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Designers Lighting Forum

Digital Design with DALI

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Credit(s) earned on completion of this course will be reported to AIA CES for AIA members. Certificates of Completion for both AIA members and non-AIA members are available upon request.

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Questions related to specific materials, methods, and services will be addressed at the conclusion of this presentation.

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LEARNING OBJECTIVES

At the end of this course, participants will be able to:

- Attendees will be able to describe DALI-2, D4i, and DALI+, including their similarities and differences, and their suitability for various types of projects and applications.
- Learn how interoperability can benefit projects and end customers, and how to navigate wired and wireless digital protocols and architectures to deliver interoperability benefits.
- Attendees will learn how to specify DALI technologies using performance spec language, and how to handle scope and accountability for installation and integration.
- Become familiar with examples of projects and case studies that use DALI.

Description

- In this world of digitization, integration, and AI, there is no doubt on the face of it—digital is better than analog. DALI-2, D4i, and DALI+ are high value but underutilized in North America. For that to change, lighting specifiers need practical knowledge. How exactly does DALI-2 improve your design? How do you deliver interoperability for both wired and wireless? How to spec and what to expect on a project, soup to nuts. This session will focus on designing with DALI, providing right-sized technical details, specification guidance and project examples to help you up your game and stay competitive in the world of digital buildings.

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Presentation Agenda

- DALI-2 Today
- D4i, LLLC, hybrid wireless
- DALI designs and project examples

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DALI Today

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The DALI Alliance

DALI® Alliance

The global industry organization for **DALI®, the internationally-standardized protocol for digital communication between lighting-control devices.**

DALI is the language of lighting control:
State-of-the-art, global, digital, standardized, specialized for lighting, data-rich

Product certification programs

Compliance with international standards, supporting cross-vendor interoperability

DALI® 2	D4™	DALI+™
Lighting control in wired networks	Luminaire-level lighting control	Lighting control in wireless & IP networks

ALL USING THE DALI PROTOCOL

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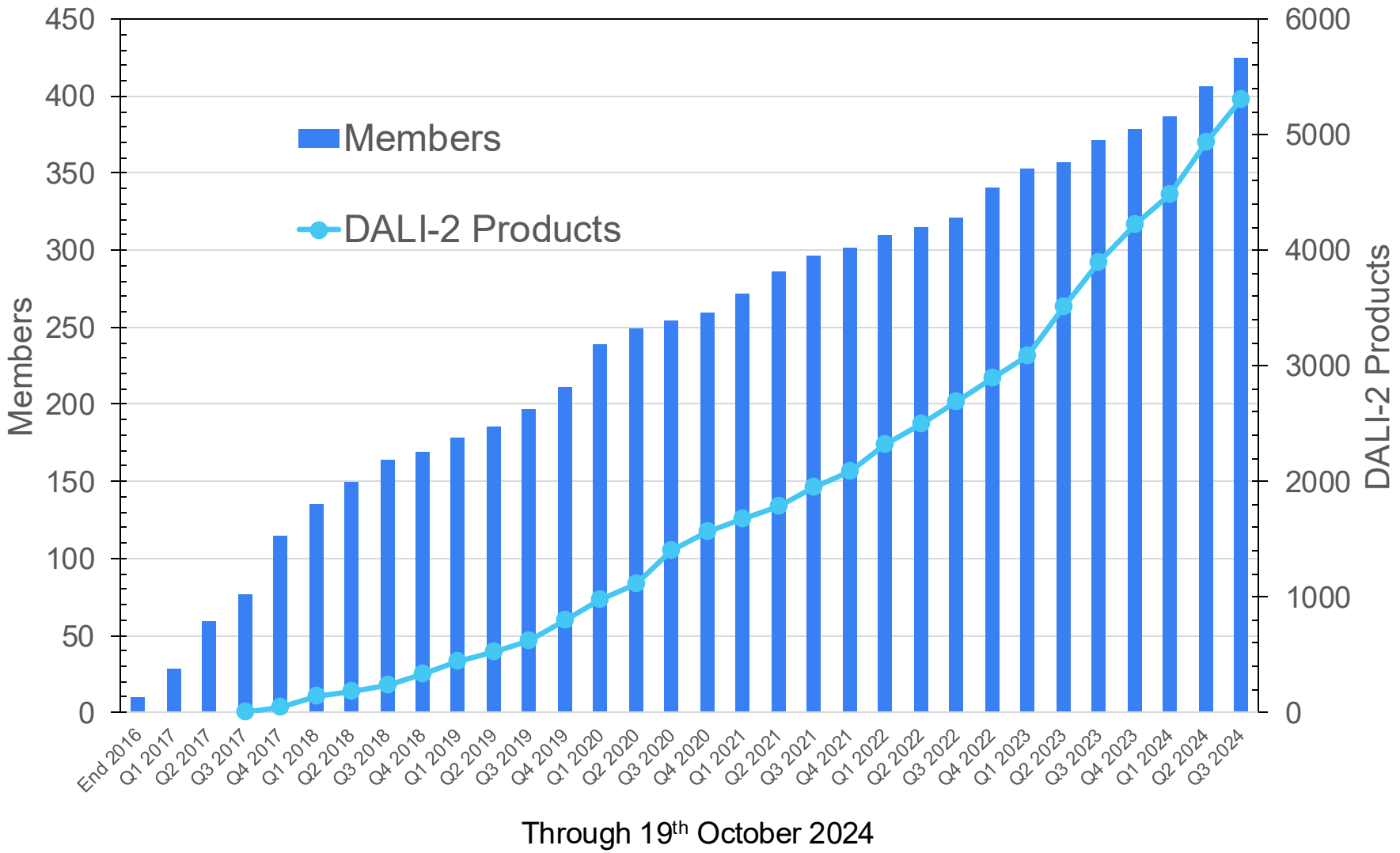
Members and DALI-2 certified products



Through 19th October 2024

Members		Change in 2024
Regular	37	-1
Associate	322	+32
Community	66	+10
Total	**425**	**+46**

Products	
DALI-2	**5,303**
DALI v1	1,613
Total	**6,919**

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The DALI family

DALI™ is the language of lighting control:

State-of-the-art, global, digital, standardized, specialized for lighting, data-rich

Product certification programs:

Compliance with international standards, supporting cross-vendor interoperability

DALI 2	DALI 4™	DALI+™
Lighting control in wired networks	Luminaire-level lighting control	Lighting control in wireless and IP networks

All using the DALI protocol

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All regions, building types, design choices, projects sizes

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Next: Education, Training and Guides

Group 1: lighting designers, specifiers	How to design and specify with DALI
Anyone new to DALI	What is DALI & How will it benefit you?
Specifier: Lighting Designer, Engineer , Architect (Beginner)	Benefits of/Why would I use DALI
Building Owner , Developers, Investors	Benefits of/Why would I INVEST in DALI?
City, Municipality, Utility	Benefits of/Why would I INVEST in DALI?
Electrical Installer, Electrician, Commissioning Agents	Benefits of DALI for installers
Project Manager, System Integrators, Value-Added Reseller	Supporting DALI projects, Benefits of DALI
Maintenance Professionals: Facility and Property Managers	Benefits of DALI to Facility and Property Managers
Specifier: Lighting Designer, Engineer, Architect (Experienced)	Benefits to Specifier: Lighting Designer, Engineer, Architect (Experienced)
Specifiers	Tender text
Installers/electricians	How to install DALI systems
Luminaire makers	Guide to developing and manufacturing DALI-2 and D4i luminaires
lighting designers, specifiers	D4i and Zhaga-D4i
Product developers (components not luminaires)	Developing DALI products (general requirements and considerations) including certifying DALI products
Product developers	Developing D4i and Zhaga-D4i products
Product developers	Developing DALI+ products

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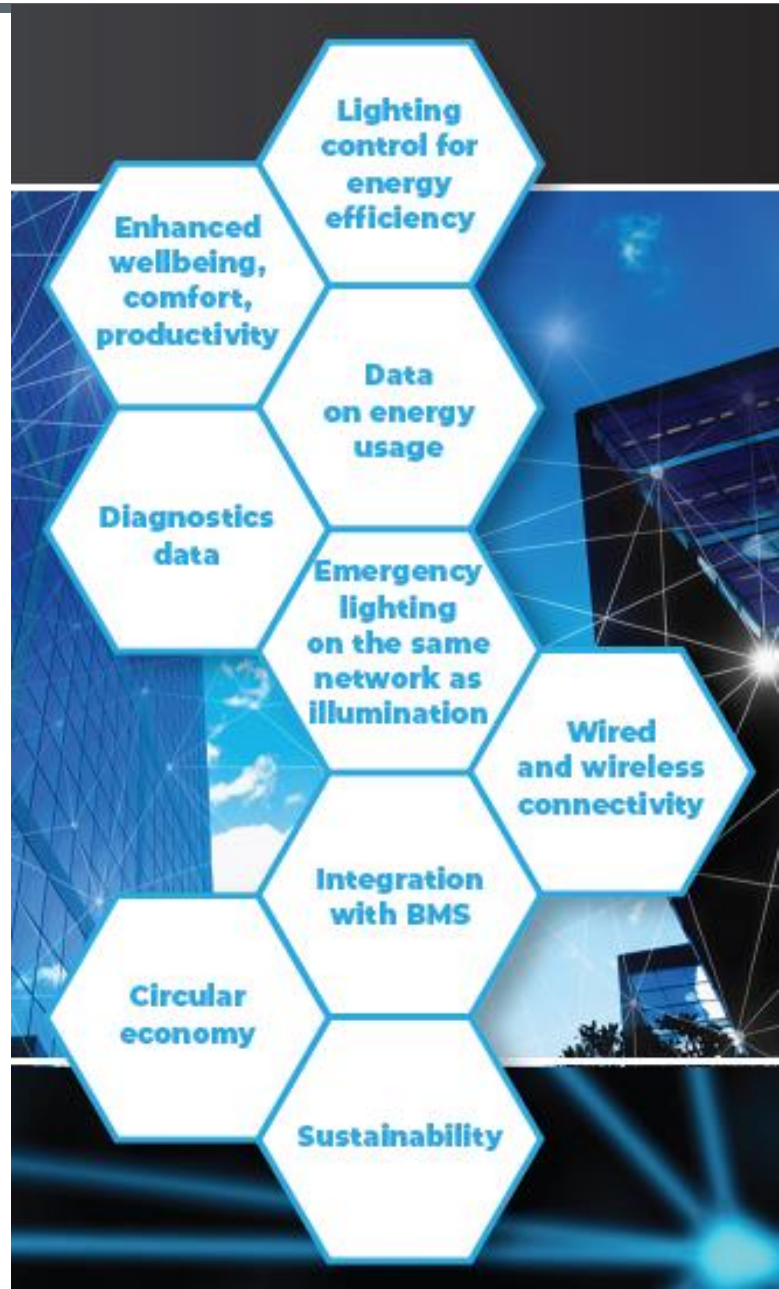
Digital control of light quality with intelligent feedback

- Precise, repeatable **light-output control** and standardized dimming curve
- **Occupancy and light-level sensing**
  - DALI-2 sensors and other input devices provide information to the system
- **Luminaire, energy & diagnostics data**
  - Data for enhanced asset management & performance monitoring
- **Emergency lighting**, automated testing and reporting
- **Colour control** for human-centric lighting, enhanced comfort and well-being
- DALI is already positioned for the **Internet of Things (IoT)**
- New specifications enable DALI connectivity via **wireless networks** and **IP-based networks**



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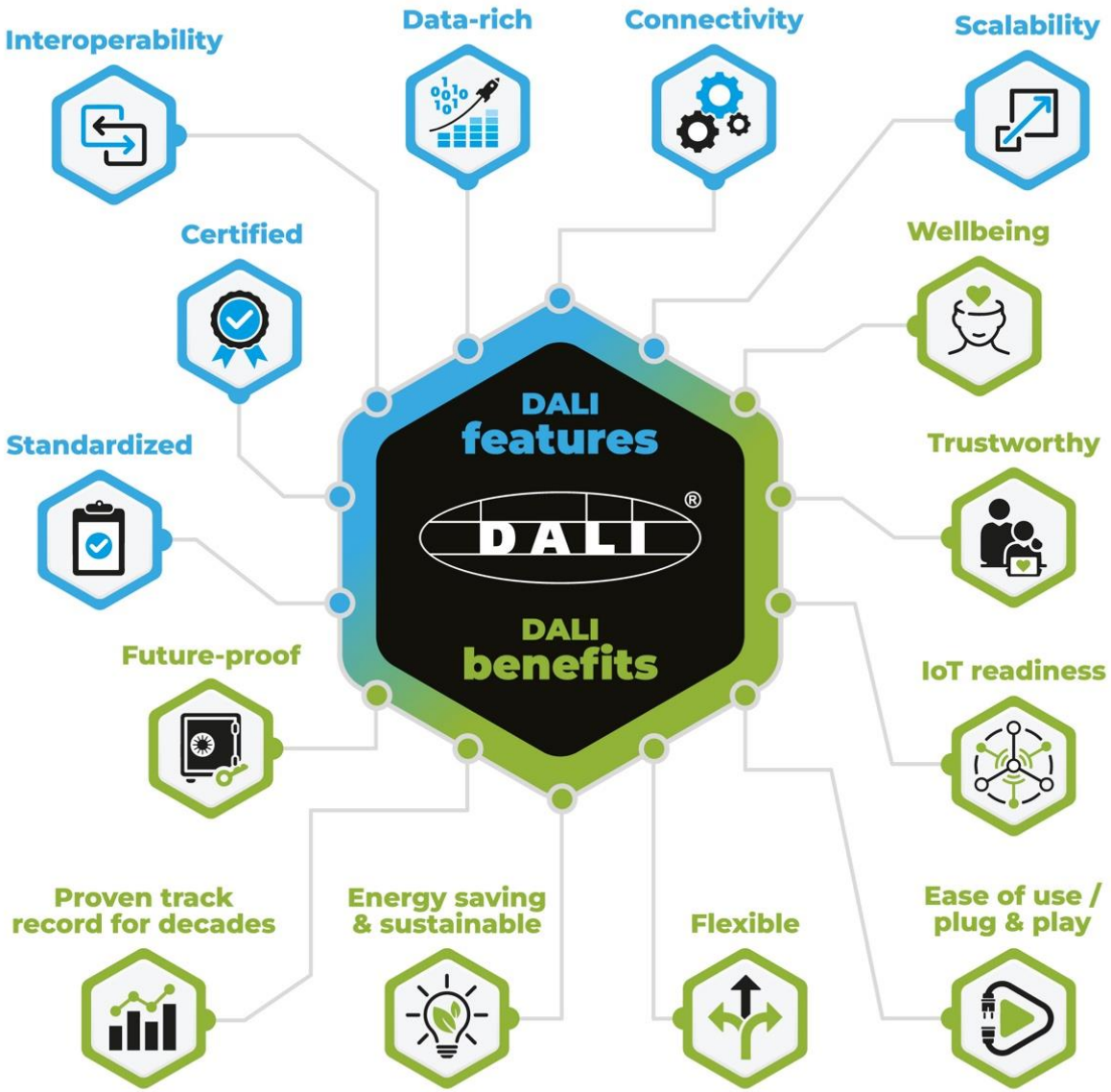
DALI features and benefits



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Why DALI

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Voice of the Customer (VOC) feedback

Macro Trends & Drivers

Decarbonization

- Climate change is driving decarbonization
- Building Performance Standards (BPS) often impose fines
- Decarbonization is a top-level priority for large owners and operators
- Projects are bundled with different priorities per building, so ROI numbers have changed

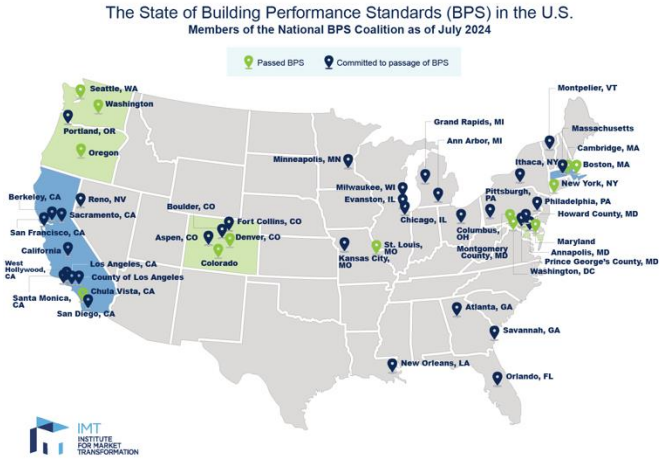
Electrification

- Electrification contributes to decarbonization by replacing gas
- EV charging is creating grid capacity issues
- Grid capacity issues are driving energy reduction projects
- Grid-Interactive Energy Efficient Buildings (GEBs) contribute by helping to manage load

Financial

"If we don't decarbonize our long-term assets now, we are going to lose serious money."

▻ CREtech panel presenter



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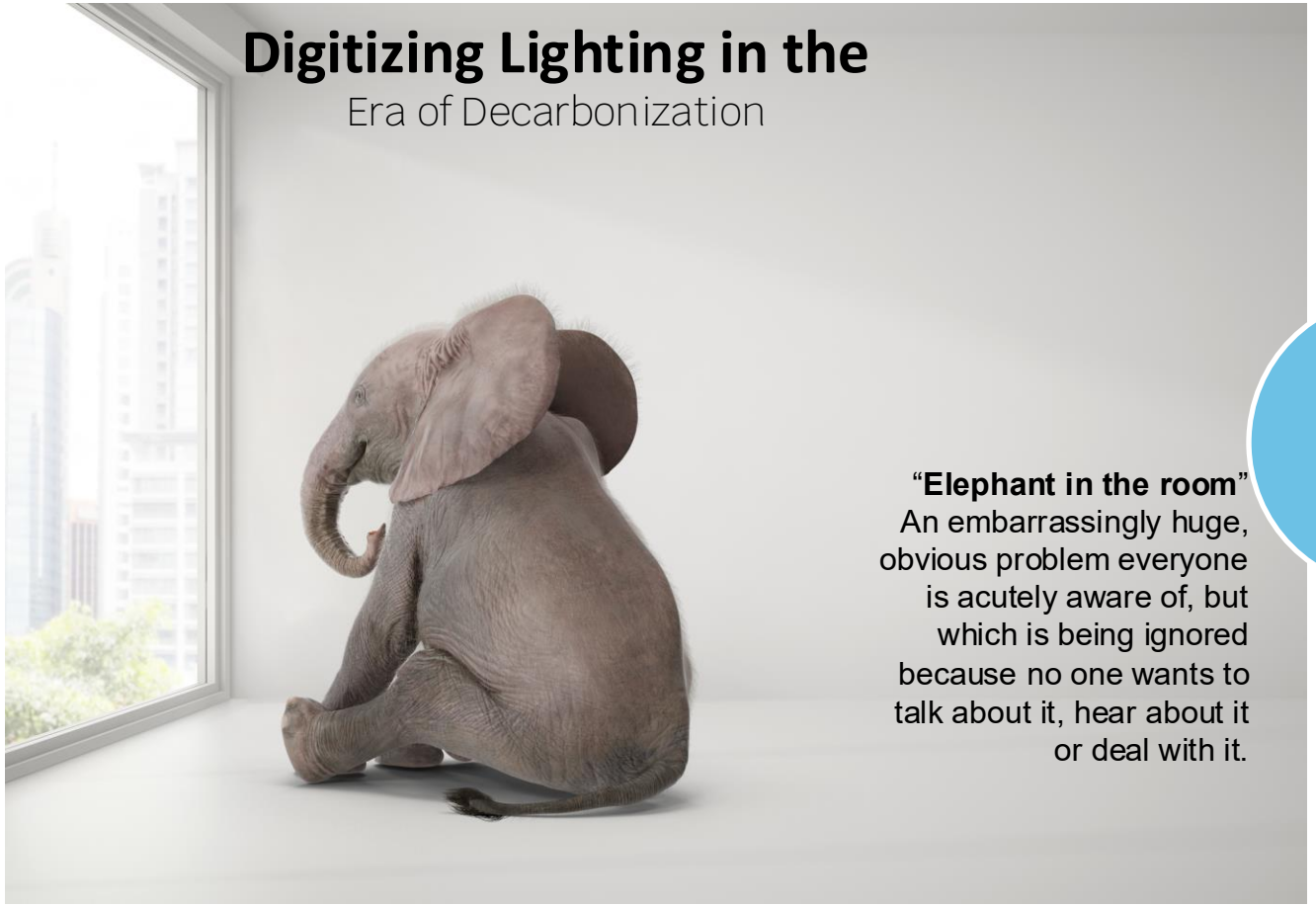
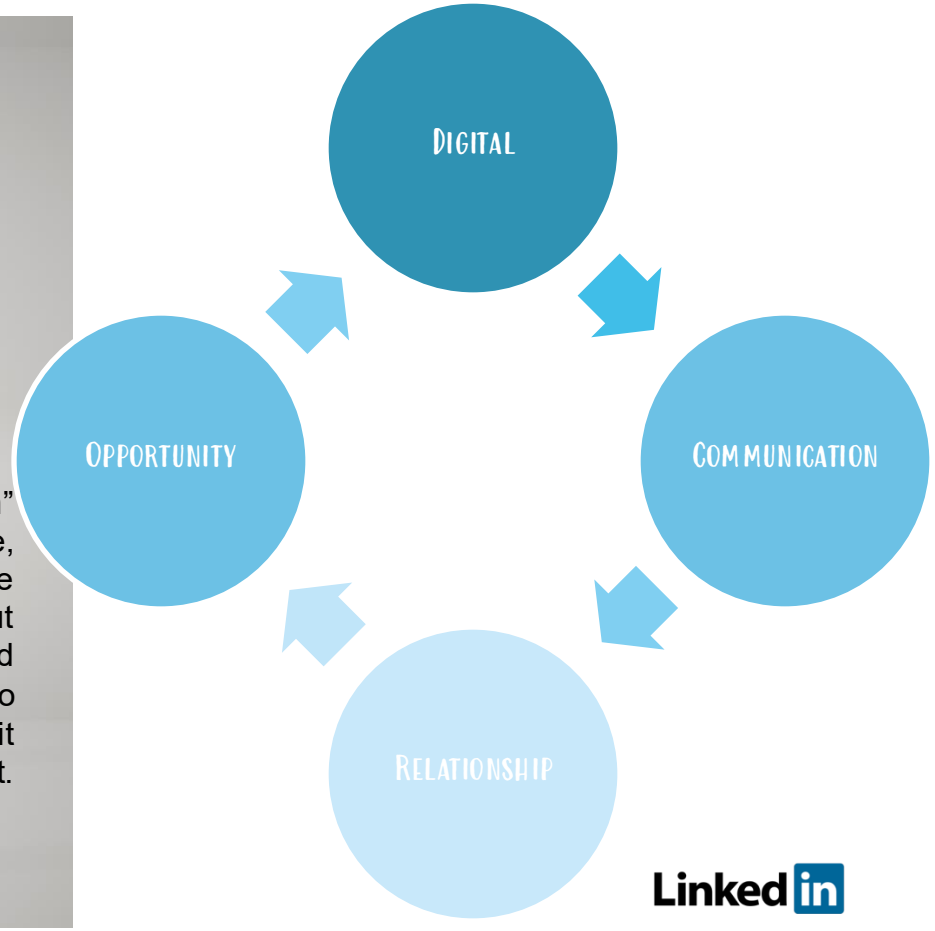
The need for interoperability is not a surprise.





https://issuu.com/designinglighting/docs/digital_october_2023_v2/16

designing lighting *Magazine, by Carol Jones, October 2023*

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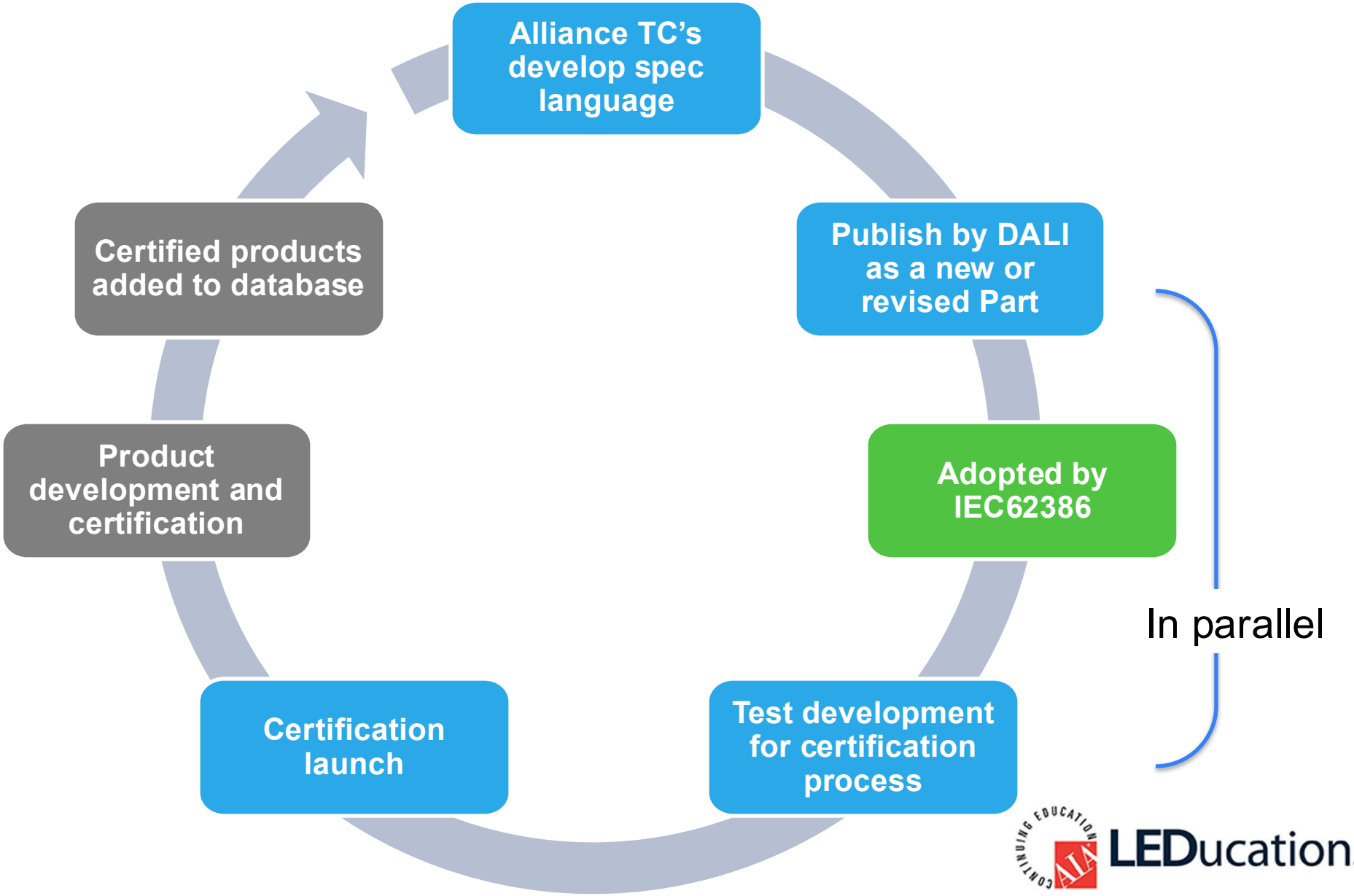
DALI Specifications Development

DALI Alliance

IEC

Members



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Voice of the Customer (VOC) feedback

Gathered input from Market Actors across buildings ecosystem: IT & OT

BUILDINGS		LIGHTING	NA REGION	PERSONAS
Owners & Asset Managers	GCs, ESCOs, Integrators	Ltg Designers, Electrical Engineers	Utility Programs & Implementers	Responsibilities
Sustainability & Decarbonization Officers	Facility & Property Managers	Luminaire & Controls Manufacturers	Building Performance Standards	Beliefs
Architects, Owners Reps	Tenants	Luminaire and Controls Reps, Distributors	Green Groups, Voluntary Programs	Mission & Motivation
Interiors and Space Designers		Electrical Contractors, Ltg Commissioning	Legislation (e.g., IRA + Infrastructure)	Drivers and Influencers
				Pain points

VOC= Voice of the Customer; IT= Information Technology; OT=Operational Technology;
GCs=General Contractors; ESCO= Energy Services Company; CxA= Commissioning Agent; IRA= Inflation Reduction Act

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Why DALI? The world is going digital

- Significant trends
- operational and embedded decarbonization, sustainability and circularity, Building Performance Standards
- beginnings of AI in buildings
- electrification and interactive grid
- hybrid workplaces and adoption of tenant engagement apps
- View of the outside in, using market data and end customer interviews

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Macro Trends & Drivers

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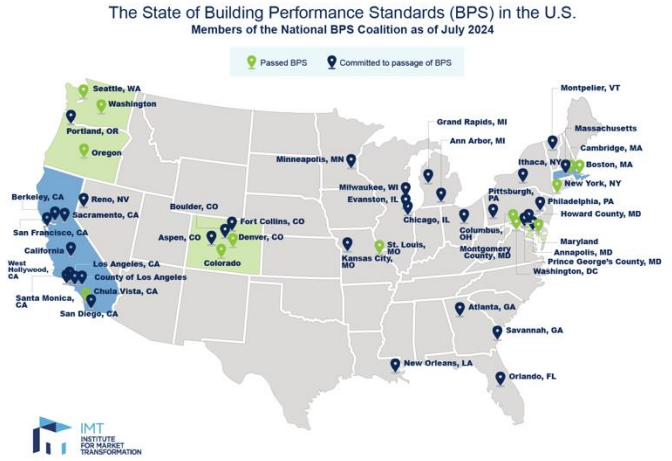

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DALI-2

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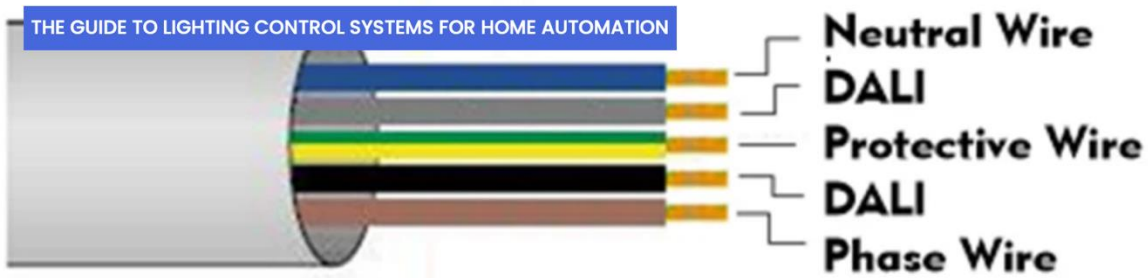
That was then…

- What control wiring used to be
- Think about the impact of reducing copper
- Environmental impact of electronics
- Circularity



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Digital options

DMX

- Suitable for interior and exterior, digital 2-way communication
- Color control, dynamic “shows,” creative eye-catching solutions, featured areas

DALI

- Suitable for interior and exterior, digital 2-way communication
- More widely used for general lighting, included digital features that make it suitable for integrations in buildings at scale

LED Driver

A device composed of a power source and LED control circuitry designed to operate an LED package (component), an LED array (module), or an LED lamp.

Communication Protocols

- How information and commands are shared or communicated
- Examples: 0-10V, DALI v1, DALI-2, DMX, Bluetooth, Zigbee, etc.

Dimming Methods

- Modulates output of light from LEDs
- Examples: forward phase, reverse phase, universal phase modulation, pulse-width modulation, constant current reduction

Wiring Topologies

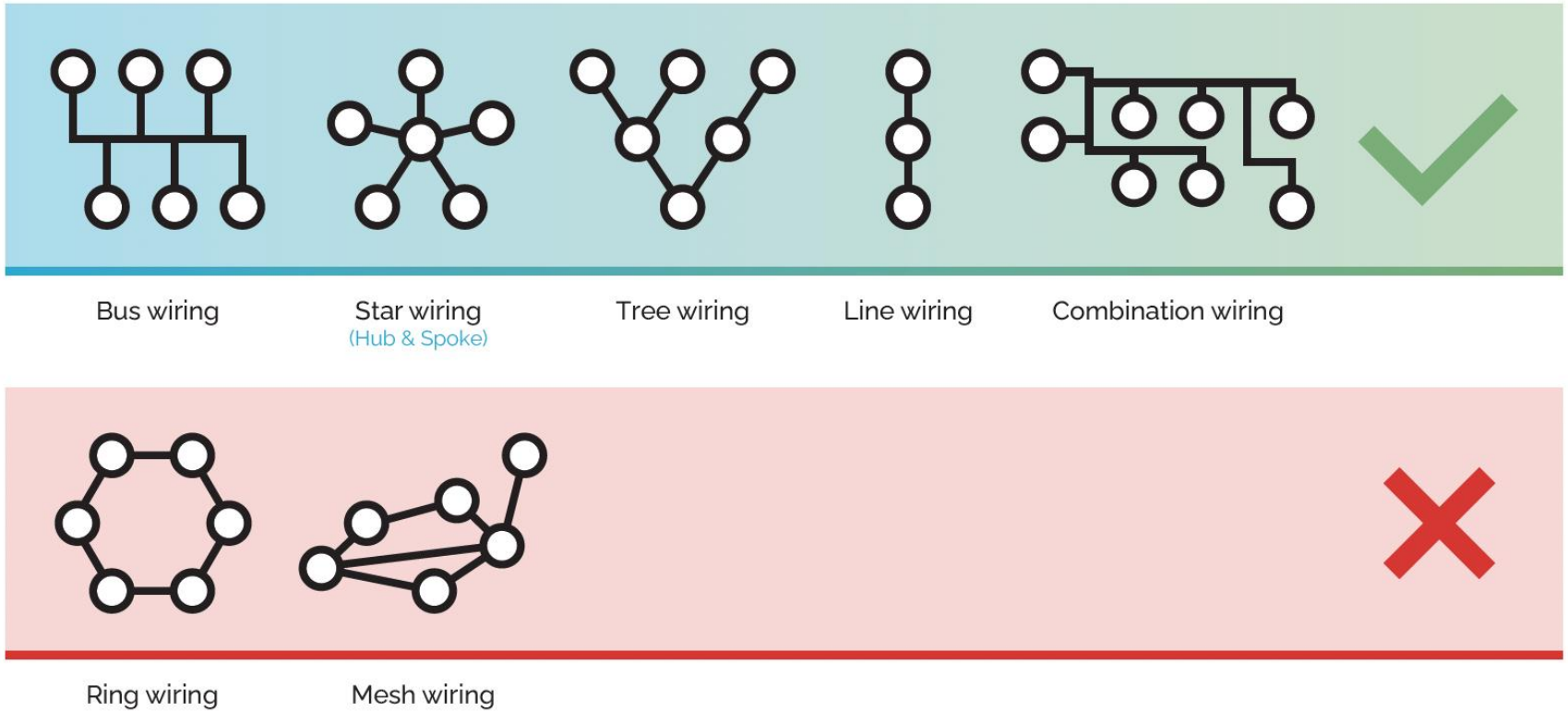
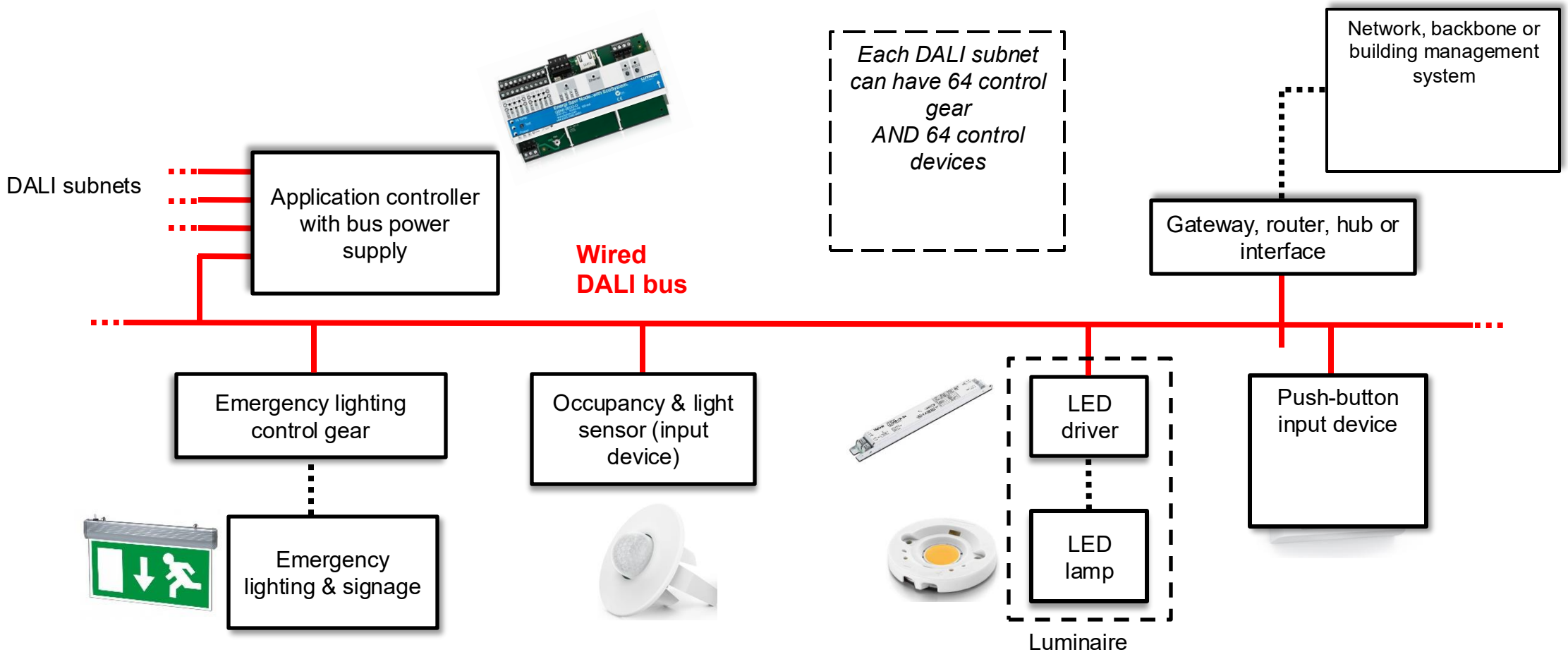


Figure 2. DALI Wiring Topologies

Wired DALI lighting control system example



DALI Alliance Parts and Certifications

CATEGORY	NAME	PUBLISHED	DALI-2	D4i
Power Supply Specifications	**DALI Part 150** – AUX Power Supply	v1.1, Oct 2019	✓	✓
	DALI Part 250 – Integrated Bus Power Supply	v1.1, Oct 2019	✓	✓
Data Specifications for LED Drivers	**DALI Part 251** – Memory Bank 1 Extension (luminaire data)	v1.1, Oct 2019	✓	✓
	DALI Part 252 – Energy Reporting (energy data)	v1.1, Oct 2019	✓	✓
	DALI Part 253 – Diagnostics & Maintenance (diagnostics data)	v1.1, Oct 2019	✓	✓
Specifications for Control Devices	**DALI Part 351** – Luminaire-mounted Control Devices	v1.0, Oct 2019	✓	✓
Connectivity Specifications	**Part 104** Changes & Additions	v1.01, April 2021	n/a	n/a
	Part 341 – Bluetooth Mesh to DALI Gateway	v1.01, April 2021	□	n/a
	Part 342 – Zigbee to DALI Gateway	v1.01, April 2021	□	n/a

✓ Availability of DALI-2 and D4i certification

□ Certification in progress

Published DiiA Specification:

www.dali2.org/specifications/download.html

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Research on 0-10v shows wide variability

2023 Report using 0-10V streetlights characterizing 0 – 10 V control

ENERGY IMPACTS OF USING 0-10V CONTROL

PNNL study characterizes energy impacts of using 0-10V control based on current standards; results expected to inform industry conversations and standards updates.

Analog 0-10V control is the most commonly available option offered by North American manufacturers of LED luminaires and lighting controllers, even as LED systems have adopted modern digital network interfaces and luminaire-level sensors. Predicting light output and input power at any particular 0-10V control voltage is difficult due to dependencies on LED driver design and loading, and in practice the performance across luminaires can be inconsistent. Unpredictable and varying luminaire responses to input control signals—and a standard practice that does not compensate for these variations—can result in unexpected and undesirable performance. Moreover, energy and cost savings estimates associated with reduced lighting levels may not be realized.

To improve understanding and possibly resolve the shortcomings of 0-10V products, the Department of Energy recently published the results of a study conducted by Pacific Northwest National Laboratory (PNNL). The study characterized 23 LED streetlights that claimed dimmability via a 0-10V interface, quantified the performance variation found in market-available LED drivers, and explored the potential impact of the most recent 0-10V voluntary standard, ANSI C137.1-2022.

The study results and recommendations for driver and luminaire manufacturers, developers of connected lighting systems, and standards development organizations offer a potential path toward more accurate and consistent dimming performance across all luminaires in a lighting system, guaranteeing the delivery of expected light levels, energy, and cost savings. For example, the ANSI C137 committee is reviewing these findings as they consider updates to the standard.

"This comprehensive report is very detailed and thorough. It provides important considerations for any system operator looking to reduce energy levels by dimming," notes Adam Chaffey, Technical Director for Smart Lighting at LED Roadway Lighting. "This topic needs more attention industry-wide. I look forward to our standards bodies and all stakeholders restarting conversations on 0-10V dimming."

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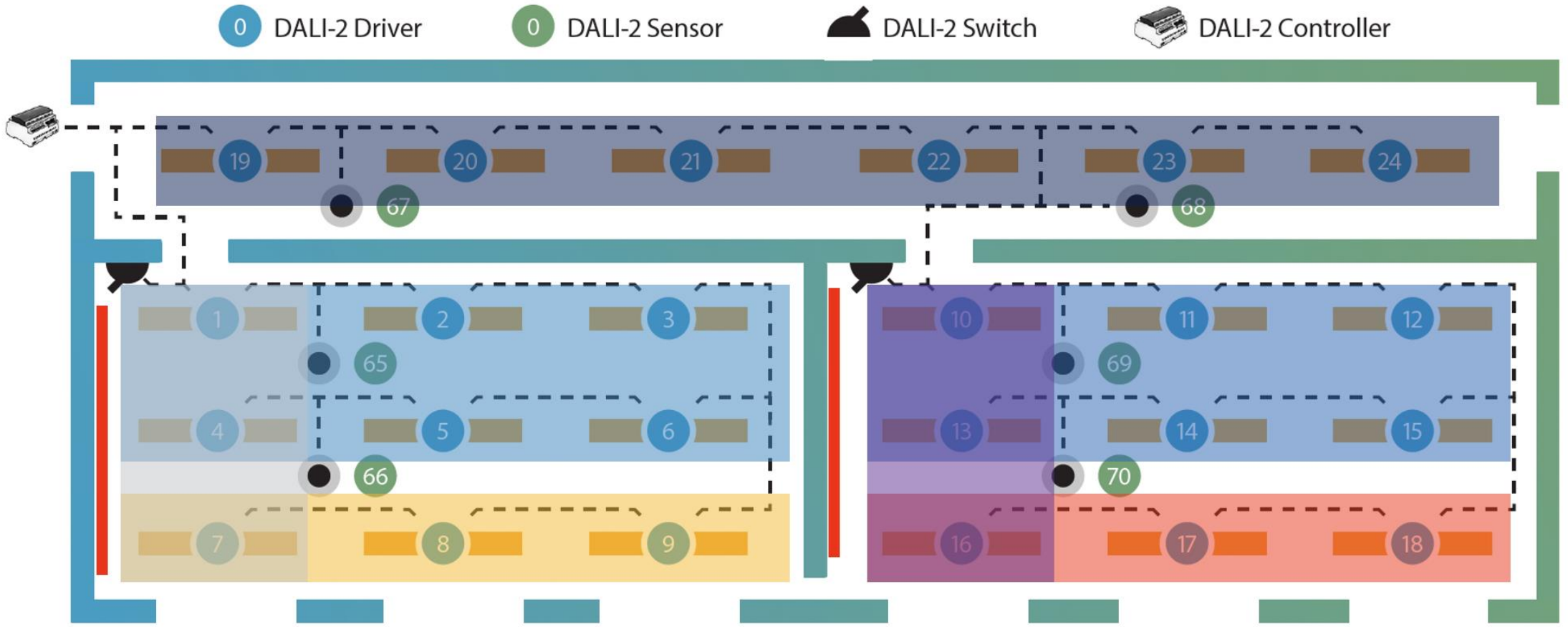
Addresses and Groups in a DALI System



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What does interoperability mean for wireless lighting?

DEFINITIONS

- Interoperable
- Compatible
- Changeable

STANDARD vs. CERTIFIED

- ANSI/ASHRAE/IES 90.1
- NEMA 137.4
- DALI certified
- Bluetooth NLC qualified

EXAMPLES

Interchangeable is: *Graphic of T8 lamp*

Compatible is: *API to bridge communication for functionality*

Interoperability: *Multi-vendor device maintenance*

EXAMPLE:
Decarbonization project, long-term asset, fault detection and diagnostics (FDD) reduces risk and cost over time.

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Color Tuning

Needs

- Consistency in generating color
- Consistency between luminaires in the space that are color tuning
- Ideally separate control of light output and color
- Methods to control variety of color mixing options (tunable white, RGBWAF, etc.)

0 – 10 V

- 2 different CCT LED boards
- 2700 K & 6500 K boards
- Vary light output of each board to make a "color"
- Example: 60% output 2700 K & 25% output 6500 K --> 4000 K color
- Fixture 1 0-10 V is linear, and Fixture 2 0-10 V is logarithmic – color of fixtures?

DALI-2

- DT8 / Part 209
- Values between 0 – 255 establish color
- Separate control of light output and color
- Can do RGBWAF, tunable white, or x,y coordinates
- Standard --> Consistent between fixtures of different mfrs & output

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Emergency Lighting

Basics

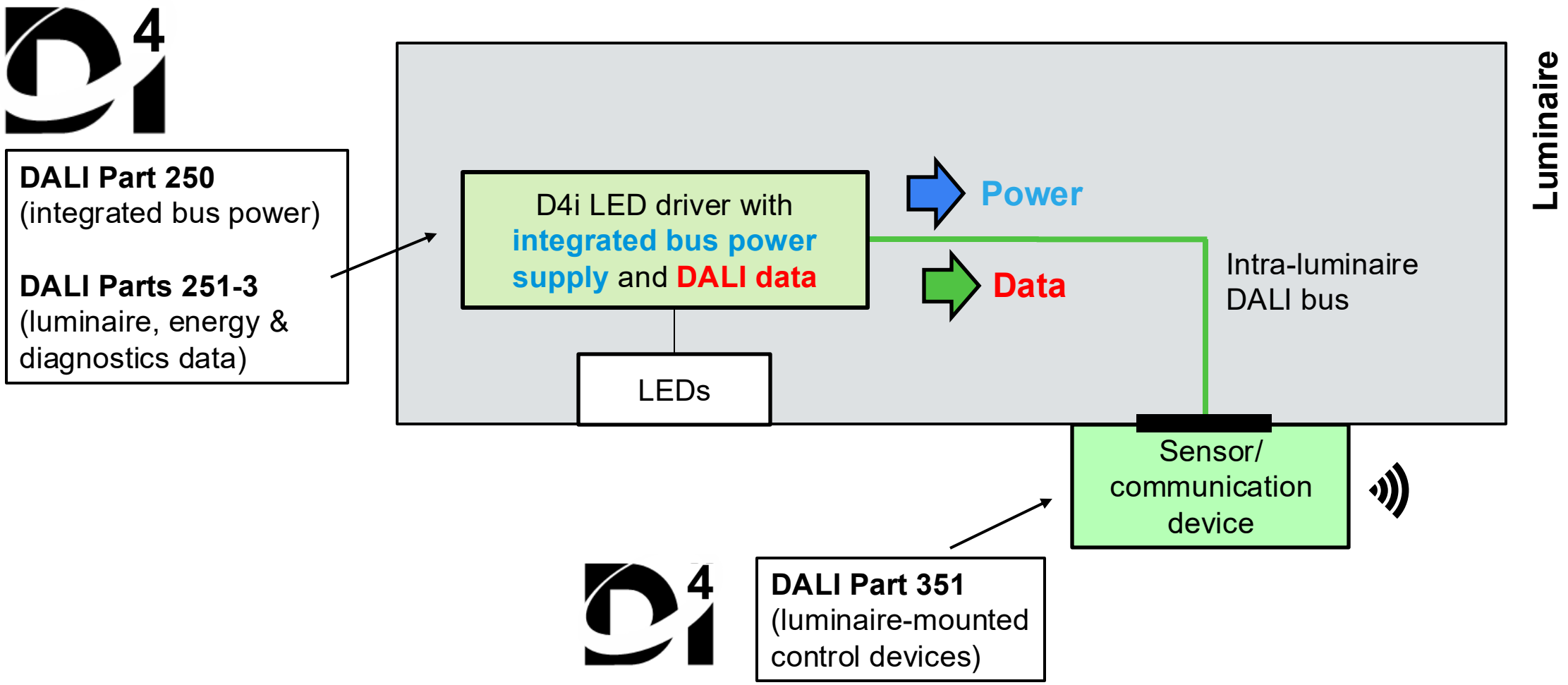
- Provides lighting when normal power failures
- Monthly tests
- Annual 90-minute tests
- Emergency power can be generator, invertor, or integral to the luminaire
- DALI-2 Part 202 works w/ integral/adjacent to luminaire

Part 202

- Automated self-testing
- Additional memory bank, specifically related to emergency testing
- Can provide a report
- Installation inhibit feature
- Deep discharge prevention
- Extended-duration tests

Source: Cintas

D4i example: Indoor luminaire



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Zhaga-D4i certification

A joint certification program based on complementary specifications

Specifications enabling D4i certification

Book 18 & Book 20 specifications from Zhaga

DALI Part 250: Integrated bus power supply

DALI Part 251: Luminaire data

DALI Part 252: Energy data

DALI Part 253: Diagnostics data

DALI Part 351: Luminaire-mounted control devices

DALI Part 150: AUX power supply

Book 18 for outdoor:

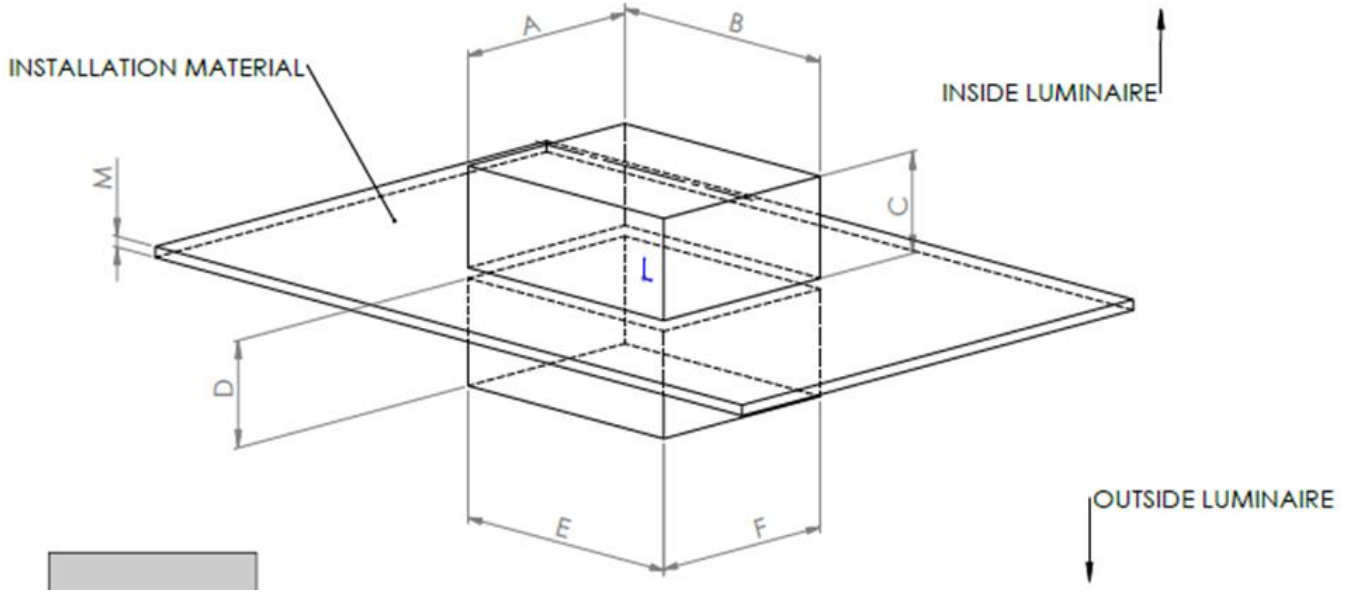
Book 20 for indoor:

- Mechanical interfaces
- Electrical pin assignment (Book 18)
- Electrical connectors (Book 20)
- References to D4i specs for power & control, and luminaire tests

Sensor Keep-Out Space

Features

- Specified volume inside luminaire (for sensor body) and outside luminaire
- Volume set aside to allow for sensor installation / components
- Creates a defined shape and volume --> allows for more options of sensors going into a luminaire
- Reduces complexity



Source: NEMA LS 20000-2021

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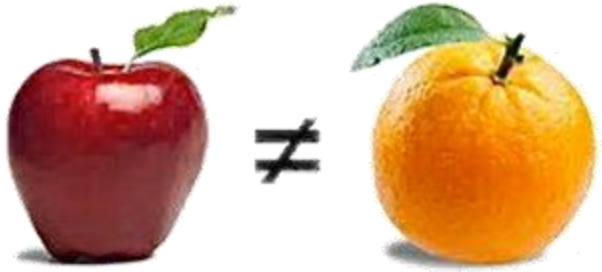
False Equivalency

- Current and power
- Digital user interfaces
- On / Off / Dim

- Current and power
- Digital user interfaces
- On / Off / Dim



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Digital users

CO2, VOC/particulates, temperature, janitorial, security, access and lift systems, shading

Multi-sensor

Variety of Platforms

LLLC and space

Integration with HVAC, Space utilization

Digital Addressability, dimming per space type, supports renewables, real-time reduction

Load Management

Grid-Interactive Energy Efficient Buildings

Variety of Platforms

Lighting apps and software, IWMS, BAS, Tenant engagement apps

Why Design with DALI?

- Controls with DALI just work.
- High-quality dimming and interoperability is built in.
- Reduced complexity.
- Scope lines are clear.
  - Dimming happens in the luminaire, so flicker cannot be caused by the lighting system / controller / wires / etc.

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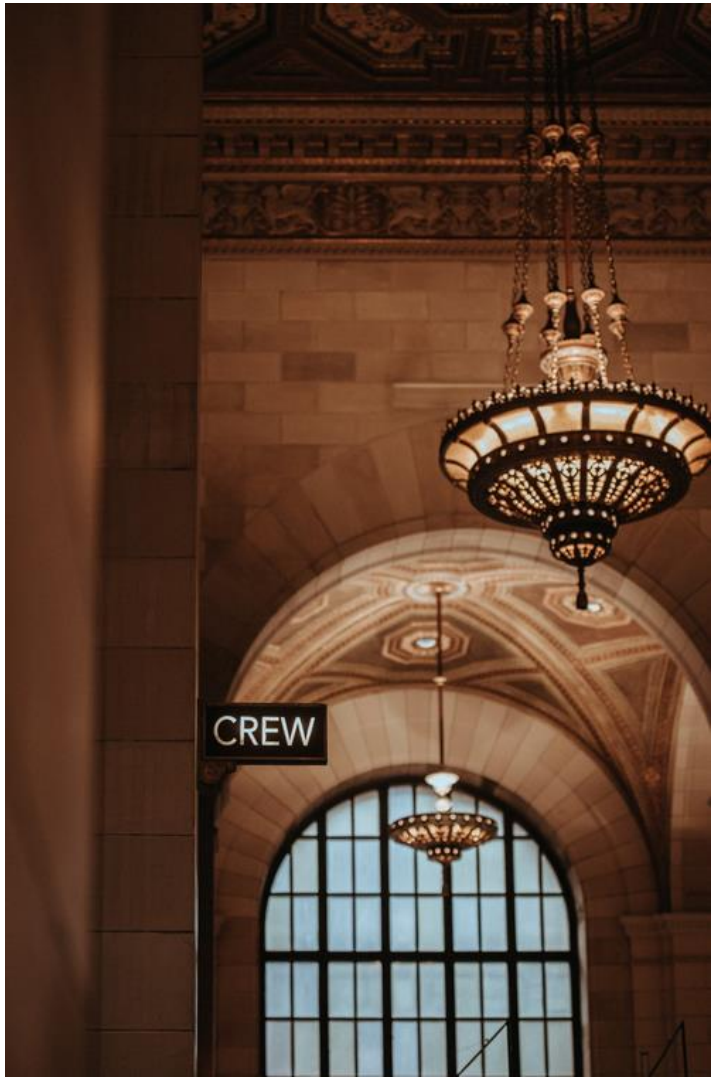
How to Specify DALI?

- Specify luminaires with DALI-2 certified drivers
  - Ensure you specify the luminaire parts that are required, and that the luminaire manufacturer can provide the necessary functionality.
- Ensure lighting system or lighting components provide the functionality you require
  - Examples include fade time, fade time modification, using the DALI group paradigm for your lighting control zones. Saving and recalling scenes.
- Include DALI requirements in specification sections.
- Require all luminaire submittals include the driver make and model.
- Require all linear and tape light luminaires include number of drivers in submittals.

- More and more decorative luminaire manufacturers are providing DALI drivers.
  - This is especially true in newer designs, or designs that embrace native LED illumination sources.
- When a decorative selection must be used that doesn't offer DALI native control
  - You can use a gateway to convert DALI to 0-10v
  - You can use a DALI controlled forward or reverse phase dimmer.



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D4i, LLLC, Wireless

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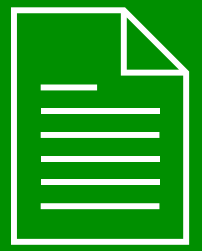

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Context for D4i, LLLC, and Hybrid Wireless

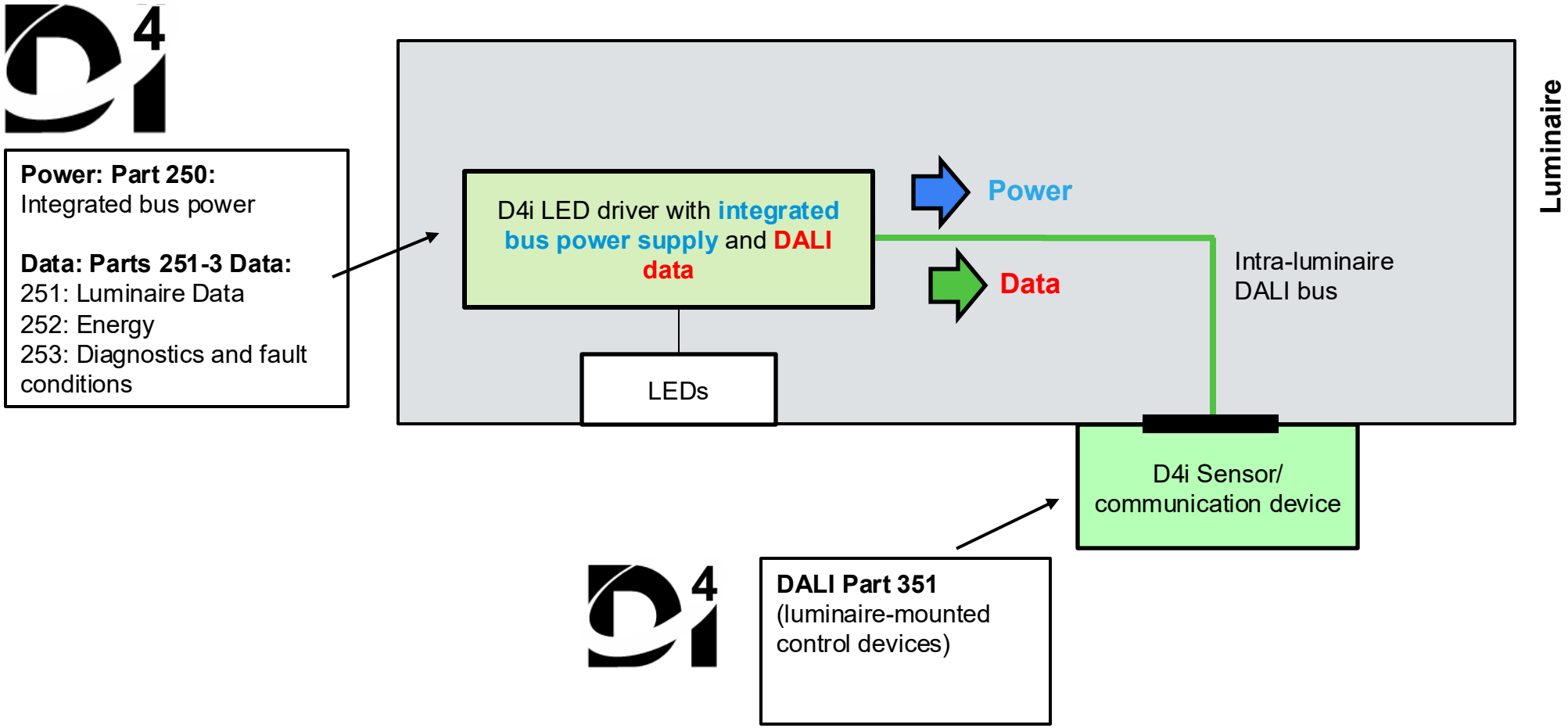
LEARNING OBJECTIVES

- What is D4i and its beneftits
- How D4i enhance Luminaire-Level Lighting (LLLC)
- Wireless Network Lighting Control (NLC) and D4i LLLC
- Where to find certified products

What is D4i

- D4i is a certification program for interoperable DALI devices that enable smart, connected luminaires. It is an extension of DALI-2 certification. D4i enables intra-luminaire DALI interoperability.
- D4i components have a mandatory set of features that are based on power-supply and data specifications from DiiA.
- All D4i LED drivers provide luminaire, energy & diagnostics data.
- All D4i control devices can be powered by D4i drivers and communicate with D4i LED drivers via the drivers' build-in DALI buses.
- D4i enables plug-and-play interoperability when combined with a standardized connector such as Zhaga Book 18 & 20 or NEMA/ANSI C136.41
- D4i luminaires are smart and IoT-ready. D4i simplifies addition of sensors and communication devices (NLCs) to luminaires

D4i In a Luminaire



Data, Data, Data …… AI?

DALI Part 251: Luminaire Data

Luminaire Manufacturer GTIN

Luminaire Identification Number

ContentFormatID

Luminaire Yr of Manufacture

Luminaire Wk of Manufacture

NominalInputPower

PowerAtMinDimLevel

Nominal Minimum AC input voltage

Nominal Maximum AC Input Voltage

Nominal Minimum AC input voltage

Nominal Maximum AC Input Voltage

Nominal Light Output

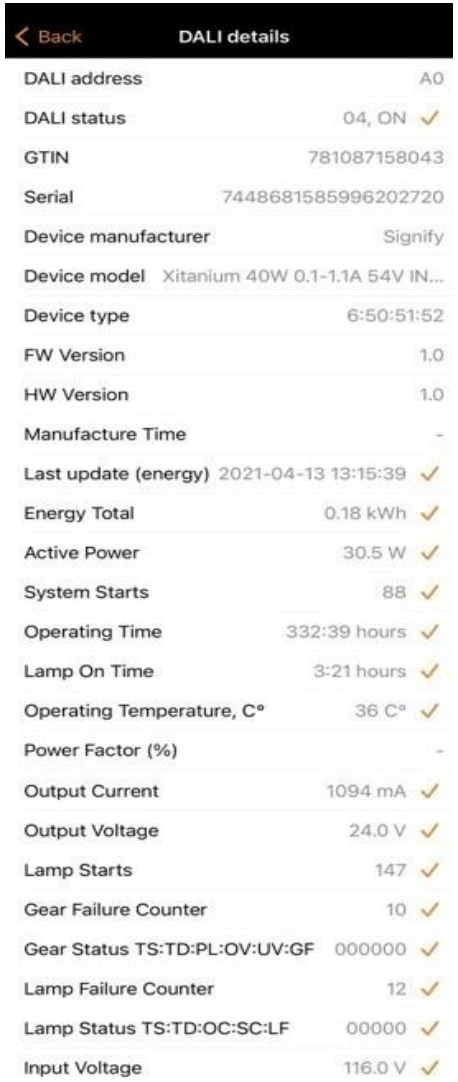
CRI

Correlated Color Temperature (K)

Light Distribution Type

Luminaire Color

Luminaire Identification Number



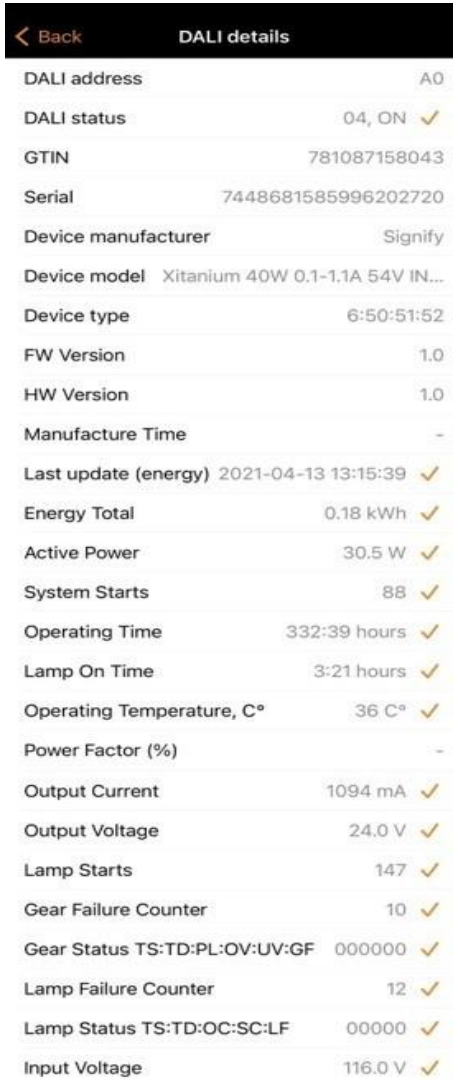
Data, Data, Data …… AI?

DALI Part 252: Energy

Active Energy and Power

Apparent Energy and Power (Optional)

Load Side Energy and Power (Optional)



Data, Data, Data …… AI?

DALI Part 253: Diagnostics and fault conditions

Time CG is powered (1s)

CG power cycle starts

RMS external supply voltage (0.1Vrms)

Supply voltage frequency (1Hz)

Power factor 0-100 (0.01)

CG Failure status byte

Count of CG failures

CG supply voltage < lo threshold

Count of CG undervoltage failures

CG supply voltage > hi threshold

Count of CG overvoltage faillures

CG output power > threshold

Count of CG output power failures

CG temperature > thermal threshold

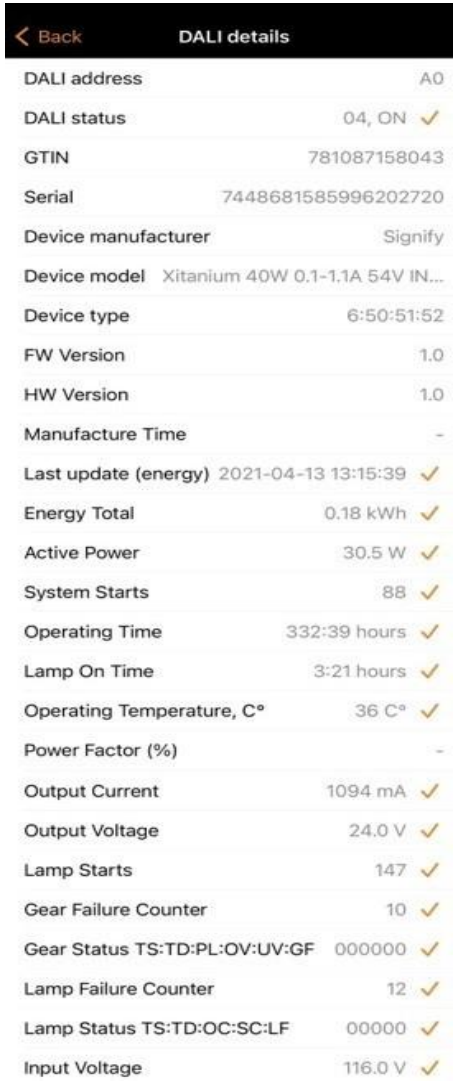
Count of CG thermal derating failures

CG temperature > shutdown threshold

Count of CG shutdown failures

CG internal temperature (1degC)

CG current output 0-100% (1%)



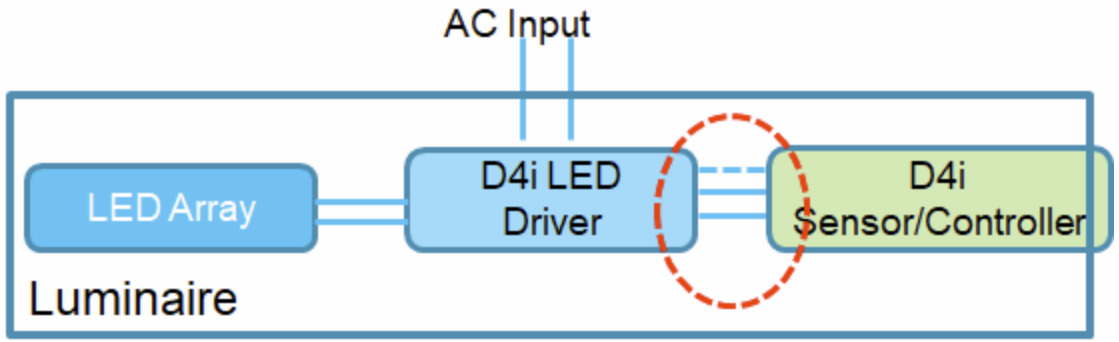
LLLC and D4i

- Luminaire-Level Lighting Control (LLLC)
  - LLLC means each luminaire (light fixture) has built-in sensors and controls for independent operation.
- Integrated Sensors & Controls
  - In a LLLC system, each fixture has built-in motion, ambient light, and sometimes temperature and humidity sensors.
- D4i and LLLC
  - A fixture equipped with a D4i driver and D4i controller is typically qualify for LLLC
- The DALI Advantage
  - Integrated power from D4i driver.
  - Data rich
  - Standard DALI communication protocols between control devices and drivers
  - Standard mechanical interface (such as book 18 & 20) for plug and play

Benefit of D4i LLLC

- Energy Saving
- Lower Cost in both Labor and Material
- Adaptive Control for Occupants comfort
- Granular Control for Maximum Data Output
- Future Proof with Open standards for Interoperability

D4i LLLC Connected Luminaire Architecture



Digital D4i

- Simple with few components
- Standardized connection for power and digital data from LED driver
- High reliability – AC mains to the LED driver only

D4i, LLLC, and Wireless Network Lighting Control (NLC)

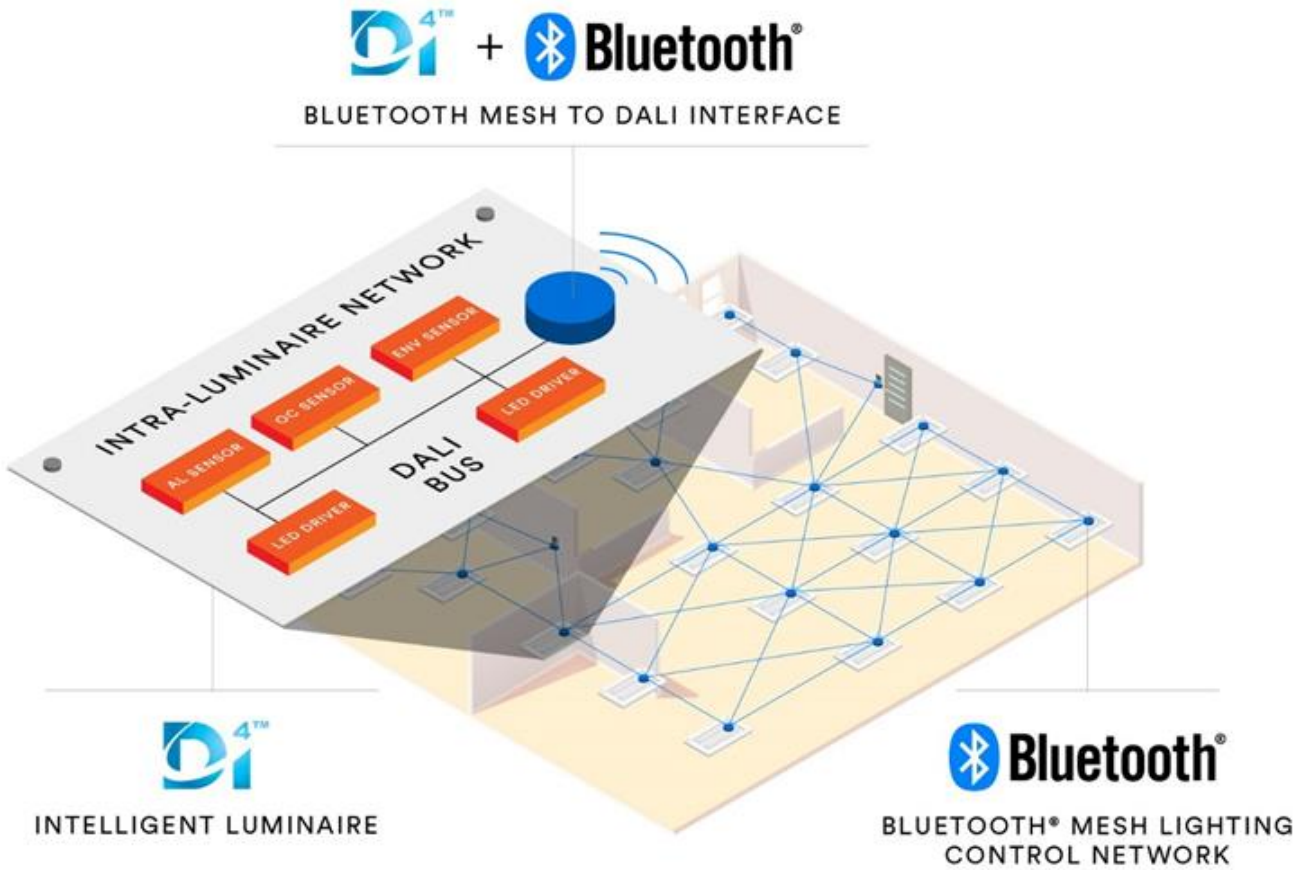
- D4i LLLC and Wireless: A Perfect Marriage

- Open Wireless Protocols
  - Bluetooth NLC
  - Zigbee
  - DALI Plus

- Proprietary Wireless Protocols
  - 2.4 GHz (Mesh)
  - 915 MHz
  - Others

DALI Gateway to Bluetooth® NLC

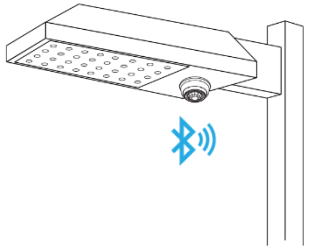
- Enable DALI luminaires to communication and connect wireless onto a Bluetooth Mesh network
- A simple way to add standardized wireless mesh capability to luminaires
- Global cross-vendor interoperability between lighting components, wireless control systems, and intelligent luminaires
- Further accelerate the adoption of advanced IoT-enabled intelligent lighting systems
- DALI spec Part 341



Architecture of D4i LLLC + Wireless (Bluetooth NLC)

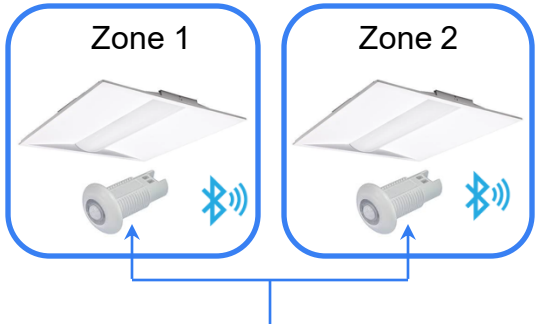
Smart Devices:
Commissioning
Control
Diagnostics

OUTDOOR



Bluetooth NLC Nodes + DALI D4i Drivers

INDOOR



Bluetooth NLC Nodes + DALI D4i Drivers

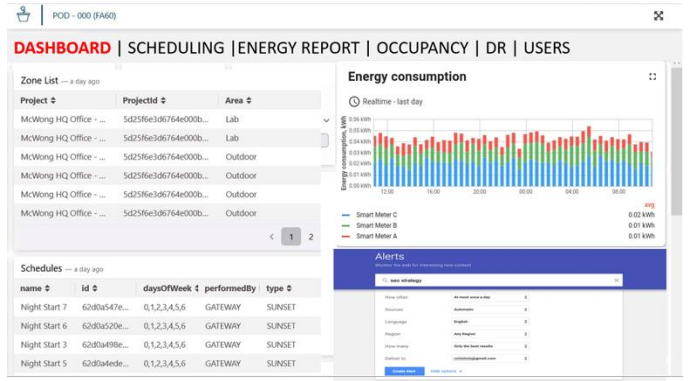
Gateway (Optional)

Internet

Energy Monitoring, Scheduling

Data Analytics

Open ADR



Dashboard (Optional)

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Trade Show and Conference

The DOE L Prize is designed to advance the U.S. clean energy economy for next-generation LED lighting. There are total three phases:

- Concept (2022)
- Prototype (2023)
- Manufacturing & Installation (2025)

A. Key requirements in Prototype and Manufacturing & Installation phase:

Standards-based lighting control solutions for interoperability

DALI D4i features align very well: part 252 power metering and part 253 fault conditions report

B. Two DALI members received award on Protype phase.

Certifications: The Key for Interoperability

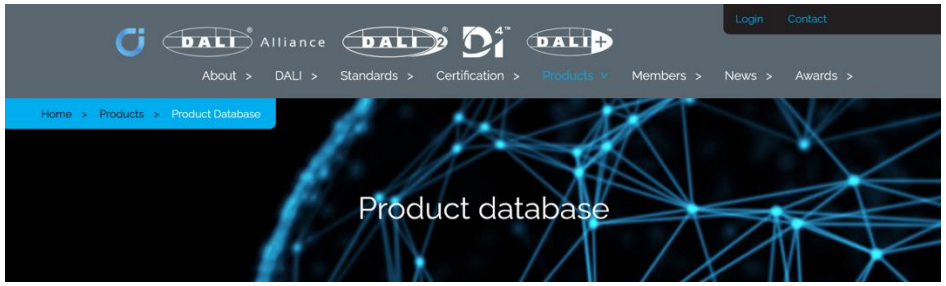
Where to find certified products

Bluetooth® NLC

- https://qualification.bluetooth.com/Listings/Search

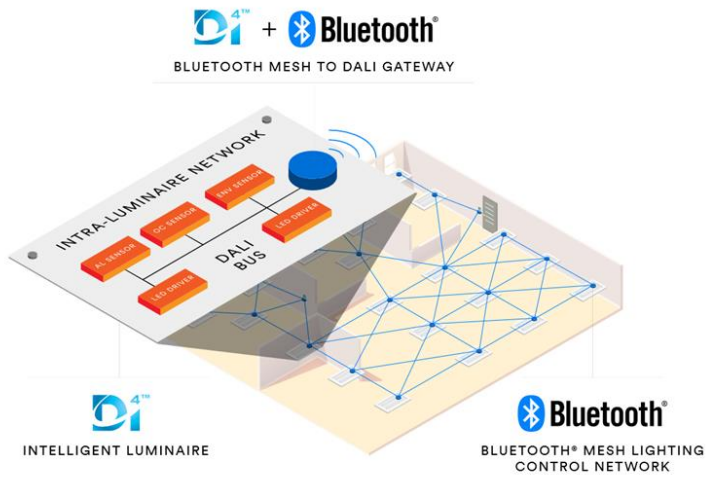
DALI: DALI Alliance Website

- https://www.dali-alliance.org/products
- Driver: Control Gear
- Wireless Node: Control Device



Bluetooth NLC + DALI

- DALI + Bluetooth Gateway: upcoming



on.org

LEDucation
Trade Show and Conference

DALI by Design

Clifton Manahan

LEDucation.org

Associated Press NY (2005)

- Individual control of light levels per department
- Frequent space reconfiguration

Control Impact

- DALI system allowed flexibility and improved maintenance

University of Washington Bill and Melinda Gates Center

- Tuneable white ceiling uplights to balance skylights

Control Impact

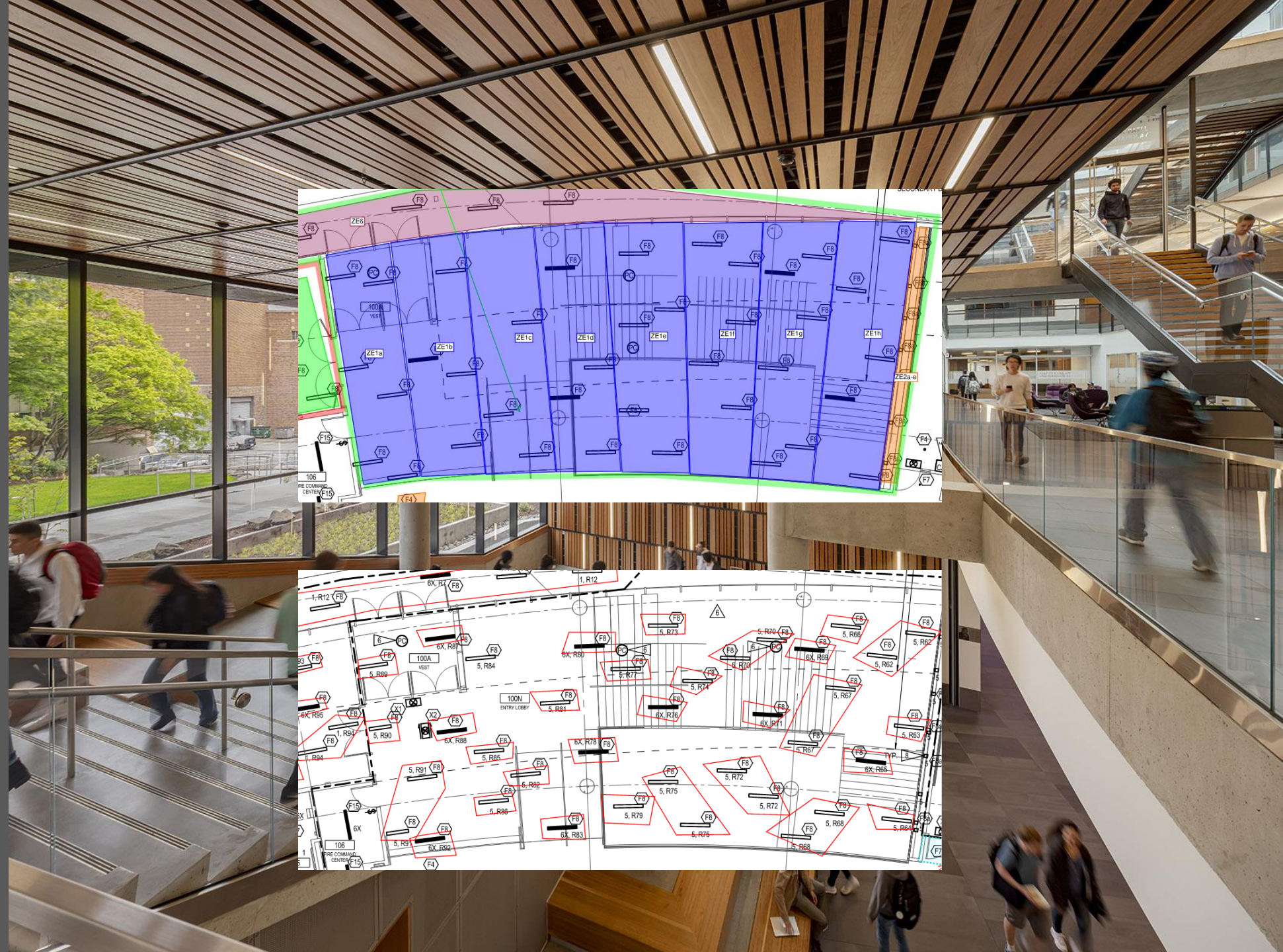
- Dual-0-10V imprecise fades based on timeclock – limited to just one fixture

University of Washington Bill and Melinda Gates Center

- Entry ceiling/wall linears slow “breathing”

Control Impact

- Slow fades per 0-10V zones

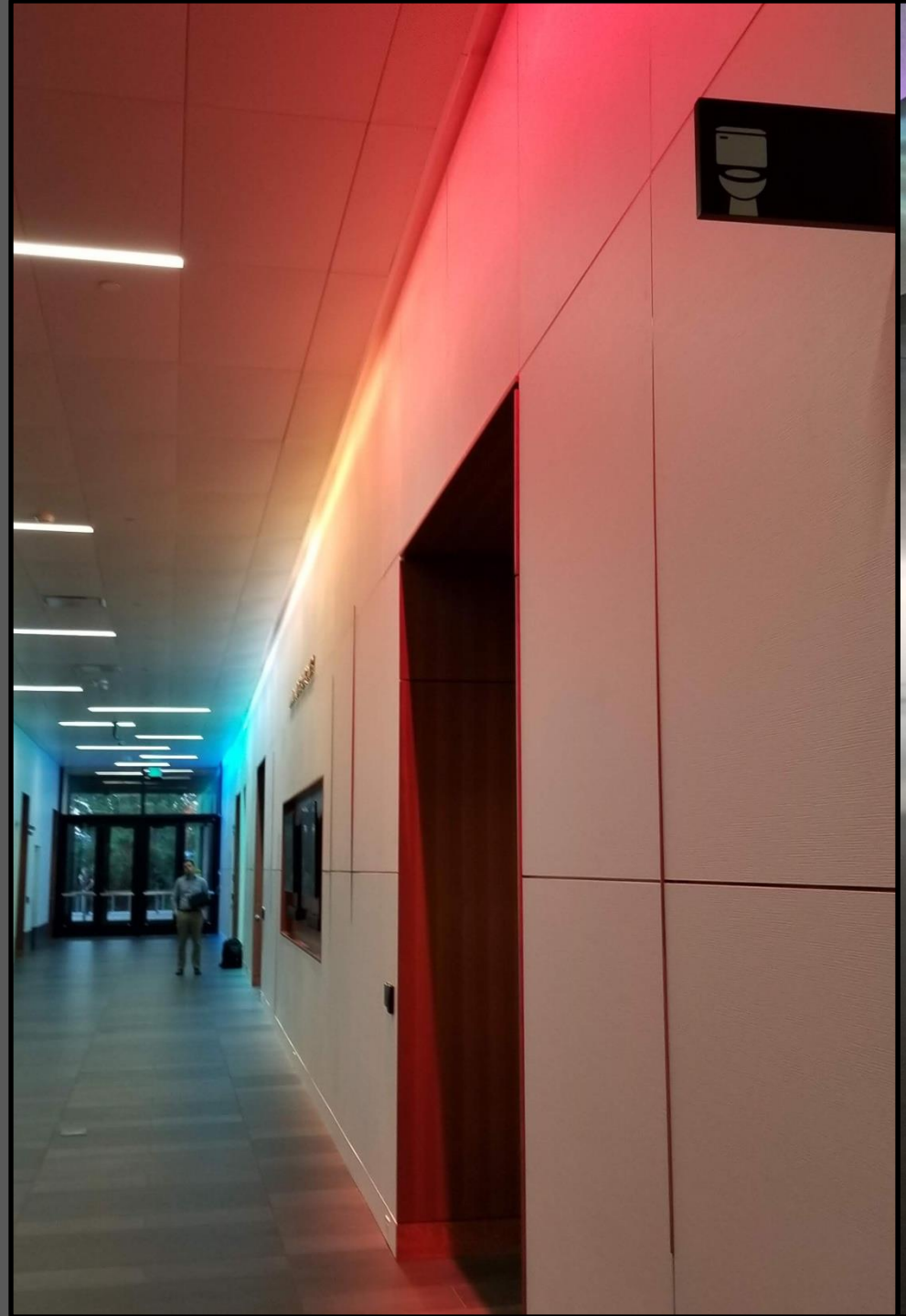


University of Washington Bill and Melinda Gates Center

- Prefunction and elevator color-changing coves with simple school colors or special event scenes

Control Impact

- Separate DMX system with color dial and pre-loaded scenes



University of Washington Bill and Melinda Gates Center

- Clamp-mounted flexible art lighting system

Control Impact

- Proprietary PoE power distribution system, no connection to lighting control system (DMX only)

University of Washington Founder's Hall

- Mass timber construction – exposed conduit and wiring

Control Impact

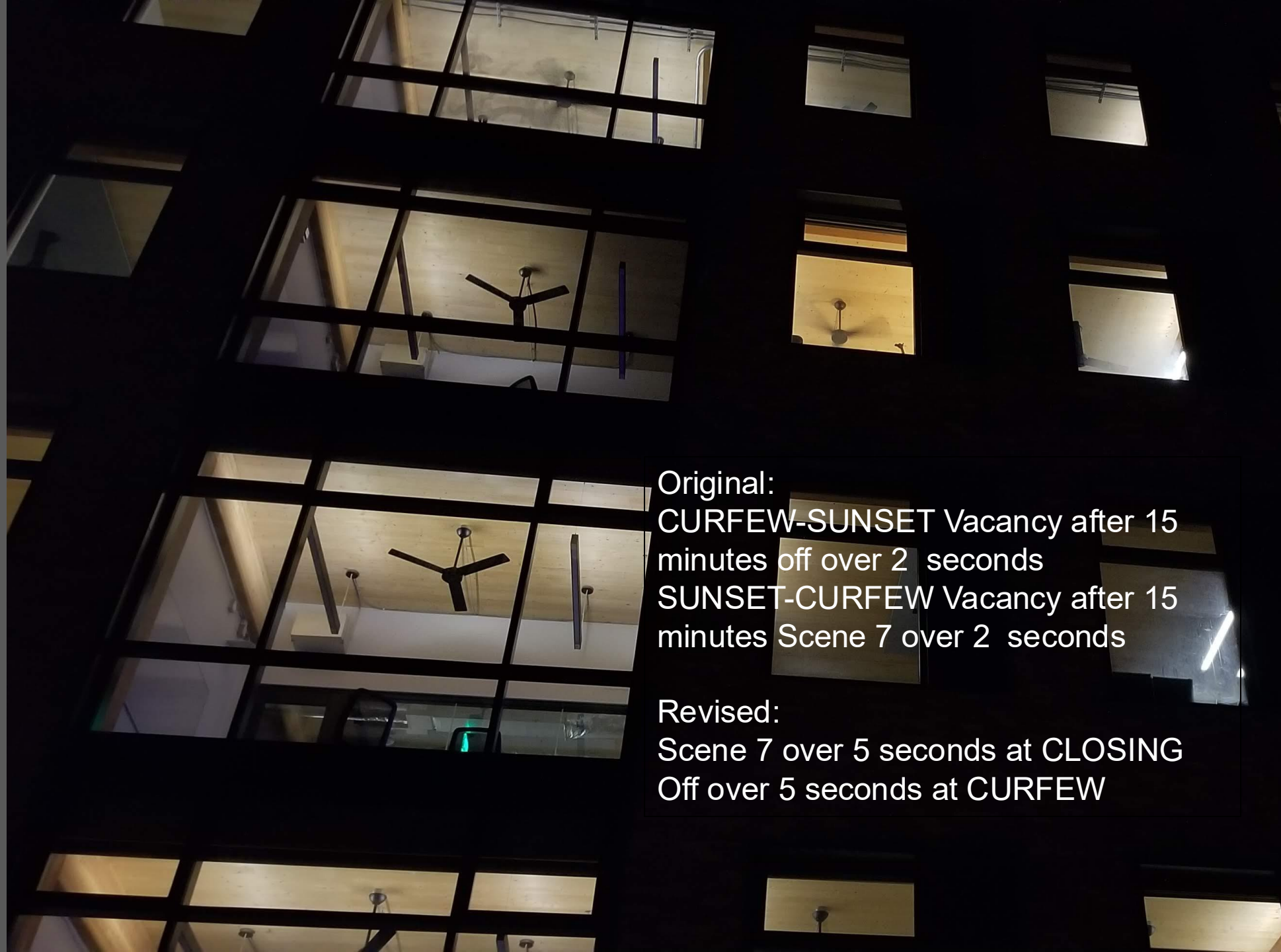
- Proprietary wireless 0-10V system

University of Washington Founder's Hall

- Private offices late night soft glow automatic scene

Control Impact

- SOO limitations in wireless 0-10V system



Original:
CURFEW-SUNSET Vacancy after 15 minutes off over 2 seconds
SUNSET-CURFEW Vacancy after 15 minutes Scene 7 over 2 seconds

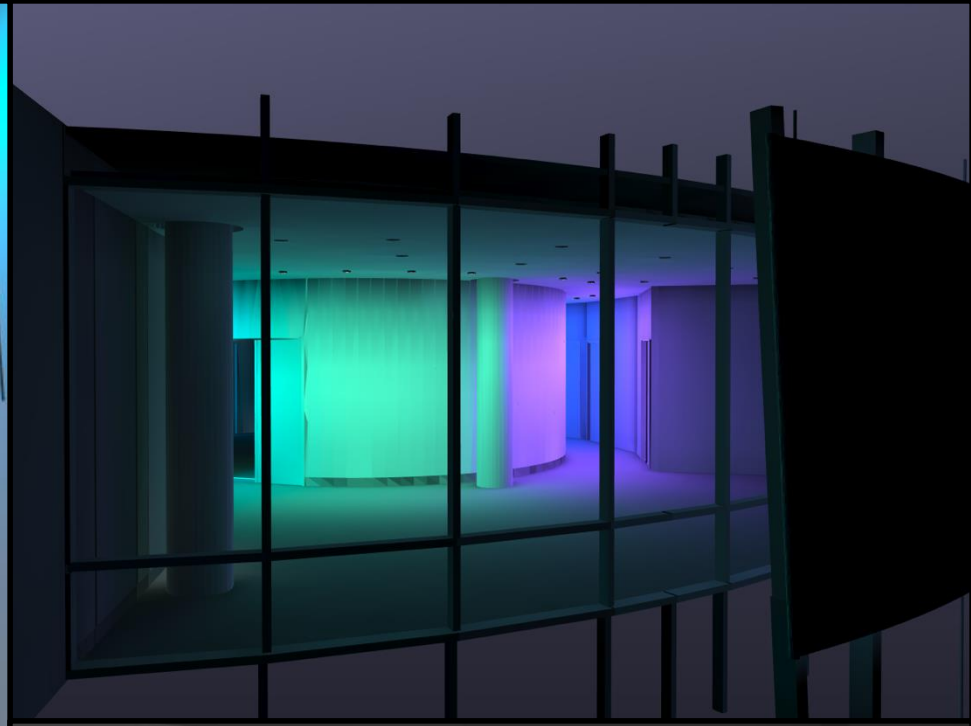
Revised:
Scene 7 over 5 seconds at CLOSING
Off over 5 seconds at CURFEW

University of San Diego Triton Center (Not Complete)

- Simple color-changing lighting across multiple buildings to coordinate with school colors, special events or media

Control Impact

- Separate DMX systems with network connections to media server, trigger each building separately



Washington University in St. Louis Olin School of Business

- Used a proprietary digitally addressable system, shown as an example

Control Impact

- Reconfigurable atrium space for events, seminars, performances etc.

LAX Curbside

- Custom pole lights operating 24/7 instead of timeclock as designed, fixture/driver failures

Control Impact

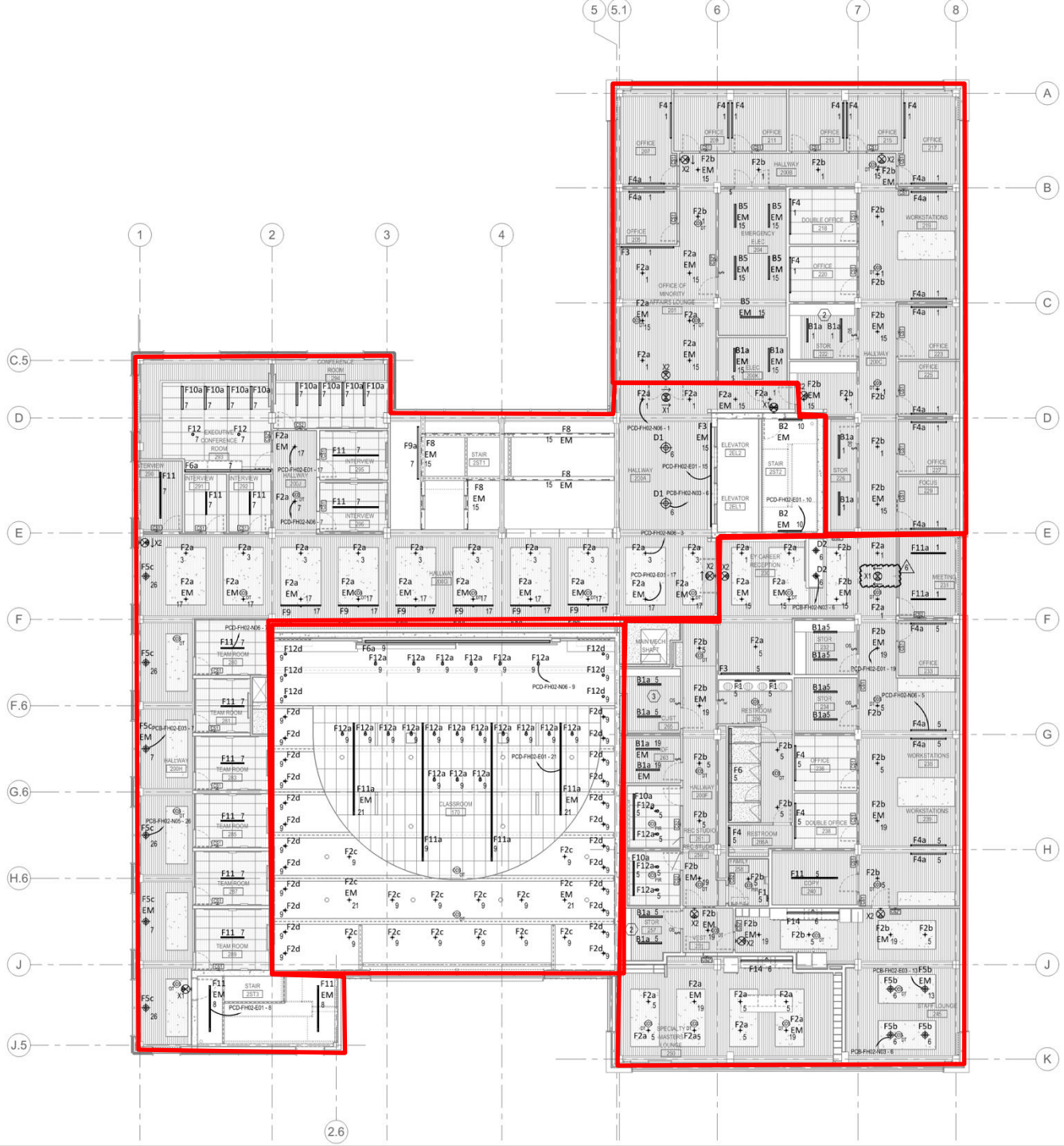
- Difficult to update programming, no reporting capabilities

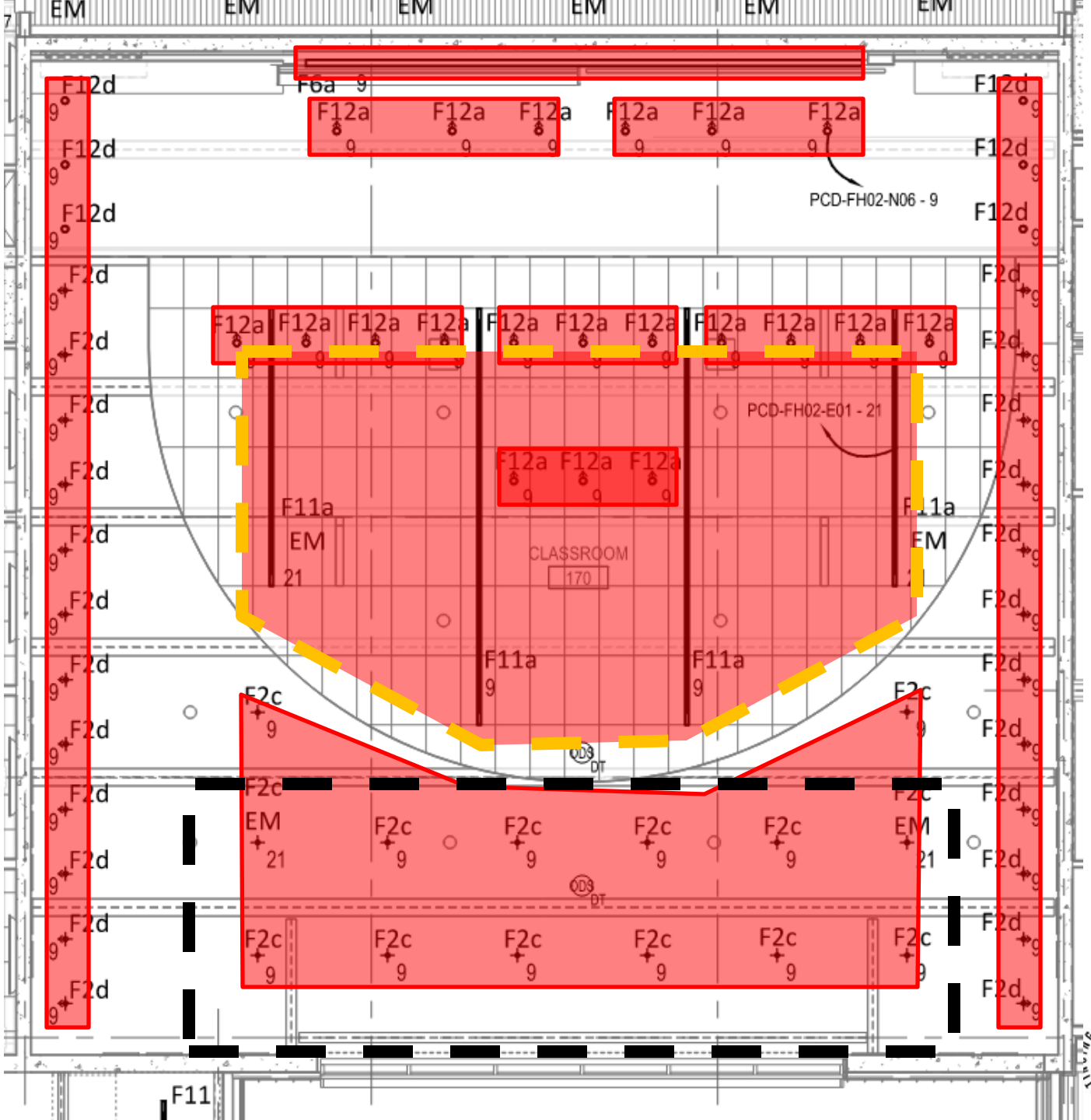
LAX Curbside

- Color-changing ribbon programming across the entire campus, coordination with other/future elements

Control Impact

- Separate DMX systems difficult to connect





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This concludes The American Institute of Architects
Continuing Education Systems Course

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Thank you for attending!

Please scan the QR code to rate it and leave feedback.

Sutton North Room

LEDucation Presentation Committee

Wendy Kaplan, Kelvix | Craig Fox, ETC | Shaun Fillion, NYSID / RAB | Stacey Bello, KGM Lighting