Connected Vehicles/ Infrastructure

Carl K. Andersen

U.S. Department of Transportation
Federal Highway Administration

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Session Agenda

• Overview of the USDOT Connected Vehicle (CV) Research Program
• Overview of V2I Safety, Mobility and Environment/Road Weather Program Areas
• Overview of CV Architecture and Standards Program
• V2I Enabling Technologies
• Early Application Concepts at the Intersection
• V2I Deployment Guidance
• Notification of CV Pilots
Overview of USDOT CV Research Program
Fully Connected Vehicles

Vehicle Data:
- Latitude, Longitude, Speed, Brake Status, Turn Signal Status, Vehicle Length,
- Vehicle Width, Bumper Height

Infrastructure Data:
- Signal Phase and Timing,
- Drive 35 mph,
- 50 Parking Spaces Available
CV Communications Technology

- 5.9 GHz dedicated short range communication (DSRC), wireless
- 4G and older 3G cellular networks can provide wide-area data communications
- Other technologies such as Wi-Fi, satellite, and HD radio may have roles to play
- Fiber optic backhaul
ITS Research Program Components

**Applications**
- Safety
  - V2V
  - V2I
  - Safety Pilot
- Mobility
  - Real Time Data Capture & Management
  - Dynamic Mobility Applications
- Environment
  - 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
Path To Deployment

- Defined V2V Apps
- Defined Safety (V2I), Mobility (V2V & V2I), AERIS, and Weather Apps
- Application Development
- Pilots/Early Deployments

- FHWA Deployment Guidelines
- NHTSA Decision to Move Forward with V2V Communication for Light Vehicles
- NHTSA Decision for Heavy Vehicles
- Safety Pilot Model Deployment in 2013

Timeline:
- 2011: FHWA Deployment Guidelines
- 2012: NHTSA Decision to Move Forward with V2V Communication for Light Vehicles
- 2013: Safety Pilot Model Deployment in 2013
- 2014
- 2015
- 2016
Overview of CV Application Program Areas
Connected Vehicle Applications

- Safety
  - V2V
  - V2I

- Mobility
  - Dynamic Mobility Applications

- Environment
  - AERIS
  - Road Weather Applications
# Safety Applications: V2V

<table>
<thead>
<tr>
<th>V2V Safety Applications</th>
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<tbody>
<tr>
<td>Forward Collision Warning</td>
<td>FCW</td>
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<tr>
<td>Emergency Electronic Brake Light</td>
<td>EEBL</td>
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<tr>
<td>Blind Spot/Lane Change Warning</td>
<td>BSW/LCW</td>
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<tr>
<td>Do Not Pass Warning</td>
<td>DNPW</td>
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<tr>
<td>Intersection Movement Assist</td>
<td>IMA</td>
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<tr>
<td>Left Turn Assist</td>
<td>LTA</td>
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![Diagram showing vehicle communication](image-url)
## Safety Applications: V2I

<table>
<thead>
<tr>
<th>V2I Safety Applications</th>
<th>Abbreviation</th>
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<tbody>
<tr>
<td>Curve Speed Warning</td>
<td>CSW</td>
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<tr>
<td>Red Light Violation Warning</td>
<td>RLVW</td>
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<tr>
<td>Spot Weather Information Warning</td>
<td>SWIW</td>
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<tr>
<td>Reduced Speed Zone Warning</td>
<td>RSZW</td>
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<tr>
<td>Stop Sign Gap Assist</td>
<td>SSGA</td>
</tr>
<tr>
<td>Smart Roadside</td>
<td>SRI</td>
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<tr>
<td>Transit Pedestrian Warning</td>
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</tbody>
</table>
## Dynamic Mobility Applications

<table>
<thead>
<tr>
<th>Application</th>
<th>Acronym</th>
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<tbody>
<tr>
<td>Multimodal Intelligent Traffic Signal System</td>
<td>MMITSS</td>
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<tr>
<td>Intelligent Traffic Signal System</td>
<td>I-SIG</td>
</tr>
<tr>
<td>Transit Signal Priority</td>
<td>TSP</td>
</tr>
<tr>
<td>Mobile Accessible Pedestrian Signal System</td>
<td>PED-SIG</td>
</tr>
<tr>
<td>Freight Signal Priority</td>
<td>FSP</td>
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<tr>
<td>Emergency Vehicle Preemption</td>
<td>PREEMPT</td>
</tr>
<tr>
<td>Intelligent Network Flow Optimization</td>
<td>INFLO</td>
</tr>
<tr>
<td>Dynamic Speed Harmonization</td>
<td>SPD-HARM</td>
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<tr>
<td>Queue Warning</td>
<td>Q-WARN</td>
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<tr>
<td>Cooperative Adaptive Cruise Control</td>
<td>CACC</td>
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</tbody>
</table>
# Dynamic Mobility Applications

<table>
<thead>
<tr>
<th>Dynamic Mobility Applications</th>
<th>Short Code</th>
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<tbody>
<tr>
<td>Integrated Dynamic Transit Operations</td>
<td>IDTO</td>
</tr>
<tr>
<td>Connection Protection</td>
<td>T-CONNECT</td>
</tr>
<tr>
<td>Dynamic Transit Operations</td>
<td>T-DISP</td>
</tr>
<tr>
<td>Dynamic Ridesharing</td>
<td>D-RIDE</td>
</tr>
<tr>
<td>Freight Advanced Traveler Information Systems</td>
<td>FRATIS</td>
</tr>
<tr>
<td>Dynamic Travel Planning and Performance</td>
<td></td>
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<tr>
<td>Drayage Optimization</td>
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</tbody>
</table>
# Environment Applications: AERIS

## Cleaner Air Through Smarter Transportation

<table>
<thead>
<tr>
<th>ECO-SIGNAL OPERATIONS</th>
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<tbody>
<tr>
<td>Eco-Approach and Departure at Signalized Intersections</td>
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<tr>
<td>Eco-Traffic Signal Timing</td>
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<tr>
<td>Eco-Traffic Signal Priority</td>
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<tr>
<td>Connected Eco-Driving</td>
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<tr>
<td>Wireless Inductive/Resonance Charging</td>
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</tbody>
</table>

![Image of bus and traffic signals](image1.jpg)
![Image of optical detector and emitter](image2.jpg)
![Image of busy road](image3.jpg)
Road Weather Applications
Research Data Exchange Release 2.0

• Promotes sharing of archived and real-time data
• Multiple data environments
• Multi-source data
• Improved search and download functions
• Exploring integrated real-time data environments
• Adding additional data environments
Overview of CV Architecture and Standards Program
The CVRIA provides a reference for applications and systems as well as identifying interfaces for standardization within the architecture.

**Standardization** is a critical component of implementation. The standardization plan will provide a strategy for ensuring that there are appropriate standards to support implementation and ensure interoperability.
CVRIA Viewpoints

• CVRIA uses multiple viewpoints to capture stakeholders’ concerns
  o Enterprises to carry out applications
  o Functions to satisfy requirements
  o Physical objects to implement that functionality
  o Communications protocols necessary
• ~100 connected vehicle applications included
Connected Vehicle Architecture

- Systems Engineering Tool for Intelligent Transportation (SET-IT)
  - Support connected vehicle project architecture
  - Connects to commercial drawing and database capabilities
  - Integrate CVRIA into existing National ITS Architecture
- CVRIA Public Meetings:
  http://www.its.dot.gov/meetings/cv_architecture_meeting.htm

![SET-IT](http://www.iteris.com/cvria/html/resources/tools.html)
V2I Enabling Technologies
V2I – Enabling Technologies

- Goal – Develop and integrate the infrastructure components necessary to provide the foundation for V2I deployment
  - Signal Phase and Timing (SPaT)
  - Mapping
  - Positioning
  - Communications
  - Roadside Unit (RSU)
  - Integrated V2I Prototype
Signal Phase and Timing (SPaT) & Related Messages

• Develop interface between signal controllers and RSU to enable 2-way data exchange between vehicles and controllers
  o SPaT data
  o Geometric intersection description (GID)
  o Signal request messages (SRM)
  o Signal status messages (SSM)
  o Position correction
  o Standards to promote interoperability
Signal Phase and Timing (SPaT)

• Past and current activities
  o Interface testing at Safety Pilot
    ➢ 12 intersections equipped with controllers from two vendors
    ➢ Transit application using SPaT data
    ➢ SPaT data logged to facilitate future application development
  o Lessons learned from Safety Pilot and other studies, and industry comment, used to refine SPaT message

• Planned near-term steps
  o Analyze SPaT Prototype in test beds to support field testing of Multi-Modal Intelligent Traffic Signal System (MMITSS)
  o Refine SPaT and MAP messages and software to conform to SAE J2735 (2014 updated version)
Mapping

• Collect and broadcast relevant roadway geometry and attribute data for use by V2I applications
  o Initial research proved concept of generating and broadcasting maps for V2I applications
  o LIDAR and 360 optical are promising technologies for developing the initial map; other technologies promising for map updates

• Planned near-term steps
  o Identify gaps in standards and actions going forward
  o Harmonize with international standards effort
  o Assess role of “Digital Infrastructure” initiatives and Geospatial mapping
Positioning

• Determine positioning technologies that enable V2I applications
  o Wrap up unit testing at Connected Vehicle Highway Testbed (CVHT)
    ➢ GPS combined with IMU provided the best positioning solutions
  o Complete development of positioning correction messages
  o Integrate positioning technologies within the connected vehicle environment

Positioning and mapping are closely related
Communications

• Test multiple communication technologies for potential use by V2I applications
  - Develop test plans to assess promising technologies
    - 5.9 GHz DSRC
    - Cellular 4G/LTE
  - Monitor/support NTIA study on spectrum sharing
  - Investigate DSRC bandwidth issues (data transfer frequency, packet drops, etc.)
  - Document technologies tested
Formal Roadside Unit (RSU) Definition

An Roadside Unit is a device that:

- Contains multiple radio sets for localized communication over 5.9GHz, compliant with FCC regulations for DSRC
- Contains an integrated GPS receiver for positioning and UTC time
- Contains a PoE capable Ethernet interface that supports IPv4 and IPv6 connectivity, compliant with IEEE 802.3at
- Is housed in a NEMA 4X-rated enclosure
- Has a clearly defined interface between the RSU and back-office
Evolution of RSU

- Specification 3.0
  - Updated from prior tests/studies
  - Used for Safety Pilot

- Specification 4.0
  - Based on lessons learned from Safety Pilot
  - Improve performance reliability, strengthen security protocols and promote common configurations and user interfaces across different vendors
  - Pre-production units anticipated December 2014
RSU v4

- Foster development of deployment-ready RSU
  - Stakeholder workshop on August 8, 2013
  - Weekly teleconferences with working group
  - Stakeholder conference call held in early March 2014
  - Version 4.0 of the specification published April 15, 2014

- Next steps
  - Assist in set up of independent test labs for certification testing of devices
  - Conduct functional testing of units at TFHRC
  - Limited purchase to refresh test beds
Integrated V2I Prototype (IVP)

• “Identify, develop, implement, test, document and deploy a roadside prototype system that supports an integrated, interoperable deployment of multiple V2I safety, mobility, and environmental applications.”
  - Incorporate all parts of the enabling technologies program to work seamlessly to enable V2I applications
  - Integration and testing of a complete infrastructure system
    - Data flows
    - Information exchange
    - Standards
IVP Components

• IVP Includes:
  o Signal Phase and Timing
  o Mapping (Intersections and Road Segments)
  o Other Roadside Equipment (i.e. signage, detectors)
  o Positioning / Corrections
  o Communications (DSRC, cellular)
  o Security (Over-the-air-security)
  o Road Condition and Weather Data
IVP Detailed System View with Potential Message Handlers

- **Integrated V2I Prototype Platform**
- **Infrastructure Sensor System**
- **Vehicle and Nomadic Device App Platform**
- **IVP Local/Back Office User Interface**
- **Traffic Management Entity**

**Infrastructure Sensor Systems**
- Position Correction Infra Data Systems
- Veh Detection Sensor Systems (radar, loop det)
- Ped & Bicycle Infra Sensor Systems
- CMV Virtual Weigh Station Sensor Systems

**Vehicle and Nomadic Device App Platform(s)**
- High Latency/Quasi-Static Message Storage
- Dynamic Roadside Message System

**Traffic Management Entity**
- INFLO TME App (inc SPD-HARM, Q-WARN)
- Road Weather TME App (inc WRTM)
- AERIS/Ecodriving TME App
- FRATIS TME App
- MMITIS Central System

**Low Latency/Quasi-Static Message Storage**
- GPS Positioning
- Pedestrian Crossing Request Sensor

**High Latency/Quasi-Static Message Storage**
- Rail Crossing Signal Request Sensor

**Low Latency Wireless Message Service** (e.g. DSRC)
- Low Latency Radio Communications (e.g. DSRC)

**Vehicle and Nomadic Device App Platform(s)**
- Basic Safety Message Generator
- Onboard Positioning Service
- Onboard Map Service
- Vehicle Weather Data Message Generator
- INFLO Message Generator (incl SPD-HARM, Q-WARN)
- V2I Safety App Vehicle Platform
- AERIS/Ecodriving Application

**Driver/User Message Arbitrator**
- Local/BO IVP Platform Install, Configure, Management
- Local/BO IVP Message Handler User Interfaces
- Local/BO IVP Quasi-static Data File Upload (incl Map)
Traffic Signal Controller Interface

- NTCIP 1202 - Object Definitions for Actuated Traffic Signal Controller (ASC) Units
- Interface to legacy systems
- Includes:
  - Rail crossing signal request
    - Standalone 2 wire interface
    - Integrated Rail crossing traffic signal
  - Pedestrian crossing signal request
  - MMITSS, Freight, Transit,
  - Integration and optimization of all of the above
Traffic Management Entity Interface

- Internet Protocol Interface / continuous broadband communications
- Center-to-Center: Traffic Management Data Dictionary (TMDD) Standard v3.03
- Local Area Net: IEEE Standards
- Interface to central communications hub and “arterial” or “regional” application components
- Integrate and process data from multiple IVPs / deliver data to multiple IVPs for distribution of coordinated, synchronized operations
V2I Reference Implementation

• System of specifications and requirements that allow various components of V2I hardware, software, and firmware to work together

• Agencies will be able to select capabilities and applications desired at a given installation

• Based on Integrated V2I Prototype with physical manifestation at TFHRC in 2015 timeframe

• Incorporated into CVRIA
Early Applications at the Intersection
V2I Safety Applications - Selection

• Five applications selected for prototype development based upon:
  o Stakeholder feedback
  o Number of potential infrastructure deployments
  o Availability of standards necessary for implementation
  o Capabilities of existing infrastructure
  o Technical feasibility
  o High level assessments of benefits and order of magnitude costs
Red Light Violation Warning

- Roadside Unit (RSU): broadcast Signal Phase and Timing (SPaT) message, MAP, 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
V2I Mobility Applications

Real-time Data Capture and Management

- Vehicle Status Data
- Weather Data
- Truck Data
- Transit Data
- Location Data

Data Environment

Infrastructure Status Data

Dynamic Mobility Applications

- Multimodal Intelligent Traffic Signal System
- Intelligent Network Flow Optimization
- Advanced Integrated Corridor Management
- Response, Emergency Staging, Communications, Uniform Management, and Evacuation
- Enable Advanced Traveler Information Systems
- Intelligent Dynamic Transit Operations
- Road Weather Applications
- Freight Advanced Traveler Information Systems
MMITSS: Status of Networks

- Arizona Test Bed
  - Ready to upgrade RSU from version 2.0 to 3.0 (2 radio system)
    - In Lab for testing
    - IPv6 to IPv4 Tunnel Broker Testing
  - Lab Testing
    - Security, WSA, BSM, SRM, MAP, SPaT
  - Simulation Testing
    - OBE, RSU, MRP components

- Palo Alto, CA
  - 11 intersections
  - 10 RSU installed, 1 pending
  - 2070 controllers at 4 intersections
  - 2070 upgrades planned for 7 intersections
  - Additional installations at Richmond field station for testing
Guidelines and Pilots
AASHTO National CV Field Infrastructure Footprint Analysis

• Phase 1 Final Report available on USDOT National Transportation Library (NTL)

• Next Phase Overview
  o Process & tool for prioritizing application deployments
  o Process & tool for phasing V2I infrastructure deployments
  o Life cycle costs for V2I application deployments
  o Propose phasing scenarios
  o Plan to create decision tool for agencies
FHWA V2I Deployment Guidance

- **Guidance** - not regulation
- What and how to implement infrastructure and supporting systems
  - Guidelines
  - Best Practices
  - Toolkit
- Supporting high-priority applications
  - V2I safety applications (crash warnings at traffic signals, etc.)
  - Dynamic mobility
  - Road-weather
  - Environmental
- Based on USDOT research and AASHTO analysis of infrastructure needs and deployment approaches
- Initial Deployment Guidance available at [www.its.dot.gov/meetings/V2I_feedback.htm](http://www.its.dot.gov/meetings/V2I_feedback.htm)
Connected Vehicle Pilot Deployment Program
ITS Joint Program Office

- **CV Pilot Program Goals**

  - **Spur Early CV Tech Deployment**
  - **Measure Deployment Benefits**
  - **Resolve Deployment Issues**

  - **Wirelessly Connected Vehicles**
  - **Safety**
  - **Technical**

  - **Mobile Devices**
  - **Mobility**
  - **Institutional**

  - **Infrastructure**
  - **Environment**
  - **Financial**

- **Proposed Program Schedule**
  - Summer-Fall 2014 - Regional Pre-Deployment Workshops/Webinars
  - Early 2015 - Solicitation for Wave 1 Pilot Deployment Concepts
  - Early 2017 - Solicitation for Wave 2 Pilot Deployment Concepts
  - September 2020 - Pilot Deployments Complete

- **Resources**
  - ITS JPO Website: [http://www.its.dot.gov/](http://www.its.dot.gov/)
  - CV Pilots Program Website: [http://www.its.dot.gov/pilots](http://www.its.dot.gov/pilots)
Concluding Remarks
Contact Information

Carl K. Andersen
Connected Vehicle Program Manager
FHWA (HRT-01)
Phone: +1 (202) 493-3045
Email: carl.andersen@dot.gov