U.S. DEPARTMENT OF ENERGY

Office of ENERGY EFFICIENCY & RENEWABLE ENERGY

Investigating the Health Impacts of Outdoor Lighting

Virginia Tech Transportation Institute

Dr. Ronald Gibbons, Director, Center for Infrastructure Based Safety Systems

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Project Summary

Timeline:
Start date: 9/1/2017
Planned end date: August 31, 2018
Key Milestones

Key Milestones & Deliverables

Year 1
Test protocols, lighting test setups and participant recruitment completed

Year 2
Completed Participant Testing
Complete analysis and results reporting

Budget:

Total Project $ to Date:

- DOE: $390,065
- Cost Share: $192,202

Total Project $:

- DOE: $1,214,625
- Cost Share: $303,566

Key Partners:

Thomas Jefferson University	Penn State University

Project Outcome:

This project comprises the measurement of the impact of lighting on Melatonin levels in realistic outdoor lighting levels. Using a variety of Correlated Color Temperatures, the lighting impact on drivers, pedestrians and those experiencing light trespass will be measured in a naturalistic environment for a period of 2 to 4 hours. The results should provide guidance for decisions makers selecting light sources for outdoor spaces and inform the public on the potential health impacts of outdoor lighting

Team

- Thomas Jefferson University
  - Bud Brainard
  - John Hanifin
    - Provide support for the Experimental Design, Blood Drawing and Analysis of Blood Levels
- Penn State University
  - Kevin Houser
    - Provide Support for the lighting design and validation
- Philips Lighting / Cree Lighting
  - Equipment support

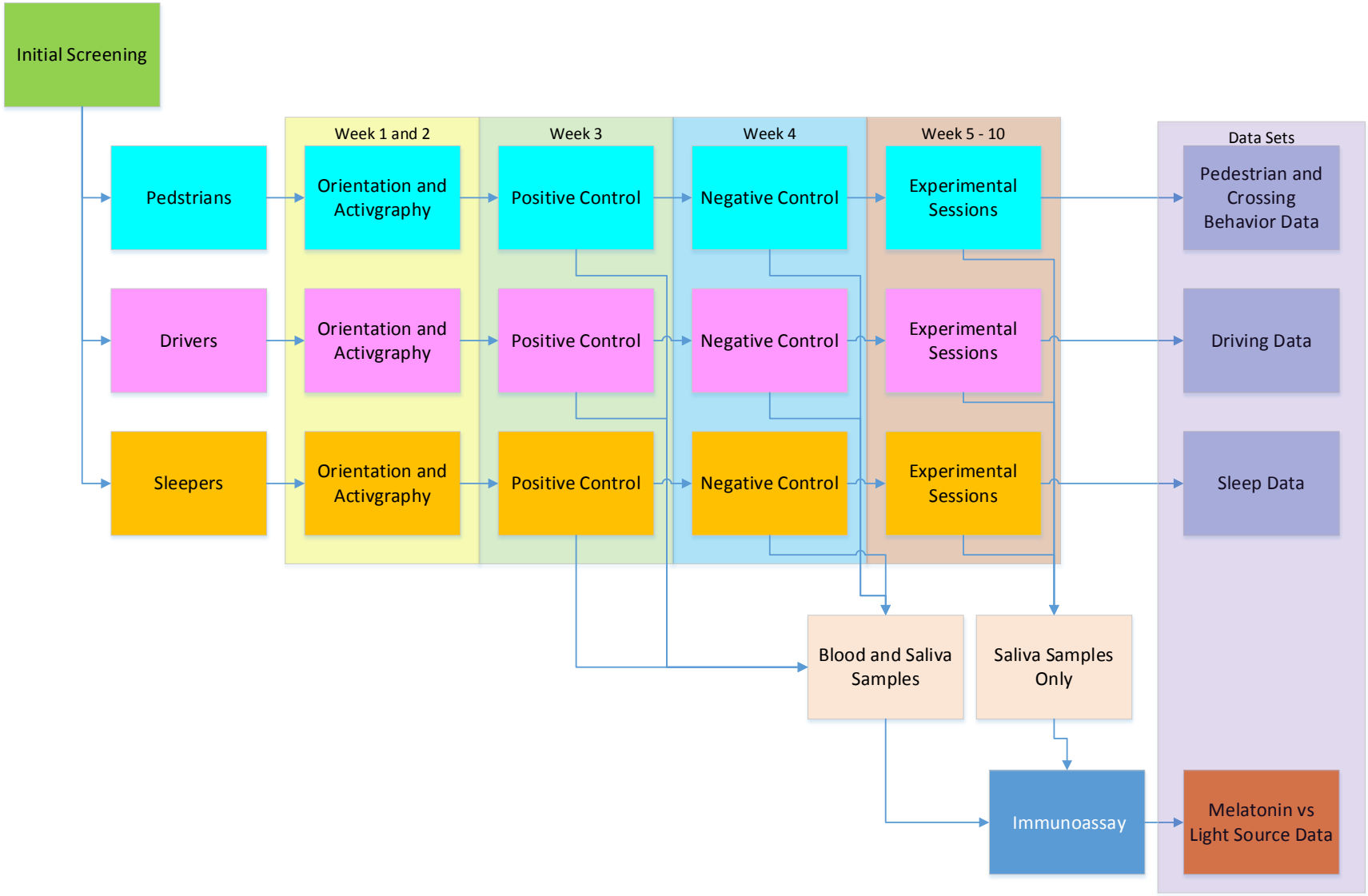
Challenge

- There is an impact of lighting on the human melatonin system through the retina of the eye. Several studies have shown this Melatonin impact may change circadian rhythms and impact sleep and health.
- This impact may impact the users of lighted roadways including drivers, pedestrians and those living along the roadway
- This is an impediment to the implantation of Solid State Roadway Lighting as agencies may not want to convert due to the negative health issues,
- However, this effect has never been measured in a Naturalistic Lighting Environment.
- Data is needed to show this impact and provide specification of the lighting requirements to provide the best possible balance of the positive visibility and energy based benefits of SSL while minimizing the negatives.

Approach

- **This project will measure the impact of different lighting types on melatonin in the blood of users of a lighted space at dosage levels appropriate to that space.**
  - Not full field
  - No fixed observation point
- Evaluated for all roadway users
  - Drivers
  - Pedestrians
  - “Sleepers” – Those living along the side of the roadway
- Established on the Virginia Smart Road

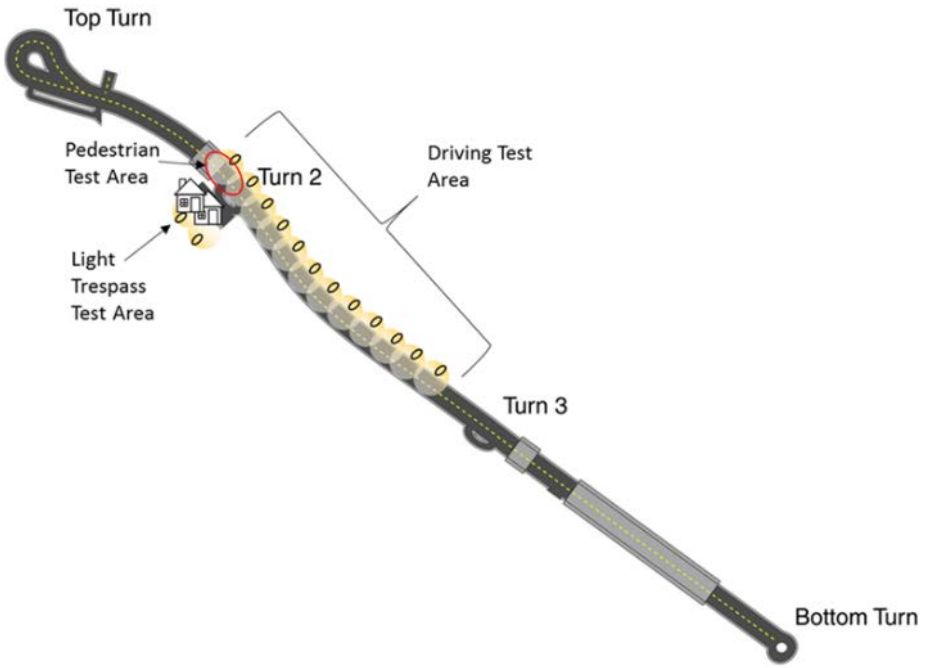
Approach


Initial Screening
Week 1 and 2
Week 3
Week 4
Week 5 - 10
Data Sets
Pedstrians
Drivers
Sleepers
Orientation and Activgraphy
Orientation and Activgraphy
Orientation and Activgraphy
Positive Control
Positive Control
Positive Control
Negative Control
Negative Control
Negative Control
Experimental Sessions
Experimental Sessions
Experimental Sessions
Pedestrian and Crossing Behavior Data
Driving Data
Sleep Data
Blood and Saliva Samples
Saliva Samples Only
Immunoassay
Melatonin vs Light Source Data

Approach

Virginia Smart Road

- Variable lighting section
  - 39 light towers
  - ~95% of lighting configurations found on U.S. highways
  - Differential spacing
  - Height adjustable
  - Intelligent Transportation Systems (ITS) equipment
  - 3 luminaires/poles
  - Varying intensities



Approach

Experimental Design

Independent Variable	Luminaires to be tested
Lighting Type	No roadway lighting, 2100K HPS 2700K LED 4000K LED 5000K LED 6500K LED
Exposure Time	Between 1.5 and 6 hours, depending on the task

Test Methods

- **2 Test Methods will be performed**
  - Positive and Negative Control
    - Positive and negative controls of melatonin secretion will serve as reference points to compare the melatonin levels in the three experimental scenarios
    - Based on Blood and Saliva Samples
    - Positive control is to strongly suppress the dim light melatonin onset (DLMO) and peak melatonin secretion.
    - Negative control is to allow the normal onset of DLMO in the evening and the first half of peak melatonin secretion.
  - Naturalistic Exposure Testing
    - Testing of light performance under a variety of Blue Content Lighting systems
    - Based on Saliva Samples only
- **Melatonin assay**
  - Blood and saliva samples will be analyzed for melatonin by radioimmunoassay

Approach

Test Session

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Approach - Driving Exposure Experiment

- Participants will drive the experimental vehicle from 1:00 a.m. to 3:00 a.m. at a speed of 35 mph. with Low-beam headlamps
- Participants will be given detection tasks (detection of small wooden targets of 18 cm × 18 cm or detection of pedestrians) to keep them engaged.
- Two participants at once.

Time of Exposure	Duration of Exposure	Light Level/ Corneal Irradiance	Light Source	Blood/Saliva Sampling	Tasks
11 a.m. to 1 a.m.	2 hours	200 lux	Incandescent	No sampling	
1 a.m. to 3 a.m.	2 hours	1.0 cd/m^2	No roadway lighting 2100K HPS 2700K LED 4000K LED 5000K LED 6500K LED	Saliva at 30-minute intervals	Visibility assessment tasks

Approach – Test Methods

- **Pedestrian Exposure Experiment**
  - Spending time along the side of the Smart Road as a pedestrian

Time of Exposure	Duration of Exposure	Light Level/ Corneal Irradiance	Light Source	Blood/Saliva Sampling	Tasks
8 p.m. to 10 p.m.	2 hours	200 lux	Incandescent	No sampling	
10 p.m. to 2 a.m.	4 hours	1.0 cd/m^2	No roadway lighting 2100K HPS 2700K LED 4000K LED 5000K LED 6500K LED	Saliva at 40-minute intervals	Gap acceptance tasks, walking, sitting at a table, etc.

- **Light Trespass Exposure Experiment**
  - Sleeping in a bedroom located along the side of the Smart Road

Time of Exposure	Duration of Exposure	Light Level/ Corneal Irradiance	Light Source	Blood/Saliva Sampling	Tasks
10 p.m. to 12 a.m.	2 hours	200 lux	Incandescent	No sampling	
12 a.m. to 2 a.m.	2 hours	Maximum light trespass allowed by IES RP-8-14	No roadway lighting 2100K HPS 2700K LED 4000K LED 5000K LED 6500K LED	Saliva at 40-minute intervals	Participants will lie on the bed in the simulated bedroom.

Impact

- The results of the project will have significant impacts on the design and implementation of Solid State Roadway Lighting.
  - Provide guidance on the light source characteristics and lighting level limitation to ensure that the roadway users are not impacted.
  - Will provide data for the continued modeling of the lighting impact on users
  - Breakdown the confusion in the industry to impact of the lighting
    - Provide a data to respond to AMA positions statement on the impact of Solid State Lighting on Health.

Progress

Test Spaces	Space Usage	Requirements	Complete
Conditioning Room	This room is setup to be the waiting area where participants gather a controlled dosage of light in an relaxed environment before testing begins	200 Lux average, 4000K, Seating for at least 4 people	90%
Experimental Room	This area is where participants are dosed with a established light level for the positive and negative controls	This space requires individual test booths that are light controlled with an exposure light, a table and a chair	100%
Blood Protocol Room	This space requires the equipment and material necessary for the processing of the samples.	The room requires a lock, a plastic washable floor, freezer and blood sampling equipment.	100%
Light Trespass Building	This is the building along the Smart Road which will provide the location to test light trespass.	Weather tight. Room for a bed with a reclined participant, a window where light can enter, room for 2 participants	70%
Smart Road	This test area is the Virginia Smart Road.	Room for the pedestrians, the driving course and the light trespass location also must have the 6 light sources to be used for testing installed.	50%

- **Protocols have been developed**
  - Institutional Review Board Approval has been obtained
- **Staff have been trained**
  - Hired a Phlebotomist/EMT for the blood collection

Stakeholder Engagement

- This project is early stage.
- We have presented the plan at:
  - 2 DOE workshops
  - 1 DOE Roundtable
  - Discussed the plan at 2 IES Roadway Lighting Committee Meetings
- **Additional funding has been discussed with:**
  - NCHRP -5-23
    - Effects of LED Roadway Lighting on Driver Sleep Health and Alertness
  - Virginia DOT
    - Additional Light Sources and additional lighting levels
- **Future Plans**
  - Additional Meetings and Presentations
  - Published papers and workshops once project is complete

Remaining Project Work

- **Testing**
  - Commence testing once the facilities have been setup (May 2018)
  - 33 participants (11 in each task group)
- **Analysis**
  - A linear mixed model analysis will be used to assess the effects of lighting type on melatonin level in each of three experiments.
- **Reporting**
  - Report will document the analysis and is expected to provide insights into the overall effect of light exposure on the melatonin levels of drivers on the roadway, pedestrians, and homeowners with bedrooms exposed to street lighting.

Thank You

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REFERENCE SLIDES

Project Budget

Project Budget: The Budget is $1,214,325 with $303,566 Cost Share. At this point only $390,065 has been awarded. A Request for the additional funding has been prepared.
Variances: No Variances at this point
Cost to Date: 76.58%
Additional Funding: None at this time

Budget History					
September 1, 2017– FY 2018 (Spent to Date)		FY 2018 (Pending)		FY 2019 – August 31, 2019 (planned)	
DOE	Cost-share	DOE	Cost-share	DOE	Cost-share
$190,604	$30, 645	$199,461	$161,557	$824,560	$111,364

Project Plan and Schedule

ID	WBS	Task Name	Duration	Start	Finish
1	1	Task 1 – Project Planning	21 days	Fri 9/1/17	Fri 9/29/17
2	2	Task 2 – Review of Existing Literature and Experimental Results	45 days	Mon 10/2/17	Fri 12/1/17
3	**3**	**Task 3 - Experimental Setup**	**150 days**	**Mon 10/2/17**	**Mon 4/30/1**
4	3.1	Task 3.1 – Smart Road Setup	120 days	Mon 10/2/17	Fri 3/16/18
5	3.2	Task 3.2 – Photometric Characterizatio	30 days	Mon 3/19/18	Fri 4/27/18
6	3.3	Go/NoGo Complete Roadway Preparation	0 days	Mon 4/30/18	Mon 4/30/18
7	**4**	**Task 4 – Experimental Performance**	**220 days**	**Mon 4/30/18**	**Fri 3/1/19**
8	**4.1**	**Task 4.1 – Positive and Negative Control**	**50 days**	**Mon 4/30/18**	**Fri 7/6/18**
9	4.1.1	Task 4.1.1 – Driving Experiment	50 days	Mon 4/30/18	Fri 7/6/18
10	4.1.2	Task 4.1.2 – Pedestrian Experiment	50 days	Mon 4/30/18	Fri 7/6/18
11	4.1.3	Task 4.1.3 – Light Trespass Experiment	50 days	Mon 4/30/18	Fri 7/6/18
12	**4.2**	**Task 4.2 – Naturalistic Testing**	**170 days**	**Mon 7/9/18**	**Fri 3/1/19**
13	4.2.1	Task 4.2.1 – Driving Experiment	170 days	Mon 7/9/18	Fri 3/1/19
14	4.2.2	Task 4.2.2 – Pedestrian Experiment	170 days	Mon 7/9/18	Fri 3/1/19
15	4.2.3	Task 4.2.3 – Light Trespass Experiment	170 days	Mon 7/9/18	Fri 3/1/19
16	5	Task 5 – Analysis	65 days	Mon 3/4/19	Fri 5/31/19
17	6	Task 6 – Results Reporting	65 days	Mon 6/3/19	Fri 8/30/19