MUNICIPAL
SOLID-STATE STREET LIGHTING
SYMPOSIUM
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Tale of Four Cities

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Research Questions

Which light source is preferred by the community?

Is there a visibility enhancement with broad spectrum (white) light sources?

- Detection distances
- Color contrast

Can lighting levels be reduced (50% - 75%) and still achieve safety goals?

What is the difference in energy use?

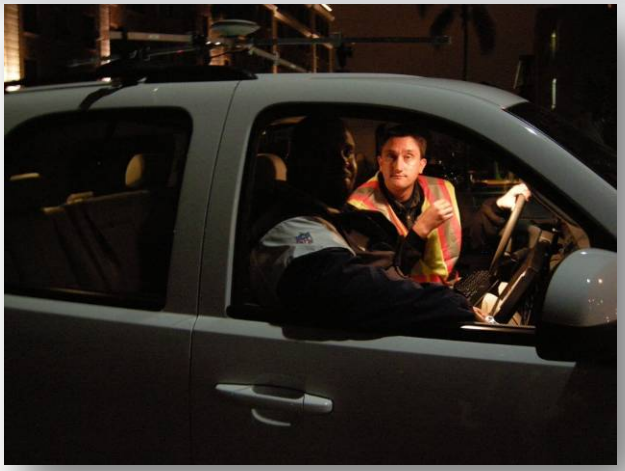
Subjective Evaluation

‘It would be safe to walk here, alone, during daylight hours’
‘It would be safe to walk here, alone, during darkness hours’
‘The lighting is comfortable’
‘There is too much light on the street’
‘There is not enough light on the street’
‘The light is uneven (patchy)’
‘The light sources are glaring’
‘It would be safe to walk on the sidewalk here, alone, during darkness hours’
‘I cannot tell the colors of things due to the lighting’
‘The lighting permits safe navigation.’
‘I like the color of the light.’
‘I would like this style lighting on my city streets.’
‘How does the lighting in this area compare with the lighting of similar city streets at night?’

Visibility Tests

Objective assessment of small target visibility

Response metric (object detection distance)
Illuminance and luminance metrics (meters mounted on the car)



Experimental Vehicle with RLMMS Components

San Diego and Anchorage: Targets

Visual target types also varied, with small targets placed at all locations

Pedestrians (San Diego only) placed at intersections.

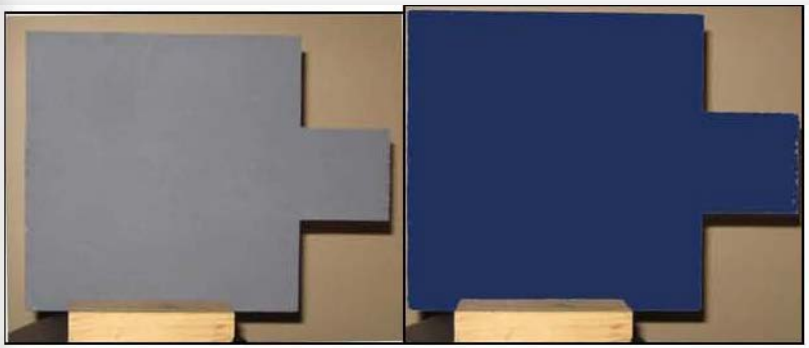


Figure 9: Example of Detection Targets along Experimental Route

San Jose: Targets

Variable	Description
Lighting	5 alternative light sources (LED_a, LED_b, LED_c, IND, and HPS), and the existing LPS control condition
Output/Power	Full and Low
Color	Gray (17% reflectance), Green (17% reflectance), Blue (15% reflectance), Red (12% reflectance), and Yellow (57% reflectance) targets

Table 9: Objective Testing Experimental Variable Descriptions.

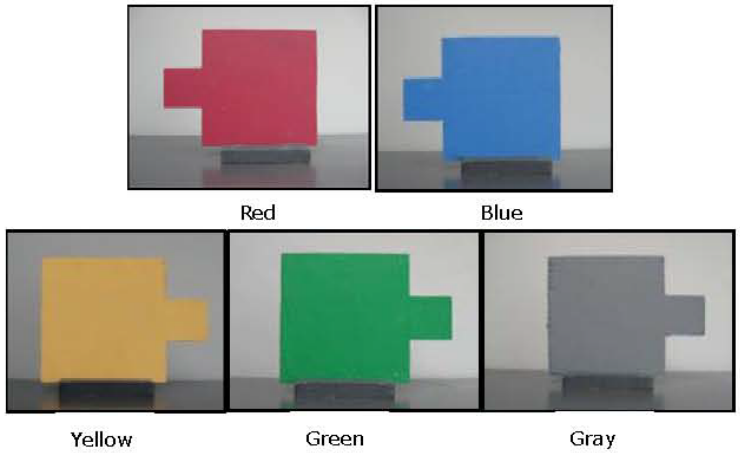


Figure 9: Detection Targets used within Test Areas

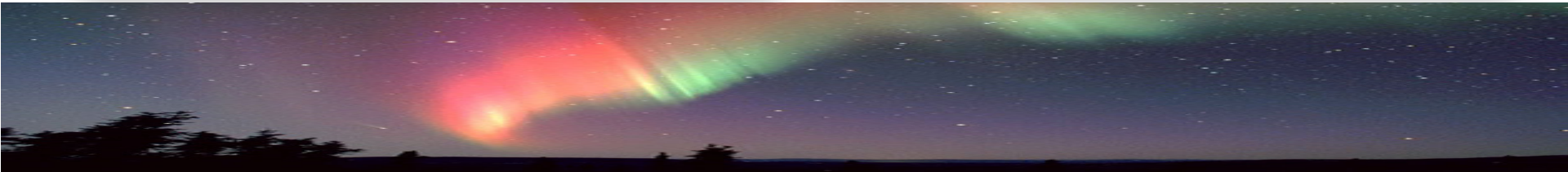
Lighting Levels (100% and 50%)

Anchorage Residential Demonstration Lighting Equipment

- HPS – orange light (250 watts – control)
- LED (81 watts, 108 watts)
- Induction – white light (85 and 165 watts)

Anchorage Residential Community Results (48 respondents)

- Preferred lower wattage white light sources
- Highest ratings: 81 watt LED
- Lowest ratings: 250 watt HPS

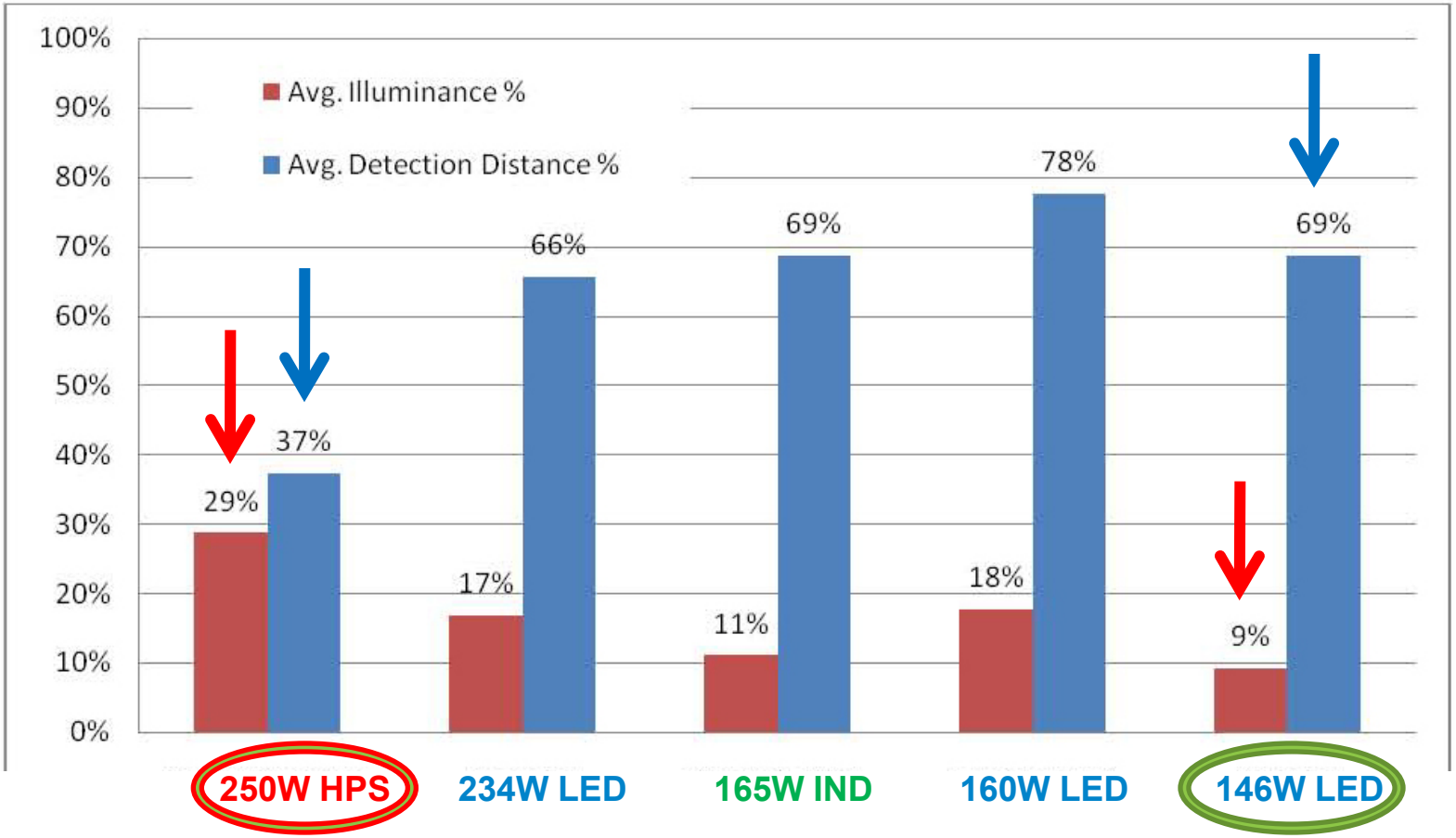


Anchorage Commercial Streetlighting Demonstration Evaluation

Each technology area included at least two blocks

- Quantitative light levels
- Electrical power measurements
- Subjective lighting survey
- Object and pedestrian visibility detection, 'performance'

Comparison to Anchorage:
Average Illuminance vs.
Detection Distance (as % of 400W HPS)



Anchorage Results

- Energy Savings (up to 60%)
- Less maintenance
- Greatest flexibility for community
- Lower lighting levels during lower activity levels are acceptable
- Payback in 8 to 10 years

San Diego: Test Set-up (one block including intersection)

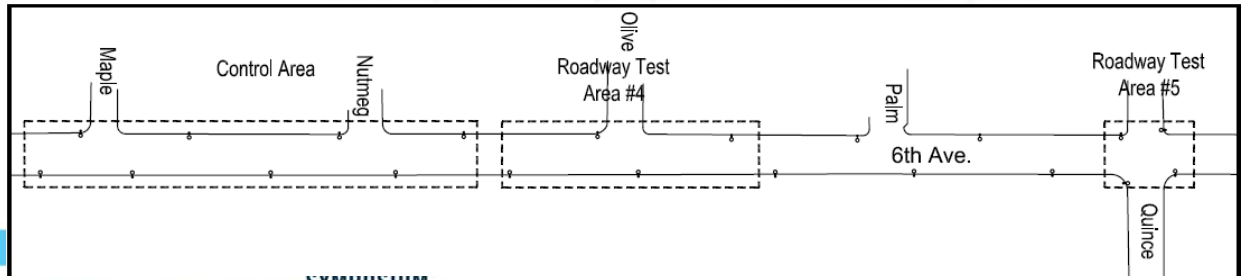
- Three areas used LED technology (3500K)
- Three areas used induction lamp technology (3000K)
- Two areas used the existing High Pressure Sodium (HPS) technology as a baseline comparison.

San Diego Streetlighting Demonstration Evaluation

- Each technology area included an intersection test area.
- Quantitative light levels
- Electrical power measurements,
- Subjective lighting survey
- Object and pedestrian visibility detection, 'performance'

Variable	Description
Lighting	6 alternative light sources (3 induction and 3 LED), and the existing condition (HPS 250W)
Lighting Level	High (4.5-6.3 fc) and Low (2.1-3.1 fc) Illuminance (target position)
Color	Grey (18% reflectance) or Blue target (6.2% reflectance)
Target Type	STV Target or Pedestrian
Section	Roadway or Intersection

Table 4: Objective Testing Experimental Variable Descriptions



San Diego: Subjective Evaluation

Community Input is extremely important

Safe to walk, alone, during darkness

Highest wattage LED rated the highest

Cannot tell colors

Lowest wattage LED was ranked the lowest (colors were accurately rendered)

Low and high wattage HPS were ranked the highest (colors were not accurately rendered).

Safe to walk on sidewalk, alone, during darkness

Highest wattage LED was ranked the highest

Lowest wattage LED was ranked the lowest

Compare the lighting in each of the test areas to existing street lighting

Lower wattage LED rated better than existing light sources.

Participants liked the color of the light.

Lowest wattage LED ranked the highest.

HPS ranked the lowest.

Like the style of lighting for their city streets

Lowest wattage LED the highest.

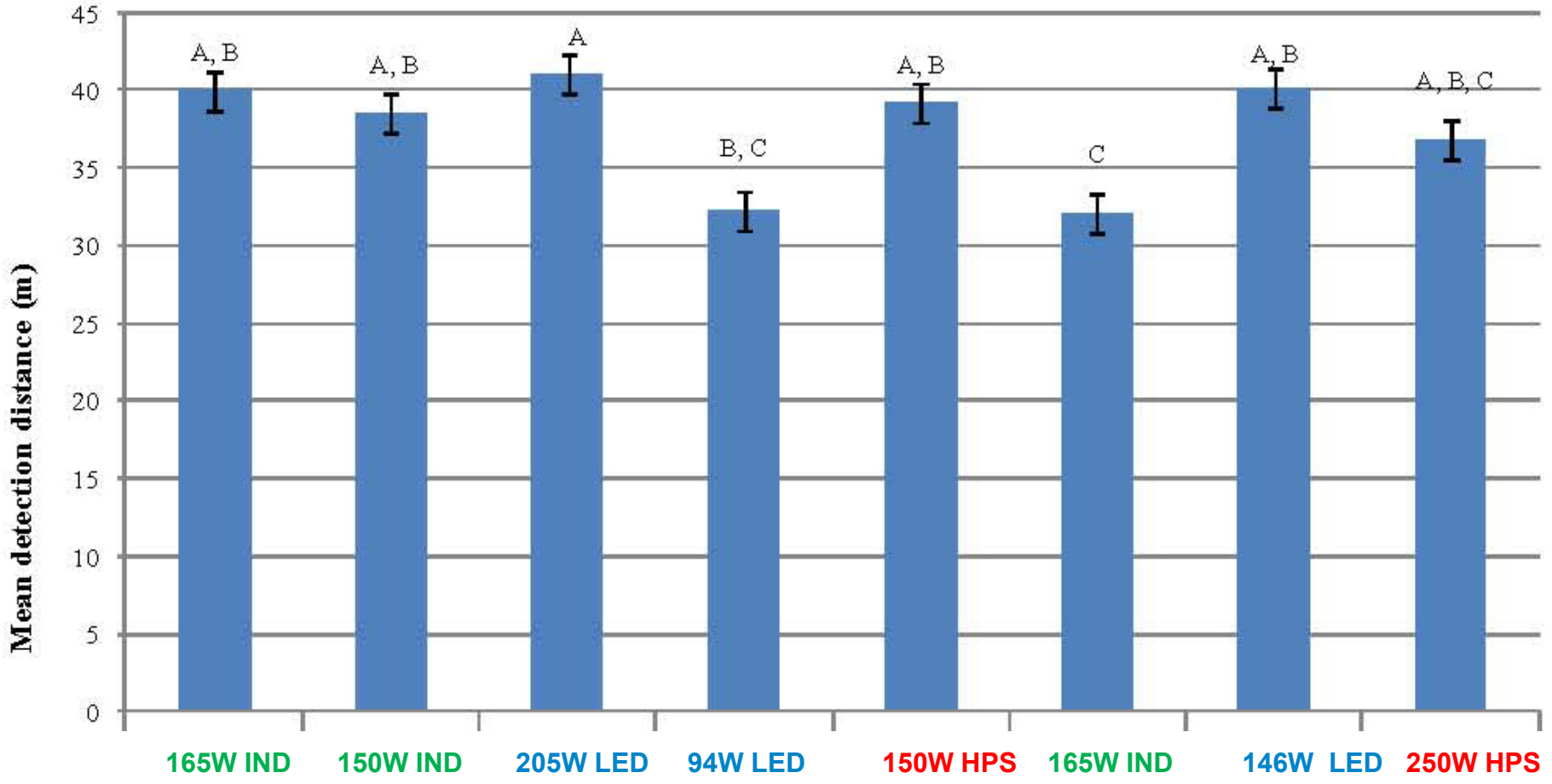
High wattage HPS ranked the lowest.

San Diego: Subjective Evaluation Results

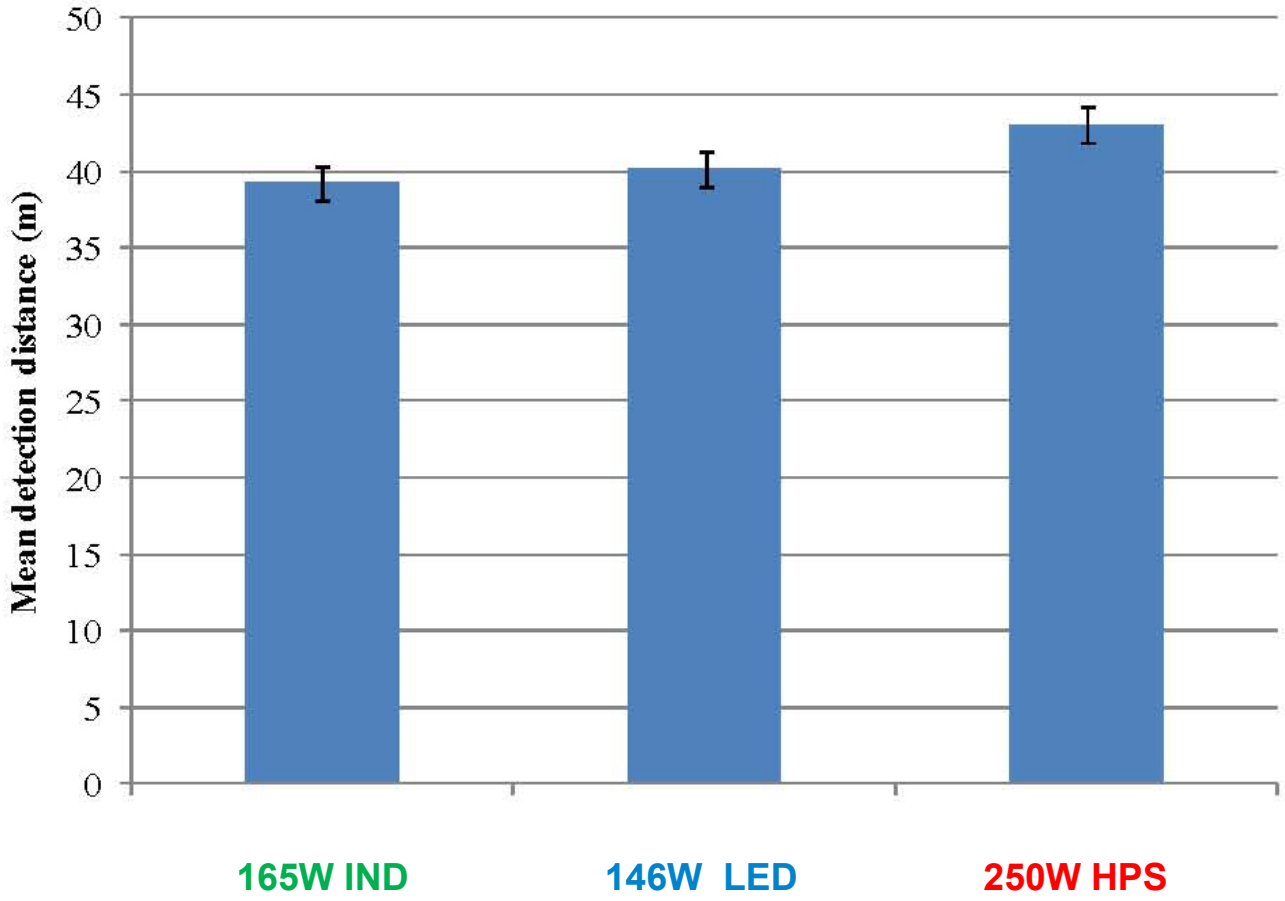
- The subjective lighting survey indicates that there is not a strong preference for or against broad-spectrum light sources for the street lighting in San Diego.

- This implies that the community will accept change from HPS light sources (mild yellow-light sources) to another technology that is perceived as 'white' light.

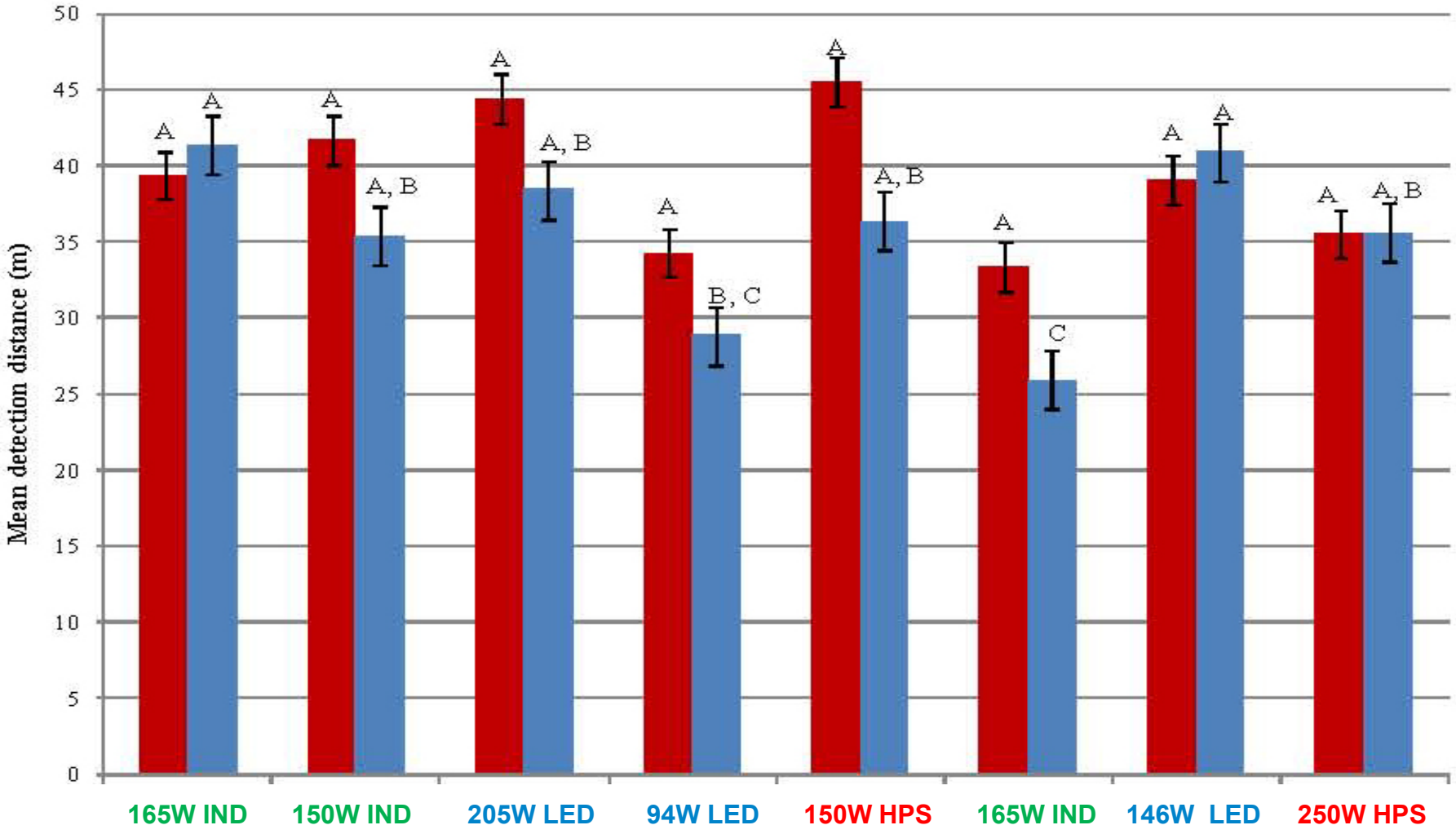
White Light and HPS had Comparable Detection Distances (small targets)



Pedestrian Detection Distance Comparison



Detection Distance vs High Illuminance and Low Illuminance Levels



Intersections

San Jose Streetlight Demonstration

Full power night 1 (wet pavement)

50% power night 2 (dry pavement)

6 types of lights: HPS, LPS, Induction & 3 LED

Color Temperatures Tested

Sought to test different Kelvin temperatures to see if it made difference in detection distances

- LED 3500K
- LED 4000K*
- LED 5000K
- Induction 4000K*

Findings: Subjective Evaluation

Public preferred the White Light Options

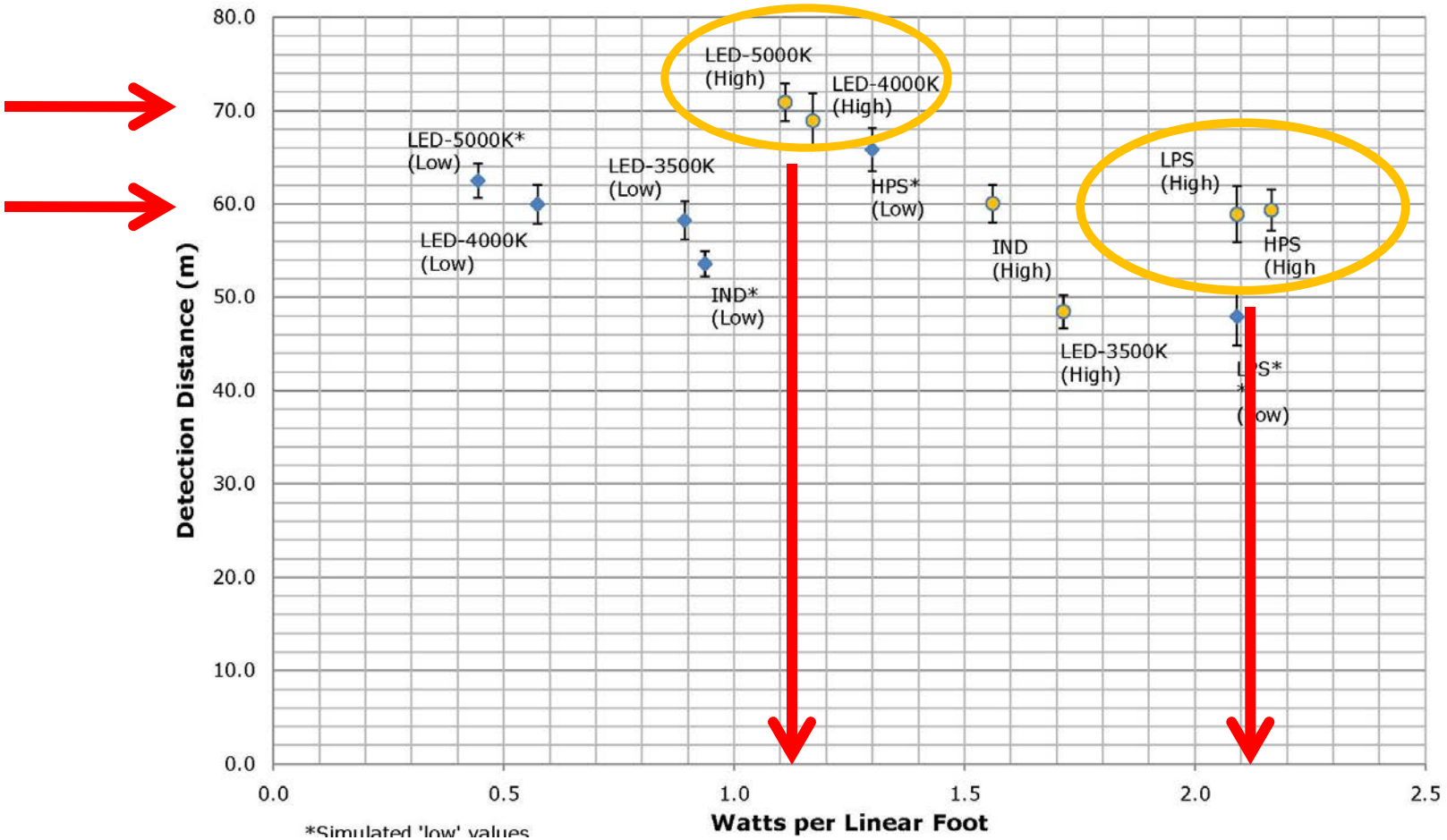
Warmer looking white light options were preferred

Even at half the lighting level, people felt there was enough light

Public did not like LPS or HPS

San Jose – Detection distance

vs watts per linear feet HIGH (100%) setting



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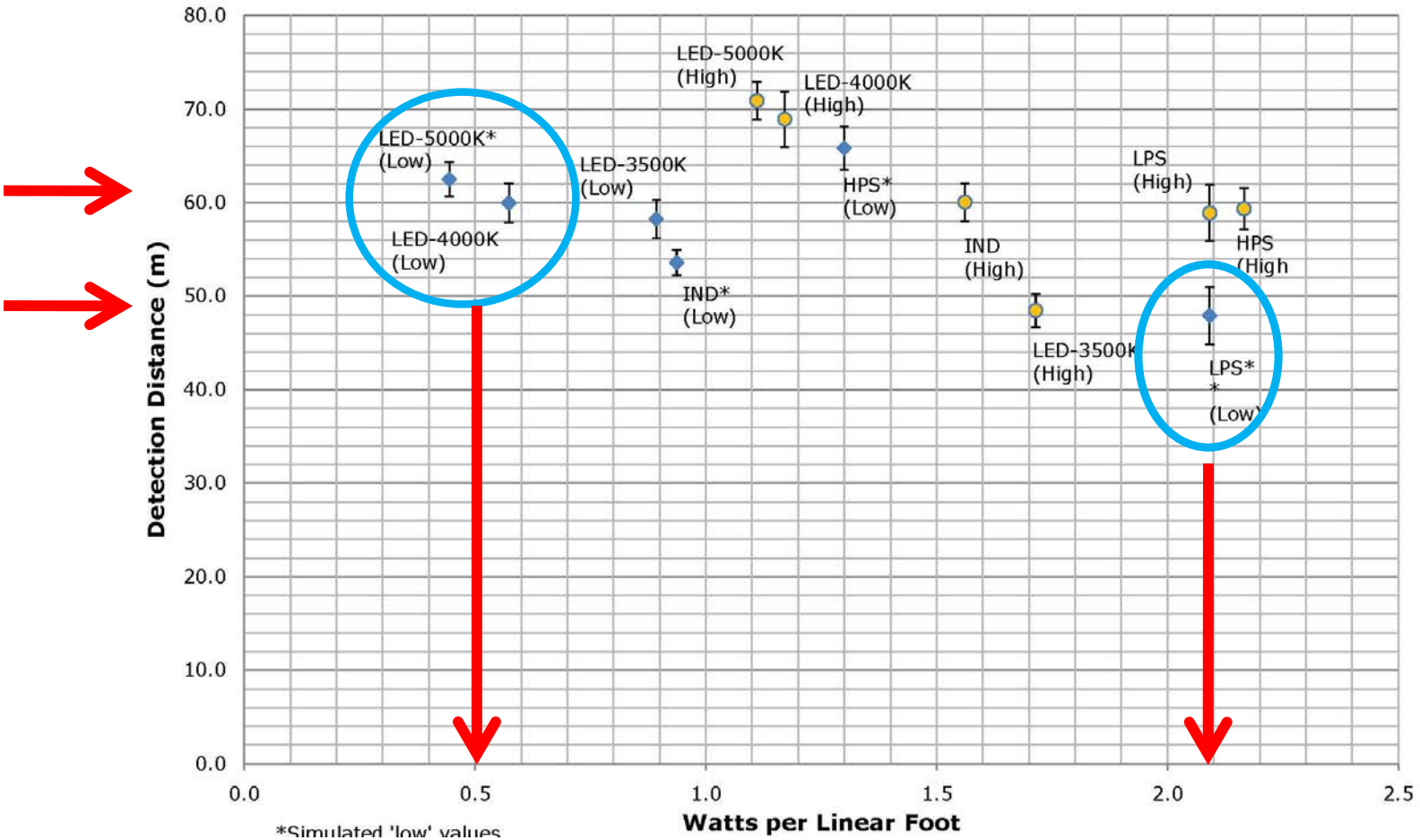
San Jose – Detection distance

vs watts per linear feet LOW (50%) setting



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San Jose Findings

Broad Spectrum (White) Light

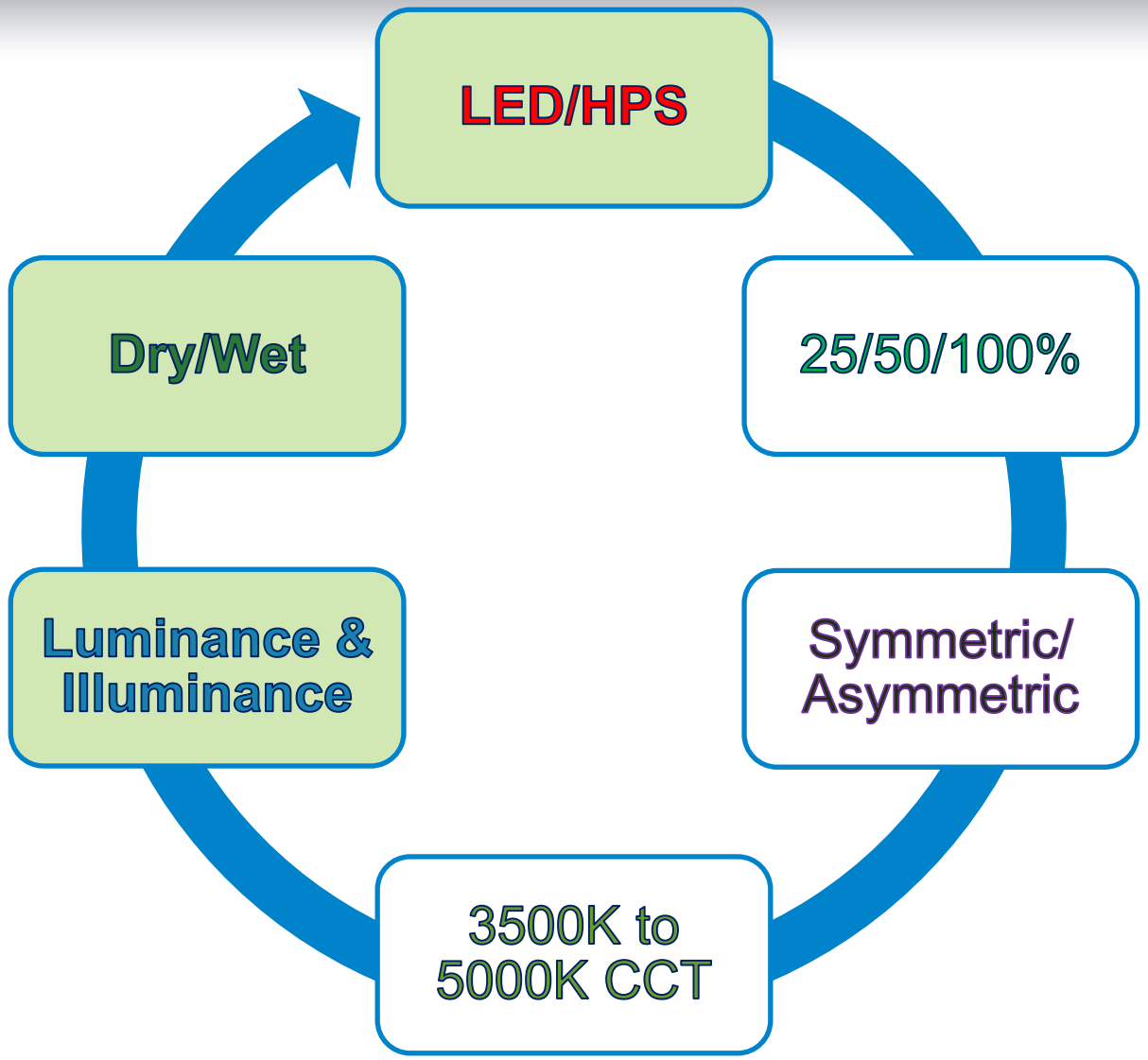
- *Prefer white light*
- *See as far if not further than HPS/LPS*

Dimming

- *At 50%, most thought light sufficient*
- *At 50%, minor reduction in detection distance*

Public did not like LPS or HPS

NEEA – Seattle Experiment Variables



Color Contrast

Color Contrast

It is not a black and white world

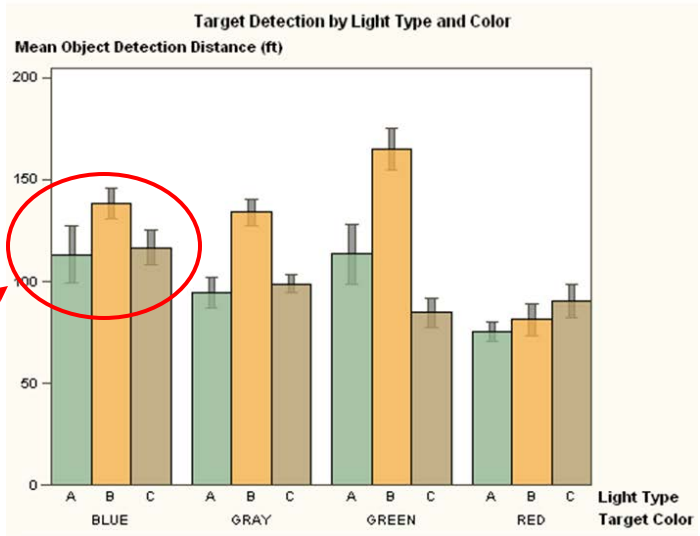
Roadway lighting design does not consider color

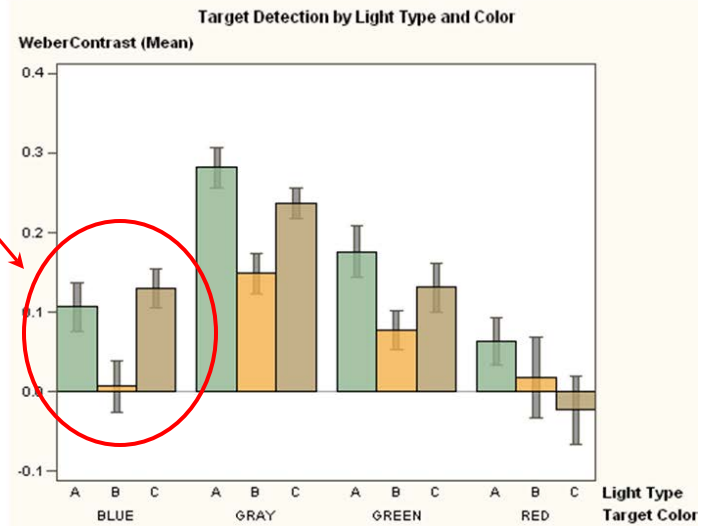
Color provides additional information to the driver and can assist in the identification of objects

Impact of Color Temperature

Color Contrast Investigation

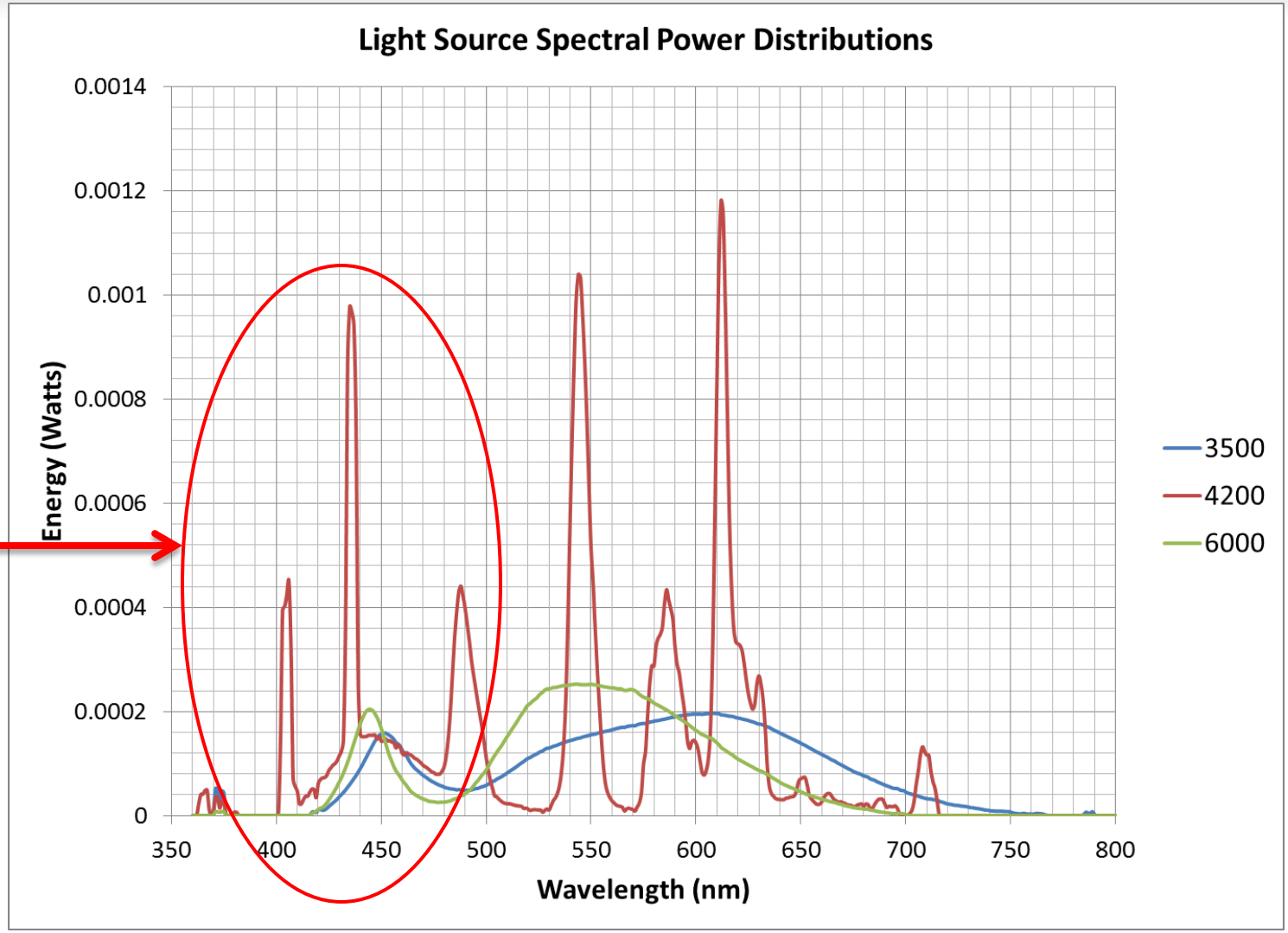
Equivalent Performance for significantly less contrast





Why? Spectral Energy

More Spectral Energy

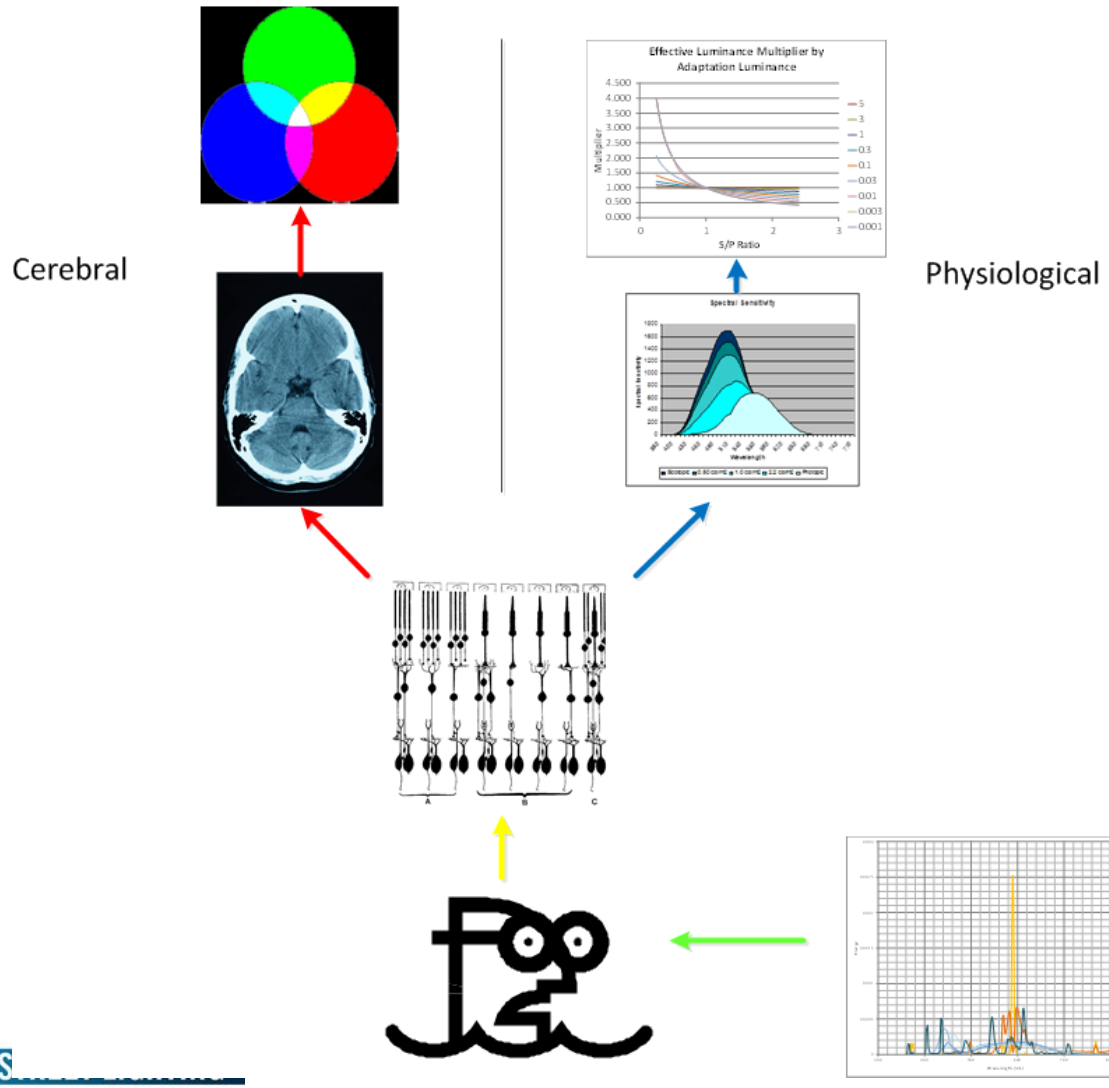


FHWA Sponsored Spectral Effects Project

Establish the relationship of Spectrum to performance at a wide variety of lighting levels and applications

- 4 Year project
- Results will be incorporated into FHWA Roadway Design guides

Our Approach



Phase 1 – Initial Evaluation

This phase of the project will include:

- A scoping experiment which defines the relationship of the spectral component to driver visual performance
  - Includes Mesopic and Color Contrast Concepts
  - Includes headlamps and overhead lighting
- Initial Development of a Momentary Peripheral Illumination System

Initial Evaluation Experimental Design

Independent Variable	Experimental Levels
Headlamps Type	Standard HID, 50 % Filtered HID, Yellow Filtered HID
Overhead Lamp Type/Color	High Pressure Sodium, 6000 Kelvin LED
Roadway Luminance	High (2.0 cd/m^2) and Low (0.1 cd/ m^2)
Roadway Type	High Speed Roadway Conditions (55mph), Low Speed Street Lighting Applications (30 mph)
Age	Younger, Older

Experimental Lighting Testbed

Three luminaires

- Patterned spacing that allows simulation of 40, 60, 80, and 120 meter light pole spacing (130-260 ft)
- Current Configuration
  - 400w HPS luminaire with flat glass w/ M-C-II
  - 150w HPS luminaire with flat glass w/ M-C-II
  - 150w Cosmopolis luminaire with flat glass w/ M-C-II
  - 228 Watt 3500K LED
  - 228 Watt 6000K LED
  - 228 Watt 4200K Fluorescent
- Any 2” luminaire can be adapted

Variable Bracket Height

Experimental Concept

Participants will be asked to detect and recognize pedestrians and targets on the Smart Road facility

- Detection Distance will be measured using the vehicle instrumentation
- Lighting characteristics will also be measured
- Targets and Pedestrians will be both placed foveally and peripherally.

STRATEGIC INITIATIVE FOR EVALUATION OF REDUCED LIGHTING ON ROADWAYS

Possibility of changing the lighting characteristics based on the conditions within the roadway

- Traffic Volume
- Presence of Pedestrians
- Weather
- Astronomical Observation
- Ambient Lighting Conditions

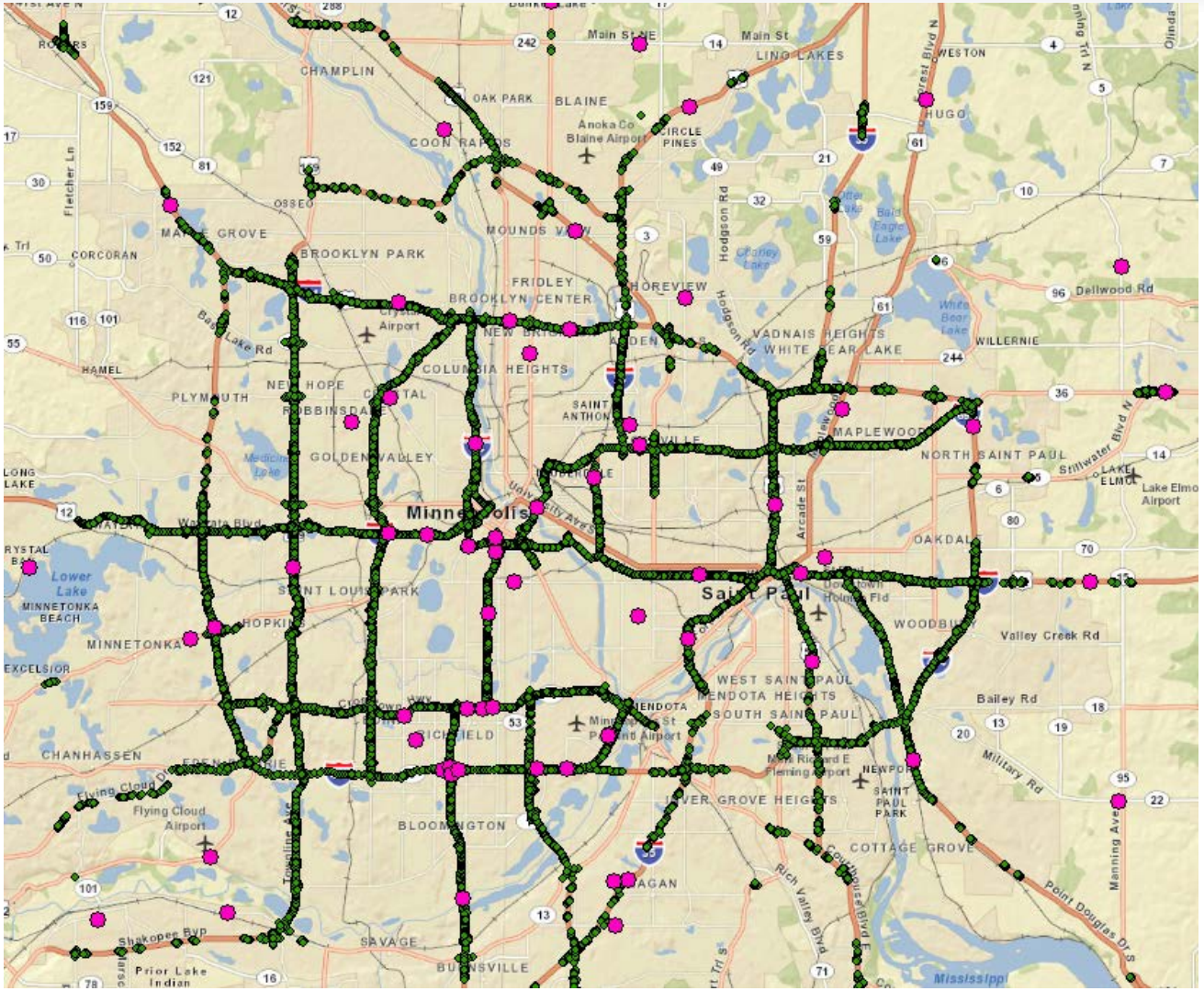
Project Process

Site Selection
Data Analysis
Perform Cross Sectional Crash Analysis
Establish Methods and Criteria for Dimming
Legal Review
Final Guidelines

Data Requirements

- Crash Data
  - Crash locations
  - Time of day
  - Contributing factors and potential causes
  - Traffic Volume – Hourly
- Roadway Design Data
  - The presence of curves, intersections, parking, pedestrians and presence of other safety systems
- Lighting Design Data
  - Includes:
    - Luminaire type (Intensity Distribution Type not manufacturer)
    - Luminaire installation criteria
    - Design layout
    - Predicted luminance and illuminance from the design
    - Maintenance records
    - Costs
- Lighting Performance Data
  - In-situ data collection
  - Measured with the RLMMS

Data Layering



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Results Summaries from all Cities

- Combining all of the results, these studies suggest that broad spectrum (white) light sources (3000K to 4000K) provide equivalent or better visual performance than the existing HPS luminaires.

- These alternative light sources provide equivalent performance at a lower roadway illuminance level.

- This suggests that the broad spectrum light sources do provide additional information in the visual scene and a higher potential performance

Lighting Levels (100% and 50%)