TEAM
Transportation Engineers Association of Missouri

Presentation for 2019 Annual TEAM Conference

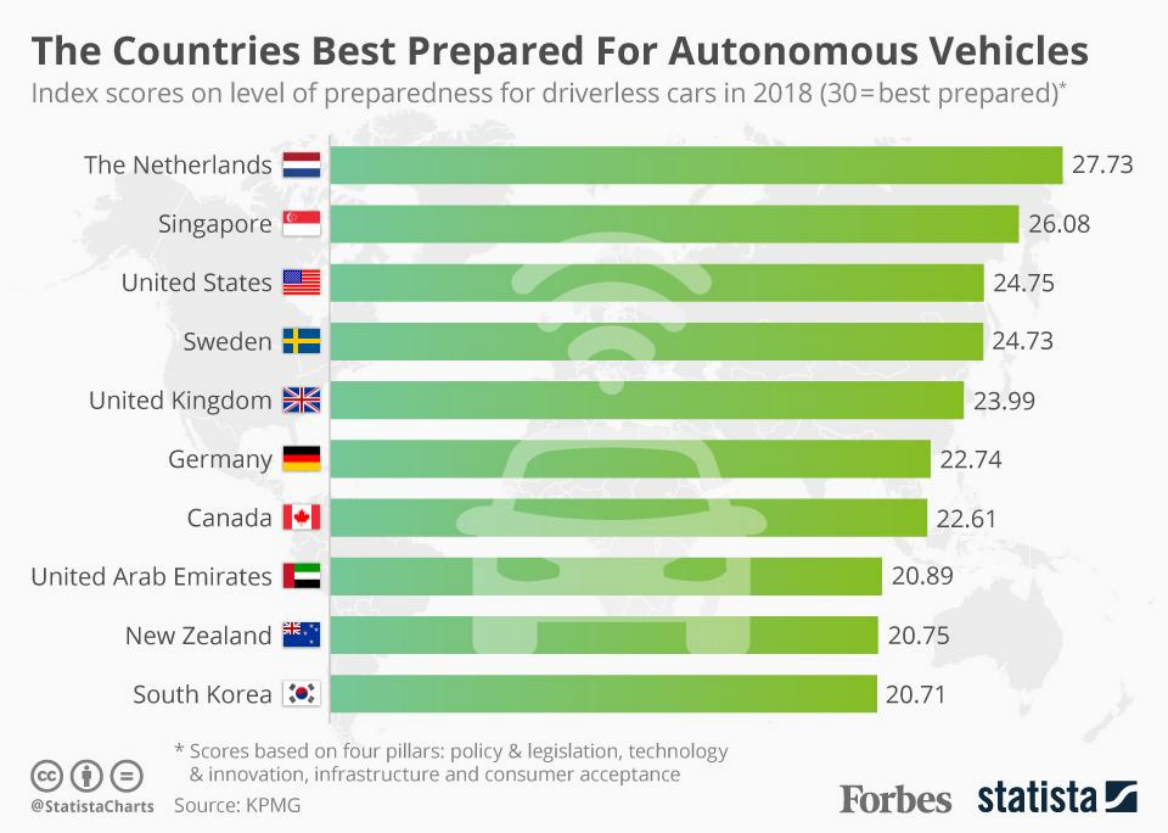
Technology Advancements Beyond Missouri

CAV Technology Foundations & State DOT Implementation

Breakout Session #1: 9:20 AM – 10:00 AM | March 14, 2019

Presented by: Maureen Paz de Araujo, FAICP CTP CEP

International Trends: CAV Preparedness



- The Netherlands - #1
  - Policy – 3
  - Technology/Innovation – 4
  - Infrastructure – 1
  - Consumer Acceptance – 2
- Japan - #11
  - **Policy – 12**
  - Technology/Innovation – 7
  - Infrastructure – 3
  - **Consumer Acceptance – 16**

Source: The Countries Best Prepared For Autonomous Vehicles [Infographic], Forbes.com, December 2018.

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International Trends: Preparedness Details

Overall Rank	Country	Total Score	Policy		Technology		Infrastructure		Acceptance	
			Rank	Score	Rank	Score	Rank	Score	Rank	Score
1	The Netherlands	27.73	3	7.89	4	5.46	1	7.89	2	6.49
2	Singapore	26.08	1	8.49	8	4.26	2	6.72	1	6.63
3	United States	24.75	10	6.38	1	6.97	7	5.84	4	5.56
4	Sweden	24.73	8	6.83	2	6.44	6	6.04	6	5.41
5	United Kingdom	23.99	4	7.55	5	5.28	10	5.31	3	5.84
6	Germany	22.74	5	7.33	3	6.15	12	5.17	12	4.09
7	Canada	22.61	7	7.12	6	4.97	11	5.22	7	5.30
8	UAE	20.89	6	7.26	14	2.71	5	6.12	8	4.79
9	New Zealand	20.75	2	7.92	12	3.26	16	4.14	5	5.43
10	South Korea	20.71	14	5.78	9	4.24	4	6.32	11	4.38
11	Japan	20.28	12	5.93	7	4.79	3	6.55	16	3.01
12	Austria	20.00	9	6.73	11	3.69	8	5.66	13	3.91
13	France	19.44	13	5.92	10	4.03	13	4.94	10	4.55
14	Australia	19.40	11	6.01	13	3.18	9	5.43	9	4.78
15	Spain	14.58	15	4.95	16	2.21	14	4.69	17	2.72

Source: Autonomous Vehicles Readiness Index, KPMG International, 2018.

- The Netherlands - #1
  - Policy/Legislation – 3
  - Technology/Innovation – 4
  - Infrastructure – 1
  - Consumer Acceptance – 2
- United States - #3
  - **Policy/Legislation – 10**
  - Technology/Innovation – 1
  - **Infrastructure – 7**
  - Consumer Acceptance – 4

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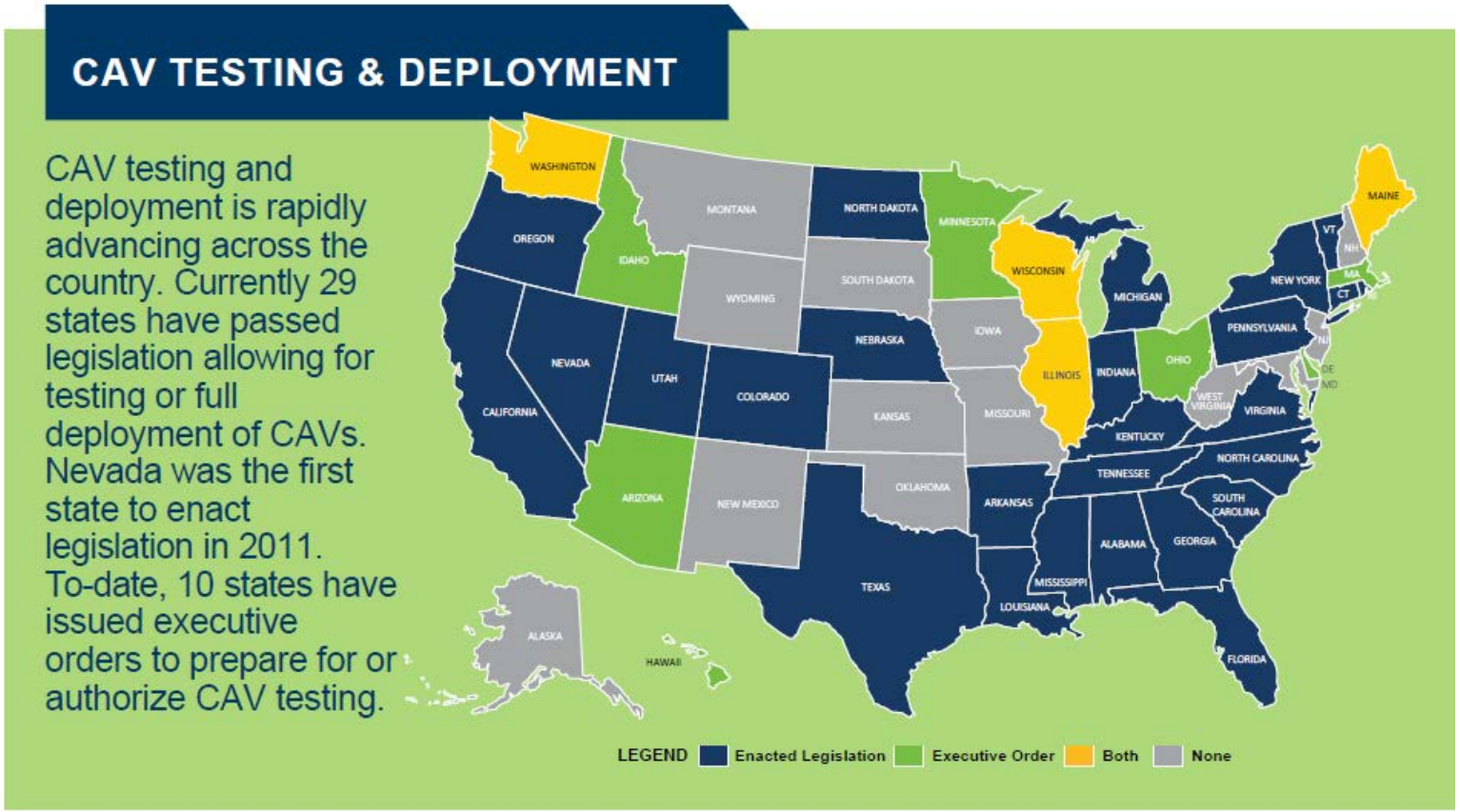
National Trends: CAV Testing & Deployment

- States Passed Legislation Allowing CAV Testing and/or Deployment (29)
  - Enacted Legislation (25)
  - Executive Orders (4)
  - Both Legislation and Executive Orders (4)



Source: Governor's Advisory Council on Connected & Autonomous Vehicles Executive Report, MnDOT, December 2018.

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National Trends: Truck Platooning

- States Allow Truck Platooning on Public Roads (23)
  - Platooning Allowed (23)
  - Limited Commercial Deployment (4)
  - Platoon Testing Allowed (3)
  - Legislation Pending (2)

Source: Governor's Advisory Council on Connected & Autonomous Vehicles Executive Report, MnDOT, December 2018.

Connected Vehicle Pooled Fund Study

PROGRAM TO SUPPORT THE DEVELOPMENT AND DEPLOYMENT OF CONNECTED VEHICLE APPLICATIONS

- Arizona DOT
- Caltrans
- Colorado DOT
- Connecticut DOT
- Delaware DOT
- FHWA
- Florida DOT
- Georgia DOT
- Idaho DOT
- Maryland DOT
- Michigan DOT
- Minnesota DOT
- Mississippi DOT
- New Hampshire DOT
- New Jersey DOT
- New York DOT
- Ohio DOT
- Pennsylvania DOT
- Tennessee DOT
- Texas DOT
- Transport Canada
- New Jersey DOT
- New York DOT
- Ohio DOT
- Washington DOT
- Wisconsin DOT
- UVA Transportation Research Center
- Virginia DOT

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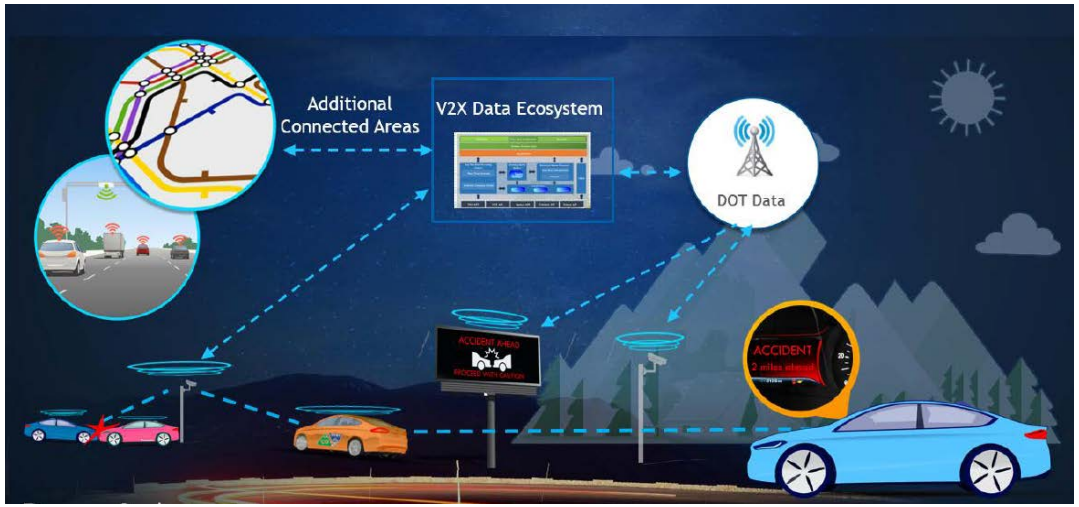
Colorado | Smart 70

Source: CDOT – Kozinski/Ford/Rice, Presentation to Transportation Commission, October,2017.

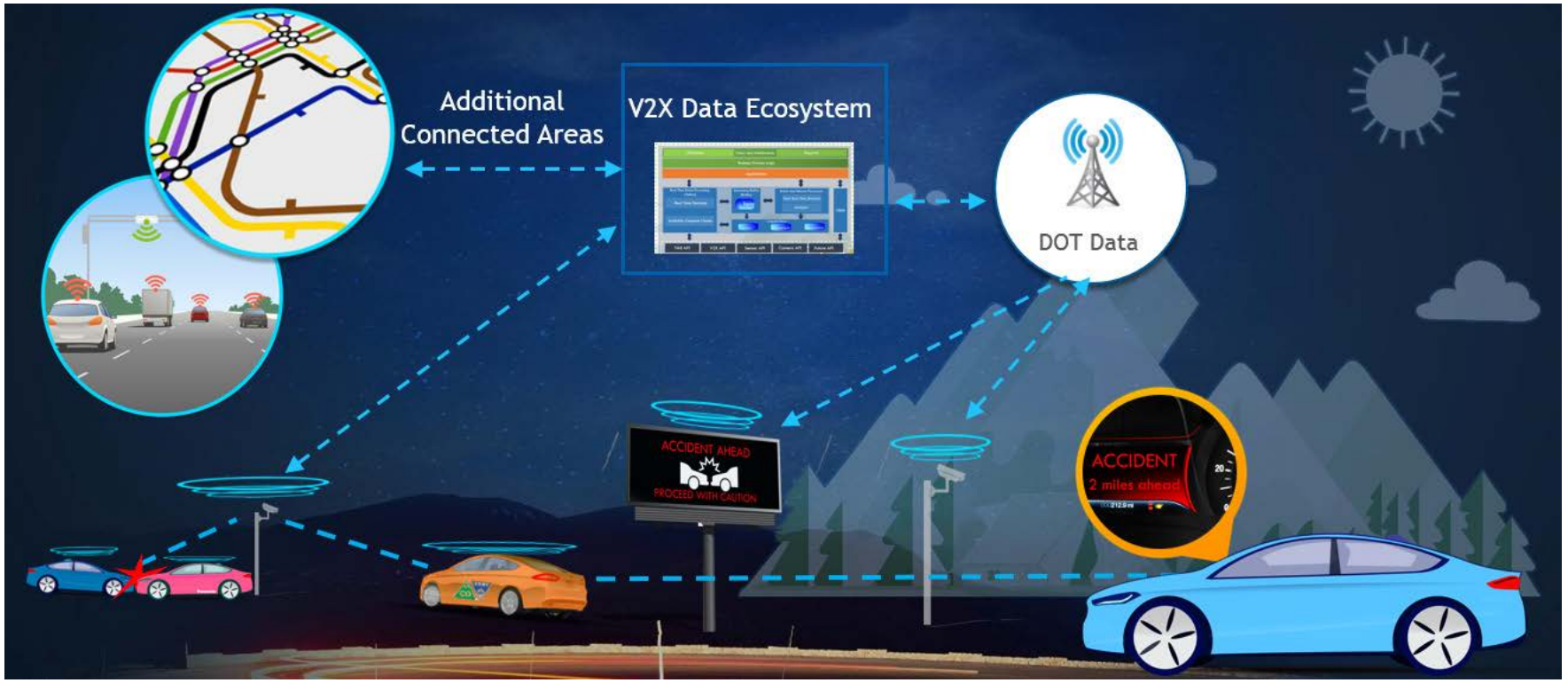
CDOT – PANASONIC: I-70 MOUNTAIN CORRIDOR PARTNERSHIP



Connected Vehicle Technology via investing in a Connected Vehicle Ecosystem pays dividends for urban and rural mobility and safety

Colorado | Vehicle Ecosystem

V2X | C-V2X CONNECTIVITY

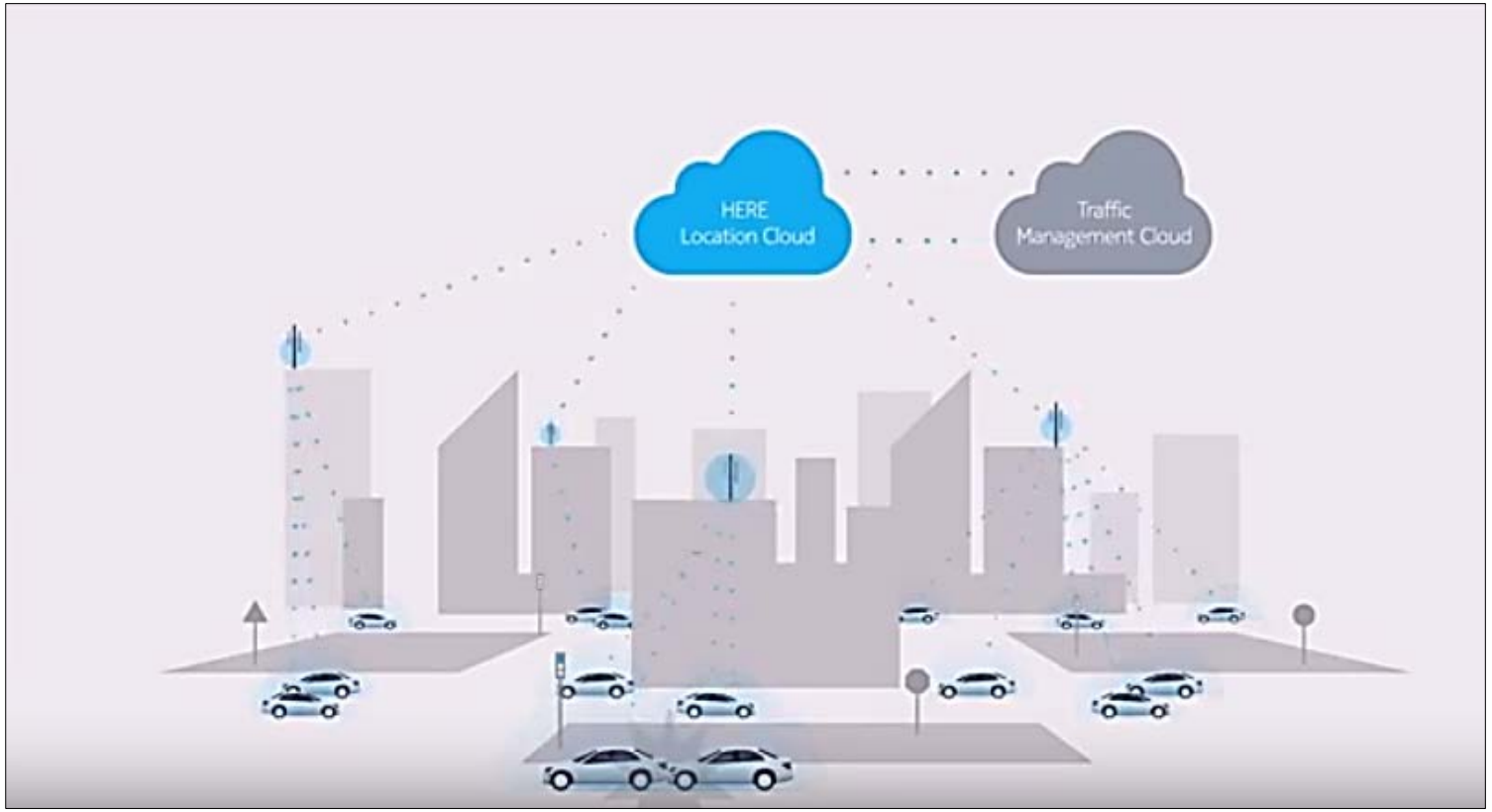


Source: CDOT – Kozinski/Ford/Rice, Presentation to Transportation Commission, October,2017.

Colorado | Vehicle Ecosystem

HERE | C-V2X & CLOUD-BASED ANALYTICS

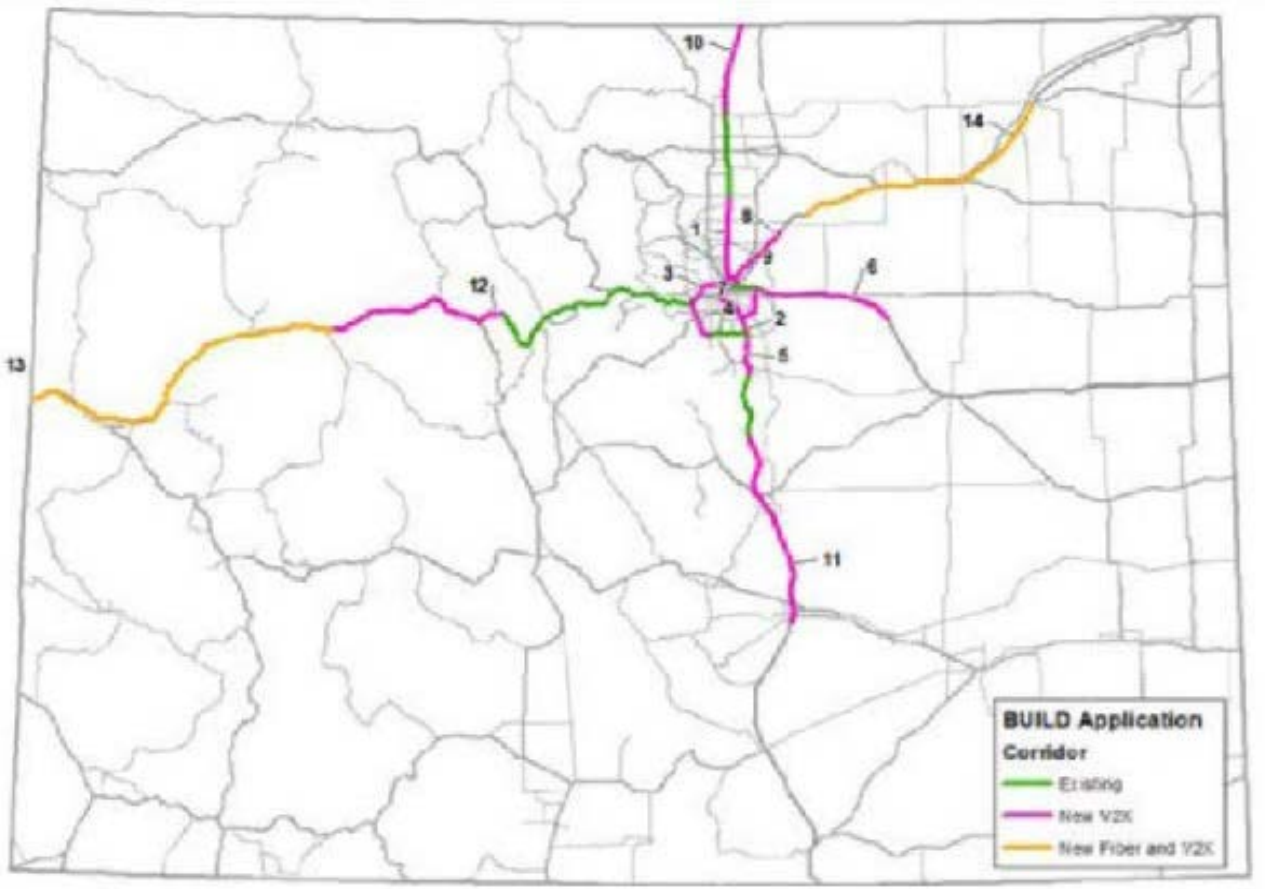
A Partnership of CDOT, QUALCOMM, Ford Motor Company & Panasonic



Colorado | Connectivity

INTERNET OF ROADS

- Stage 1 Timeline: 2019-2022
- 14 Corridors: 500+ miles
- Ready for Automaker Rollout
- Smart Systems Approach
- Aligns with V2X timeline



Colorado | DAISy

DATA INTELLIGENCE SYSTEM (DAISy) IS A CLOUD-BASED DATA ANALYTICS PLATFORM THAT BRINGS:

- Near-term intelligence, efficiency and interoperability of existing network
- Long-term enablement of world-leading automated transportation systems

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Colorado | Smart 25

MANAGED ROADWAY PILOT

- Upgrade 19 ramps along northbound I-25 in metro Denver
- Connects freeway operations to ramp metering systems for coordinated entrance of vehicles to keep interstate flowing
- Technology partnership with Australia with cloud-based traffic management; first in U.S.; reduces congestion without adding lanes

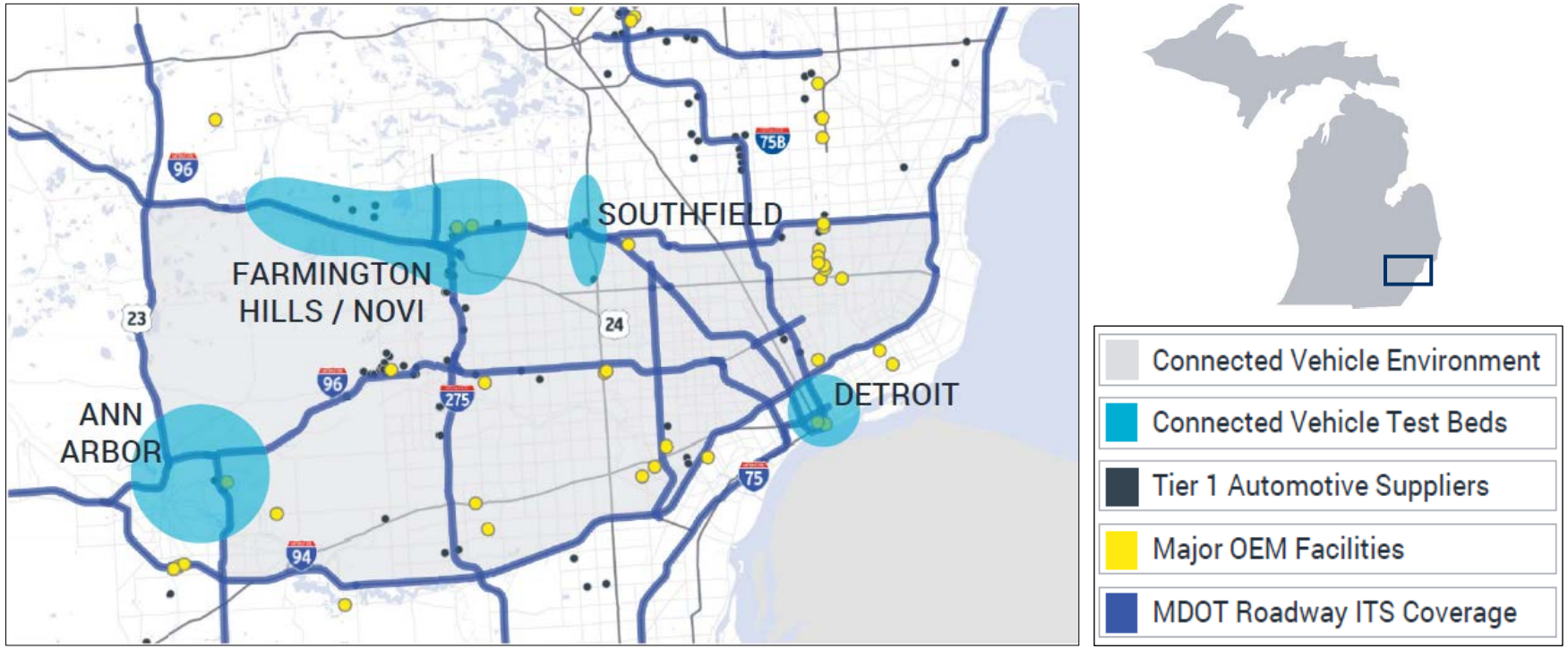
Colorado | Hyperloop One

HYPERLOOP ONE

- 2,600 Submissions
- 10 Routes Selected
- 4 U.S. Routes
  - Chicago - Columbus - Pittsburgh
  - Cheyenne - Denver - Pueblo
  - Dallas - Laredo - Houston
  - Miami - Orlando

Michigan | Infrastructure

SOUTHEAST MICHIGAN CONNECTED VEHICLE ASSETS



Source: Michigan Connected Vehicle Initiatives, MDOT, April 2016.

Michigan | Infrastructure

CONNECTED VEHICLE INFRASTRUCTURE

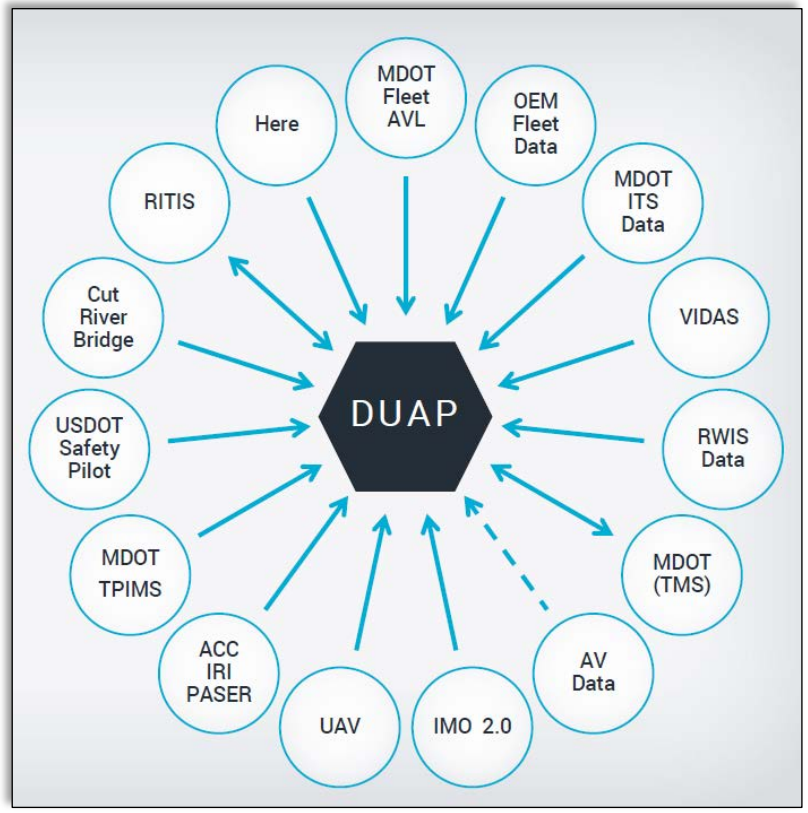
MDOT's CV infrastructure investments are key to creating an environment supportive of V2I testing

115

RSU's

Source: Michigan Connected Vehicle Initiatives, MDOT, April 2016.

Michigan | Data Management



Source: Michigan Connected Vehicle Initiatives, MDOT, April 2016.

DATA USE ANALYSIS & PROCESSING PROGRAM (DUAP)

MDOT's Data Use Analysis and Processing (DUAP) program is pioneering the collection and fusion of CV data with a wide range of data sources.

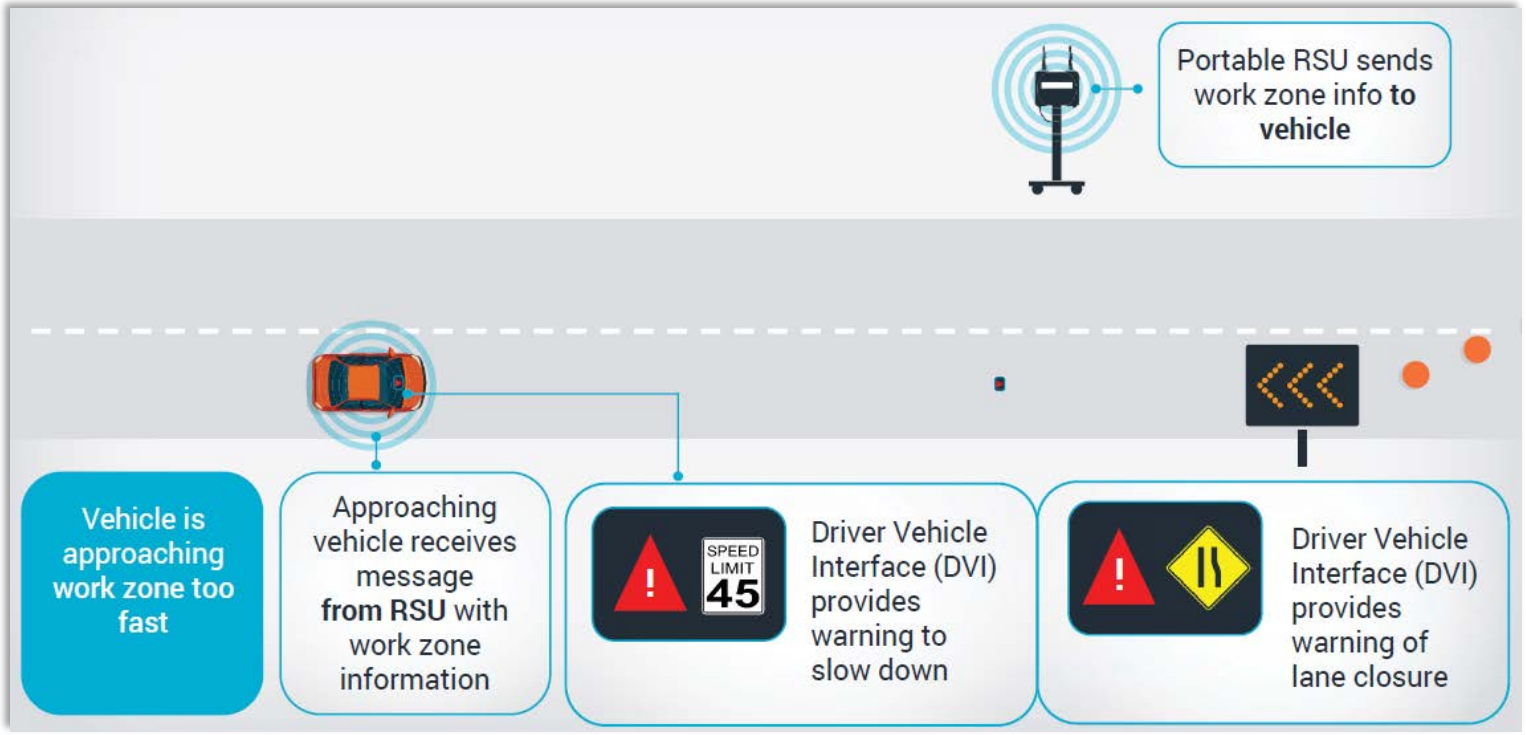
Michigan | V2I Applications

TRUCK PARKING INFORMATION & MANAGEMENT SYSTEM (TPIMS)

Source: Michigan Connected Vehicle Initiatives, MDOT, April 2016.

Michigan | V2I Applications

WORK ZONE WARNING - MANAGEMENT



Source: Michigan Connected Vehicle Initiatives, MDOT, April 2016.

Michigan | Partnerships

MOBILITY TRANSFORMATION CENTER

Source: Michigan Connected Vehicle Initiatives, MDOT, April 2016.
Photo Courtesy of the University of Michigan.

Minnesota | CAV Initiatives

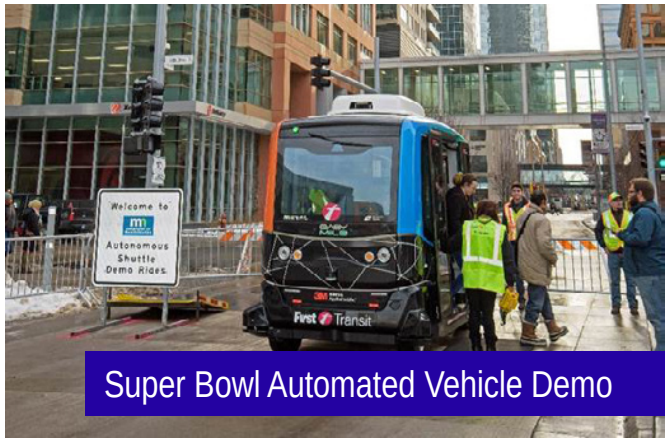
DEPARTMENT OF TRANSPORTATION

PUBLIC OUTREACH

- Automated Shuttle Demonstrations
- CAV Strategic Plan Outreach

Automated Vehicle Demo at Polaris Headquarters

Source: Governor's Advisory Council on Connected & Autonomous Vehicles Executive Report, MnDOT, 12-2018.



Super Bowl Automated Vehicle Demo

State Fair Automated Vehicle Demo

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Minnesota | CAV Initiatives

DEPARTMENT OF TRANSPORTATION

RESEARCH AND TESTING

- Cold Weather Testing
- Connected Corridor (Trunk Highway 55) Interstate 494 to Minneapolis
- Connected Corridor (Trunk Highway 52) St. Paul to Rochester
- Private Industry R & D: VSI Labs, 3M's Connected Roads, Polaris CAV Technologies

Automated Shuttle Cold Weather Research at MnROAD

Source: Governor's Advisory Council on Connected & Autonomous Vehicles Executive Report, MnDOT, December 2018.

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Minnesota | CAV Initiatives

DEPARTMENT OF TRANSPORTATION

INNOVATIVE PARTNERSHIPS

- Strategic Visioning
  - MnDOT, Hennepin County, Metropolitan Council and the McKnight Foundation to host a two-day strategic visioning workshop on automated vehicles in June 2018.
- Information Sharing
  - Minnesota County Engineers Association, Minnesota Guidestar and ITS Minnesota
- Regional and National Sharing
  - MnDOT and other state and local agencies are collaborating with other states in "pooled fund" studies to research CAV technology.
- Innovative Procurement and Ideas

Source: Governor's Advisory Council on Connected & Autonomous Vehicles Executive Report, MnDOT, December 2018.

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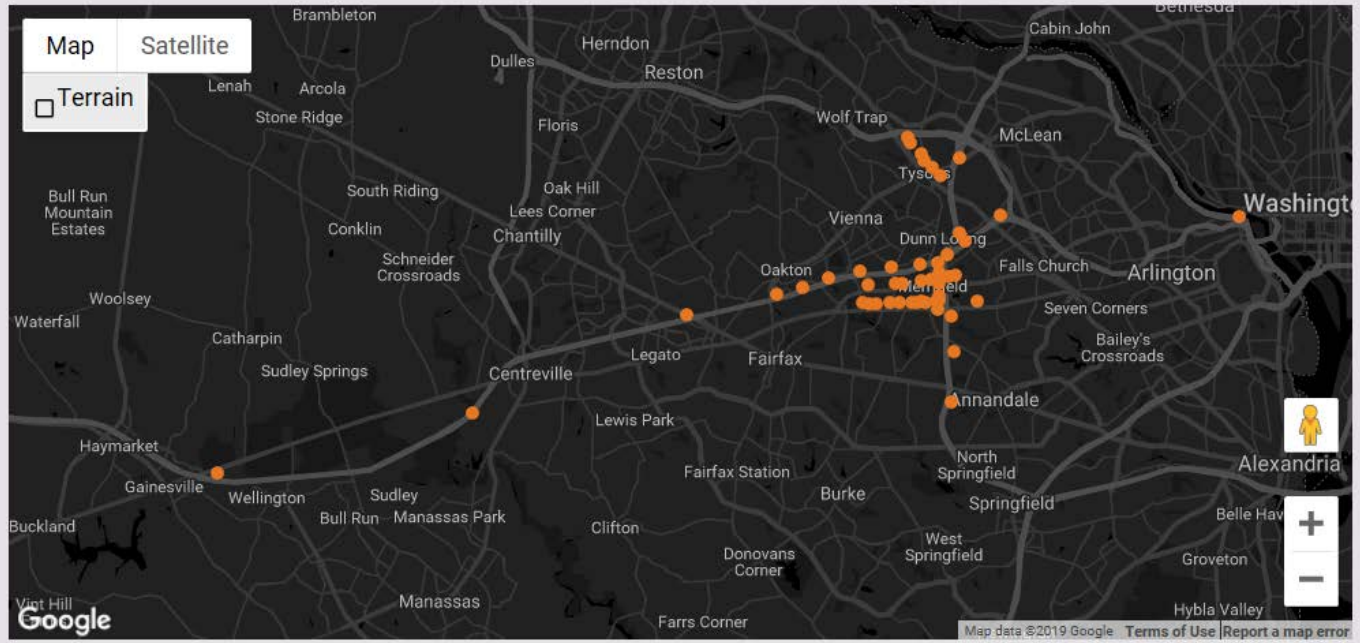
Virginia | CV Test Beds

NORTHERN VIRGINIA

"Urban" Test Bed Features:

- High-operating capacity roadways (I-66, I-495, U.S. 29, and US 50)
- Recurring congestion
- Top 25 "crash hot spots"
- 49 roadside units (RSUs) located within Northern Virginia test bed



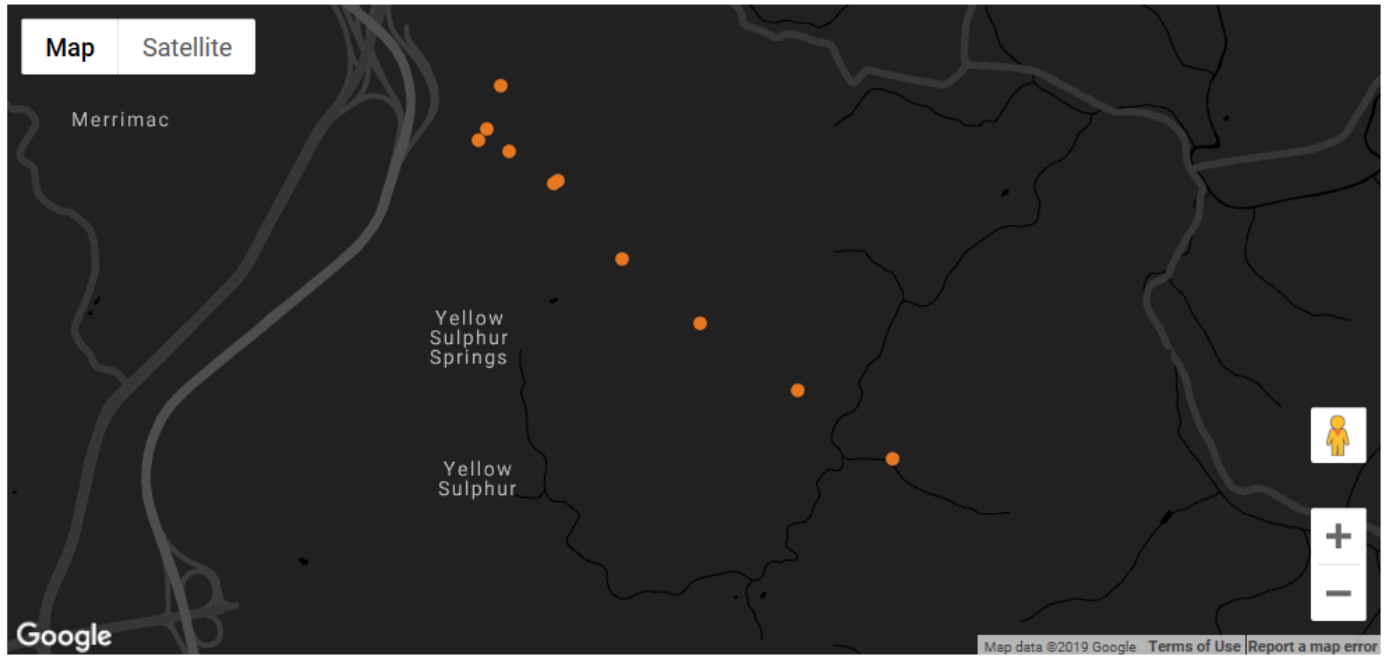
Source: Virginia Roads website, https://www.vtti.vt.edu/vcc/ , accessed March 2019.

Virginia | CV Test Beds

VIRGINIA SMART ROADS – BLACKSBURG, VA

Smart Roads Test Bed Features:

A controlled, “laboratory” environment that allows CV applications to be developed and proven safely before they are deployed on public roadways.



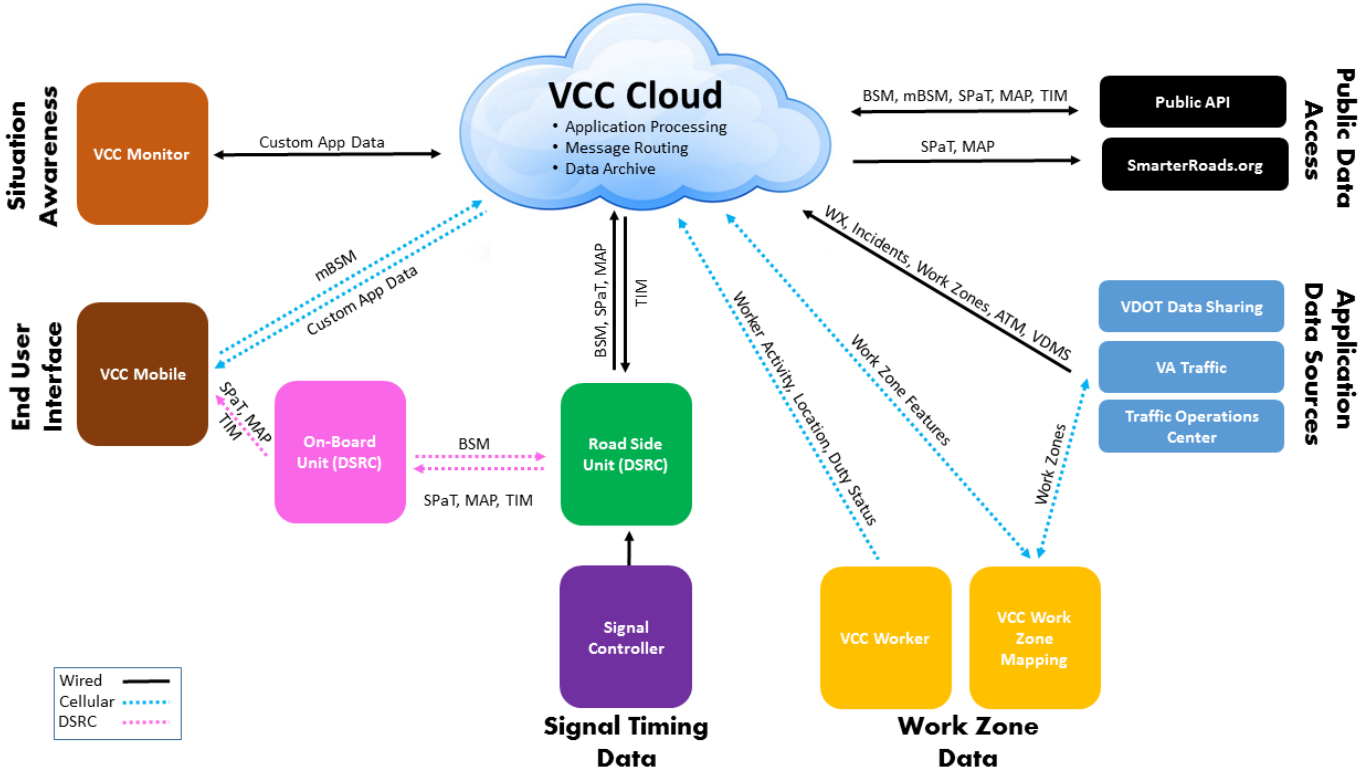
● - RSU location.

Source: Virginia Roads website, https://www.vtti.vt.edu/vcc/ , accessed March 2019.

Virginia | V2X Infrastructure

VCC CLOUD

- Centralized System - To manage CV message traffic
- Connected Vehicles - Connect to VCC Cloud via cellular or DSRC communications
- Interfaces - Pull traffic, incident, weather and dynamic message sign data from VDOT data-sharing website



Source: Virginia Roads website, https://www.vtti.vt.edu/vcc/, accessed March 2019.

Virginia | V2X Infrastructure

DEDICATED SHORT RANGE COMMUNICATIONS (DSRC)

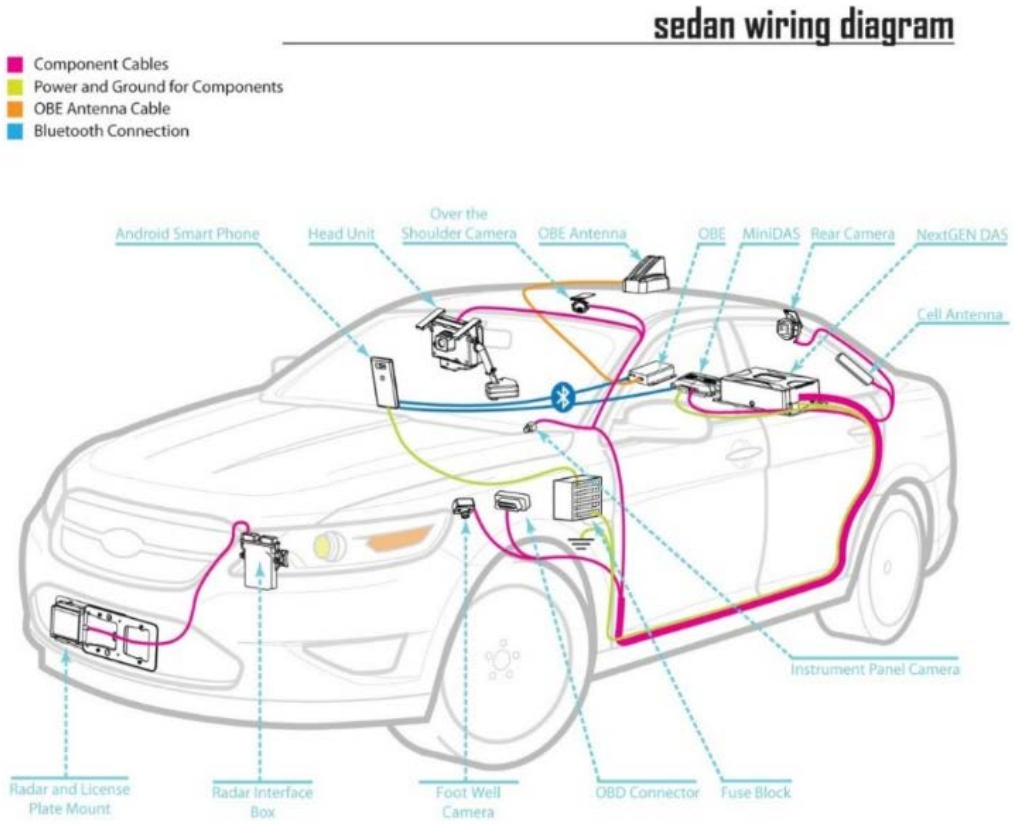
- 64 Roadside Units (RSUs) - Located throughout the Northern Virginia Test Bed
- 10 Roadside Units - On the Virginia Smart Roads
- 45 Arterial/Intersection RSUs – Cohda MK5, located on arterials
- 19 Freeway RSUs - Cohda MK5, located on the freeways

Source: Virginia Roads website, https://www.vtti.vt.edu/vcc/, accessed March 2019.

Virginia | Deployed Vehicle Fleet

CONNECTED VEHICLE FLEET

- Fleet of 50 Vehicles - Highly instrumented light vehicles was deployed within the Northern Virginia Test Bed
- Level 2 Automation - Vehicles with features such as adaptive cruise control and lane-keeping assist
- Instrumented with Data Collection Equipment - To capture video of the vehicles' automation features at work as well as driver responses



Source: Virginia Roads website, https://www.vtti.vt.edu/vcc/, accessed March 2019.

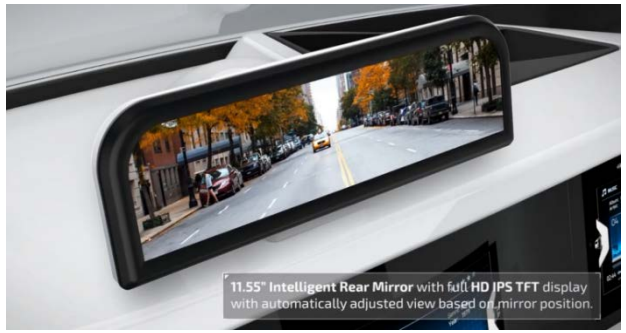
Panasonic | Communications Technology

V2X (EVERYTHING) COMMUNICATIONS

- (V2V) Vehicle to Vehicle
- (V2I) Vehicle to Infrastructure
- (V2P) Vehicle to Pedestrian

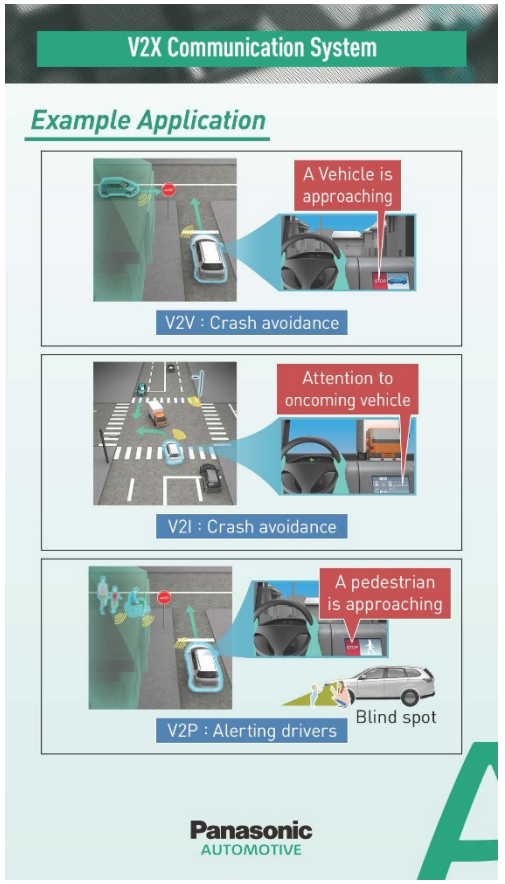
Panasonic | Vehicle Technology

ADAS (ADVANCED DRIVER ASSISTANCE SYSTEMS)

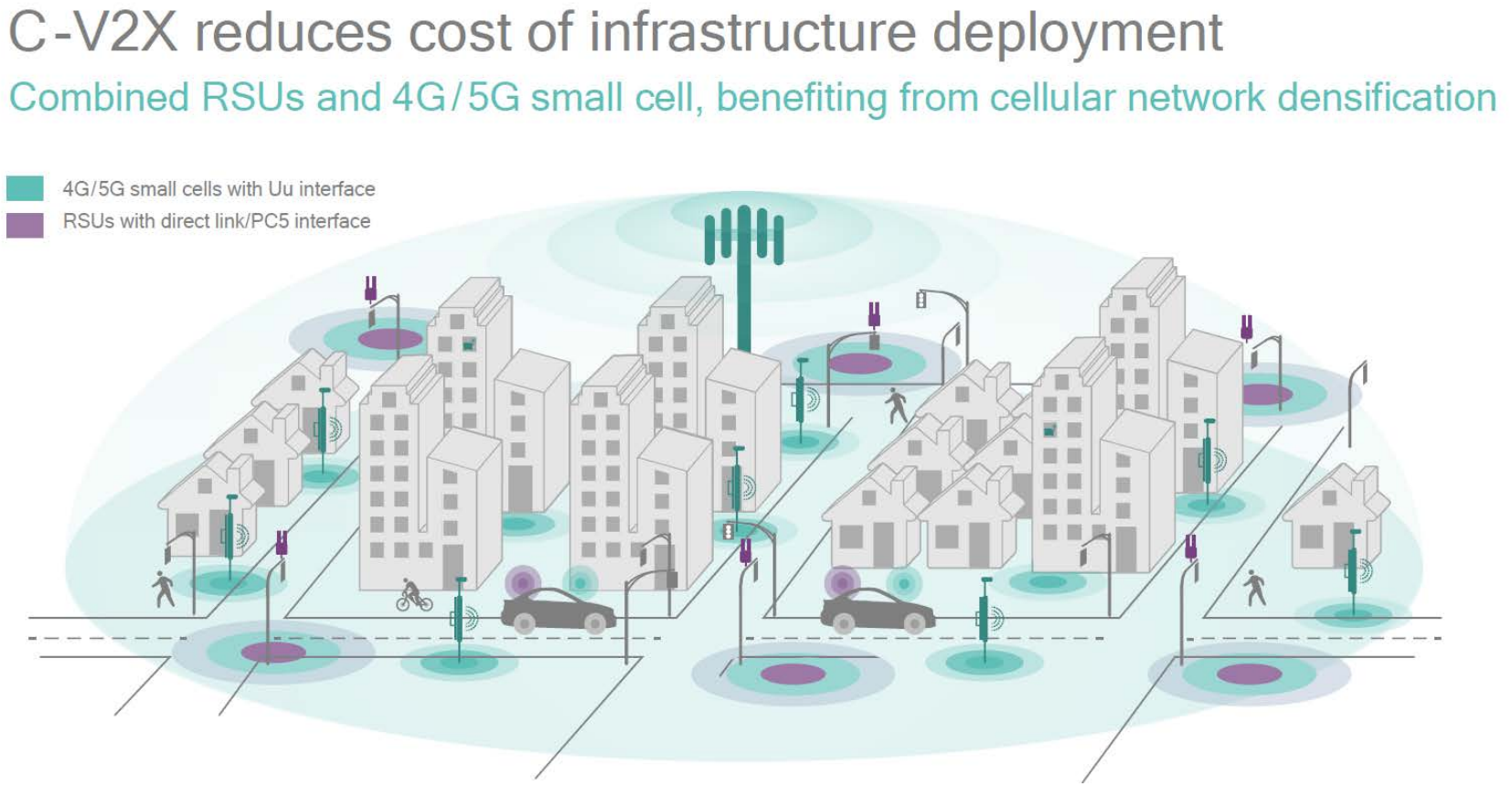


Panasonic | ITS System Integration

CONNECTED VEHICLES V2X COMMUNICATION TECHNOLOGY

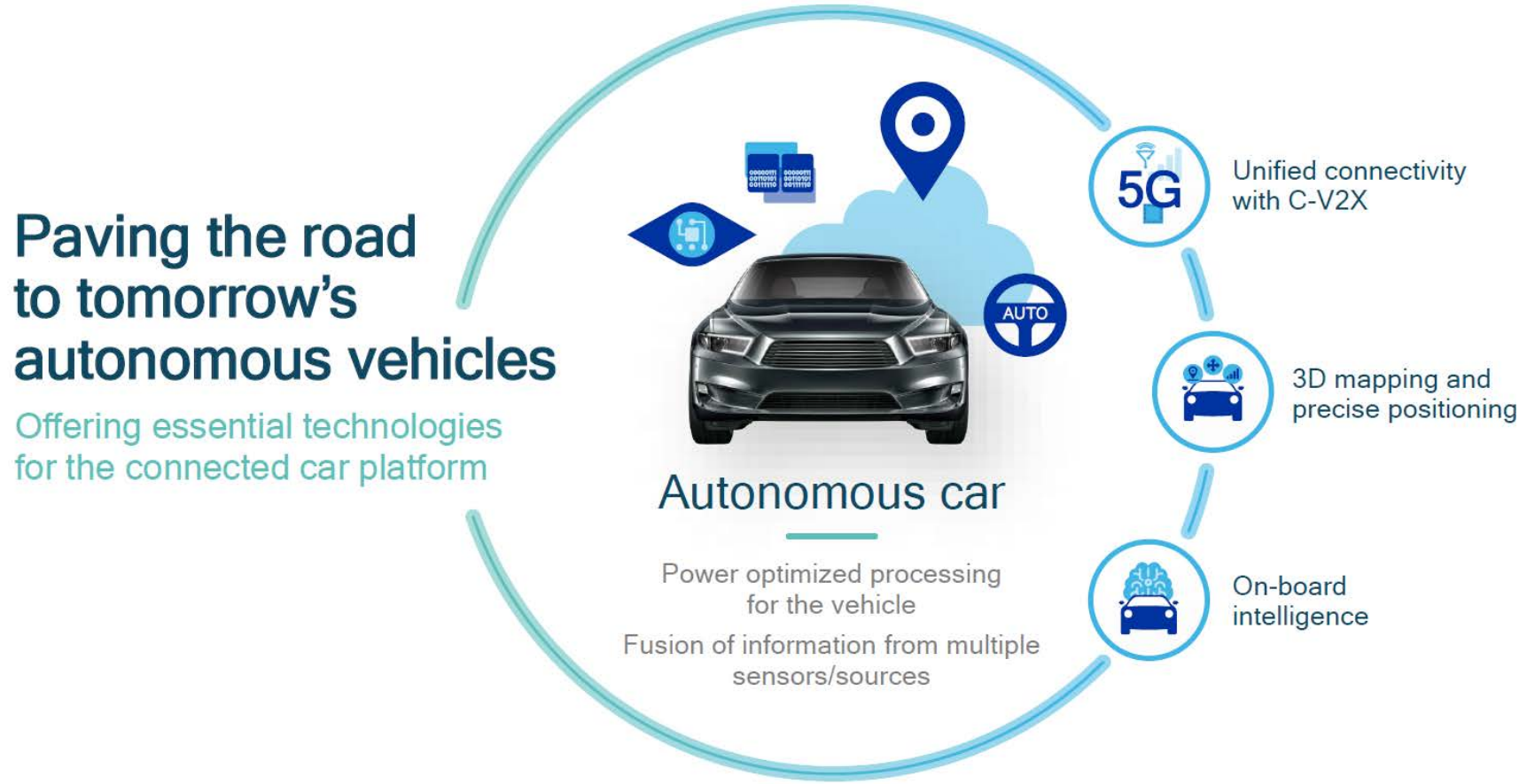


QUALCOMM | CAV Infrastructure



Source: Accelerating C-V2X Commercialization, QUALCOMM, 2017. www.qualcomm.com .

QUALCOMM | Connected Car Platform



Source: Accelerating C-V2X Commercialization, QUALCOMM, 2017. www.qualcomm.com .

QUALCOMM | C-V2X For ADAS

On-board intelligence: C-V2X complements other sensors

Providing higher level of predictability and autonomy

Radar
Bad weather conditions
Long range
Low light situations

Camera
Interprets objects/signs
Practical cost and FOV

Lidar
Depth perception
Medium range

Ultrasonic
Low cost
Short range

ADAS
Advanced Driver Assistance Systems

Brain of the car to help automate the driving process by using:

Immense compute resources
Sensor fusion
Machine learning
Path planning

V2X wireless sensor
See-through, 360° non-line of sight sensing, extended range sensing

3D HD maps
HD live map update
Sub-meter level accuracy of landmarks

Precise positioning
GNSS positioning
Dead reckoning
VIO

Source: Accelerating C-V2X Commercialization, QUALCOMM, 2017. www.qualcomm.com .

Conclusions

- Smart Mobility is part of the “Industrial Revolution 4.0”
- The Timeline:
  - 2019 – 8 Billion devices are already “connected” -

    There are now more devices than there are people
  - 2020 – 20 Billion connected devices
  - 2050 – “Trillions” of connected devices predicted

Conclusions

- The infrastructure in the electronics realm is already "Part of the Economy" so it is not hard to envision that:

  The "Physical Infrastructure" and the "Electronic Infrastructure" will soon become unified into "Smart Countries" versus "Developing Countries".

- Response on all fronts (Government, Academic, Ethics and Business, etc.) is already part of the equation.
- Our profession ignores this new "Organization of Society" at great peril.

Thank You

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