Change History

Date	Description of Change	Pages / Sections Modified	Change Approver Initials
11/24/2021	New Lighting Control Standard	All	JR

DESIGN STANDARD INTENT:

The intention of this standard is to guide electrical and lighting designers with a process to understand various approaches to lighting control in line with energy code and Yale's preference to choose the best lighting control scheme for a project specific set of requirements.

Yale's goal is to use the lighting control method that is most simple, hands-off, user-friendly, maintainable, and has longevity. The following table describes various configurations presently on campus:

1	*Local zone control (non network)*	*Individual zones equipped with switching, dimming, and occupancy sensing – with any combination of photocells, occupancy sensors, timers, and the ability to override from a wall switch. All devices hard wired. All devices hold their own "settings." Occupancy sensors equipped with dual relay for tie-in to building automation system. This is the most common approach on campus.*
2	*Local zone control with some networked zones*	*Most individual zones controlled locally. Some zones within the building may be further equipped with scene selection, user interface, and/or networked scheduling.*
3	*Building level network control*	*System that consolidates all local zone controls into one lighting control interface. Central system holds all device "settings." May allow for collection of performance data including energy use and occupancy patterns. Requires a customized user interface to be accessed in the building and HTML.*
4	*Campus level network control*	*System that consolidates controls from many buildings into one lighting control enterprise, like the building automation system. This*

		does not exist currently on campus outside of the building automation system.

A **network lighting control system** may be selected only when local devices will not easily meet all the project requirements. Such requirements may include:

- Complex scheduling: building operation requires lamps in multiple zones to be on/off at various times based on building occupancy schedule, and the schedule is likely to change over the course of the year.
- Complex scenes: building operation requires lamps in multiple zones to be at various states of on/off/dim based on building use and scenes, and the scenes are likely to change over the course of the year.
- Asset tracking and load shedding: building operation requires the sensors in a lighting system to track moving/traveling building products or requires sensors to turn on/off building equipment (load shed).
- Zoning and task tuning: building operation has different requirements for occupancy/vacancy dependent upon zone, and certain areas require tunable lighting dependent upon tasks being performed in that area.
- Data Collection: building operation requires lighting information to be collected in order to analyze the efficiency of occupancy, scheduling, daylighting, and zoning.

When a network lighting control system is selected, it is important to identify the stakeholders, users, and operators of the system during the design process and that appropriate commissioning, project turnover, training, and operations and maintenance requirements are identified.

Wired devices shall be implemented in locations where the following features exist.

- Open wall access
- Easy access to low voltage electrical panel.

Wireless devices shall be implemented in locations where the following features exist.

- No open walls
- No local access to low voltage electrical panel.

- ONLY with explicit Yale approval.

TABLE 1: SPACE TYPE VS. CONTROL SOLUTION

SPACE TYPE	OCCUPANCY PATTERN	CONTROL SOLUTION
Dining Hall	Scheduled occupancy	Shall provide timeclock control during operating hours with daylighting control, and occupancy control during non-operating hours. [1, 3, 4]
Classroom	Usually occupied	Shall provide manual dimming and preset scene control for a minimum of four zones: 1.One zone to provide full brightness for general-use lights. 2.One zone to provide low level lights for note taking. 3.One zone to provide chalkboard lights for the front of the room. 4.One zone to provide Shall provide vacancy control and daylighting control. [1, 4]
Computer Room	Usually unoccupied	Shall provide vacancy control with manual dimming. [1]
Conference Room	Occasionally occupied	Shall provide manual dimming and preset scene control for different tasks: overhead projectors, chalkboard, note taking, presentations. Shall provide vacancy control and daylighting control. [1, 4]

SPACE TYPE	OCCUPANCY PATTERN	CONTROL SOLUTION
Gymnasium or Fitness	Occasionally occupied	Shall provide occupancy control and daylighting control. [2, 4] Coverage is particularly important, and sensors should overlap to keep the lights on when the room is occupied.
Hallways and Corridors	Any	Shall provide occupancy control with sensors with elongated throw (long range) and daylighting control. [2, 4]
Health Care—Examination Rooms	Occasionally occupied	Shall provide vacancy control, manual dimming and on/off control.
Health Care—Hallways	Usually occupied	Shall provide occupancy control, manual dimming and on/off control. Shall provide daylighting control for day-time periods, and a dimmer on a timer for lower lighting level at night. [3, 4]
Health Care—Patient Rooms	Usually occupied	Shall provide vacancy control, manual dimming and on/off control.
Laboratories	Usually occupied	Shall provide occupancy control and daylighting control. [2, 4]
Libraries—Reading Areas	Usually occupied	Shall provide timeclock control and daylighting control. [3,3]

SPACE TYPE	OCCUPANCY PATTERN	CONTROL SOLUTION
		Shall provide a dimmer on a timer for lower lighting level at night. [3]
Libraries—Stack Areas	Usually unoccupied	Shall provide a combination of ceiling-mounted occupancy sensors [1] and manual control for select areas.
Lobby or Atrium	Usually occupied	Shall provide daylighting control. [4] Shall provide a timer for no or lower lighting level at night. [3]
Office, Open	Usually occupied	Shall provide occupancy control and daylighting control. [1, 4]
Office, Private	Primarily one person, coming and going	Shall provide vacancy control and daylighting control. [1, 4]
Restroom/Locker room	Any	Shall provide occupancy sensors. [2]
Storage Rooms and Janitorial Closets	Usually unoccupied	Shall provide vacancy control and manual on/off switch.
IT and Security Rooms	Usually unoccupied	Shall provide vacancy control and manual on/off switch.
Mechanical/Electrical Room	Usually unoccupied	Shall provide vacancy control and manual on/off switch.

NOTES: (reference IECC 2015)

1. For areas with Occupancy Sensors:
    a. Lights shall automatically turn off within 20 minutes of no occupancy.
    b. Lights shall turn on by either manual control (with occupancy sensor in “vacancy mode”) or by automatic control to no more than 50% power
    c. Occupancy Sensors shall be provided with manual on/off control for occupants.
    d. Occupancy sensor shall be equipped with dual technology: PIR (major motion) and Ultrasonic (minor/fine motion) unless otherwise required (i.e. animal areas that are sensitive to ultrasonic should use PIR with additional signal processing to detect for minor/fine motion)
    e. Occupancy sensor shall be equipped with dual relay for potential tie-in to BAS for HVAC control in same zone.
2. Occupancy sensors can turn lights automatically on to 100% power in hallways, stairways, restrooms, lobbies or areas where reduced lighting would endanger the safety or security of building occupants.
3. All areas NOT provided with an Occupancy Sensor, shall be provided with time switch control.
    a. Time switch control shall be provided with a manual dimmer and manual override. Time of day schedule shall be coordinated and documented by project team.
    b. The manual override, when activated, shall control the lighting to remain on for not more than 2 hours.
4. Daylighting control shall be provided in location of more than 150 watts of general lighting in daylit areas.
    a. All daylighting controls shall be provided with manual override.
    b. Daylighting control shall dim lights from 100% output down to at least 15%, or lower.

REFERNCE DOCUMENTS:

- 26 51 00 Interior Lighting Standard
- 26 56 00 Exterior Lighting Standard
- Basis of Design Document

A. LightingControls

PART 1 GENERAL

1.1 SECTION INCLUDES

A. Digital-network lighting control system and associated components:

1. Power panels.
2. Fluorescent electronic dimmingballasts.
3. LED drivers.
4. Control units.
5. Digital dimming ballast and switchingmodules.
6. Lighting management hubs.
7. Lighting management systemcomputers.
8. Lighting management systemsoftware.
9. Control stations.
10. Low-voltage controlinterfaces.
11. Wired sensors.
12. Wireless sensors.

1.2 ADMINISTRATIVE REQUIREMENTS

1. Coordination:
   1. Coordinate the placement of sensors and wall controls with work and equipment installed under other sections or by others.
   2. Notify Architect of any conflicts or deviations from the contract documents to obtain direction prior to proceeding with work.
2. Preinstallation Meeting: Conduct on-site meeting with lighting control system manufacturer prior to commencing work as part of manufacturer's standard startup services.
3. Sequencing
   1. Do not install sensors and wall controls until final surface finishes and painting are complete.

1.3 QUALITY ASSURANCE

1. Conform to requirements of NFPA 70.
2. Maintain at the project site a copy of each referenced document that prescribes execution requirements.
3. Manufacturer Qualifications:

1. Company with not less than ten years of experience manufacturing lighting control systems of similar complexity to specified system.
2. Registered to ISO 9001, including in-house engineering for product design activities.
3. Qualified to supply specified products and to honor claims against product presented in accordance with warranty.

4. Maintenance Contractor Qualifications: Manufacturer's authorized service representative.

1.4 DELIVERY, STORAGE, AND HANDLING

A. Store products in a clean, dry space in original manufacturer's packaging in accordance with manufacturer's written instructions until ready for installation.

1.5 WARRANTY

1. Manufacturer's Standard Warranty, With Manufacturer Start-Up:
   1. Lighting Control System Components, Except Lighting Management System Computer, Ballasts and Ballast Modules:
      a. First Two Years:
         1) 100 percent replacement parts coverage, 100 percent manufacturer labor coverage to troubleshoot and diagnose a lighting issue.
         2) First-available on-site or remote response time.
      b. Telephone Technical Support: Available 24 hours per day, 7 days per week, excluding manufacturer holidays.
   2. Lighting Management System Computer: One year 100 percent parts coverage, one year 100 percent manufacturer labor coverage.
   3. Ballasts and Ballast Modules: Five years 100 percent parts coverage, no manufacturer labor coverage.

PART 2 LOCAL/ZONE CONTROL PRODUCTS

2.1 MANUFACTURERS

A. Local/Zone Control Manufacturers:
   1. Lutron

2. Phillips
3. Acuity (SensorSwitch)
4. Wattstopper

2.2 DIGITAL LIGHTING CONTROL SYSTEM - GENERAL REQUIREMENTS

1. Provide products listed, classified, and labeled by Underwriter's Laboratories Inc. (UL) as suitable for the purpose indicated.
2. Design lighting control equipment for 10 year operational life while operating continually at any temperature in an ambient temperature range of 32 degrees F (0 degrees C) to 104 degrees F (40 degrees C) and 90 percent non-condensing relative humidity.
3. Electrostatic Discharge Tolerance: Design and test equipment to withstand electrostatic discharges without impairment when tested according to IEC 61000-4-2.
4. Dimming and Switching Equipment:
    1. Power Failure Recovery: When power is interrupted and subsequently restored, within 3 seconds lights to automatically return to same levels (dimmed setting, full on, or full off) as prior to power interruption.
    2. Dimming Requirements:
        a. Line Noise Tolerance: Provide real-time cycle-by-cycle compensation for incoming line voltage variations including changes in RMS voltage (plus or minus 2 percent change in RMS voltage per cycle), frequency shifts (plus or minus 2 Hz change in frequency per second), dynamic harmonics, and line noise.
        b. Incorporate electronic "soft-start" default at initial turn-on that smoothly ramps lights up to the appropriate levels within 0.5 seconds.
        c. Control all light sources in smooth and continuous manner. Dimmers with visible steps are not acceptable.
        d. Load Types:
            1) Assign a load type to each dimmer that will provide a proper dimming curve for the specific light source to be controlled.
            2) Provide capability of being field-configured to have load types assigned per circuit.

e. Minimum and Maximum Light Levels: User adjustable on a circuit- by-circuit basis.

3. Switching Requirements:
   a. Rated Life of Relays: Minimum of 1,000,000 cycles at fully rated current for all lighting loads.

5. Device Finishes:
   1. Standard Colors: Comply with NEMA WD1 where applicable.

2.3 POWER PANELS

1. Provide power panels with configurations as indicated on the drawings.
2. General Requirements:
   1. Listed to UL 508 as industrial control equipment.
   2. Comply with UL 508A and IEC 60669-2-1 as applicable.
   3. Delivered and installed as a listed factory-assembled panel.
   4. Field wiring accessible from front of panel without removing dimmer assemblies or other components.
   5. Passively cooled via free-convection, unaided by fans or other means.
   6. All power panels and dimmer panels shall have a main circuit breaker. The main breaker shall be lockable.
   7. Panel shall incorporate up to 4 normally closed latching relays capable of switching 120/277 VAC or up to 2 Dual Phase relays capable of switching 208/240/480 VAC loads.
   8. Relays shall be rated to switch up to a 30A ballast load at 277 VAC.
   9. Panel shall provide one 0-10VDC dimming output paired with each relay.
   10. Panel shall power itself from an integrated 120/277 VAC supply.
   11. Panel shall provide auxiliary low voltage device power connected wired directly to a dedicated terminal connection.
   12. Panel shall supply current limited low voltage power to other networked devices connected via CAT-5.
   13. Provide panels with listed short circuit current rating not less than the available fault current at the installed location as indicated on the drawings.
       a. Minimum Short Circuit Current Rating (SCCR): 25,000 Amps.

2.4 LED DRIVERS

1. General Requirements:
    1. UL 8750 recognized or listed as applicable.
    2. Comply with IEC 61347-2-13 as applicable.
    3. Manufactured in a facility that employs ESD reduction practices in compliance with ANSI/ESDS20.20.
    4. Class A sound rating; Inaudible in a 27 dBA ambient.
    5. No visible change in light output with a variation of plus or minus 10 percent line voltage input.
    6. Total Harmonic Distortion (THD): Less than 20 percent; comply with ANSI C82.11.
    7. Drivers to track evenly across multiple lamp lengths and all light levels.
    8. Constant Current Drivers:
        a. Support from 200 mA to 2.1 A (in 10 mA steps) to ensure a compatible driver exists.
        b. Support LED arrays up to 40W or 50 W (710 mA to 1.05 A in 10 mA steps).
    9. Constant Voltage Drivers:
        a. Support from 10 V to 40 V (in 0.5 V steps) to ensure a compatible driver exists.
        b. Support LED arrays up to 40W.
    10. Configuration tool available to optimize the following for LED fixtures:
        a. Light level.
        b. Efficiency.
        c. Thermal performance.
2. 3-Wire Control:
    1. Dimming Range: 100 to one percent relative light output.
    2. Provide integral fault protection to prevent driver failure in the event of a mis-wire.
    3. Operate from input voltage of 120 V through 277 V at 60 Hz.
3. Digital Control:
    1. Dimming Range: 100 to one percent relative light output.
    2. Lights automatically return to the setting prior to power interruption.
    3. Operate from input voltage of 120 V through 277 V at 60 Hz.
    4. Each driver responds independently to:

a. Up to 32 occupant sensors.
b. Up to 16 daylight sensors.

5. Responds to digital load shed command.

4. Forward Phase Control (Neutral Wire Required):
   1. Dimming Range: 100 to one percent relative light output.

2.5 CONTROL UNITS

1. Provide main units with configuration and quantity of zones as indicated or as required to control the loads as indicated.
2. Connects to lighting management hub via RS485.
3. Engrave units with button, zone, and scene descriptions as indicated on the drawings.
4. Preset Lighting Control with Zone Override:
   1. Intensity for each zone indicated by means of one illuminated bar graph per zone.
   2. User-programmable zone and scene names.
   3. Astronomical time clock and programmer interface provides access to:
      a. Scene selections.
      b. Fade zone to a level.
      c. Fine-tuning of preset levels with scene raise/lower.
      d. Lock out scenes and zones.
      e. Fine-tuning of light levels with individual zone raise/lower.
      f. Terminal block for wired infrared signal input.
      g. Enable/disable wall station.
   4. Light intensity with real time energy savings by digital display.
   5. Fade time indicated by digital display for current scene while fading.
   6. Integral wide-angle infrared receiver.
   7. For temporary local overrides, individual raise/lower buttons to allow zones to be adjusted without altering scene values stored in memory.
   8. Direct Low-Voltage Control of Digital Ballasts and LED drivers (120V, 220/240V, 277V and/or 347V Lighting):
      a. Electronically link a digital fluorescent lighting ballast to a zone for both dimming and turning on/off.

b. Electronically assign daylight sensors to digital ballasts and line voltage dimmers for proportional daylight harvesting.
c. Single integral controller with Class 1 or Class 2 isolated digital output signal conforming to IEC 60929; capable of direct control without interface.

9. Creates daylighting rows independent of control zones.
10. Capable of re-zoning without re-wiring using programming display on unit.
11. Outputs can be virtually mapped to other device's outputs.
12. Zone raise/lower buttons capable of controlling local lighting loads connected to the main unit or remote lighting zones in the system.

5. Provides one direct-wired occupancy sensor connection without interface or powerpack.

2.6 DIGITAL DIMMING BALLAST AND SWITCHING MODULES

1. Provide digital dimming ballast and switching modules as indicated or as required to control the loads as indicated.
2. General Requirements:
   1. Provide continuous 3-wire signal dimming to compatible 3-wire electronic dimming ballasts.
   2. Utilize air gap off to disconnect the load from line supply.
   3. Connect without interface to:
      a. Occupancy sensor.
      b. Daylight sensor.
      c. Personal control input (wall station or infrared receiver).
   4. Generate digital communication commands to distribute ballast and sensor data on the digital bus.
   5. If power is interrupted and subsequently restored, lights automatically return to the setting prior to power interruption.
   6. Each ballast module responds independently to:
      a. Up to 32 occupancy sensors.
      b. Up to 64 personal control inputs.
      c. Two daylight sensors.
   7. Unique internal reference number visible displayed on module cover.
   8. Averages two independent daylight harvesting inputs internally.

9. Responds to digital load shed command.
    a. Sets high end trim.
    b. Automatically scales light output proportional to load shed command.

2.7 WIRED SENSORS

1. Wired Occupancy Sensors:
    1. General Requirements:
        a. Wired sensors are Yale's preference for all open wall (new construction) projects, and in most cases, for retrofits to existing construction. Exceptions to wired sensors to be approved by Yale.
        b. Connects directly to compatible ballasts and modules without the need of a power pack or other interface.
        c. Turns off or reduces lighting automatically after reasonable time delay when a room or area is vacated by the last person to occupy the space.
        d. Accommodates all conditions of space utilization and all irregular work hours and habits.
        e. Comply with UL 94.
        f. Furnished with field-adjustable controls for time delay and sensitivity to override any adaptive features.
        g. Provide capability to:
            1) Add additional timeout system-wide without need to make local adjustment on sensor.
            2) Group multiple sensors.
        h. Power Failure Memory: Settings and learned parameters to be saved in non-volatile memory and not lost should power be interrupted and subsequently restored.
        i. Furnished with all necessary mounting hardware and instructions.
        j. Class 2 devices.
        k. Ceiling-Mounted Sensors: Indicate viewing directions on mounting bracket.
        l. Wall-Mounted Sensors: Fixed mounted base.
        m. Color: White unless otherwise specified.
        n. Dual technology: PIR and Ultrasonic.

o. Dual relay for potential tie-in to BAS controller.
p. Please reference table 1 for sensor settings in different space types.

2. Sensor Power Packs:
   1. Provide sensor power packs where required for power connection to sensors.
   2. For ease of mounting, installation and future service, power pack(s) to be able to mount through a 1/2 inch knockout in a standard electrical enclosure and be an integrated, self-contained unit consisting internally of an isolated load switching control relay and a transformer to provide low-voltage power. Transformer is to provide power to a minimum of three sensors.
   3. Plenum-rated.
   4. Control Wiring Between Sensors and Control Units: Class 2, 18-24 AWG, stranded UL Classified, PVC insulated or TEFLON jacketed cable suitable for use in plenums, where applicable.
3. Infrared Receivers:
   1. Use Class 2 wiring for low voltage communication.
   2. Can be replaced without reprogramming.
   3. 360 degree reception of wireless infrared remote controls
   4. Immediate local LED response upon reception of handheld transmitter communication.
   5. Mountable on lighting fixtures or recessed acoustical ceiling tiles.
   6. Color: White.
4. Wired Daylight Sensors:
   1. Digital Interior Daylight Sensor:
      a. Use Class 2 wiring for low voltage communication.
      b. Can be replaced without reprogramming.
      c. Open-loop basis for daylight sensor control scheme.
      d. Partially shielded for accurate detection of available daylight to prevent fixture lighting and horizontal light component from skewing sensor detection.
      e. Provide linear response from 0 to 500 foot-candles.
      f. Integral IR receiver for personal control.
      g. Mountable on lighting fixtures or recessed acoustical ceiling tiles.
      h. Constructed via sonic welding.
      i. Color: White.

5. Infrared Partition Sensors:
    1. Provide contact closure based on status of the partition wall (open/close) enabling automatic linking of controls.

2.8 WIRELESS SENSORS

6. General Requirements:
    a. Wireless sensors are only to be used for closed wall (existing construction) retrofit solutions and must be explicitly approved by Yale.
    b. Communicates directly to compatible RF receiving devices through use of a radio frequency communications link.
    c. Does not require external power packs, power wiring, or communication wiring.
    d. Capable of being placed in test mode to verify correct operation from the face of the unit.
7. Wireless Occupancy/Vacancy Sensors:
    a. General Requirements:
    b. Provides a clearly visible method of indication to verify that motion is being detected during testing and that the unit is communicating to compatible RF receiving devices.
    c. Utilize multiple segmented lens, with internal grooves to eliminate dust and residue build-up.
    d. Sensing Mechanism: Passive infrared coupled with technology for sensing fine motions. Signal processing technology detects fine- motion passive infrared (PIR) signals without the need to change the sensor's sensitivity threshold.
    e. Provide optional, readily accessible, user-adjustable controls for timeout, automatic/manual-on, and sensitivity.
    f. Turns off lighting after reasonable and adjustable time delay once the last person to occupy the space vacates a room or area. Provide adjustable timeout settings of 1, 5, 15, and 30 minutes.
    g. Capable of turning dimmer's lighting load on to an optional locked preset level selectable by the user. Locked preset

range to be selectable on the dimmer from 1 percent to 100 percent.

h. Color: White.

i. Provide all necessary mounting hardware and instructions for both temporary and permanentmounting.

j. Provide temporary mounting means to allow user to check proper performance and relocate as needed before permanently mounting sensor. Temporary mounting method to be design for easy, damage- free removal.

k. Sensor lens to illuminate during test mode when motion is detected to allow installer to verify coverage prior to permanent mounting.

l. Ceiling-Mounted Sensors:

1) Provide surface mounting bracket compatible with drywall, plaster, wood, concrete, and compressed fiber ceilings.

2) Provide recessed mounting bracket compatible with drywall and compressed fiber ceilings.

3) Provide customizable mask to block off unwanted viewing areas.

m. Wall-Mounted Sensors: Provide wall or corner mounting brackets compatible with drywall and plaster walls.

3. Wireless Combination Occupancy/Vacancy Sensors:

a. Ceiling-Mounted Sensors: Programmable to operate as an occupancy sensor (automatic-on and automatic-off), an occupancy sensor with low light feature (automatic-on when less than one foot candle of ambient light available and automatic-off), or a vacancy sensor (manual-on andautomatic-off).

b. Wall-Mounted Sensors: Programmable to operate as an occupancy sensor (automatic-on and automatic-off), or a vacancy sensor (manual-on andautomatic-off).

4. Wireless Vacancy-Only Sensors:

a. Operates only as a vacancy sensor (manual-on and automatic-off)

5. Wireless Daylight Sensors:

a. Open-loop basis for daylight sensor control scheme.

b. Partially shielded for accurate detection of available daylight to prevent fixture lighting and horizontal light component from skewing sensor detection.
c. Provide linear response from 0 to 10,000 foot-candles.
d. Color: White.
e. Mounting:
f. Provide surface mounting bracket compatible with drywall, plaster, wood, concrete, and compressed fiber ceilings.
g. Provide all necessary mounting hardware and instructions for both temporary and permanentmounting.
h. Provide temporary mounting means to allow user to check proper performance and relocate as needed before permanently mounting sensor. Temporary mounting method is to be designed for easy, damage-free removal.

PART 3 NETWORK CONTROL PRODUCTS

3.1 MANUFACTURERS

A. Network Control Manufacturers:

1. Lutron
2. Acuity (nLight)
3. WattStopper
4. Siemens with full BAS integration only

3.2 LIGHTING MANAGEMENTHUBS

1. Provided in a pre-assembled NEMA listed enclosure with terminal blocks listed for field wiring.
2. Connects to controls and power panels via RS485.
3. Enables light management software to control and monitor compatible dimming ballasts and ballast modules, power panels, power modules, and window treatments.
4. Utilizes Ethernet connectivity to light management computer utilizing one of the followingmethods:

a. Dedicated network.
b. Dedicated VLAN.
c. Shared network with Building Management System (BMS).
d. Corporate network where managed switches are configured to allow multicasting and use of IGMP.

5. Integrates control station devices, power panels, preset lighting controls, and external inputs into a single customizable lighting control system with:
6. Multiple Failsafe Mechanisms:
   a. Power failure detection via emergency lighting interface.
   b. Protection: Lights go to full on if ballast wires are shorted.
   c. Distributed architecture provides fault containment. Single hub failure or loss of power does not compromise lights connected to other lighting management hubs.
7. Manual overrides.
8. Automatic control.
9. Central computer control and monitoring.
10. Integration with BMS via BACnet.
11. Furnished with astronomical time clock.
12. Maintains a backup of the programming in a non-volatile memory capable of lasting more than ten years without power.
13. BACnet Integration License:
15. Provide ability to communicate by means of native BACnet IP communication (does not require interface) to lighting control system.
16. Requires only one network connection per system.
17. Lighting control system to be BACnet Test Laboratory (BTL) listed.
18. Basic BACnet integration license:
    a. The BACnet integrator can command:
       1) Area light output.
       2) Area enable or disable after hours mode.
       3) Area load shed level.
       4) Area load shed enable/disable.
       5) Enable/Disable:
          (a) Area occupancy sensors.

(b) Area daylighting.

6) Daylighting level.
7) Area occupied and unoccupied level
8) Occupancy sensor timeouts.

b. The BACnet integrator can monitor:
1) Area on/off status.
2) Area occupancy status.
3) Area fault.
(a) Lamp failures.
(b) Control devices not responding.
4) Area load shed status.
5) Area instantaneous energy usage and maximum potential power usage.
6) Cloudy day and shadow sensor status.
7) Light levels from window mounted sensors.
8) Enable/Disable:
(a) Area occupancy sensors.
(b) Daylighting.
9) Daylighting level.
10) Light levels from photo sensors and window mount shadow sensors.
11) Area occupied and unoccupied level.
12) Occupancy sensor timeouts.

3.3 LIGHTING MANAGEMENT SYSTEM COMPUTERS

A. Computers:

1. System PC (Desktop/Laptop) and Display Terminals:
a. Suitable for occasional programming, monitoring, and control of digital network lighting controls via web access
b. Unless otherwise indicated, computer(s) to be provided by lighting control system manufacturer.
c. If requested, at least one remote display terminal should be provided for the Yale facilities team responsible for maintaining the building lighting system.
d. Quantity: As indicated on the drawings.

e. Location(s): As indicated on the drawings.
f. Minimum HardwareRequirements:
g. Processor: Single Intel® Xeon® processor with minimum speed of 2.0 GHz.
h. 1 GB RAM.
i. 80 GB hard drive (30 GB for application).
j. One 10/100/1000 Ethernet network interface for communication with lighting managementhubs.
k. 17 inch (43 cm) monitor with 1024 x 768 resolution.
l. 48X CD/DVD-ROM drive.
m. 4 USB 2.0 ports.
n. Minimum SoftwareRequirements:
   1) Licensed installation of US English 32-bit or 64-bit Microsoft® Windows® Server with Service Pack.

2. Server:
   a. Suitable for 24 hour per day, 7 day per week programming, monitoring, control, and data logging of digital-network lighting controls.
   b. Suitable to handle client machine request in multi-computer systems.
   c. Unless otherwise indicated, computer to be provided by lighting control system manufacturer.

3.4 LIGHTING MANAGEMENT SYSTEM SOFTWARE

1. Provide system software license and hardware that is designed, tested, manufactured, and warranted by a single manufacturer.
2. Every device parameter (e.g. sensor time delay) shall be available and configurable remotely from the software.
3. The following status monitoring information shall be made available from the software for all devices for which it is applicable: current occupancy status, remaining occupancy time delay, current photocell reading, current photocell inhibiting state, photocell transitions time remaining, current dim level, device temperature, and device relay state.

4. The following device identification information shall be made available from the software: model number, model description, serial number, manufacturing date code, custom label(s), and parent network device.
5. A printable network inventory report shall be available via the software.
6. A printable report detailing all system profiles shall be available via the software.
7. Software shall require all users to login with a User Name and Password.
8. Software shall provide at least three permission levels for users.
9. All sensitive stored information and privileged communication by the software shall be encrypted.
10. All device firmware and system software updates must be available for automatic download and installation via the internet. Yale shall receive notification of all system updates within 2 weeks of release date.
11. Software shall be capable of managing systems interconnected via a WAN (wide area network)

PART 4 EXECUTION

4.1 EXAMINATION

A. Verify that field measurements are as shown on the drawings.
B. Verify that ratings and configurations of system components are consistent with the indicated requirements.
C. Verify that mounting surfaces are ready to receive system components.
D. Verify that conditions are satisfactory for installation prior to starting work.

4.2 INSTALLATION

A. Perform work in a neat and workmanlike manner in accordance with NECA 1 and, where applicable, NECA 130, except for mounting heights specified in those standards.
B. Install products in accordance with manufacturer's instructions.

C. Provide dedicated network between lighting management system computer and lighting management hubs.
D. Define each dimmer/relay load type, assign each load to a zone, and set control functions.
E. Sensor Locations: Locate in accordance with layout provided by lighting control manufacturer as part of sensor layout and tuning services.
F. Mount exterior daylight sensors to point due north with constant view of daylight.
G. Ensure that daylight sensor placement minimizes sensor view of electric light sources. Locate ceiling-mounted and luminaire-mounted daylight sensors to avoid direct view of luminaires.
I. Lamp Burn-In: Operate lamps at full output for prescribed period per manufacturer's recommendations prior to use with any dimming controls. Replace lamps that fail prematurely due to improper lamp burn-in.

4.3 FIELD QUALITY CONTROL

A. Correct defective work, adjust for proper operation, and retest until entire system complies with contract documents.

4.4 SYSTEM STARTUP

A. Provide services of a manufacturer's certified service representative to perform system startup.

4.5 ADJUSTING

A. On-Site Scene and Level Tuning: visit site to conduct meeting with Engineer to make required lighting adjustments to the system for conformance with original design intent.
B. Sensor Fine-Tuning: Lighting control manufacturer to provide up to two additional post-startup on-site service visits for fine-tuning of sensor calibration as part of sensor layout and tuning services.

4.6 CLEANING

A. Clean exposed surfaces to remove dirt, paint, or other foreign material and restore to match original factory finish.

4.7 COMMISSIONING

A. See contract documents for commissioning requirements.

4.8 CLOSEOUTACTIVITIES

A. Demonstration:
   1. On-Site Performance-Verification Walkthrough: provide on- site demonstration of system functionality to commissioning agent.

B. Training:
   1. Include services of manufacturer's certified service representative to perform on-site training of Owner's personnel on operation, adjustment, and maintenance of lighting control system as part of standard system start-up services.
      a. Include training on software to be provided:
         1) Configuration software used to make system programming and configuration changes.
         2) Control and monitor.
         3) Energy savings displaysoftware.
         4) Personal web-based controlsoftware.

4.9 MAINTENANCE

A. See manufacturers' documents for additional requirements relating to maintenance service.