# Connected Vehicles

ORNL SMMC

October 27th , 2023

GLOBAL DEVELOPMENT CENTER FOR MOBILITY

- Transforming the way industries advance safe, sustainable, and secure mobility technologies

- At Our Core:

  Advanced Proving Ground

  Specialized Equipment

  Connectivity & Data Infrastructure

  EV Testing Environments (2023)

  H2 on Prem (2024)

  Garage / Lab / Resident Space

  Meetings, Training, Event Space

  Industrial Tech Park

HI-SPEED
Highway Loop
Willow Run Tunnel
Urban Arterial
User-Defined Areas East/West
6x6 Intersection
Planet M Boulevard

LOW-SPEED
Technology Development Area
Bicycle & Pedestrian Corridor
Urban Canyon
Parking Area
Off-Road Area North/South
Roundabout
2-Track Off-Road
Residential
Radius Testing

TECH & INNOVATION CAMPUS
Vehicle Laboratories
ACM Foundation
EV Charging Interoperability
Hydrogen Facility

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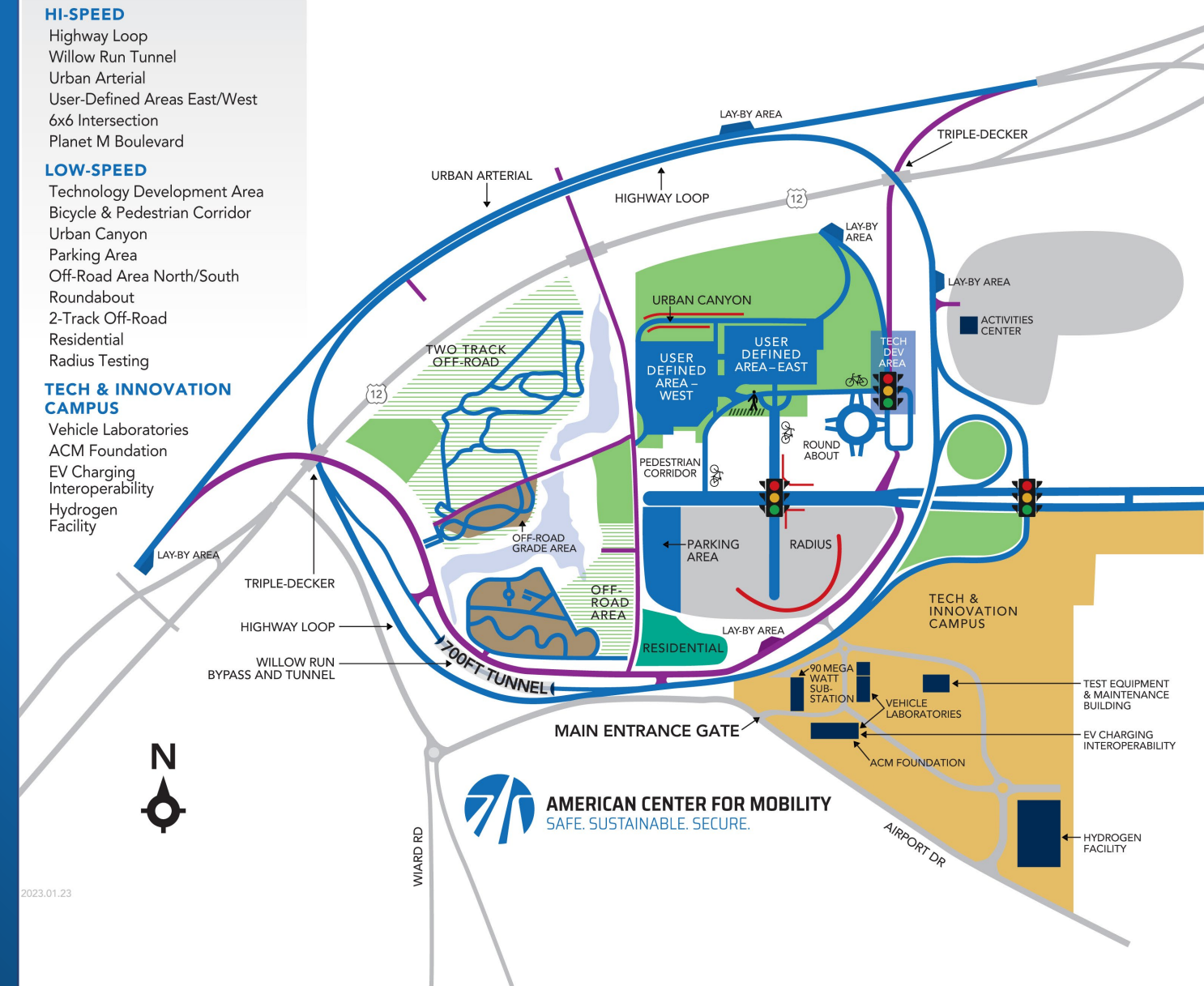
COMPREHENSIVE REAL-ROAD TEST ENVIRONMENT

- 500 Acres

- Repurposed real road systems

- Built to public road specs

- High speed environments (65 mph)

- Configurable test environments

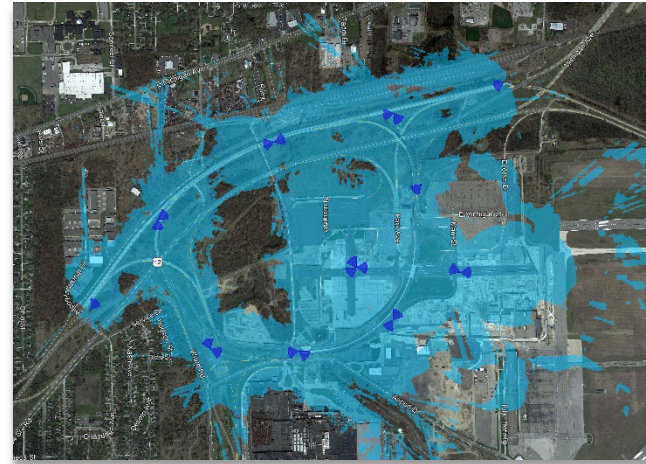- Environments to challenge technologies
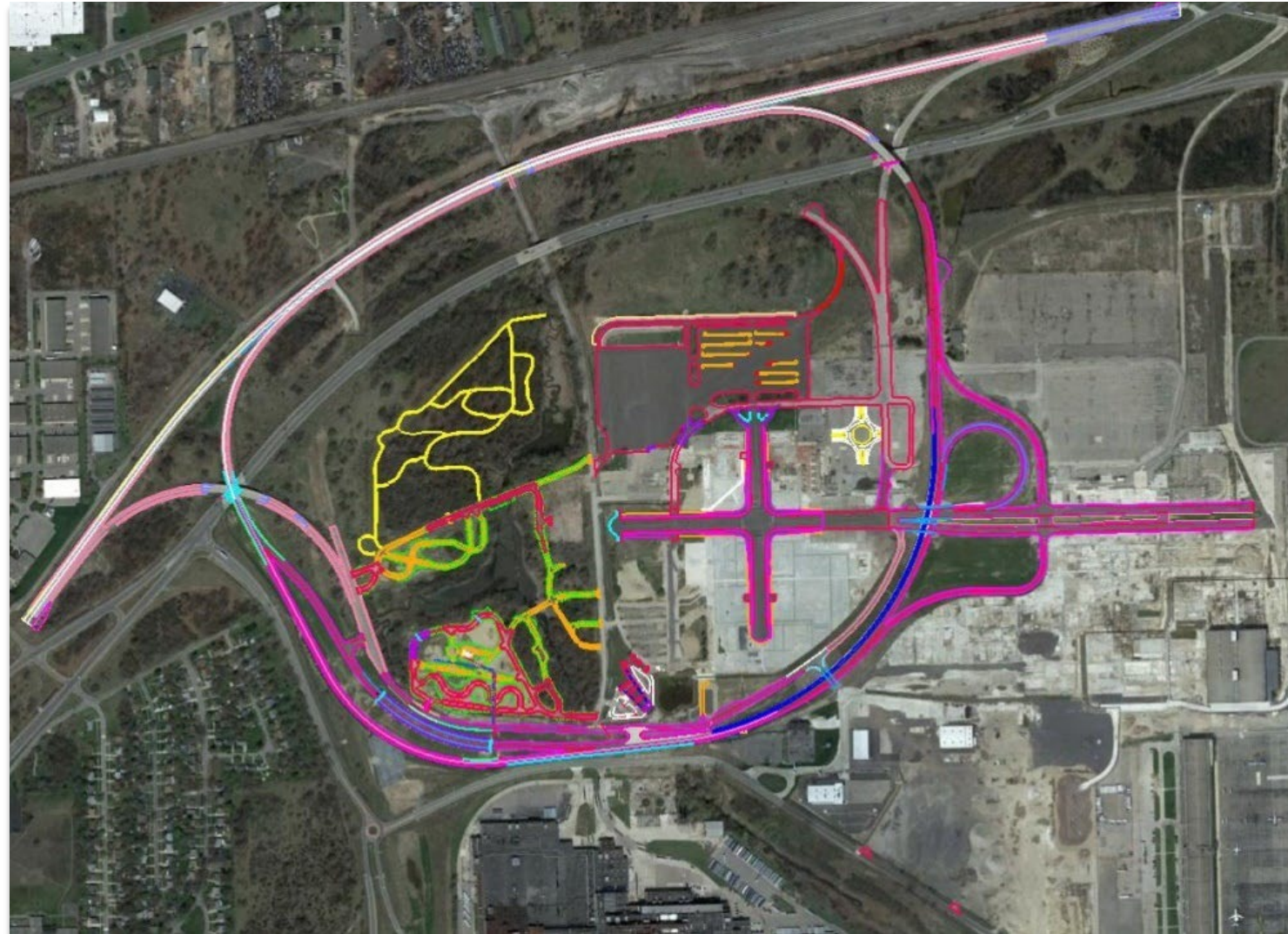
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Road infrastructure complemented by ITS infrastructure

NETWORK INFRASTRUCTURE

PRIVATE 4G LTE & 5G SUB-6 CELLULAR

OPTIMIZED CELL COVERAGE

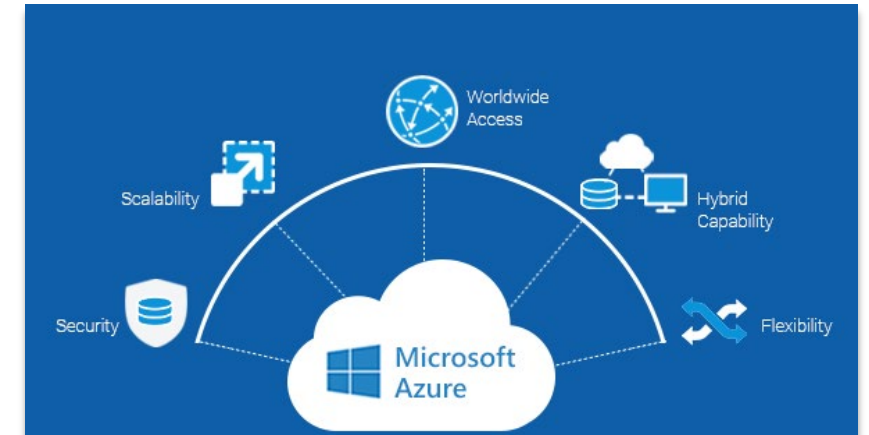FIBER OPTIC CABLE BACKBONE

DSRC (15 RSUS)
C-V2X (WIP)

UP TO 100 GBPS DATA TRANSFER

CLOUD - DATA MANAGEMENT & ANALYTICS PLATFORM

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Advanced communications and network infrastructure

SPECIALIZED TEST EQUIPMENT

RAIN AND GRIME TRAILER TRUCK

PEDESTRIAN SOFT TARGETS

SIMULATED CITY ENVIRONMENT

SR60 TORUS STEERING ROBOT

CBAR600 – COMBINED BRAKE AND ACCELERATOR ROBOT

GST – GUIDED SOFT TARGET

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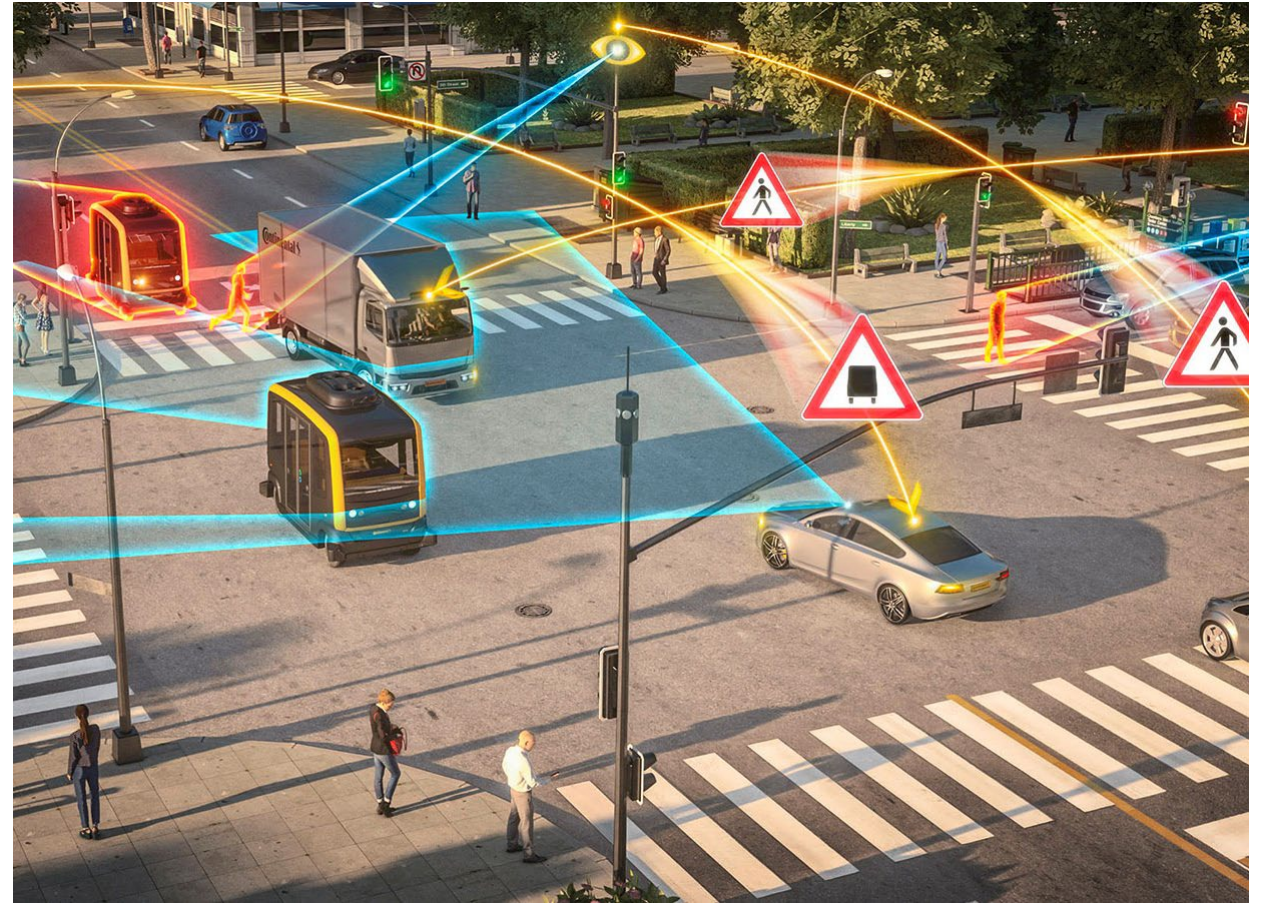SAFE. SUSTAINABLE. SECURE.

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CAV TESTING NEEDS

Replicating Real World Scenarios:

- Sensors & perception

- Connectivity

- Interoperability

- Vehicle Interactions:
  Real-world roads
  Other vehicles
  Other types of road use

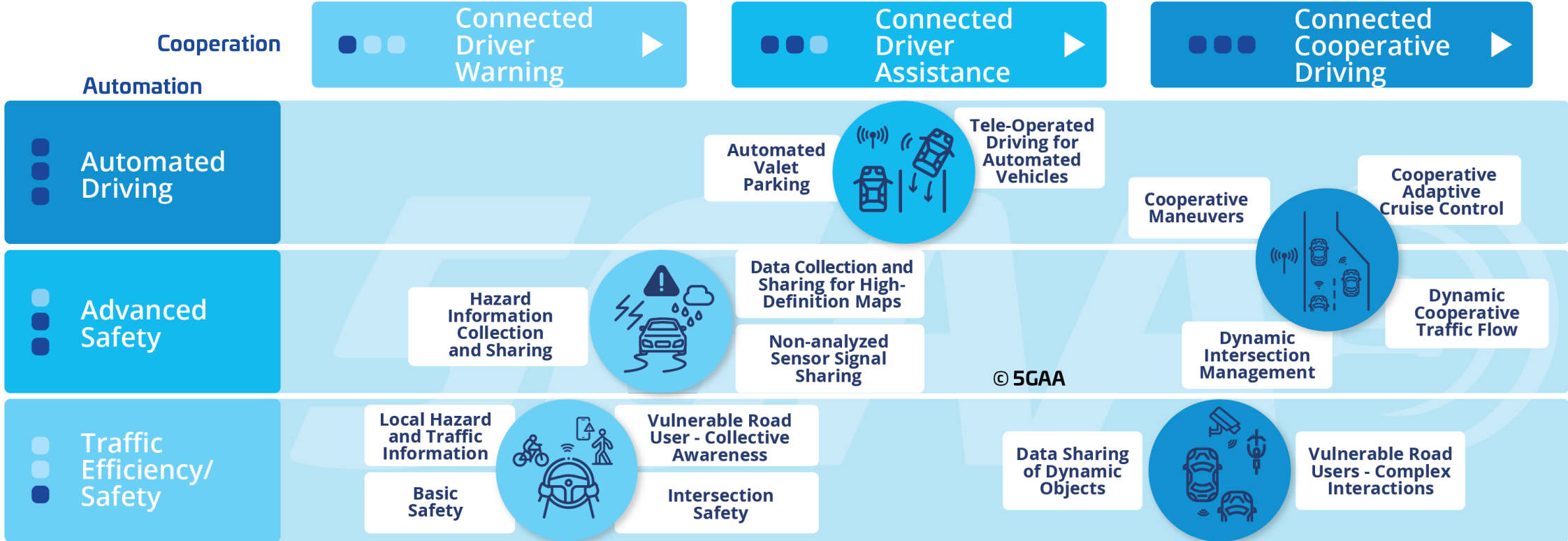Bringing together roads, sensors, ITS, tool chain and AV specific testing strategies to accelerate validation

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Connected + Automated ≠ Connected and Automated

CONNECTIVITY + AUTOMATION

Roadmap towards Cooperative Driving

5GAA — Automotive Association

Cooperation	Connected Driver Warning ▶	Connected Driver Assistance ▶	Connected Cooperative Driving ▶
Automated Driving		Automated Valet Parking; Tele-Operated Driving for Automated Vehicles	Cooperative Maneuvers; Cooperative Adaptive Cruise Control
Advanced Safety	Hazard Information Collection and Sharing	Data Collection and Sharing for High-Definition Maps; Non-analyzed Sensor Signal Sharing	Dynamic Intersection Management; Dynamic Cooperative Traffic Flow
Traffic Efficiency/ Safety	Local Hazard and Traffic Information; Basic Safety	Vulnerable Road User - Collective Awareness; Intersection Safety	Data Sharing of Dynamic Objects; Vulnerable Road Users - Complex Interactions

© 5GAA

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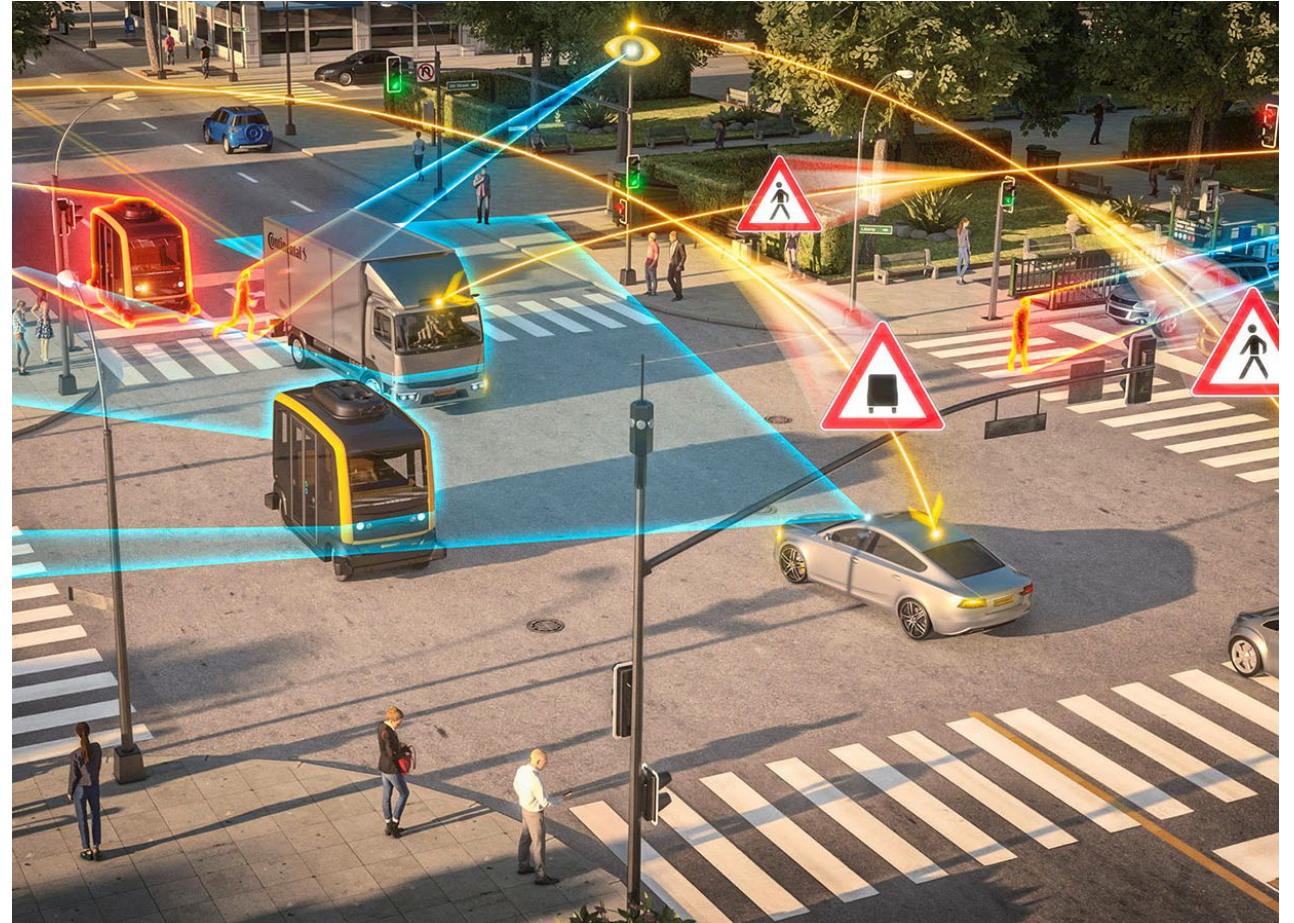*Primary focus of connectivity is not integrated yet with automation*

Connectivity

Connectivity is required for true cooperative driving automation

Connectivity can see beyond sensors

- Around Corners and Objects
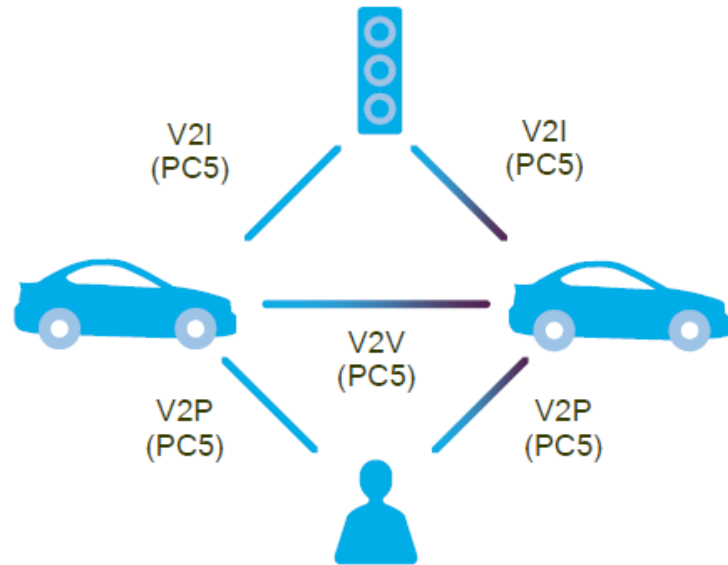
- DSCR phasing out in in U.S.
- C-V2X Phasing In

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C-V2X (TWO COMPLEMENTARY MODES)
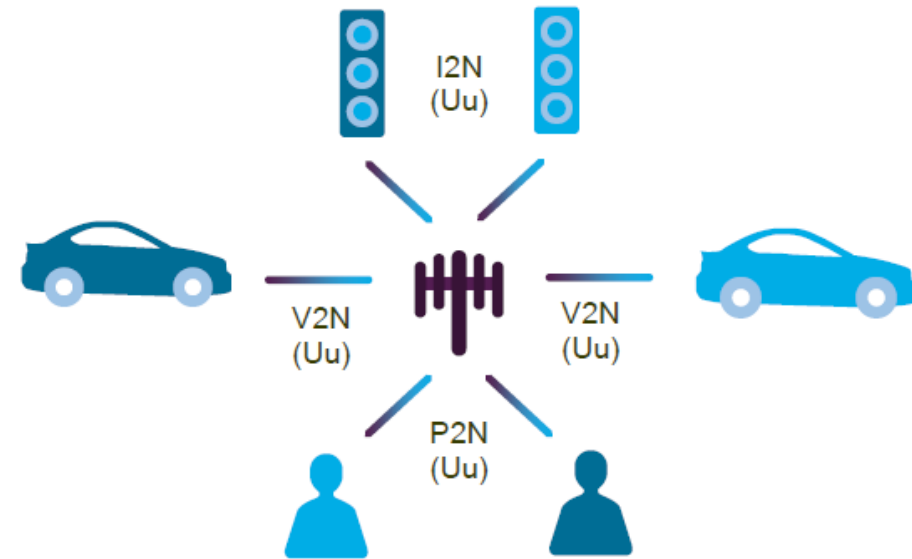

Direct

V2V, V2I, and **V2P** operating in ITS bands (e.g. ITS 5.9 GHz) independent of cellular network

V2I (PC5)   V2I (PC5)

V2V (PC5)

V2P (PC5)   V2P (PC5)

Short range (<1 kilometer), location, speed ...
Implemented over "PC5 interface"

Network

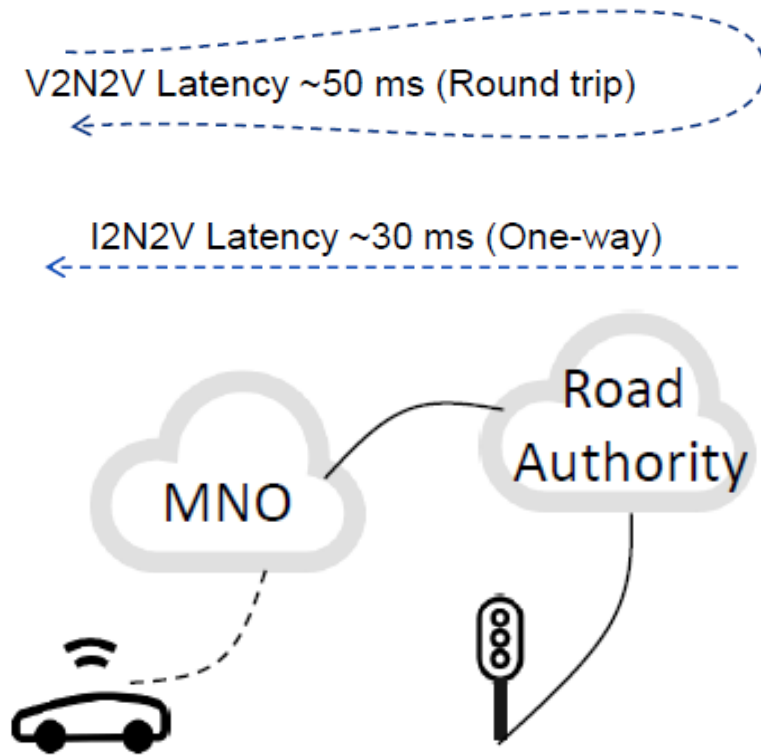**V2N** operates in traditional mobile broadband licensed spectrum

I2N (Uu)

V2N (Uu)   V2N (Uu)

P2N (Uu)

Long range (>1 kilometers). e.g. accident ahead
Implemented over "Uu interface"

5GAA The C-V2X Proposition:
https://5gaa.org/wp-content/uploads/2018/05/3.-The-C-V2X-Proposition-Ford.pdf

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MNO's have proposed that V2N can be fast and lower cost for early deployment

A POTENTIALLY FASTER PATH TO DEPLOYMENT THROUGH V2N?

Uu Optimized for V2X

V2N2V Latency ~50 ms (Round trip)

I2N2V Latency ~30 ms (One-way)

MNO

Road Authority

5GAA Virtual Roadside Unit Architecture.
https://5gaa.org/wp-content/uploads/2019/05/06.Virtual_RSU_Architecture.pdf

- V2N2V to circumvent some V2V to provide BSMs w/o RSUs
  - "Virtual RSU"

- Push safety messages through Uu link to phone apps

- Video Analytics with MEC in lieu of RTK

- Uu Link for SPaT
  - App count down to green
  - Traffic signal prioritization

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Trials and use cases with cities are the way to drive adoption

Status of 5G

- Still early stages for mobility
- Coverage vs. Bandwidth
  - low, mid, mm-wave
- Mid-Band is said to be sweet spot
- Advances mm-wave Antenna Systems
- Limited commercial private network for transportation
- Public network with network slicing?
- Demonstration of V2N use cases
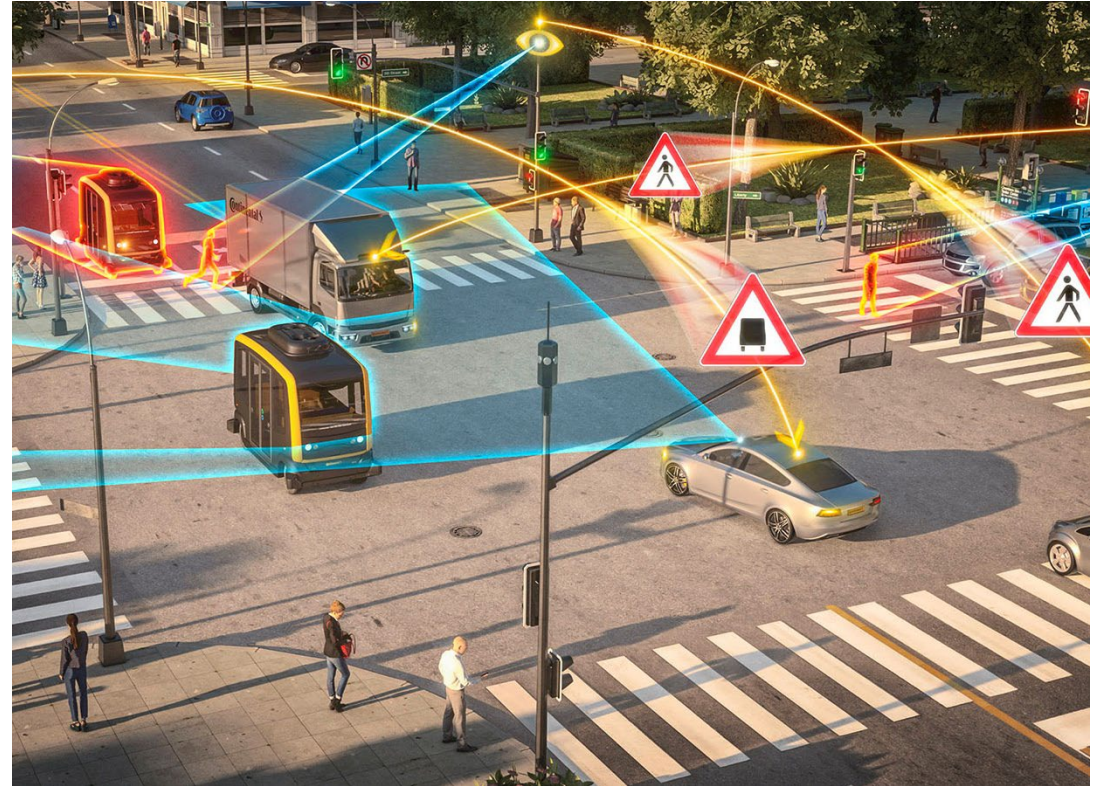
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VULNERABLE ROAD USERS (VRU)

- A VRU is a non-motorist - pedestrian, bicyclist, other cyclist, and person on personal conveyance or an injured person

VRUs include:

- People walking, biking, or rolling.
- Includes a highway worker on foot in a work zone,
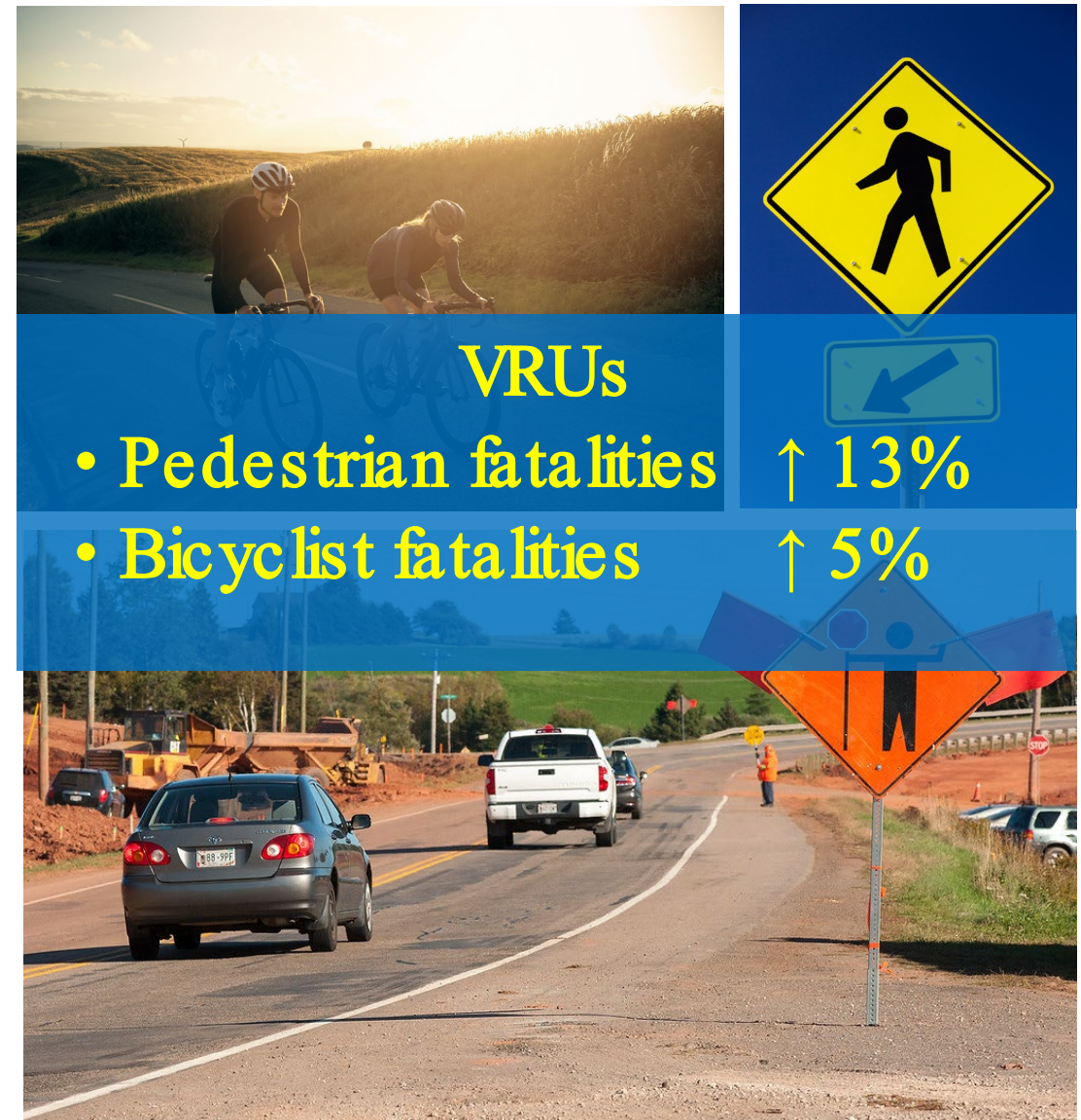- Does not include a motorcyclist

THE STATS ARE ALARMING

According to NHSTA

- 42,915 Traffic fatalities in 2021
  16-year high
  >10.5% increase over 2020

- 7,388 pedestrians were killed and more than 60,000 were injured

- 2022 little to no improvement

NHTSA Early Estimates: 2022 Traffic Crash Deaths | NHTSA

https://crashstats.nhtsa.dot.gov/Api/Public/ViewPublication/813283

VRUs
- Pedestrian fatalities ↑ 13%
- Bicyclist fatalities ↑ 5%

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VRU TEST BEDS

SIMULATED CITY ENVIRONMENT

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Test beds are essential for developing, validating, and demonstration VRU solutions in a safe, controlled environment

SMART WORK ZONES

- **Leveraging Connected Vehicle Technology to Improve Work Zone Safety**

- **Proof of Concepts:** for Work Zone Data Exchange (WZDx) with Live Information Sharing

- Using Cellular Connections

WZDx
WORK ZONE DATA EXCHANGE

WORK ZONE DATA EXCHANGE

The Work Zone Data Exchange (WZDx) Specification enables infrastructure owners and operators (IOOs) to make harmonized work zone data available for third party use. The intent is to make travel on public roads safer and more efficient through ubiquitous access to data on work zone activity. Specifically, the project aims to get data on work zones into vehicles to help automated driving systems (ADS) and human drivers navigate more safely.

(Source: https://www.transportation.gov/av/data/wzdx)

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Michigan Department of Transportation

PROOF OF CONCEPT: WORK ZONE DATA EXCHANGE (WZDX) LIVE INFORMATION SHARING

## How can MDOT leverage connected vehicle technology to improve work zone safety?
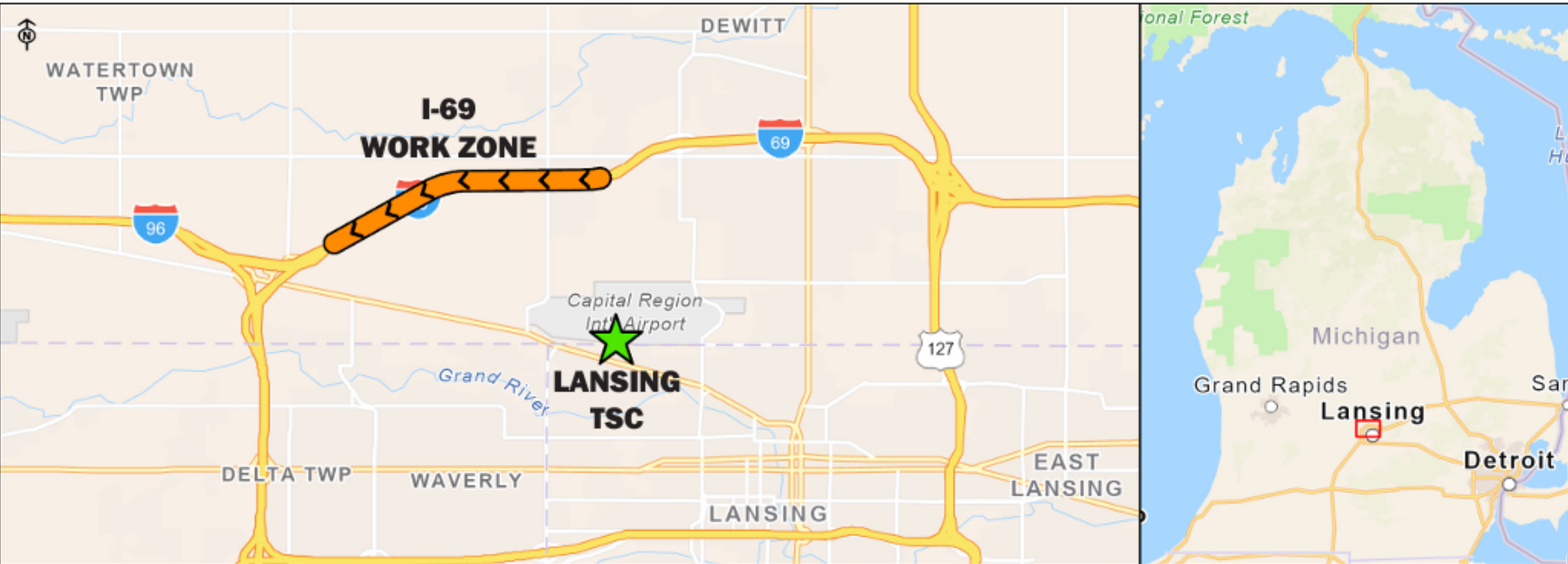
PROJECT OVERVIEW

The Michigan Department of Transportation has partnered with General Motors to demonstrate how GM's connected vehicles can receive work zone data directly from MDOT's work zone data platform. Using a cellular data connection, the GM vehicle will receive a notification that it is approaching a lane closure at the I-69 work zone shown above. This information can then prompt the GM Super Cruise feature to automatically change lanes, hands-free.

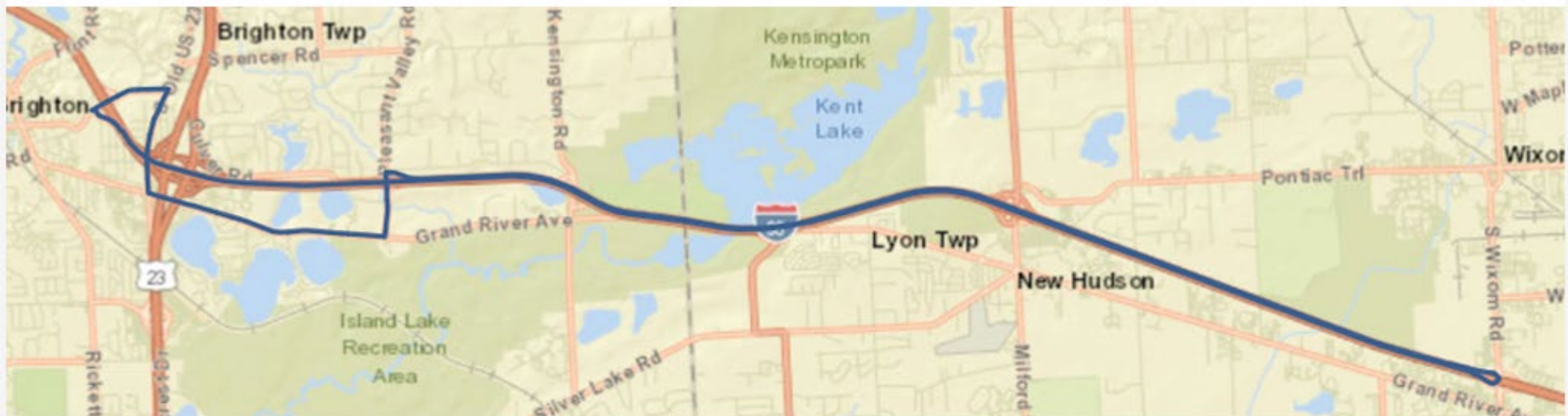# PROOF OF CONCEPT: LANE CLOSURE WITH ADS
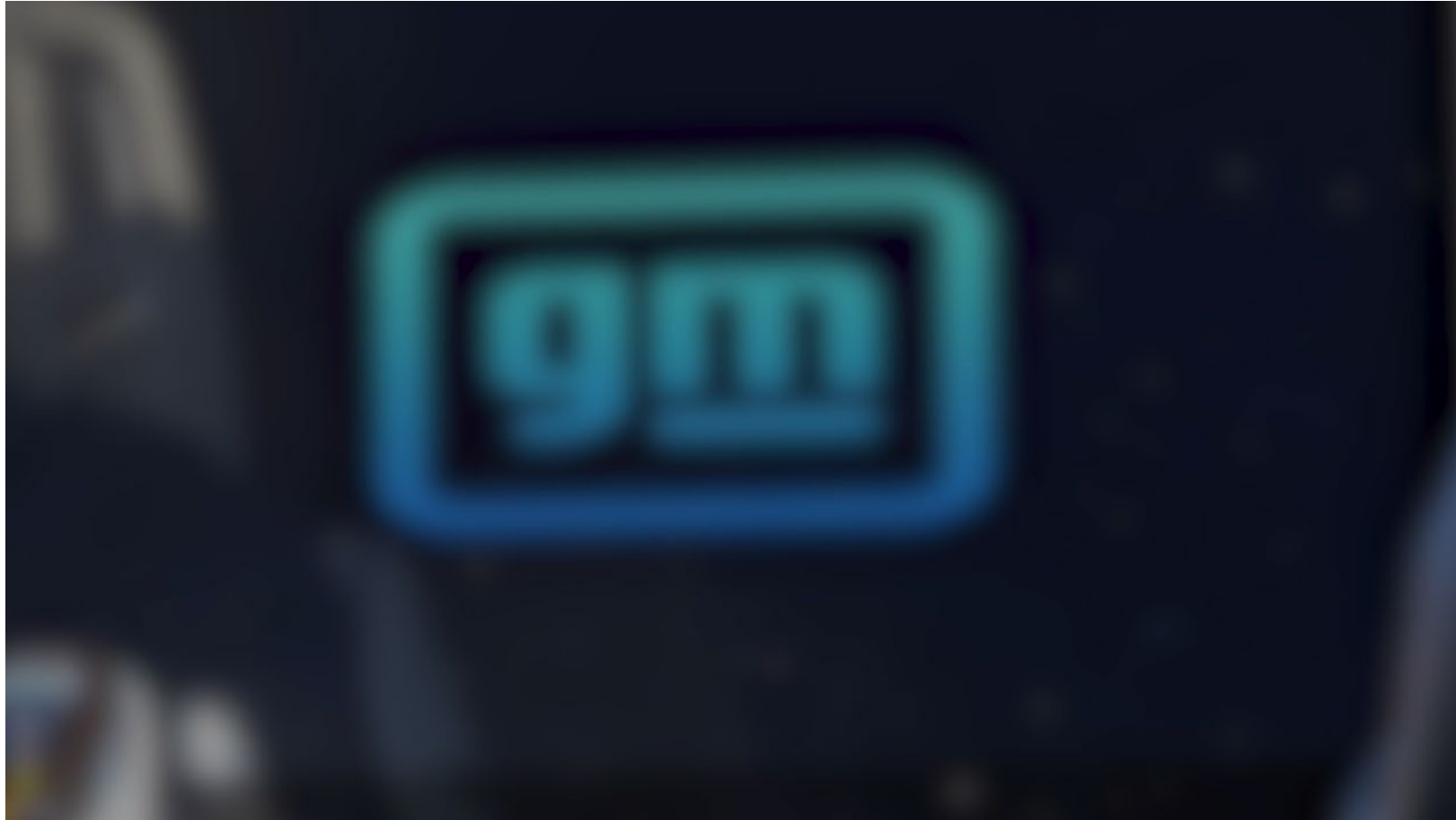
2nd Proof of Concept

- Utilizing a common passenger vehicle such as a Chevrolet Tahoe
- Testing worker presence in live construction zones
- Utilizing smart work zone devices for information in real time

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Michigan Department of Transportation

I-96 Flex Route Construction Project

Roughly 60% people throughout the United States use a GPS service at least once a week (Utires). In fact, the navigation application Waze has a community of over 115 million users alone. Through the open WZDx feed, Ver-Mac's Connected Work Zone Notification system shares real-time road construction information to drivers in Waze. Notifying drivers of work zone challenges in real-time can encourage safer and efficient decision making. Ver-Mac's Connected devices and the WZDx feed alert motorists as they enter and leave work zones, approach lane closures, or near the presence of construction workers. Additionally, this system delivers data to the Michigan Department of Transportation and its Traffic Service Centers through the feed.
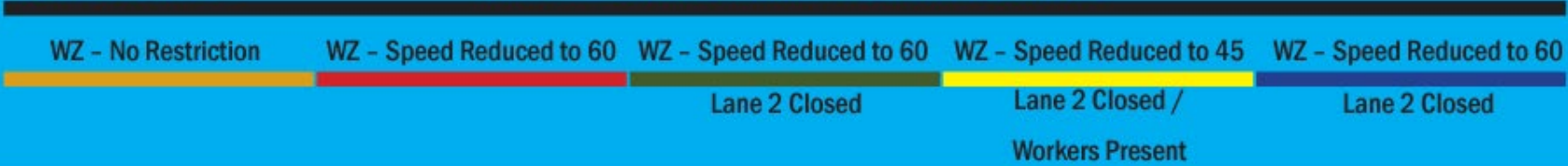
LEVERAGING CONNECTED VEHICLE TECHNOLOGY TO IMPROVE WORK ZONE SAFETY

Trial our use of new WZDx 4.0 JSON data structures in a Chevrolet Tahoe:

- Workers Present
- Lane Closures from arrow boards
- Variable speed limit
- Road construction start/end points

In-vehicle dash display features real-time road construction alerts

Pictured: Interior of a Chevrolet Tahoe

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See-Through & Do Not Pass Warning Application

USE CASE - AUTOMATED VALET PARKING

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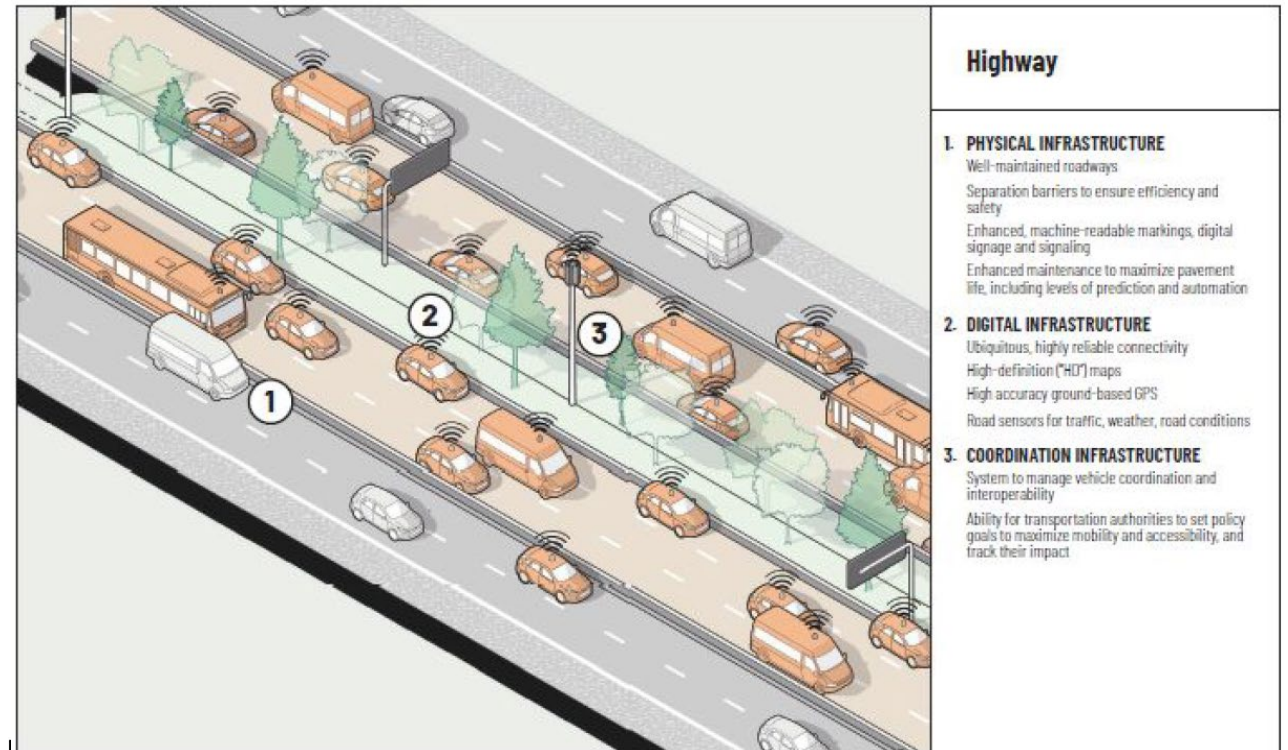Level 2 vehicles with Level 4 like automation in connected environments
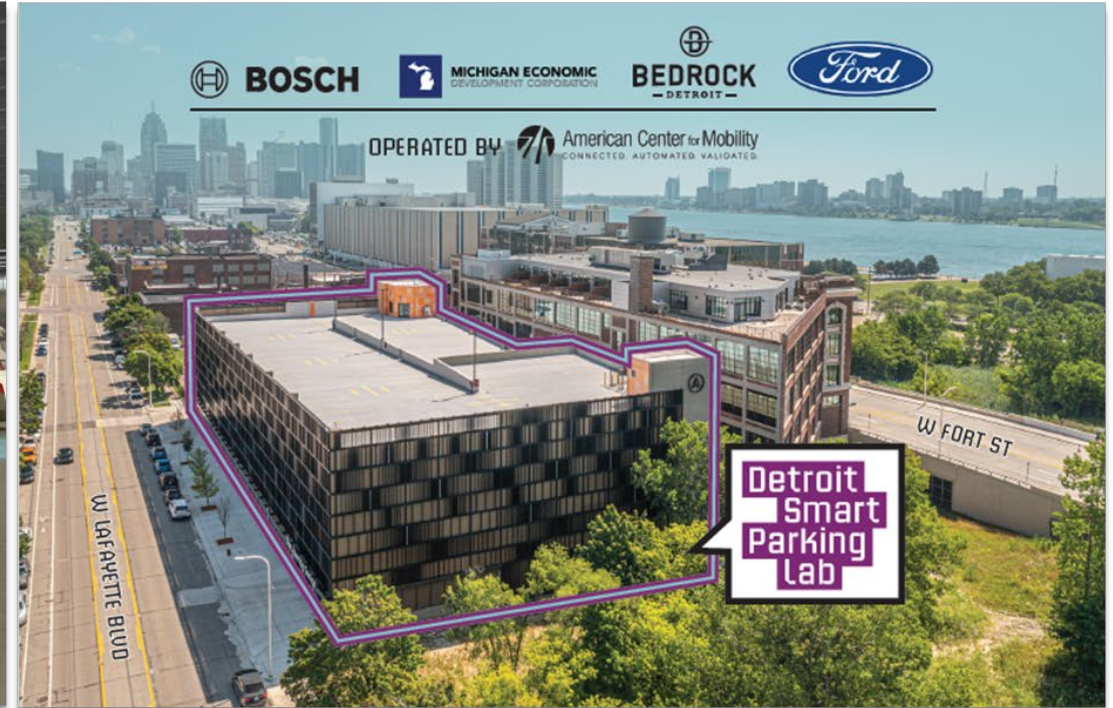
Connected and Automated Vehicle (CAV) Corridors

- Managed lane for CAVs with connectivity to infrastructure

- Level 4 CAV experiences sooner through policy and business model innovation

Example Components of Integrated Infrastructure Technology Framework for CAV Corridors

Highway

1. **PHYSICAL INFRASTRUCTURE**
   Well-maintained roadways
   Separation barriers to ensure efficiency and safety
   Enhanced, machine-readable markings, digital signage and signaling
   Enhanced maintenance to maximize pavement life, including levels of prediction and automation

2. **DIGITAL INFRASTRUCTURE**
   Ubiquitous, highly reliable connectivity
   High-definition ("HD") maps
   High accuracy ground-based GPS
   Road sensors for traffic, weather, road conditions

3. **COORDINATION INFRASTRUCTURE**
   System to manage vehicle coordination and interoperability
   Ability for transportation authorities to set policy goals to maximize mobility and accessibility, and track their impact

Detroit-Ann Arbor Corridor
Illustrative Routes and Points of Interest

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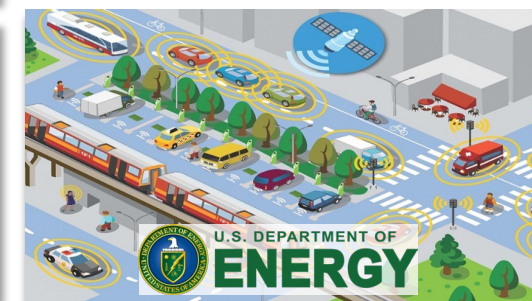# ACM CAV R&D

Connectivity is a core focus of Federal R&D

About 50% of ACM R&D is on use of connectivity to optimize efficiency

Cooperative Driving Automation (CDA) required for full transportation safety, efficiency and mobility benefits
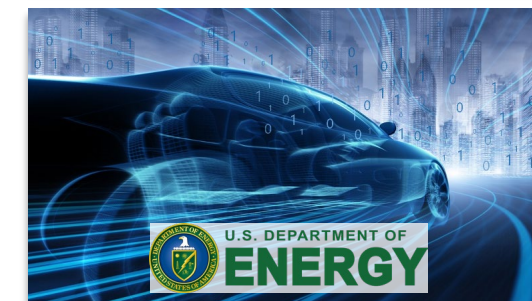

V2V/AV TRUCK PLATOONING IN REAL WORLD CONDITIONS

VALIDATING NATIONAL LABOROTORY CAV ENERGY EFFICIENCY ALGORITHMS

ENERGY OPTIMIZATION OF MIXED VEHICLE COHORTS

NEXTCAR II - CONNECTIVITY & L4 AUTOMATION FOR FUEL SAVINGS & EV RANGE OPTIMIZATION

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What is the business model?

Who pays and who benefits?

Will people pay for the safety of others?

What about safety of themselves?

KEY EVENTS FOR THE CONNECTIVITY AGENDA

Aug 2022

April 2023

Aug 2023

Oct 2023

DOT V2X Communication summit on "Identifying A Path Forward For V2X Deployment Agenda"

DOT "Enhancing Interoperable Connectivity For Safe Transportation"

ITS America National V2X Deployment Plan : An Infrastructure and Automaker Collaboration

FCC C-V2X Waivers

5GAA Day 1 CV2X North American Deployment Guide

To Be Released

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