LiDAR and Retroflectivity. The Good, Bad, and what you should know about Road Marking Assessments

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INTERTRAFFIC
AMSTERDAM

Summit Theatre 4
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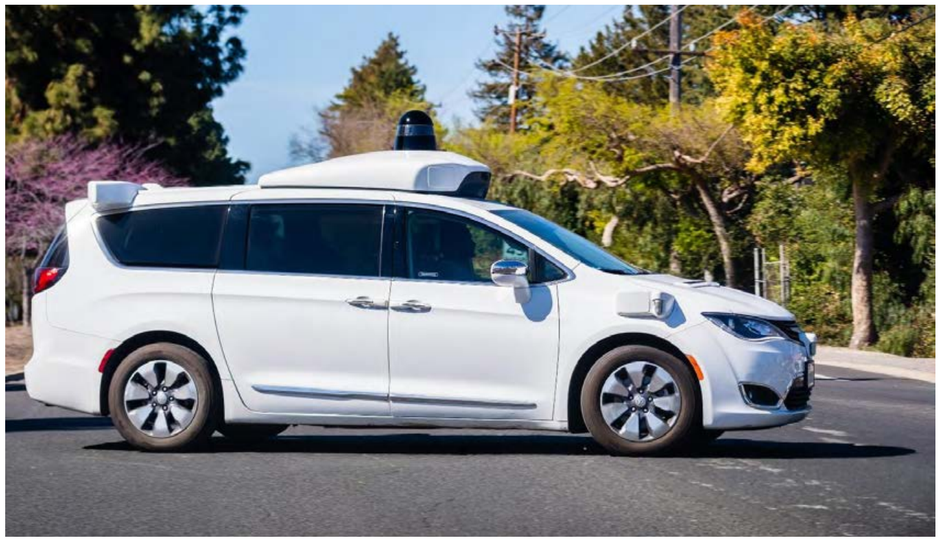
Introduction

With the proliferation of automated vehicles, LiDAR systems are becoming more common and more affordable.

Because LiDAR is a good tool to create a digital visualization of the environment around the vehicle, maybe it can be used to determine the retroreflective performance of pavement markings

This presentation will cover the good and the bad when utilizing LiDAR data to determine retroreflectivity values



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Agenda

Topic 1	• What is Retroreflectivity?
Topic 2	• What is LiDAR?
Topic 3	• Effects of Geometry on the Measurement
Topic 4	• Correlating LiDAR Data to Retroreflectivity Data

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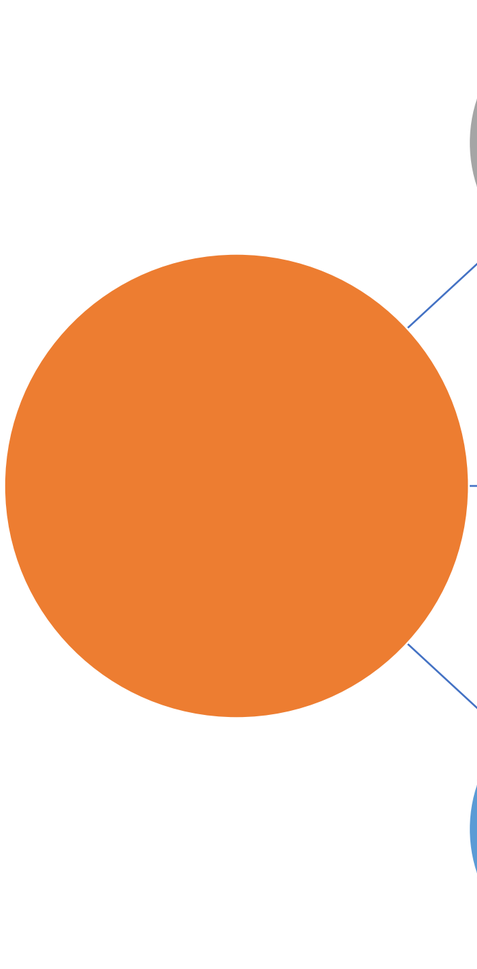
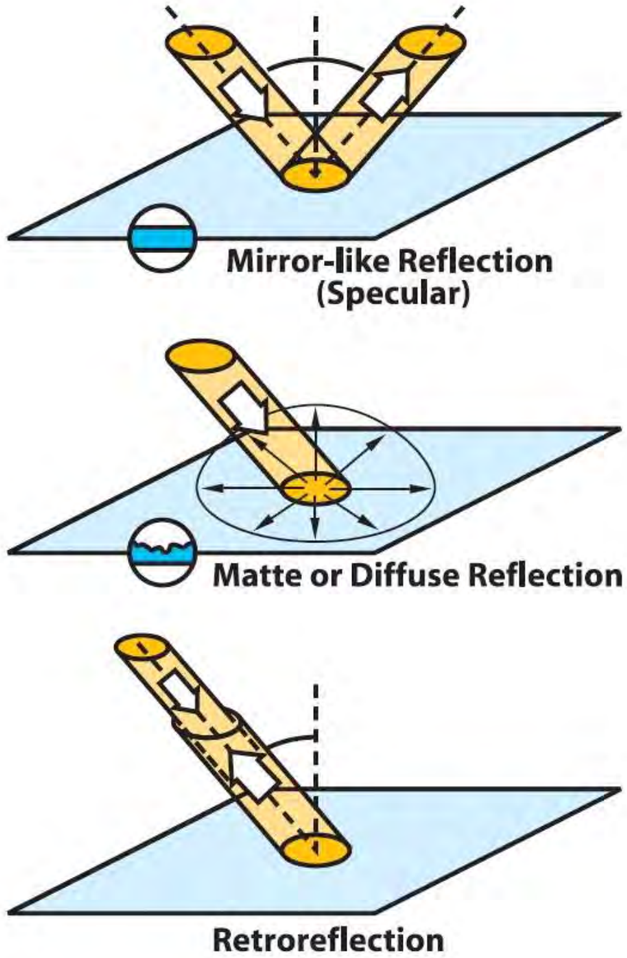
What is Retroreflectivity?

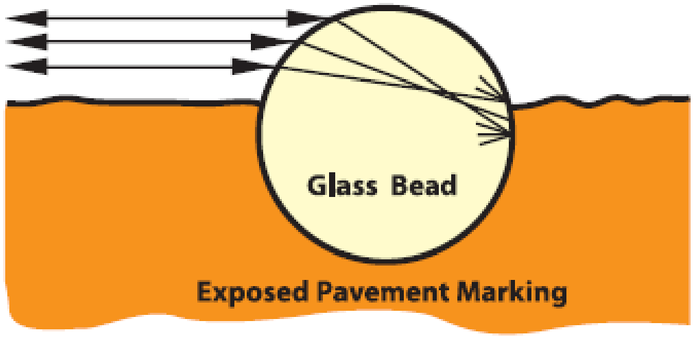


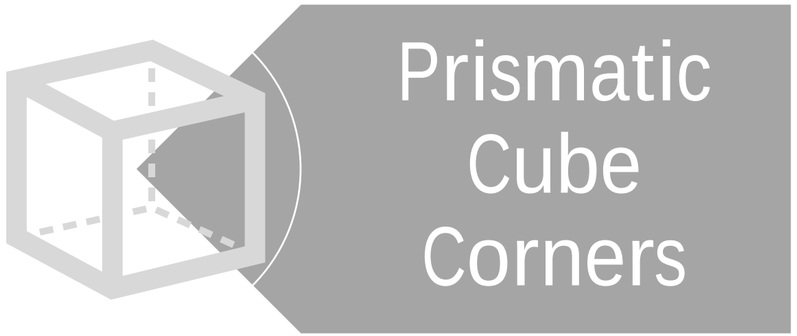
- Like a Mirror
- Scatters in all directions
- Reflects back to source



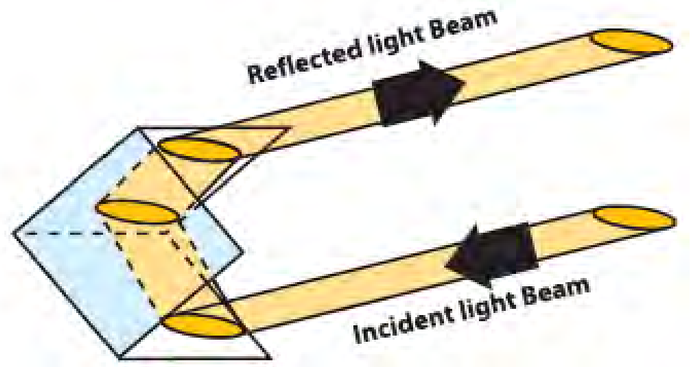
Types of Retroreflectors

Glass Beads





Prismatic Cube Corners



Why is Retroreflectivity Used?

Drivers and highway departments have long recognized that good road markings make roads safer and easier to navigate

Retroreflection enhances the visibility of road markings and signs at night and during inclement weather when overall visibility is reduced.

Retroreflection has expanded beyond roadway applications and is used in commercial aviation, railroads, and military applications.

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Why Create Minimums for Retroreflectivity

- Over the past 40 years, approximately 2/3rds of the fatal crashes have occurred at night
- Nighttime fatal crash rate is about three times higher than during the day
- Encourage agencies to improve pavement markings
- Improves performance of automated vehicle functions

U.S. Department of Transportation
National Highway Traffic Safety Administration

NHTSA

DOT HS 813 266

March 2022

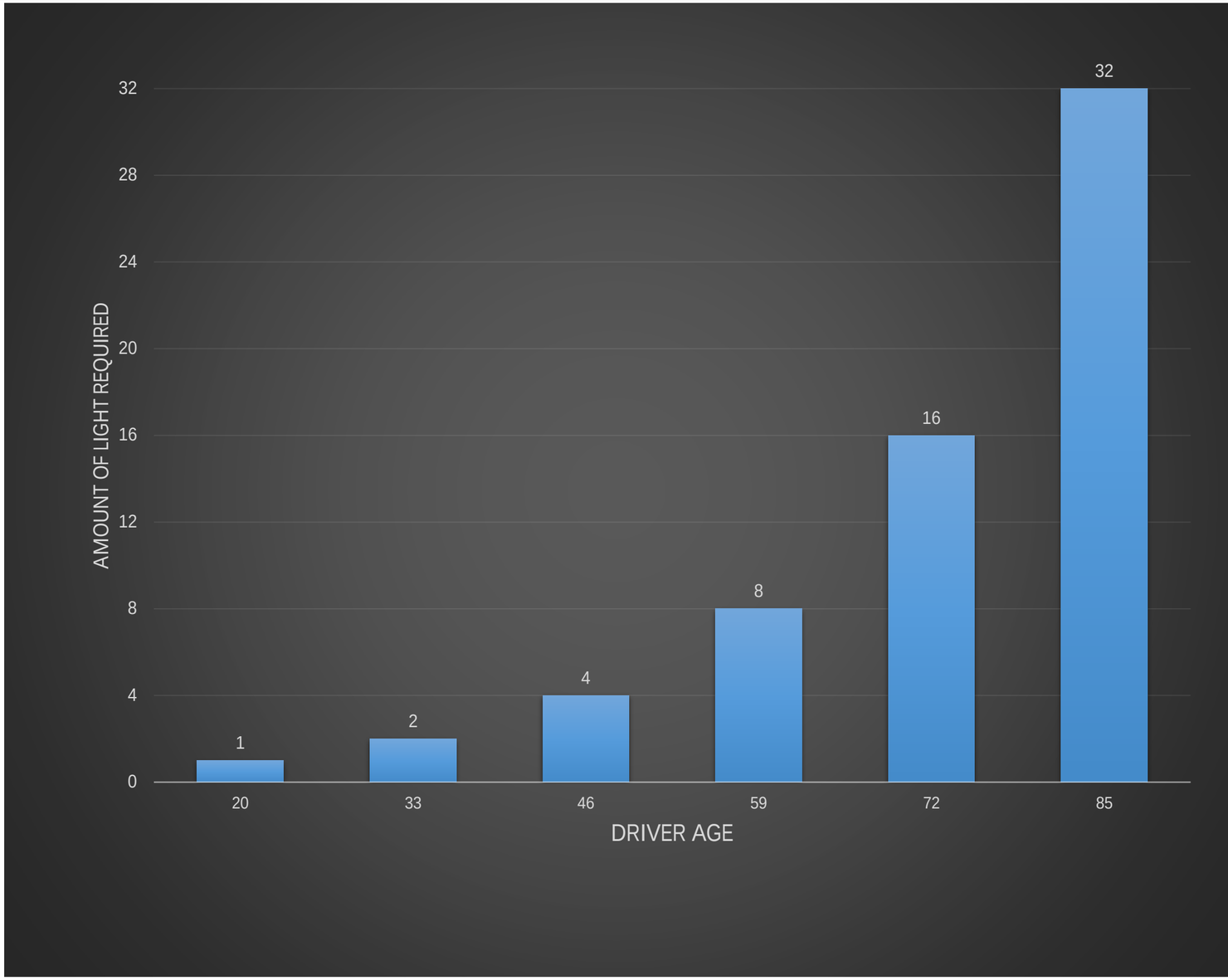
Table 7. Passenger Vehicle Occupants Involved in Fatal Crashes, by Restraint Use, Survival Status and Time of Day, 2019 and 2020

Description	2019	2020	Change	% Change	Restraint Use Percent Based on Known Use	
					2019	2020
Passenger Vehicle Occupants Killed						
Total	**22,372**	**23,824**	**+1,452**	**+6.5%**		
Restrained	10,891	10,483	-408	-3.7%	53%	49%
Unrestrained	9,523	10,893	+1,370	+14%	47%	51%
Unknown	1,958	2,448	+490	+25%		
Time of Day						
Daytime	11,840	11,787	-53	-0.4%		
Restrained	6,678	6,113	-565	-8.5%	61%	56%
Unrestrained	4,317	4,740	+423	+9.8%	39%	44%
Unknown	845	934	+89	+11%		
Nighttime	10,345	11,846	+1,501	+15%		
Restrained	4,150	4,319	+169	+4.1%	45%	42%
Unrestrained	5,110	6,034	+924	+18%	55%	58%
Unknown	1,085	1,493	+408	+38%		

Why Create Minimums for Retroreflectivity

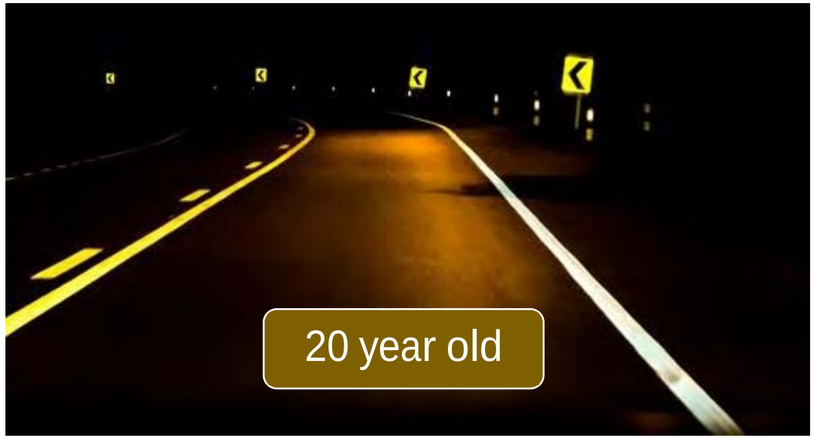
Starting at age 20 the amount of light required to see doubles every 13 years

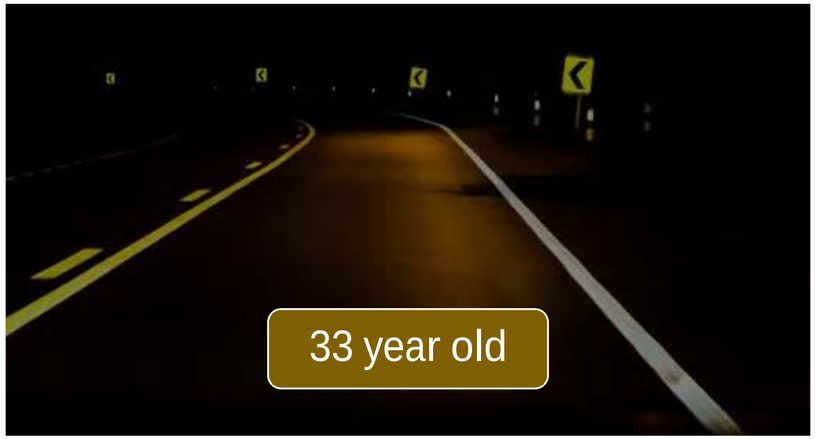
A 72 year old driver requires 16x more light to see than a 20 year old

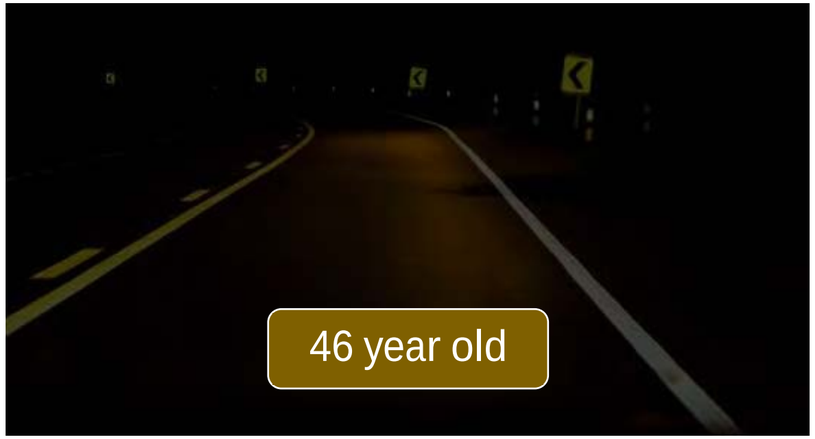


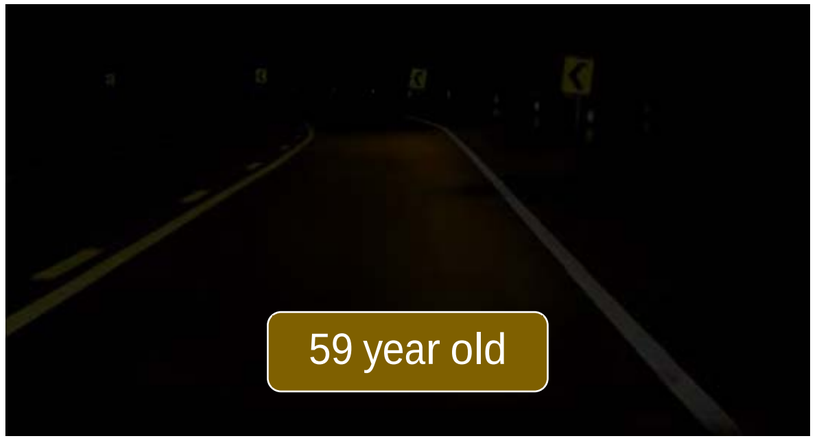
Why Create Minimums for Retroreflectivity

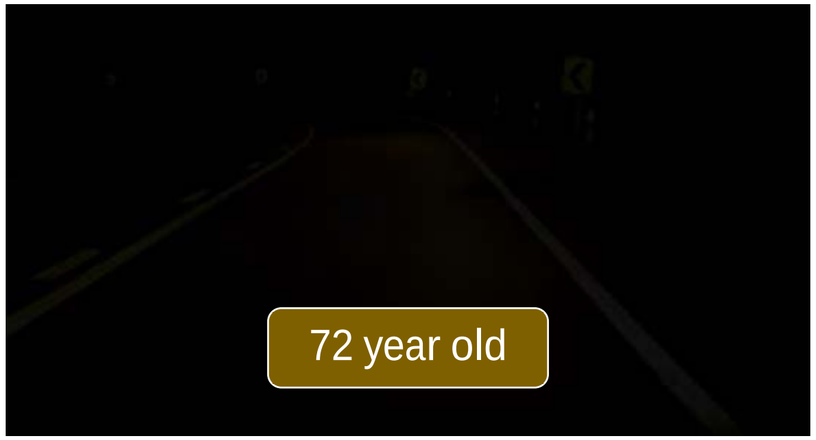
Simplified visualization of the difference drivers of different ages will see if the lighting remains constant

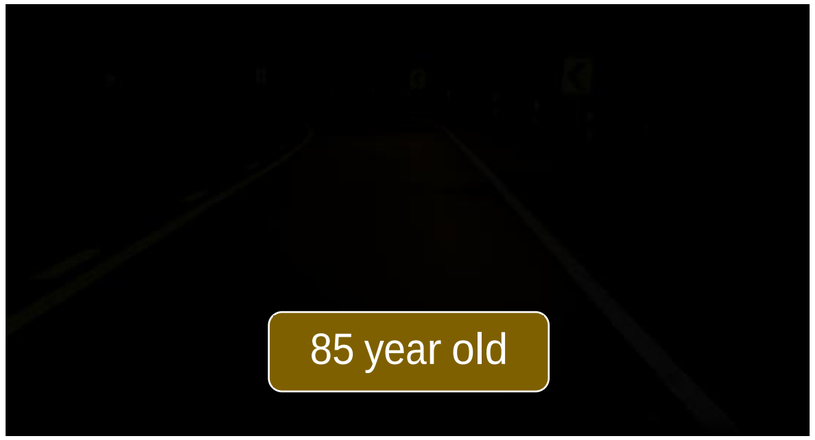




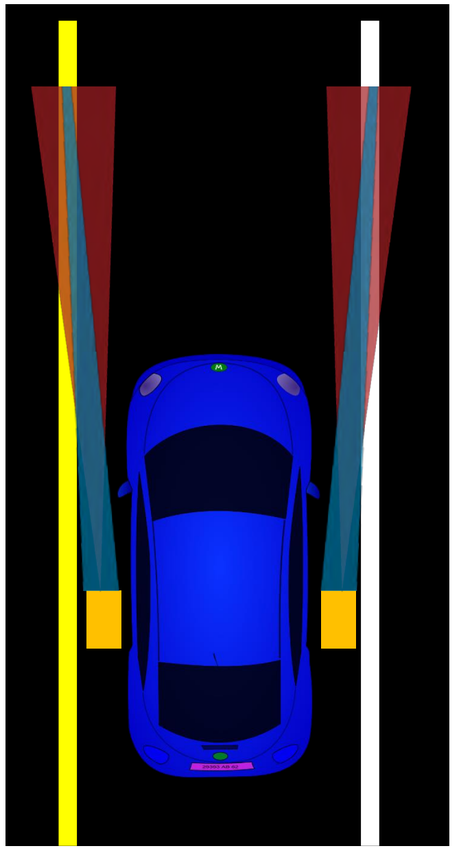








How Do We Measure Retroreflectivity?



Field Measurements are performed using either a…

- Handheld Retroreflectometer
- Mobile Retroreflectometer

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Topic 3	• Effects of Geometry on the Measurement
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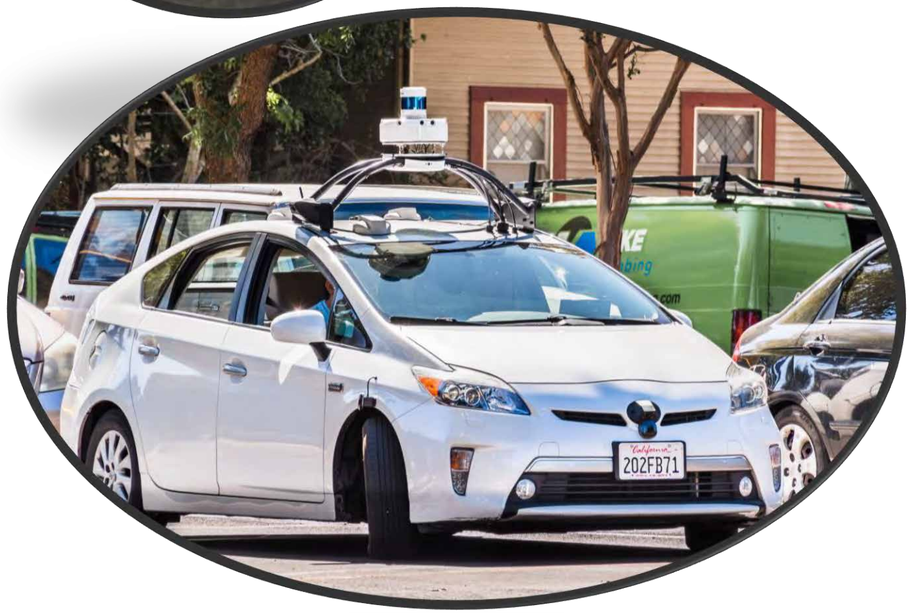
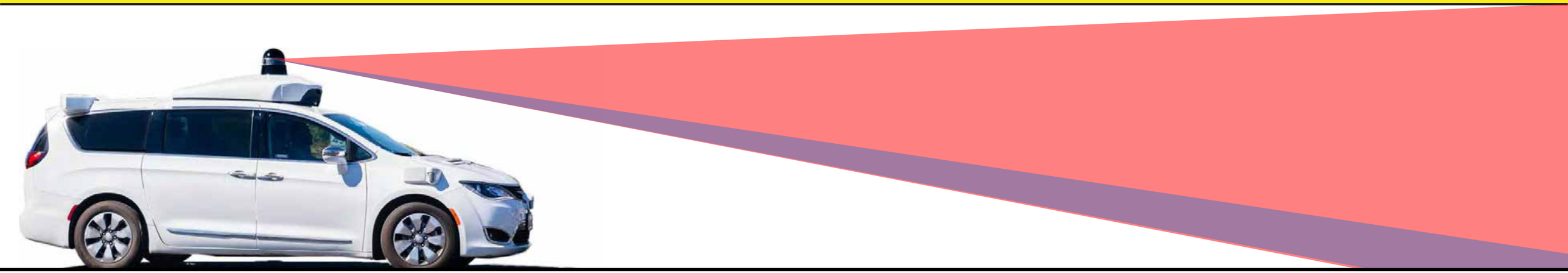
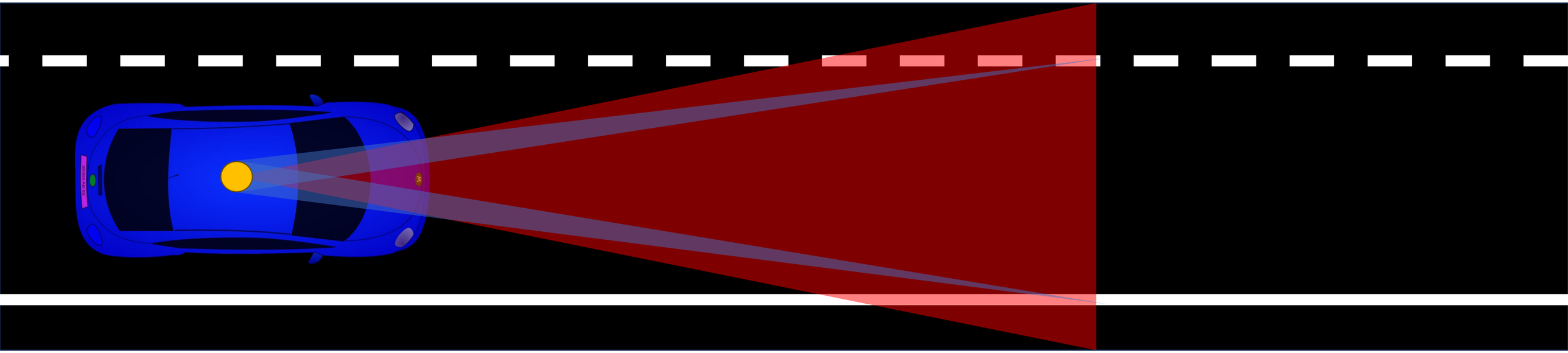
What is LiDAR?

LiDAR is an acronym for Light Detection and Ranging	• It is similar in function to Radar, except using light waves instead of radio waves
A laser scanner emits rapid pulses of laser light out.	• The laser is scanned both in the horizontal and vertical directions
Time of Flight is used to determine distance	• This allows for 3D visualizations of the surrounding environment
Return signal intensity	• Helps determine the type of object • Retroreflective objects have artificially higher intensities
LiDAR systems typically use near-IR	• Other wavelengths can be used.



What is LiDAR?





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Standards for Pavement Marking Retroreflectivity

ASTM E1710

Using a portable retroreflectometer

ASTM E3320

Using a vehicle mounted dynamic retroreflectometer

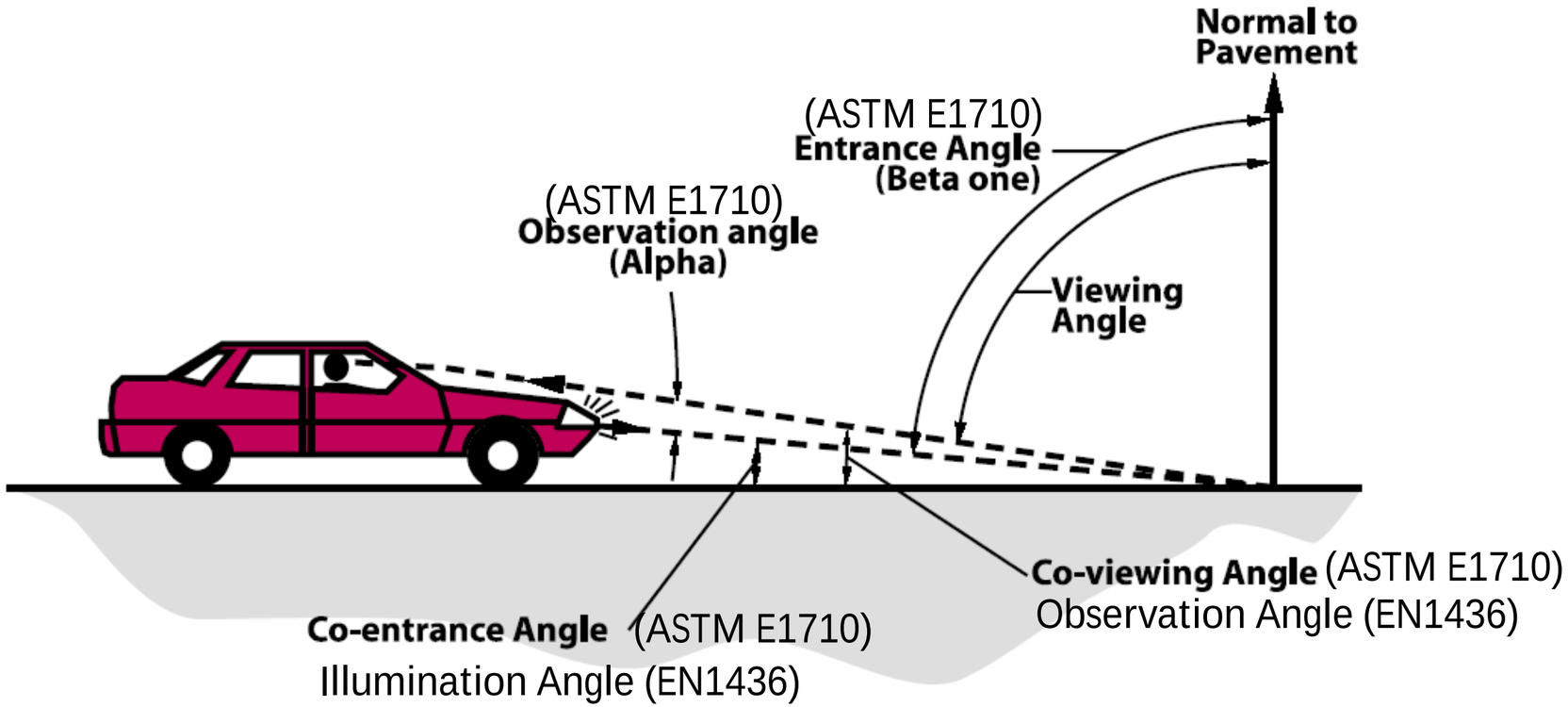
CEN EN1436

Using all types of retroreflectometers

All three standards define the “30-Meter Geometry”

Uses a defined standard vehicle and human driver

Road Geometry for Pavement Markings



30-Meter Geometry

Co-Entrance Angle (E1710): 1.24º

Illumination Angle (EN1436): 1.24º

Co-Viewing Angle (E1710): 2.29º

Observation Angle (EN1436): 2.29º

Observation Angle (E1710): 1.05º

Standard Car Geometry:

Driver Eye Height = 1.20 meters (3.9 feet)

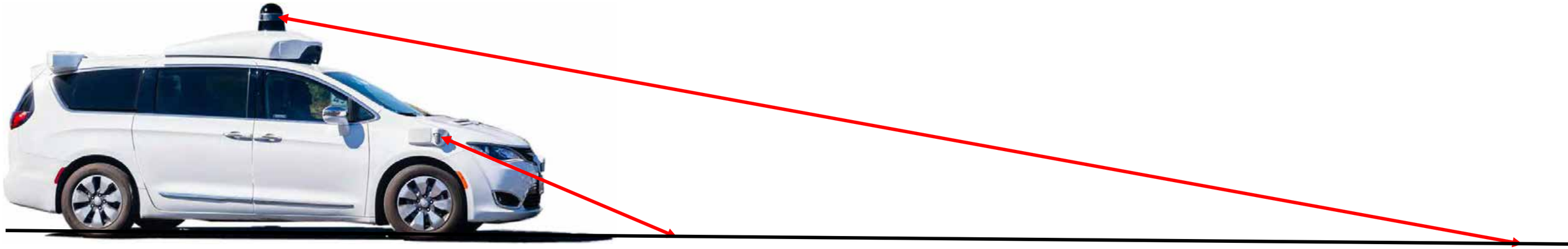
Car Headlamp Height = 0.65 meters (2.1 feet)

Road Geometry for Pavement Markings

LiDAR Geometry

Various sensors mounted at different heights looking at different distances

Emitter and Receiver very close to each other = small Observation Angle (E1710)



Standard LiDAR Geometry:
None

Laboratory Study

Goal

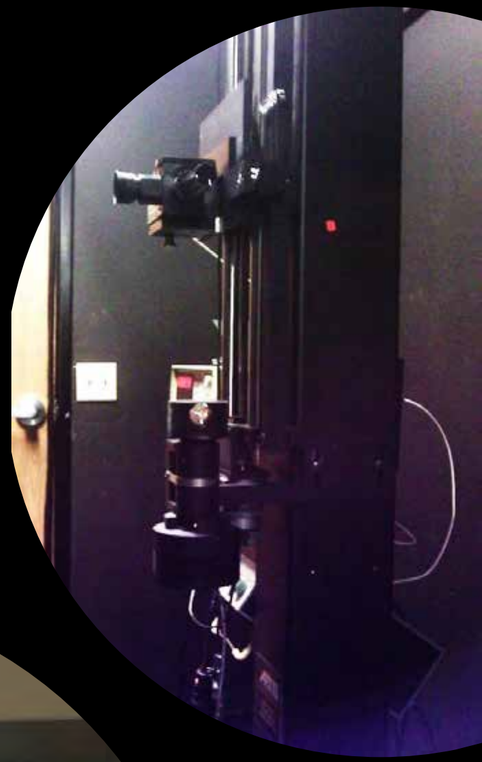
- Determine a way to correlate measurements of pavement markings done at different geometries

Purpose

- To allow LiDAR data to be used to determine 30-meter retroreflectivity values per international standards

Test Performed

- 16 different pavement marking samples of various types
- Measured in the lab 15-meter photometric range to ASTM D4061
- Each sample was measured at 9 different geometries and a Correlation Factor (K) was calculated
- K Factor defined to be: K = TestGeometry / GeometryH
- The H Geometry was chosen as the basis at random.
- Similar results are obtained using other geometries as the basis



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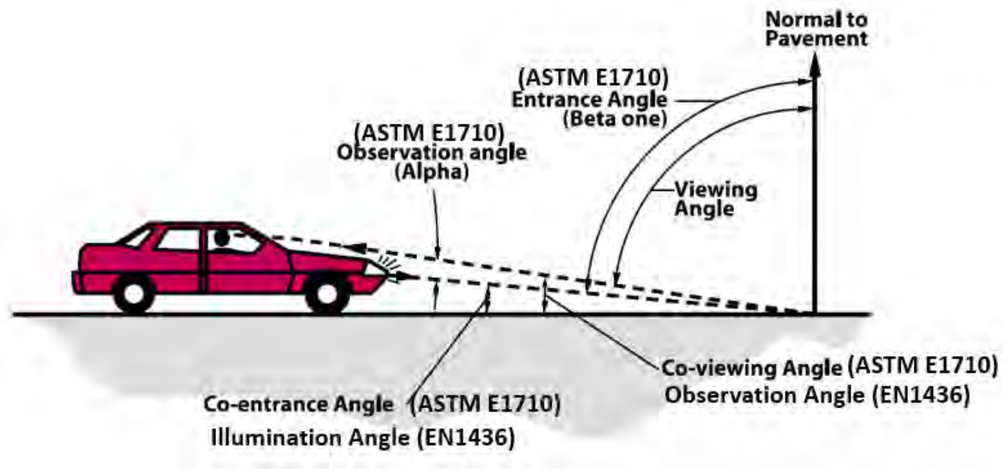
Measurement Geometries



Geom.	Entrance Angle	Illumination Angle	Observation Angle	Co0Viewing Angle
A	86.0	4.0	0.2	4.2
B	86.0	4.0	0.5	4.5
C	89.26	0.74	0.63	1.37
D	85.48	4.52	0.82	5.34
E	86.5	3.5	1.00	4.5
F	88.5	1.5	1.00	2.5
G	88.76	1.24	1.05	2.29
H	86.5	3.5	1.50	5.00
I	88.3	1.7	1.50	3.20

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Variation of K Factors for 16 Materials

Geometry	Max	Min	Difference
A	4.09	1.84	122.7%
B	2.71	1.56	73.4%
C	1.06	0.62	72.0%
D	1.95	1.31	49.1%
E	1.53	1.20	27.8%
F	1.16	0.79	47.2%
G	1.02	0.67	52.2%
I	0.84	0.64	30.7%

- Geometry H was arbitrarily used as the basis for all other samples
- The large K factor difference illustrates poor correlation between different measurement geometries

Reasons for Poor Correlation

- Pigmentation
- Bead Size, Index, and Distribution
- Penetration
- Binder Material Index
- Surface Characteristics
- Pavement Type

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Correlating LiDAR Data to Retroreflectivity Data

- Correlation factors between different geometries and stripe types vary
- Multiple correlation factors must be used to determine 30-meter retroreflectivity from LiDAR data
- Use a 30-meter retroreflectometer to scale LiDAR data for a particular stripe/road type
- Simpler and more cost-effective to use a vehicle mounted dynamic mobile retroreflectometer

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Conclusion

LiDAR is a great tool for mapping out the roadway system

Use a retroreflectometer to comply with EN1436 and ASTM requirements

Scale LiDAR data to measured retroreflectivity data for each line material type

Do we need a new “Standard Observer?”

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