

**CROSS/
ROADS**
LINKING MOBILITY SOLUTIONS

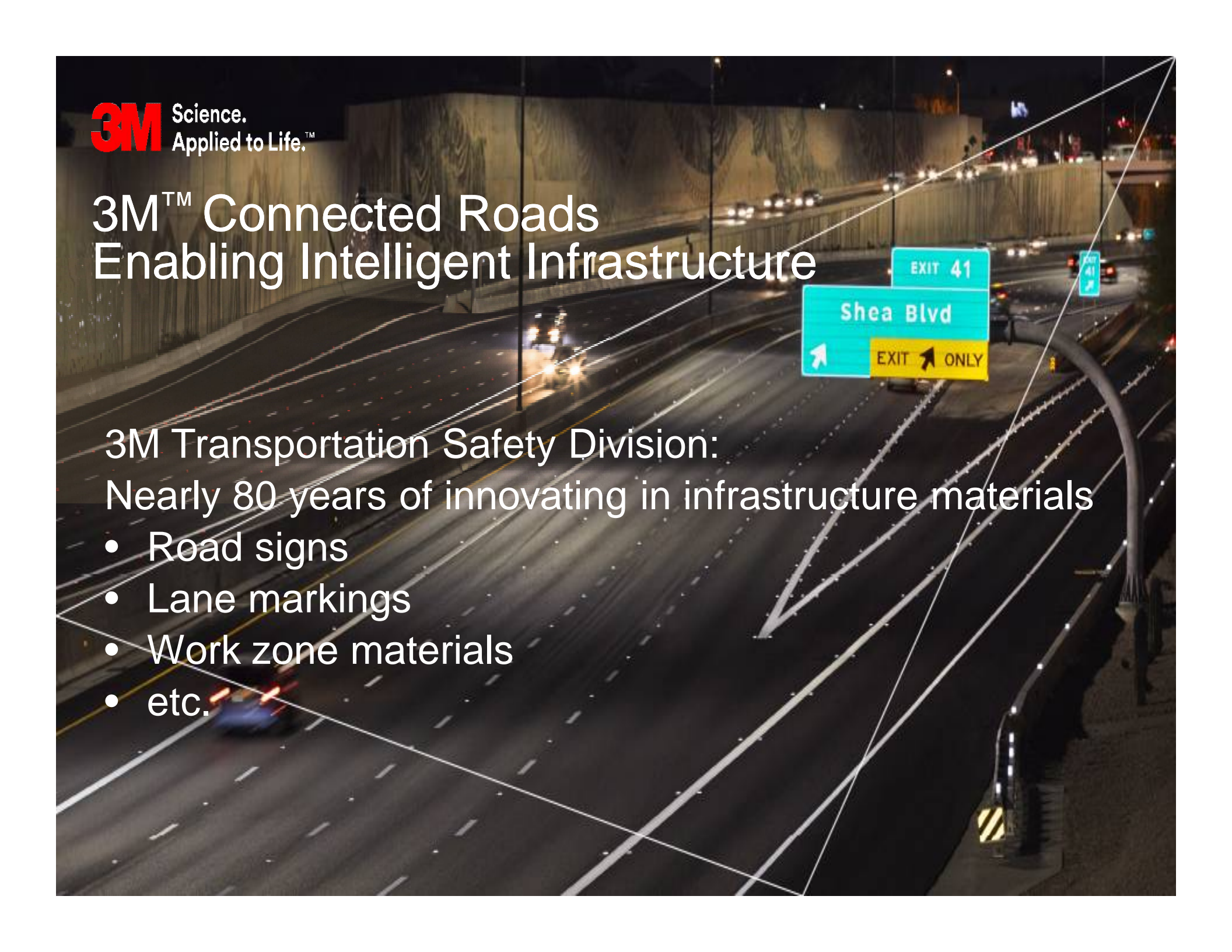


**IRF WORLD ROAD
MEETING 2017**

/ 14-17 NOVEMBER / DELHI / INDIA /

**INFRASTRUCTURE TO FACILITATE
AUTOMATED AND ASSISTED DRIVING**

Dr Kenneth Smith
Corporate Scientist
3M Co.
klsmith@mmm.com



3M Science.
Applied to Life.™

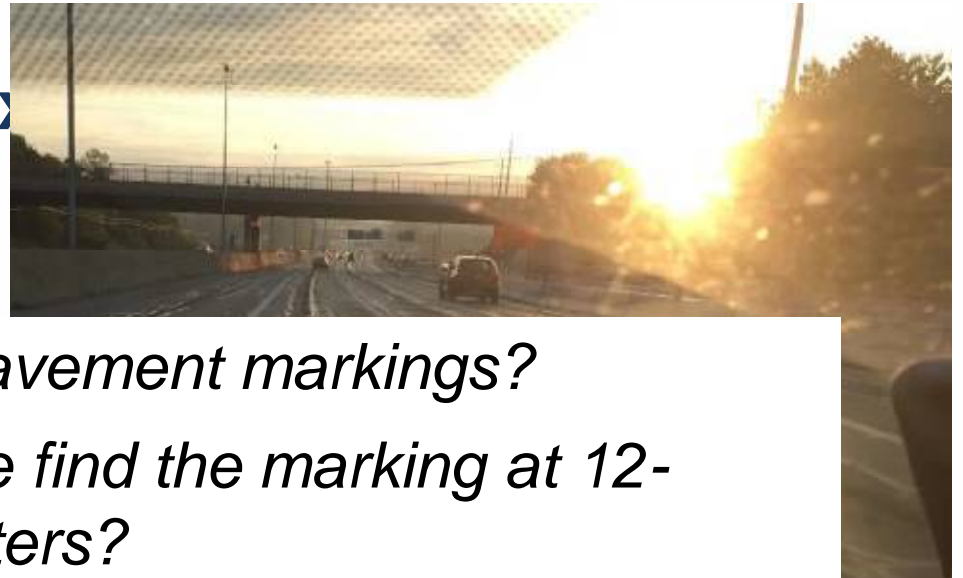
3M™ Connected Roads Enabling Intelligent Infrastructure

3M Transportation Safety Division:
Nearly 80 years of innovating in infrastructure materials

- Road signs
- Lane markings
- Work zone materials
- etc.

Infrastructure has a key role to play in the successful migration to Connected and Automated Vehicles

- **Humans and assisted/automated vehicles will coexist for many years**
- **Simple solutions can enhance safety and redundancy**
- **Redundancy is critical for robust and safe CAV decisions**
- **“Corner cases” include adverse weather & work zones**



- *What is “typical” for pavement markings?*
- *Can the Driver/Vehicle find the marking at 12-30meters? At 100meters?*
- *Humans can often interpret what’s not standard – can machines?*
- *Is the marking visible in rain? At night? Under glare?*

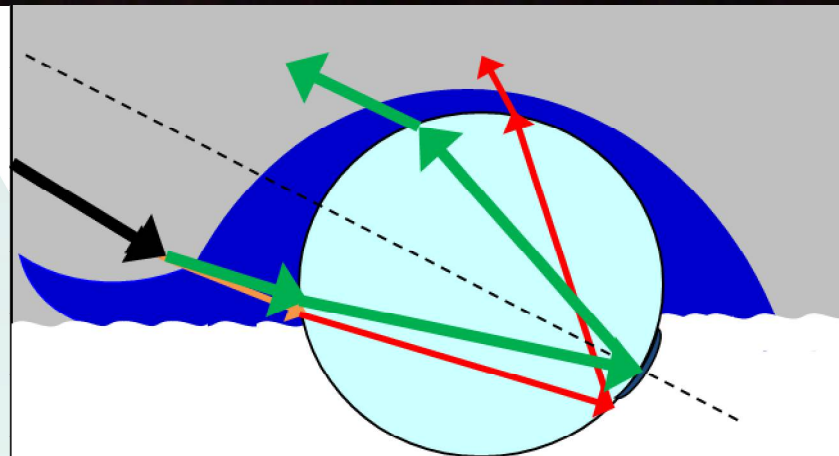


Side by Side

Conventional lane markings



Wet reflective markings



- Refractive Index, 1.9
- Refractive Index 2.4

Luminance and Contrast of Pavement Markings on Asphalt

- Pavement markings with a range of Y evaluated against both a dark asphalt and a black contrast tape
- Viewing distance of 20 m
- Calibrated absolute luminance measured with a Radiant ProMetric I-16 with 200mm e-lens
- Measurements were recorded from noon until past sunset on tapes oriented NW-SW

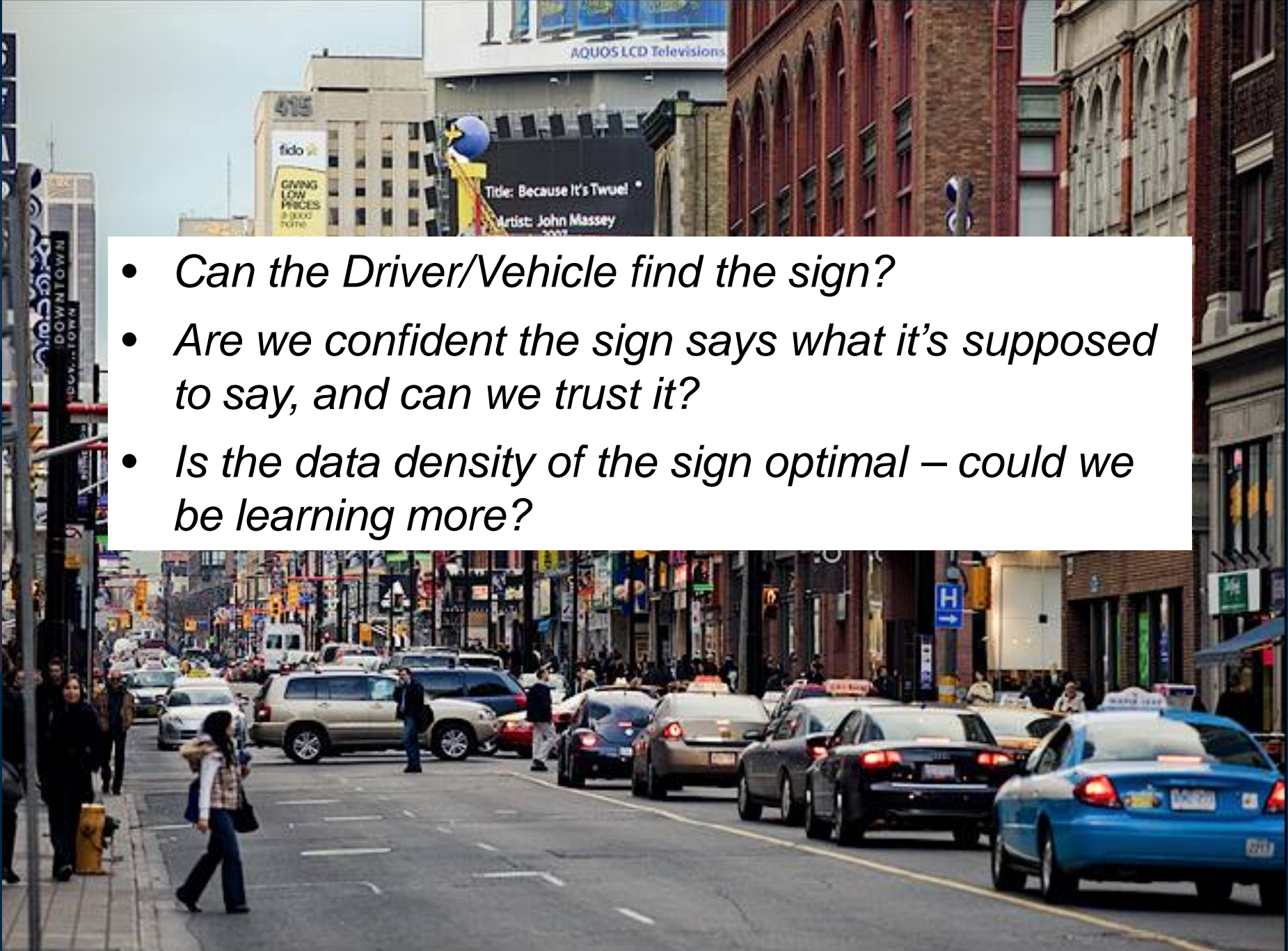
Two representative concrete samples had $Y = 17.7$ (dark concrete) and 35.1 (light concrete), for comparison

Y: CIE xyY color space,
ASTM D6628-03, 45°:0°



Characteristics of PM for optimal detection by ADAS

- **Higher luminance** over all lighting conditions means more light is available to each pixel on visible camera to enable detection.
- **Higher contrast** over all lighting conditions improves differentiation between marking and pavement substrate and detection of marking by visible cameras
- **Wet retroreflective markings** improve light return to visible camera in nighttime and low-light wet conditions, improving detection of pavement marking

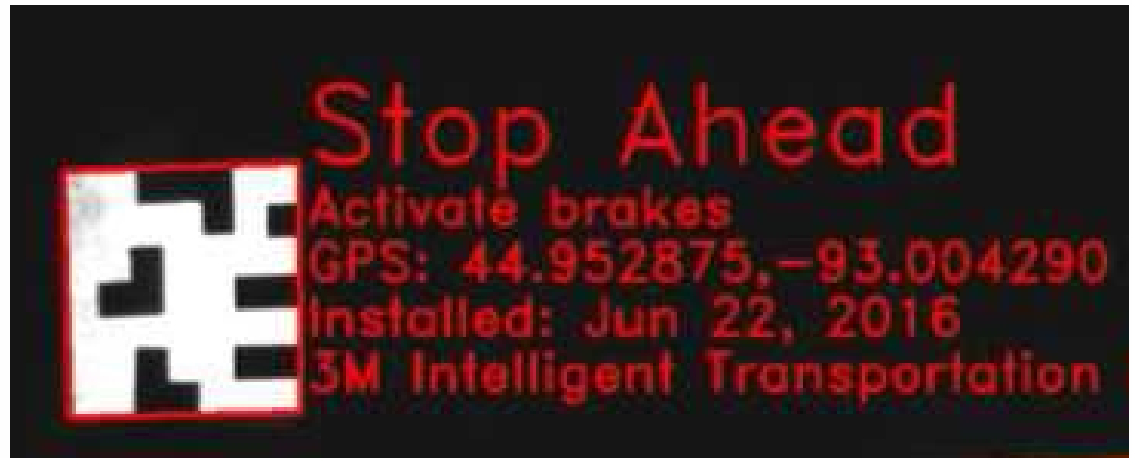
- 
- *Can the Driver/Vehicle find the sign?*
 - *Are we confident the sign says what it's supposed to say, and can we trust it?*
 - *Is the data density of the sign optimal – could we be learning more?*

Optimized Messaging: Machine Readable Signage

May enable more reliable sign detection and classification



Visible Spectrum Image



Computer Vision Image and Associated Meta-Data

Signing Performance Goals

- Embeddable digital information
- Encoded error recovery
- Digitally certain results
- Encryptable
- Authenticatable
- Redundant classification
- Dynamically changeable
- Maintains visible light performance

3M Smart Codes, Michigan I-75 Corridor, day (Aug 2017)

No Signs Found



Left Lane Closed 1 Mile

Move to the right when you can

ID: 50040087591260

Seen: 0s ago

Quality: 10/10



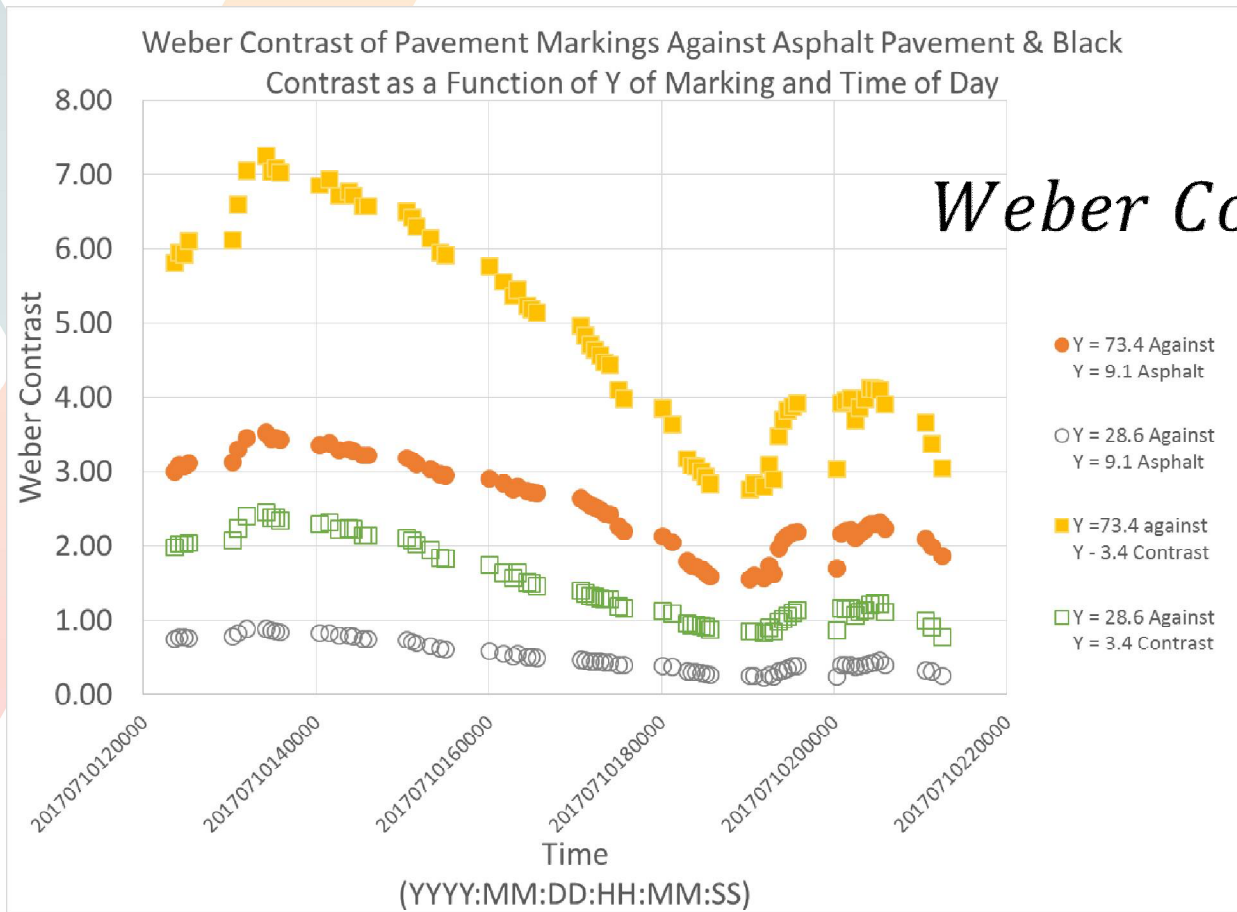
Conclusions

- **The infrastructure is not an immovable object.**
 - **In Fact: Changes to infrastructure are needed and desired by roadway users, CAV's and infrastructure owner operators**
- **True interoperability is only enabled through standardization of these next generation infrastructure and CAV sensors.**
- **Redundancy of roadway information is critical to enabling autonomous driving in non-optimal (real-world) scenarios.**



Thank you!

Weber Contrast From Midday to After Sunset



$$Weber\ Contrast = \frac{(I - I_b)}{I_b}$$

- I = intensity of the feature of interest
- I_b = intensity of the background

Contrasts were calculated from the calibrated absolute values of luminance for the asphalt or the black contrast tape

Read Distance by Sign

Testing at Rellis Campus, TTI

