UNITED STATES
DEPARTMENT OF TRANSPORTATION

Connected Vehicle Program 101

April 21, 2013

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Intelligent Transportation Systems Joint Program Office
Research and Innovative Technology Administration, USDOT

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Overview

- Introduction
- Connected Vehicle Implementation Concepts
- Connected Vehicle Applications
- Affiliated Test Beds Lessons Learned
- Connected Vehicle Implementation Issues
- Discussion: What we can do to move Connected Vehicle implementation forward?
- Wrap up

I. Introduction to Connected Vehicle

Today's Transportation Challenges

LIMIT 35

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

Data Sources:
Traffic Safety Facts: 2010 Data, National Highway Traffic Safety Administration (June 2012)
2011 Annual Urban Mobility Report, Texas Transportation Institute (Feb 2013)

Solving Transportation Issues Through Greater Situational Awareness

Drivers/Operators

Vehicles and Fleets

Infrastructure

Connectivity

Wireless Devices

Opportunity for Safer Driving

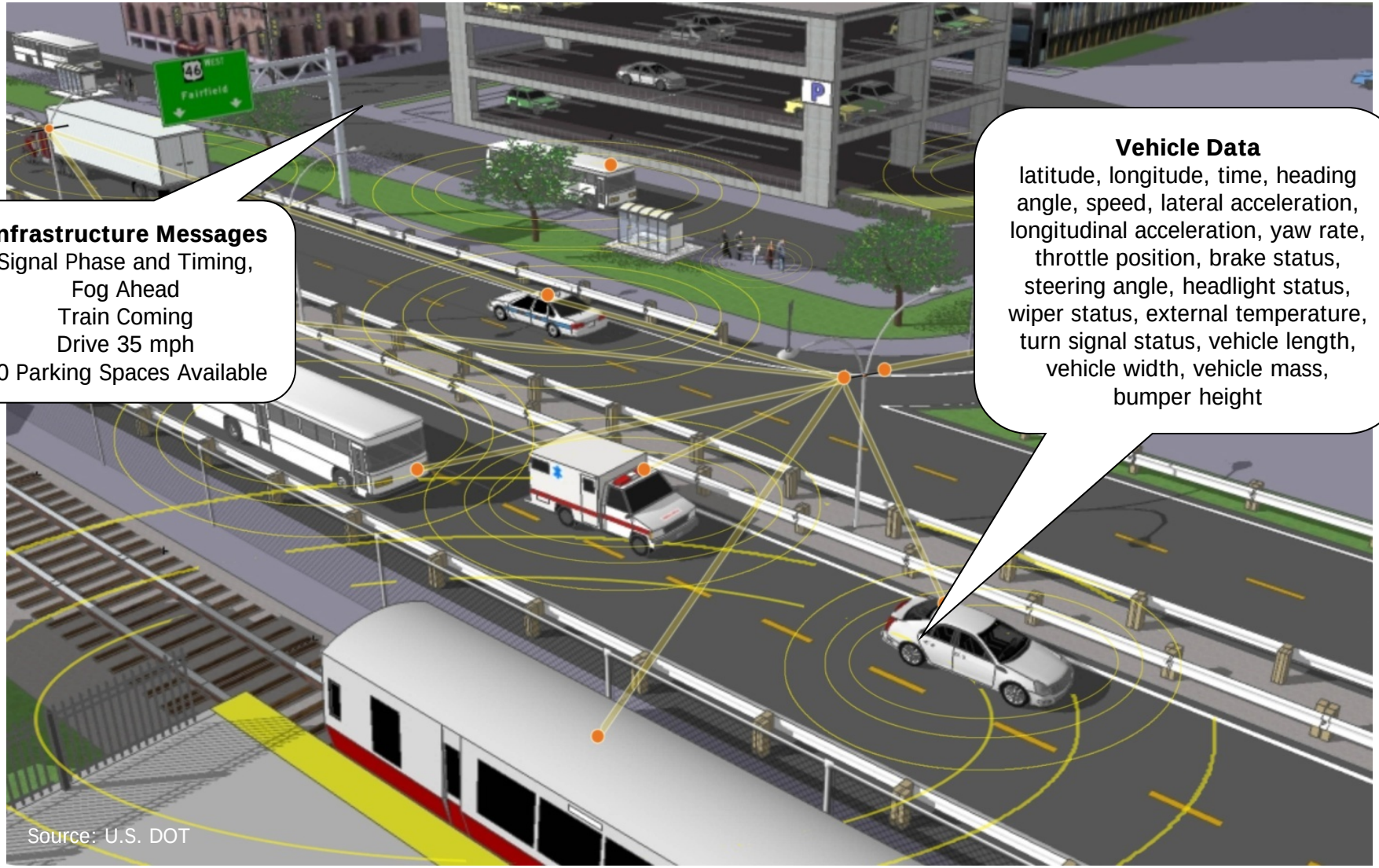
- Greater situational awareness
  - Your vehicle can “see” nearby vehicles and knows roadway conditions you can’t see
  - 360 degree “visibility”
- Reduce or even eliminate crashes thru:
  - Driver Advisories
  - Driver Warnings
  - Vehicle Control

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

Key Program Objectives

- 2013 Decision on Vehicle Communications for Safety (light vehicles)
- 2014 Decision on Vehicle Communications for Safety (heavy vehicles)
- 2015 Infrastructure Implementation Guidance

Fully Connected Vehicle



Infrastructure Messages
Signal Phase and Timing,
Fog Ahead
Train Coming
Drive 35 mph
50 Parking Spaces Available

Vehicle Data
latitude, longitude, time, heading angle, speed, lateral acceleration, longitudinal acceleration, yaw rate, throttle position, brake status, steering angle, headlight status, wiper status, external temperature, turn signal status, vehicle length, vehicle width, vehicle mass, bumper height

Source: U.S. DOT

Connected Vehicle Technology – 5.9 GHz DSRC

Image Source: USDOT

- **What it is**
  - 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
- **How the technology works**
  - Messages transmitted 10 times/sec (300m range – line of sight)
    - Basic Safety Message: vehicle position, speed, heading, acceleration, size, brake system status, etc.
    - Privacy is protected (vehicle location is NOT recorded or tracked)
- **Benefits of DSRC technology compared to radar/laser technology**
  - Reduced price
  - Improved reliability → fewer false alarms
  - Increased performance → addresses more crash scenarios
- **Drawbacks of the technology**
  - Both vehicles need to be equipped to gain benefit
  - Requires security infrastructure

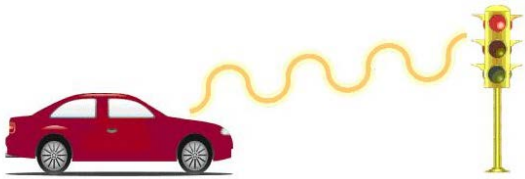
Safety Applications

V2V

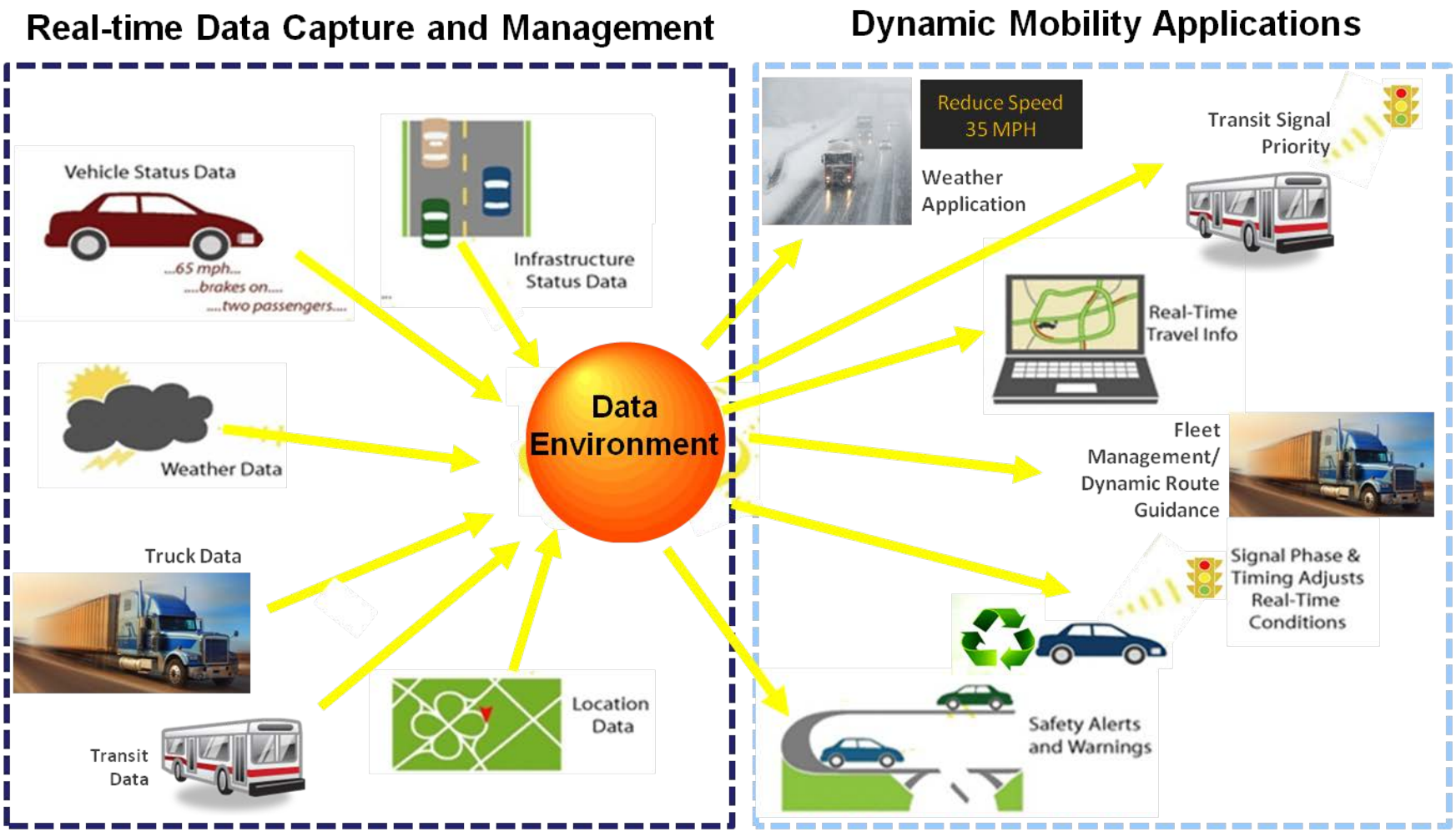
- Forward Collision Warning (FCW)
- Emergency Electronic Brake Light (EEBL)
- Blind Spot/Lane Change Warning (BSW/LCW)
- Do Not Pass Warning (DNPW)
- Intersection Movement Assist (IMA)
- Left Turn Assist (LTA)

V2I

- Curve Speed Warning (CSW)
- Red Light Violation Warning (RLVW)
- Stop Sign Gap Assist (SSGA)
- Smart Roadside
- Transit Pedestrian Warning



Mobility Applications



Environmental Applications

- **Eco-Signal Operations**
  - Eco-Approach and Departure at Signalized Intersections*, *DSRC*
  - Eco-Traffic Signal Timing*
  - Eco-Traffic Signal Priority*, *DSRC*

- **Dynamic Eco-Lanes**
  - Dynamic Eco-Lanes Management*
  - Eco-Speed Harmonization*
  - Eco-Cooperative Adaptive Cruise Control*, *DSRC*
  - Eco-Ramp Metering*

- **Dynamic Low Emissions Zones**
  - Dynamic Emissions Pricing*

Notes

* *Denotes Application requiring V2I Communication*

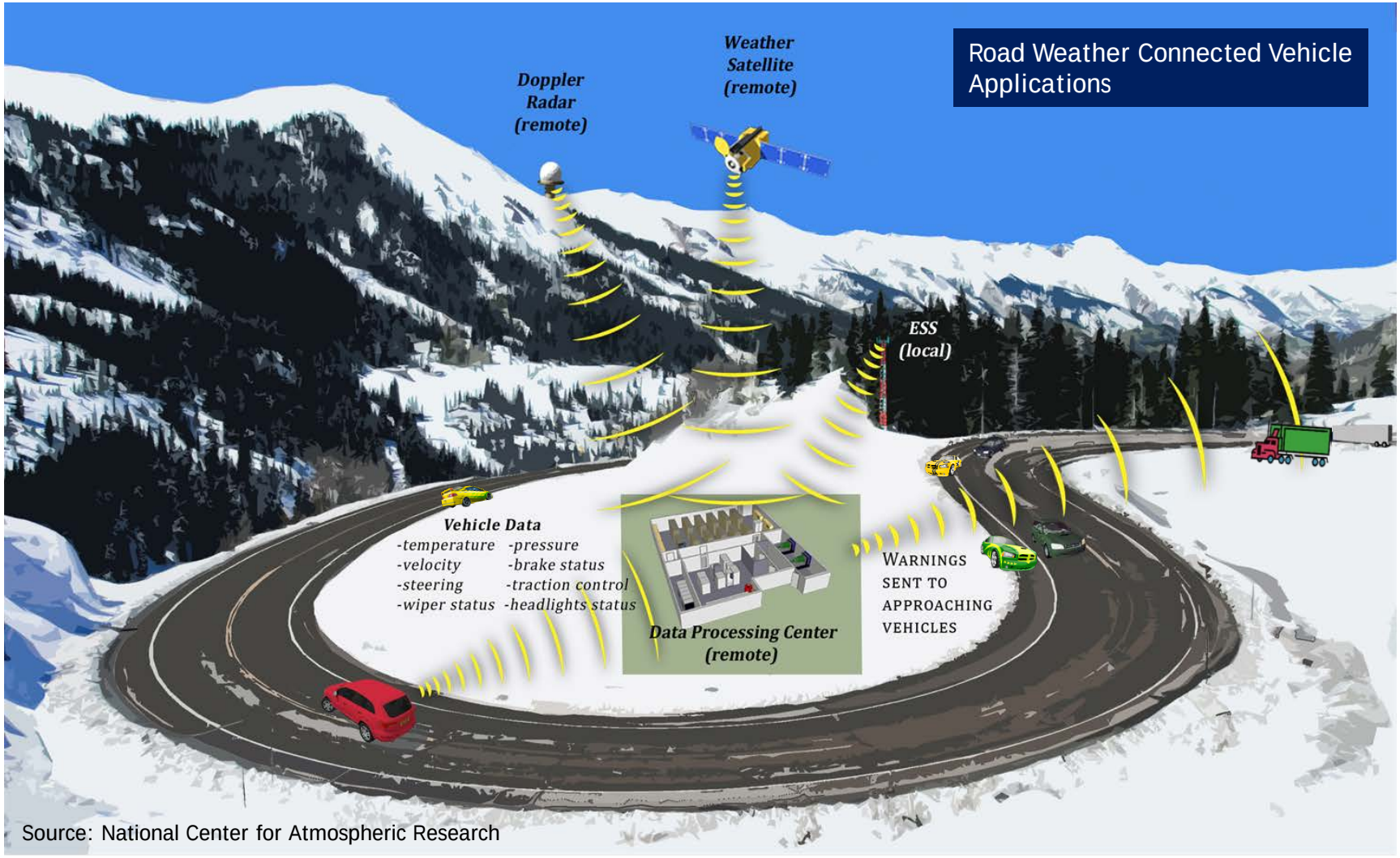
DSRC *Denotes Applications Requiring Dedicated Short Range Communications (DSRC) or Other Low Latency Communications*

- **Support for Alternative Fuel Vehicle Operations**
  - Engine Performance Optimization
  - Alternative Fuel Vehicle (AFV) Charging / Fueling*

- **Eco-Traveler Information**
  - Dynamic Eco-Routing*
  - Eco-Smart Parking*
  - Connected Eco-Driving *DSRC*
  - Multi-Modal Traveler Information*

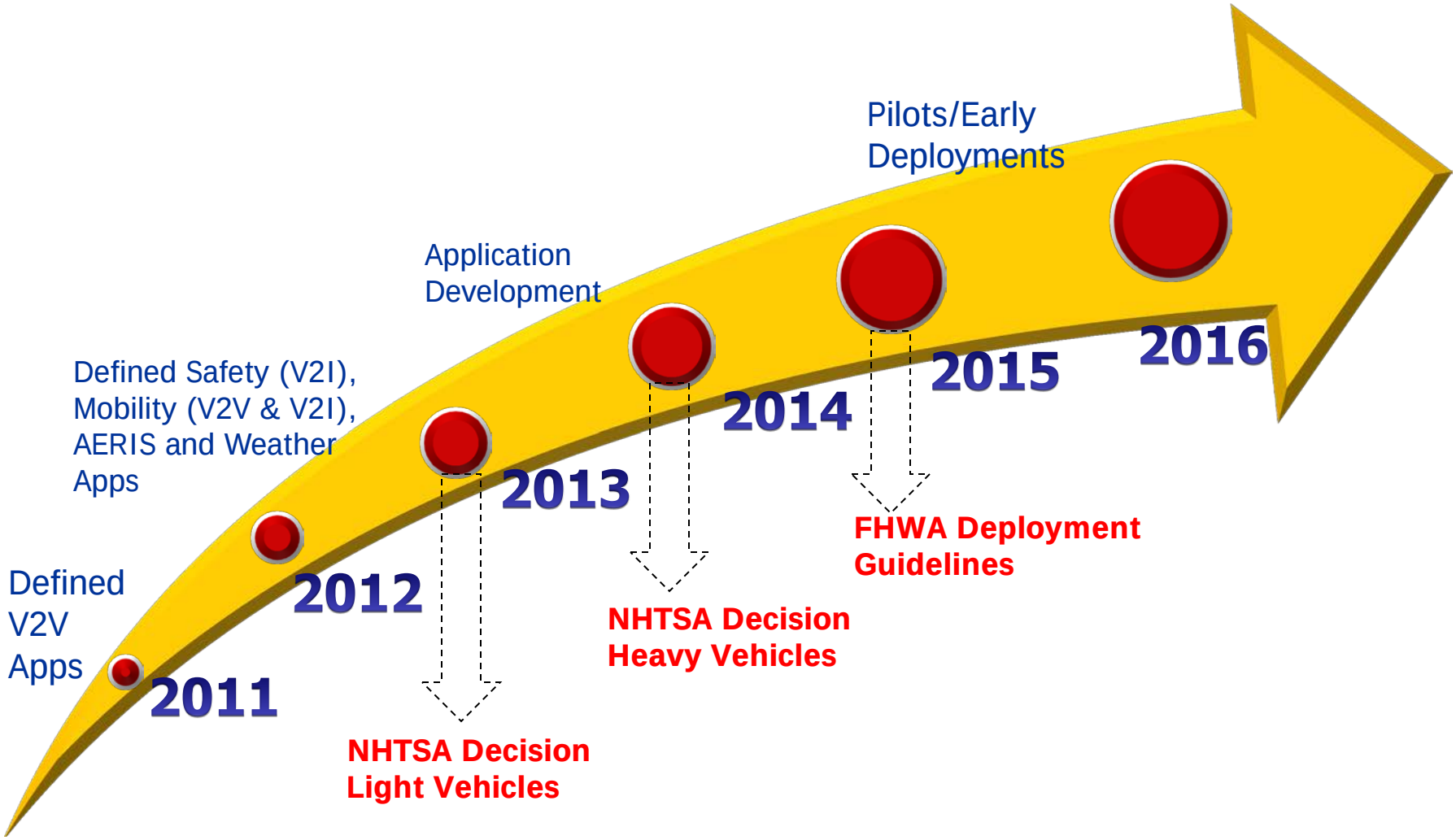
- **Eco-Integrated Corridor Management (Eco-ICM)**
  - Eco-ICM Decision Support System
  - *Applications from the Other Transformative Concepts*

Connected Vehicles & Road Weather: Illustrative Concept



Source: National Center for Atmospheric Research

Moving Towards Deployment



Safety Pilot Model Deployment

- ~2,800 vehicles (cars, buses, and trucks) equipped with V2V devices
- Provide data for determining the technologies' effectiveness at reducing crashes
- Includes vehicles with integrated safety applications and others that use aftermarket devices (i.e., not built into the vehicle)
- Applications to be 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

Photo Source: UMTRI

Photo Source: UMTRI

Infrastructure Deployment Planning

- 2015 FHWA Deployment Guidance
- National Cooperative Highway Research Program (2013 completion)
  - Benefit Cost Analysis for state and local DOTs, including funding options
  - DSRC deployment guidance for state DOTs
- National Connected Vehicle Field Infrastructure Footprint Analysis (AASHTO led, 2014 completion)
- Standardized interfaces
- Certification processes for equipment and systems
- Nationwide Security Credential Management System (SCMS)
- USDOT is working with state and local DOTs and private industry to plan for deployment

Photo Source: U.S. DOT

Photo Source: Thinkstock

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

Source: ThinkStock

Source: U.S. DOT

Source: Continental Automotive Group

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

Video

http://clips.shadowtv.net/media/download/20121012115800/NBCToday8-21-2012-7AM-USDOT.mov

II. Connected Vehicle Implementation Concepts

Research Towards Implementation

Connected Vehicle Research

- *Multi-modal, transformational applications*
- *Requires a robust, underlying technological platform:*
  - *well-defined technologies,*
  - *interfaces,*
  - *and processes*
- *Goal to deploy stable, interoperable, reliable systems*

ITS Research Program Components

Applications

Safety			Mobility		Environment	
V2V	V2I	Safety Pilot	Real Time Data Capture & Management	Dynamic Mobility Applications	AERIS	Road Weather Applications

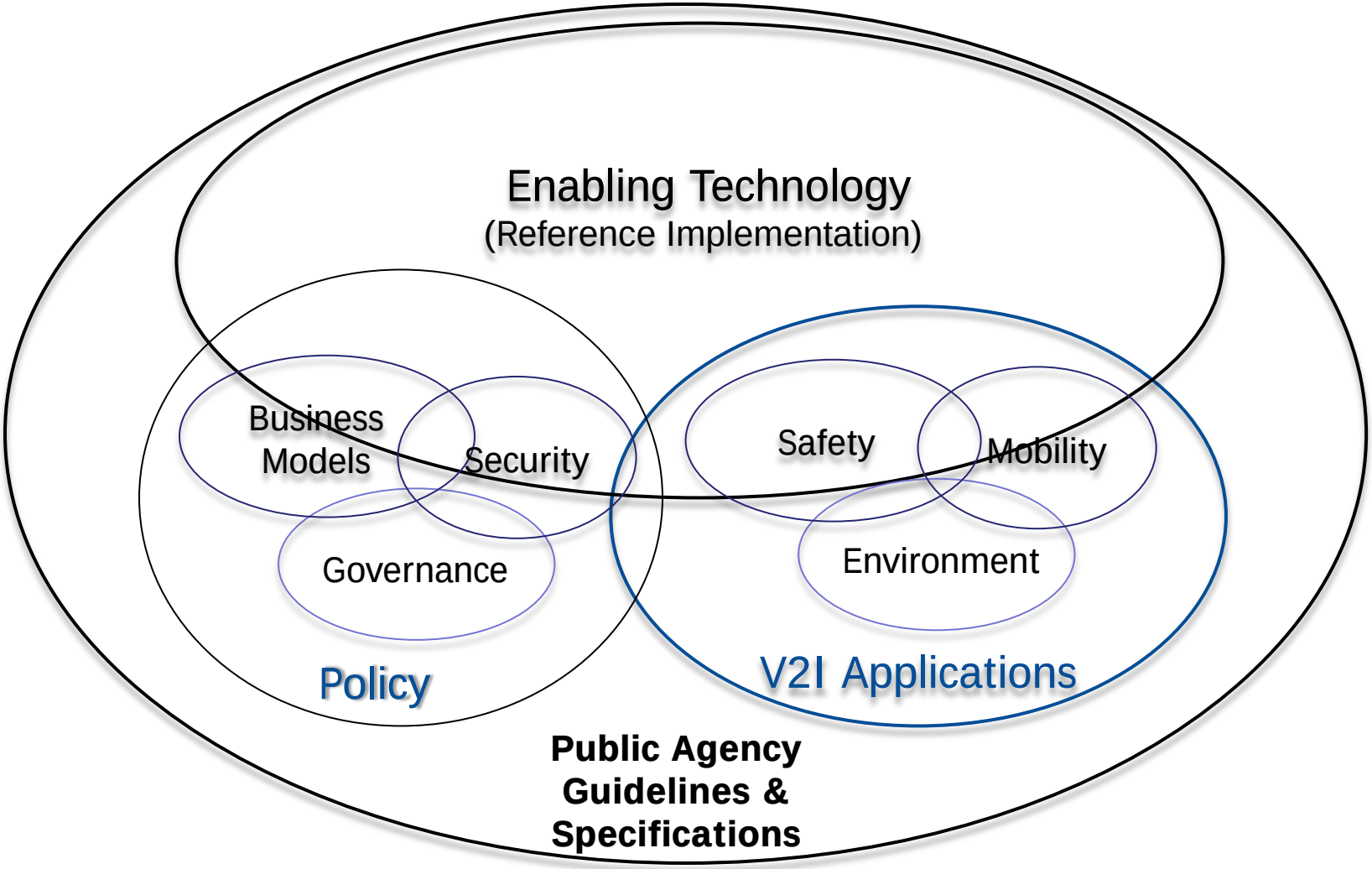
Technology

- Harmonization of International Standards & Architecture
- Human Factors
- Systems Engineering
- Certification
- Test Environments

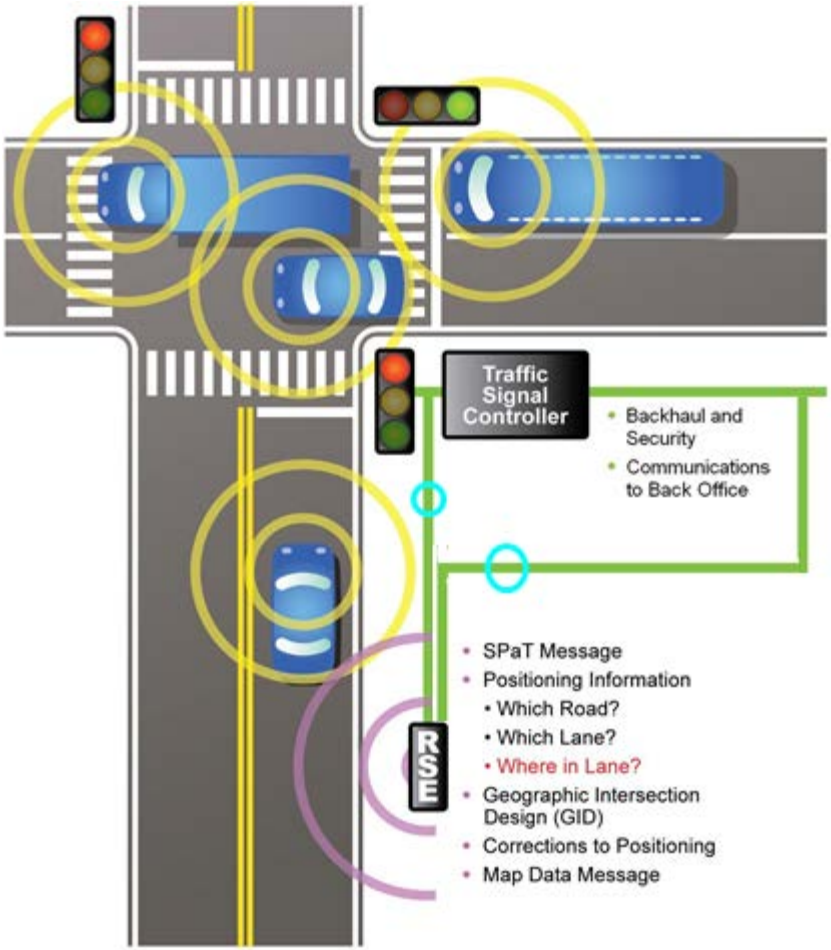
Policy

- Deployment Scenarios
- Financing & Investment Models
- Operations & Governance
- Institutional Issues

V2I Communications – Major Activities



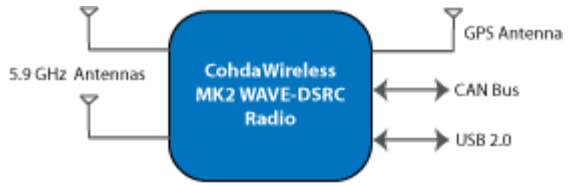
Enabling Technologies - Role of Standards in Connected Vehicles

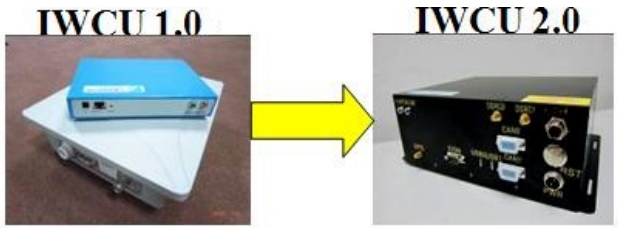


- Interface Standards are essential
- USDOT working with public and private sector to define:
  - Communications standards for DSRC
  - Other media, e.g., 4G LTE and/or HD radio may be used for appropriate applications
  - Information Exchange Standards
    - Message Sets for V2X
    - Minimum performance requirements for V2X messaging
    - Signal controller messages

Enabling Technologies - Role of Equipment in Connected Vehicles

Multiple vendors are developing interoperable infrastructure equipment.





IWCU:ITRI WAVE/DSRC Communication Unit

- USDOT testing devices for placement on the *Research Qualified Products List (rQPL)*
- Five RSE's are currently on the list:
  - Arada Systems
  - Cohda Wireless/Cisco Systems
  - Kapsch TrafficCom, Inc.
  - Savari Networks
  - Industrial Technology Research Institute (ITRI)
- Other connected vehicle test beds encouraged to use equipment from the rQPL list
- Results from Safety Pilot and Integrated V2I Prototype development will be used to develop a V2I Reference Implementation

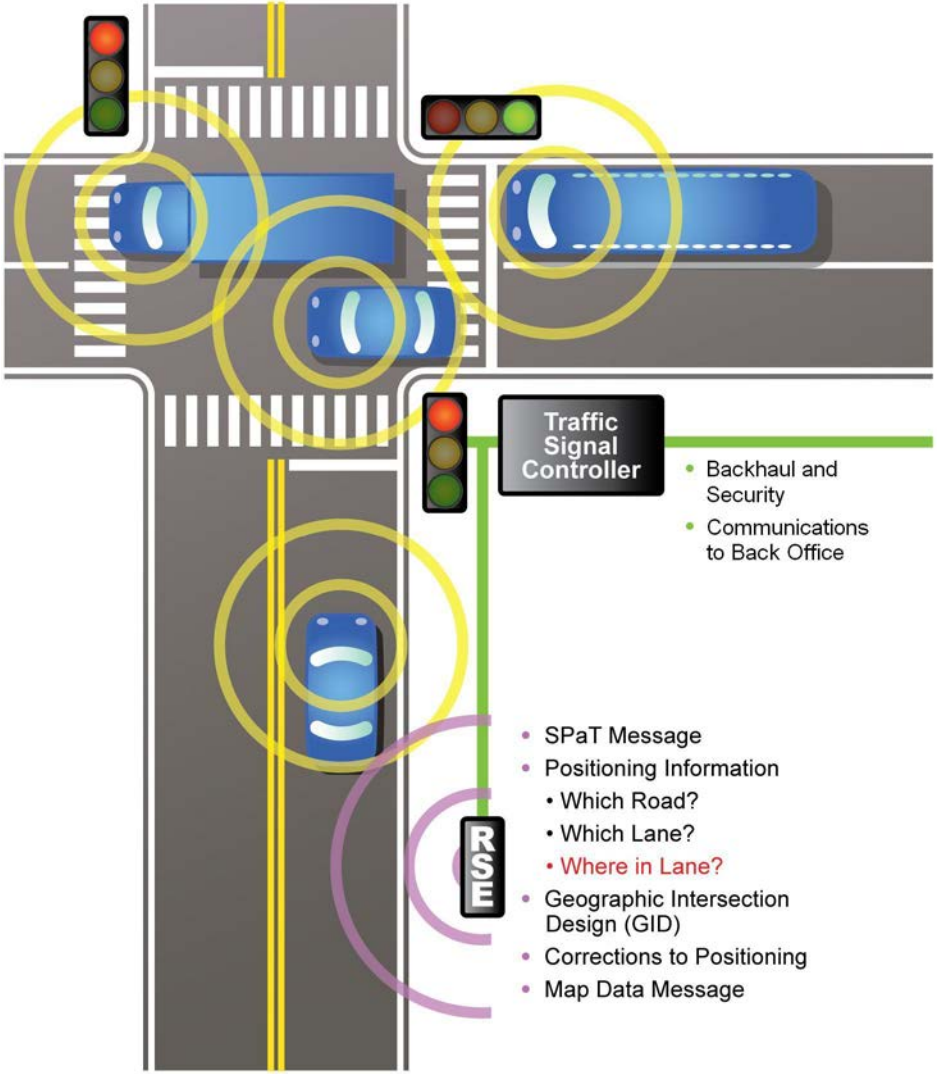
Enabling Technologies - Role of Data in Connected Vehicles

Information exchange is key: One set of data, many applications.

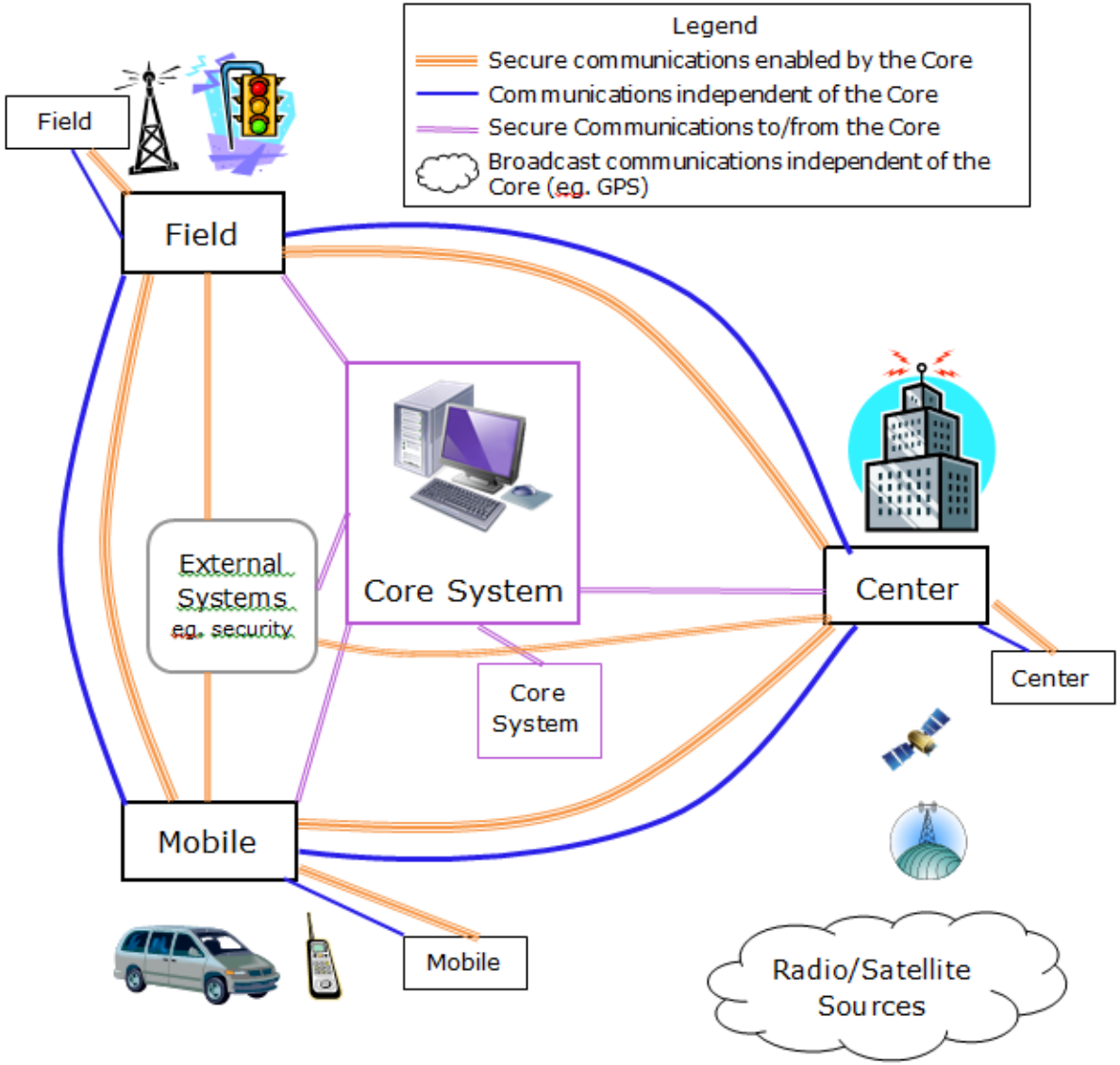
- V2I Communications Support Safety, Mobility, and Environmental Applications
  - Signal Phase and Timing data supports red light violation warning (safety), arterial speed harmonization (mobility), and Eco signal operations (environment)
  - The Basic Safety Message, developed for V2V safety applications, also supports the Intelligent Traffic Signal Systems mobility application
  - Probe data supports transportation operations, traveler information, transportation planning and asset management.
- Common functions shared across applications: positioning, mapping, and communications
- Process for Application Testing (e.g., leverage affiliated test beds)

V2I Reference Implementation

- A system of specifications and requirements that allow the various components of V2I hardware, software and firmware to work together.
- An agency will be able to select the capabilities and applications desired at a given installation.



Core System Concept



Core System Benefits

Today's capabilities:

- **Separate agreements** to access data from organizations
- Applications navigate to organizations individually to find accessible data—**slow**
- **Island solutions** – no easy data exchange
- Gains still possible but **some capabilities and functionalities will remain out of reach**

Capabilities with a core system:

- Can request any data **without having a relationship to the data provider** – no need for existing contracts or agreements
- Data is readily **accessible and trusted from multiple sources; rapid access in real-time; and of consistent format/quality**.

Core System Policy Research Questions:

- **Development of policy options:**
  - What is the role of a core system in supporting a connected vehicle environment? Is it necessary or optional?
  - What are the costs? Risks? Opportunities?
  - Will devices, applications, equipment need to be certified to connect with the core? Do specific standards apply?
  - Who will certify that a system meets the requirements to be a core system?
- **Business Case research questions:**
  - Why would any organization want to implement a core system or procure core system services?
  - Can organizations leverage their systems and equipment?
    - Do elements/functions of a core need to remain separate?
    - What is the costs/impact of implementing a core?

Quiz

- Connected Vehicle Implementation Concepts Mythbusters

III. Connected Vehicle Applications

Safety Applications

V2V

- Forward Collision Warning (FCW)
- Emergency Electronic Brake Light (EEBL)
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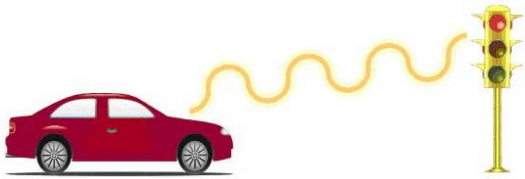
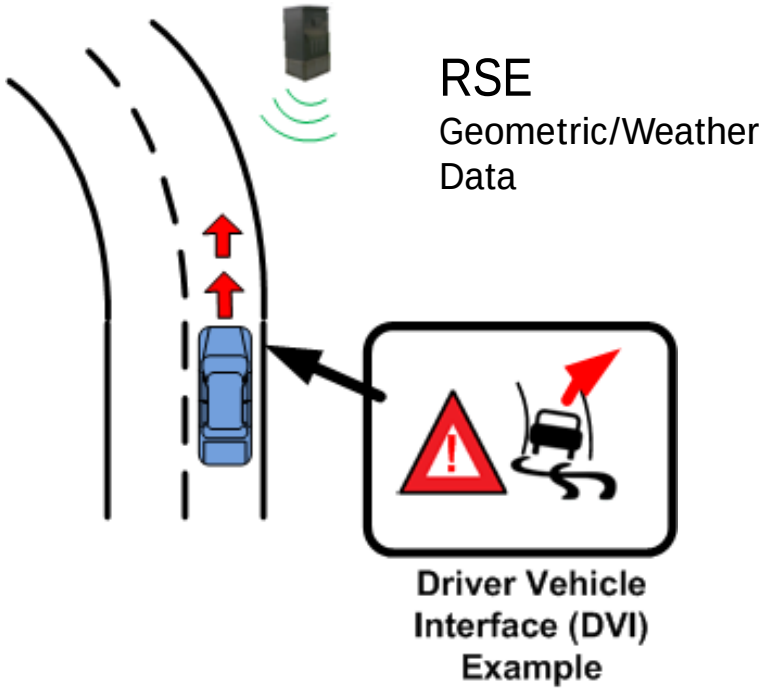


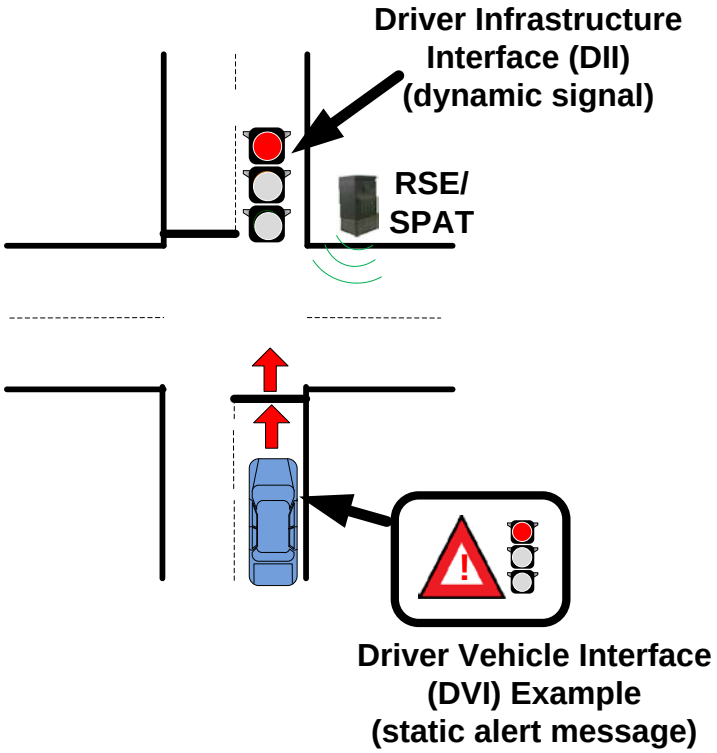
Curve Speed Warning (CSW)

- Roadside Equipment (RSE): broadcast geometric and weather information under a Traveler Information Message (TIM) for use by in-vehicle device.
- In-vehicle Device: determine appropriate speed for that particular vehicle based on TIM. Warnings can be tailored to the specific vehicle capabilities.
- Potentially could be linked to dynamic driver feedback signs until majority of vehicles are equipped.



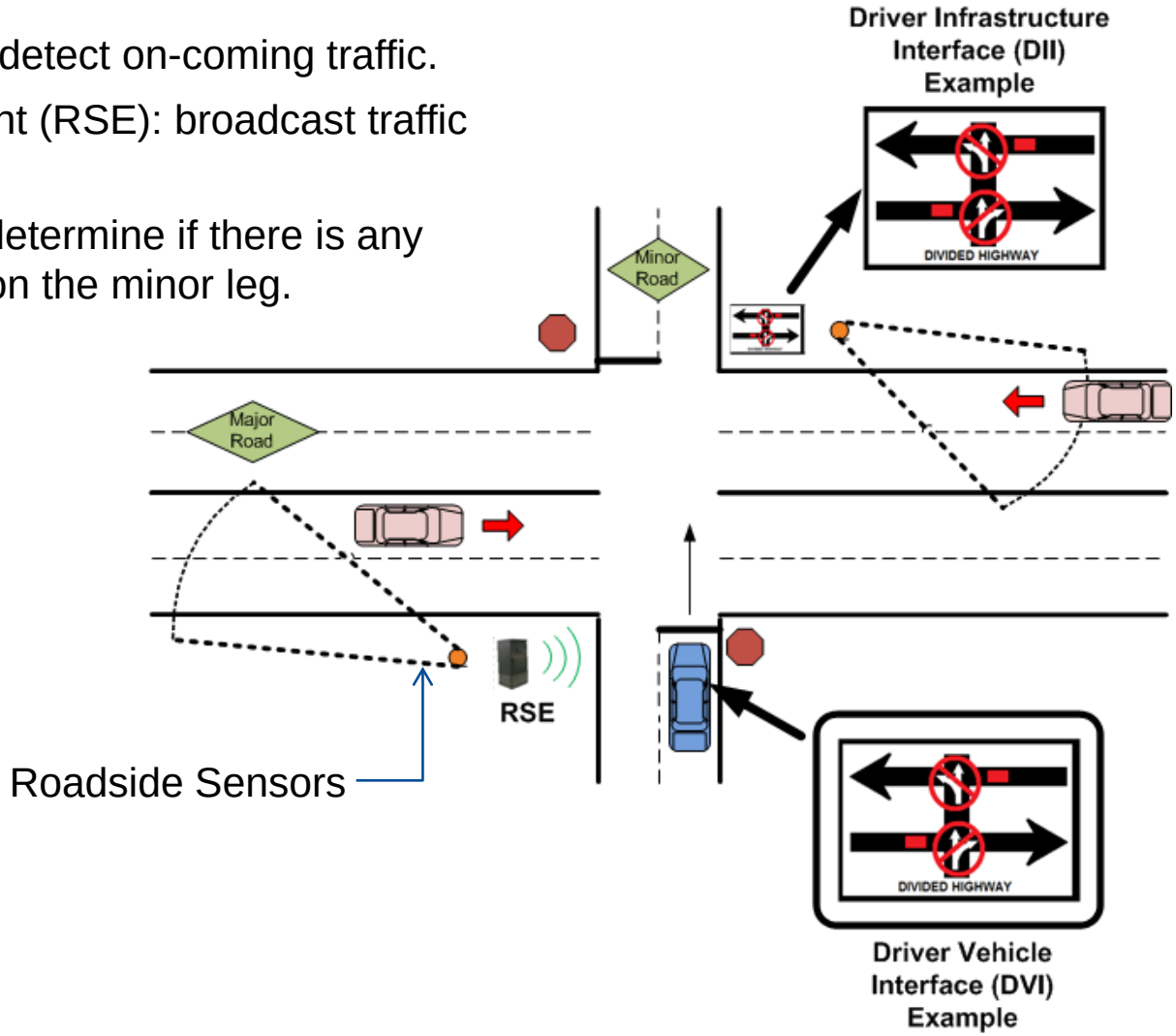
Red Light Violation Warning (RLVW)

- Roadside Equipment (RSE): broadcast Signal Phase and Timing (SPaT) message, Geometric Intersection Description (GID), and GPS correction.
- In-vehicle Device: determine if the vehicle is in danger of violating a red light.
- Traffic signal logic may be evaluated to determine if extension of all-red phase is warranted to prevent crashes involving early violators.



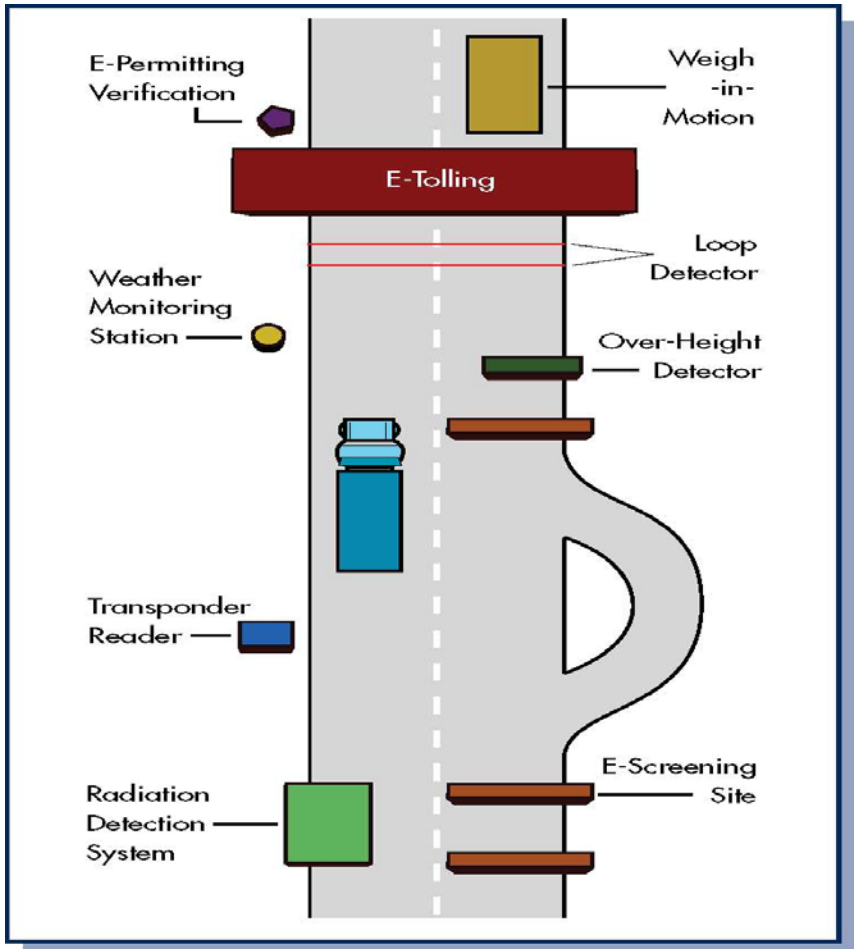
Stop Sign Gap Assist (SSGA)

- Roadside sensors: detect on-coming traffic.
- Roadside Equipment (RSE): broadcast traffic status.
- In-vehicle Device: determine if there is any danger for vehicle on the minor leg.

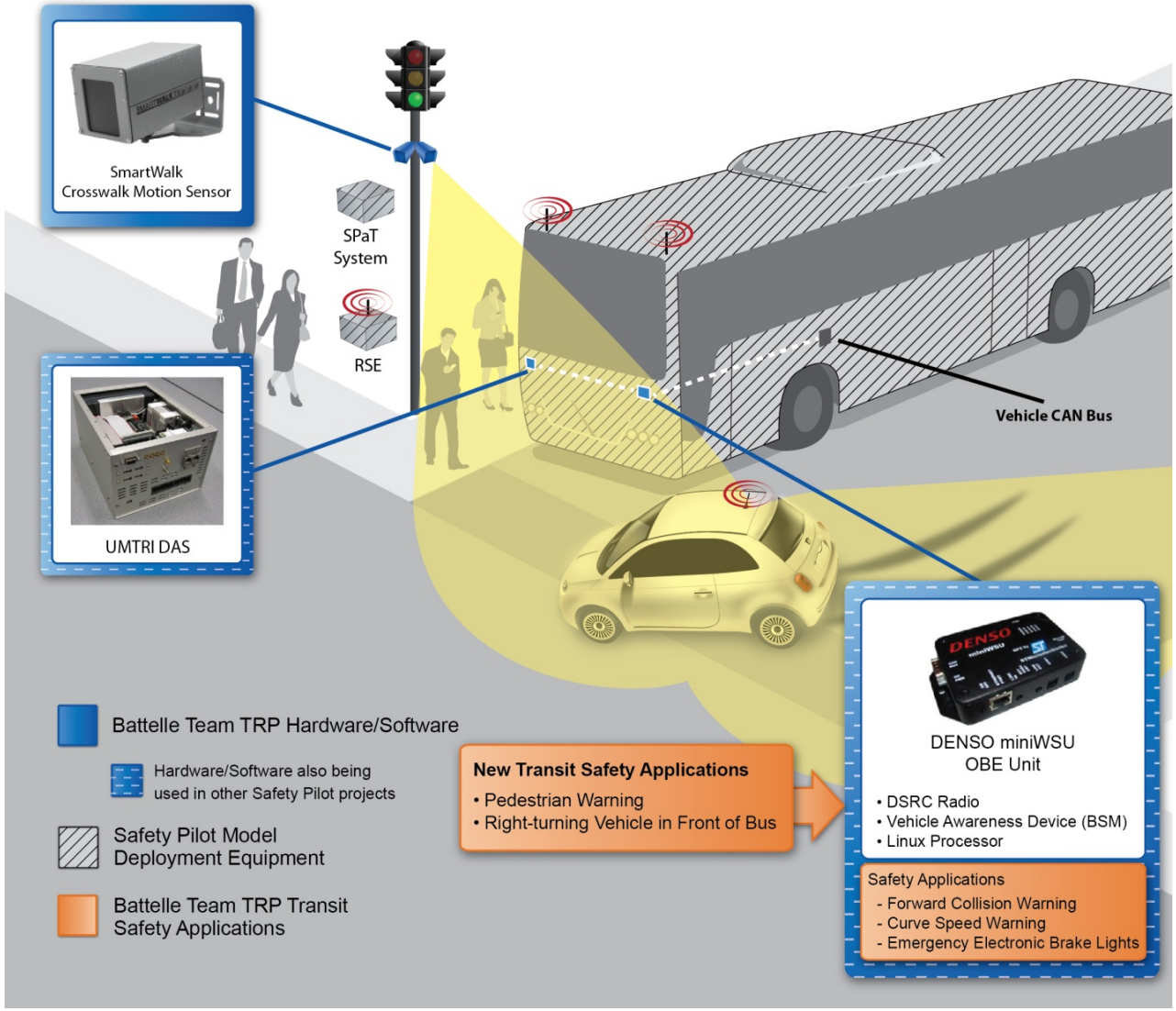


Smart Roadside

- The Smart Roadside Program allows truck and driver to be screened with roadside sensors while traveling.
- Regulatory functions can be employed while not interrupting the travel of compliant carriers.
- Safety is improved by eliminating stop and go traffic.
- Sensors can provide shippers greater visibility of goods movement.



Transit Safety Applications



Dynamic Mobility Application Bundles

MMITSS:
Multimodal Intelligent Traffic Signal System

INFLO:
Intelligent Network Flow Optimization

R.E.S.C.U.M.E.:
Response, Emergency Staging and Communications, Uniform Management, and Evacuation

Enable ATIS:
Enable Advanced Traveler Information Systems

IDTO:
Integrated Dynamic Transit Operations

FRATIS:
Freight Advanced Traveler Information Systems

Other Programs: **ICM** **ATDM**

Weather

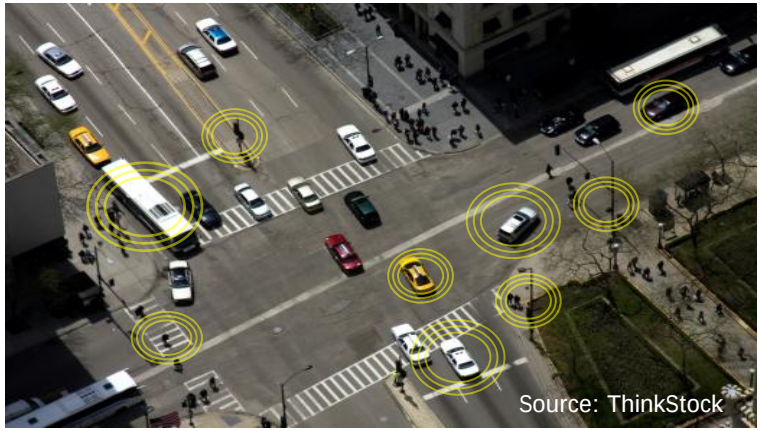
MMITSS: Multi-Modal Intelligent Traffic Signal System

Next generation of traffic signal systems that seeks to provide a comprehensive traffic information framework to service all modes of transportation:

- Intelligent Traffic Signal System (I-SIG)
- Transit Signal Priority (TSP)
- Mobile Accessible Pedestrian Signal System (PED-SIG)
- Freight Signal Priority (FSP)
- Emergency Vehicle Preemption (PREEMPT)

Source: Microsoft

Jointly funded by Cooperative Transportation System Pooled Fund Study (CTS PFS) and the DMA Program



Source: ThinkStock

INFLO: Intelligent Network Flow Optimization

A collection of high-priority, transformative applications that aim to maximize roadway throughput, reduce crashes, and reduce fuel consumption through the use of frequently collected and rapidly disseminated multisource data drawn from connected vehicles, travelers' mobile devices, and infrastructure.

Source: USDOT/ iStockphoto

- *Queue Warning (Q-WARN)*
- *Dynamic Speed harmonization (SPD-HARM)*
- *Cooperative Adaptive Cruise Control (CACC)*

R.E.S.C.U.M.E.: Response, Emergency Staging and Communications, Uniform Management, and Evacuation

Next generation of applications that transform the response, emergency staging and communications, uniform management, and evacuation process associated with incidents:

- *Incident Scene Pre-Arrival Staging Guidance for Emergency Responders (RESP-STG)*
- *Incident Scene Work Zone Alerts for Drivers and Workers (INC-ZONE)*
- *Advanced Automatic Crash Notification (AACN)*
- *Emergency Communications and Evacuation (EVAC)*

Source: Greg Carter Herald Sun

Source: John Bodie

EnableATIS: Enable Advanced Traveler Information System

Represents framework around a desired end state for a future traveler information network, with a focus on:

- multimodal integration
- facilitated sharing of data
- end-to-end trip perspectives
- use of analytics and logic to generate predictive information specific to users.

IDTO: Integrated Dynamic Transit Operations

Source: Thinkstock/ iStockphoto

Integrated transit operations that provide dynamic scheduling, dispatching, and routing of transit vehicles, and facilitate passenger connection protection and dynamic ridesharing:

- *Connection Protection (T-CONNECT)*
- *Dynamic Transit Operations (T-DISP)*
- *Dynamic Ridesharing (D-RIDE)*

FRATIS: Freight Advanced Traveler Information System

Freight traveler information system that provides freight-specific route guidance and optimizes drayage operations so that load movements are coordinated between freight facilities to reduce empty-load trips:

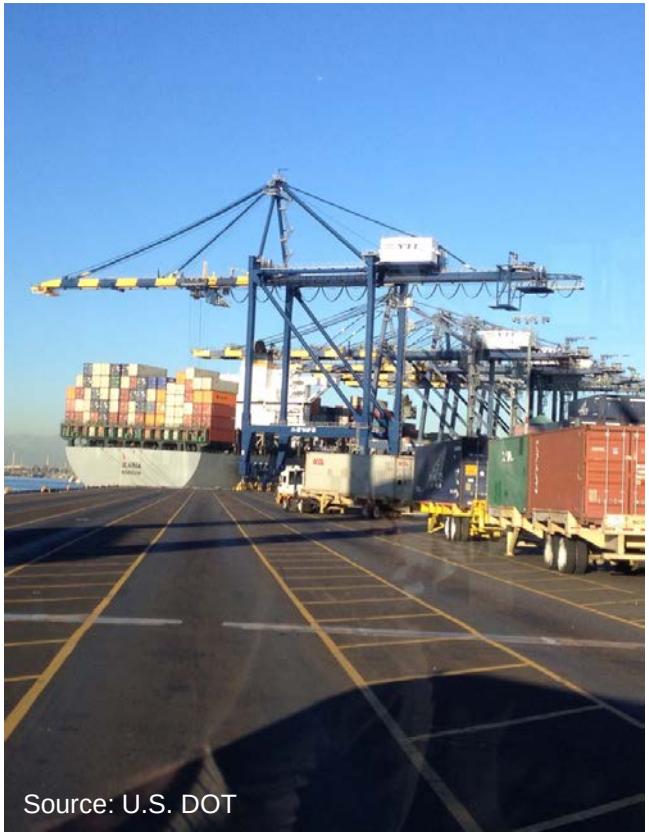
- *Freight-Specific Dynamic Travel Planning and Performance*
- *Drayage Optimization*

Source: iStockphoto

Source: iStockphoto

FRATIS Prototypes

- **Los Angeles-Gateway Region**
- **Dallas-Fort Worth, Texas**
- **South Florida**


Source: U.S. DOT

Source: ThinkStock

FRATIS Video

http://www.youtube.com/watch?v=c71Qm6HxVTY

Cleaner Air Through Smarter Transportation

http://www.its.dot.gov/aeris

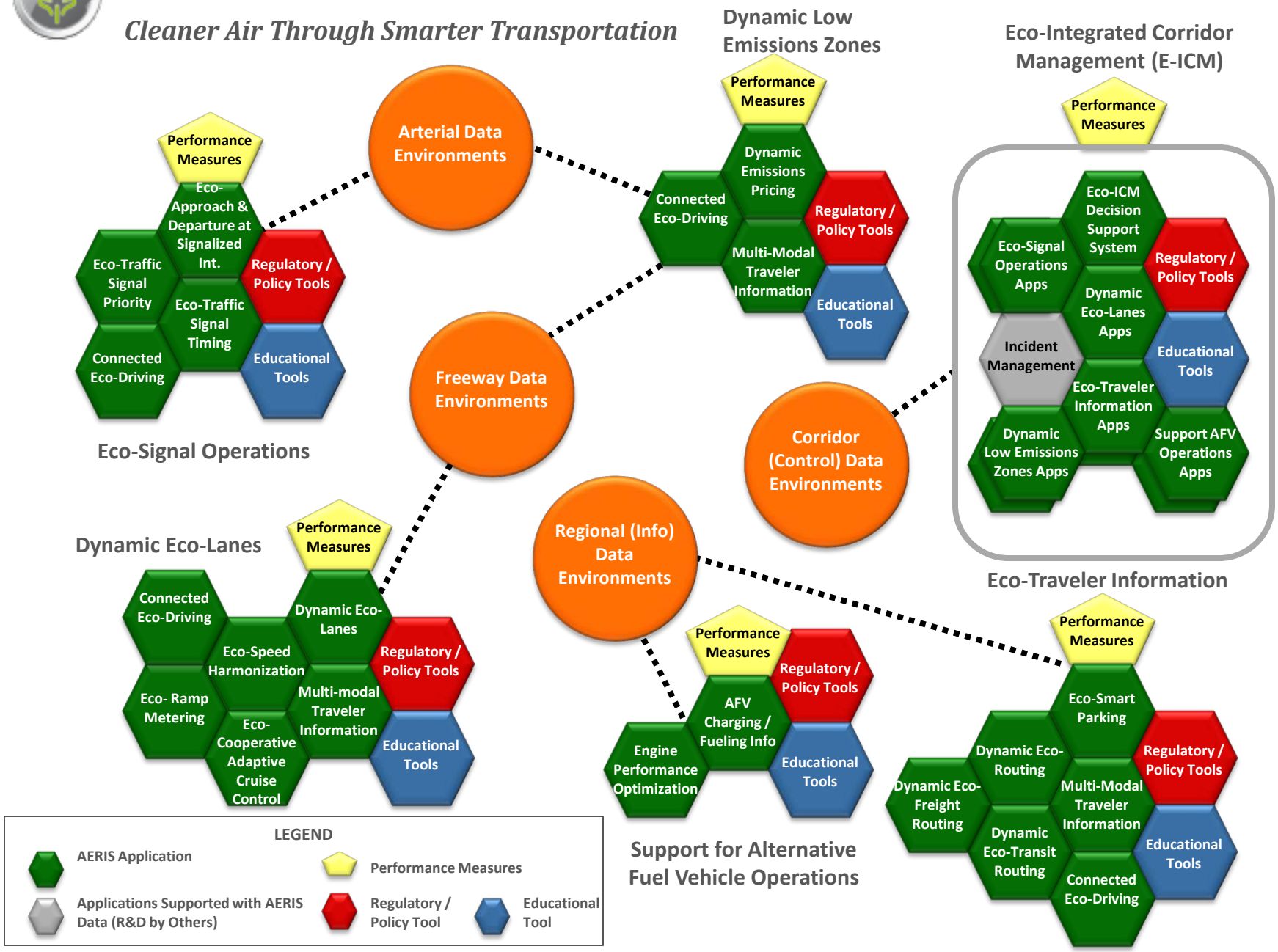
AERIS

AERIS: Applications for the Environment Real-Time Information Synthesis

UNITED STATES
DEPARTMENT OF TRANSPORTATION

AERIS TRANSFORMATIVE CONCEPTS

Cleaner Air Through Smarter Transportation

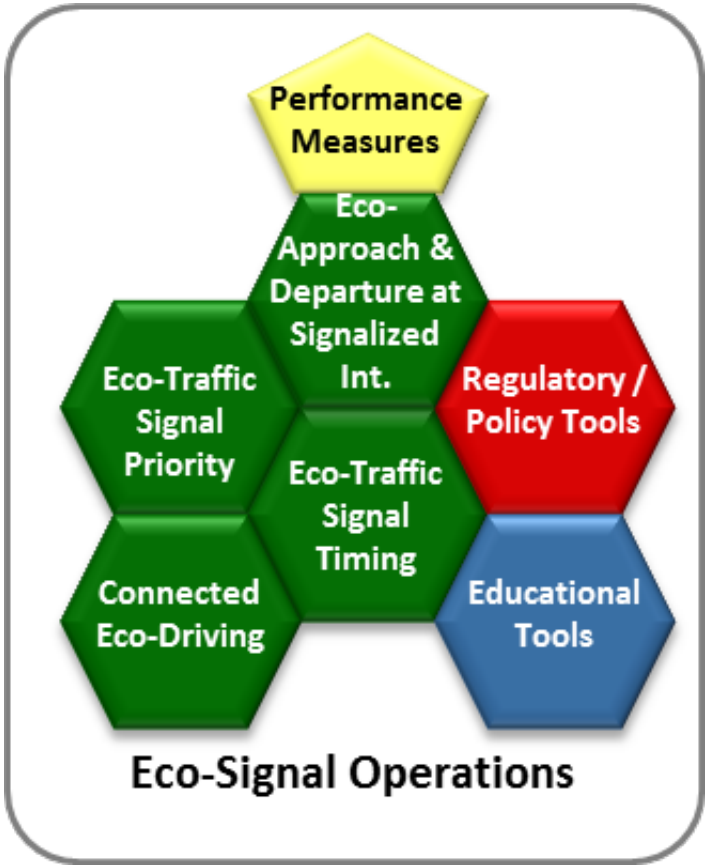


Eco-Signal Operations

Similar to today's ITS: adaptive traffic signal systems and traffic signal priority applications

Imagine tomorrow's connected vehicle applications:

- Signal phase and timing (SPaT) data sent to vehicles to optimize driving.
- Traffic signal systems optimized for the environment
- Transit signal priority based on vehicle emissions, transit vehicle occupancy, and schedule adherence
- Wireless (inductive) charging

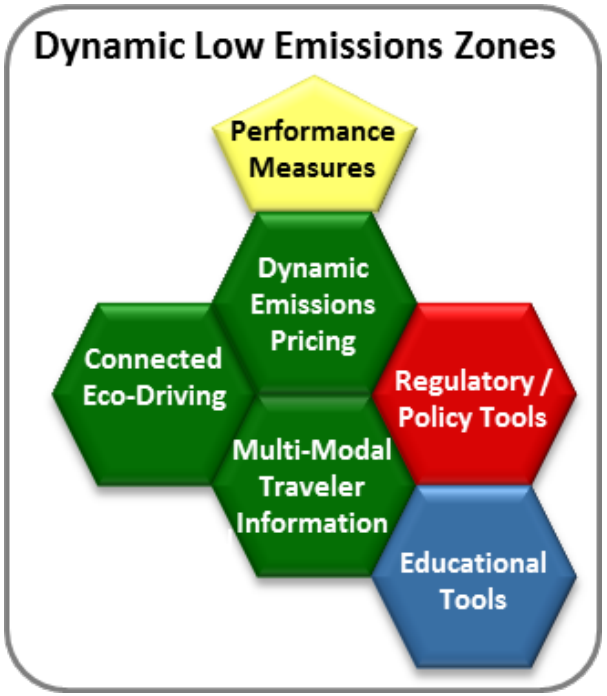


Dynamic Low Emissions Zones

Similar to today's ITS: cordons with fixed infrastructure (e.g., London's Congestion Pricing)

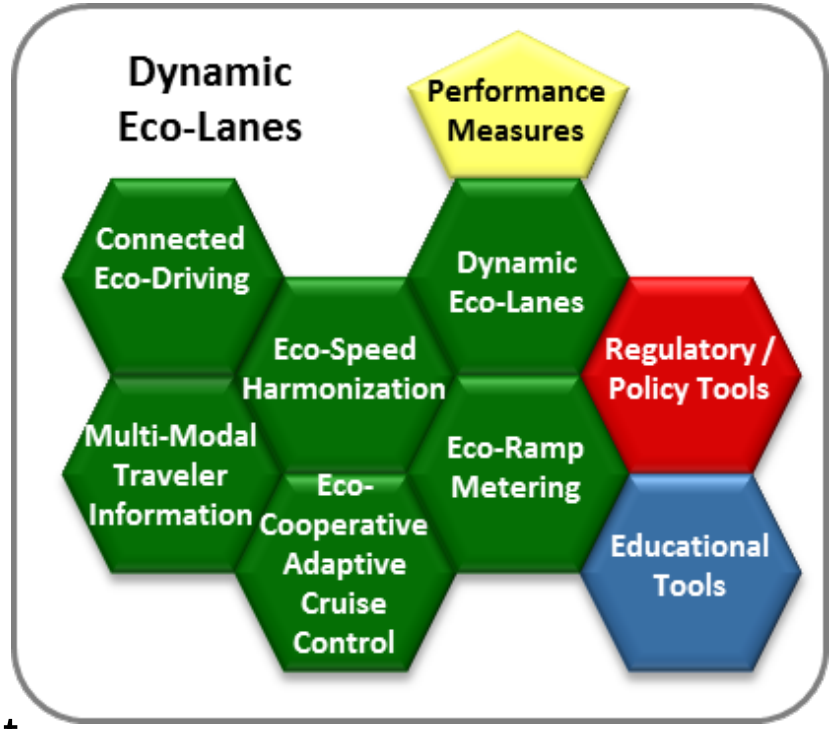
Imagine tomorrow's connected vehicle applications:

- Geo-fencing of low emission zone boundaries
- "Pop-up" low emissions zones not dependent on conventional infrastructure
- Provide incentives for "eco-driving" in the low emission zone
- Encourage "green" transportation choices, including transit options and freight operations.



Dynamic Eco-Lanes

Similar to today's ITS: managed lanes (e.g., HOV and HOT lanes)

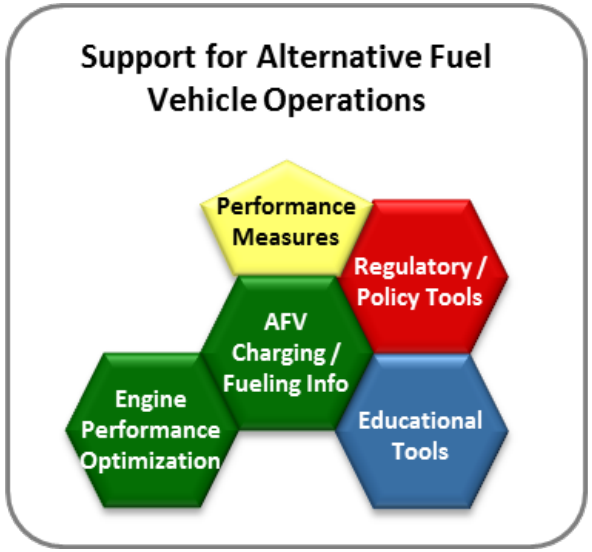


Imagine tomorrow's connected vehicle applications:

- Dedicated eco-lanes
- Dynamic parameters including location and duration, and types of vehicles
- Speed optimized for the environment.
- Eco-cooperative adaptive cruise control (eco-CACC) and vehicle platooning
- Wireless (inductive) charging infrastructure

Support Alternative Fuel Vehicle Operations

Similar to today's ITS: hybrid vehicle engine optimization, electric vehicle charging stations



Imagine tomorrow's connected vehicle applications:

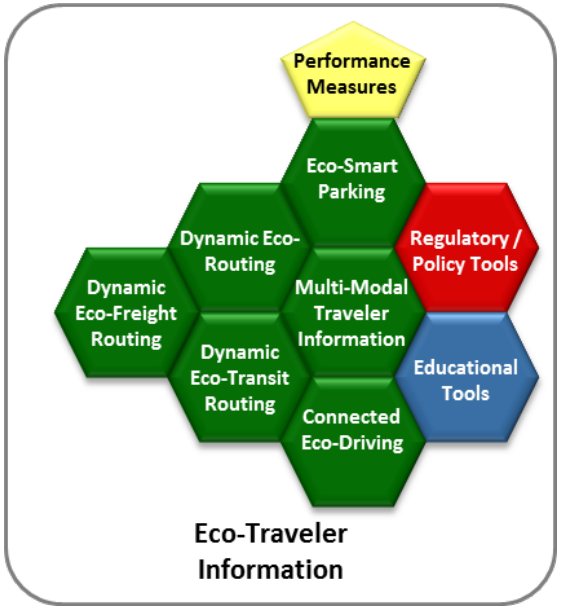
- Enhance engine performance in real-time, an AFV could: dynamically switch power sources or turn off engine
- Provide locations of charging/fueling stations
- Allow users to make reservations from their vehicles based on traffic conditions and distance to the station.
- Enables wireless (inductive) charging of electric vehicles from embedded infrastructure
- Reduce range anxiety for drivers of electric vehicles, reduce dependence on fixed infrastructure.

Eco-Traveler Information

Similar to today's ITS: 511 and traveler information websites, navigation systems, and traffic related phone applications

Imagine tomorrow's connected vehicle applications:

- Provide instantaneous feedback on driver behavior.
- Dynamic Eco-Routing through real-time data collected from vehicles
- Multimodal Real-Time Traveler Information to convey real-time pre-trip and en-route information
- Smart Parking applications to provide real-time parking information
- New paradigms for car sharing and car ownership.

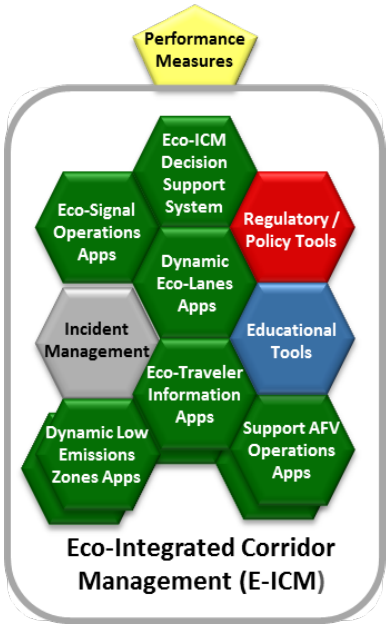


Eco-Integrated Corridor Management

Similar to today's ITS: Integrated Corridor Management for mobility

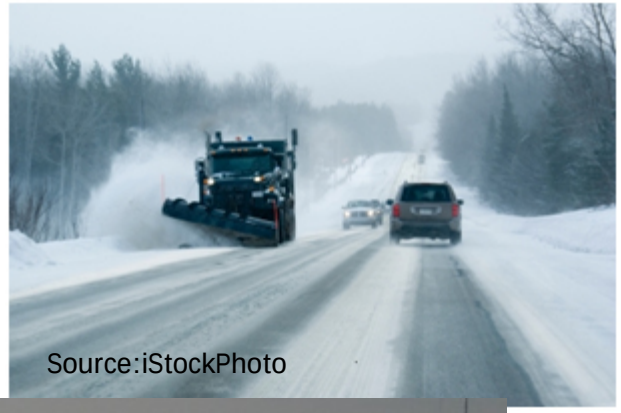
Imagine tomorrow's connected vehicle applications:

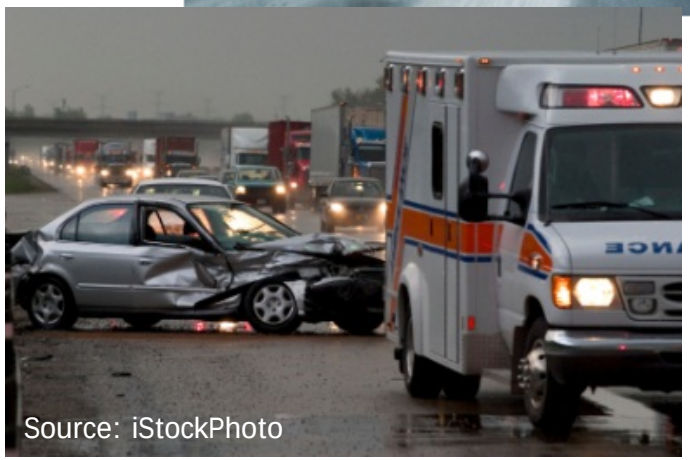
- Various transportation modes working together to achieve the maximum environmental benefit for the entire transportation system.
- A Code Red Air Quality Day where a "switch" is flipped that maximizes operations within an entire corridor or region to achieve a maximum environmental benefit **<u>on that day</u>**.



Road Weather CV Applications

- Enhanced Maintenance Decision Support
- Information for Maintenance and Fleet Management Systems
- Weather-Responsive Traffic Management
- Variable Speed Limits
- Signal Timing Optimization
- Motorist Advisories and Warnings
- Information for Freight Carriers
- Information and Routing Support for Emergency Responders





Exercise 1

- What is your top challenge in Safety?
- What is your top challenge in Mobility?
- What is your top challenge in Environment?
- What is your top challenge in Road Weather?

Applications Address Challenges

- Refer to your workbook for the names of the applications.
- Of these top three challenges, which of the applications discussed would have the greatest impact?

Break

IV. Affiliated Connected Vehicle Test Beds

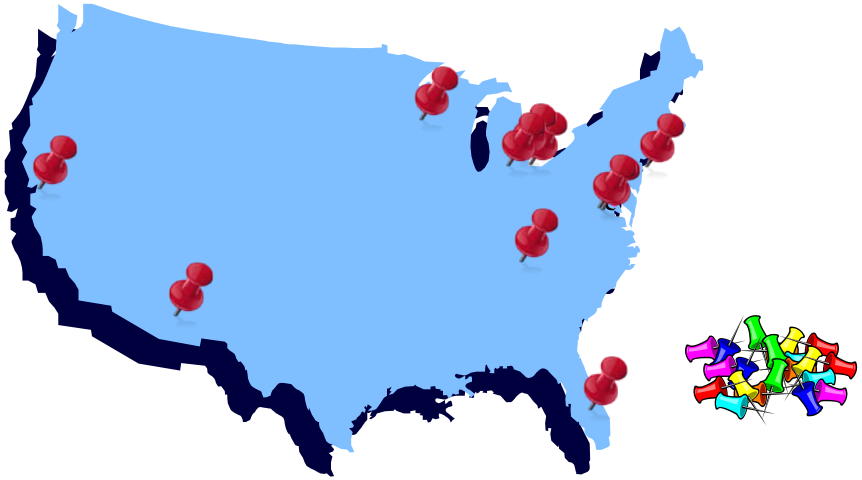
Key Objectives of the Affiliated Test Beds

"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

Multiple Operational Systems

- The Vision:
  - Multiple Interoperable Locations as part of One Connected System
  - Moving toward a nation-wide deployment
- Common Architecture
- Common Standards
- Shared Resources
- Independent Operations



USDOT Connected Vehicle Test Bed Resources

- Qualified Product List for RSE's
  - 5 vendors
- Qualified Product List for OBE's
  - Vehicle Awareness Devices
  - Aftermarket Safety Devices
- Portable RSE trailers
- Network listeners / sniffers
- Test Bed Operations staff
- SPaT Resources
  - Listeners
  - Interface standards from FHWA
- Security Credential Management System (SCMS)
  - 1609.2 certificate management system

Source: U.S. DOT

Source: U.S. DOT

Memorandum of Understanding

- Open to all
- Focused Activities
- Authority:
  - 49 U.S.C. 112(e) MAP-21 Legislation
- Contributions of the Government
- Contributions of the Collaborator
- Intellectual Property

Video

http://www.its.dot.gov/library/media/8testbed.htm

Highlights of Individual Test Beds

- Anthem, AZ
  - Advance multiple vehicle signal priority technology in a ‘live’ traffic environment
  - Traffic Signal Priority for EV and Transit (MCDOT/UA)
  - InFusion: Performance improvements of traffic controllers by data fusion and analysis
  - SmartCross: Smartphone Signal Alert Status

- Palo Alto, CA
  - Assess real-world implementations of VII for future investment decisions
  - Vehicles: OEMs; transit buses; commercial trucks; OBEs from multiple vendors
  - Infrastructure Components
    - RSE, PC104, Signal Sniffer, Signal Controllers (Being updated from 170 to 2070)
  - Back End Servers
    - SDN @ 511 TIC in Oakland, Health Monitoring and management, Signage server

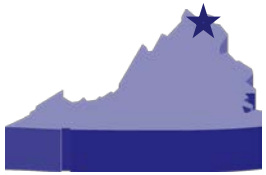
- Orlando, FL
  - Support 18th ITS World Congress Technology Showcase demos in Orlando
  - Vehicles (Road Rangers, Lynx buses, I-Ride Trolleys)
  - Infrastructure Components
    - 24 RSEs connected to FDOT fiber network
  - Back End Servers
    - District 5 RTMC SunGuide production servers
  - SunGuide Data Management Systems

Highlights of Individual Test Beds

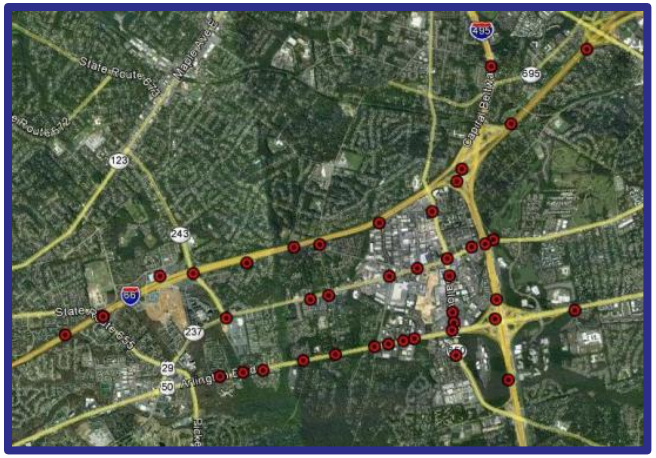
- Novi, MI
  - Research and testing resource for private developers to test DSRC-enabled applications:
    - SPaT (with portable listener and GUI)
    - Security Credential Management System (SCMS)
- Minnesota – Various Locations
  - Minnesota Road Fee Test
    - Demonstrate technical feasibility of MBUF
    - Demonstrate flexibility of in-vehicle signage
    - Collect anonymous traveler info from consumer devices
  - CICAS-SSA
    - Obtain driver feedback on CICAS-SSA
  - Clarus
    - Collect, process and use mobile weather data

- New York City – Manhattan
  - To support the 2008 ITS World Congress in Manhattan and demonstrate capabilities of Connected Vehicle technologies
  - Applications
    - CVII compliant 5.9 GHz DSRC OBE system
    - CVII DSRC applications:
      - CV driver I.D and verification
      - Wireless vehicle safety inspection (brake condition, tire pressure, light status, etc.)
      - CV to maintenance vehicles communication
    - Grade Crossing Driver Warnings (In-vehicle signage & crossing signal activation)
    - Heavy Vehicle to Light Vehicle Driver Safety Warnings

Highlights of Individual Test Best



- Northern Virginia
  - Focus on testing connected vehicle technologies in congested urban areas
  - Safety and Congestion Issues Related to Public Transportation, Pedestrians, and Bicyclists
  - Possible Applications:
    - Adaptive Lighting
    - Freeway Merge Management
    - Cooperative Intersection Control
    - Freeway Speed Harmonization
    - Freeway CACC Systems
    - Emergency V2V Communication
    - Eco-Speed Control Using V2I Communication
    - “Intelligent" Awareness System for Roadside Workers
    - Pavement Condition Measures and Utility Assessment
    - Adaptive Stop/Yield Signs

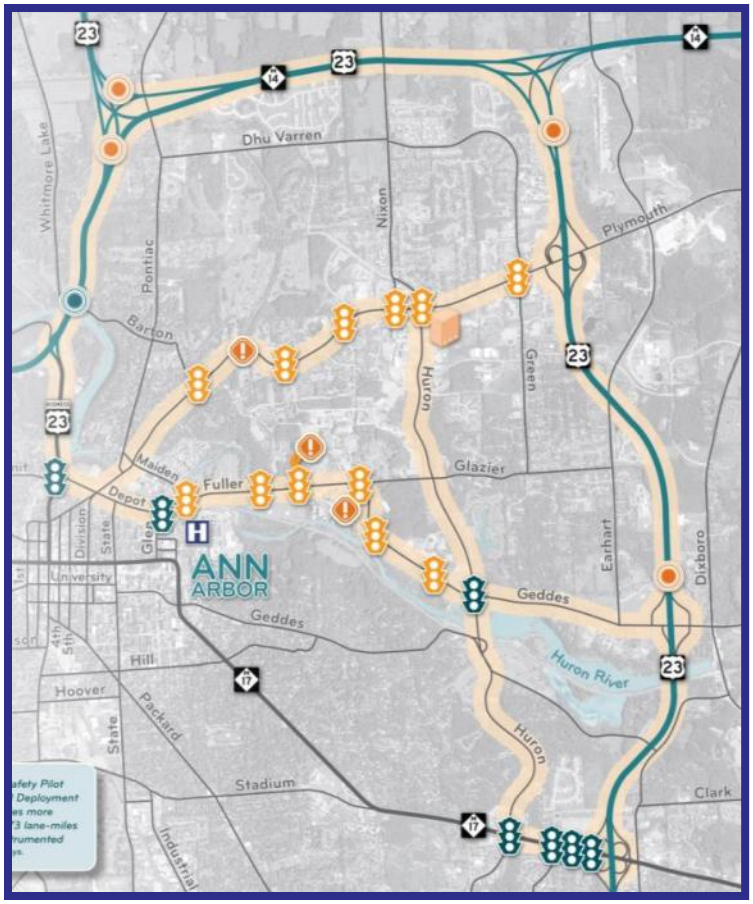


Source: Google Earth

- Saxon Labs, McLean, VA
  - Enhancing the state of the art of transportation operations research
  - Fully instrumented intelligent Intersection with left turn and pedestrian signaling, 2 Jeep Cherokees and X OBEs
  - Range of Applications being tested

Michigan *Safety Pilot, Ann Arbor*

- Purpose
  - 1 year of data collection to support 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

Lessons Learned & Issues from Test Beds - Technical

- Consensus on design and freezing of ConOps for applications after fine-tuning early in the lifecycle
- Remote monitoring of roadside equipment is necessary
- DSRC is highly reliable
  - Location of antenna important
- Clock Synchronization Critical
  - Using absolute time for traffic control/priority
- Overlapping MAPs
  - When two RSE's have range that overlaps, the OBE must determine which is the current and active MAP
- Non-safety critical operations are deployable now
- Heavy vehicles generally seen as easier to deploy

Lessons Learned & Issues from Test Beds – Technical (Cont.)

- Better change management and proper documentation of hardware and software is required
- Need management application for startup/shutdown of RSEs and the ability to log and retrieve data
- VISSIM Hardware-in-the-loop simulation environment to support development testing would be a useful tool
- Federal changes to standards and requirements drastically impact ability to deploy operational systems.
- Interpretation of standards still differs amongst system designers which adversely affects interoperability.
- Existing back office systems (GIS platform/mapping capabilities, system health and status, safety data feeds) require modification/enhancement to work in a connected vehicle environment
- Agreement on inter-system interfaces is necessary

Lessons Learned & Issues from Test Beds – Connected Vehicle Model Deployment

- Allow additional time for end-to-end system testing
  - Increased maturity levels of device developers
  - Identified ambiguous parts of specifications
- GPS antenna placement had a major impact on the performance
  - Internal placement was not viable
  - Viable external locations identified (roof, trunk)
- Monitoring the data collection in real-time allows for rapid risk response
  - Implemented risk response plans for interactions

Lessons Learned – Policy / Institutional

- Business models are extremely important as we lead to deployment
- Choose a clear direction and clearly assign and define roles for all participants
- Effective communication is vital to success
- Develop rich set of applications to attract users
- Ensure optimal set of equipped vehicles
- Enhanced synergy between software development teams and also between system architects
- Effectively engage private partners

Show of Hands

- Have you seen any of these Connected Vehicle applications or participated in the test beds?

Discussion Q&A

Affiliated Test Bed Charter

- Developing an organizational structure and charter to make membership “official”
- How to become an Affiliated Test Bed:
  - Have connected vehicle infrastructure deployed
  - Use (or willing to use) current standards where appropriate
  - Willing to share information and participate in ongoing discussions
- Benefits of Membership
  - Designation of Affiliated Test Bed
  - Access to USDOT support staff and resources
  - Increased access to lessons learned, documentation and other information from peers deploying test beds
  - Test Beds Serve as a Model for Future Permanent Deployments
  - Provide Opportunities for Future Testing

V. Policy and Institutional Issues

Why It Matters

Up to 80% of non-impaired crash types may be impacted by connected vehicle technology

Source: NHTSA

Based on initial estimates and studies.
Actual benefits are not determined at this time.

Program Milestones

- 2013 Decision on Vehicle Communications for Safety (light vehicles)
- 2014 Decision on Vehicle Communications for Safety (heavy vehicles)
- 2015 FHWA Guidance on Infrastructure Implementation

Source: U.S. DOT

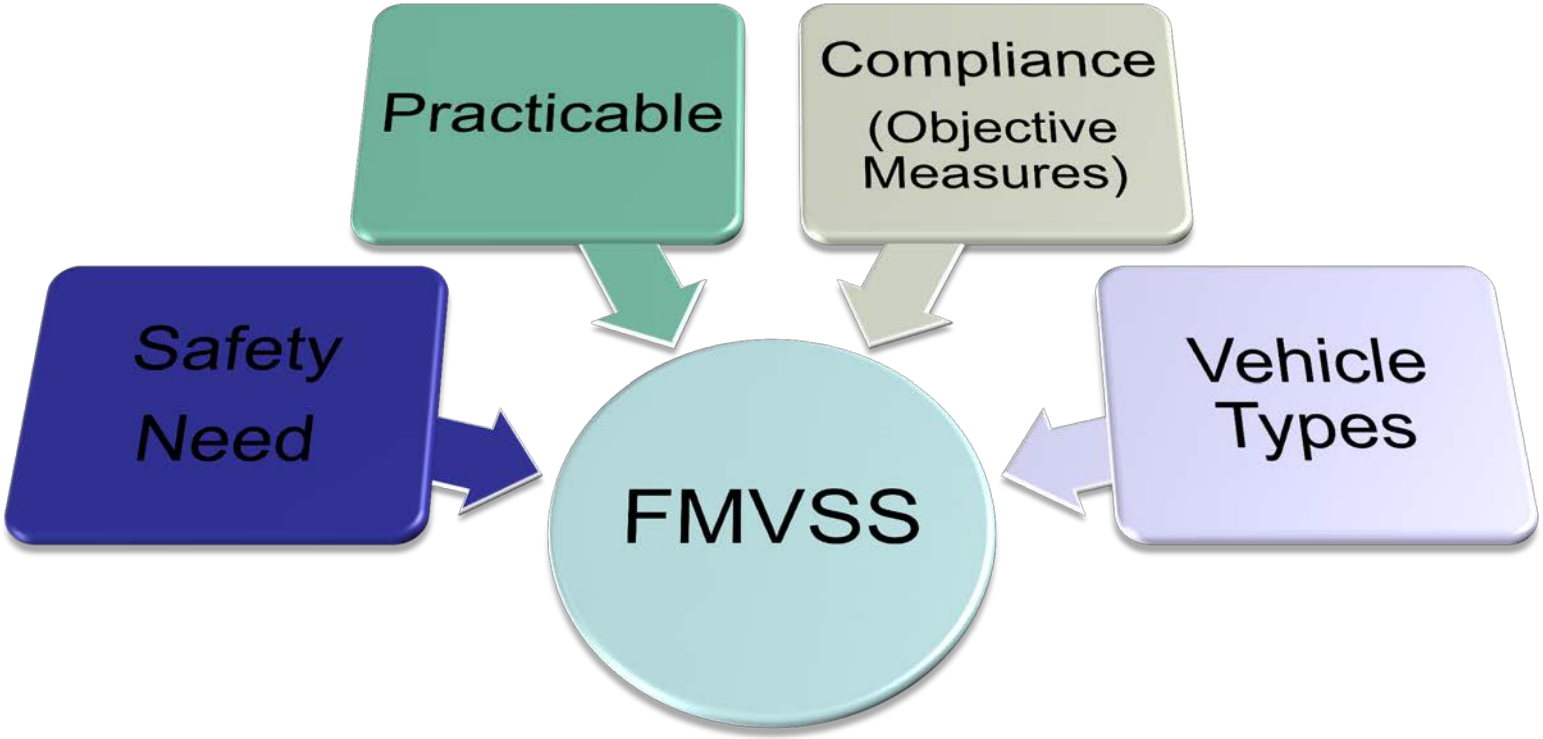
NHTSA Agency Decision on Vehicle Communications, 2013

- NHTSA Vehicle Safety and Fuel Economy Rulemaking and Research Priority Plan 2011-2013

  "The agency will assess the research data, technologies and potential countermeasures and decide on next steps."

The NHTSA decision will consider all viable options based on the data

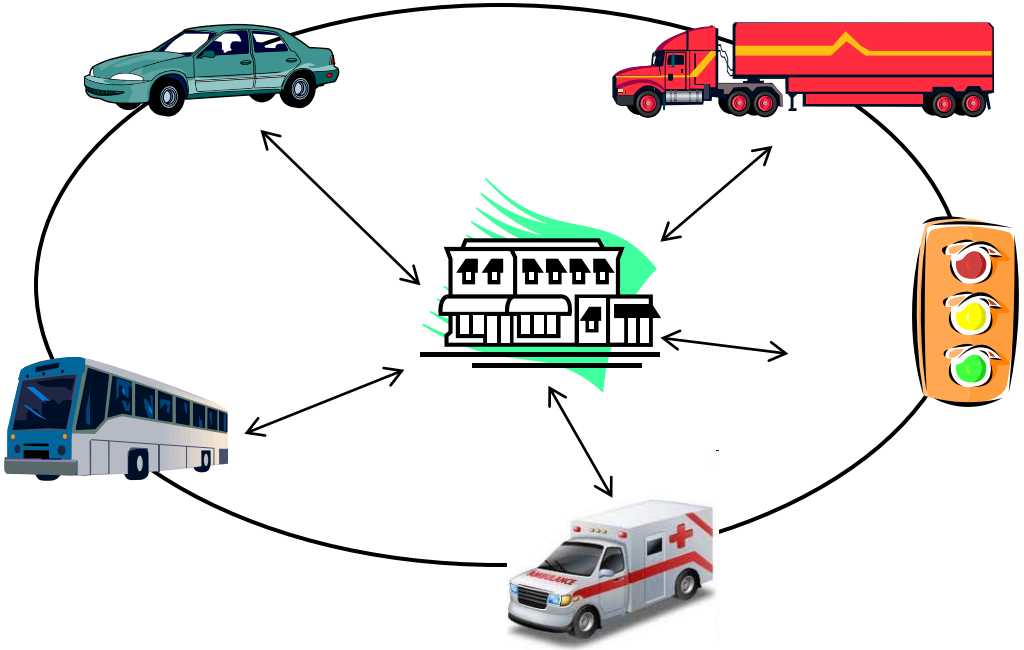
Federal Motor Vehicle Safety Standards



FHWA Guidance on Infrastructure Implementation, 2015

- Guidance - not regulation
- What and how to implement infrastructure and supporting systems → Toolkit
- Supporting high-priority applications
  - V2I safety applications (crash warnings at traffic signals, etc.)
  - Dynamic mobility
  - Road-weather
  - Environmental
- Based on DOT research and AASHTO analysis of infrastructure needs and deployment approaches

Challenge - Need for Security

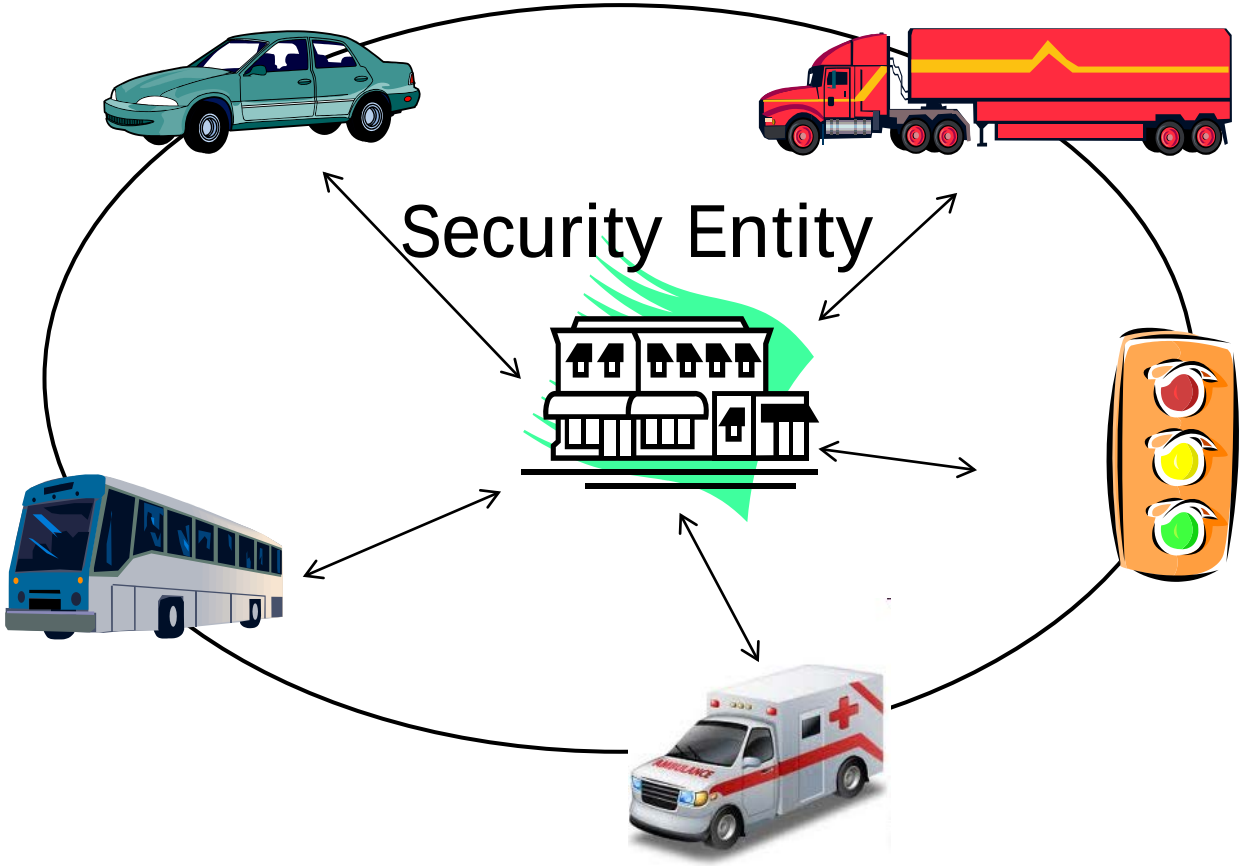


Trust

Message Validity

Defense Against Attacks

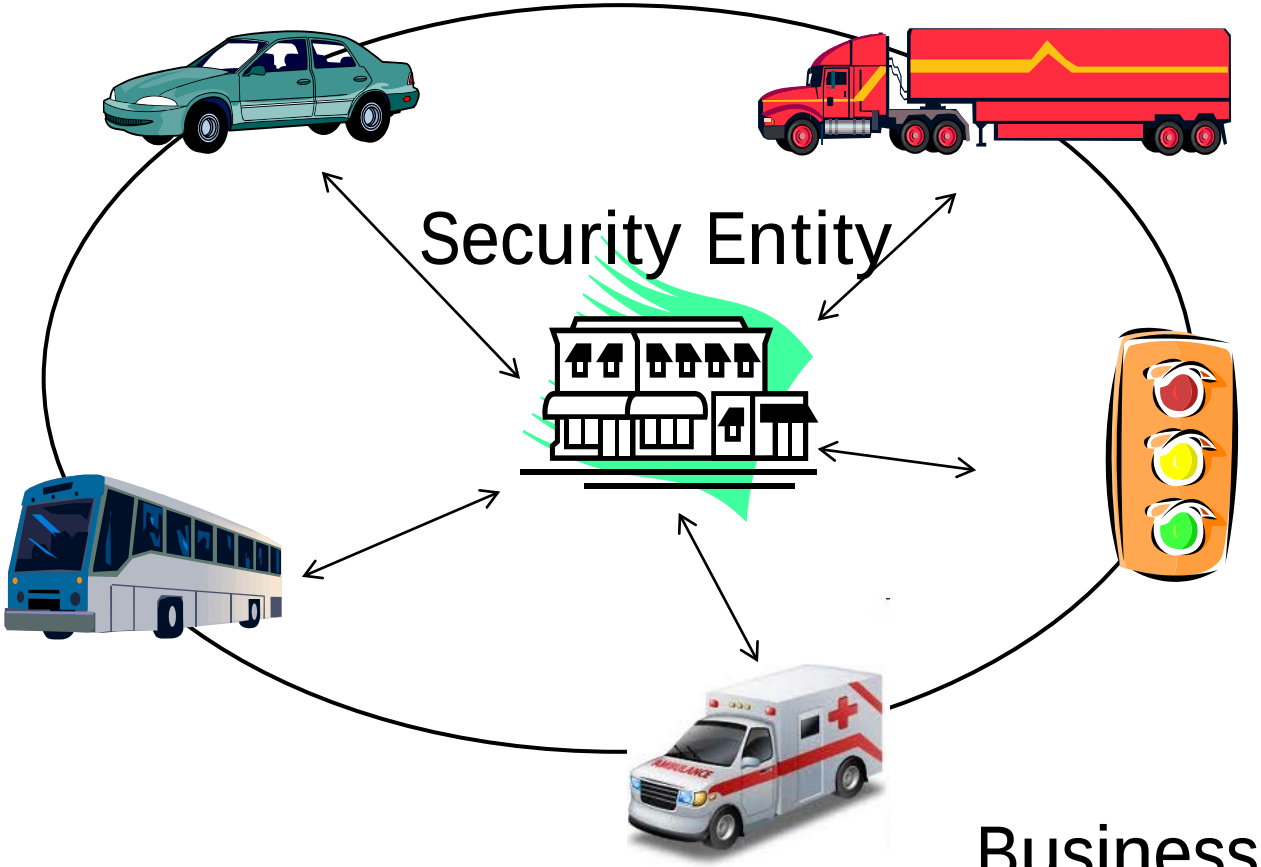
Challenge - Need for Security (Cont.)



Network:

- Cellular?
- DSRC?

Challenge - Need for Security (Cont.)



Network:

- Cellular?
- DSRC?

Privacy

Business Models for Security Operations

Legal Policy Issues

- U.S. DOT Authority
- Privacy
- Liability/Risk Sharing
- Intellectual Property
- Data Ownership/Access
- Antitrust/Spectrum

Legal Policy Issues

Policy Opportunities & Challenges

- USDOT Authority
  - USDOT **has sufficient *current* legal authority** to support implementation of many critical aspects of a connected vehicle environment, including:
    - Equipment in new vehicles
    - Aftermarket devices
    - Security system
      - Potentially through a contract or other arrangement to procure the build-out and operation on a for-cost, shared-cost or no-cost basis
  - USDOT **does *not* have legal authority** to require States to install infrastructure

NCHRP 03-101:Costs and Benefits of Public Sector Connected Vehicle Deployment

The **objective** of this research is to evaluate and document agency benefits and costs of connected vehicles in order to assist with deployment decisions by state and local DOTs

- Leverage knowledge of current CV Deployments
- Document the costs and benefits
- Focus on direct impacts of applications
- Document the impacts on DOT business practices

Potential Connected Vehicle Direct Benefits

- ✓ Reduced need for 511 infrastructure
- ✓ Reduction of infrastructure required to monitor traffic
- ✓ Lower cost of pavement condition detection
- ✓ Adaptive Lighting
- ✓ Crash response and clean up cost reduction
- ✓ Work zone accident reduction
- ✓ DOT Vehicle Fleet insurance reduction
- ✓ Improved access to data for planning studies
- ✓ Potential for improved long-term planning, program management
- ✓ Faster and more cost effective response to public issues and policy change
- ✓ Ability to measure performance of DOT operations on an accelerated schedule
- ✓ Cost savings to transit agencies by better optimizing fleet
- ✓ Increased safety may allow reorganization of safety roles at the DOT

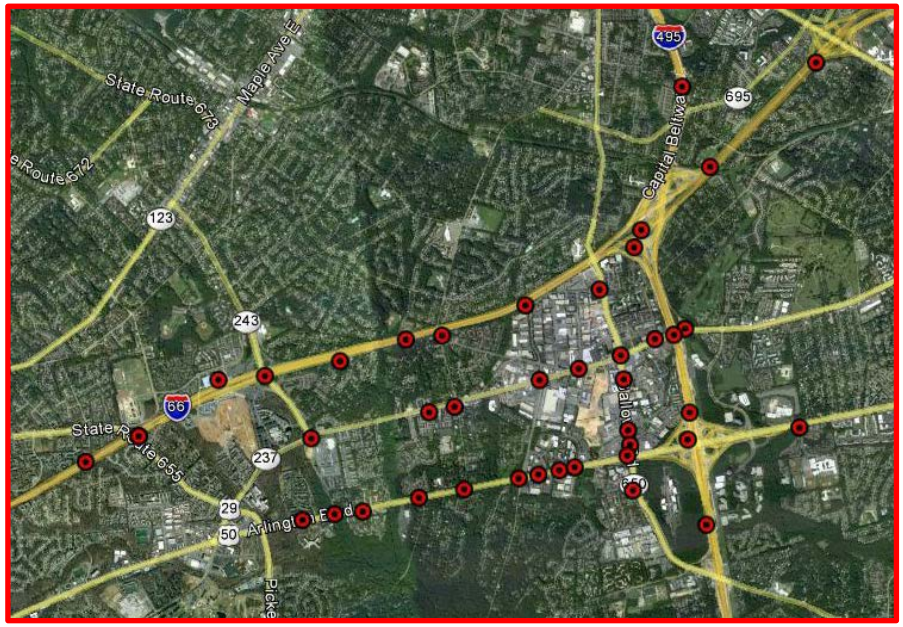
Case Study: Virginia

VDOT selected the specific location based on the following criteria:

- Proximity to existing project to deploy active transportation and demand management
- Has transportation system deficiencies (congestion, high crash rates, air quality non-attainment) and includes a high level of multimodal interactions
- Provides a variety of roadway types, topography and driver types, yet provides opportunities for containment

<u>Site features</u>:

- Major merge/diverge locations
- Metro stations/public transport & commuter routes
- HOT and HOV lanes
- A large county hospital
- A fire station
- Multiple schools, pedestrian trails, and mixed-use commercial/residential areas
- Major roadway construction



VDOT Cost Categories

***Asset* Categories:**

- **OBEs:** Both DSRC and cellular
- **RSEs:** 45 RSEs
- **Infrastructure Components:** Ethernet backhaul for the interstate, wireless for signalized intersections
- **Back End Servers:** Data will be transmitted over VDOT network and transferred to servers at an off-site location
- **Data Management Systems:** Off-site Data Warehouse

***Cost* Categories:**

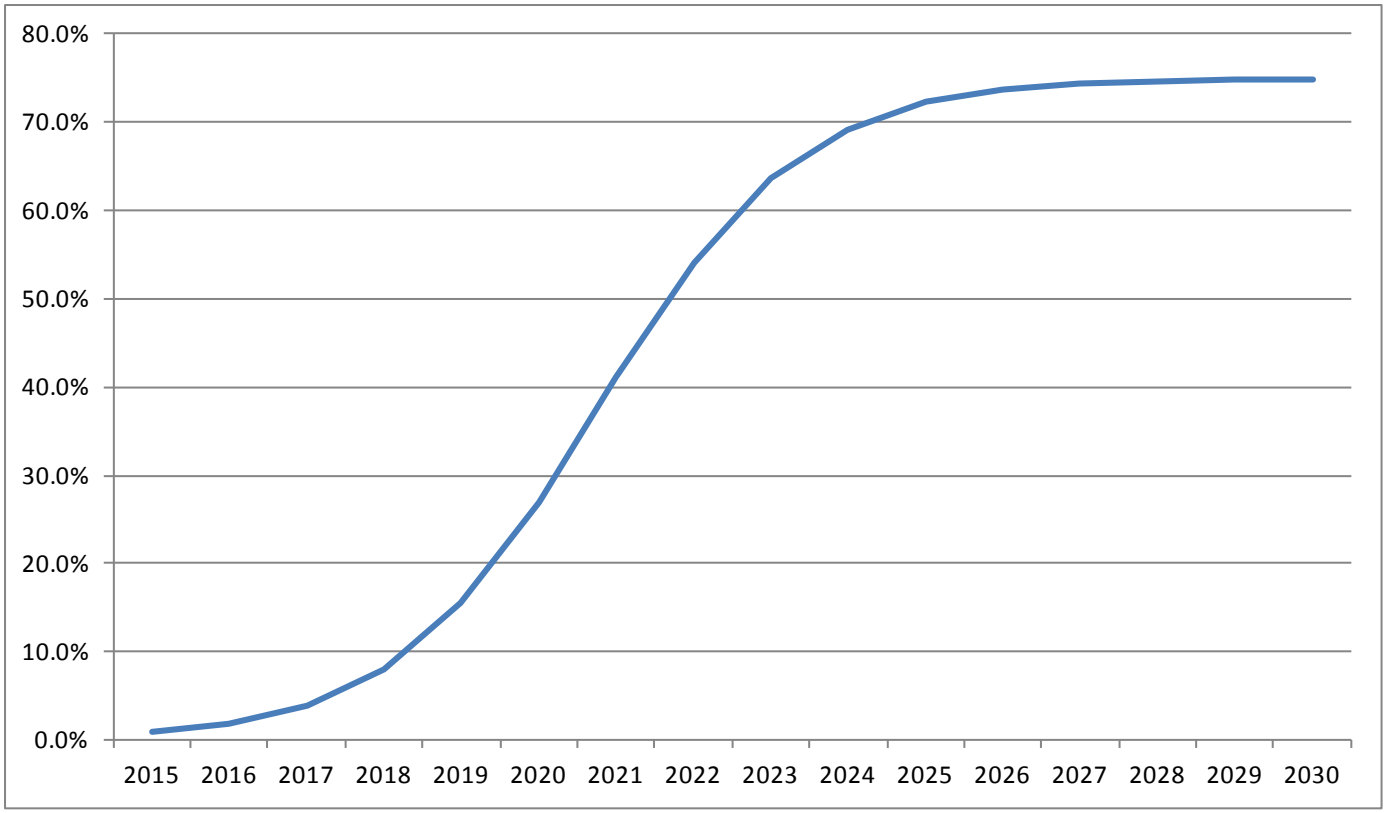
- **Installation:**
  - Oversight/PM/Integrator Costs
  - Arterial Installation
  - Interstate Installation
- **Equipment:**
  - RSE Units
  - OBE Units
  - Antenna Kits
- **Backhaul:**
  - Non-recurring
  - Recurring

Installation and Equipment costs were provided by VDOT and the Backhaul cost are based on the U.S. Department of Transportation, Research and Innovative Technology Administration, Task 3 Draft Report: Modeling of Promising Options for Secure Communications Data Delivery Systems, Booz Allen Hamilton, Sept. 2012

VDOT CV Test Bed Analysis

- Analyzing the VDOT Connected Vehicle Test Bed made it clear that there are significant benefits that directly impact the DOT.
- For the quantitative analysis the study focused on 5 areas of benefits for which adequate data was available:
  - Reduced need for 511 infrastructure
  - Reduction of infrastructure required to monitor traffic
  - Lower cost of pavement condition detection
  - Adaptive lighting
  - Crash response and clean up cost reduction
- How fast the benefits will be realized will depend on the penetration levels of OBE and their relationship to benefits

VDOT Case Study - Market Penetration Projection



- Assumption market penetration per year, y=1% in 2015 and reaches 75% in 2030
- Different benefits will accrue at varies stages of OBE penetration
  - Pavement condition monitoring will only need a few vehicles, but crash reduction and 511 savings will require larger percentage of vehicles with OBE

VDOT Study Outcomes (to date)

- Over time as more vehicles have OBE, these benefits can offset the initial expenditures required to provide the RSE
- Study applied sensitivity analysis by using range estimates for all input variables to determine their impact on the overall results, e.g., accident reduction rate varying between 7.5% and 12.5%
- The inputs with the greatest impact on the results are:
  - Accident Response Cost
  - Accident Rate Reduction
  - RSE Unit Cost
  - RSE Maintenance Cost
  - Recurring Backhaul Cost
- In addition, there are long term strategic effects on DOT business practices that can further reduce cost

Next Steps

- Wrap up VA case study
  - Address deployment
  - Explain in more detail how benefits are derived
    - E.g., VMS cost reduction benefits are from eliminating the need to purchase new signs as CV technology is deployed (versus removing existing signs)
    - Provide real life examples on how things would change with CV technology available and how that change will lead to savings for the DOTs
- Conduct 1 or 2 more case studies
  - Conducting case studies for Arizona and Michigan
  - Obtain study data and conduct for analysis, similar to VA case study
- Develop Final Report
  - Integrate results from all analysis and define extrapolated results
  - Provide detailed analysis and supporting data
  - Develop the deployment guidance

Benefits and Costs Q&A

Exercise 2:

What barriers do you perceive with respect to making a Connected Vehicle Implementation happen?

Discussion

How can your organization overcome barriers to Connected Vehicle implementation?

- Discuss barriers and brainstorm ways to overcome then.
- Propose ownership of recommended actions.

- Report out

<u>Draft</u> Themes, ITS Research 2015 – 2019

- Maturing Connected Vehicle Systems
- Piloting and Deployment Readiness
- Integrating with the Broader Environment

Stakeholder Involvement is Critical

http://www.its.dot.gov/press/2013/stakeholder_strategicplan.htm

http://itsstrategicplan.ideascale.com/

Upcoming Stakeholder Meetings and Webinars

VI. Wrap Up

Please complete the course evaluation!

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