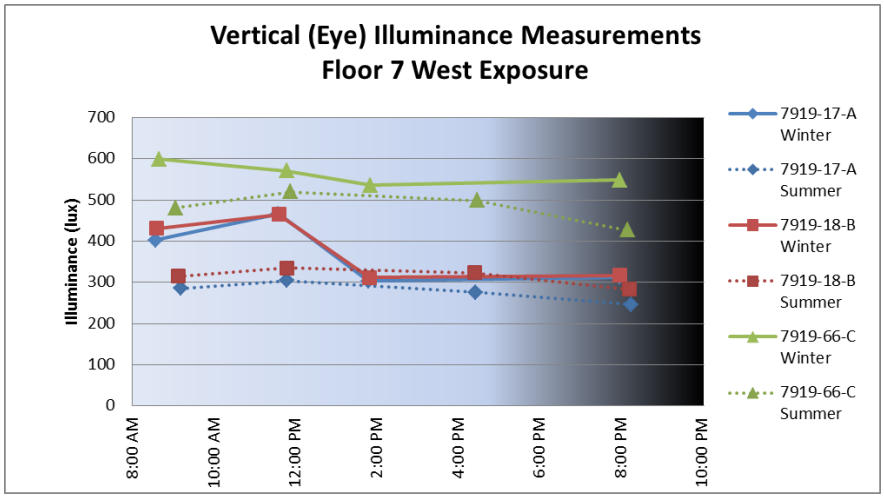
Horizontal illuminance measurements at 3 desks on the north side of the 7th floor, during the day and in the evening.

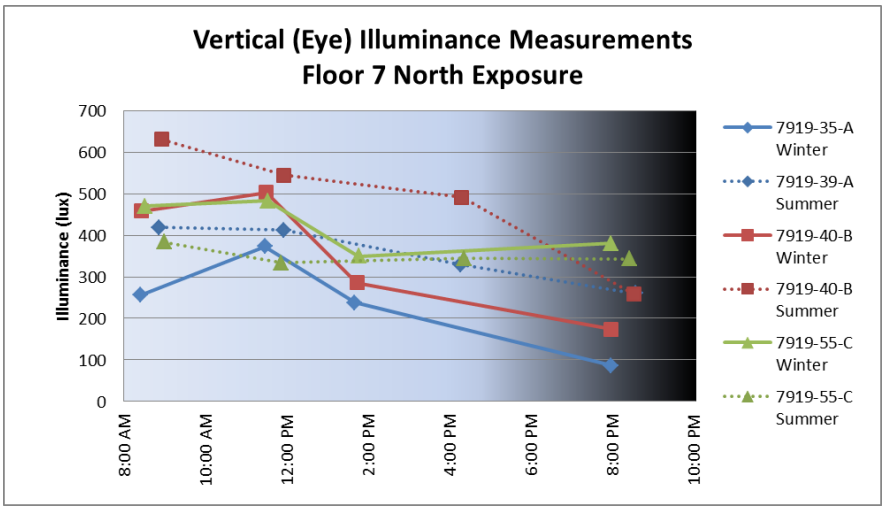


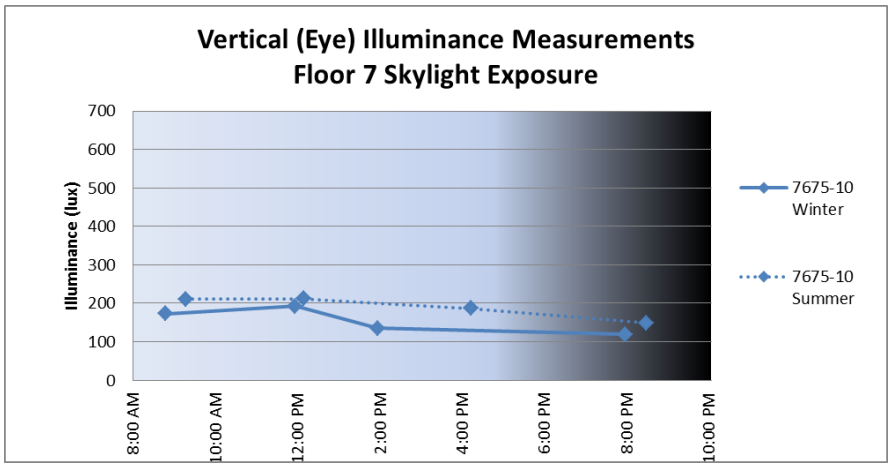
Horizontal illuminance measurements at 3 desks on the west side of the 7th floor, during the day and in the evening.



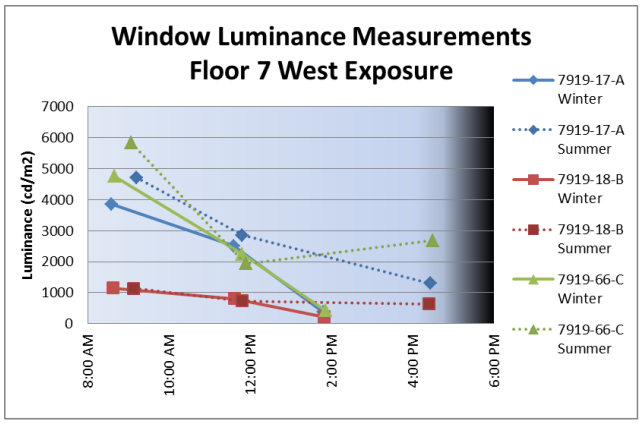
Horizontal illuminance measurements at 1 desk with skylight exposer on Floor 7, during the day and in the evening.

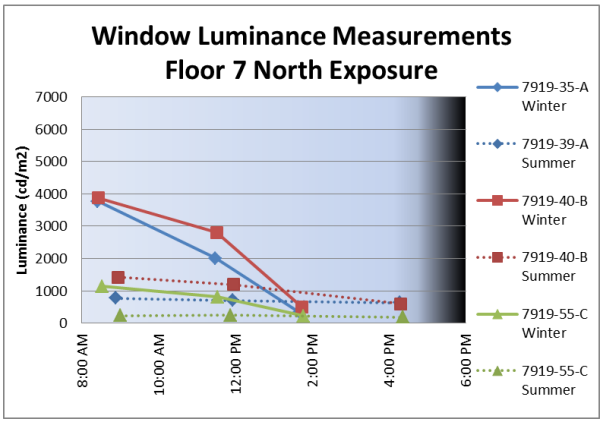




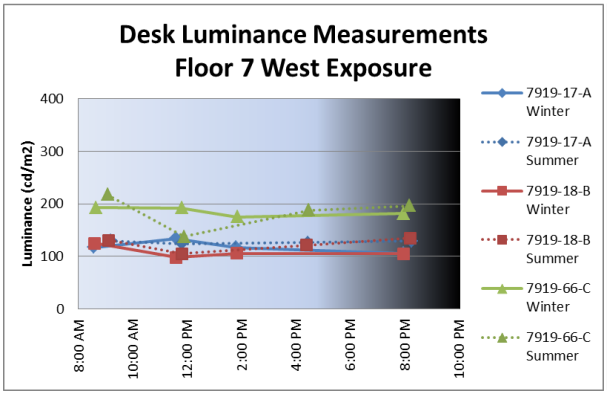


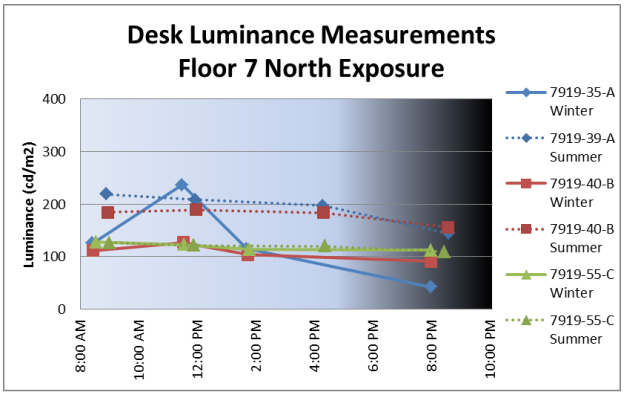
Vertical illuminance (at the eye) at ROB desks, during the day and in the evening.

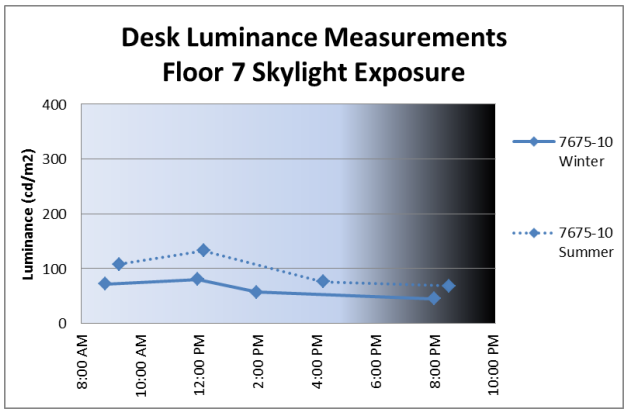




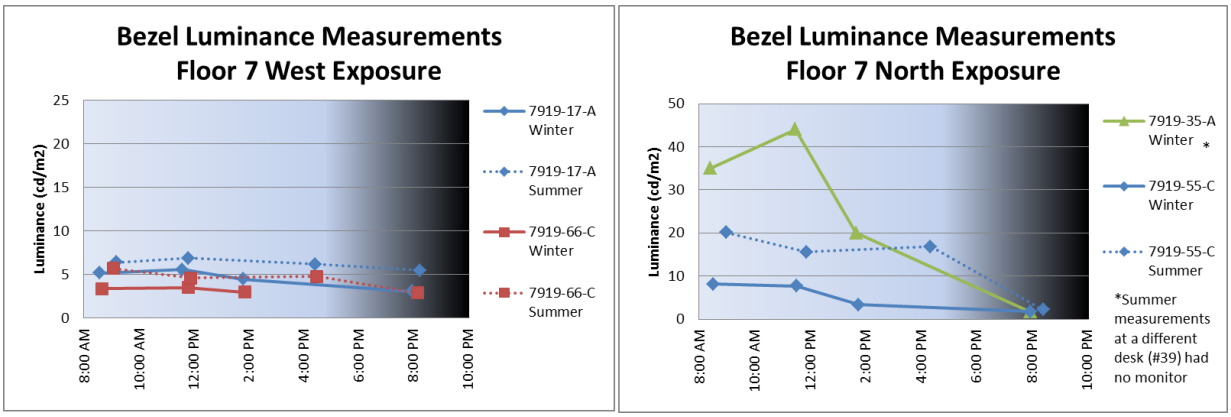
Window luminance at the 6 desks with access to windows, during the daytime measurements.





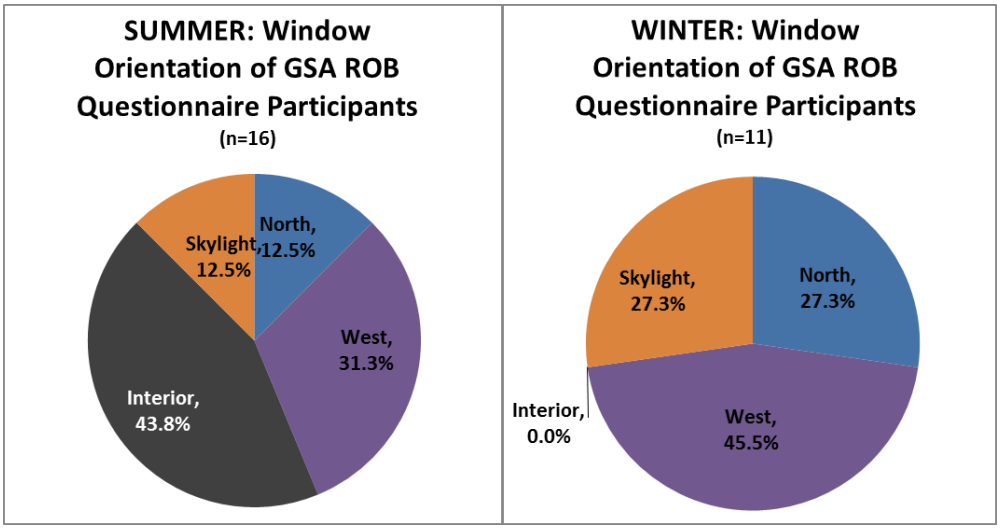


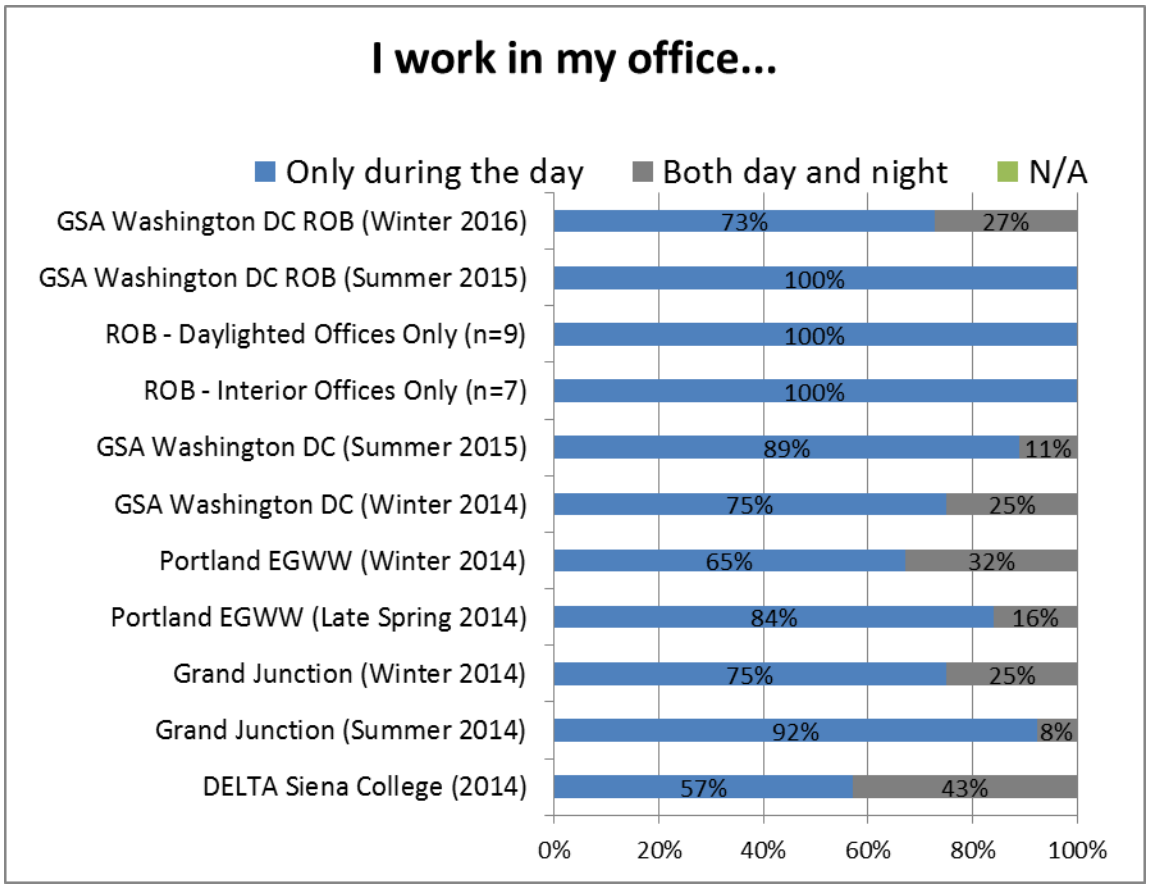
Desk luminance at ROB desks, during the day and in the evening.

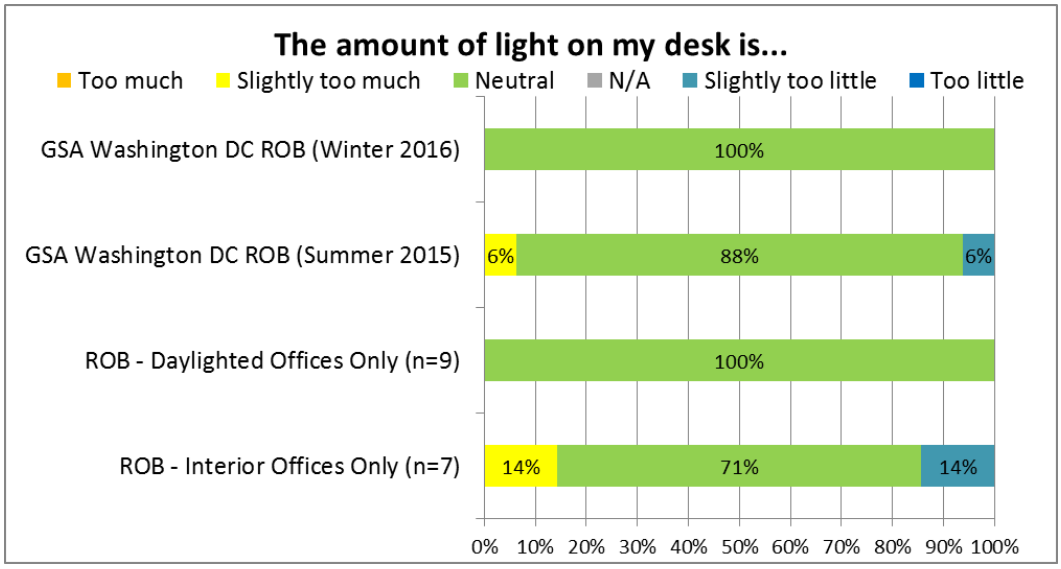


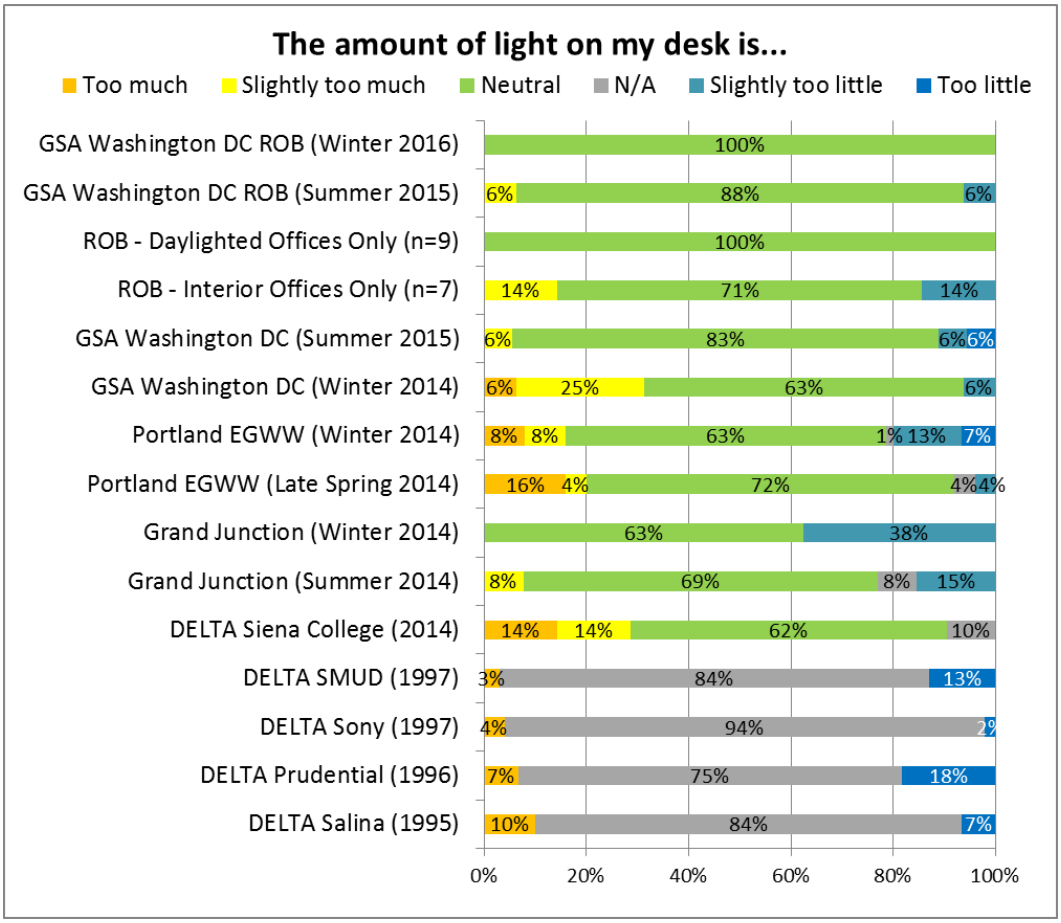
Bezel luminance at ROB desks, during the day and in the evening.

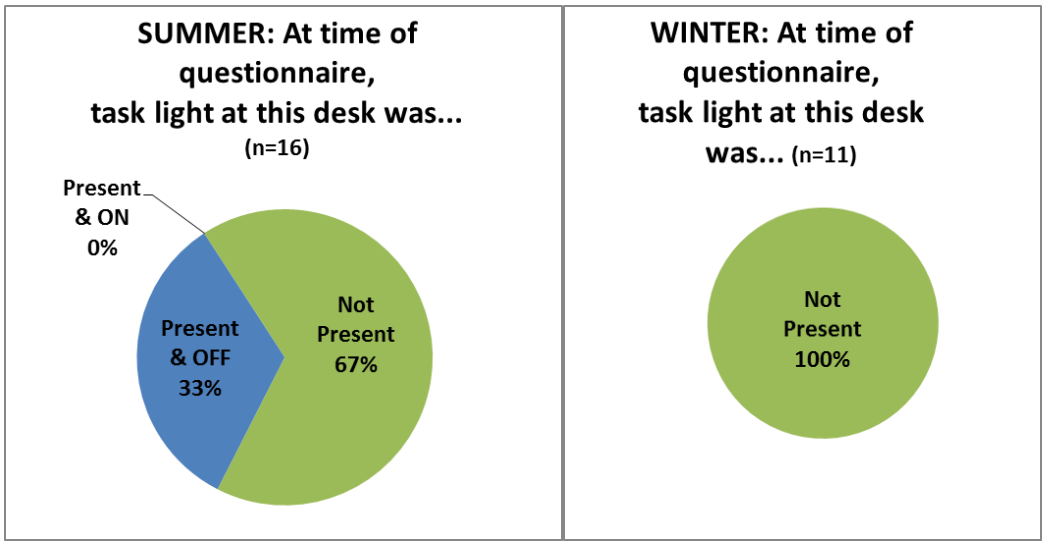
APPENDIX B: QUESTIONNAIRE RESULTS

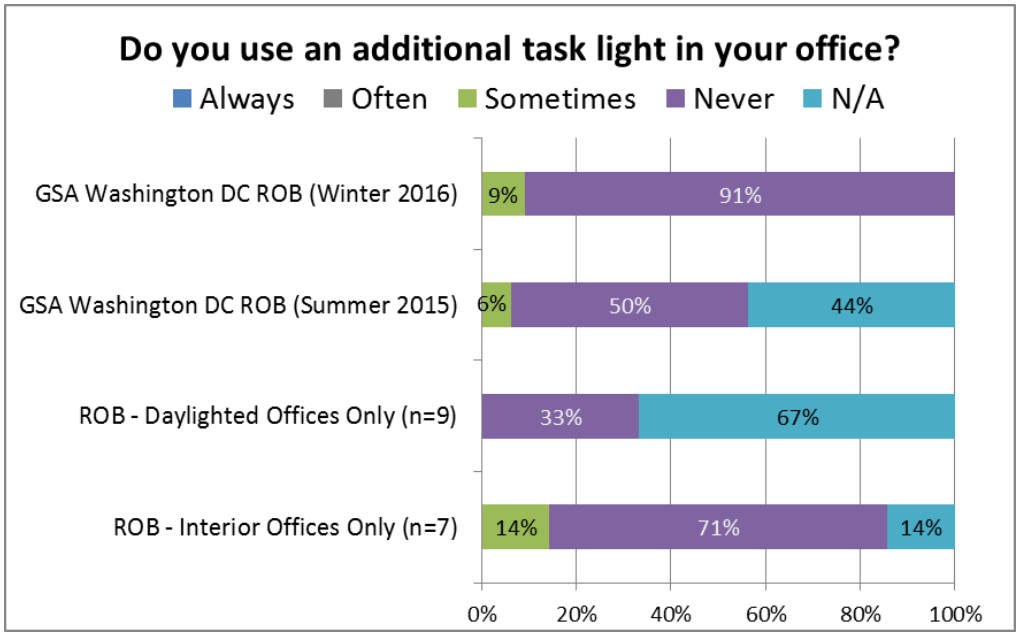


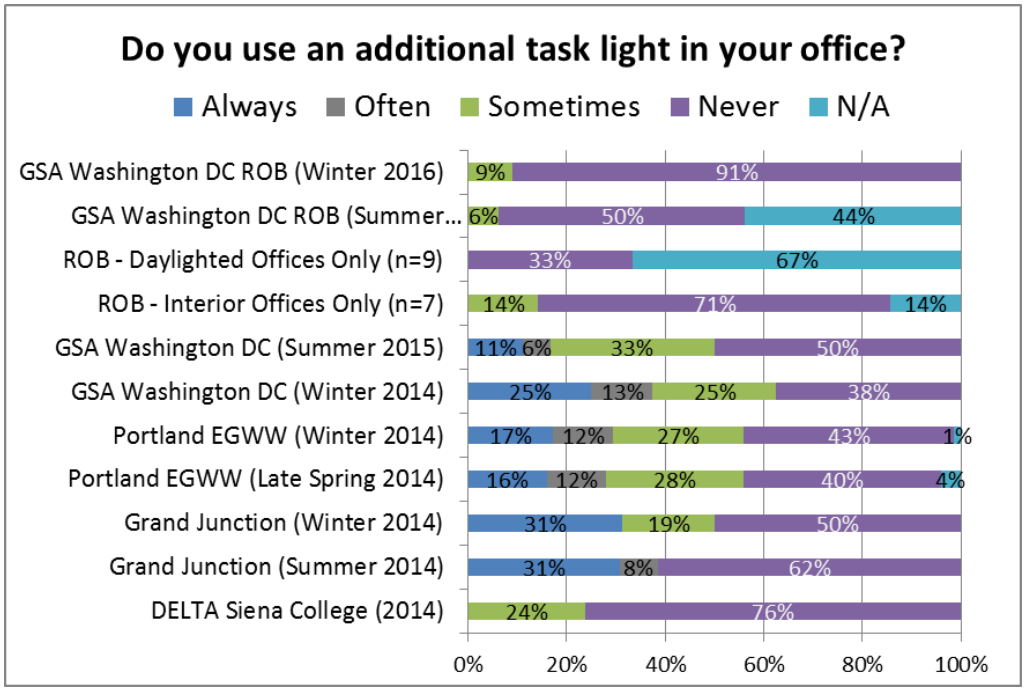


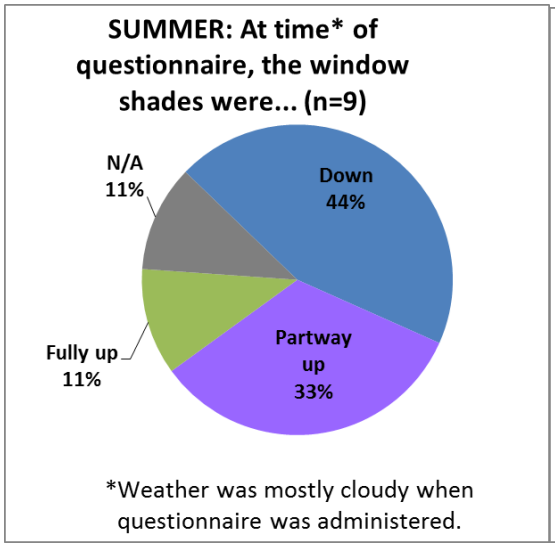

The amount of light on my desk is...
Too much
Slightly too much
Neutral
N/A
Slightly too little
Too little
GSA Washington DC ROB (Winter 2016)
GSA Washington DC ROB (Summer 2015)
ROB - Daylighted Offices Only (n=9)
ROB - Interior Offices Only (n=7)
100%
6%
88%
6%
100%
14%
71%
14%
0% 10% 20% 30% 40% 50% 60% 70% 80% 90% 100%

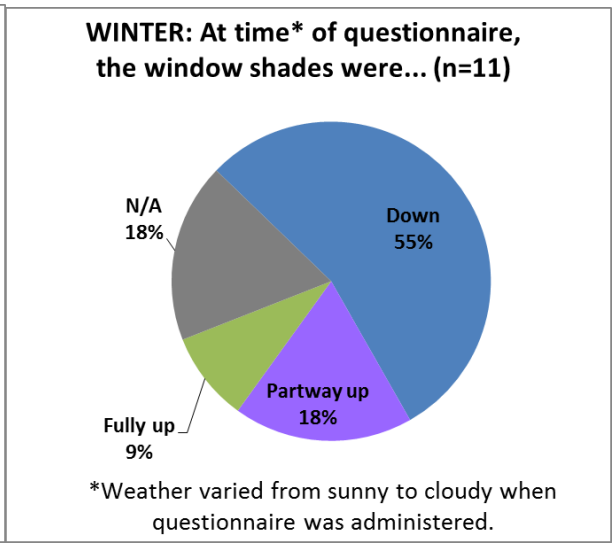

The amount of light on my desk is...
Too much
Slightly too much
Neutral
N/A
Slightly too little
Too little
GSA Washington DC ROB (Winter 2016)
GSA Washington DC ROB (Summer 2015)
ROB - Daylighted Offices Only (n=9)
ROB - Interior Offices Only (n=7)
GSA Washington DC (Summer 2015)
GSA Washington DC (Winter 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%

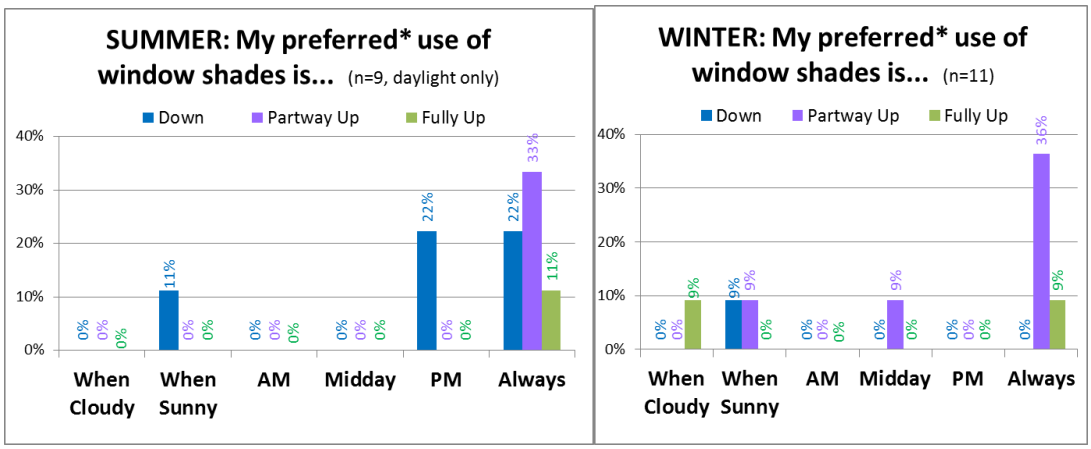

SUMMER: At time of questionnaire, task light at this desk was... (n=16)
Present & ON 0%
Present & OFF 33%
Not Present 67%
WINTER: At time of questionnaire, task light at this desk was... (n=11)
Not Present 100%


Do you use an additional task light in your office?
Always
Often
Sometimes
Never
N/A
GSA Washington DC ROB (Winter 2016)
9%
91%
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 (Winter 2016)
GSA Washington DC ROB (Summer...
ROB - Daylighted Offices Only (n=9)
ROB - Interior Offices Only (n=7)
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)
9%
91%
6%
50%
44%
33%
67%
14%
71%
14%
11%
6%
33%
50%
25%
13%
25%
38%
17%
12%
27%
43%
1%
16%
12%
28%
40%
4%
31%
19%
50%
31%
8%
62%
24%
76%
0%
20%
40%
60%
80%
100%

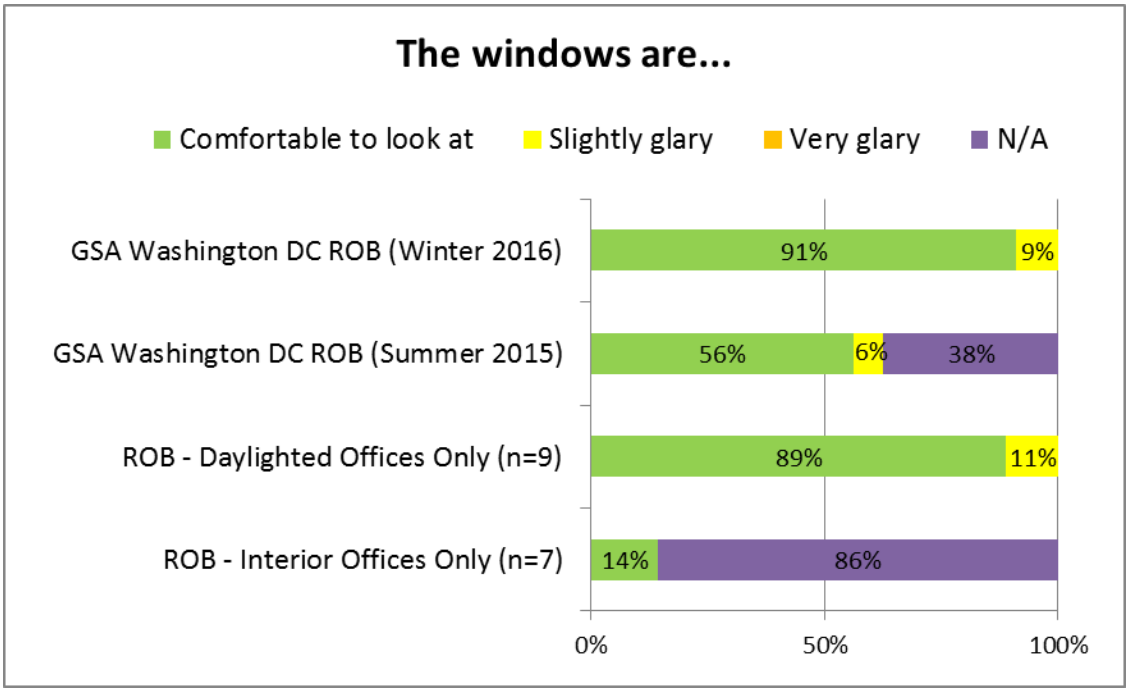

SUMMER: At time* of questionnaire, the window shades were... (n=9)
N/A 11%
Down 44%
Fully up 11%
Partway up 33%
*Weather was mostly cloudy when questionnaire was administered.

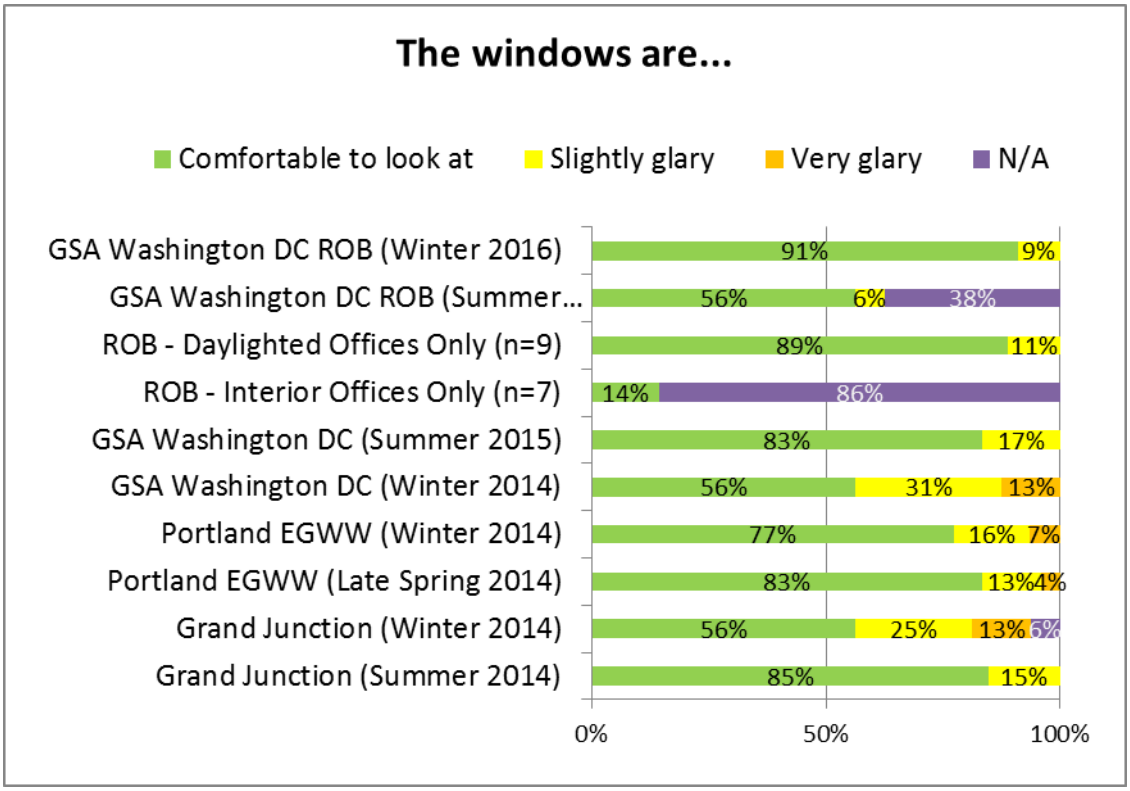

WINTER: At time* of questionnaire, the window shades were... (n=11)
N/A 18%
Down 55%
Partway up 18%
Fully up 9%
*Weather varied from sunny to cloudy when questionnaire was administered.

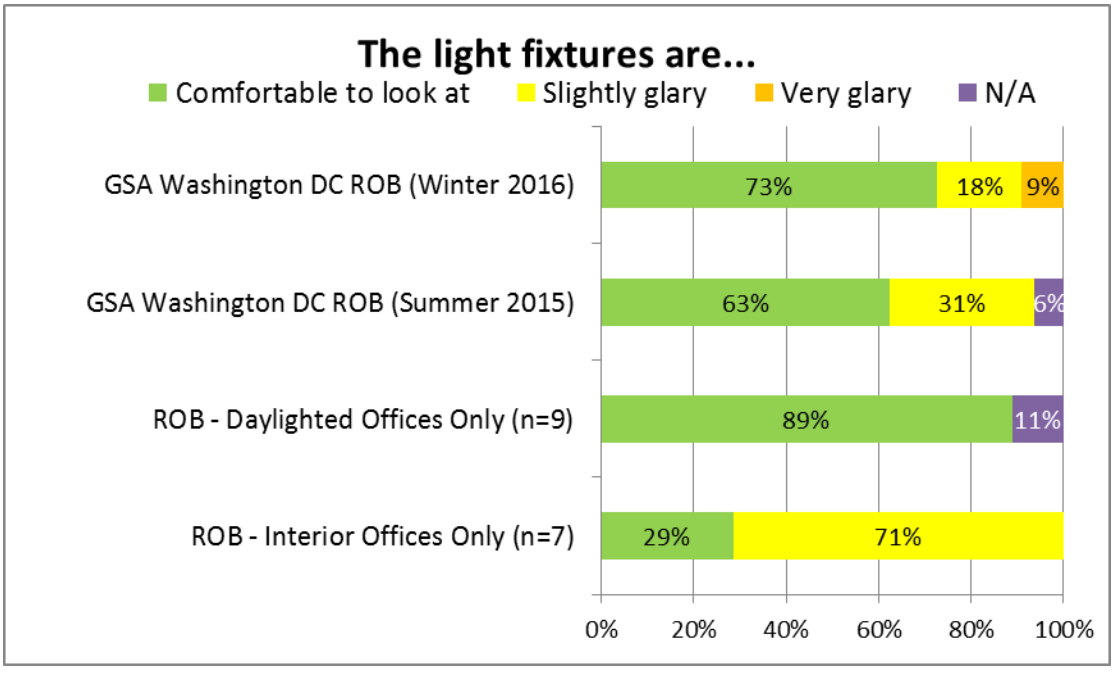


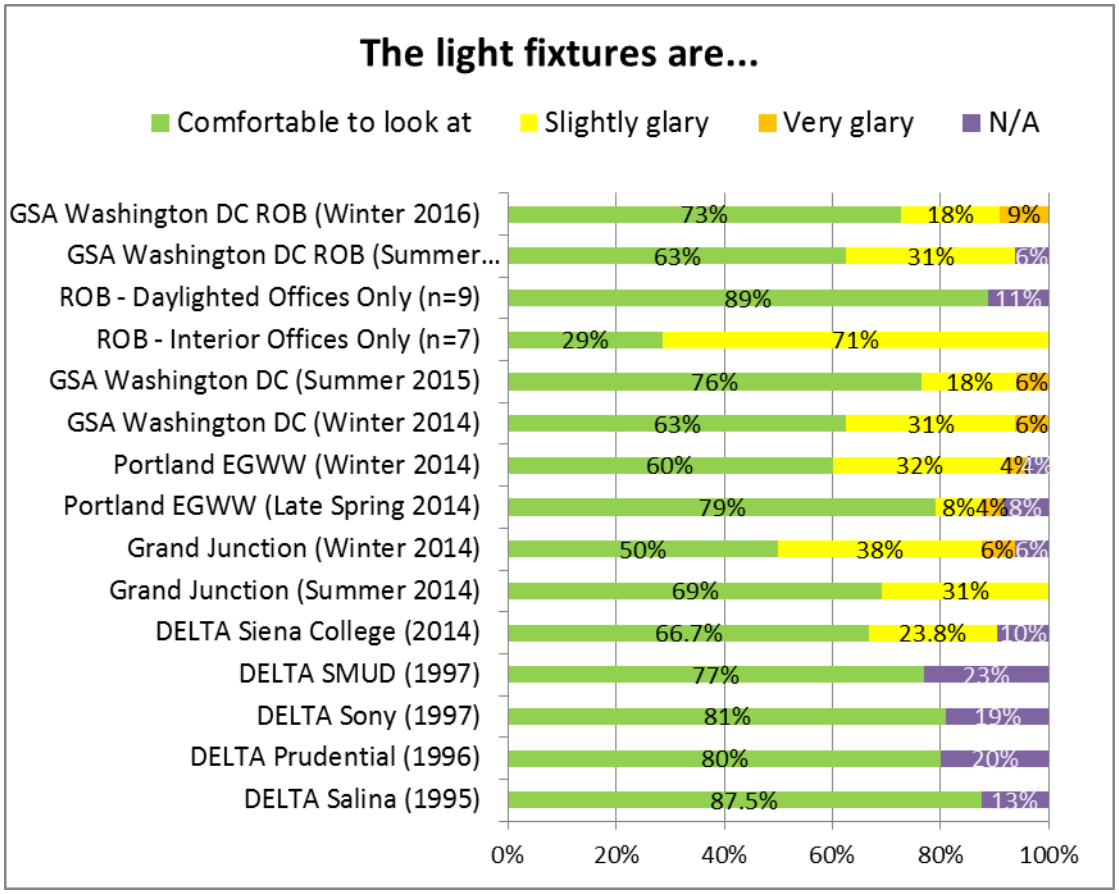
SHADES COMMENTS

- (None)



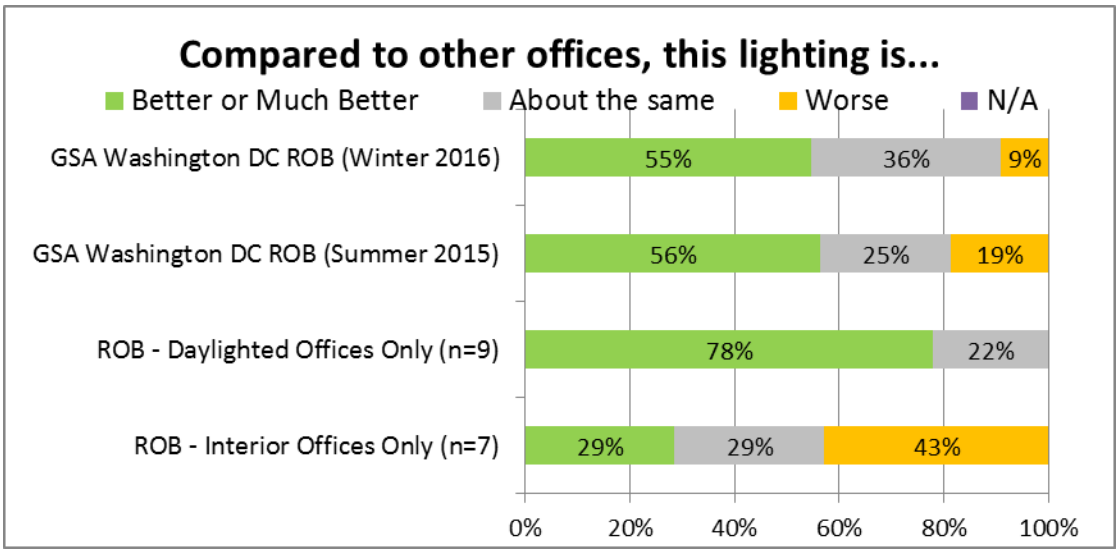

The windows are...
Comfortable to look at
Slightly glary
Very glary
N/A
GSA Washington DC ROB (Winter 2016)
GSA Washington DC ROB (Summer...
ROB - Daylighted Offices Only (n=9)
ROB - Interior Offices Only (n=7)
GSA Washington DC (Summer 2015)
GSA Washington DC (Winter 2014)
Portland EGWW (Winter 2014)
Portland EGWW (Late Spring 2014)
Grand Junction (Winter 2014)
Grand Junction (Summer 2014)
91%
9%
56%
6%
38%
89%
11%
14%
86%
83%
17%
56%
31%
13%
77%
16%
7%
83%
13%
4%
56%
25%
13%
6%
85%
15%
0%
50%
100%

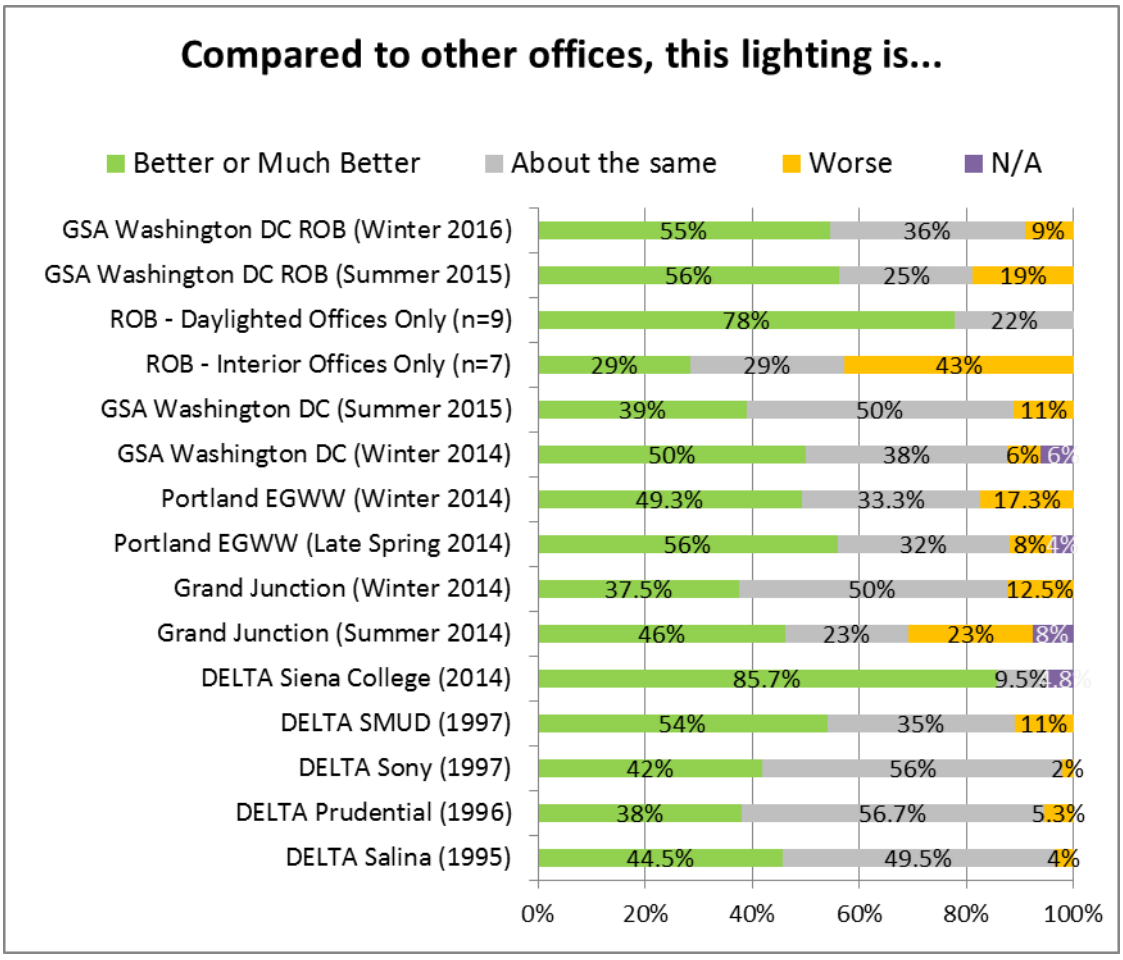

The light fixtures are...
Comfortable to look at
Slightly glary
Very glary
N/A
GSA Washington DC ROB (Winter 2016)
GSA Washington DC ROB (Summer 2015)
ROB - Daylighted Offices Only (n=9)
ROB - Interior Offices Only (n=7)
73%
18%
9%
63%
31%
6%
89%
11%
29%
71%
0%
20%
40%
60%
80%
100%



LUMINAIRE COMMENTS

- "Lights tend to flicker"





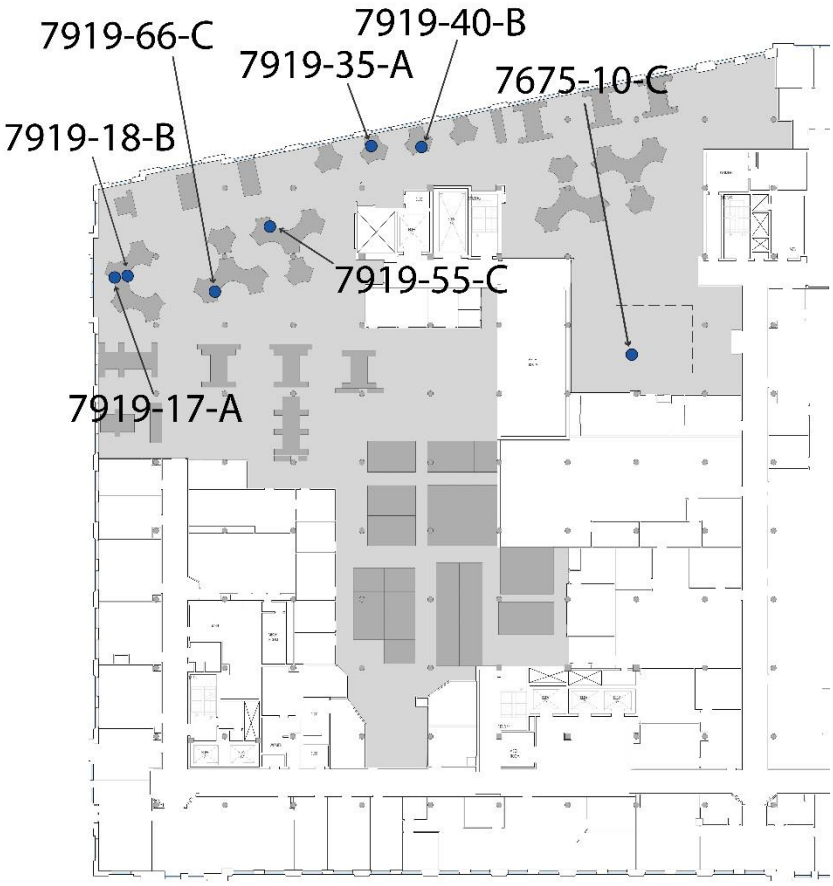
Overall Comments

- "I don't have a window seat. The lighting is comfortable for me."

APPENDIX C: SPECTRAL PHOTOMETRIC DATA

Spectral power distribution (SPD) was measured at ROB desks. Desk 7919-35 replaced desk 7919-39, which was no longer vacant/available for measurement. The remaining desks were the same ones measured in summer 2015.

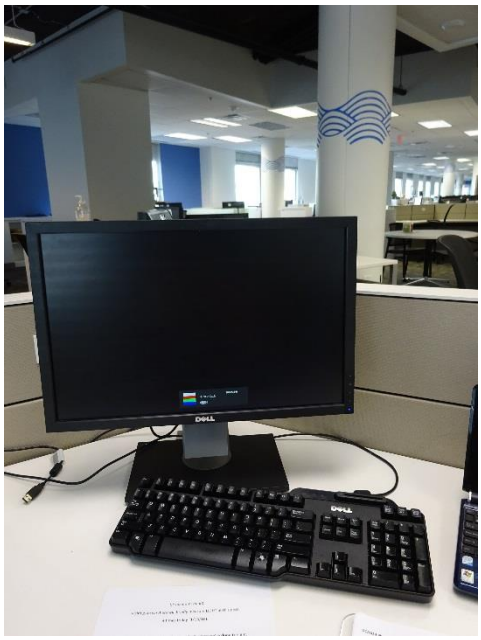
As in Summer 2015, desks with access to daylight were measured repeatedly throughout the day and evening, in the same locations and on the same frequency as other measurements (see Appendix A). Desks without access to daylight or view of windows were not measured in this seasonal, follow-up visit.



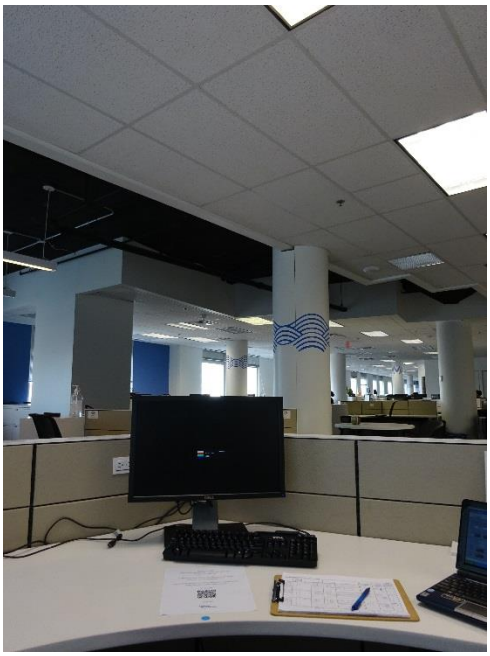
Desks at ROB where SPD measurements were collected (Winter).

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.

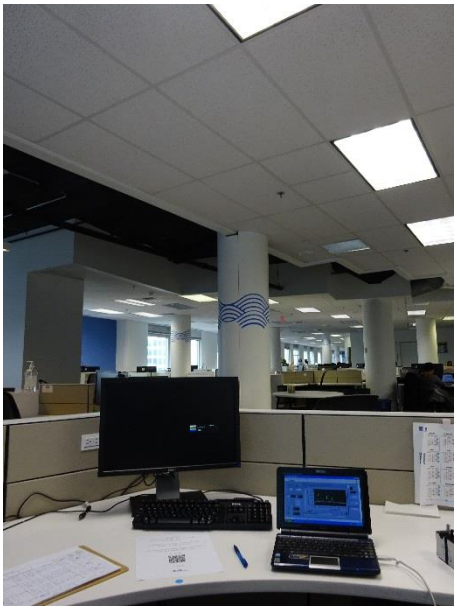
Regional Office Building –Desk 7919-17



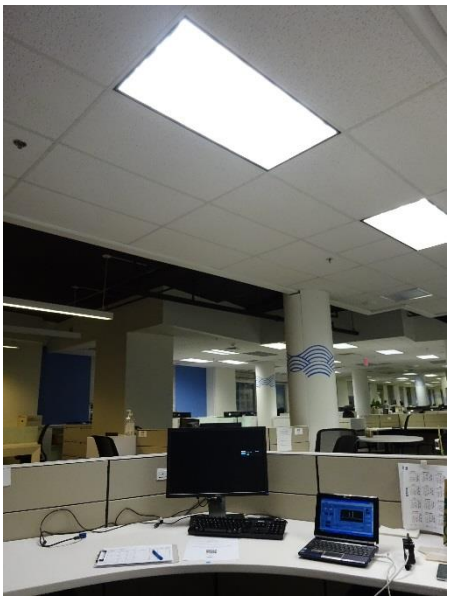
8:35 AM



11:37 AM

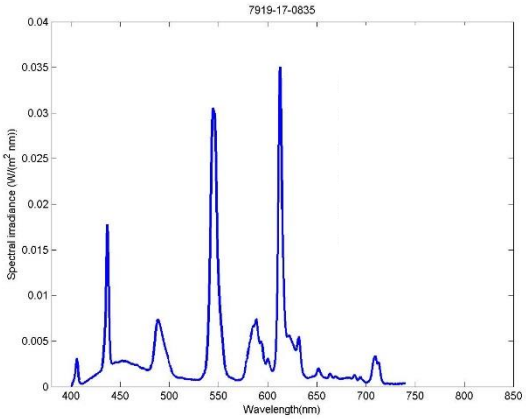


1:49 PM

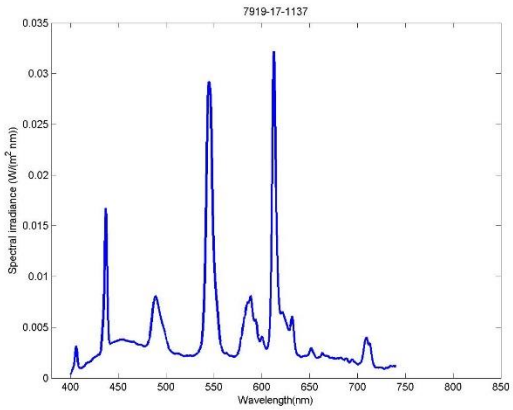


5:28 PM

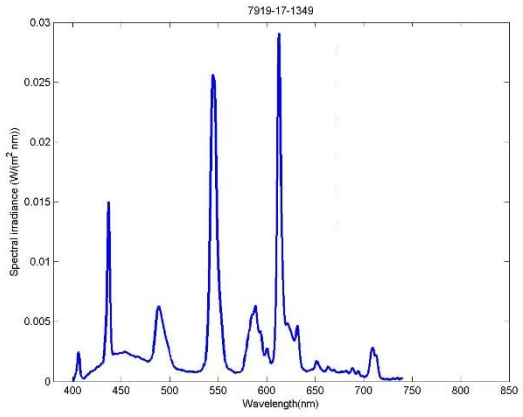
REGIONAL OFFICE BUILDING –DESK 7919-17
(SPECTRAL POWER DISTRIBUTION)



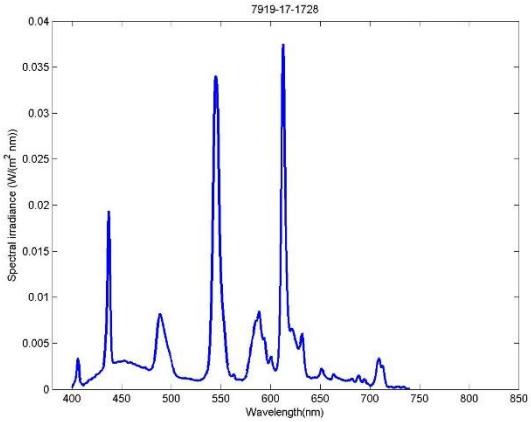
8:35 AM



11:37 AM

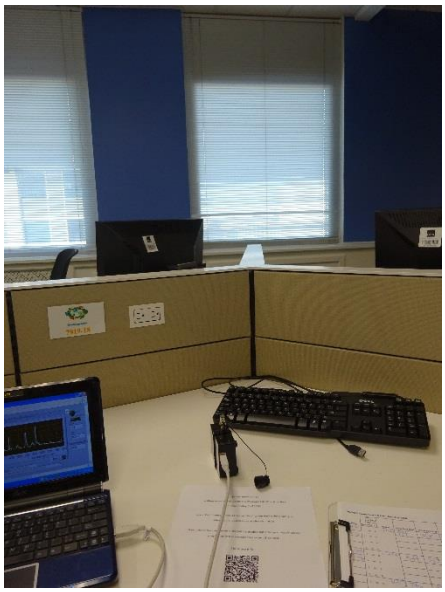


1:49 PM



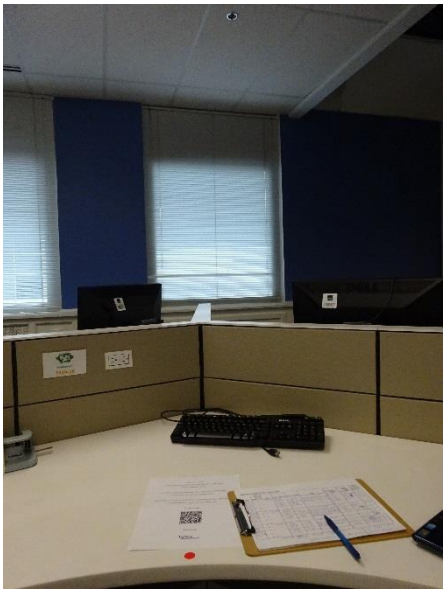
5:28 PM

Regional Office Building –Desk 7919-18

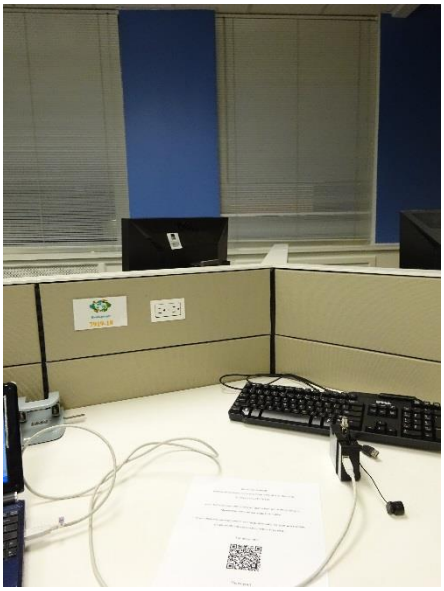


8:38 AM

11:38 AM

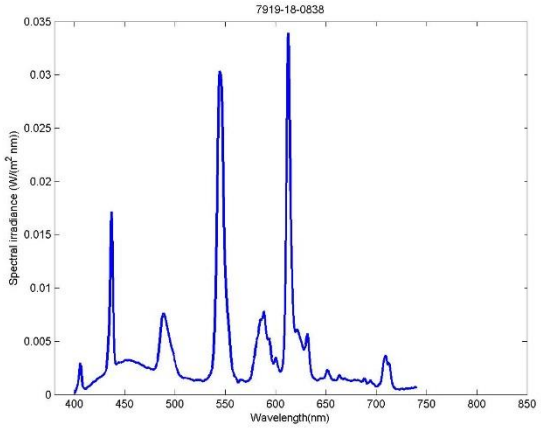


1:51 PM

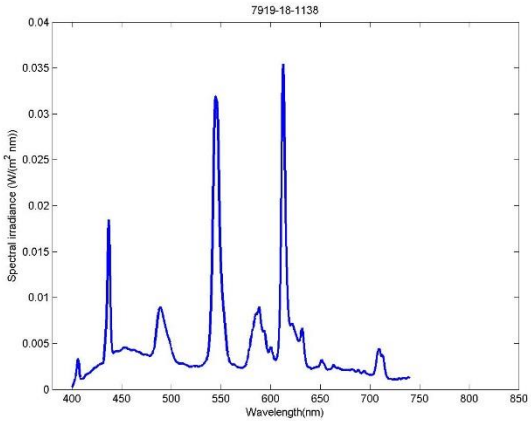


5:30 PM

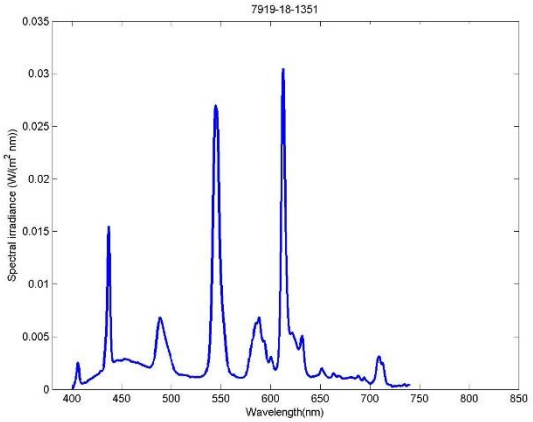
REGIONAL OFFICE BUILDING –DESK 7919-18 (SPECTRAL POWER DISTRIBUTION)



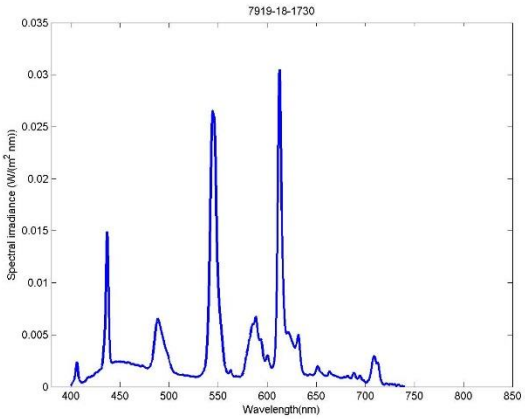
8:38 AM



11:38 AM

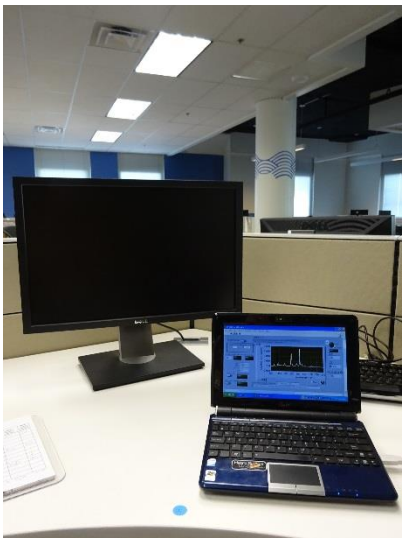


1:51 PM



5:30 PM

Regional Office Building –Desk 7919-66



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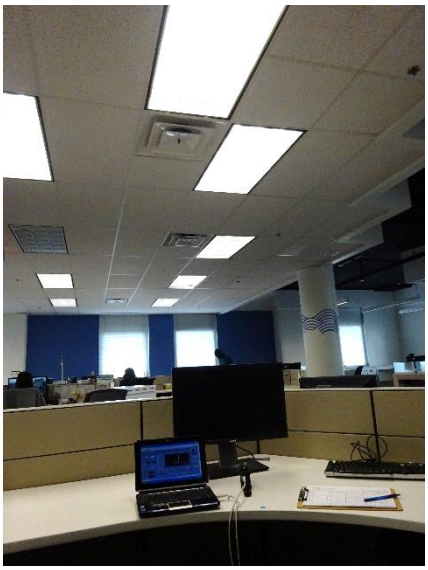

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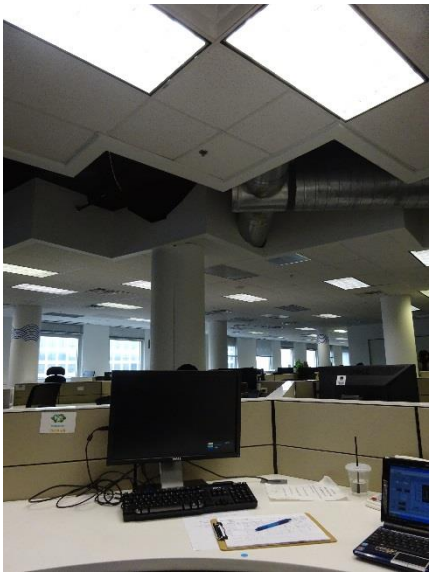

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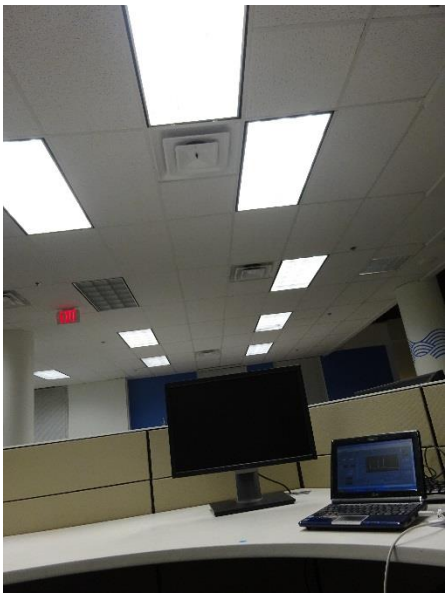

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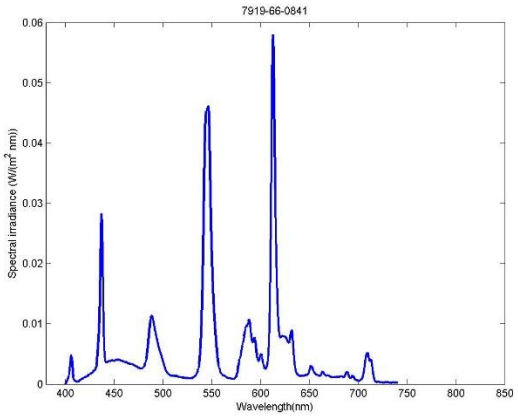
REGIONAL OFFICE BUILDING –DESK 7919-66 (SPECTRAL POWER DISTRIBUTION)



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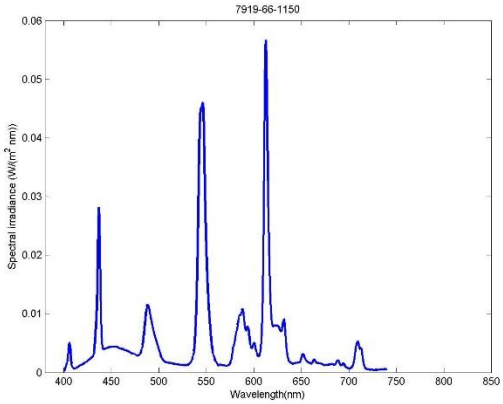

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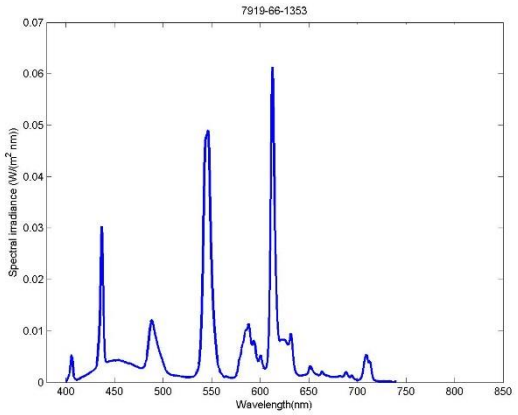

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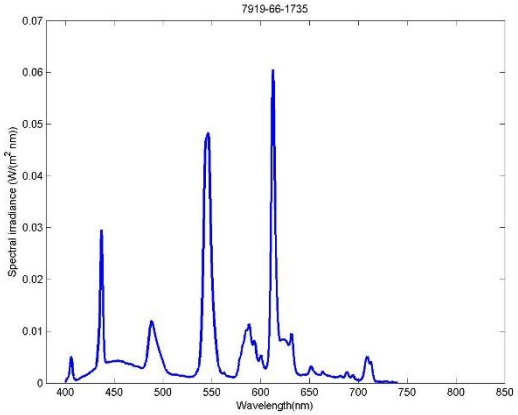
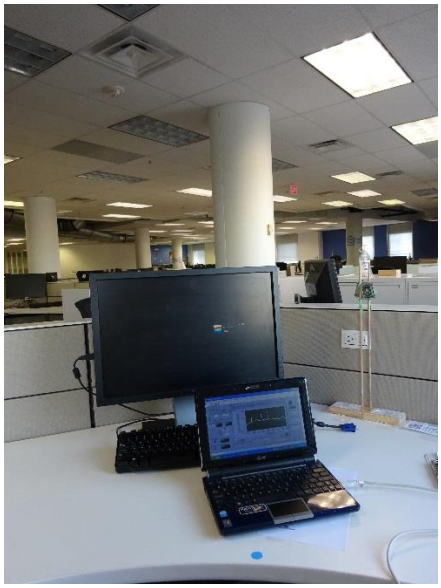


5:35 PM

REGIONAL OFFICE BUILDING –DESK 7919-35



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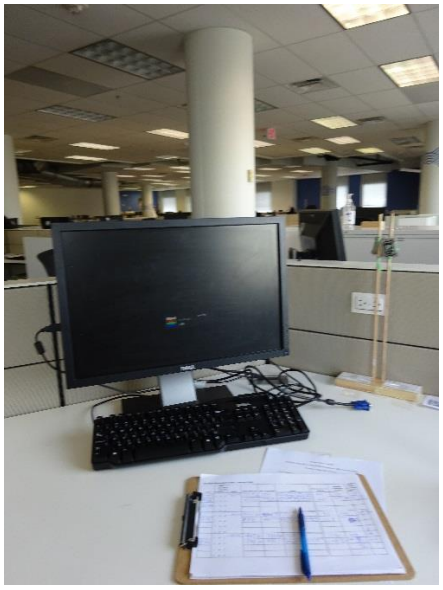

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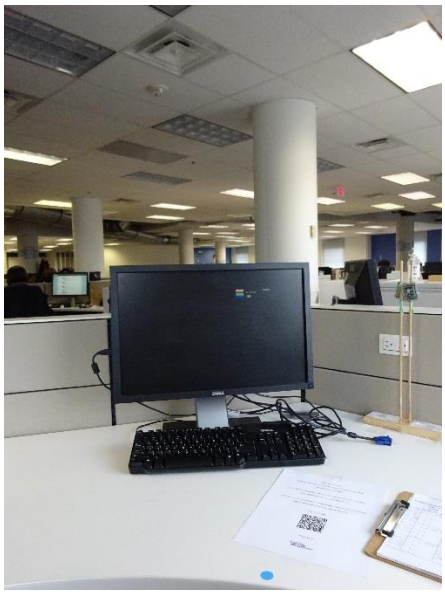
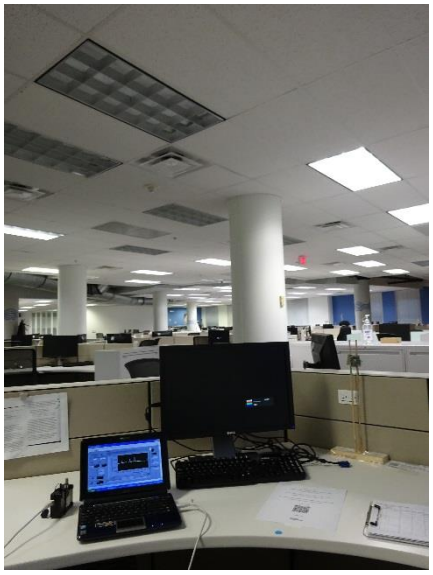
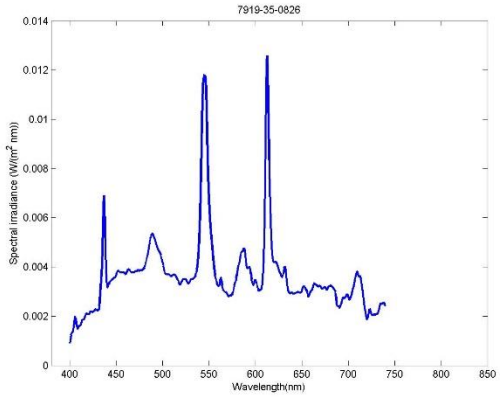


1:42 PM

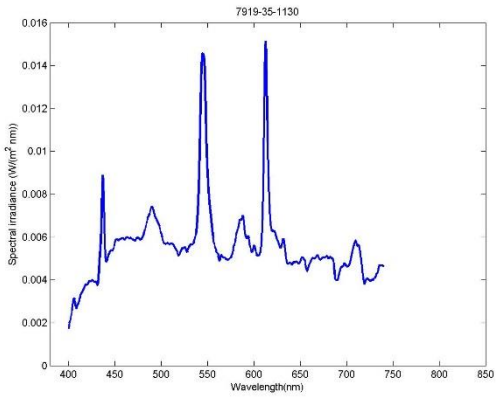


5:21 PM

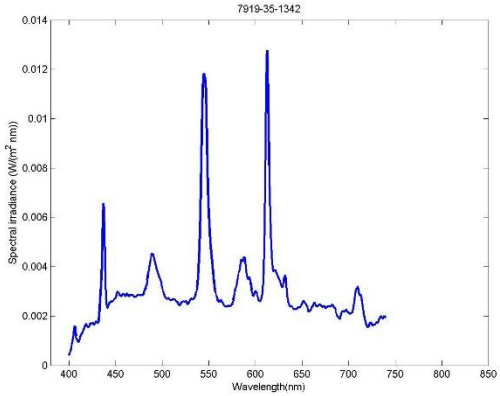
REGIONAL OFFICE BUILDING –DESK 7919-35 (SPECTRAL POWER DISTRIBUTION)



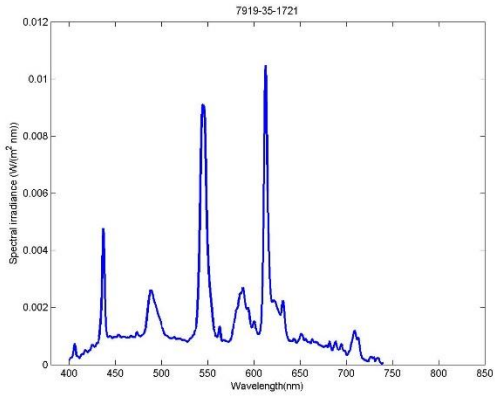
8:26 AM



11:30 AM



1:42 PM



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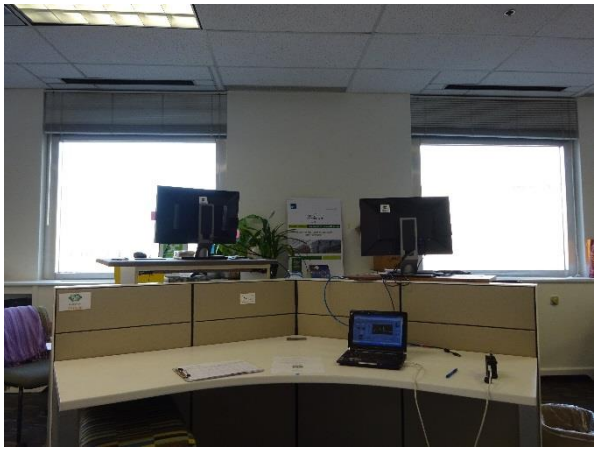
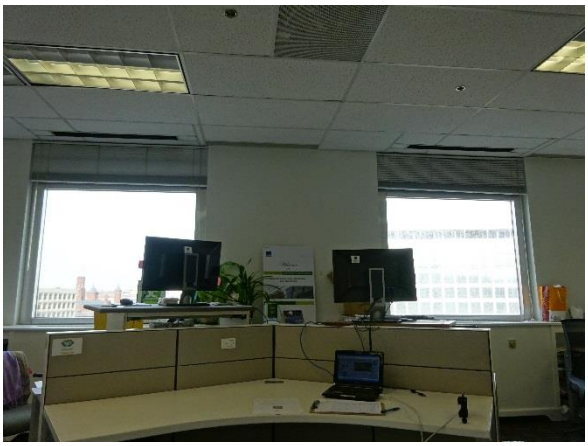
REGIONAL OFFICE BUILDING –DESK 7919-40



8:26 AM



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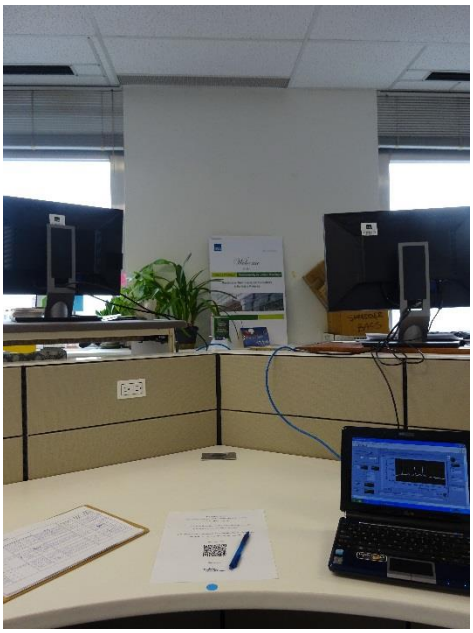
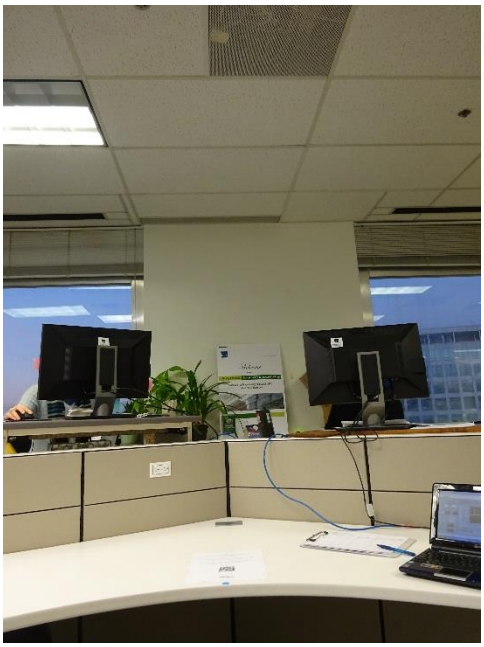


1:45 PM



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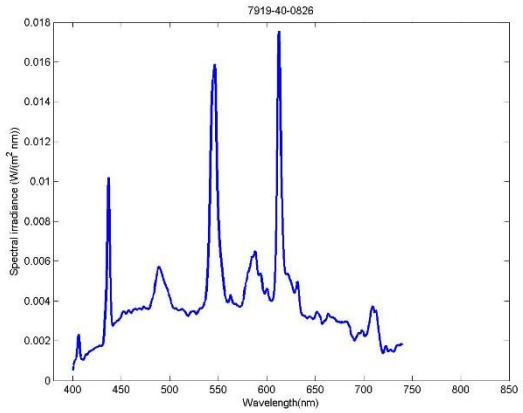
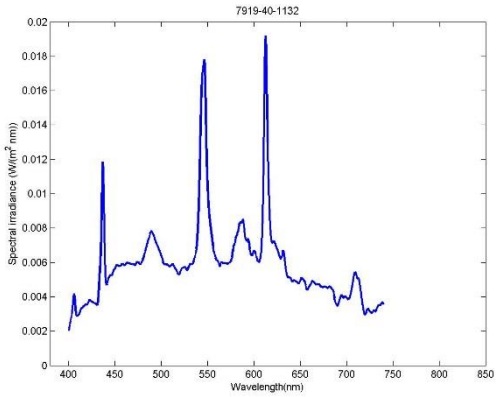
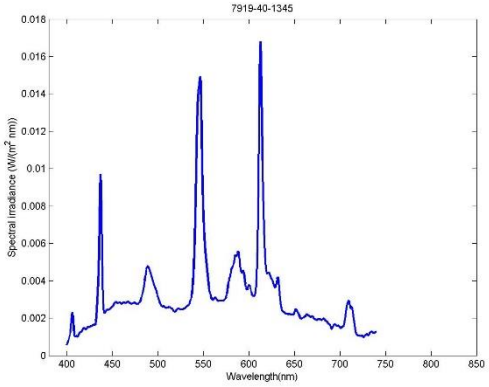
REGIONAL OFFICE BUILDING –DESK 7919-40 (SPECTRAL POWER DISTRIBUTION)



8:26 AM



11:32 PM



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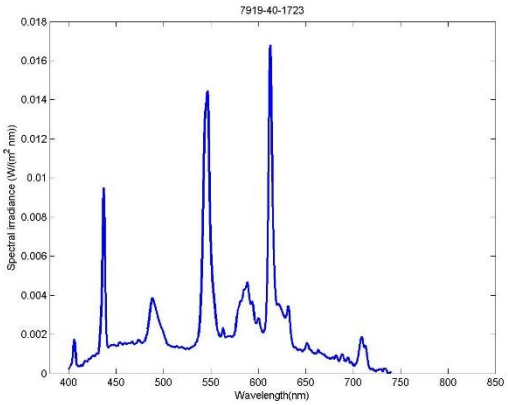

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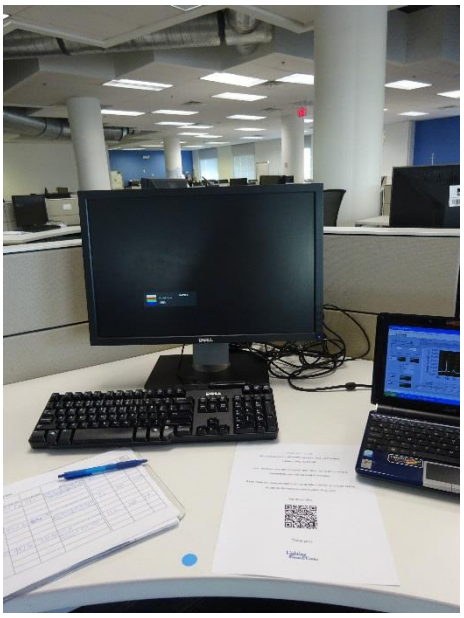
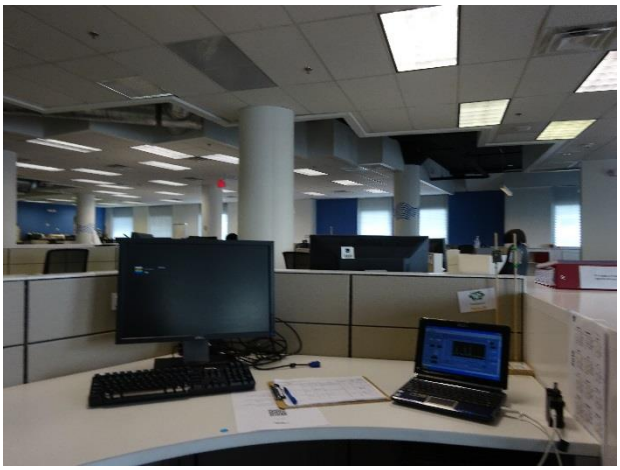
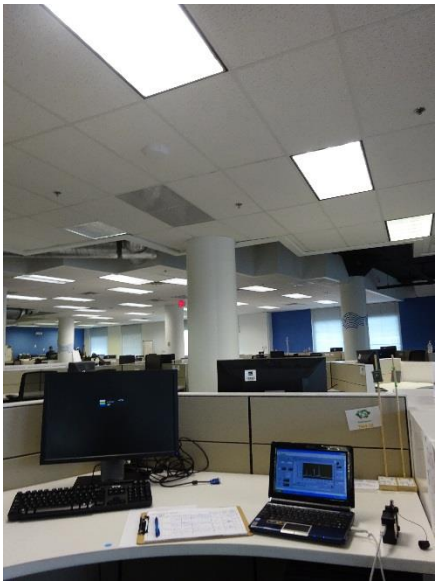
REGIONAL OFFICE BUILDING –DESK 7919-55



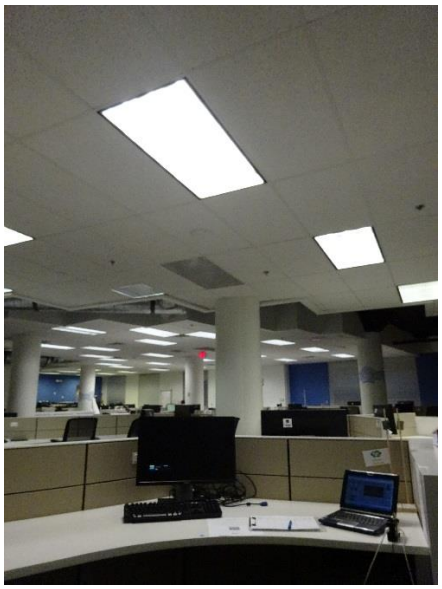
8:33 AM



11:34 AM

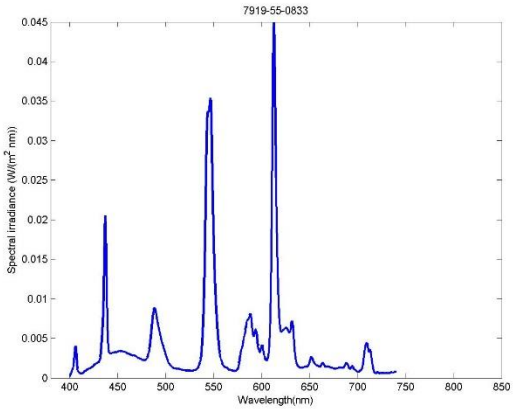


1:47 PM



5:25 PM

REGIONAL OFFICE BUILDING –DESK 7919-55 (SPECTRAL POWER DISTRIBUTION)



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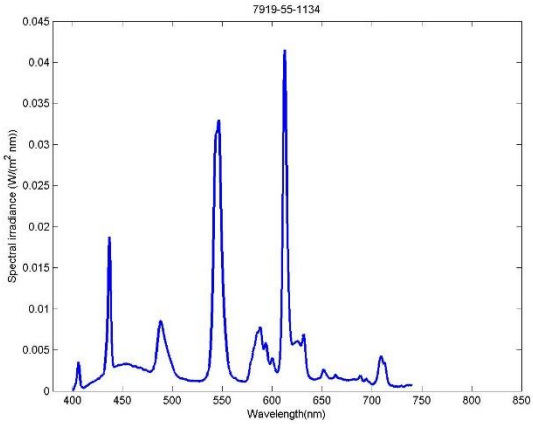

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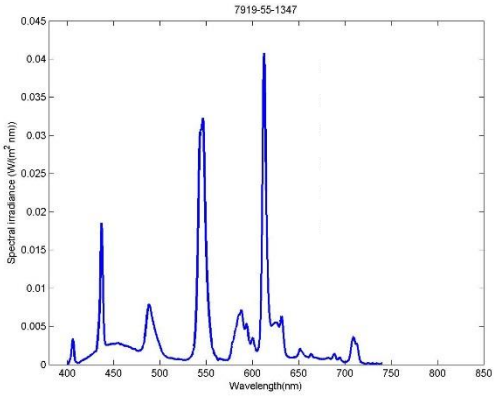

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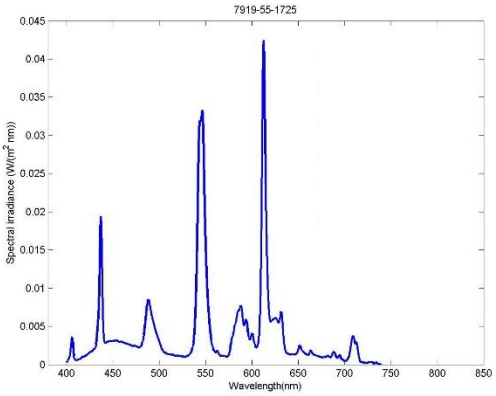
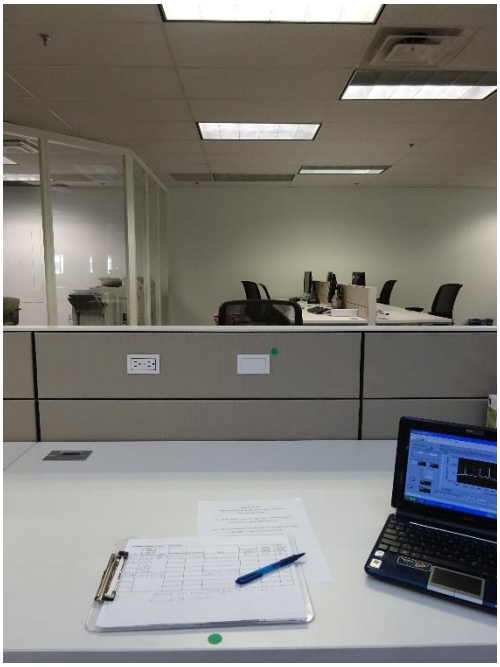
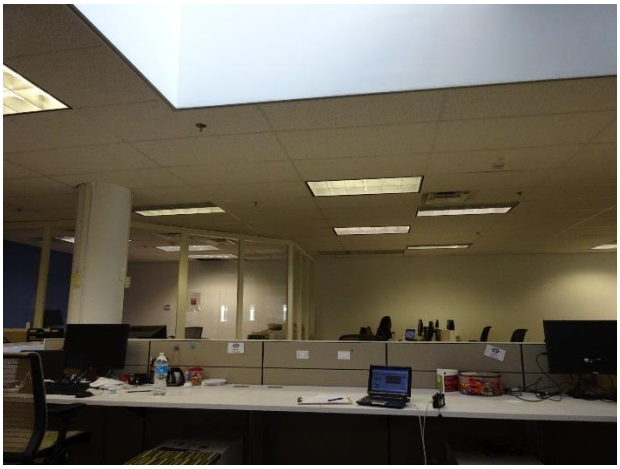


5:23 PM

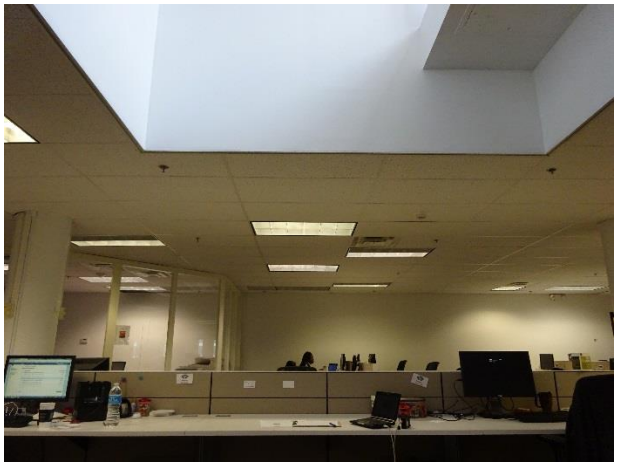
REGIONAL OFFICE BUILDING –INTERIOR DESK 7675-10-WINTER



8:48 AM



11:58 AM



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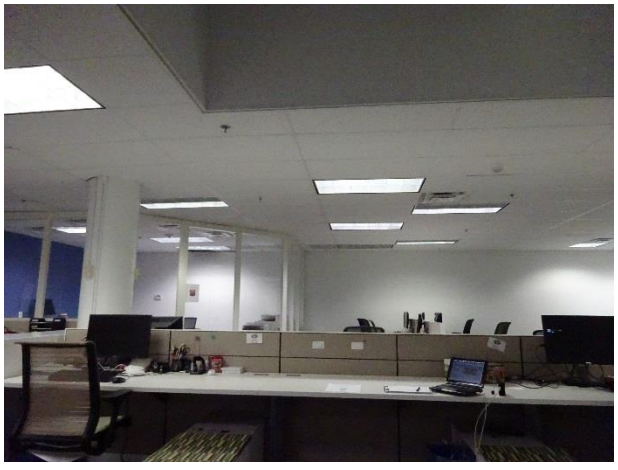
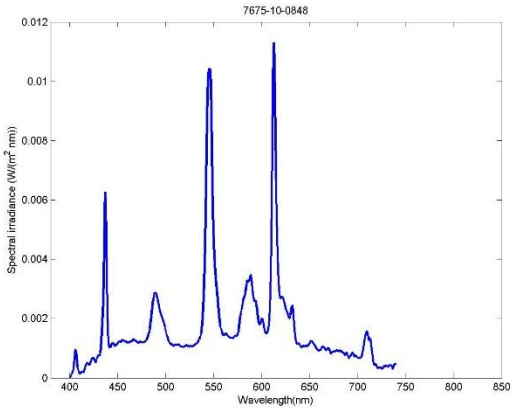


5:37 PM

REGIONAL OFFICE BUILDING –DESK 7675-10-WINTER (SPECTRAL POWER DISTRIBUTION)



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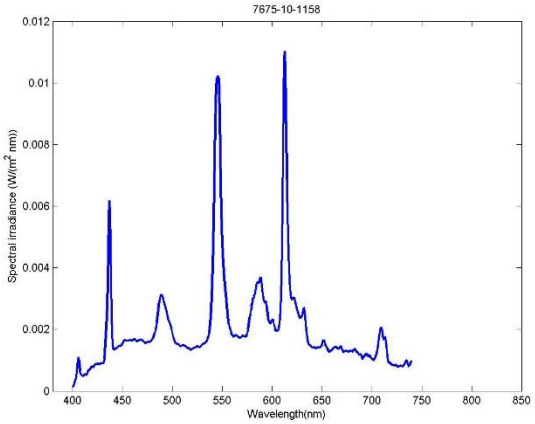

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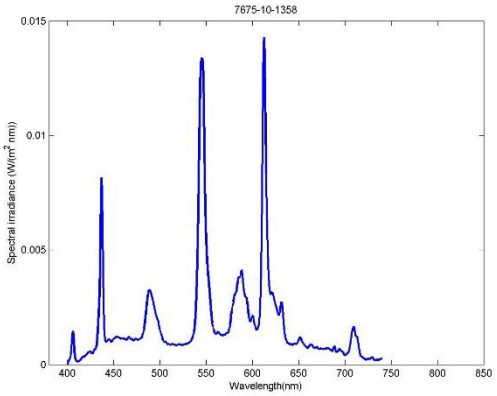
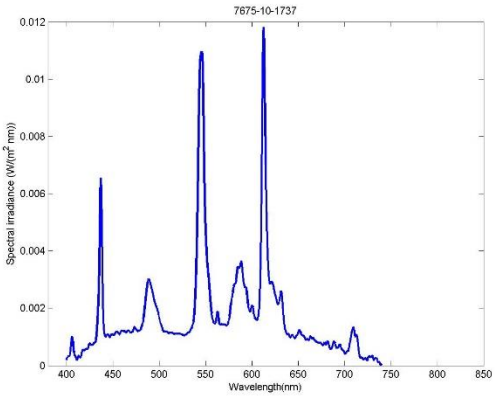


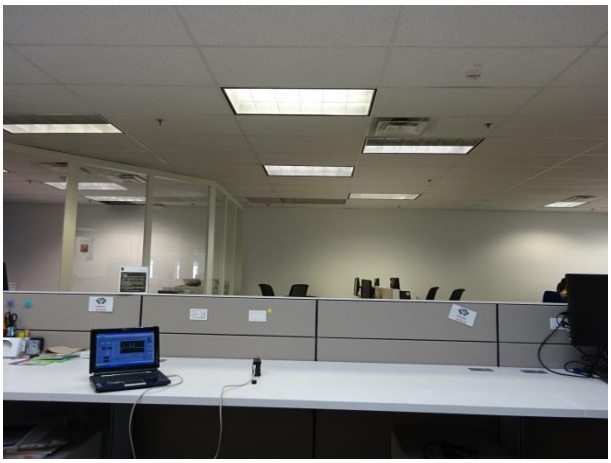
1:58 PM



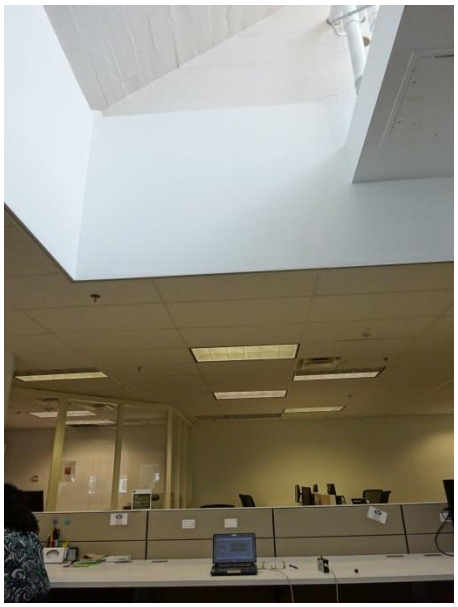
5:37 PM

The following data were inadvertently omitted from the ROB summer report, Appendix C.

REGIONAL OFFICE BUILDING –INTERIOR DESK 7675-10-SUMMER

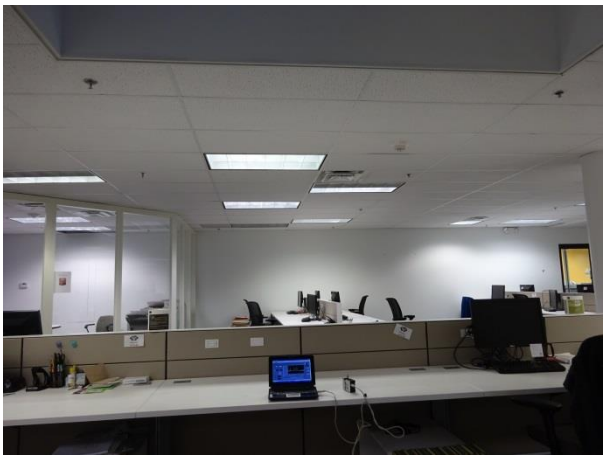


9:38 AM



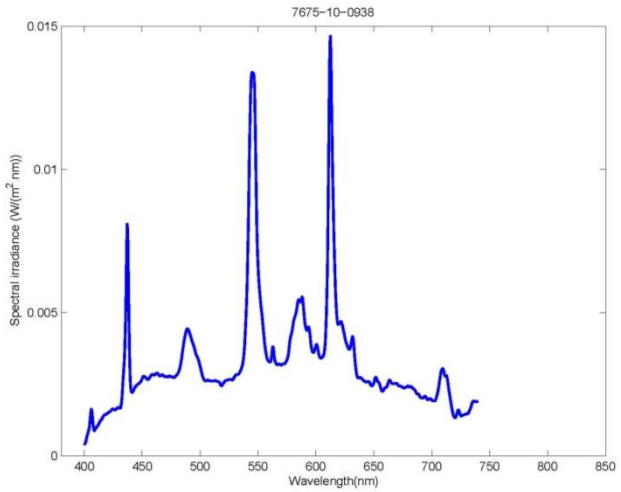
12:15 PM

4:16 PM

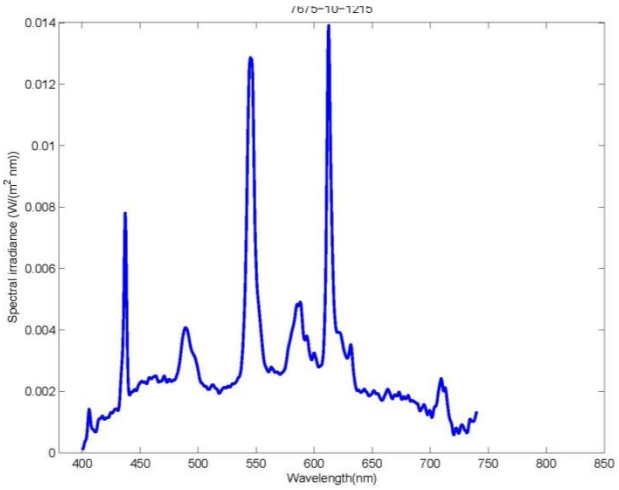


8:33 PM

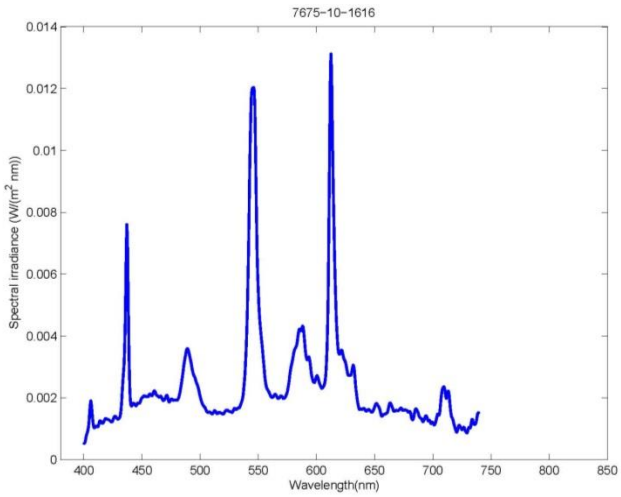
REGIONAL OFFICE BUILDING –DESK 7675-10-SUMMER (SPECTRAL POWER DISTRIBUTION)



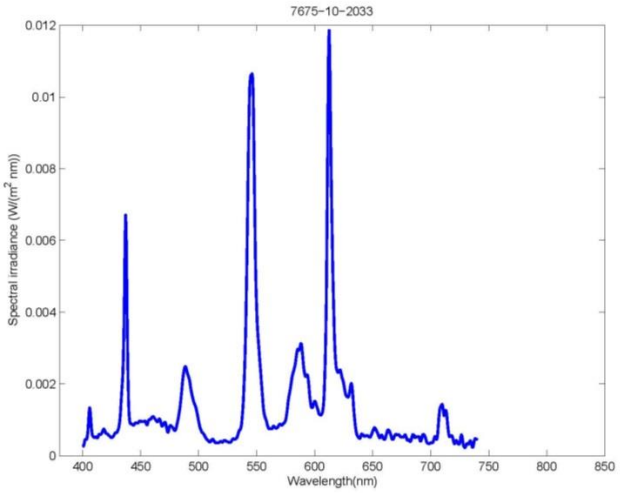
9:38 AM



12:15 PM



4:16 PM



8:33 PM

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	8:35	375	0.381	0.382	4021	224.4	0.26	599.7
7919-17	A	West	11:37	443	0.369	0.378	4319	319.8	0.33	731.3
7919-17	A	West	13:49	323	0.379	0.382	4069	196.9	0.24	518.1
7919-17	A	West	17:28	418	0.380	0.382	4039	254	0.29	670.2
7919-18	B	West	8:38	400	0.376	0.379	4148	263.7	0.29	650.3
7919-18	B	West	11:38	490	0.366	0.374	4403	380.2	0.36	820.3
7919-18	B	West	13:51	357	0.376	0.380	4141	232.5	0.27	579.9
7919-18	B	West	17:30	344	0.383	0.385	4001	200	0.24	549.3
7919-66	C	West	8:41	590	0.385	0.388	3955	319.9	0.33	926.0
7919-66	C	West	11:50	602	0.381	0.384	4030	356.4	0.35	957.2
7919-66	C	West	13:53	622	0.384	0.386	3976	349.1	0.35	981.2
7919-66	C	West	17:35	627	0.384	0.387	3990	349.3	0.35	987.9
7919-35	A	North	8:26	323	0.341	0.363	5188	336	0.34	579.9
7919-35	A	North	11:30	476	0.340	0.358	5219	528.3	0.43	866.2
7919-35	A	North	13:42	280	0.355	0.373	4732	242.7	0.28	481.6
7919-35	A	North	17:21	152	0.380	0.395	4141	83.86	0.12	242.3
7919-40	B	North	8:26	393	0.368	0.384	4408	285.4	0.31	651.2
7919-40	B	North	11:32	544	0.353	0.368	4789	513.9	0.42	951.4
7919-40	B	North	13:45	326	0.370	0.382	4321	231.1	0.27	539.4
7919-40	B	North	17:23	253	0.388	0.396	3941	125.9	0.17	395.3
7919-55	C	North	8:33	468	0.384	0.386	3966	259.8	0.29	738.3
7919-55	C	North	11:34	454	0.383	0.388	4027	253.9	0.29	717.3
7919-55	C	North	13:47	410	0.387	0.390	3933	210.4	0.25	639.6
7919-55	C	North	17:25	451	0.384	0.388	3995	247.3	0.28	711.1
7675-10	Skylight	Skylight	8:48	186	0.384	0.397	4050	95.88	0.13	292.5
7675-10	Skylight	Skylight	11:58	208	0.377	0.388	4174	128.6	0.17	336.0
7675-10	Skylight	Skylight	13:58	208	0.392	0.403	3896	88.86	0.12	319.0
7675-10	Skylight	Skylight	17:37	194	0.386	0.401	4018	94.16	0.13	303.5

AVERAGE SPECTRORADIOMETRY RESULTS

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

Winter			**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**	**Average CS**	**Median CS**	**Bright-ness**
A	2	3	370	0.36	0.37	4591	308	281	0.31	0.30	272
B	2	3	418	0.37	0.38	4368	318	275	0.32	0.30	298
C	2	3	524	0.38	0.39	3981	292	290	0.31	0.31	347
Skylight	1	3	201	0.38	0.40	4040	104	96	0.14	0.39	129
Orientations											
W	3	3	467	0.38	0.38	4118	294	320	0.31	0.33	319
N	3	3	408	0.36	0.38	4509	318	260	0.32	0.29	293
Skylight	1	3	201	0.38	0.40	4040	104	96	0.14	0.13	129

Summer 2015			**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**	**Average CS**	**Median CS**	**Bright-ness**
A	2	3	529	0.37	0.38	4247	370	362	0.35	0.35	369
B	2	3	595	0.37	0.38	4358	456	437	0.39	0.39	425
C	2	3	629	0.38	0.38	4062	380	411	0.36	0.38	425
Skylight	1	3	281	0.37	0.38	4263	192	187	0.23	0.55	194
Interior	1	3	476	0.39	0.40	3861	311	242	0.31	0.28	295
Orientations											
W	3	3	553	0.38	0.38	4165	361	342	0.35	0.34	381
N	3	3	616	0.37	0.38	4279	443	442	0.38	0.39	431
Skylight	1	3	281	0.37	0.38	4263	192	187	0.23	0.23	194
Interior	1	3	476	0.39	0.40	3861	311	242	0.31	0.28	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).

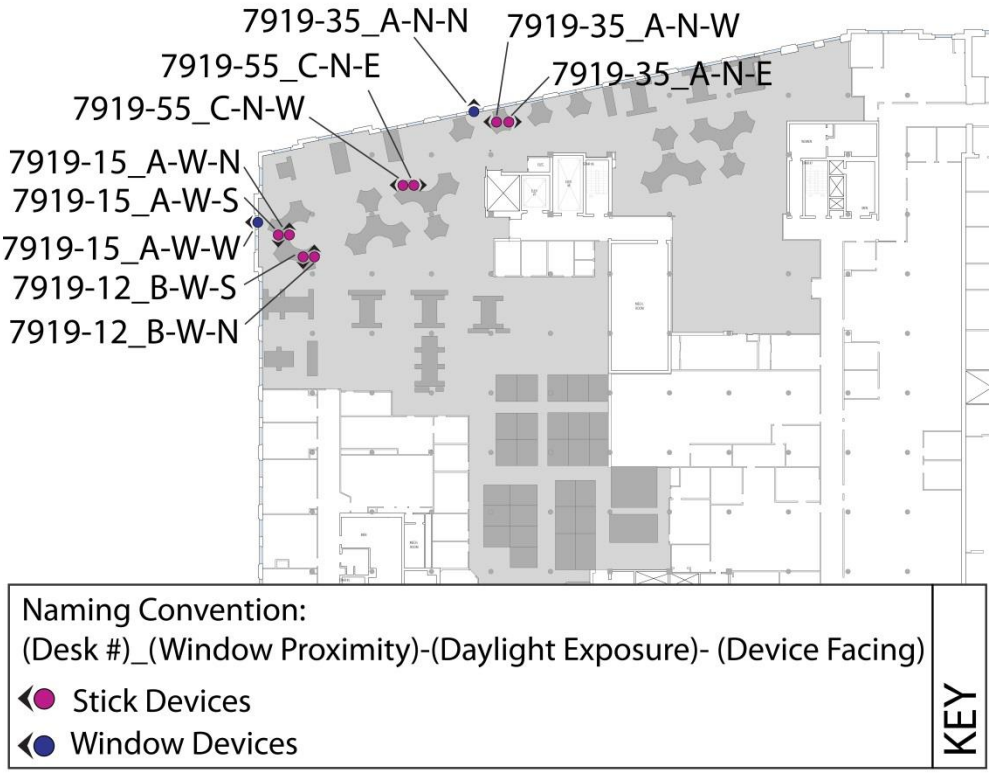
The spatial uncertainty depends greatly on the spatial distribution of light for each measurement; for light of normal incidence the error is near zero, but the error increases significantly, always underreporting the illuminance, for light incident at large angles. An estimate of the spatial uncertainty 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

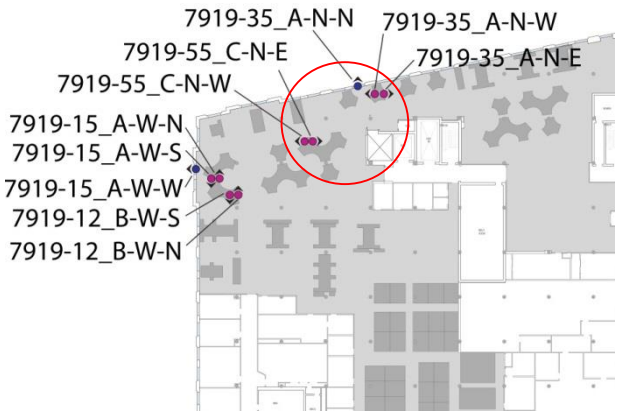
CROPPED TO JANUARY 15, 2016 – FEBRUARY 14, 2016

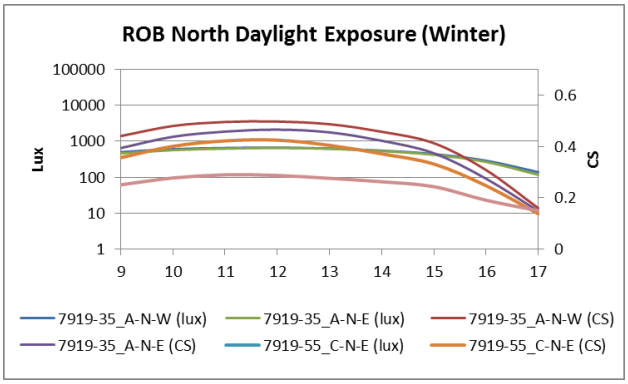
(EXCLUDING MLK AND PRESIDENTS' DAY HOLIDAYS)



Locations where measurements were collected.

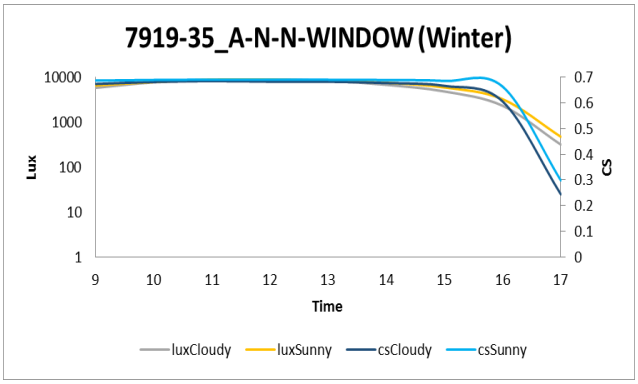
7TH FLOOR NORTH DAYLIGHT EXPOSURE





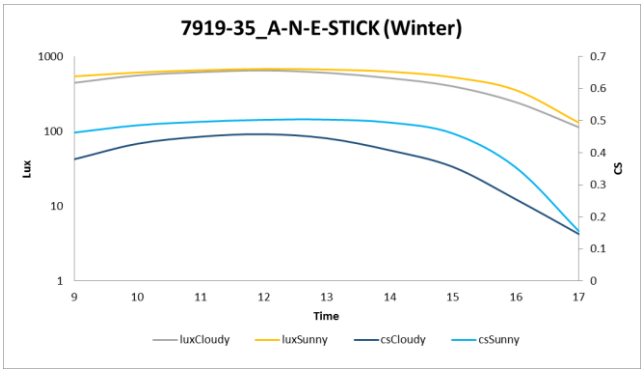
Average Lux and CS – North Side - Winter

7919-35_A-N-N-WINDOW

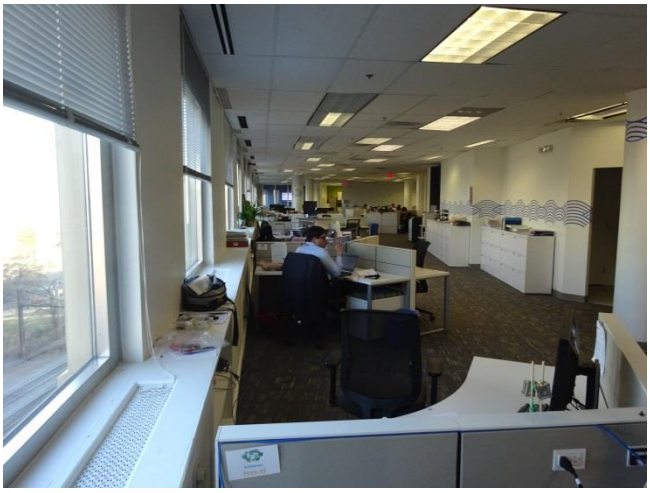


Daysimeter 263: 7919-35_A-N-N-WINDOW. Mean photopic light level during working hours (08:00 am to 05:00 pm) was 5914 ± 2953 lux on cloudy days. The mean CS value was 0.62 ± 0.14 on cloudy days. On sunny days mean photopic light level during working hours was 6380 ± 2824 lux. The mean CS value on was 0.64 ± 0.13 on sunny days.

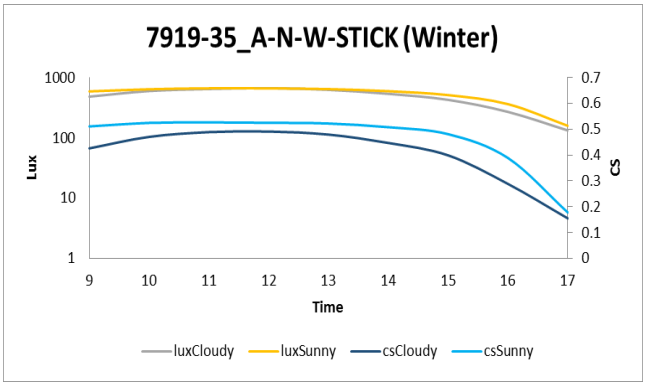
7919-35_A-N-E-STICK



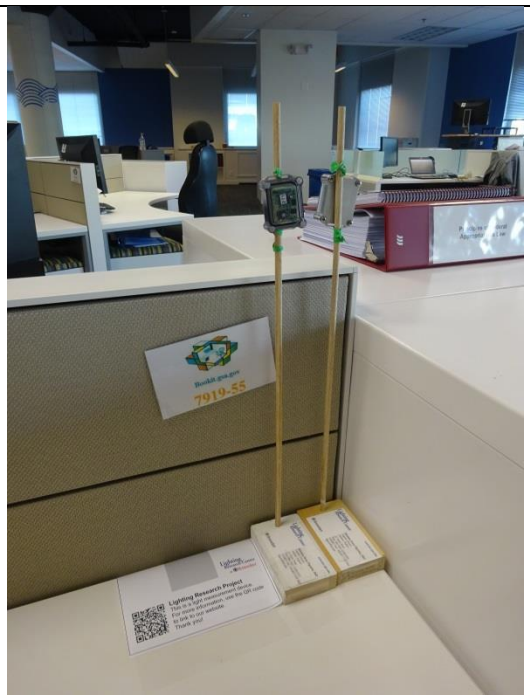
Daysimeter 268 – 7919-35_A-N-E-STICK. Mean photopic light level during working hours (08:00 am to 05:00 pm) was 462 ± 182 lux on cloudy days. The mean CS value on was 0.37 ± 0.10 on cloudy days. On sunny days mean photopic light level during working hours was 534 ± 182 lux. The mean CS value on was 0.44 ± 0.11 on sunny days.



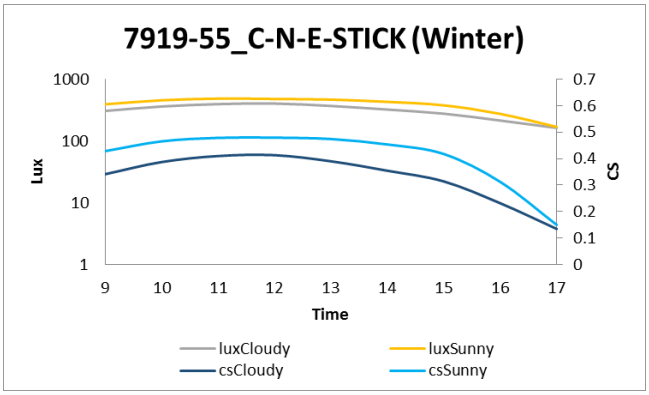
7919-35_A-N-W-STICK



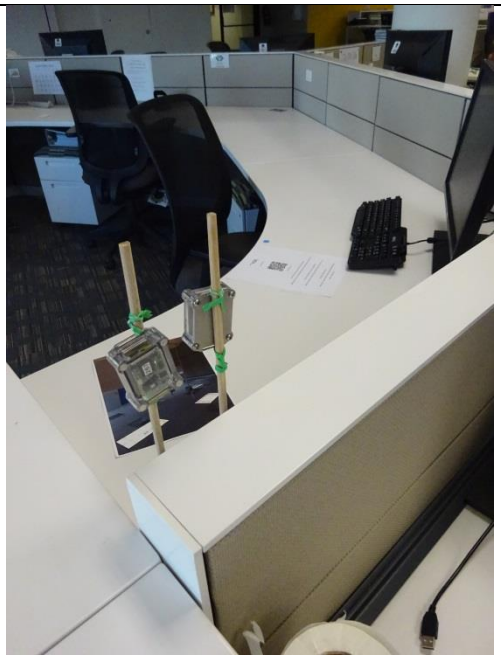
Daysimeter 269 – 7919-35_A-N-W-STICK. Mean photopic light level during working hours (08:00 am to 05:00 pm) was 488 ± 183 lux on cloudy days. The mean CS value on was 0.41 ± 0.11 on cloudy days. On sunny days mean photopic light level during working hours was 536 ± 171 lux. The mean CS value on was 0.46 ± 0.12 on sunny days.



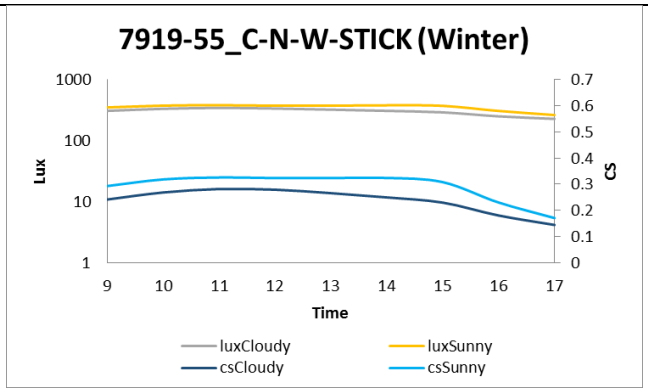
7919-55_C-N-E-STICK



Daysimeter 271 – 7919-55_C-N-E-STICK. Mean photopic light level during working hours (08:00 am to 05:00 pm) was 314 ± 83 lux on cloudy days. The mean CS value on was 0.33 ± 0.09 on cloudy days. On sunny days mean photopic light level during working hours was 394 ± 107 lux. The mean CS value on was 0.41 ± 0.11 on sunny days.

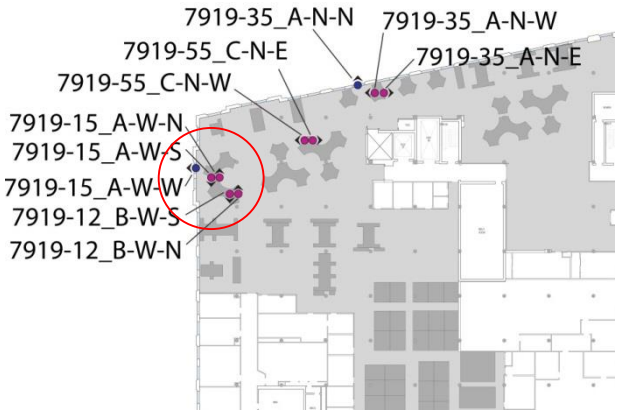


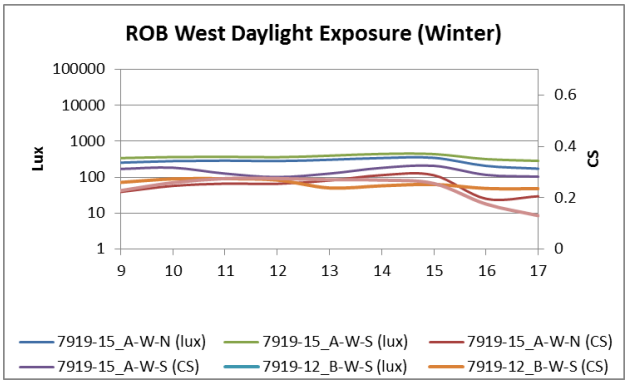
7919-55_C-N-W-STICK



Daysimeter 267 – 7919-55_C-N-W-STICK. Mean photopic light level during working hours (08:00 am to 05:00 pm) was 302 ± 40 lux on cloudy days. The mean CS value on was 0.24 ± 0.05 on cloudy days. On sunny days mean photopic light level during working hours was 352 ± 41 lux. The mean CS value on was 0.29 ± 0.05 on sunny days.

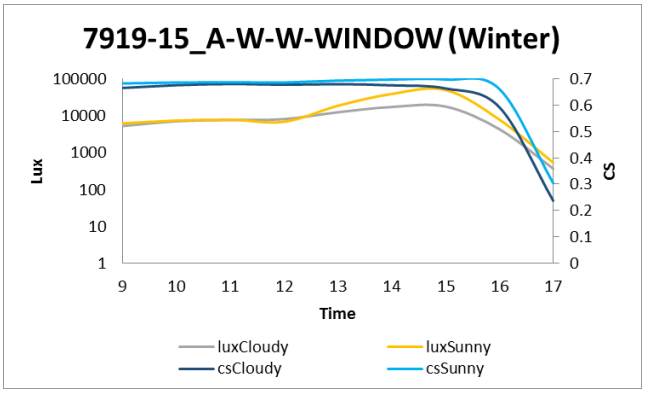
7TH FLOOR WEST DAYLIGHT EXPOSURE



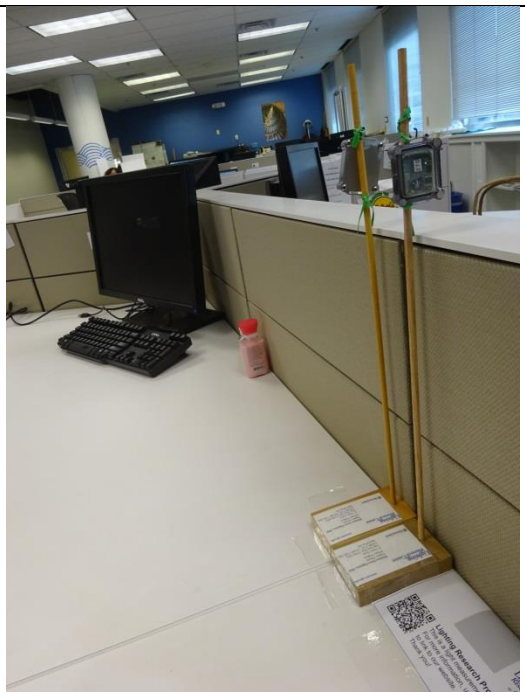


Average Lux and CS – West Side - Winter

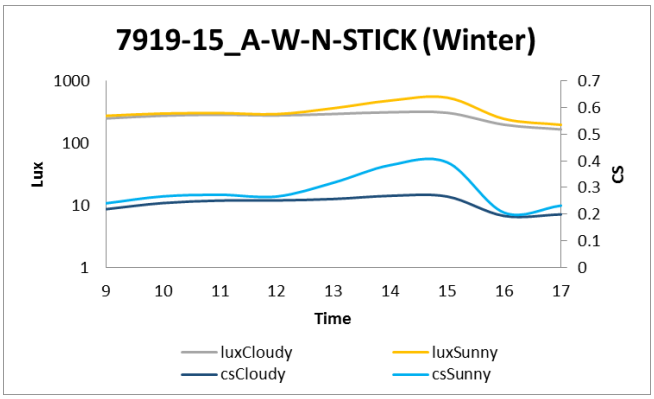
7919-15_A-W-W-WINDOW



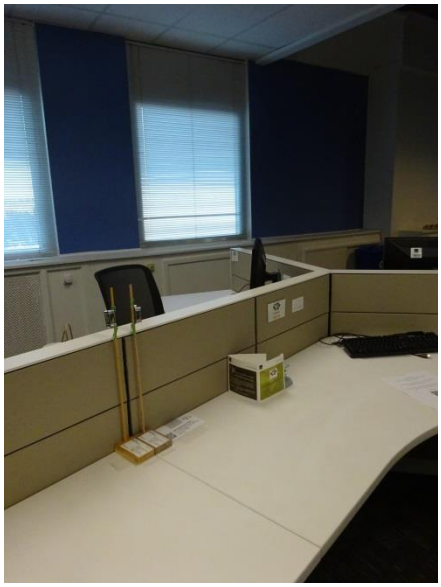
Daysimeter 262 – 7919-15_A-W-W-WINDOW. Mean photopic light level during working hours (08:00 am to 05:00 pm) was 8954 ± 5884 lux on cloudy days. The mean CS value on was 0.62 ± 0.15 on cloudy days. On sunny days mean photopic light level during working hours was 16100 ± 17105 lux. The mean CS value on was 0.64 ± 0.13 on sunny days.



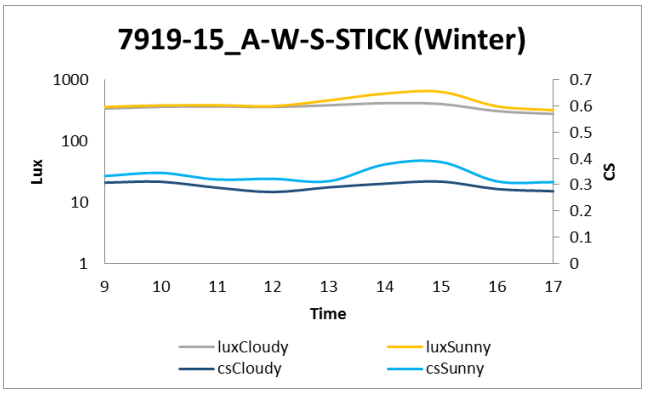
7919-15_A-W-N-STICK



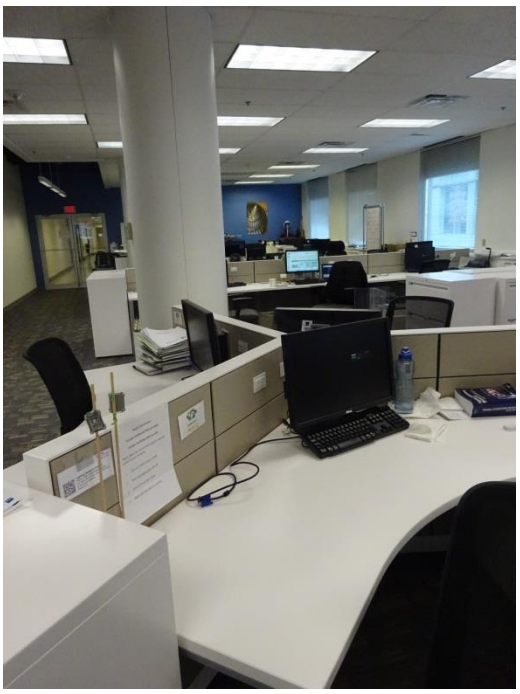
Daysimeter 270 – 7919-15_A-W-N-STICK. Mean photopic light level during working hours (08:00 am to 05:00 pm) was 263 ± 50 lux on cloudy days. The mean CS value on was 0.24 ± 0.03 on cloudy days. On sunny days mean photopic light level during working hours was 333 ± 111 lux. The mean CS value on was 0.29 ± 0.07 on sunny days.



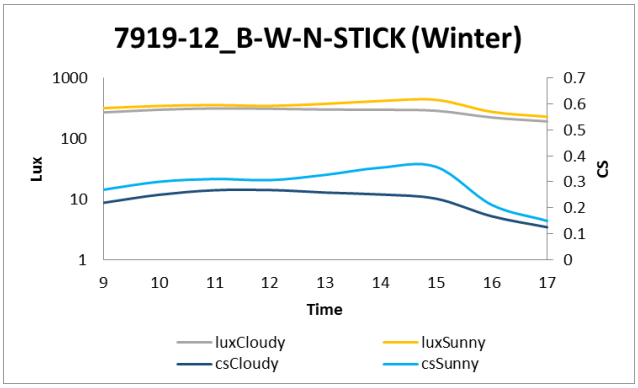
7919-15_A-W-S-STICK



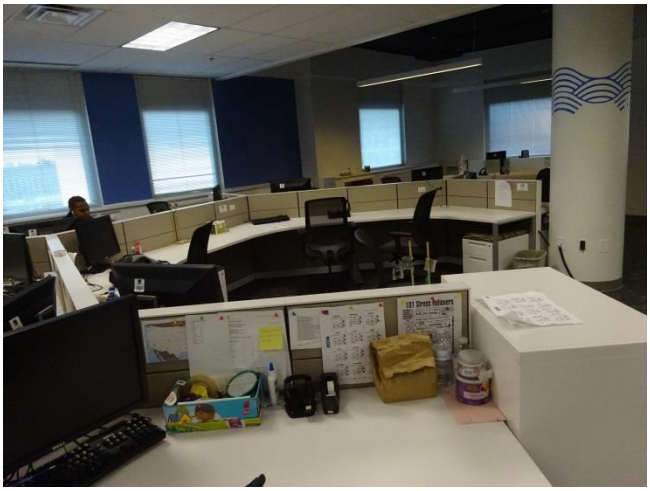
Daysimeter 266 – 7919-15_A-W-S-STICK. Mean photopic light level during working hours (08:00 am to 05:00 pm) was 356 ± 44 lux on cloudy days. The mean CS value on was 0.29 ± 0.02 on cloudy days. On sunny days mean photopic light level during working hours was 430 ± 111 lux. The mean CS value on was 0.34 ± 0.03 on sunny days.



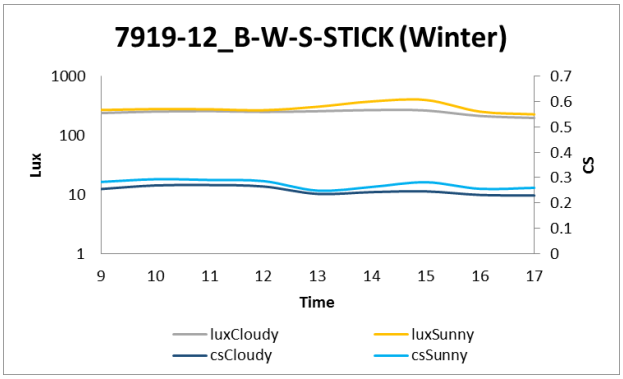
7919-12_B-W-N-STICK



Daysimeter 264 – 7919-12_B-W-N-STICK. Mean photopic light level during working hours (08:00 am to 05:00 pm) was 278 ± 42 lux on cloudy days. The mean CS value on was 0.23 ± 0.05 on cloudy days. On sunny days mean photopic light level during working hours was 344 ± 65 lux. The mean CS value on was 0.29 ± 0.07 on sunny days.



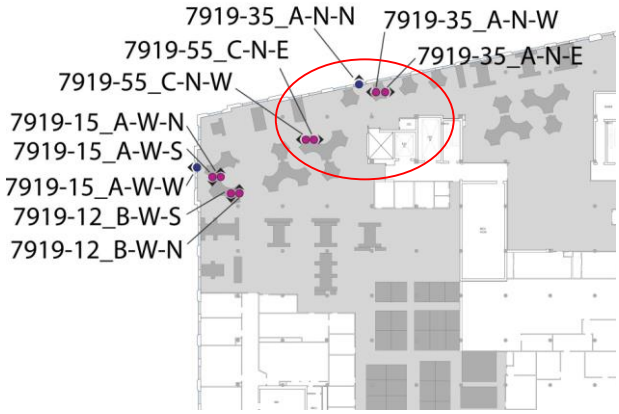
7919-12_B-W-S-STICK



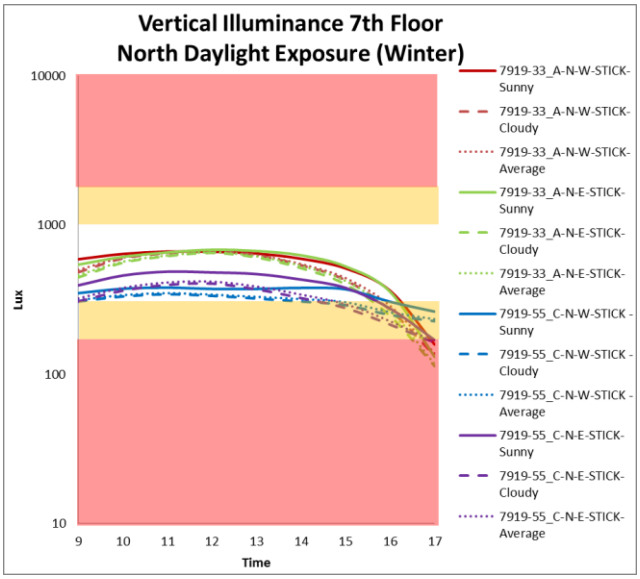
Daysimeter 265 – 7919-12_B-W-S-STICK. Mean photopic light level during working hours (08:00 am to 05:00 pm) was 244 ± 24 lux on cloudy days. The mean CS value on was 0.25 ± 0.02 on cloudy days. On sunny days mean photopic light level during working hours was 294 ± 56 lux. The mean CS value on was 0.27 ± 0.02 on sunny days.

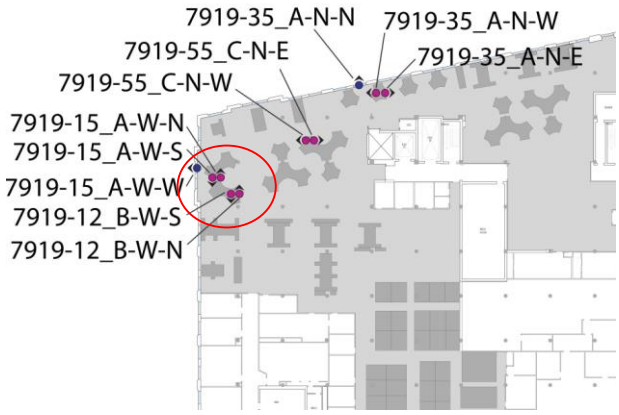
APPENDIX F: VERTICAL ILLUMINANCE FOR STICK DEVICES

ROB 7TH FLOOR



7th Floor North Daylight Exposure





7th Floor West Daylight Exposure