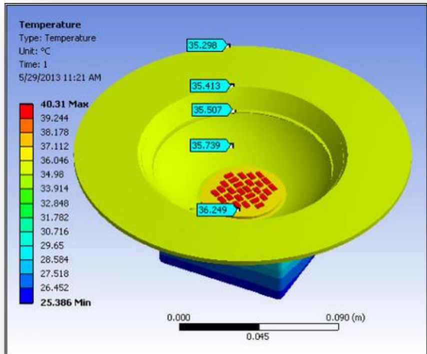
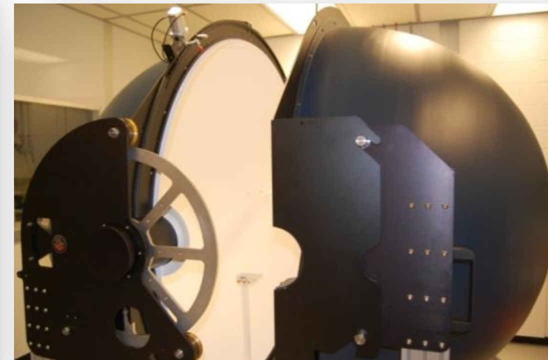
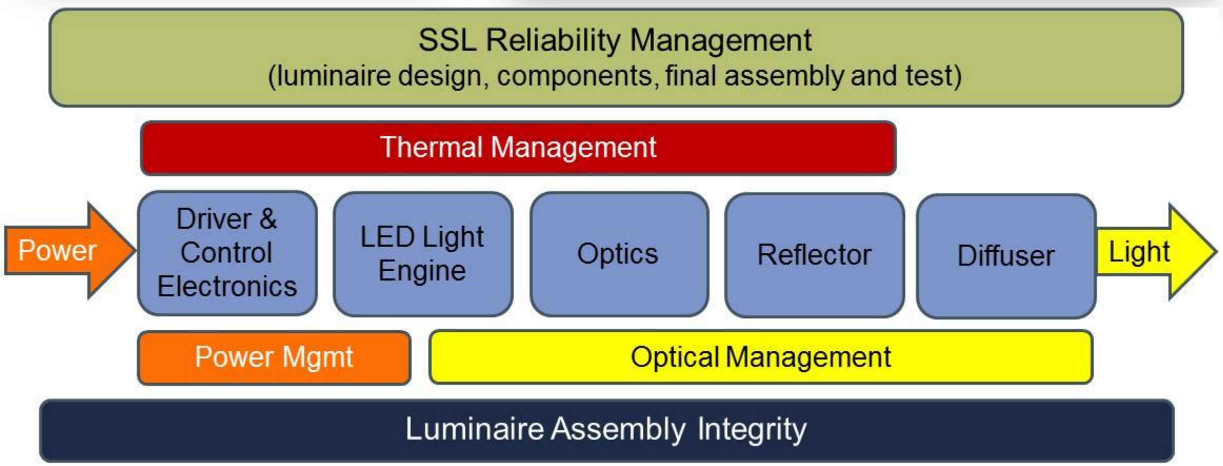
Solid State Lighting Reliability

2015Building Technologies Office Peer Review







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Project Summary

Timeline:

Start date: September 2011

Planned end date: September 2016

Key Milestones

1. Decision Support Tool for luminaire lumen maintenance
2. Performed accelerated life testing on more than **>400** LED devices
3. Collected industry data on **190** LED products
4. Development of an accelerated test for dirt depreciation

Budget:

Total DOE $ to date: $1.8 MM

Total future DOE $: $1.05 MM

Target Market/Audience:

Manufacturers, specifiers, and potential users of SSL products looking to justify higher upfront costs for SSL products.

Key Partners:

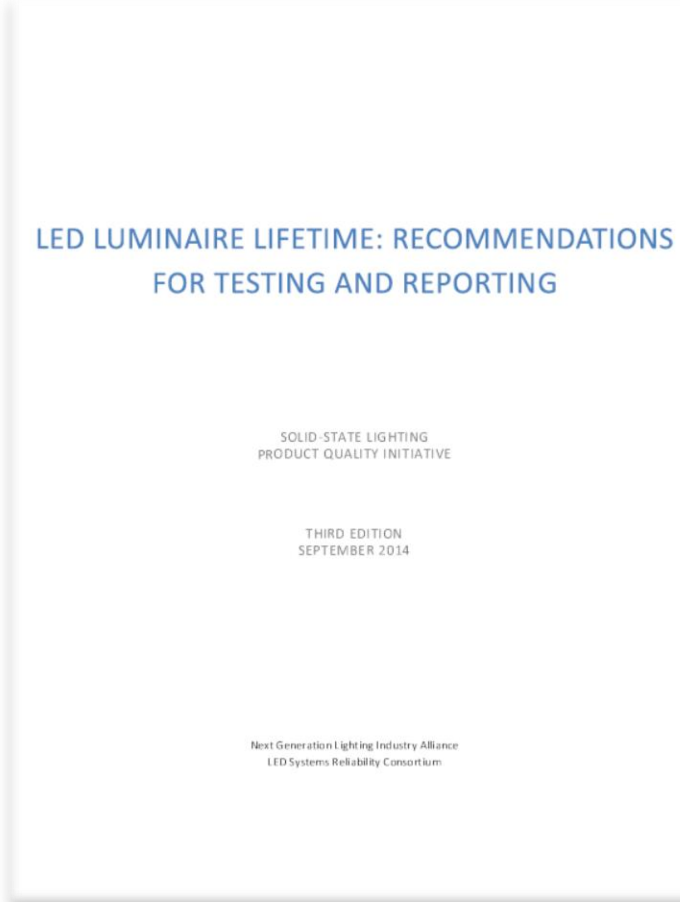
Auburn University
Cree
SAS Institute
PPG Industries
State of North Carolina
LED Systems Reliability Consortium

Project Goal:

To develop and validate a probabilistic reliability prediction tool and accelerated life testing methodologies that help lighting manufacturers and key stakeholders and promote the adoption of energy efficient SSL lighting technologies.

Problem Statement

- SSL products have achieved roughly 5% market penetration (Strategies Unlimited). So the technologies is just getting started.
- Initial purchase price for SSL products have dropped significantly over the past decade but costs are still higher than conventional lighting technologies.
- Use of SSL technologies may require more upfront planning for the lighting system. Issues such as dimming methods, line quality, and harmonics may need to be addressed. Still a lot of questions.
- Confidence in the reliability and performance of SSL technologies is needed to justify higher upfront costs and to continue driving market acceptance.


LED LUMINAIRE LIFETIME: RECOMMENDATIONS FOR TESTING AND REPORTING

SOLID-STATE LIGHTING
PRODUCT QUALITY INITIATIVE

THIRD EDITION
SEPTEMBER 2014

Next Generation Lighting Industry Alliance
LED Systems Reliability Consortium

DOE & NGLIA Sponsored Effort

http://apps1.eere.energy.gov/buildings/publications/pdfs/ssl/led_luminaire_lifetime_guide_sept2014.pdf

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Target Market and Audience

- Manufacturers, specifiers, and users of SSL products (e.g., utilities, businesses, and taxpayers) seeking to justify higher first costs for SSL products over less efficient legacy lighting technologies.
- This group annually consumes ~650 TWh in electricity for illumination, and adoption of SSL technologies can reduce this consumption by ~ 30%.

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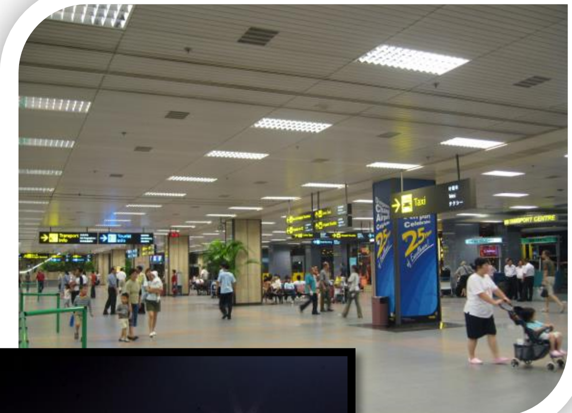
Impact of Project

This project will provide the target audience with methods to assess the expected lifetime of SSL products

- Increased consumer/end user confidence in energy saving SSL technologies
- Increased market pull for energy efficient lighting
- Potential impact could be 100s MWh per year by 2030



Project Endpoints

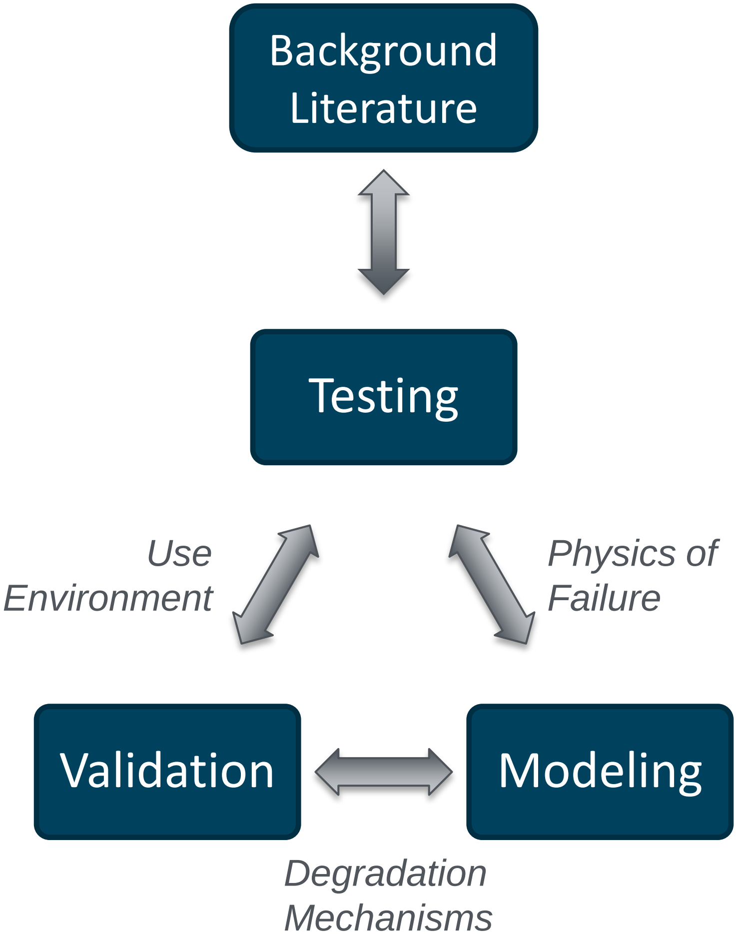
- Reliability models and software
- Improved ALT methods
- Information and resources for target market and audience

Measures of Impact

- Near – term: Publications and resource use
- Intermediate: Resource and methods use
- Long-term: Standards impact

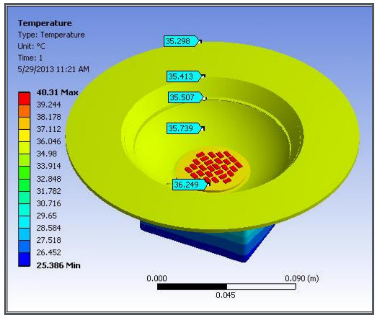
Approach

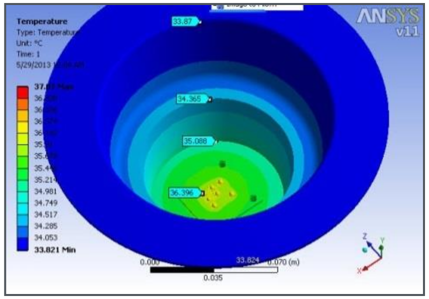
System-level approach consisting of both **accelerated life tests (ALT)** and **modeling** of both entire luminaires and key system components such as LEDs, drivers, and optical elements



6” downlights have been chosen as representative luminaires because they combine several desirable attributes:

- Low cost, readily available, and widely used
- Multi-generational products
- Incorporate many design features
  - HBLEDs, mid power& hybrid LEDs
  - Different driver topologies





Key Issues

- Industry data on LEDs such as LM-80 provides a snapshot of performance at the LED level. It should not be used as a proxy for lifetime at the luminaire level.
- Accelerated tests should not significantly add to manufacturer's testing burden but should give meaningful information in a shortened test time.
- Usage environments and product expectations differ greatly between products (e.g. disposable vs. "appliance" luminaires and lamps).
- Public sources of data on accelerated & robustness testing of SSL lamps and luminaire are often not available.

What is Life?

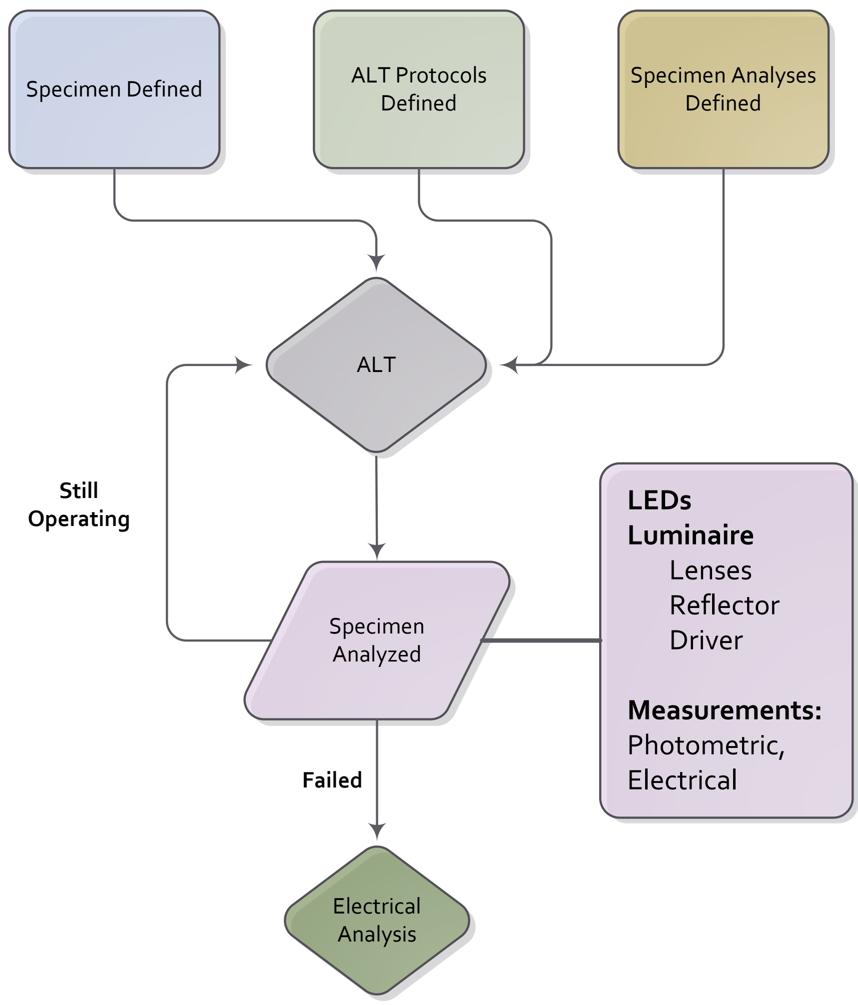
SSL luminaires do not always fail in a "lights out" fashion as with other lighting sources

Possible SSL failures include:

- Catastrophic – abrupt failure
- Lumen maintenance – lighting levels reduced below a lower limit
- Color shift – Change in color of light

Distinctive Characteristics

- Performing “test to failure” at the luminaire and component level.
- *In situ e*valuation of luminaire components enables aging models to be built for optical components.
- Models have been created for the impact of optical component aging and luminaire design on lumen maintenance.
- Detailed tear down and root-cause analysis on drivers provides insights into electrical failure modes in luminaires.



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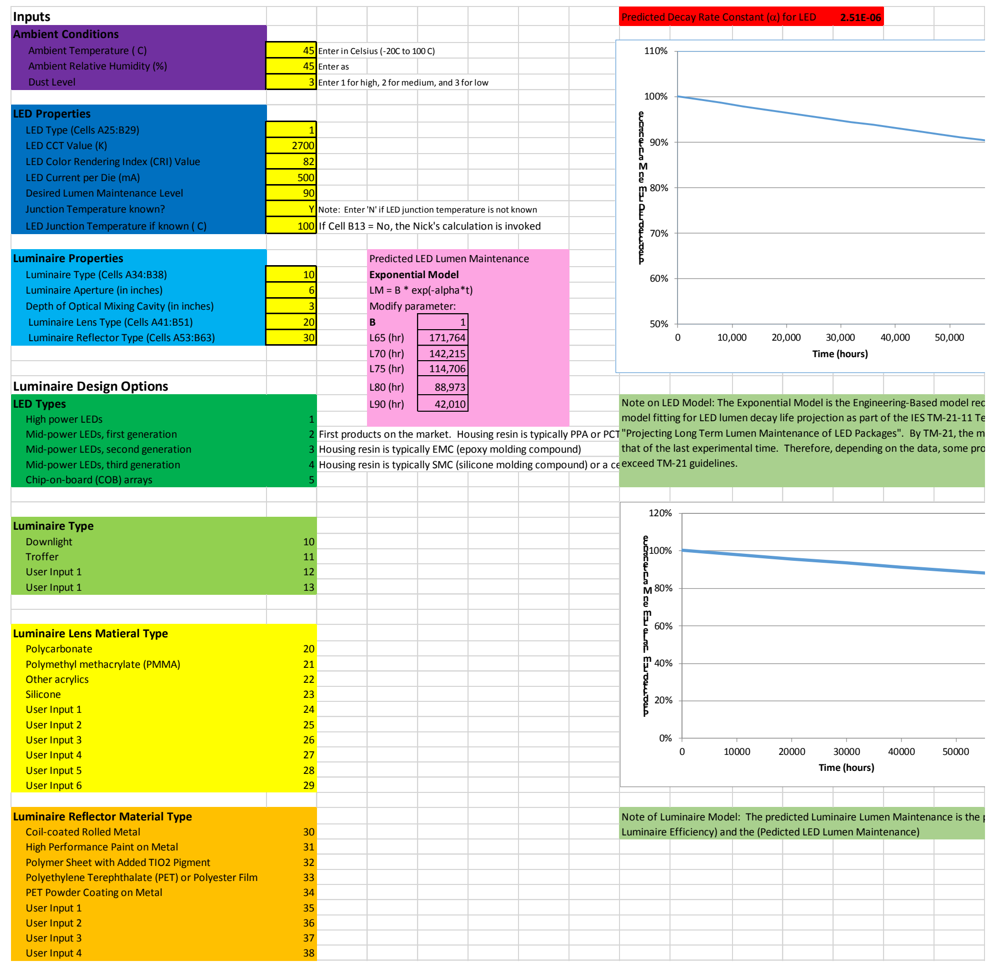
Lessons Learned

- Shift in LED product mix from high power to mid power and COB arrays
  - Places greater emphasis on materials choices for color stability at the LED level
- The rising importance of color shift to customer satisfaction of luminaires
  - Involves more than just the LED
    - Optics, power supply
- Limitations on LM-80 data for LEDs
  - Accuracy depends on test length
  - Absence of chromaticity coordinates

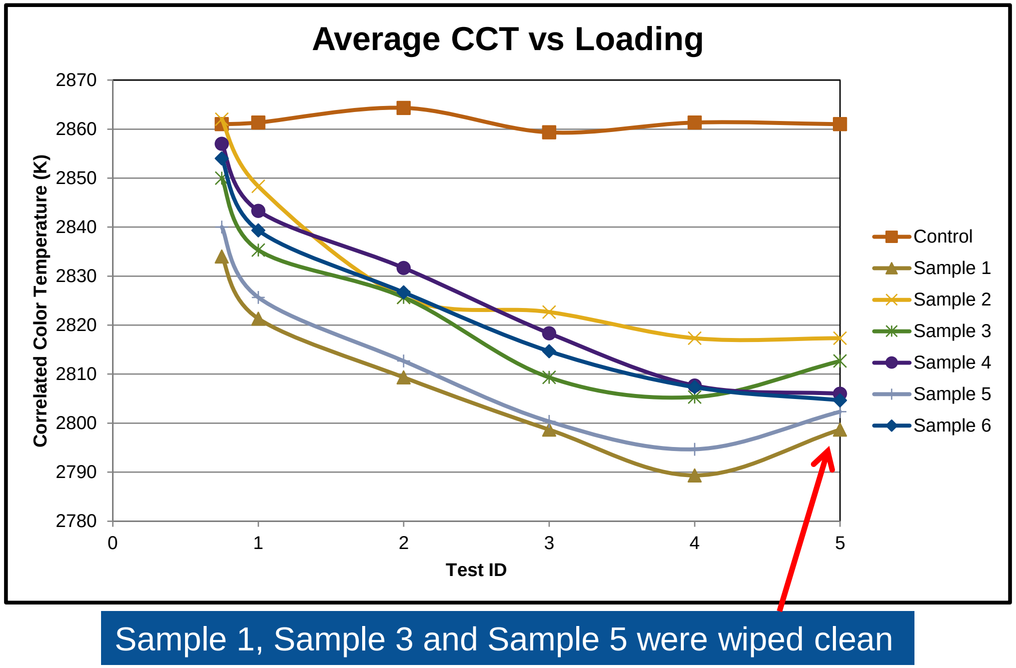
Accomplishments

- Developed Decision Support Tool (DST) for predicting lumen maintenance performance at the luminaire level.
  - Used LM-80 data from major manufacturers to build predictive models of LED lumen maintenance.
  - Takes into account changes in optical components, such as lenses and reflectors.
  - Includes the impact of luminaire design (H, W, D) for downlights, troffers, and linear luminaires (soon).
  - Paradigm shift from LED-only calculations.



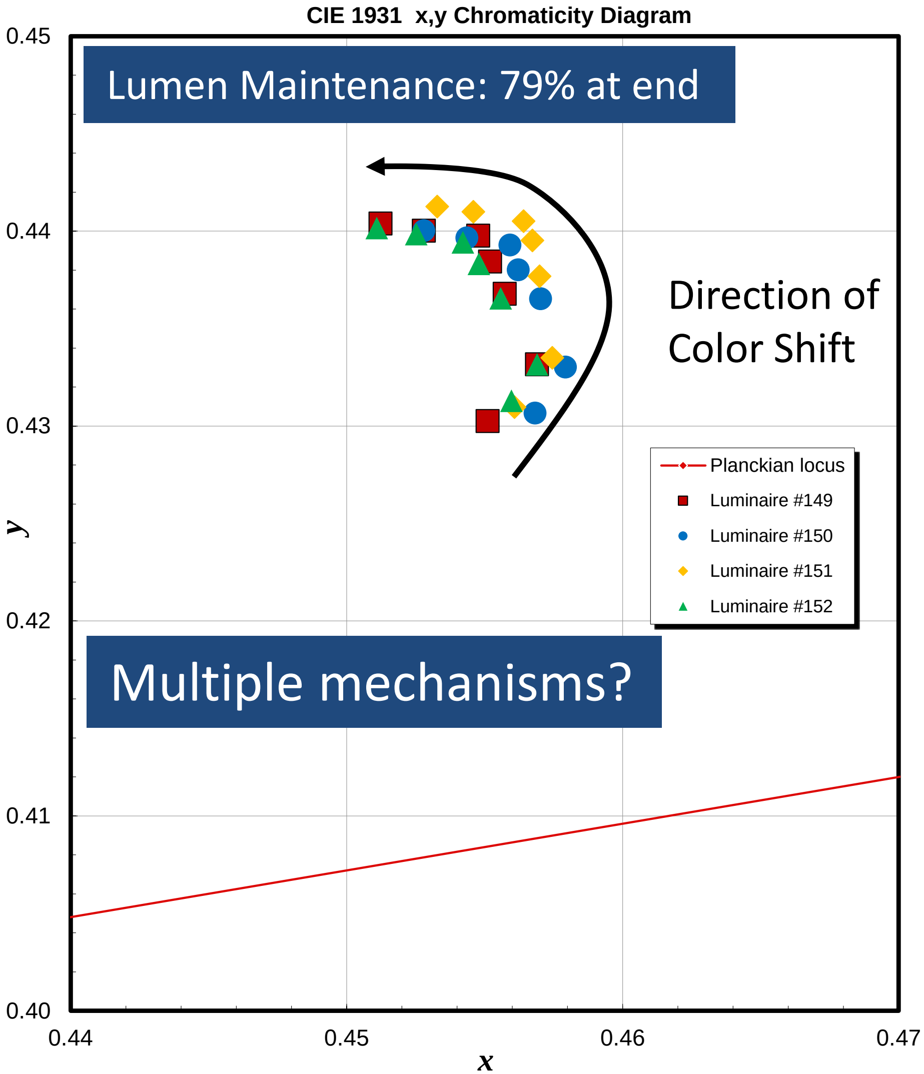
Accomplishments

- Developed an accelerated test for lumen dirt depreciation and demonstrated its utility on indoor luminaires.
  - Small decrease (roughly 0.2% per year) in lumen depreciation from dirt accumulation of luminaires in an office environment
  - Dirt depreciation produces a color shift resulting in roughly a 2% decrease in CCT over the roughly 20 year exposure time
  - Wiping exterior surfaces (i.e., dusting) restores roughly 25% of lost illuminance and color shift



Accomplishments

- Developed methods to accelerate lumen maintenance testing for luminaires to < 3,000 hours.
- Assigned root causes of color shift at the LED level and have begun to use vast collection of accelerated test data on downlights to look at luminaire level efforts.
- Test data available on
  - >200 luminaires (~ 500K hours)
  - > 1,500 LEDs (> 7 MM hours)
  - > 100 60 W equivalent lamps
- Also working to include data on LED lamp and luminaire lifetime from PNNL & other sources.



Project Integration and Collaboration

Project Integration: Project activities are closely coordinated with an advisory board consisting of key collaborators and the broader lighting industry through the LSRC

Partners, Subcontractors, and Collaborators:

DOE's LED Systems Reliability Consortium

Auburn University

SAS Institute

Cree Lighting

PPG Industries

State of North Carolina

Communications: This work has been presented at 7 DOE-sponsored workshops, 11 technical conferences, and in 16 technical publications

Next Steps and Future Plans

- Validate current models for lumen maintenance and driver reliability through additional testing
- Extend models to include color shift as a mode of failure taking into account the impact of
  - LEDs
  - Luminaire optical components (e.g., lenses and reflectors)
  - Power suppliers
  - Use environments and other factors
- Expand activities to look at Power Management System changes which impact power consumption, electrical efficiency , and power factor

Acknowledgements

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REFERENCE SLIDES

Project Budget

Project Budget: DOE total $2.85 M for FY2011 – FY2016
Variances: None
Cost to Date: on schedule at $1.8 M to date
Additional Funding: No other funding sources

Budget History					
FY2012 – FY2014 (past)		FY2015 (current)		FY2015 (planned)	
DOE	Cost-share	DOE	Cost-share	DOE	Cost-share
$1.7 MM	$425 K	$96 K	$124 K	$575 K	$143 K

Project Plan and Schedule

- Initiation date: Oct. 2011, Planned completion date: Sept. 2016
- Milestones through project include: development of accelerated lifetime tests (ALT) procedures and development of a refined probabilistic reliability model
- Milestone 6 was postponed in order to continue focusing on ALT work