

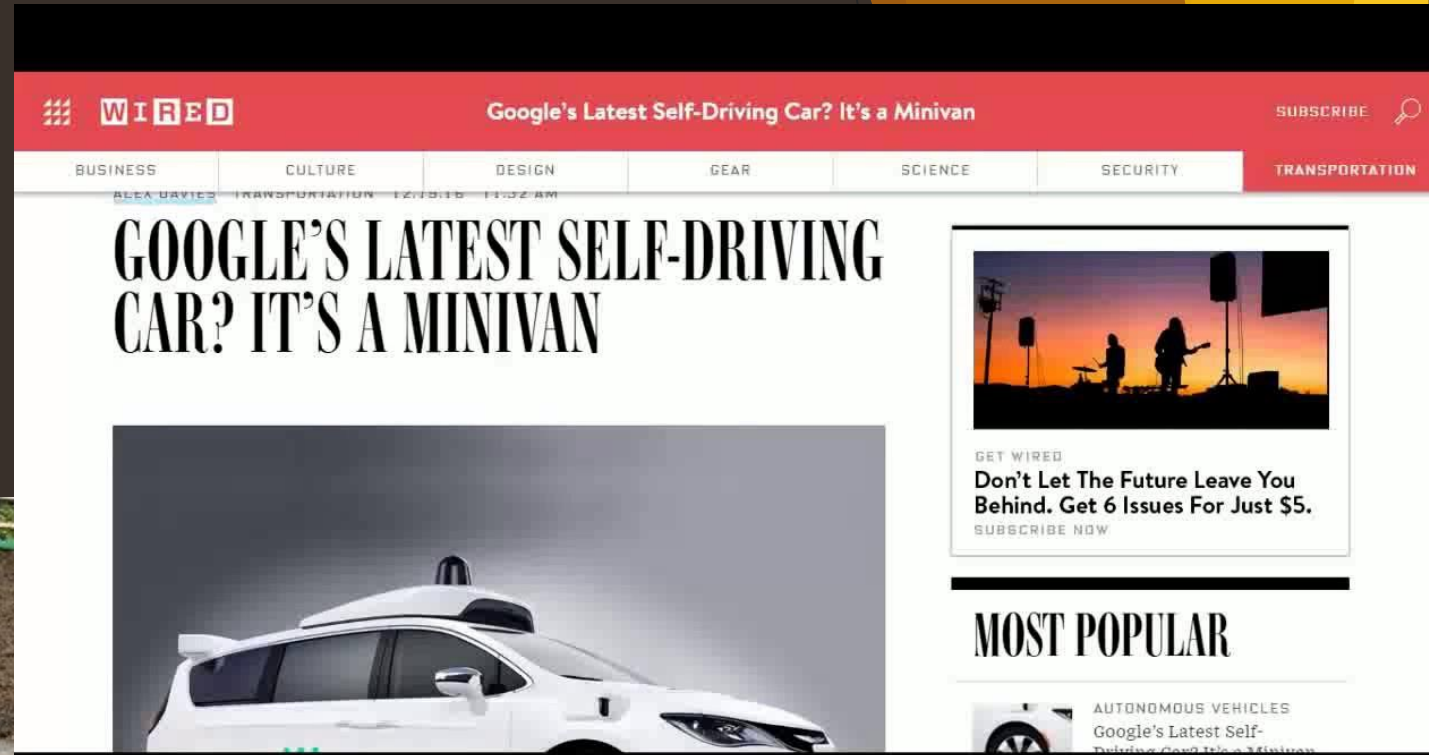
Connected & Autonomous Vehicles - What should be done *Now*

ASHE Mid-Atlantic Spring Technical Conference

David Metcalf, Ryan McCreedy, Diederick VanDillen

April 9, 2018

CAV is coming!



Google's autonomous vehicle unit to test semis in Atlanta

Driverless vehicles will continue to dominate auto headlines

But when?

Challenges:

- ▶ Urban environment
- ▶ Policy
- ▶ Culture
- ▶ Insurance
- ▶ Externalities

Uber Suspends Driverless-Car Program After Pedestrian Is Killed

March 18, 2018

Accident in Tempe, Ariz., is believed to be the first such fatality from an autonomous vehicle

GM sued by motorcyclist in first lawsuit to involve autonomous vehicle

Uber

Video released of Uber self-driving crash that killed woman in Arizona

And How?

- ▶ Connect or Not to Connect?
- ▶ Connected Vehicles - DSRC or 5 G?
- ▶ What are interim steps?
- ❖ What should States and Local Jurisdiction do Now?



Agenda

- ▶ Background: CAV 101 *DAVE*
- ▶ Connecting the Vehicle to the Infrastructure *RYAN*
- ▶ Autonomous Vehicles & Adoption *DIEDERICK*
- ▶ What can Local Jurisdiction do. *DAVE.*



Connected Vehicles

Automated Vehicles

Autonomous Vehicles

Connected and Autonomous Vehicles 101

Connected Vehicles



Regulatory & Government Efforts to Date







- ▶ FCC DSRC Frequency Allocation (1999)
- ▶ V2V & V2I Standards Development (2000-present)
- ▶ CV Test Beds (2007-present)
- ▶ CAV Deployment Guidelines (2014-present)
- ▶ NHTSA V2V Notice of Proposed Rulemaking (2014-2015)
- ▶ CV Reference Implementation Architecture (2013-present)
- ▶ CV Pilots (NYC, Tampa, Wyoming) (2015-present)
- ▶ CV Pooled Fund Study (VDOT lead) (2017-present)
- ▶ Additional Standards Development (NTCIP 1218 RSU) (2018-present)

Connected Vehicles

<https://youtu.be/W1ljnAYZBGs>

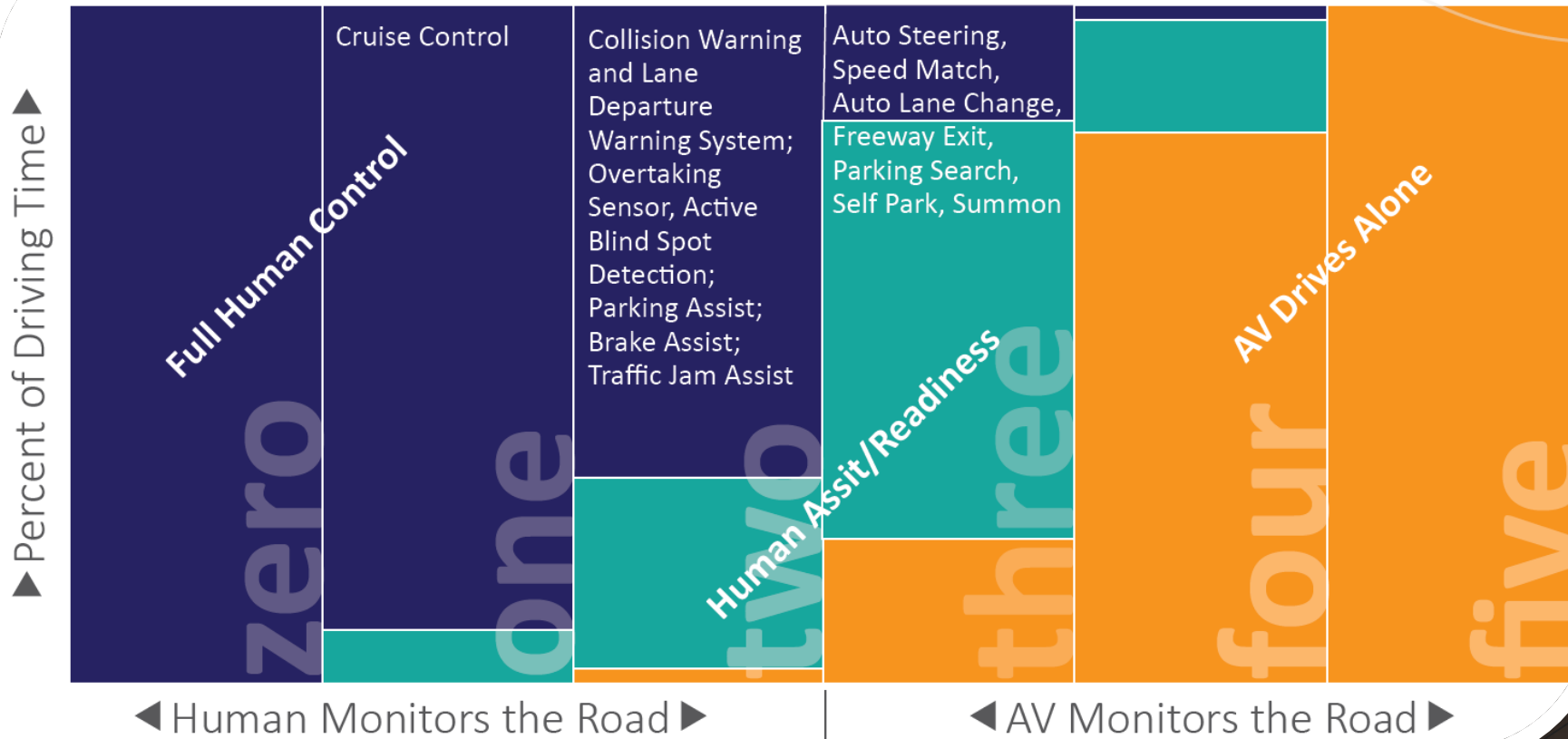
- ▶ Communicate with vehicles out of sight
- ▶ Share roadway conditions
- ▶ Share incident information
- ▶ Communicate with Transportation Management Centers (TMC)
- ▶ Communicate with Signals - Adaptive Traffic Signal Control
- ▶ Smart Parking
- ▶ Internet of Things IoT.

SAE Levels of Automation (alternative)

					
0	1	2	3	4	5
No Automation	Driver Assistance	Partial Automation	Conditional Automation	High Automation	Full Automation
Zero autonomy; the driver performs all driving tasks.	Vehicle is controlled by the driver, but some driving assist features may be included in the vehicle design.	Vehicle has combined automated functions, like acceleration and steering, but the driver must remain engaged with the driving task and monitor the environment at all times.	Driver is a necessity, but is not required to monitor the environment. The driver must be ready to take control of the vehicle at all times with notice.	The vehicle is capable of performing all driving functions under certain conditions. The driver may have the option to control the vehicle.	The vehicle is capable of performing all driving functions under all conditions. The driver may have the option to control the vehicle.

Levels of Vehicle Autonomy (alternative)

Levels of Automated Vehicles (Adopted from SAE)



Connected Automated Vehicles (CAV)

Autonomous Vehicle

Operates in isolation from other vehicles using internal sensors



Connected Automated Vehicle

Leverages autonomous and connected vehicle capabilities



Connected Vehicle

Communicates with nearby vehicles and infrastructure

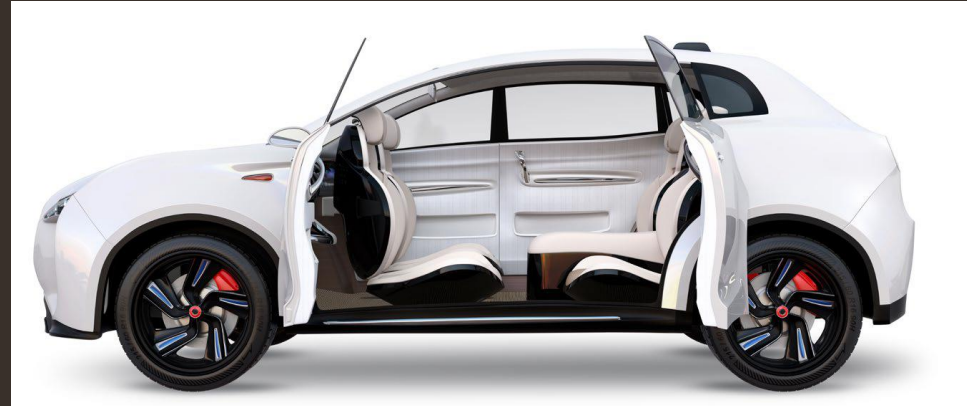


Autonomous Vehicles

Vehicles that incorporate connectivity and/or automation to allow vehicles to operate anywhere with no human assistance whatsoever -
“Level 5”

Alternative Approaches:

- Operate autonomously - do not have two-way communication with any other vehicle or road side equipment.
- Operate cooperatively and “talk” only with other similarly equipped vehicles.
- Operate with a combination of the two approaches, plus communications with road side equipment.



Connected Technologies & Infrastructure

ITS Infrastructure

VS

Connected/Automated Vehicles

A blue Chevrolet van is shown with a large, complex sensor array mounted on its roof. The array includes a camera, radar, and other sensors. The van is parked outdoors, and the background shows trees and a building. The text "History of On-Board Technology" is overlaid on the right side of the image in yellow.

History of On-Board Technology

1989 - ALVINN
Carnegie Mellon

1989 - ALVINN Carnegie Mellon

- ▶ Autonomous Land Vehicle In A Neural Network
- ▶ 1/10th CPU Power of Apple Watch
- ▶ Machine Learning from Driver Input
- ▶ 1 Picture/ 2 Seconds
- ▶ 5,000 Watt Processor (Size of a Refrigerator)
- ▶ Laser use by 1997 for low-speed





History of On-Board Technology

2018 - Volvo XC-90
Uber

2018 - Volvo XC 90 Uber

- ▶ Machine Learning from Driver Input
- ▶ Iterative Coding Updates Based on Data Collection
- ▶ LIDAR, GPS, IMUs, Radar, & Cameras
- ▶ Working with Carnegie Mellon



Connecting Vehicles to Infrastructure

“Sensing” Surroundings

VS

“Communicating”

DSRC, 4G LTE, 5G, “Mesh”

Current Use

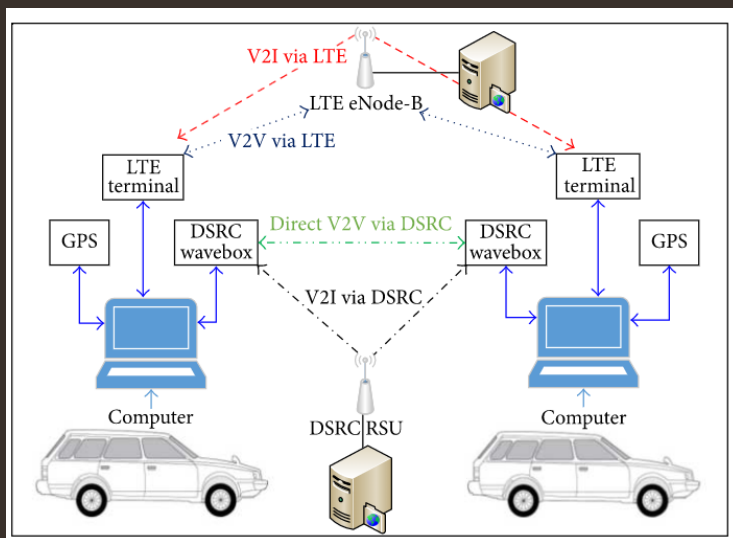
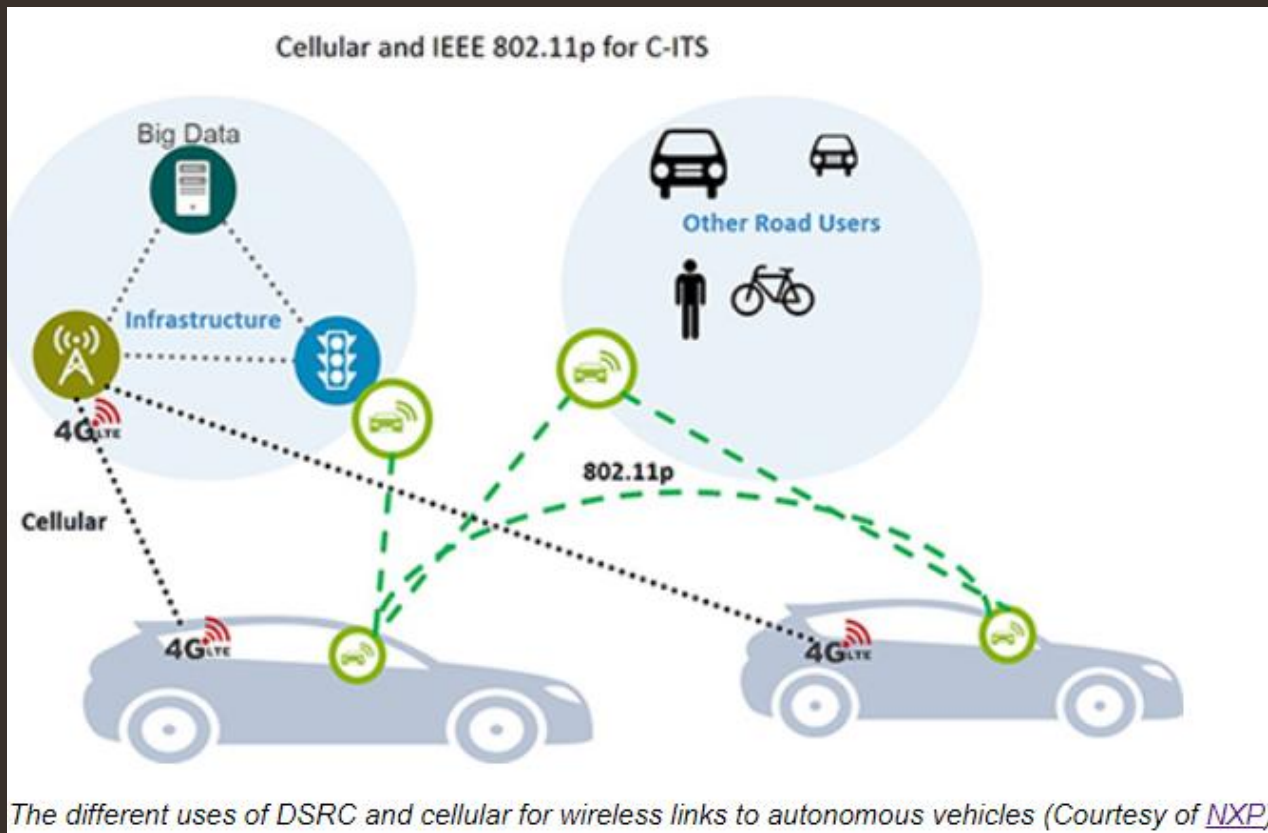
DSRC

- ▶ Dedicated Short-Range Communication - IEEE 802.11p (WLAN Mod)
- ▶ Extremely quick/Real time
- ▶ Collision Avoidance, Electronic Traffic Signs, Safety/Roadside Interaction
- ▶ Limited Bandwidth / Distance

4G LTE

- ▶ Cellular Data
- ▶ Large Bandwidth
- ▶ Traffic Conditions, Travel Times, Signal Phasing Info
- ▶ High-Latency (Can't Be Used for Instant Safety Actions)





Working Together DSRC & 4G LTE

Future Use (IoT)

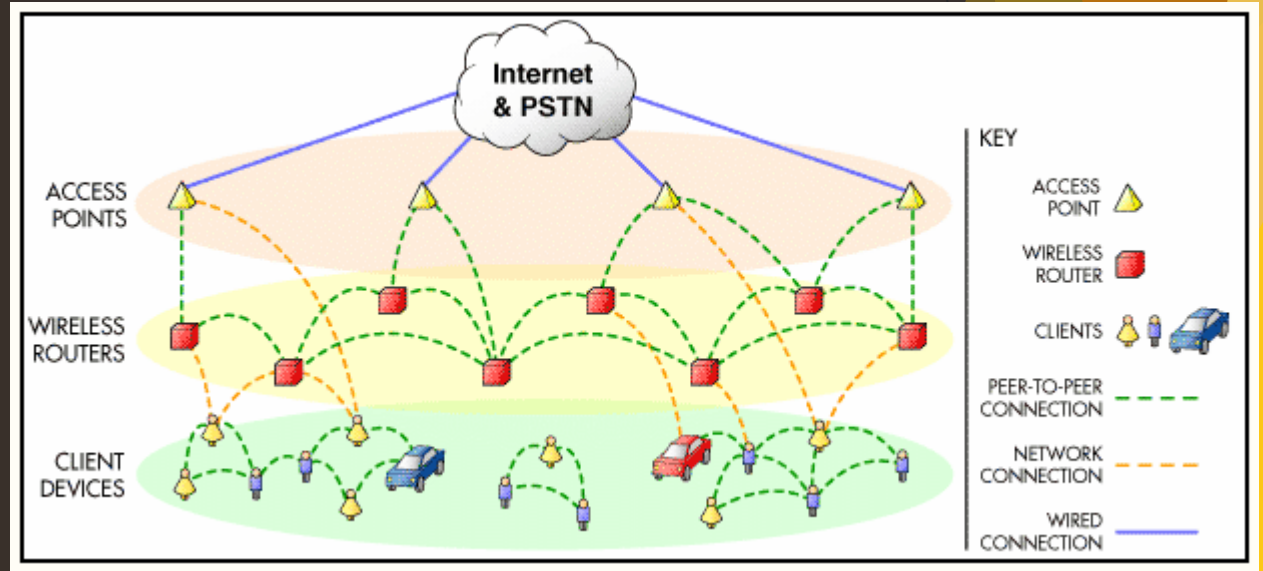
5G

Mesh

- ▶ WiFi/Ethernet in the sky
- ▶ 1ms latency
- ▶ Smart Cities will be built on this
- ▶ Most likely challenge V2V DSRC

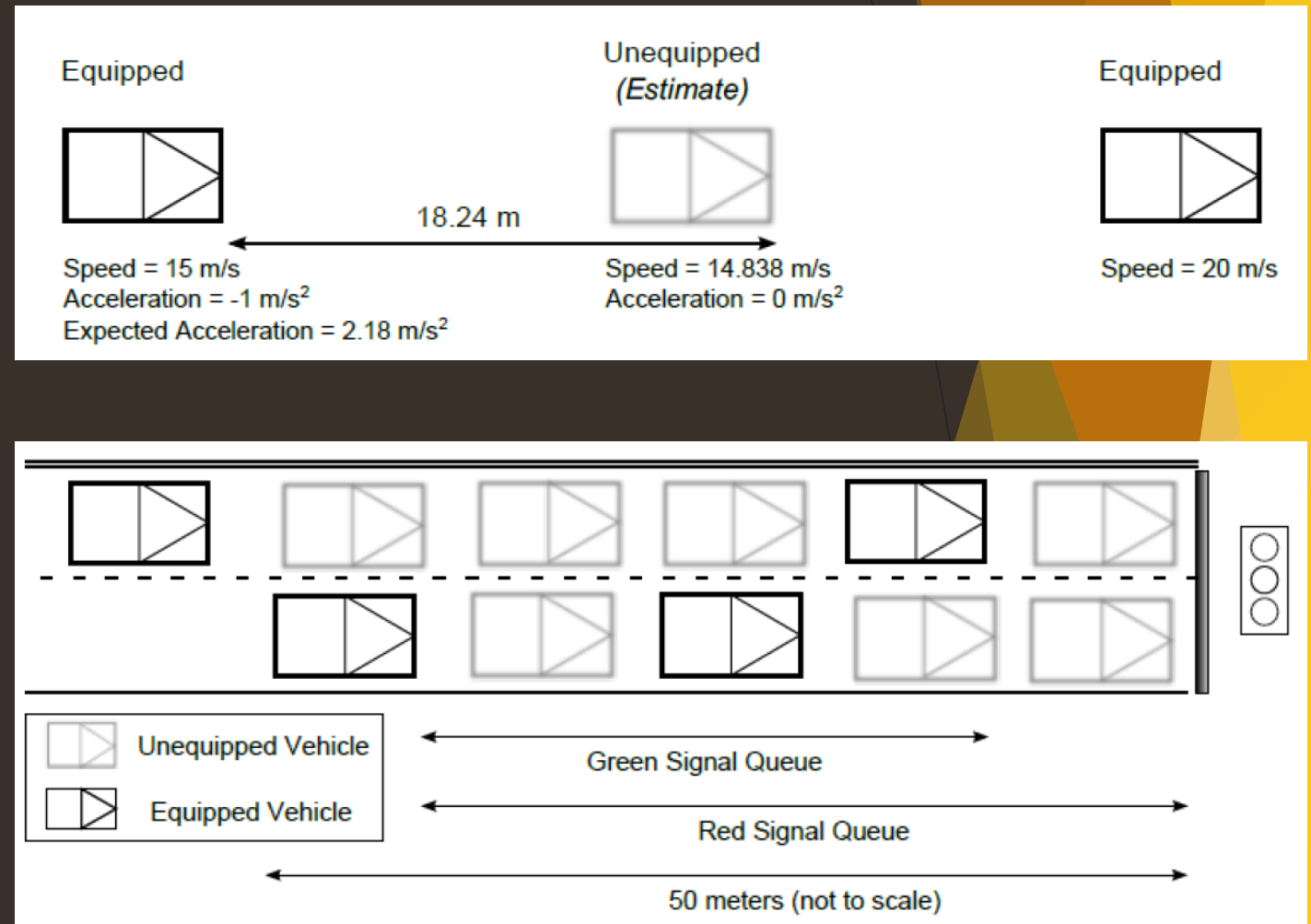
- ▶ Networking method
- ▶ Clients interact with each other and broadcast simultaneously
- ▶ Applications on micro and macro scale

1G	2G	3G	4G	5G
1981	1992	2001	2010	2020(?)
2 Kbps	64 Kbps	2 Mbps	100 Mbps	10 Gbps
Basic voice service using analog protocols	Designed primarily for voice using the digital standards (GSM/CDMA)	First mobile broadband utilizing IP protocols (WCDMA / CDMA2000)	True mobile broadband on a unified standard (LTE)	'Tactile Internet' with service-aware devices and fiber-like speeds
				?



What about dumb cars?

- ▶ Dr. Noah J. Goodall, P.E.
- ▶ VCTIR
- ▶ “Real-Time Prediction of Vehicles in a Connected Vehicle Environment”
- ▶ 8% Delay Reduction in Ramp Metering
- ▶ 4.4% Reduction in Signal Delay
- ▶ 20-30% Market Penetration Needed



America's Next Big Network



- ▶ Mario Cardullo
- ▶ Inventor of RFID Chip

Autonomous Vehicles & Adoption

Our Future But when does it become reality

Early Commercial Applications

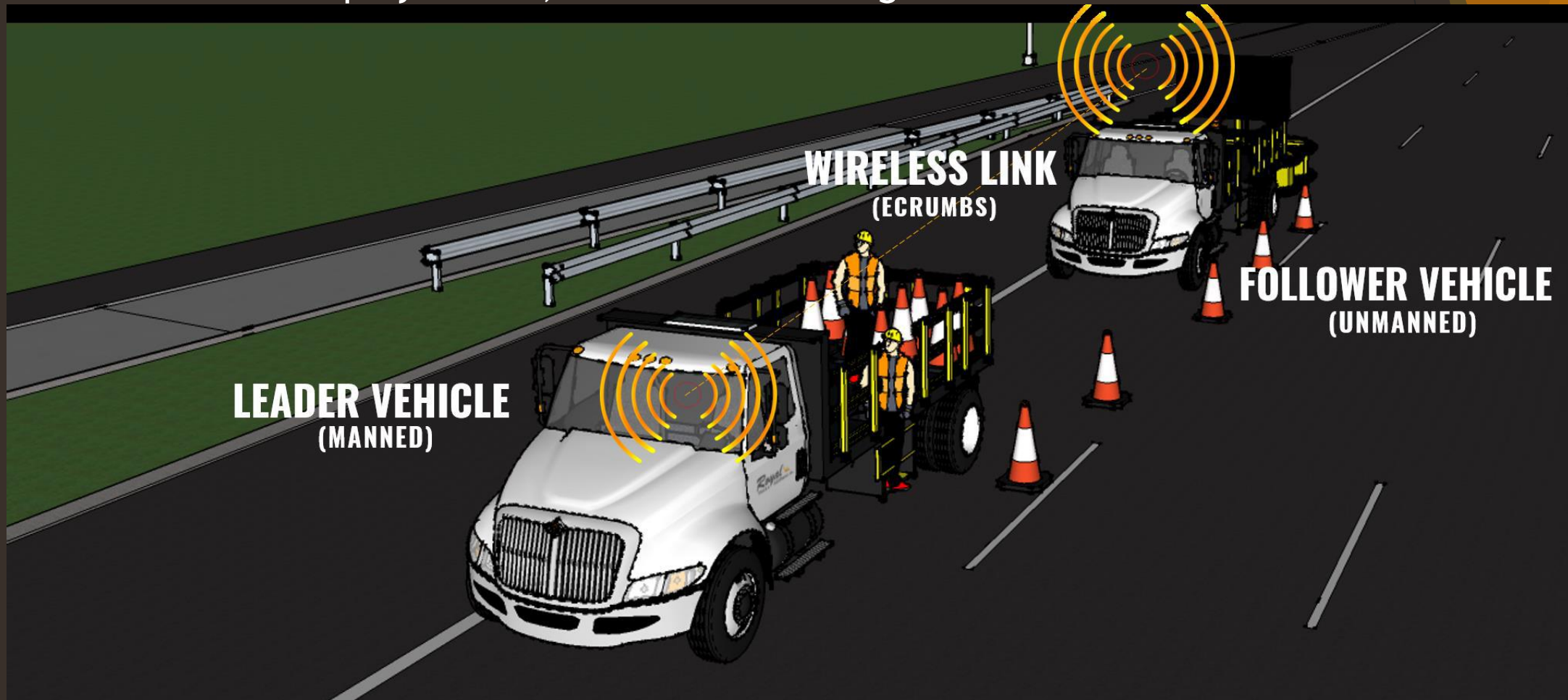
Cellular V2I

- ▶ Traffic Technology Services (TTS)
 - ▶ Personal Signal Assistant - SPaT / MAP from TMC to vehicle (Audi) - Washington DC
 - ▶ Personal Freeway Assistant - ATM, DMS, VSL from TMC to vehicle (Europe)
- ▶ Connected Signals
 - ▶ Enlighten - RT signal information on Smartphone
 - ▶ Study: Phoenix, Portland, Las Vegas and San Jose
 - ▶ Eco-driving (8-12% improvement), safety



Autonomous TMA Truck

- ▶ Kratos (Defense Contractor) & Royal Truck and Equipment manufacturer
- ▶ CDOT field deployed - CA, Missouri evaluating



Automated Shuttles - Micro-transit

- ▶ Circulator, Hop on/off
- ▶ First Mile / Last Mile Connectors



Las Vegas - Navya Arma 8-person Shuttle



Las Vegas - Navya Autonom AV Taxi

Ride Hailing & Mobility on Demand

- ▶ On-line subscription service
- ▶ First Mile / Last Mile Connectors



Waymo Chrysler Pacifica - Phoenix, AZ



Uber Volvo - Pittsburg, PA

Observations & Predictions from Industry

- ▶ Ride share will be the conduit for increased use of the technology
 - ▶ Cars spend 96% of their time NOT in use
- ▶ Uber CEO - AV's will start picking up passengers in 2019
 - ▶ Recent deal with Volvo to buy up to 24,000 AV's
- ▶ Half of Lyft will be AV by 2021
 - ▶ First self-driving car pilot started in Boston (12/2017)
 - ▶ Still has a "safety driver"
- ▶ Car manufacturers are investing \$\$\$
 - ▶ Despite lack of federal framework



Observations & Predictions from Industry

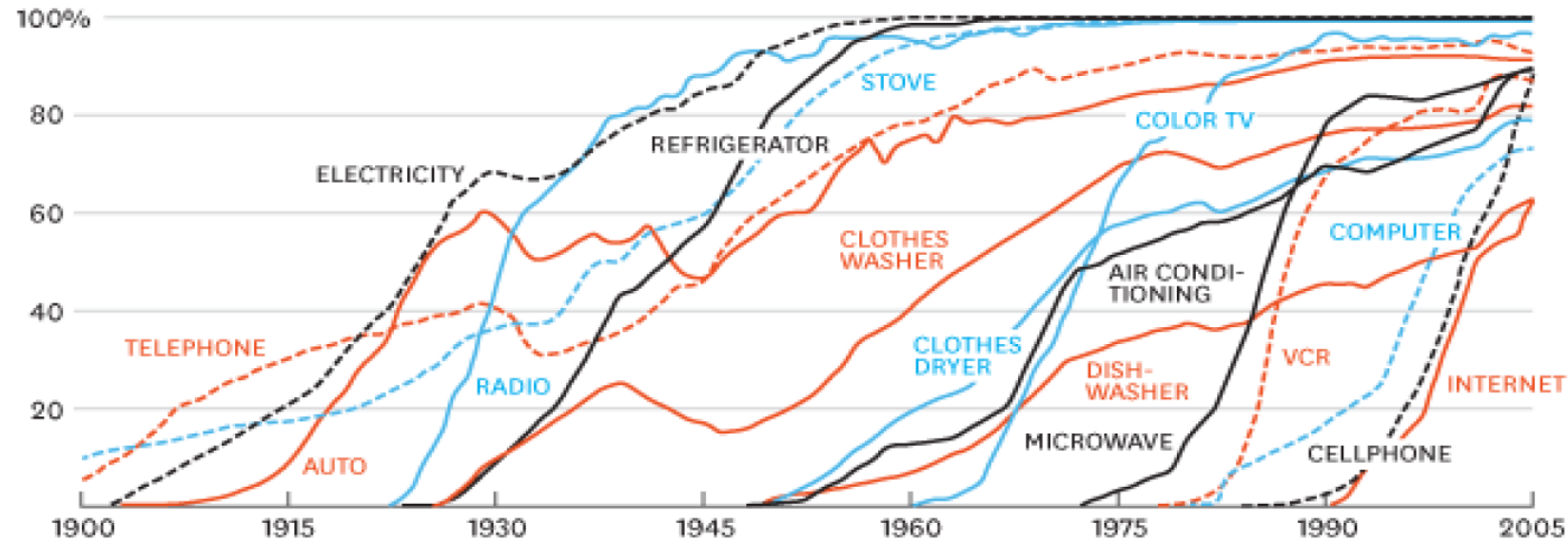
- ▶ “By 2030, within 10 years of regulatory approval of autonomous vehicles, 95% of U.S. passenger miles traveled will be served by on-demand autonomous electric vehicles owned by fleets, not individuals, in a new business model we call “transport-as-a-service”.”
 - ▶ RethinkX, “Rethinking Transportation 2020-2030”, May 2017
- ▶ “By 2020, it is expected that 10 million self-driving cars will be on the road while there will be more than 250 million smart cars —cars connected to high-tech networks—sharing the road with them.”
 - ▶ Forbes, November 2017

How Quickly with CV/AV be adopted

History tells us that consumer adoption of new technology is speeding up over time...

CONSUMPTION SPREADS FASTER TODAY

PERCENT OF U.S. HOUSEHOLDS

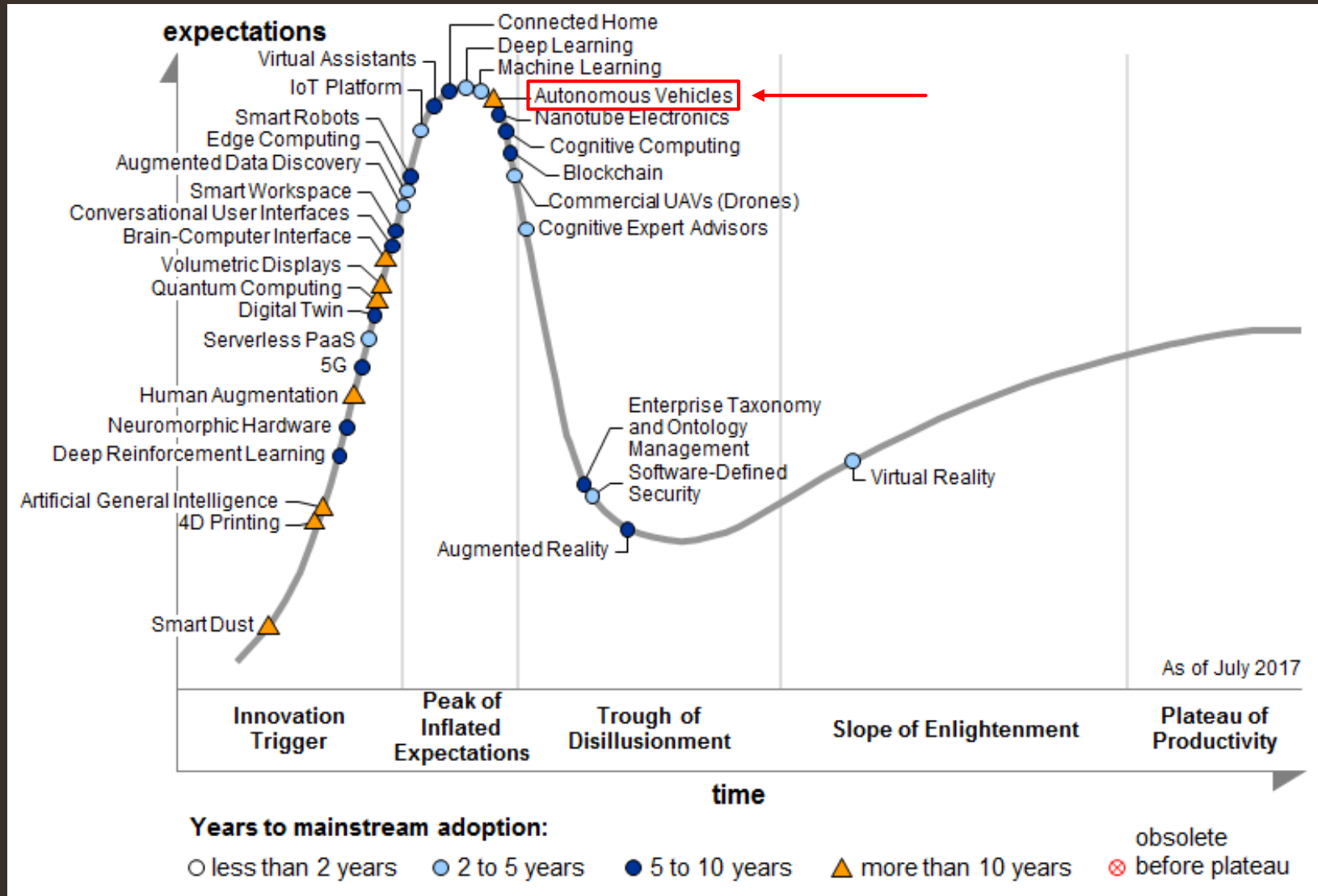


SOURCE MICHAEL FELTON, THE NEW YORK TIMES

HBR.ORG

But Fleet Turnover Period is Increasing;
Average Age of Vehicle Fleet is Increasing - 11.6yrs

Gartner Hype Cycle



Many Issues Still to be Addressed

- ▶ Communications
 - ▶ Ongoing V2I and V2V communications standards development
 - ▶ Uncertainty with spectrum allocation for DSRC
- ▶ Cyber-Security and Data Encryption
 - ▶ Potential for hacking
- ▶ Privacy
 - ▶ Government snooping on travel routes and times
- ▶ Planning Data Needs and Collection Techniques for CV/AV Applications
 - ▶ Big data management - Data analytics, traffic/transit trends, mobility needs
 - ▶ Data governance - Who owns the data?
 - ▶ Open Source Application Development Portal - CV application deployment guidance

Many Issues Still to be Addressed

- ▶ Safety Standards
 - ▶ Crashworthiness
 - ▶ Minimum Safety Data Needed for Automated Vehicle Operations and Crash Analysis
- ▶ Interoperability between auto manufacturers
- ▶ Liability and Insurance Clarifications
- ▶ Decreased need for driving jobs
- ▶ Market Penetration and Transitioning
 - ▶ Driver education
 - ▶ CAV and driven vehicles on the same roadway

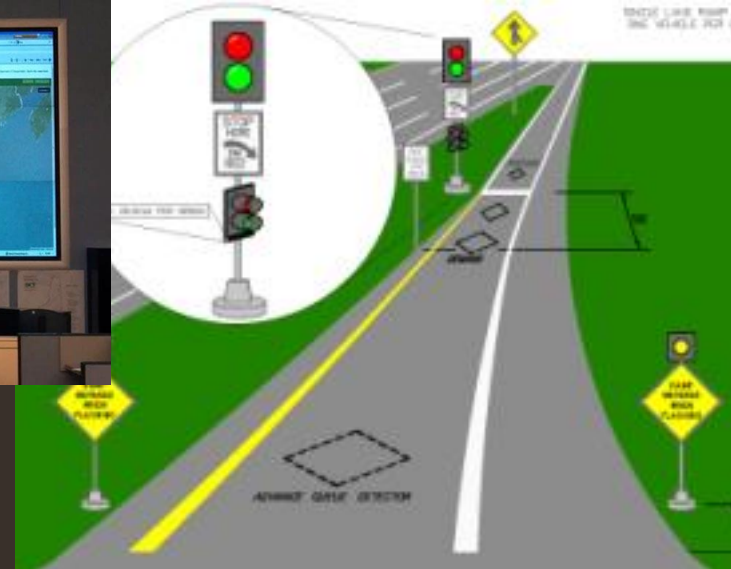
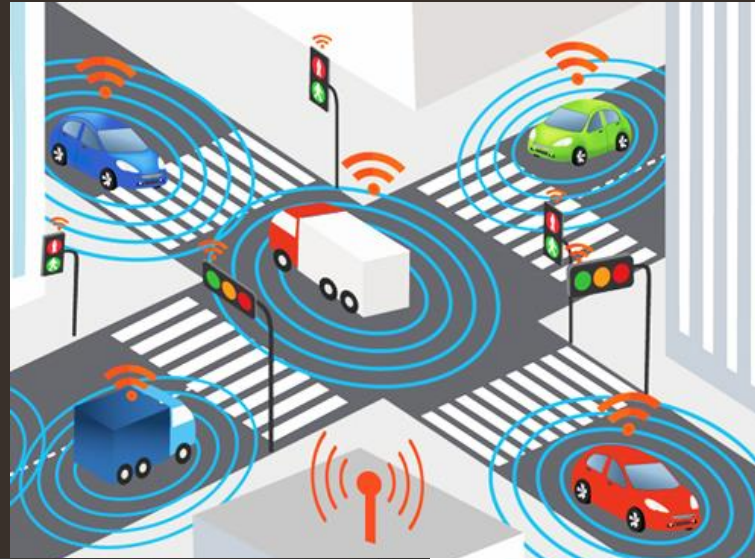
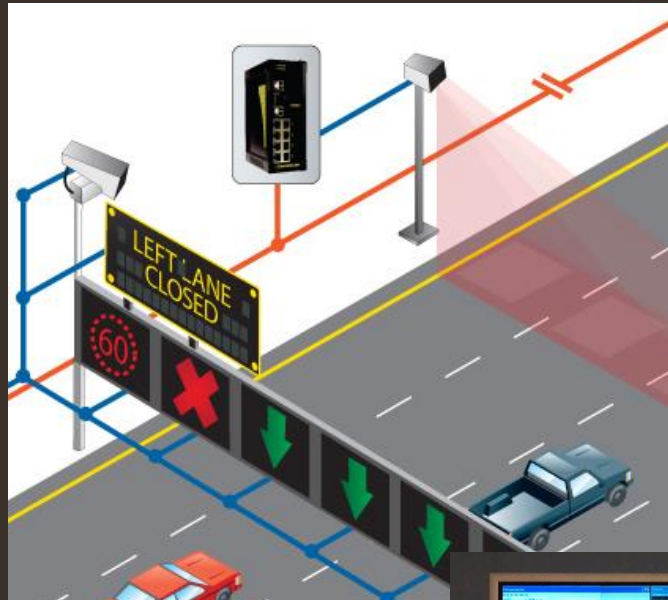
Many Issues Still to be Addressed

- ▶ CV Infrastructure Deployment Models to support AV Operations
 - ▶ DSRC/ MAP infrastructure & data management
 - ▶ Public agency staff readiness and training
- ▶ Impact of Mobility-on-Demand Services and Highly Automated Vehicles on the Transportation System
- ▶ Understanding the Impacts of the Physical Highway Infrastructure Caused by the Increased Prevalence of Advanced Vehicle Technologies

What Should be Done *Now*

- ▶ Our Future But when does it become reality

Not Going Away Anytime Soon!



What should be done *Now*

- ▶ NCRP 845
- ▶ Leveraging the Promise of Connected and Autonomous Vehicles
- ▶ Case Study - City of Alexandria ITS Master PLaN



NCHRP 845

Strategies by Desired Societal Outcome

Outcome: To mitigate safety risks through testing, training, and public education

1. Enact legislation to legalize AV testing.
2. Enact legislation to stimulate AV or CV testing.
3. Modify driver training standards and curricula.
4. Increase public awareness of benefits and risks.

Outcome: To encourage SAV use

5. Subsidize SAV use.
6. Implement transit benefits for SAVs.
7. Implement a parking cash-out strategy.
8. Implement location-efficient mortgages.
9. Implement land use policies and parking requirements.
10. Apply road use pricing.

Outcome: To address liability issues that may impact market development

11. Implement a no-fault insurance approach.
12. Require motorists to carry more insurance.

Outcome: To enhance safety, congestion, and air quality benefits by influencing market demand

13. Subsidize CVs.
14. Invest in CV infrastructure.
15. Grant AVs and CVs priority access to dedicated lanes.
16. Grant signal priority to CVs.
17. Grant parking access to AVs and CVs.
18. Implement new contractual mechanisms with private-sector providers.



NCHRP 845

SAV - Shared
Autonomous
Vehicle

Outcome: To encourage SAV use

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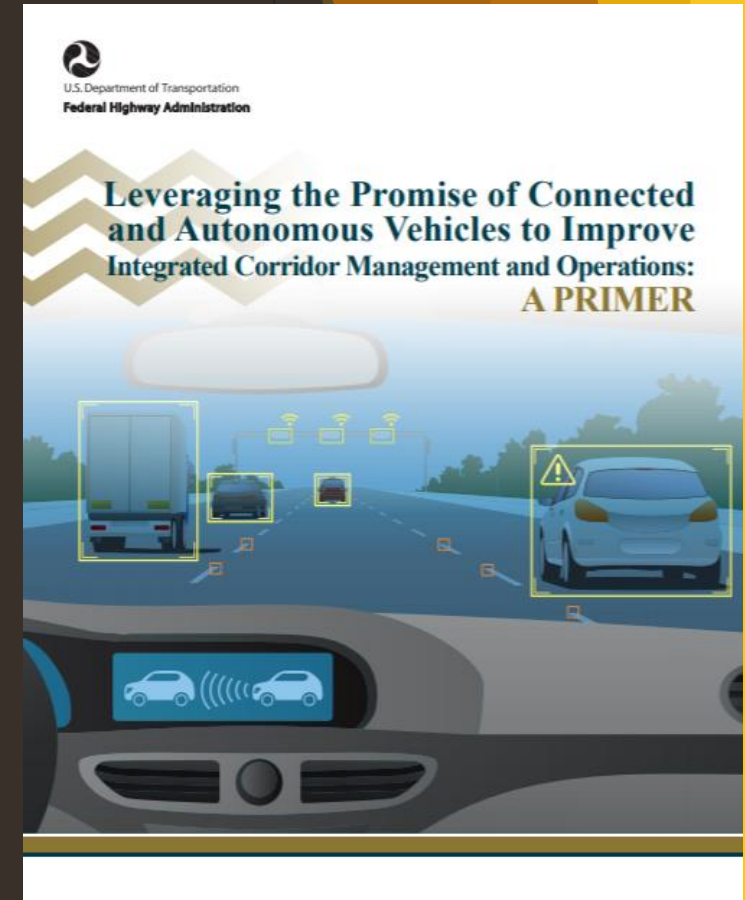
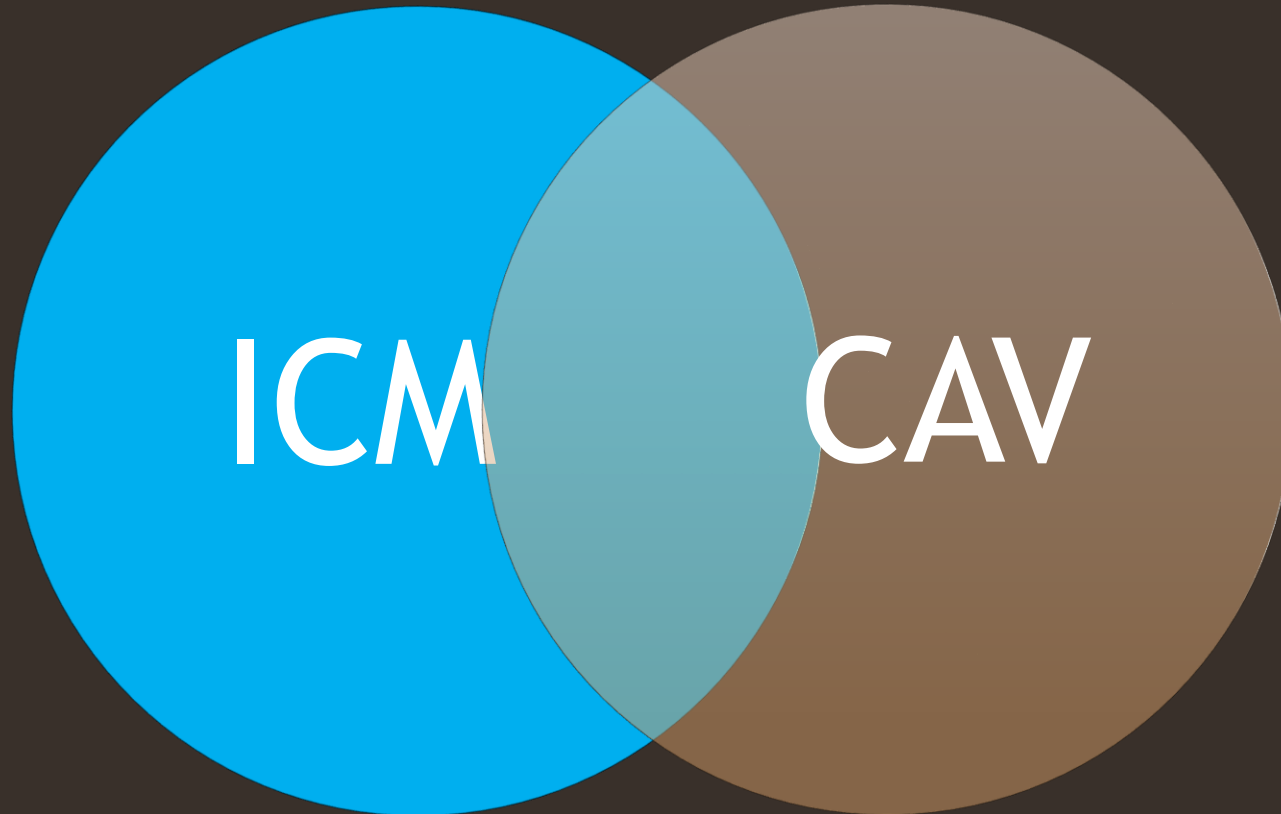
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NCHRP
RESEARCH REPORT 845

NATIONAL
COOPERATIVE
HIGHWAY
RESEARCH
PROGRAM

Advancing Automated
and Connected Vehicles:
Policy and Planning Strategies
for State and Local
Transportation Agencies

Leveraging the Promise of Connected and Autonomous Vehicles to Improve Integrated Corridor Management and Operations

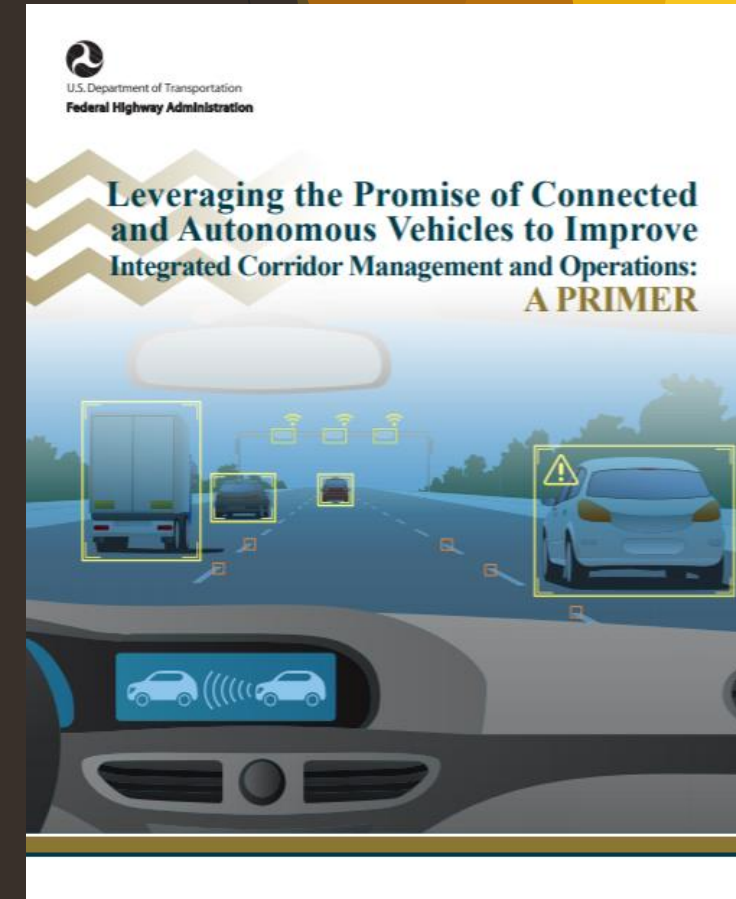


Leveraging the Promise of Connected and Autonomous Vehicles to Improve Integrated Corridor Management and Operations

▶ Integrated Corridor Management:

“A set of policies and procedures for coordinating transportation operations in order to improve travel management”

- ▶ Adaptive Traffic Signal Control (ATSC)
- ▶ Ramp metering
- ▶ Travel information,
- ▶ Transit signal priority
- ▶ Adaptive pricing
- ▶ Inter-agency information sharing



Summary: Leveraging ICM and CAV

- ▶ ICM Project Teams and CAV Stakeholders need to engage. “It is appropriate for ICM stakeholders to get ready for CAV now”.
- ▶ ICM stakeholders should plan infrastructure to support CAV.
- ▶ ICM stakeholders should plan for large amounts of data from CV.
- ▶ ICM needs to “follow, observe and even participate....”

- ▶ CAV systems will receive detailed information about state of the corridor
- ▶ CAV systems will have access in operational guidance.

Summary: Leveraging ICM and CAV Benefits to each

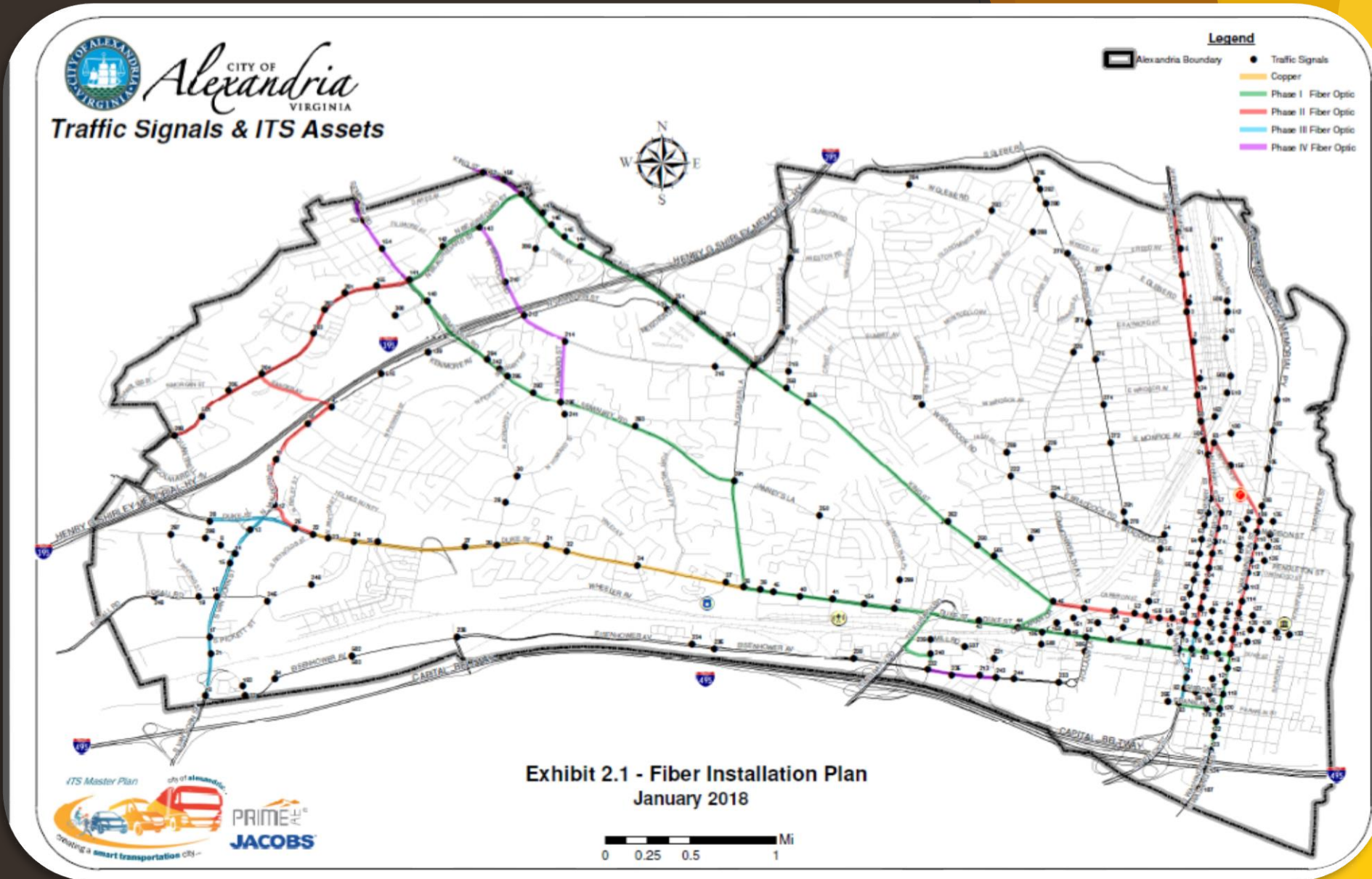
ICM Benefits

- ▶ Detailed real time data
- ▶ Improved traveler information
- ▶ Eliminate need for new traveler information infrastructure.

CAV Benefits

- ▶ Detailed information about state of the corridor
- ▶ Operational guidance.

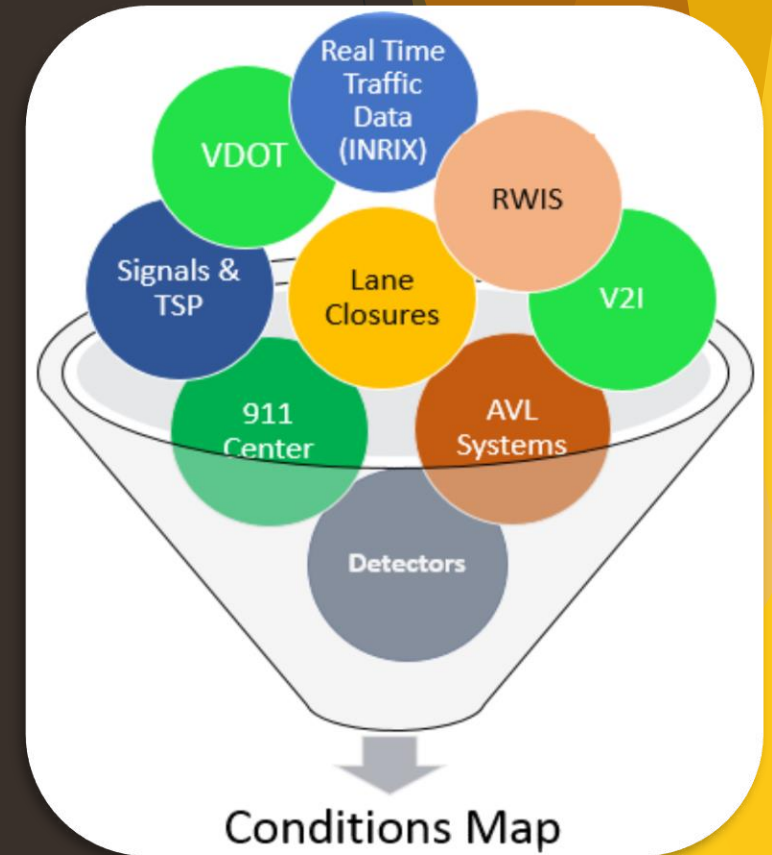
Case Study: City of Alexandria



City of Alexandria: Case Study

Near Term

- ▶ Fiber Optic Communications
- ▶ Upgrades to signal system hardware and software
- ▶ Transit Signal Priority
- ▶ Adaptive Traffic Signal Control
- ▶ Roadway Weather Information Systems
- ▶ Automated Vehicle Location (AVL) Systems
- ▶ CCTV
- ▶ Central Transportation Operation Center (TOC) Upgrades



City of Alexandria: Case Study

Future Deployments Phase VI

- ▶ CV DSRC at key locations,
- ▶ Expanded Bike and Ped detection,
- ▶ Implement Complete Streets Plan
- ▶ Further ATMS capabilities with CV application integration,
- ▶ CAV Pilot on one or two locations.

City of Alexandria: Case Study

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Thank You!

David Metcalf



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