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Clearing the Validation Hurdle for Connected and Autonomous Vehicles

41st Automotive-Petroleum Industry Forum

April 12th, 2022

SO HOW MANY MILES TO VALIDATE AN AV?

Waymo >20M total self-driving miles, 74,000 driverless miles (2019)

To prove AV's are 20% better than human drivers using a fleet of 100 AV's driving 25 mph:

- Avoiding Crashes – 28M miles (1.3 years)
- Avoiding Injuries –170M miles (7.6 years)
- Avoiding fatalities – 5B miles (225 years)

Kalra, Nidhi and Susan M. Paddock, *Next Stop, Neptune? Why We Can't Rely on Test-Driving Alone to Assess the Safety of Autonomous Vehicles*, Santa Monica, Calif.: RAND Corporation, IG-128, 2017. As of April 08, 2021: https://www.rand.org/pubs/infographics/IG128.html

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A SOBERING TREND IN TRAFFIC DEATHS

According to NHSTA

1.1 deaths per 100M miles (2019)

1.37 deaths per 100M miles (2020)

↑7.2% despite driving ↓13.2%

↑ 12% first 9 months of 2021

2019 Roadway Fatalities Report Released | NHTSA

2020 Fatality Data Show Increased Traffic Fatalities During Pandemic | NHTSA

Traffic Fatalities Rise in First Nine Months of 2021 | NHTSA

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SOLVING THE LONG-TAIL PROBLEM IN AUTONOMOUS DRIVING

According to NHSTA

1.1 deaths per 100M miles (2019)

1.37 deaths per 100M miles (2020)

↑7.2% despite driving ↓13.2%

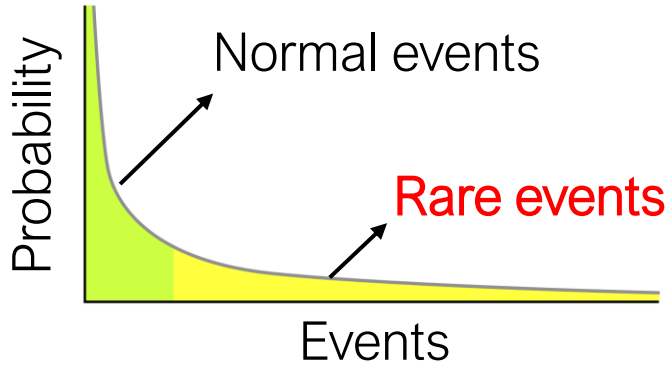
↑ 12% first 9 months of 2021

[2019 Roadway Fatalities Report Released | NHTSA]

[2020 Fatality Data Show Increased Traffic Fatalities During Pandemic | NHTSA]

[Traffic Fatalities Rise in First Nine Months of 2021 | NHTSA]

Long Tail of Events



Identifying and validating to edge cases is essential to widespread AV deployment

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EXISTING TESTING METHODS

CONTROL & REPEATABILITY

Simulation

Overnight SW Updates

Controlled Track Testing

Daily Shakedown

On-Road Testing

Nightly Scenario Learning

TIME-SCALE, REAL-WORLD, COMPLEXITY

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A smart mobility test center integrates the physical and the virtual

SMART MOBILITY TEST CENTER

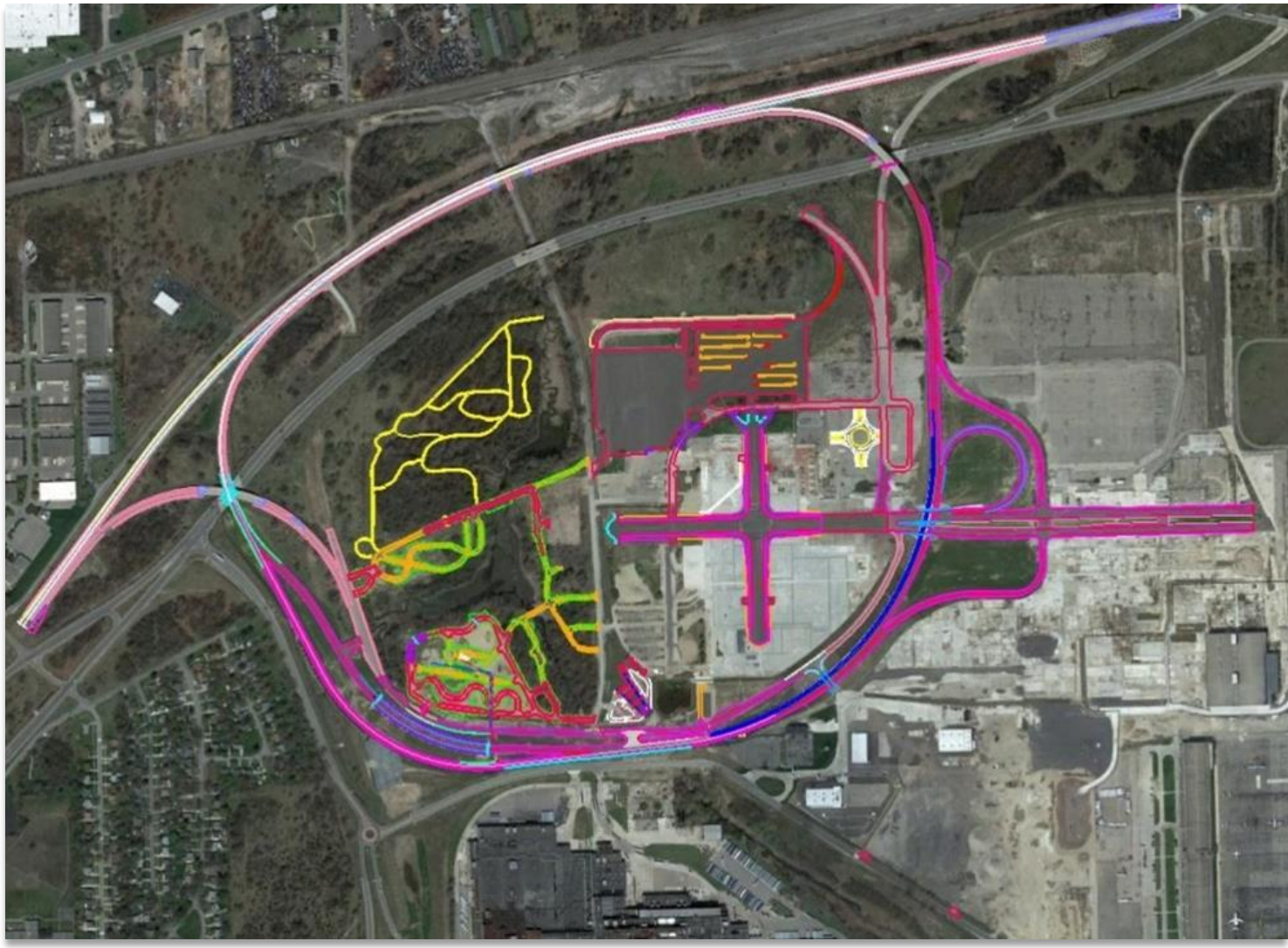
Testing & Validation of Advanced Mobility Technologies

Connected and Autonomous Vehicles

Advanced Driver Assistance Systems

Electrification (XFC, V2G, Cyber)

Ecosystem for Future Mobility



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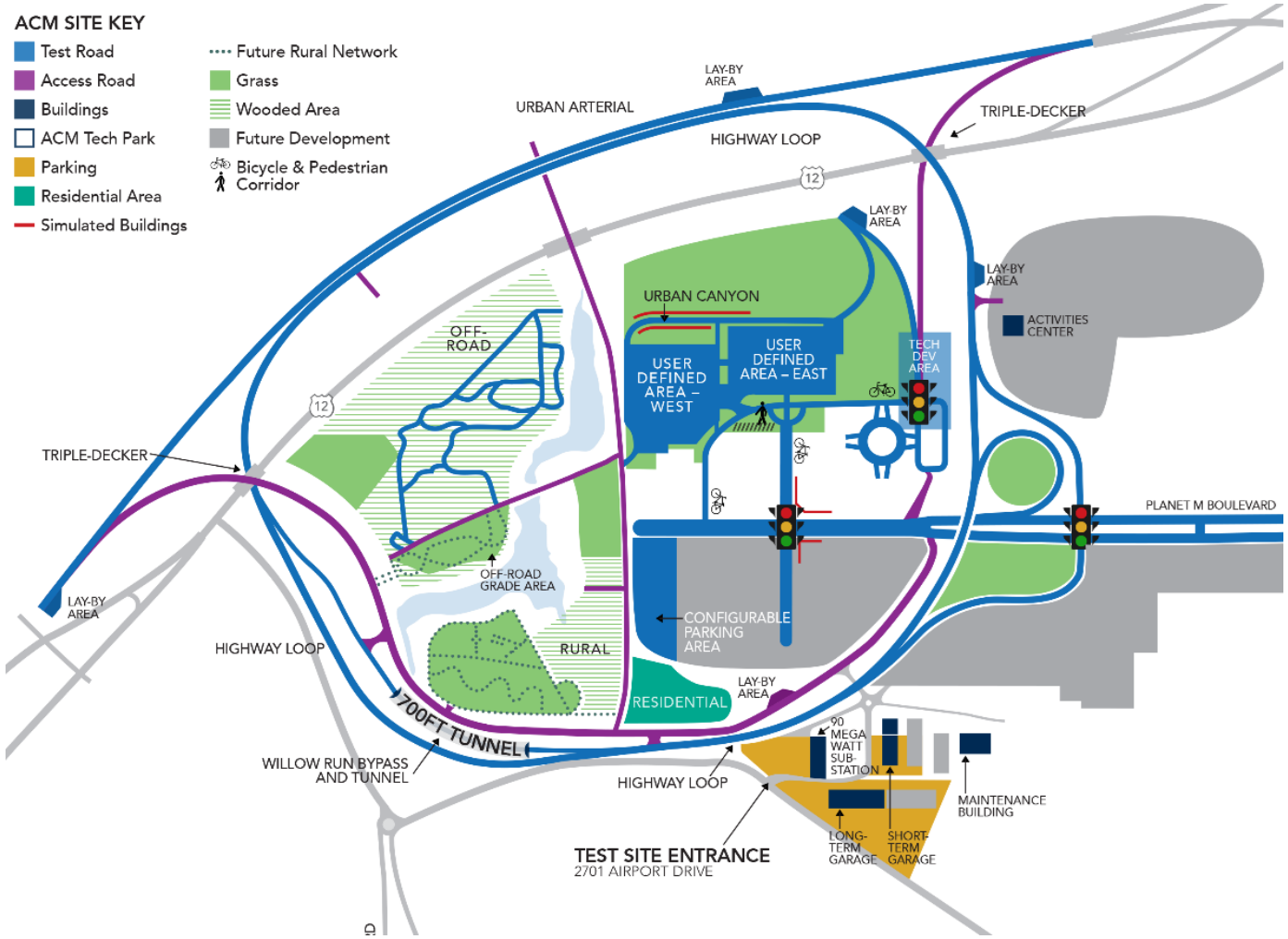
COMPREHENSIVE REAL-ROAD TEST ENVIRONMENT

1. Real road systems
2. ITS Network Infrastructure
3. Specialized Test Equipment
4. Virtual/Digital Tool Chain



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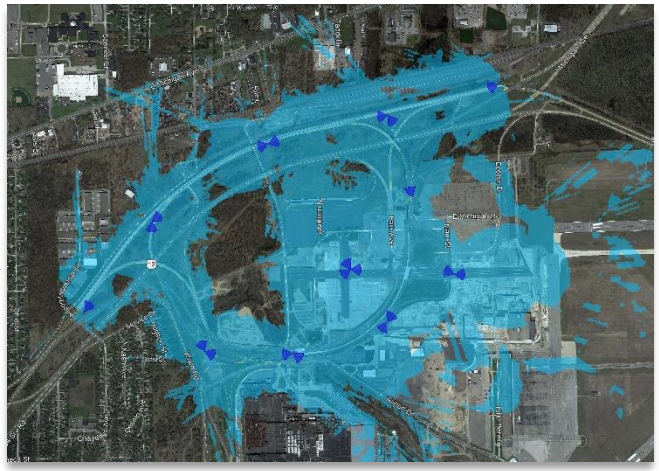
NETWORK INFRASTRUCTURE

PRIVATE 4G LTE & 5G SUB-6 CELLULAR

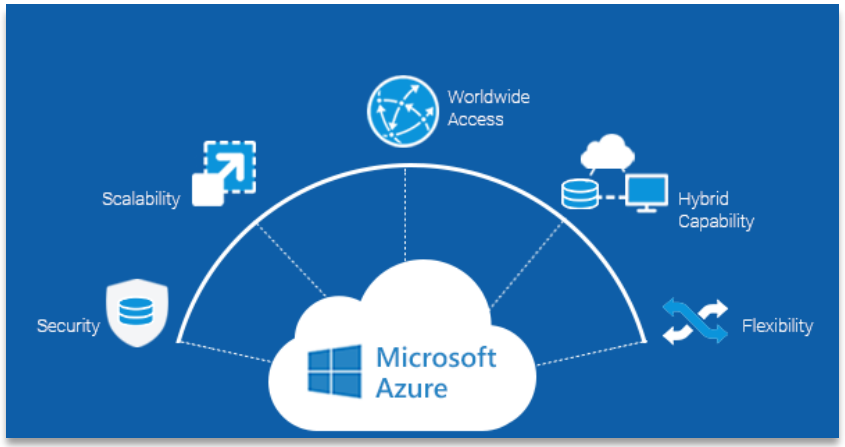


OPTIMIZED CELL COVERAGE

FIBER OPTIC CABLE BACKBONE

DSRC (15 RSUS)
Upgrading to C-V2X

UP TO 100 GBPS DATA TRANSFER



CLOUD - DATA MANAGEMENT &
ANALYTICS PLATFORM

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Advanced communications and network infrastructure

TEST EQUIPMENT: ROBOTIC SOLUTIONS, WEATHER, TARGETS

RAIN AND GRIME TRAILER TRUCK

PEDESTRIAN SOFT TARGETS

SR60 TORUS
STEERING ROBOT

CBAR600 – COMBINED BRAKE AND
ACCELERATOR ROBOT

GST – GUIDED SOFT TARGET

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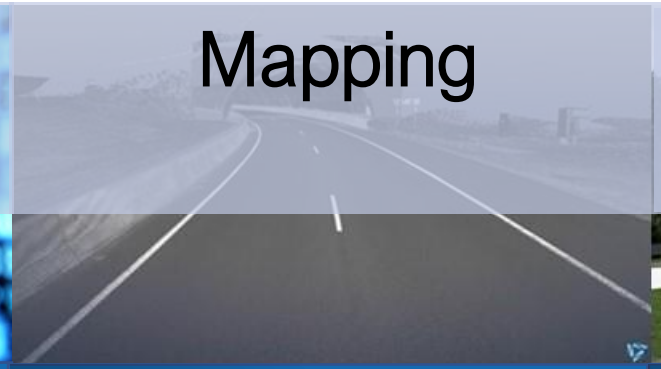
Rental equipment and support services available

Autonomous Cloud Introduction

- Managed Service supporting critical data, analytics and development capabilities
- Eliminates upfront, multi-million $ investment and frees talent to focus on mission-critical activities
- Client-specific MVP release is delivered in approx. 12 weeks.

Data & Analytics

Data Management & Analytics Platform (DMAP)
+
Cloud Services

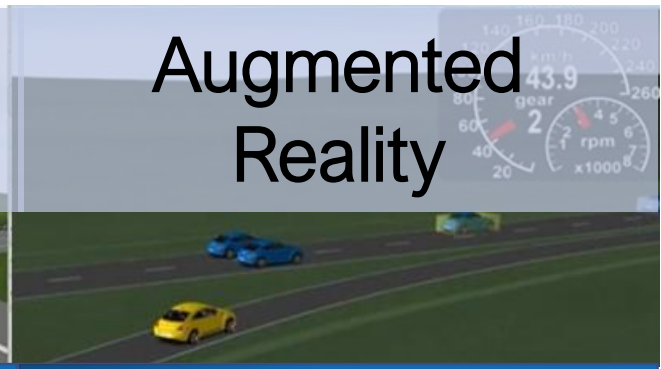


Mapping

3D Point Cloud Maps
+
Public Roads

Modeling & Simulation

Cloud Based Simulation Tools
+
Edge Case Solutions



Augmented Reality

Mixed Reality Simulation
+
Naturalistic Adversarial Driving Environment (NADE)

DEMONSTRATION AT ACM: CRASH BV CUT-IN AV

DEMONSTRATION AT ACM: HIGHWAY MERGING

CCAT CENTER FOR CONNECTED AND AUTOMATED TRANSPORTATION

SIEMENS

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Values of SAFE-TEST:

1 ACM Mile = 5000+Road Miles

Cost 50 – 100x Less

1. Reduce development costs
2. Compress development cycle

CCAT CENTER FOR CONNECTED AND AUTOMATED TRANSPORTATION

SIEMENS

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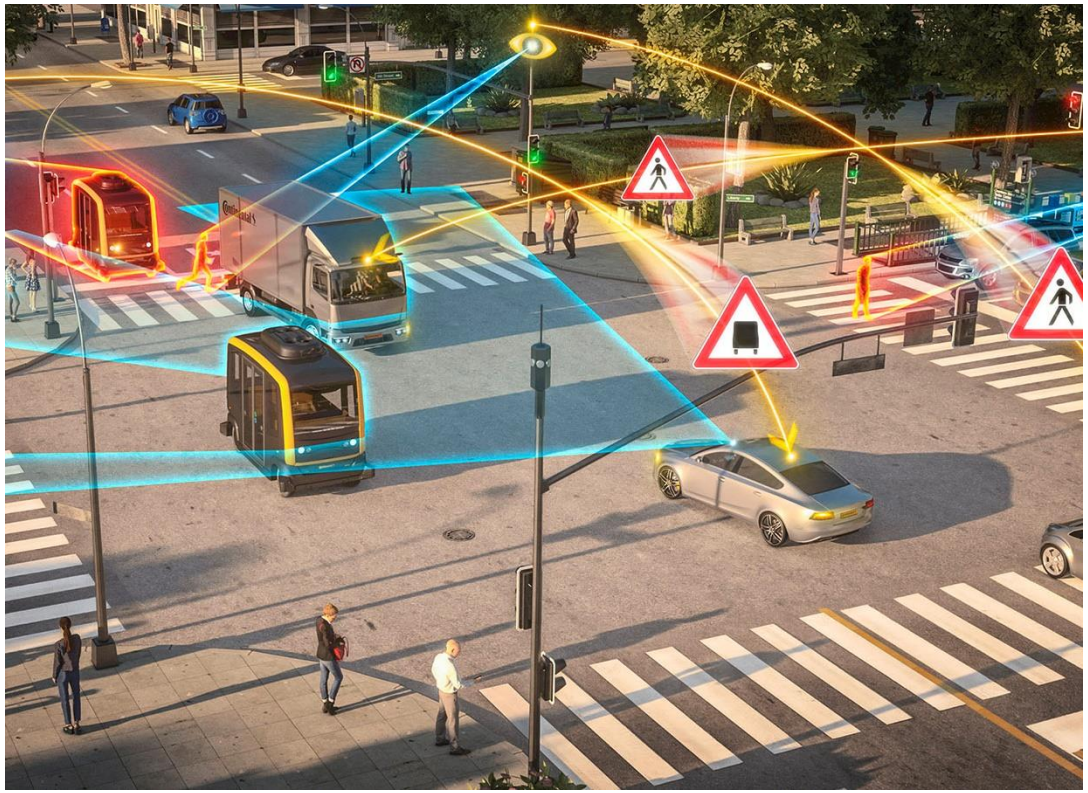
CAV TESTING NEEDS

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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CLEARING THE AV VALIDATION HURDLE

More advanced validation tools and resources are required to help reduce the amount of public road testing to validate AV's for deployments

- Public road testing is necessary but insufficient
- Integrated approach simulation, track, road
- More advanced tools
  - Augment Reality, Scenario Generation
- Affordable cloud-based tools
  - Data Management & Analytics
  - Simulation & Compute
- Interoperability (still yet to come)
- Standards (Industry, Federal, State)

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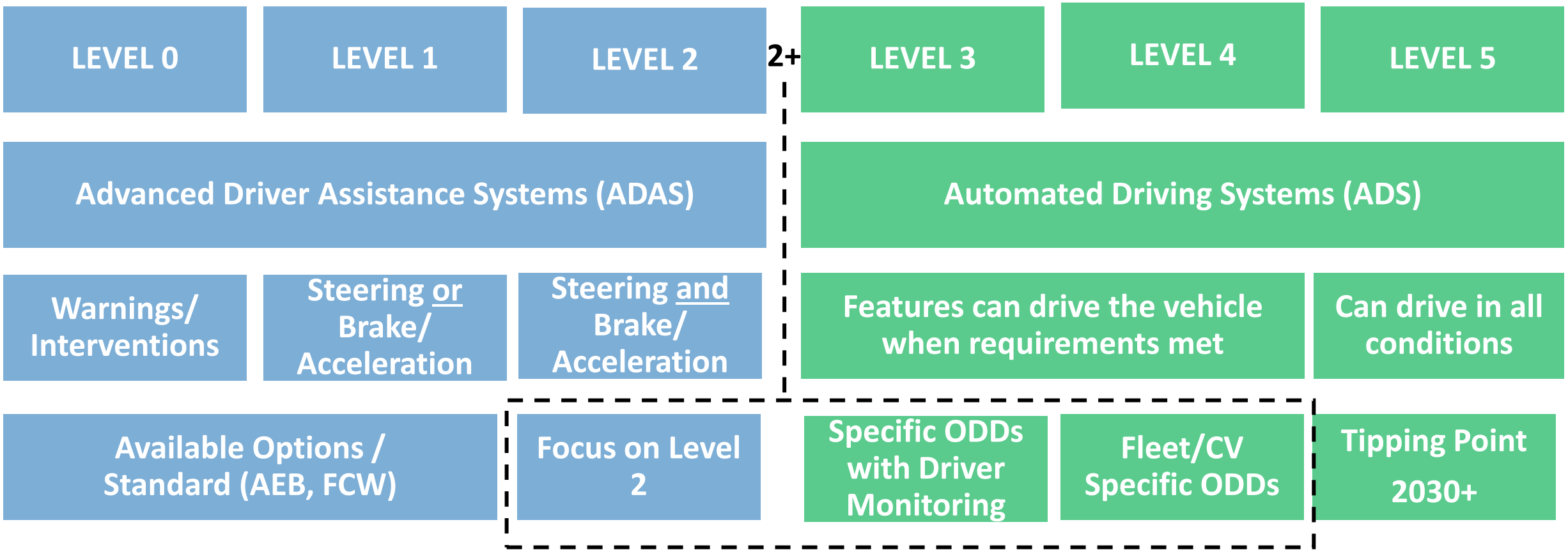
Perspectives on Market Commercialization

CURRENT INDUSTRY FOCUS ON AUTOMATION



- Level 2+ is not industry standard definition
- Implies Level 3 capabilities but with driver fully engaged

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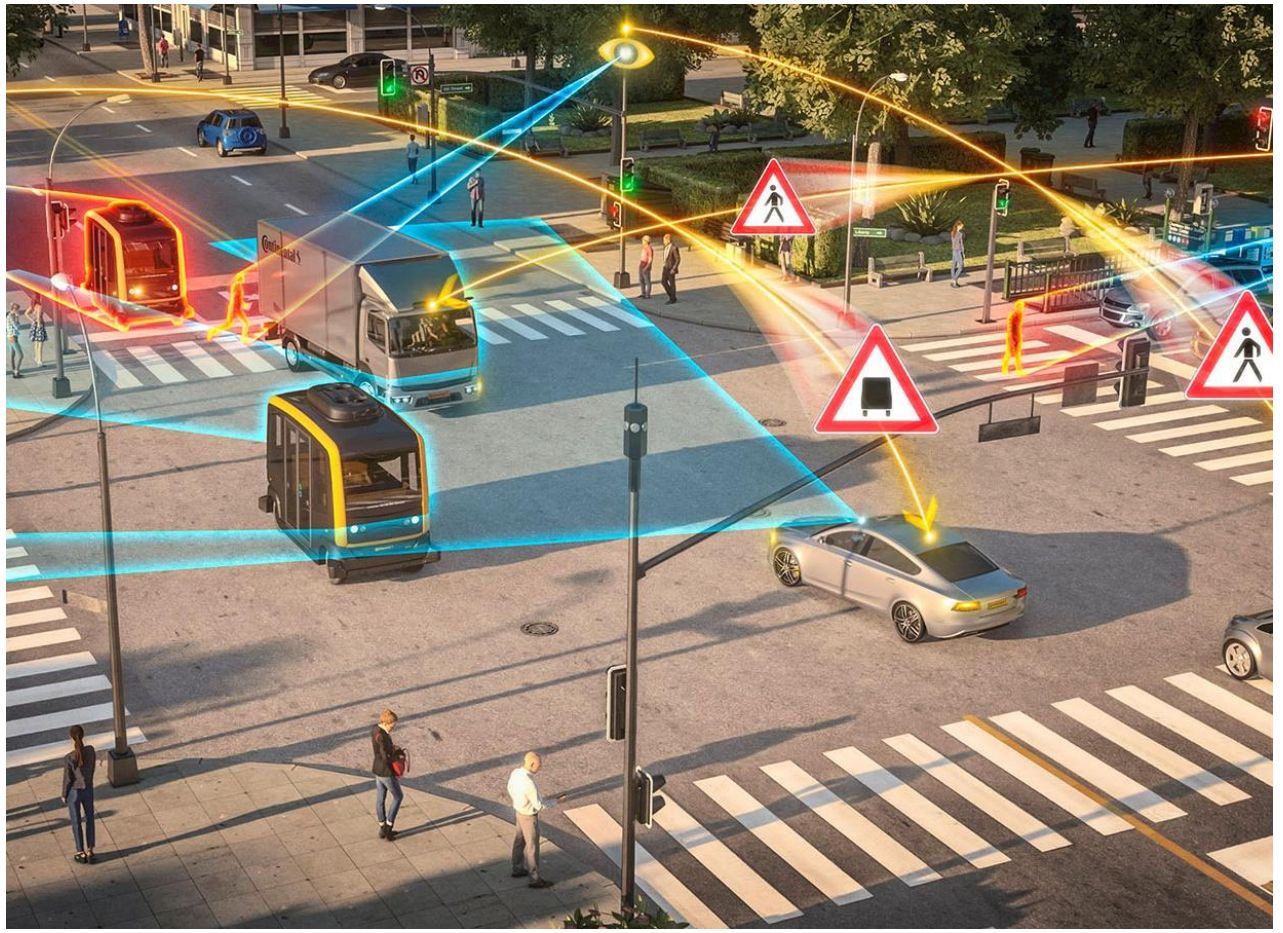
Heavy focused on deployment of level 2+, with some level 3 for consumer vehicles and level 4 for commercial fleets

CONNECTIVITY

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

- V2X (DSCR) – phasing out
- C-V2X / 5G – phasing in
- Assumes FCC ruling stands

AV's will be deployed in parallel with increasing levels of connectivity



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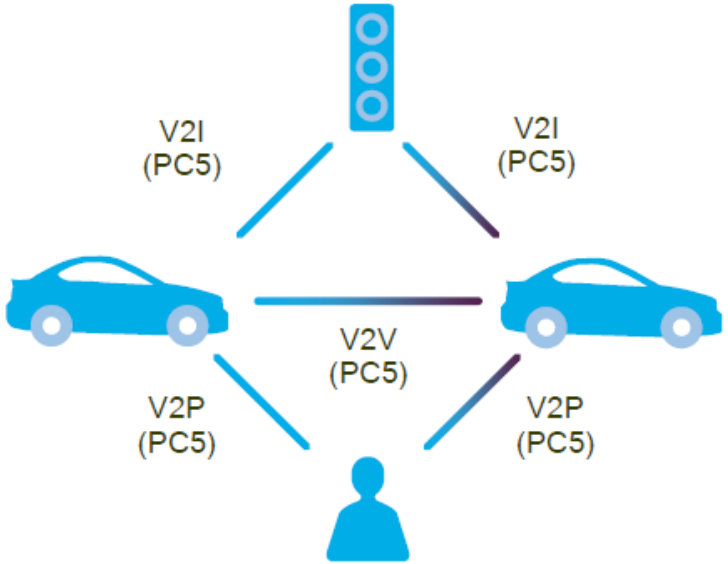
CELLULAR VEHICLE TO EVERYTHING (C-V2X) (TWO COMPLEMENTARY MODES)

Direct

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

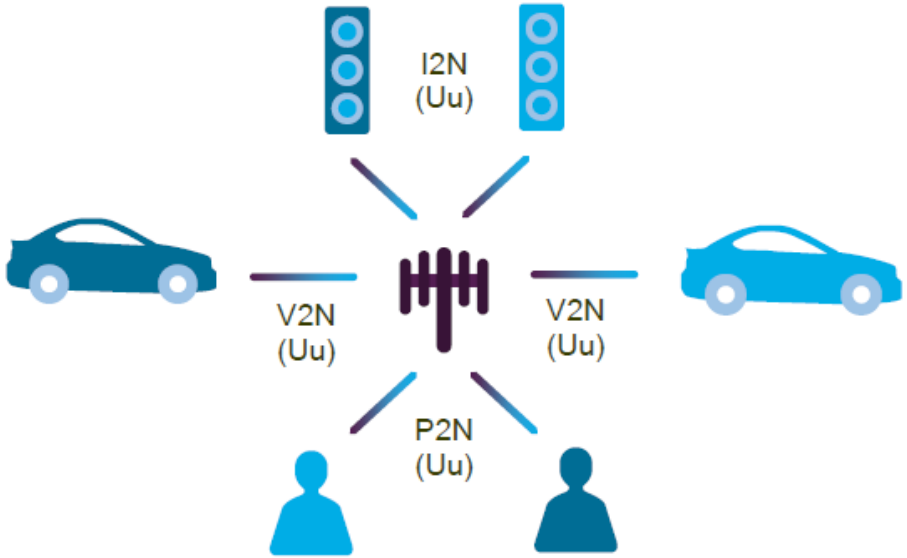


Short range (<1 kilometer), location, speed …

Implemented over "PC5 interface"

Network

V2N operates in traditional mobile broadband licensed spectrum



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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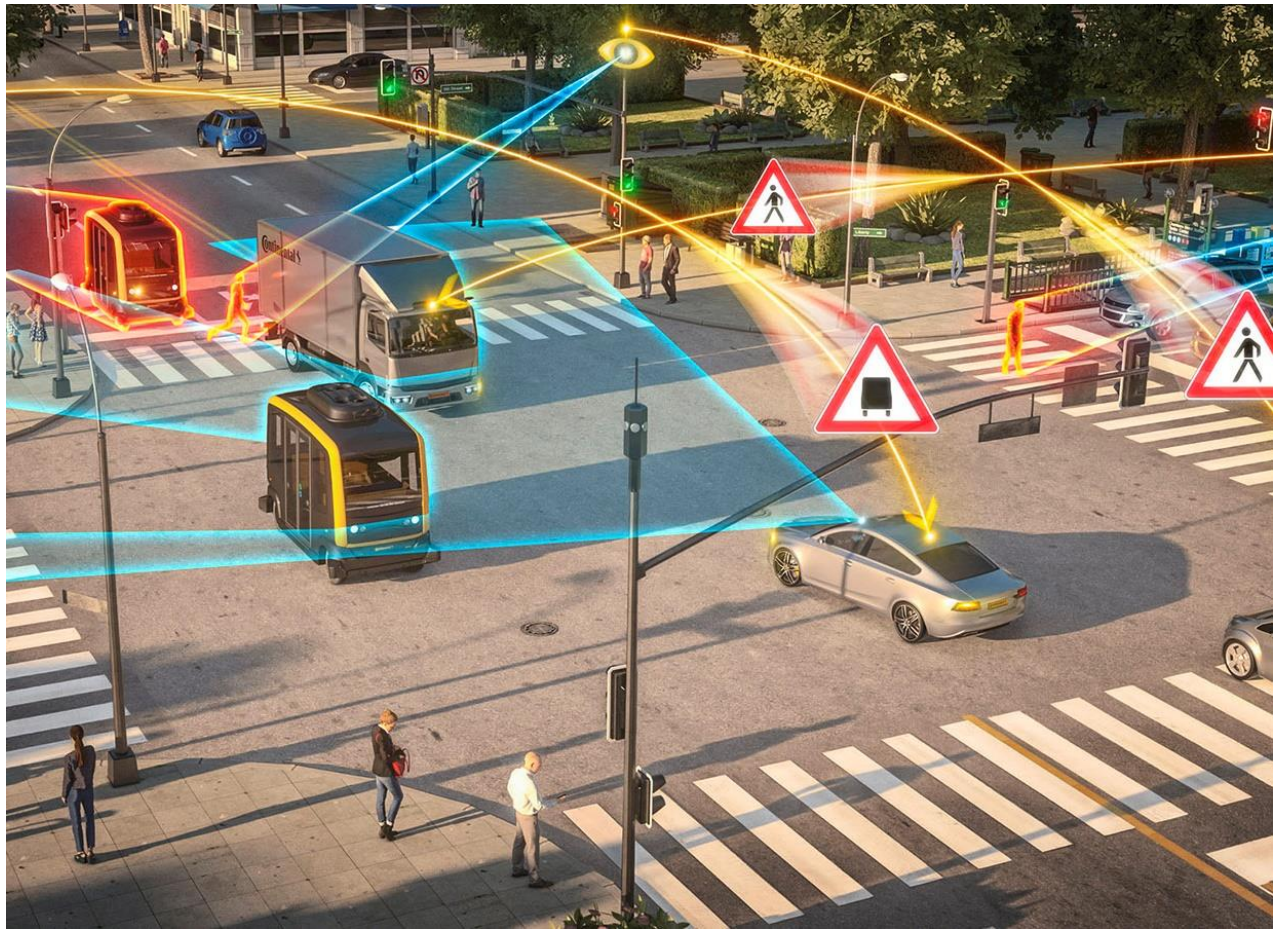
Mobile Network Operators (MNOs) have proposed that V2N can be fast and lower cost for early deployment

STATUS OF 5G

- Still early stages of roll out
- Not all 5G is the same
  - Low, Mid, mm-wave
  - Coverage vs. Bandwidth
- Mid-Band is said to be sweet spot
- Advances mm-wave Antenna Systems
- Demonstration of V2N use cases
- Limited commercial private network deployment for transportation



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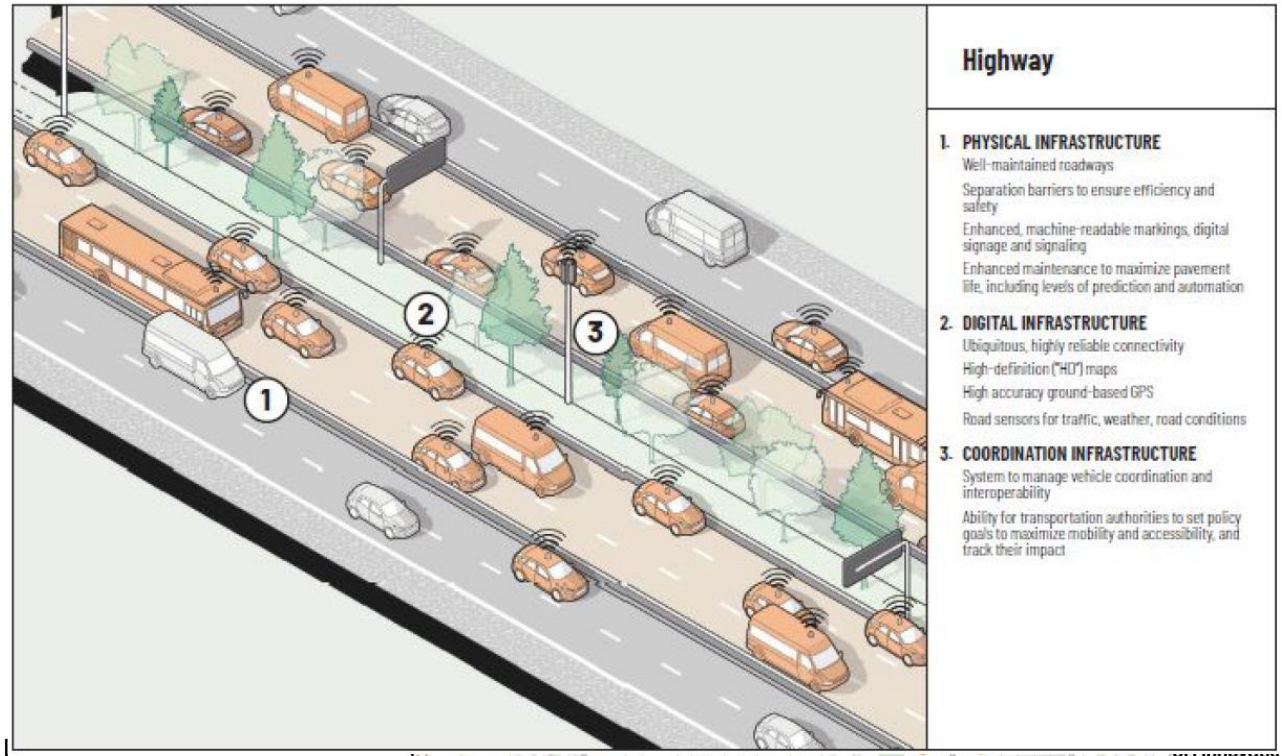
CONNECTED AND AUTOMATED VEHICLES CORRIDOR

- MDOT working with Cavnue
- 40-mile CAV corridor between Ann Arbor and Detroit
- Managed lane for CAVs with connectivity to infrastructure
- Infrastructure financing model
- “Automated Vehicle Roadway” Proposed MI legislation SB 706

Example Components of Integrated Infrastructure Technology Framework for CAV Corridors

Source: Cavnue



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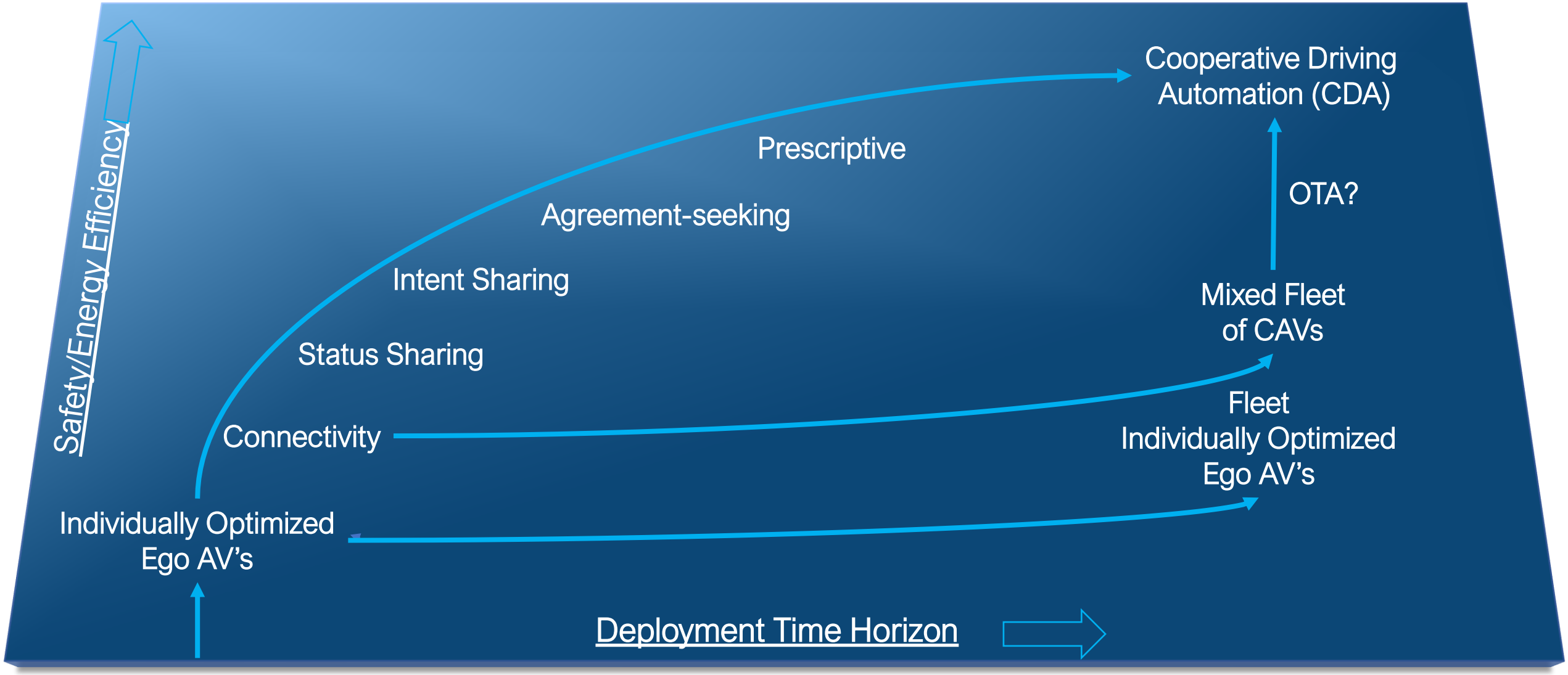
PATHWAYS TO COOPERATIVE DRIVING AUTOMATION



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Is C-V2X / 5G sufficient for CDA? Can you get there with a mixed fleet?

COMMERCIALIZATION PERSPECTIVES

- **Technology** - Not the limiting the factor. Building blocks are available.
- **Design** - Many possible vehicle-infrastructure configurations. Which meet use case requirements?
- **Validation** - Use cases and with proper edge cases is a long pole in the tent
- **Build, Operate, and Maintenance of Infrastructure**
  - Municipalities want to see more vehicles before they invest in infrastructure
  - OEMs reluctant to burden vehicles with chip sets until they see more infrastructure
- **Finance** - Who pays for the benefits (public service, fee for service) is key?
- **Regulatory** – Both safety an energy efficiency policy considerations
  - NHTSA (FMVSS), States for Licensing & Operation
  - New Fuel economy test cycles, EPA window stickers (mpg, EV range), and innovative policy design
- **Market Acceptance** – Will adoption be market-driven by consumers?

Technology is not the main limiting factor for commercialization of L4/L5

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Ways for API to Engage

Going Beyond CAV Testing

GROWING A DIVERSE MOBILITY ECOSYSTEM

ACM's targeted efforts and customer base extends across a variety of industries that comprise the mobility ecosystem.

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ACM's focus is broad towards future mobility

ACM AREAS OF FOCUS

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There are many ways to engage in ACM ecosystem

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