BUILDING INFRASTRUCTURE FOR THE FUTURE

Federal Highway Administration

Why Do We Care?

Where we've BEEN…

1950-2000

Safety/Convenience Features

~Cruise Control

~Seat Belts

~Antilock Brakes

2000-2010

Advanced Safety Features

~Electronic Stability Control

~Blind Spot Detection

~Forward Collision Warning

~Lane Departure Warning

2010-2016

Advanced Driver Assistance Features

~Rearview Video Systems

~Automatic Emergency Braking

~Pedestrian Automatic Emergency Braking

~Rear Automatic Emergency Braking

~Rear Cross Traffic Alert

~Lane Centering Assist

NHTSA's 5 Eras of Safety

Where we've GOING…

2016-2025

Partially Automated Safety Features

~Lane Keeping Assist

~Adaptive Cruise Control

~Traffic Jam Assist

~Self-Park

2025 +

Fully Automated Safety Features

~Highway Autopilot

NHTSA's 5 Eras of Safety

Where we ARE...

Monitored Driving			Non-Monitored Driving		
Level 0	**Level 1**	**Level 2**	**Level 3**	**Level 4**	**Level 5**
No Automation (driver only)	**Driver Assistance** (driver assisted by automation)	**Partial Automation** (self-driving on occasion)	**Conditional Automation** (self-driving for specific uses)	**High Automation** (self driving under defined conditions)	**Full Automation** (driverless)
Driver has longitudinal AND lateral control	*Driver has longitudinal OR lateral control; System has the other*	*System has longitudinal AND lateral control for specific uses*	*System has longitudinal AND lateral control for specific uses; informs Driver to resume control if necessary*	*System has control in defined use case; assumes good weather conditions*	*System has control in all situations*
	Example: Cruise Control	Example: Cruise Control and Lane Positioning			

NHTSA & Society of Automotive Engineers (SAE) Automation Levels

Where we ARE...

Monitored Driving			Non-Monitored Driving		
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	1			Low Speed Automated Shuttles	

NHTSA & Society of Automotive Engineers (SAE) Automation Levels

"Smart Cities use data and technology to create efficiencies, improve sustainability, create economic development, and enhance quality of life factors of people living and working in the city." Wikipedia

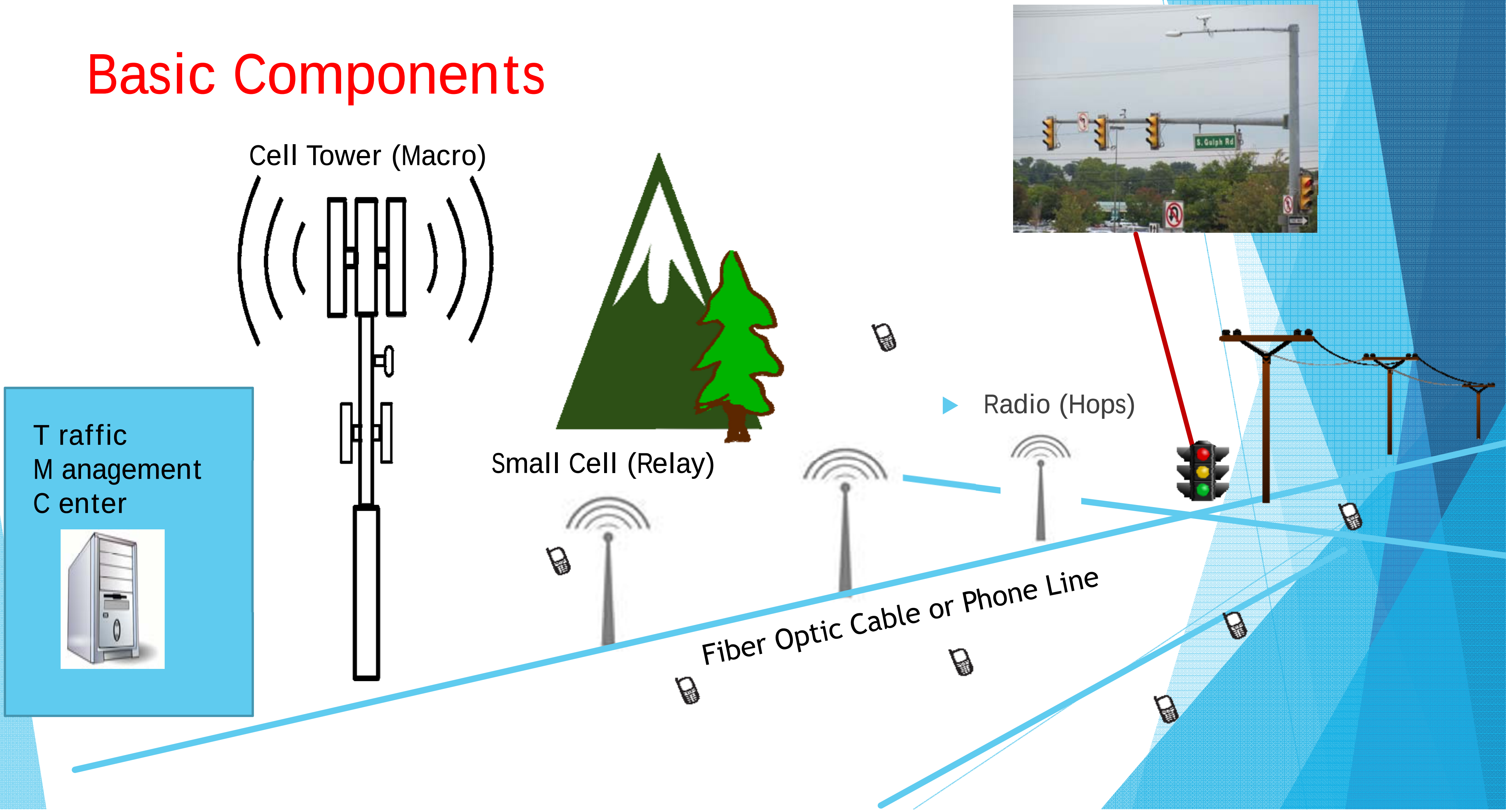
"We need to build the infrastructure, add the technology, collect the data, and then we can provide the services."

Ed Blayney, Louisville Metro

→ One type of service is the Connected/Autonomous Vehicles (CAV)

The BASICS

Basic Components

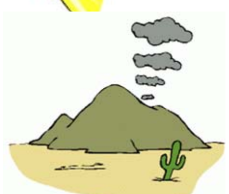


Infrastructure: HOW WE'RE USING THE TECHNOLOGY NOW

- Signal Controllers use "Bandwidth" to send data
- Closed Circuit (CCTV) cameras are used for traffic surveillance.

CCTVs use 3 components to operate effectively

- Resolution (pixels)



- Latency
  - panning camera
  - speed for humans shouldn't be > 250 milliseconds
- Frame Rate (requires Bandwidth)
  - HDTV – 30 frames/second
  - Computer – 60 frames/second

Infrastructure: BANDWIDTH

In 2017

High

AVERAGE Internet connection speed (Bandwidth): 28.6 Mbps

A movie can be downloaded in hi-def in 30 minutes
A song download – 3 ½ seconds

Average GLOBAL internet connectivity speed: 7.2 Mbps

AVERAGE Internet connection speed (Bandwidth): 300 kbps
A movie takes 30 hours to download

Low

Reported by US News & World Report.
Taken from Akamai's State of the Internet report, 2017

1.	South Korea	28.6 Mbps
2.	Norway	23.5 Mbps
3.	Sweden	22.5 Mbps
4.	Hong Kong	21.9 Mbps
5.	Switzerland	21.7 Mbps
6.	Finland	20.5 Mbps
7.	Sinapore	20.3 Mbps
8.	Japan	20.2 Mbps
9.	Denmark	20.1 Mbps
10.	USA	18.7 Mbps

Internet access in the USA:
1. Iowa

36. Kentucky
- Broadband access: 34
- Ultra-Fast Internet Access (> 1 GB): 24

50. Alaska

Reported by US News & World Report.
Best States report, 2017

Infrastructure: PHONE LINES versus FIBER OPTIC

Dial-Up Connections via Phone Lines

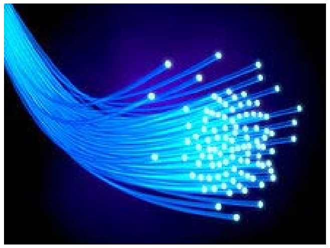
- **Low Bandwidth Capacity**
  - Cameras can NOT be added
- **High Latency** (Low speed connection)
  - Cannot collect much data
  - Signal data takes *5-10 minutes* to download.
  - It takes hours or days to retime signal systems

- **Expensive**
  - 10 years ago in Lexington – phone bill was **$300,000+/yr**

NOTE: Depending upon installation..

Range is associated with Distance from main line. The further away the less data. Works at 11,000 – 15,000'

Infrastructure: PHONE LINES versus FIBER OPTIC



Fiber Optic Cable Network

- **High Bandwidth Capacity**
  - Operate High Definition Cameras
    - Used on busiest corridors to monitor congestion and traffic incidents.
    - Photo every 1/10 second
  - Collects traffic volumes, record phase timings, more….

- **Low Latency** (High Speed Connection)
  - Required for Safety Critical Functions
  - Monitor Signal System in Real Time
  - Signal changes take *5-10 seconds (Real Time)*

- **Low Cost**
  - No overhead, **$30,000/yr for entire network - includes maintenance costs**

Infrastructure: PHONE LINES versus FIBER OPTIC

Fiber Optic Cable Network (continued)

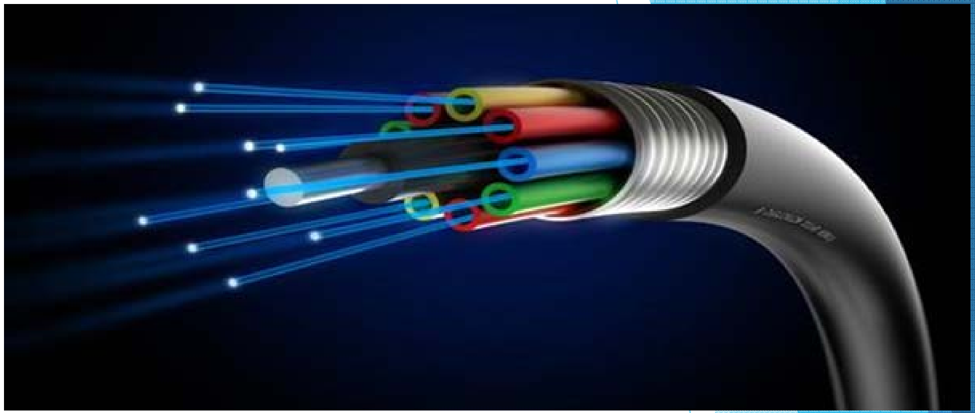
- **Reduces Manpower Needs**
  - In 2007, Lexington had 20 traffic signal technicians
  - In 2018, Lexington has 9 traffic signal technicians

- **Security Credential Management System (SCMS)**
  - Used to authenticate all messages
    - Between vehicles
    - Between vehicles and infrastructure
  - Guarantees safety information is from a trusted source
  - Cybersecurity feature
    - Protects our 4th amendment right to privacy

https://www.its.dot.gov/resources/scms.htm

Infrastructure - FIBER OPTIC

Usually a combination of:



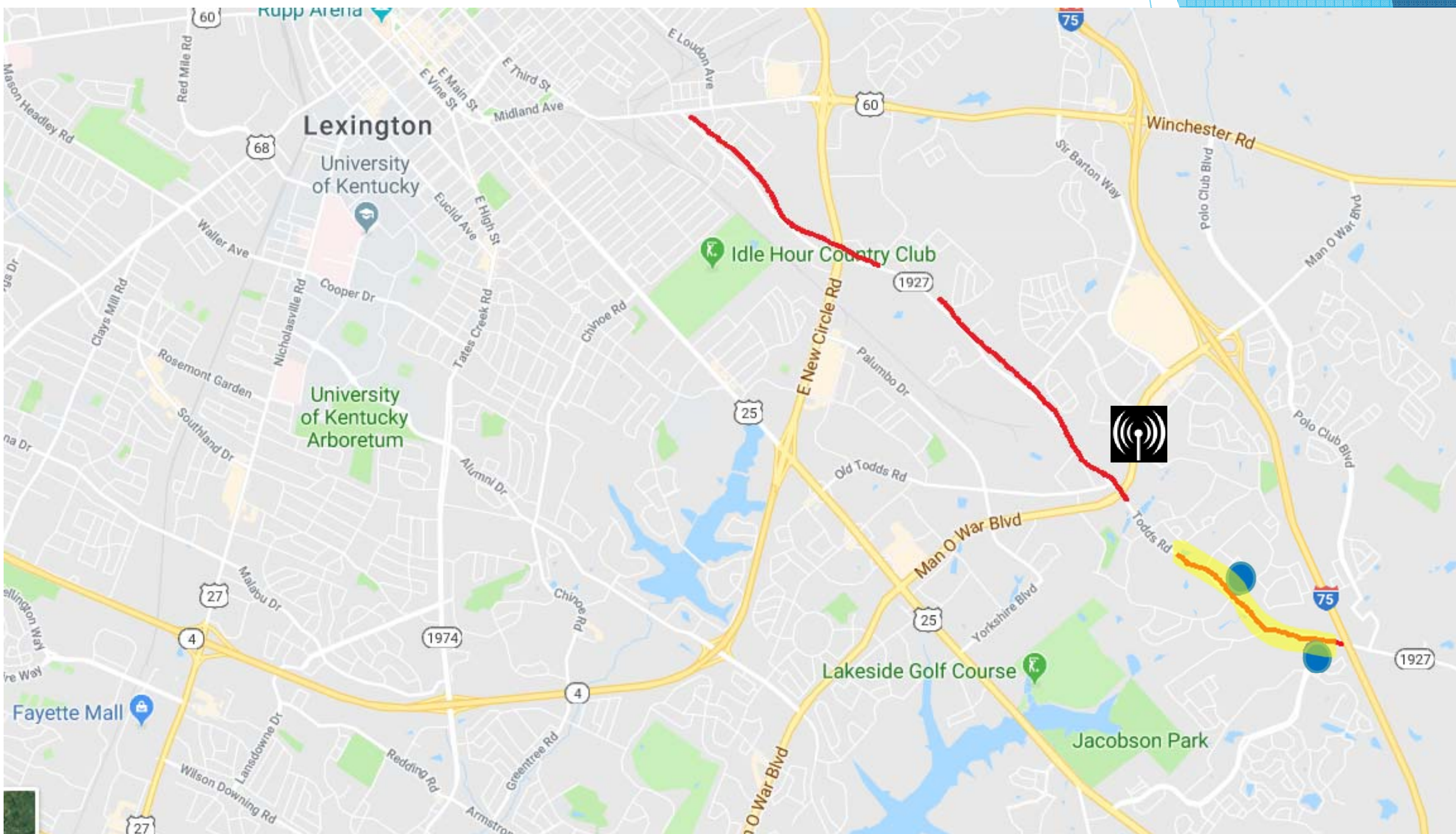
- **Fiber optic cable AND**
- **High speed radio**
  - Radios connections are "last mile connections".
  - Radio "hops" are installed at locations where
    - Fiber has not yet been installed, or
    - It wouldn't make sense spend the money to get it installed.

HOW IT WORKS:
Most of the road is connected with fiber, but there is a radio installed that interfaces with the fiber network. The radio transmits information from the intersections.

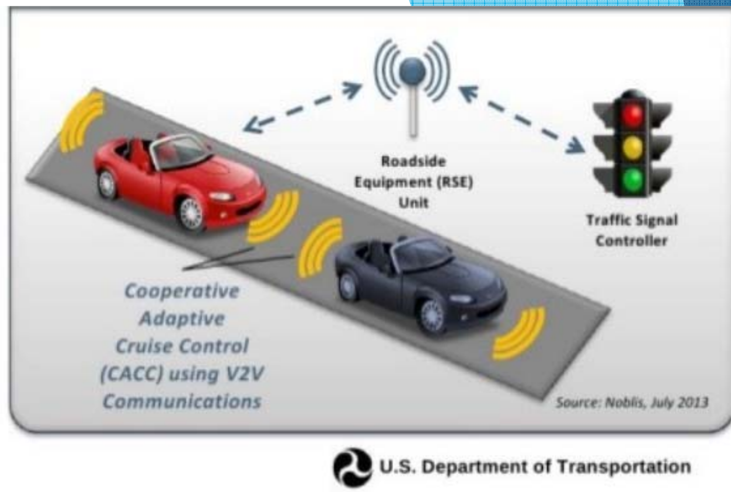
Man-o-War at Liberty Road,

Todd's Rd/Hayes and Todd's Rd/Autumn Ridge

Lexington, KY



▶Data - is being collected now



Until wireless technology is ready…

- **Signal Phase and Timing (SPaT)** data is shared with software developers
  - Current state (Green, Yellow, Red, Flashing, Off)
  - Time until current signal state changes
  - Lane set (lane 1 is moving, etc.)

- Software developers then process that information and make it usable to car manufacturers for secure units within the automated cars.

Technology - DSRC vs Cellular

- *Wireless Technology* will be the way *Self-Driving Cars* talk to each other
- Dedicated Short Range Communications (DSRC) versus Cellular Network (4G or 5G)
- Private industry will most likely determine which is most viable
- Be cautious about spending resources until market more clear

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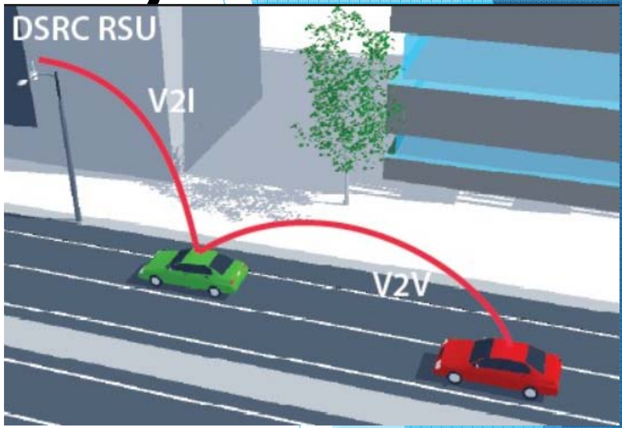
Technology - DSRC vs Cellular (C-V2X)

DSRC *(similar to Wi-Fi)*

- Readily available in US and Europe
- Operates in adverse weather
- **Low Latency** (high speed)
  - Time delay of milliseconds
  - Safety Critical
- **Expensive**
  - **$10,000+ per intersection (Lex)**
  - Includes hardware, software, setup, and licensing



NOTE: DSRC communications occur in a 75 MHz bandwidth of the 5.9 GHz spectrum, That bandwidth was allocated to DSRC for use by ITS vehicle safety and mobility applications in **1999**.

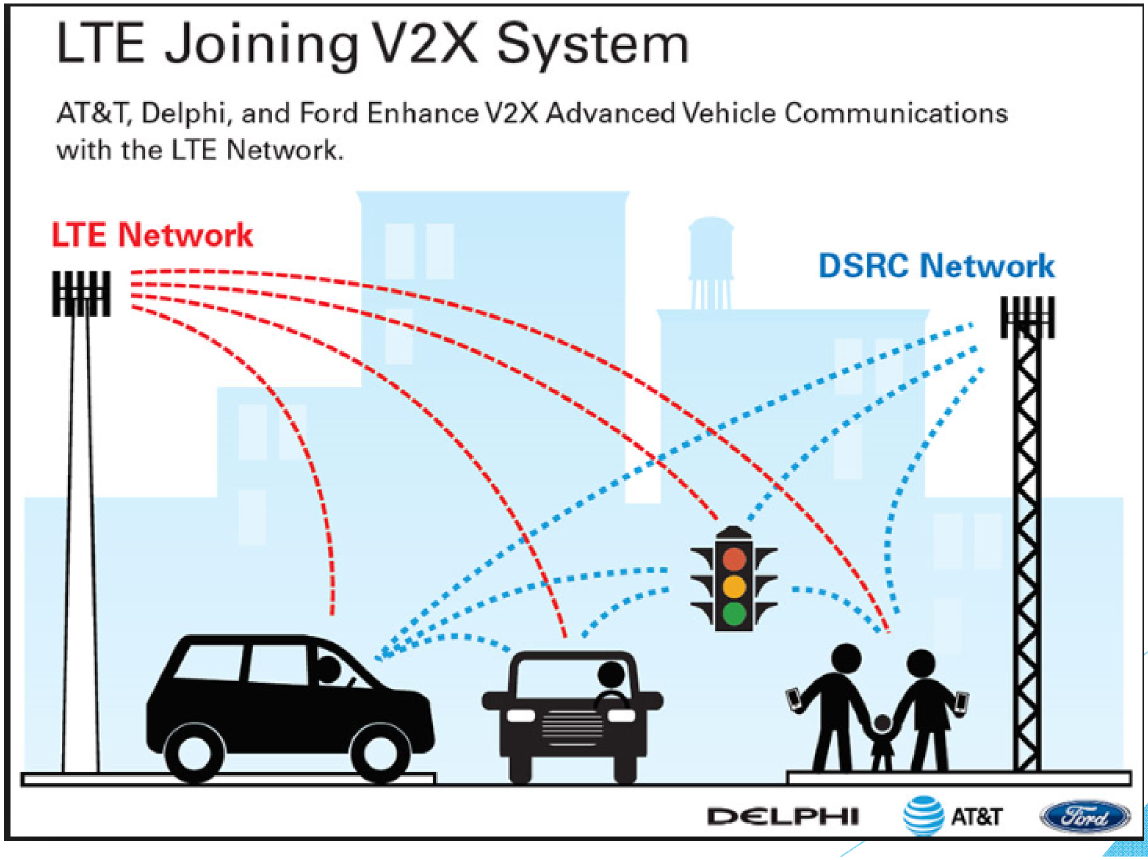
DSRC + GPS = V2V

NEW!

NOTE: GM put DSRC in CTS Cadillacs in 2017; and will put in ALL Cadillacs by 2021
Toyota will put DSRC in ALL vehicles by 2021

Technology - DSRC vs Cellular (C-V2X)

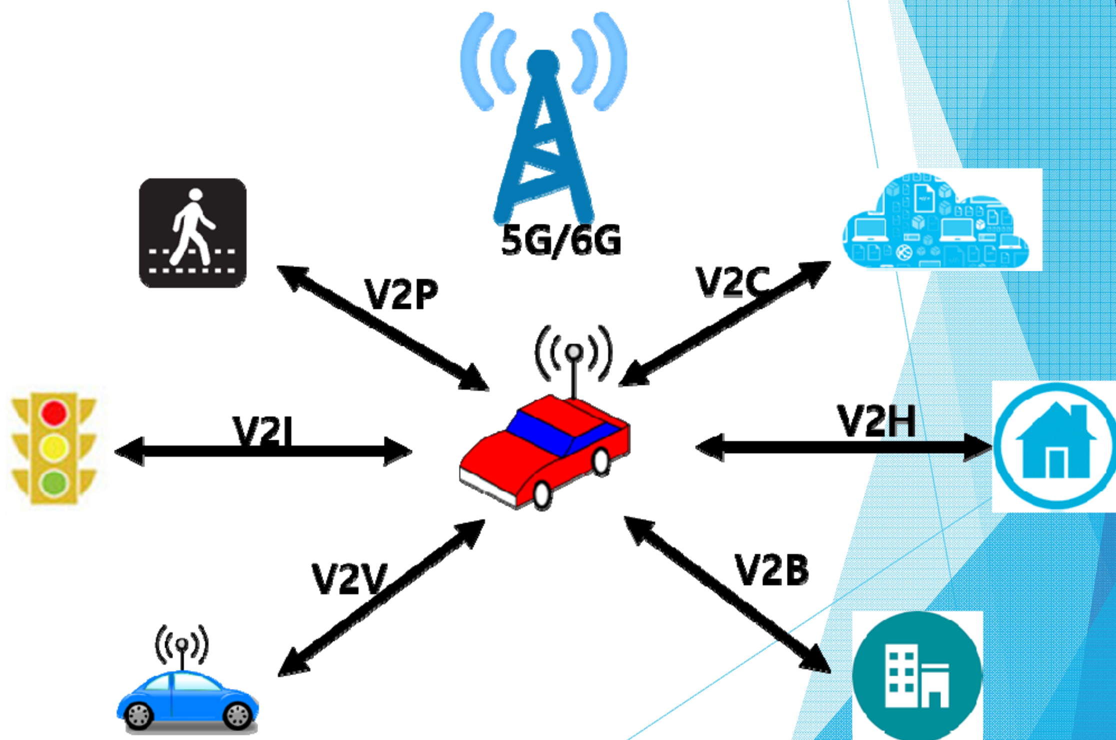
Cellular – ONE TO ONE **DSRC – ONE TO MANY**



Technology - DSRC vs Cellular

C- V2X (Vehicle to Everything)

- V2V (Vehicle to Vehicle)
- V2P (Vehicle to Pedestrian)
- V2I (Vehicle to Infrastructure)
- V2N (Vehicle to Network/Computer)
- V2H (Vehicle to Home)
- V2B (Vehicle to Business)



▶Technology - DSRC vs Cellular

Cellular (4G or 5G) –

- Network very limited at the moment
- 4G has latency problems (doesn't communicate fast enough) for collision avoidance

- **5G is promising to be faster.**
- 5G has a significant improvement in safety
- 5G can provide mobile entertainment that passengers want
- 5G will have many other commercial uses, so it will eventually be built by private companies

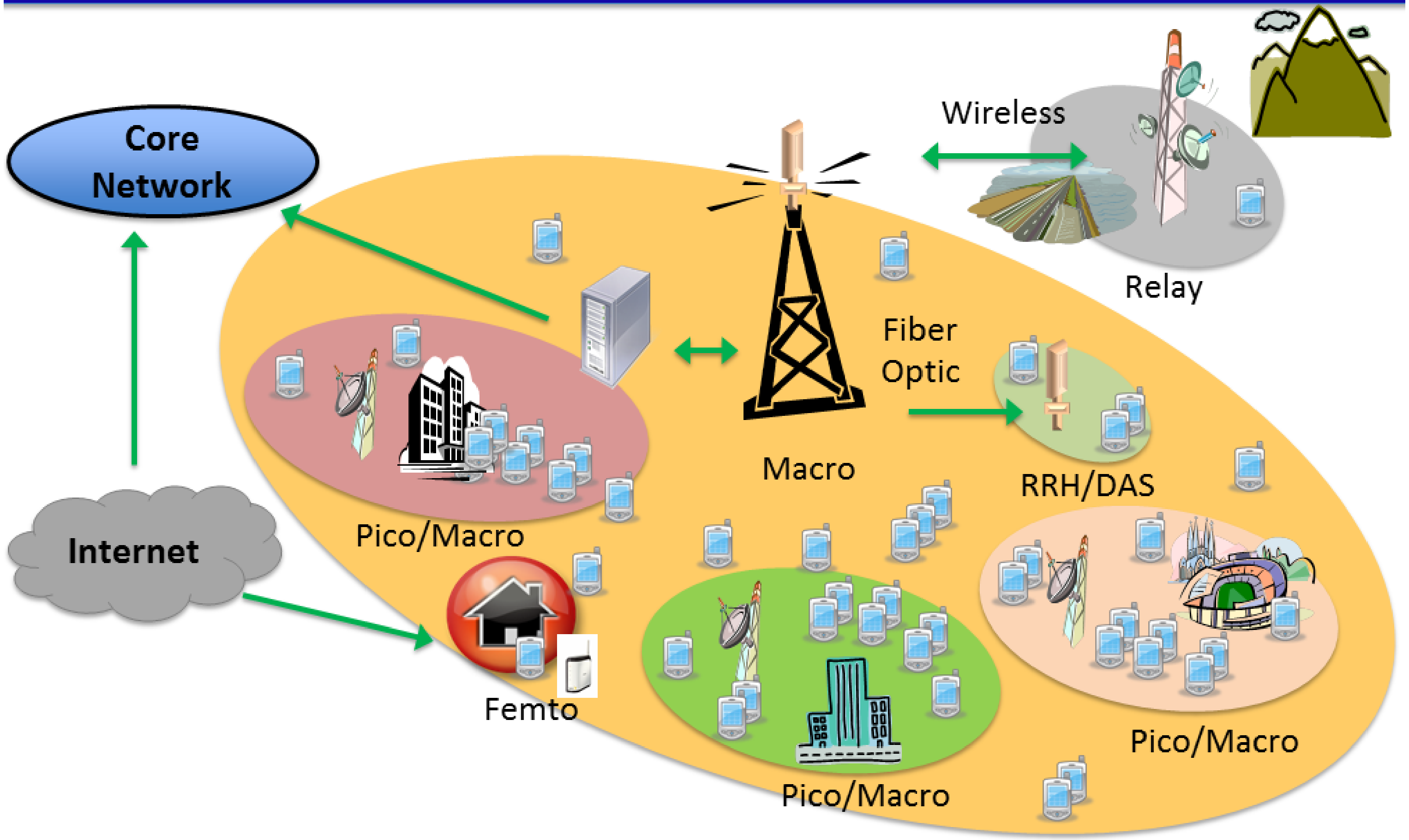
Technology - DSRC vs Cellular

Future

- Might be a combination of both DSRC and 5G
- OR

- (10 years perhaps), 5G will be capable of supporting all the CV applications that DSRC radios can, but cities won't have to maintain a piece of hardware at every single intersection.

Heterogeneous Networks



Connecting computers and other devices with different operating systems

Infrastructure: HETEROGENEOUS NETWORKS

- **Shared infrastructure**
  - Wi-Fi public or private service
  - Traffic generated by IP cameras for video surveillance systems

- Provides products and services across both **Macro** and **Small Cells** to optimize the mix of capabilities.

- **Macro** and **Small Cells** use different frequencies

Infrastructure: SMALL CELLS OR RELAY

- Usually needed when mountains, etc., block radio signals

- Usually installed near densely populated areas
  - i.e. large businesses, schools, etc.

- Range is from 150’-500’

- Generate a lot of heat, therefore not good under ground.

- Standing 9’ away, you will get the same exposure as a cell phone

Federal Highway Administration

Infrastructure: SMALL CELLS OR RELAY

What are the local restrictions?

- **Location?**
  - ADA Compliant?
  - Fire Hydrants?
  - Parking Spaces (opening doors)
  - In ROW?
  - Distance between small cells?

Infrastructure: SMALL CELLS OR RELAY

- **Facility Design?**
  - Height? – 40’ max?
  - Boxes on Pole? Who owns poles?
    - If on Ground (OH found that on the ground the boxes were very big and VERY loud and the Providers were worries about flooding their equipment)
    - Don’t recommend a minimum distance between Macro Cell Tower & Small Cell
  - *Stealth Design* for poles and equipment? Some just painted black

Infrastructure: SMALL CELLS OR RELAY

- **Regulations?**
  - FCC – 1996 Federal Regulation – limits on radio frequency
  - State of OH - HB 478 - Communities work with telecommunications providers
  - City of Cincinnati - Chapter 719

- **Application Process?**
  - Fee?

What’s Going On In Kentucky?

ITS and CAV Peer Exchange

- Intelligent Transportation Systems (ITS) and
- Connected and Autonomous Vehicles (CAV)

- One day event held in Lexington on May 30, 2018.
- About 30 participants
  - MPOs: Lexington, Louisville, Cincinnati
  - KYTC
  - FHWA
  - UKTC

Federal Highway Administration

LEXINGTON

Lexington Fayette Urban County Government

LFUCG Contact:

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Signal Systems Manager
Lexington-Fayette Urban County Government
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Lexington, KY 40507
(859)258-3491

Advantages include:

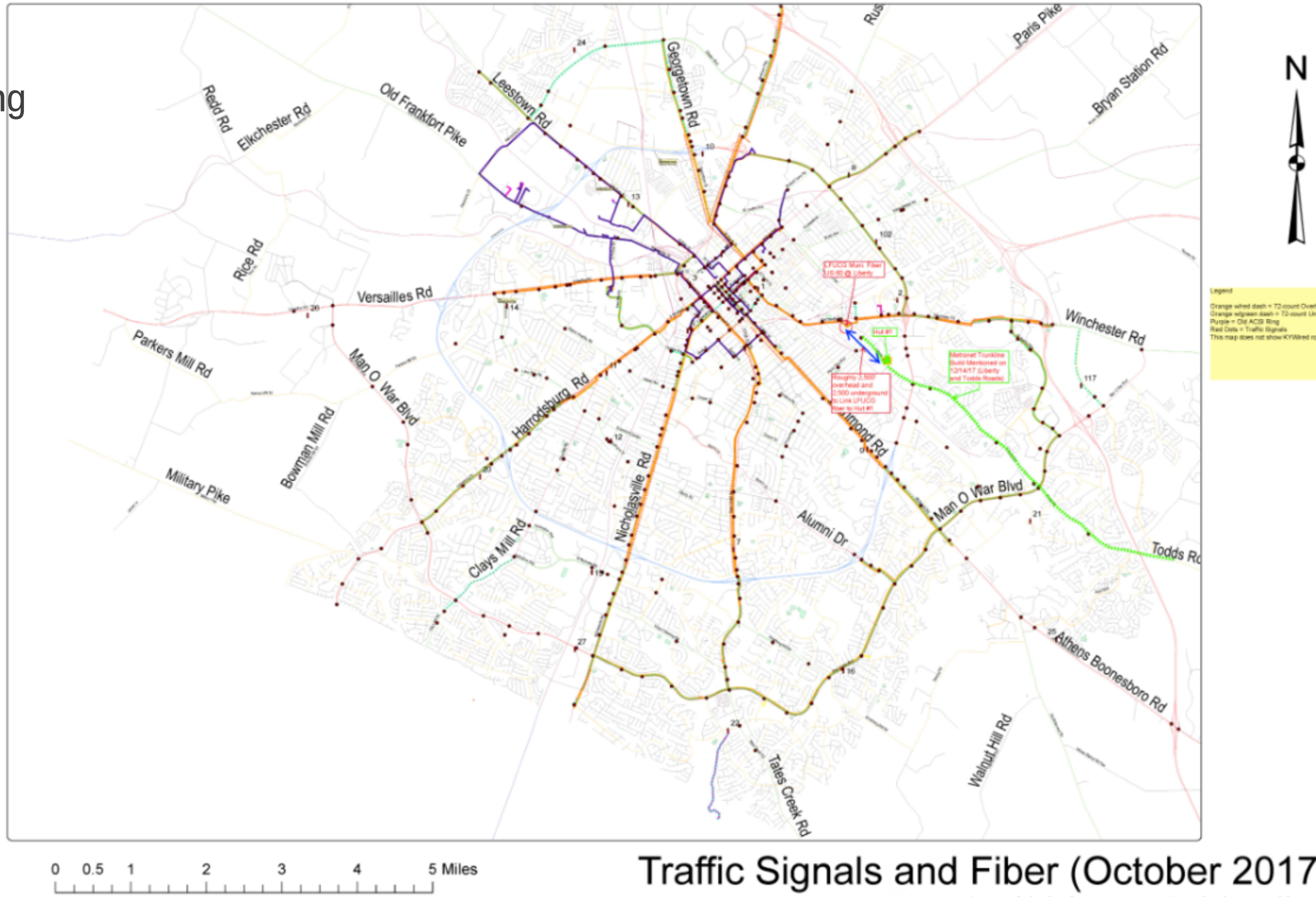
- MPO provides a portion of their dedicated STP money on a regular basis
- CMAQ awards
- Consolidated Cities

Infrastructure - Fiber Optic Cable

- 95% of city covered
  - 80% connected directly via fiber optic cable
  - 15% connected via high speed radio
    - Radios connections are “last mile connections”.
    - Radio “hops” are installed at locations where
      - Fiber has not yet been installed
      - It wouldn’t make sense spend the money to get it installed.
        - (I-75 at Athens-Boonesboro Rd)

Infrastructure – Fiber Optic Cable

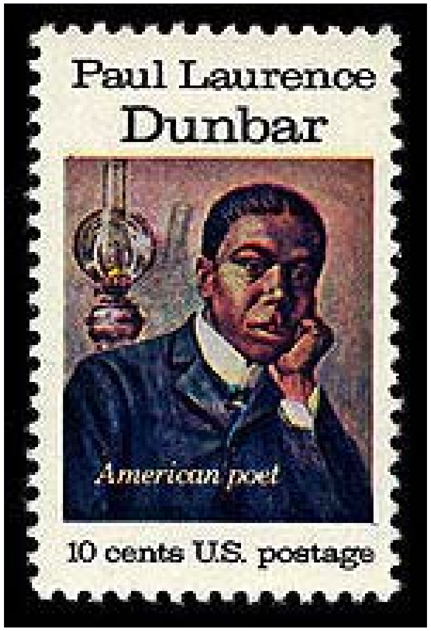
- 90 miles of cable connecting
  - 402 traffic signals
  - 24 fire and police stations



Traffic Signals and Fiber (October 2017)

Infrastructure - Small Cell

Lexington has 1
– Call it a “Sector Antenna”
- Located at Paul Laurence Dunbar High School



LEXINGTON

ITS Applications

1) **Fiber Optic Cable Network**:

- Lexington is collecting SPaT data every 1/10 of a second and making it available on a server

LEXINGTON

ITS Applications (continued)

2) Central Video Management System (software/architecture)

- Better utilize traffic surveillance camera network
- Aide in other transportation projects

3) Travel Time Analytics Platform (system)

- Uses data from GPS/Cell Probe Data providers to provide travel time information for city.
- Meets FHWA requirements
- Can monitor changing traffic conditions

LEXINGTON

ITS Applications (continued)

4) LiDAR Asset Management

- Plan to use LiDAR surveys to inventory and map
- Lane markings
- Signage
- Curb Conditions
- Other assets

Louisville Metro

Louisville Metro Contacts:

Ed Blayney, Innovation Project Manager
Mayor's Office
Office of Performance Improvement and Innovation
Louisville, KY
(502) 574-6309

Jason Yeager, Pat Johnson, Al Andrews
Louisville Metro – Division of Traffic Engineering

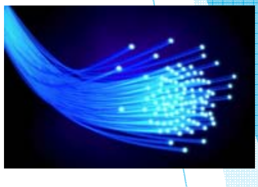
Advantages include:

- Consolidated 81 Small Cities
- Tiger Grant
- Partnership with KY Wired

Louisville Metro

ITS Applications

1) Louisville Metro’s Network



Louisville Metro	CURRENTLY	GOAL
Miles of FIBER OPTIC CABLE	10	120 miles by end of 2018
Intersections with FIBER OPTIC CABLE	0	Add 350 more outside service area
Intersections Wired by PHONE LINES	650 in Downtown Area	no more – converting to FIBER OPTIC CABLE
Percentage of Metro Area Connected	63%	100%

Louisville Metro

ITS Applications (Continued)

- **2) Dixie Highway**
  - Main Goal is Safety
  - $50 M investment, $18.8 M TIGER grant
  - 1st Bus Rapid Transit (BRT) in the region
    - State-of-the-art buses – uses technology to load and unload faster
    - Real-time information about bus arrival times
    - New route with 36 bus stops and stations
  - 1st *local* deployment of 2070 Traffic Signal Controllers
  - 1st modernized communications network on a significant arterial

Louisville Metro

ITS Applications (Continued)

- **2) Dixie Highway (continued)**

  KY Wired (Partner)

  - Providing traffic controllers for ½ of Dixie Highway project
  - Goal is to provide interoperability for public safety agencies at all levels of Government.
  - Commonwealth of KY’s open-access broadband network

Louisville Metro

CAV Initiatives

- Louisville Metro-has developed an "Autonomous Vehicle Playbook".

- Using guiding principles generated from extensive outreach for their 2040 Comprehensive Plan to inform their AV efforts.
  - Vision Statement - Acronym – CHASE PRINCIPLES — SMART CITY DEFINITION

C onnected
H ealthy
A uthentic
S ustainable
E quitable

KENTUCKY TRANSPORTATION CABINET

Kentucky Transportation Cabinet

ITS Applications

- I-Cones – record speeds as you drive through construction sites

- GoKy@ky.gov
  - Replaces 511
  - Real time travel data working in conjunction with Waze

- Signal Phase and Timing (SPaT) messages broadcast through enabled traffic signal controllers.
  - Louisville, Lexington and the City of Newport are interested KYTC

Kentucky Transportation Cabinet

ITS Applications

- EDC-4: Automated Traffic Signal Performance Measures to improve retiming processes by providing continuous performance monitoring capability. The signal retiming efforts are based on actual performance, rather than software modeling or manually collected data.

- Applied for an EDC-4 AID Grants – Automated Traffic Controllers (ATC) for two corridors, one in Richmond and one in Bowling Green.
  - V2I communications will be part of this project if successful

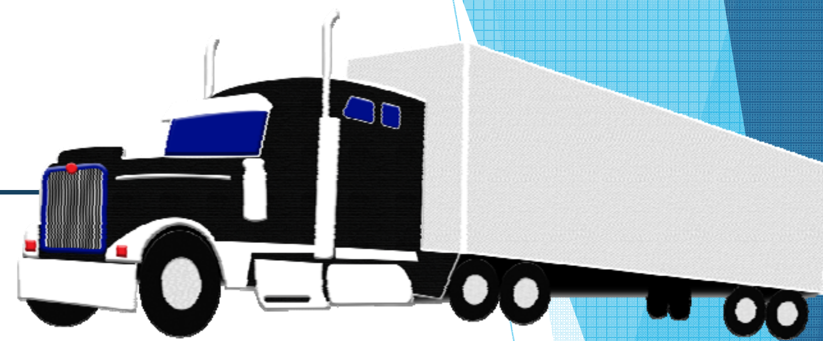
KENTUCKY TRANSPORTATION CABINET

Kentucky Transportation Cabinet

CAV Initiatives

- Identified internal stakeholders and are developing a **"CAV Road Map".**
- Plans to launch an internal **CAV webpage** by the end June 2018.
- Commissioned **research project to identify any barriers**, regulations, or policies that might prevent implementation of CAV in 2017. https://uknowledge.uky.edu/ktc_researchreports/1568/

Kentucky Transportation Cabinet



CAV Initiatives

- KYTC worked on a MAASTO taskforce to research policy and regulatory issues related to truck platooning in an effort to define a framework or model for regulatory changes that might result in harmony among MAASTO States

- The Governor also **signed a bill that allows "Truck Platooning"**.

CAV Initiatives

- **Ohio’s CAV Peer Exchange** to learn from Ohio’s experience in CV/AV research, testing, and development through Ohio’s Transportation Research Center and Columbus deployments, applications and open source data collection (April 2018).

Summary: Why Do We Care?

V2V, V2I, V2P, V2N is coming….

- Prevent accidents and collisions
- Assist traffic flow,
- Enhance driving experiences, and
- Enable higher levels of automated driving

So we need to plan…

- Prioritize CAV projects
- Provide funding for CAV projects

If you're an MPO, then

- Check your MTP – then perhaps there should be some CAV projects included in the project list
- Check your ITS Architecture
  1. Is it up-to-date?
  2. Does it include ITS/CAV applications?

QUESTIONS?

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