ITS ePrimer
Module 13: Connected Vehicles

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**ITS Professional Capacity Building
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Instructor

Gregory D. Krueger, P.E.

Director of Emerging Technology

HNTB Corporation

Okemos, MI, USA

Author

Christopher Hill, Ph.D., PMP

Principal

Booz Allen Hamilton

Washington, DC, USA

Learning Objectives

1. Provide an overview of the connected vehicle program
2. Understand history, evolution, and future direction of connected vehicle program
3. Understand the tools that are available from the USDOT
4. Understand basic technologies and core systems
5. Understand key policy, legal, and funding issues

Definition of a Connected Vehicle Environment

Wireless connectivity among vehicles, the infrastructure, and mobile devices, resulting in transformative change to:

- Highway safety
- Mobility
- Environmental impacts

Source: USDOT

Wireless Communications for Connected Vehicles

Core technology for Connected Vehicle applications

- Safety-related systems to be based on Dedicated Short Range Communications

- Non-safety applications may be based on other technologies

- DSRC characteristics:
  - 75 MHz of dedicated bandwidth at 5.9 GHz
  - Low latency
  - Limited interference
  - Performance under adverse conditions
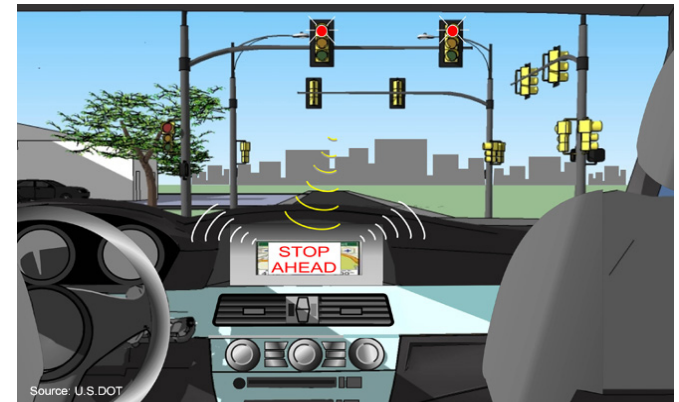
Source: USDOT

Connected Vehicle Benefits

Connected Vehicles will benefit the public good by:

- Reducing highway crashes
  - Potential to address up to 81% of unimpaired crashes
- Improving mobility
- Reducing environmental impact

Additional benefits to public agency transportation system management and operations

Historical Context

Current program results from more than a decade of research:

- 2003 – Vehicle Infrastructure Integration (VII) program formed by USDOT, AASHTO, and carmakers
- 2006 – VII Concept of Operations published by USDOT
- 2007-2009 – VII Proof-of-Concept testing with CAMP in Michigan
- 2011 – VII renamed to Connected Vehicle program
- 2011-2013 – Testing to determine future of NHTSA Rulemaking
- 2014-2016 – Focus of program shifts towards deployment

Connected Vehicle Program Today

Current research addresses key strategic challenges:

- Remaining technical challenges
- Testing to determine actual benefits
- Determining if benefits are sufficient to warrant implementation of infrastructure components
- Issues of public acceptance
- Address deployment related issues

Key Milestones

- There are many key milestones associated with the program
  - 2014 NHTSA Advanced Notice of Proposed Rulemaking focused on the implementation of DSRC in light vehicles
  - 2016 NHTSA Final Rulemaking on DSRC implementation is expected
  - FHWA Infrastructure Deployment Guidance

U.S. Department of Transportation

SAFETYPILOT

CONNECTED VEHICLE TECHNOLOGY

Source: USDOT

Dedicated Short-Range Communications

- Technologies developed for vehicular communications
  - FCC allocated 75 MHz of spectrum in 5.9 GHz band
  - To be used to protect the safety of the traveling public
- A communications protocol similar to WiFi
  - Derived from the IEEE 802.11 standard
  - DSRC includes WAVE Short Message protocol defined in IEEE 1609 standard
- Design range of a DSRC access point is 200 m
  - Actual range varies
  - Typical installations at intersections and other roadside locations

Key DSRC Functional Capabilities

- DSRC is the only short-range wireless technology that provides:
  - Fast network acquisition, low-latency, high-reliability communications link
  - An ability to work with vehicles operating at high speeds
  - An ability to prioritize safety messages
  - Tolerance to multipath transmissions typical of roadway environments
  - Performance that is immune to extreme weather conditions (e.g., rain, fog, snow)
  - Protection of security and privacy of messages

Cellular Communications

- USDOT committed to DSRC for active safety, but will explore other wireless technologies
- Cellular communications is a candidate for some safety, mobility, and environmental applications
  - LTE technologies can provide high-speed data rates to a large number of users simultaneously
  - Technologies are intended to serve mobile users
  - Good coverage – all urban areas and most major highways
- Next generation cellular technologies have potential to expand the role cellular plays

Connected Vehicle Safety Pilot

- Approximately 2,800 vehicles (cars, buses, and trucks) equipped with V2V devices

- Provided data for determining the technologies' effectiveness at reducing crashes

- Includes vehicles with embedded equipment and others that use aftermarket devices or a simple communications beacon
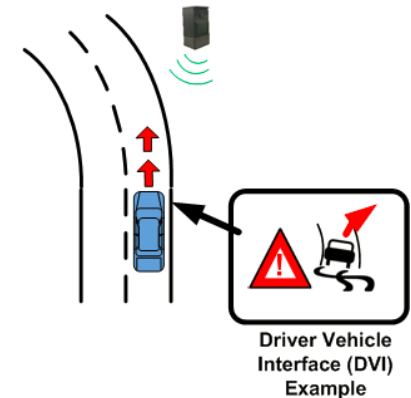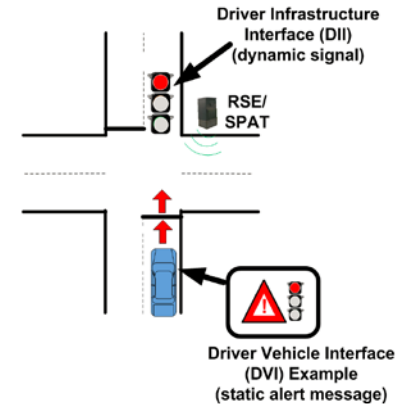

Image source: USDOT

Safety Pilot V2V Applications

- 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

Source: USDOT

V2I Safety Applications

- Use data exchanged between vehicles and roadway infrastructure to identify high-risk situations and issue driver alerts and warnings

  □ Traffic signals will communicate signal phase and timing (SPaT) data to vehicles to deliver active safety messages to drivers

Source: USDOT

Connected Vehicle Applications

V2I Safety

Red Light Violation Warning
Curve Speed Warning
Stop Sign Gap Assist
Spot Weather Impact Warning
Reduced Speed/Work Zone Warning
Pedestrian in Signalized Crosswalk
Warning (Transit)

V2V Safety

Emergency Electronic Brake Lights
(EEBL)
Forward Collision Warning (FCW)
Intersection Movement Assist (IMA)
Left Turn Assist (LTA)
Blind Spot/Lane Change Warning
(BSW/LCW)
Do Not Pass Warning (DNPW)
Vehicle Turning Right in Front of Bus
Warning (Transit)

Agency Data

Probe-based Pavement Maintenance
Probe-enabled Traffic Monitoring
Vehicle Classification-based Traffic
Studies
CV-enabled Turning Movement &
Intersection Analysis
CV-enabled Origin-Destination Studies
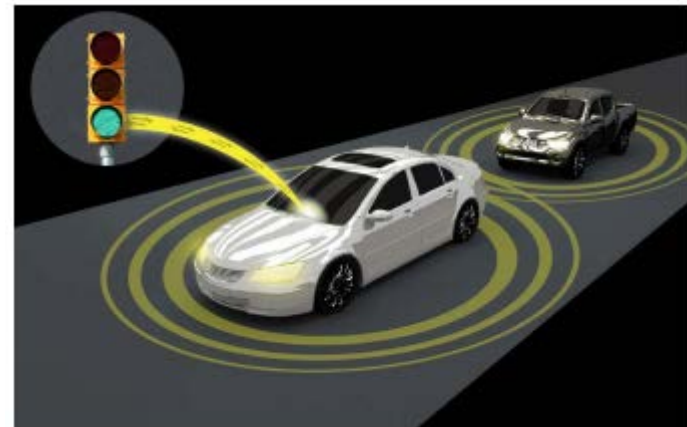Work Zone Traveler Information

Environment

Eco-Approach and Departure at
Signalized Intersections
Eco-Traffic Signal Timing
Eco-Traffic Signal Priority
Connected Eco-Driving
Wireless Inductive/Resonance
Charging
Eco-Lanes Management
Eco-Speed Harmonization
Eco-Cooperative Adaptive Cruise
Control
Eco-Traveler Information
Eco-Ramp Metering
Low Emissions Zone Management
AFV Charging / Fueling
Information
Eco-Smart Parking
Dynamic Eco-Routing (light
vehicle, transit, freight)
Eco-ICM Decision Support System

Road Weather

Motorist Advisories and Warnings
(MAW)
Enhanced MDSS
Vehicle Data Translator (VDT)
Weather Response Traffic
Information (WxTINFO)

Mobility

Advanced Traveler Information System
Intelligent Traffic Signal System
(I-SIG)
Signal Priority (transit, freight)
Mobile Accessible Pedestrian Signal
System (PED-SIG)
Emergency Vehicle Preemption (PREEMPT)
Dynamic Speed Harmonization (SPD-
HARM)
Queue Warning (Q-WARN)
Cooperative Adaptive Cruise Control
(CACC)
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)
Connection Protection (T-CONNECT)
Dynamic Transit Operations (T-DISP)
Dynamic Ridesharing (D-RIDE)
Freight-Specific Dynamic Travel Planning
and Performance
Drayage Optimization

Smart Roadside

Wireless Inspection
Smart Truck Parking

Source: USDOT

Building Blocks

Source: USDOT

Source: USDOT

Connected Vehicle Technology

- Onboard or mobile equipment
- Roadside equipment

- Communications systems
- Core systems
- Support systems

Source: USDOT

Standards

- Base Building Block
  - A vehicle must communicate with all enabled vehicles
  - A vehicle's ability to communicate with roadside infrastructure must not be limited
  - Vehicles must work into the future
- SAE J2735
- SAE J2945
- IEEE 1602
- CVRIA helps designers make decisions regarding proper standards use

Source: USDOT

CVRIA

- Connected Vehicle Reference Implementation Architecture
- Uniform process, tools and graphical language to support CV deployment and operations
- Creates three distinct but related views:
  - Physical View (Things)
  - Enterprise View (People / Organizations)
  - Communications Views (Information)
- SET-IT – Visio-based tool to create architecture views
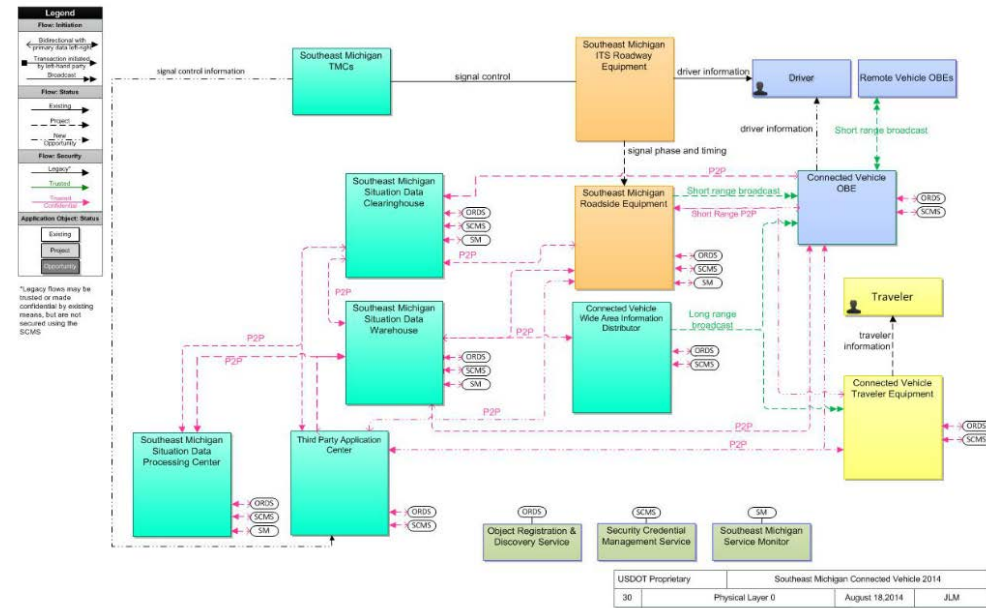
Source: USDOT

Security Credential Management

- Connected Vehicle Environment relies on the ability to trust the validity of the message source
  - Accidental or malicious issue of false messages could have severe consequences
  - Users have and expectation of appropriate privacy in the system
- A prototype system was deployed and used as part of the Safety Pilot Model Deployment
- The second generation or Proof of Concept system is being developed by CAMP and NHTSA and will be used to support the CV Pilot program

Certification

- Certification of devices is critical to long-term success and operations

- USDOT is working with industry to develop a certification process and service to support the CV Pilots and other early deployers

- Certification activities are focused on Road Side Units

  □ Conformance to the message protocols

  □ Conformance to performance requirements
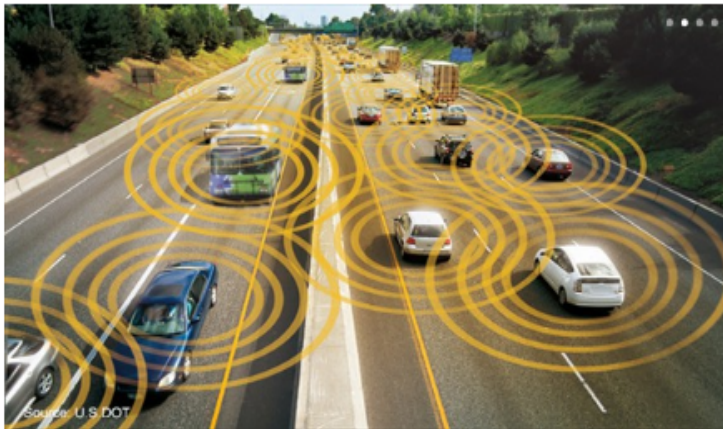
The Research Data Exchange

www.its-rde.net

Source: USDOT

Data Environments in the RDE

- 14 Current Data Environments:
  - CV data from Leesburg, Ann Arbor, Orlando, and Detroit
  - Road Weather warnings from Detroit demo
  - Multi-modal traffic and signal data from Pasadena, Seattle, Portland, and San Diego
  - Probe data from Southeast Michigan testbed

- 8 Data Environments Coming Soon - Dynamic Mobility Applications
  - Multi-Modal Intelligent Signal Systems (MMITSS)
  - Intelligent Network Flow Optimization (INFLO)
  - Integrated Dynamic Transit Operation (IDTO)

- 25+ New Data Sets to Be Added to RDE in 2016

Open Source Application Development Portal (OSADP)

www.itsforge.net
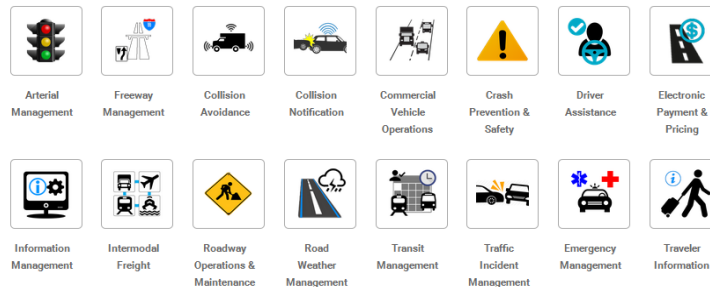
40+ applications available to download

Source: USDOT

OSADP

- Purpose: web-based access & collaboration on source code & documentation for open source transportation applications

- Objectives:
  - Reuse of software wherever possible
  - Transparent and collaborative application development
  - Provide complete application package
- Features: Over 40 applications available
  - Resources to use & download applications
  - Forums for discussions on applications
  - Platform to test (GitHub) applications before posting
  - Developer uploader guide & submittal (e.g., upload, collaboration)

Connected Vehicle Core Systems Support

- Current implementations of CVRIA, including:
  - Situation Data Warehouse and Clearinghouse
  - SCMS and ORDS
- All applications are free to use and include support from USDOT CVCS Contractor.
- All support requests will come through new online Service Desk
- Sign up for support at https://cvcs.samanage.com
- Service Desk phone number will be established in near future

USDOT Connected Vehicle Pilot Program

- USDOT initiative to spur deployment and begin to address ongoing deployment and operational issues.
- Proposed projects identified local needs, set performance goals and selected CV applications to meet those goals

Source: USDOT

CV Pilot Wave 1 Sites

New York City Pilot Deployment Site Map
(Source: http://www.its.dot.gov/pilots/pdf/02_CVPilots_NYC.pdf)
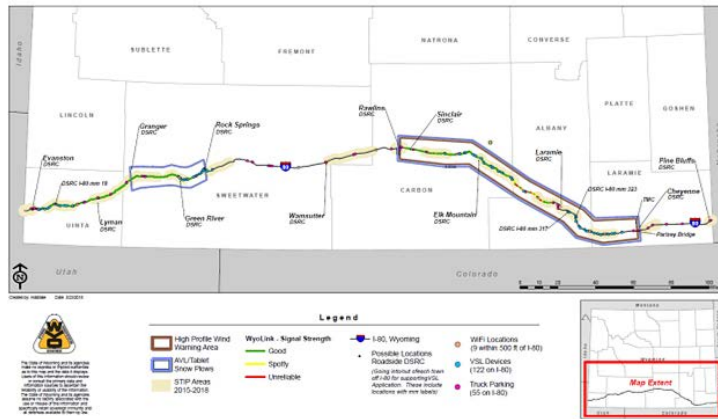
Wyoming I-80 Corridor-Connected Vehicle Map
(Source: http://www.its.dot.gov/pilots/pdf/04_CVPilots_Wyoming.pdf)
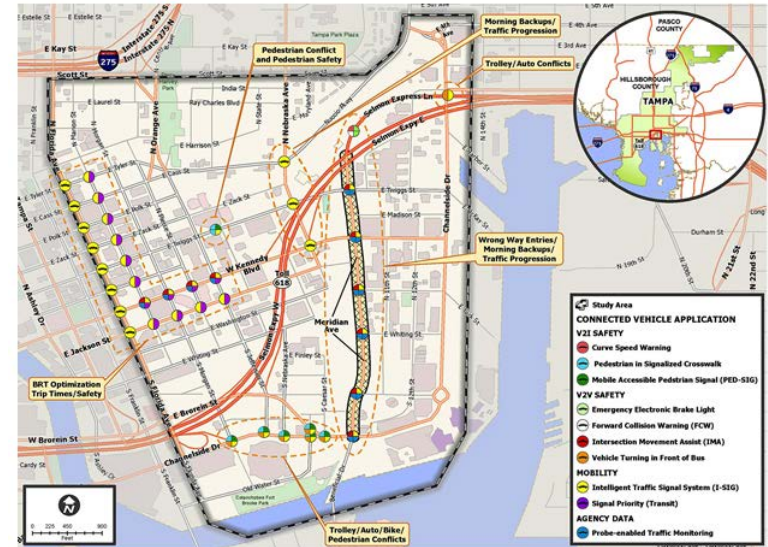
Connected Vehicle Pilot Deployment-Downtown Tampa
(Source: http://www.its.dot.gov/pilots/pdf/03_CVPilots_Tampa.pdf)

All figures - Source: USDOT

Smart Cities Challenge

- $40m to support technology deployments to help mid-sized cities prepare for the future.

- Integrate emerging transportation data, technologies, and applications with existing systems across a city

- Help cities, citizens, and businesses achieve goals for safety, mobility, sustainability, and economic vitality in an increasingly complex, interdependent and multimodal world.

- 78 Applicants

- 7 Finalists announced March 12

- Winner to be announced in June/July

Source: USDOT

Policy and Institutional Issues

- May limit successful deployment
- Collaborative effort among USDOT, industry stakeholders, vehicle manufacturers, state and local governments, associations, and citizens
- Policy issues and associated research fall into four categories:
  - Implementation Policy Options
  - Technical Policy Options
  - Legal Policy Options
  - Implementation Strategies

Implementation Policy Options

- Topics to be addressed:
  - Viable options for financial and investment strategies
  - Model structures for governance with identified roles and responsibilities
  - Analyses required to support infrastructure deployment decisions
- SCMS Implementation and Operations
- Availability of the 5.9GHz band

Technical Policy Options

- Analysis of technical choices for V2V and V2I technologies and applications

  - Identify if options require new institutional models or can leverage existing assets and personnel

- Technical analyses related to Core System, deployment and operations, system interfaces, and device certification and standards

Legal Policy Options

- Analysis of liability and limitations to risk
- Policy and practices regarding privacy
- Policies on intellectual property and data ownership

Implementation Strategies

- AASHTO conducted a Connected Vehicle Field Infrastructure Deployment Analysis and a Footprint Analysis of a national deployment

  - Infrastructure deployment decisions by state and local transportation agencies depend on nature and timing of benefits

  - Benefits depend on availability of Connected Vehicle equipment installed in vehicles

    - Original equipment
    - After-market devices

Funding for Infrastructure Deployment

- Key task facing state and local DOTs is the need to identify a funding mechanism.
  - Capital and ongoing operations and maintenance costs
- Agencies can consider various funding categories to support deployment.
  - ITS budget or federal/state funds with ITS eligibility
  - Safety improvement program
  - Funds set aside for congestion mitigation or air quality improvement projects
  - Public–private partnerships
- FAST-Act mainstreams CV infrastructure funding

Summary

- The Connected Vehicle Environment:

  - Wireless connectivity among vehicles, infrastructure, and mobile devices

  - Transformative changes in highway safety, mobility, and environmental impact

  - Broad stakeholder base – government, industry, researchers

- Potential benefits

  - Use of V2V and V2I may address 81% of unimpaired crashes in all vehicle types

  - Reduce congestion and vehicle emissions

Summary (cont'd)

- USDOT has provided a number of tools to support deployment, including the CVRIA, RDE an OSADP

- NHTSA rule on V2V is expected in 2016.

- Applications allow systems and technologies to deliver services and benefits to users in three broad categories
  - Safety applications (including those based on V2V or V2I communications)
  - Dynamic mobility applications
  - Environmental applications

Summary (cont'd)

- DSRC technologies developed specifically for vehicular communications

  - 5.9 GHz reserved for transportation safety by the FCC

  - Bandwidth is under attack

- DSRC will be used for V2V and V2I active safety

  - Cellular communications can be explored for other safety, mobility, and environmental applications

- The Security Credential Management System is being developed to establish trust and privacy amongst users

  - Long-term issues associated with the operations of the SCMS are still unresolved.

Summary (cont'd)

- Policy and institutional issues are topics that may limit or challenge successful deployment.
- The USDOT continues to invest in the deployment of these technologies to support ongoing development activities.
  - Connected Vehicle Pilot Program
  - Smart Cities Challenge
  - USDOT Test Bed and Connected Vehicle Core Services
- AASHTO has developed a significant body of work to support deployment decisions by the public sector

References

- AASHTO Subcommittee on Transportation Systems Web site: stsmo.transportation.org/

- Vehicle to Infrastructure Deployment Coalition Web site: www.transportationops.org/V2I/V2I-overview

- ITS America Web site: Knowledge Center 2.0, http://www.itsa.org/knowledgecenter/knowledge-center-20

- U.S. Department of Transportation, Research and Innovative Technologies Administration, Web site: ITS JPO, http://www.its.dot.gov

- Connected Vehicle Reference Implementation Architecture Web Site: www.iteris.com/cvria

Contact Information

Gregory D. Krueger, P.E.

Director of Emerging Technologies

HNTB

gkrueger@hntb.com

517.897.5841

Questions?

1. What types of benefits may accrue from the implementation of the Connected Vehicle Environment?

2. Over the next few years, where will the USDOT be testing and demonstrating CV Technologies through their Connected Vehicle Pilot Program?