New Approaches in Warning Beacon Design to Improve Worker Safety

April 6, 2016 Symposium Summary

National Institute for Occupational Safety and Health (NIOSH)
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Under the grant to Professor Mark S. Rea (PI), Director of the Lighting Research Center (LRC) at Rensselaer Polytechnic Institute (RPI), a half-day workshop was held at the Larson Transportation Institute (LTI) at Pennsylvania State University (PSU) on April 6, 2016 to share research results with stakeholders and conduct a demonstration of a prototype intelligent warning beacon system developed by the LRC. The workshop was held at the Penn Stater Conference Center and the demonstration occurred at the LTI's test track in State College, Pennsylvania.

Event Agenda

The following items were included in the day's agenda:

- Welcome and Introductions (Pietrucha, LTI & Rea, LRC)
- Presentation: The Safety of Workers: A NIOSH Perspective (Sammarco, NIOSH)
- Presentation: Warning Beacon Intensity, Visibility, Glare and Closure Detection (Skinner, LRC)
- Presentation: Optical Design Characteristics and Visibility in Fog (Bullough, LRC)
- Presentation: The Impact of Highway Safety Flares on Driver Behavior (Garvey, LTI)
- Presentation: Impacts of Warning Light Intensity and Flash Patterns on Driver Behavior (Rea, LRC)
- Presentation: Evaluation of Striped Vertical Panels in Temporary Traffic Control Zones (Garvey, LTI)
- Discussion of Presentations (all)
- Warning Beacon Prototype Demonstration at LTI Test Track (all)

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Speakers

John Bullough, Ph.D.

Dr. Bullough is Director of Transportation and Safety Lighting Programs at the LRC, and an Adjunct Faculty member in RPI's graduate program in lighting. His research focuses on visual performance, glare, and color vision in transportation and outdoor lighting, and human factors of roadway lighting, vehicle lighting, aviation lighting, and signs and signals. Bullough is a Fellow of the Illuminating Engineering Society and a member of the Society of Automotive Engineers, the International Municipal Signal Association, and the U.S. National Committee of the International Illumination Commission. He also serves on the Board of Directors of the Council for Optical Radiation Measurements and the Academic Advisory Council for Signage Research and Education, and chairs the Transportation Research Board's Committee on Visibility. He has written or co-written more than 400 articles and technical publications on lighting and safety.

Philip M. Garvey

Mr. Garvey's academic background is in psychology, visual perception, and experimental design. He has been designing and conducting human factors research experiments that explore the interaction between humans and their visual environment for 25 years. He recently wrote the human factors chapter on signage for the Handbook of Transportation Engineering published by McGraw-Hill. In other related work, Garvey wrote the Federal Highway Administration's guidelines for changeable message sign visibility, and the FHWA's Manual on Uniform Traffic Control Devices chapter on community wayfinding signs. He has also conducted several studies evaluating the effectiveness of temporary traffic control devices (e.g., arrow panels and drums) for use in highway construction work zones for PennDOT and the FHWA.

Garvey's expertise in human factors led to his selection as chairman of the National Academy of Sciences' Transportation Research Board's Committee on User Information Systems, a post he served for six years. He also established TRB's Committee on Advanced Traveler Information Systems. ATIS is TRB's liaison with the international intelligent transportation systems (ITS) community, which is concerned with testing and developing emerging technologies for information transfer between environments and users. In 2004, Garvey was invited to join the National Committee on Uniform Traffic Control Devices' Human Factors Resource group, and in June of 2006 he was appointed Chairman of the National Committee's Human Factors Task Force, a post he served for four years.

Mark S. Rea, Ph.D.

Dr. Rea is Director of the LRC and Professor of Architecture and Cognitive Sciences at RPI. He teaches courses in leadership and in visual and circadian processes, and supervises graduate students at M.S. and Ph.D. levels. Rea is well known for his research in circadian photobiology, mesopic vision, psychological responses to light, lighting engineering, and visual performance. He is the author of more than 250 scientific and technical articles related to vision, lighting engineering, and human factors and was the editor-in-chief of the 8th and 9th editions of the Illuminating Engineering Society (IES) Lighting Handbook. Rea has been elected Fellow of the Society of Light and Lighting (UK) and Fellow of the IES. In addition, he is recipient of the IES Medal. Rea has also been honored

with the William H. Wiley Distinguished Faculty Award for those who have won the respect of the faculty at Rensselaer through excellence in teaching, productive research, and interest in the totality of the educational process. Dedicated to the notion that our society undervalues light because we do not properly measure its benefits, his recent book, *Value Metrics for Better Lighting*, brings together a wide range of research to illustrate how the effective use of light can benefit society and the environment.

John J. Sammarco, Ph.D.

Dr. Sammarco is a Principal Research Engineer at NIOSH. Sammarco has authored 67 publications covering the topics of machine safety, machine control, and mine illumination. His research areas concern system safety, hazard/risk analysis of programmable-electronic systems, and the human factors of lighting. He was recognized by the 2016 Federal Engineer of the Year Agency Award and the 2016 Public Health Service/Center for Disease Control Engineer of the Year. His Federal Liaison duties include Past Chair of the Engineering Technology Accreditation Commission (ETAC) of ABET, and the ETAC of ABET representative to the IEEE Committee on Engineering Technology Accreditation Activities.

Sammarco holds these degrees: Ph.D. Computer Engineering, West Virginia University; M.S. Computer Engineering, National Technical University; M.S. Industrial Engineering, University of Pittsburgh; B.S. Electrical Engineering Technology, Pennsylvania State University.

Nicholas P. Skinner, M.S.

Mr. Skinner is a Lead Research Specialist at the LRC. He has had the opportunity to participate in research into many topics relevant to lighting, but primarily focuses on transportation topics including aviation lighting, motor vehicle lighting, interaction between motorists and the roadway environment, and road work zone safety. Skinner holds an M.S. in Lighting and B.S. in Mechanical Engineering from Rensselaer Polytechnic Institute, as well as a B.S. in Physics from Siena College.

Attendees

A list of attendees is included in Appendix A.

Presentation Abstracts

The Safety of Workers: A NIOSH Perspective

Dr. John Sammarco, NIOSH

Dr. Sammarco discussed worker safety in general, its importance, and several projects that he and his group have worked on in mine safety. Among these were mining machine lighting, mine ambient lighting, miner cap lighting, and mine life-line egress lighting. Sammarco concluded by summarizing the importance of worker safety and the role lighting can play in promoting it.

Comments following this presentation included the observation that improved area illumination would be useful not only for mine workers but could assist in making public safety workers easier to see by nearby traffic while increasing the likelihood of detecting hazards in the work area.

Warning Beacon Intensity, Visibility, Glare and Closure Detection

Nicholas Skinner, LRC

The presentation discussed two laboratory studies performed by the Lighting Research Center. The first investigated the range of intensity needed for warning beacons to be detected in day and night scenes with and without visual clutter (750 cd minimum). Maximum intensity levels were determined which would insure that disability glare wouldn't prevent observers from seeing visual targets near the warning beacons (2000 cd). The second laboratory study investigated various flash configurations and their effect on the ability of observers to detect motion of an object. It was concluded that two lights in an On-10% configuration provided best closure detection.

Following this presentation, several participants stated that intensity control was desirable and available in some warning light products, but that this functionality was not always used by workers. In addition a participant mentioned the use of wig-wag flash pattern may help with detection.

Optical Design Characteristics and Visibility in Fog

Dr. John Bullough, LRC

The presence of fog results in scattered light from warning beacons that can make workers and other hazards less visible, despite the fact that standards do not address performance in fog. An analytical study of visibility as affected by warning beacon intensity and distribution, object location, fog density and vehicle headlights was undertaken. Each factor was found to affect visibility and could impact vehicle stopping distances by substantial amounts in some situations, possibly justifying limits on intensity and spatial distribution in foggy conditions.

The Impact of Highway Safety Flares on Driver Behavior

Philip Garvey, LTI

The presentation summarized a research project that investigated the use of pyrotechnic flares as a method of creating a safety zone around a disabled vehicle on a roadside. Various configurations of flare numbers, spacing, and patterns were investigated both with and without the presence of a police car. The researchers concluded that the presence of flares (regardless of number or

configuration) resulted in speed reductions and the movement of traffic into the adjacent lane and was superior to the presence of a police vehicle alone or no protection at all.

Impacts of Warning Light Intensity and Flash Patterns on Driver Behavior

Dr. Mark Rea, LRC

Dr. Rea discussed a recent field study conducted to assess how drivers responded to flashing barricade lights in a road constriction. A high-intensity light at the start of the constriction was judged as beneficial in the daytime, but created glare at night. Higher intensities (up to 250 cd peak intensity) were preferred in the daytime, but an optimal value of 25 cd for the peak intensity was found at night. Sequential flash patterns were preferred over random flashing, especially at night. Individuals from transportation agencies in New York State liked the ability to control intensity based on day/night conditions, and also stated that synchronized and sequential flashing was useful.

Alternative Color Channelizing Devices in Work Zones

Philip Garvey, LTI

A study was performed investigating the demarcation of highway exits in construction zones by use of channelizing devices with green markings near exits rather than orange markings only. Testing on a closed course with simulated highway exits found that the use of green markings in addition to orange allowed subjects to detect the presence of an exit sooner than orange alone. The second portion of the study utilized the green markings on actual highway construction zones to denote exits. The use of green markings in addition to the standard orange were found to decrease excursions into work zones, increase turn signal use, and reduce erratic maneuvers. Drivers surveyed about the highway exits exhibited a preference for the devices with green markings, and indicated that such devices helped them to find the highway exit more readily.

Group Discussion

Warning beacon topics

- Participants mentioned that SAE has various brightness intensity specifications for beacons based on whether the lights are for indication, warning or emergencies.
- Wig-wag pattern (one is on while other is off) was mentioned as a possible method to increase conspicuity of warning light systems.
- Participants mentioned that the use of multiple warning lights should be considered as a system rather than as individual, uncoordinated lights.

Traffic control topics

- Opinion was expressed that FHWA may have denied the use of green barrel striping to denote highway exits because of lack of evidence that accidents were prevented.
- A discussion about how to characterize safety in controlled experimental studies followed this point.
- Challenges with balancing innovation with existing standards were also discussed.

Law enforcement topics

- Police purchase vehicle lighting as a package with new vehicles.
- Troopers have manual control of lighting intensity, but don't always use it.
- Concern exists that an automated control of intensity could fail and result in inadequate lighting intensity.
- Participants expressed that a prevailing opinion that 'brighter is better' exists in law enforcement.
- Educational outreach to troopers could be helpful, especially video and demonstrations.

Field Demonstration of Lighting System

The demonstration was comprised of ten intelligent barricade-type warning beacons mounted on plastic drums placed on a curve on the LTI's closed track. The symposium attendees were introduced to the software developed under the grant and shown different beacon intensities, flash rates, and flash patterns.

The impact of visibility-reducing glare from the beacons that were too bright was clearly demonstrated. Consistent with the research findings presented earlier in the day, there was a preference among the attendees for a sequential pattern of beacon onsets (near-to-far sequence) at 1 Hz, where the beacons did not go fully off (25 cd/2.5 cd).

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Appendix A: Symposium Attendees

Attendees are listed alphabetically herein by their respective organizations.

Last Name	First Name	Title	Organization
Watson	Brian	Director, Business Development	ATSSA
Scott	Jeff	Road Safety Specialist	Beth's Barricades
Shaw	Brian	Deputy Directory	Emergency Medical Service Institute
Czajkowski	Bob	Principal Mechanical Engineer	Federal Signal Corporation
Chang	Arthur Chihhua	General Manager	ISOQA Technical Service LLC
Lin	Aaron	Measuring Engineer	ISOQA Technical Service LLC
Donnell	Eric	Associate Professor of Civil Engineering	Larson Transportation Institute (PSU)
Eie	Weiyin	Student	Larson Transportation Institute (PSU)
Garvey	Philip	Researcher, Transportation Operations Program	Larson Transportation Institute (PSU)
Klena	Jennifer	Extension Project Assistant	Larson Transportation Institute (PSU)
Pietrucha	Martin	Professor of Civil Engineering	Larson Transportation Institute (PSU)
Bullough	John	Director of Transportation and Safety Lighting Programs	Lighting Research Center (RPI)
Rea	Mark	Director of the LRC and Professor of Architecture and Cognitive Sciences	Lighting Research Center (RPI)
Skinner	Nicholas	Lead Research Specialist	Lighting Research Center (RPI)
Sammarco	John	Principal Research Engineer	NIOSH
Briggs	Matthew	Traffic Control Specialist Manager	Pennsylvania DOT
Dougherty	Gerald	Fleet Manager	Pennsylvania State Police
Flynn	Tracy	Corporal	Pennsylvania State Police
Matiskella	Eric	Trooper	Pennsylvania State Police
Matuella	Joseph	Director, Transportation Division	Pennsylvania State Police
Witalec	Todd	Sergeant	Pennsylvania State Police
Macchione	Tom	Manager of Traffic Engineering	Pennsylvania Turnpike Commission
Carroll	Jim	Altoona Branch Manager	Rae-Lyn Enterprises, Inc (PA ATSSA)
Olson	Lyndsay	Administrative Assistant	Rae-Lyn Enterprises, Inc (PA ATSSA)
Olson	Marshall	Superintendent	Rae-Lyn Enterprises, Inc (PA ATSSA)
Taylor	Nathan	Engineering Manager	Superior Signals
Golden	John	Amber National Sales Manager	Whelen Engineering
Kehoe	Matt	DOT Sales Manager	Whelen Engineering