

Advanced High-Resolution Controls for Dimmable LED Lighting in Offices

Specification & Procurement Support Materials



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Overview

This package of materials is intended to guide you through the specification, procurement, and selection of luminaires and lighting control systems for retrofit applications in office spaces (or spaces with similar uses) with daylight through vertical windows. The specification targets advanced lighting control systems where the resolution of control is highly granular (e.g., on a fixture-by-fixture basis) and the type of control involves dimming the lighting system for daylighting, setpoint tuning and demand response, as well as incorporating conventional occupancy sensing and scheduling functions, plus provision for manual control (manual override).

This package includes two sections:

1. A **Request for Proposals (RFP) Template** that can be filled out to create a project-specific RFP for luminaire and lighting control system vendors.
2. A **Technology Specification Template** that can be tailored to generate owner-driven requirements for technology features and capabilities, metering and integration, maintenance support, and more. The tailored specification should be included in the Scope of Work in Section 3 of the RFP.

Scope of materials

These technology specifications and associated materials were developed primarily to address lighting retrofit projects incorporating LED luminaires and advanced lighting control systems.

Assumptions defining the scope of materials

These documents and the processes they outline assume that an owner or specifier has little expertise in the design, specification, selection, procurement and installation of energy-efficient luminaires for office areas, as well as advanced lighting control systems. Therefore, one assumption is that an owner will hire project team members as required in order to effectively and efficiently complete this process. See Appendix D for a list of typical project team members and their respective tasks. Depending on the project size, an owner may consolidate some of these tasks in order to reduce the number of people required on the project team. For example, an owner may ask a licensed electrical engineer to perform tasks that might otherwise be done by an independent lighting designer on a much larger project.

Another assumption is that for cost effective retrofit applications, a lighting control system will only be deployed if an owner also retrofits or replaces existing fluorescent luminaires with LED luminaires or retrofit kits. Given the cost and complexity of “weaving in” new control components and control wiring to existing fluorescent luminaires, it’s unlikely that an owner would choose to deploy a lighting control system without also upgrading or changing the fixtures in the process. However, most of the specification language contained herein is applicable to fluorescent luminaires as well as new LED luminaires or retrofit kits. Because there are a variety of factors affecting the purchase and installation of lighting control systems, it’s possible that under certain circumstances it may be as cost effective and efficient to retrofit existing fluorescent luminaires instead of replacing them with new LED luminaires.

Similarly, these materials were developed with an emphasis on issues affecting “retrofit” projects. However, most of the specification language contained herein is equally applicable to

new construction, gut rehab (tenant fit-out) or retrofit projects. One important consideration that may govern some of the choices affecting equipment, methods of installation or staging of the work is whether or not the space is “occupied”. For example, it may be considerably more efficient and less intrusive to use luminaires with all required controls components factory-installed if the space is occupied. If the project is new construction, gut rehab or tenant fit-out, this may not be a critical factor.

Typically, advanced lighting control systems are installed with “maximum granularity”. As described in the technology specifications, this means that every luminaire is individually addressable. Depending on the granularity of occupancy sensors and photosensors deployed, using a system with individually addressable luminaires is generally preferred. Not only does it allow unrestricted rezoning based on future changes to the space, but it is also expected to provide the highest degree of energy efficiency as well as maximize comfort for occupants.

The technology specifications contain language addressing both wired and wireless transmission of control signals. Similarly, the language contained herein is protocol-agnostic. This means that a variety of commonly used protocols would satisfy the requirements described in the specification language. Over time, lighting controls manufacturers continue to explore different protocols (such as IP and others), different methods of signal transmission, different topologies and other methods of configuring their systems. These documents are not meant to serve as a survey or summary of these variables, ranked by popularity or by usage in the market (for example). Rather, they are meant to guide the user and to serve as a reminder of the various options that affect the selection of equipment for a specific project.

Lastly, these materials were created based on the assumption that the owner and project team would develop specifications for luminaires and a lighting control system irrespective of who would ultimately install them. It’s possible that an owner might decide to solicit proposals only for “turnkey” solutions, in which vendors would provide the equipment as well as the labor for the installation work. Depending on the locale, existing relationships or standing agreements with electrical contractors, this may or may not be possible. Requesting proposals for “turnkey” solutions may also limit the range of equipment for consideration by the owner. Therefore, the approach suggested in this document is to issue an RFP for the equipment (Section 1), evaluate the proposals from prospective vendors, then solicit bids from potential electrical contractors. Appendix D shows typical tasks for each project team member. This may be used as a basis for soliciting bids from electrical contractors.

How these materials were developed

The specification was developed using subject matter expertise combined with experience gained from actual installations.

How to use these materials

- This document describes a range of desired performance criteria. Where more than one possibility is listed in the specifications, interpret these as follows, then select the choice that best suits your needs and delete the others:
 - **Options** represent different methods to achieve the result. There is no predetermination about which option may result in the easiest installation, lowest cost, best quality, etc.

- **Tiers** also represent different methods to achieve the result. However, higher-level tiers (e.g., Tier 3 is higher than Tier 2) indicate preferred options based on increased performance, easier installation, lower cost or possibly other factors. Keep in mind that in some situations, it's possible that higher-tier choices may also result in increased cost and/or complexity of installation (or they may not). The specifier and owner must weigh all of the factors when choosing which options they want for a specific project.
- Content that can be directly copied-and-pasted or transferred into your tailored document is shown in plain (black) text.
- Instructions and content that you should customize, fill in, or supply yourself are shown in *[blue text and in brackets and italics]*.
- Descriptive text appearing below a specific item that explains that part of the specification in greater detail is shown in green (and should be deleted in the final version of your tailored document). Note that this document contains both a version with descriptive text to aid in understanding each section and in Appendix B a “clean” version of the specifications (without descriptive text). It may be easier to use the “clean” version as the basis for your own project, then modify as necessary, and refer to the version with descriptive text to learn more about particular issues.
- Any content that is not relevant to your organization or project can be deleted, and additional content can be added.
- Definition of roles:
 - The word “Owner” refers to the name of the organization soliciting proposals and procuring the equipment.
 - The word “Proposal” refers to the response of a person, company, or corporation proposing to provide the technology and/or services sought in the RFP.
 - The word “Proposer” means the person, company, or corporation that submits the RFP.
- These are not legally binding documents, and they do not serve as contracts. Legal and executive reviews are recommended to ensure that appropriate language is included in the documents that you create.

Section 1: Request for Proposals (RFP) Template

This section of the package contains a template to guide your creation of a request for proposal (RFP) for office lighting luminaires and lighting control systems. By editing and filling in the template, you will produce a draft RFP for your organization's lighting retrofit implementation effort.

Request for Proposals

Project: *[Title of project in which the luminaires and lighting control system will be deployed]*
To: Prospective vendors
From: *[Point of contact for owner]*
Date of Issue: *[Date]*

Request for Proposals

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1. Introduction

1.1 Purpose

[Include a brief description of the purpose of this RFP, as follows.]

[Name of organization] is soliciting proposals for qualified companies to provide luminaires as well as a lighting control system. You are invited to submit a proposal in accordance with this Request for Proposals (RFP).

1.2 Background

[Include a description of the project with background information, including but not limited to the following elements:]

Project scope: *[Describe the number of sites and floor area included in the scope of the retrofit. If there is any possibility that the deployment of the lighting control system may be expanded in the future, indicate that here, including specific information about possible additional areas or floors that may be addressed.]*

Project objectives: *[Describe the goals of the project. For example, you might specify that the technology selected as a result of this RFP will be expected to:]*

- *Take advantage of (or increase the use of) daylight harvesting control strategies.*
- *Provide public energy dashboards to inform and educate occupants and visitors.*
- *Incorporate enhanced control strategies (such as manual overrides, local dimming, etc.).*
- *Implement Auto Demand Response strategies for electric lighting.*
- *Reduce lighting energy use by __%.*
- *Benefit from all available financial incentives to reduce purchase and installation costs.*
- *Track the impact of the lighting retrofit project, and measure and verify utility cost savings.*
- *Track and manage peak demand associated with lighting energy use.*
- *Report reduction in lighting energy use and greenhouse gas emissions.*
- *Produce reports for operations and maintenance.*
- *Facilitate ease of operation by engineering or other building staff.*

Project budget: *[Include a not-to-exceed budget, or range, as applicable.]*

2. Schedule of Events

This RFP will be governed by the following schedule:

<u>Event</u>	<u>Date</u>
Release of RFP (including documentation of existing conditions)	<i>[Date]</i>
<i>[The RFP should also include estimates of the following deadlines: 1.) luminaire delivery to job site, 2.) lighting control system delivery to job site, 3.) start of installation, 4.) installation completion, 5.) lighting control system commissioning.]</i>	
Owner’s or designer’s conference with prospective vendors (optional)	<i>[Date]</i>
Electrical engineer’s conference with prospective vendors	<i>[Date]</i>
Last day to submit written questions	<i>[Date]</i>
Last day for <i>[Owner/designer]</i> to respond to questions	<i>[Date]</i>
Proposal due date. Late proposals will not be accepted. Note that prospective luminaire and lighting control system vendors will not be expected to prepare “final” (“hardline”) drawings of proposed equipment at this time. However, at a minimum, all vendors will be expected to prepare sketches showing all details and information needed by the owner, designer and electrical engineer to assess the proposed equipment and associated wiring requirements. Successful bidders will be required to prepare all necessary “final” drawings during the submittal phase (as described in the Technology Specification section).	<i>[Date and Time]</i>
Optional interviews with prospective vendors	<i>[Date]</i> to <i>[Date]</i>
Notice of intent to award. Note that the owner is under no obligation to proceed with the project, and to award a contract for the equipment described in this document for the entire project or any part of the project as described.	<i>[Date]</i>
Contract award	<i>[Date]</i>

3. Scope of Work

[Paste “Technology Specifications” here from Section 2, after carefully reviewing and editing to include all applicable information particular to your project. Alternately, attach the “Technology Specifications” as an appendix and reference them here.]

4. Proposal Format Guidelines

[Describe the required proposal format and contents, and what information they should provide in their response, in what order, and by what date. See below for suggested proposal format and contents. Include any additional contents you see fit. Indicate how the proposal must be issued (e.g., paper, electronically via PDF, etc.). Note that certain vendors may propose providing both luminaires as well as a lighting control system. Alternately, proposals may be solicited from manufacturer rep agencies or from electrical distributors. In those situations, a single proposal should cover all of the content as suggested below. However, most luminaire vendors do not also fabricate and sell lighting control systems (and vice versa). The owner must decide if they want to solicit only “integrated” proposals, or allow individual vendors to submit proposals for either luminaires or lighting control systems.]

Proposers are to provide the Owner a thorough proposal according to the following guidelines.

Proposals should use simple language with minimal jargon, and avoid the use of elaborate marketing material beyond that necessary to provide a complete, accurate, and reliable offer. Each Proposal will adhere to the order and content of sections defined below, and each section must be completed in full. Incomplete proposals will not be considered.

- 1) Cover letter – *[number]* pages, maximum:

Include a cover letter signed by a principal in the company, indicating full contact information (mailing address, telephone number, and e-mail address). The cover letter may also summarize key elements of the proposal, and unique aspects of the proposed equipment.

- 2) Summary of qualifications for prospective luminaire vendors – *[number]* pages, maximum:

Describe the qualifications of the proposing company, to demonstrate the capability to provide the equipment and services required in this RFP. Information shall include:

- a. Company information including name, address, business type, and website
- b. Description of the company, including:
 - An overview of products that the company provides.
 - The number of years that the company has provided the equipment requested in the RFP.
 - The number of completed deployments of the proposed luminaires.
 - Primary building sectors (office, higher education, hospital, food service, etc.) that the company has worked with in the past.
 - Any other relevant information about the company.
- c. Provide at least *[number]* references for customers that have deployed similar luminaires as those detailed in the RFP. The Owner reserves the right to contact any of the organizations or individuals listed. Information provided shall include:
 - Customer name.
 - Brief description of the products installed, total project square footage and facility types.
 - Primary point of contact for the customer including name, telephone number, and e-mail address.

- 3) Summary of qualifications for prospective lighting control system vendors – [number] pages, maximum:

Describe the qualifications of the proposing company and project leads, to demonstrate the capability to provide the equipment and services required in this RFP. Information shall include:

- a. Company information including name, address, business type, and website
 - b. Description of the company, including:
 - The total number of employees.
 - Brief bios of key personnel who are expected to interface with the project team throughout design, installation and commissioning, including their years of experience.
 - An overview of all the products and services that the company provides.
 - The number of years that the company has provided the equipment and services requested in the RFP.
 - The number of completed deployments of the proposed lighting control system.
 - Experience in assisting customers to receive available financial incentives such as utility rebate programs, government incentives and grants, and other options.
 - Primary building sectors (office, higher education, hospital, food service, etc.) that the company has worked with in the past.
 - Any other relevant information about the company.
 - c. Provide at least [number] references for customers that have deployed similar lighting control systems as those detailed in the RFP. The Owner reserves the right to contact any of the organizations or individuals listed. Information provided shall include:
 - Customer name.
 - Brief description of the scope of products and services deployed, current status, project start and end dates, total project square footage, number of facilities served and facility types.
 - Primary point of contact for the customer, including name, telephone number, and e-mail address.
- 4) Technology features and implementation plan for lighting control systems – [number] pages, maximum:

Provide a description of the proposed approach and methodology to satisfy the Scope of Work defined in this RFP. This section shall include:

- a. A diagram of the architecture of the proposed lighting control system.
- b. A detailed description of how the proposed technology provides the capabilities listed in Scope of Work in Section 3 of the RFP.
- c. A description of any additional capabilities that may be of interest to the Owner but are not specified in the Scope of Work in Section 3 of the RFP.
- d. Where applicable, screenshots to clearly illustrate key operational, reporting, visualization, or analysis capabilities.
- e. A description of how the proposed technology satisfies the IT requirements listed in the Scope of Work in Section 3 of the RFP.
- f. A description of the training and ongoing technical support and maintenance services that will be provided as outlined in the Scope of Work in Section 3 of the RFP.

- g. A detailed project implementation plan, including all tasks and subtasks, durations, milestones, and deliverables. Refer to Appendix C showing a typical project timeline including specific tasks.
- h. A thorough description of specific responsibilities required of the Owner (e.g., site access, provision of electrical and network diagrams, network access, etc.) in conducting the project. Refer to Appendix C showing a typical project timeline including specific tasks.

5) Cost proposal

The cost proposal shall explain the pricing structure for all hardware, software, integration, commissioning, and any other services required for the project (for both luminaire as well as lighting control system vendors). Include an itemized list of all direct and indirect costs (e.g., personnel, travel, supplies, fringe benefits) associated with the deployment of the proposed equipment. Proposal shall include pricing for the following:

- a. Luminaires.
- b. Lighting control system.
- c. Any additional required hardware.
- d. Software set-up fees (e.g., software configuration, programming, license, training, etc.).
- e. Ongoing software usage fees (e.g., data storage and hosting, maintenance, access, technical support and maintenance, or if the system uses a SaaS <software as a service> model, etc.).
- f. Any specified technology features or capabilities that add significantly to project costs.
- g. Any additional optional services or fees.

6) Staffing for lighting control system vendors (and any independent commissioning agents, as required)

Describe the team that will be assigned to the project, with each member's areas of responsibility. Identify lead personnel and include a résumé for each lead.

7) Protections and assurances

Describe the specific measures and protections that the responding company can provide to the Owner to ensure continuity of services in the event of bankruptcy, transfers of ownership, or other disruptions to business-as-usual operations.

5. Proposal Submission and Eligibility

[Describe the RFP procedures, including your organization's point of contact for respondent inquires, submission instructions, modification and withdrawal process, confidentiality, and other procedural details.]

1) Eligibility

[Include any eligibility requirements or preferences that may apply, considering, for example, foreign vs. domestically owned companies; multi-party joint responses; small businesses; citizenship; and other criteria.]

2) Preparation

The Proposal content and format must follow the guidelines provided in Section 4, "Proposal Format Guidelines," in the RFP.

3) Submission and due date

[Provide a website, e-mail address, and/or mailing address for the proposal submission; identify whether electronic or paper submissions are preferred or required.]

Proposals are due by *[insert the time and date from the schedule summarized in Section 2 of the RFP]*. Late Proposals will not be accepted.

4) Inquiries

Questions about this RFP must be directed in writing, via e-mail, no later than *[insert the time and date from the schedule summarized in Section 2 of the RFP]*. Send to:

[Provide the name and either e-mail address or telephone number for the desired organizational point of contact.]

5) Proposal validity

Proposals are to be valid for a minimum of *[number of days]* days to allow sufficient time for evaluation and selection, and any unforeseen delays in the review process.

6) Modification and withdrawal

Any proposal may be modified or withdrawn by written request of the Proposer, provided that the request is received prior to the submission deadline.

7) Right to reject proposals

This RFP does not commit the Owner to award a contract, pay any costs incurred in the preparation of a response to this RFP, or to procure or contract for equipment or services. The Owner reserves the right to accept or reject any or all proposals received as a result of this RFP, to negotiate with any qualified Proposers, or to cancel this RFP in part or in its entirety.

8) Confidential material

All the proposals will become the property of the Owner. Proposers should not include proprietary or confidential information in their response, unless required to clearly convey the proposed work or technology solution. Financial, commercial, or technical information that is considered confidential should be clearly indicated in the proposal.

9) Terms and conditions

[In partnership with your organization's legal department or representatives, include specific terms and conditions that will govern the contracting and procurement of the technology and required services, as well as on-site work conducted to complete the project.]

6. Evaluation and Selection Criteria

[Describe how proposals will be evaluated. You may choose to use a qualitative description, including key criteria, or to include quantitative point and scoring information.]

Appendix A. Existing site characteristics

[Describe in detail, the site characteristics, details on the existing lighting system, task requirements, and other relevant information. Proposers can use this information in combination with the Scope of Work in Section 3 of the RFP to understand key aspects of scope and estimated project costs. You may wish to append spreadsheets, if that is a more convenient format to present the information.]

Section 2: Technology Specification Template

This section of the package contains the template to guide your creation of a specification for office luminaire and lighting control systems. This template is intended to provide a structure and content foundation to facilitate an owner-driven process to define technology capabilities.

By editing, adding to, and deleting from the template, you will produce a custom specification based on your organization's specific goals and energy management processes. This specification should be included in the Scope of Work in Section 3 of the RFP. See the Overview section of this document for additional information.

Technology Specification

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Glossary of Terms

Baseline: A representation of “standard” or typical energy performance, used for comparative purposes. Baseline may be expressed according to a variety of metrics. In a lighting control system, a baseline may represent pre-install conditions.

Building Management System (BMS): A system that is designed to control building operations and indoor climate.

Communication Protocols: Standardized rules or languages governing the transmission of information between devices. Common protocols for lighting control include (among others) DALI and 0-10V. BACnet, LonTalk, and Modbus are examples of protocols used by Building Management Systems.

Controller: A device that switches a luminaire or group of luminaires on and off, and signals the luminaire(s) to dim up or down based on input from a control system or manual override device such as a wallbox dimmer. Controllers are typically mounted within a luminaire housing. However, some systems use controllers that are centrally located.

Demand: The amount of energy use by a particular building or system, i.e., power at a given point in time. Electrical power demand is expressed in kilowatts (kW).

Demand Response: Changes in electric usage by customers in response to changes in the price of electricity over time or when system reliability is jeopardized.

Energy Savings: Accrued energy savings (or potentially increases) over a certain time frame, relative to the baseline.

Greenhouse Gas (GHG) Emissions: The carbon dioxide (CO₂), methane (CH₄), and nitrous oxide (N₂O) gases released into the atmosphere as a result of electrical energy consumption at the facility.

Illuminance: Incident light falling on a surface, measured in footcandles (English units) or in lux (SI units). Roughly, 1 footcandle (fc.) = 10 lux. Recommended target values for illuminance (for example, as listed in the IES Handbook) are typically for average horizontal maintained values based on the entire task surface or plane.

Lighting Power Density (LPD): Electric power required to energize all luminaires at maximum light output, divided by the area. In the U.S., LPD is measured in Watts/square foot (W/sq. ft.).

Luminaire: A device used to create artificial light by use of an electric light source. A luminaire consists of a fixture that houses the light source (e.g., LED matrix, fluorescent lamp, etc.), electrical gear required to power the light source (e.g., LED drivers, ballasts, etc.), and any additional components required for mounting and optical control.

Luminance: Reflected or transmitted light. The amount of luminance is typically used to determine if a given light source will create glare. Luminance is measured in candelas/meter² (cd/m²).

Peak Load: The maximum load during a specified period of time, usually within 15-minute periods as defined by electric utilities.

Performance Specifications (*with comments*)

1. Light level target values and energy goals:

- a. Task illuminance: at full light output, the lighting system will produce a minimum of 30 average horizontal maintained footcandles on task surfaces (assuming no daylight contribution).

This is based on methodology for selecting task illuminance target values in the IES (Illuminating Engineering Society) Handbook, 10th Edition, including the following factors:

- Average age of occupants – three values of recommended target illuminance are typically recommended for each visual task based on the average age of at least half of the occupants. Typically, lighting designers recommend target levels for office lighting tasks based on the middle age range, where at least half of the occupants have an average age between 25-65 (as opposed to <25 or >65). This age range usually encompasses the vast majority of occupants in an office environment.
- CSA/ISO monitor type – VDTs (video display terminals <computer screens>) used in offices may be CSA/ISO type I, II or III. Type I screens produce diffuse reflections from incident light, whereas Type II screens produce semi-diffuse reflections, and Type III screens produce specular reflections. With Type III screens, lower light levels would be required to lower the possibility of disabling, veiling glare. Based on industry trends for monitor types, designers typically assume that the monitors will be Type I or Type II.
- Positive polarity versus negative polarity – most software used in office applications employs color schemes that mimic paper tasks. For example, word processing software typically displays black fonts on a white background. This is an example of positive polarity. Some software (e.g., most CAD programs) typically uses a negative polarity color scheme. For example, white or colored lines are drawn on a black background. Generally, designers assume that software will produce positive polarity on the monitor.

Based on these factors, assuming that the average age of at least half the occupants is between 25-65, the highest target illuminance for horizontal work surfaces is 30 footcandles (average, horizontal maintained). This is based on assuming that monitors will be CSA/ISO Type I or Type II, and that software will produce positive polarity. Theoretically, based on the <25 age bracket, assuming that monitors were CSA/ISO Type III, and that software produced negative polarity, the target illuminance could be as low as 7.5 footcandles. Based on typical conditions in most office spaces as described above, lighting designers typically select 30 footcandles as an appropriate recommended level.

It should be noted that based on the previous edition of the IES Handbook, it was common for designers to select 50 footcandles as a target illuminance level, if they assumed that the main visual task was paper-based. In the more distant past, 100 footcandles was a typical target level selected by many designers. Obviously, a careful determination of appropriate target levels is essential, especially because there is a direct correlation between target light levels and maximum power draw from the lighting system. However, if a lighting control system is used that can dim or raise light levels based on the needs of the occupants, the power draw of the lighting system at full output may be less significant

– as long as the new system still meets code requirements and the existing power distribution can handle the loads (at full output).

Note that per the IES Handbook, 10th Edition, it is permissible to consider the “task surface” as the desks only. Therefore, through a combination of ambient and (presumably furniture-mounted) task lighting, this target average illuminance level may be met at the work surfaces, but not necessarily on an imaginary plane 2’-6” AFF throughout the entire open office floor. This would result in a reduction of the connected lighting load. Under these conditions the ambient (overhead) lighting system may produce less than 30 average horizontal maintained footcandles as long as task lights can bring the average light level on all task surfaces (in aggregate) to that level of illuminance. This is a decision that needs to be made by the designer and owner during the design phase.

b. Lighting power density (LPD): *[select one]*

- i. Tier 1 – Maximum connected lighting load including task lighting shall not exceed 75% of applicable code restrictions. *[Determine which code(s) are applicable to the project; e.g., IECC 2012/ASHRAE 90.1-2010/CA Title 24/etc. Then determine the maximum permissible connected lighting load.]*

For example, in California, the current LPD limit for office lighting using the “Complete Building Method” is 0.8 watts/foot². Therefore, 75% of that limit is 0.6 watts/foot².

- ii. Tier 2 – Maximum connected lighting load including task lighting shall not exceed 50% of applicable code restrictions. *[Determine which code(s) are applicable to the project; e.g., IECC 2012/ASHRAE 90.1-2010/CA Title 24/etc. Then determine the maximum permissible connected lighting load.]*

For example, in California, the current LPD limit for office lighting using the “Complete Building Method” is 0.8 watts/foot². Therefore, 50% of that limit is 0.4 watts/foot².

c. Annual lighting energy use: *[select one]*

Annual lighting energy use is defined as (Lighting Power Density x annual hours of operation)/1000. For example, If an open office space has an LPD = 1.0 watts/ft² with 4000 hours of operation per year, then the resulting annual lighting energy use = (1.0 x 4000)/1000 = **4.0 kWh/square foot/year**.

- i. Tier 1 – Energy use from connected lighting load (including task lighting) shall not exceed 2.0 kWh/square foot/year.
- ii. Tier 2 – Energy use from connected lighting load (including task lighting) shall not exceed 1.5 kWh/square foot/year.
- iii. Tier 3 – Energy use from connected lighting load (including task lighting) shall not exceed 1.0 kWh/square foot/year.

2. Overhead light fixtures for ambient light:

a. Dimming: *[select one]*

- i. Tier 1 – All overhead light fixtures shall be dimmable in a continuous range between 10-100% of full light output.
- ii. Tier 2 – All overhead light fixtures shall be dimmable in a continuous range between 1-100% of full light output.

Note that some lighting control systems, LED drivers and/or fixture controllers may allow lamps or fixtures to dim below 10% of full light output. Certain codes (such as California Title 24-2013) required any LED lamp or fixture to be dimmable between 10-100% of full light output. However, in certain applications, it may be desirable to dim lights to substantially lower levels. If desired, verify that any control system or equipment under consideration will allow for dimming to the levels required (e.g., 1-100%).

- b. Control system components – modify existing lighting scheme to incorporate dimming and any other required control system components as follows: *[select one]*

Note that most existing overhead light fixtures have switched (on/off) ballasts for fluorescent lamps. In order to reap the most benefit from installing a new lighting control system, it is essential to use fully controllable (dimmable) light sources. When using a system in which all light sources are fully dimmable, in a continuous range, all control strategies may be used – such as daylight harvesting, demand response, institutional or setpoint tuning, personal tuning, etc. Some current codes already require either multiple intermediate dimmed levels or full-range dimming capability depending on the light source (e.g., California Title 24-2013). Additionally, LED fixtures or lamps may need to be listed on a “qualified products list” in order to comply with applicable codes, or to qualify for financial incentives from utilities or other entities. For example, LED fixtures may need to meet NYSERDA’s “Existing Facilities Solid State Lighting Policy” (essentially, for quality assurance, LED products must be ENERGY STAR® qualified or on the DesignLights™ Consortium’s Qualified Products Lists).

In addition to the components listed below, note that if a wired control system is used, then low-voltage control wires will need to be connected to the existing fixtures so they can join the control system’s network. Assuming that no such advanced lighting control system already exists in the space, those wires will have to be run through the plenum and connected to every fixture, whether they are retrofitted or new, and terminate in panels for the new lighting control system (those panels are typically mounted in an electrical closet). This is in addition to the reuse of existing line-voltage power wires.

As described below, there are a variety of ways to incorporate LED luminaires and advanced lighting control systems into an existing space. There are many factors that affect the cost of equipment as well as installation. It’s tempting to assume that using new fixtures with pre-installed control components which communicate wirelessly with the control system would be the easiest and least-cost solution. That may be true based on every factor affecting the installation, but it might not. It’s important to consider all factors that contribute to the equipment and installation costs before making purchase decisions, taking into account all of the owner’s needs.

Note that some fixture types and/or project conditions may preclude fixtures from containing on-board controls components (such as controllers, sensors, etc.), because of space restrictions or other factors. The easiest and lowest-cost options for deploying an advanced lighting control system in an existing space are typically to use new LED fixtures with all required components pre-installed in the fixture (Options 2 or 3 below). This includes LED drivers, fixture controllers (if required), sensors, etc. If the

controllers and/or sensors communicate wirelessly with the control system, then the installation is as simple as replacing the existing fixtures with new fixtures, reattaching the existing power feeds to the new fixtures, then commissioning the control system. Due to their small size or other factors, some fixtures cannot accommodate additional controls components, and/or equipment required for code-compliant emergency lighting. Some fixtures must even remote the LED drivers to the plenum. In some situations, available recessing height in the plenum due to structure or HVAC ductwork can even preclude the installation of luminaires, remotely mounted controls or LED drivers, or even the junction boxes required for mounting pendant fixtures in the same locations as existing luminaires. Using the same layout as the existing fixtures may reduce the cost for both wiring as well as structural support, particularly for pendant fixtures. However, all of these issues must be carefully considered especially with regard to available space in the plenum. These issues will no doubt have a direct impact on the complexity and cost of the installation, so it's important for the designer to carefully consider all of these issues during the selection process both for luminaires as well as lighting control systems.

- i. Option 1 – Retrofit existing luminaires to incorporate LED lamps, LED matrices or use complete “retrofit kits”, incorporating dimmable LED drivers as required. Incorporate additional control system components and new optical control media (e.g., lenses or diffusers) as required. Leave existing luminaire housings and primary power feeds in place. Connect new low-voltage network wires as required for communication with the lighting control system.
 - ii. Option 2 – Replace existing luminaires one-for-one with new LED luminaires incorporating dimmable drivers for LEDs, with any required control system components factory-installed. Reuse existing primary power feeds and connect to new luminaires. Connect new low-voltage network wires as required for communication with the lighting control system.
 - iii. Option 3 – Remove existing luminaires and install new LED luminaires with a new layout. Provide new luminaires incorporating dimmable drivers for LEDs, with any required control system components factory-installed, using appropriate spacings/locations to achieve the target illuminance levels. Patch ceiling and/or replace tiles as required. Reroute primary power feeds to new luminaires as required.
- c. Light source color: [\[select one\]](#)
- i. Tier 1:
 - 1. Correlated color temperature (CCT) – LEDs shall have a published CCT of 3500K or 4100K. Actual CCT for LEDs as shown on IES LM-79 tests may have a tolerance of $\pm 100\text{K}$. Therefore they must be in the range of either 3400-3600K (for nominal 3500K) or 4000-4200K (for nominal 4100K).
 - 2. Color rendering index (CRI) – LEDs or LED lamps shall have a published CRI of 80 or greater.

- ii. Tier 2 – LEDs shall have a base CCT and CRI as described above. However, the CCT may be continuously increased up to 5000K at the user’s discretion (to more closely approximate the cooler color temperature of daylight), either by manually adjusting the color temperature (for example using some form of wallbox device) or by setting the desired CCT in the control system software. Fade rate for any such change in CCT may range from 0-59 seconds, or up to 60 minutes.

Note that the IES has approved **TM-30-15 – Method for Evaluating Light Source Color Rendition**. This is a new approach to quantifying and qualifying the rendition of a given light source. It provides certain enhanced information beyond what CRI indicates, and it may be used in place of specific CRI requirements as described above. For more information about this new method for evaluating light source color rendition, go to <http://www.ies.org/store/product/ies-method-for-evaluating-light-source-color-rendition-3368.cfm>.

- d. Glare and luminance limits – to minimize direct glare from fixtures, restrict luminance as follows for any azimuth angle: *[select one]*

Many currently available LED luminaires for ambient lighting do not meet the luminance limits as described in the IES Handbook, 9th Edition (see Tier 2 below). Some currently available LED luminaires do not even meet the higher luminance limits (see Tier 1 below). Despite the proliferation of LED lamps and luminaires in recent years, many of these products have not been designed with a goal of reducing high-angle brightness. Manufacturers’ catalog sheets for the highest specification-grade luminaires typically publish luminance data. If such data is not published on catalog sheets, it should be possible to find this information on an LM-79 report.

- i. Tier 1 – Restrict luminance at any vertical angle at or above 55° from nadir (from 55-90°) to 2000 candelas/square meter (cd/m²).
- ii. Tier 2 – Restrict luminance at the following vertical angles to:
 - 1. 850 cd/m² at 55° from nadir.
 - 2. 350 cd/m² at 65° from nadir.
 - 3. 175 cd/m² at or above 75° from nadir.

3. Wiring

- a. Wiring to and between luminaires – since all overhead luminaires need to be dimmable, it may be necessary to reroute existing wires or to run additional power wires and/or control wires. Methods of wiring include: *[select one]*
 - i. Option 1 – Reroute existing power wires and/or run additional power or control wires as necessary from existing or new luminaires locations to a centrally located electrical room(s). Terminate in existing or new distribution panels, depending on the control system.

Certain lighting control systems require that low-voltage control wires connect all fixtures (and in some cases sensors and switches) in a network terminating in centrally located panels. If those panels are located in an electrical closet in the core, then the new low-voltage “network” wires will have to be run from the plenum back to the core (“homeruns”).

- ii. Option 2 – Distribute controllers in the plenum and run power and/or control wires as necessary to luminaires, or to distinct zones. Controllers shall not require “homeruns” back to a centrally located electrical closet(s) for either power or control wiring. Communicate between controllers, from controllers to server, and between controllers to user access points (terminal, switches, etc.) via a new data bus, company local area network (LAN), or wirelessly using radio frequency (RF) or other method of communication.

These systems may be similar to (or exactly the same) as those described in Option 1. There may be a provision for such systems to terminate in controllers or gateways in the plenum; the controllers or gateways may communicate wirelessly or via an existing intranet to the server centrally located in an electrical closet or IT room. This may have a distinct impact on reducing installation cost by eliminating the need for “homeruns”.

- iii. Option 3 – Use existing power wires to luminaires. Luminaires shall be “self-contained”, with on-board components required to switch and dim fixtures, to communicate with the lighting control system (dimming ballasts, dimming drivers, controllers, radios, etc.), and to reconfigure the zoning. The luminaires shall communicate wirelessly with a gateway. If this option is selected, no additional wiring is required to existing (or new) luminaires.

Wireless systems as described in Option 3 have the potential to substantially reduce installation cost. Keep in mind that “wireless” may refer to the transmission of the control signal to/from luminaires. However, it may also refer to the transmission of signals/data to sensors or switches. Some systems allow for the use of wireless sensors or switches, but still require that luminaires are connected via low-voltage control wires to a centrally-located panel. Other systems use wireless signals to communicate with both luminaires as well as sensors or switches.

Remember that one or more “wireless gateways” will need to be installed in the open office space and they are typically connected to the server via Ethernet cables. If the wireless gateways can tie in to existing intranet ports available in the open office space, this eliminates the need to run additional Ethernet cables back to the server (typically located in an electrical closet in the core). However, that means that the owner must be willing to install the new lighting control system components on an existing enterprise network.

- a. Wire colors – luminaire vendors shall use industry-standard wire colors for all line-voltage power feeds as well as low-voltage control connections.

Incorrect, non-standard wire colors in a luminaire’s cord set or internal wiring can cause electrical contractors to inadvertently miswire the luminaires. This can potentially damage or destroy LED drivers and/or on-board control equipment. In order to reduce/eliminate installation errors, it’s imperative that luminaire vendors provide cord sets with standard wire colors. For example, luminaires that require external connections for 0-10V control should have violet and gray conductors for the low-voltage

signal. Luminaires that require external connections for DALI control should have two violet conductors (or, preferably, one violet conductor and another violet conductor with a white stripe).

4. Lighting control system for overhead luminaires:

- a. Dimming – as previously noted, all overhead luminaires shall be dimmable. Dimming range: *[select one]*
 - i. Tier 1 – All luminaires shall be continuously dimmable in a range of 10-100% measured light output.
 - ii. Tier 2 – All luminaires shall be continuously dimmable in a range of 1-100% measured light output.

Note that certain codes (e.g., California Title 24) mandate that any LED luminaire or lamp is continuously dimmable in a range of 10-100%. However, most lighting control systems allow users to select light levels as low as 1%.

- b. Minimum power at lowest light output: *[select one]*
 - i. Tier 1 – At the lowest light output, input power to the luminaire shall be no greater than 20% of the input power at maximum light output.
 - ii. Tier 2 – At the lowest light output, input power to the luminaires shall be no greater than 10% of the input power at maximum light output.
- c. Control zones for overhead luminaires: *[select one]*

“Control zones” are defined as a luminaire or group of luminaires that respond to specific input(s). Depending on the lighting control system design, control zones for scheduling, daylight harvesting, occupancy sensing, tuning, personal control and demand response may or may not be co-located. In some systems, the “occupancy” zone defines the zone for all other control strategies. In other systems, zoning of luminaires can be configured differently for different types of control strategies. Consult with lighting control manufacturers to understand the capabilities of their product lines. Delineate the desired zoning on plans and include as part of the specification package. See Appendix E for generic zoning diagrams based on some currently available lighting control systems.

Scheduling:

“Scheduling” is defined as a mode of control where luminaires are turned on at a predetermined time, then turned off after a sufficient warning to the occupants (e.g., blinking the lights on and off). Scheduling is typically mandated by energy-efficiency codes. Occupants can override this scheduled behavior by calling the building manager to turn the lights back on, or they can turn the lights on for some predetermined period (e.g., 1 hour) using a manual wall switch located in a central location on the floor, or other form of manual override (app, internet-based program, phone, etc.). Lights are typically scheduled to be off after work hours and on weekends.

Scheduling is typically accomplished by establishing blocks of time in a calendar-style format. Variables for all other control strategies as described in the control profiles (e.g., how occupancy sensors operate, daylight harvesting settings, etc.) are established for each block of time.

“Occupancy” control zones:

Occupancy-based controls dim or turn the lights off if there is no one in the area or space. An occupancy or vacancy sensor mounted at the ceiling or in a luminaire detects whether there is a person/people in the space typically based on movement and/or infrared heat. The field of view, type, design, sensitivity and/or masking (if any) of the occupancy sensor determine how large or small the occupancy zone is. The occupancy zone defines which luminaires are controlled by which occupancy sensor(s). The following provides guidance on how zones can be defined for large (low granularity) or small (high granularity) areas. Smaller occupancy zones (Option 3) are expected to provide greater energy savings.

Occupancy sensor data can also be used for other purposes. Trended data can be used for financial analysis; for example, to track where retail sales are occurring in a store. Define how important it is to have reliable trending of occupancy data then select control systems that have sufficient memory and reliable data transmission, if the networking and communication mode is wireless, to cover periods when connectivity may be interrupted.

Real-time occupancy status data can also be used to turn down fresh air volume when the space is unoccupied to meet demand-side ventilation energy-efficiency code requirements or to signal other systems to take actions to minimize energy use (e.g., increase the setpoint temperature deadband, lower automated shades to reduce cooling loads when the space is unoccupied, etc.). Discuss options for sharing data between different control systems (HVAC, building envelope) with the lighting control system vendor and ensure that the networking and communication system is designed to minimize the time delay between acquiring data from occupancy sensors and sharing data with other building controls. In some wireless systems, for example, it can be 15 minutes or more before the HVAC system receives occupancy data due to network latency issues. (Within the HVAC or shading control system, one should be able to define zone assignments based on occupancy independent of the lighting control system.)

- i. Option 1 – Low granularity occupancy zones: create zones corresponding to the coverage pattern of the occupancy sensors to be used (e.g., 500, 1000 or 2000 foot²). *[If occupancy sensors with specific coverage areas (or shapes) are desired, include those specific amounts or shapes in the specification language (and/or attach diagrams showing the coverage area/shape as appendices, or by including manufacturer’s catalog sheets).]*

Ceiling-mounted occupancy sensors for open offices typically have coverage areas of 500, 1000 or 2000 square feet – for detecting “major motion”. Coverage area for “minor motion” is typically smaller. Consult manufacturer’s catalog sheets to determine specific coverage areas for the occupancy sensors to be used. Note that in many systems, more than one sensor may be used in/associated with a given zone. Whether those sensors are wired or wireless, their operation may be “paralleled” (meaning that any sensor in a given zone can turn on lights in that zone). This allows the creation of larger zones than only one sensor can cover.

- ii. Option 2 – Medium granularity occupancy zones: create zones that are smaller than the coverage pattern of the occupancy sensors to be used (e.g., 200 foot²). This may be accomplished by masking portions of a ceiling-mounted sensor. Alternately, use occupancy sensors that have smaller coverage patterns than typical ceiling-mounted sensors (e.g., 200 foot²). *[If occupancy sensors with specific coverage areas (or shapes) are desired, include those specific amounts or shapes in the specification language (and/or attach diagrams showing the coverage area/shape as appendices, or by including manufacturer's catalog sheets).]*

It's generally possible to mask portions of a PIR (passive infrared) occupancy sensor. Therefore, the coverage pattern can be reduced to a smaller area or its shape can change. Ultrasonic (or dual-technology) occupancy sensors may be used for open office areas. However, if an ultrasonic occupancy sensor (or if the ultrasonic portion of a dual-technology sensor) is used, then the coverage pattern/area of the sensor may be greater than a PIR sensor with a clearly defined cone of view. In that case, it may not be possible to carefully control which occupants will be detected by a sensor in a specific control zone.

Alternately, other occupancy sensors have smaller coverage areas than those designed to cover large, open areas. For example, occupancy sensors designed for integral mounting within luminaires typically have considerably smaller coverage patterns. Since the size of the coverage area of the occupancy sensors may have a big impact on the reduction of energy use, it's important to carefully consider which sensors are preferable in a given space.

- iii. Option 3 – Maximum granularity occupancy zones: create zones that correspond to individual luminaires. *[If occupancy sensors with specific coverage areas (or shapes) are desired, include those specific amounts or shapes in the specification language (and/or attach diagrams showing the coverage area/shape as appendices, or by including manufacturer's catalog sheets).]*

This is typically accomplished by using integral fixture-mounted sensors as described above.

Note that most lighting control systems use individually-addressable ballasts or drivers – or individually-addressable on-board controllers that signal the fluorescent ballast or LED driver to switch and dim. Therefore, with most systems, it's possible to achieve maximum granularity of control zones if desired. The specifier and owner must determine how the system will actually be used in operation, and whether or not that granularity of control zone breakdown will help or hinder the project goals. For example:

- Will creating one control zone per luminaire increase the potential for energy savings? For example, if there are substantial changes in occupancy (people coming in and leaving the office a lot) during operating hours, fixture-integrated sensors may help to reduce energy.
- Will creating one control zone per luminaire increase the project cost? Note that in most systems, each zone requires its own occupancy sensor and/or photosensor if those functions are desired. Therefore, if individual luminaire control is desired, that may require substantially more equipment than other systems.

- Will creating one control zone per luminaire increase the complexity of operation for the building staff? Note that in most systems, it is possible to create sub-zones based on individual luminaires, with “parent” level zones that control certain aspects of operation for the lower-level zones under them. For example, all sub-zones might refer to the “parent” zone for scheduling or demand-response, but individual luminaires might respond to their own fixture-mounted sensors for occupancy and/or photosensor input.

“Tuning” control zones:

Institutional (facility-wide) or individual setpoint tuning allows the facility manager or end user to tune the task’s setpoint (target illuminance) level based on the preference of the work group or occupant(s). The range of setpoint tuning is limited by the maximum illuminance level from electric light only (i.e., measured when all lights are on at full power at night). Some tasks may require a higher light level (e.g., fine detailed work on paper performed by older employees) while other tasks may be performed more comfortably at a lower ambient light level. It’s important that the client understands that the tuning setpoint value represents the minimum (without daylight contribution). In daylit spaces, the total illuminance can be significantly greater (e.g., 200 fc. or more on a sunny day). The tuning setpoint level will affect the dimmed level of the electric lights during the day based on the use of daylighting controls (photosensors).

In most advanced lighting control systems, zones for tuning are usually the same as those for occupancy. As such, target (tuned) light levels may be different for different zones. Depending on the needs in a given space, it may be desirable to provide a variety of options for setpoint tuning levels for different occupants. This can be accomplished by creating high-granularity zones (with small areas per zone). However, keep in mind that in an open office space, widely varying setpoint tuning levels in small zones may have a negative affect on the daylight control algorithms and behavior of luminaires. Remember that light distribution either from pendant or recessed luminaires will likely spread beyond the area of their respective zones. On the other hand, establishing one setpoint tuning level that is applied to all zones in an open office space shouldn’t have any deleterious affect on the daylight control algorithms or luminaire behavior.

“Daylighting” control zones:

Zones for daylighting are typically created based on distance from the daylight sources (windows, skylights), and based on shade control zones (whether the shades are manual or automated). A daylit zone can be defined as a group of luminaires that are all dimmed to the same level of output, or as individual or groups of luminaires that are dimmed to different levels of output in proportion to the light detected by the photosensor(s). Some of the more common modes of control are as follows:

- **Closed-loop** – a ceiling-mounted, shielded photosensor located in the zone that it controls. A shielded closed-loop photosensor has a fairly narrow field of view so that it detects light only in the zone that it controls. Daylight zones should be created based on the published definition of the photosensor’s field of view (e.g., 60° cone of view). All luminaires in the control zone are typically dimmed to the same level. In some systems, individual or different groups of luminaires in the same zone can be dimmed to different levels in response to the same photosensor signal. For zones located next to the window wall with manually operated shades at various heights across the zone, locate the photosensor to detect the average light level across the depth of the zone parallel to the window. For high-resolution (high granularity)

controls where each luminaire has its own individual daylight sensor, it will be important to restrict the photosensor's field of view to avoid control hysteresis between adjacent zones but also to ensure that sufficient light is delivered at the minimum illuminance point between two adjacent luminaires.

- **Open-loop** photosensors are usually located near the window with a limited field of view so that the photosensor signal is minimally influenced by the luminaire(s) it controls. Multiple zones (near the window or deeper into the space) may be controlled by the same photosensor. Each zone, each group of luminaires within the zone, or each individual luminaire may be dimmed to different levels of output in proportion to the photosensor signal (depending on the control system used).

See Appendix E for generic zoning diagrams based on some common lighting control systems. Examples are given for spaces with continuous linear fixture rows and also for recessed troffers.

Future reconfiguration of zones:

Space needs, partition layout and/or furniture layout may change at any time. Therefore, in the future, it must be possible to reassign luminaires to different zones or to increase or decrease the number of zones. Typically, lighting control systems have individually addressable luminaires (using digital ballasts or drivers, or on-board controllers). If a lighting control system is installed with individually addressable luminaires, then rezoning can be accomplished entirely in the system's software. If luminaires are not individually addressable, then rewiring of power and/or control wires may be necessary.

- d. Control strategies – the lighting control system shall be capable of implementing the following lighting control strategies:
 - i. Daylight harvesting – the availability and amount of daylight shall be determined by the use of photosensors. Luminaires in areas with sufficient daylight shall dim (or potentially turn off) in response to available daylight if those options are selected in the control profile in use at a specific time. Photosensors shall meet the following criteria:

The spatial distribution of daylight in a space varies with time of day, season, sky conditions and shade position. Daylight dimming systems use real-time measured data from a photosensor(s) to determine how much to dim the electric lighting in different areas of the space. Direct sunlight or strong directional sources of reflected daylight from snow or water create the most challenging conditions, causing over-dimming and inadequate lighting in some areas. Different photosensor designs, different control algorithms and/or preferred mounting locations are used to achieve reliable dimming across this broad range of conditions. Use of automated shades can help to dampen the variation of daylight in a space and improve dimming performance of electric lighting.

Photosensors typically have published specifications indicating their field of view (e.g., 60° cone of view), spectral sensitivity (calibrated to match the photopic response of the eye), measurement range and, in some cases, a profile of its spatial response (sensitivity within the cone of view; e.g., photodiodes coupled with a white diffusing lens could be collecting light from a 180° cone of view, leading to unreliable control). Below, the term “photosensor” is used to describe both the actual light-detecting sensor and the algorithms used to convert the sensor input to a control signal to dim the electric light(s).

These algorithms may be implemented in circuitry integral to the photosensor housing or in separate dimming electronics located in the ceiling or within the fixture housing.

1. Photosensor type *[select one]*:

a. Closed-loop.

Closed-loop photosensors are typically ceiling-mounted and respond to both daylight and electric light on the task surface below. Proportional closed-loop control is much more likely to lead to reliable control compared to integral reset control. Verify the functionality of operation in a system that can take input from a closed-loop photosensor(s).

b. Open-loop.

Open-loop photosensors are typically ceiling-mounted, located to primarily measure the influx of daylight near the window. The sensor may be used to control some or all luminaires or zones in the space. In certain systems, the use of open-loop photosensors only allows luminaires to toggle between two different dimmed levels (which may include full on and/or full off). Therefore, the continuously variable signal received at the photosensor isn't actually used to dim luminaires throughout their entire dimming range. Verify the functionality of operation in a system that can take input from an open-loop photosensor(s).

c. Dual-loop.

These photosensors, incorporating functionality of both closed- and open-loop sensors, may be used by certain systems. Verify the compatibility and functionality of such photosensors with any control system under consideration.

2. Signal transmission method *[select one]*.

Photosensors may be "analog" or "digital". This refers to the method of communication between the photosensor and the control system. See descriptions below.

Most lighting control systems enable the end user to access to the raw, time-series or event-based photosensor data (e.g., list of times when the measured light level changes at the photosensor). Access to this data may assist with fault diagnostics or optimal programming of system variables. For these reasons, it is preferable to use a lighting control system that stores this data and allows users to access it.

a. Analog.

Some lighting control systems use analog photosensors and the control system decides what to do with the raw signal as reported by the analog sensor. As previously mentioned, most lighting control systems also store the raw signal data as reported by the analog photosensor(s).

b. Digital.

Some lighting control systems use digital photosensors. The conversion of the analog signal to a digital signal happens within the photosensor, and the digital signal is then transmitted back to the lighting

control system via wires or wirelessly. Other functions are sometimes incorporated into a digital photosensor (such as an occupancy sensor or an infrared receiver for “manual override” operation or commissioning). If such “multi-sensors” are desired (for example, to reduce the amount of equipment needed), describe all of their integral functions in the specifications.

3. Viewing cone – closed-loop photosensors shall be ceiling- or fixture-mounted *[select one]* with a viewing cone limited to an angle of 30-60° *[edit and provide a specific angle]*. Open-loop photosensors shall have a viewing angle that limits its cone of view to *[provide a specific angle; the designer may determine the desired angle based on plans and section drawings]*° and the width of its view parallel to the window wall to *[provide a specific angle; the designer may determine the desired angle based on plans and section drawings]*°.

The appropriate selection of the viewing cone size will depend on the size of the control zone and height of the photosensor above the task surface. This enables the photosensor to be matched with an individual shade control zone.

4. Spectral filtering – photosensors shall incorporate a photodiode to measure light levels that can be correlated to the desktop illuminance. The photodiode shall be spectrally filtered (color-corrected) to measure light that approximates the human photopic response.
5. Range – photosensors shall operate within a range of 0-300 footcandles of incident light on the task surface (or greater if the setpoint <target> illuminance level is higher). This may be modified to a more limited range either by physical adjustment at the photosensor, or (preferably) by changing settings in the control system software.
6. Accuracy – photosensors shall be accurate to within 1% of reading in an operating environment between 15-30°C.
7. Calibration *[select one]*:
 - a. Option 1 – Nighttime calibration. Calibrate the photosensors by adding a “photosensor calibration” event to the schedule in the system’s software. The calibration will be scheduled to take place during nighttime hours (with no available daylight). The control system will turn luminaires on and leave them at full output for 10 minutes to insure that all luminaires are fully warmed up. Then the system will dim luminaires by 10% every 2 minutes (allowing light levels to stabilize with temperature), recording the resulting levels measured by the photosensors. The final dimmed levels shall be 5% and 1% once the photosensors have been calibrated for all levels in 10% increments. Once the calibration is done, the system will use these recorded values to determine the appropriate mix of daylight and electric light to achieve the target illuminance

levels during daylight hours when daylight harvesting profiles are active.

This is a common calibration approach used by many current systems. Some currently available control systems use different variables than those listed above. For example, some systems may keep luminaires at specific dimmed levels for greater lengths of time during the calibration process. Remember that control systems may also be used to dim and switch fluorescent luminaires. Using different/greater lengths of time for each dimmed level may be desirable to optimize temperature stabilization to more accurately calibrate the photosensors. If a large number of luminaires or zones are used, all of which need to be calibrated independently, this may have a big impact on the time required to run through the entire calibration process. It is important to understand these variables by reviewing the calibration process in detail with a lighting control system vendor during the design phase.

- b. Option 2 – Other methods of calibrating the photosensors may be proposed by a lighting control system vendor.

For example, in some systems, after a “nighttime” calibration is completed, the commissioning agent must return to the space during daylight hours to verify that target illuminance levels on the task (desk) surfaces match what was specified in the control profiles. If not, then further adjustments will be made at that time. Especially in occupied spaces, it’s important to understand how a lighting control system will be commissioned and what will have to be done during normal business hours versus overnight.

- 8. Deadband – a range of values shall be set in the control system software that achieves the following:
 - a. Maximum setpoint – upper limit of the target illuminance range. When a combination of daylight and electric light exceeds this setpoint (for a period of time specified in the software), the control system will dim luminaires (or turn them off).
 - b. Minimum setpoint – lower limit of the target illuminance range. When a combination of daylight and electric light fall below this setpoint (for a period of time specified in the software), the control system will increase the level of the luminaires (or turn them on if they were previously off).
 - c. Time delays & fade rates – time delays and fade rates may be set in the control system software for dimming luminaires up or down. (For example, set variables in the system so that luminaires will not dim up or down until 5 minutes after a change in light level registers at the photosensor.)

Differential dimming within a control zone – in certain systems, luminaires can be dimmed to different levels of light based on input from only one photosensor. This function may be referred to as a “gain” (slope of the line correlating photosensor signal to task illuminance) or sensitivity setting in the control system software, or there may be another method to achieve this differential dimming within the same control zone. The effect of this “differential dimming”, as an example, is that it may allow for dimming luminaires closer to a window wall more than those farther from the window wall. The result may be

greater energy savings. Verify the availability as well as functionality of operation in a system that allows for differential dimming based on photosensor input.

- ii. Occupancy/vacancy sensing – occupancy/vacancy shall be determined by the use of passive infrared (PIR), ultrasonic (US), dual-technology or other types of occupancy sensors (microwave, acoustic, etc.). *[if a specific type of occupancy sensor is desired (some of which are described above in “Control Zones”), indicate that here and delete the others.]*
 1. Signal transmission method. Occupancy/vacancy sensors may be “analog” or “digital” *[select one]*.

This refers to the method of communication between the occupancy/vacancy sensor and the control system.

- a. Analog.

Some systems use analog occupancy/vacancy sensors and the control system components decide what to do with the raw signal as reported by the analog sensor. Some occupancy sensor vendors describe this as a “digital” signal, because the signal returned from the sensor to the control system essentially varies only between “on” and “off”. However, this isn’t a true “digital” signal (such as in a sensor that converts it to data using an open or proprietary protocol, such as DALI). An analog signal is not a proprietary protocol of data transmission.

- b. Digital.

Some systems use digital occupancy/vacancy sensors. The conversion of the analog signal to data happens within the sensor, and that data is then transmitted back to the system over Ethernet or other low-voltage cables (or in some cases, wirelessly). This data is typically transmitted back to the system using a proprietary protocol. Some systems may use a non-proprietary protocol such as DALI.

2. Adjustment of sensors shall be as follows *[select one]*:

- a. Tier 1 – Adjustment for “sensitivity” may be preset at the sensor before installation, or field-adjusted at the sensor after installation. “Time delay” may be set at the sensor as well as in the system software.

Time delays as set in the lighting control system software can be different for different control “profiles” or during different “schedules” (see below). Analog sensors usually have “pots” or dip switches which allow for setting sensitivity and/or time delay. This is **not** the preferred method of adjustment. Also note that adjustments at the sensor itself **may not be allowed** depending on applicable code requirements (such as California Title 24). If sensors with on-board adjustments are used, note that time delays should be set to the minimum value, since the lighting control systems have their own variable controlling time delays. In those cases, the systems start timing down only after the sensor has timed out and sent a “vacant” signal to the control system.

- b. Tier 2 – Adjustments for “sensitivity” as well as “time delay” shall be made in the system software. Time delays can be

different for different control “profiles” or during different “schedules” (see below).

“Self-adjusting” (or “auto-commissioning”) sensors may or may not be desirable since they may override or reset specific time delays as desired by the owner and design team. If such sensors are proposed for use, verify their compatibility with any lighting control system under consideration. The lighting control system software would need to have an option to allow for “self-adjusting” time delays for occupancy sensors.

3. Fade upon sensing occupancy or vacancy – fade time to raise/dim luminaires up or down, between 0-59 seconds or up to 60 minutes, may be programmed in the control system software. Different fade times may be used for occupancy versus vacancy.
4. “Daylight hold off” – if sufficient daylight is present in the space, allow the lighting control system to “hold off” luminaires in certain zones (keeping those luminaires off or at a minimum light level preset in the system software, based on the prevailing control profile).

The intent of the “daylight hold off” function is to override the function of an occupancy sensor that would otherwise turn lights on in a given zone when there is sufficient daylight present to achieve the target illuminance level.

Note that many analog occupancy/vacancy sensors contain integral circuitry to provide this “daylight hold off” function before sending an on or off signal through a control wire back to the system. This integral function in an analog sensor may cause confusion in the system. For example, which really determines if luminaires should turn on or shut off – the lighting control system or the sensor?

When an analog sensor has an integral “daylight hold off” function, there is usually some provision for adjusting the ambient light level required to trigger the hold-off function (pots, dip switches, etc.). It is essential to determine what effect this may have on the normal system operation.

Analog sensors that have an integral “daylight hold off” function may have an extra wire that is connected to a device such as a relay, power pack, controller, etc. Some lighting control systems have provisions for using the signal from this extra control wire, but others do not. It is essential to determine how a lighting control system interfaces with such a sensor – and even if it doesn’t, if this extra function or control wire may have any effect at all on the behavior of the system (whether it is connected or not).

5. Programming of system behavior based on occupancy and vacancy sensing *[select one]*:
 - a. Tier 1:
 - i. Upon sensing occupancy, turn luminaires on to a predetermined level set in the lighting control system software. Allow for a “transition” time (to fade luminaires up) from 0-59 seconds or up to 60 minutes.

- ii. Upon sensing vacancy, and after a specified “time delay”, turn luminaires off or dim to a predetermined level set in the lighting control system software. Allow for a “transition” time (to fade luminaires down) from 0-59 seconds or up to 60 minutes. Time delays and fade rates can be different for occupancy sensing versus vacancy sensing.
 - b. Tier 2 – In addition to the behavior as described in Tier 1, after sensing vacancy, allow for an “intermediate step” where luminaires dim to a different predetermined level after a specified “time delay”. Alternately, allow lights to “blink” off then on as a visual indication to occupants that the occupancy sensors have already timed out – before reducing light levels based on settings for the “vacant” state. Fade rates for this intermediate step may be different than for the base behavior as described in Tier 1.
 - c. Tier 3 – Allow for two “intermediate steps” as described above in Tier 2.
 - d. Tier 4 – Allow for an unlimited number of “intermediate steps” as described above in Tier 2.
- iii. Scheduling – control system shall allow the creation of a schedule that will determine which “control profiles” are in effect at what times, including:

- 1. Normal schedule – allows creation of “typical” schedules.

For example, the following might be common blocks of time for standard operation: weekday daytime, weekday evening, weekday overnight hours, weekend.

- 2. Temporary schedule – allows creation of atypical or one-time events that would override the normal schedule.

For example: holiday, initial system testing, demand response event, photosensor calibration, special function.

- 3. Format:
 - a. The lighting control system shall utilize a Microsoft Outlook-style calendar for the creation of “normal” as well as “temporary” (or “exception”) schedules. Any “temporary” schedule shall override the “normal” schedule in effect at that time.
 - b. “Default” behavior – default behavior may be created without selecting specific blocks of time to determine when the default behavior is in effect.

- c. Individual events for either “normal” or “temporary” schedules may be any duration of time based on increments of 1 minute, and as short as 2 minutes in duration.

The purpose of creating individual events for a system’s or zone’s schedule is to use modes of behavior that differ from the default mode. For example, the default mode may be set to “auto on/auto off”, making use of the occupancy sensors. During nighttime hours, an event may be created so the system performs in a “manual on/timed off” mode, requiring activation of lights by switches that only keep lights on for a specified period of time.

- d. The control system shall be capable of creating “overnight” events (spanning midnight).
- e. Events may be created that repeat indefinitely (with no end date).

Verify with the manufacturer what happens at the transition from one event to an adjacent event (or to/from default operation) in the schedule. For example, in some systems, “exception” events to the normal schedule only allow you to program a duration of 23 hours and 59 minutes (12:00 a.m. to 11:59 p.m.). As a result, the system reverts to “default” mode behavior for 1 minute until the exception event for the following day takes effect at 12:00 a.m. In other words, it’s not true 24-hour operation. This may be problematic in certain applications. A similarly awkward transition may happen where any two blocks of time bump into each other on a “normal” or “exception” schedule. What happens at that transition point? Verify with the manufacturer.

- f. Provide automatic system time adjustments for Daylight Savings Time as well as for leap years. This may be achieved internally, or it may be done by reference to an external NTP (Network Time Protocol) server. *[If an NTP server is available and can be linked to the lighting control system, keep that language and delete reference to this being done “internally”.]*

Some systems may allow for the use of an “astronomical time clock” function (that determines sunrise and sunset throughout the year). They may use this function to determine when specific behavior will occur with the fixtures (dimming, switching on or off, etc.). If this function is desired, verify its availability and functionality for any control system being considered.

- iv. Tuning – the control system shall allow for presetting a reduction in light levels throughout a specific zone(s). This variable will be set in each control profile and will be active when a given profile is active based on the schedule.

For example, control profiles may set the default maximum light level at 80% for typical daytime use and at 50% for typical evening use based on their respective control profiles.

- v. Demand response/demand reduction (DR):
 - 1. Methods of activation: *[select one]*

- a. Tier 1 – The lighting control system shall allow programming of manual or scheduled reduction of light levels based on preprogrammed values.

Examples of specific behavior that might be programmed as part of a demand response/demand reduction strategy might include:

- Reduction of light levels in specified zones by a certain percentage (in a range of 0-100% of current light output).
- Reduction of light levels in specified zones to a specific light output (in a range of 0-100% of maximum light output).
- Turning off specified zones.
- Override of occupancy sensors so that even if a space is occupied, the luminaires in designated zones shall turn or remain off.

In some lighting control systems, demand response/demand reduction (DR) behavior can be activated by establishing specific events with preprogrammed values (as described above). These scheduled events typically override normal behavior for that period of time. This requires that someone create these events in the system's calendar. Some electric utilities have pricing programs that incentivize customers who incorporate DR strategies to reduce the load in their facilities. One such utility's program requires that participants reduce their electric load during at least 9 of the 15 days per year when the utility deems that demand reductions are necessary. The utility determines which days qualify based on forecasted weather, temperature, etc. This determination is typically made one day in advance of a DR "event". As such, this behavior needs to be preprogrammed in the system during commissioning, so that activating DR behavior is as simple as adding block of time to the system's schedule the day prior to the DR "event".

- b. Tier 2 – Provide all of the options for preprogramming a reduction of light levels as mentioned for Tier 1. In addition, provide an interface to an Automated Demand Response (ADR) server to automatically activate demand response/demand reduction functions in the lighting control system as described above.

If the lighting control system can be linked to an Automated Demand Response (ADR) signal from an outside source, the system can be preprogrammed to reduce loads as described above (by certain percentages, to specific levels, to shut lights off, etc.). The activation of these events would then occur automatically and would not require any user input after the system is initially commissioned and preprogrammed. Verify the availability and function of linking to an ADR signal if this is desired. It's also worth checking with local utilities and/or other entities that may offer financial incentives for participation in such an ADR program. In some cases, incentive levels for participation in ADR programs are greater than for participation in programs utilizing manual activation of DR events. It's also important to discuss possible ADR or other energy-efficiency projects with the utility or other entities up-front, since most require an application for incentives in advance of installation.

2. Severity of events – regardless of whether demand response events are activated manually or by a signal from an ADR server, allow for preprogramming demand response/demand reduction events with at least three degrees of severity.

As examples, luminaires may behave as follows for events of different severity:

- Medium severity – for example, reduce light levels by 15% from current levels.
 - High severity – for example, reduce light levels to 50% of the maximum output.
 - Critical severity – for example, turn lights off.
3. “Opting out” – the lighting control system must allow any zone to “opt out” of a manual or automated demand response event.

For example, a specific area or room may require luminaires to remain on for safety reasons and they should not be dimmed or turn off even in a load-shedding situation. Allowing those zones to “opt out” of a demand response event allows the luminaires to continue to operate at normal levels.

- vi. Manual overrides – the following devices or methods may be used to manually control any zone or combination of zones *[include those that are required on a project and delete the others]*:
 1. Types/methods of manual override:
 - a. Wallbox switches/dimmers.
 - b. Preset scene selector panels (for example, used in a conference room to dim all zones to predetermined levels by pushing a single button for each scene).
 - c. Touch screens.
 - d. Smartphone apps.
 - e. Software-based control.
 - f. Input from a BMS (for example to turn all luminaires to full on in an emergency situation other than during loss of normal power).
 2. “Logic” for override behavior – variables can be set in the system software to control the behavior of manual override devices or methods. *[Based on descriptions below, if specific behaviors are required in your project, make sure to describe them here.]*

Examples of/issues regarding override behavior logic:

- The default system logic may dictate that after a zone is manually overridden, it will automatically revert to the preprogrammed behavior after the next change in the normal schedule – or it may not. Applicable codes may limit the duration of any manual override period.
- A time delay may be set in the system software that causes an overridden zone to revert to the default behavior based on the schedule after a specified period of time. It may be desirable to set different time delay periods for different profiles or schedules. For example, a wallbox switch/dimmer may override the operation of a zone for up to 2 hours during normal daytime use, but only for 1 hour during evening or nighttime use to provide enough light for cleaning crews before reverting to default operation.
- A hierarchical structure may be created such that different devices and/or methods have greater levels (and/or longer periods) of control over the default system behavior. For example, an “emergency” input signal from a BMS may override all default system behavior and prevent the system from automatically reverting to normal operation until the BMS and/or authorized personnel have cleared the emergency condition.
- It is incumbent upon the vendors to clearly indicate and explain the sequence of control logic in operation manuals and on-line help screens. If this is not clearly explained, then the system may exhibit behavior that is confusing. For example, what happens if you switch a zone off using a wallbox switch/dimmer? Does the zone switch back on after the specified “manual override time delay” is over? Does the zone remain off irrespective of the “manual override time delay” as programmed in the system, only turning back on if occupancy is sensed, or only at the next normal schedule change? Verify system operation with the manufacturer.

e. Control profiles:

- i. Control system software shall allow for creation of “profiles” that contain variables for controlling the behavior of luminaires. Control profiles may be activated automatically by creating blocks of time in the schedule during which a specific profile is in effect. The software shall also allow for creation of a “default” – when a specific control profile is active unless a separate scheduled event is created that overrides the default control profile. These variables include (but are not limited to):
 1. Occupancy sensor input – whether or not occupancy/vacancy sensors are used, time delays upon sensing occupancy or vacancy before lights turn on or off (or dim), sensitivity, transition times between states, etc.
 2. Daylight harvesting – high and low setpoints to create a deadband for dimming or switching fixtures in response to available daylight, time delay before change of electric lighting is allowed, fade rate(s) for dimming lights up or down, etc.
 3. Daylight “hold off” – keeps lights off if there is enough available daylight even if there is occupancy in the space, and allows setting the threshold for the “hold off” function.

4. Manual override – allows for occupant override of the preprogrammed control profile, and for setting the maximum override time period before luminaires revert to preprogrammed operation.
- ii. Writing control profiles: control profiles (also called control narratives or sequences of operation) must be written that contain values for all of the variables provided by the system. Unless there is already a company-wide standard for typical lighting control profiles, the designer shall create control profiles prior to commissioning and submit to the owner for review and approval.

It is **extremely** important to create these control profiles prior to system commissioning. Otherwise, the installing contractor, manufacturer, manufacturer’s agent or independent commissioning agent won’t know how to program the system based on the owner’s requirements. Preferably, control profiles should be written as early as possible during the design phase, because the desired behavior of a lighting control system is likely to impact which systems are considered for use. Writing control profiles is part of the design and specification process, and they should be included as part of the final specification documents.

- f. Power metering – the lighting control vendor shall provide a means to measure instantaneous power use on a per-luminaire or per-zone basis. *[Verify the availability of power metering functions with the manufacturer, and if so, how they operate in the proposed system. If this function is desired, indicate the granularity required for the measured power use data.]*

Some currently available systems provide a means to measure actual power use on a per-luminaire or per-zone basis. Other systems only provide an estimate of actual power use by correlating dimmed levels to specific power levels using lookup tables. If actual power metering is desired (or required, for example to demonstrate compliance with a utility incentive program), verify that a system being considered incorporates some method for measuring actual power use – for example by using on-board current transducers (CTs) housed in a controller or LED driver, or other circuitry that provides the same information. Other systems may allow for the provision of third-party meters such as current transducers that can be connected to the lighting control system for purposes of reporting instantaneous power levels. Certain electric utilities have already started to test products that contain integral CTs or other circuitry to measure actual power. At some point, utility companies may develop incentive programs that require confirmation of reduced energy use levels. It may be advantageous to use a lighting control system that already incorporate provision for measuring actual power use. Discuss the availability and functionality of such provisions during the design phase.

- g. Node licenses or additional recurring costs. *[Verify with the manufacturer whether licenses or other charges are assessed based on the quantity of system components or for any other reason at all].*

Some lighting control systems require the purchase of licenses for “nodes”. For example, in a wireless control system, a node may be an on-board controller in a luminaire, a wireless sensor or a wireless switch. In order to avoid surprises during initial installation or during any future expansion of the system, it’s essential to determine if licensing or any other costs may be incurred in addition to the physical equipment itself.

- h. BACnet integration:
 - i. Some lighting control systems have provisions to allow for integration with other building management systems using BACnet (or other) protocol. If this function is desired, verify the availability of a BACnet (or other) interface with the vendor during design and specification.
 - ii. Integration with other systems using BACnet (or other) protocol may require the purchase of additional licenses for the BACnet portion of the lighting control system. Verify with the vendor during design and installation.
 - iii. Integration with other systems using BACnet (or other) protocol may bypass the programming that controls behavior of luminaires in the lighting control system. In that case they would “pass through” commands and usage data. Verify with the vendor during design and installation.
- i. Graphic user interface (GUI): *[select one]*
 - i. Tier 1 – Display “near real time” status of zones (for example – on, off, dimmed level) overlaid onto a floor plan of the space. “Near real time” is defined as the status of zones being updated at intervals of no greater than 1 minute.
 - ii. Tier 2 – In addition to the display of “near real time” status of the zones as described in Tier 1, allow for manual override of a zone(s) directly from the graphic user interface.
 - iii. Tier 3 – In addition to the functionality as described in Tier 2, allow for access to reporting of historical zone information directly from the graphic user interface. Such information shall include (but not be limited to):
 - 1. Peak demand (kW) in any 15-minute period.
 - 2. Energy use for every 15-minute period (measured in kWh).
 - 3. Occupancy for every 1-hour period (in both minutes of occupancy and percentage).
 - 4. Demand response/demand reduction condition (if any, including level of severity).
 - 5. Alarms, alerts or error messages for any equipment not performing as required, including control system communication errors.
- j. Emergency (EM) lighting – for overhead luminaires:
 - i. A licensed electrical engineer shall determine which new or retrofitted luminaires (or which fixture segments in continuous rows) require EM power

feed or integral batteries for emergency lighting, in accordance with applicable code requirements.

- ii. EM luminaires designated by the electrical engineer shall provide emergency lighting functions upon loss of normal power.
- iii. When normal power is available, all EM luminaires shall operate according to the control profiles as set in the system for normal operation in their respective zones.

Verify whether applicable codes allow dimming in luminaires designated to provide emergency lighting. Additionally, certain codes **prohibit** turning off luminaires designated as EM, even if they can be dimmed in a normal-power condition (e.g., New York City). Other codes require that fixtures designated as EM **must** be turned off in a normal-power condition (e.g., California Title 24).

- iv. If required by code, bypass control system wiring (power and/or control wiring) to maintain code-compliant emergency egress lighting functions.

In many lighting control systems, the equipment is designed to operate appropriately during an emergency condition. For example, DALI ballasts and drivers are designed to automatically bring the light output to full upon loss of the control signal (in the DALI wires). In other systems, controllers are designed to close relays and turn luminaires to full on when the signal on the 0-10V control wires is lost. However, in certain locations, applicable codes require additional components to insure that these ballasts, drivers or controllers are totally bypassed, even if they are designed to operate appropriately in an emergency condition. This may necessitate the use of additional components (e.g., UL924 relays) either centrally located or within fixture housings. This may have a substantial impact on installation complexity and cost. As such, it's important to consult with a licensed electrical engineer to make this determination at the outset of a project.

- v. A licensed electrical engineer shall determine if a change to the normal or emergency operation of EM luminaires will require submission of documents to an "authority having jurisdiction" (AHJ), to verify that they will still provide emergency lighting according to applicable codes.
- vi. A licensed electrical engineer shall determine if new or retrofitted luminaires will change the light levels or power draw on emergency power sources in an emergency lighting situation, and if any such changes prevent the lighting system and luminaires from operating according to code requirements or within the capacity of the EM power source.

It's likely that the electric load and/or light output provided by EM luminaires will change once they are replaced or retrofitted with LED luminaires, lamps or retrofit kits. It may be necessary to consult the building operation staff, a licensed electrician and/or a licensed electrical engineer to insure that the emergency power source (such as centralized batteries or a generator) can handle any additional (or even reduced) load. Additionally, a licensed electrical engineer may have to perform new calculations to verify that the new or retrofitted EM luminaires will provide adequate light levels to meet applicable code requirements.

- k. System failures – verify with the manufacturer what will happen when each component fails, considering (by not limited by) the following questions *[list specific requirements based on the questions below]*:

In a complex lighting control system, it's possible that centralized or distributed components may fail from time to time. It's important to determine how the system deals with failures including fault detection, warnings, alarms, alerts, error messages, and resolution.

- i. Server – for example, if a centrally located server fails or loses power, will other system components continue to operate normally? Will there be a loss of usage data during the time that the server was down?
 - ii. Gateways – for example, if wired or wireless gateways fail or lose power, will luminaires still operate normally? Will usage data be lost during that time?
 - iii. On-board controllers – for example, if controllers fail or lose a signal from the control system, will they still operate normally, or shut off, or turn on to full output?
 - iv. Sensors and switches – for example, if sensors or switches fail, will luminaires still operate based on default behavior as determined by the server/software?
 - v. Software – for example, similarly to any complex computerized system, software for lighting control systems may be regularly updated by the manufacturer. What happens if the software is updated and causes the system to operate abnormally? Is there a way to force the software to revert back to a previous version that is known to make the system work as specified? What is the procedure used by the manufacturer to correct bugs in the software or firmware in devices (and how regularly is that done)? How will bug fixes affect the operation of the system in the space?
 - vi. Normal vs. abnormal operation – if there are critical tasks being performed in a space, it's essential to know how the system will operate under “normal” as well as “abnormal” conditions. Any manufacturer with a proven track record of having deployed their system for at least three years should have a clear understanding of what happens based on various configurations and topologies and under different conditions.
 - vii. “Failsafe” operation – if the system starts to behave erratically for any reason at all, is there a method available to entirely bypass the system and operate luminaires manually? Will local switches (or any other components or methods) still operate luminaires even if the rest of the system is disabled? How about occupancy sensors or photosensors?
- l. Standby power – if “standby power” in luminaires is necessary to maintain continuity in on-board control circuitry, that power usage shall be limited to a maximum of 1 Watt per luminaire.

For example, in certain DALI systems, sensors may be connected to the fluorescent ballasts or LED drivers integral to each luminaire. If so, then minimal power must be maintained even if the fluorescent lamp or LED array is off, to continuously provide power and signal to the sensors.

- m. Fade rate – the lighting control system shall be capable of allowing the light level to fade (raise/dim up or down) between 0-59 seconds, or up to 60 minutes *[if longer fade rates are required, change these values as necessary]*. Fade rates may be different for different control profiles and/or during different schedules.
- n. Reporting:
 - i. Information to be reported/saved/stored by the control system:
 - 1. Peak demand (kW) in any 15-minute period.
 - 2. Energy use for every 15-minute period (measured in kWh).
 - 3. Occupancy for every 1-hour period (in both minutes of occupancy and percentage).
 - 4. Demand response/demand reduction condition (if any, including level of severity).
 - 5. Alarms, alerts or error messages for any equipment not performing as required (including control system communication errors).
 - ii. Event logs – record logs of all events in the system (schedule changes, occupancy or vacancy, dimming lights in response to photosensor input, manual overrides, alarms, errors, etc.).
 - iii. Storage – store all historical data indefinitely in server, including energy usage and event logs.
 - iv. Data format – CSV (comma separated values) or Microsoft Excel. Data files may be exported from the system on an as-needed basis.

Increasingly, lighting control system usage and event logs are treated as data sources similarly to other building systems. It may be desirable to review or even export such data on a regular basis, perhaps even automatically. If so, then it's important to discuss desired reporting or data access with a lighting control system vendor to determine if and how this may be accomplished. Additionally, regular or even intermittent exporting of data may require "remote" access to the lighting control system. If remote access to the system is not provided, then exporting such data would need to be accomplished manually by trained personnel.

- v. Access to historical data. *[If data cannot be accessed through the graphic user interface, allow data to be accessed through standard menu options in the control system software – verify with the manufacturer.]*

- vi. Reports and graphs. *[Verify with the manufacturer what types of reports and graphs the system can create during design and specification.]*

Most lighting control systems have various options for creating reports and/or graphs of the system's usage and operation. Typically this can be created for the entire facility or by zone.

o. Notifications:

- i. The lighting control system shall have some method of sending notifications about errors, alarms, alerts, warnings, etc.

Most currently available lighting control systems have methods of sending notifications about problems that require attention. These notifications are usually sent via e-mail, but it's possible that they may also be sent by text or other methods.

- ii. E-mail or text notifications – the lighting control system's notification function shall send e-mails and/or texts *[specify which are desired]* to designated staff. *[Determine if the lighting control system can be programmed to send notifications to only one or more than one person, and if each recipient can receive different forms of alerts, warnings, error messages, etc.]*
 - iii. Daily reports – send daily reports of equipment requiring servicing or replacement. *[Verify with potential vendors if such a function is available, and if so, how it operates.]*
- p. Backup – provide a means to automatically backup programming (schedules, control profiles, etc.), usage data files and event logs on a regularly scheduled basis.
- i. Backup files on the system's server.
 - ii. Provide some method to backup files to a USB drive and/or remote storage device, or to e-mail backup files. In the event of loss of program or usage data on the server, backup files may be uploaded to the server to restore normal operation (for control profiles and schedules, in addition to usage and event logs). *[Verify with potential vendors if such a function is available and, if so, how it operates.]*
- q. Energizing system before commissioning – provide a means to energize all luminaires at full output prior to commissioning the lighting control system.

Often, the commissioning agent is not the installing electrical contractor. Therefore, some means must be provided to energize luminaires upon completion of installation but before commencement of the commissioning process. This is especially important in a retrofit situation where the space remains occupied throughout the installation period.

- r. Connecting control system components and connecting to the system: *[Review all of these considerations in this section with the owner at the outset of the project; include language describing the desired (or allowable) methods of connection and delete the others.]*

It's **extremely** important to review IT and connectivity issues with the owner at the outset of the design process. Many owners are open to allowing existing internal networks (intranets) to be used for connections to the system and between system components. Others are not. Some companies have extremely robust prohibitions about allowing anything to be connected to existing networks for security reasons. These determinations have a very substantial effect on the complexity and cost of installation.

i. Connections between system components:

1. Most (but not all) lighting control systems have a centrally located server. This will usually be installed in an IT server room or electrical closet. Typically, some of the components are connected to the server – such as gateways to luminaires, controllers, sensors, switches, touch panels, DALI ballasts or drivers, etc.
2. Most systems allow for connection between some or all of these components and the server via the owner's existing communications network (intranet) – if the owner allows that. For example, gateways connected to luminaires are often provided with IP addresses and can therefore be connected to an existing communication network (intranet). If the server is also connected to the network, then it can communicate with the gateways without the need for additional wiring.
3. If the owner will not allow for using any of their internal communications networks (intranets) to connect system components, then they will need to be connected with additional dedicated wiring, unless the system is designed to allow some or all of these connections to be made wirelessly.

ii. Connecting to the system (remote access):

As described below, there are several major benefits to allowing "remote access" to the lighting control system. However, lighting control systems are typically designed to operate without remote access in situations where the owner will not allow that. In those cases, the system would only be accessible by trained personnel, on-site. Many of the functions described below wouldn't be available – such as the ability of the vendor to remotely update the server's software, troubleshoot, or examine usage or event logs. Therefore, it's important to make this determination at the outset of a project.

1. Most lighting control systems are designed to allow remote access to the operating software as previously described, usually residing on a centrally-located server. A common method is to access a webpage or program on the server from a remote location.
2. If the owner allows the server (and/or other system components) to reside on an internal communications network (intranet), then it may be possible to access the system's software from any computer on the owner's network. It may also be possible to access the software from any remote location. In some cases, this may require a VPN (virtual private network) to access the server from outside the owner's internal

network. It is essential to make this determination during the design and specification of the lighting control system.

3. If the owner will not allow for using their internal communications network to access the software residing on the server (or other system components), then it may be necessary to install a dedicated wireless access point (for example, using a 3G modem, aircard, etc.) – or some other method of communicating with the system without accessing the existing building network – in order to gain remote access.
4. Access to the system’s software will be needed by some or all of the following:
 - a. System operator/administrator – this is usually someone on the building operation/engineering staff.
 - b. Lighting control system manufacturer – this may be required for troubleshooting, software updates, commissioning, recommissioning, rezoning, etc.
 - c. Lighting designer/electrical engineer/others – specifiers may want access to verify that the system has been installed and is operating as designed, or to retrieve usage data for analysis.
 - d. Users – many systems have methods to allow individual occupants to control luminaires and/or other devices connected to the system. For example, an occupant in a private office may be given access to or have control over the luminaires only in his or her room, but is not able to control luminaires in other private or open office areas.
 - e. “Dashboards” – many systems have methods to allow for displaying system usage (e.g., kWh/hour, kW <load> in percent or amount, usage compared to baseline <actual kW/max kW>, demand response event status, if any, etc.). A common method is for a remotely located monitor to connect to the server’s software by accessing its URL for the dashboard display.
- s. User access levels – allow different users to access different functions in the system. *[Verify whether the system allows for different access levels during design and specification and, if so, how.]* Examples of different levels of access and functionality might include: *[Include those required by the owner and delete the others.]*
 - i. System administrator – has access to all functions and control over all luminaires (and/or other devices) on the system.
 - ii. Tenants – if a system is used to control luminaires in a multi-tenant space, tenants may be given access only to luminaires in their space.

- iii. Individual users – occupants may be given control over the luminaires in their own private office, or luminaires that are located over their workstation in an open office area.
 - iv. Guests – other people may be given access to monitor the system, without being able to make any changes.
- t. Commissioning – a commissioning agent for the lighting control system shall be selected by the owner and design team. The commissioning process shall include the following steps:

In certain situations, if applicable codes allow, the manufacturer or manufacturer’s representative may provide some or all of the commissioning services as described below.

- i. Verification of correctly installed wiring and components.

“Verification” of the wiring is typically performed by the installing contractor prior to commissioning by an independent agent. Additionally, certain systems have devices that allow testing of the network as it’s being installed (for example, to check for continuity of the control signal on low-voltage wiring). *[If these are required, verify the availability of such devices with the manufacturer and make sure that they are specified and included in the purchase order.]* Once this initial wiring verification is complete, the remainder of the commissioning process can continue as described below by the control system vendor, or by an independent agent (and/or others), if required. Note that some vendors require that the verification be successfully completed by factory-trained staff before they are willing to schedule a date for the remainder of commissioning and programming. If the system doesn’t “pass” verification the first time, the electrical contractor must correct any wiring errors, and this may also delay when the system finally gets commissioned and programmed.

- ii. Creating zones in the lighting control system software (including graphic overlays for the graphic user interface).

In many systems, zones can be created in advance before the server is installed on the job site. This may reduce the time required on-site to get the system up and running.

- iii. Discovery of lighting control system components including gateways, controllers, sensors, switches, wall panels, etc. (This can only be accomplished once the system is installed and up and running.)
- iv. Creating profiles and schedules for typical operation, as well as atypical events like testing after initial start-up, daylight calibration, demand response events, 100-hour fluorescent lamp burn-in, etc.

As with zone creation, many systems allow creation of profiles and/or schedules in advance.

- v. Assignment of luminaires/groups of luminaires to appropriate zones as created above. (This can only be accomplished once the system is installed and up and running.)
- vi. Calibration of photosensors.

Different systems have different methods of calibration, and may also have different methods depending on what type of photosensor is installed (closed-loop, open-loop, etc.). Some systems or methods of calibration require adjustment of photosensors during daylight hours while the commissioning agent checks target light levels with a light meter. Others require recording light levels achieved by electric light only during nighttime hours as previously described. Some may require both. *[Verify the method(s) of calibration with the manufacturer during the design phase and describe in the specifications.]* Typically, luminaires assigned to zones controlled by photosensors will not dim until the photosensor for that zone has been successfully calibrated.

- vii. Correction of any faults, warnings, alerts, alarms, etc.
- viii. Verification that all aspects of the control system software are operating properly and that the system is recording data as described above.
- ix. Setting appropriate values to establish baselines. These typically include any or all of the following:
 - 1. Hours of operation.
 - 2. Fixture types and wattages. Note that it may be desirable to have a “pre-install” baseline as well as a “post-install” baseline if the luminaires are replaced or retrofitted.
 - 3. Electricity cost (per kWh, which may vary based on time of day).
 - 4. Percentage of occupancy (this can be established beforehand by using loggers and analyzing the data).
 - 5. Cost of CO₂ (carbon dioxide emissions rate, based on electricity or gas cost – in some cases, CO₂ emission reductions are taken into account when considering financial incentives, payback, etc.).
- x. Resetting all usage and event data recorded since initial system installation to zero, if desired.

Caution – it may or may not be desirable to reset usage and event data to zero. Resetting this data may delete any history of the system operation as of initial power-up. It may be highly desirable to retain access to the history of the system’s operation from the moment of initial power-up for the purpose of troubleshooting any problematic system behavior.

- xi. Clearing all active alarms, warnings, alerts, etc. (after insuring that the system is functioning normally).

After all of these steps are completed as described above, the lighting control system should be functioning normally, and recording data.

- u. User training:

- i. Lighting control system vendor shall provide *[specify amount]* hours of on-site training for designated representatives of owner and design team to learn how to operate the system.
 - ii. Lighting control system vendor shall provide reference manuals in print and/or PDF form *[specify which]*, as well as context-sensitive help screens in the control system software itself.
- v. Technical support:
- i. Allow remote access to the lighting control system server (with appropriate safeguards including firewalls, passwords, etc.). At a minimum, the lighting control system vendor shall be granted remote access in order to troubleshoot the system in the event of a malfunction of any of the hardware or software as described in this document.

As previously mentioned, specific owners may not be willing to allow for remote access to a lighting control system by anyone – even people in their own organization. This decision has a major impact on the ongoing operation of the system. For example, remote access may be used for any or all of the following: 1.) vendor updates of system software or firmware, 2.) remote troubleshooting by vendor, 3.) remote commissioning or rezoning by vendor, 4.) checks by owner, design team or others on the system operation, zone behavior or status, etc., 5.) offloading backup files to remote locations, 6.) linking monitors external to the system to display a “dashboard” (such as in a building’s lobby). If the owner specifically prohibits any form of remote access to the system, it will preclude most or all of those activities. It’s **extremely** important to determine if the owner is willing to allow remote access – or not – at the outset of the design and specification process.

- ii. Within *[specify period of time, e.g., one month, one year, etc.]* from initial system power-up, the lighting control system vendor will make site visits at their own expense in order to correct any problems within the lighting control system.

Before placing a purchase order for a lighting control system, it’s essential to know how the vendor handles troubleshooting or other problematic issues. *[After reviewing these questions with potential vendors as well as the owner, it may be desirable to include these answers in the specification text.]* For example:

- Does the vendor typically allow time to meet with the electrical contractor in advance of installation to review wiring terminations, topology of cable runs, and/or other issues specific to their system? Note that many electrical contractors are unfamiliar with advanced lighting control systems and their underlying technology – such as DALI, 0-10V, other protocols, topologies, emergency transfer methods, etc. It’s important for someone to provide a minimum amount of education to the installing electrical contractor in advance of actual installation to reduce errors and eliminate delays.
- Does the vendor provide a “factory start-up” (meaning that someone from the factory will be on-site to initially power-up the system)?

- What will happen if the vendor is on-site for initial power-up, but finds that the system hasn't been installed as shown in the submittal documents?
- What will happen if any system components fail upon initial installation or do not operate as expected? How will they be replaced? How will the replacement components be shipped to the job site, and at whose cost?
- What will happen if there are problems with the software not behaving as expected? Who will troubleshoot and resolve those?
- How quickly will the vendor address problems that arise during or after initial commissioning? Will the vendor only remotely investigate system problems or will a designated representative be available to troubleshoot on-site if necessary? If so, will the vendor make a commitment to getting this personnel to the job site within a specific period of time (1 day, 1 week, etc.)?
- How will problems be addressed and handled that arise after any initial warranty period has expired?

It's also essential to determine how technical support will be handled both during the initial warranty period as well as afterwards. For example, are unlimited calls to the vendor allowed during installation, commissioning, on-going operation, etc.? If not, what is the limit? Is there an additional cost for on-going technical support? *[Verify all of these issues with prospective control system vendors and incorporate that information into the specifications.]*

- w. Vendor experience – any prospective lighting control system vendor must have at least three years of experience in supplying and successfully implementing advanced lighting control systems with similar features and operation as described above.
- x. Procurement process issues for luminaires:
 - i. Submittals – luminaire vendors shall submit the follow for approval before fabrication and shipping equipment to the job site. *[Verify how long the manufacturer will need to produce these drawings and whether they will require any materials from the owner or specifier (such as CAD background drawings, control schedules, etc.). Determine who will review and approve these materials prior to releasing a purchase order.]* The submittals must include (but are not limited to) the following:
 1. Luminaire detail drawings – showing all views necessary to fully describe the luminaire. This may include plan views, section drawings, run configurations, mounting details and/or any other drawings necessary to show every aspect of the luminaires to be installed.
 2. Integral controls components – besides the LED driver(s), which may or may not be part of the lighting control system itself, any additional on-board or remote-mounted components must be shown on the drawings, as well as all associated wiring (cord sets, individual conductors, etc.). These may include fixture controllers, on-board

sensors, UL924 relays and/or other components required by the lighting control system.

3. Quantities – the luminaire vendor shall indicate quantities required for each fixture type (based on different fixture types, different mounting conditions, different length units, different on-board control equipment, normal vs. EM, etc.).

Note about fixture type letters – specifiers often note minor differences between fixture types in the written descriptions in a luminaire schedule. For example, 4' versus 8' lengths may be noted in the written portion, but not otherwise distinguished by type letter (e.g., TYPE A-4 versus TYPE A-8). Another example is that luminaires intended to provide EM lighting in emergency conditions may be indicated on lighting plans by drawing a diagonal line through the fixture and filling in half of the symbol. However, it is vastly preferable to use distinct type letters to indicate every unique fixture type. In that case, fixture types might be listed in the luminaire schedule as TYPE LA versus TYPE LA-EM, for example. Keep in mind that “-EM” versions of the same fixture may need additional on-board equipment (such as integral UL924 relays). Another example of a slight difference between fixture types is that the base fixture may not incorporate on-board sensors, but 5-10% of the fixtures throughout the open office may in fact have on-board sensors. This may be indicated as, for example, TYPE MA versus TYPE MA-1. There are a variety of reasons why each unique fixture type should be given its own distinct type letter. 1.) Different versions of the same fixture type may actually have difference characteristics – such as maximum input wattage – that may affect other documents or calculations. 2.) It makes it much easier to do accurate takeoffs to provide accurate quantities to vendors for fabrication. 3.) It makes it much easier for whoever receives shipments of fixtures to verify that the order is correct before accepting delivery. 4.) It makes it much easier for the electrical contractor to insure that they are installing the appropriate fixtures in the right locations.

- ii. Samples – luminaire vendors shall provide a working sample of each fixture type for review and approval by the owner and design team. Each sample shall be a complete, functional unit ready to be energized, including any on-board lighting control equipment required.

y. Procurement process issues for lighting control systems:

- i. Submittals – lighting control system vendors shall submit the following for approval before fabrication and shipping equipment to the job site. *[Verify how long the manufacturer will need to produce these drawings and whether they will require any materials from the owner or specifier (such as CAD background drawings, control schedules, etc.). Determine who will review and approve these materials prior to releasing a purchase order.]* The submittals shall include (but are not limited to) the following:

Most (but not all) manufacturers have historically required approval of submittal drawings, a Bill of Materials and/or other documents before they ship products to the job site. It's **imperative** to require a lighting control system vendor to go through the submittal process. Otherwise, the designer and owner have no recourse if equipment is delivered that doesn't meet the project requirements.

1. Plans – showing location of all lighting control system components and how they are connected.

2. One-line diagrams – showing all lighting control system components and how they are connected (but not showing exact locations on a plan of the space).
3. Wiring diagrams – the lighting control system vendor shall provide drawings showing **every wiring connection for all system components**.

Historically, vendors have **not** created project-specific drawings showing every wiring connection for all system components. Manufacturers usually rely on catalog sheets to indicate typical wiring connections for each component. However, many controls components are designed to be wired in a variety of ways. Therefore, to avoid any confusion on the job site during installation, every single wiring connection should be shown on the drawings. These drawings, as well as electrical engineering drawings (as prepared by a licensed electrical engineer) should be printed and available on the job-site for review by the installing electrical contractor. Often, a licensed electrical engineer will use a vendor's drawings as a basis for "official" electrical engineering drawings. Remember that the licensed electrical engineer is responsible for showing things like EM luminaires and any additional required equipment (e.g., dedicated computer terminals, existing networks, etc.). Therefore, it's essential that full-size prints of the electrical engineer's drawings be available on-site throughout the installation process. If those drawings incorporate information as prepared and submitted by the lighting control system vendor, then it may be adequate to only have prints of the official electrical engineering drawings available on-site without additional vendor-supplied drawings.

4. Control schedules – these are typically spreadsheets that indicate what resides in each control zone, such as:
 - a. Luminaires, including quantity of each fixture type in that zone, wattage for each fixture type, type of load (incandescent, fluorescent, LED, low-voltage magnetic, etc.).
 - b. Total wattage for the entire zone.
 - c. It is also desirable to indicate if any of the luminaires in a particular zone provide emergency lighting.
 - d. Occupancy sensors associated with that zone.
 - e. Photosensors associated with that zone.
 - f. Dimmer switches or touch screens associated with that zone.
 5. Manufacturer's catalog sheets of all equipment.
- ii. Samples – the lighting control system vendor shall provide the following sample equipment: *[The topology and wiring methods for many new lighting control systems are different than the existing topology and wiring in most buildings. It is advantageous for the installing contractor to acquire samples of certain equipment in advance of the installation. These may be provided as free samples by the manufacturer prior to received a purchase order, or subsequent to receiving a purchase order, or the manufacturer may want to*

provide these samples only as part of an actual order. Verify with the lighting control vendor.]

1. LED drivers – these may be 0-10V, DALI and/or other types. (Not all electrical contractors have experience installing ballasts that contain more than just a hot wire, neutral wire, and a ground.)
 2. Fluorescent ballasts (assuming that any fluorescent luminaires are still used in the space) – these may be 0-10V, DALI and/or other types.
 3. On-board controllers (such as wired or wireless controllers that switch power to as well as dim the driver or ballast).
 4. Centrally located load controllers.
 5. Sensors – wired or wireless occupancy sensors or photosensors.
 6. Wall-mounted dimmer switches or touch panels.
 7. Emergency transfer devices (such as UL924 compliant components).
- iii. Takeoffs/Bill of Materials – the lighting control system vendor shall provide a Bill of Materials for review by the project team based on takeoffs prepared by the electrical contractor. Takeoffs (counting number of luminaires and other components such as sensors, switches, etc.) shall be created by the electrical contractor based on drawings and a walk-through of the existing space and submitted to the luminaire and lighting control system vendors to aid them in preparing Bills of Materials for the project.

This will need to be accurate so the manufacturer can prepare a realistic quote for the project. Note that when deploying a lighting control system, topology and wiring methods may change. For example, existing luminaires may be wired with switch legs to provide multiple levels of light from two or more switches. A new lighting control system will make use of dimming drivers for LED luminaires instead of multiple switch legs to provide different levels of light. This may have an impact on the required topology, wiring or equipment. In any retrofit project, it's extremely important to have an accurate understanding of what currently exists in the space versus what the new design calls for.

- iv. Spares – the lighting control system vendor shall provide limited quantities of spare components for certain items. *[Specify which (e.g., LED drivers, on-board controllers, sensors, switches, etc.) and quantities or percentages of additional spares required.]*

Usually these would not include spares for expensive, centrally located components such as servers, gateways, etc. However, it may be desirable to procure an extra quantity of other control system components for a variety of reasons, such as:

- It's possible that any component may arrive at the job site in nonworking or damaged condition. If spare components are available, the installation work can continue while defective equipment is replaced.

- Availability of spares for components such as on-board controllers can allow for additional zone creation that may not have been anticipated during the design and specification phase.
 - v. Service plans – the lighting control system vendor shall provide a plan to cover on-going service of the lighting control system. *[Verify the availability and details of such plans with the manufacturer prior to placing a purchase order.]* These service plans might cover any or all of the following (or more): *[Keep items desired in a service plan and delete the others.]*
 1. Troubleshooting – either during or after the warranty period ends. (See u. Technical Support for a more detailed discussion about troubleshooting considerations.)
 2. Training – beyond what is provided immediately upon completion of system commissioning.
 3. Software and firmware upgrades:
 - a. Manufacturer shall provide upgrades for system software and component firmware for a period of *[specify time period]* from the date of completion of the on-site commissioning process. It may be desirable to negotiate a longer period for receiving software and firmware upgrades as part of the initial system cost.
 - b. Lighting control system software is typically upgraded by the manufacturer by remotely accessing the server. Component firmware may be upgraded by remotely accessing the component, or directly via a USB drive and/or other external method. *[Verify the methods of upgrade with the manufacturer.]*
 4. Recommissioning – changing or adding control zones, recalibrating sensors, adding any additional equipment or components, etc.
 - 5. Warranties – vendors shall provide the following warranty periods from date of final acceptance:
 - a. Luminaires – Ten (10) years.
 - b. LED drivers – Five (5) years.
 - c. Lighting control system – Five (5) years.

Appendix B: Performance Specifications (*without comments*)

1. Light level target values and energy goals:

- a. Task illuminance: at full light output, the lighting system will produce a minimum of 30 average horizontal maintained footcandles on task surfaces (assuming no daylight contribution).
- b. Lighting power density (LPD): *[select one]*
 - i. Tier 1 – Maximum connected lighting load including task lighting shall not exceed 75% of applicable code restrictions. *[Determine which code(s) are applicable to the project; e.g., IECC 2012/ASHRAE 90.1-2010/CA Title 24/etc. Then determine the maximum permissible connected lighting load.]*
 - ii. Tier 2 – Maximum connected lighting load including task lighting shall not exceed 50% of applicable code restrictions. *[Determine which code(s) are applicable to the project; e.g., IECC 2012/ASHRAE 90.1-2010/CA Title 24/etc. Then determine the maximum permissible connected lighting load.]*
- c. Annual lighting energy use: *[select one]*
 - i. Tier 1 – Energy use from connected lighting load (including task lighting) shall not exceed 2.0 kWh/square foot/year.
 - ii. Tier 2 – Energy use from connected lighting load (including task lighting) shall not exceed 1.5 kWh/square foot/year.
 - iii. Tier 3 – Energy use from connected lighting load (including task lighting) shall not exceed 1.0 kWh/square foot/year.

2. Overhead light fixtures for ambient light:

- a. Dimming: *[select one]*
 - i. Tier 1 – All overhead light fixtures shall be dimmable in a continuous range between 10-100% of full light output.
 - ii. Tier 2 – All overhead light fixtures shall be dimmable in a continuous range between 1-100% of full light output.
- b. Control system components – modify existing lighting scheme to incorporate dimming and any other required control system components as follows: *[select one]*
 - i. Option 1 – Retrofit existing luminaires to incorporate LED lamps, LED matrices or use complete “retrofit kits”, incorporating dimmable LED drivers as required. Incorporate additional control system components and new optical control media (e.g., lenses or diffusers) as required. Leave existing luminaire housings

and primary power feeds in place. Connect new low-voltage network wires as required for communication with the lighting control system.

- ii. Option 2 – Replace existing luminaires one-for-one with new LED luminaires incorporating dimmable drivers for LEDs, with any required control system components factory-installed. Reuse existing primary power feeds and connect to new luminaires. Connect new low-voltage network wires as required for communication with the lighting control system.
 - iii. Option 3 – Remove existing luminaires and install new LED luminaires with a new layout. Provide new luminaires incorporating dimmable drivers for LEDs, with any required control system components factory-installed, using appropriate spacings/locations to achieve the target illuminance levels. Patch ceiling and/or replace tiles as required. Reroute primary power feeds to new luminaires as required.
- c. Light source color: *[select one]*
- i. Tier 1:
 - 1. Correlated color temperature (CCT) – LEDs shall have a published CCT of 3500K or 4100K. Actual CCT for LEDs as shown on IES LM-79 tests may have a tolerance of $\pm 100\text{K}$. Therefore they must be in the range of either 3400-3600K (for nominal 3500K) or 4000-4200K (for nominal 4100K).
 - 2. Coloring rendering index (CRI) – LEDs or LED lamps shall have a published CRI of 80 or greater.
 - ii. Tier 2 – LEDs shall have a base CCT and CRI as described above. However, the CCT may be continuously increased up to 5000K at the user’s discretion (to more closely approximate the cooler color temperature of daylight), either by manually adjusting the color temperature (for example using some form of wallbox device) or by setting the desired CCT in the control system software. Fade rate for any such change in CCT may range from 0-59 seconds, or up to 60 minutes.
- d. Glare and luminance limits – to minimize direct glare from fixtures, restrict luminance as follows for any azimuth angle: *[select one]*
- i. Tier 1 – Restrict luminance at any vertical angle at or above 55° from nadir (from $55\text{-}90^\circ$) to 2000 candelas/square meter (cd/m^2).
 - ii. Tier 2 – Restrict luminance at the following vertical angles to:
 - 1. 850 cd/m^2 at 55° from nadir.
 - 2. 350 cd/m^2 at 65° from nadir.

3. 175 cd/m² at or above 75° from nadir.

3. Wiring:

- a. Wiring to and between luminaires – since all overhead luminaires need to be dimmable, it may be necessary to reroute existing wires or to run additional power wires and/or control wires. Methods of wiring include: *[select one]*
 - i. Option 1 – Reroute existing power wires and/or run additional power or control wires as necessary from existing or new luminaire locations to a centrally located electrical room(s). Terminate in existing or new distribution panels, depending on the control system.
 - ii. Option 2 – Distribute controllers in the plenum and run power and/or control wires as necessary to luminaires, or to distinct zones. Controllers shall not require “homeruns” back to a centrally located electrical closet(s) for either power or control wiring. Communicate between controllers, from controllers to server, and between controllers to user access points (terminal, switches, etc.) via a new data bus, company local area network (LAN), or wirelessly using radio frequency (RF) or other method of communication.
 - iii. Option 3 – Use existing power wires to luminaires. Luminaires shall be “self-contained”, with on-board components required to switch and dim fixtures, to communicate with the lighting control system (dimming ballasts, dimming drivers, controllers, radios, etc.), and to reconfigure the zoning. The luminaires shall communicate wirelessly with a gateway. If this option is selected, no additional wiring is required to existing (or new) luminaires.
- b. Wire colors – luminaire vendors shall use industry-standard wire colors for all line-voltage power feeds as well as low-voltage control connections.

4. Lighting control system for overhead luminaires:

- a. Dimming – as previously noted, all overhead luminaires shall be dimmable. Dimming range: *[select one]*
 - i. Tier 1 – All luminaires shall be continuously dimmable in a range of 10-100% measured light output.
 - ii. Tier 2 – All luminaires shall be continuously dimmable in a range of 1-100% measured light output.
- b. Minimum power at lowest light output: *[select one]*
 - i. Tier 1 – At the lowest light output, input power to the luminaire shall be no greater than 20% of the input power at maximum light output.
 - ii. Tier 2 – At the lowest light output, input power to the luminaires shall be no greater than 10% of the input power at maximum light output.

- c. Control zones for overhead luminaires: *[select one]*
- i. Option 1 – Low granularity occupancy zones: create zones corresponding to the coverage pattern of the occupancy sensors to be used (e.g., 500, 1000 or 2000 foot²). *[If occupancy sensors with specific coverage areas (or shapes) are desired, include those specific amounts or shapes in the specification language (and/or attach diagrams showing the coverage area/shape as appendices, or by including manufacturer’s catalog sheets).]*
 - ii. Option 2 – Medium granularity occupancy zones: create zones that are smaller than the coverage pattern of the occupancy sensors to be used (e.g., 200 foot²). This may be accomplished by masking portions of a ceiling-mounted sensor. Alternately, use occupancy sensors that have smaller coverage patterns than typical ceiling-mounted sensors (e.g., 200 foot²). *[If occupancy sensors with specific coverage areas (or shapes) are desired, include those specific amounts or shapes in the specification language (and/or attach diagrams showing the coverage area/shape as appendices, or by including manufacturer’s catalog sheets).]*
 - iii. Option 3 – Maximum granularity occupancy zones: create zones that correspond to individual luminaires. *[If occupancy sensors with specific coverage areas (or shapes) are desired, include those specific amounts or shapes in the specification language (and/or attach diagrams showing the coverage area/shape as appendices, or by including manufacturer’s catalog sheets).]*
- d. Control strategies – the lighting control system shall be capable of implementing the following lighting control strategies:
- i. Daylight harvesting – the availability and amount of daylight shall be determined by the use of photosensors. Luminaires in areas with sufficient daylight shall dim (or potentially turn off) in response to available daylight if those options are selected in the control profile in use at a specific time. Photosensors shall meet the following criteria:
 1. Photosensor type *[select one]*:
 - a. Closed-loop.
 - b. Open-loop.
 - c. Dual-loop.
 2. Signal transmission method *[select one]*.
 - a. Analog.
 - b. Digital.
 3. Viewing cone – closed-loop photosensors shall be ceiling- or fixture-mounted *[select one]* with a viewing cone limited to an angle of 30-60°

[edit and provide a specific angle]. Open-loop photosensors shall have a viewing angle that limits its cone of view to *[provide a specific angle; the designer may determine the desired angle based on plans and section drawings]*° and the width of its view parallel to the window wall to *[provide a specific angle; the designer may determine the desired angle based on plans and section drawings]*°.

4. Spectral filtering – photosensors shall incorporate a photodiode to measure light levels that can be correlated to the desktop illuminance. The photodiode shall be spectrally filtered (color-corrected) to measure light that approximates the human photopic response.
5. Range – photosensors shall operate within a range of 0-300 footcandles of incident light on the task surface (or greater if the setpoint <target> illuminance level is higher). This may be modified to a more limited range either by physical adjustment at the photosensor, or (preferably) by changing settings in the control system software.
6. Accuracy – photosensors shall be accurate to within 1% of reading in an operating environment between 15-30°C.
7. Calibration *[select one]*:
 - a. Option 1 – Nighttime calibration. Calibrate the photosensors by adding a “photosensor calibration” event to the schedule in the system’s software. The calibration will be scheduled to take place during nighttime hours (with no available daylight). The control system will turn luminaires on and leave them at full output for 10 minutes to insure that all luminaires are fully warmed up. Then the system will dim luminaires by 10% every 2 minutes (allowing light levels to stabilize with temperature), recording the resulting levels measured by the photosensors. The final dimmed levels shall be 5% and 1% once the photosensors have been calibrated for all levels in 10% increments. Once the calibration is done, the system will use these recorded values to determine the appropriate mix of daylight and electric light to achieve the target illuminance levels during daylight hours when daylight harvesting profiles are active.
 - b. Option 2 – Other methods of calibrating the photosensors may be proposed by a lighting control system vendor.
8. Deadband – a range of values shall be set in the control system software that achieves the following:
 - a. Maximum setpoint – upper limit of the target illuminance range. When a combination of daylight and electric light exceeds this setpoint (for a period of time specified in the software), the control system will dim luminaires (or turn them off).

- b. Minimum setpoint – lower limit of the target illuminance range. When a combination of daylight and electric light fall below this setpoint (for a period of time specified in the software), the control system will increase the level of the luminaires (or turn them on if they were previously off).
 - c. Time delays & fade rates – time delays and fade rates may be set in the control system software for dimming luminaires up or down. (For example, set variables in the system so that luminaires will not dim up or down until 5 minutes after a change in light level registers at the photosensor.)
 - ii. Occupancy/vacancy sensing – occupancy/vacancy shall be determined by the use of passive infrared (PIR), ultrasonic (US), dual-technology or other types of occupancy sensors (microwave, acoustic, etc.). *[if a specific type of occupancy sensor is desired (some of which are described above in “Control Zones”), indicate that here and delete the others.]*
 - 1. Signal transmission method. Occupancy/vacancy sensors may be “analog” or “digital” *[select one]*.
 - a. Analog.
 - b. Digital.
 - 2. Adjustment of sensors shall be as follows *[select one]*:
 - a. Tier 1 – Adjustment for “sensitivity” may be preset at the sensor before installation, or field-adjusted at the sensor after installation. “Time delay” may be set at the sensor as well as in the system software.
 - b. Tier 2 – Adjustments for “sensitivity” as well as “time delay” shall be made in the system software. Time delays can be different for different control “profiles” or during different “schedules” (see below).
 - 3. Fade upon sensing occupancy or vacancy – fade time to raise/dim luminaires up or down, between 0-59 seconds or up to 60 minutes, may be programmed in the control system software. Different fade times may be used for occupancy versus vacancy.
 - 4. “Daylight hold off” – if sufficient daylight is present in the space, allow the lighting control system to “hold off” luminaires in certain zones (keeping those luminaires off or at a minimum light level preset in the system software, based on the prevailing control profile).
 - 5. Programming of system behavior based on occupancy and vacancy sensing *[select one]*:

- a. Tier 1:
 - i. Upon sensing occupancy, turn luminaires on to a predetermined level set in the lighting control system software. Allow for a “transition” time (to fade luminaires up) from 0-59 seconds or up to 60 minutes.
 - ii. Upon sensing vacancy, and after a specified “time delay”, turn luminaires off or dim to a predetermined level set in the lighting control system software. Allow for a “transition” time (to fade luminaires down) from 0-59 seconds or up to 60 minutes. Time delays and fade rates can be different for occupancy sensing versus vacancy sensing.
 - b. Tier 2 – In addition to the behavior as described in Tier 1, after sensing vacancy, allow for an “intermediate step” where luminaires dim to a different predetermined level after a specified “time delay”. Alternately, allow lights to “blink” off then on as a visual indication to occupants that the occupancy sensors have already timed out – before reducing light levels based on settings for the “vacant” state. Fade rates for this intermediate step may be different than for the base behavior as described in Tier 1.
 - c. Tier 3 – Allow for two “intermediate steps” as described above in Tier 2.
 - d. Tier 4 – Allow for an unlimited number of “intermediate steps” as described above in Tier 2.
- iii. Scheduling – control system shall allow the creation of a schedule that will determine which “control profiles” are in effect at what times, including:
 - 1. Normal schedule – allows creation of “typical” schedules.
 - 2. Temporary schedule – allows creation of atypical or one-time events that would override the normal schedule.
 - 3. Format:
 - a. The lighting control system shall utilize a Microsoft Outlook-style calendar for the creation of “normal” as well as “temporary” (or “exception”) schedules. Any “temporary” schedule shall override the “normal” schedule in effect at that time.

- b. “Default” behavior – default behavior may be created without selecting specific blocks of time to determine when the default behavior is in effect.
 - c. Individual events for either “normal” or “temporary” schedules may be any duration of time based on increments of 1 minute, and as short as 2 minutes in duration.
 - d. The control system shall be capable of creating “overnight” events (spanning midnight).
 - e. Events may be created that repeat indefinitely (with no end date).
 - f. Provide automatic system time adjustments for Daylight Savings Time as well as for leap years. This may be achieved internally, or it may be done by reference to an external NTP (Network Time Protocol) server. *[If an NTP server is available and can be linked to the lighting control system, keep that language and delete reference to this being done “internally”.]*
- iv. Tuning – the control system shall allow for presetting a reduction in light levels throughout a specific zone(s). This variable will be set in each control profile and will be active when a given profile is active based on the schedule.
- v. Demand response/demand reduction (DR):
1. Methods of activation: *[select one]*
 - a. Tier 1 – The lighting control system shall allow programming of manual or scheduled reduction of light levels based on preprogrammed values.
 - b. Tier 2 – Provide all of the options for preprogramming a reduction of light levels as mentioned for Tier 1. In addition, provide an interface to an Automated Demand Response (ADR) server to automatically activate demand response/demand reduction functions in the lighting control system as described above.
 2. Severity of events – regardless of whether demand response events are activated manually or by a signal from an ADR server, allow for preprogramming demand response/demand reduction events with at least three degrees of severity.
 3. “Opting out” – the lighting control system must allow any zone to “opt out” of a manual or automated demand response event.

- vi. Manual overrides – the following devices or methods may be used to manually control any zone or combination of zones *[include those that are required on a project and delete the others]*:
 - 1. Types/methods of manual override:
 - a. Wallbox switches/dimmers.
 - b. Preset scene selector panels (for example, used in a conference room to dim all zones to predetermined levels by pushing a single button for each scene).
 - c. Touch screens.
 - d. Smartphone apps.
 - e. Software-based control.
 - f. Input from a BMS (for example to turn all luminaires to full on in an emergency situation other than during loss of normal power).
 - 2. “Logic” for override behavior – variables can be set in the system software to control the behavior of manual override devices or methods. *[Based on descriptions below, if specific behaviors are required in your project, make sure to describe them here.]*
- e. Control profiles:
 - i. Control system software shall allow for creation of “profiles” that contain variables for controlling the behavior of luminaires. Control profiles may be activated automatically by creating blocks of time in the schedule during which a specific profile is in effect. The software shall also allow for creation of a “default” – when a specific control profile is active unless a separate scheduled event is created that overrides the default control profile. These variables include (but are not limited to):
 - 1. Occupancy sensor input – whether or not occupancy/vacancy sensors are used, time delays upon sensing occupancy or vacancy before lights turn on or off (or dim), sensitivity, transition times between states, etc.
 - 2. Daylight harvesting – high and low setpoints to create a deadband for dimming or switching fixtures in response to available daylight, time delay before change of electric lighting is allowed, fade rate(s) for dimming lights up or down, etc.
 - 3. Daylight “hold off” – keeps lights off if there is enough available daylight even if there is occupancy in the space, and allows setting the threshold for the “hold off” function.

4. Manual override – allows for occupant override of the preprogrammed control profile, and for setting the maximum override time period before luminaires revert to preprogrammed operation.
- ii. Writing control profiles: control profiles (also called control narratives or sequences of operation) must be written that contain values for all of the variables provided by the system. Unless there is already a company-wide standard for typical lighting control profiles, the designer shall create control profiles prior to commissioning and submit to the owner for review and approval.
 - f. Power metering – the lighting control vendor shall provide a means to measure instantaneous power use on a per-luminaire or per-zone basis. *[Verify the availability of power metering functions with the manufacturer, and if so, how they operate in the proposed system. If this function is desired, indicate the granularity required for the measured power use data.]*
 - g. Node licenses or additional recurring costs. *[Verify with the manufacturer whether licenses or other charges are assessed based on the quantity of system components or for any other reason at all].*
 - h. BACnet integration:
 - i. Some lighting control systems have provisions to allow for integration with other building management systems using BACnet (or other) protocol. If this function is desired, verify the availability of a BACnet (or other) interface with the vendor during design and specification.
 - ii. Integration with other systems using BACnet (or other) protocol may require the purchase of additional licenses for the BACnet portion of the lighting control system. Verify with the vendor during design and installation.
 - iii. Integration with other systems using BACnet (or other) protocol may bypass the programming that controls behavior of luminaires in the lighting control system. In that case they would “pass through” commands and usage data. Verify with the vendor during design and installation.
 - i. Graphic user interface (GUI): *[select one]*
 - i. Tier 1 – Display “near real time” status of zones (for example – on, off, dimmed level) overlaid onto a floor plan of the space. “Near real time” is defined as the status of zones being updated at intervals of no greater than 1 minute.
 - ii. Tier 2 – In addition to the display of “near real time” status of the zones as described in Tier 1, allow for manual override of a zone(s) directly from the graphic user interface.
 - iii. Tier 3 – In addition to the functionality as described in Tier 2, allow for access to reporting of historical zone information directly from the graphic user interface. Such information shall include (but not be limited to):

1. Peak demand (kW) in any 15-minute period.
 2. Energy use for every 15-minute period (measured in kWh).
 3. Occupancy for every 1-hour period (in both minutes of occupancy and percentage).
 4. Demand response/demand reduction condition (if any, including level of severity).
 5. Alarms, alerts or error messages for any equipment not performing as required, including control system communication errors.
- j. Emergency (EM) lighting – for overhead luminaires:
- i. A licensed electrical engineer shall determine which new or retrofitted luminaires (or which fixture segments in continuous rows) require EM power feed or integral batteries for emergency lighting, in accordance with applicable code requirements.
 - ii. EM luminaires designated by the electrical engineer shall provide emergency lighting functions upon loss of normal power.
 - iii. When normal power is available, all EM luminaires shall operate according to the control profiles as set in the system for normal operation in their respective zones.
 - iv. If required by code, bypass control system wiring (power and/or control wiring) to maintain code-compliant emergency egress lighting functions.
 - v. A licensed electrical engineer shall determine if a change to the normal or emergency operation of EM luminaires will require submission of documents to an “authority having jurisdiction” (AHJ), to verify that they will still provide emergency lighting according to applicable codes.
 - vi. A licensed electrical engineer shall determine if new or retrofitted luminaires will change the light levels or power draw on emergency power sources in an emergency lighting situation, and if any such changes prevent the lighting system and luminaires from operating according to code requirements or within the capacity of the EM power source.
- k. System failures – verify with the manufacturer what will happen when each component fails, considering (by not limited by) the following questions *[list specific requirements based on the questions below]*:
- i. Server – for example, if a centrally located server fails or loses power, will other system components continue to operate normally? Will there be a loss of usage data during the time that the server was down?

- ii. Gateways – for example, if wired or wireless gateways fail or lose power, will luminaires still operate normally? Will usage data be lost during that time?
 - iii. On-board controllers – for example, if controllers fail or lose a signal from the control system, will they still operate normally, or shut off, or turn on to full output?
 - iv. Sensors and switches – for example, if sensors or switches fail, will luminaires still operate based on default behavior as determined by the server/software?
 - v. Software – for example, similarly to any complex computerized system, software for lighting control systems may be regularly updated by the manufacturer. What happens if the software is updated and causes the system to operate abnormally? Is there a way to force the software to revert back to a previous version that is known to make the system work as specified? What is the procedure used by the manufacturer to correct bugs in the software or firmware in devices (and how regularly is that done)? How will bug fixes affect the operation of the system in the space?
 - vi. Normal vs. abnormal operation – if there are critical tasks being performed in a space, it's essential to know how the system will operate under “normal” as well as “abnormal” conditions. Any manufacturer with a proven track record of having deployed their system for at least three years should have a clear understanding of what happens based on various configurations and topologies and under different conditions.
 - vii. “Failsafe” operation – if the system starts to behave erratically for any reason at all, is there a method available to entirely bypass the system and operate luminaires manually? Will local switches (or any other components or methods) still operate luminaires even if the rest of the system is disabled? How about occupancy sensors or photosensors?
- l. Standby power – if “standby power” in luminaires is necessary to maintain continuity in on-board control circuitry, that power usage shall be limited to a maximum of 1 Watt per luminaire.
- m. Fade rate – the lighting control system shall be capable of allowing the light level to fade (raise/dim up or down) between 0-59 seconds, or up to 60 minutes *[if longer fade rates are required, change these values as necessary]*. Fade rates may be different for different control profiles and/or during different schedules.
- n. Reporting:
- i. Information to be reported/saved/stored by the control system:
 - 1. Peak demand (kW) in any 15-minute period.
 - 2. Energy use for every 15-minute period (measured in kWh).

3. Occupancy for every 1-hour period (in both minutes of occupancy and percentage).
 4. Demand response/demand reduction condition (if any, including level of severity).
 5. Alarms, alerts or error messages for any equipment not performing as required (including control system communication errors).
- ii. Event logs – record logs of all events in the system (schedule changes, occupancy or vacancy, dimming lights in response to photosensor input, manual overrides, alarms, errors, etc.).
 - iii. Storage – store all historical data indefinitely in server, including energy usage and event logs.
 - iv. Data format – CSV (comma separated values) or Microsoft Excel. Data files may be exported from the system on an as-needed basis.
 - v. Access to historical data. *[If data cannot be accessed through the graphic user interface, allow data to be accessed through standard menu options in the control system software – verify with the manufacturer.]*
 - vi. Reports and graphs. *[Verify with the manufacturer what types of reports and graphs the system can create during design and specification.]*
- o. Notifications:
- i. The lighting control system shall have some method of sending notifications about errors, alarms, alerts, warnings, etc.
 - ii. E-mail or text notifications – the lighting control system’s notification function shall send e-mails and/or texts *[specify which are desired]* to designated staff. *[Determine if the lighting control system can be programmed to send notifications to only one or more than one person, and if each recipient can receive different forms of alerts, warnings, error messages, etc.]*
 - iii. Daily reports – send daily reports of equipment requiring servicing or replacement. *[Verify with potential vendors if such a function is available, and if so, how it operates.]*
- p. Backup – provide a means to automatically backup programming (schedules, control profiles, etc.), usage data files and event logs on a regularly scheduled basis.
- i. Backup files on the system’s server.
 - ii. Provide some method to backup files to a USB drive and/or remote storage device, or to e-mail backup files. In the event of loss of program or usage

data on the server, backup files may be uploaded to the server to restore normal operation (for control profiles and schedules, in addition to usage and event logs). *[Verify with potential vendors if such a function is available and, if so, how it operates.]*

- q. Energizing system before commissioning – provide a means to energize all luminaires at full output prior to commissioning the lighting control system.
- r. Connecting control system components and connecting to the system: *[Review all of these considerations in this section with the owner at the outset of the project; include language describing the desired (or allowable) methods of connection and delete the others.]*
 - i. Connections between system components:
 - 1. Most (but not all) lighting control systems have a centrally located server. This will usually be installed in an IT server room or electrical closet. Typically, some of the components are connected to the server – such as gateways to luminaires, controllers, sensors, switches, touch panels, DALI ballasts or drivers, etc.
 - 2. Most systems allow for connection between some or all of these components and the server via the owner’s existing communications network (intranet) – if the owner allows that. For example, gateways connected to luminaires are often provided with IP addresses and can therefore be connected to an existing communication network (intranet). If the server is also connected to the network, then it can communicate with the gateways without the need for additional wiring.
 - 3. If the owner will not allow for using any of their internal communications networks (intranets) to connect system components, then they will need to be connected with additional dedicated wiring, unless the system is designed to allow some or all of these connections to be made wirelessly.
 - ii. Connecting to the system (remote access):
 - 1. Most lighting control systems are designed to allow remote access to the operating software as previously described, usually residing on a centrally-located server. A common method is to access a webpage or program on the server from a remote location.
 - 2. If the owner allows the server (and/or other system components) to reside on an internal communications network (intranet), then it may be possible to access the system’s software from any computer on the owner’s network. It may also be possible to access the software from any remote location. In some cases, this may require a VPN (virtual private network) to access the server from outside the owner’s internal

network. It is essential to make this determination during the design and specification of the lighting control system.

3. If the owner will not allow for using their internal communications network to access the software residing on the server (or other system components), then it may be necessary to install a dedicated wireless access point (for example, using a 3G modem, aircard, etc.) – or some other method of communicating with the system without accessing the existing building network – in order to gain remote access.
4. Access to the system’s software will be needed by some or all of the following:
 - a. System operator/administrator – this is usually someone on the building operation/engineering staff.
 - b. Lighting control system manufacturer – this may be required for troubleshooting, software updates, commissioning, recommissioning, rezoning, etc.
 - c. Lighting designer/electrical engineer/others – specifiers may want access to verify that the system has been installed and is operating as designed, or to retrieve usage data for analysis.
 - d. Users – many systems have methods to allow individual occupants to control luminaires and/or other devices connected to the system. For example, an occupant in a private office may be given access to or have control over the luminaires only in his or her room, but is not able to control luminaires in other private or open office areas.
 - e. “Dashboards” – many systems have methods to allow for displaying system usage (e.g., kWh/hour, kW <load> in percent or amount, usage compared to baseline <actual kW/max kW>, demand response event status, if any, etc.). A common method is for a remotely located monitor to connect to the server’s software by accessing its URL for the dashboard display.
- s. User access levels – allow different users to access different functions in the system. *[Verify whether the system allows for different access levels during design and specification and, if so, how.]* Examples of different levels of access and functionality might include: *[Include those required by the owner and delete the others.]*
 - i. System administrator – has access to all functions and control over all luminaires (and/or other devices) on the system.
 - ii. Tenants – if a system is used to control luminaires in a multi-tenant space, tenants may be given access only to luminaires in their space.

- iii. Individual users – occupants may be given control over the luminaires in their own private office, or luminaires that are located over their workstation in an open office area.
 - iv. Guests – other people may be given access to monitor the system, without being able to make any changes.
- t. Commissioning – a commissioning agent for the lighting control system shall be selected by the owner and design team. The commissioning process shall include the following steps:
 - i. Verification of correctly installed wiring and components.
 - ii. Creating zones in the lighting control system software (including graphic overlays for the graphic user interface).
 - iii. Discovery of lighting control system components including gateways, controllers, sensors, switches, wall panels, etc. (This can only be accomplished once the system is installed and up and running.)
 - iv. Creating profiles and schedules for typical operation, as well as atypical events like testing after initial start-up, daylight calibration, demand response events, 100-hour fluorescent lamp burn-in, etc.
 - v. Assignment of luminaires/groups of luminaires to appropriate zones as created above. (This can only be accomplished once the system is installed and up and running.)
 - vi. Calibration of photosensors.
 - vii. Correction of any faults, warnings, alerts, alarms, etc.
 - viii. Verification that all aspects of the control system software are operating properly and that the system is recording data as described above.
 - ix. Setting appropriate values to establish baselines. These typically include any or all of the following:
 1. Hours of operation.
 2. Fixture types and wattages. Note that it may be desirable to have a “pre-install” baseline as well as a “post-install” baseline if the luminaires are replaced or retrofitted.
 3. Electricity cost (per kWh, which may vary based on time of day).
 4. Percentage of occupancy (this can be established beforehand by using loggers and analyzing the data).

- 5. Cost of CO₂ (carbon dioxide emissions rate, based on electricity or gas cost – in some cases, CO₂ emission reductions are taken into account when considering financial incentives, payback, etc.).
- x. Resetting all usage and event data recorded since initial system installation to zero, if desired.
- xi. Clearing all active alarms, warnings, alerts, etc. (after insuring that the system is functioning normally).
- u. User training:
 - i. Lighting control system vendor shall provide *[specify amount]* hours of on-site training for designated representatives of owner and design team to learn how to operate the system.
 - ii. Lighting control system vendor shall provide reference manuals in print and/or PDF form *[specify which]*, as well as context-sensitive help screens in the control system software itself.
- v. Technical support:
 - i. Allow remote access to the lighting control system server (with appropriate safeguards including firewalls, passwords, etc.). At a minimum, the lighting control system vendor shall be granted remote access in order to troubleshoot the system in the event of a malfunction of any of the hardware or software as described in this document.
 - ii. Within *[specify period of time, e.g., one month, one year, etc.]* from initial system power-up, the lighting control system vendor will make site visits at their own expense in order to correct any problems within the lighting control system.
- w. Vendor experience – any prospective lighting control system vendor must have at least three years of experience in supplying and successfully implementing advanced lighting control systems with similar features and operation as described above.
- x. Procurement process issues for luminaires:
 - i. Submittals – luminaire vendors shall submit the follow for approval before fabrication and shipping equipment to the job site. *[Verify how long the manufacturer will need to produce these drawings and whether they will require any materials from the owner or specifier (such as CAD background drawings, control schedules, etc.). Determine who will review and approve these materials prior to releasing a purchase order.]* The submittals must include (but are not limited to) the following:
 - 1. Luminaire detail drawings – showing all views necessary to fully describe the luminaire. This may include plan views, section

drawings, run configurations, mounting details and/or any other drawings necessary to show every aspect of the luminaires to be installed.

2. Integral controls components – besides the LED driver(s), which may or may not be part of the lighting control system itself, any additional on-board or remote-mounted components must be shown on the drawings, as well as all associated wiring (cord sets, individual conductors, etc.). These may include fixture controllers, on-board sensors, UL924 relays and/or other components required by the lighting control system.
 3. Quantities – the luminaire vendor shall indicate quantities required for each fixture type (based on different fixture types, different mounting conditions, different length units, different on-board control equipment, normal vs. EM, etc.).
- ii. Samples – luminaire vendors shall provide a working sample of each fixture type for review and approval by the owner and design team. Each sample shall be a complete, functional unit ready to be energized, including any on-board lighting control equipment required.
- y. Procurement process issues for lighting control systems:
- i. Submittals – lighting control system vendors shall submit the following for approval before fabrication and shipping equipment to the job site. *[Verify how long the manufacturer will need to produce these drawings and whether they will require any materials from the owner or specifier (such as CAD background drawings, control schedules, etc.). Determine who will review and approve these materials prior to releasing a purchase order.]* The submittals shall include (but are not limited to) the following:
 1. Plans – showing location of all lighting control system components and how they are connected.
 2. One-line diagrams – showing all lighting control system components and how they are connected (but not showing exact locations on a plan of the space).
 3. Wiring diagrams – the lighting control system vendor shall provide drawings showing **every wiring connection for all system components.**
 4. Control schedules – these are typically spreadsheets that indicate what resides in each control zone, such as:
 - f. Luminaires, including quantity of each fixture type in that zone, wattage for each fixture type, type of load (incandescent, fluorescent, LED, low-voltage magnetic, etc.).

- g. Total wattage for the entire zone.
 - h. It is also desirable to indicate if any of the luminaires in a particular zone provide emergency lighting.
 - i. Occupancy sensors associated with that zone.
 - j. Photosensors associated with that zone.
 - k. Dimmer switches or touch screens associated with that zone.
5. Manufacturer's catalog sheets of all equipment.
- ii. Samples – the lighting control system vendor shall provide the following sample equipment: *[The topology and wiring methods for many new lighting control systems are different than the existing topology and wiring in most buildings. It is advantageous for the installing contractor to acquire samples of certain equipment in advance of the installation. These may be provided as free samples by the manufacturer prior to received a purchase order, or subsequent to receiving a purchase order, or the manufacturer may want to provide these samples only as part of an actual order. Verify with the lighting control vendor.]*
- 1. LED drivers – these may be 0-10V, DALI and/or other types. (Not all electrical contractors have experience installing ballasts that contain more than just a hot wire, neutral wire, and a ground.)
 - 2. Fluorescent ballasts (assuming that any fluorescent luminaires are still used in the space) – these may be 0-10V, DALI and/or other types.
 - 3. On-board controllers (such as wired or wireless controllers that switch power to as well as dim the driver or ballast).
 - 4. Centrally located load controllers.
 - 5. Sensors – wired or wireless occupancy sensors or photosensors.
 - 6. Wall-mounted dimmer switches or touch panels.
 - 7. Emergency transfer devices (such as UL924 compliant components).
- iii. Takeoffs/Bill of Materials – the lighting control system vendor shall provide a Bill of Materials for review by the project team based on takeoffs prepared by the electrical contractor. Takeoffs (counting number of luminaires and other components such as sensors, switches, etc.) shall be created by the electrical contractor based on drawings and a walk-through of the existing space and submitted to the luminaire and lighting control system vendors to aid them in preparing Bills of Materials for the project.

- iv. Spares – the lighting control system vendor shall provide limited quantities of spare components for certain items. *[Specify which (e.g., LED drivers, on-board controllers, sensors, switches, etc.) and quantities or percentages of additional spares required.]*
- v. Service plans – the lighting control system vendor shall provide a plan to cover on-going service of the lighting control system. *[Verify the availability and details of such plans with the manufacturer prior to placing a purchase order.]* These service plans might cover any or all of the following (or more): *[Keep items desired in a service plan and delete the others.]*
 - 1. Troubleshooting – either during or after the warranty period ends. (See u. Technical Support for a more detailed discussion about troubleshooting considerations.)
 - 2. Training – beyond what is provided immediately upon completion of system commissioning.
 - 3. Software and firmware upgrades:
 - a. Manufacturer shall provide upgrades for system software and component firmware for a period of *[specify time period]* from the date of completion of the on-site commissioning process. It may be desirable to negotiate a longer period for receiving software and firmware upgrades as part of the initial system cost.
 - b. Lighting control system software is typically upgraded by the manufacturer by remotely accessing the server. Component firmware may be upgraded by remotely accessing the component, or directly via a USB drive and/or other external method. *[Verify the methods of upgrade with the manufacturer.]*
 - 4. Recommissioning – changing or adding control zones, recalibrating sensors, adding any additional equipment or components, etc.
- 5. Warranties – vendors shall provide the following warranty periods from date of final acceptance:
 - a. Luminaires – Ten (10) years.
 - b. LED drivers – Five (5) years.
 - c. Lighting control system – Five (5) years.

Appendix C: Typical Project Timeline

1. Pre-design phase

- a. Set project goals (i.e. energy reduction, light level target values, etc.). **Owner**
- b. Set budget for design, equipment and installation. **Owner**
- c. Assist owner in setting project goals (e.g., energy reduction and light level target values), as well as budget. **Lighting designer**
- d. Install or assist with installation of power and occupancy loggers (if desired by the owner) in advance of the retrofit design work to establish baseline conditions (e.g., maximum connected load, typical daily or weekly energy usage, etc.). **Building maintenance/engineering staff**
- e. Obtain as-built drawings of existing spaces showing existing luminaires, ceiling grid, etc. Drawings must be in CAD format in order for design and engineering consultants to do their work. **It is also desirable to have drawings showing the current furniture layout. Building maintenance/engineering staff**
- f. Receive drawings and any other required information from maintenance and/or building engineering staff. **Lighting designer**
- g. Perform blink test to determine which branch circuits control which existing luminaires. Mark up drawings to indicate existing (as-built) branch circuitry and communicates this information to the lighting designer and electrical engineer. This must include a precise determination about which fixtures or fixture segments are powered by EM (emergency) lighting circuits. **Building maintenance/engineering staff**
- h. If required, install power and/or occupancy loggers (such as CTs, etc.) to determine baseline information. **Electrical contractor**
- i. Check and record existing light levels at representative locations throughout existing space. Existing light levels should be checked at night with no daylight contribution, as well as during daytime hours. **Note that if daytime light levels clearly exceed current standards for task illuminance, there's a good chance that the space is a great candidate for energy savings by deploying a lighting control system with daylight harvesting capabilities. Lighting designer**
- j. Determine applicable codes and specific requirements (e.g., required lighting control equipment, zoning, power density limits, etc.). **Lighting designer or electrical engineer**

2. Design phase

- a. Create schedules for normal lighting control system operation based on input from owner. **Lighting designer**
- b. Create control profiles ("sequences of operation") based on input from owner. **Lighting designer**
- c. Research viable LED luminaires or retrofit kits. **Lighting designer**
- d. Draw new lighting plan using new LED luminaires or retrofit kits. **Lighting designer**

- e. Calculate new light levels using calculation software (e.g., Visual, AGI, etc.). **Lighting designer**
- f. Calculate new emergency light levels using calculation software and reviews results with electrical engineer. **It should be noted that only a licensed electrical engineer has legal authority to officially verify that new luminaires and lighting control systems will meet applicable emergency code requirements.** **Lighting designer and electrical engineer**
- g. Research viable lighting control systems. **Lighting designer**
- h. Review new lighting plan, new LED fixture candidates or retrofit kits, as well as lighting control system candidates, with owner and project team. **Lighting designer**
- i. Formulate guidelines for the connectivity and security aspects of a lighting control system (e.g., preferred network topology, control signal transmission methods, remote access to systems, etc.). **Owner's IT staff**
- j. Review recommendations for lighting control systems based on IT guidelines. **Owner's IT staff**
- k. Provide input on viability of recommended lighting control system(s) based on existing branch circuitry, electrical closets, etc. **Electrical engineer**
- l. Review and approve recommendations from lighting designer or other specifier for lighting plan, luminaires, lighting control systems, schedules, control profiles, etc. **Owner**

3. Specification phase

- a. Create drawings showing all required details including mounting, typical run configurations, electrical connections and any additional components such as on-board controllers, UL924 relays, etc. **Luminaire vendors typically do not prepare and issue formal "submittal" drawings before receiving a purchase order for the project. However, it's very common for the project team to be unaware of certain luminaire details that might have a major impact on the project until formal submittal drawings have been prepared and issued for review. This may include, for example, mounting details, required hardware, wiring methods, run configurations, etc. Therefore, during this phase, it is highly desirable to require any prospective luminaire vendor(s) to at least submit "informal" drawings showing every detail of the fixtures being considered. Once a purchase order is finally issued, it should be easy for the luminaire vendor(s) to convert any "informal" drawings into formal "submittal" drawings for official approval by the project team.** **Luminaire vendor(s)**
- b. Create drawings describing the lighting control system (e.g., one-line diagrams, details such as mounting requirements, etc.). Additionally, all wiring connections must be clearly indicated on the drawings. **As noted in the specifications, lighting control system vendors typically do not provide project-specific drawings showing wiring connections for all equipment. In many cases, catalog sheets are provided that show typical connections. However, it's not uncommon for a specific project to require wiring connections that are not shown on the catalog sheets. Therefore, it's essential for the vendor to provide project-specific details about all wiring connections to avoid incorrectly wiring equipment on-site, which may lead to damaging or destroying luminaires or lighting control equipment. In addition, similarly to luminaires, formal**

“submittal” drawings for lighting control systems are not typically prepared prior to the vendor receiving a purchase order. Just as with luminaires, during this phase, it is highly desirable to require any prospective lighting control system vendor to at least submit “informal” drawings showing every detail of the system being considered. Once a purchase order is finally issued, it should be easy for the lighting control system vendor to convert any “informal” drawings into formal “submittal” drawings for official approval by the project team. **Lighting control system vendor**

- c. Create drawings and specifications showing all luminaire locations, desired zoning, lighting control system components and/or any other information pertinent to the project. Note that this task may be completed by lighting designers and/or electrical engineers. Lighting designers typically do not provide drawings and specifications for emergency lighting, nor typically create drawings for power distribution, riser diagrams, etc. Therefore, at the outset of the project, it is imperative to determine who will create which drawings and specifications. Typically, a lighting designer will create drawings and specifications that address much – but not all – of the required equipment, zoning, EM designations, etc. Typically, lighting designers are not licensed electrical engineers. Therefore, a licensed engineer will be responsible for issuing all “final” documents. Also note that most commercial office buildings have some form of rudimentary lighting control system already installed in the space. The most typical control system is a low-voltage relay system that turns lighting circuits on and off according to a preprogrammed schedule. It’s **extremely** important that any existing lighting control system does not interfere in any way with the normal operation of a new system. It is vastly preferable to disconnect and remove any existing lighting control system (such as a low-voltage relay system). At the absolute minimum, it is essential to maintain constant power to a new system and to the luminaires they control. Therefore, even if an existing system is not disconnected and removed from the building, it should be reprogrammed to keep all circuits energized all the time. **Lighting designer and/or electrical engineer**
- d. Issue all final schedules and control profiles. **Electrical engineer**

4. Procurement phase

- a. Create formal “submittal” drawings showing all required details including mounting, typical run configurations, electrical connections and any additional components such as on-board controllers, UL924 relays, etc. Submit drawings to the owner and project team for approval. **Luminaire vendor(s)**
- b. Create formal “submittal” drawings describing the lighting control system (e.g., one-line diagrams, details such as mounting requirements, etc.). Additionally, all wiring connections must be clearly indicated on the drawings. Submit drawings to the owner and project team for approval. **Lighting control system vendor**
- c. Review and approve formal “submittal” drawings from luminaire vendor(s) and lighting control system vendor. **Owner, lighting designer and electrical engineer**
- d. Prepare bid package describing the project and installation work to prospective electrical contractors. Note that at this point in the process, luminaire and lighting control system vendors have expended a very significant amount of time providing input, drawings, etc. The owner may desire to have preliminary reviews with one or

more prospective electrical contractors during an earlier phase of the work to gauge the potential cost of the retrofit project. **Lighting designer and electrical engineer**

- e. Provide guidance as to scheduling and staging the work. For example, will work be done at night? On weekends? Will a floor be partially vacated so work can be done during the day? **Owner**
- f. Submit bid package to qualified electrical contractors. **Owner**
- g. Attend meetings with owner, project team and/or vendors as required to understand the scope of work. **Electrical contractor**
- h. Prepare proposal for installing equipment and submit to the owner for approval. **Electrical contractor**
- i. Indicate what additional equipment, if any, must be ordered prior to installation if that equipment is not on the original purchase order for either luminaires or the lighting control system. For example, a lighting control system vendor may not typically provide a rack for holding the server, assuming that an existing space will be available in a rack already installed in an IT room. What if there isn't? Similarly, lighting control system vendors typically do not include quantities (lengths) for low-voltage cable required to connect sensors, switches, etc. Additionally, it is not uncommon for a vendor to assume that there is space on an owner's existing server, obviating the need to supply a dedicated server for the lighting control system. These determinations should already have been made during the design and specification process because they have a major affect on the cost and scheduling of the work. If for any reason they have not, then it is essential to finalize these determinations during the procurement phase so that any additional equipment can be obtained prior to the start of installation. **Luminaire vendor(s) and/or lighting control system vendor**
- j. Arrange for procurement of equipment (negotiate pricing, review and agree to Terms and Conditions, submit purchase orders, etc.). **Owner**
- k. Fabricate fixtures using standard wire colors. Leads from new fixtures should be labeled, and should not contain any unnecessary conductors. **Luminaire vendor(s)**
- l. Ship fixtures to job site with clear and concise documentation about what is (or is not) being shipped. Any equipment on back-order must be clearly noted in all shipping documentation. **Luminaire vendor(s)**
- m. Ship lighting control system components to job site with clear and concise documentation about what is (or is not) being shipped. Any equipment on back-order must be clearly noted in all shipping documentation. **Lighting control system vendor**

5. Installation phase

- a. Prepare documents (drawing and specification package) for submission to building department or other AHJ (authority having jurisdiction). **Electrical engineer**
- b. Submit documents (drawing and specification package) to building department or other AHJ (authority having jurisdiction) as required, and obtain applicable installation permits. **Expediter**

- c. Attend meetings with electrical contractor in advance of and/or during installation to educate the electrical contractor about the fixtures and lighting control equipment. **Lighting designer**
- d. Assist during installation by providing access to the space, turning branch breakers on and off as required by the electrical contractor, etc. **Building maintenance/engineering staff**
- e. Install luminaires and lighting control system according to drawings and specifications created by the lighting designer and electrical engineer. **Electrical contractor**
- f. Provide support to the lighting designer, electrical engineer and/or electrical contractor during installation (answering installation questions, etc.). **Lighting control system vendor**
- g. Provide personnel to verify that the control system is correctly installed (prior to commissioning). **Lighting control system vendor**
- h. Receive and store drawings and any other pertinent information from luminaire vendors to assist in replacing defective fixture components or entire luminaires. **Building maintenance/engineering staff**
- i. Receive and store record drawings, operation manuals and any other pertinent information from lighting control system vendors. **Building maintenance/engineering staff**
- j. Obtain IP addresses and/or any other pertinent information required to make a lighting control system work during and after installation. **Owner's IT staff**

6. Commissioning

- a. Communicate with lighting control system vendors about schedules and control profiles to insure that commissioning is done accurately and in a timely manner. **Note that schedules and control profiles should already have been completed and incorporated into the specifications early on in the project work.** **Lighting designer**
- b. Provide electricians on-site during lighting control system commissioning (usually performed by a third-party commissioning agent or lighting control system vendor). **Electrical contractor**
- c. Provide personnel to commission the control system. **There may or may not be applicable code or other requirements (e.g., LEED) requiring that a third-party commissioning agent commission the lighting control system.** **Lighting control system vendor or third-party commissioning agent**
- d. Receive training from lighting control system vendor on the system's operation (including normal operation, checking and clearing alarms/alerts/etc., how and where backup files are stored, etc.). **Building maintenance/engineering staff**
- e. Check light levels after commissioning to insure that the control system is performing as specified. **Lighting designer**
- f. Perform a walk-through(s) after completion of installation and create a punch-list showing items that need to be corrected before final acceptance by owner. **Lighting designer**

- g. Maintain contact information for all vendors to assist in troubleshooting or replacing defective components. **Building maintenance/engineering staff**

Appendix D: Project Team Members and Typical Tasks

(based on the typical project timeline, with tasks sorted by project team member)

1. Owner

- a. Set project goals (i.e. energy reduction, light level target values, etc.).
- b. Set budget for design, equipment and installation.
- c. Review and approve recommendations from lighting designer or other specifier for lighting plan, luminaires, lighting control systems, schedules, control profiles, etc.
- d. Provide guidance as to scheduling and staging the work. **For example, will work be done at night? On weekends? Will a floor be partially vacated so work can be done during the day?**
- e. Submit bid package to qualified electrical contractors.
- f. Arrange for procurement of equipment (negotiate pricing, review and agree to Terms and Conditions, submit purchase orders, etc.).
- g. Review and approve formal “submittal” drawings from luminaire vendor(s) and lighting control system vendor (after soliciting comments from lighting designer and electrical engineer).

2. Building maintenance/engineering staff

- a. Install or assist with installation of power and occupancy loggers (if desired by the owner) in advance of the retrofit design work to establish baseline conditions (e.g., maximum connected load, typical daily or weekly energy usage, etc.).
- b. Obtain as-built drawings of existing spaces showing existing luminaires, ceiling grid, etc. Drawings must be in CAD format in order for design and engineering consultants to do their work. **It is also desirable to have drawings showing the current furniture layout.**
- c. Perform blink test to determine which branch circuits control which existing luminaires. Mark up drawings to indicate existing (as-built) branch circuitry and communicates this information to the lighting designer and electrical engineer. This must include a precise determination about which fixtures or fixture segments are powered by EM (emergency) lighting circuits.
- d. Assist during installation by providing access to the space, turning branch breakers on and off as required by the electrical contractor, etc.
- e. Receive and store drawings and any other pertinent information from luminaire vendors to assist in replacing defective fixture components or entire luminaires.
- f. Receive and store record drawings, operation manuals and any other pertinent information from lighting control system vendors.
- g. Receive training from lighting control system vendor on the system’s operation (including normal operation, checking and clearing alarms/alerts/etc., how and where backup files are stored, etc.).

- h. Maintain contact information for all vendors to assist in troubleshooting or replacing defective components.

3. Owner's IT staff

- a. Formulate guidelines for the connectivity and security aspects of a lighting control system (e.g., preferred network topology, control signal transmission methods, remote access to systems, etc.).
- b. Review recommendations for lighting control systems based on IT guidelines.
- c. Obtain IP addresses and/or any other pertinent information required to make a lighting control system work during and after installation.

4. Lighting designer

- a. Assist owner in setting project goals (e.g., energy reduction and light level target values), as well as budget.
- b. Receive drawings and any other required information from maintenance and/or building engineering staff.
- c. Check and record existing light levels at representative locations throughout existing space. Existing light levels should be checked at night with no daylight contribution, as well as during daytime hours. **Note that if daytime light levels clearly exceed current standards for task illuminance, there's a good chance that the space is a great candidate for energy savings by deploying a lighting control system with daylight harvesting capabilities.**
- d. Determine applicable codes and specific requirements (e.g., required lighting control equipment, zoning, power density limits, etc.). **This task may be performed by a lighting designer or electrical engineer.**
- e. Create schedules for normal lighting control system operation based on input from owner.
- f. Research viable LED luminaires or retrofit kits.
- g. Draw new lighting plan using new LED luminaires or retrofit kits.
- h. Calculate new light levels using calculation software (e.g., Visual, AGI, etc.).
- i. Calculate new emergency light levels using calculation software and reviews results with electrical engineer. **Note that only a licensed electrical engineer has legal authority to officially verify that new luminaires and lighting control systems will meet applicable emergency code requirements.**
- j. Create control profiles ("sequences of operation") based on input from owner.
- k. Research viable lighting control systems.
- l. Review new lighting plan, new LED fixture candidates or retrofit kits, as well as lighting control system candidates, with owner and project team.
- m. Create drawings and specifications showing all luminaire locations, desired zoning, lighting control system components and/or any other information pertinent to the project. **Note that this task may be completed by a lighting designer and/or electrical engineer. Lighting designers typically do not provide drawings and specifications for**

emergency lighting, nor typically create drawings for power distribution, riser diagrams, etc. Therefore, at the outset of the project, it is imperative to determine who will create which drawings and specifications. Typically, a lighting designer will create drawings and specifications that address much – but not all – of the required equipment, zoning, EM designations, etc. Typically, lighting designers are not licensed electrical engineers. Therefore, a licensed engineer will be responsible for issuing all “final” documents. Also note that most commercial office buildings have some form of rudimentary lighting control system already installed in the space. The most typical control system is a low-voltage relay system that turns lighting circuits on and off according to a preprogrammed schedule. It’s extremely important that any existing lighting control system does not interfere in any way with the normal operation of a new system. It is vastly preferable to disconnect and remove any existing lighting control system (such as a low-voltage relay system). At the absolute minimum, it is essential to maintain constant power to a new system and to the luminaires they control. Therefore, even if an existing system is not disconnected and removed from the building, it should be reprogrammed to keep all circuits energized all the time.

- n. Prepare bid package describing the project and installation work to prospective electrical contractors. Note that at this point in the process, luminaire and lighting control system vendors have expended a very significant amount of time providing input, drawings, etc. The owner may desire to have preliminary reviews with one or more prospective electrical contractors during an earlier phase of the work to gauge the potential cost of the retrofit project.
- o. Review and comment on formal “submittal” drawings from luminaire vendor(s) and lighting control system vendor. Review comments with electrical engineer and owner.
- p. Attend meetings with electrical contractor in advance of and/or during installation to educate the electrical contractor about the fixtures and lighting control equipment.
- q. Communicate with lighting control system vendors about schedules and control profiles to insure that commissioning is done accurately and in a timely manner. Note that schedules and control profiles should already have been completed and incorporated into the specifications early on in the project work.
- r. Check light levels after commissioning to insure that the control system is performing as specified.
- s. Perform a walk-through(s) after completion of installation and create a punch-list showing items that need to be corrected before final acceptance by owner.

5. Electrical engineer

- a. Determine applicable codes and specific requirements (e.g., required lighting control equipment, zoning, power density limits, etc.). This task may be performed by the lighting designer or electrical engineer.
- b. Provide input on viability of recommended lighting control system(s) based on existing branch circuitry, electrical closets, etc.
- c. Review and verify new emergency light levels based on calculations performed by the lighting designer. Note that only a licensed electrical engineer has legal authority to

officially verify that new luminaires and lighting control systems will meet applicable emergency code requirements.

- d. Create drawings and specifications showing all luminaire locations, desired zoning, lighting control system components and/or any other information pertinent to the project. Note that this task may be completed by a lighting designer and/or electrical engineer. Lighting designers typically do not provide drawings and specifications for emergency lighting, nor typically create drawings for power distribution, riser diagrams, etc. Therefore, at the outset of the project, it is imperative to determine who will create which drawings and specifications. Typically, a lighting designer will create drawings and specifications that address much – but not all – of the required equipment, zoning, EM designations, etc. Typically, lighting designers are not licensed electrical engineers. Therefore, a licensed engineer will be responsible for issuing all “final” documents. Also note that most commercial office buildings have some form of rudimentary lighting control system already installed in the space. The most typical control system is a low-voltage relay system that turns lighting circuits on and off according to a preprogrammed schedule. It’s extremely important that any existing lighting control system does not interfere in any way with the normal operation of a new system. It is vastly preferable to disconnect and remove any existing lighting control system (such as a low-voltage relay system). At the absolute minimum, it is essential to maintain constant power to a new system and to the luminaires they control. Therefore, even if an existing system is not disconnected and removed from the building, it should be reprogrammed to keep all circuits energized all the time.
- e. Prepare bid package describing the project and installation work to prospective electrical contractors. Note that at this point in the process, luminaire and lighting control system vendors have expended a very significant amount of time providing input, drawings, etc. The owner may desire to have preliminary reviews with one or more prospective electrical contractors during an earlier phase of the work to gauge the potential cost of the retrofit project.
- f. Issue all final schedules and control profiles.
- g. Prepare documents (drawing and specification package) for submission to building department or other AHJ (authority having jurisdiction).

6. Expediter

- a. Submit documents (drawing and specification package) to building department or other AHJ (authority having jurisdiction) as required, and obtain applicable installation permits.

7. Luminaire vendor(s)

- a. Create drawings showing all required details including mounting, typical run configurations, electrical connections and any additional components such as on-board controllers, UL924 relays, etc. Luminaire vendors typically do not prepare and issue formal “submittal” drawings before receiving a purchase order for the project. However, it’s very common for the project team to be unaware of certain luminaire details that might have a major impact on the project until formal submittal drawings have been prepared and issued for review. This may include, for example, mounting details, required hardware, wiring methods, run configurations, etc. Therefore, during

this phase, it is highly desirable to require any prospective luminaire vendor(s) to at least submit “informal” drawings showing every detail of the fixtures being considered. Once a purchase order is finally issued, it should be easy for the luminaire vendor(s) to convert any “informal” drawings into formal “submittal” drawings for official approval by the project team.

- b. Create formal “submittal” drawings showing all required details including mounting, typical run configurations, electrical connections and any additional components such as on-board controllers, UL924 relays, etc. Submit drawings to the owner and project team for approval.
- c. Indicate what additional equipment, if any, must be ordered prior to installation if that equipment is not on the original purchase order for either luminaires or the lighting control system. For example, a luminaire vendor may or may not provide all required mounting hardware, or remote junction boxes required for wiring the fixtures. These determinations should already have been made during the design and specification process because they have a major affect on the cost and scheduling of the work. If for any reason they have not, then it is essential to finalize these determinations during the procurement phase so that any additional equipment can be obtained prior to the start of installation.
- d. Fabricate fixtures using standard wire colors. Leads from new fixtures should be labeled, and should not contain any unnecessary conductors.
- e. Ship fixtures to job site with clear and concise documentation about what is (or is not) being shipped. Any equipment on back-order must be clearly noted in all shipping documentation.

8. Lighting control system vendor

- a. Create drawings describing the lighting control system (e.g., one-line diagrams, details such as mounting requirements, etc.). Additionally, all wiring connections must be clearly indicated on the drawings. As noted in the specifications, lighting control system vendors typically do not provide project-specific drawings showing wiring connections for all equipment. In many cases, catalog sheets are provided that show typical connections. However, it’s not uncommon for a specific project to require wiring connections that are not shown on the catalog sheets. Therefore, it’s essential for the vendor to provide project-specific details about all wiring connections to avoid incorrectly wiring equipment on-site, which may lead to damaging or destroying luminaires or lighting control equipment. In addition, similarly to luminaires, formal “submittal” drawings for lighting control systems are not typically prepared prior to the vendor receiving a purchase order. Just as with luminaires, during this phase, it is highly desirable to require any prospective lighting control system vendor to at least submit “informal” drawings showing every detail of the system being considered. Once a purchase order is finally issued, it should be easy for the lighting control system vendor to convert any “informal” drawings into formal “submittal” drawings for official approval by the project team.
- b. Create formal “submittal” drawings describing the lighting control system (e.g., one-line diagrams, details such as mounting requirements, etc.). Additionally, all wiring connections must be clearly indicated on the drawings. Submit drawings to the owner and project team for approval.

- c. Indicate what additional equipment, if any, must be ordered prior to installation if that equipment is not on the original purchase order for either luminaires or the lighting control system. For example, a lighting control system vendor may not typically provide a rack for holding the server, assuming that an existing space will be available in a rack already installed in an IT room. What if there isn't? Similarly, lighting control system vendors typically do not include quantities (lengths) for low-voltage cable required to connect sensors, switches, etc. Additionally, it is not uncommon for a vendor to assume that there is space on an owner's existing server, obviating the need to supply a dedicated server for the lighting control system. These determinations should already have been made during the design and specification process because they have a major affect on the cost and scheduling of the work. If for any reason they have not, then it is essential to finalize these determinations during the procurement phase so that any additional equipment can be obtained prior to the start of installation.
- d. Ship lighting control system components to job site with clear and concise documentation about what is (or is not) being shipped. Any equipment on back-order must be clearly noted in all shipping documentation.
- e. Provide support to the lighting designer, electrical engineer and/or electrical contractor during installation (answering installation questions, etc.).
- f. Provide personnel to verify that the control system is correctly installed (prior to commissioning).
- g. Provide personnel to commission the control system. There may or may not be applicable code or other requirements (e.g., LEED) requiring that a third-party commissioning agent commission the lighting control system.

9. Electrical contractor

- a. If required, install power and/or occupancy loggers (such as CTs, etc.) to determine baseline information.
- b. Attend meetings with owner, project team and/or vendors as required to understand the scope of work.
- c. Prepare proposal for installing equipment and submit to the owner for approval.
- d. Install luminaires and lighting control system according to drawings and specifications created by the lighting designer and electrical engineer.
- e. Provide electricians on-site during lighting control system commissioning (usually performed by a third-party commissioning agent or lighting control system vendor).

10. Third-party commissioning agent

- a. Provide personnel to commission the control system. There may or may not be applicable code or other requirements (e.g., LEED) requiring that a third-party commissioning agent commission the lighting control system.

Appendix E: Generic Zoning Diagrams for Lighting Control Systems

Introduction

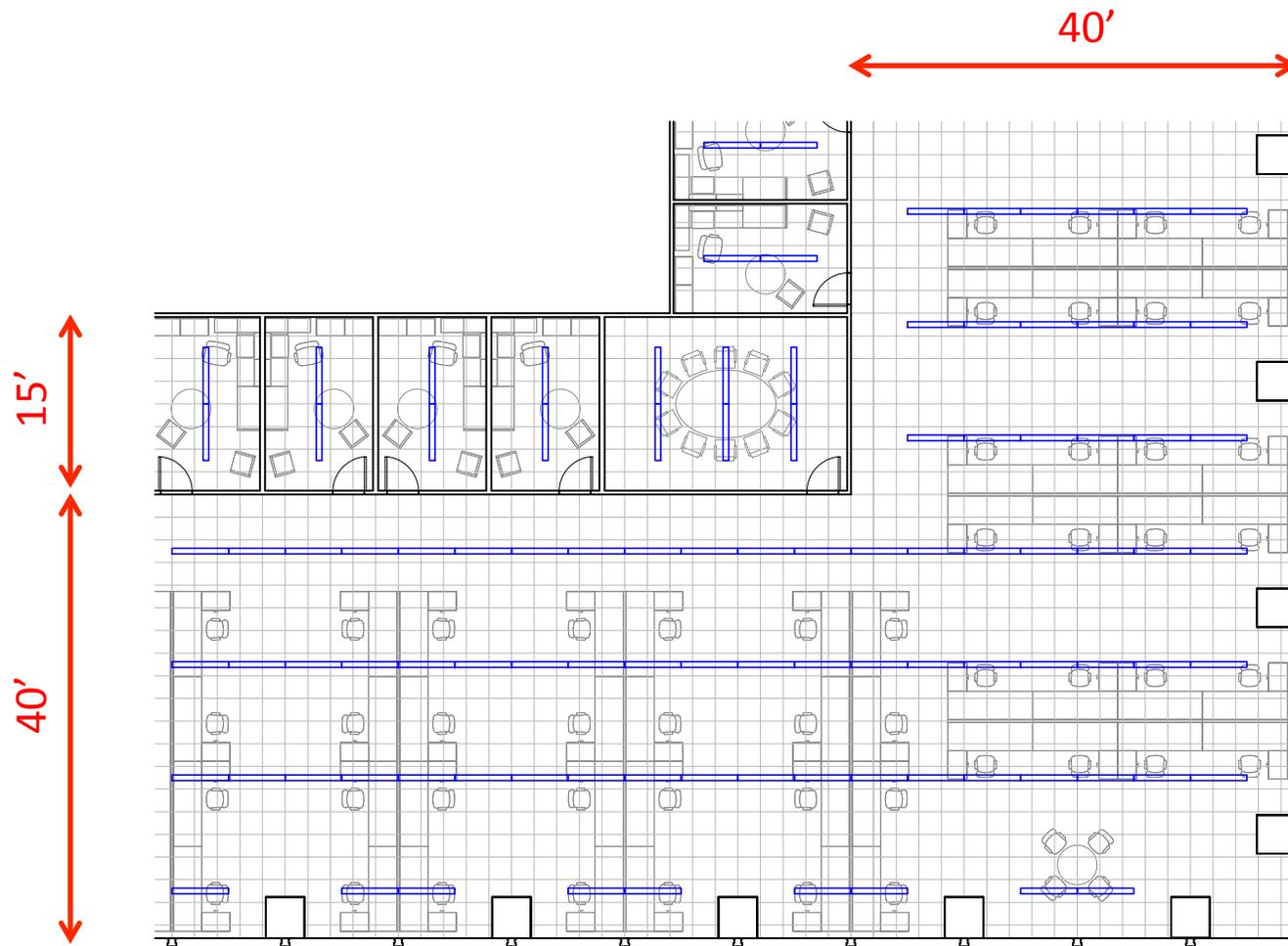
- When designing an advanced lighting control system, one major consideration is the desired granularity. This affects:
 - **Occupancy zones** based on occupancy sensor coverage and operation
 - **Daylight zones** based on photosensor coverage and operation
 - **Other possible fixture groupings** based on functional reasons (for example, fixtures grouped over a specific desk or workstation)
- A specifier may desire low- or high-granularity based on these considerations. The highest degree of granularity would involve the use of integral sensors and controllers in every single fixture.

Introduction

- Most advanced lighting control systems rely on individually-addressable fluorescent ballasts, LED drivers or on-board controllers. This allows the specifier to group fixtures based on desired zoning. However, it's also possible to use one ballast, driver or on-board controller to control a group of fixtures if individual addressability isn't required. However, this would reduce options for future rezoning.
- Some lighting control systems allow the specifier to configure the desired degree of granularity in the system's software and may even allow for zones to "overlap", while others are more rigid in their operation. The following slides contain graphic depictions of some methods used by systems currently available in the market.

Granularity in offices with
continuous rows of fixtures

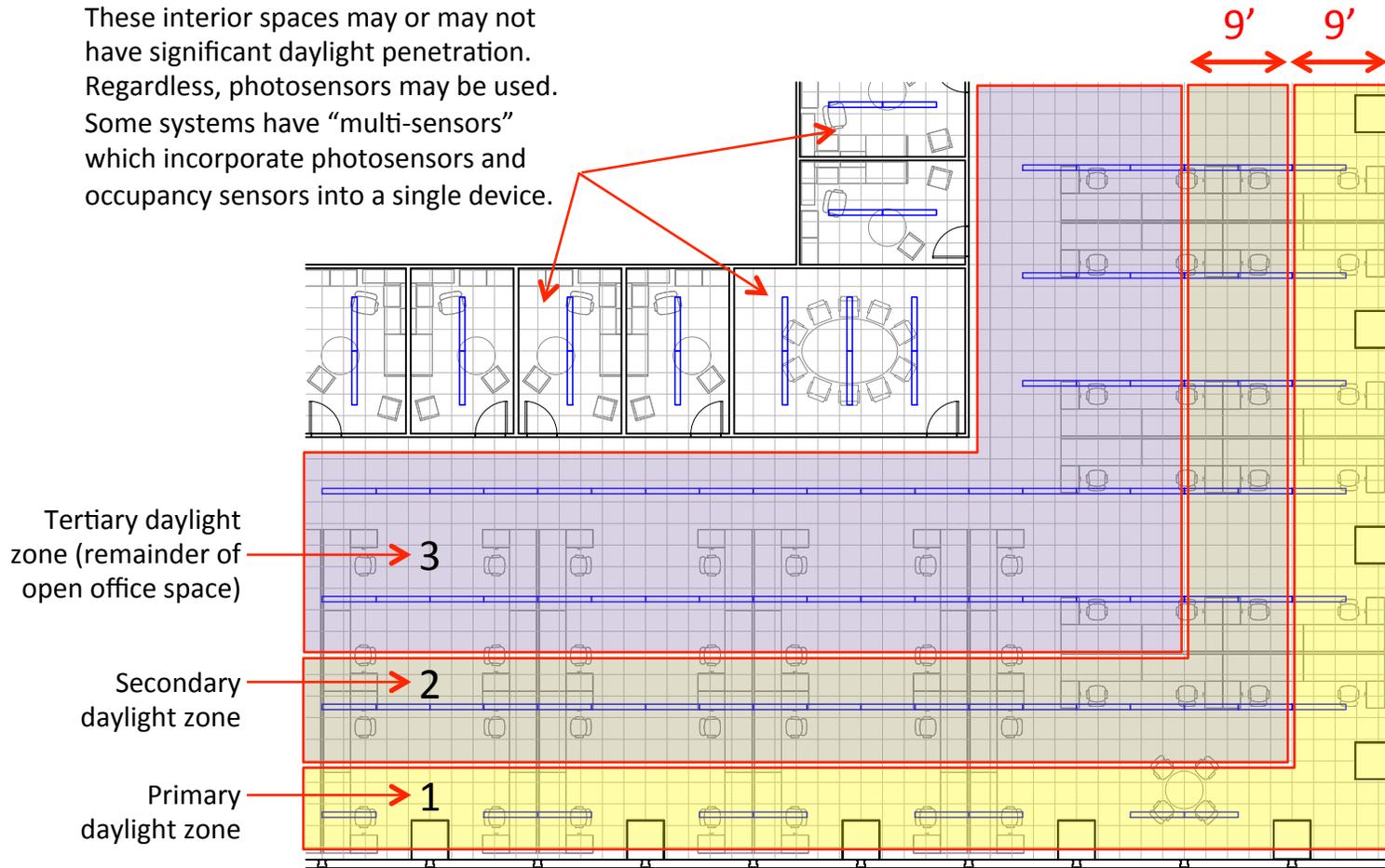
Open office floor plan with continuous pendant fixture rows



This is an example office space with open office areas at the perimeter, and private offices and conference rooms adjacent to the core. In this example, pendant fixtures are mounted in continuous rows. The ceiling height is 9'-0" and the exterior is a full-height window wall.

Daylight zones

These interior spaces may or may not have significant daylight penetration. Regardless, photosensors may be used. Some systems have “multi-sensors” which incorporate photosensors and occupancy sensors into a single device.

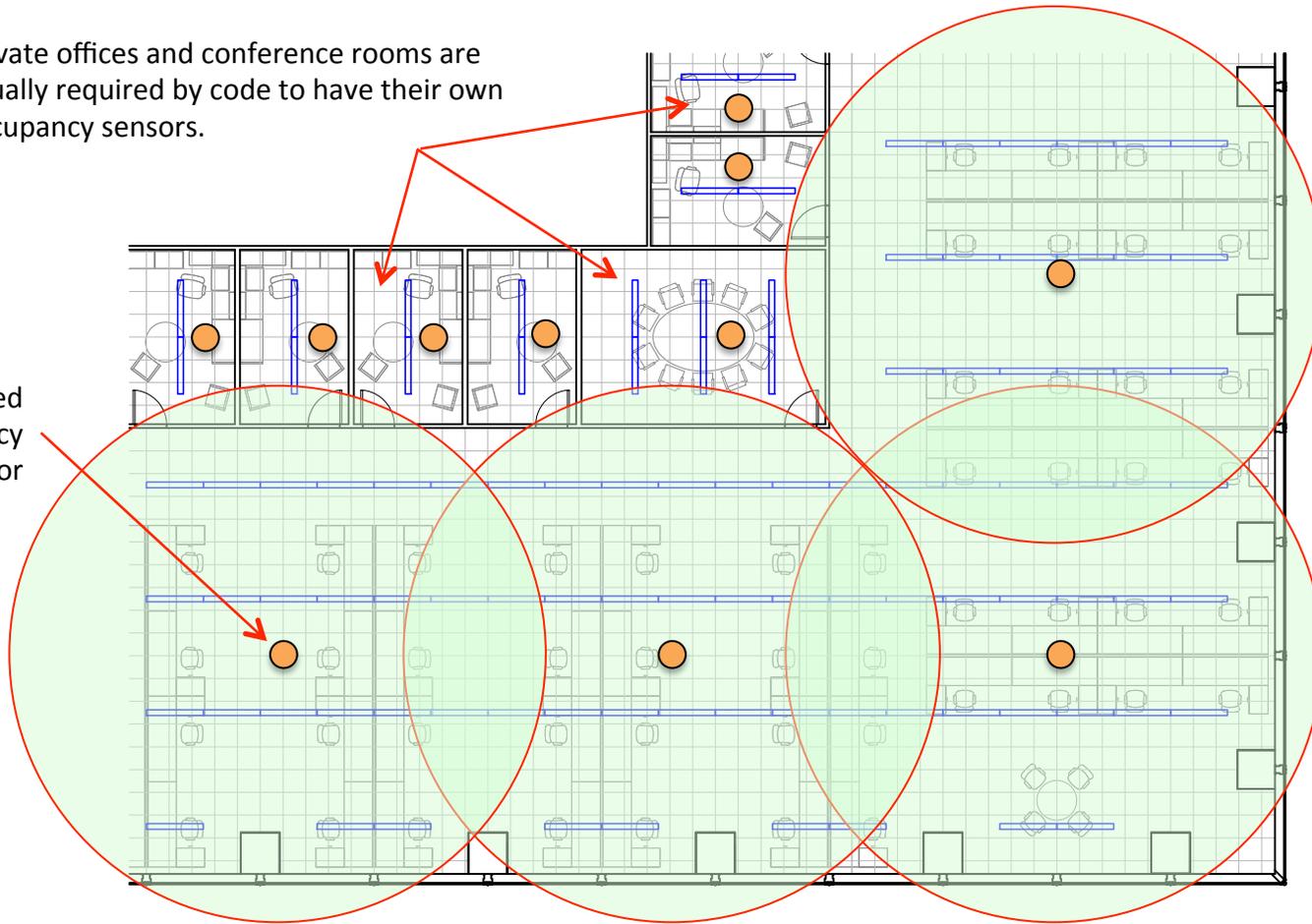


Daylight zones (as designated by numbers in the above example) are based on penetration of daylight into the interior. This example shows a succession of primary, secondary and tertiary daylight zones. Some codes (such as California Title 24) require all fixtures located in primary and secondary daylight zones to be **automatically** controlled. In California Title 24, the width of the primary and secondary zones is equal to the window head height as shown in the example above.

Occupancy sensor coverage in open office space (2,000 ft², radius=25')

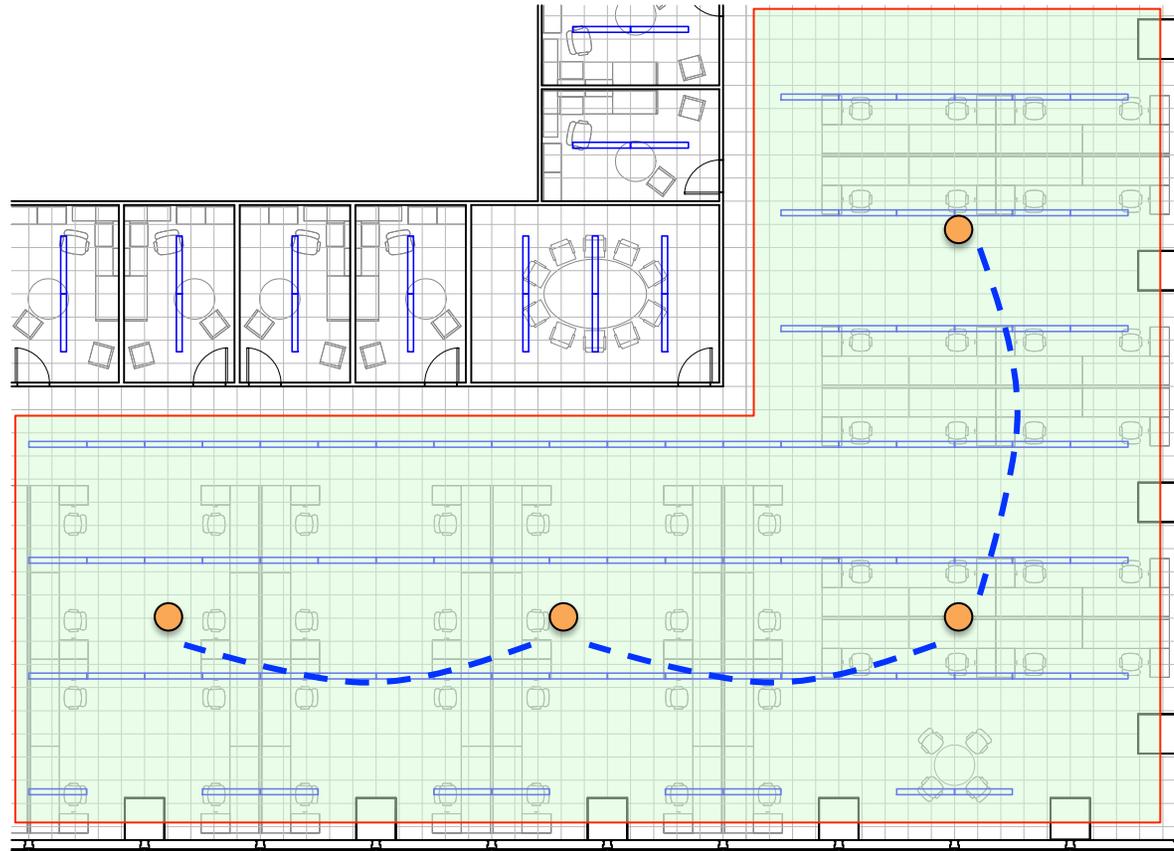
Private offices and conference rooms are usually required by code to have their own occupancy sensors.

Ceiling-mounted
occupancy
sensor



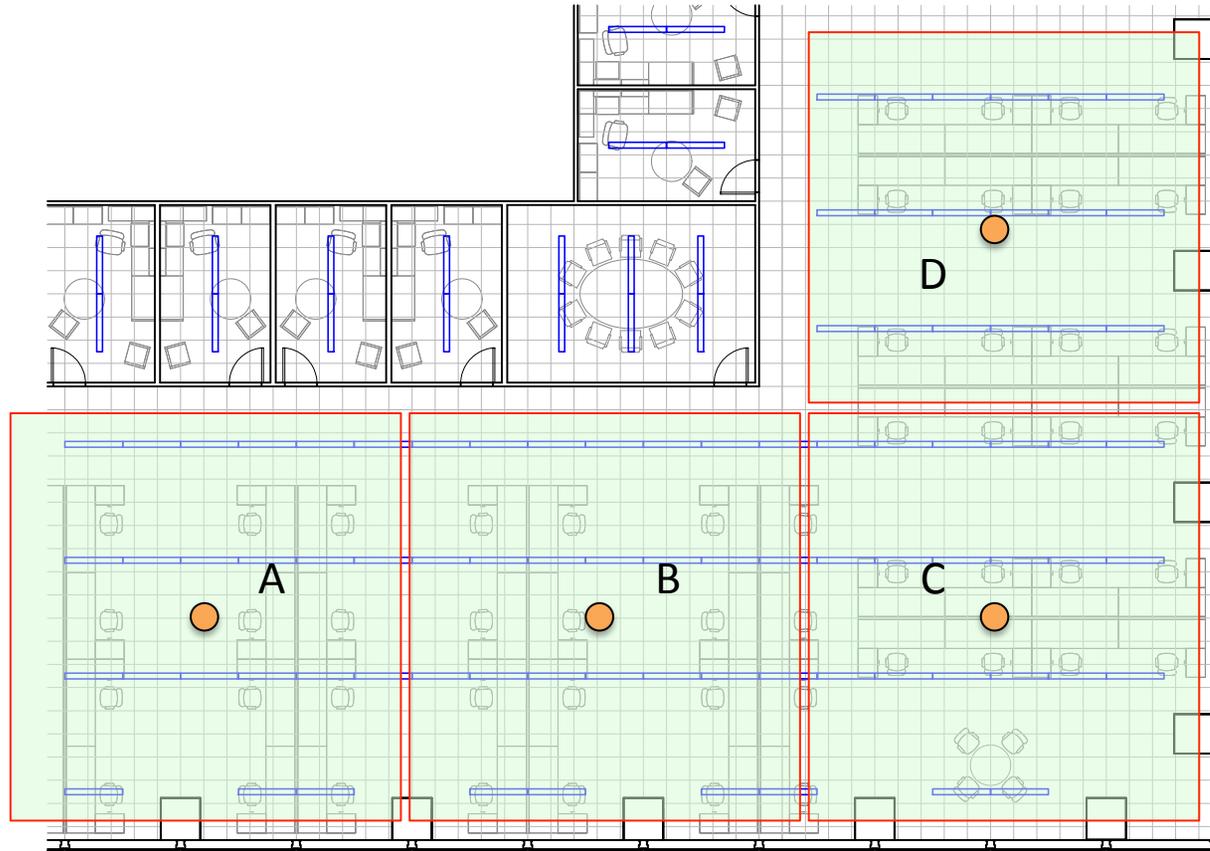
The green circles represent the coverage pattern of typical ceiling-mounted occupancy sensors with 2,000 ft² coverage in open office areas.

Occupancy sensors used in parallel operation in open office areas



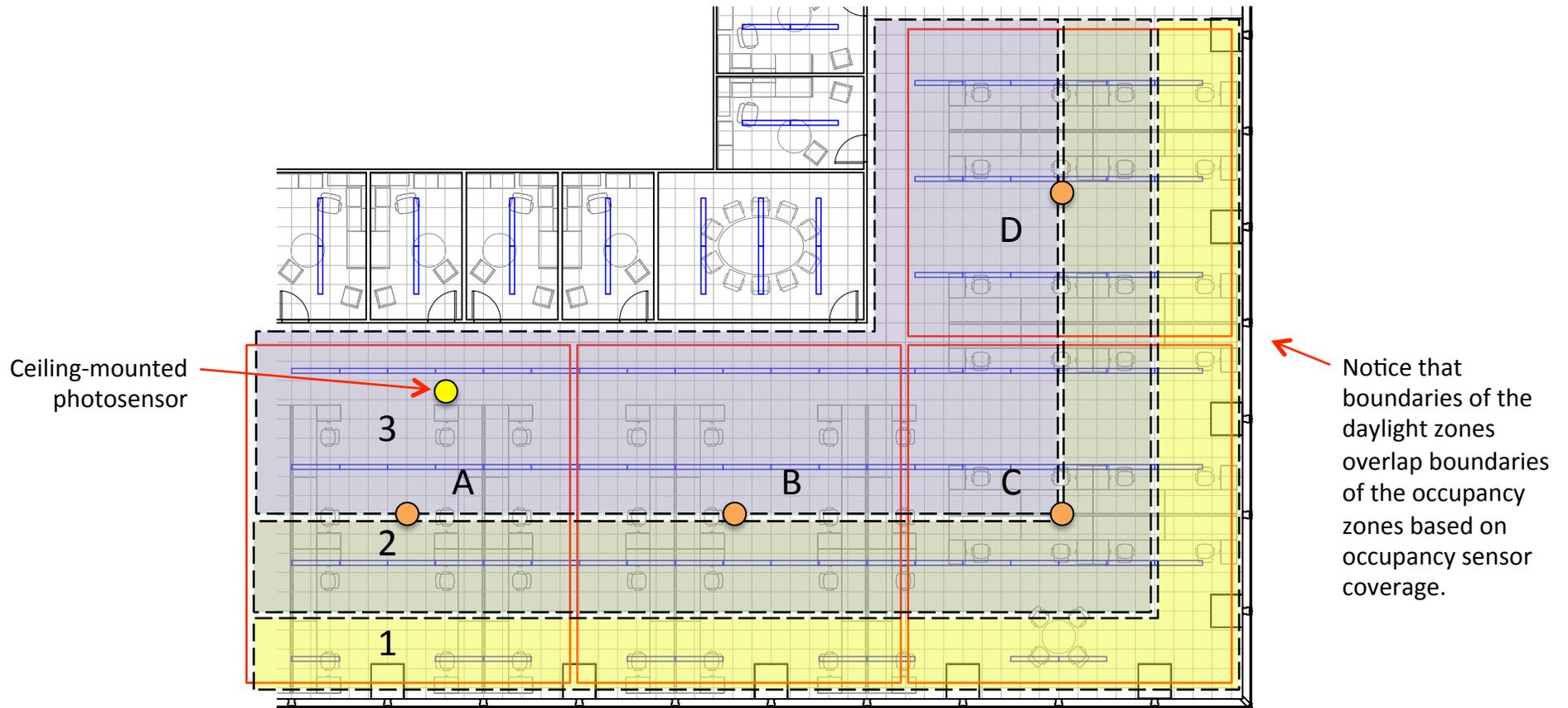
Just as with standalone analog devices, occupancy sensors in digital control systems can also be used “in parallel” (even if they’re not wired together). Essentially this means that the entire space would be one large occupancy zone. In that case, movement detected by any occupancy sensor would keep all of the lights on throughout the entire open office space. This approach would result in the least amount of energy savings.

Low granularity – occupancy zones based on occupancy sensors with 2,000 ft² coverage



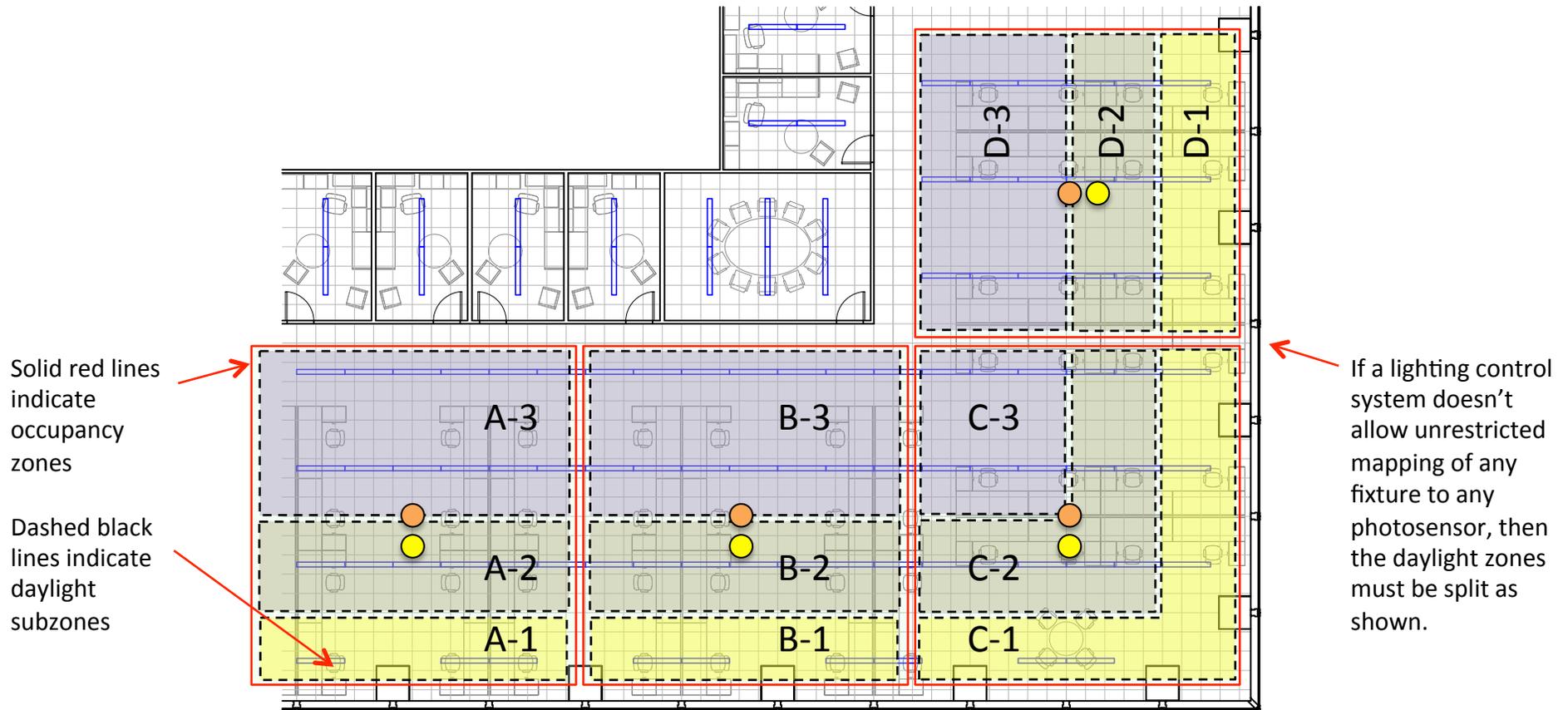
Establishing occupancy zones (as designated by letters in the above example) based on the coverage of each occupancy sensor allows groups of lights to be separately controlled. Once there is a distinct occupancy zone for each occupancy sensor, there's a greater chance of reducing energy use – since lights in a specific zone can dim or turn off once that zone is vacant.

Overlap of daylight zones with low granularity occupancy zones (using occupancy sensors with 2,000 ft² coverage) – unrestricted mapping of fixtures to photosensors



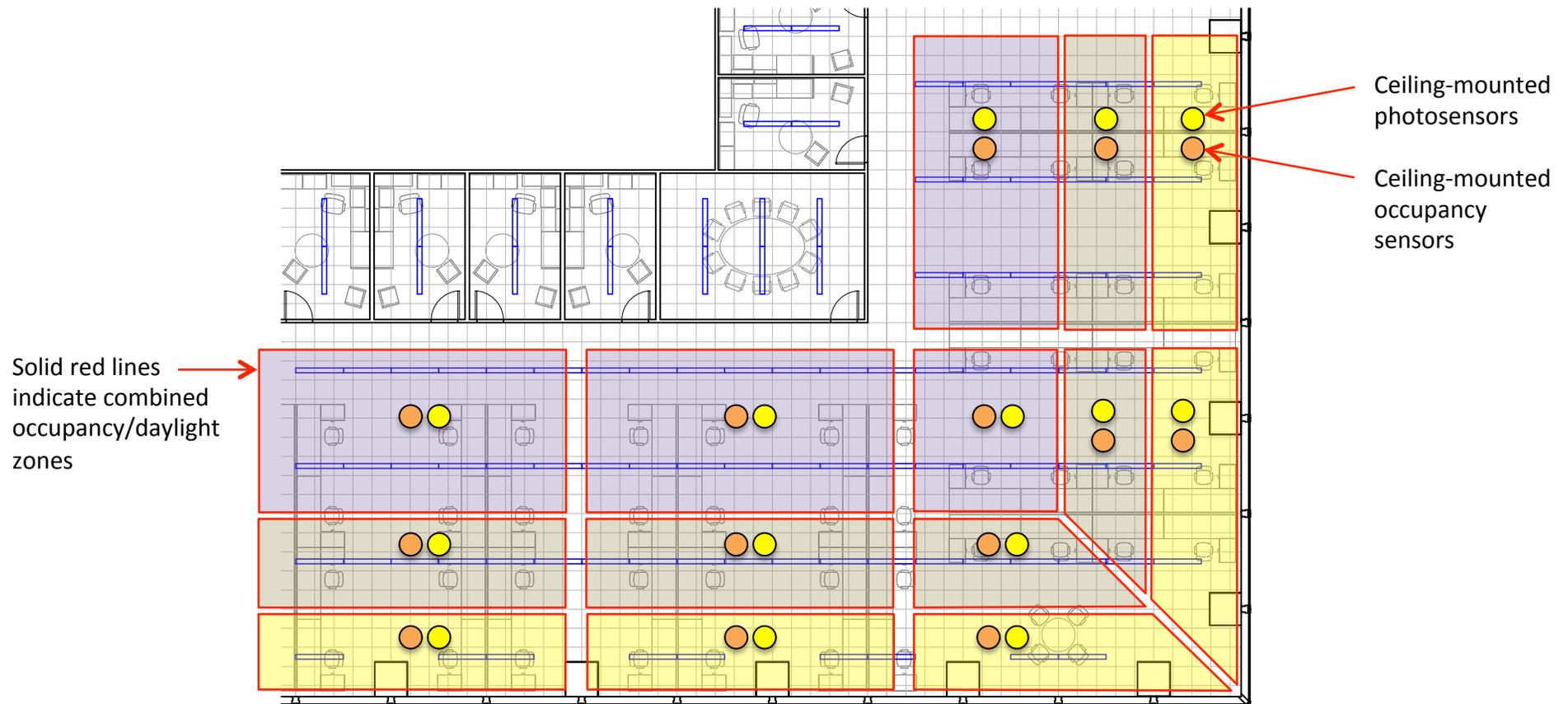
When these daylight zones are overlaid onto the occupancy zones, they overlap (they are not aligned). Some lighting control systems allow **any** fixture to be mapped to **any** photosensor – regardless of which control zone they’re in. If such a system is used, then as shown above daylight zones **do not need to align** with occupancy zones. Additionally, some systems can work with as little as one photosensor for an entire open office area, reducing equipment and labor costs.

Separation of daylight zones for systems that **do not** allow unrestricted mapping of fixtures to photosensors



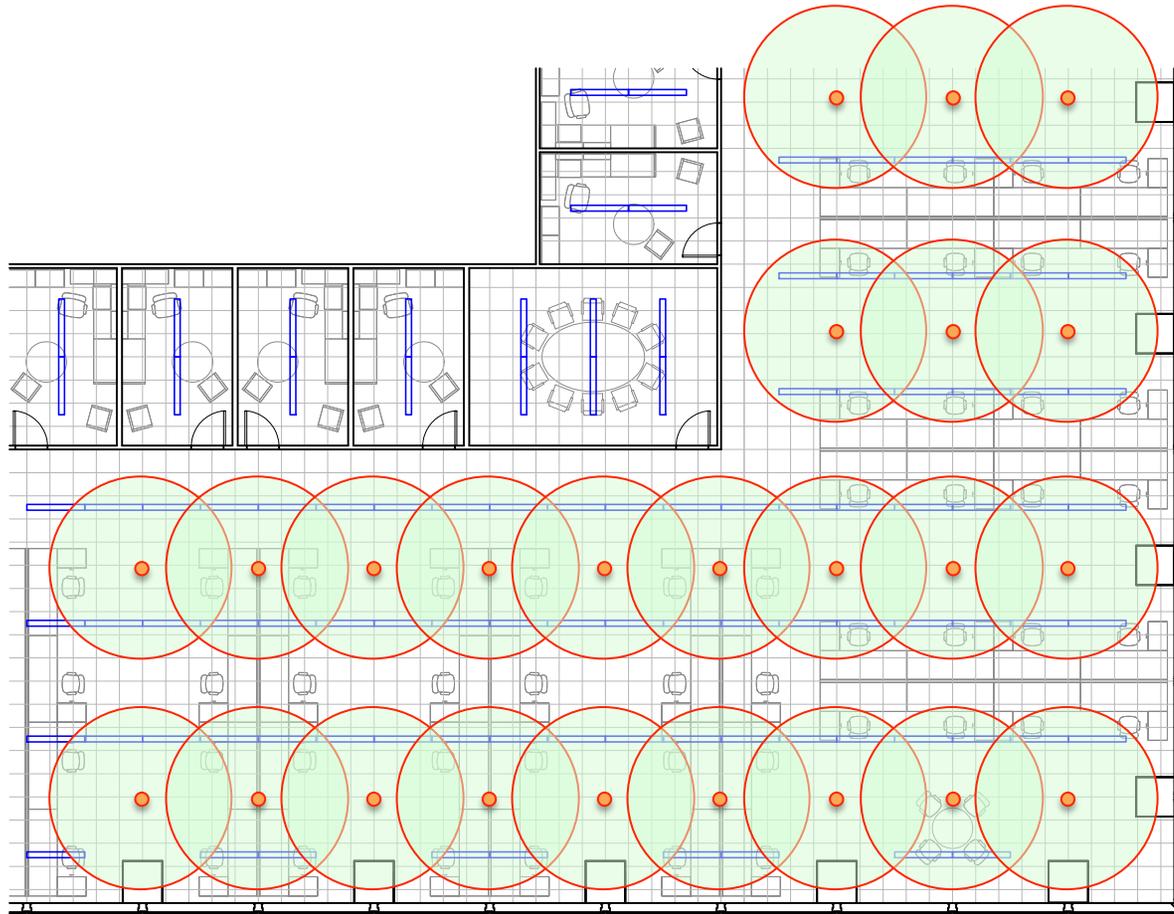
Some systems allow for “differential dimming” of fixtures within an occupancy zone – groups of fixtures can be dimmed to different levels based on the input from one photosensor (as shown above). However, each occupancy zone usually requires its own photosensor as well as occupancy sensor.

Zoning for systems where occupancy zones must exactly match daylight zones



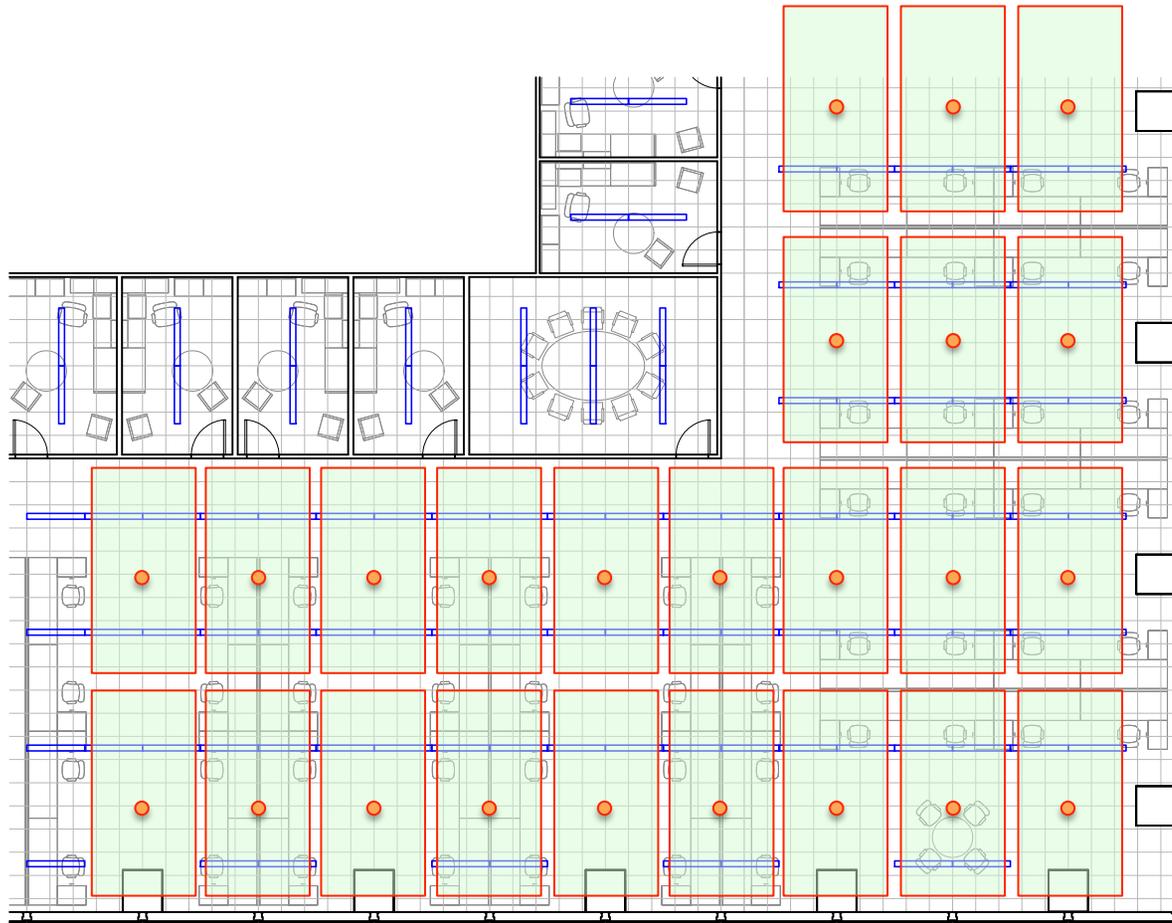
Certain systems require that fixtures responding to a photosensor **exactly** correspond to those in a distinct occupancy zone based on an occupancy sensor. If so, then zones for daylighting would be exactly the same as for occupancy (as shown above). Each zone would require its own occupancy sensor **and** photosensor, potentially increasing the cost of the system.

Occupancy sensor coverage (200 ft², radius=8')



Certain occupancy sensors, such as those designed for use in individual fixtures, have a much smaller area of coverage. If these sensors are mounted separately (as shown), they can control small groups of fixtures. (In some systems, these sensors are combined with transceivers that communicate with a wireless gateway via RF transmission, then back to a server.)

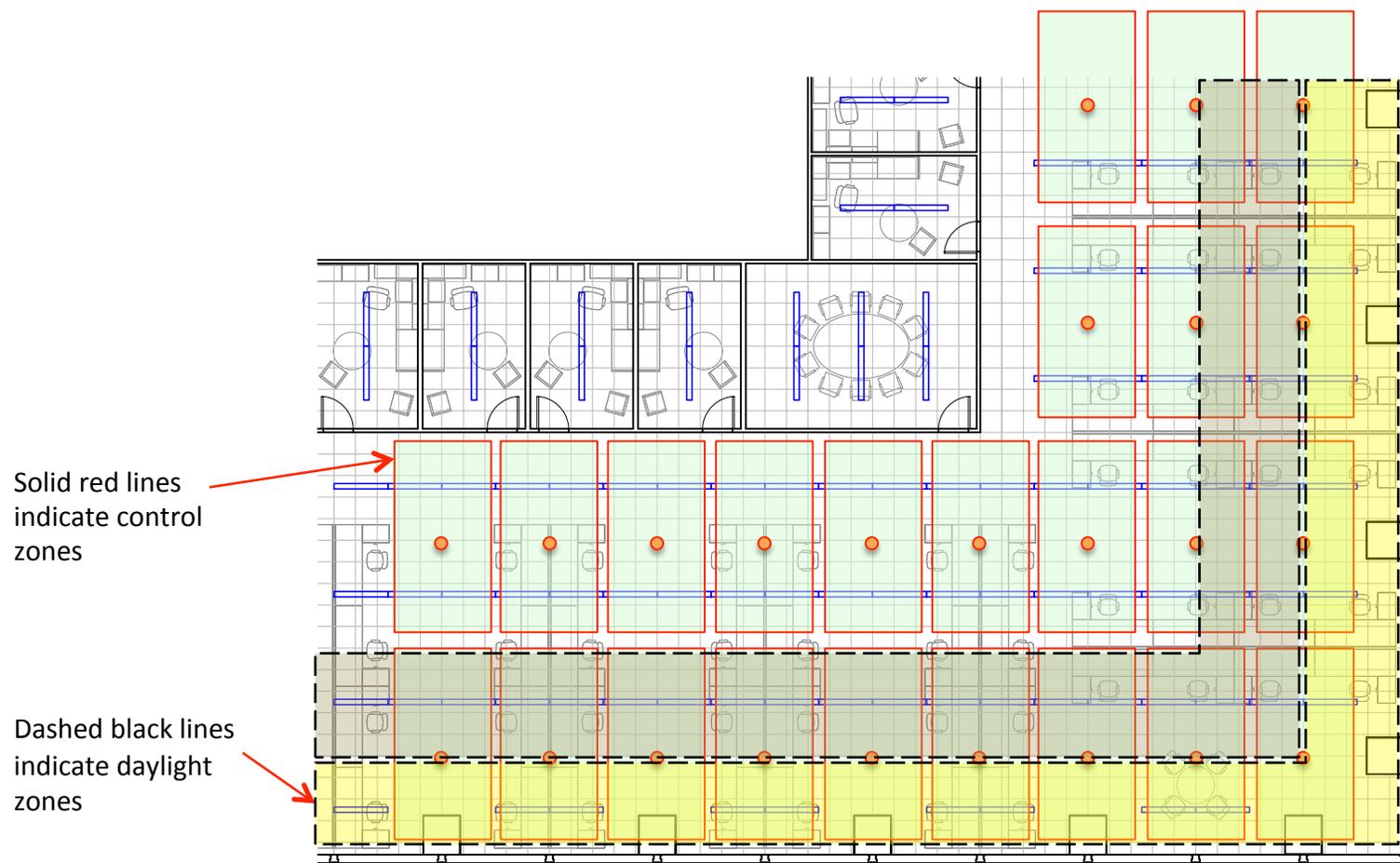
High granularity – occupancy zones based on occupancy sensors with 200 ft² coverage



14

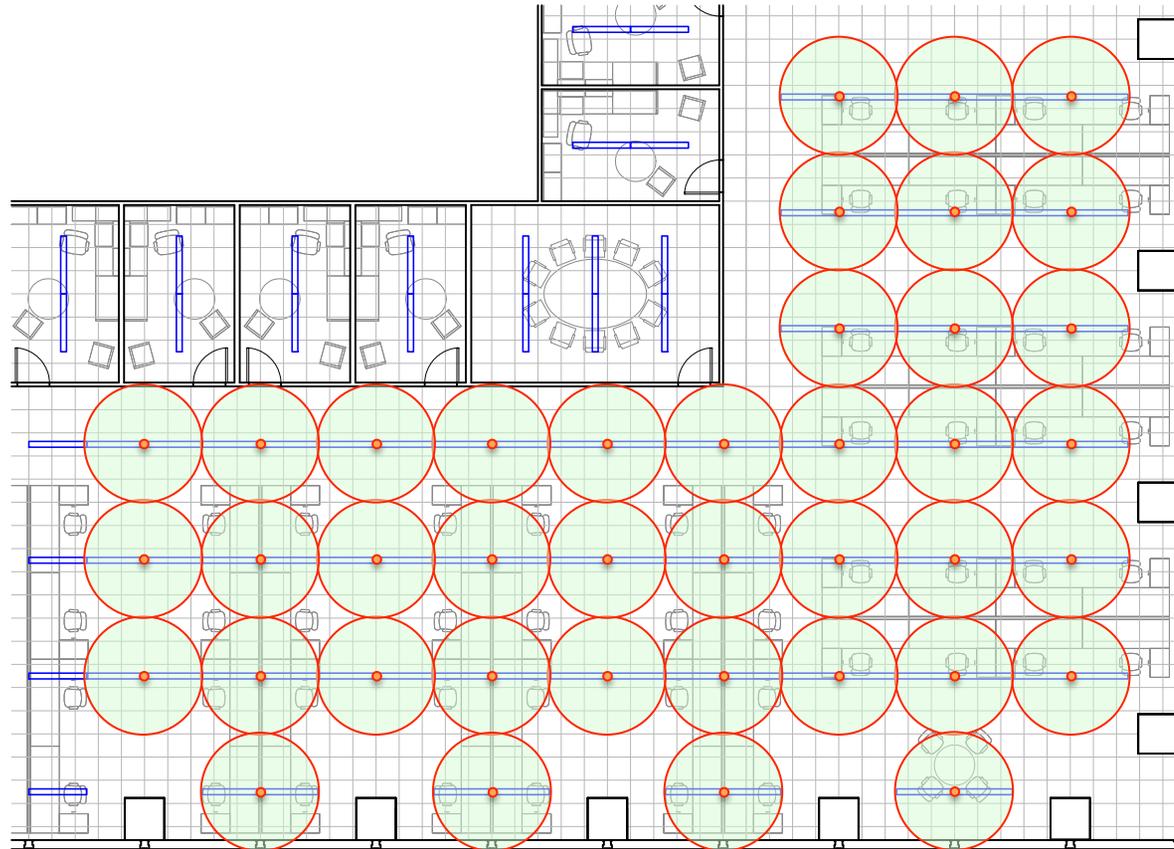
The benefit of having small occupancy zones is that there's a better chance that lights in certain zones will dim or turn off upon vacancy – as compared to those in larger occupancy zones where occupancy sensors have much greater areas of coverage. This will also result in a greater number of zones in the system's software. However, this is purely “administrative” and shouldn't have any significant impact on the operation of the system or the complexity for the owner.

Overlap of daylight zones with high granularity occupancy zones (using occupancy sensors with 200 ft² coverage)



Notice that in this example daylight zones do not coincide with the occupancy zones. When using a system that **doesn't** allow unrestricted mapping of fixtures to photosensors, it may be necessary to shift the occupancy and/or daylight zones (if possible). It may be worth considering the highest degree of granularity – using a system with integral occupancy sensors and photosensors in every fixture.

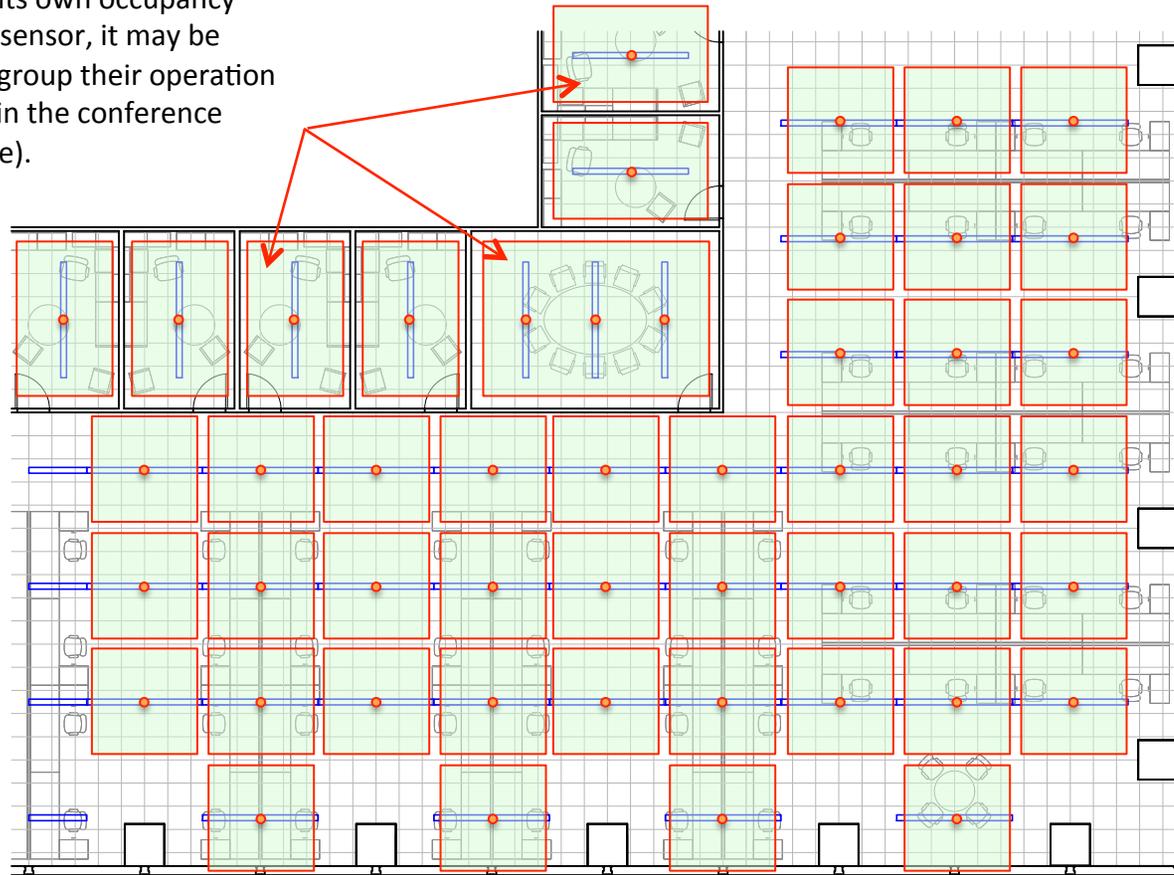
Fixture-integrated occupancy sensors (highest granularity)



Since the quantity of occupancy zones is typically unlimited in the system software, it's possible to use fixture-integrated sensors – every fixture has its own occupancy sensor and photosensor. Then each fixture can respond to daylight availability and occupancy based on its location on the plan.

Occupancy zones using fixture-integrated occupancy sensors (highest granularity)

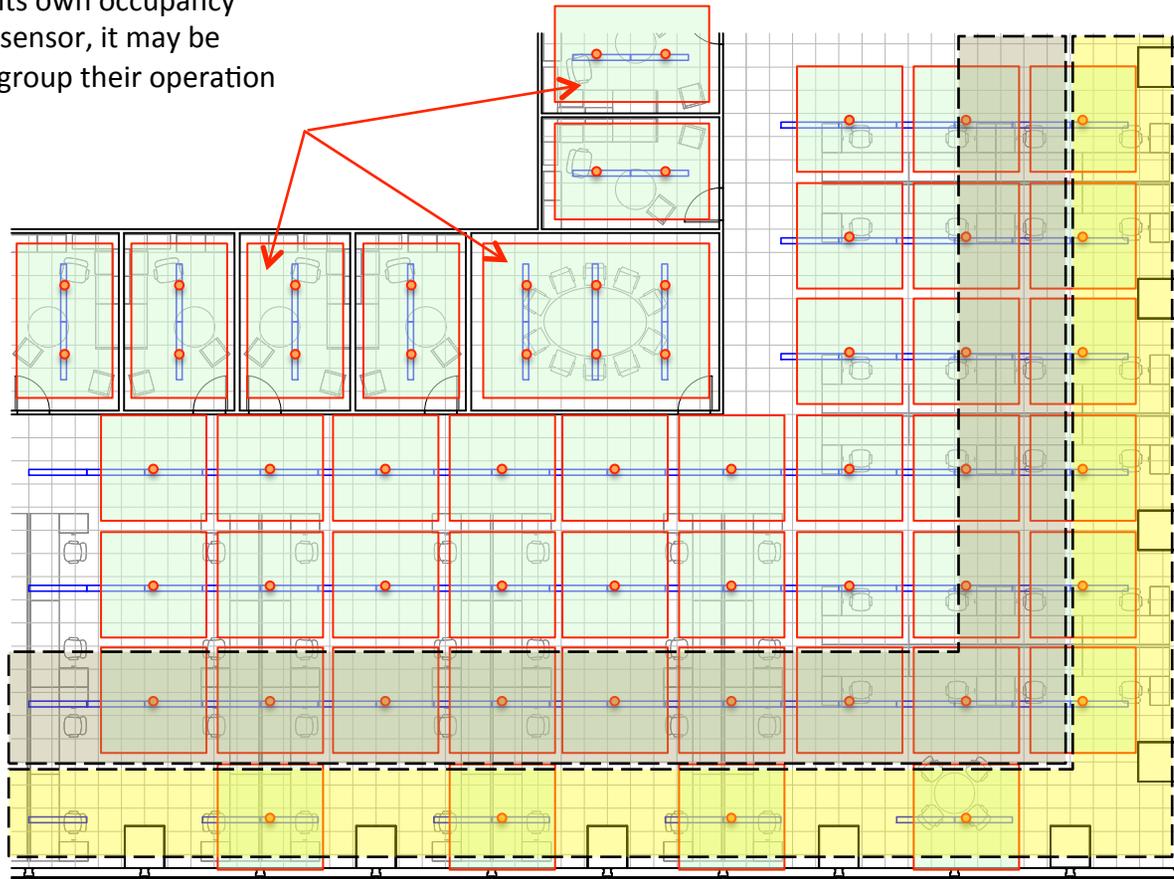
Even though every fixture in each of these spaces has its own occupancy sensor and photosensor, it may be advantageous to group their operation and behavior (as in the conference room, for example).



Using fixture-integrated photosensors and occupancy sensors results in the greatest amount of hardware. However, as shown in the conference room above, it may still be preferable to use one photosensor and one occupancy sensor to control all fixtures within certain spaces. Alternatively, some systems that rely on fixture-integrated sensors allow for the creation of “groups” even though every fixture still has its own sensor – for open or enclosed spaces.

Occupancy zones using fixture-integrated multi-sensors (highest granularity)

Even though every fixture in each of these spaces has its own occupancy sensor and photosensor, it may be advantageous to group their operation and behavior.



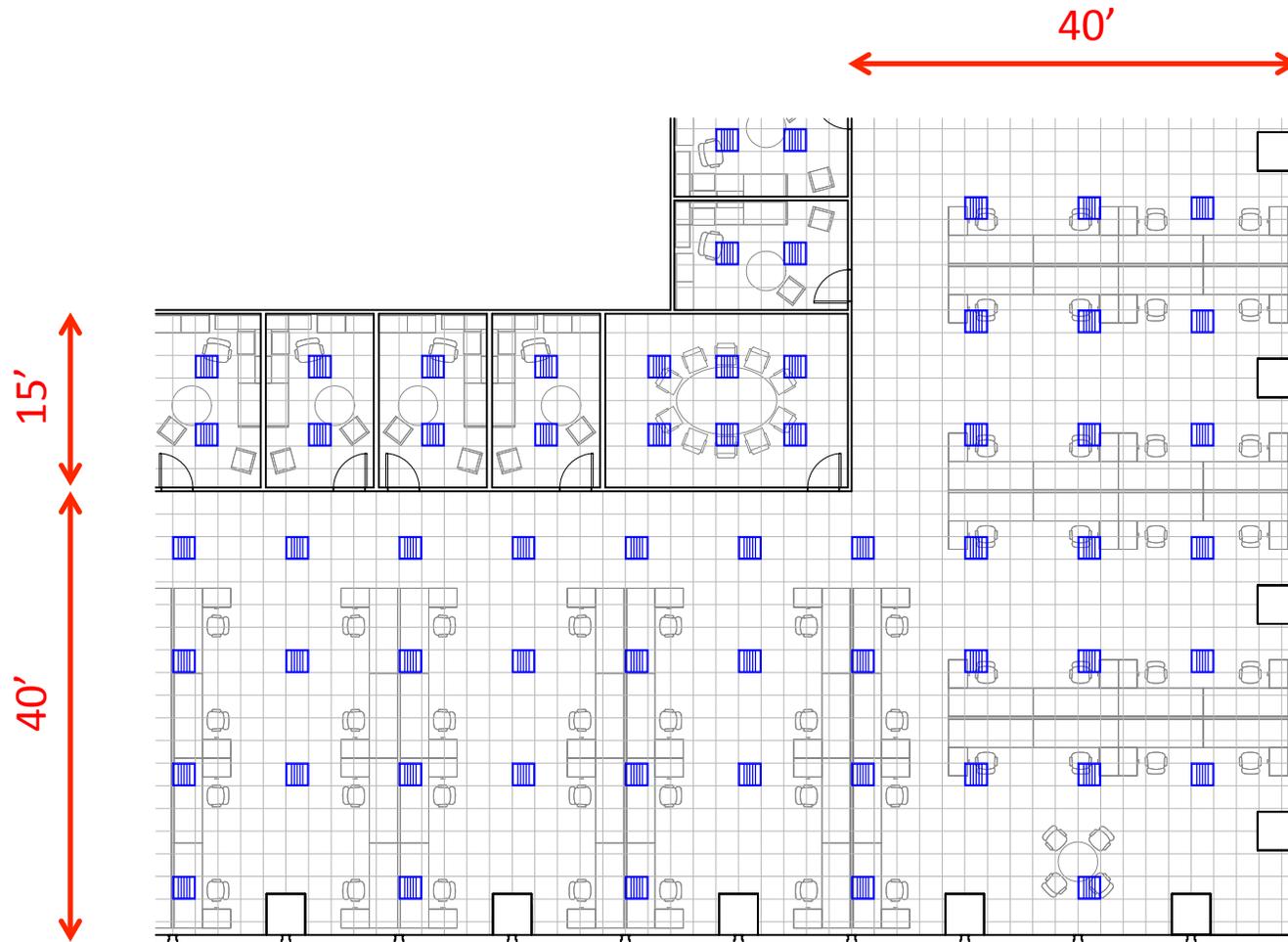
If the fixtures contain both an occupancy sensor as well as photosensor (sometimes combined into a single unit called a “multi-sensor”), then it’s likely that each fixture can be appropriately programmed to respond to available daylight as well as occupancy.

Questions to ask about zoning when specifying a lighting control system

- Do code provisions specify or limit the size or shape of daylight or occupancy zones? For example:
 - Occupancy (control) zones must be limited to a maximum of 5,000 ft²? 1,000 ft²? ____ ft²?
 - Daylight zones: width must equal window head height for primary and secondary daylight zones?
- Control of fixtures in daylight zones. For example:
 - Provisions must be made for manual control in primary daylight zones only?
 - All lights in primary as well as secondary daylight zones must be automatically controlled?
- Does the owner have specific needs for controlling groups of fixtures? For example:
 - Fixtures over each open desk group must be controlled separately?
 - Fixtures in each department must be controlled separately from those in other departments?
 - Fixtures lighting circulation areas must be controlled separately from those lighting desks or other work spaces? (This may help to provide “wayfinding” after hours, and/or to reduce energy use.)
- Are DR (demand response) provisions required? For example:
 - Provisions must be made to automatically dim or turn off fixtures during a DR “event”. However, the owner needs to control which zones can be dimmed more ... or less ... or not at all.

Granularity in offices with
individual recessed fixtures

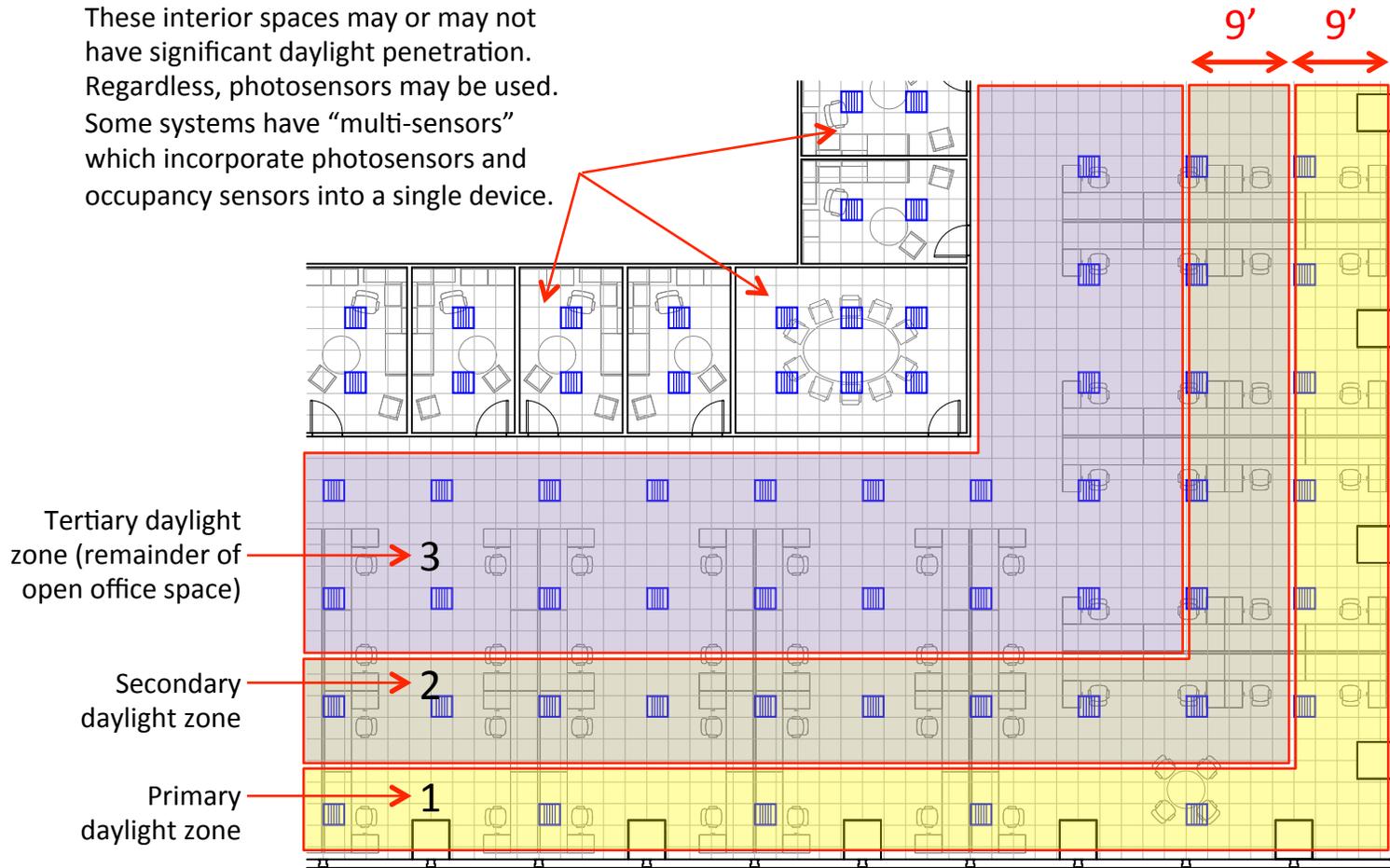
Open office floor plan with recessed troffers



This is an example office space with open office areas at the perimeter, and private offices and conference rooms adjacent to the core. In this example, individual recessed fixtures are used. The ceiling height is 9'-0" and the exterior is a full-height window wall.

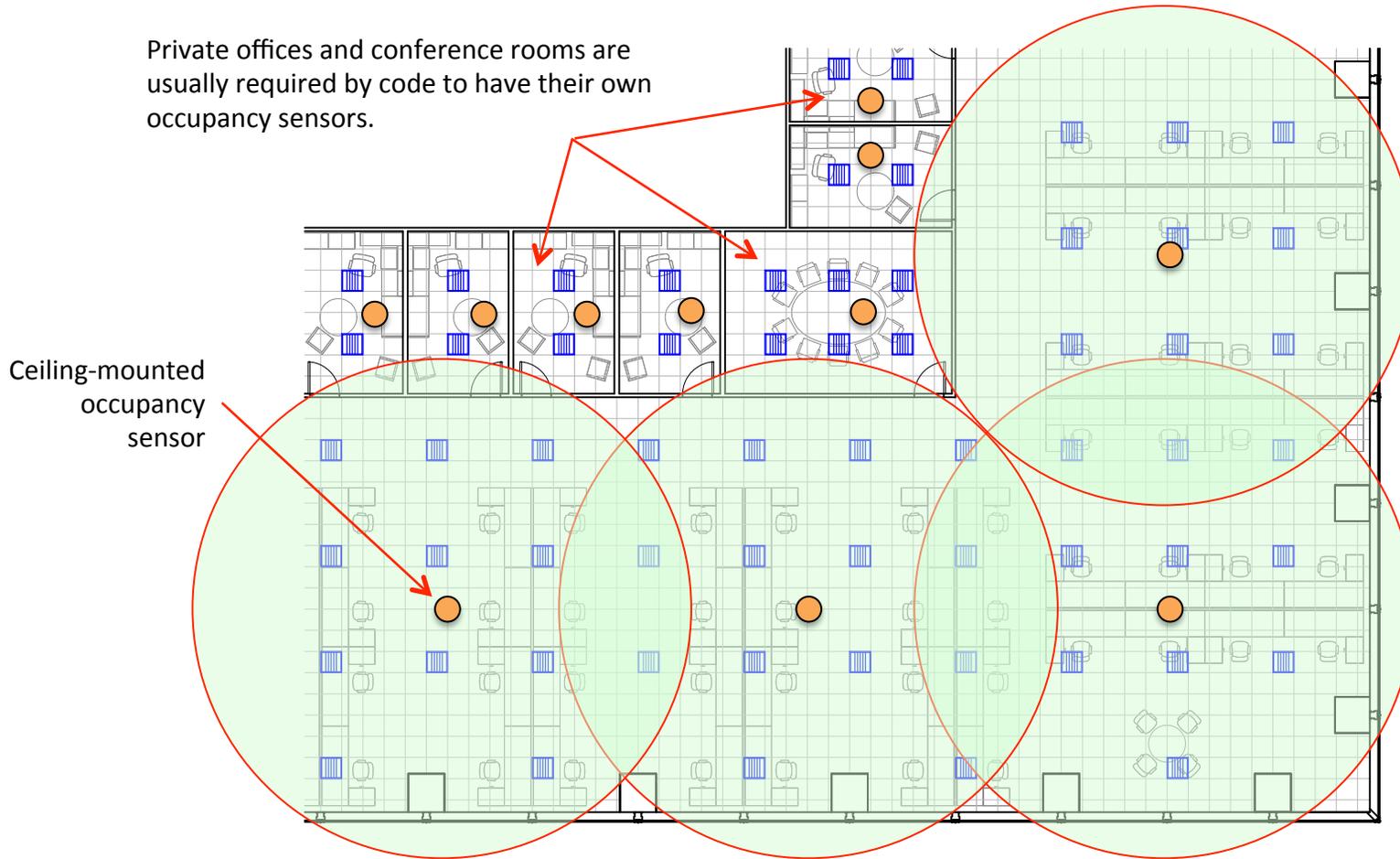
Daylight zones

These interior spaces may or may not have significant daylight penetration. Regardless, photosensors may be used. Some systems have “multi-sensors” which incorporate photosensors and occupancy sensors into a single device.



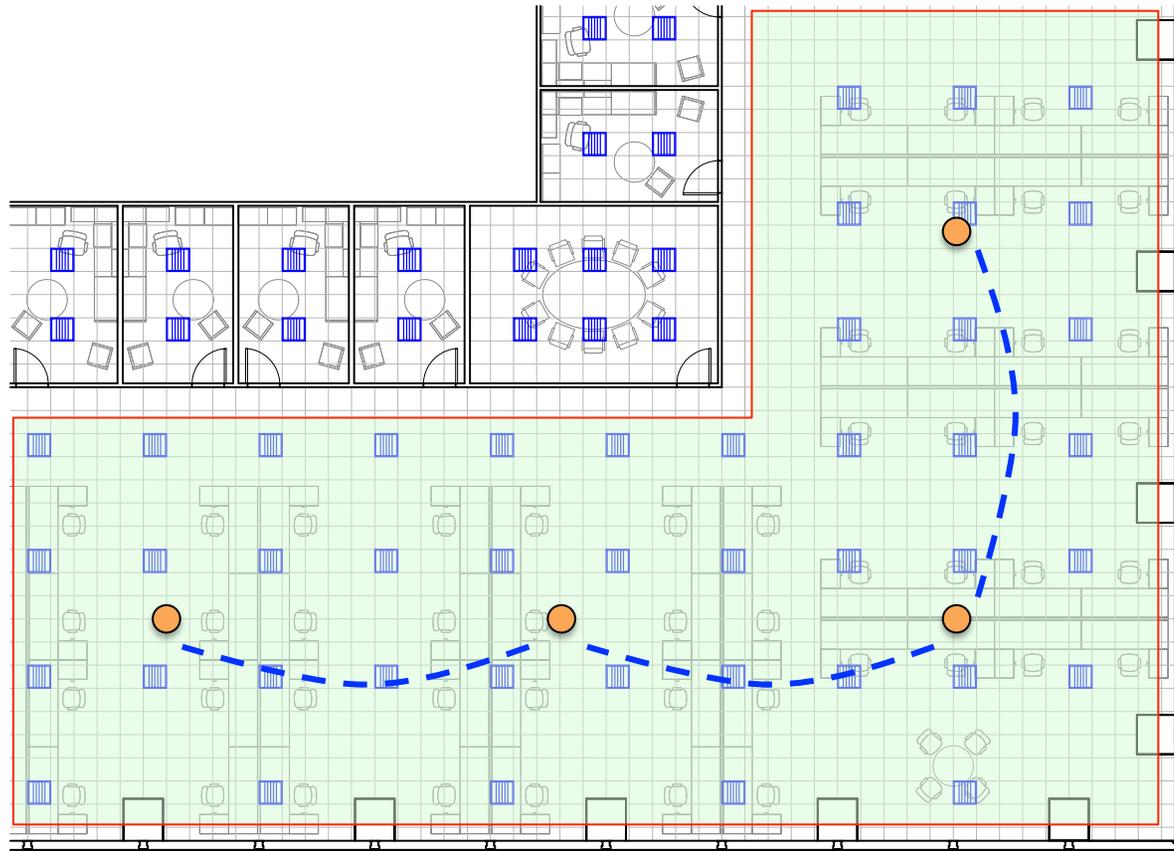
Daylight zones (as designated by numbers in the above example) are based on penetration of daylight into the interior. This example shows a succession of primary, secondary and tertiary daylight zones. Some codes (such as California Title 24) require all fixtures located in primary and secondary daylight zones to be **automatically** controlled. In California Title 24, the width of the primary and secondary zones is equal to the window head height as shown in the example above.

Occupancy sensor coverage in open office space (2,000 ft², radius=25')



The green circles represent the coverage pattern of typical ceiling-mounted occupancy sensors with 2,000 ft² coverage in open office areas.

Occupancy sensors used in parallel operation in open office areas



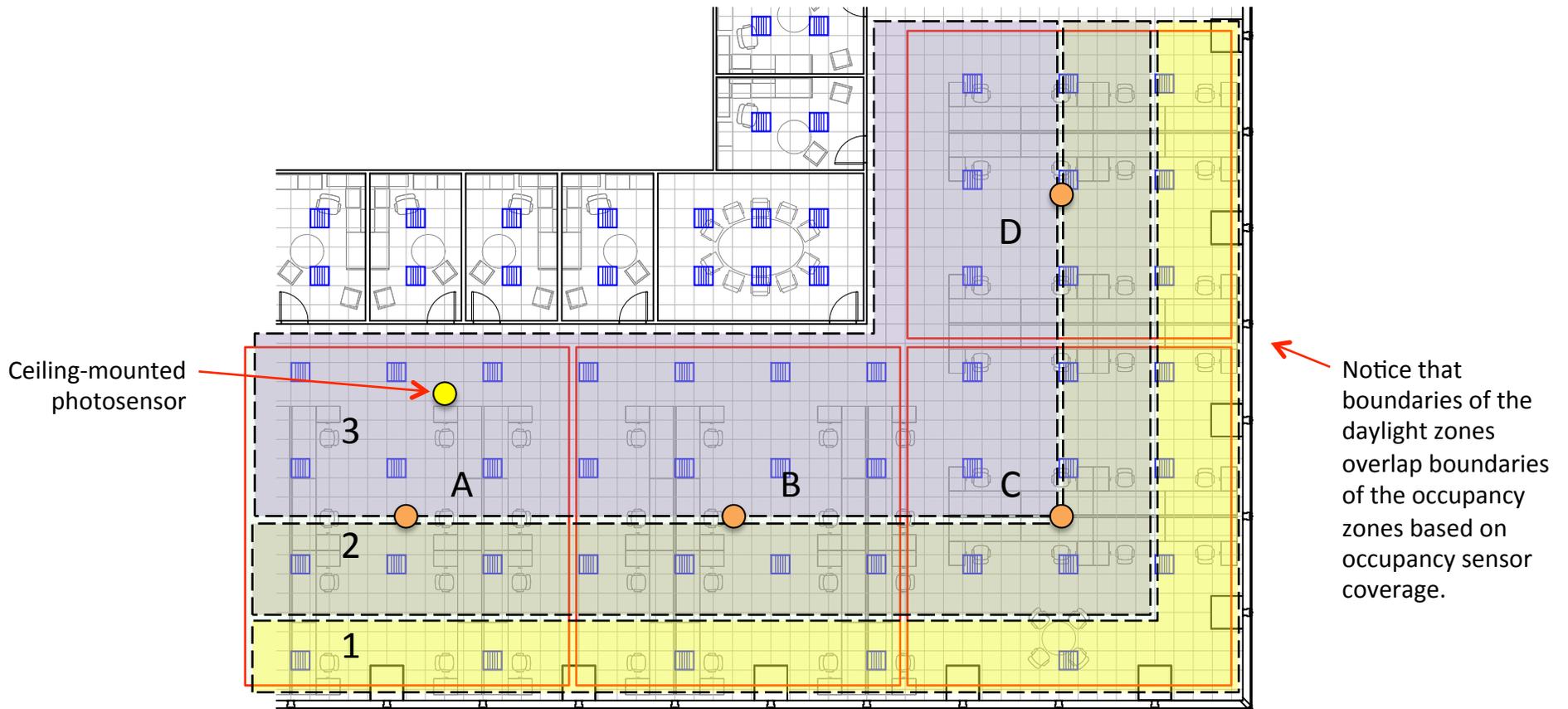
Just as with standalone analog devices, occupancy sensors in digital control systems can also be used “in parallel” (even if they’re not wired together). Essentially this means that the entire space would be one large occupancy zone. In that case, movement detected by any occupancy sensor would keep all of the lights on throughout the entire open office space. This approach would result in the least amount of energy savings.

Low granularity – occupancy zones based on occupancy sensors with 2,000 ft² coverage



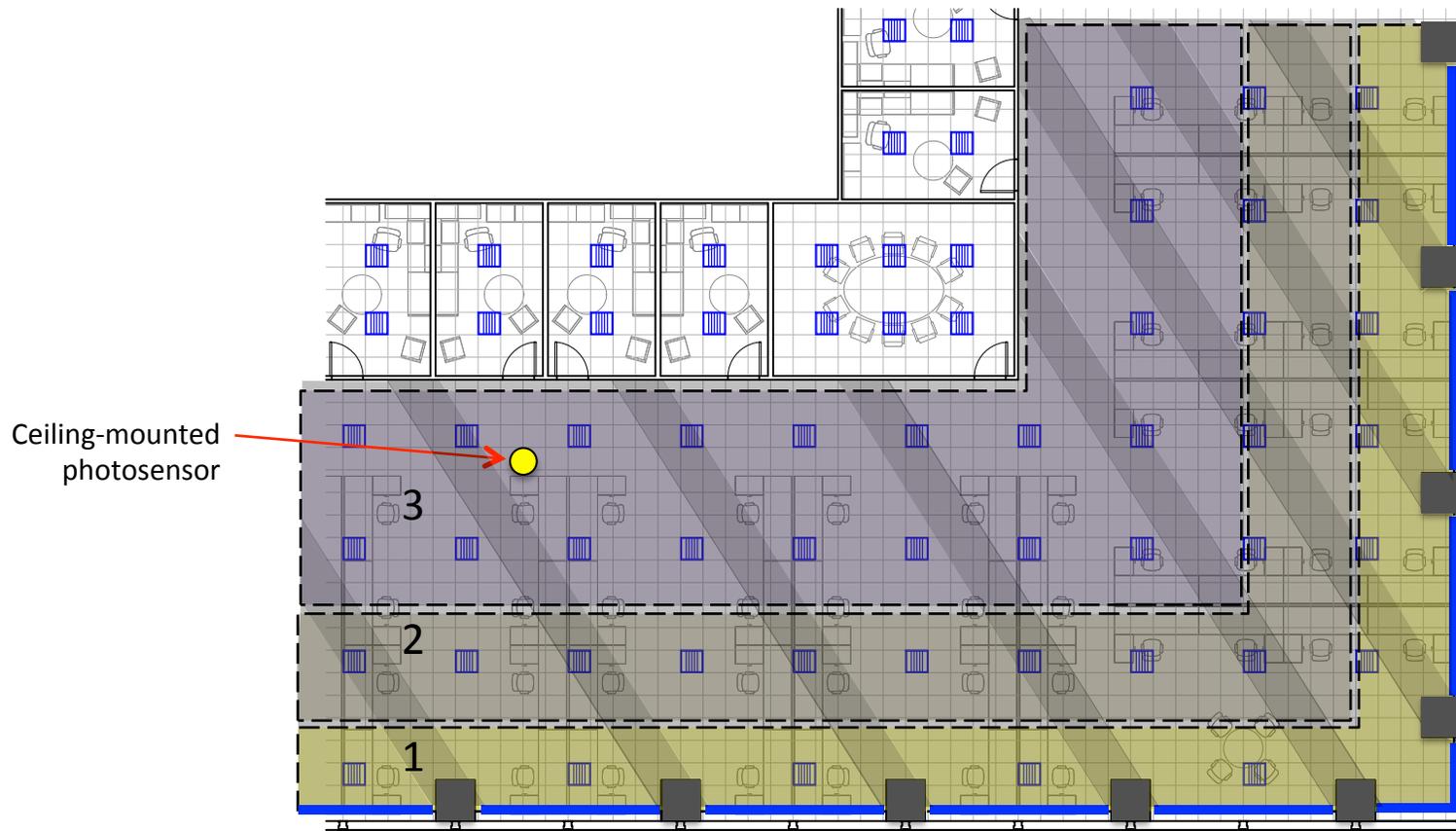
Establishing occupancy zones (as designated by letters in the above example) based on the coverage of each occupancy sensor allows groups of lights to be separately controlled. Once there is a distinct occupancy zone for each occupancy sensor, there's a greater chance of reducing energy use – since lights in a specific zone will dim or turn off once that zone is vacant.

Overlap of daylight zones with low granularity occupancy zones (using occupancy sensors with 2,000 ft² coverage) – unrestricted mapping of fixtures to photosensors



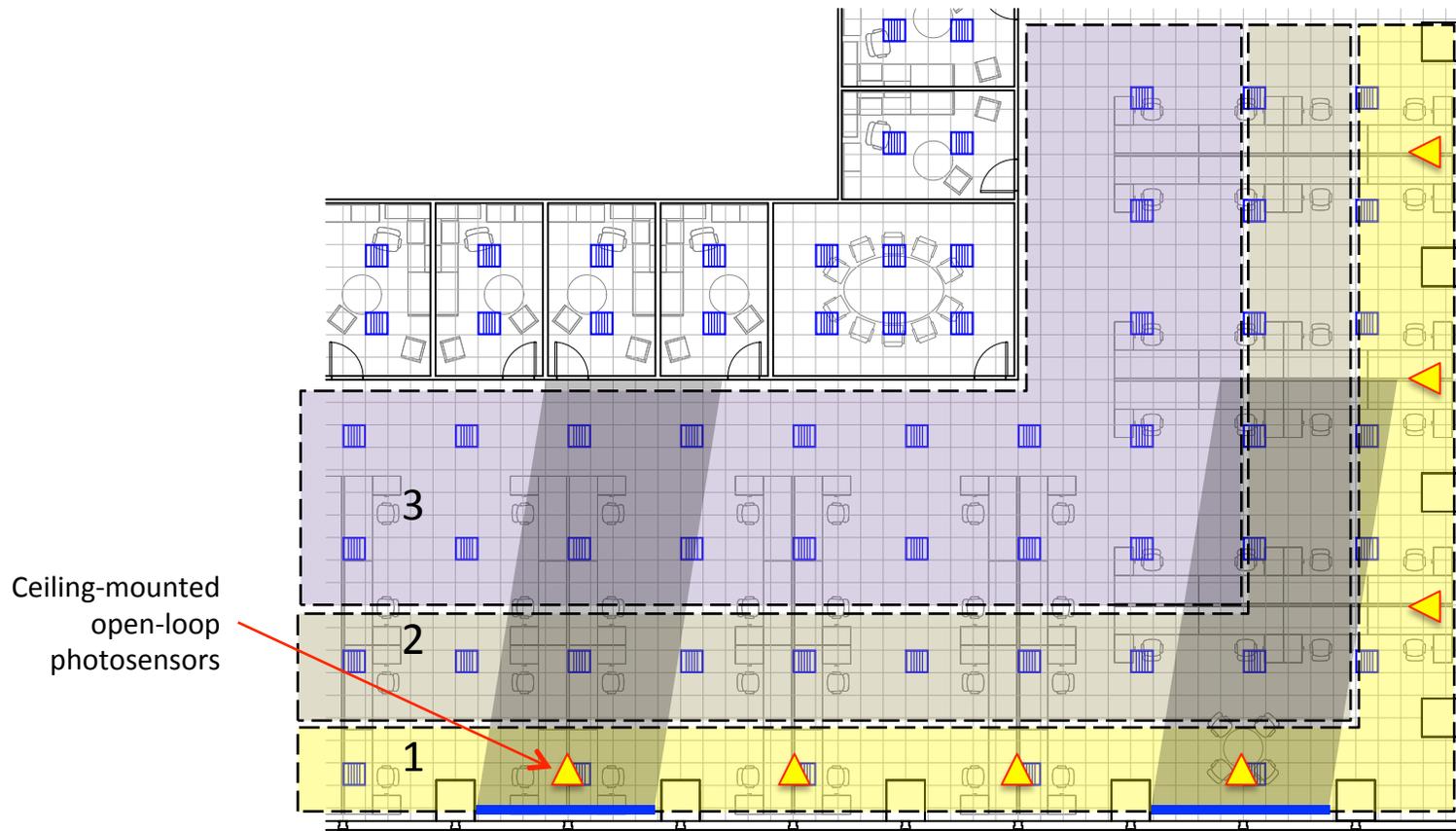
When these daylight zones are overlaid onto the occupancy zones, they overlap (they are not aligned). Some lighting control systems allow any fixture to be mapped to any photosensor – regardless of which control zone they’re in. If such a system is used, then daylight zones **do not need to align** with control zones (as shown above). Additionally, some systems can work with as little as one photosensor for an entire open office area, reducing equipment and labor costs.

Using photosensors to automatically adjust electric lights in response to shading systems



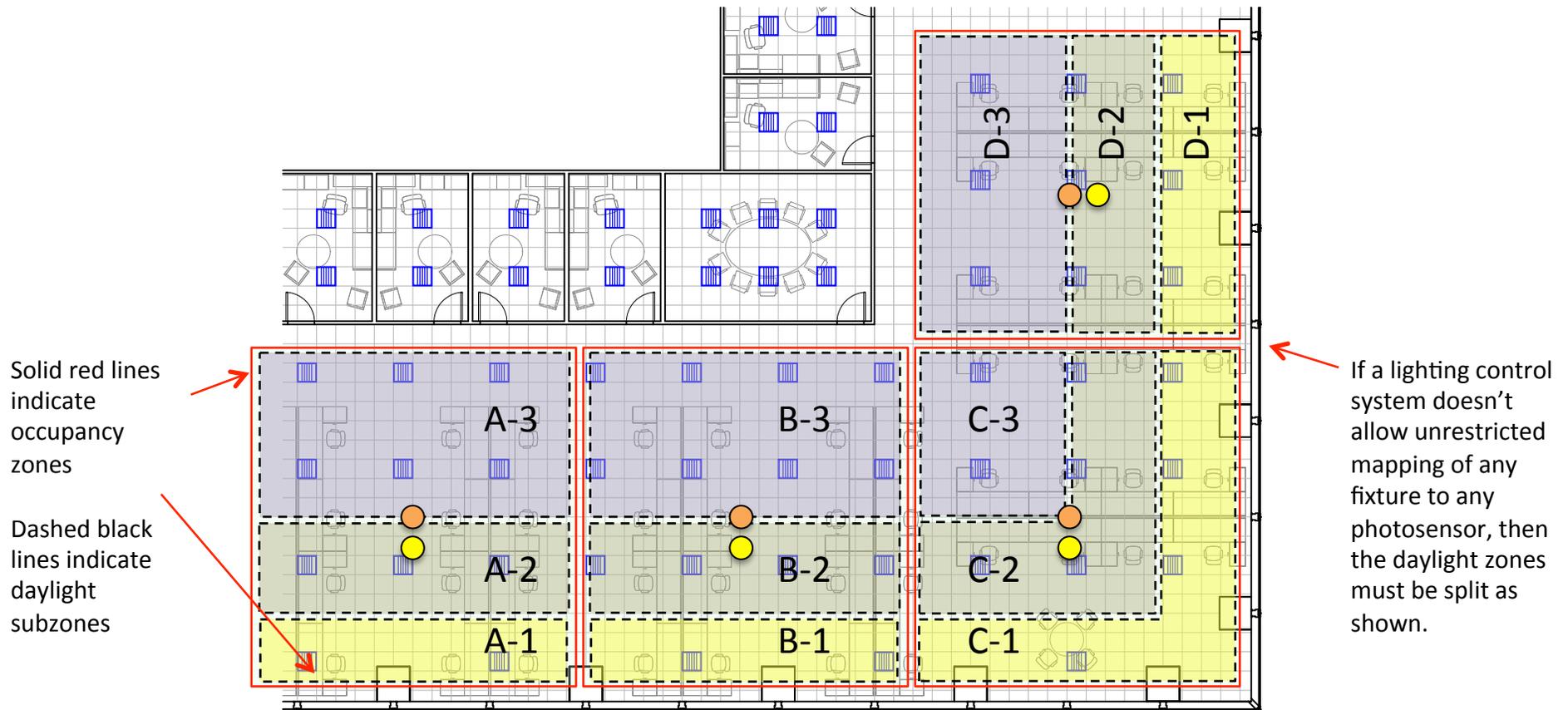
A shading system may be installed without individual “user override” control. In that case, it’s reasonable to expect that all fixtures within a specific “daylight zone” should dim to the same level for uniform lighting. However, it may be desirable to split each zone as shown into separate subzones based on the predominant exposure of the façade. For example, even with the same shades, fixtures near the east façade may need to be dimmed differently than those near the south façade.

Using open-loop photosensors to accommodate differences in façade shading



Many shading systems allow each section to be separately controlled – either manually and/or automatically. If so, then a logical strategy would be to use one “open-loop” photosensor corresponding to each shade. If a system is used that allows for unrestricted mapping of fixtures to photosensors, then the owner can decide which photosensor controls which fixture. In some systems, signals from more than one photosensor can be programmed to appropriately dim each specific fixture.

Separation of daylight zones for systems that **do not** allow unrestricted mapping of fixtures to photosensors



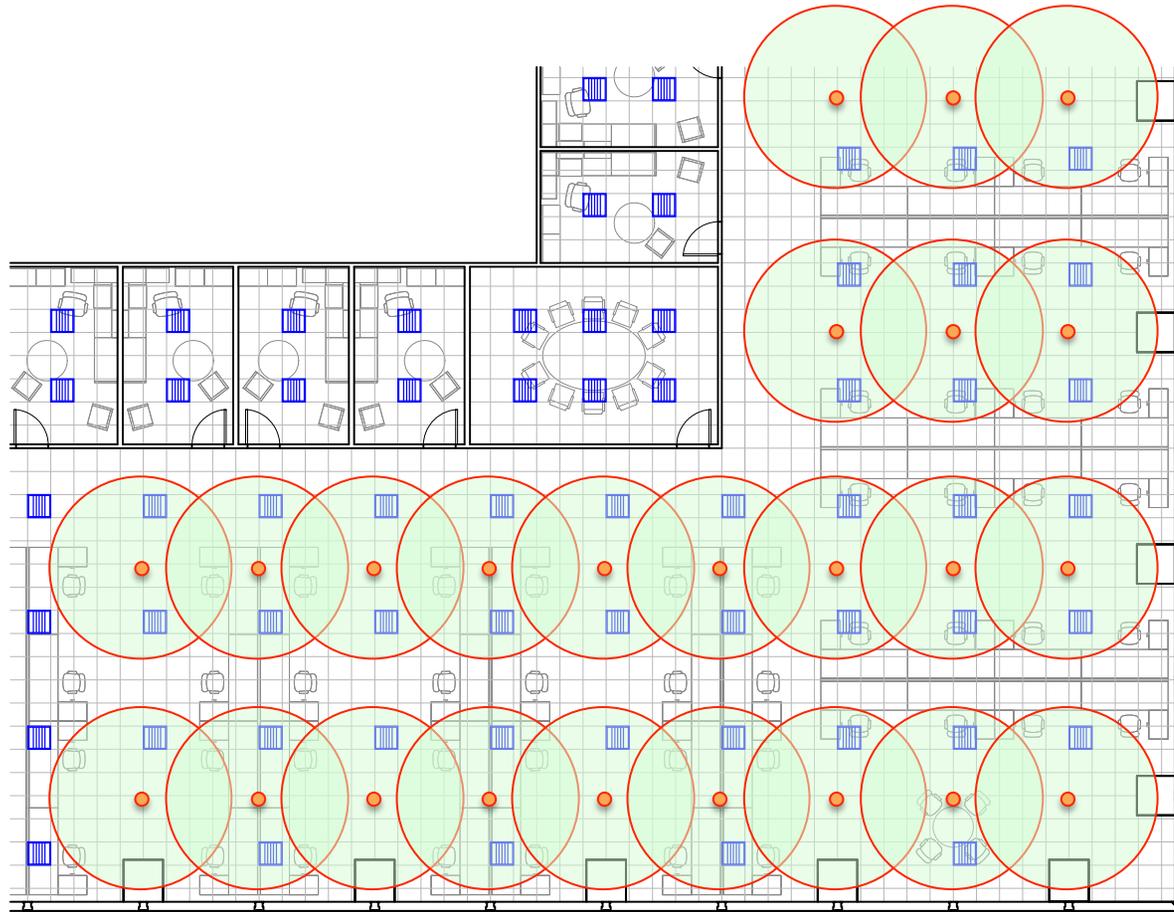
Some systems allow for “differential dimming” of fixtures within an occupancy zone – groups of fixtures can be dimmed to different levels based on the input from one photosensor (as shown above). However, each occupancy zone usually requires its own photosensor as well as occupancy sensor.

Zoning for systems where occupancy zones must exactly match daylight zones



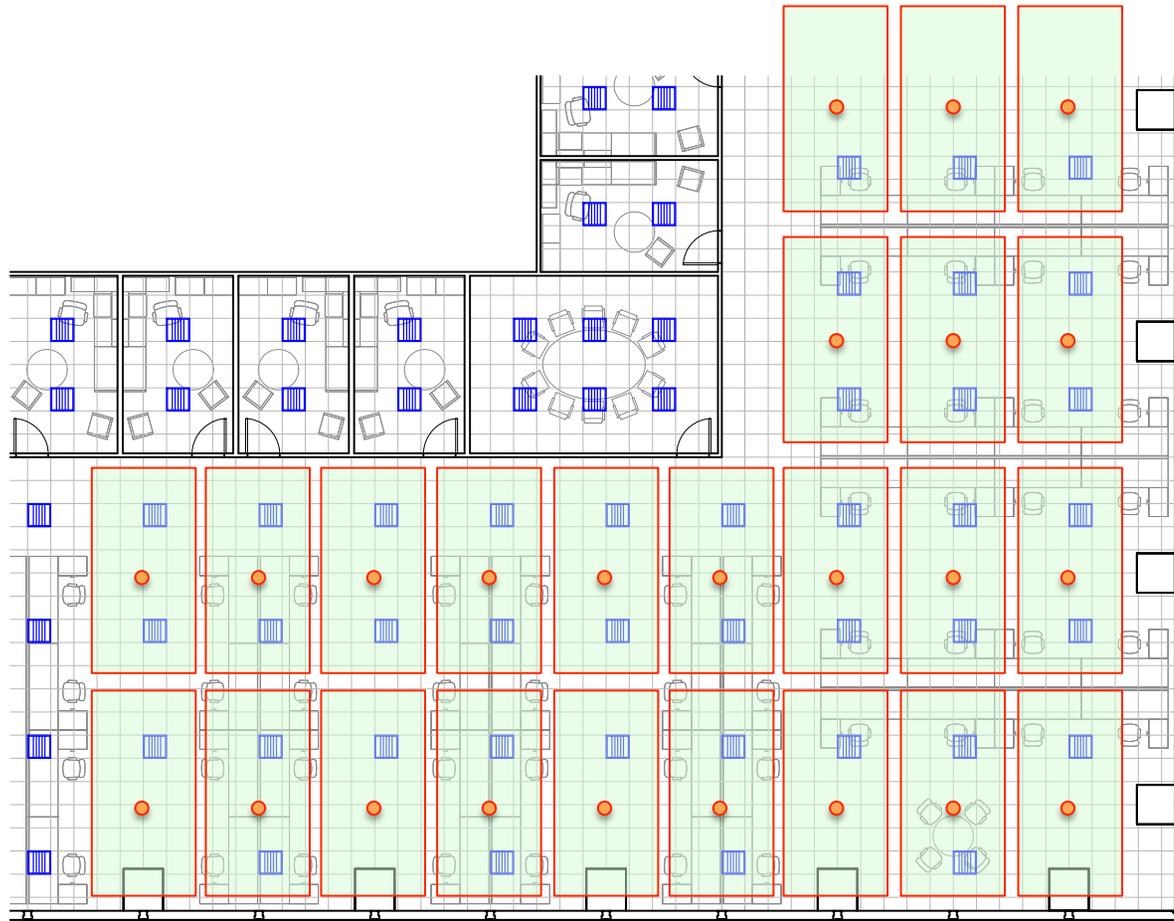
Certain systems require that fixtures responding to a photosensor **exactly** correspond to those in a distinct occupancy zone based on an occupancy sensor. If so, then zones for daylighting would be exactly the same as for occupancy (as shown above). Each zone would require its own occupancy sensor **and** photosensor, potentially increasing the cost of the system.

Occupancy sensor coverage (200 ft², radius=8')



Certain occupancy sensors, such as those designed for use in individual fixtures, have a much smaller area of coverage. If these sensors are mounted separately (as shown), they can control small groups of fixtures. (In some systems, these sensors are combined with transceivers that communicate with a wireless gateway via RF transmission, then back to a server.)

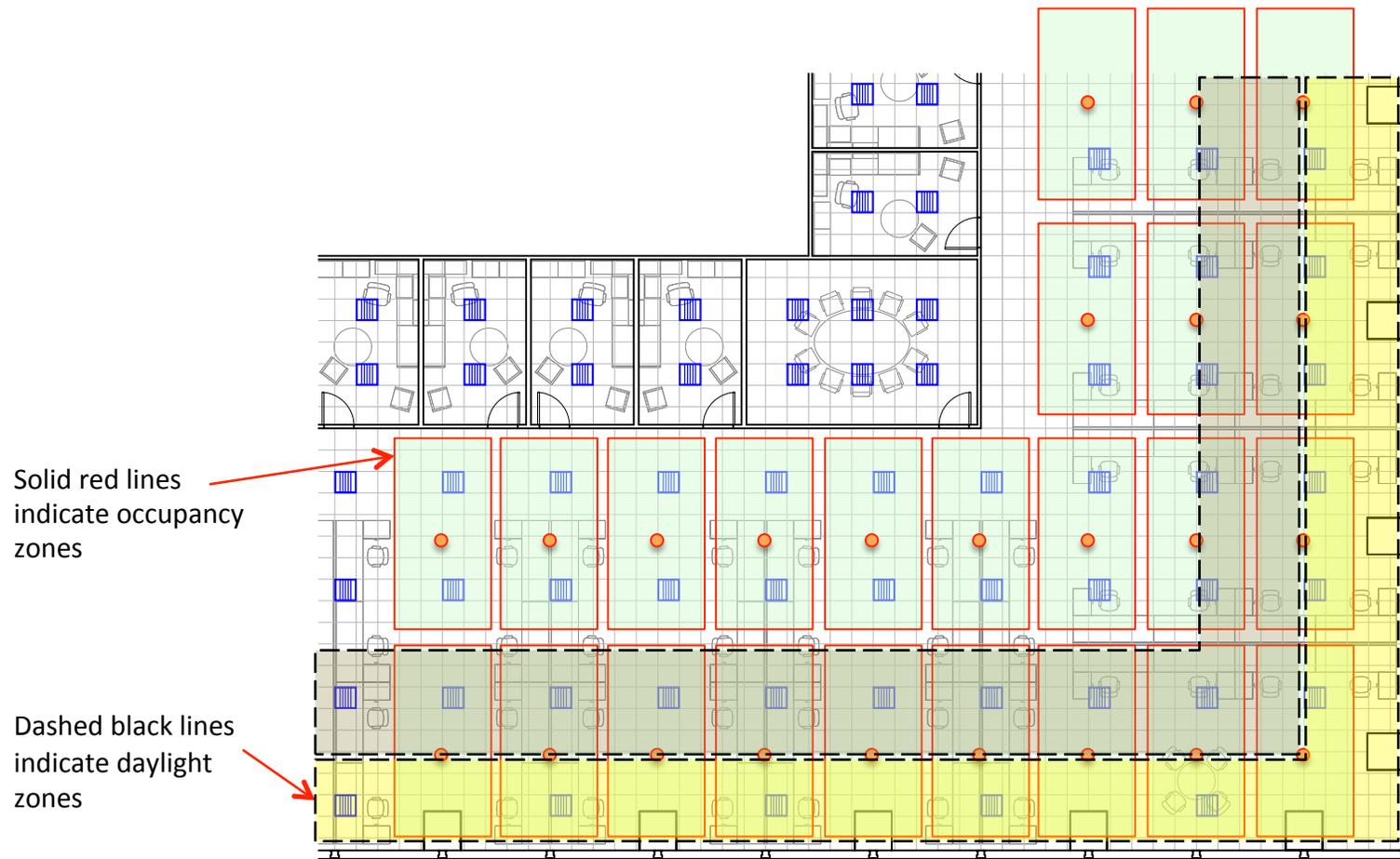
High granularity – occupancy zones based on occupancy sensors with 200 ft² coverage



32

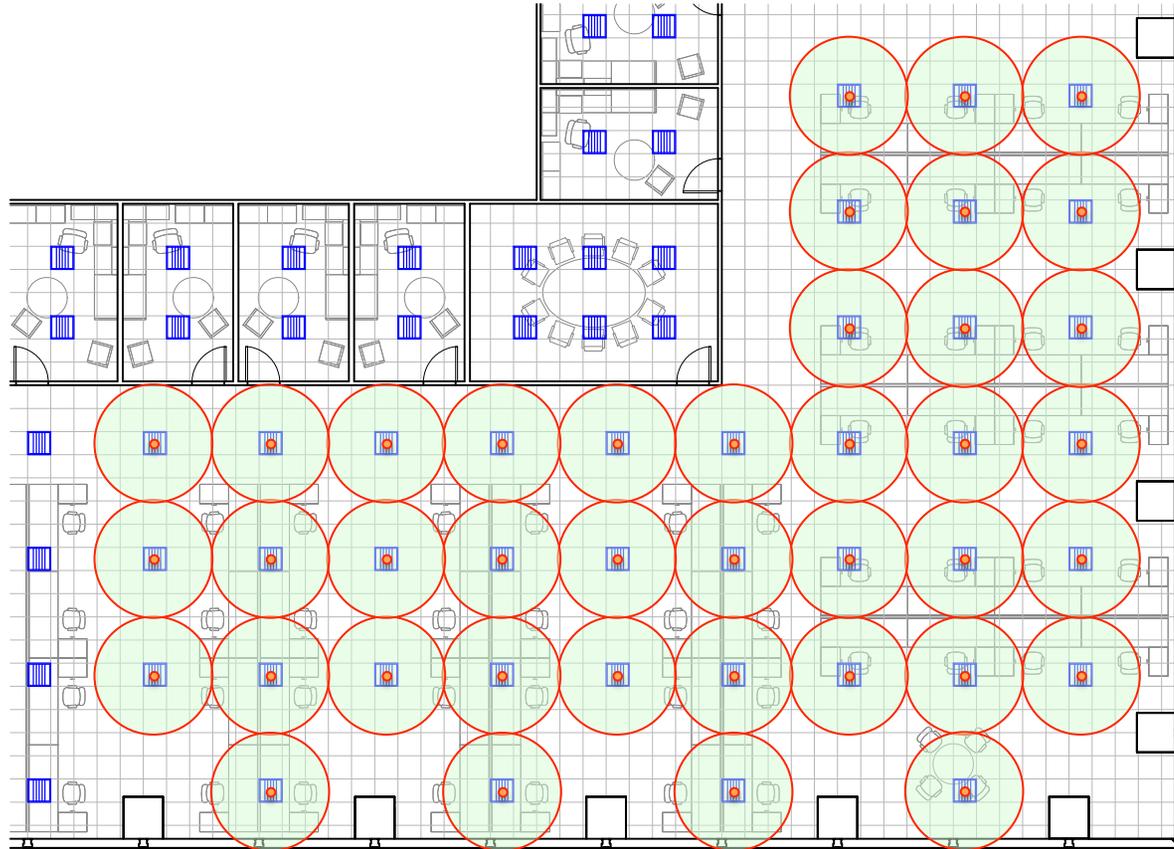
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Overlap of daylight zones with high granularity occupancy zones (using occupancy sensors with 200 ft² coverage)



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Occupancy zones using fixture-integrated occupancy sensors (highest granularity)

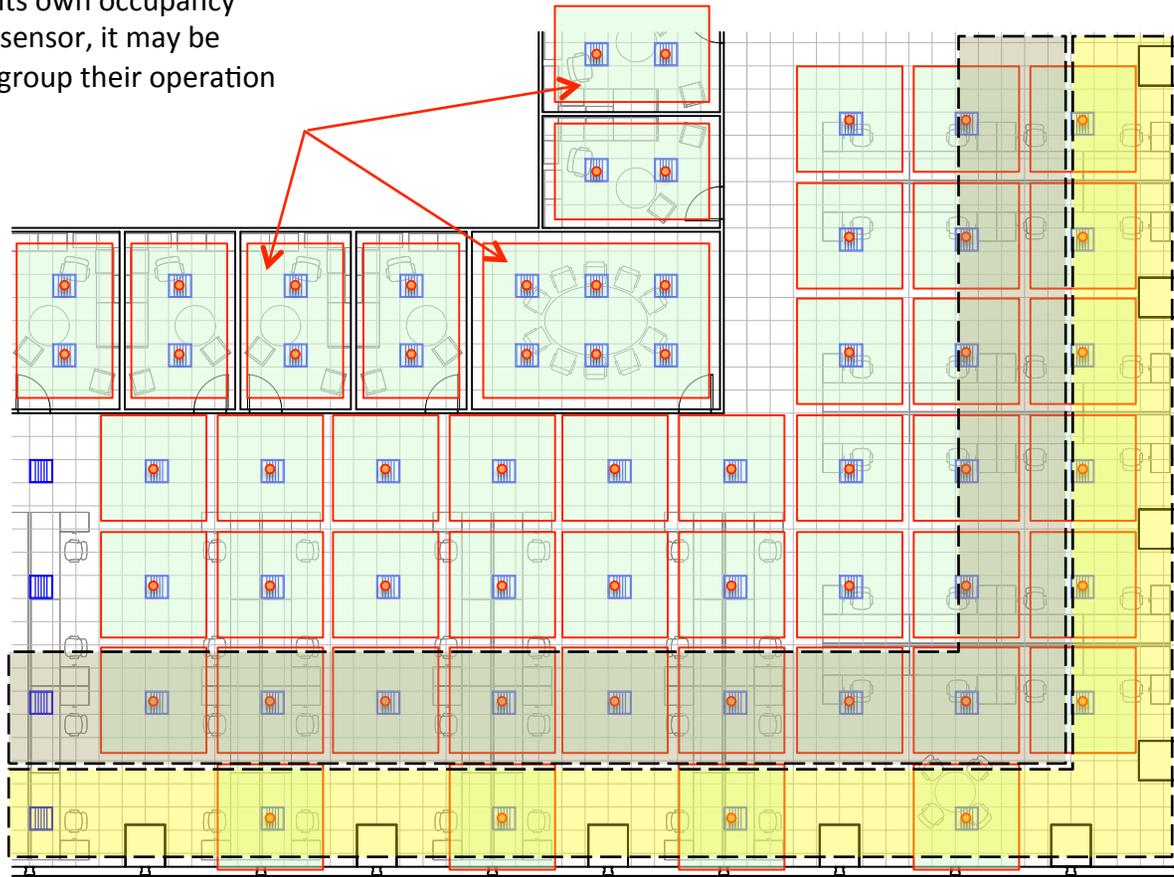
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