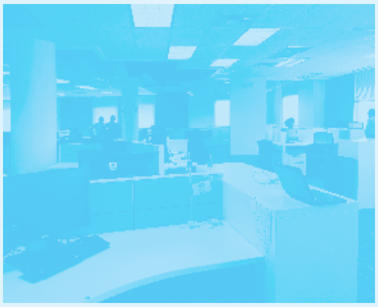
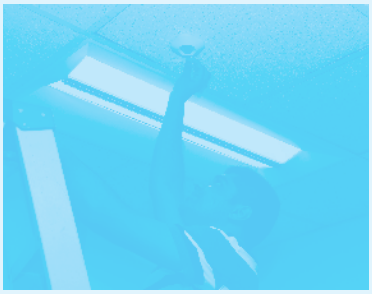




5 Projects in 5 Pages

Everything from a state capitol building to roadway work zones feel the reach of LRC's research endeavors

BY REBEKAH MULLANEY

One of the highlights of the Lighting Research Center's Partner-Alliance Event, a conference held each year at the LRC, is the presentation of major projects conducted by LRC researchers over the past year. Inspired by LRC Associate Director Russ Leslie's presentation "30 projects in 30 slides," we bring you "five projects in five pages"—offering a preview of recent and ongoing projects that, through collaboration, are transforming the way we light the world.

1 OFFICE LIGHTING FOR CIRCADIAN HEALTH AND WELL-BEING

Humans spend more than 90 percent of their time indoors, yet little attention has been given to understanding how light affects health in the built environment. A team of researchers led by LRC Light and Health Program Director Mariana Figueiro recently conducted one of the first studies to measure circadian light exposures in office workers and to relate those measures to mood and sleep outcomes.

The study included 109 participants at five office buildings managed by the U.S. General Services Administration (GSA). Sites included the GSA Central Office in Washington, D.C.; the Edith Green-Wendell Wyatt Federal Building in Portland, OR; the Federal Center South Building 1202 in Seattle; the Wayne N. Aspinall Federal Building and U.S. Courthouse in Grand Junction, CO; and the GSA Regional Office Building in Washington, D.C.

Each study participant wore a Daysimeter, a research tool developed by the LRC in 2004 and used in frequent studies to measure the amount of circadian stimulus (CS) a person actually receives, along with their activity patterns. CS, the calculated effectiveness of light's impact on the circadian system, ranges from 0.1, the threshold for circadian system activation, to 0.7, response saturation. LRC researchers also collected data on the participants' sleep and mood.

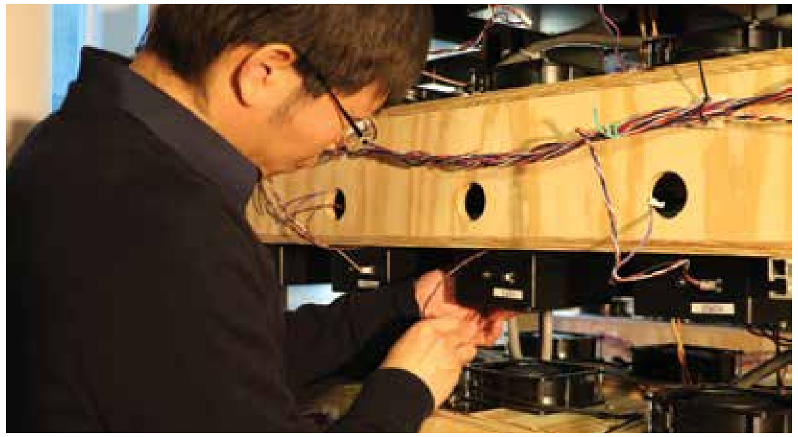
Study results show that office workers receiving CS greater than 0.3 in the morning exhibited greater circadian entrainment, were able to fall asleep more quickly at bedtime and experienced better quality sleep than those receiving a morning CS of 0.15 or less. While receiving high CS in the morning is hypothetically the most beneficial for entrainment, participants receiving high CS during the entire workday, from 8 a.m. to 5 p.m., also exhibited reduced depression and better sleep quality compared to those receiving low CS.

In 2016, the LRC took the project a step further by installing experimental desktop and overhead lighting providing CS greater than 0.3 for 36 participants at two additional federal buildings. Participants reported feeling less sleepy and more energized after experiencing the lighting intervention.

With funding from the GSA and the U.S. Department of State, the LRC is currently performing similar studies at U.S. embassies in Reykjavík, Iceland and Riga, Latvia—northern locales known for reduced daylight hours and extended darkness in winter. Results will be available later this year.

Many electric lighting systems currently installed in office buildings provide too little CS during the day. For office buildings designed to maximize daylight availability indoors, factors such as season, weather, desk orientation and window-shade position affect CS levels. Lighting professionals should consider how to effectively use electric lighting to supplement daylight to ensure that every worker receives enough light during the day to support health and well-being in the office environment.

RESEARCH



2 PREDICTING LED SYSTEM LIFE UNDER REAL-WORLD CONDITIONS

Longer lifetime is one of the claimed features of LED products. The lifetime of an LED lighting product is dependent upon numerous factors, including the quality of system components, the environment it is used in, and how often it is switched on and off during the day.

Generally, LED lamps undergo two types of failures, catastrophic and parametric. In catastrophic failure, the lamp ceases to produce light, and in parametric failure, the lamp produces light, but much less than what it was designed to produce. Present industry practice, however, considers only the parametric failure of a single component in the system, the LED lumen depreciation time, L70, as the rated life of LED systems. This practice can lead to inaccurate lifetime reporting and dissatisfied consumers when lamps fail more rapidly.

Since 2009, a team of researchers led by LRC Director of Research Nadarajah Narendran has been investigating the life of LED lighting systems in order to develop a shorter duration, predictive life-test procedure that accounts for both catastrophic and parametric failures. This method allows users to estimate how long the product will last in the application if the environment temperature and the use pattern are known. Early studies funded by the Alliance for Solid-State Illumination Systems and Technologies (ASSIST) found that time to failure was affected by delta temperature (ΔT), the temperature change during the on-off cycle, and dwell time, the duration the system is operating at its maximum steady-state temperature. In 2014, the Bonneville Power Administration (BPA)* and the New York State Energy Research and Development Authority (NYSERDA) provided co-funding to expand the earlier studies.

The LRC found both types of failures with the LED lamps tested in the study. *Contrary to popular belief, on-off switching can reduce LED system life.* On-off switching encourages catastrophic failure, which results from the stresses experienced by the interface material due to thermal expansion mismatch between the different layers in the system that lead to fatigue failure. Maximum operating temperature influences the lumen depreciation rate and thus, the parametric failure time. Post-failure analysis showed that catastrophic failures for the tested lamps were mostly due to failure of solder joints, attaching the LED to the electronic board. The parametric failures were due to either yellowing of the binding materials used in LED packages and/or the driver output current changing due to degrading electronics within the driver. Such failures become rapid at higher temperatures. For the lamps tested, catastrophic failure times were shorter than parametric failure times.

Therefore, the LRC recommends that, when reporting LED system life, the shorter of the two failure times, catastrophic and parametric, should be considered as the lifetime of the product because, in applications, LED systems will experience both types of failure. Depending on the conditions, one failure type could dominate. To obtain more accurate life estimates for LED systems, new life-testing practices should include whole system and on-off power cycling with sufficient dwell time.

The LRC study demonstrated that a short-duration, less than 3,000-hour, test procedure can be developed to accurately predict LED system life in any application if the LED operating temperature and the on-off switching pattern are known.

**BPA support does not constitute an endorsement by BPA of the views expressed herein.*

3 IMPROVING VISUAL GUIDANCE IN WORK ZONES

For many drivers, work zones at night can be unpleasant places. For transportation, construction and utility workers, work zones mean increased risk of injury or even death. The combination of ambient darkness, glare from work-zone lights, unfamiliar traffic patterns and the presence of multiple flashing yellow beacons can create visual chaos that is difficult to decode. Adding to the challenge, performance standards for flashing lights used in work zones only specify minimum intensity requirements with no maximum limits to avoid glare at night. Nor are there requirements for coordinating multiple lights, so they often generate random, confusing flash patterns.

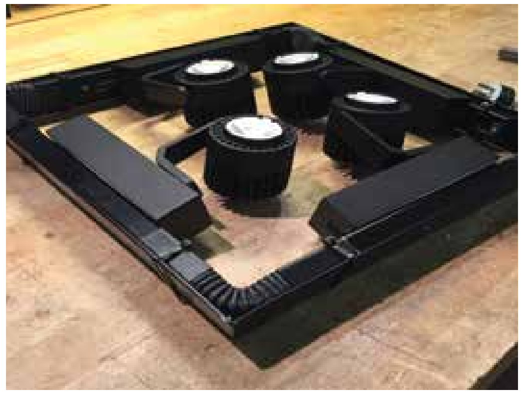
Working under a grant from the National Institute for Occupational Safety and Health (NIOSH), LRC Director Mark Rea and Director of Transportation and Safety Lighting Programs John Bullough are conducting a series of research studies that will ultimately improve worker safety by reducing the chaotic conditions faced by drivers in work zones.

Human factors studies in the laboratory led to recommendations for daytime and nighttime luminous intensities that help ensure visual detection without creating excessive glare or distraction, and for flash patterns that do not allow warning lights to switch off completely, so that drivers can make better judgments about the relative speed of vehicles. Analyses of visual performance under conditions like heavy fog helped identify intensity distributions that minimize scattered light and keep nearby workers visible.

The project also includes outdoor field evaluations to validate findings from the laboratory. In one field study, participants drove along daytime and nighttime work zones delineated by orange traffic drums and flashing yellow lights. The intensity of the lights and their flashing patterns were changed systematically. The lights could flash with a random pattern, a synchronized pattern where all lights turned on and off simultaneously, or a sequential pattern where lights flashed one after another along the boundary of the work zone.

Not unexpectedly, drivers preferred lower intensities at night, with a peak intensity of approximately 25 cd, reporting that the lights produced less glare and were easier to navigate than lights having higher intensities. In the daytime, higher intensities, up to a peak intensity of 750 cd, were judged as equally non-glaring and easy to navigate. The random flashing pattern was also judged as the most glaring and the sequential pattern was least glaring, even when the peak intensities were the same. Drivers noted that the sequential pattern was the easiest to navigate.

The LRC's research findings will inform standards for flashing lights that are bright enough to be detected, yet not too bright nor too confusing to help drivers navigate through work zones without increasing risks to road workers.



4 LIGHTING THE GOVERNOR'S RECEPTION ROOM

Commonly known as the "War Room" for its prominent ceiling mural depicting New York State military history from early settlement to World War I, the Governor's Reception Room at the New York State Capitol showcases several historic artifacts, including survey maps associated with the construction of the Erie Canal and models of the *Victorine*, a Hudson River sloop built in 1848, and the *Half Moon*, a Dutch exploration ship captained by Henry Hudson in 1609.

The War Room was intended to be a rotunda with a 40-ft high-domed ceiling, featuring murals chronicling important military events in New York State history. The architect's plan required removal of the second floor to create this open space. The artist William de Leftwich Dodge painted the murals anticipating that they would be viewed from the first floor of the building, but the top floor was never removed. For this reason, some visitors may find the magnitude of the paintings to be overwhelming, yet the space provides a rare opportunity to see a ceiling mural at close range. The War Room is lighted by eight bronze torchieres, the design of which represents the water patterns of the Hudson River and the prows of packet ships upon the river. Their placement reinforces the octagonal pattern of the ceiling.

In 2016, the New York State Office of General Services awarded a contract to the LRC to design a lighting upgrade of the NYS Capitol War Room. The LRC project team, Russ Leslie, Kassandra Gonzales and Martin Overington, first developed a simulation model of the space to evaluate the existing lighting conditions. Next, the LRC investigated possible dimming systems, and selected and installed several fixture options to evaluate color properties, distribution and other lighting characteristics. After installation of the final selections, the LRC commissioned and aimed the fixtures.

The LRC design uses LED lighting technology to provide an 86 percent energy savings compared to the original design, higher overall illuminance in the space, enhanced color, and improved accent lighting for ceiling murals and portraits. Using high CRI, 3000K, 16-W LEDs, the design illuminates the entirety of the mural and brings attention to previously underrepresented areas. The original lighting primarily lit the portions of the mural directly above the torchieres and neglected the bottom portions of the mural that slope into the wall. To address this issue, the LRC designed a special track configuration, holding three to four track heads each, that precisely fits into each of the eight bronze torchieres. Each track head can tilt 180 deg, allowing for a single torchiere to illuminate multiple parts of the mural at once. Each track head was aimed at a specific part of the mural to highlight the depth of the painting.

The new lighting design enhances the rich colors and important historic details of the central mural on the ceiling of the War Room and the "cloud" murals which surround it, while significantly reducing energy use.

5 CONNECTED LIGHTING AND REMOTE MONITORING OF LED PERFORMANCE

In a 25,000-sq ft commercial office on the Rensselaer Technology Park campus in Troy, NY, LRC researchers are installing LED lighting with fixture-integrated and network-connected controls. The controls are being tested in a broad-based field evaluation to compare and quantify the additional benefits that connected lighting systems offer to users. Led by LRC Director of Research Nadarajah Narendran, the LRC is investigating everything from ease of installation to user satisfaction.

Connected lighting is defined as the connection of lighting, controls, and sensors to a local network that can be monitored and controlled, either wired or wirelessly, through a dashboard accessed by a computer, tablet or smartphone. With connected lighting, the system is automated based on predetermined conditions, such as those defined by timers, and on sensing information, such as that gathered by occupant and daylight sensors. While these devices have existed for some time, until now there was no way to remotely control and override the commissioned settings on the fly for one fixture at a time.

Connected lighting systems are new and still evolving, and as such are mostly untested and have not been compared in the field with traditional lighting controls including autonomous fixture-integrated sensors. This has prompted the LRC, with support from the New York State Energy Research and Development Authority (NYSERDA), to evaluate how this networked technology might work in the real world. In this two-year project, the LRC is evaluating what types of networked and fixture-integrated systems work best for different types of spaces and will produce results and best practices guides for buyers and manufacturers.

Power over Ethernet (PoE) is another technology that is currently being explored for IoT-enabled lighting. In PoE systems, standard Ethernet cable carries power and data to and from the luminaire. With funding from the Alliance for Solid-State Illumination Systems and Technologies (ASSIST), the LRC is developing a methodology to compare electrical performance of PoE-enabled LED lighting systems and also compare the performance of PoE-enabled LED lighting systems to traditional alternating current (AC) powered LED lighting systems.

The LRC is also exploring the potential benefits of remote monitoring, whereby data is gathered to monitor the "health" of connected lighting systems—a welcome feature for building managers who want to optimize energy usage and improve maintenance scheduling and fixture replacement.

Since 2015, the LRC has been investigating a methodology that allows for the real-time prognostic health monitoring of connected lighting systems using wireless data transfer to a smart device. The study aims to investigate different parameters and identify the most suitable one to estimate the remaining useful life of a lamp or lighting system. The initial study shows promising results to accurately predict failure time sufficiently early, at around 60 percent of the operating life. ☐

THE AUTHOR

Rebekah Mullaney, M.S., is manager of research communications at the Lighting Research Center at Rensselaer Polytechnic Institute.