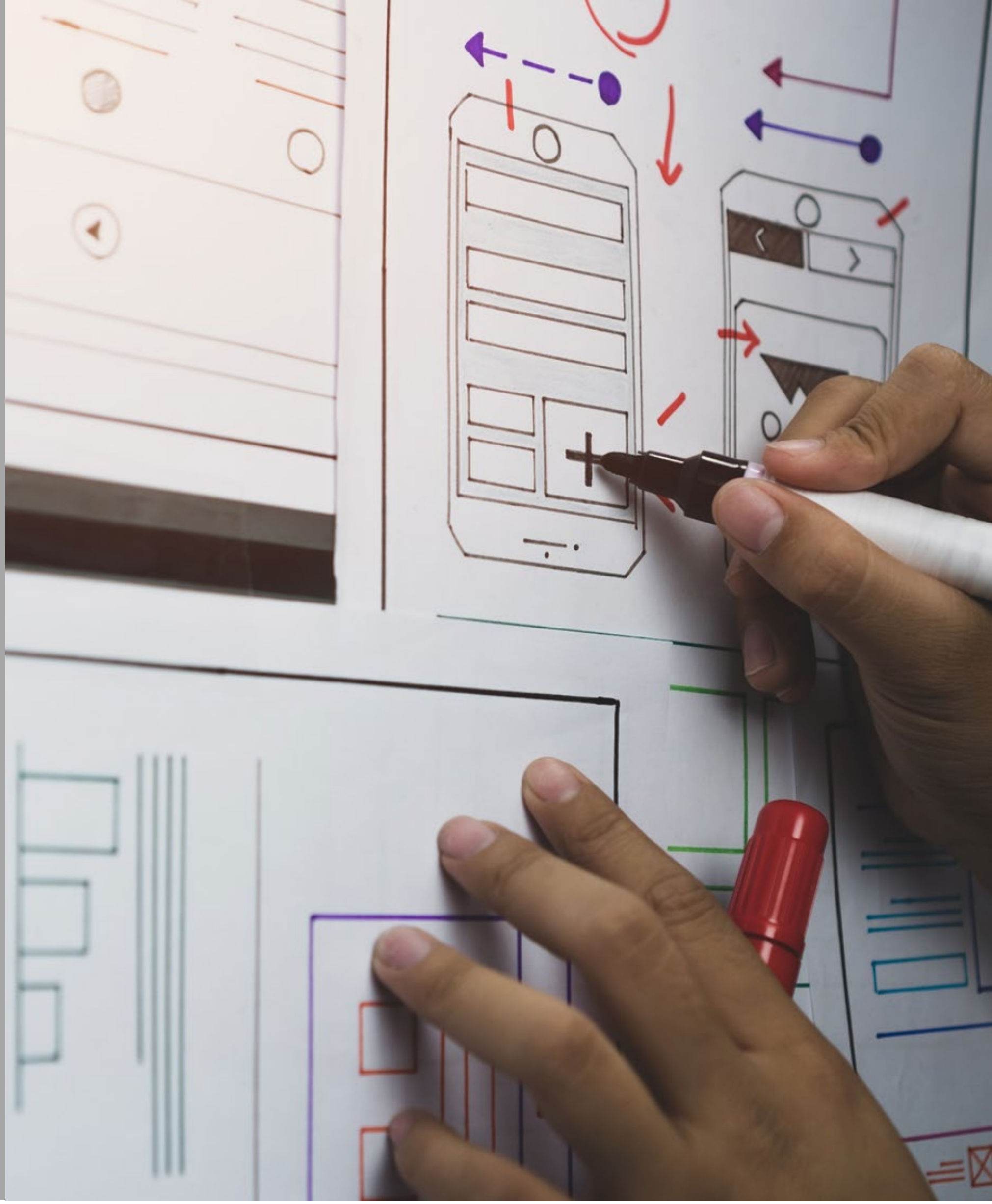
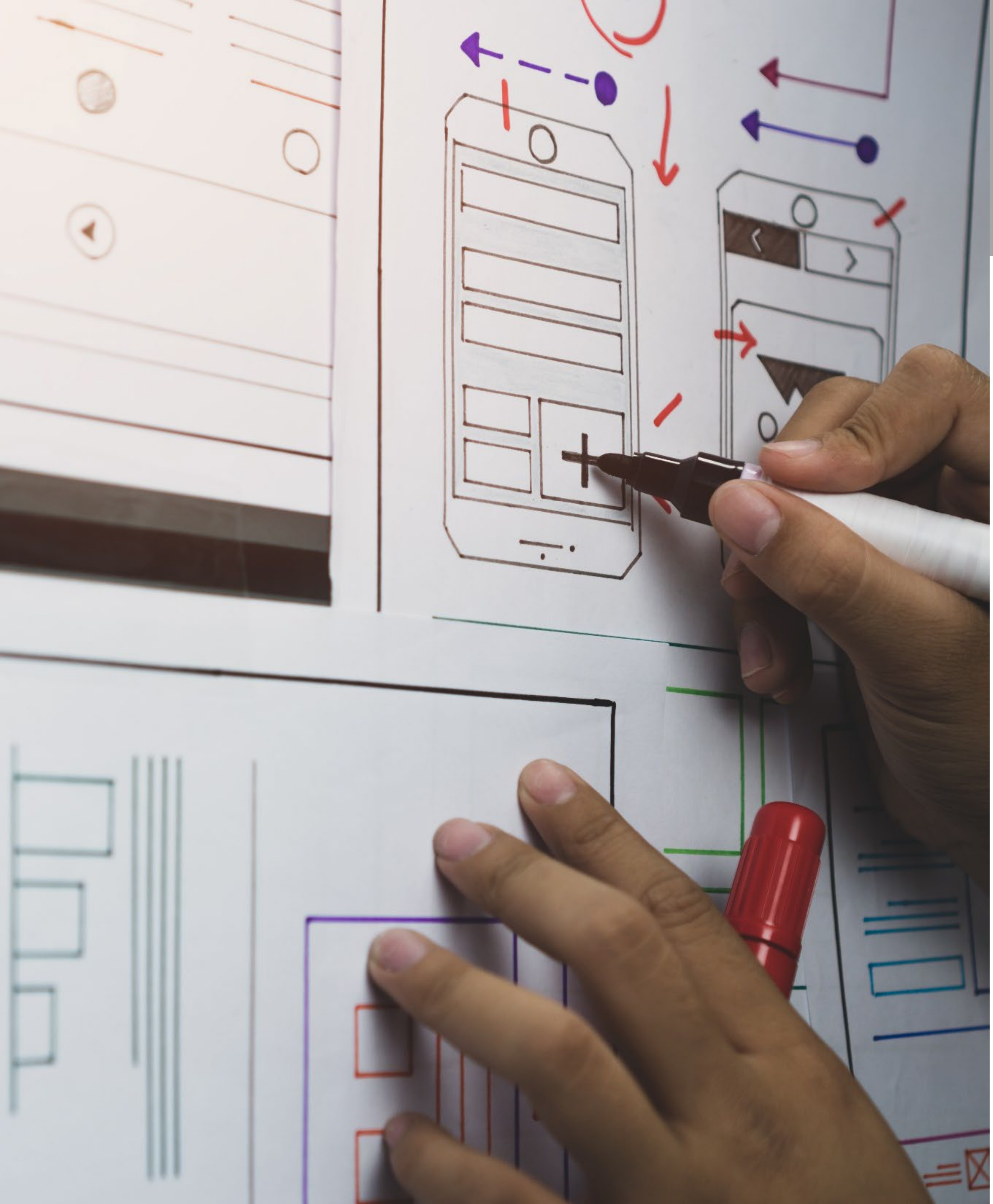
Modeling a New Approach to the Design of Lighting Controls

3 Hour Educational Workshop





Today’s Agenda

Lighting Controls System Selection

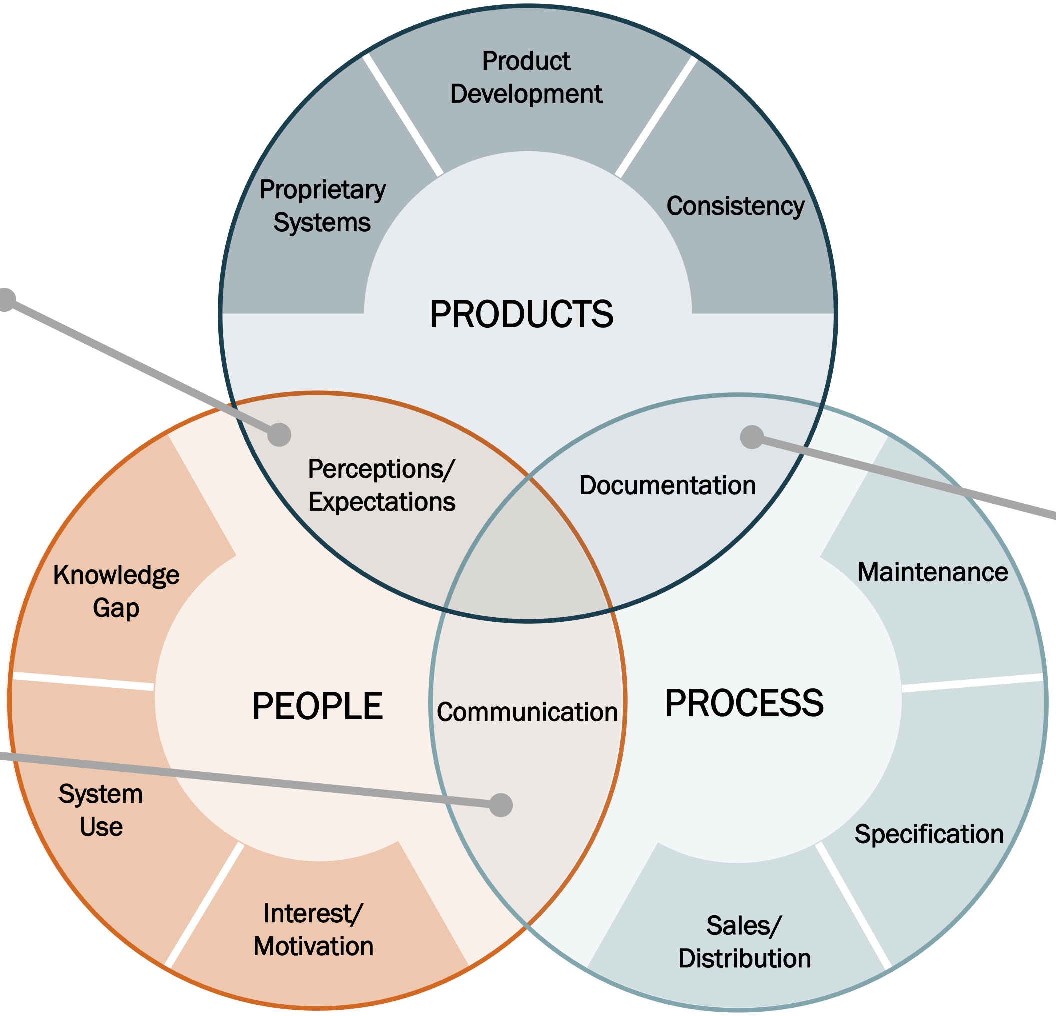
- The problem: complexity and lack of clarity, due in part to proprietary thinking
- An alternative approach to consider: non-proprietary thinking to align objectives with system capabilities and architecture
- **Exercise 1** – Connect Capabilities and Use Cases
- **Exercise 2** – Assess Risk
- **Exercise 3** – Review Manufacturer Documentation
- **Exercise 4** – Create a Controls Intent Narrative (CIN)
- **Exercise 5** – Document System Attributes and Assess System Risk
- **Exercise 6** - Create a Sequence of Operations (SOO)
- Discussion – Next Steps, Additional Resources

Distilling the Issues

Complexity and lack of clarity, due in part to proprietary thinking

Key Challenges Observed in the Industry

Failure to align lighting control system capabilities to project objectives



Unclear or incomplete documentation of objectives, desired capabilities, and system features

Misunderstandings in design and setup due to ambiguity in terminology

Limits of Proprietary Thinking

- Fewer options
- Sub-optimal performance
- Difficult communication
- Inhibits standardization

Let's Try Another Approach

Consider designing controls
before selecting a specific system.

A Different Approach

Non-proprietary thinking to align objectives with system capabilities and architecture

1 Establish Controls Objectives → 2 Define System Capabilities → 3 System Architecture Impacts → 4 Document Design and Operation →

1 Identify controls-specific objectives based on the owner's project requirements (OPR).

Use cases can help to set priorities. Examples include:

- Energy Code Compliance (Required)
- Enhanced Lighting Performance
- Enhanced Energy Management
- Enhanced Facility Productivity

2 Define capabilities needed to support objectives. Capabilities will include those required for energy code compliance as well as those drawn from more than one use case.

- Assess System Capabilities

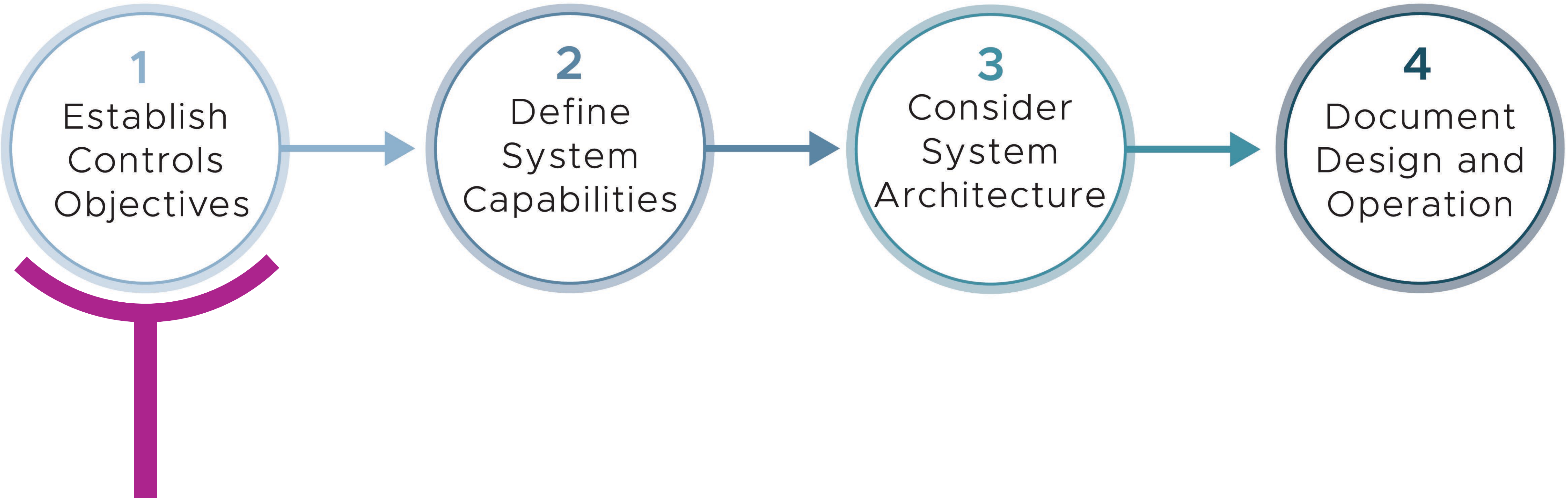
3 Understand how the structure and components of the system contribute to the desired capabilities and satisfy project limitations and owner preferences.

- System Scale
- Networking Options
- Wired and Wireless Networks
- System Components

4 Create documents that support accurate installation, configuration, and operation of the control system. The task of documenting begins with the Controls Intent Narrative and continues throughout the design process.

- Controls Intent Narrative
- Sequence of Operation
- Drawings and Specifications

Step 1: Establish Controls Objectives



Step 1: Establish Controls Objectives

Defining project goals and objectives creates an outline for system requirements.

- Project objectives may be established during initial design meetings or more formally in an Owner's Project Requirements (OPR) document.
  - **Specificity may vary** – "I want an LLLC" vs. "minimize environmental impact." **It is the specifiers job to bridge the gap.**
  - Will vary by application – use cases appropriate for a large hospital may or may not apply to hospitality environments, for example.

- Instead of starting with the manufacturer menu, **begin with the end users and project objectives in mind**.
  - Similar to the conceptual lighting design phase, disregard specific equipment or manufacturers in favor of design intent.

- Ask the question: **What do we need the lighting control system to do?** These use cases are a starting point in defining system requirements for selection and specification.

Objectives and Use Cases

Code Compliance

Code compliance represents the minimum requirement for most projects and is generally the least costly.

Enhanced Lighting Performance

Improving workforce productivity, wellness, satisfaction, and facility appeal.

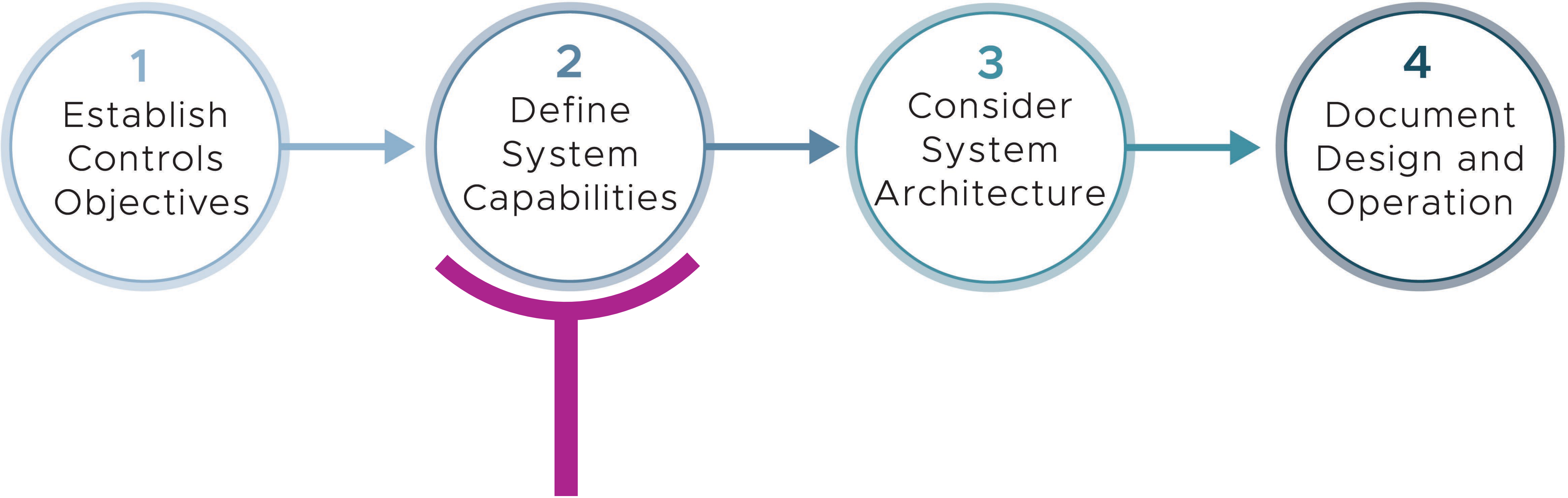
Enhanced Energy Management

Energy conservation and management beyond minimal code compliance.

Enhanced Facility Productivity

Greater spatial and asset efficiency, improved retail performance, and increased engagement, safety, and security.

Step 2: Define System Capabilities



Exercise 1 Capabilities

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Identify capabilities for each use case

- As a group, list the capabilities that contribute to achieving each use case. Capabilities may support more than one use case.
- **10 minutes**

Example: Energy Code Compliance Capabilities

- Switching and local control
- Occupancy sensing

Exercise 1 Capabilities

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Exercise 1: Identify Supporting Capabilities for each Use Case

As a group, list the capabilities that contribute to achieving each use case. Capabilities may support more than one use case.

Use Case	Supporting Capabilities
Energy Code Compliance	*Switching and local control, occupancy sensing…*
Enhanced Lighting Performance	
Enhanced Energy Management	
Enhanced Facility Productivity	

Exercise 1 Capabilities

Identify capabilities for each use case

- As a group, list the capabilities that contribute to achieving each use case. Capabilities may support more than one use case.
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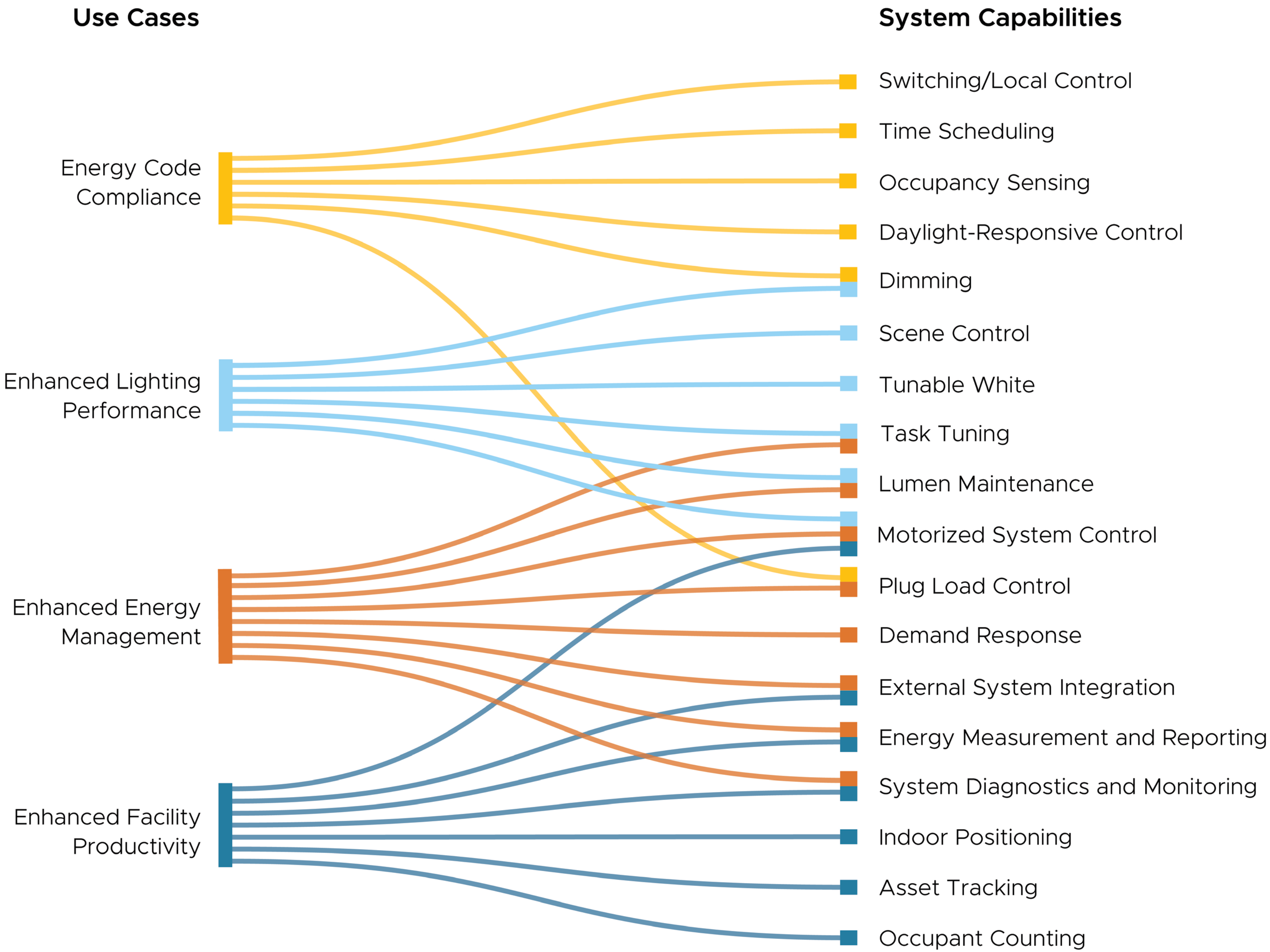
Exercise 1 Discussion

What capabilities support each use case to achieve project objectives?


Use Cases
System Capabilities
Energy Code Compliance
Enhanced Lighting Performance
Enhanced Energy Management
Enhanced Facility Productivity
Switching/Local Control
Time Scheduling
Occupancy Sensing
Daylight-Responsive Control
Dimming
Scene Control
Tunable White
Task Tuning
Lumen Maintenance
Motorized System Control
Plug Load Control
Demand Response
External System Integration
Energy Measurement and Reporting
System Diagnostics and Monitoring
Indoor Positioning
Asset Tracking
Occupant Counting

Wants vs. Needs – Consider the Risk

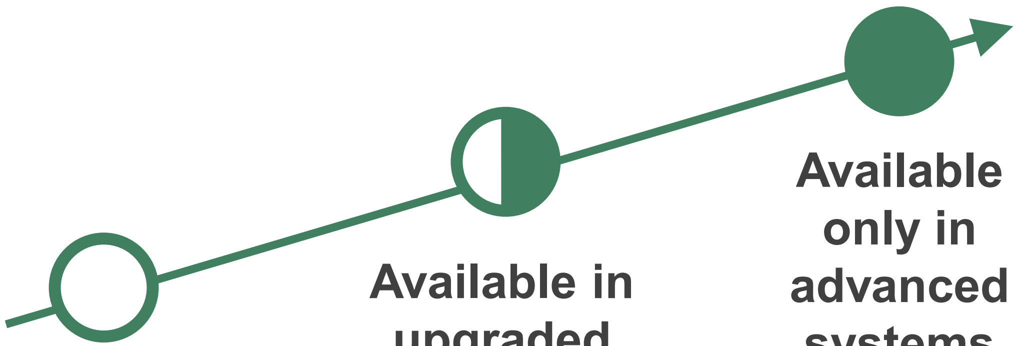
Increased system complexity

yields higher cost and risk of failure.

A Risk Assessment Approach

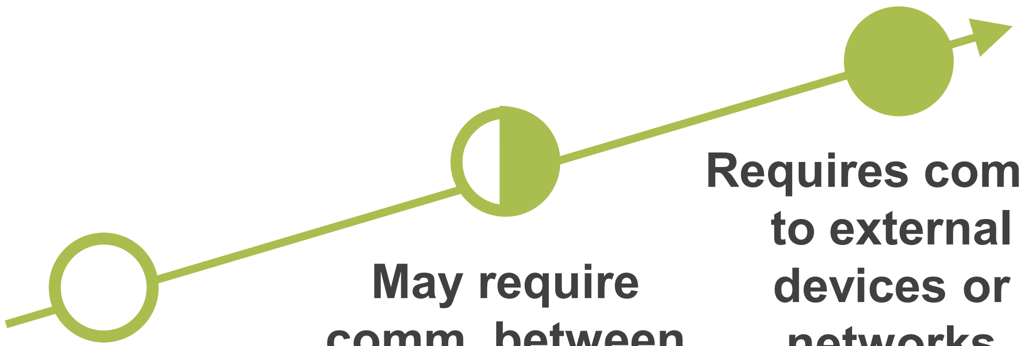
Technology Availability

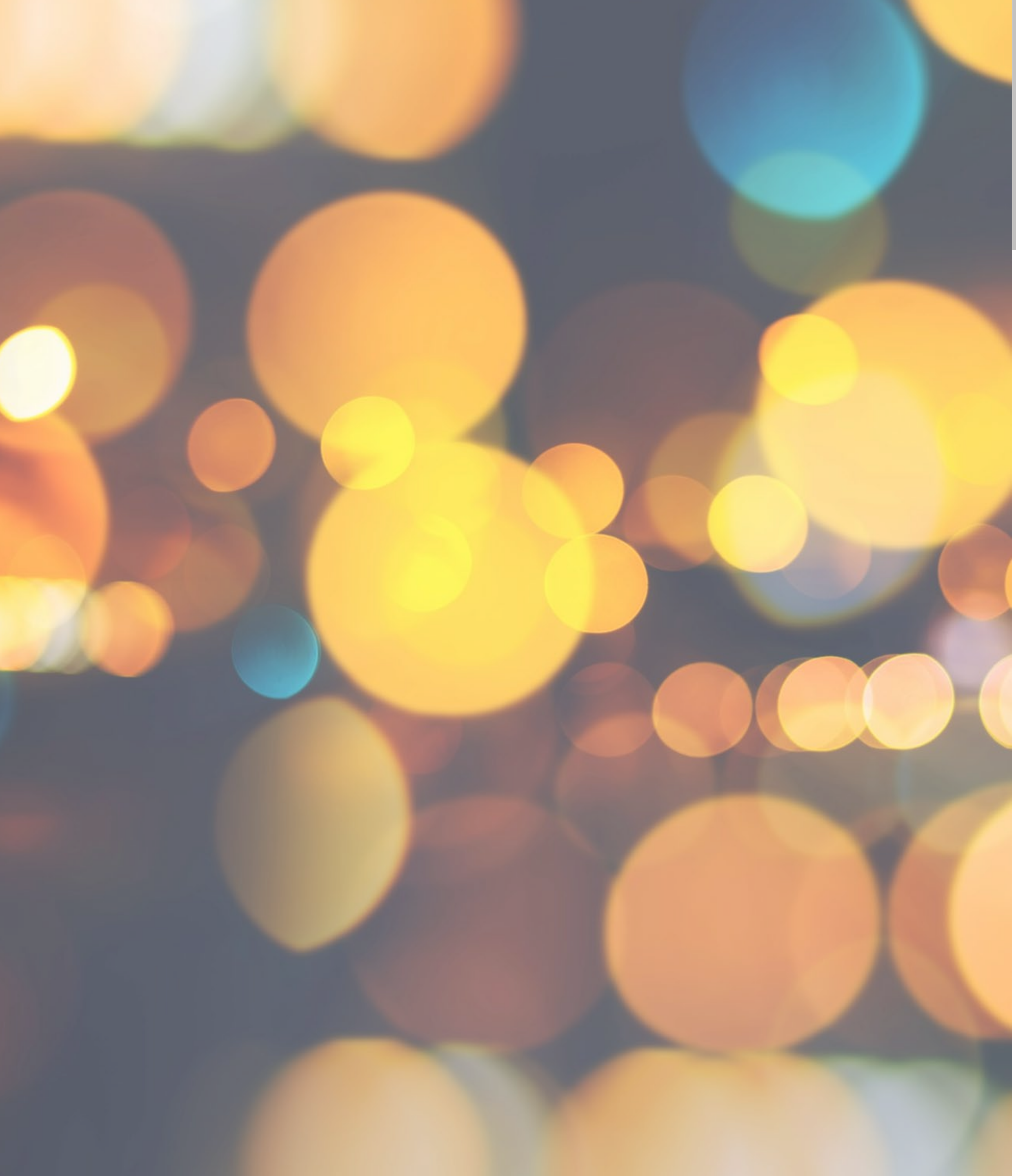
Is the capability widely available and frequently used? Availability may provide an estimate of technology maturity. Emerging features may come with unforeseen hurdles.



Communication Requirements

Lighting control systems can stand alone or become the backbone for data exchange and communication infrastructure. Interoperability must be addressed as communication requirements increase.

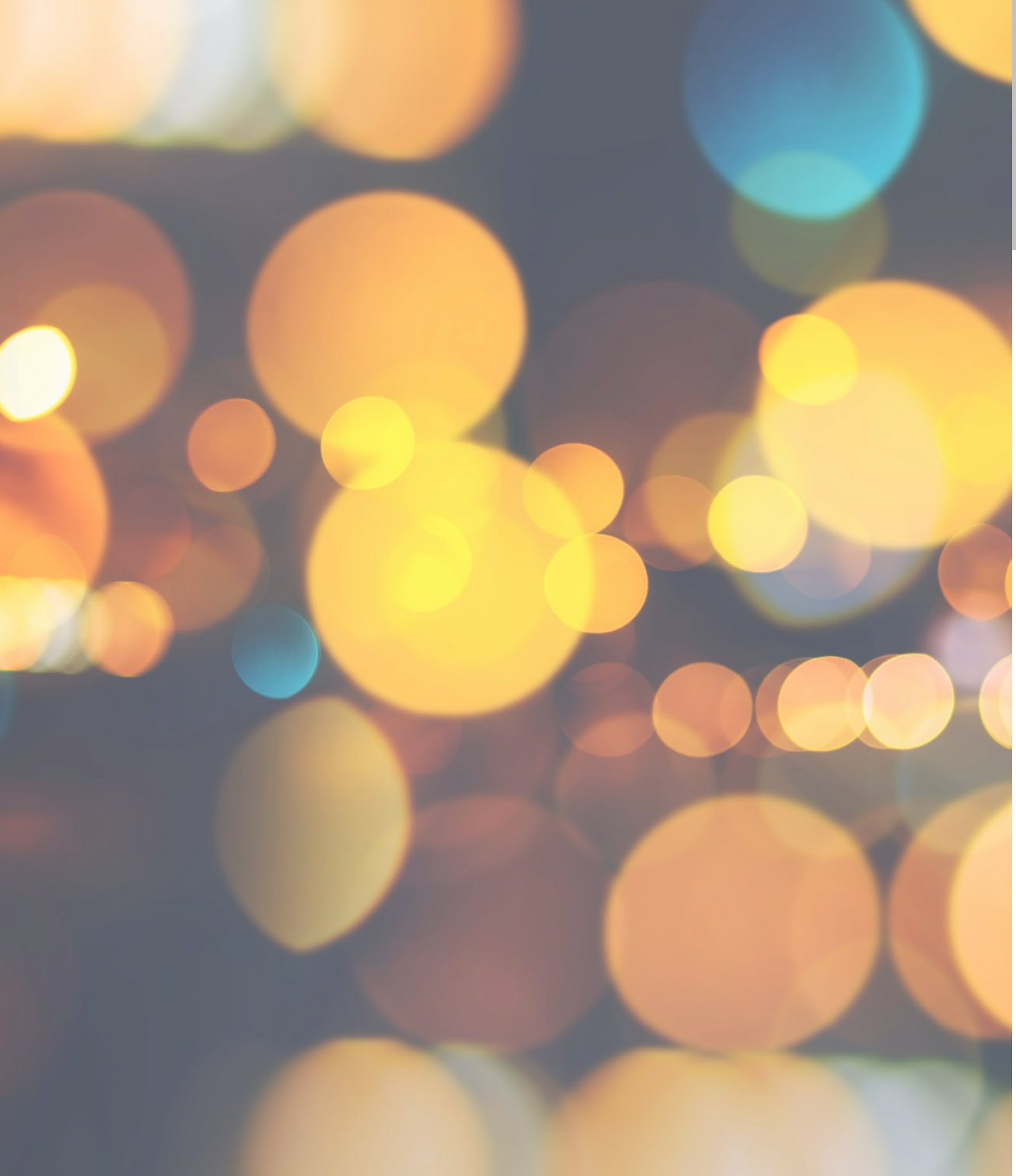




Exercise 2

Characterize potential risks

Work as groups. Rate each capability in terms of availability as well as communication requirements based on your experience. Feel free to add additional capabilities you listed during the first exercise.



Exercise 2

Exercise 2b: Characterize Potential Risks

Individually, consider the potential risks associated with implementing each capability. Start by implementing the typical approach you just defined in the "Individual Measures" column. Then, rate each capability in terms of availability (TA) as well as communication requirements (CR) based on your experience. Feel free to add additional capabilities you listed during the first exercise.

Technology Availability (TA)

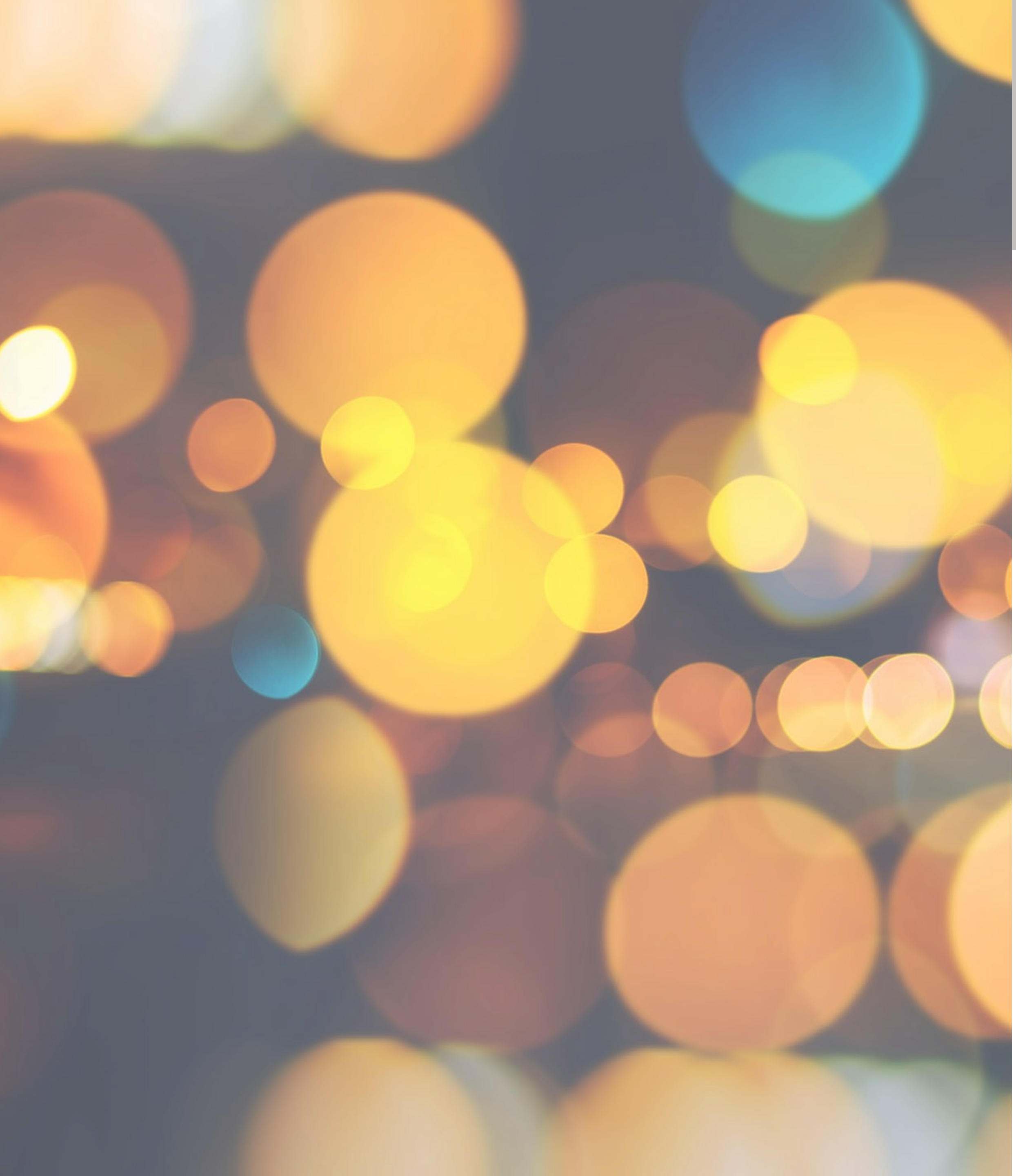
- ○ Capability is ubiquitous in lighting controls systems.
- ◑ Capability is offered in an upgraded tier of most controls systems.
- ● Availability in current market is limited to specialized or advanced systems.

Communication Requirements (CR)

- ○ Basic communication or does not require an exchange of data.
- ◑ Capability may require communication between devices within the lighting controls system. Standardized methods for data exchange may be required.
- ● Capability requires communication between devices or networks outside of the lighting controls system.

Based on your experience, rate each capability and note any additional risks. Discuss your ratings and experiences with your table.

System Capability	Individual Measures of Risk / Notes	TA	CR
Occupancy Sensing	*Sensor placement is critical*	○ ◑ ●	○ ◑ ●
Scheduling		○ ◑ ●	○ ◑ ●
Daylight-Responsive Control		○ ◑ ●	○ ◑ ●
Dimming		○ ◑ ●	○ ◑ ●
Scene Control		○ ◑ ●	○ ◑ ●
White Tuning		○ ◑ ●	○ ◑ ●



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Characterize potential risks

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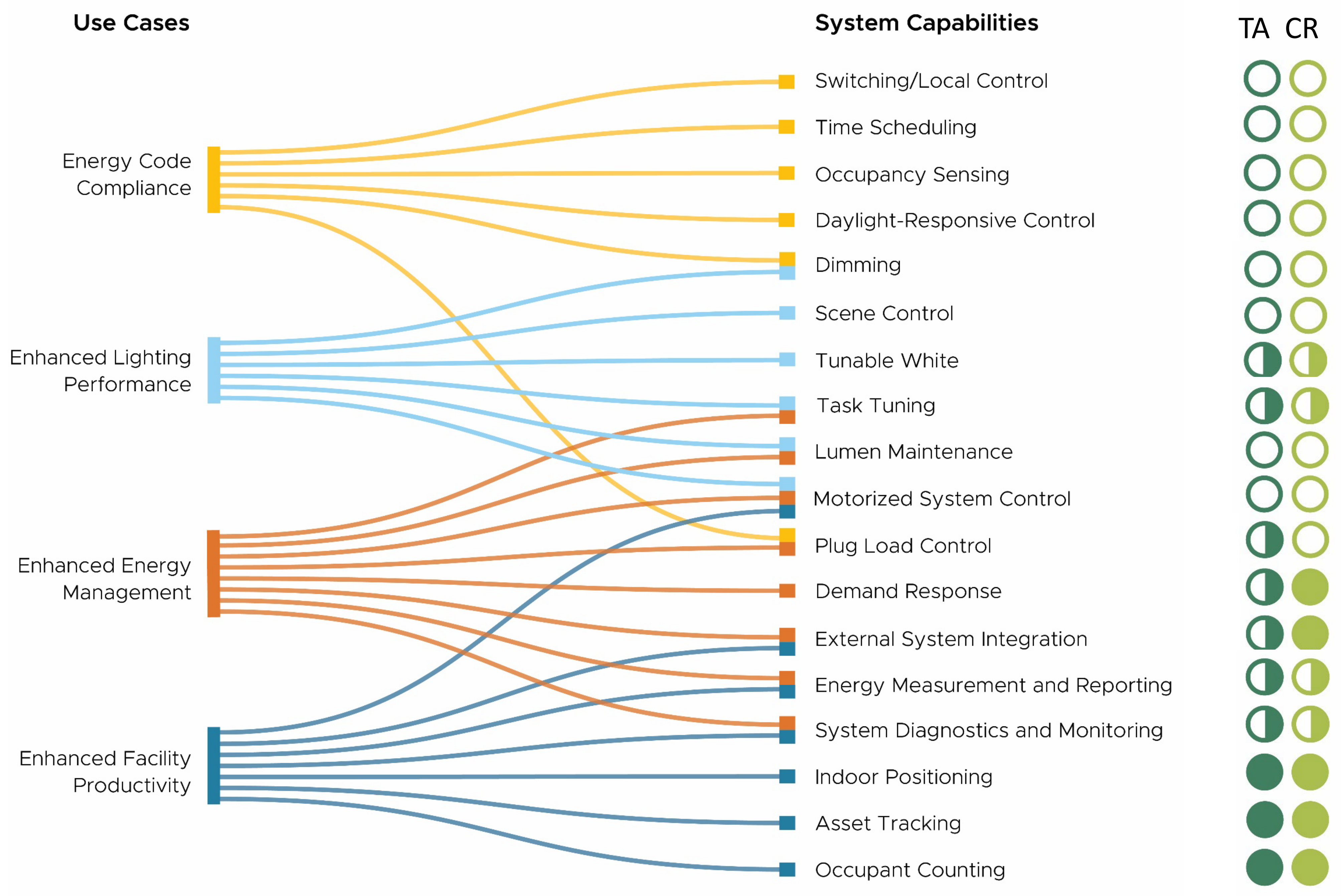
Exercise 2 Discussion

Does the group agree on the capabilities with the greatest risk?

Which outcomes that made you say “Never again!”

What other risk metrics would you consider?



Use Cases
System Capabilities
TA
CR
Energy Code Compliance
Enhanced Lighting Performance
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Enhanced Facility Productivity
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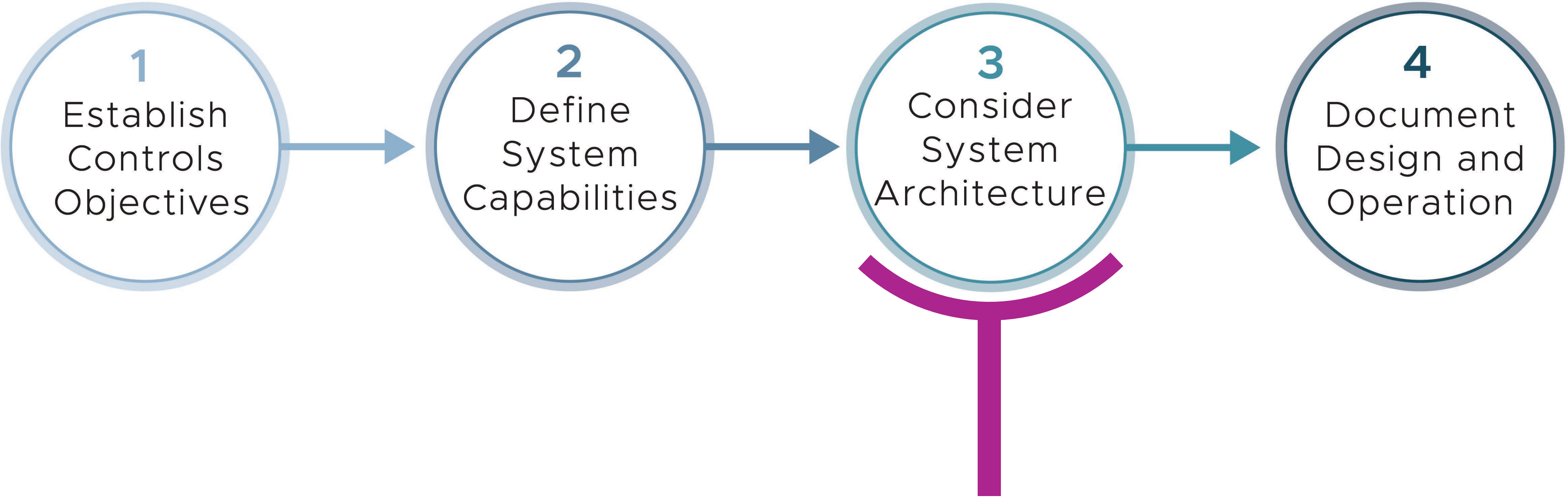
System Diagnostics and Monitoring
Indoor Positioning
Asset Tracking
Occupant Counting

Step 3: Consider System Architecture

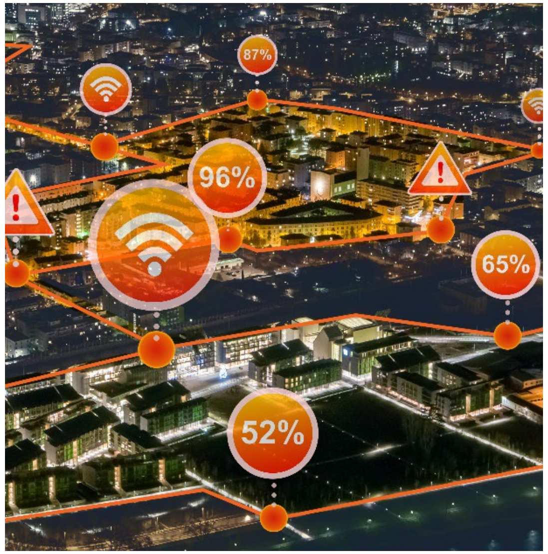


Can Do or Should Do?

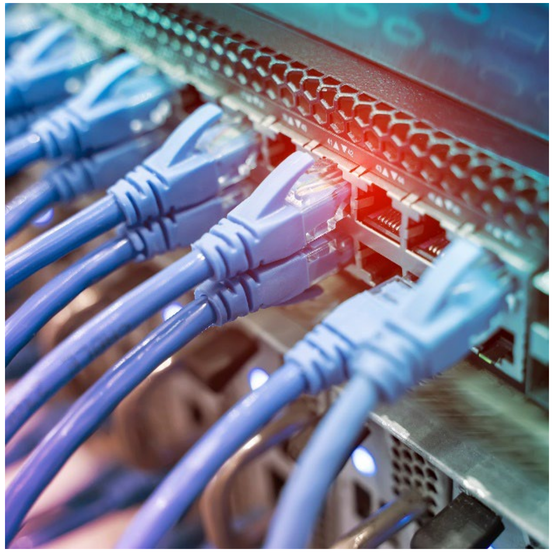
Lighting Controls System Architecture Overview

System capabilities and project requirements should influence system architecture decisions.

System Scale



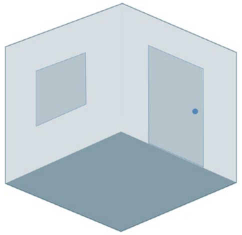
System Intelligence



Wiring and Communication

System Scale

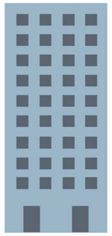
The scale of the control system is typically dictated by the physical size of the project; however, system scale impacts communication as well. Some advanced capabilities require advanced communication regardless of the project scope.



Single Space

Non-networked

- Each room operated independently without external communication
- Advanced capabilities requiring data collection or exchange may be limited



Floor or Building

Hybrid or Networked

- Some or all spaces are communicating with each other or a central device
- Baseline communication infrastructure for most advanced capabilities.

Campus/Portfolio

Networked

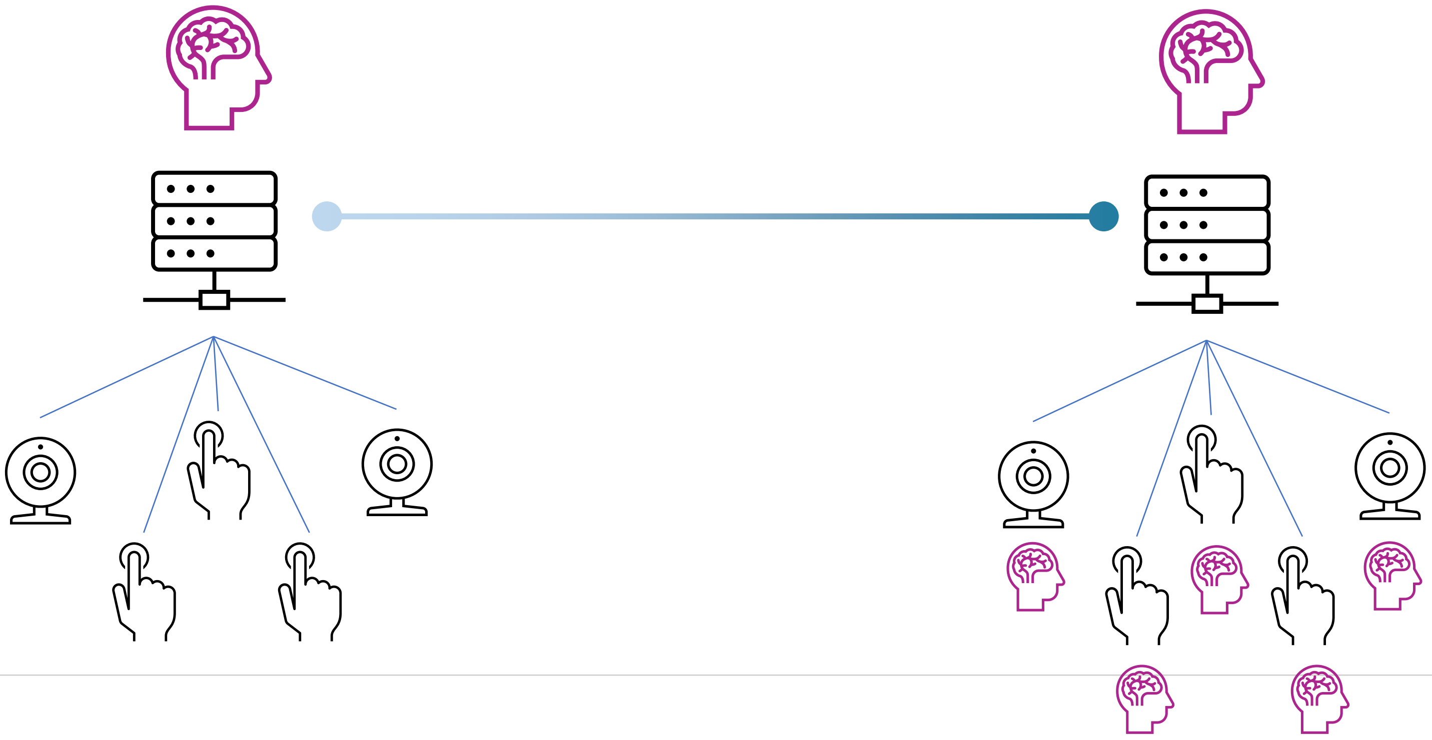
- Similar to floor or building scale system
- Incorporates an additional layer of communication for building-to-building interaction

System Intelligence

Control systems may rely on a central "brain" or may distribute intelligence to end devices like user interfaces and load controllers. Distributed intelligence systems may or may not utilize a central server or processor.

Central Processor

- Central processor is used to signal networked components
- Can be configured to communicate with the building management system



Distributed Intelligence

- End devices have communication, networking, and storage functions
- Can increase system resilience by relying on locally stored data

Wiring and Communication

Wired

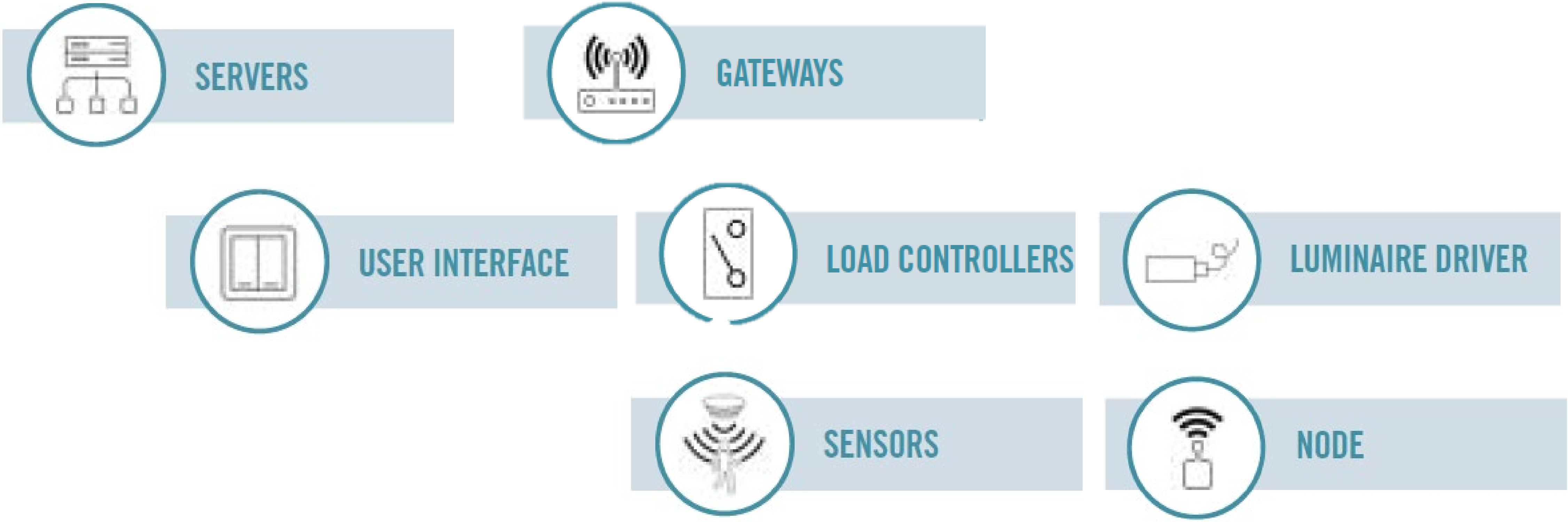
- Limited access for security
- Installation cost
- Analog or digital

Wireless

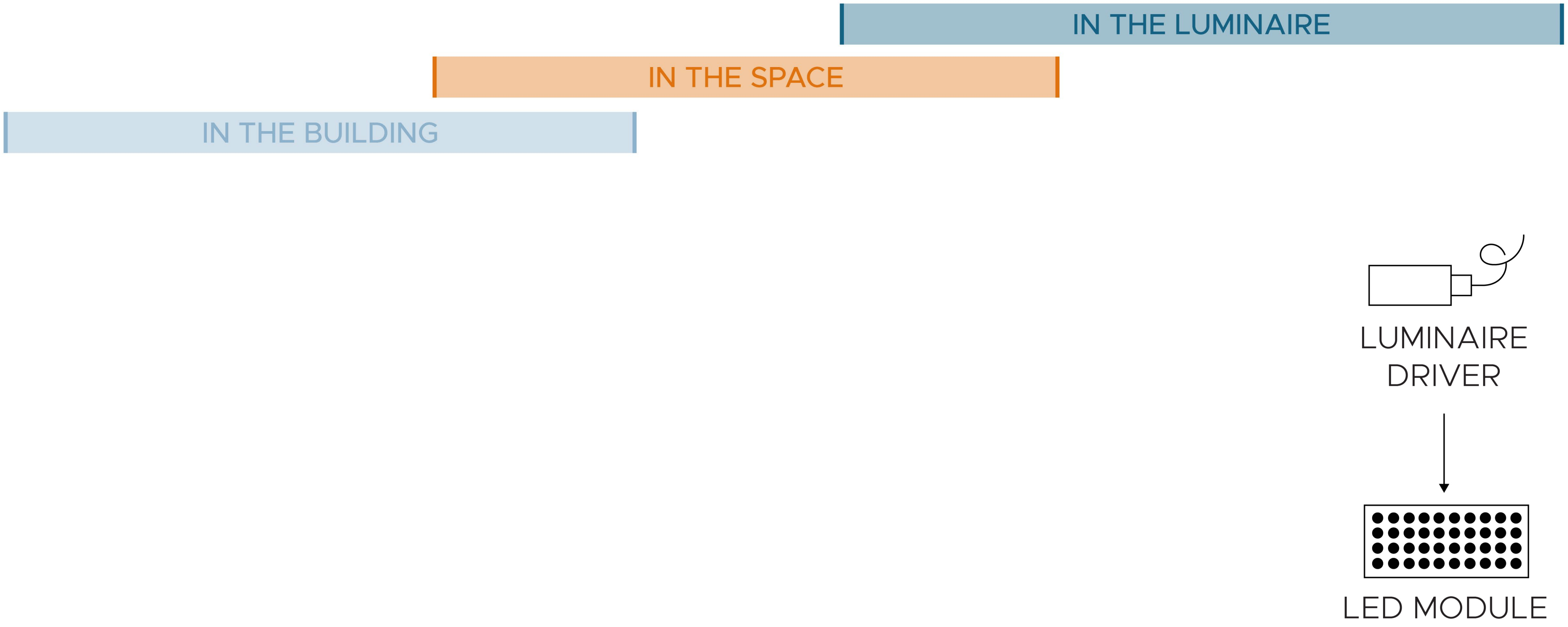
- Good for renovations
- Digital RF communication
- Open v. proprietary limitations

SYSTEM ATTRIBUTE	ANALOG	DIGITAL
Data Exchange	One-way	Two-way
Luminaire Addressability	No	Yes
Zoning Flexibility	Determined by wiring	Can be reconfigured in software

Components


SERVERS
GATEWAYS
USER INTERFACE
LOAD CONTROLLERS
LUMINAIRE DRIVER
SENSORS
NODE

Controls Components

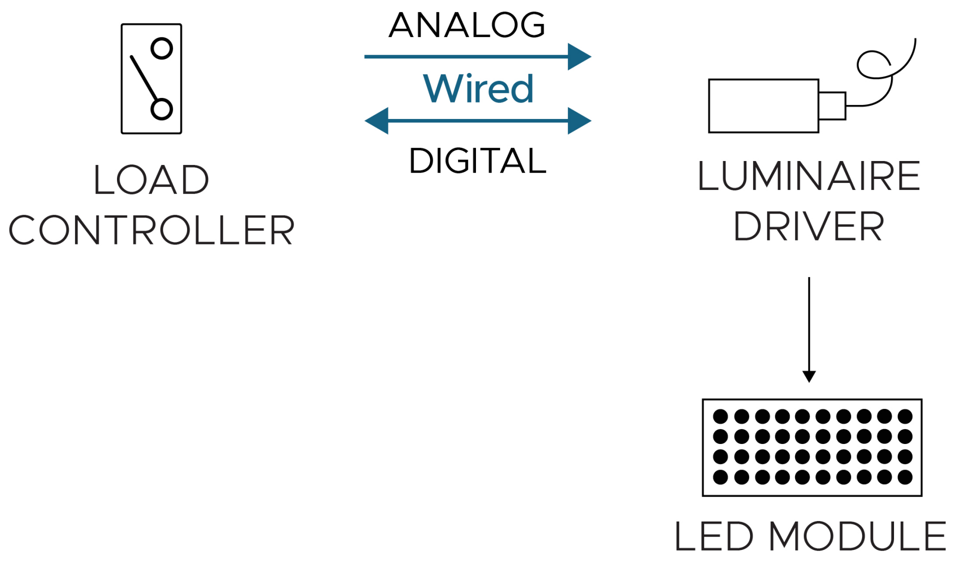


Controls Components

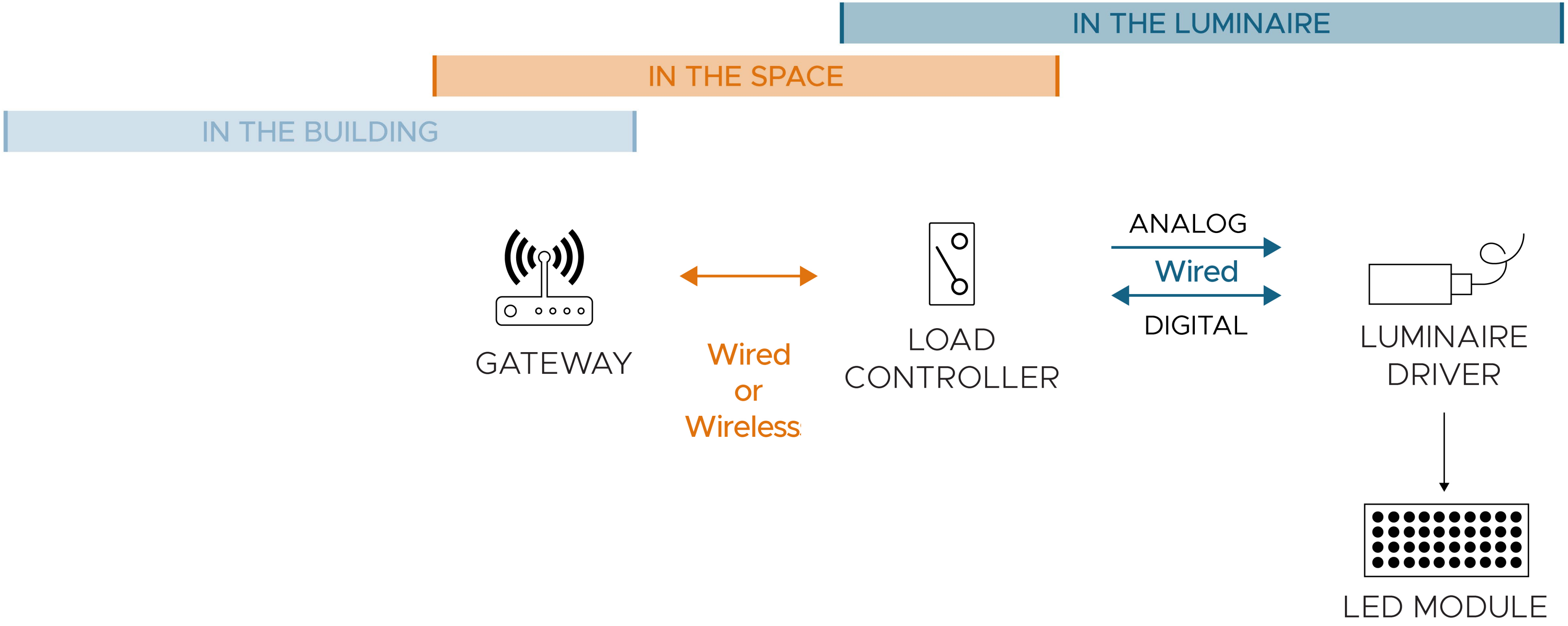
IN THE LUMINAIRE

IN THE SPACE

IN THE BUILDING



Controls Components



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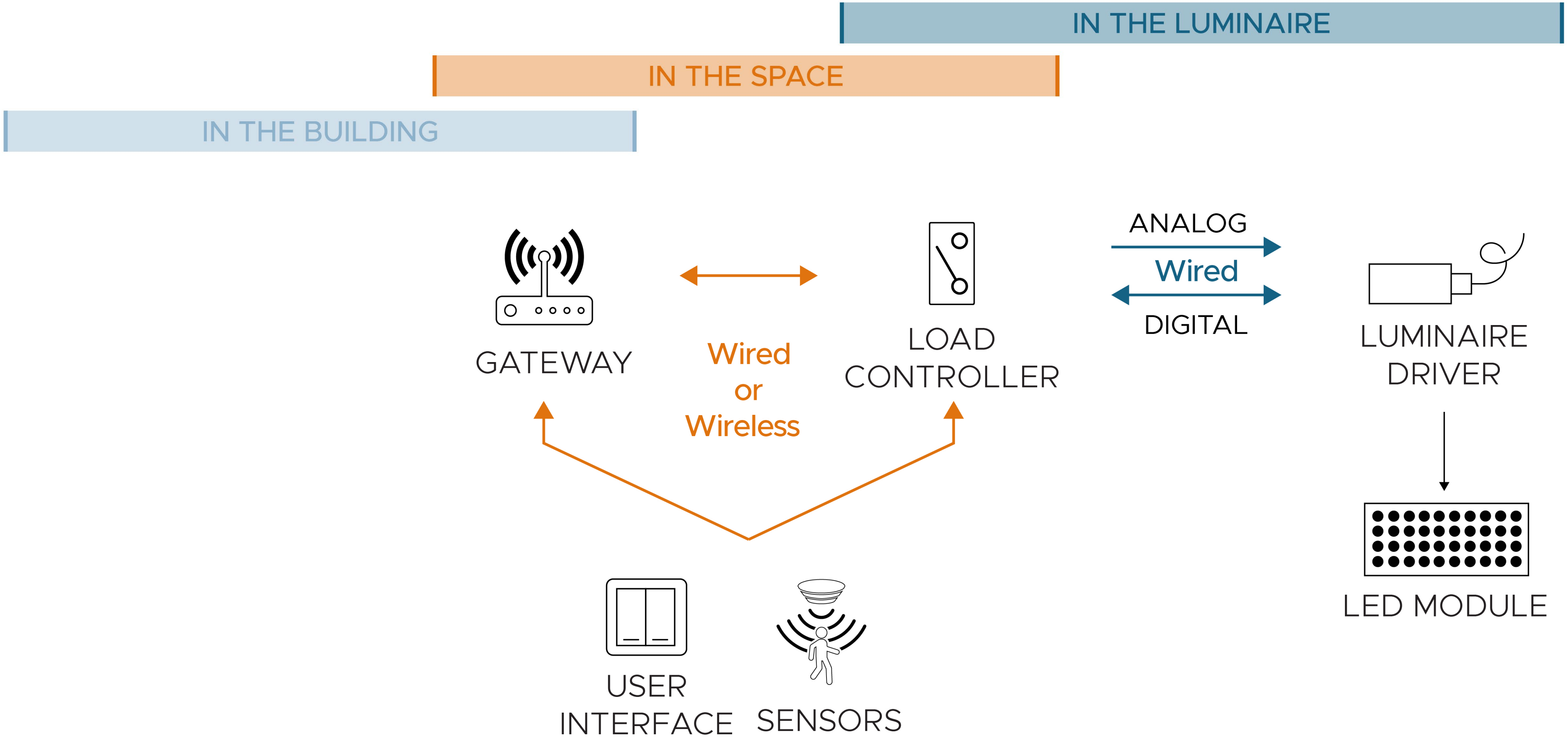
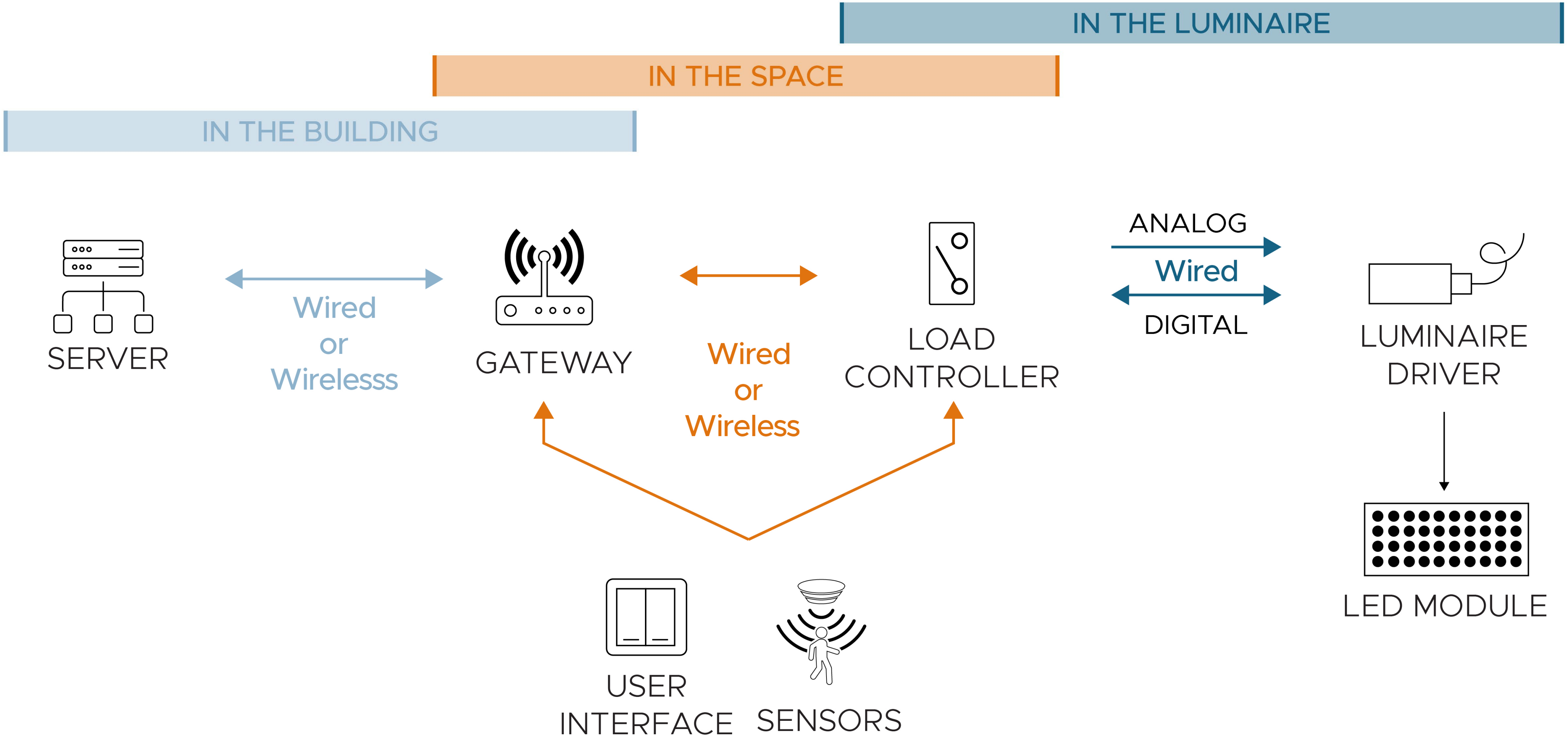
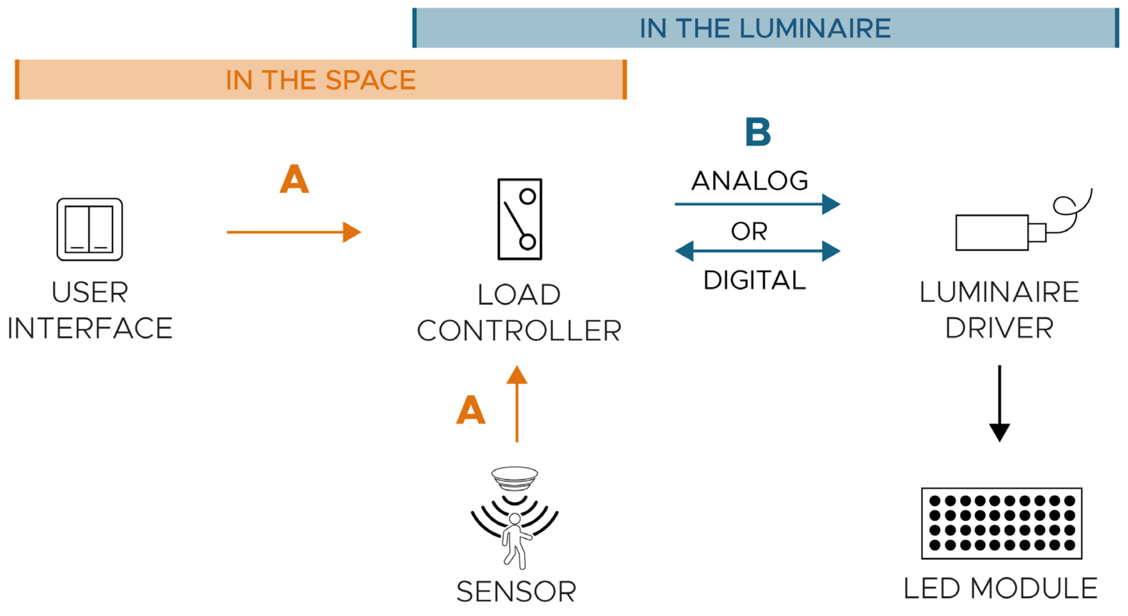


Controls Components



Single-Space System



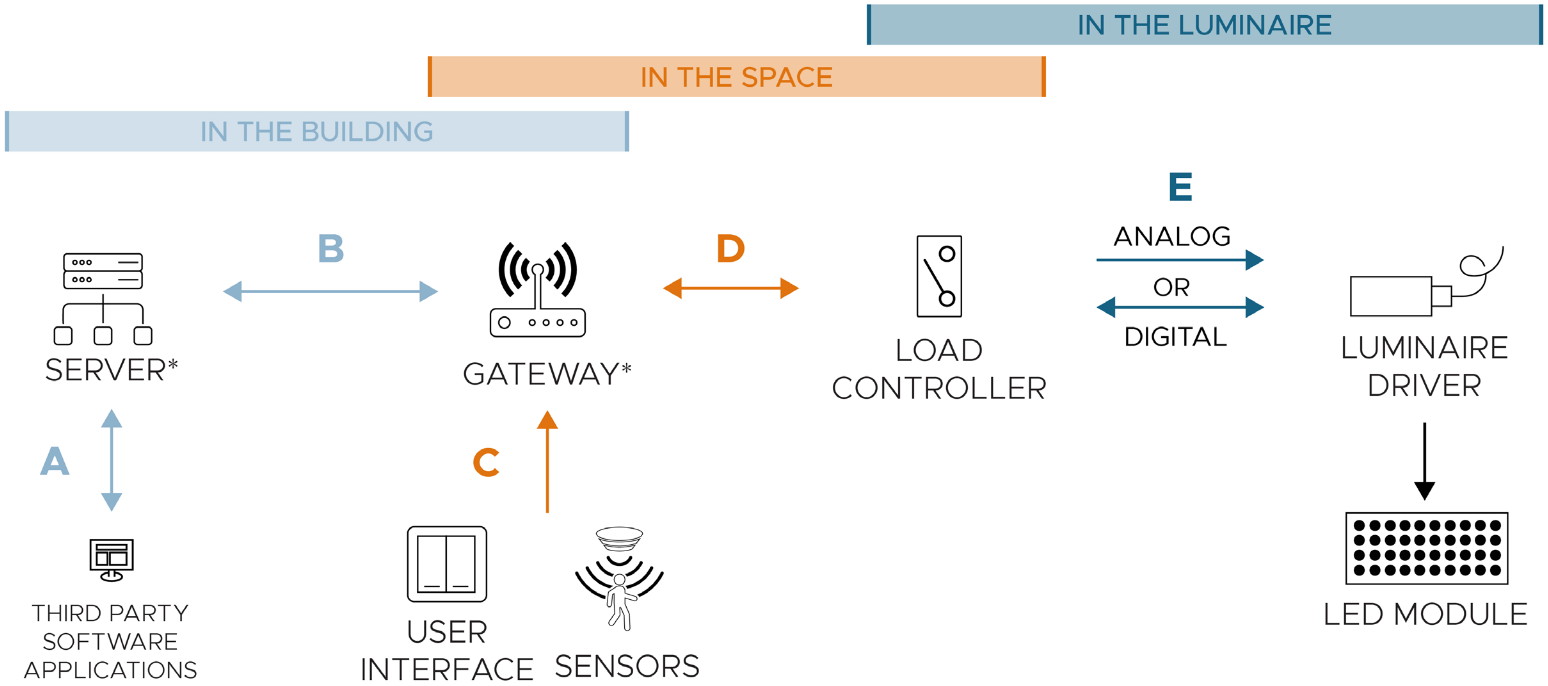
A HARD-WIRED:
Cat5e

WIRELESS:
BLE, Zigbee, Thread, etc.

B HARD-WIRED:
Low-voltage wiring

Analog (one-way) - 0-10V
Digital (two-way) - DALI 2 (including D4i drivers), DMX 512, manufacturer specific, etc.

Centralized Intelligence



*In most systems, the gateway or a local server will act as the central controller.

Not all systems will require a connection to external applications or other building systems via a gateway or server. In some systems, the load controller may be integral to the driver, the sensors, or the user interfaces.

A Internet

B HARD-WIRED:
Cat5e

WIRELESS:
Wi-Fi

C HARD-WIRED:
Cat5e

WIRELESS:
Bluetooth Low Energy (BLE), Zigbee, Thread, etc.

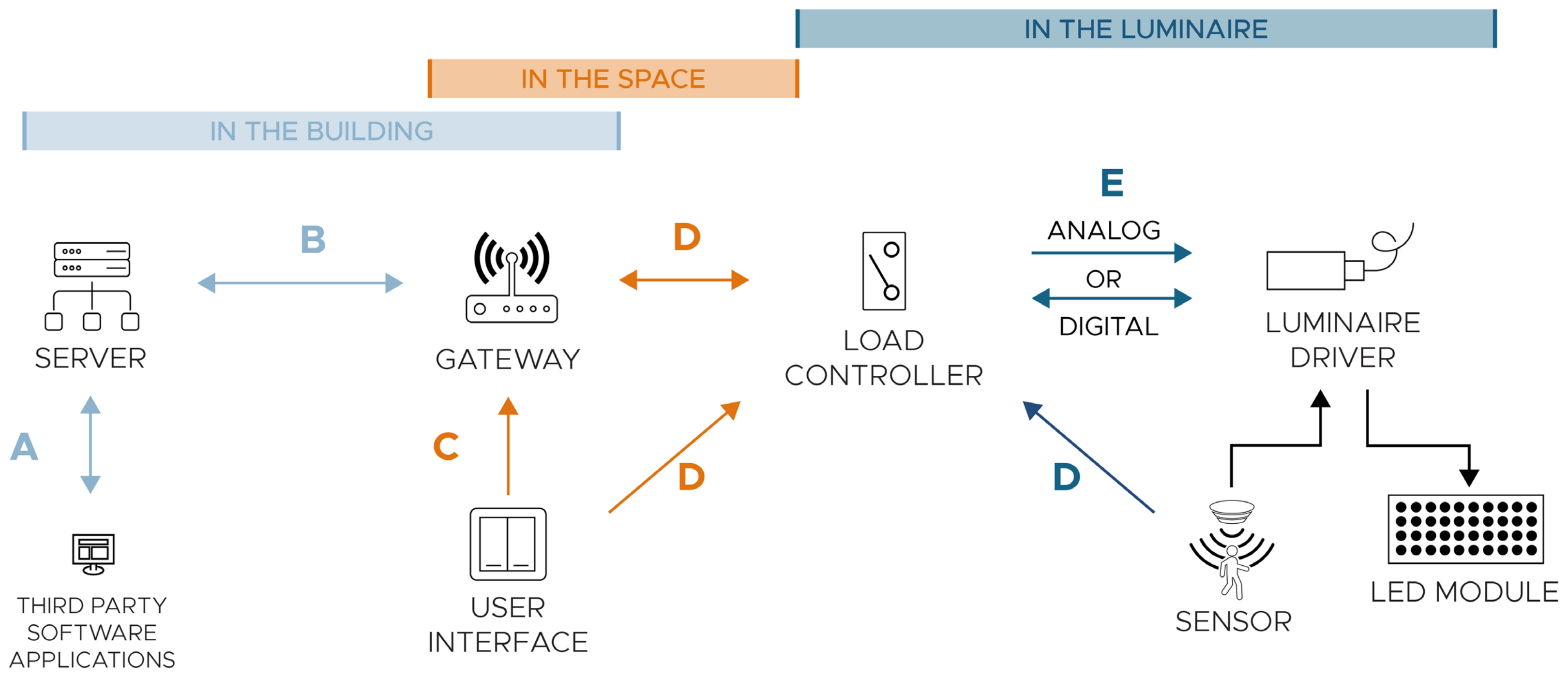
D HARD-WIRED:
Cat5e

WIRELESS:
BLE, Zigbee, Thread, etc.

E HARD-WIRED:
Low-voltage wiring

Analog (one-way) - 0-10V
Digital (two-way) - DALI 2, DMX 512, manufacturer specific, etc.

LLLC



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C HARD-WIRED:
Cat5e

WIRELESS:
Bluetooth Low Energy (BLE), Zigbee, Thread, etc.

D/D HARD-WIRED:
Cat5e

WIRELESS:
BLE, Zigbee, Thread, etc.

E HARD-WIRED:
Low-voltage wiring

Analog (one-way) - 0-10V
Digital (two-way) - DALI 2 (including D4i drivers), DMX 512, manufacturer specific, etc.

Exercise 3

Browse Manufacturer Documentation

- Individually, browse system documentation:
  - System scale (e.g., zone, room, portfolio, etc.) Are certain devices required to increase scale?
  - Wired or wireless options
  - Distributed or centralized intelligence
  - Communication protocols / compliance with standards
  - Does the system require a gateway or server? What do these components facilitate?
  - External communication
  - Luminaire compatibility
  - Capabilities
- **15 minutes**

Exercise 3

Exercise 3: Browse Manufacturer Documentation

Individually, browse the provided documentation for each lighting control system. Can you find the follow questions below? Share information on systems with your table.

	System 1	System 2	
System Name			
System scale options			
Are certain devices required to increase scale?			
Wired or wireless options			
Distributed or centralized intelligence			
Communication protocols			
Analog or digital communication options			
Requires a gateway? What does it facilitate?			
Requires a server? What does it facilitate?			
Is external communication possible? How?			
Are luminaires from any manufacturer compatible?			
What capabilities does the system support? Any special requirements?			
Is there an explanatory diagram of the system architecture? If so, is it useful?			

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  - Does the system require a gateway or server? What do these components facilitate?
  - External communication
  - Luminaire compatibility
  - Capabilities
- **15 minutes**

Exercise 3 Discussion

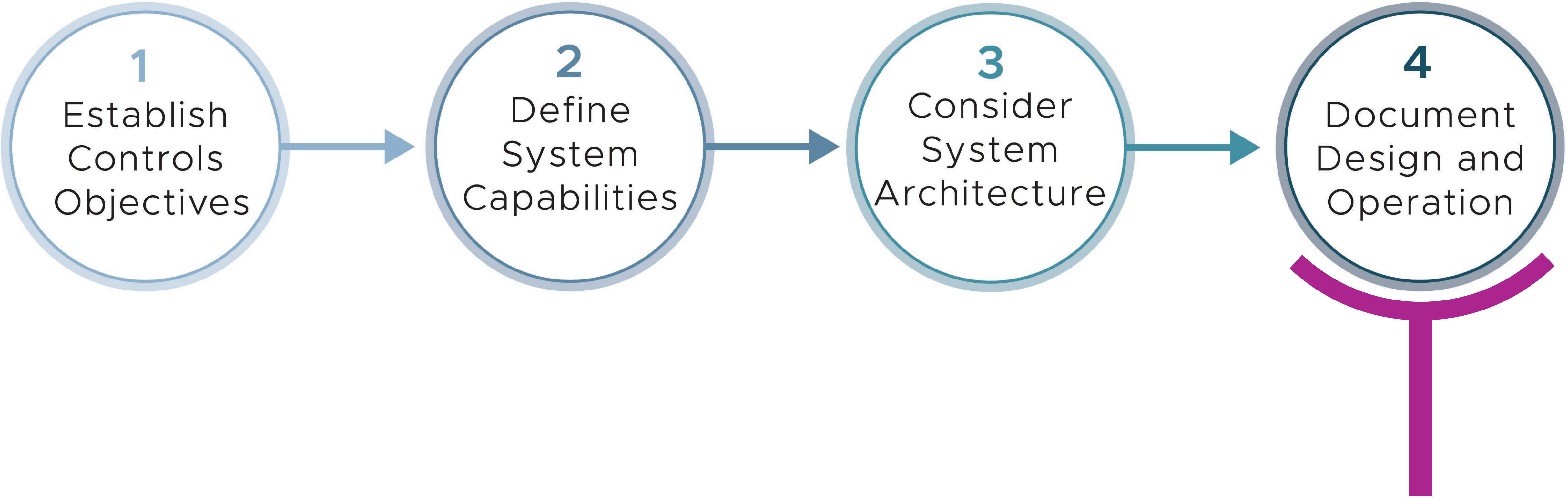
Were you able to find everything?

Was the information clearly stated?

Overall pros or cons for controls design?

Where else might you go for information?

Step 4: Document Design and Operation



Controls Intent Narrative

- Initial CIN during schematic design
- Control capabilities to satisfy goals
- Description of the control system
- Clear and unambiguous

Exercise 4

Create a Control Intent Narrative

Based on the provided Owner's Project Requirements, create a CIN for the office with your table.

Organized by space type, define required control strategies and capabilities.

Space Specific Requirements:

List specific control strategies that will be deployed in each space. Will the space use occupancy or vacancy sensing? Will daylight responsive controls be implemented? Will there be scheduled changes? Document how the existing conditions may influence your design, if appropriate.

WHAT SHOULD BE INCLUDED IN A CONTROL INTENT NARRATIVE?

The CIN is typically organized by space type. Include an overview of the control strategies and capabilities deployed in each space to satisfy project objectives and code requirements.

- System scale
- Networking and communication requirements
- Existing conditions (where applicable)
- Sensor functionality requirements
- User interface and local control intent
- Application of automatic and/or manual lighting control
- Accent or specialized lighting features
- Emergency lighting approach

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- Accent or specialized lighting features
- Emergency lighting approach

Exercise 4

Exercise 4: Create a Control Intent Narrative (CIN)

Based on the provided Owner's Project Requirements, create a CIN for the office renovation with your table. Document the general control capabilities that will be applied to each space within the project. Consider listing project "must haves" separately from project "nice to haves".

Space Type	Control Intent
Open Office	
Private Office	
Conference/Meeting Rooms	
Break Room	
Corridor	
Lobby	

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- Sensor functionality requirements
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- Accent or specialized lighting features
- Emergency lighting approach

Exercise 4 Discussion

What strategies did you use beyond those needed for code compliance?

What in the OPR suggested those strategies?

How did you consider risk?

How often are you involved in creating a CIN?

Controls Intent Narrative

WHAT SHOULD BE INCLUDED

The CIN is typically organized by space type. Include an overview of the control strategies and capabilities deployed in each space to satisfy project objectives and code requirements.

- System scale
- Networking and communication requirements
- Existing conditions (where applicable)
- Sensor functionality requirements
- User interface and local control intent
- Automatic and/or manual lighting control
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- Emergency lighting approach

Space Type	Line-Voltage Switch	On/Off/Raise/Lower Keypad	Scene Select Keypad	Occupancy Sensor (Auto Part On)	Vacancy Sensor	Time Schedule	Astro Time Switch	Daylight Photosensor	Demand Response	Emergency Ltg Control
Break Rm, Lounge		•			•			•	•	
Conference Rms			•		•			•	•	
Corridors, Halls		•		•		•			•	•
Elect, Elev, Mech	•									•
Elevator Lobby		•		•		•				•
Janitor, Storage	•				•					
Lobby			•		•	•	•	•	•	•
Office <25 sq.m.		•		•				•	•	
Office >25 sq.m.		•			•	•		•	•	•
Parking Garage		•		•			•	•	•	•
Restrooms		•		•	•	•				•

Exercise 5

Consider System Architecture Attributes

Based on your CIN and system requirements stated in the OPR, make appropriate decisions regarding system scale, networking, and communication requirements. Do you need a digital protocol? A portfolio-scale or room-based, non-networked system? Would you suggest a system with distributed intelligence for the application?

- Do any of the systems we reviewed earlier fit the description?

Exercise 5 Discussion

Do any of the systems we reviewed earlier match this description?

Sequence of Operations

- Detailed map for controls design
- Legally enforceable document
- Fit for system programming
- Describes what controls should do
- Space-by-space
- What initiates change
- Desired outcome in detail
- Device description
- Device location

Room Number	Space Type	Control Designation	Design Illuminance (lux)	N1 – Line-Voltage Switch	N2 – On/Off/Raise/ Lower Keypad	N3 – Scene Select Keypad	N4 – Task Tuning	N5 – Occupancy Sensor (Auto Part On)	N6 – Vacancy Sensor	N7 – Time Schedule	N8 – Astro Time Switch	N9 – Daylight Harvesting	N10 – Demand Response	N11 – Emergency Ltg Control	Other Notes
001	Parking Garage	LC10	150		•			•			•	•	•	•	
101	Lobby	LC7	25			•	•		•	•	•	•	•	•	
102	Office-1 <25 sq.m.	LC8	300		•		•	•			•	•			
103	Conference Rm 1	LC2	350			•	•		•		•	•	•		
104	Retail Sales	LC12	500		•	•	•			•	•		•	•	
105	Corridor	LC3	200		•		•	•		•	•		•	•	
106	Conference Rm 2	LC2	350			•	•		•		•	•	•		
107	Elev Machine Rm	LC4	200	•										•	
108	Lounge	LC1	250		•		•		•		•	•	•		
109	Elevator Lobby	LC5	100												N12
110	Janitor	LC6	150	•											
111	Break Rm	LC1	250		•		•		•		•	•	•		
112	Storage	LC6	150	•											
113	Office >25 sq.m.	LC9	300		•		•			•	•	•	•	•	
114	Stairwells	LC14	100					•						•	N13
115	Office-2 <25 sq.m.	LC8	300		•		•	•			•	•			
116	Hall	LC3	200		•		•	•		•	•		•	•	
117	Mech Rm	LC4	200	•										•	
118	Restrooms – Men	LC11	250				•	•	•	•	•			•	
119	Restrooms – Women	LC11	250				•	•	•	•	•			•	
120	Science Lab	LC13	500		•		•		•			•	•	•	
121	Elect Rm	LC4	200	•										•	
300	Site Lighting	LC15	30		•			•	•					•	N14

Table notes:

N 1 Manual on/off device located within the area it controls.

N 2 Controls that allow the lighting level to be adjusted up and down.

N 3 8-buttons: On, Off, Raise, Lower, and 4 additional scene buttons.

N 4 Adjust the maximum allowed illuminance to be no more than 10% above the design illuminance as measured at the task. Record the new maximum setpoint.

N 5 Auto-on to 50% of maximum light output. Manual raise/lower. Manual-off and Auto-off.

N 6 During normal hours, Auto-off after 15 minutes of vacancy using a 5-second fade. During non-normal hours, Auto-off after 5 minutes of vacancy using a 5-second fade.

N 7 Lighting controls are enabled during normal hours of operation (7 a.m. to 7 p.m. weekdays). During non-normal hours, lighting is turned off automatically following a flash warning. May be manually overridden to on, or automatically via occupancy sensor.

N 8 At 30 minutes after civil dusk, interior lighting shall be reduced by 25% over 10 minutes. At 30 minutes after civil dawn, interior lighting shall return to its normal levels over 10 minutes.

N 9 When daylight illuminance from daylight is >150% of design illuminance, reduce lighting power by 65%. When illuminance is more than 200% of design illuminance, lighting power shall fade to off over 60 seconds.

N 10 During a demand-response event, the lighting power shall be reduced by 15% and shall not be allowed to exceed that value during the event. After the demand-response event, the lighting shall return to the level preceding the event.

N 11 If the general-lighting luminaires are used to provide the code-required emergency illumination, then means shall be provided (e.g., via a UL924 relay) to cause the designated emergency luminaires to go to full light output upon loss of the normal lighting power to the area.

N 12 Elevator lobbies shall provide a minimum of 100 lux 24/7 at the door sill of the elevators. The sills may have greater illuminance to match adjacent corridors during normal hours.

N 13 Stairwells shall have a minimum of 100 lux while the stairwell is occupied and shall remain at this lighting level for 10 minutes after vacancy. During vacancy, the illuminance shall not be less than 10 lux.

N 14 Site Lighting: All lighting shall be tied to an astronomical time switch. Occupancy sensors shall be used only where required by code. Where occupancy sensors are required, the lights shall remain on for a duration of 20 minutes after last occupancy.

CIN vs SOO

CONTROL INTENT NARRATIVE

- Wall switch at each entrance providing on, off and dimming control
- Energy code compliant (2018 IECC)
- Auto on lighting in each zone to last lighting level
- Automatically turn off all lighting when unoccupied
- Daylight responsive controls automatically and continuously dims lighting in window daylight zone
- Turn emergency lighting full on when power is lost

SEQUENCE OF OPERATION

1. General lighting in each ≤600 ft^2 zone (a, b, c, adz1, bdz1, cdz1) shall auto On to last light level when occupancy detected.
2. Manual On/Off/Dim general lighting for all zones (a, b, c, adz1, bdz1, cdz1) in unison with dimmer switch.
3. Auto Off all lighting in an individual zones within 20 minutes of occupants leaving individual zone.
4. Lighting in daylight area (adz1, bdz1, cdz1) shall continuously dim based on daylight contribution to maintain at least 30FC (adj.) at task level
5. Emergency lighting transfers to emergency power source and shall turn full On with loss of normal power.

Exercise 6

Create a Sequence of Operations (SOO)

- Exercise 6: Create a Sequence of Operations (SOO)
- Write a SOO narrative for one or several spaces within the project. Document specific setpoints and control strategies that would enable a programmer to setup and commission the lighting system. Think about events that may trigger certain actions or behaviors. Events may include time of day, user interface interactions, or motion sensing, for example.

Exercise 6 Discussion

Can you complete a Sequence of Operations without identifying a specific lighting control system?

What information do you need from the manufacturer (if any) to create a thorough and contractually enforceable SOO?

For Additional Information:

Pacific Northwest
NATIONAL LABORATORY

SELECTING LIGHTING CONTROL SYSTEMS

What's inside: A systematic approach to networked lighting controls

- Controls Objectives and Use Cases
- System Capability Considerations
- Networking and Communication Options
- Documenting a Lighting System

Introduction

The objective of this resource is to assist decision-makers in understanding how networked lighting control system attributes can satisfy project objectives at an appropriate cost and functionality. This resource is intended for members of the project team involved in the design and selection of lighting control systems, especially team members with limited-to-moderate controls experience.

Over the last five years, Pacific Northwest National Laboratory has conducted extensive research on the problems affecting lighting controls, from analysis and evaluation of a wide range of installations to dozens of interviews with industry participants. Some key challenges that have impacted successful lighting controls installations include:

- Failure to align lighting control system capabilities to project objectives
- Unclear or incomplete documentation of objectives, desired capabilities, and system features
- Misunderstandings in design and set up due to ambiguity in terminology.

These challenges can be compounded by reliance on the system architecture and vocabulary of individual manufacturers, which may limit one's understanding of lighting control systems. Developing a non-proprietary understanding of lighting control systems can offer broad options for achieving project objectives and desired performance while minimizing cost and complexity.

This document offers a systematic approach to establish objectives for lighting controls, identify relevant system capabilities, and narrow the choices in system architecture to those that support the desired system capabilities and availability of organizational resources during operation.

TABLE OF CONTENTS:

https://www.energy.gov/eere/ssl/next-generation-lighting-systems