



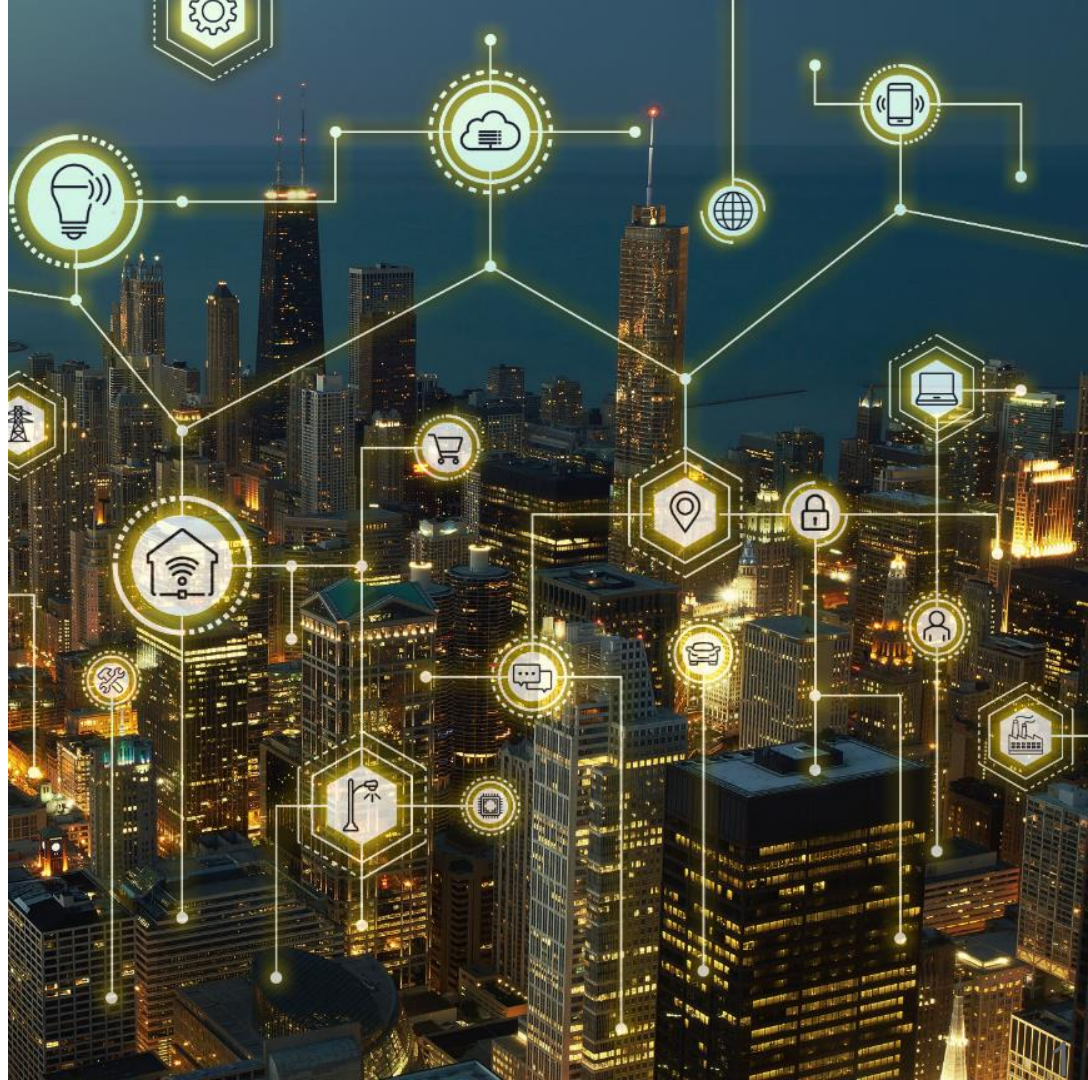
# DOE Solid-State Lighting Workshop

Taming Advanced Lighting System Complexity:  
A Call to Action

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PNNL is operated by Battelle for the U.S. Department of Energy





# Taming the Tiger



# The Promise 'Easy' Configuration

Quotes from **2015**  
DOE Connected  
Lighting Workshop

*... to a large degree, self-configuration is about auto-commissioning ... advanced analytics can be applied to connected lighting systems so that they become as easy to use as smartphones, which hide their complexity behind a simple interface.*

*... intelligence, communication, sensors, and even energy measurement will be incorporated into every luminaire in a way that's standardized, interoperable, and interchangeable.*



# The Warnings of Configuration Complexity

“If the whole commissioning process becomes a painful thing, we’ve achieved nothing,”

“The technologies don’t matter if you don’t get the user experience right,”

... networked lighting controls have seen low penetration to date, ... expensive and time-consuming commissioning is to blame...

... reducing that complexity will speed market adoption, ...



*DOE 2015 CLS Workshop, Configuration Complexity Panel*





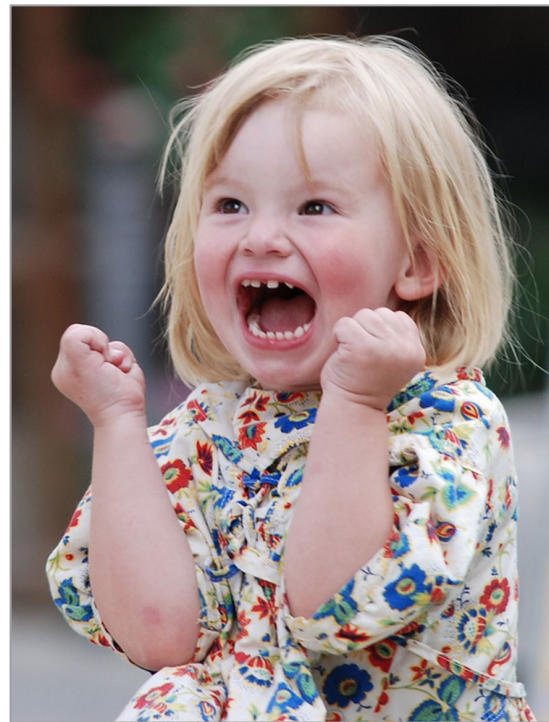
# The Warning was Clear

..if the lighting industry does not change its ways, it will continue to be hampered by a profusion of new vendors and standards, varying levels of compatibility and interoperability, and an inability to handle the pace of change that is emblematic of the IT and computing worlds it is colliding with.

Tanuj Mohan, Enlighted Co-Founder  
2016 Connected Lighting Workshop

# What We (I) Thought in 2015

- Everything was going to move VERY FAST – and lighting was going to get left behind if we weren't proactive
- IT big players would be eager to work with us
- Lighting industry would see all the potential and embrace the change
- Technology had advanced enough to facilitate 'auto commissioning' and systems would be as easy to set up use as a smart phone



# What's Happening Instead?

- Manufacturers have pursued in isolation – proprietary systems
- Lighting specification and distribution processes have not adapted
- Complexities have been underestimated (compounded by proprietary systems and protocols)
- Slow movement to digital (0-10V still predominates)
- Standardized protocols are still often customized
- Owners/users have not embraced or understood the potential of advanced lighting systems



# DOE's Connected Lighting Systems Strategy





# NGLS's Role in the Strategy



Energy  
Reporting



System Configuration  
Complexity



Interoperability



Stakeholder  
Collaboration



Key New Features

# What We've Been Seeing and Hearing

- DOE NGLS Living Labs (2017-present)
- DOE CBI Field Validations (ongoing)
- Guidehouse CLS Stakeholder Research Study (2021)
- DOE Realistic Settings Research (ongoing)
- Industry Interviews (late 2021)

**Widespread reports of failures  
and problems**



**What is the extent?  
What are the causes?  
What to do!**

# Chipping Away

- Matrix of Issues (seen in research field demos and from industry interviews)
- Outlined by where they fall in the process
  - Product development
  - Documentation
  - Specification
  - Installation and set up
  - Usage
  - Maintenance
  - Troubleshooting
- Categorized by affected and responsible parties
  - Manufacturers
  - Specifiers
  - 'Sellers'
  - Installers
  - Occupants
  - Facilities Staff
  - Owners

ISSUES IN DETAIL	PARTIES MOST AFFECTED						
	Gray shows major sources the	MANUFACTURERS	SPECIFIERS	SELLERS	INSTALLERS	OCCUPANTS	FACILITIES OWNERS
<b>PRODUCT</b>	<b>SOURCES</b>						
1 Product complexity exceeds understanding of many other parties		x	x	x	x	x	x
2 Mfrs modify standard protocols so they are not truly standard		x	x	x	x	x	x
3 Upgrades are not backward compatible affecting installed systems		x			x	x	x
4 Faulty programming at the factory		x	x	x	x	x	
5 Product launched before thorough testing		x	x	x	x	x	
6 Faulty software		x	x	x	x	x	
7 Faulty hardware		x	x	x	x	x	
8 Controls and luminaires from different mfrs are incompatible		x	x	x	x	x	x
9 Product doesn't meet owner expectations		x	x	x		x	x
10 Proprietary products are not interoperable		x	x	x	x	x	x
11 Customized system components do not function correctly		x	x	x	x	x	x
<b>DOCUMENTATION</b>	<b>SOURCES</b>						
12 No consistency in terminology or organization		x	x	x	x	x	x
13 Lengthy and complex documents deter careful reading by installers		x	x	x	x	x	x
14 Inaccurate documentation that doesn't reflect current product		x	x	x	x	x	x
<b>SPECIFICATION</b>	<b>SOURCES</b>						
15 No Narrative written		x	x	x	x	x	x
16 No Sequence of Operations (SoO) written		x	x	x	x	x	x
21 Specifier is unfamiliar with system		x	x	x	x	x	x
17 Narrative and SoO are inconsistent		x	x	x	x	x	x
18 Internal conflicts within the specification		x	x	x	x	x	x
19 LD specifications are not up-to-date with latest product		x	x	x	x	x	x
20 Gaps or overlaps in Scope of Work among design team		x	x	x	x	x	x
<b>INSTALL &amp; SET UP</b>	<b>SOURCES</b>						
21 Installers are unfamiliar with system		x			x		
22 Proprietary (inconsistent) set up tools are hard to learn and use						x	
23 Construction schedule requires install before documentation is ready					x		
24 Inadequate money in contract to pay for necessary set up work				x	x		x
25 Capable job superintendent is unavailable at critical set up times					x		
26 Project manager doesn't share documents with installers on site					x		
<b>USAGE</b>	<b>SOURCES</b>						
27 Owners don't value controls (and so pay little for them)						x	x
28 Users don't know how to use controls						x	x
29 Product doesn't meet occupant expectations (see also 4 above)						x	x
30 Owners don't pay for needed user/facilities training						x	x
31 Users are unfamiliar with system features and capabilities						x	x
32 Occupants don't know how to diagnose/fix simple problems						x	x
33 Code requirements exceed owner needs/desires						x	x
<b>MAINTENANCE</b>	<b>SOURCES</b>						
34 Maintenance team is unfamiliar with system						x	x
35 Easier to disconnect system than to diagnose or fix						x	x
36 Upgrades upset configuration of existing installation		x				x	x
37 No maintenance contracts		x				x	x
38 Poor recordkeeping limits ability to track and correct problems		x				x	x
<b>TROUBLESHOOTING</b>	<b>SOURCES</b>						
39 No single point of responsibility (see 47 above)		x		x	x	x	x
40 Multiple product suppliers confuse responsibility (permits shirking)		x		x	x	x	x
41 Difficult to reach a person who understands or can solve problem				x			x
42 No standard troubleshooting process/protocol							x
43 Trouble shooting often provides no revenue, hence little interest		x		x	x		





# What We're Learning So Far - Root Causes

- Confusing configuration instructions
- Inconsistent terminology
- Inexperienced installers, limited preparation
- Changing software and firmware
- Unintuitive user interfaces
- Miscommunication between manufacturers
- Proprietary system design



## Current Recommendations

- Focus on the essential capabilities
- Avoid mixed systems and protocols, if possible
- Engage trusted partners experienced with the system
- Develop detailed and consistent documentation
- Over-communicate among all participants
- Ensure documentation reaches the installation and set up teams
- Train end users
- Budget to do it right the first time



**Communication is the Key**



WHAT DO WE  
DO NOW?



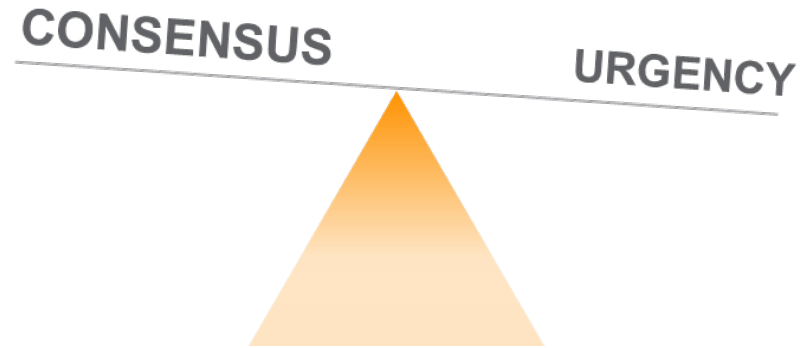
# Types of Market 'Interventions'

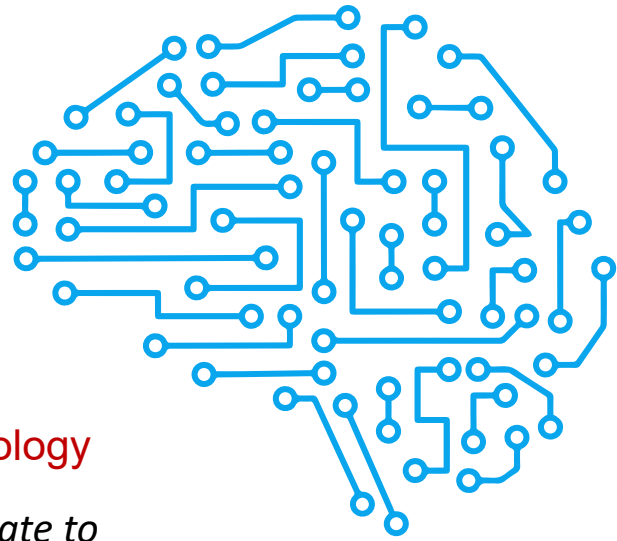
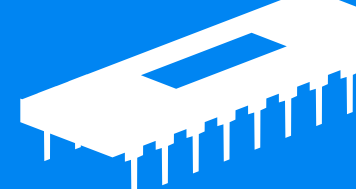
- Pure upside: (prizes, challenges, and other competitive DOE funding processes)
- Educational/communication resources (model specifications/templates)
- Consensus voluntary standards (best practices, minimum performance requirements, test procedures)
- Requirements (codes, mandates, bans, and other regulations)



# Prioritizing Solutions

- Low hanging fruit
- Impact
- Timeline
- Disruption





Constancy of hardware installation wiring  
Ability to communicate with others (easily)  
Long-term upgradability  
Setup Easy (Even in mid-sized systems)  
Interchangeable parts between vendors  
Longevity of maintenance ability  
Industry API Theory  
Minimum set of standards

Technology

*Manufacturers will have to collaborate to make progress*

Technological

A minimal but defined consistency across all NLCs

Uniform vocabulary  
Uniform installation process  
Published cross vendor expectations  
Industry control specification narrative  
Published fundamentals of security

People

Process

*Can other stakeholders work together to make progress here?*

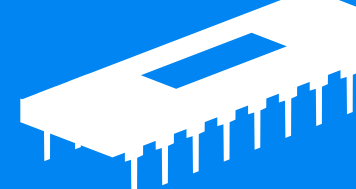
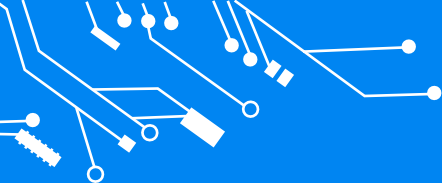


# People Side

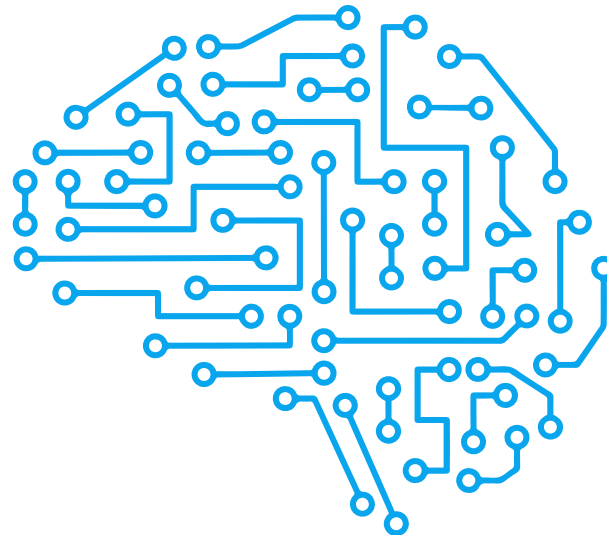
It's one thing to understand the technology problems, it's an entirely different challenge to solve the people problems.

The use of observational research by the NGLS program is all about figuring out the people problem.





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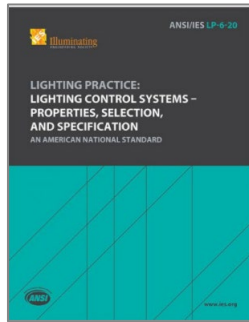
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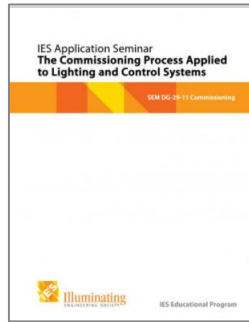
A minimal but defined consistency across all NLCs

# Why Focus of the Sequence of Operations?

- It is an important vehicle to tackling many communication challenges
- Lots of work has been done to build on
- How do we make it easier?



ANSI/IES LP-6-20,  
111 pages



IES DG-29-11,  
50 pages

Documenting Control  
Intent Narratives and  
Sequence of  
Operations

ANSI/IES LP-14-22?,  
90+ pages  
*in development*

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# Panel Discussion Outline

- What is a SoO and why is it so important? – Charles Knuffke (Wattstopper/Legrand)
- The designer perspective – David Ghatan (C.M. Kling & Associates)
- The manufacturer & start-up tech perspectives – Charles Knuffke
- The manufacturer rep perspective – Brian Coddington (Chicago Lightworks)
- Panel live discussion/rebuttal
- Attendee Q&A
- Wrap up - how to get involved





# Panel Presentations



# Places to Start? Ways to Get Involved

- Sequence of Operation templates (model spec)
- Vocabulary standardization (work with IES, use SoO templates as a vehicle)
- Workforce educational materials (focus on installers, facility managers)
- Integrator certification/training
- Maintenance/upgrade/troubleshooting protocols
- Wall control standardization (work with ANSI 137.8 committee)