UNITED STATES
DEPARTMENT OF TRANSPORTATION

Connected Vehicles – Improving Safety, Mobility, and the Environment

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U.S. Department of Transportation
Intelligent Transportation Systems Joint Program Office

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Presentation Overview

- Overview of Intelligent Transportation Systems
- Transportation Challenges
- Overview of Connected Vehicle Environment
- Connected Vehicle Research
- Deployment of Connected Vehicle Technology
- Exploratory Research
- Vehicle Automation Research

Overview of Intelligent Transportation Systems

What is ITS?

Information and communications technology to manage and operate surface transportation systems.

- **Transaction Automation**

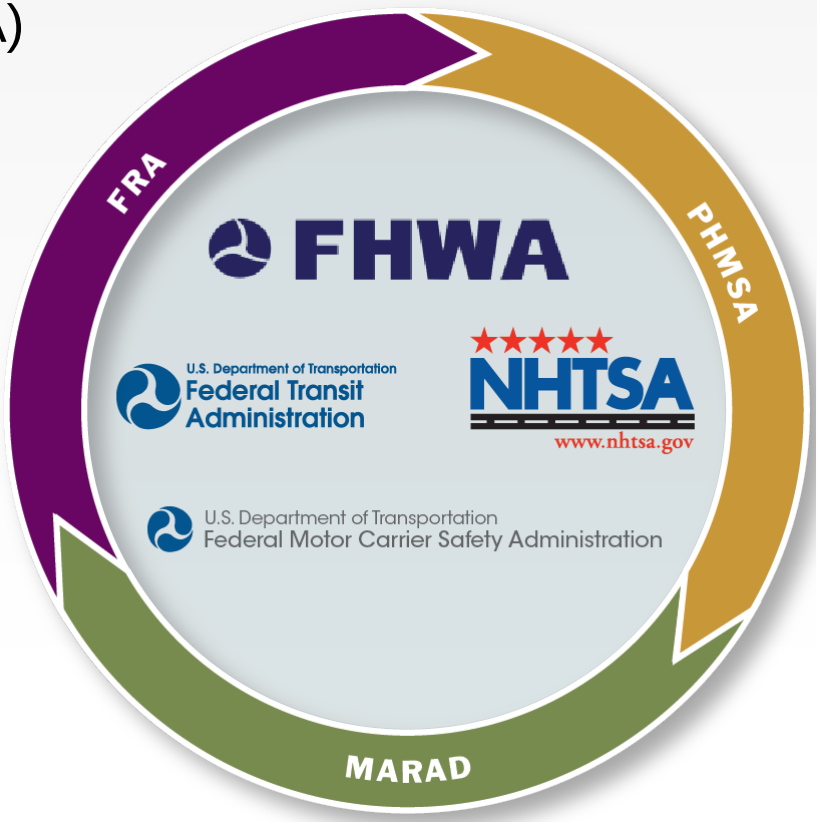
- **Decision Information**

- **System Control**

ITS Joint Program Office

The ITS JPO has Department-wide authority in coordinating the ITS program and initiatives among the following DOT Offices:

- Federal Highway Administration (FHWA)
- Federal Motor Carrier Safety Administration (FMCSA)
- Federal Transit Administration (FTA)
- Federal Railroad Administration (FRA)
- National Highway Traffic Safety Administration (NHTSA)
- Maritime Administration (MARAD).



Transportation Challenges

Safety

- 32,367 highway deaths in 2011
- 5.3 million crashes in 2011
- Leading cause of death for ages 4, 11–27

Mobility

- 5.5 billion hours of travel delay
- $121 billion cost of urban congestion

Environment

- 2.9 billion gallons of wasted fuel
- 56 billion lbs of additional CO_2

Overview of Connected Vehicle Systems

Connected Vehicle Concept

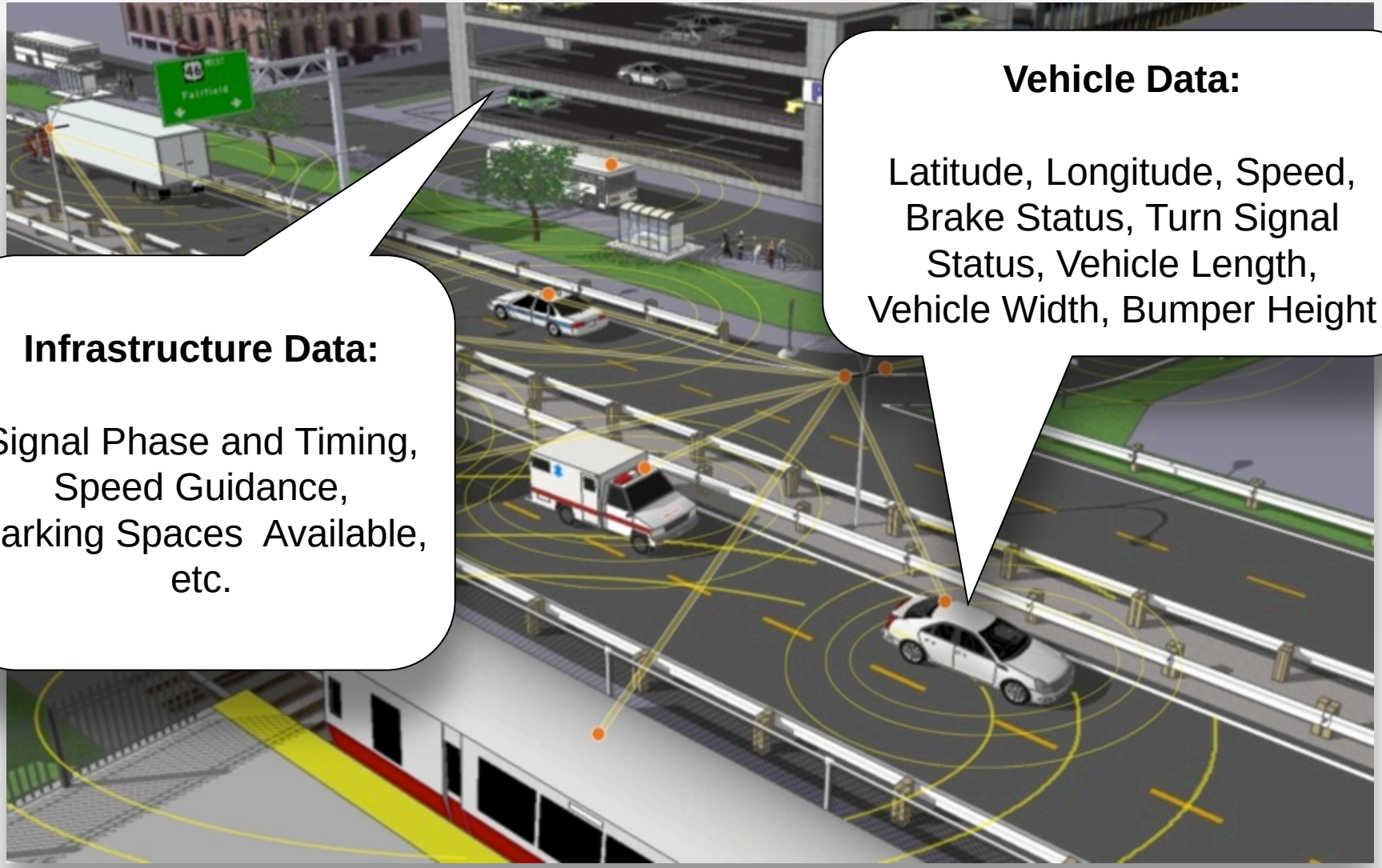
Today Show Segment

Today Show Video Recap

Connected vehicles have the potential to address approximately 80% of vehicle crash scenarios involving unimpaired drivers.

- Vehicle-to-vehicle (V2V) and vehicle-to-infrastructure (V2I) communication technology and standards
- Enables crash avoidance and other safety applications
- Testing and pilot deployments
- USDOT regulatory decisions

Fully Connected Environment



Dedicated Short Range Communications Technology

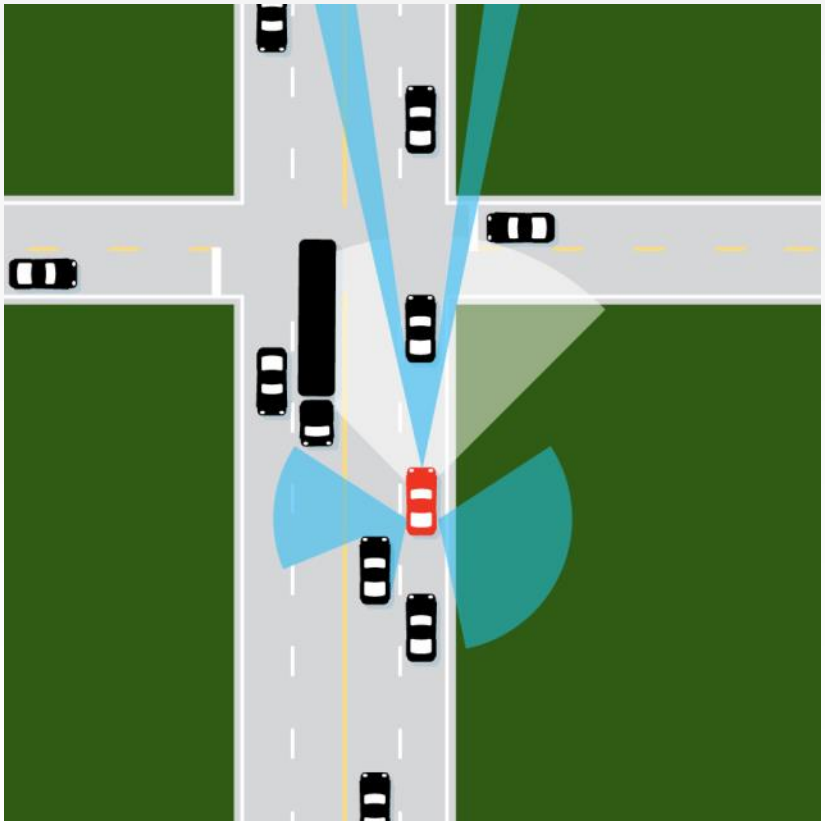
- 5.9 GHz DSRC
- Wi-Fi radio adapted for vehicle environment
- Inexpensive to produce in quantity
- Original FCC spectrum allocation in 1999
- FCC revised allocation in 2004 and 2006

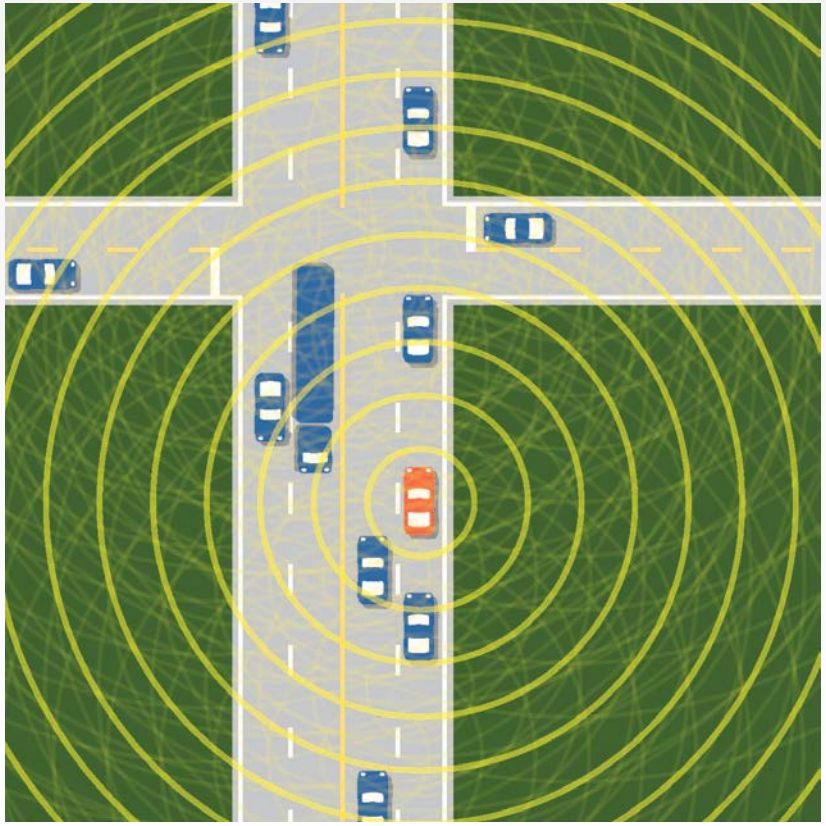
Connected Vehicle Communications Technology: DSRC

- Data is transmitted 10 times/sec (300m range – line of sight)
- Privacy is protected (vehicle location is NOT recorded or tracked)

Benefits of V2V communications....

Uses a single sensor (radio) to receive threat data from all directions



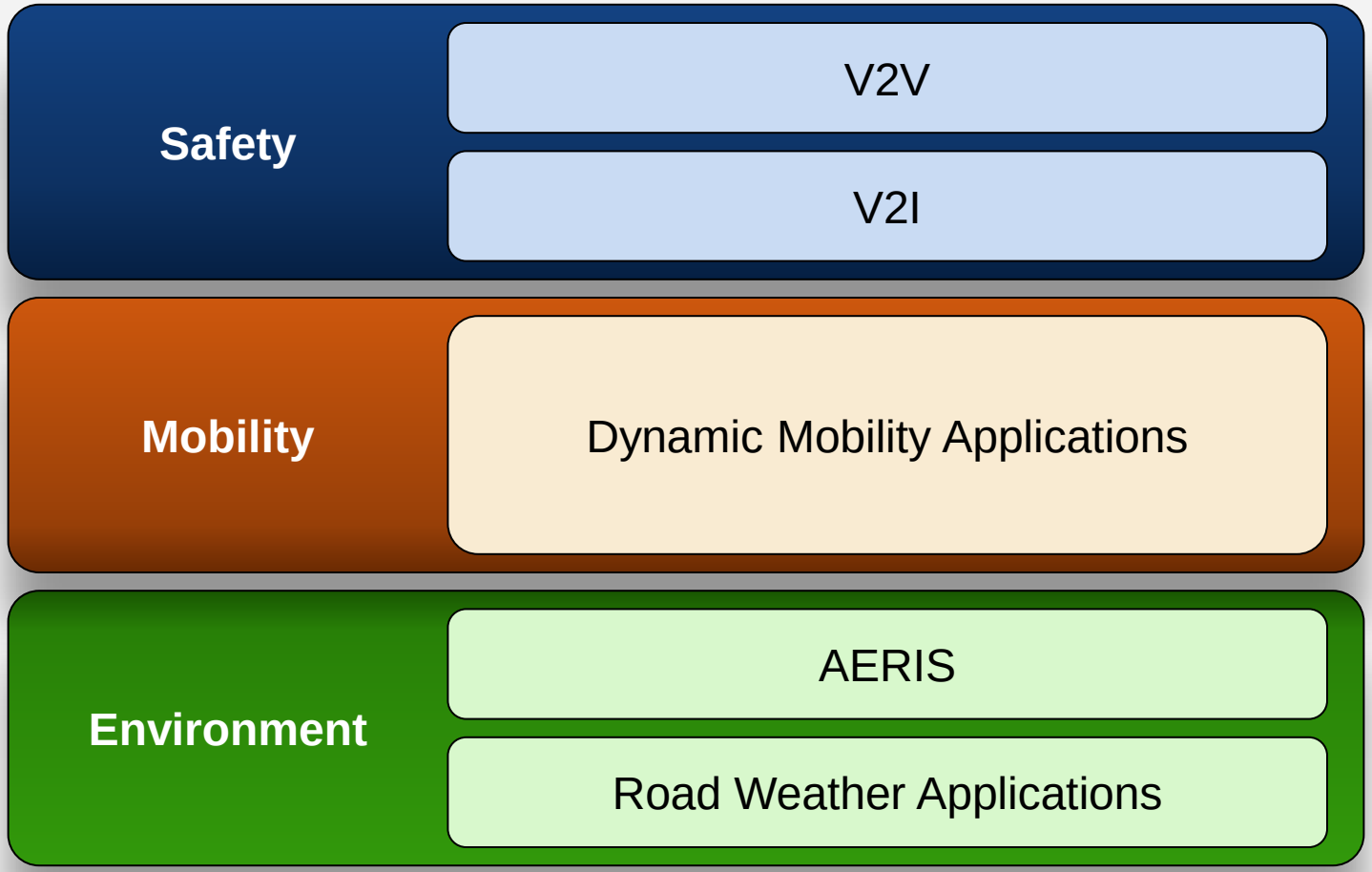


Compared with non-cooperative detection systems (e.g., radar, camera), V2V offers potentially lower cost for more comprehensive situational awareness

Connected Vehicle Communications Technology: Other Options

- 4G and older 3G cellular networks provide high-bandwidth data communications over widely deployed commercial networks
- Increasingly available in vehicles
- Not suitable for safety applications that require low latency
- Other wireless technologies such as Wi-Fi, satellite, and HD radio may have roles to play

Connected Vehicle Applications



Safety Applications: V2V

V2V Safety Applications
Forward Collision Warning
Emergency Electronic Brake Light
Blind Spot/Lane Change Warning
Do Not Pass Warning
Intersection Movement Assist
Left Turn Assist

Forward Collision Warning & Lane Change Warning

FCW

Lead Vehicle Stopped

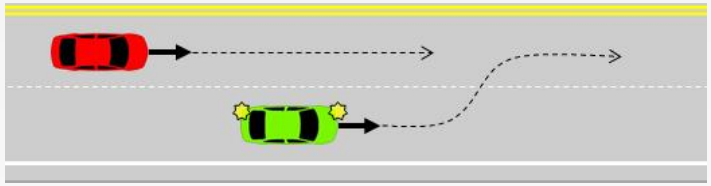
Lead Vehicle Slower

Lead Vehicle Decelerating

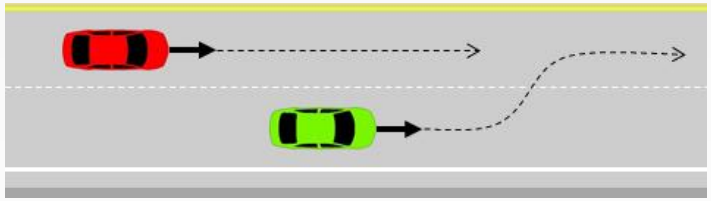
FCW: Forward Crash Warning

LCW

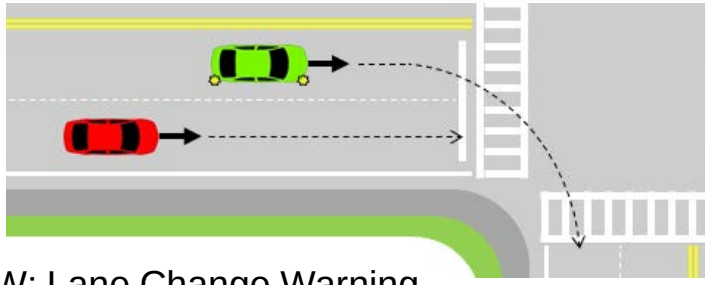
Changing Lanes/Same Direction



Drifting/Same Direction



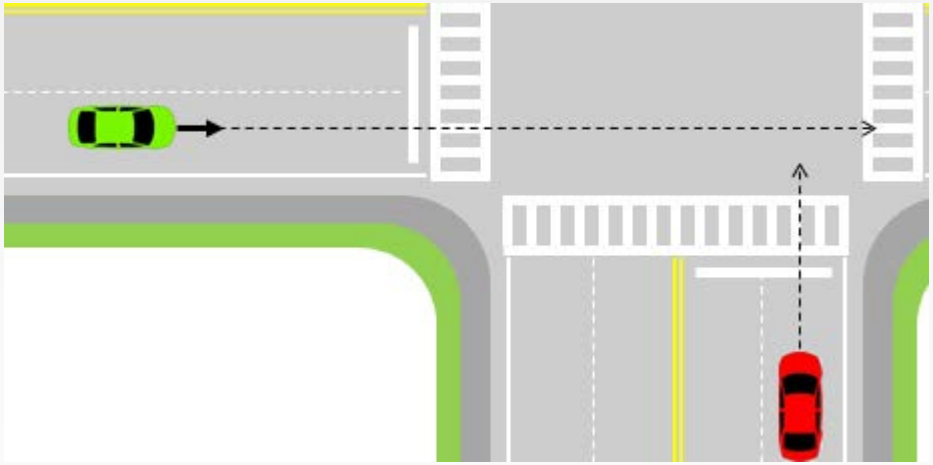
Turning/Same Direction



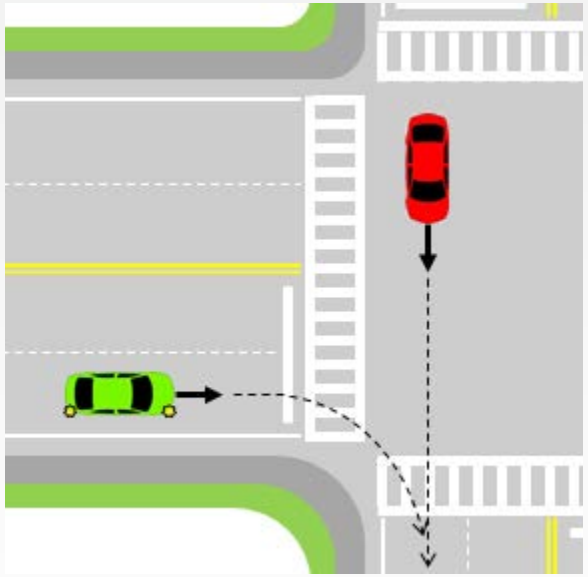
LCW: Lane Change Warning

Intersection Movement Assist Application

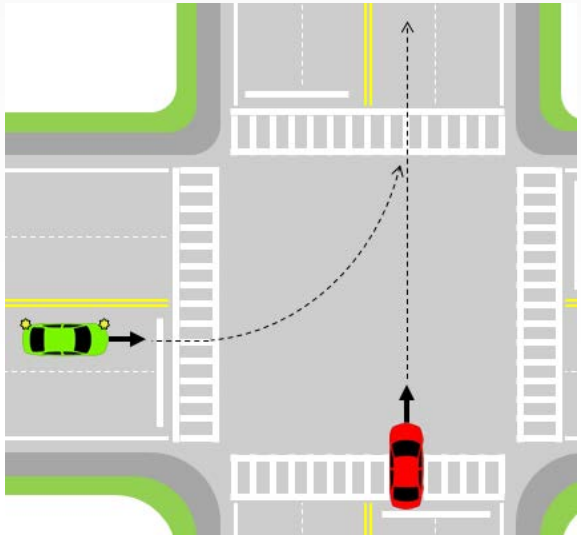
Straight Crossing Paths



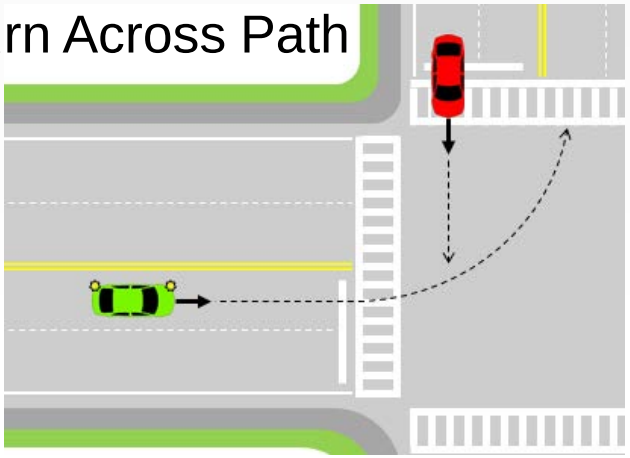
Right Turn Into Path



Left Turn Into Path

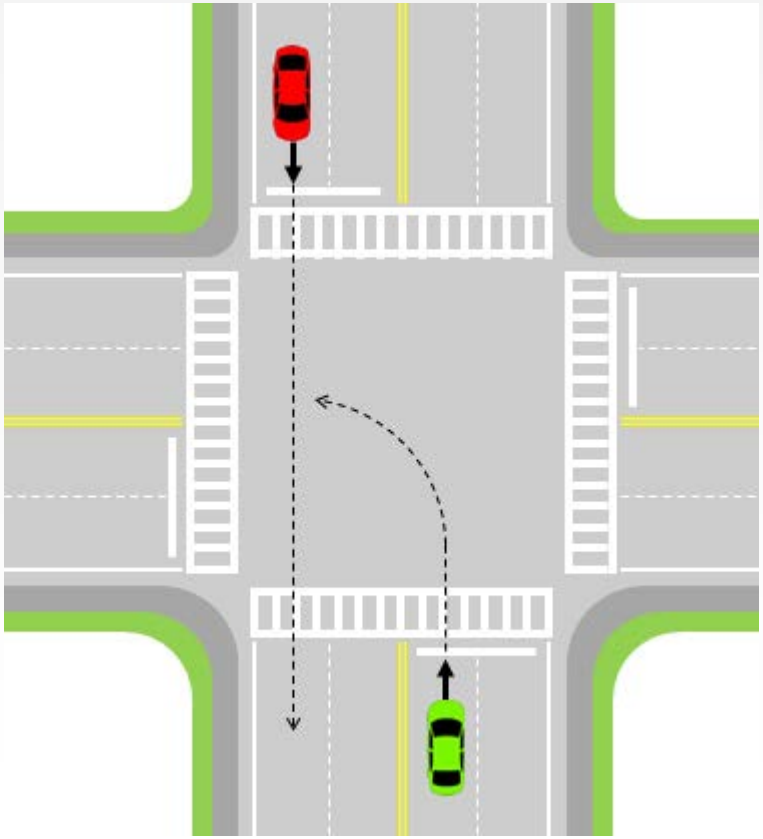


Left Turn Across Path

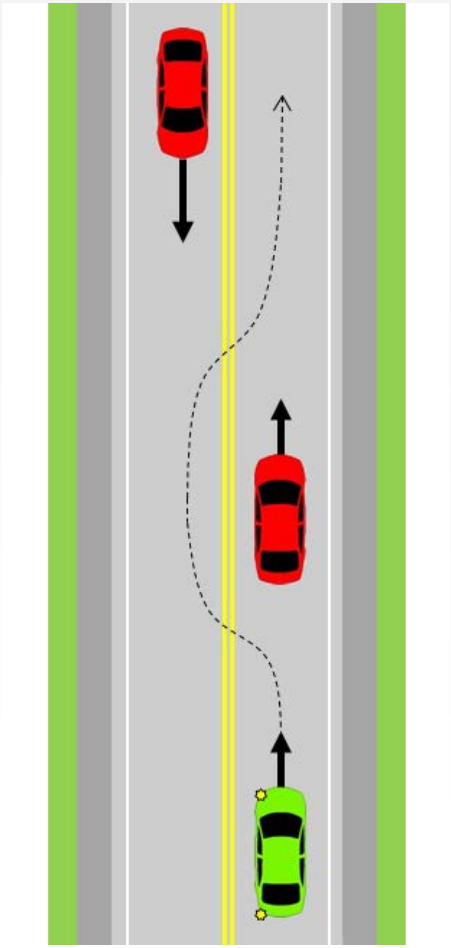


LTA & DNPW Applications

LTA



DNPW

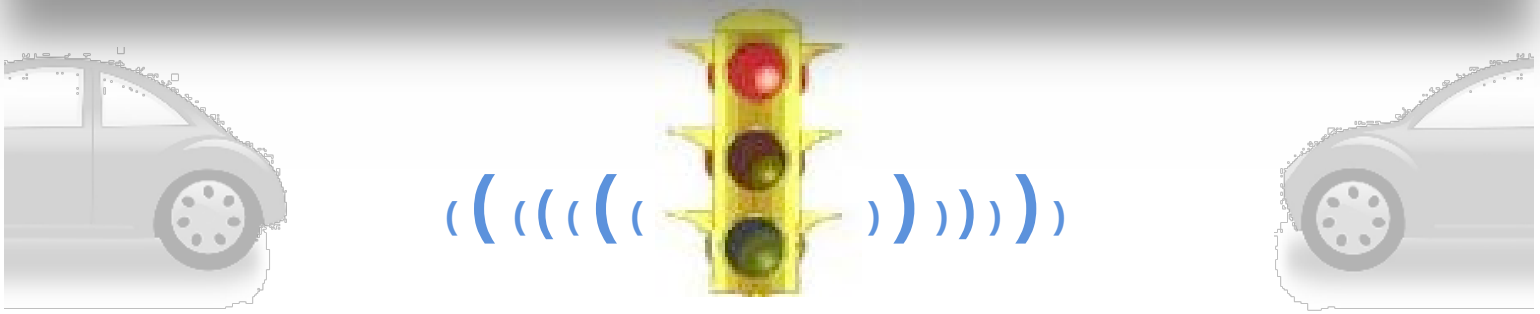


LTA: Left Turn Assist

DNPW: Do Not Pass Warning

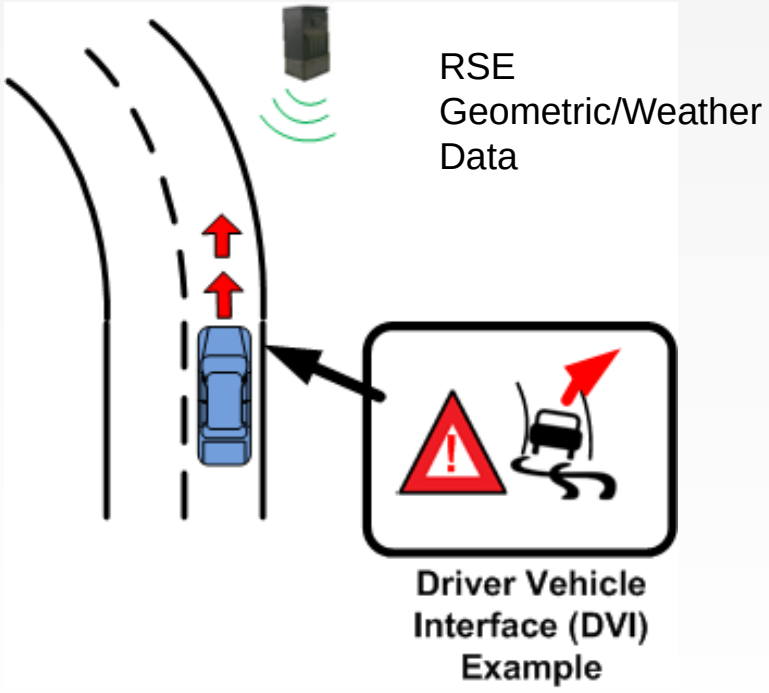
Safety Applications: V2I

V2I Safety Applications
Curve Speed Warning
Red Light Violation Warning
Spot Weather Information Warning
Reduced Speed Zone Warning
Stop Sign Gap Assist
Smart Roadside
Transit Pedestrian Warning

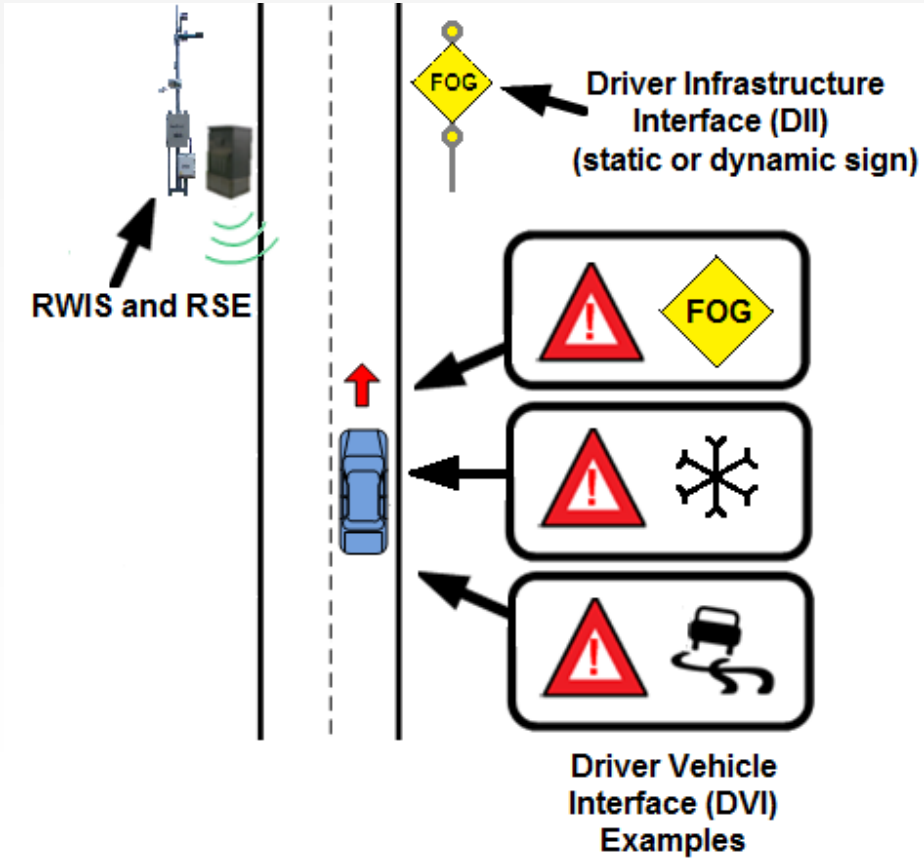


Curve Warning & Spot Weather Information Warning

Curve Warning

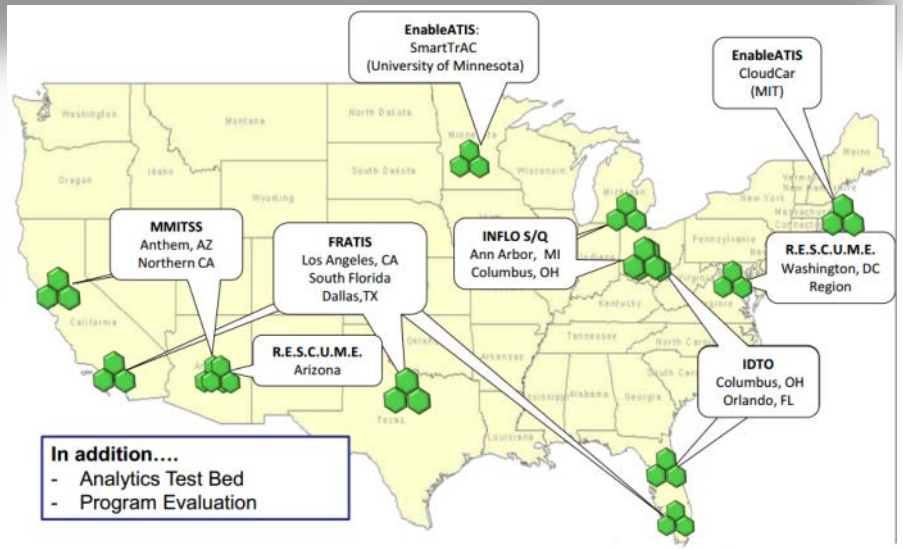


SWIW

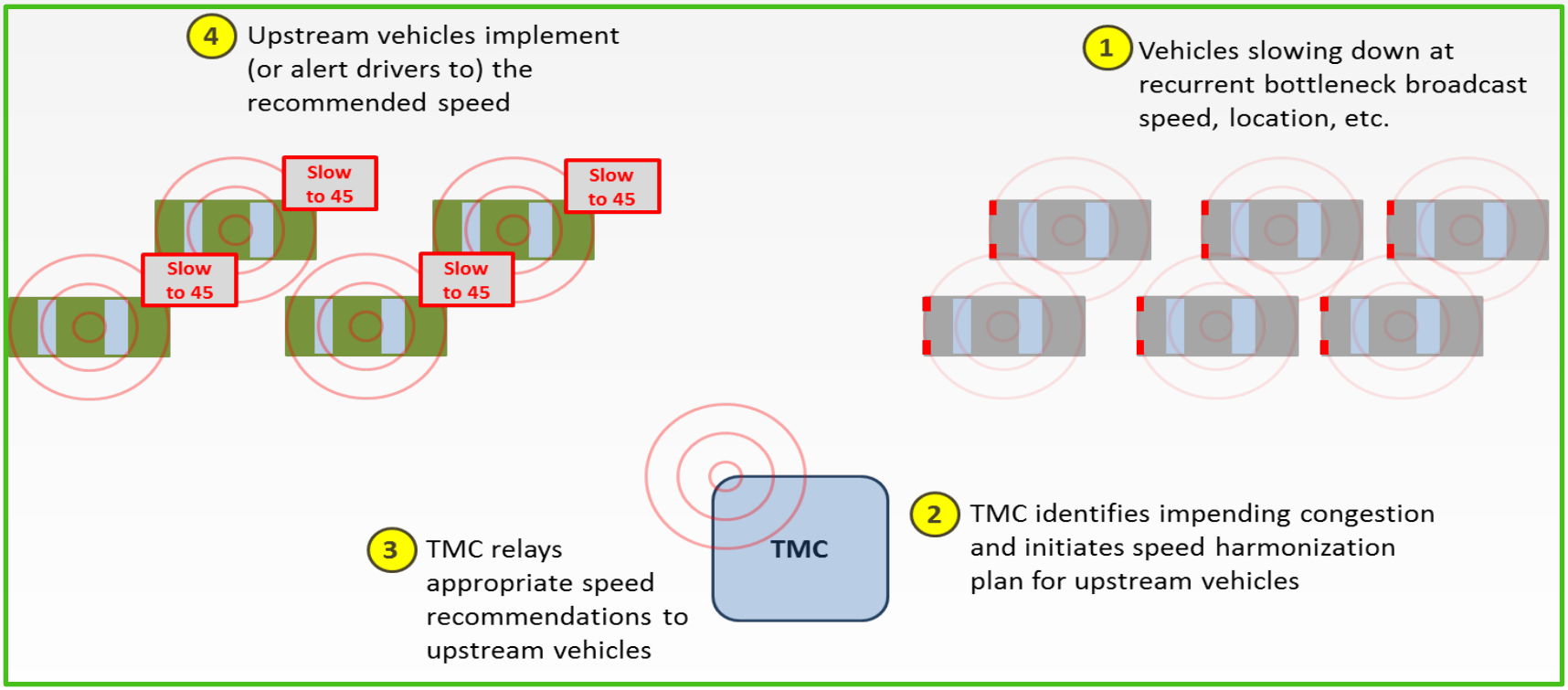


Dynamic Mobility Applications

Enable Advanced Traveler Information Systems
Intelligent Network Flow Optimization
Response, Emergency Staging and Communications, Uniform Management, and Evacuation
Integrated Dynamic Transit Operations
Multimodal Intelligent Traffic Signal Control
Freight Advanced Traveler Information Systems



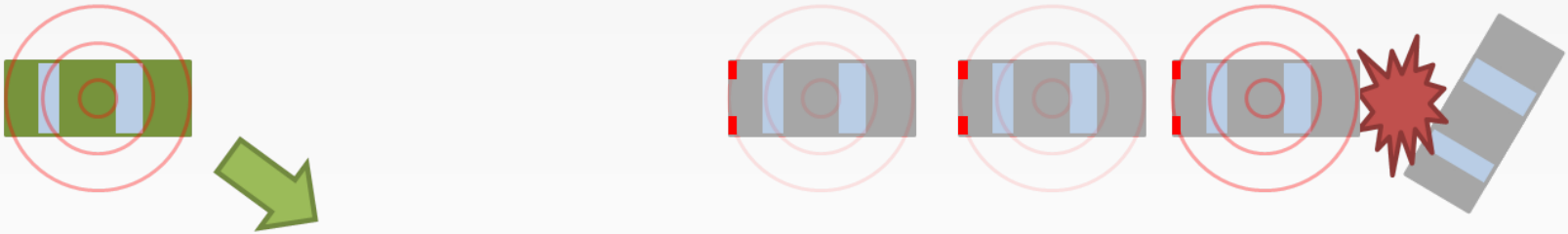
Dynamic Speed Harmonization



Queue Warning

3 Host Vehicle receives data and provides driver with imminent queue warning

1 Queue condition forms



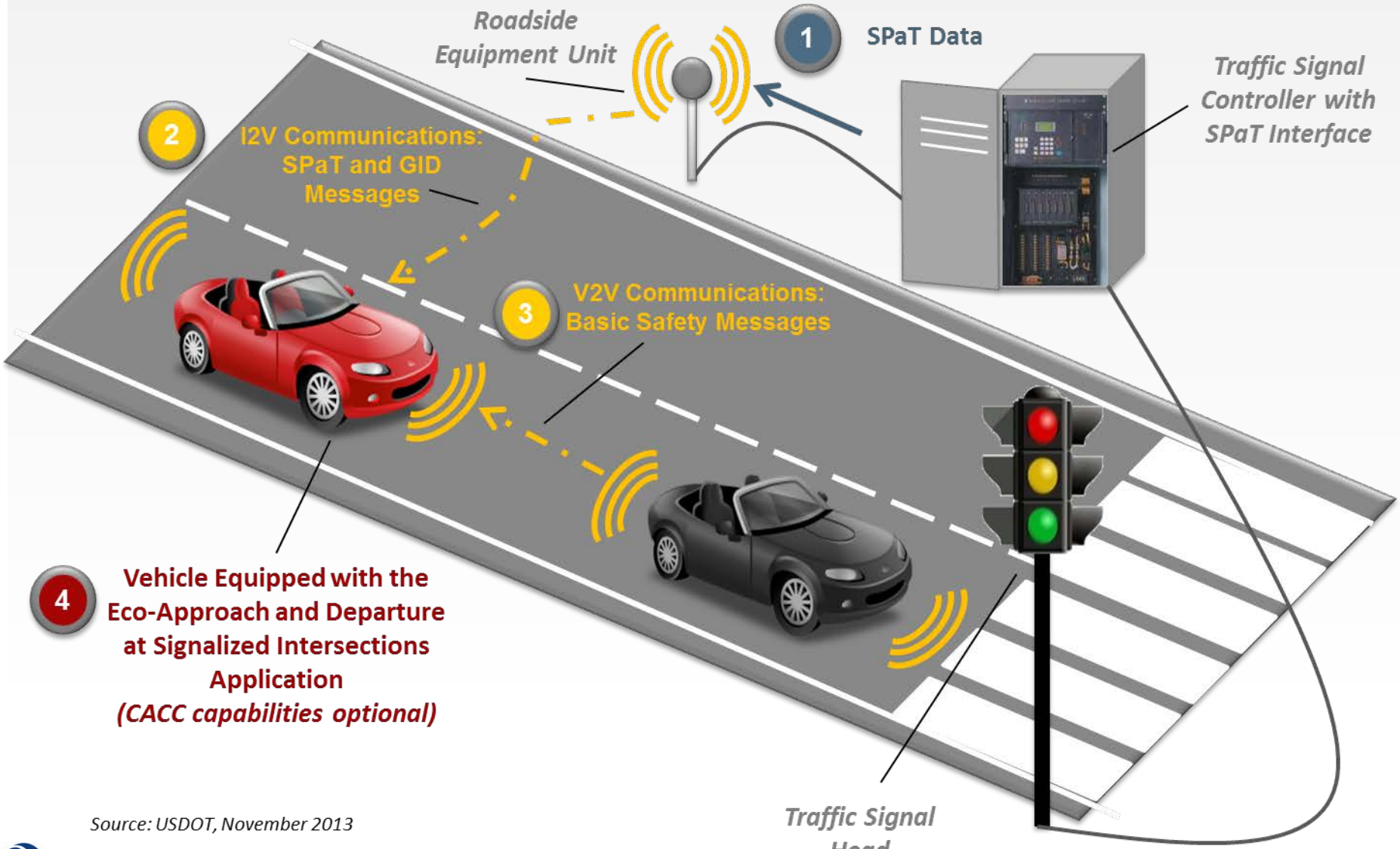
2 Vehicles broadcast their rapid changes in speed, acceleration, position, etc.

4 Driver provided sufficient time to brake safely, change lanes, or even modify route

Environment Applications: AERIS

Eco-Signal Operations
Eco-Lanes
Low Emissions Zones
Eco-Traveler Information
Eco-Integrated Corridor Management

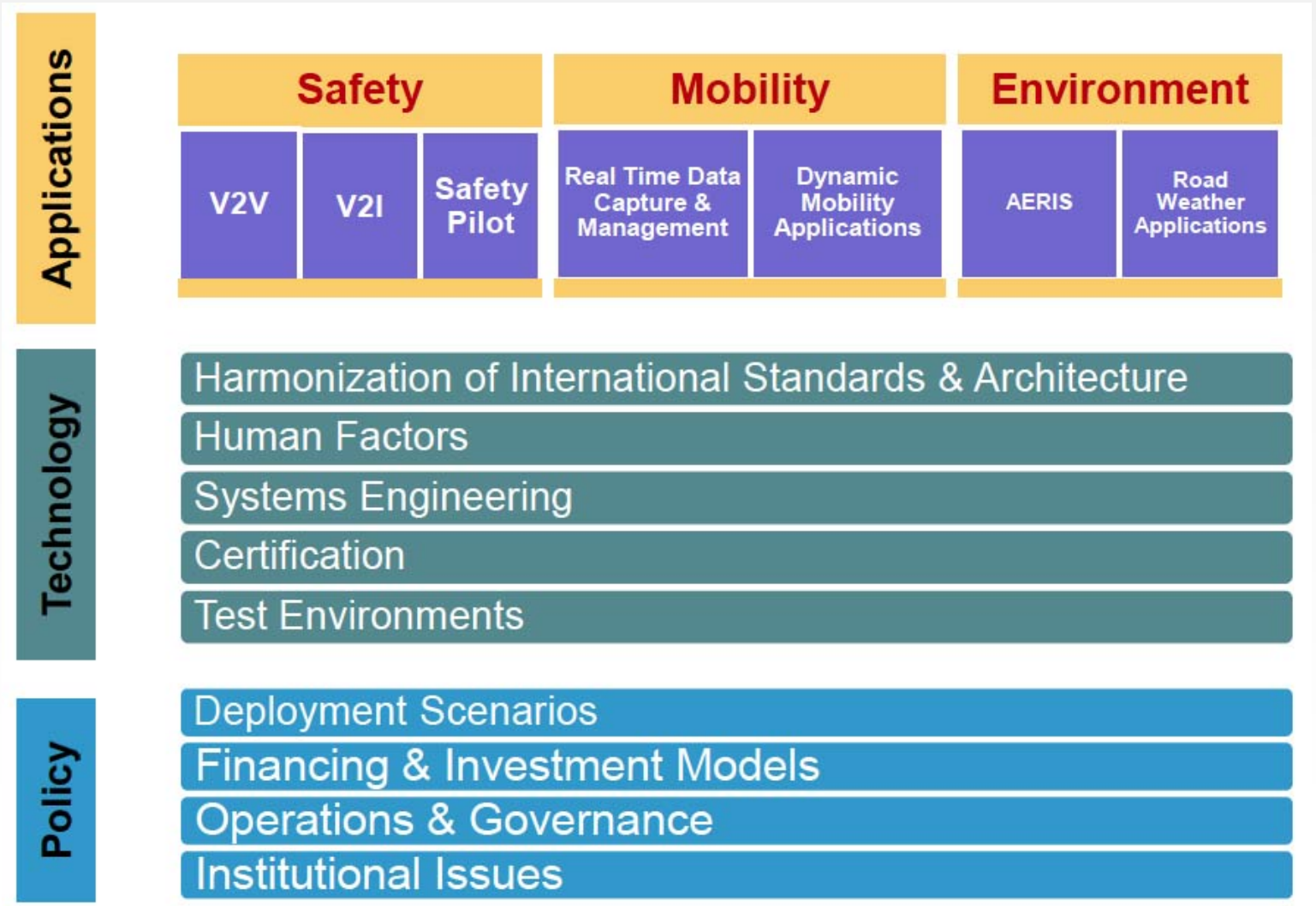
Eco-Signal Operations



Source: USDOT, November 2013

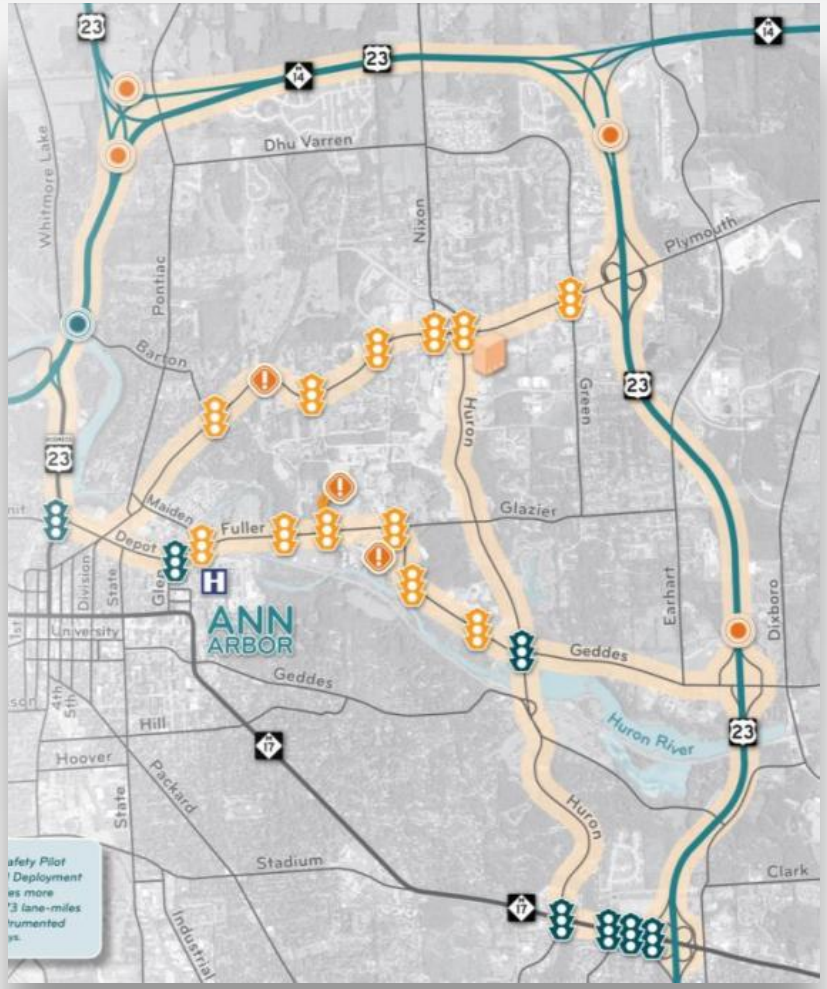
Connected Vehicle Research

USDOT's Connected Vehicle Research Program



Safety Pilot: Ann Arbor, MI

- The purpose of the Ann Arbor test bed was to gather 1 year of data to support the NHTSA decision.
- Assets
  - More than 2,800 vehicles (cars, commercial trucks, transit)
  - Integrated Safety Systems, Vehicle Awareness Devices, and Aftermarket Safety Devices
  - 73 lane miles of roadway instrumented with 29 roadside-equipment installations



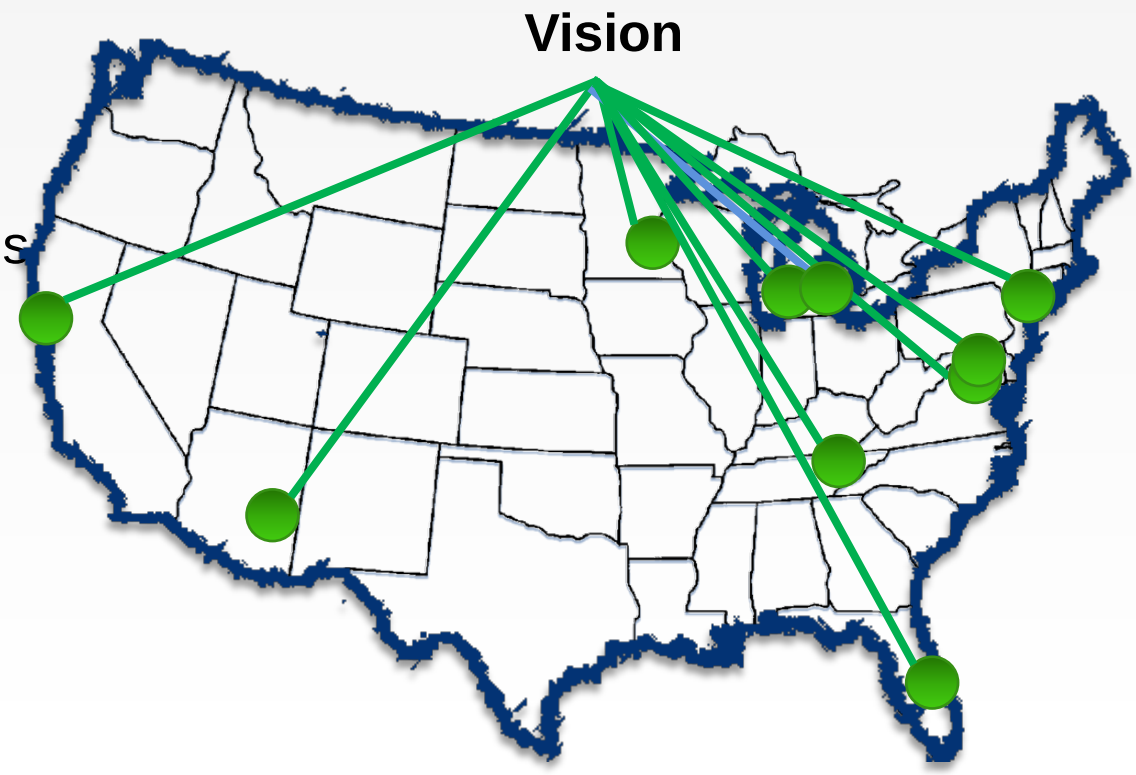
Source: U.S. DOT/UMTRI

Safety Pilot: Ann Arbor, MI

- Applications that were tested include:
  - Forward Collision Warning
  - Electronic Emergency Brake Lights
  - Blind Spot Warning/Lane Change Warning
  - Intersection Movement Assist
  - Do Not Pass Warning
  - Left Turn Assist

A Path to Multiple Operational Systems – Affiliated Test Beds

- The vision is to have multiple interoperable locations as part of one connected system moving toward nation-wide deployment.
  - Common architecture
  - Common standards
  - Independent operations
  - Shared resources



Key Objectives of the Affiliated Test Beds

- Harness the abilities of existing researchers and installations to move the technology toward full deployment.
  - Create an organizational structure
  - Share deployment lessons learned
  - Develop a common technical platform
  - Expand test bed options for users
  - Share tools and resources across all facilities
  - Serve as models for future deployments

USDOT Connected Vehicle PlugFests

- Events where devices are tested for interoperability with emerging standards.
- Provide essential feedback to standardization organizations as well as to the developer community.
- Events in 2014:
  - Midwestern PlugFest: March 12-13, 2014, Novi, MI
  - Western PlugFest: June 2014, Palo Alto, CA
  - Bimonthly World Congress Mini-Fests tentatively scheduled for:
    - May 2014 – Novi, MI
    - July 2014 – Detroit, MI
    - Mid-August 2014 – Detroit, MI
  - Hackathon: Early November 2014/January 2015, Novi, MI

Connected Vehicle Pilot Deployment Program

- Synergy among technologies, messages, and concepts
- In pre-deployment development since July 2013
  - First wave of deployments in 2015
  - Program runs through 2020
- Pilots will be *pilot deployments*, that is, real-world environment
  - If successful, deployed technologies are expected to remain as permanent operational elements
- There will be *multiple* pilot deployment sites across the nation
  - Each site may have different needs, focus and applications
  - Performance-driven deployment concepts will *address integrated objectives* related to mobility, safety, and environmental impacts
  - Sites will deploy *multiple applications* drawing on current research

Example Application Bundle to Explore in CV Pilots

- Eco-Traffic Signal Timing
- Dynamic Parking Guidance

Reduced Emissions
Reduced Fuel Consumption

- Enhanced Maintenance Decision Support

Reduced public agency spending

Increased Transit Use

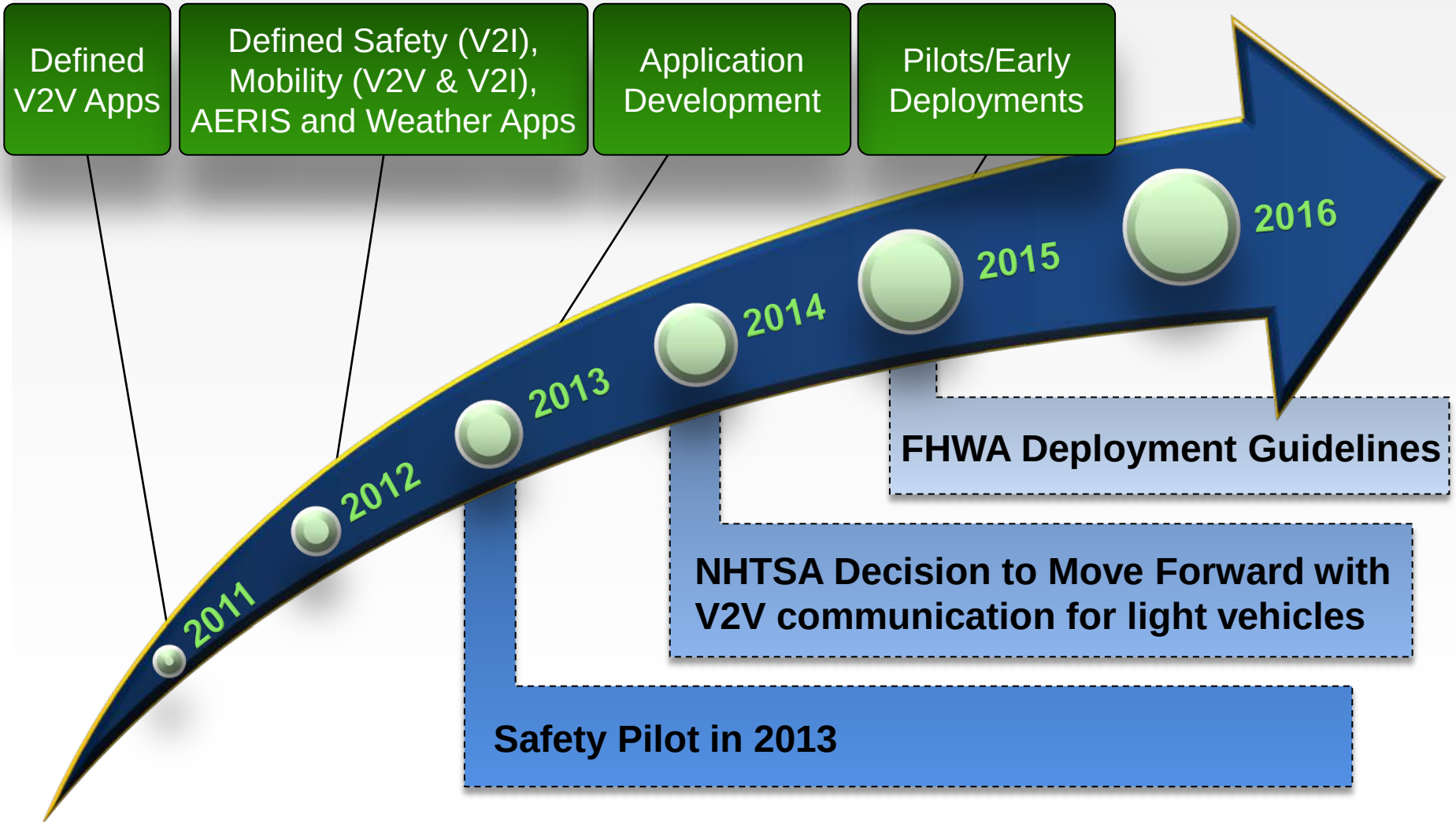
- Transit Connection Protection

Reduced Emissions from Idling at Ports

- Drayage Optimization

Deployment of Connected Vehicle Technology

Path to Deployment



USDOT/NHTSA Decision on V2V

- Announced on February 3, 2014 for light vehicles
  - Primary purpose: enable collision warnings to drivers prior to a crash
  - Based on several years of research including the safety pilot model deployment – 3000 vehicle road test in Ann Arbor, Michigan
    - Report pending
  - Security and privacy protections built into contemplated system
    - No exchanging or recording of personal information
    - No tracking of vehicle movements
  - After circulating the research report for public comment, NHTSA will then begin working on a regulatory proposal to require V2V devices in new light vehicles in a future year
  - Decision on heavy vehicles planned at end of 2014

Infrastructure Deployment Planning

- National Connected Vehicle Field Infrastructure Footprint Analysis
- Standardized interfaces
- Certification processes for equipment and systems
- Nationwide Security Credential Management System (SCMS)

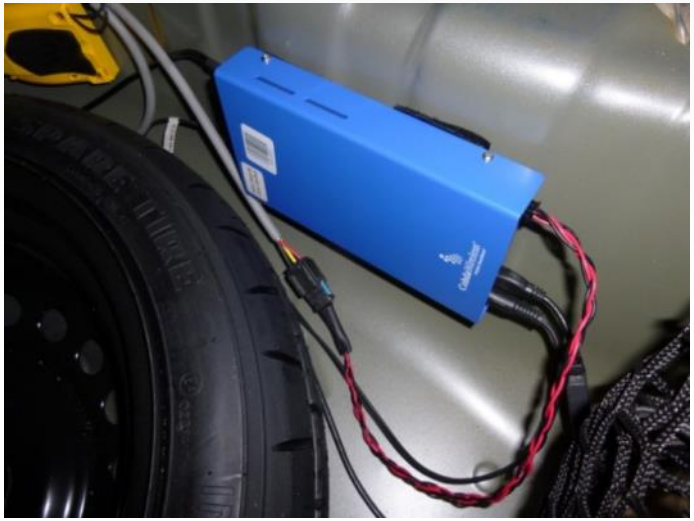
2015 FHWA Deployment Guidance

Deployment Challenges

- Aftermarket Devices
- Security
- Privacy
- Spectrum Demands
- Communications Congestion Potential

Aftermarket Devices

- Developed and demonstrated devices that can bring the technology to the existing vehicle fleet in Safety Pilot Model Deployment
  - Aftermarket Safety Devices (Light Vehicles)
  - Vehicle Awareness Devices (Light Vehicles)
  - Retrofit Safety Devices (Trucks/Buses)
- Aftermarket devices allow for the acceleration of benefits

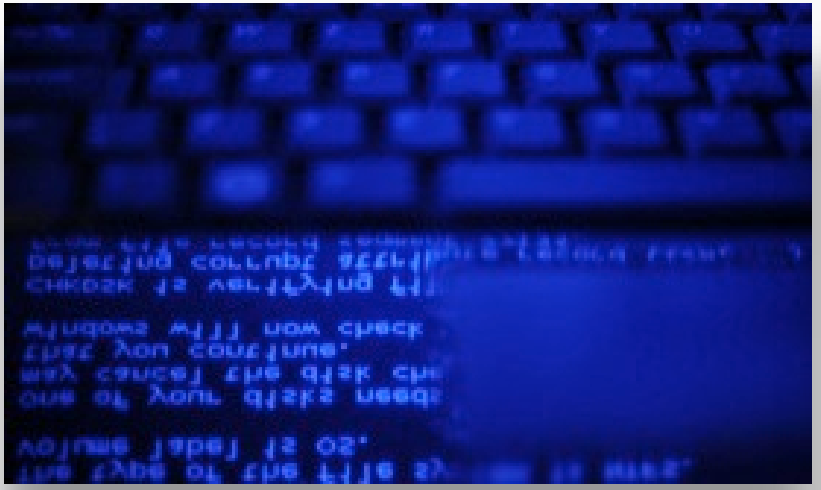


Security Challenges

- Message validity
- Security entity
- Network
- Business models for security operations

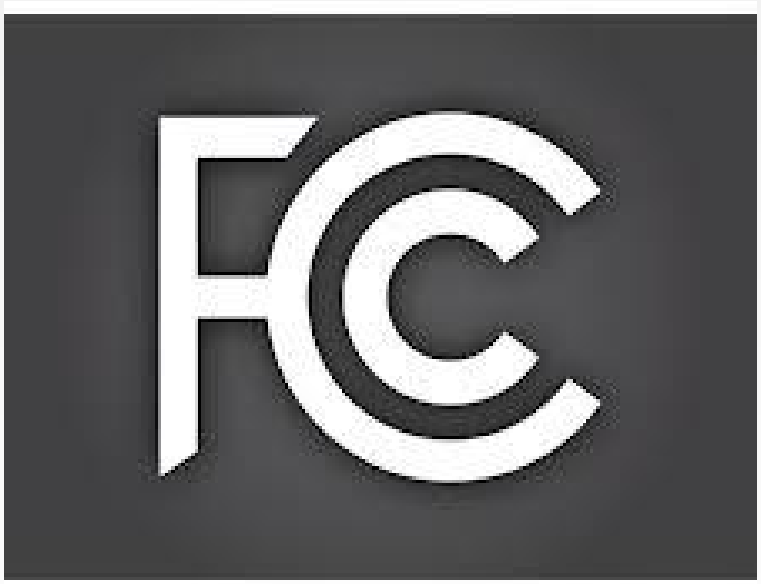
Privacy Challenges

- A user cannot be tracked along his journey or identified without appropriate authorization.
- User privacy can be protected further through policy means. We've done initial privacy analysis of the system and will have privacy experts do a comprehensive review of any final system proposed for implementation.



5.9 GHz Spectrum Issue

- **Federal Communication Commission's (FCC) Notice of Proposed Rulemaking (NPRM**); The FCC is seeking to open up additional spectrum for unlicensed Wi-Fi devices within the 5.9 GHz band which serves as the platform for connected vehicle technology.
- **5.9 GHz Spectrum:** The connected vehicle environment that is being researched is based on reliable access to the 5.9 GHz wireless spectrum.
- **Spectrum Sharing:** Any changes to the 5.9 GHz spectrum may jeopardize crash avoidance capabilities.

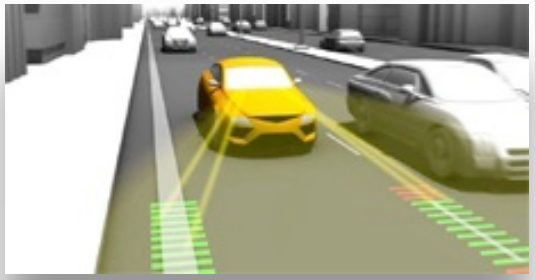


Communications Scalability

- Ensure that V2V safety communication protocol(s) that will support large-scale deployment level of vehicles while preserving the performance of V2V safety applications in congested environments
- Tested impacts of 100, 200, and 400 devices all transmitting on the safety applications
- Developing simulations to estimate impacts of larger numbers of devices all within communication range.

Exploratory Research

- Vehicle to Motorcycle
- Vehicle to Pedestrian
- Vehicle Automation
  - Can proceed independently of connectivity to a point
  - Greatly enhanced with connectivity to other vehicles and infrastructure
- Benefits of Connectivity
  - Increases availability, speed, and reliability of information
  - Enables coordination of automated traffic streams



The full potential benefits of road vehicle automation can only be achieved through a connected environment

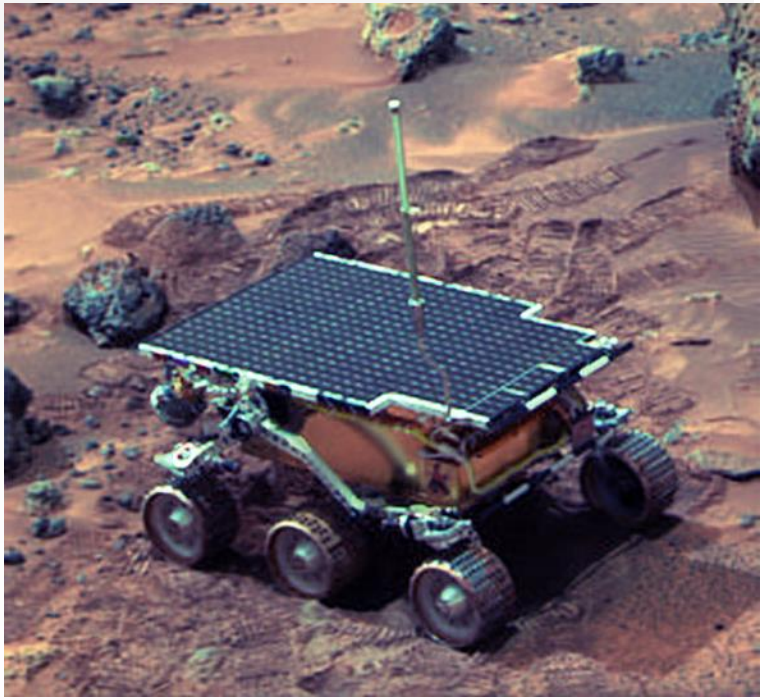
Source: Continental Automotive Group

Vehicle Automation Research

Some Previous Federal Automated Vehicle Programs

Summer of 1997…

Buicks in San Diego

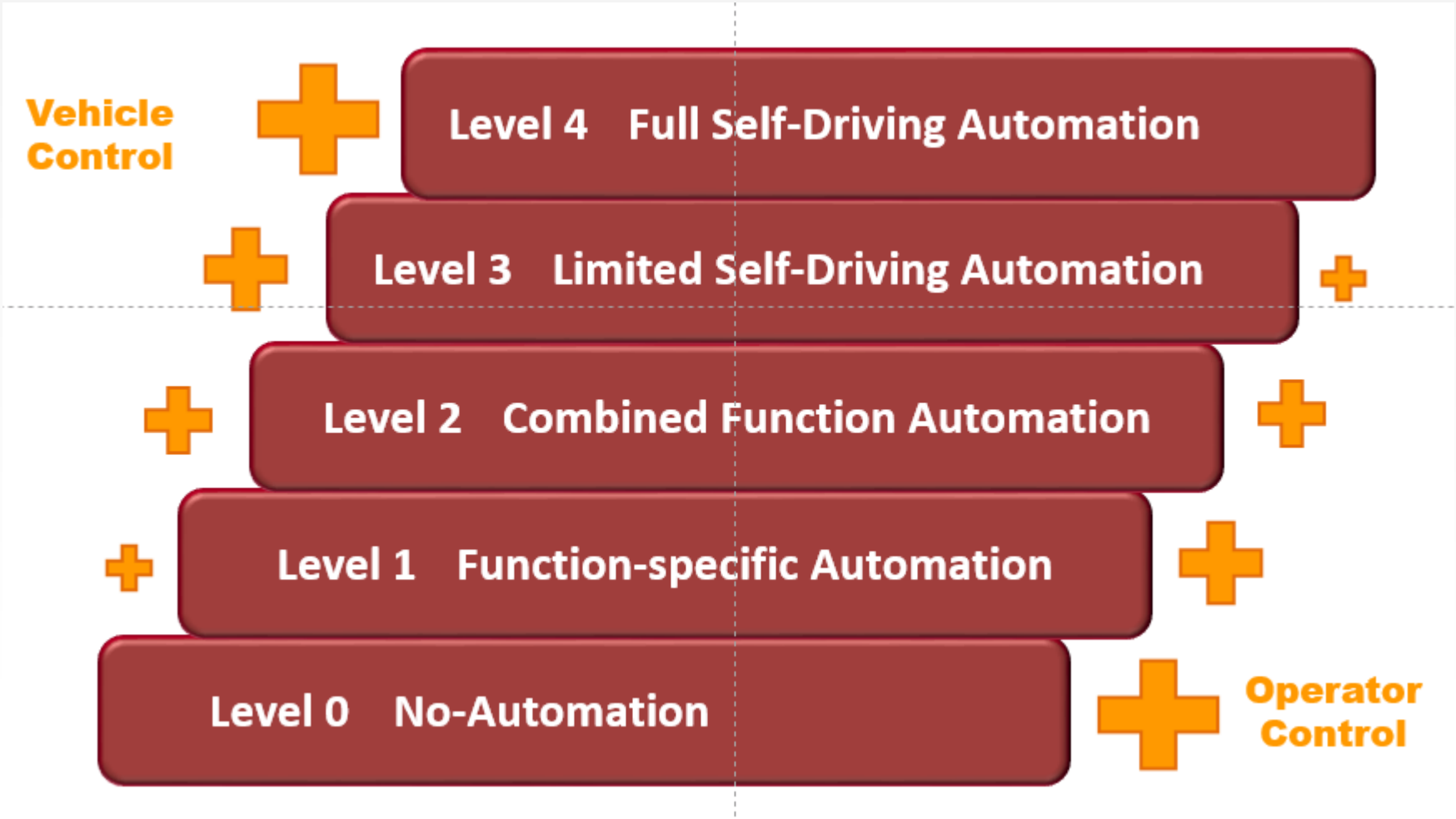


Sojourner in Ares Vallis

Automation - Role of the Federal Government

- Facilitate development and deployment of automated transportation systems that enhance safety, mobility, and sustainability
- Identify benefit opportunities in automated vehicle technology
- Invest in research areas that further industry investments and support realization of benefit opportunities
- Establish Federal Motor Vehicle Safety Standards (NHTSA)
- Ensure a safe transitional period during mixed traffic operations

NHTSA Levels of Automation



Connected and Automated Vehicles

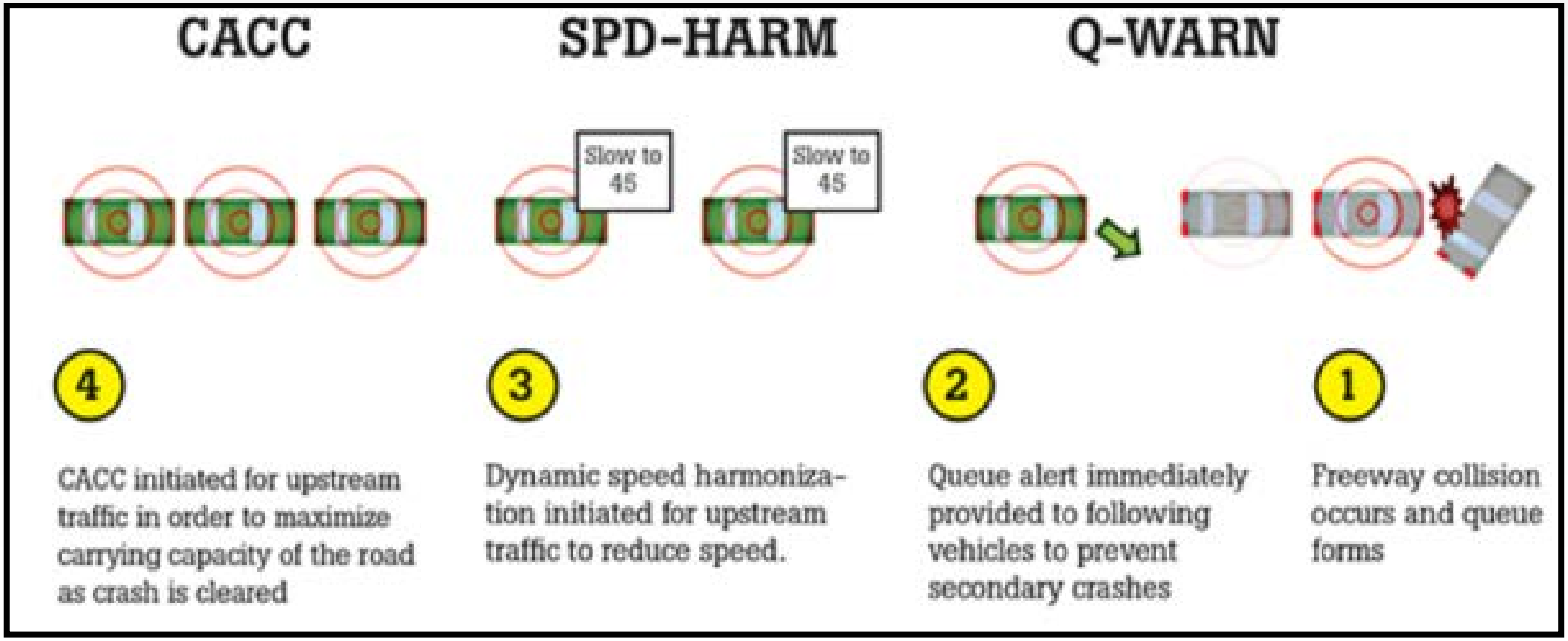
Autonomous Automated Vehicle
Operates in isolation from other vehicles using internal sensors

Connected Automated Vehicle
Leverages autonomous automated and connected vehicles

Connected Vehicle
Communicates with nearby vehicles and infrastructure
Not automated (level 0)

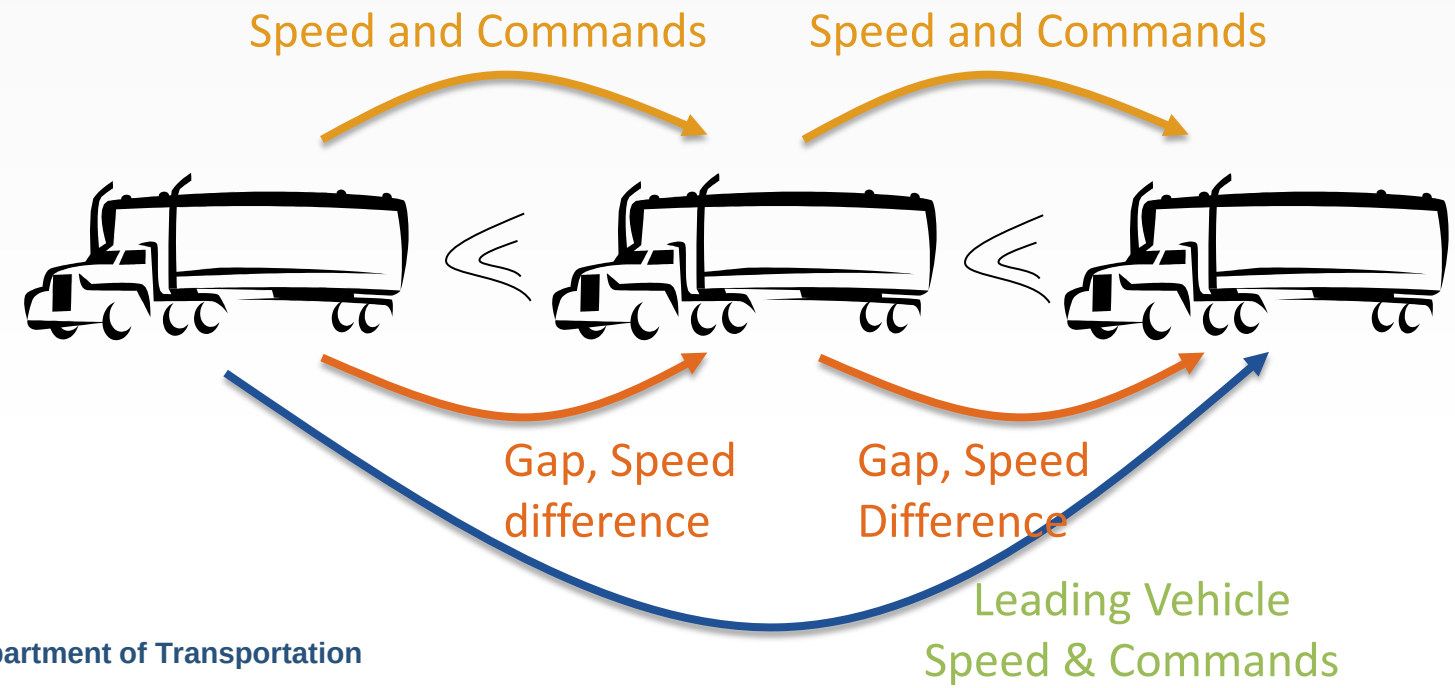
L1 example: Integrate CACC with applications

- Driver advisory and warning applications (presented earlier) with limited control functionality added.



L1 Example: Truck Platooning Research

- Three truck platoon
- 5.9 GHz DSRC Communication
- Longitudinal control only (throttle and brakes) driver, steers the truck
- Vehicles already equipped with production ACC
- Lead truck either manually or automatically (ACC) driven
- Gap is based on time headway – consistent with driver preference



L2/L3 Example: Human Factors Research

Project Objective

- Addresses human factors research questions focused on drivers transitioning into and out of automated driving states enabled by Level 2 and Level 3 automated driving concepts.

Project Deliverable

- Driver-Vehicle Interface Design Principles

Virginia Tech Transportation Institute
Battelle Bishop Consulting GM Google SwRI

Summary

- Connected vehicle technologies have been extensively tested
- Large potential safety benefits
- DSRC radios in all new cars in a few years
- Options for other vehicles and pedestrians
- Partial connected automation offers near term safety, mobility and environmental benefits.
- Research continuing toward vision of fully automated vehicle operations

Questions / Follow-up

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