Exo-Visibility Modeling – Working around the Endo

Ron Gibbons

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1872

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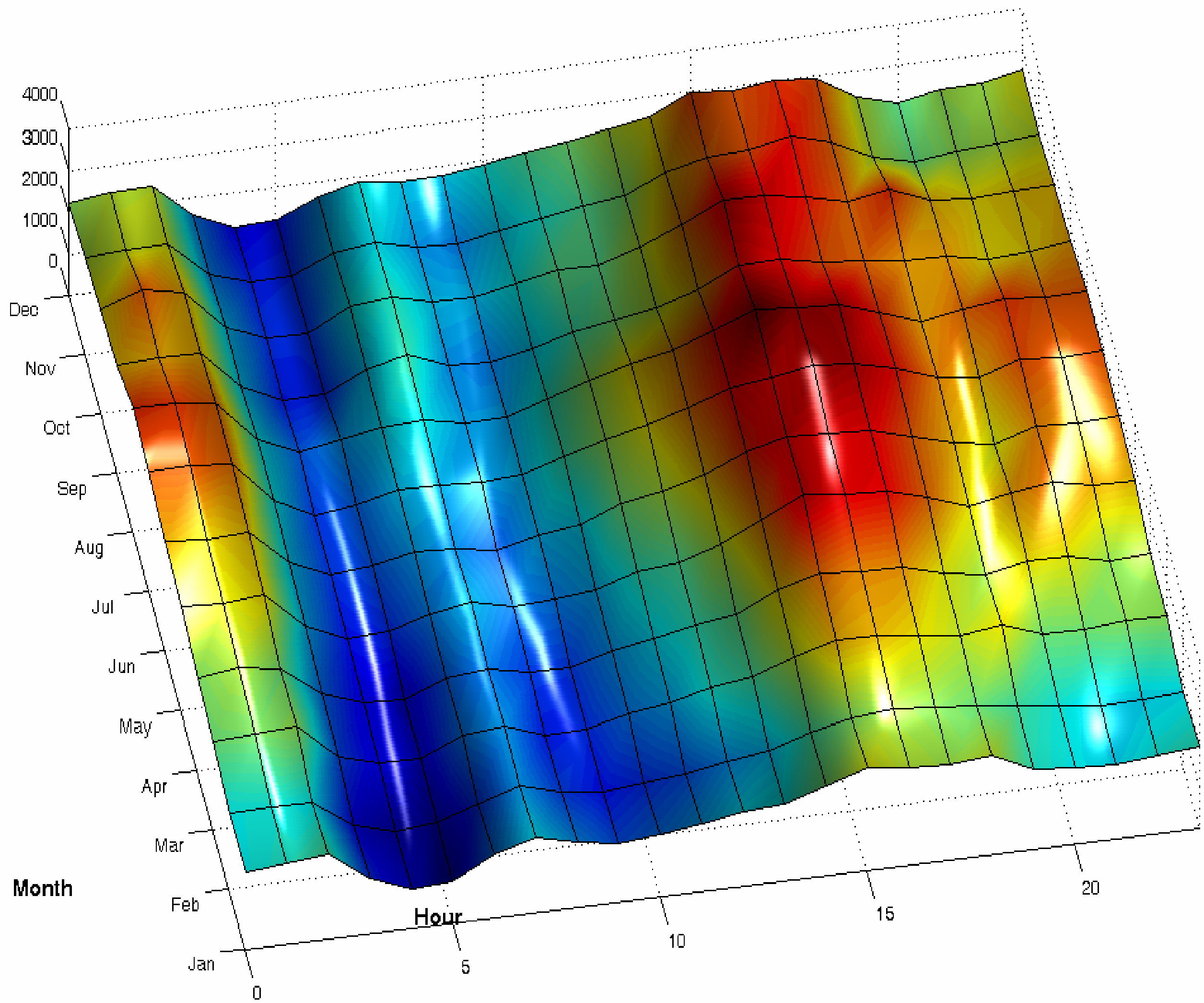
Lighting and Driver Safety What we know…

- Box [1972] showed that the night/day accident ratio was 66% higher on unlighted freeways than on lit ones.
  - 0.5 lux appeared to be the illuminance level which provided the lowest accident rate
- Osner [1973] and Nishimori[1973] both showed a 56% reduction in accidents when lighting was added to a roadway.
- CIE Pub. Nº 93 ***"Road Lighting as an Accident Countermeasure"*** rigorously analyzed 62 lighting and accident studies from 15 countries.
  - "(S)tatistically significant results show reductions (in nighttime accidents) of between 13 and 75 percent."

Motor Vehicle Crashes – Implications of Darkness



Vehicle occupant deaths, FARS, 1987-2003

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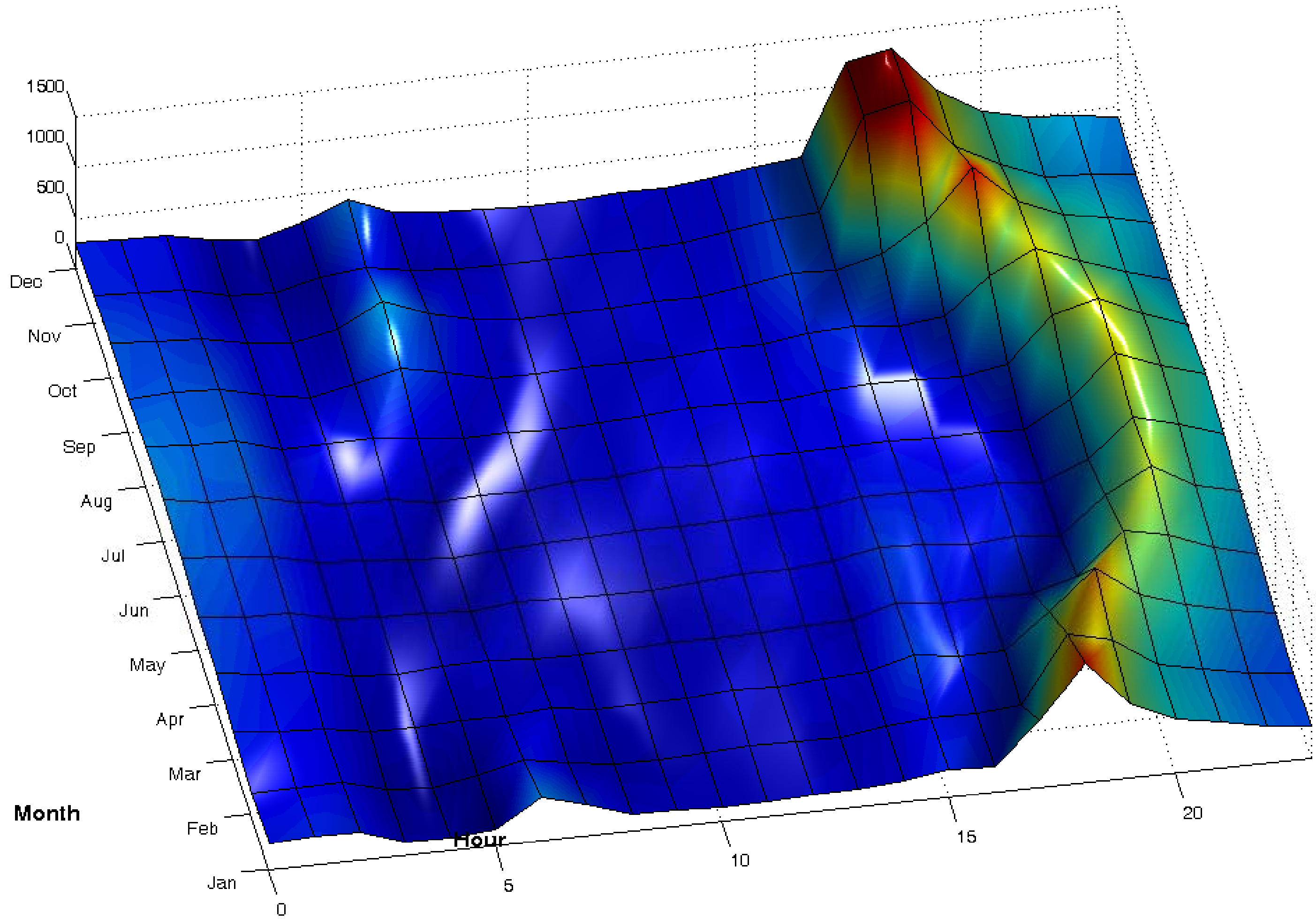
Motor Vehicle Crashes – Implications of Darkness



Pedestrian deaths, FARS, 1987-2003

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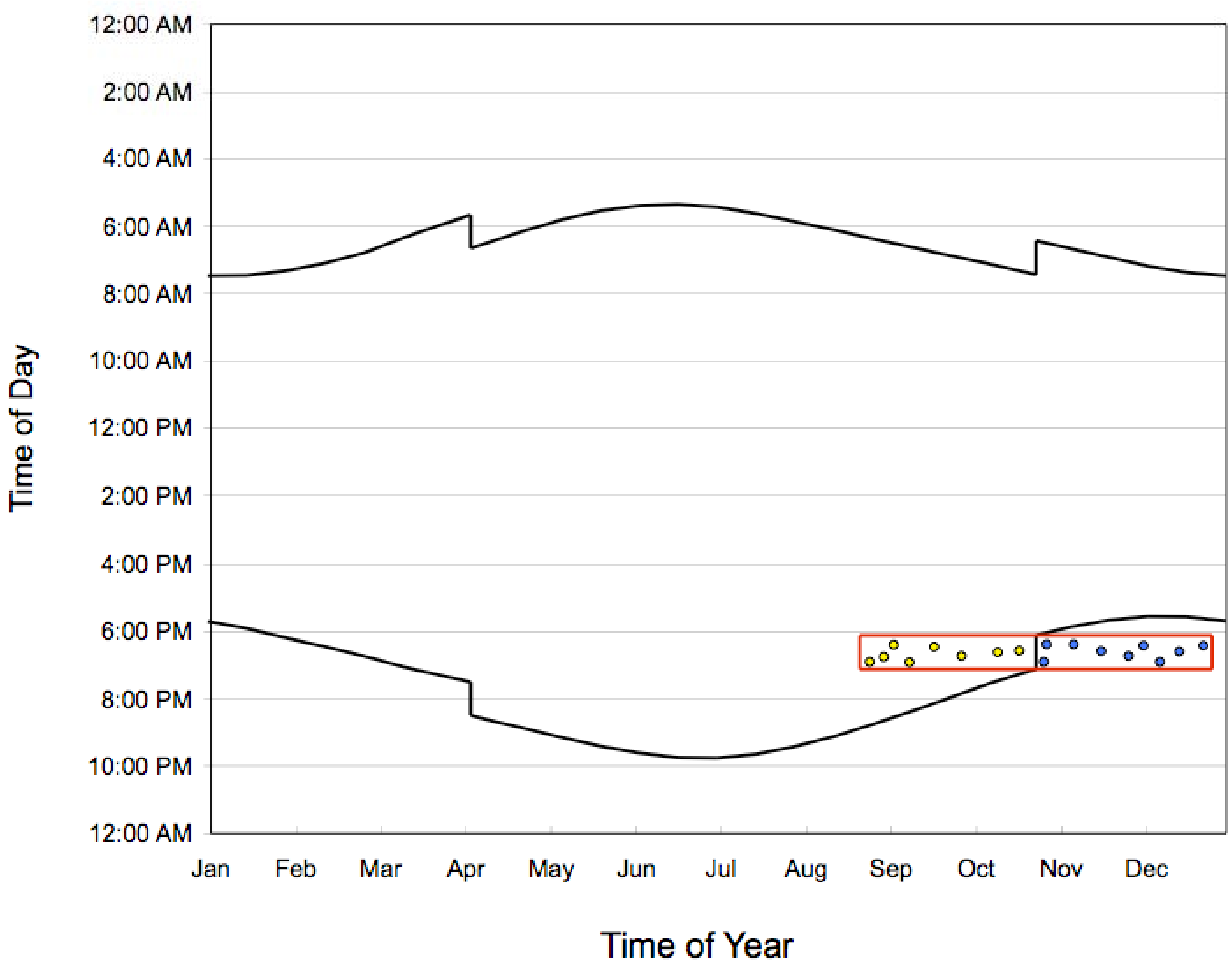
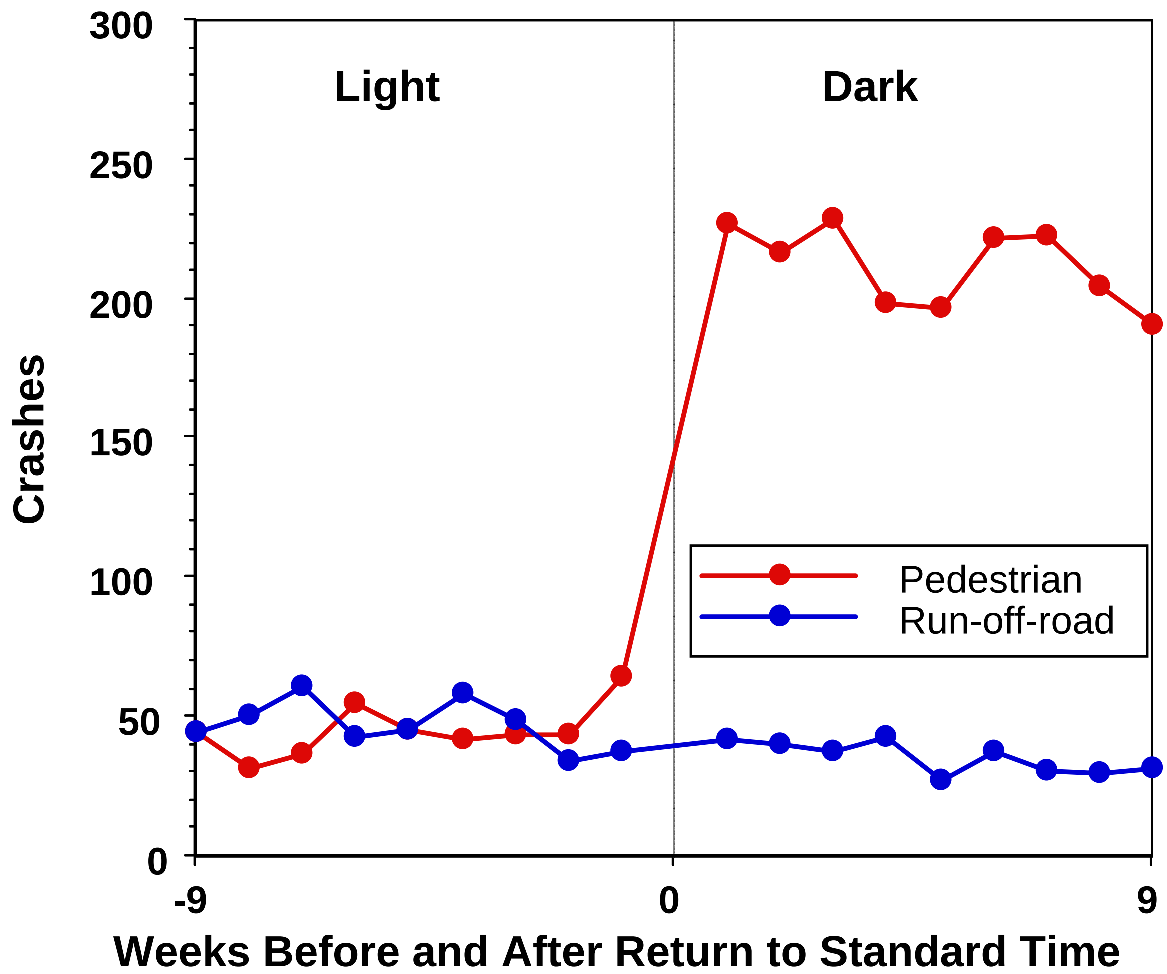
Evaluating Impact of Light



Pedestrian Fatalities – Fall PM Return to Standard Time



Exo-Visibility Modeling

- The Goal
  - We want to provide a visual environment that will allow every driver to see the objects they are required to see to travel safely.

- The Reality
  - Determining the what the driver is doing is nearly impossible
  - The Metrics to be used are widely varying

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Visual Activity

- As drivers, the visual task is a very complex activity
  - Detection of road hazards
  - Lane keeping
  - Wayfinding
  - Monitoring of the instrument panel
  - Observing other drivers
  - Pedestrian Detection
  - Sightseeing?
  - Minding the other occupants in the vehicle
- We distribute our visual resources between all of these activities
  - We allot attention to the task which seems most demanding
  - Not necessarily the most important

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Object Detection Process

- Visual Search
  - We have a standard search pattern as we drive
    - Looking for objects
    - Looking at signage
    - Following the road path
- Detection
  - Through the visual search, we find an object of interest
    - This detection can be peripheral
      - Spotted to the side as a result of motion or through high conspicuity
    - This detection can be foveal
      - Found through the visual search pattern
- Recognition
  - We attend to the objects of interest
  - This is a foveal task
- Reaction
  - We decide what the appropriate course of action
    - Braking, steering etc.

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Object Visibility

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Visibility with Glare

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Visibility with Extreme Glare

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Visibility of Objects

- We see objects based on their contrast to the background
  - This can either be color contrast or luminance contrast
  - In roadway lighting design, color is not considered
- The IES lighting design requirements are consensus standards based on experience
  - Lighting design can be performed based on illuminance, luminance or STV
    - The STV is a weighted average of a series of calculated Visibility Levels for a defined target
      - Current target is a flat 7" square with 50% reflectance which represents the smallest object which will collide with a vehicle
      - VL is calculated as: $VL = \frac{C_{act}}{C_{th}} = \frac{L_{Target} - L_{Background}}{\Delta L_{th}}$

What is the Metric?

- Utilizing the Luminance Camera results we are looking at current metrics for analyzing roadway luminance visual Scenes
  - In addition to standard contrast we also calculate RSS, PSS, Doyle, and Michelson contrast metrics

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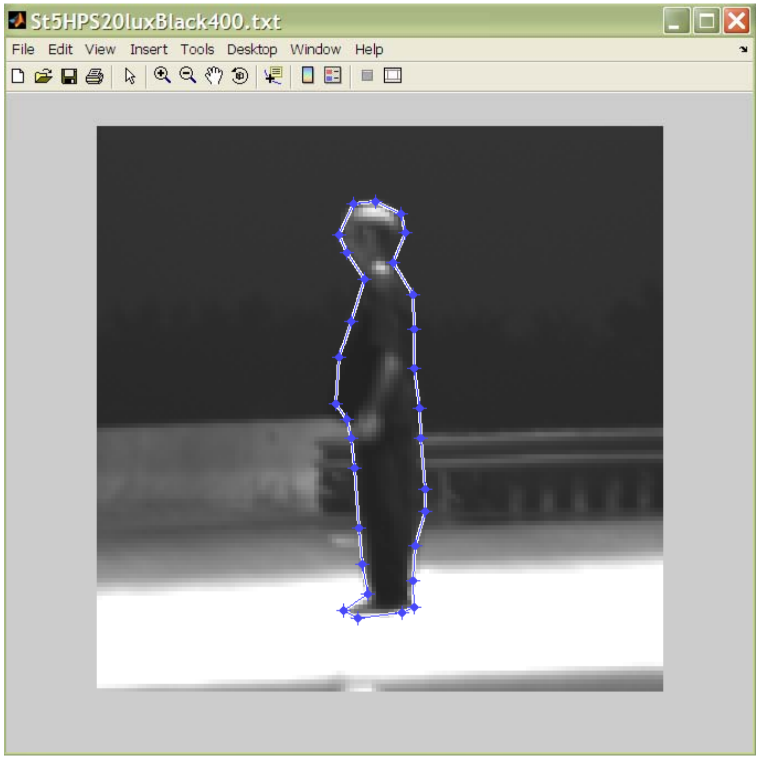
Luminance Metrics

- Applying multiple contrast metrics to images
- Semi-automated process
  1. Accesses database of images for analysis
  2. User selects target
  3. Automatically calculates contrast metrics



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Luminance Metrics

- Results in luminance and contrast information

Mean Luminance of Target	0.677cd/m^2	0.961cd/m^2
Mean Luminance of Background	1.579cd/m^2	1.492cd/m^2
Weber Contrast	-0.571	-0.356
Simple Contrast	2.331031	1.552046
Michelson Contrast	0.399585	0.216315

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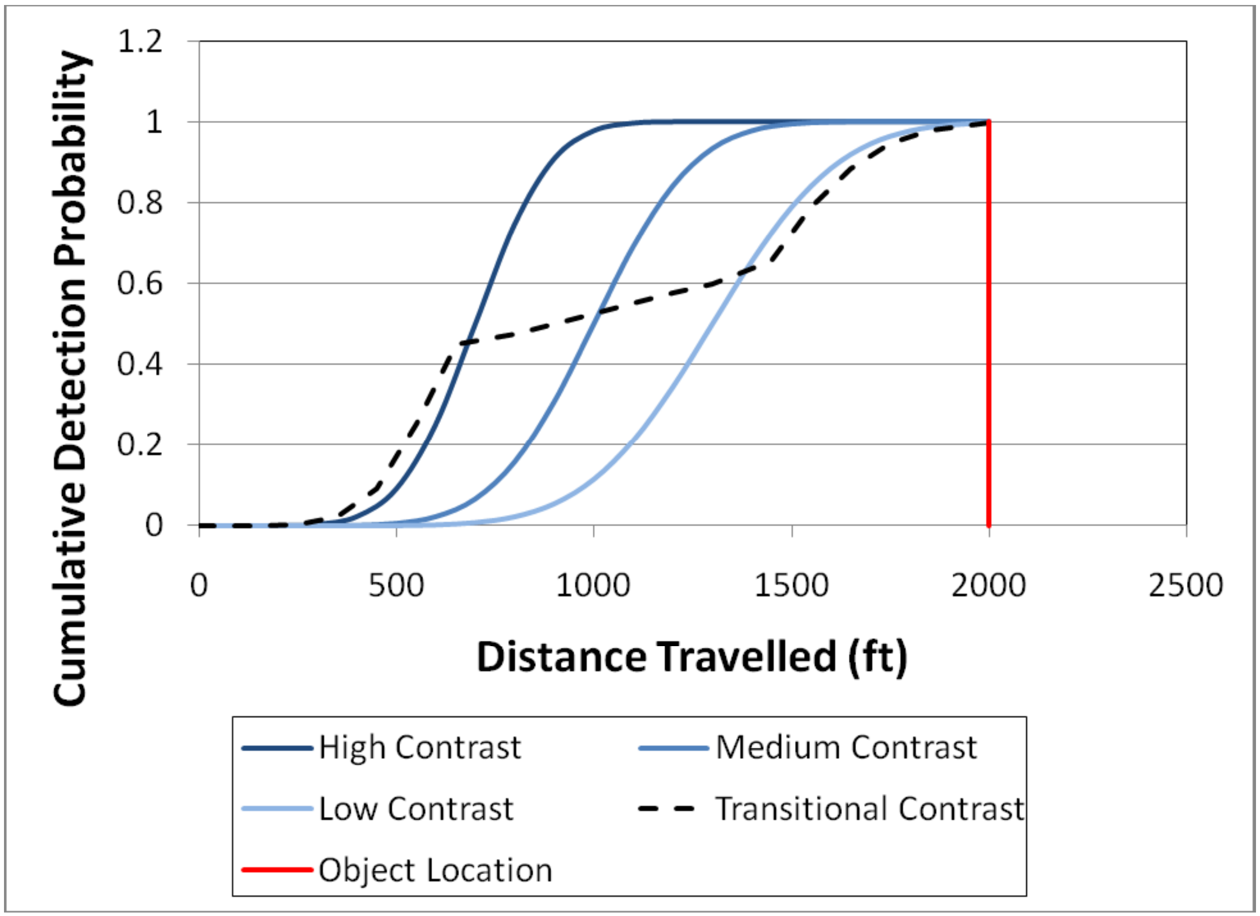
Dynamic Driver Vision Model

- As an approach to establishing the visual needs of a driver, this research project considers the development of a model of driver vision.
- This model will establish the framework of the visual processes utilized by a driver.
- The needs of the driver in any situation can then be assessed and lighting, delineation and signage requirements established.

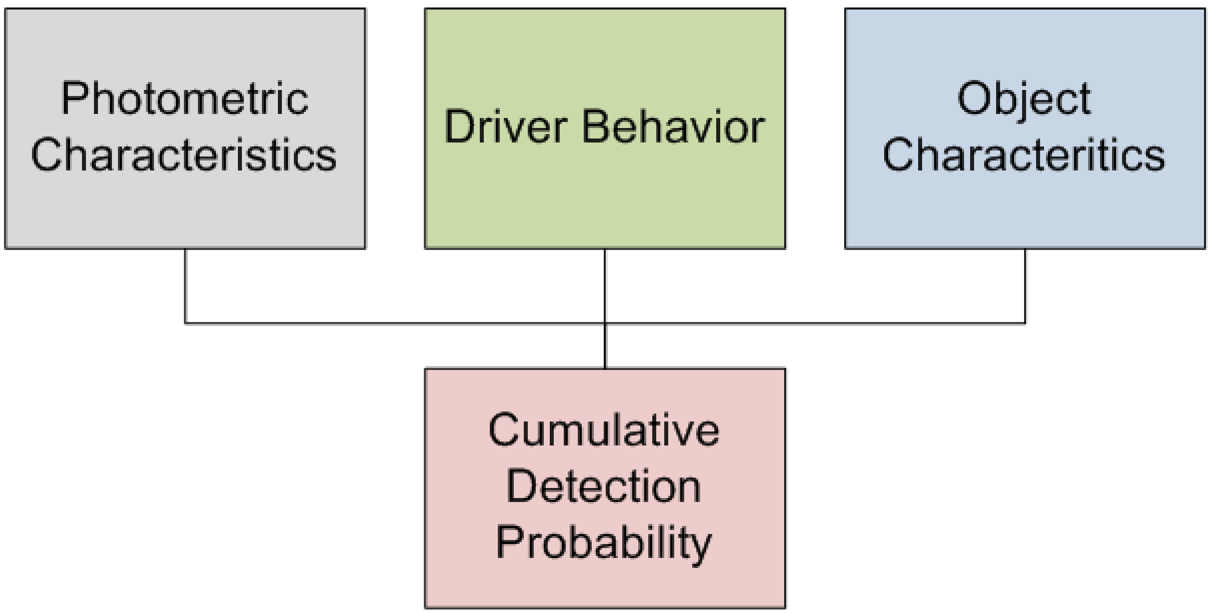
Visual Scene Assessment

- Traditionally, visual aspects of the road environment have been considered in "silos".
  - Roadway lighting design is performed independently from signage, delineation, and head-lighting.
  - Similarly, ambient lighting is not considered in definitions of require sign and light levels.
- Consideration must be made of the entire visual scene.
  - The visibility of all objects within a visual scene can be established by considering the cumulative detection probability

Cumulative Detection Probability



CDP



$$CDP = f\left(Photometry, Behavior, Objects\right)$$

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Simple Model Characteristics

- Photometric
  - Contrast
  - Luminance
  - Glare
  - Ambient Lighting
  - Color
- Object
  - Size
  - Interest / Relevancy
  - Shape
  - Position
  - Movement
- Human Behavior
  - Eye Scanning Behavior
  - Fatigue
  - Attention
  - Age
  - Experience

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The Dynamic Driver Vision Model

- The DDVM will consider all of the interactions in the characteristic categories
- The requirements and limitations for lighting, delineation and signage are established to ensure that the CDP reaches the required level
- As an extension of this model, Empirical Bayesean techniques may be used to evaluate the safety impact on the driver

$$y_{ni} \sim Poisson(\lambda_i)$$

$$\log(\lambda_i) = \beta_0 + \beta_1 \text{lighting} + \beta_2 \log(AADT) + \beta_3 region + \cdots$$

Experimental Method

- We will be gathering data in all three factor categories on closed test facilities at VTTI and TTI.
- Using an eye-tracker and a dynamic luminance camera, the detection of objects in the roadway will be measured.
  - Eye Glances will provide driver behavior
  - Luminance Camera will provide photometric characteristics
  - Experimental control will provide object characteristics

Experimental Design

Table 1. Data collection experimental design

Factor	Levels	Test Location
Age	2 Age Levels (Young and Older)	VTTI and TTI
Lighting	2 levels of Overhead Lighting (No Lighting, High Pressure Sodium,)	VTTI
Signage	2 Different Sign Types at Varying Locations	TTI
Object	2 Varying object types at differing locations (Pedestrians, Roadway Obstacles)	VTTI and TTI
Glare	2 Levels (Other vehicles Present\Absent)	VTTI
Markings	2 different pavement Marking Types	TTI

Eye Tracker

- Arrington Research Binocular Head Mounted Eye Tracker
- 3 Cameras, 2 IR emitters
  - Camera and IR on each eye
  - Center mounted scene camera

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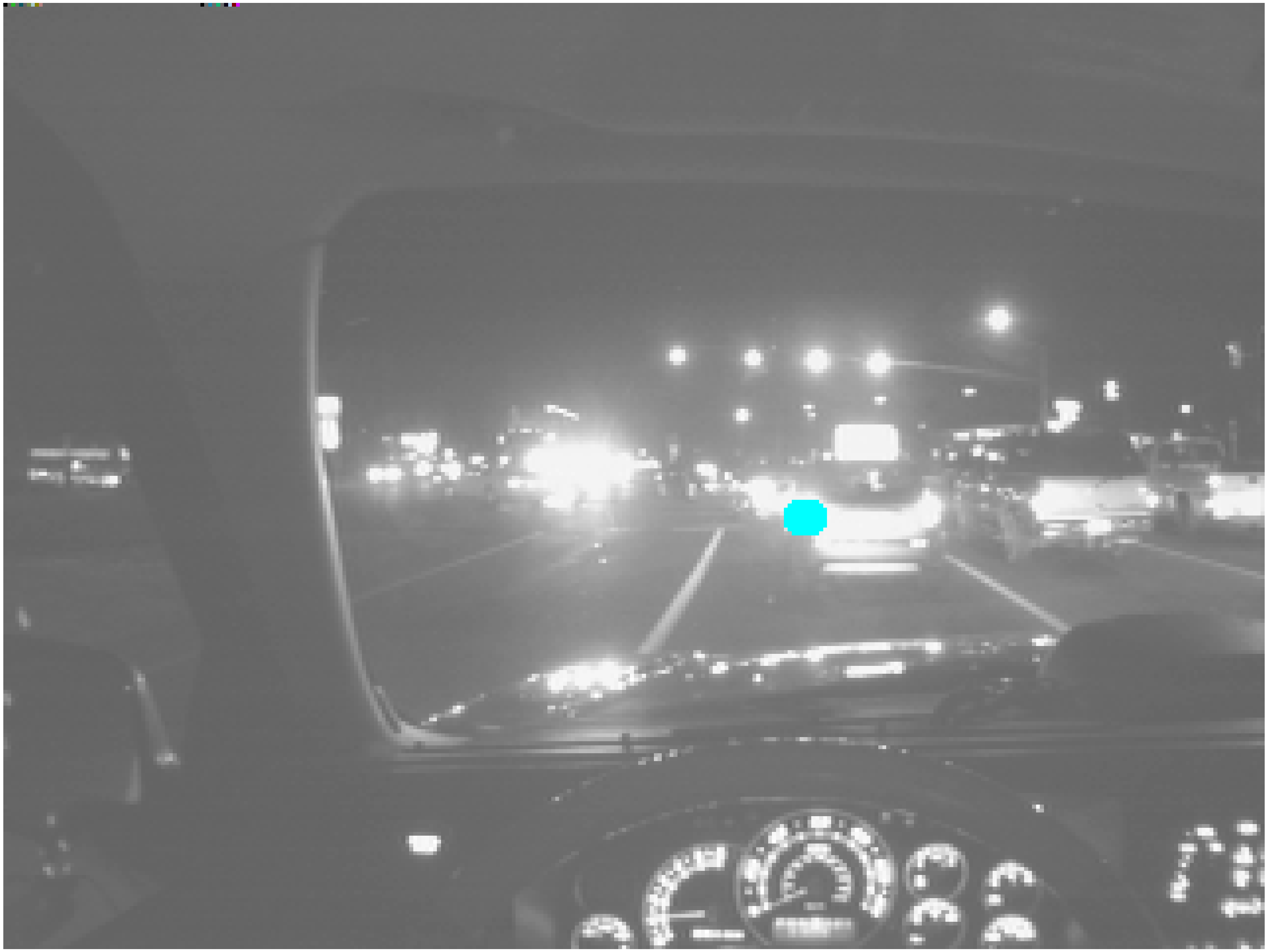
Eye Tracking Demo



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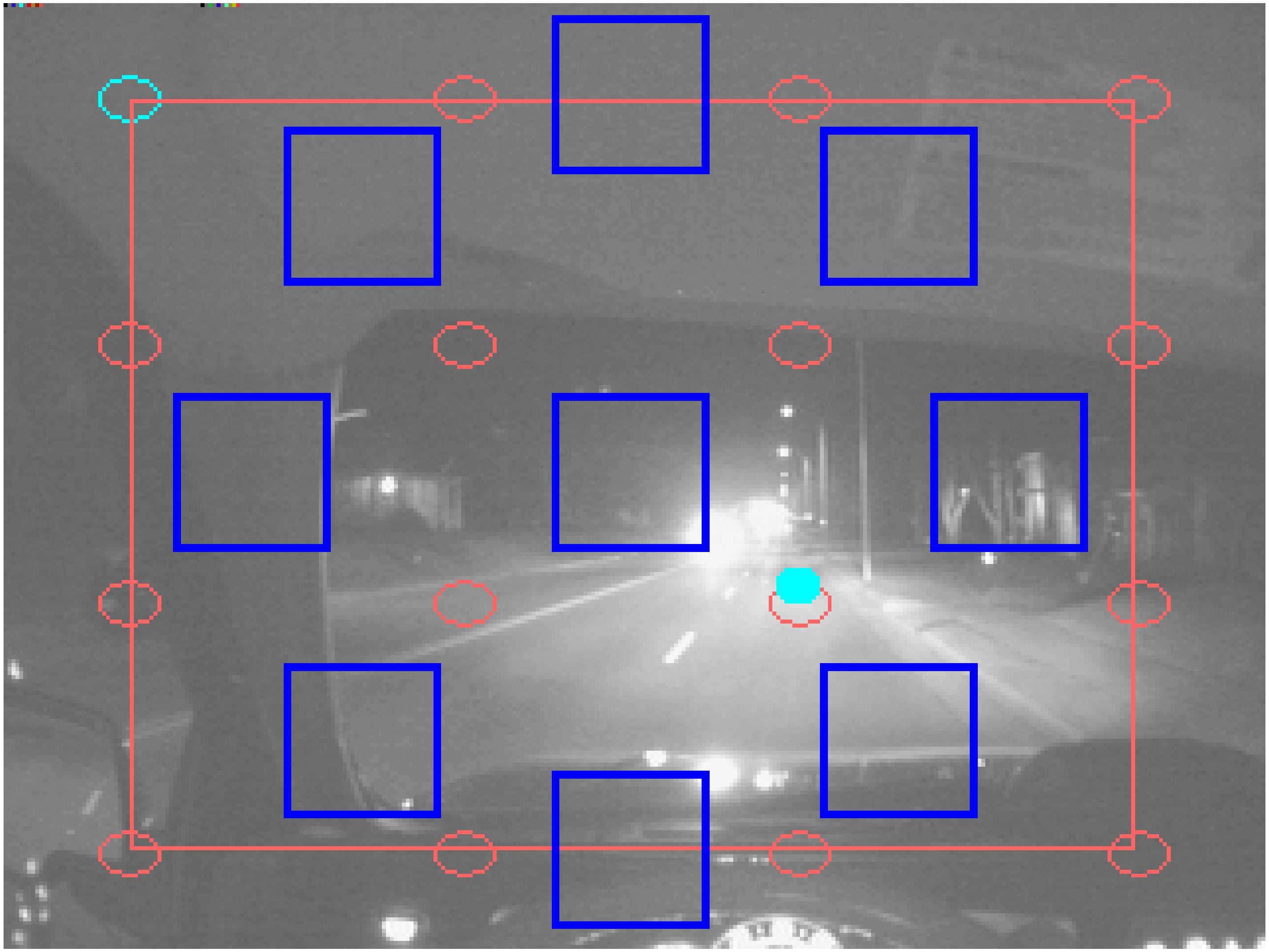
Downtown Eye Tracking



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Luminance Camera

- 12 bit Point Grey Digital Firewire camera.
  - Calibrated against a Prometric Still Luminance Camera
- Varying shutter and gain values determine the range of luminance measured
  - 2 cameras can be coupled to increase dynamic response
- Individual images are stored for later analysis

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Luminance Camera

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Objects

- Potential Objects for the investigation are:
  - Pedestrians
  - Bicycles
  - Tires
  - Animals
  - Off and on-axis objects
  - Surrogates
  - Other vehicles
  - Glare
  - Signs
  - Pavement Markings

Experimental Method

- Participants will be tested in a vehicle with the established instrumentation package,
- Driving on the test facilities, objects will be presented at the given locations
- Object detection will be self reported by the participant.
- The photometric characteristics of the object will be established at the point of detection using the luminance camera
- The detection mode and other visual behavior will be established using the eye tracker
- The driver will be unaware (waiting for IRB)
  - No dogs (too traumatic)

Model Framework

- Logistic Regression approach:
  - Logistic regression provides the research team with a tool that can incorporate both categorical and continuous variables
  - Also provides a probability of detection given the set of variables
  - $\text{Logit}[P\ Y=1] = \alpha + \beta_1 X_1 + \beta_2 X_2 + \ldots + \beta_k X_k$
  - Where detection: $Y = 1$

Model Framework

	Parameters				
Probability	Distance	Age Group (Young and Older)	Luminance	Roadway Objects (Pedestrian, Roadway)	Glare (Present vs. Absent)
Y = ?	500	Young	.5	Pedestrian	Present
Y = ?	1000	Older	.3	Pedestrian	Present
Y = ?	1500	Young	.15	Deer	Absent
Y = ?	2000	X_1	X_2	X_3	X_4

Model Framework

- This method only provides a snapshot at a specific distance
- Requires calculating the probability given at distances of 250ft, 500ft, …

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Project Timing

- Completing the instrumentation package
- Initial model framework being established
- Participant testing will take place over the summer and fall

- Future Testing
  - Other factors
    - Fatigue
    - Attention
    - Ambient conditions