



Connected Vehicles 102

Applications and Planning for Implementation

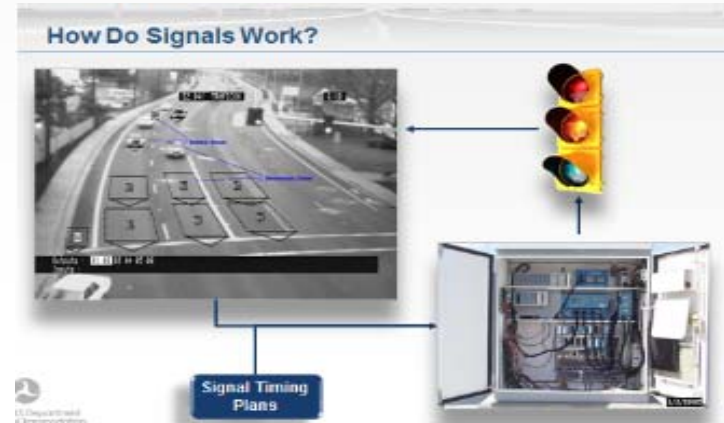


ITS Professional Capacity Building Program

- Offers FREE training to develop the ITS workforce
- Talking Transportation Technology webinars, with online archive
- ITS Standards (48 modules)
- ITS Transit Standards (14 modules)
- eLearning Courses from Consortium for ITS Education (CITE):
 - Telecommunications and Networking Fundamentals
 - Network Design and Deployment Considerations for ITS Managers
- Workshops at ITS America State chapter meetings



www.pcb.its.dot.gov



U.S. Department of Transportation
ITS Joint Program Office

Additional Connected Vehicle Training Resources

- ITS PCB online course: CV 101 eLearning Course
- ITS PCB archived webinars:
 - CV Basics
 - National Connected Vehicle Field Infrastructure Footprint Analysis
- Connected Vehicle Reference Implementation Architecture (CVRIA)
 - <http://www.iteris.com/cvria/html/resources/cvriatraining.html>
 - <http://www.iteris.com/cvria/html/forms/setitrainingform.php>
- ITS ePrimer – Connected Vehicle Chapter

Contact: Kevin Gay, Team Lead
ITS Knowledge Transfer and Policy
U.S. Department of Transportation
202.493.0259 Kevin.Gay@dot.gov

www.pcb.its.dot.gov



U.S. Department of Transportation
ITS Joint Program Office

Workshop Agenda

Topic	Title	Duration
1	Connected Vehicles: Introduction and Current Status	30 minutes
2	Preparing to Implement Connected Vehicle Applications	30 minutes
3	Safety Applications	30 minutes
4	Mobility Applications	45 minutes
5	Environmental Applications	30 minutes
6	Connected Vehicle Considerations and Resources	40 minutes
7	Course Wrap-up	15 minutes



Why Are You Here Today?

- Shout it out!
 - What is your role related to connected vehicles?
 - What are you most interested in learning more about?
 - What questions do you have that you are hoping to get answered during this session?
 - Do you know what your organization is currently doing related to connected vehicles?
- We want you to leave this workshop with an understanding of the applications available to you, and how you can use these applications to address transportation challenges



Topic 1: Connected Vehicles: Introduction and Current Status

Topic	Title	Duration
1	Connected Vehicles: Introduction and Current Status	30 minutes
2	Preparing to Implement Connected Vehicle Applications	30 minutes
3	Safety Applications	30 minutes
4	Mobility Applications	45 minutes
5	Environmental Applications	30 minutes
6	Connected Vehicle Considerations and Resources	40 minutes
7	Course Wrap-up	15 minutes



Connected Vehicle Research



Connected Vehicle Communications Technology

- 5.9 GHz DSRC
- 4G and older 3G cellular networks provide high-bandwidth data communications
- Other wireless technologies such as Wi-Fi, satellite, and HD radio may have roles to play



USDOT/NHTSA Advance Notice of Proposed Rule Making on V2V Communications Technology

In May, Secretary of Transportation Anthony Foxx directed the National Highway Traffic Safety Administration (NHTSA) to:

Accelerate the timetable for V2V communications in new vehicles

- Rapid testing of V2V transmissions
- Work on regulatory framework
- Draft rule coming soon.



Envision Connected Everything



Connected Vehicle Pilot Deployment Program



Topic 1 Wrap-up



Topic 2: Preparing to Implement Connected Vehicle Applications

Topic	Title	Duration
1	Connected Vehicles: Introduction and Current Status	30 minutes
2	Preparing to Implement Connected Vehicle Applications	30 minutes
3	Safety Applications	30 minutes
4	Mobility Applications	45 minutes
5	Environmental Applications	30 minutes
6	Connected Vehicle Considerations and Resources	40 minutes
7	Course Wrap-up	15 minutes



Topic 2: Preparing to Implement Connected Vehicle Applications

- After this topic, you will be able to:
 - Explain the process for preparing to implement connected vehicle applications
 - Identify your top regional or local transportation challenges
 - Set performance goals

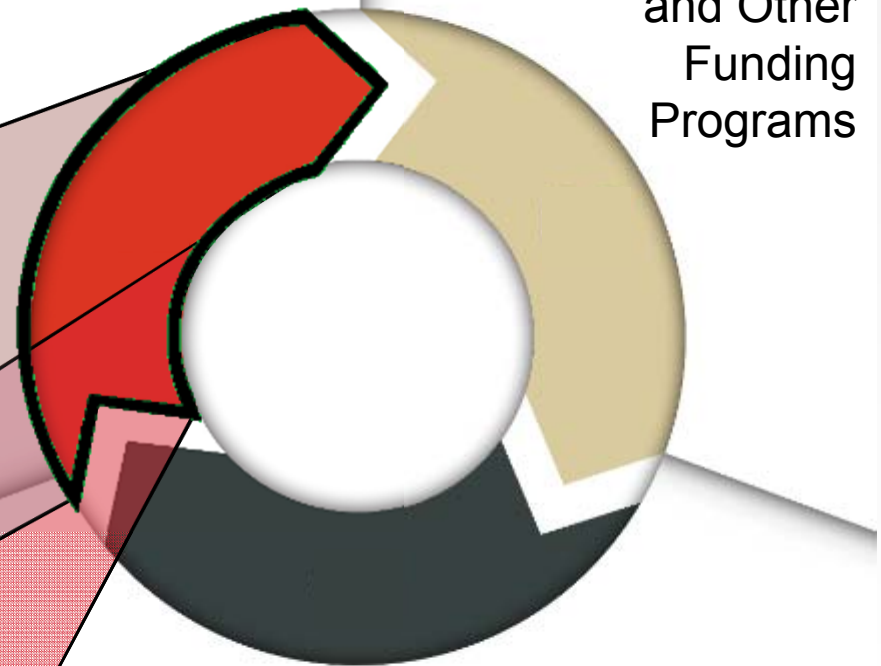
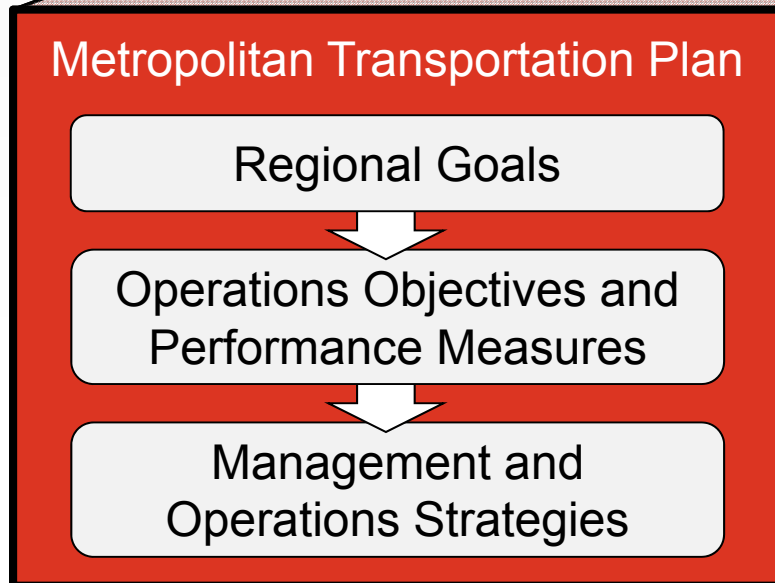


Preparing to Implement Connected Vehicles

- Infrastructure will be deployed and operated by State and local agencies/DOTs
 - Not a “shall” – Use of V2I is not mandated
 - How will you plan, fund, deploy, operate, and maintain?

Metropolitan
Transportation
Plan

Transportation
Improvement Program
and Other
Funding
Programs



Implementation



Planning for Implementation

1

IDENTIFY LOCAL NEEDS

Identify local problems, challenges, and/or issues you are trying to address

2

SET PERFORMANCE GOALS

Set measurable goals and objectives that allow you to address local needs

3

SELECT CONNECTED VEHICLE APPLICATIONS THAT WORK TOGETHER TO MEET THOSE GOALS

Identify potential solutions, including connected vehicle applications, that help you meet your goals and objectives



Identify Needs

1

IDENTIFY LOCAL NEEDS

Identify local problems, challenges, and/or issues you are trying to address

Sample Local Needs

- Safety
 - Reduce crashes and fatalities
 - Decrease conflicts between pedestrians, bicycles, and vehicles
 - Set emergency vehicle preemption
- Mobility
 - Reduce congestion on arterials
 - Improve transit schedule reliability
- Environment
 - Improve air quality in non-attainment areas
 - Reduce wasted fuel along arterials



Set Performance Goals

2

SET PERFORMANCE GOALS

Set measurable goals and objectives that allow you to address local needs

Sample Performance Goals

- Safety
 - Reduce crashes by 10%; injuries by 20%; and fatalities by 30%
 - Reduce pedestrian-vehicle conflicts by 50%
- Mobility
 - Transit vehicles on schedule 90% of the time
 - Increase peak period throughput by 8%
- Environment
 - Reduce emissions by 20%
 - Reduce fuel costs associated with operating a transit fleet by 10%

Performance goals must be measurable!



Select CV Applications That Work Together To Meet These Goals

3

SELECT CONNECTED VEHICLE APPLICATIONS THAT WORK TOGETHER TO MEET THOSE GOALS

Identify potential solutions, including connected vehicle applications, that help you meet your goals and objectives

Sample CV Applications

- Mobility and safety applications that result in environmental benefits
 - Traffic signal priority applications may improve transit performance, but may also result in fuel consumption and emissions reductions
- Applications that can perform dual roles
 - Speed harmonization may optimize for mobility and at other times may optimize for the environment



Scenario 1: Downtown Sunnyside

~ Identify Key Transportation Challenges ~



Scenario 1: Downtown Sunnyside

~ Stakeholders Set Three Performance Targets ~

Identify Needs	Performance Goal	Performance Target
Transit vehicles schedule reliability	Increase transit reliability	Transit vehicles on schedule 90% of the time
Pedestrian-vehicle conflicts	Improve pedestrian safety	Reduce pedestrian-vehicle conflicts by 50%
Emissions/air quality hot spots	Improve hot spot air quality	Reduce emissions by 20%



Scenario 1: Downtown Sunnyside

~ Improving Congestion in an Urban Arterial Network ~

Synergies among applications increase benefits and reduce costs

Improve Transit Reliability

- Application 1
- Application 2

Improve Pedestrian Safety

- Application 1
- Application 3
- Application 4
- Application 5
- Application 6

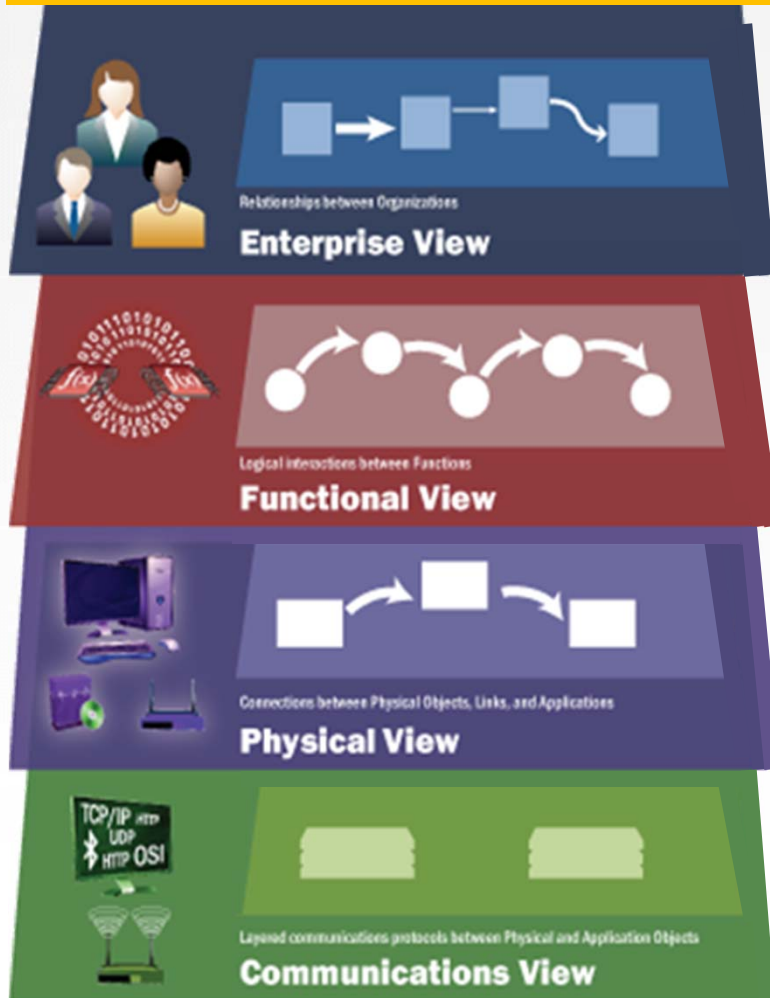
Improve Air Quality

- Application 2
- Application 7
- Application 10



Preparing to Implement Connected Vehicle Applications

Connected Vehicle Reference Implementation Architecture



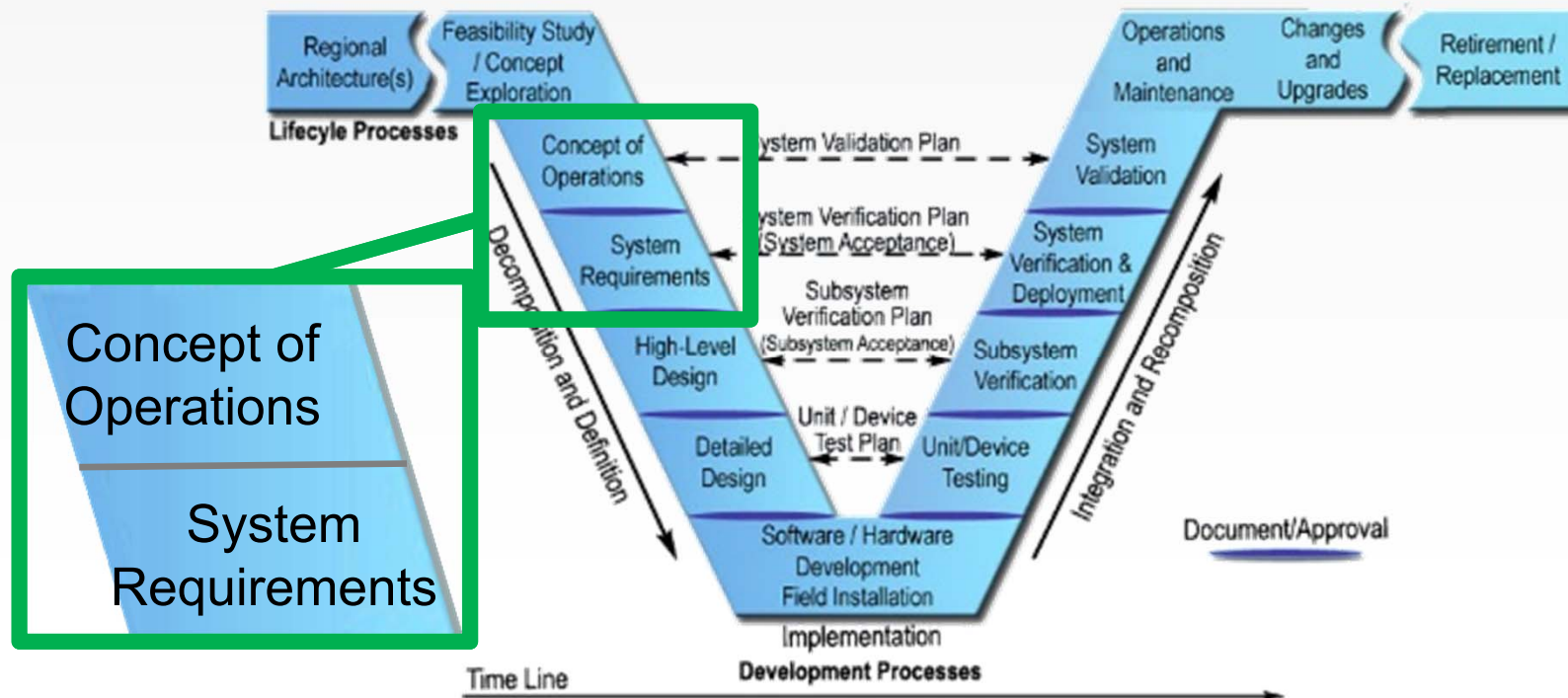
- Established a framework for integrating connected vehicle technologies and identified interfaces for standardization
 - Collected and aggregated connected vehicle needs/requirements
 - Developed a multi-faceted system architecture
 - Identified and prioritized candidate interfaces for standardization
 - Supported policy analysis

Once finalized, CVRIA will be incorporated into the National ITS Architecture.



Preparing to Implement Connected Vehicle Applications

- A systems architecture for ITS is part of an overall systems engineering approach.
- Future deployers can make use of foundational research and initial CV concept development investments made by the USDOT.





Group Exercise

- Begin planning for connected vehicle applications implementation
- Using the Implementing Connected Vehicle Applications worksheet, complete the following tasks:
 - Identify need(s)
 - Set performance goal(s)

Topic 2 Wrap-up

- Explain the process for planning to implement connected vehicle applications
- Identify your top regional or local transportation challenges
- Set performance goals



Topic 3: Safety Applications

Topic	Title	Duration
1	Connected Vehicles: Introduction and Current Status	30 minutes
2	Preparing to Implement Connected Vehicle Applications	30 minutes
3	Safety Applications	30 minutes
4	Mobility Applications	45 minutes
5	Environmental Applications	30 minutes
6	Connected Vehicle Considerations and Resources	40 minutes
7	Course Wrap-up	15 minutes

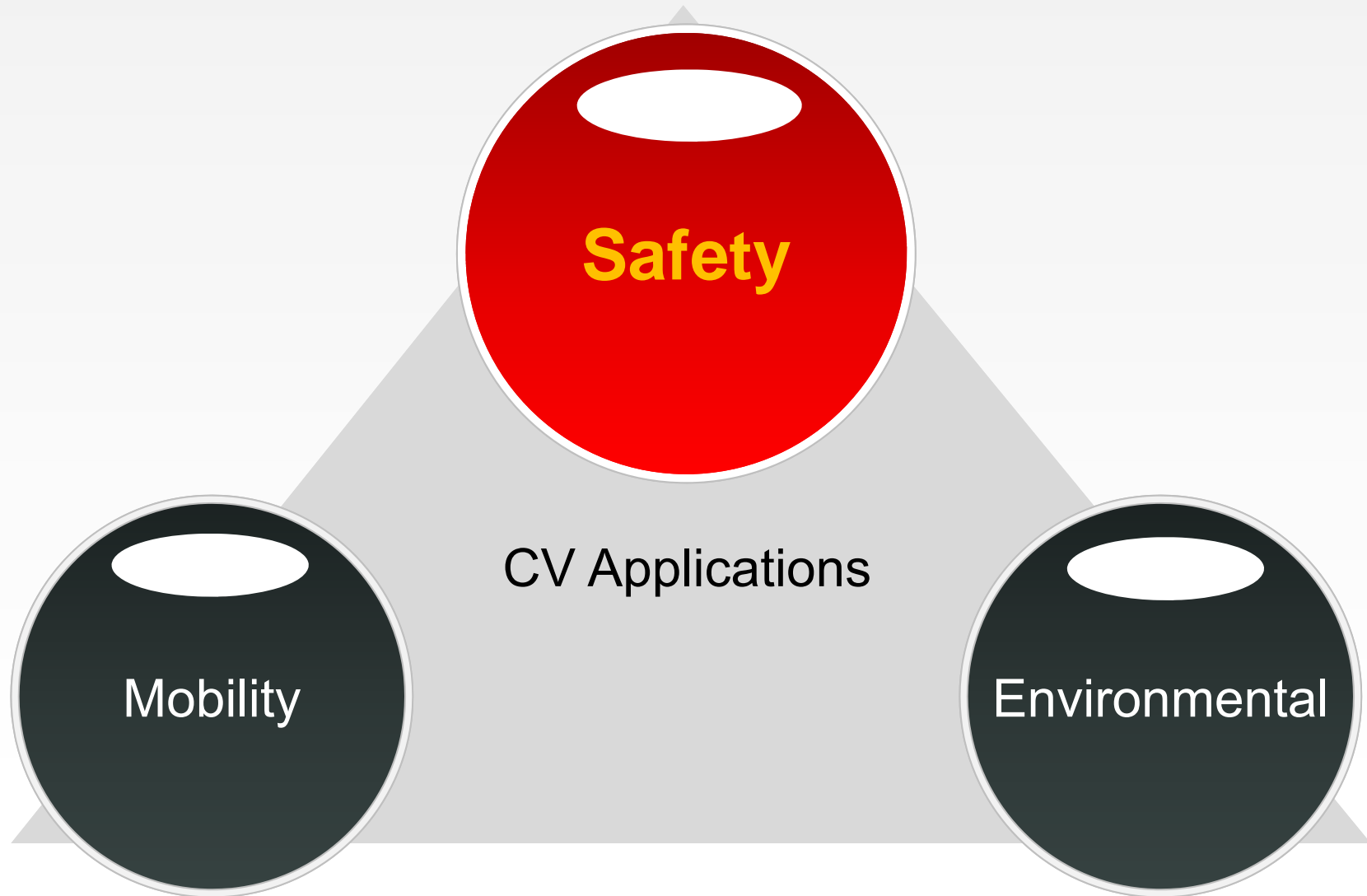


Topic 3: Safety Applications

- After this topic, you will be able to:
 - Explain the purpose and goals of the safety applications
 - Describe what different safety applications do
 - Evaluate the usefulness of a safety application or applications related to an identified need or performance measure



Connected Vehicle Applications



Connected Vehicle Applications: Safety



Purpose and Goals

- Develop V2V and V2I safety applications that address the most critical crash scenarios
- Establish guidelines and standards for the components and systems required for the functional transfer of information for V2V and V2I
- Develop and evaluate a systems environment that allows transfer of information, particularly signal phase and timing (SPaT) data, between vehicles and infrastructure
- Provide tools and guidance based on objective benefits that will guide investment decisions by public agencies on deploying, operating, and maintaining a V2I system
- Ensure appropriate strategies are implemented for privacy, security and system certification, interoperability, scalability, oversight, and public acceptance

Safety

Connected Vehicle Technology for Safety



Safety



Safety Applications: V2V

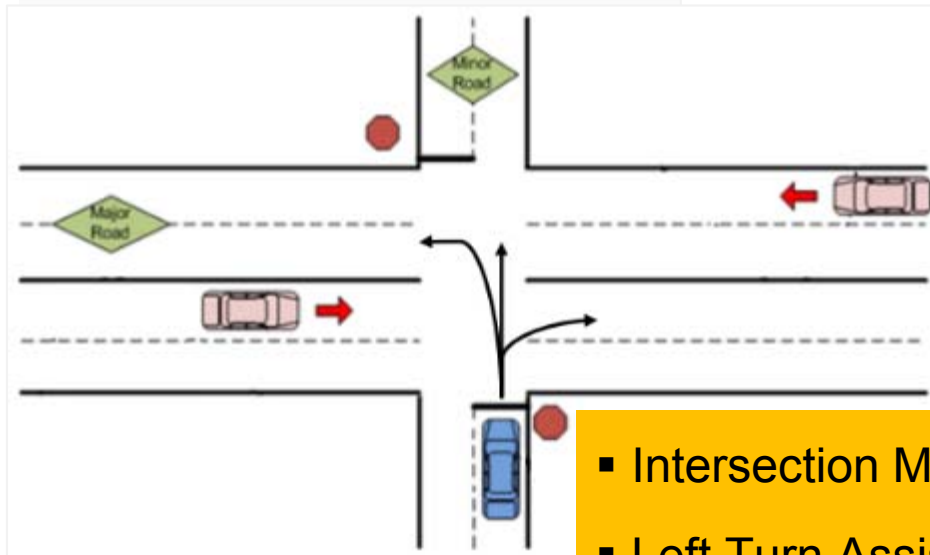
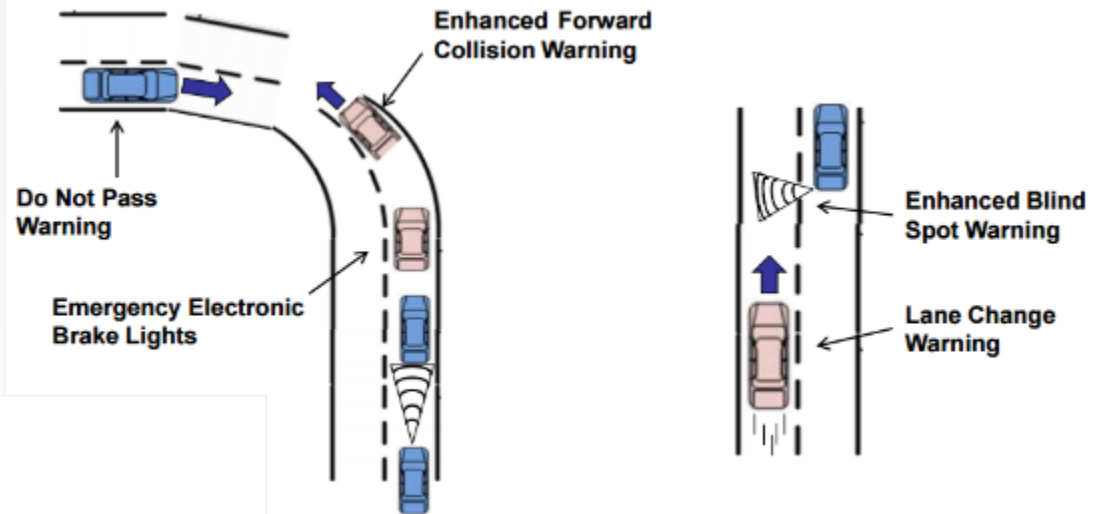
V2V Safety Applications	
Forward Collision Warning	FCW
Emergency Electronic Brake Light	EEBL
Blind Spot/Lane Change Warning	BSW/LCW
Do Not Pass Warning	DNPW
Intersection Movement Assist	IMA
Left Turn Assist	LTA



V2V Application Scenarios

- V2V applications that may enhance the current “forward collision” driver assist technologies that rely primarily on “line-of-sight” sensing

Potential V2V Applications – Forward Collision Scenarios



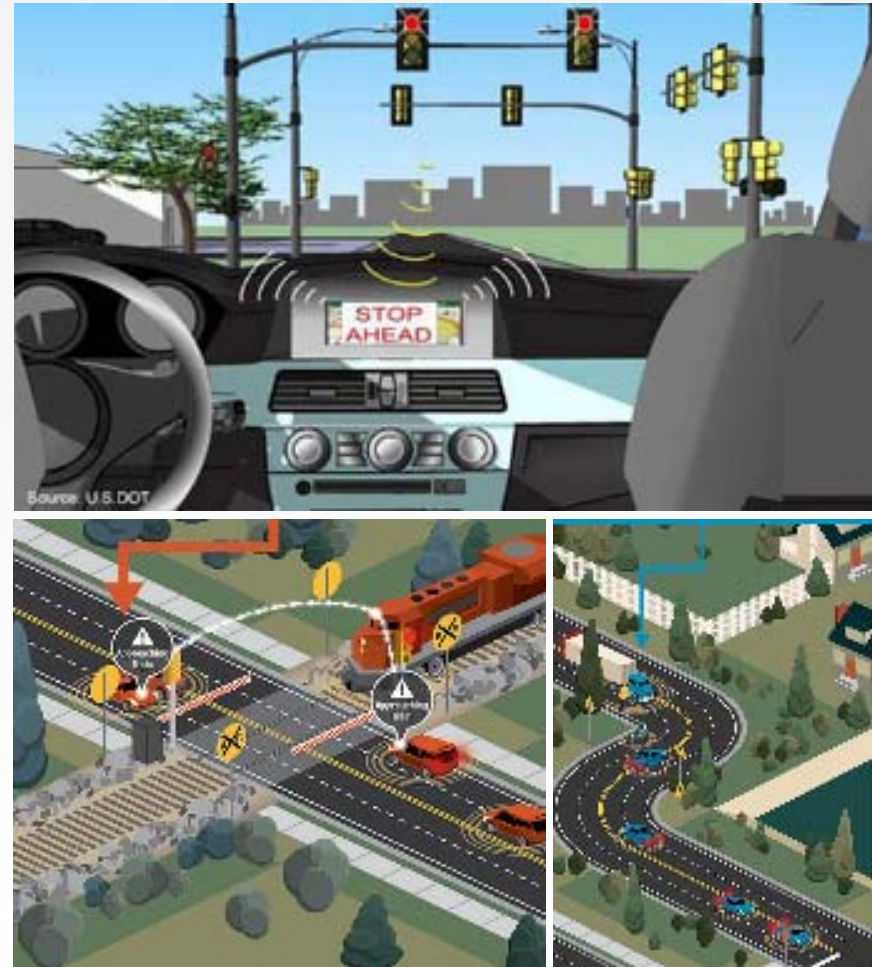
- V2V applications that may reduce “cross-path” collision risk

- Intersection Movement Assist
- Left Turn Assist
- Right Turn Into Path



Safety Applications Status

- Results from NHTSA 2014 V2V Readiness Report:
 - IMA, FCW, and LTA have proven effective in preventing or mitigating crashes
 - BSW/LCW and DNPW could address more crash situations if expanded beyond reliance on turn signal activation
 - EEBL could be revised to include different scenarios not covered by FCW



Benefits of V2V Applications

- NHTSA report produced the following potential benefits of IMA and LTA deployment:
 - 41 to 55% of target intersection accidents avoided
 - 36 to 62% of left-turn accidents avoided
 - 413,000 to 592,000 crashes prevented annually
 - 777 to 1,083 lives saved annually
 - Reduction of 191,000 to 270,000 Abbreviated Injury Scale (AIS) injuries annually



Key Challenges

- Technical

- Wireless spectrum
- V2V device certification issues
- Test procedures, performance requirements, and driver-vehicle interface issues

- Institutional

- Standing up security and communications systems to support V2V
- Liability of manufacturers
- Privacy



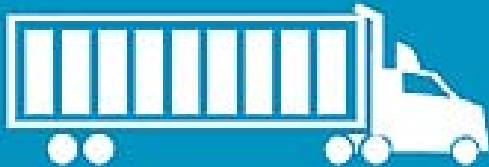
Safety Applications: V2I

V2I Safety Applications	
Curve Speed Warning	CSW
Red Light Violation Warning	RLVW
Spot Weather Information Warning	SWIW
Reduced Speed Zone Warning	RSZW
Stop Sign Gap Assist	SSGA
Smart Roadside	SRI
Transit Pedestrian Warning	



Curve Speed Warning

V2I



Curve Speed Warning

Alerts the driver if current speed is too fast for an approaching curve



- Target crashes approaching horizontal curves on segments or interchange ramps that are speed-related
- Alert trucks they are entering a curve at too high a speed to negotiate it safely
- Improve:
 - Reduction in truck rollover/run off road crashes



Red Light Violation Warning

V2I



Red Light Violation Warning
Issues warning to the driver if he/she
is about to run a red light



- Target crashes that result from signal violations
- Wireless exchange of critical safety and operational data between vehicles and the roadway infrastructure
- Reduce the frequency and severity of safety-related incidents at signalized intersections
- Improves:
 - Significant reduction in collisions, injuries, and fatalities at intersections
 - Non-recurring congestion resulting from incidents is reduced



Transit Warnings

V2I



Pedestrian in Signalized Crosswalk

Warns the bus driver when a pedestrian is crossing the street as the bus is making a right or left turn



- Transit Pedestrian Warning
 - Alert bus drivers to pedestrians in crosswalk at signalized intersections in their path.
- Curve Speed Warning for Transit
 - Alert buses they are entering a curve at too high a speed to negotiate it safely
- Improves
 - Reduction in pedestrian-bus crashes, injuries, and fatalities
 - Reduction in bus rollover/run off road crashes



Benefits of V2I Applications

- V2I applications could potentially target approximately 2.3 million crashes costing \$202 billion annually, including:
 - Red light running - 234,881 crashes, costing \$13.1 billion
 - Driver gap assist at stop-controlled intersections - 278,886 crashes, costing \$18.2 billion
 - Curve speed warning - 168,993 crashes, costing \$29 billion
 - Infrastructure pedestrian detection - 17,812, costing \$3.33 billion



Key Challenges

- Technical - Changes to the infrastructure needed to support the connected vehicle environment
 - Standardized Traffic signal controller interfaces for applications that require signal phase and timing (SPaT) data.
 - Mapping and positioning services for resolving vehicle locations to high accuracy and precision.
 - Data servers for collecting and processing data provided by vehicles and for distributing information, advisories, and alerts
- Institutional - Changing operational environment
 - Workforce/staffing skills
 - Planning and procuring for interoperability
 - Funding mechanism for public agencies





Activity

- Continue planning for connected vehicle applications implementation
- Using the Implementing Connected Vehicle Applications worksheet, complete the following tasks:
 - Document safety applications that could help you meet your performance goal(s)
 - Think about the other impacts these applications could have on mobility and the environment

Topic 3 Wrap-up

- Explain the purpose and goals of the safety applications
- Describe what different safety applications do
- Evaluate the usefulness of a safety application or applications related to an identified need or performance measure



Topic 4: Mobility Applications

Topic	Title	Duration
1	Connected Vehicles: Introduction and Current Status	30 minutes
2	Preparing to Implement Connected Vehicle Applications	30 minutes
3	Safety Applications	30 minutes
4	Mobility Applications	45 minutes
5	Environmental Applications	30 minutes
6	Connected Vehicle Considerations and Resources	40 minutes
7	Course Wrap-up	15 minutes



Topic 4: Mobility Applications

- After this topic, you will be able to:
 - Explain the purpose and goals of the mobility applications
 - Describe what different mobility applications do
 - Evaluate the usefulness of a mobility application or applications related to an identified need or performance measure



Connected Vehicle Applications: Mobility

Purpose and Goals

- Develop open-source applications that use synthesized, multisource ITS data to transform surface transportation management and information
- Develop tools (e.g. an open source portal), metrics, and concepts that support application development
- Develop related applications together in bundles for greater efficiency, less stove-piping, and greater safety and operational awareness

CV Applications

Mobility

Environmental



Mobility

Connected Vehicle Technology for Mobility

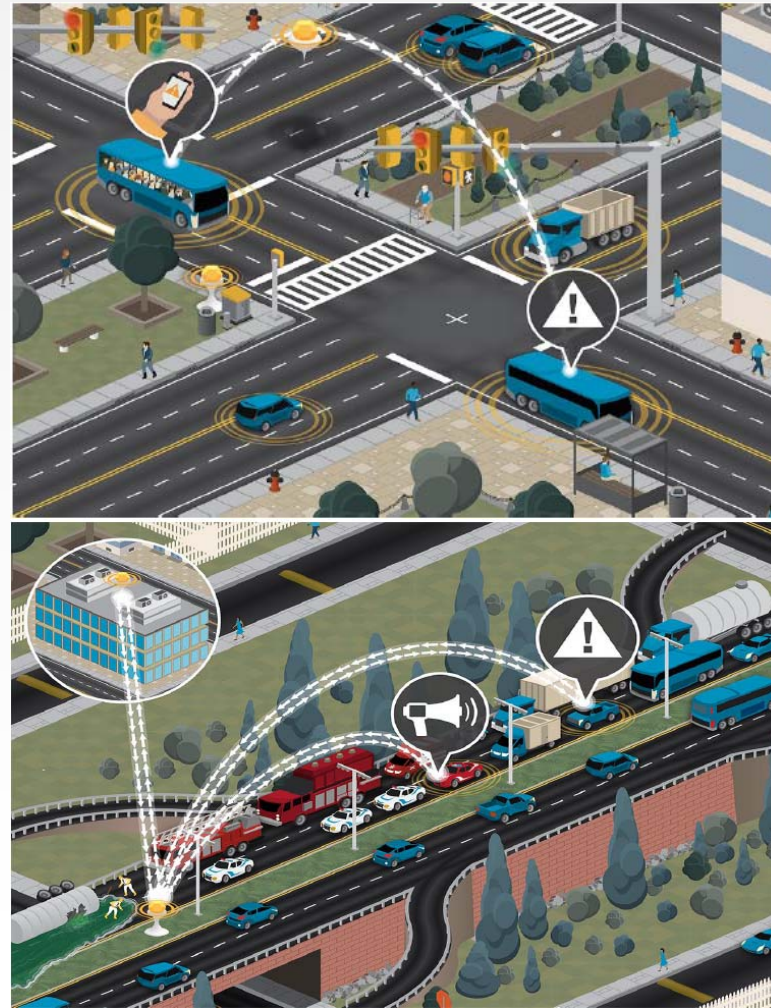


Mobility



Mobility Applications Status

- Prototype development of application bundles.
- Pilot Deployment Solicitation
 - Clear opportunity to successfully deploy collections of complementary connected vehicle applications
 - Have a cost-beneficial impact in the short-term
 - Potentially transformative impacts in the long-term



Dynamic Mobility Applications

Multi-Modal Intelligent Traffic Signal System	MMITSS
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
Intelligent Network Flow Optimization	INFLO
Dynamic Speed Harmonization	SPD-HARM
Queue Warning	Q-WARN
Cooperative Adaptive Cruise Control	CACC



Dynamic Mobility Applications

Response, Emergency Staging and Communications, Uniform Management, and Evacuation	R.E.S.C.U.M.E.
Incident Scene Pre-Arrival Staging Guidance for Emergency Responders	RESP-STG
Incident Scene Work Zone Alerts for Drivers and Workers	INC-ZONE
Emergency Communications and Evacuation	EVAC
Enable Advanced Traveler Information Systems	Enable ATIS



Dynamic Mobility Applications

Integrated Dynamic Transit Operations	IDTO
Connection Protection	T-CONNECT
Dynamic Transit Operations	T-DISP
Dynamic Ridesharing	D-RIDE
Freight Advanced Traveler Information Systems	FRATIS
Dynamic Travel Planning and Performance	
Drayage Optimization	



MMITSS Application Descriptions

Intelligent Traffic Signal System (I-SIG)

An overarching system optimization application accommodating signal priority, preemption, and pedestrian movements.

Emergency Vehicle Preemption (PREEMPT)

An application that provides signal preemption to emergency vehicles, and accommodates multiple emergency requests.

Transit Signal Priority (TSP) and Freight Signal Priority (FSP)

Two applications that provide signal priority to transit at intersections and along arterial corridors as well as signal priority to freight vehicles along an arterial corridor near a freight facility.

Mobile Accessible Pedestrian Signal System (PED-SIG)

An application that allows for an automated call from the smartphone of a visually impaired pedestrian to the traffic signal, as well as audio cues to safely navigate the crosswalk.



INFLO Application Descriptions

Dynamic Speed Harmonization (SPD-HARM)

An application that aims to recommend target speeds in response to congestion, incidents, and road conditions to maximize throughput and reduce crashes.

Queue Warning (Q-WARN)

An application that provides drivers timely warnings of existing and impending queues.

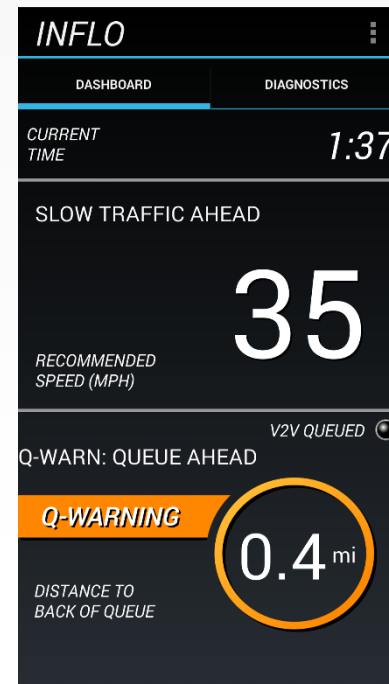
Cooperative Adaptive Cruise Control (CACC)

An application that aims to dynamically adjust and coordinate cruise control speeds among platooning vehicles to improve traffic flow stability and increase throughput.



INFLO Concepts and Performance Measures

- Concepts
 - Utilizes V2V and/or V2I communication to coordinate vehicle speeds, share vehicle position/speed/braking information, and implement gap policy
- Performance Measures
 - Reduced speed variability
 - Higher throughput
 - Reduced rear-end collisions
 - Fuel economy savings
 - Emissions reductions



Queue Ahead and Speed Harmonization Recommended Speed Message



R.E.S.C.U.M.E. Application Descriptions

Incident Scene Pre-Arrival Staging Guidance for Emergency Responders (RESP-STG)

An application that provides situational awareness to responders while on route to an incident to assist with routing, staging and secondary dispatch decisions.

Incident Scene Work Zone Alerts for Drivers and Workers (INC-ZONE)

An application that provides in-vehicle messaging to motorists as they approach an incident scene and warnings to on-scene workers.

Emergency Communications and Evacuation (EVAC)

An application that provides dynamic route guidance information, current traffic and road conditions, location and availability of essential services such as hotels. Provides information to identify and locate people who require guidance and assistance, and connect them with service providers and other resources.



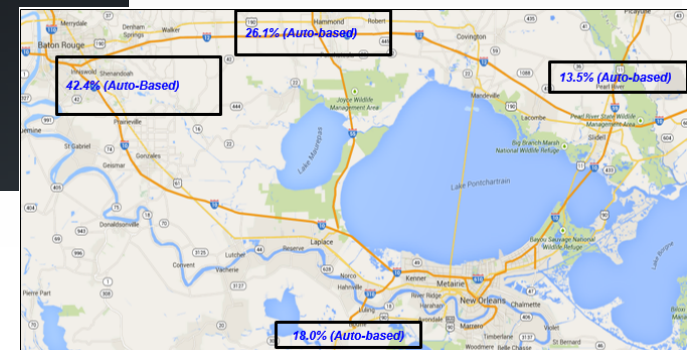
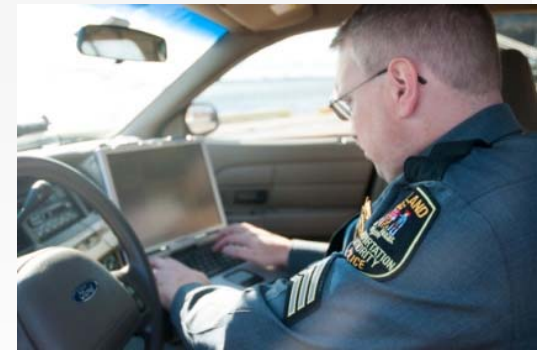
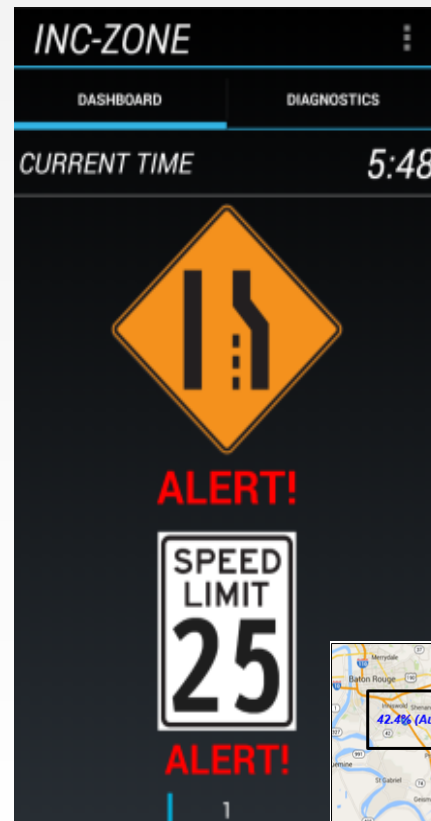
R.E.S.C.U.M.E. Concepts

■ RESP-STG and INC-ZONE

- Based on V2V connected vehicle applications
- Prototype integrates DSRC, Cellular, and Bluetooth in both oncoming and responder vehicles
- Lane level mapping and GPS positioning accuracy system critical to success

■ EVAC

- Provide traveler information to improve evacuees' mobility and clearance time



R.E.S.C.U.M.E. Performance Measures

Direct Performance Measures:

- Network mobility measures
- Average Vehicle Delay
- Average Number of Stops
- Average Travel-Speed of Vehicles
- Throughput of Incident Zones
- Average Fuel Consumption
- Average Emissions

Indirect Performance Measures:

- Surrogate safety measures derived from analysis
- Lane-changes in the vicinity of the incident-zone
- Speed-differential in the vicinity of the incident zone
- Improvement of response vehicle travel-time

EVAC Performance Measures:

- Network mobility measures
- Effectiveness measures: average travel time to lodging; number of fueling failures; average wait time for buses



Enable ATIS Overview

Foster transformative traveler information applications and strategies that:

- Goal 1: Transform the user experience on the transportation network. Future traveler information systems will intuitively provide users with trip, location, and mode specific information to empower real-time decision making.
- Goal 2: As a result of EnableATIS, the transportation networks will experience measurable gains in performance, including mobility, safety, and efficiency.
- Goal 3: A more robust traveler information suite of capabilities will be enabled through a rich and multisource data environment that leverages public sector system and operations data, transportation network operations, and user data from privately operated systems.



Enable ATIS Concepts and Performance Measures

- Concepts
 - Federal role to provide framework
 - Demonstration apps record user activity (both mobile and vehicle)
 - Provide users with information for real-time decision making
- Performance Measures
 - Travel time reliability
 - Long-term: impact on network mobility measures



IDTO Application Descriptions

T-CONNECT (Connection Protection)

Increases the likelihood of making successful transfers by monitoring inbound and outbound vehicles, as well as travelers, determining if/how a connection can be preserved, and initiating the necessary notifications to these parties

T-DISP (Dynamic Transit Operations)

For travelers, T-DISP provides an ability to access real-time information about available travel options in order to best manage their commutes. For an agency, T-DISP extends demand / response services to support dynamic routing and scheduling

D-RIDE (Dynamic Rideshare)

New, more efficient approach to rideshare concepts including real-time scheduling



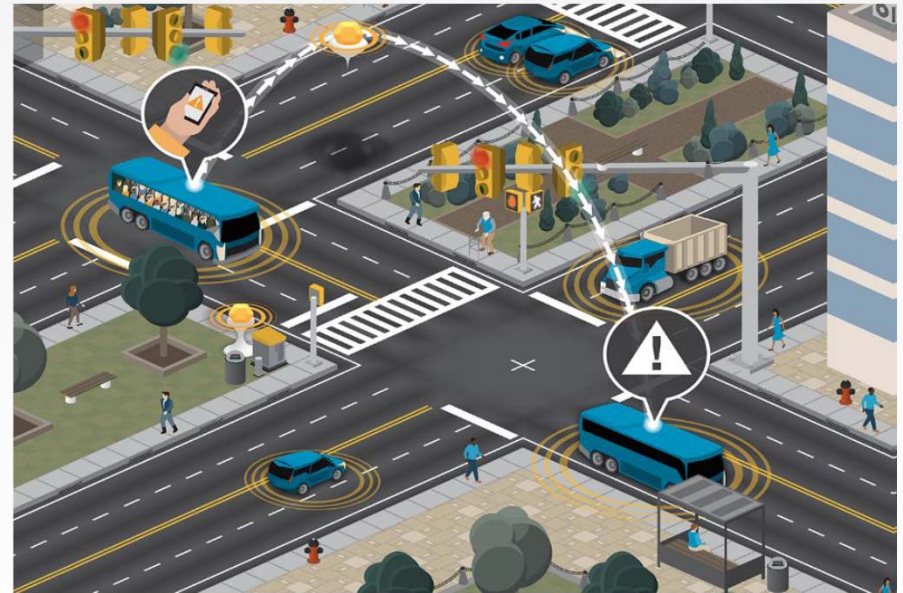
IDTO Overview

- The IDTO bundle provides benefits to travelers and transportation service providers by:
 - Bringing together public and private-sector transportation provider information and operations
 - Leveraging the widespread and growing adoption of smartphones as a travel planning and in-trip notification tool
 - Building on available standards and open-source tools
 - Integrating three travel-related apps that individually offer significant value, and when integrated, provide even greater benefits



IDTO Concepts and Performance Measures

- Concepts
 - Single user interface
 - Dispatcher interface step towards full CAD/AVL integration
 - Traveler is notified in real time using own mobile device.
- Performance Measures
 - Reduced passenger waiting times
 - Transit trip reliability
 - Fewer missed transit trips
 - Improve transit ridership



FRATIS Application Descriptions

Freight Specific Dynamic Travel Planning and Performance

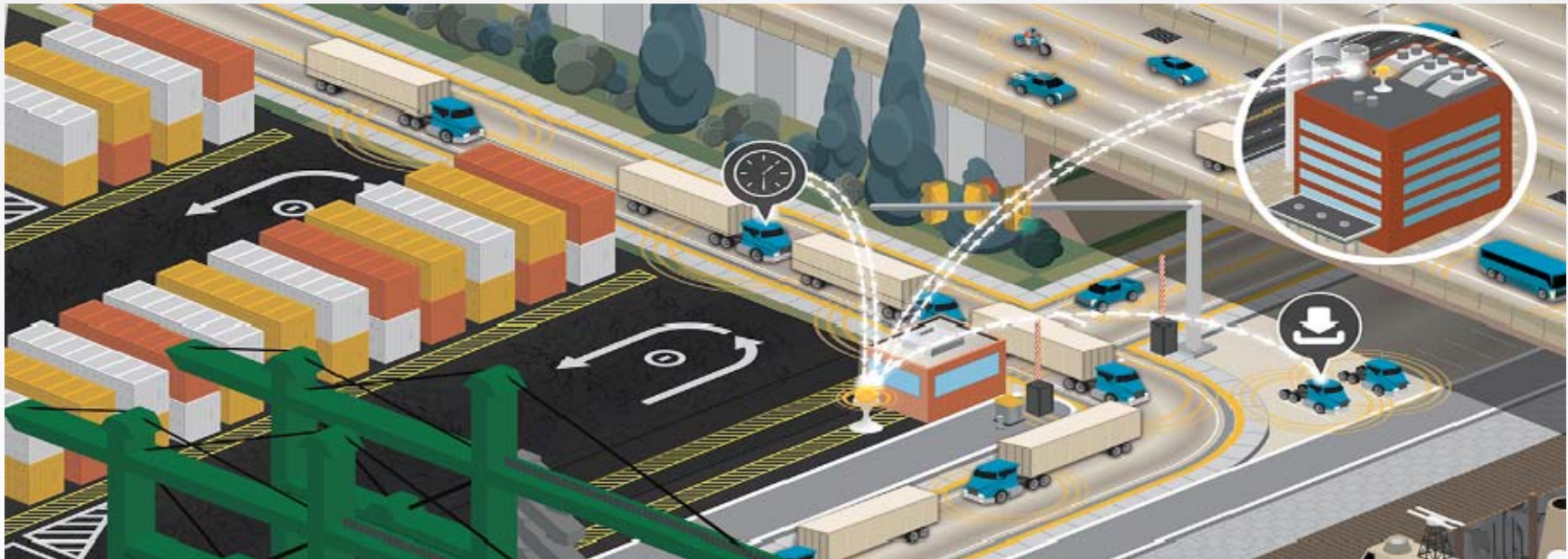
Series of applications integrating freight traveler information, dynamic route guidance, and public sector performance monitoring to improve freight travel time and reduce fuel consumption and emissions.

Drayage Optimization

Integrated load matching and freight information exchange, including appointment scheduling and equipment availability at intermodal terminals.



FRATIS Overview and Concepts



1. Drayage companies receive their Orders for a given day

2. Orders are collected and run through the optimization algorithm to create optimized plan

3. The optimized plan is reviewed and approved by the dispatcher

4. The optimized drivers plans are distributed to each truck drivers through in-vehicle units

5. Changes to orders are sent directly to the drivers

6. Order status information is sent directly back to the drayage companies



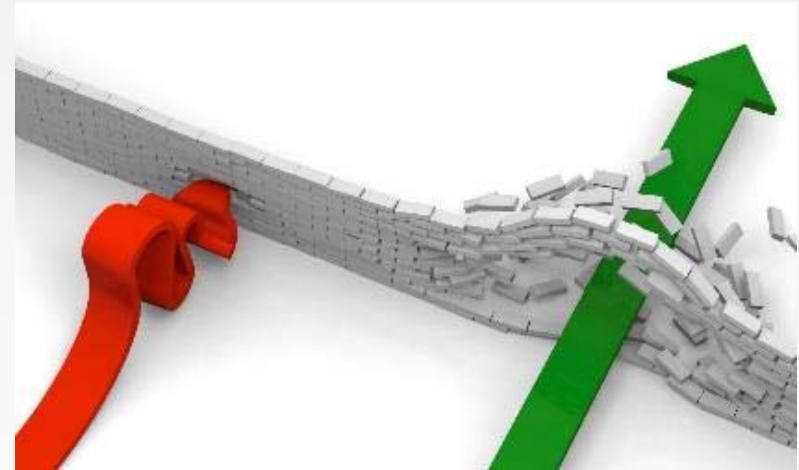
FRATIS Performance Measures

- Travel time shipper-to-terminal
- Terminal queue time
- Fleet average fuel consumption
- Emissions
- Freight data



Key Challenges

- Institutional
 - Requires training for engineering and staff to understand technology and system operation
 - Agency/Partner Cooperation
 - Driver/dispatcher acceptance and participation
- Technical
 - Standardization of the information
 - Data exchange interoperability
 - Transferability/scalability





Activity

- Continue planning for connected vehicle applications implementation
- Using the Implementing Connected Vehicle Applications worksheet, complete the following tasks:
 - Document mobility applications that could help you meet your performance goal(s)
 - Think about the other impacts these applications could have on safety and the environment

Topic 4 Wrap-up

- Explain the purpose and goals of the mobility applications
- Describe what different mobility applications do
- Evaluate the usefulness of a mobility application or applications related to an identified need or performance measure



Topic 5: Environmental Applications

Topic	Title	Duration
1	Connected Vehicles: Introduction and Current Status	30 minutes
2	Preparing to Implement Connected Vehicle Applications	30 minutes
3	Safety Applications	30 minutes
4	Mobility Applications	45 minutes
5	Environmental Applications	30 minutes
6	Connected Vehicle Considerations and Resources	40 minutes
7	Course Wrap-up	15 minutes



Topic 5: Environmental Applications

- After this topic, you will be able to:
 - Explain the purpose and goals of the environmental applications
 - Describe what different environmental applications do
 - Evaluate the usefulness of an environmental application or applications related to an identified need or performance measure



Connected Vehicle Applications: Environment

AERIS

- Identify connected vehicle applications that could provide environmental impact reduction benefits via reduced fuel use, improved vehicle efficiency, and reduced emissions.
- Facilitate and incentivize “green choices” by transportation service consumers (i.e., system users, system operators, policy decision makers, etc.).
- Identify vehicle-to-vehicle (V2V), vehicle-to-infrastructure (V2I), and vehicle-to-grid (V2G) data (and other) exchanges via wireless technologies of various types.
- Model and analyze connected vehicle applications to estimate the potential environmental impact reduction benefits.
- Develop a prototype for one of the applications to test its efficacy and usefulness

Road Weather

- Understand the impacts of weather on roadways.
- Conduct applied research to develop strategies and tools to mitigate those impacts.
- Promote the deployment of these strategies and tools.





Connected Vehicle Technology for the Environment



Environment



Environment Applications Status - AERIS



- AERIS Concept of Operations
 - Published documents: Eco-Signal Operations, Eco-Lanes and Low Emissions Zones
 - In Development: Eco-Traveler Information and Eco-Integrated Corridor Management (Eco-ICM)
- AERIS Analysis, Modeling, and Simulation (AMS)
 - Finalized Analysis, Modeling, and Simulation for Priority AERIS Operational Scenarios (Eco-Signal Operations, Eco-Lanes, and Low Emissions Zones)
 - Final reports are in the USDOT's publication process
- AERIS Prototyping Efforts
 - A field test of the Eco-Approach and Departure at Signalized Intersections application was conducted in 2012 at TFHRC with a single vehicle at a single intersection with no traffic
 - The GlidePath Prototype Application effort is building on the initial field experiment and incorporates automated longitudinal control capabilities; Final report expected December 2015



Environment Applications: AERIS



AERIS: Cleaner Air Through Smarter Transportation

ECO-SIGNAL OPERATIONS

Eco-Approach and Departure at Signalized Intersections

Eco-Traffic Signal Timing

Eco-Traffic Signal Priority

Connected Eco-Driving

Wireless Inductive/Resonance Charging

ECO-LANES

Eco-Lanes Management

Eco-Speed Harmonization

Eco-Cooperative Adaptive Cruise Control

Eco-Ramp Metering

Connected Eco-Driving

Wireless Inductive/Resonance Charging



Environment Applications: AERIS



AERIS: Cleaner Air Through Smarter Transportation

LOW EMISSIONS ZONES

Low Emissions Zone Management

Eco-Traveler Information Applications

ECO-TRAVELER INFORMATION

Connected Vehicle-Enabled Environmental Probe Data Collection

Alternative Fuel Vehicle (AFV) Charging/Fueling Information, Reservations, and Payment

Connected Eco-Driving – Gamified/Incentives-Based Apps

Dynamic Eco-Routing

Eco-Smart Parking

Gamified/Incentives-Based Multi-Modal Traveler Information



Environment Applications: AERIS



AERIS: Cleaner Air Through Smarter Transportation

ECO-INTEGRATED CORRIDOR MANAGEMENT

Eco-ICM Decision Support System

Eco-Signal Operations Applications

Eco-Lanes Applications

Low Emissions Zones Applications

Eco-Traveler Information Applications

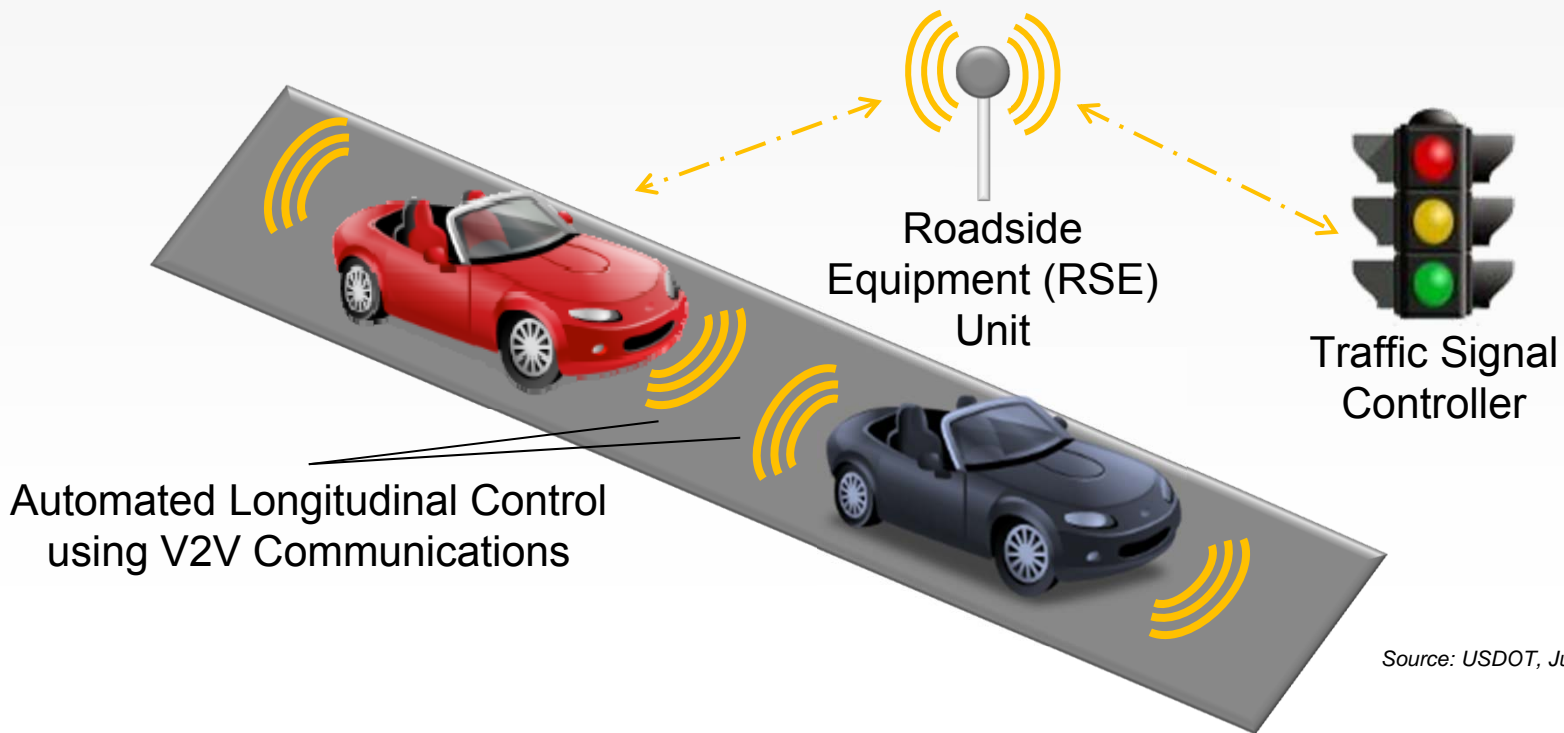


Eco-Signal Operations Overview



- Eco-Approach and Departure
- Eco-Traffic Signal Timing
- Eco-Traffic Signal Priority

Uses connected vehicle technologies to decrease fuel consumption and emissions by reducing idling, the number of stops, unnecessary accelerations/decelerations, and improving traffic flow at signalized intersections



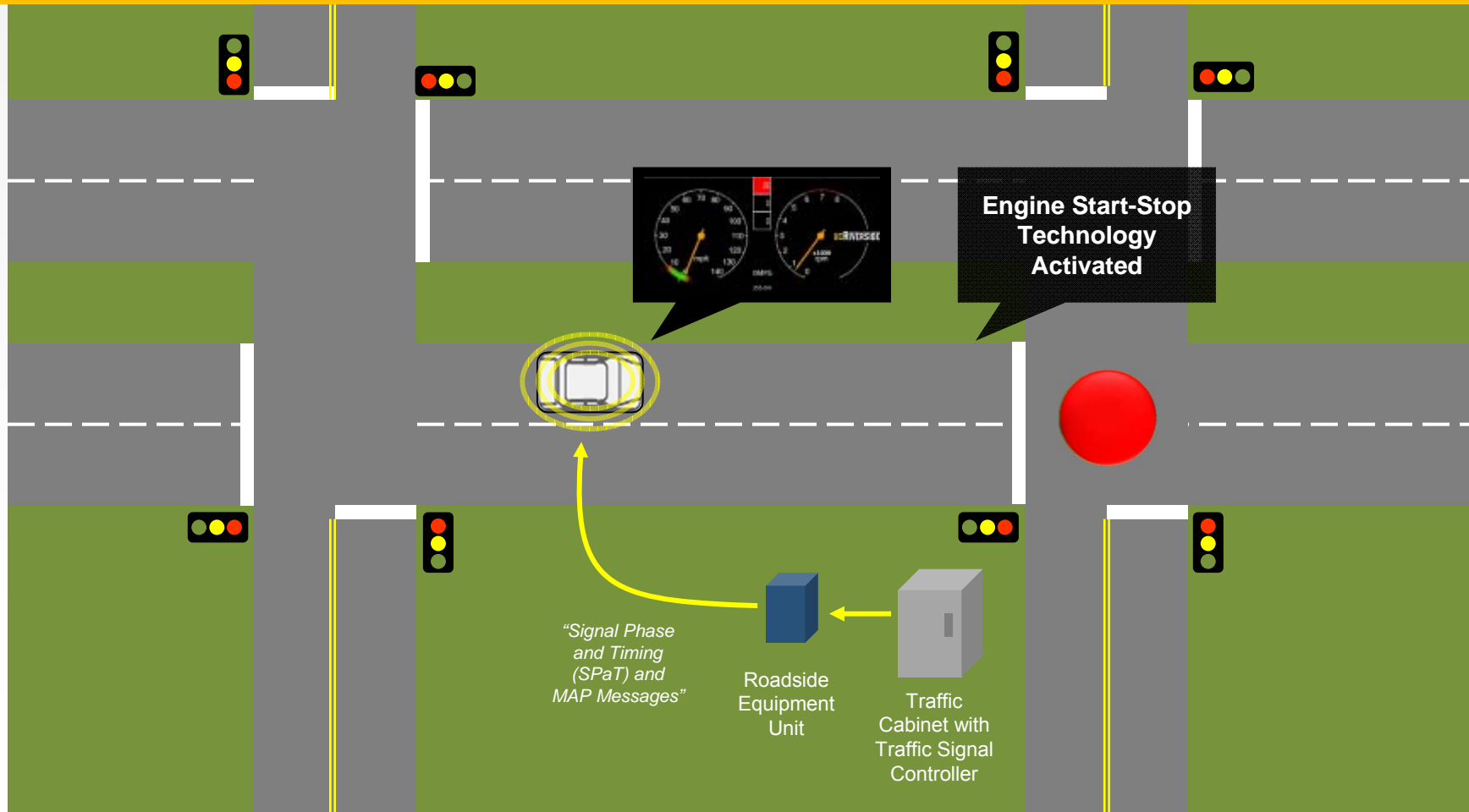
**Combined Modeling of Applications:
Resulted in a 9.6% reduction in fuel consumption.**



Eco-Signal Operations Applications Description



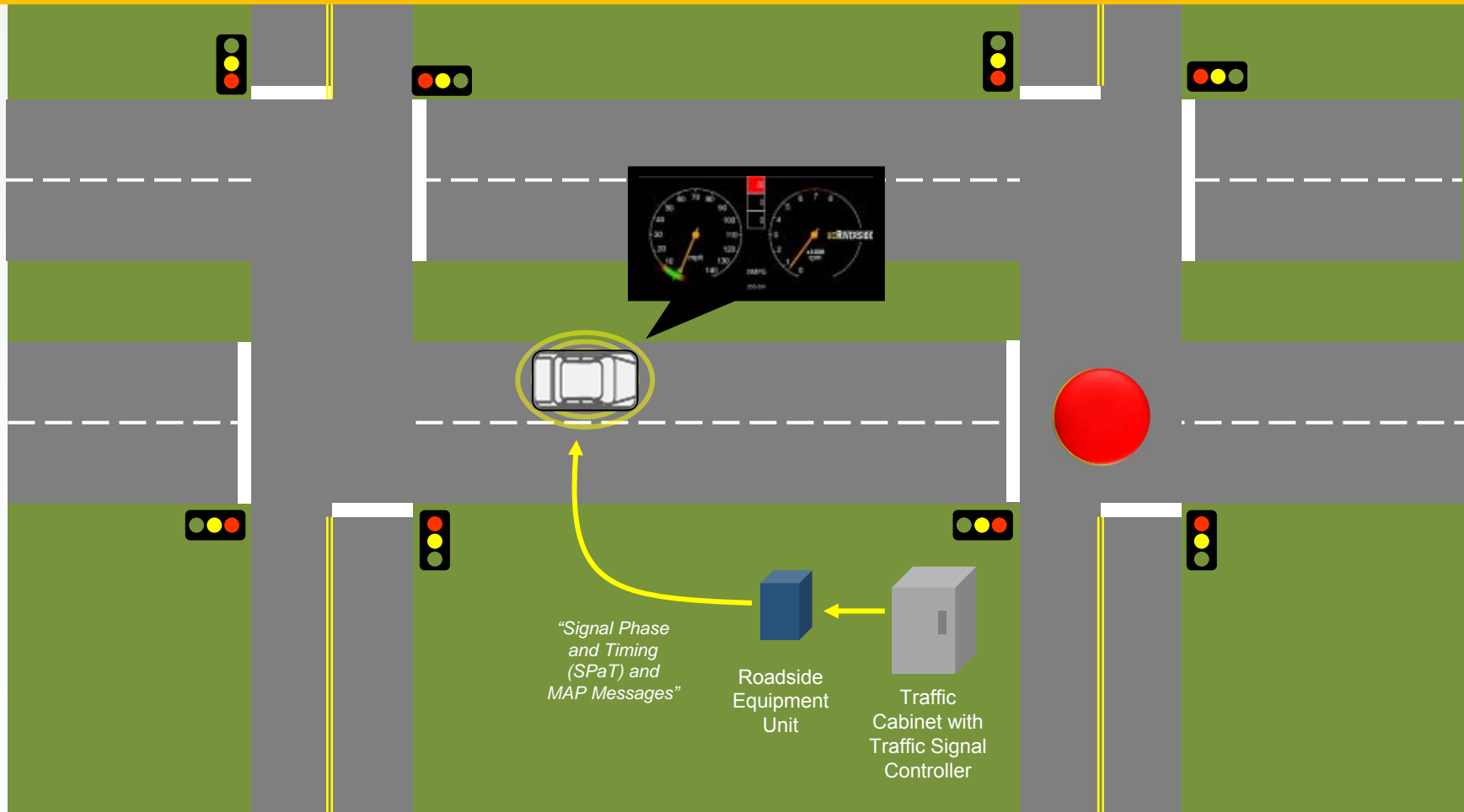
Eco-Approach and Departure at Intersections: Eco-Friendly Stop



Eco-Signal Operations Applications Description



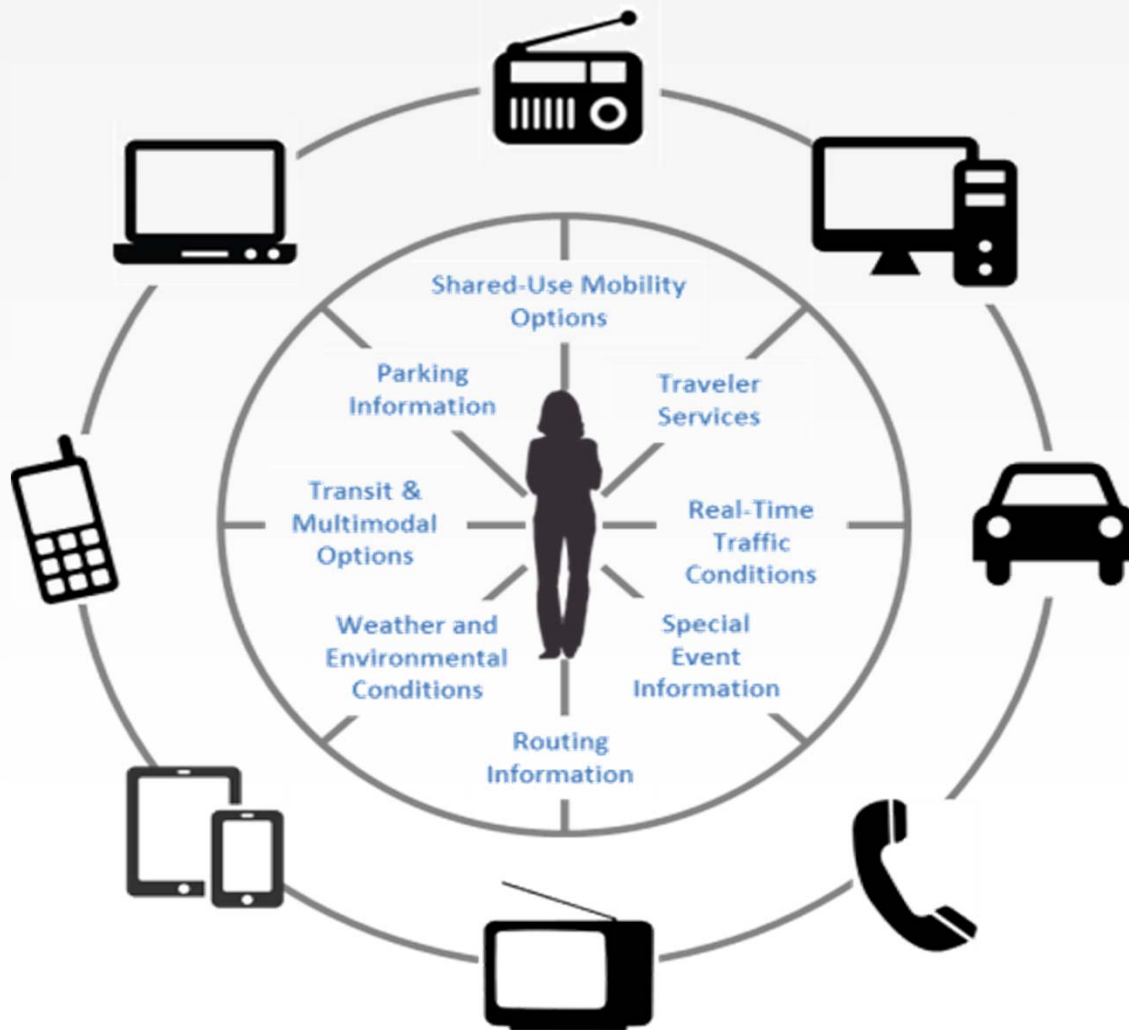
Eco-Approach and Departure at Intersections: Slowly Accelerating to Avoid Stopping





Eco-Traveler Information Overview

- Enables development of new, advanced traveler information applications through integrated, multi-source, multi-modal data



User-focused traveler information that supports a more sustainable relationship between transportation and the environment

Eco-Traveler Information Applications Description



- Alternative Fuel Vehicle (AFV) Charging/Fueling Information, Reservations, and Payment

EV Charging Information

- Electric vehicle charging information applications can inform travelers of their electric vehicle's range
- Applications can inform travelers of locations and the availability of charging stations
- Applications may allow drivers to make reservations to use charging stations before they start their trip or while en-route
- Electronic payment cards—or applications on a smart phone—may also be used to support the payment of charging and fueling stations

“Your vehicle does not have enough charge to reach your destination. Reserve a charging station in Philadelphia, PA.”



AERIS Applications Benefit Drivers, Fleet Operators and Cities



Assuming an Average Corridor

Combined Eco-Signal Operations Modeling Results Indicate:

- Light vehicles: 9.6% reduction in fuel consumption
- Freight: 9.8% reduction in fuel consumption
- Transit: 3.1% reduction in fuel consumption

Gasoline Costs:

- \$3.67/gallon (light vehicle and SUV)
- \$3.95/gallon for diesel (trucks)
- \$3.00/gallon estimated for mix of CNG and diesel fleets (transit)

Average Miles Traveled on Arterials:

- Light duty vehicle and SUVs: 8,250 miles
- City delivery truck: 30,000 miles
- Transit: 44,600 miles

Estimated Benefits

- Light Vehicle, 23 MPG ~ **\$126 per year**
- City Delivery Fleet (1,000 vehicles), 7.3 MPG ~ **\$1.6M per year**
- Transit Fleet (1,000 vehicles), 4 MPG ~ **\$918,000 per year**

AERIS applications help drivers reduce their carbon footprint and reduce their fuel consumption. **Drivers help the environment and save money at the pump.**



Fleet operators also benefit from AERIS applications. **Fuel savings help fleet operators save fuel costs resulting in lower operating costs.**



AERIS applications benefit cities, helping reduce emissions and improving the city's air quality. AERIS applications also help reduce congestion and support sustainable transportation solutions.



Key Challenges



- Increasing the overall awareness of environmental issues/challenges and the potential for ITS and connected vehicle technologies.
 - Fostering strong partnerships and commitment for environmental deployments.
- Providing eco-information to drivers in a manner that minimizes driver distraction.
 - The AERIS Research Program is investigating how partial and full automation may be used to support environmental applications.
- Ensuring environmental needs and data elements are incorporated into connected vehicle standards (e.g., J2735).
- Conveying environmental benefits to users of all types—including decision makers—that are meaningful (e.g., emissions reductions, fuel savings)



Road Weather

Connected Vehicle Technology for Road Weather Safety



Road Weather



Environment Applications: Road Weather

Motorist Advisories and Warnings (MAW)

Enhanced Maintenance Decision Support System (MDSS)

Vehicle Data Translator (VDT)

Weather-Responsive Travel Information (WxTINFO)



Road Weather Applications Overview

- Motorist Advisories and Warnings (MAW)
- Enhanced Maintenance Decision Support System (MDSS)
- Vehicle Data Translator (VDT)
- Weather-Responsive Travel Information (WxTINFO)



Photo Source: Thinkstock

Photo Source: USDOT

Road Weather Connected Vehicle Applications



U.S. Department of Transportation
ITS Joint Program Office

Benefits of Road Weather Applications

- 24 percent of all crashes occur under adverse weather conditions, resulting in more than 673,000 people injured and 7,100 fatalities.
- The estimated cost of weather-related crashes ranges from \$22 billion to \$51 billion annually.
- Road Weather applications have the potential to lower these costs.
- Current Maintenance Decision Support Systems (MDSS) show benefit cost ratios 1.33 to 8.67, with annual savings ranging from \$1.3 million to \$11 million.
- Benefit-cost analysis performed in Finland found a benefit cost ratio of 1.1 to 1.9, supporting weather information controlled variable speed limits - one potential benefit of MAW.



Road Weather Applications Status and Schedule

- Road Weather Applications development on schedule:
 - **FY15**- Connected vehicle prototype applications developed, tested, evaluated, and potential demonstration
 - **FY16** – Vehicle Data Translator and Weather Data Environment mature and ready for road weather connected vehicle data capture and management
 - **FY17** – Weather-Responsive Traffic Management strategies implemented, tested, and ready for deployment; Guidance on State DOT/NWS operations completed
 - **FY18** – High-resolution (spatial and temporal) and route/segment-specific road condition prediction capability proven for mainstream implementation
 - **FY19** – Weather-sensitive automation capabilities demonstrated; Guidance for weather-related performance measurement and management ready



Moving Towards Deployment

1

IDENTIFY LOCAL NEEDS

Identify local problems, challenges, and/or issues you are trying to address

2

SET PERFORMANCE GOALS

Set measurable goals and objectives that allow you to address local needs

3

SELECT CONNECTED VEHICLE APPLICATIONS THAT WORK TOGETHER TO MEET THOSE GOALS

Identify potential solutions, including connected vehicle applications, that help you meet your goals and objectives





Group Exercise

- Complete planning for connected vehicle applications implementation
- Using the Implementing Connected Vehicle Applications worksheet, complete the following tasks:
 - Document environmental applications that could help you meet your performance goal(s)
 - Think about the other impacts these applications could have on safety and mobility
- Choose a transportation challenge and discuss how the safety, mobility, and environmental applications would help you meet your performance goals.

Topic 5 Wrap-up

- Explain the purpose and goals of the environmental applications
- Describe what different environmental applications do
- Evaluate the usefulness of a environmental application or applications related to an identified need or performance measure



Topic 6: Connected Vehicle Considerations and Resources

Topic	Title	Duration
1	Connected Vehicles: Introduction and Current Status	30 minutes
2	Preparing to Implement Connected Vehicle Applications	30 minutes
3	Safety Applications	30 minutes
4	Mobility Applications	45 minutes
5	Environmental Applications	30 minutes
6	Connected Vehicle Considerations and Resources	40 minutes
7	Course Wrap-up	15 minutes



Topic 6: Connected Vehicle Considerations and Resources

- After this topic, you will be able to:
 - Explain the recommend approach for implementing connected vehicle applications
 - Describe security and privacy considerations
 - Identify resources for connected vehicle application deployment
 - Discuss future implementation needs – connected automation



Moving Towards Deployment

1

IDENTIFY LOCAL NEEDS

Identify local problems, challenges, and/or issues you are trying to address

2

SET PERFORMANCE GOALS

Set measurable goals and objectives that allow you to address local needs

3

SELECT CONNECTED VEHICLE APPLICATIONS THAT WORK TOGETHER TO MEET THOSE GOALS

Identify potential solutions, including connected vehicle applications, that help you meet your goals and objectives



Consider Communications Security Policy

- How do we know that the sender of a message should be 'trusted'?
 - Need to validate messages exchanged between vehicles (V2V) and between vehicles and infrastructure (V2I)
- Requires Security Credential Management System (SCMS)
 - Organizational entities for operating security management system
 - Communications network for security updates



Consider Privacy and Data Policy

- A user should not be tracked or identified (e.g., no personally identifiable information)
- Important to ensure that messages cannot be linked to personal information
 - Basic safety messages, certificates, and other information exchange should not link to personal identifiers
- Data management policies



Infrastructure Deployment Planning and Resources

- FHWA Deployment Guidance
- Standardized Interfaces (CVRIA)
- CO-PILOT
- Research Data Exchange
- SET-IT
- OSADP
- Reference Implementation



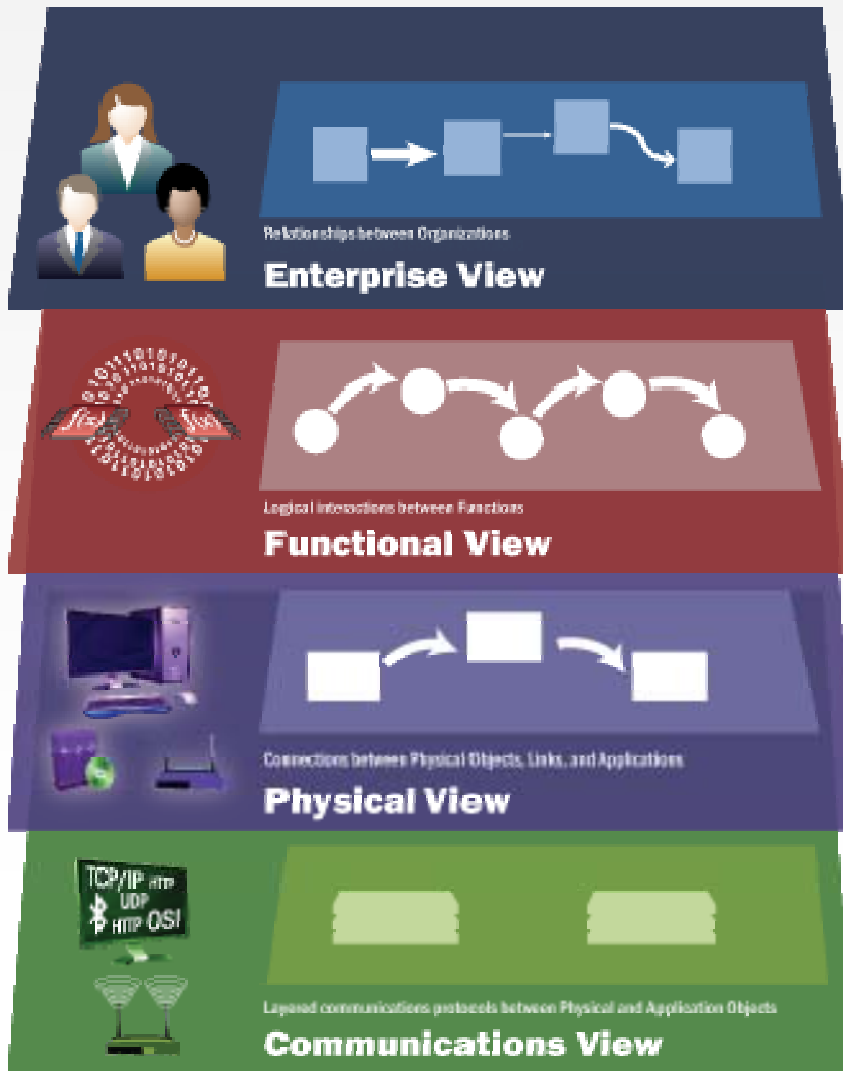
2015 FHWA Vehicle to Infrastructure Deployment Guidance and Products

- FHWA Guidance to State and local agencies for implementing V2I to ensure interoperability and efficient and effective planning, procurement, and operations
- Goal is to provide:
 - Initial advice
 - Best practices
 - Technical support tools
- Products and Tools:
 - Systems Engineering Process for V2I
 - V2I Benefit Cost Analysis Tool
 - V2I Planning Guide
 - Guide to V2I Cyber-Security
 - Guide to Licensing DSRC Roadside Units
 - Guide to V2I Communication Technology Selection
 - V2I Message Lexicon



Connected Vehicle Reference Implementation Architecture (CVRIA)

Connected Vehicle Reference Implementation Architecture



CVRIA: A Framework for integrating technologies and identifying interfaces for standardization

<http://www.iteris.com/cvria/>

- The Systems Engineering Tool for Intelligent Transportation (SET-IT) is available for download from the CVRIA website
- On-line training for CVRIA and SET-IT are available on the CVRIA website



CO-PILOT



HOME COST ESTIMATION HELP



HIGH-LEVEL ESTIMATION of your Proposed Deployment Costs



Interested in learning more about the CV Pilots Deployment Project? Visit <http://www.its.dot.gov/pilots/> for more information



CO-PILOT Values Your Input! Please take a few minutes to respond to our user-experience survey by clicking [HERE](#)

ABOUT OUR TOOL

The Cost Overview for Planning Ideas & Logical Organization Tool (CO-PILOT) is a high-level tool supporting stakeholders considering connected vehicle pilot deployments. These pilot deployments will combine connected vehicle and mobile device technologies innovations to **Improve Traveler Mobility** and **System Productivity** while **Reducing Environmental Impacts** and **Enhancing Safety**.

The CO-PILOT allows stakeholders to **Easily Estimate Costs of your Proposed Pilot Deployments**. This initial tool allows cost estimation for 56 applications in the Vehicle to Infrastructure Safety, Vehicle to Vehicle Safety, Agency Data, Environment, Road Weather, Mobility, and Smart Roadside application groups.

[Start Using The Tool](#)

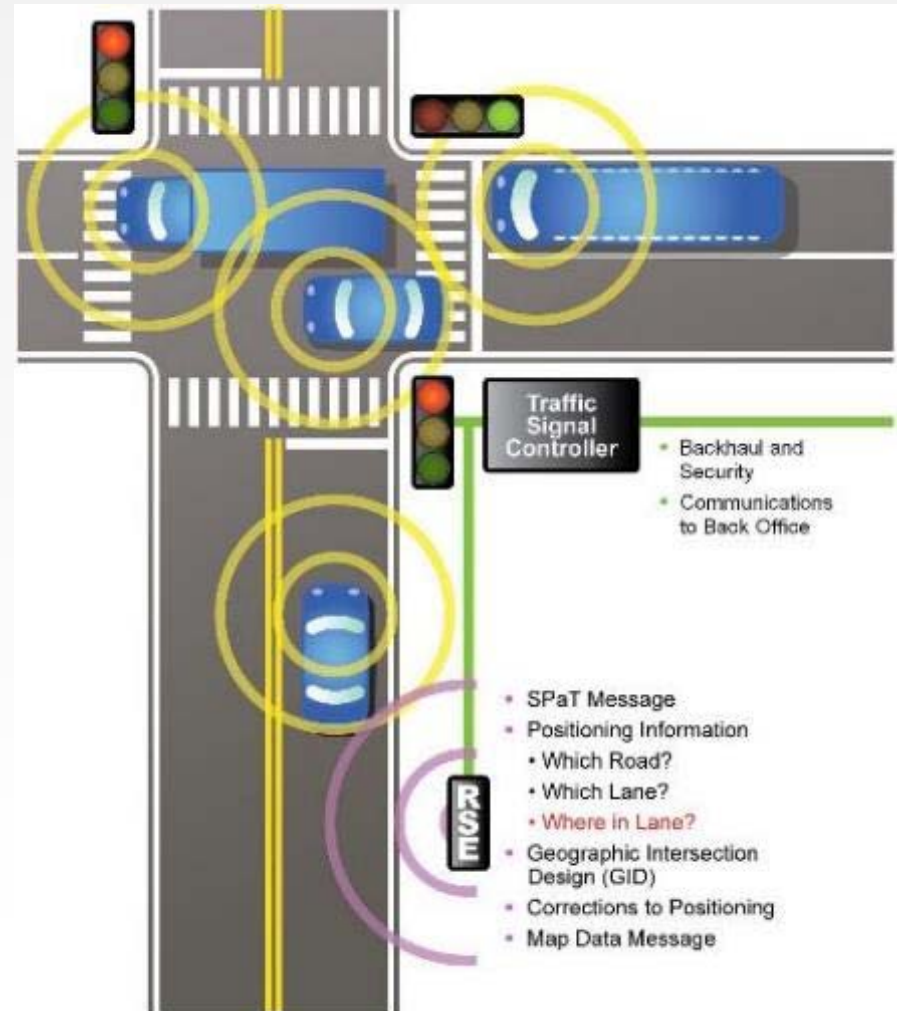
HAVE YOUR ESTIMATED COST IN 4 EASY STEPS:



HAVE QUESTIONS?

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
- Integrated V2I Prototype
 - Field research testing in 2015
 - Reference Implementation builds upon Integrated V2I Prototype



Research Data Exchange

- Promotes sharing of archived and real-time connected vehicle data collected in USDOT-sponsored research efforts and field tests
- 2 TB of well-organized and documented data
- Drawn from a dozen geographic locations across the country
- Multi-source data (traditional sensor plus probe and connected vehicle data)
- Search and download functions
- RDE release 2.0 is now available

www.its-rde.net



Open Source Application Development Portal (OSADP)

- Web-based portal for sharing open source code and software from USDOT-sponsored transportation application to the public
 - 14 open source ITS application packages, with more expected
 - Download software, code, and documentation
 - Free to use, edit, and modify under open source licenses
 - Submit and develop new project ideas (GitHub testing platform)
 - Join and interact with a community of users
 - Download - software, code and documentation

ACCESS, INNOVATE, and COLLABORATE



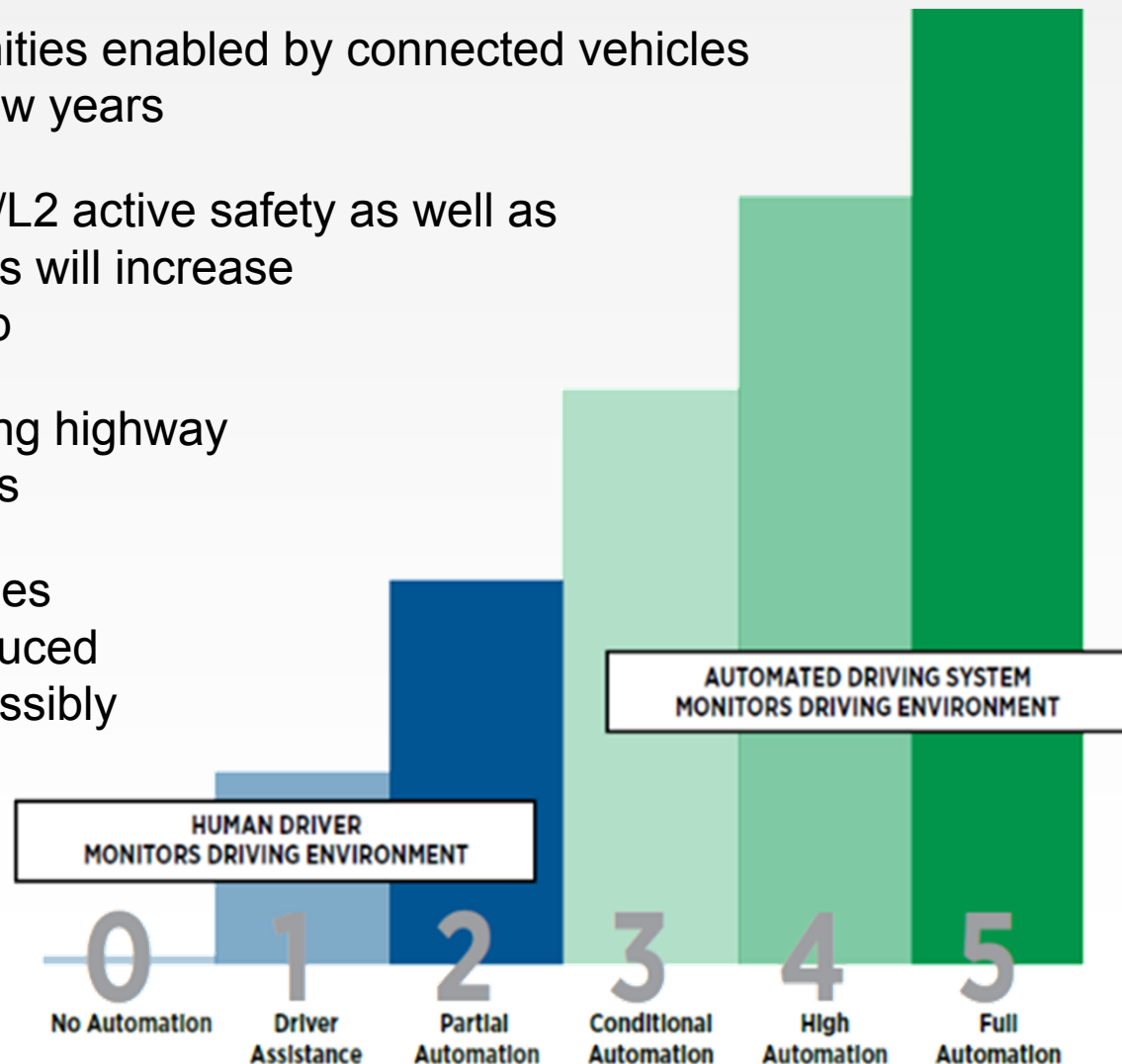
www.itsforge.net



U.S. Department of Transportation
ITS Joint Program Office

Moving Towards Connected Automation

- The technology opportunities enabled by connected vehicles will grow over the next few years
- Market penetration of L1/L2 active safety as well as driver assistance systems will increase penetration as costs drop
- OEMs will start introducing highway L3 “autopilot” applications
- L1/2 platooning capabilities (via DSRC) will be introduced for motor carriers and possibly for private light vehicles



What Can You Do To Prepare for CV Implementation?

1. Involve your stakeholders in CV planning
2. Make sure your field devices use current standards, such as NTCIP
3. Get involved with or seek out results from CV Pilots or Test Beds
4. Assess the readiness of your Center to Field network, especially system security
5. Prepare the workforce with training and recruitment in ITS disciplines



Topic 6 Wrap-up

- Explain the recommend approach for implementing connected vehicle applications
- Describe security and privacy considerations
- Identify resources for connected vehicle application deployment
- Discuss future implementation needs – connected automation



Topic 7: Course Wrap-up

Topic	Title	Duration
1	Connected Vehicles: Introduction and Current Status	30 minutes
2	Preparing to Implement Connected Vehicle Applications	30 minutes
3	Safety Applications	30 minutes
4	Mobility Applications	45 minutes
5	Environmental Applications	30 minutes
6	Connected Vehicle Considerations and Resources	40 minutes
7	Course Wrap-up	15 minutes



Course Wrap-up

- Connected Vehicle: Introduction and Current Status
- Preparing to Implement Connected Vehicle Applications
- Safety Applications
- Mobility Applications
- Environmental Applications
- Implementing Connected Vehicle Applications



Please take a moment to give us your feedback by completing the evaluation.



Stay Connected

- Visit our Web site for information on:
 - Webinars
 - Events
 - Publications
 - News



Twitter: [@ITSJPODirector](https://twitter.com/ITSJPODirector)

Facebook:

www.facebook.com/USDOTResearch

Web site: www.its.dot.gov

Free ITS Training

- ✓ Increase Your Knowledge of ITS Technologies
- ✓ Excel at Your Career
- ✓ Advance the Mission of Your Organization





Additional Examples

Sample Deployment Concept – Halleck Expressway

Synergies Among Applications Increase Benefits and Reduce Costs

Improve Incident Delay

- Incident scene pre-arrival staging guidance for emergency responders
- Incident scene work zone alerts for drivers and workers

Improve Bottleneck Throughput

- Speed harmonization and queue warning
- Emergency electronic brake lights and forward collision warning

Manage Diversions Better

- Enable ATIS
- Intelligent signal control



Sample Deployment Concept – Greypool County

Synergies Among Applications Increase Benefits and Reduce Costs

Improve Accessibility

- Dynamic transit operations

Improve Safety

- Red light violation warning
- Stop sign gap assist
- Left turn assist

Informing Drivers During Bad Weather

- Weather response traffic information

