3M Science. Applied to Life.™

3M™ Connected Roads
Enabling Intelligent Infrastructure

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3M Connected Roads Business Manager
Transportation Safety Division

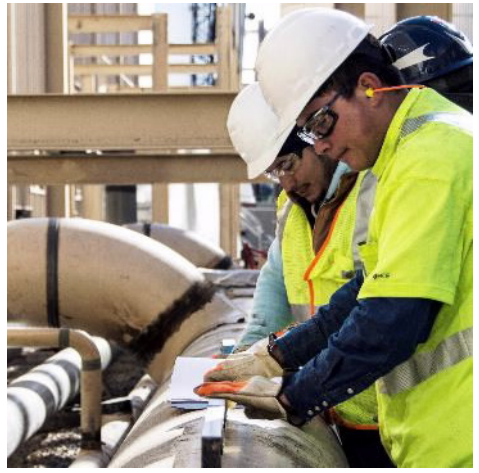
We bring solutions to markets through our business groups

2016 Results

$30.1B Revenue

Health Care

$5.5B



Safety & Graphics

$5.7B

Industrial

$10.3B

Electronics & Energy

$4.8B

Consumer

$4.5B

Global capabilities

Sales in 200 countries

Operations in 70 countries

Labs in 36 countries

Plants in 37 countries

Key

- Sales & Marketing
- Manufacturing/Converting
- Technical Capabilities

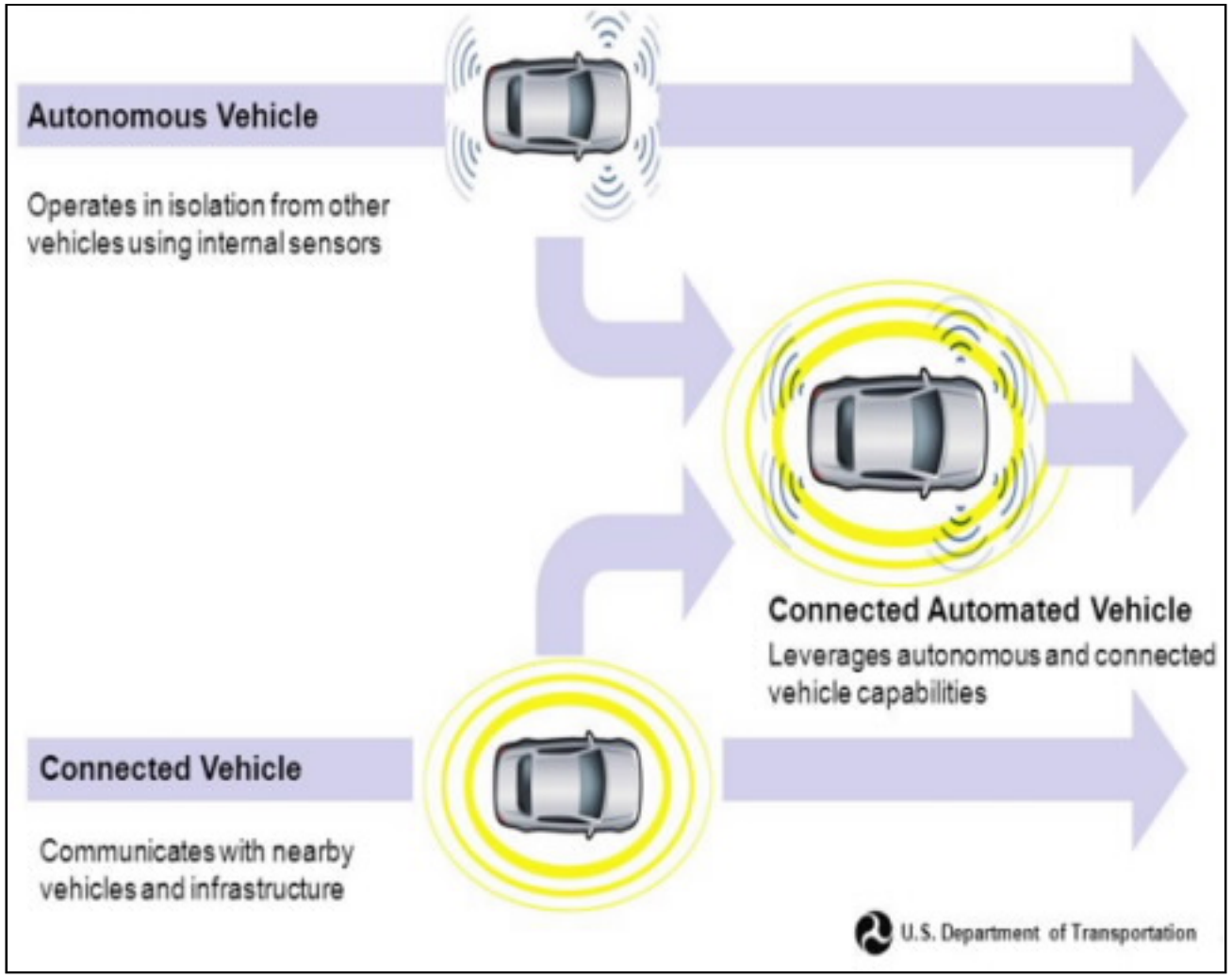
Transportation Safety Mission

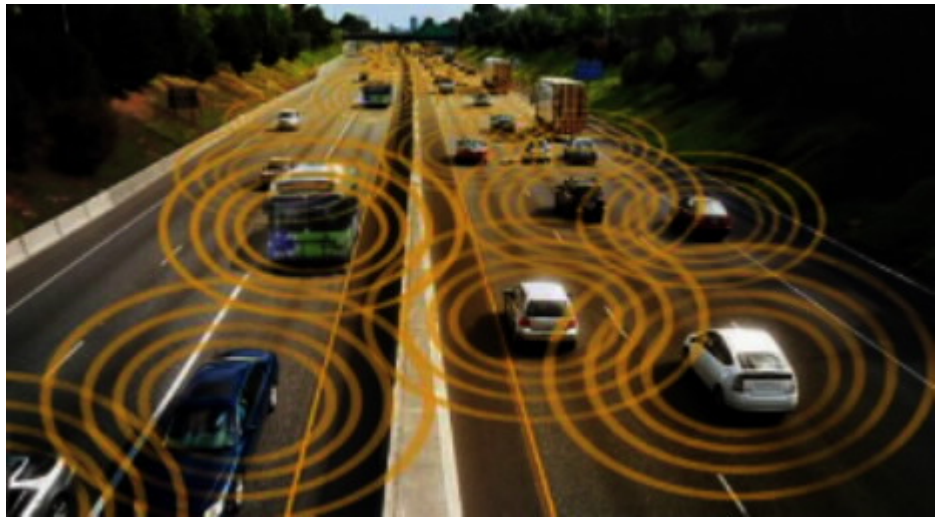
We help bring families home safely.

Complex Infrastructure System

Autonomous Vehicles are the Future of Driving

Infrastructure will play a key role in autonomous driving advancement

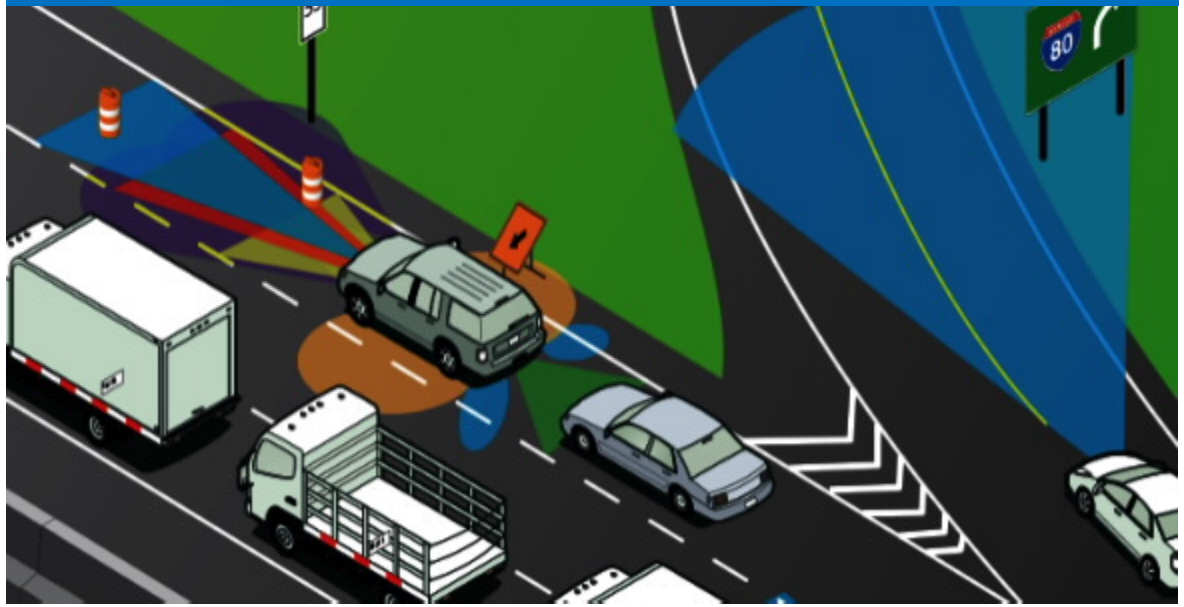




3M™ Connected Roads Technology

Apply 3M Science to solve infrastructure challenges on the road toward zero deaths

Level 1 – 3 Machine Vision



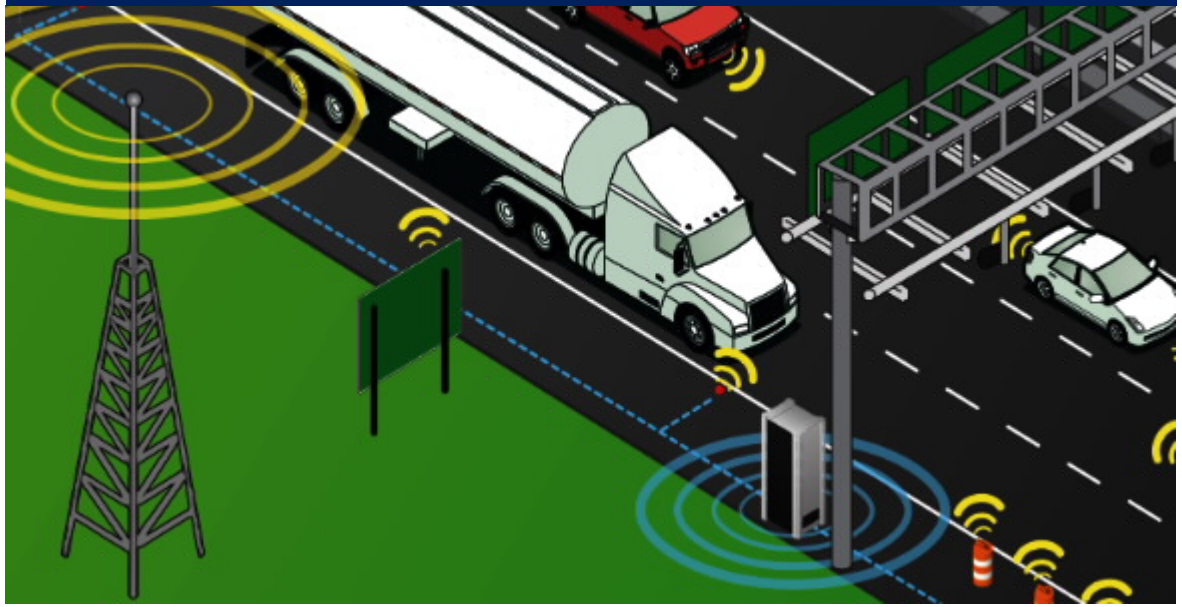
Technologies

- Vehicle sensors (visual, IR, sonic)
- Automatic braking
- Lane departure warning
- Adaptive cruise control
- Sign recognition

Challenges

- Human behavior/confidence
- Poor/inconsistent road markings
- Technology redundancy
- Inclement weather

Level 4 – 5 Broad Infrastructure Play



Technologies

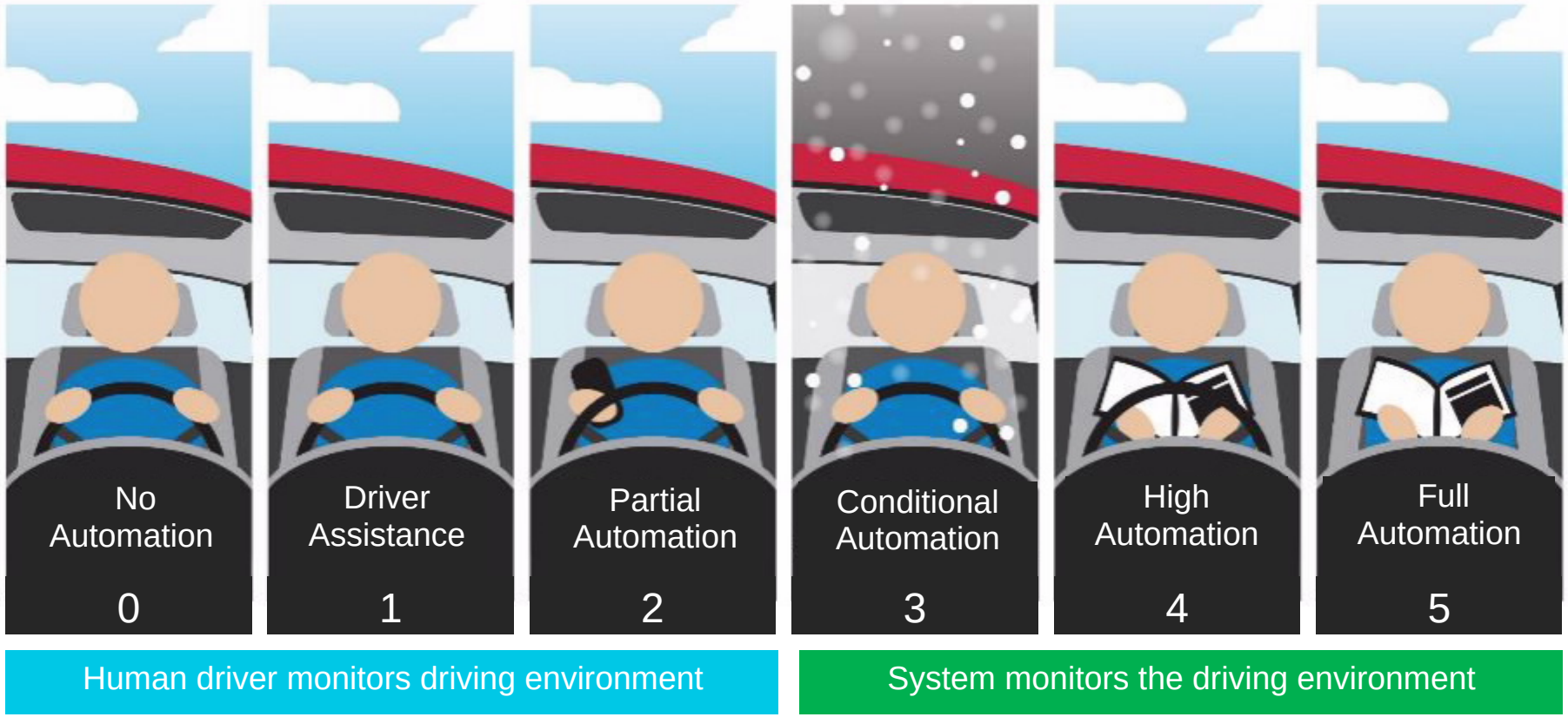
- Vehicle-to-Vehicle
- Vehicle-to-Infrastructure (beacons)
- Vehicle-to-Cloud
- Big data analytics for traffic management

Challenges

- Intersections, work zones, etc.
- Regulatory standardization
- Connectivity and bandwidth
- Inclement weather

SAE J3016 Levels of Automation

Society of Automotive Engineers (SAE) levels have become industry consensus



Pavement Marking Standards Needed for Machine Vision

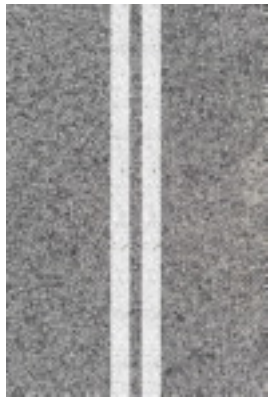
Wide variety of surfaces that effect contrast and visibility







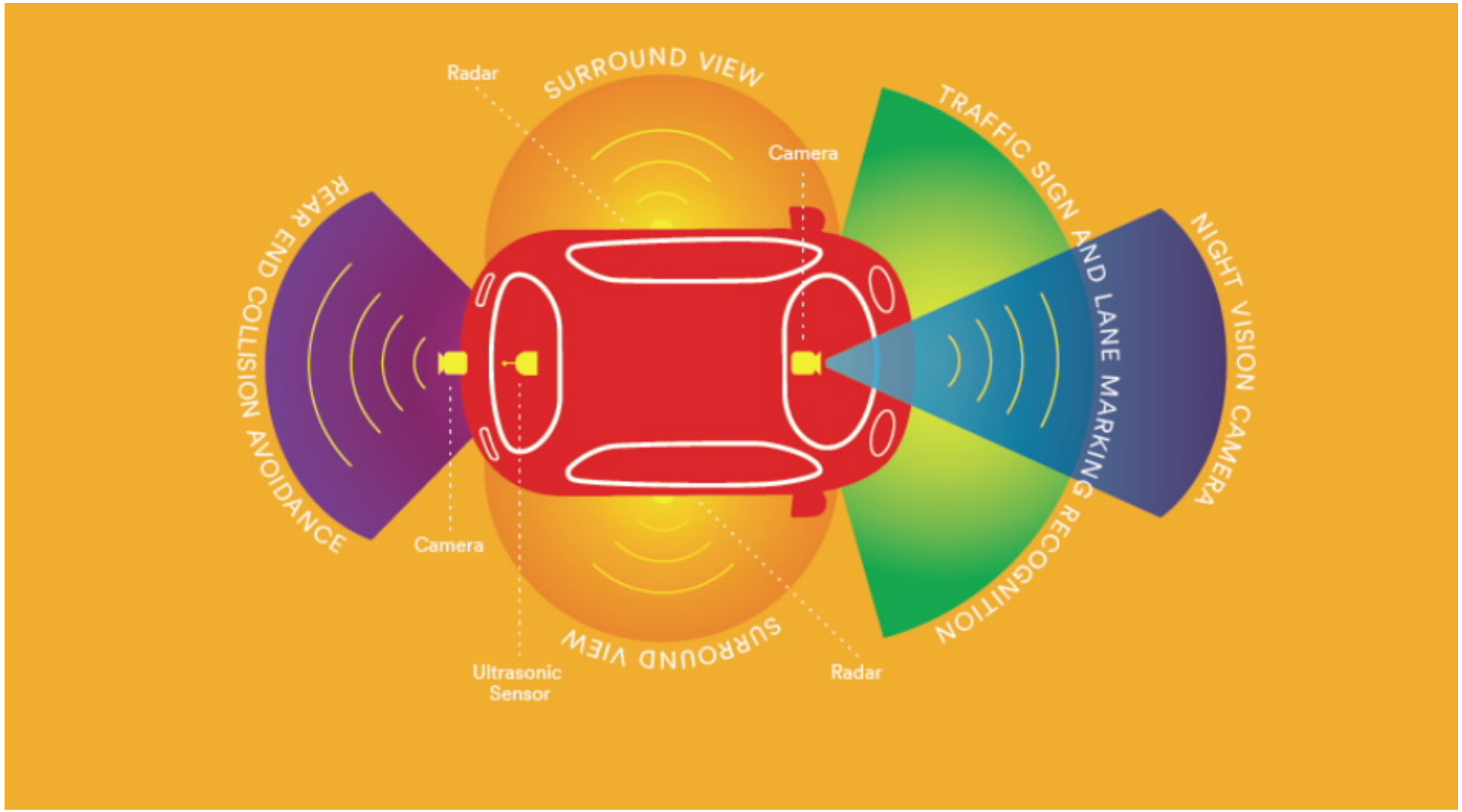



Humans can often interpret what's not standard – can machines?

Advanced Driver Assistance Systems (ADAS)

Sensory platforms have advanced to create increased safety



Characteristics of PM for optimal detection by current ADAS systems

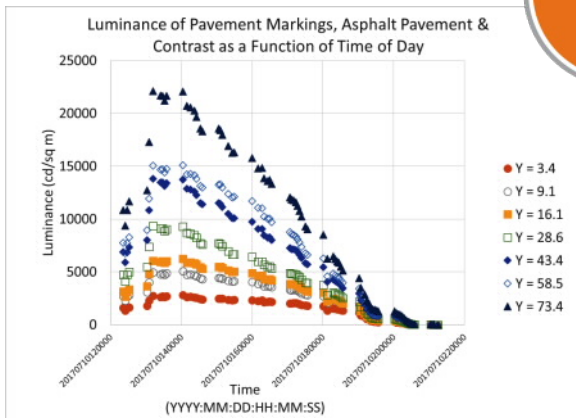
- **Higher luminance** over all lighting conditions means more light is available to each pixel on visible camera to enable detection.

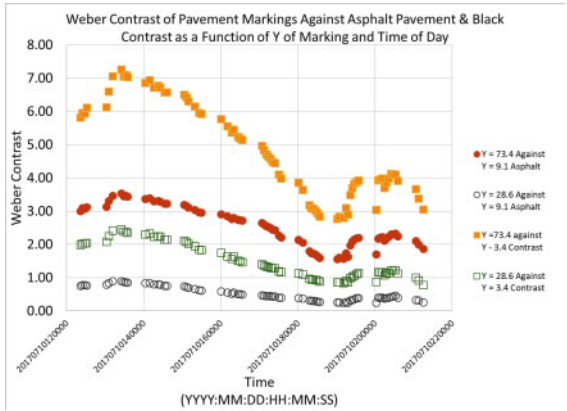
- **Higher contrast** over all lighting conditions improves differentiation between marking and pavement substrate and detection of marking by visible cameras

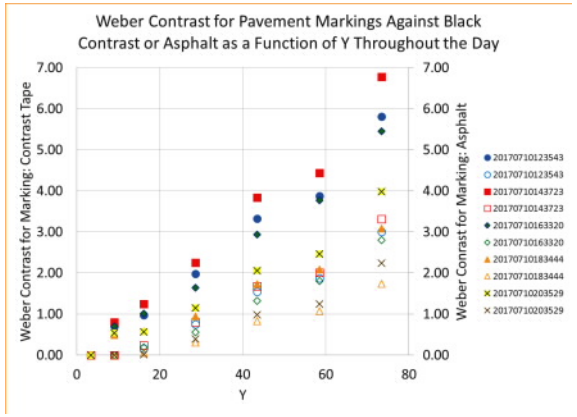
- **Wet retroreflective markings** improve light return to visible camera in nighttime and low-light wet conditions, improving detection of pavement marking

Y:	28.6	43.4	73.4	58.5	16.1	3.4

20 m





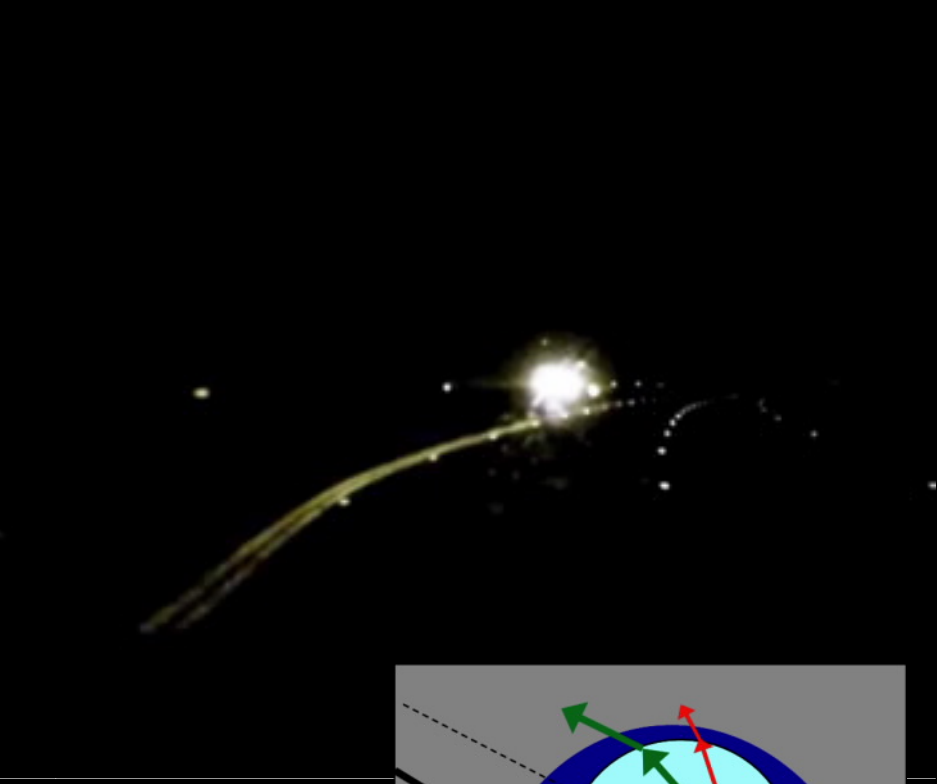


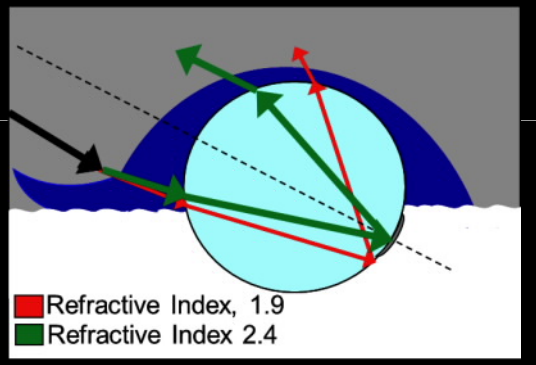
Pavement Marking Technology Comparison

Dry Daytime Conditions

Dry Nighttime Conditions

Wet Nighttime Conditions



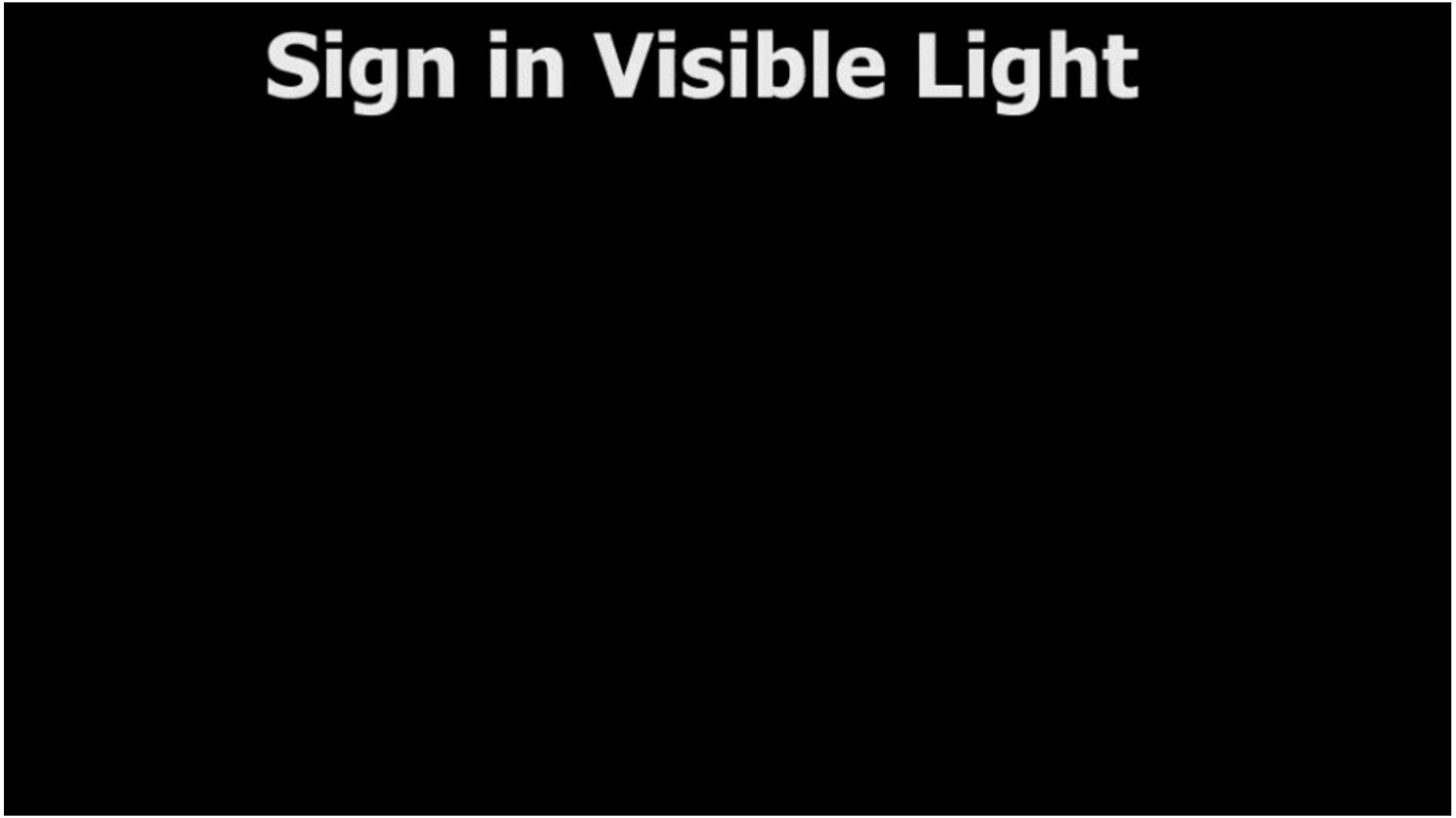


Yellow Line = Optimized for wet reflectivity

White Line & Arrow = Not optimized for wet reflectivity


AQUOS LCD Televisions
415
fido
GIVING LOW PRICES
Title: Because It's Twue!
Artist: John Massey
2007
CANON
CANON THEATRE
Canon
DOWNTOWN
Yonge
Shuter
BUFFALO
Pier 1 Imports
STOP

Finding the Sign: Selective sensors, IR vs Optical Camera

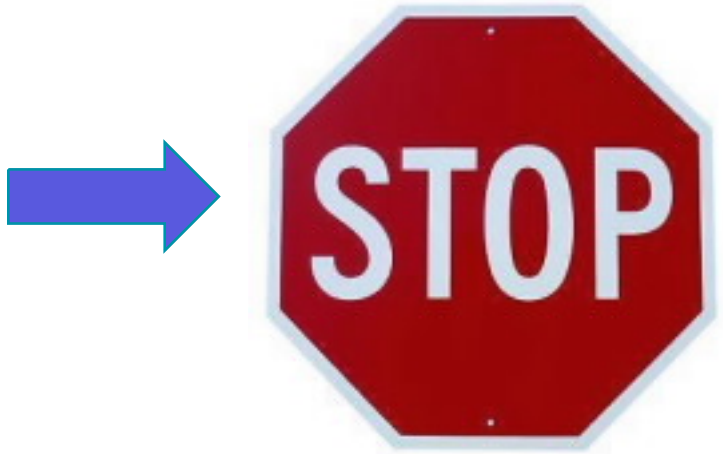


Trusting Machines: False Classification Example[1]

[1] "Robust Physical World Attributes on Machine Learning Models;" Evtimov *etal* https://arxiv.org/pdf/1707.08945.pdf

Input Image

Classification Result

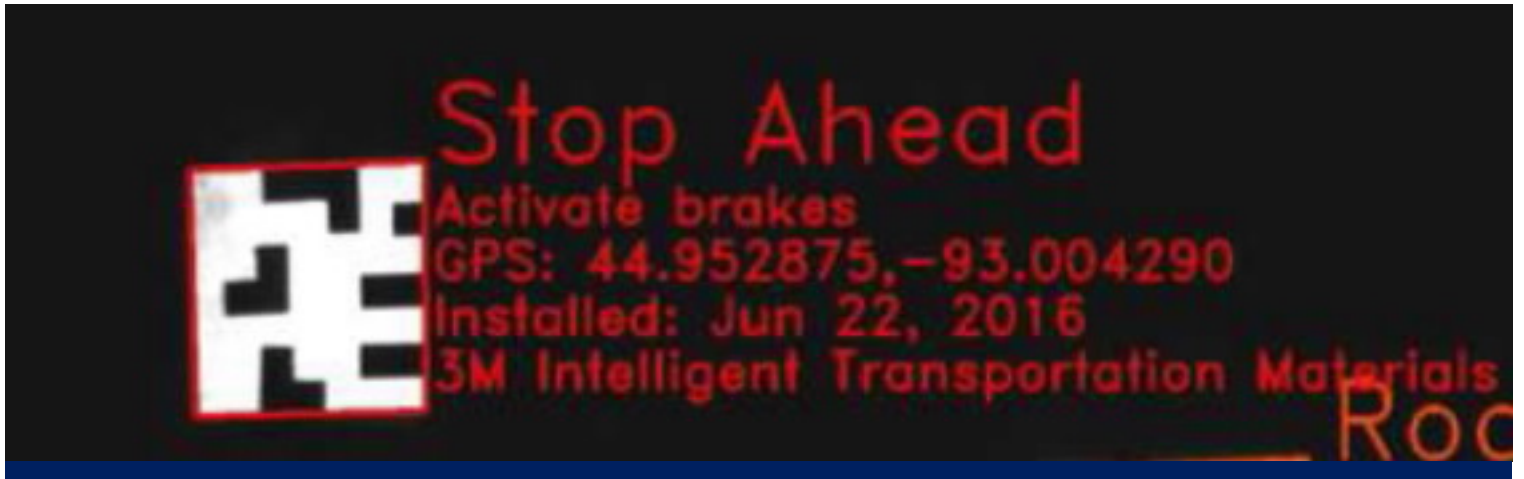


Any signing solution needs to address security concerns regarding physical "hacks" to road signs that confound AVs.

Optimized Messaging: Machine Readable Signage

Solutions that may enable more reliable sign detection and classification

Visible Spectrum Image



Computer Vision Image and Associated Meta-Data

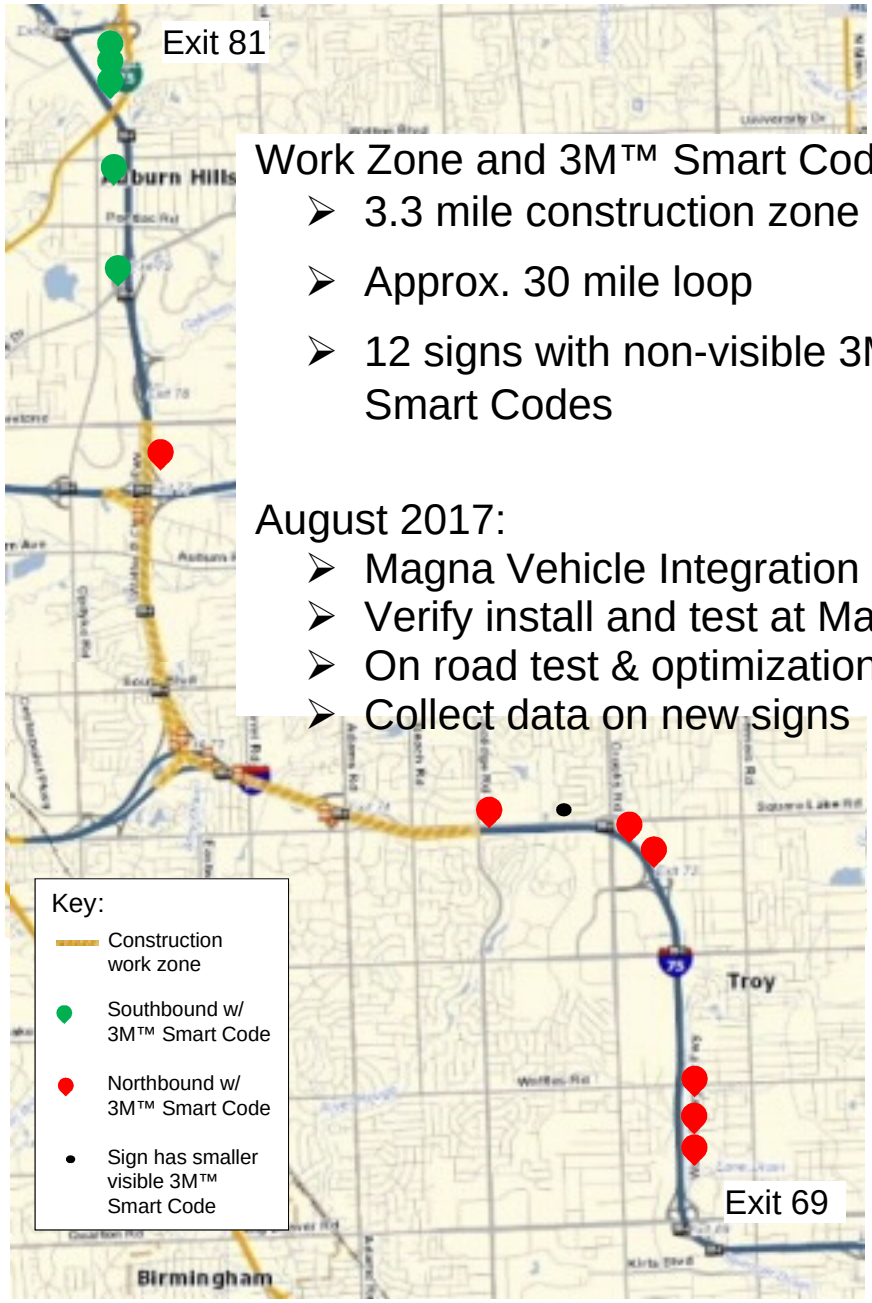
Signing Performance Goals

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

Completed Test w/ Michigan DOT

Successful installation with key lead user DOT

3M™ Smart Code Signs on 12 mile stretch of I-75
Sensor integrated in Magna's Mazda CX7
Data indicates 150 m read distance at 60 mph
→ MDOT requested a long-term install



Work Zone and 3M™ Smart Code Signs

- 3.3 mile construction zone
- Approx. 30 mile loop
- 12 signs with non-visible 3M™ Smart Codes

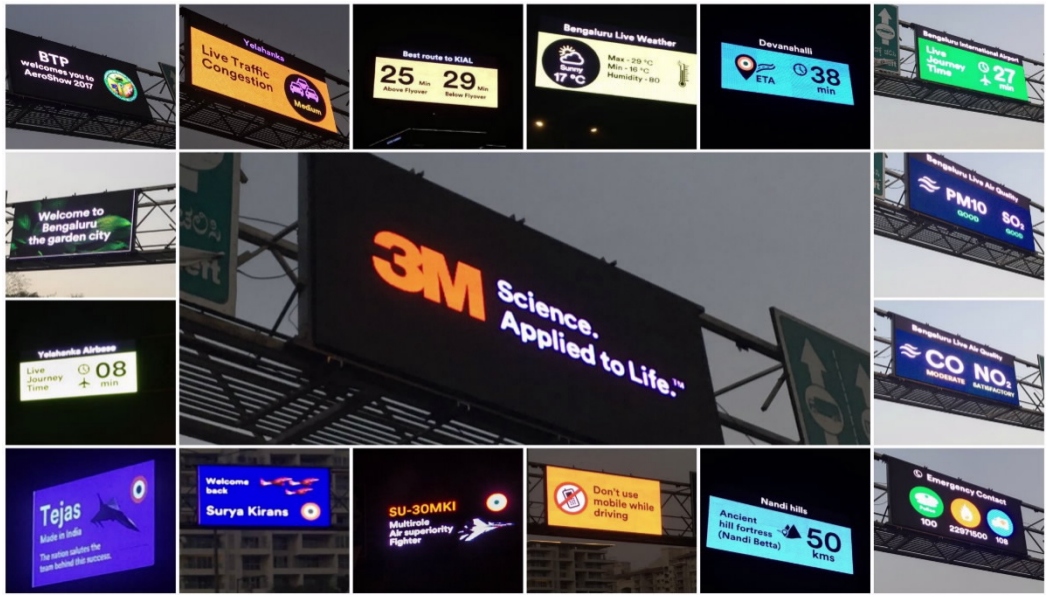
August 2017:

- Magna Vehicle Integration
- Verify install and test at Magna
- On road test & optimization
- Collect data on new signs

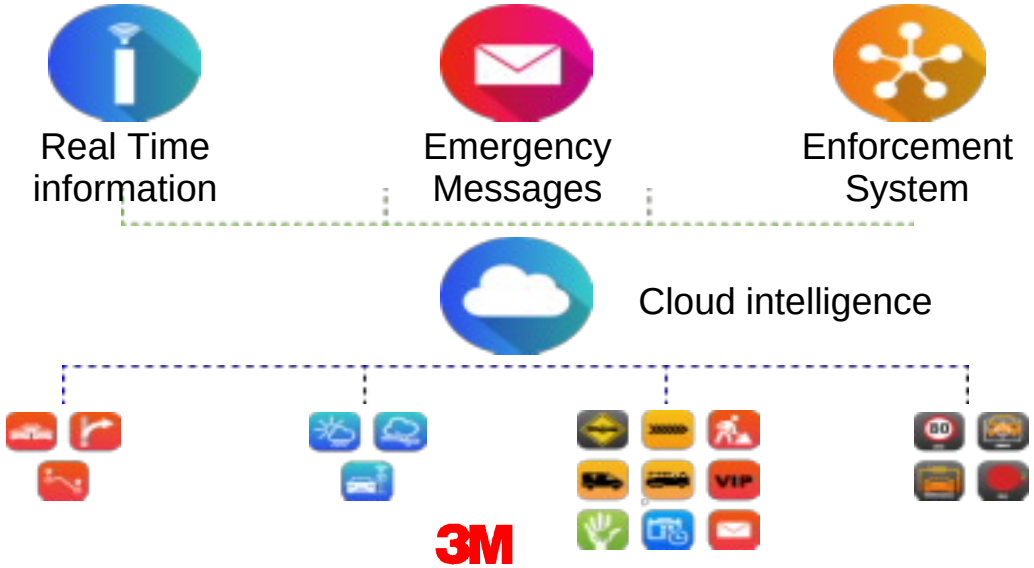
SMART Variable message signage

Description:
Electronic LED display signage that provides real time traffic data:
- Journey time,
- Congestion along the route / alternate route
- Weather information
- Emergency messages

Cloud based controlled system that provides real-time information which is captured, processed and displayed on the screens.



Key Features:
- Real time and automated information
- Live traffic information
- Live weather updates
- Emergency Messages



Autonomous Multi-Purpose Utility Vehicle

Conspicuity Reflective Tape to warn Autonomous MPUV of objects

Boundary Markings to guide Autonomous MPUV

ID Labels for Garbage Bins. Easier for MPUV to locate and identify garbage bins

i. Increasing public space required for cleaning

ii. Labour-intensive door to door collection

New Zealand Pavement Marking Trials

- NZ has one of the highest per 1000 capita vehicle ownership rates, at 774 vehicles (light)
- The rate of growth of 4.6% in 2016, and increasing distances travelled per vehicle since 2013
- Precipitation for 25-37% of the year
- 17.6 million vehicles per km on NZ roads.

HAT: Pedestrian crossing in Tauranga

Key Remarks

Changes to infrastructure are needed and desired by both roadway users and infrastructure owner operators

True interoperability is only enabled through standardization of these next generation infrastructure/sensors

Redundancy of roadway information is critical to enabling autonomous driving in non-optimal (real-world) scenarios

Several concepts driving towards a technical solution to one or more of these challenges are being developed

Thank you!