WISCONSIN
UNIVERSITY OF WISCONSIN–MADISON

WISCONSIN
AUTOMATED VEHICLE
PROVING GROUNDS

ROADVIEW

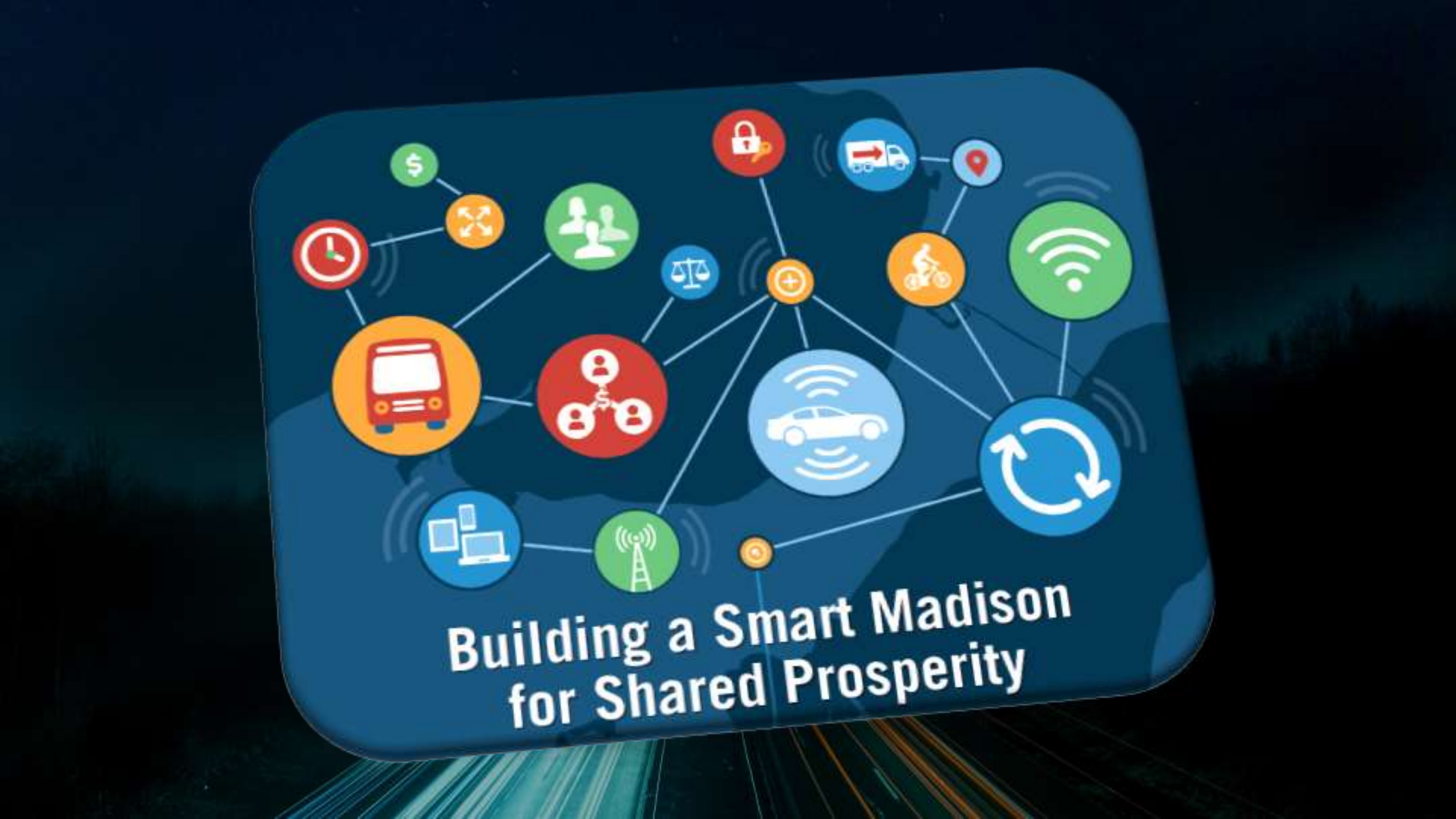

PETER RAFFERTY
WISCONSIN AUTOMATED VEHICLE PROVING GROUNDS
wiscav.org

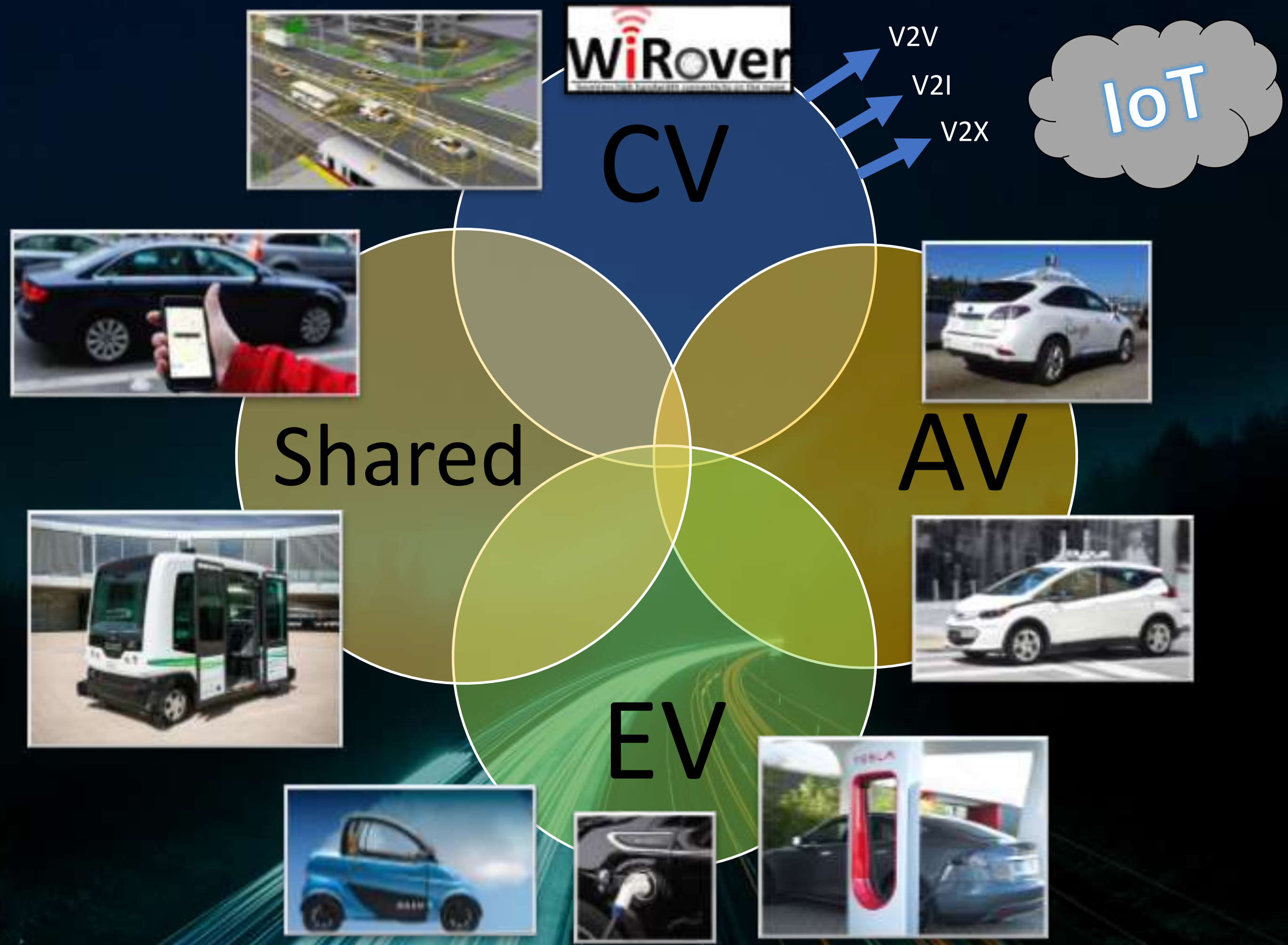
What is an AV?


“Personal
Delivery
Device”


RTC
Free
Shuttle
AAA


RTC


Building a Smart Madison
for Shared Prosperity


WiRover
CV
V2V
V2I
V2X
IoT
Shared
AV
EV

Trends and Outcomes

Mobility

- Electric
- Shared
- Connected
- Automated

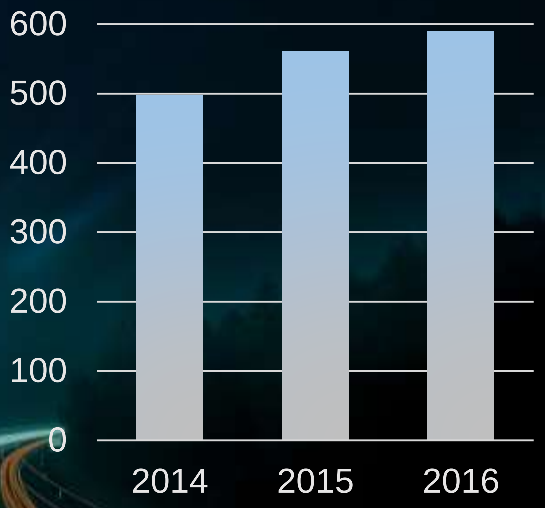
- Safety
- Vehicle Miles Traveled (VMT)
- Sprawl
- Parking
- Energy
- Air Quality
- Public Health
- Equity
- Accessibility

Traffic Fatalities Rising

Nationally:

- Increased for 2nd straight year
- Largest two-year increase in 50 years
- Approaching 40,000 deaths

Wisconsin:



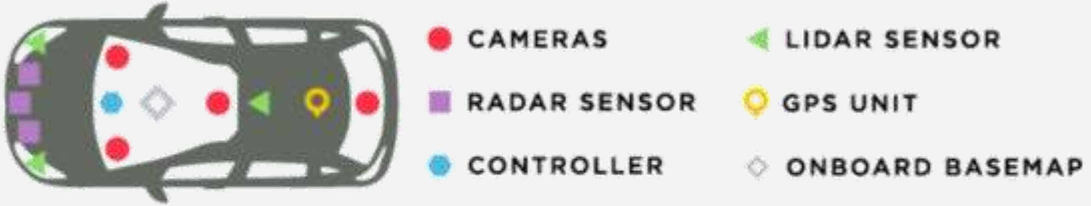
- Pedestrian deaths now up to 15% of all traffic fatalities

Motivations and Opportunities

- Safety
  - ~90% of crashes attributable to human error
  - Approaching 40,000 deaths
  - Distracted driving continues to worsen
  - Need to carefully navigate the era of partial automation
- Equity
  - Accessibility
  - First mile / last mile

- Many other motivations:
  - Economic development, startup and tech jobs
  - Underutilized vehicles
  - Efficient use of infrastructure and land
  - Health care, agriculture, and other sectors

How AVs Operate



CAMERAS
Cameras gather visual information from the road and traffic control and send them to the controller for processing.

LIDAR
LiDAR sensors bounce lasers off of detected objects. LiDAR can detect road lines and assets and differentiate objects.

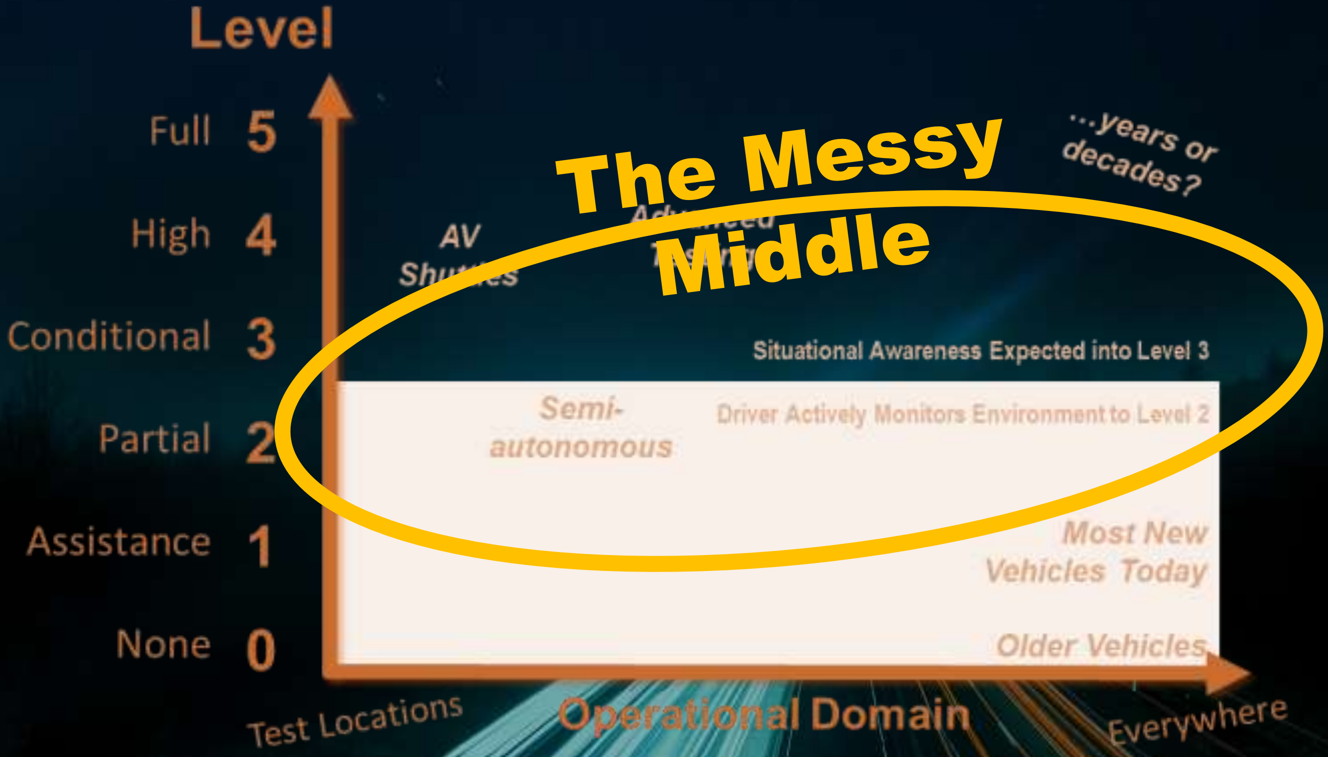
RADAR
Radar sensors bounce radio waves off detected objects. Radar cannot differentiate objects.

GPS UNIT
The GPS unit identifies the precise position of the vehicle and aids in navigation.

SAE Levels of Automation

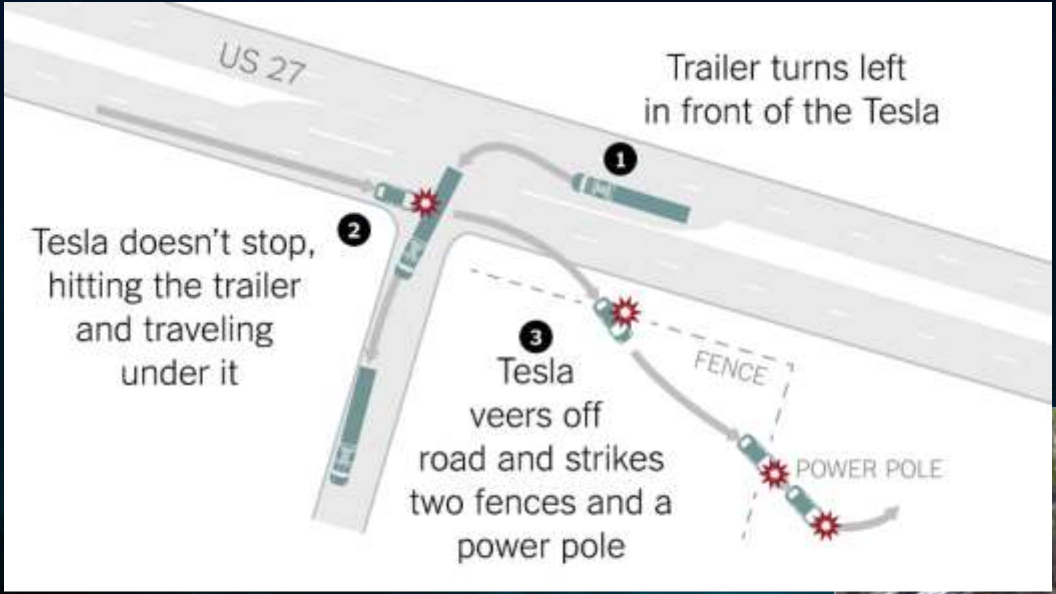
SAE level	Name	Narrative Definition	Execution of Steering and Acceleration/ Deceleration	*Monitoring* of Driving Environment	Fallback Performance of *Dynamic Driving Task*	System Capability *(Driving Modes)*
Human driver **monitors the driving environment**						
0	**No Automation**	the full-time performance by the *human driver* of all aspects of the *dynamic driving task*, even when enhanced by warning or intervention systems	Human driver	Human driver	Human driver	n/a
1	**Driver Assistance**	the *driving mode*-specific execution by a driver assistance system of either steering or acceleration/deceleration using information about the driving environment and with the expectation that the *human driver* perform all remaining aspects of the *dynamic driving task*	Human driver and system	Human driver	Human driver	Some driving modes
2	**Partial Automation**	the *driving mode*-specific execution by one or more driver assistance systems of both steering and acceleration/ deceleration using information about the driving environment and with the expectation that the *human driver* perform all remaining aspects of the *dynamic driving task*	**System**	Human driver	Human driver	Some driving modes
Automated driving system **("system") monitors the driving environment**						
3	**Conditional Automation**	the *driving mode*-specific performance by an *automated driving system* of all aspects of the dynamic driving task with the expectation that the *human driver* will respond appropriately to a *request to intervene*	System	**System**	Human driver	Some driving modes
4	**High Automation**	the *driving mode*-specific performance by an automated driving system of all aspects of the *dynamic driving task*, even if a *human driver* does not respond appropriately to a *request to intervene*	System	System	**System**	Some driving modes
5	**Full Automation**	the full-time performance by an *automated driving system* of all aspects of the *dynamic driving task* under all roadway and environmental conditions that can be managed by a *human driver*	System	System	System	**All driving modes**

Levels Depend on Circumstances



Critical implications:

- Human operator expectations, "re-engagement"
- Where certain vehicles can safely operate



Tesla
Florida
May 2016

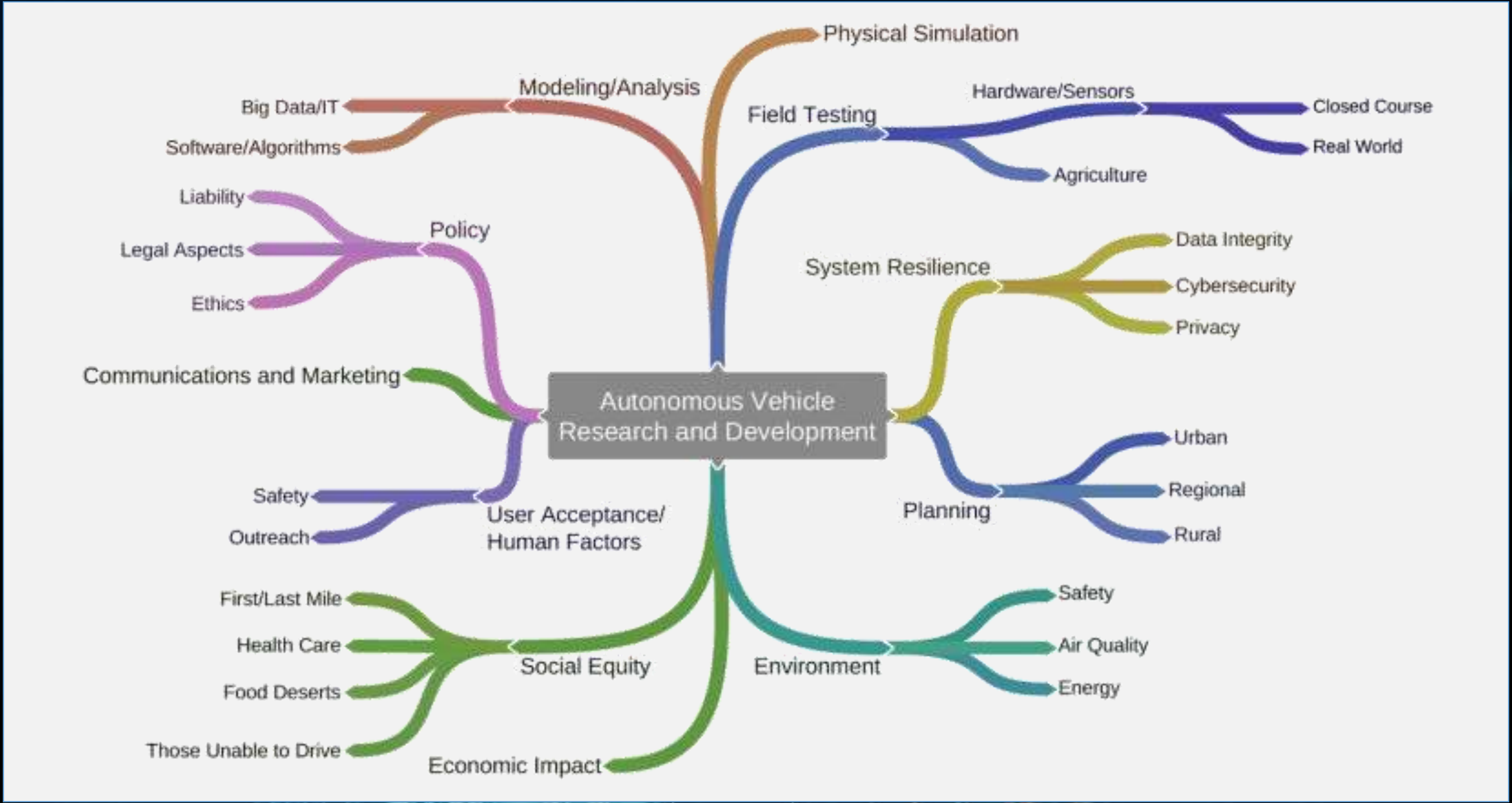
Tesla, March 2017

June 17, 2017

Destroyer Fitzgerald and ACX Crystal

Uber, March 2017

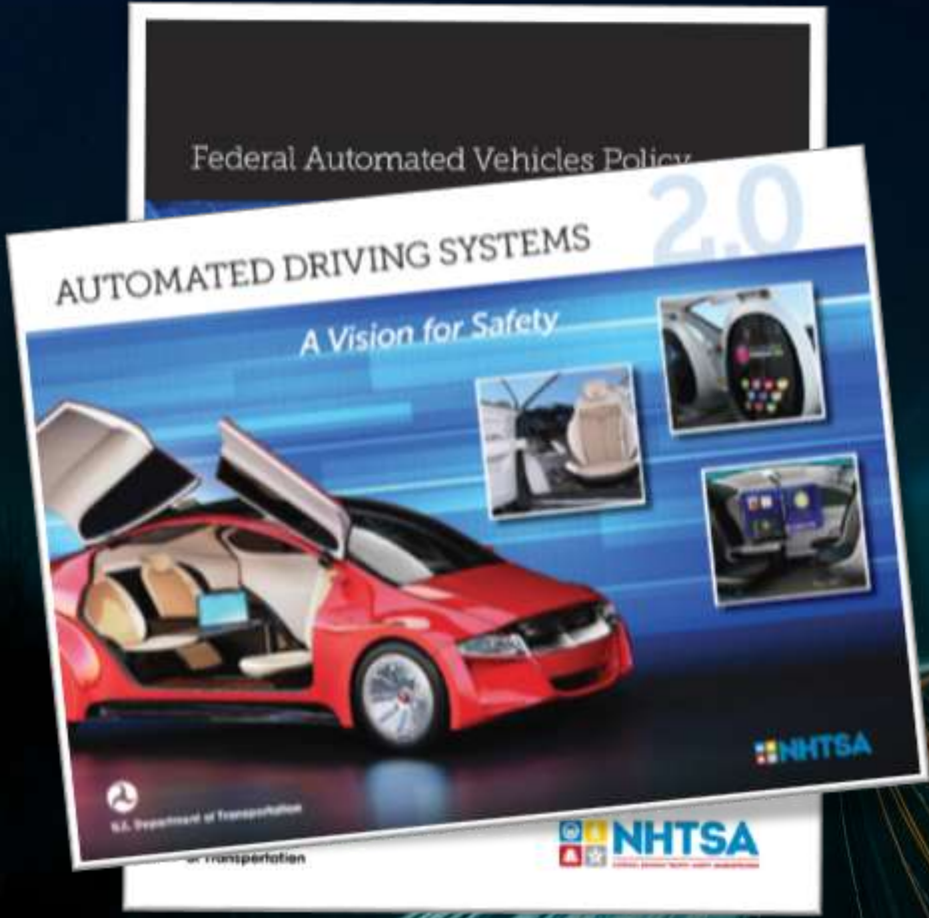
Breadth, Complexity, Edge Cases



The Road to Autonomous through Advanced Driver-Assistance Systems (ADAS)

- Driver alert systems
- Forward collision warning / automated braking
- Adaptive cruise control
- Lane keeping / departure warning
- Automated lighting
- Automatic parking
- Traffic warnings
- Smartphone/GPS connectivity
- V2V systems
- V2I/V2X systems

Back-Up Camera
Shows you a view behind your car when backing up
Blind Spot Monitor
Helps you know what cars might be hidden to your left or right
Lane Departure & Lane Keeping Systems
Warns you if you're drifting out of your lane and may steer you back
Automatic Emergency Braking System
May brake for you if a front-end crash is imminent
AUTO P
Automatic Parallel Parking
Helps you safely navigate into a parallel spot. You control braking, it controls steering
MyCarDoesWhat.org
A website that answers all your questions about new car safety technologies.
...and so much more



Federal AV Policy

- Released Sep 20, 2016
- Updated Sep 12, 2017
- Voluntary guidelines
    - Not regulations
- Level 3+ Only
- 12 Safety Elements
- Guidance for State Policy

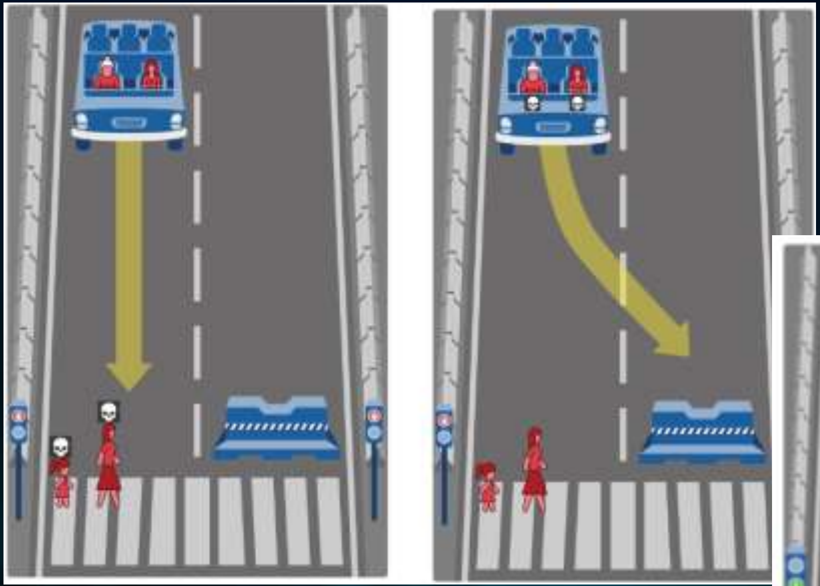
NHTSA's ~~15~~ 12 Safety Elements

1. System Safety
2. Operational Design Domain
3. Object and Event Detection and Response
4. Fall Back (Minimal Risk Condition)
5. Validation Methods
6. Human Machine Interface
7. Vehicle Cybersecurity
8. Crashworthiness
9. Post-Crash **ADS** Behavior
10. Data Recording ~~and Sharing~~
11. Consumer Education and Training
12. Federal, State and Local Laws

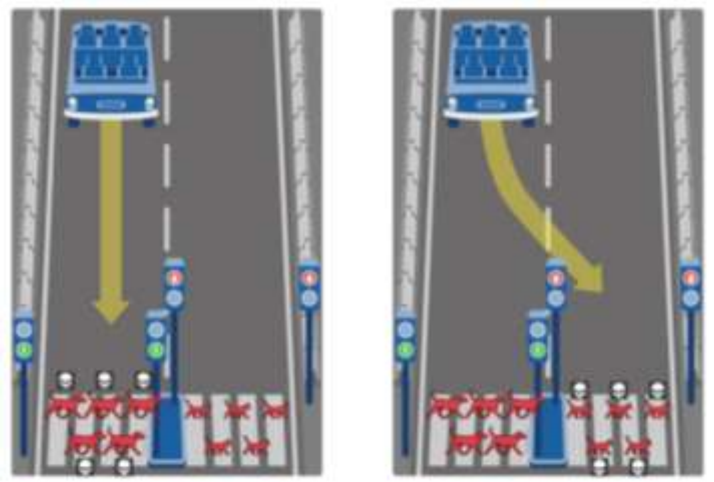
~~13. Privacy~~

~~14. Registration and Certification~~

~~15. Ethical Considerations~~



15. Ethical Considerations

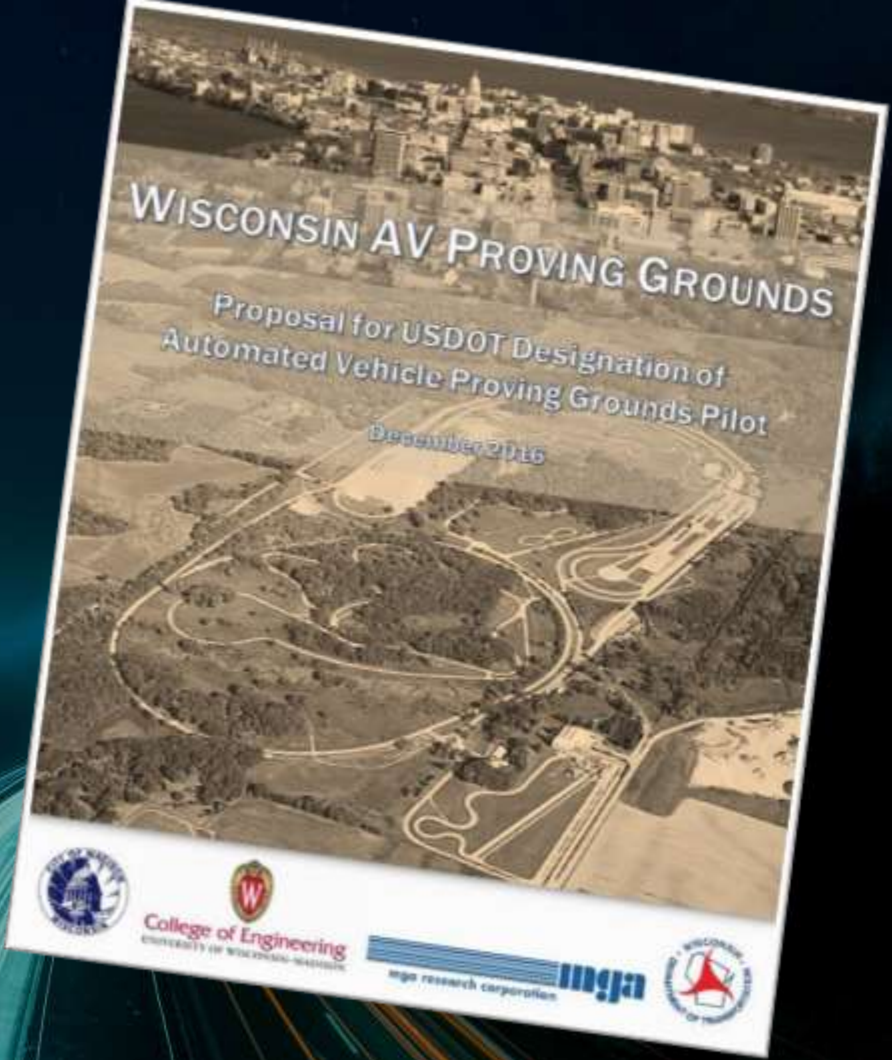


moralmachine.mit.edu

USDOT AV
Proving Grounds

- Peer network
- Advise government
- Validate industry
- Awarded January 2017

…no funding



Ten Designated AV Proving Grounds

Range of RDT&E Environments

Simulation

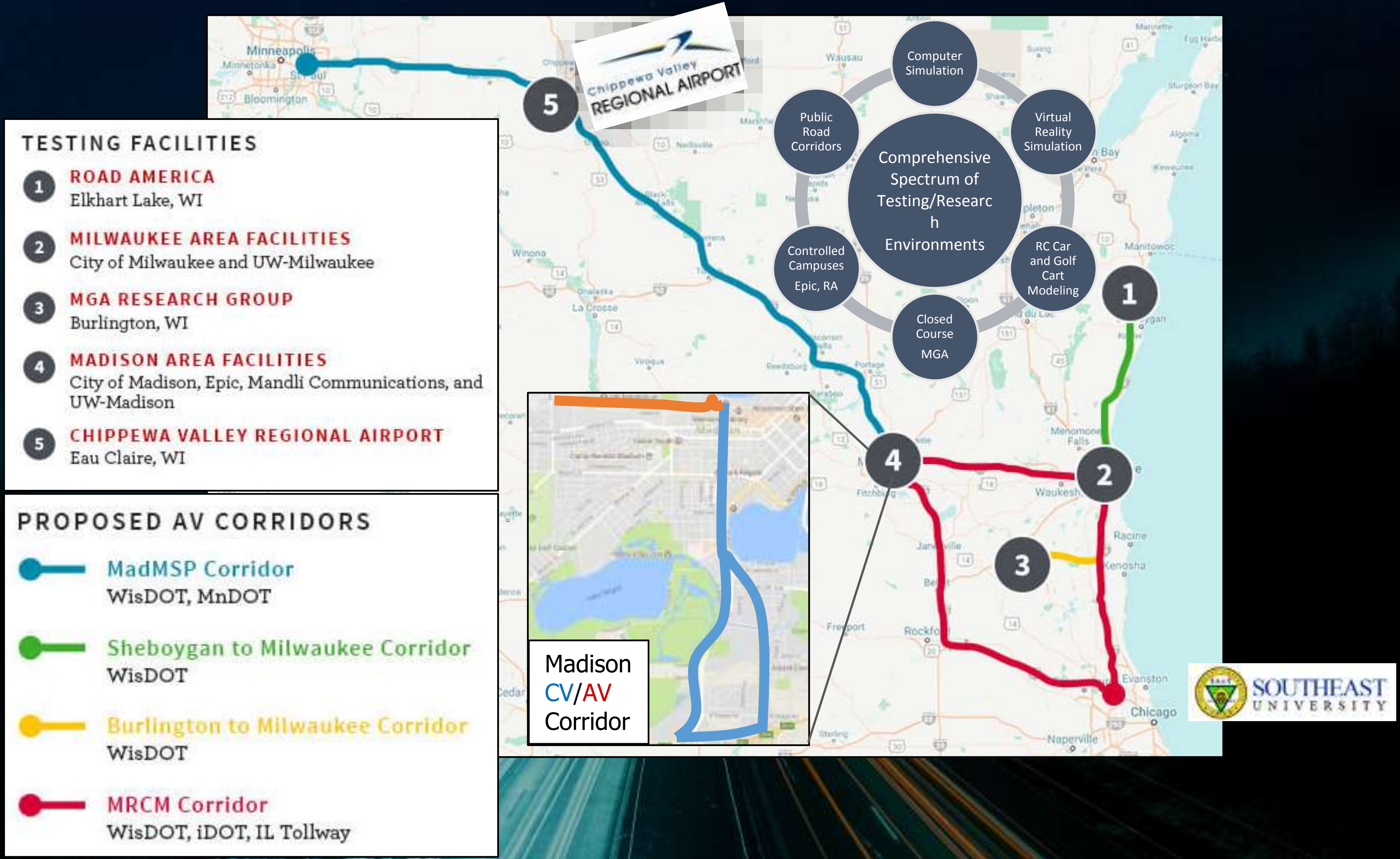
Lab

Closed Track

Controlled Demo

Limited Facility

Public Roads


TESTING FACILITIES
1 ROAD AMERICA
Elkhart Lake, WI
2 MILWAUKEE AREA FACILITIES
City of Milwaukee and UW-Milwaukee
3 MGA RESEARCH GROUP
Burlington, WI
4 MADISON AREA FACILITIES
City of Madison, Epic, Mandli Communications, and UW-Madison
5 CHIPPEWA VALLEY REGIONAL AIRPORT
Eau Claire, WI
PROPOSED AV CORRIDORS
MadMSP Corridor
WisDOT, MnDOT
Sheboygan to Milwaukee Corridor
WisDOT
Burlington to Milwaukee Corridor
WisDOT
MRCM Corridor
WisDOT, iDOT, IL Tollway
Chippewa Valley REGIONAL AIRPORT
Comprehensive Spectrum of Testing/Researc h Environments
Computer Simulation
Virtual Reality Simulation
RC Car and Golf Cart Modeling
Closed Course
MGA
Controlled Campuses
Epic, RA
Public Road Corridors
Madison CV/AV Corridor
Minneapolis
St Paul
Bloomington
Wausau
Winona
La Crosse
Portage
Manitowoc
Waukesha
Racine
Kenosha
Janesville
Rockford
Freeport
Evanston
Chicago
Naperville
SOUTHEAST UNIVERSITY

Wisconsin Facilities

UW-Madison College of Engineering

Full Scale Driving Simulator

SBEL
Simulation Based Engineering Lab

WISCONSIN
TOPS
TRAFFIC OPERATIONS & SAFETY LABORATORY


PROJECT
CHRONO

Wisconsin Facilities

MGA Research, Burlington

- 400 acres, private and secure, numerous testing capabilities

Wisconsin Facilities

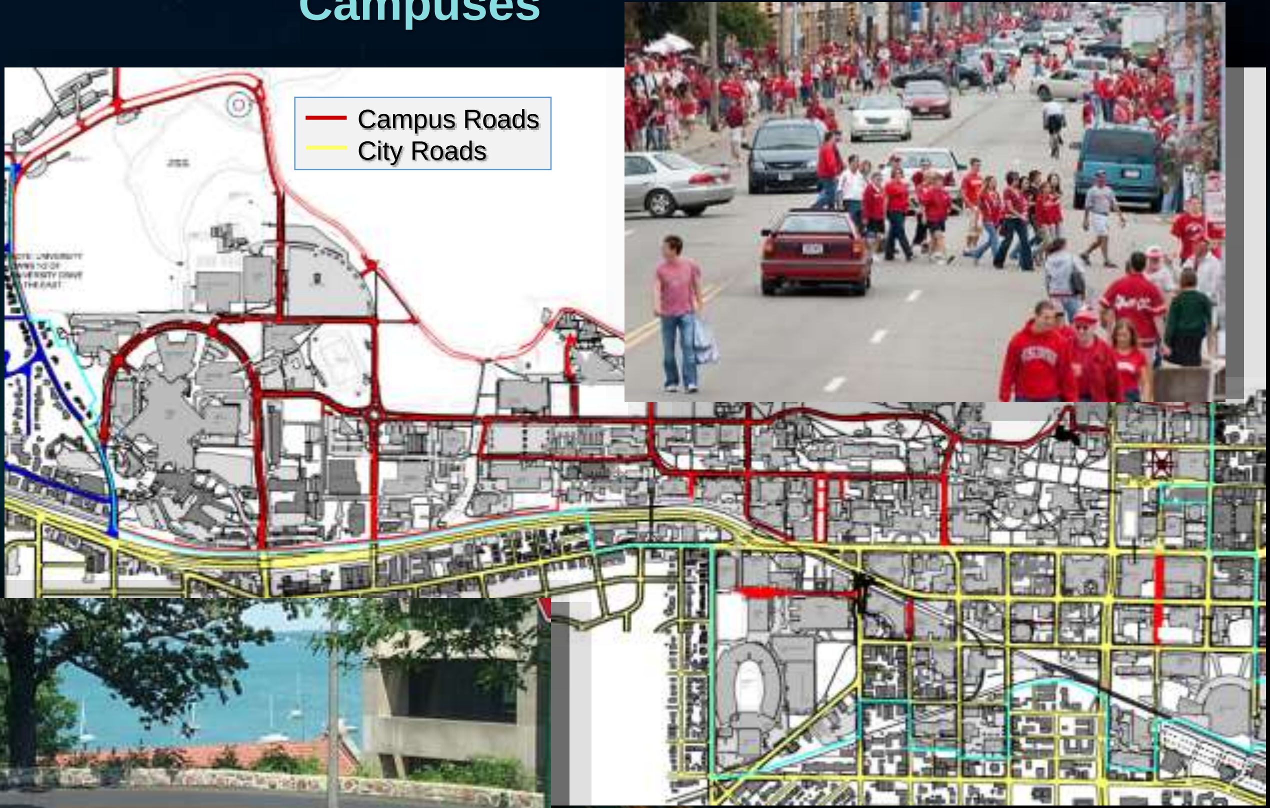
Road America, Elkhart Lake

- Road track: 4.05-mile length, 30-foot width
- 1-mile combo paved-dirt track
- 12+ miles off-road
- 10+ miles access roads
- Major race events and media presence

Wisconsin Facilities

Campuses

- Corporate Campuses
- UW-Madison Campus
- City of Madison

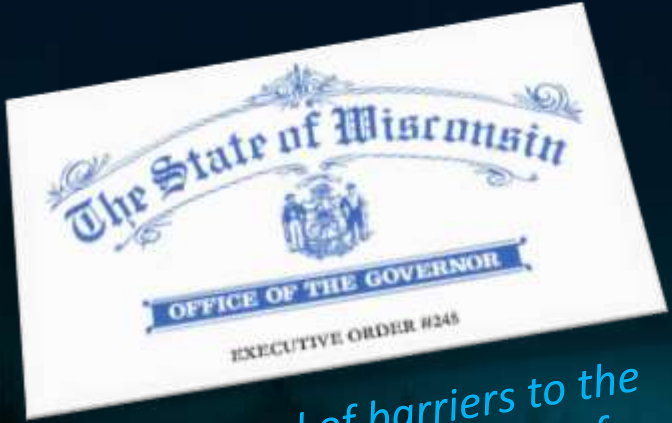


Wisconsin Facilities

Connected Park Street Corridor

- Piloting CV technology to improve:
  - Safety
  - Mobility
  - Bus on-time performance
  - Equity
- V2I, V2V, V2X
- Madison and Wisconsin as the Upper Midwest hub for CV & AV development

Governor's Committee on Automated and Connected Vehicles



"the removal of barriers to the testing and deployment of automated and connected vehicle technology in Wisconsin"

- May 2017 EO #245
- Sept 2017 Kickoff
- June 2018 Report Due
- Members:
  - Government: WisDOT, WSP, WEDC, Assembly, Senate, Iowa Co Sheriff, Insurance Commissioner
  - Academic/Nonprofit: UW-Madison, Tech Council, ABATE
  - Industry: MGA, Roadview, Waymo, Uber, Tesla, AAM, Global Automakers, Dealers Assn, Harley, Schneider, HNTB

STEVE **CAYA**

PRESIDENT, ROADVIEW

roadview.com

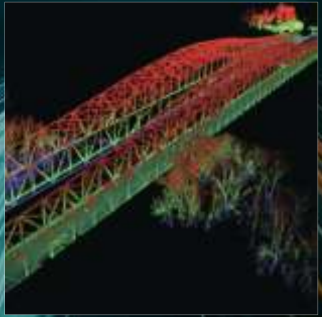
Transportation in an Automated Vehicle Wor

Steve Caya - President of Roadview, Inc.

- Member of Governor’s Steering Committee on Autonomous Vehicles (AV)
- Member of the Wisconsin AV Proving Grounds
- Board Member of Geospatial Transportation Information Management Association (GTiMA)
- UW-Madison - Detachment 925 Air Force ROTC Alumni Captain, United States Air Force

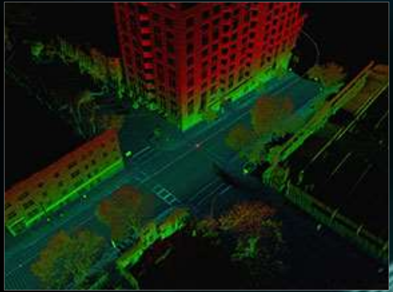
About Roadview

- A dedicated geospatial data collection, processing, and delivery company
- Based in Fitchburg, WI
- Worked with over 30 State DOTs
- First pavement collection in 2002
- 35 years experience in the Transportation industry

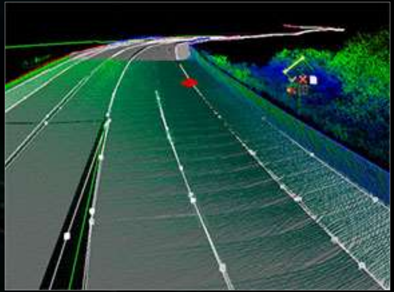


Technology

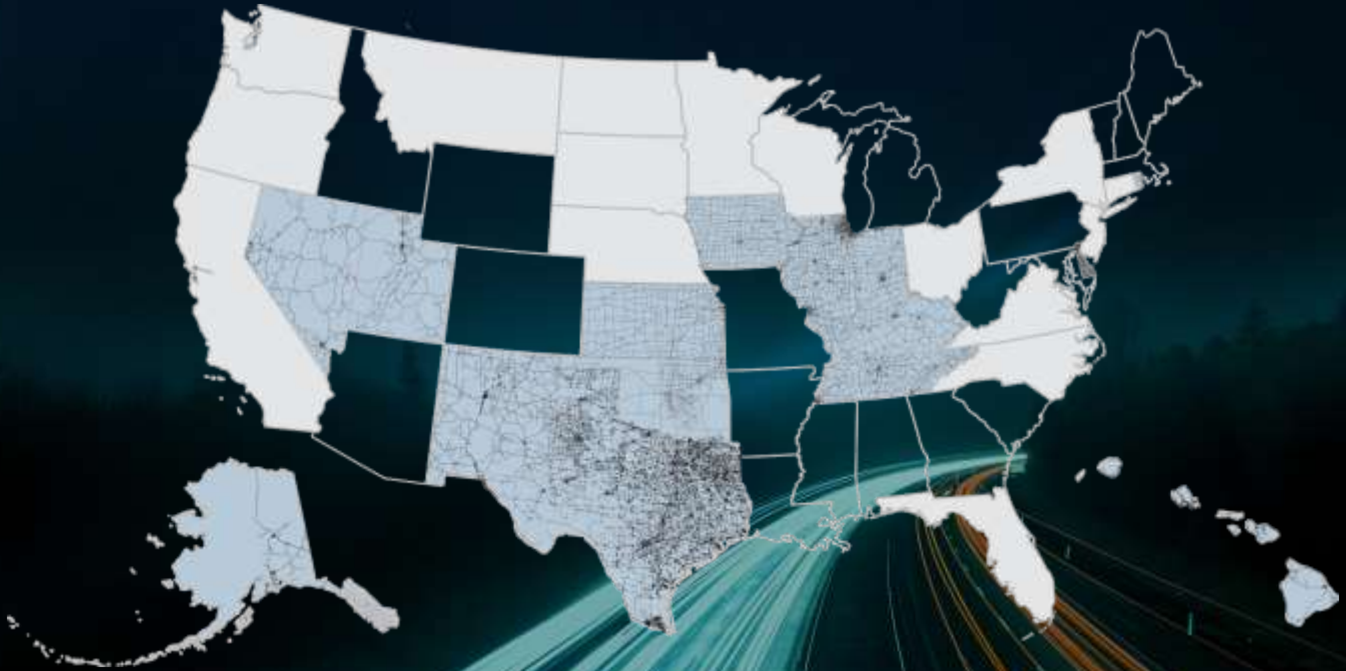
- LiDAR
- Positional Systems
- Imaging
- LCMS – Laser Crack Measurement System
- Software for data extraction and visualization







Thousands of Miles Collected



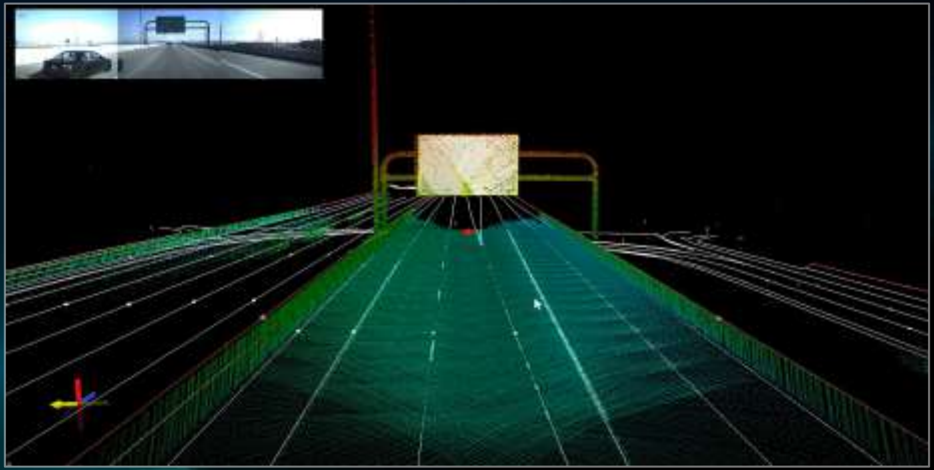
Technology

Imaging

Roadview's 2D imaging system is capable of recording high-resolution images in a variety of weather, speed, and lighting conditions. The operator can monitor all images being collected by the system in real-time. Each camera runs at a resolution up to 3296 $\times$ 2472 pixels and captures at a selectable rate of 100 to 500 frames per mile, with vehicle speeds ranging up to 65 mph during collection.

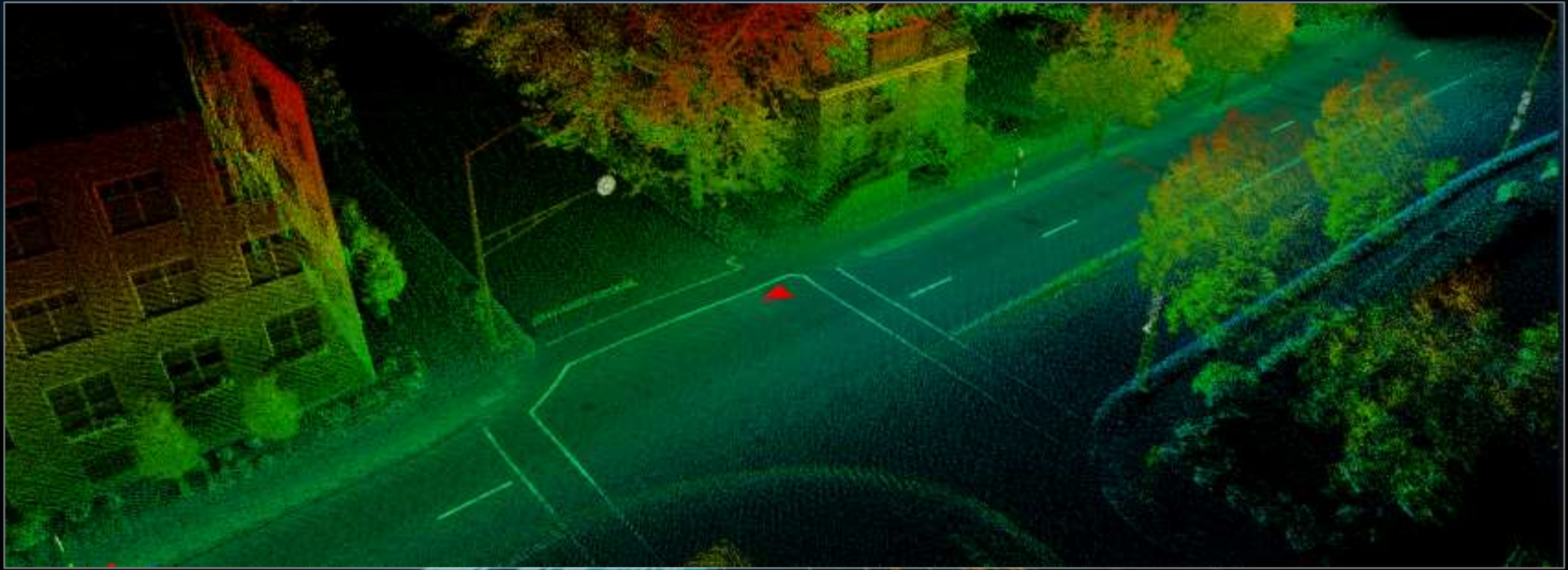
LiDAR

Mandli's LiDAR data collection system creates an accurate three-dimensional model of a scanned environment in a single pass of our collection vehicle. The system collects up to 1.4 million points of data per second at highway speeds, at ranges exceeding 100 meters. The point cloud produced by the system can be utilized to take 3D measurements of roadside assets, including width, height, and length, surpassing the measurement capabilities of 2D images.



Collection System

Spatially Accurate Maps




MANDLI
COMMUNICATIONS
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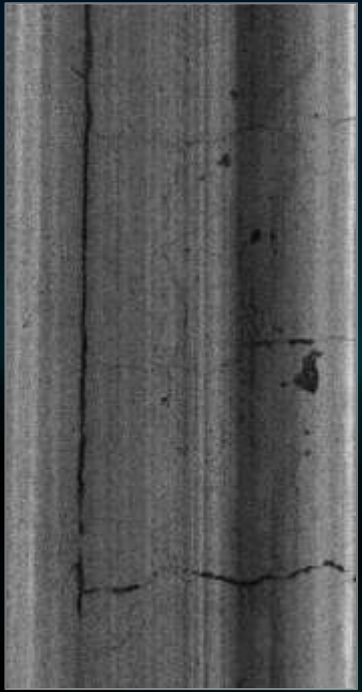
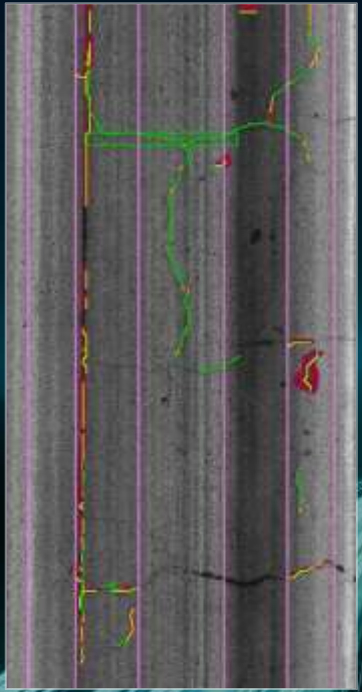
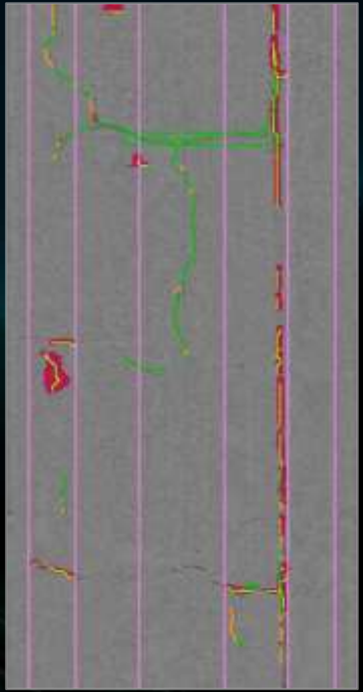
LCMS

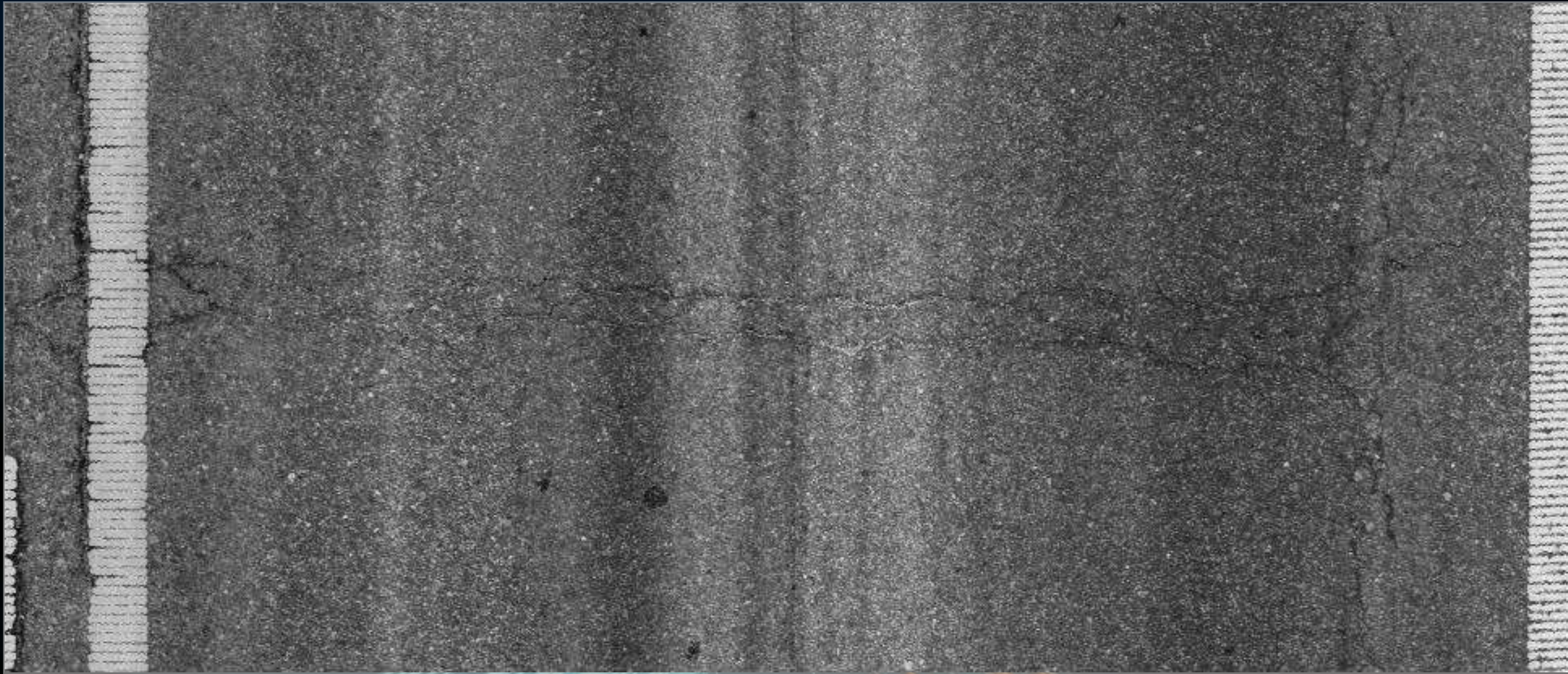
https://www.youtube.com/watch?time_continue=68&v=j_oW2q7jkjE

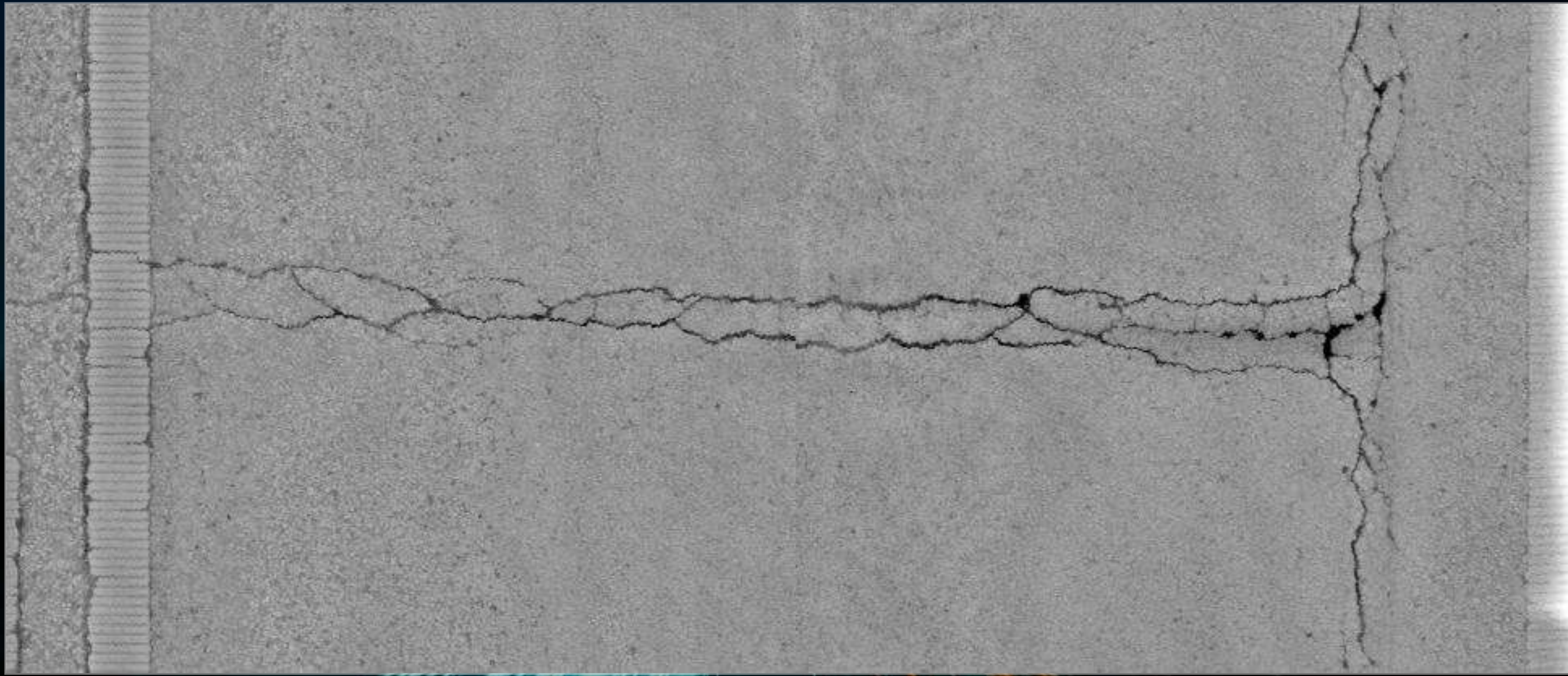
LCMS

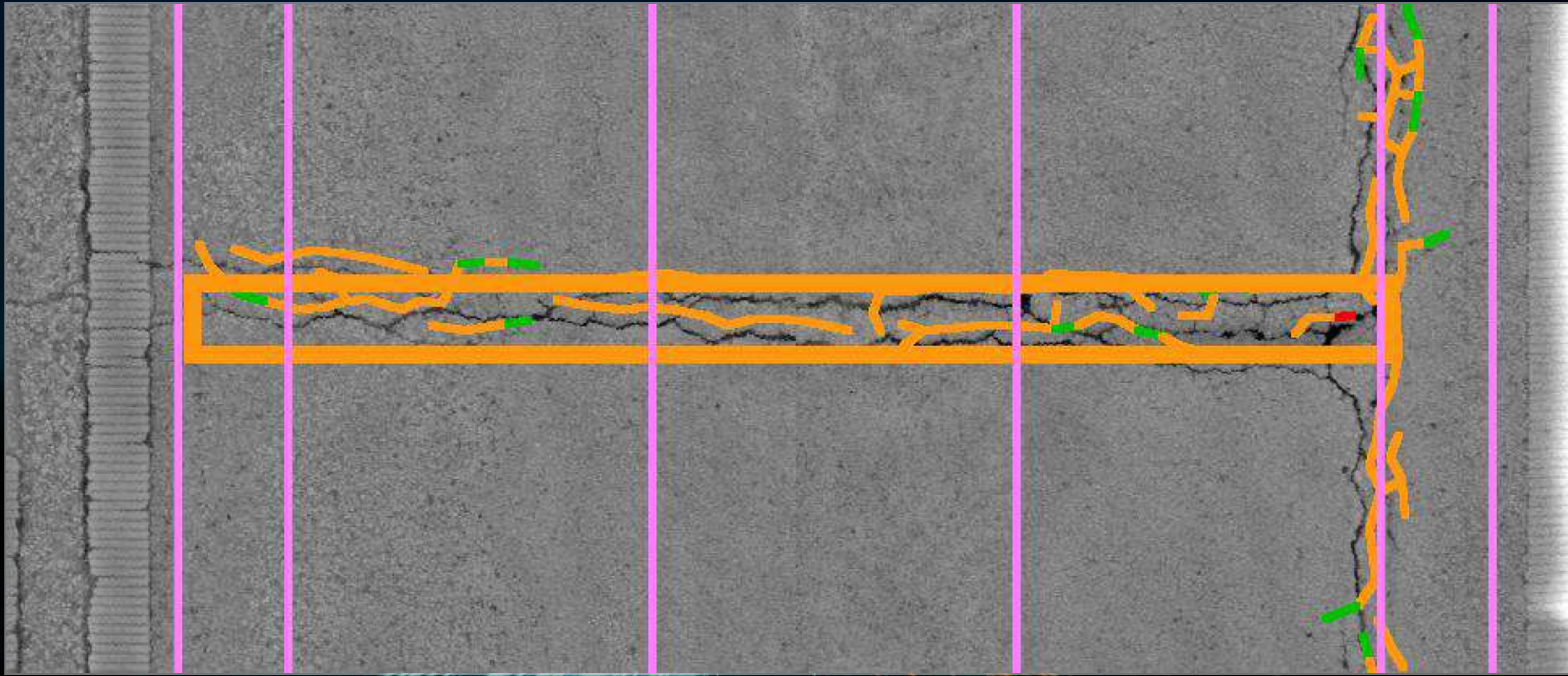








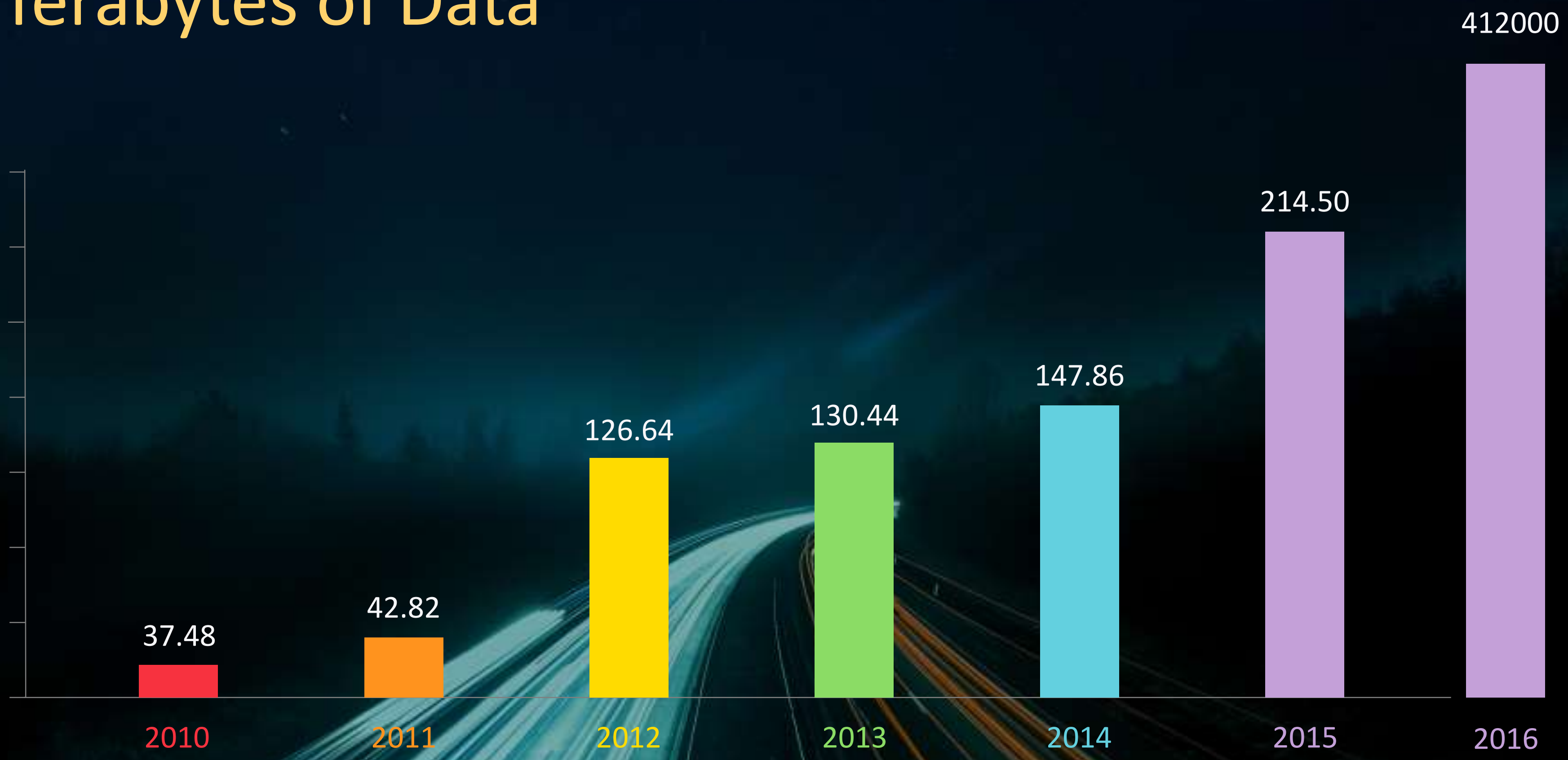




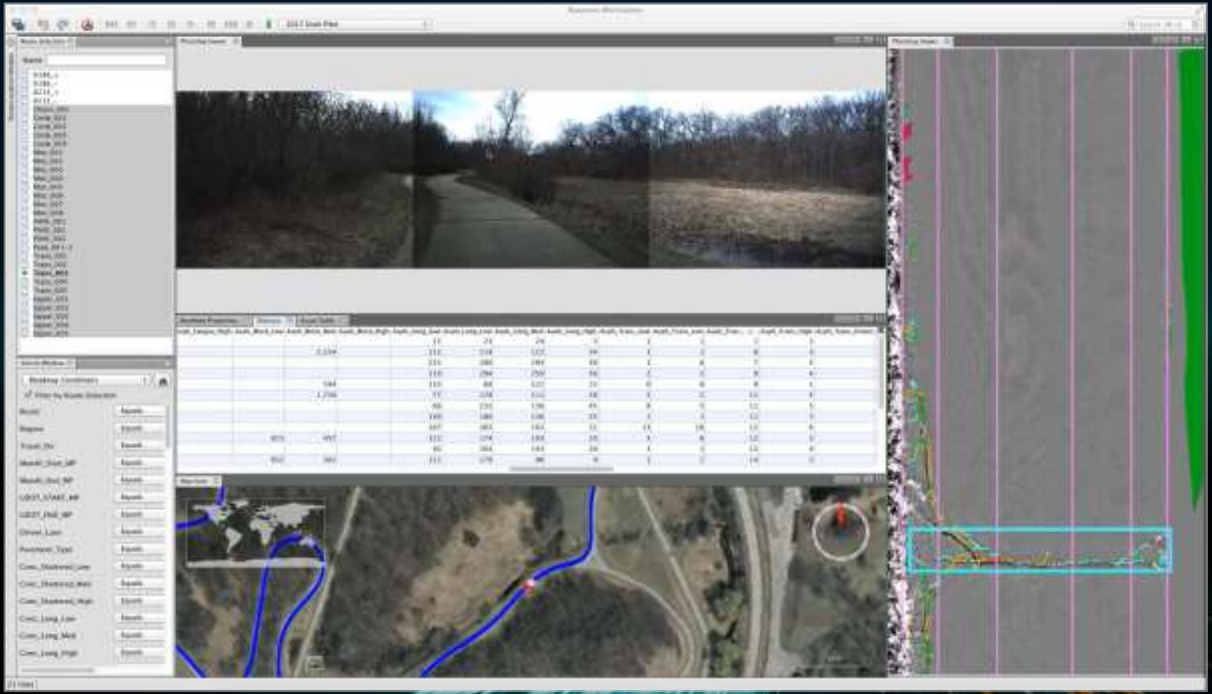
Assets Collected

- Acceleration/Deceleration Lanes
- Attenuators
- Barriers
- Bridges
- Control Fences
- Culverts
- Curbs & Gutters
- Delineators
- Ditches
- Driveways
- Guardrails
- HOV Lanes
- HOV Operation Types
- Intersections
- Landscaping
- Lane Reports
- Lane Widths
- Left Shoulder Widths
- Left Turn Lanes
- Luminaires
- Median Types
- Median Widths
- Mowable Acres
- MUTCD Sign Inventory
- Number of Lanes
- One/Two Way
- Passing Lanes
- Paved Shoulder Width
- Paved Turnouts
- Paved/Unpaved
- Pavement Widths
- Power Pedestals
- Railroad Crossings
- Raised Pavement Markers
- Ramps
- Rest Areas
- Right Shoulder Widths
- Right Turn Lanes
- Road Surfaces
- Rumble Strips
- Scenic Overlooks
- Shoulder Types
- Signal Cabinets
- Signal Poles
- Signs
- Specialty Markings
- Speed Limits
- Speed Zones
- Surface Types
- Terrain Types
- Through Lanes
- Toll Charged
- Toll Types
- Traffic Signals
- Trail Heads
- Tunnels
- Turn Lanes
- Wildflowers

Terabytes of Data



Data Examples



Roadways in a Automated world

- **Smaller and More Efficient ROWs:** AVs’ unique navigation capabilities are expected to enable narrower traffic lanes, reduce the number of lanes needed to accommodate traffic demand, and remove the need for medians.
- **A Drop-Off Revolution:** AVs are expected to create demand for drop areas that are as close as possible to the entrances of destinations.
- **Signage & Signalization:** The future will not have large numbers of traffic signs and signals, as traffic information can be transmitted to AVs wirelessly in real-time.
- **Parking:** AVs will bring massive changes to the location, form, and amount of parking, as AVs can park themselves or remain in the transportation network while awaiting their next rider.

Smaller and More Efficient Right-of-ways

- **AVs have the potential to travel more precisely than human operated vehicles and in harmony with other AVs.**
- **Reduced Lane Widths:** Lanes are designed to account for driver wander and human error. If lanes were designed to the width of a AV the lane width could be reduced by as much as 20%.
- **Fewer Traffic Lanes / Reduced Lane Expansion:** AVs will be able to safely travel closer together than human-operated vehicles. **This will significantly increase the throughput of each vehicle lane.**
  - **25% of congestion is caused by traffic incidents, since 93% of crashes are caused by human error there should a significant reduction in congestion**

Smaller and More Efficient Right-of-ways

- **Smaller Medians:** The primary purpose of medians today is to provide a safety buffer between two lanes of traffic heading in opposite directions. If AVs become reliable, as promised, the need for medians may be kept for aesthetic value only.

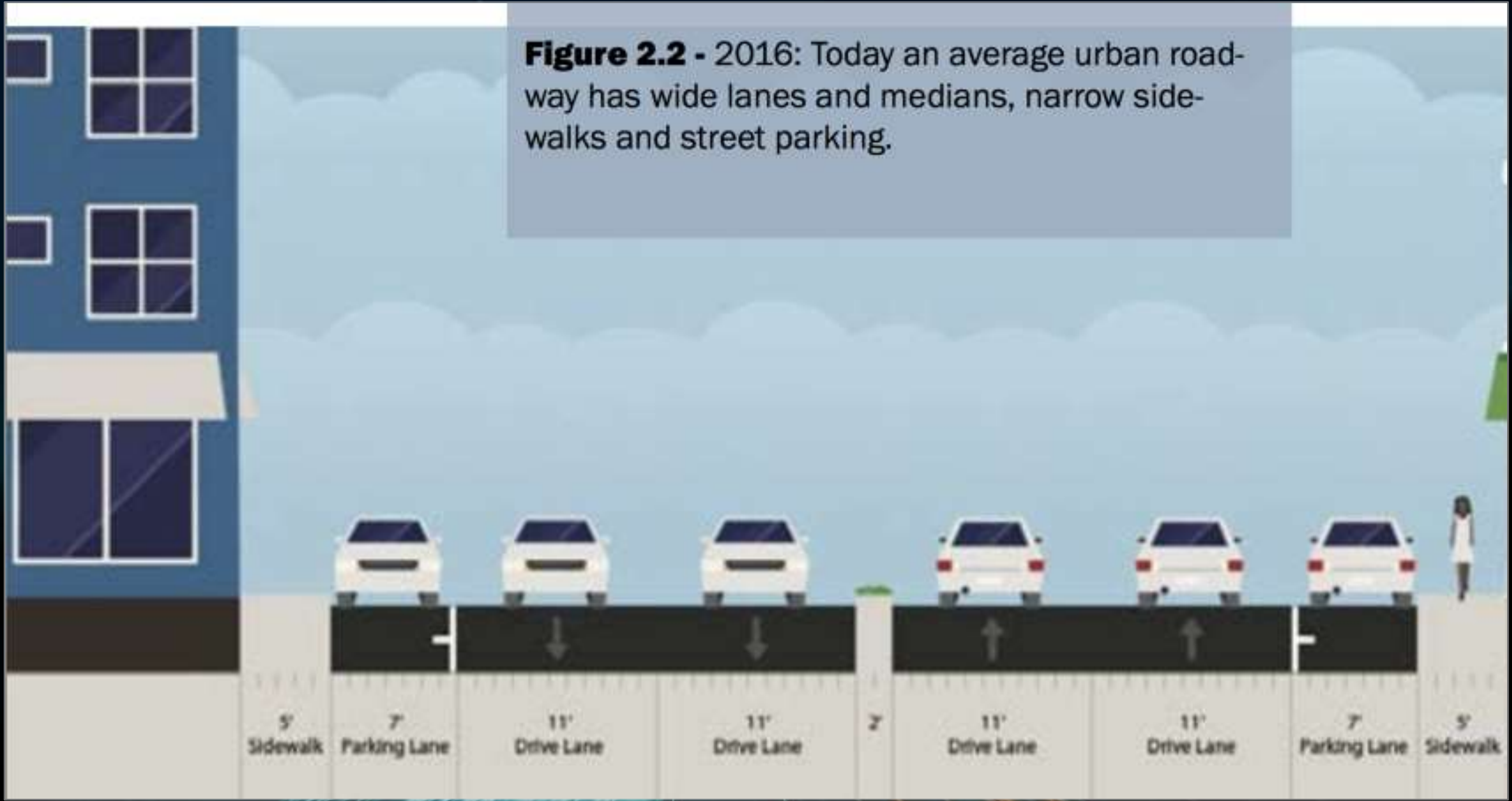


Figure 2.2 - 2016: Today an average urban roadway has wide lanes and medians, narrow sidewalks and street parking.

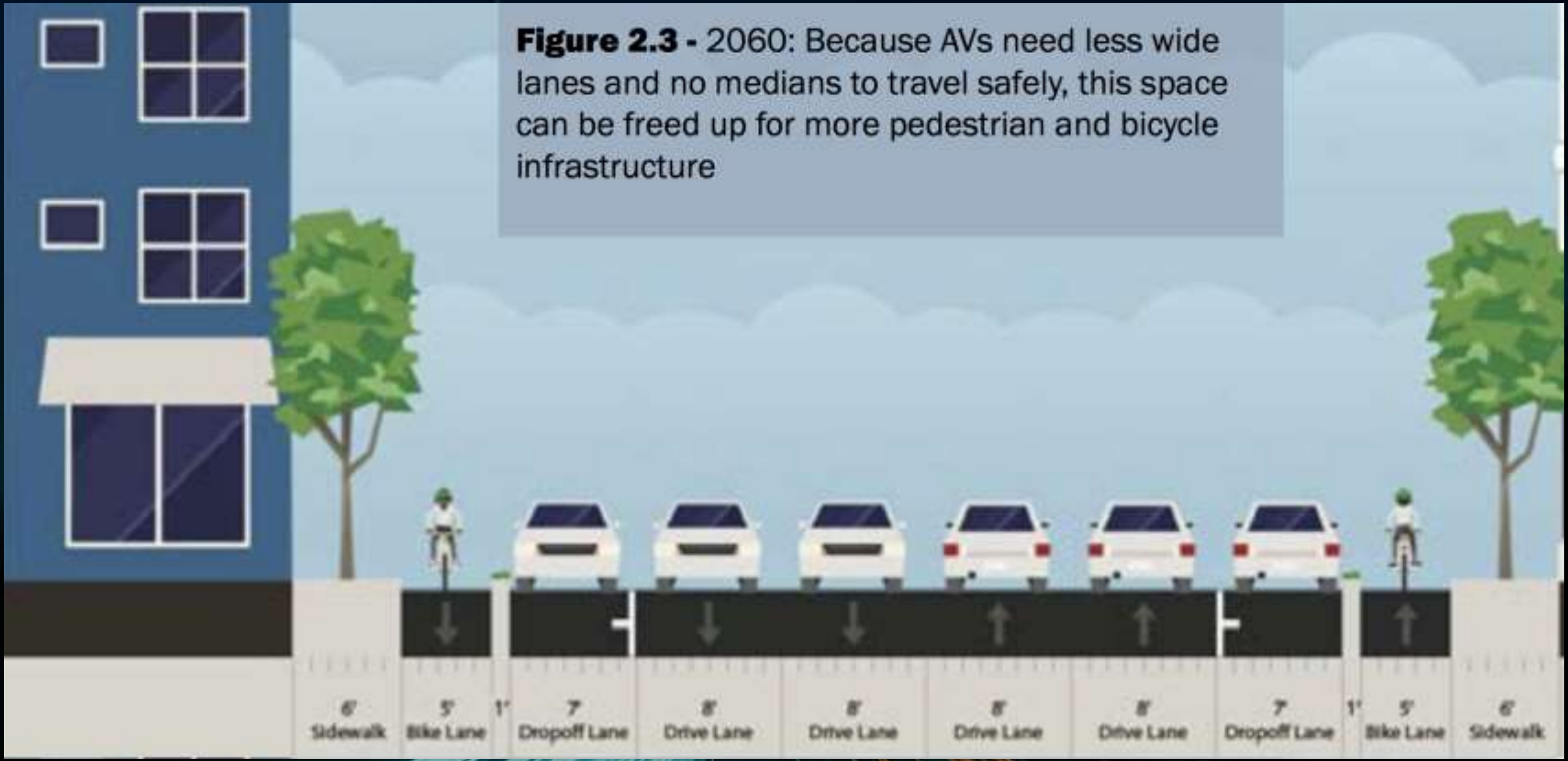


Figure 2.3 - 2060: Because AVs need less wide lanes and no medians to travel safely, this space can be freed up for more pedestrian and bicycle infrastructure

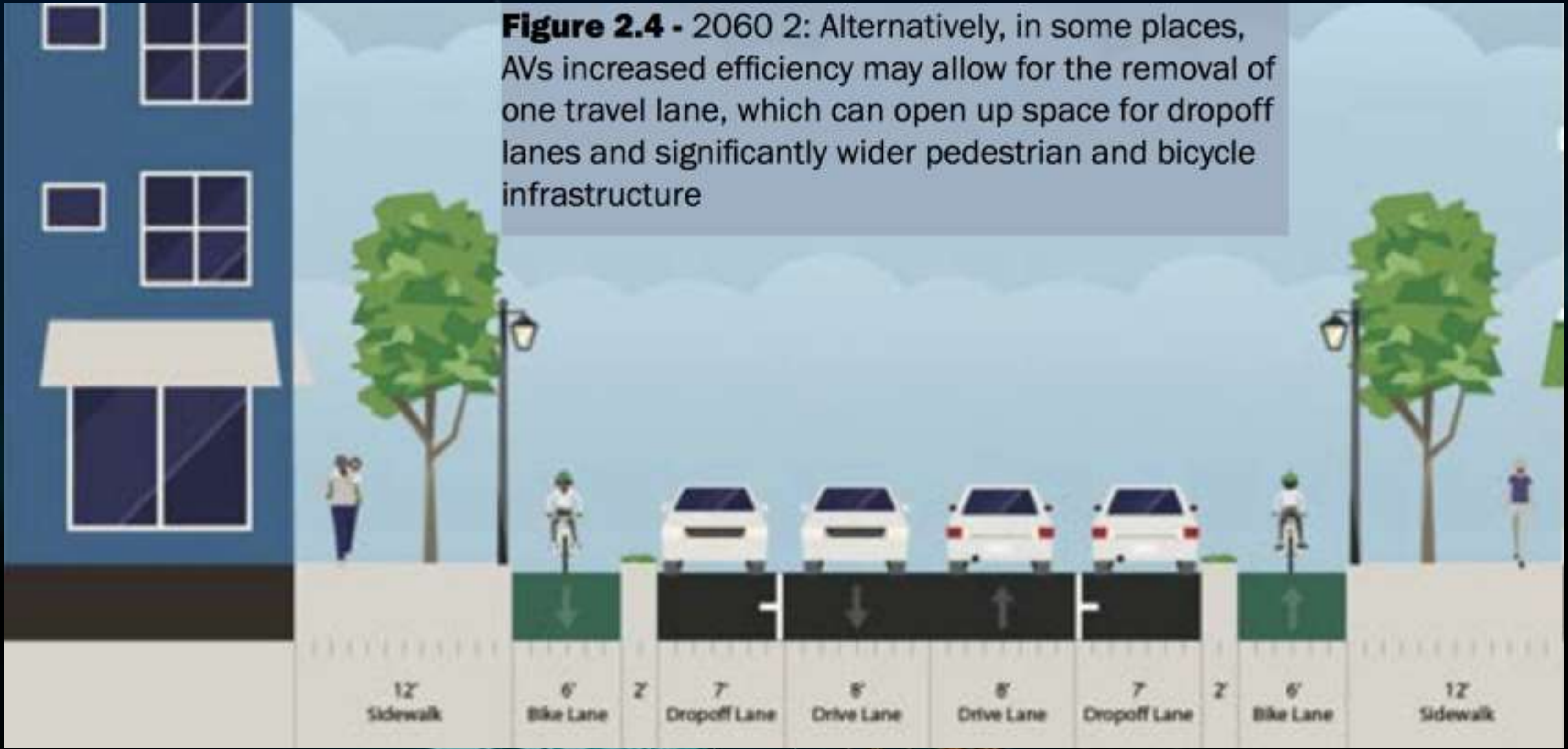


Figure 2.4 - 2060 2: Alternatively, in some places, AVs increased efficiency may allow for the removal of one travel lane, which can open up space for dropoff lanes and significantly wider pedestrian and bicycle infrastructure

Access Management

- The ability of AVs to drop-off passengers before going to park themselves or to pick-up another passenger is expected to bring a drop-off revolution to the transportation system.
- Emergence of drop-off and pick-up areas

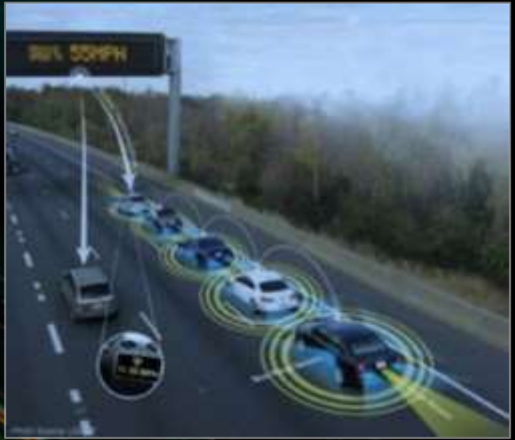
Figure 2.6 – Typical Suburban Strip Mal
Site Design in 2016

Figure 2.7 - Conceptual Site Design for
AV-Oriented Commercial Redevelopmen
2060

Signage & Signalization

- Signs and signals are among the most important features of today's transportation systems. They provide drivers with all the information they need to keep the transportation system running smoothly and efficiently.
- Emergence of Vehicle to Vehicle (V2V) and Vehicle to Infrastructure (V2I) technology will revolutionize the how information is transmitted.



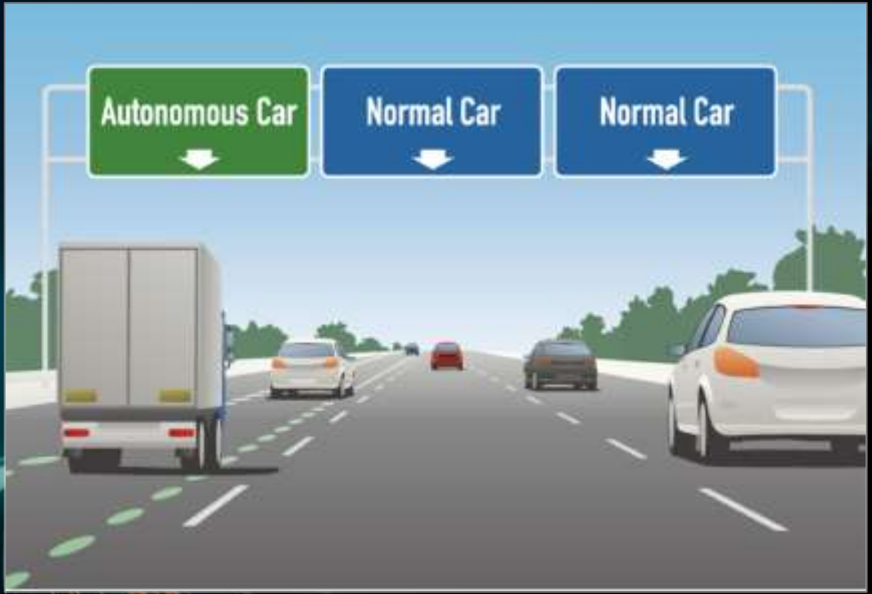


Transformation of Urban Centers

- Separation between human drivers and AVs
- Enclosed environments, such as college campus, where AV-only zones are plausible
- **Land use changes may also be more prominent along highways with dedicate AV-lanes, along AV-only drop-off and pick up areas, and in the areas surrounding AV-only parking facilities.**

Dedicated AV lanes

- State and federal highways may present easier opportunities for dedicated lanes initially because they have simpler traffic patterns, fewer intersections, and fewer points of ingress/egress than local roadways.



Dedicated AV lanes in Wisconsin????

POPULAR MECHANICS HOW-TO SHOP ELECTRIC CARS THANKSGIVING TIPS GIFT GUIDE 2017 SUBSCRIBE FOLLOW

Self-Driving Cars Could Soon Have Their Own Lane on the Highway

Wisconsin is preparing for a possible pilot test.

A US freeway may get self-driving car lanes thanks to Foxconn

The I-94 highway connects to the Apple supplier's upcoming facility in the Midwest.

Proposed highway lane for self-driving cars would link Seattle and Vancouver

A venture capital firm envisions replacing HOV lanes with lanes just for autonomous vehicles

BY BARBARA ELDREDGE | @BARBARAELDREDGE | OCT 3, 2016, 12:37PM EDT

Hyper Lanes

http://www.bbc.com/news/av/technology-40382959/hyperlane-a-special-lane-for-self-driving-vehicles

In Summary


THANK YOU