Proactive, Connected, and Automated Transportation

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Proactive Transportation
Shifting Operations Mindset

Operate what we have

- Detection
- Field devices
- Communication
- Data quality

Operate what we have more effectively

- Predicting future conditions
- Adaptive/Responsive signals
- Variable speed limits
- System ramp metering
ICM Example

- US 75, Dallas, TX
  - Anticipating growth in congestion
  - Simulation of future conditions
  - Recommending alternate routes and modes
ICM Example

- I-35, Waco, TX
  - Predicting work zone related congestion
  - Negotiations with contractors on schedule
  - Advanced traveler information
  - Daily Evaluation
Connected Transportation
Recent History

1999 - 2002-2005
FCC allocated 75MHz bands at 5.9GHz for DSRC Communications

2006-2008
CICAS field demos and other VII POC tests;

2009
Calls for more safety, mobility, and environment applications

2010
DSRC standard matured; “VII” restructured to include other aftermarket wireless technologies

2012-2013
Safety Pilot CV Model Deployment, Ann Arbor, Michigan

2014
AASHTO CV Footprint Analysis

2015
CV Pilot Deployment RFP

NHTSA DSRC Announcements

FHWA V2I Deployment Guidance

Initial safety applications developed under VII initiative
NHTSA DSRC Rule Timeline

- February 3, 2014 Announcement
  - Intent of starting the process
  - Light-duty vehicles

- Potential Next Steps
  - Heavy-Duty vehicles Spring 2014
  - Notice of Proposed Rule Making ~2015
  - Rule Making 2016
  - Implementation ~2020

- Basic messages, but not applications
Communication

- Dedicated Short-Range Communication
  - 5.9 Ghz Radio
  - Nomadic / Handheld Devices
- Cellular 4G LTE
- Others
  - WiFi
  - Satellite
  - HD Radio
Connected

- Vehicle-to-Vehicle (V2V)
- Vehicle-to-Infrastructure (V2I)
- Infrastructure-to-Vehicle (I2V)
- Vehicle-to-Pedestrian (V2P)
- Pedestrian-to-Infrastructure (P2I)
- Vehicle-to-Bicycle (V2B)
- Vehicle-to-Motorcycle (V2M)
### USDOT CV Pilot Deployments

#### 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)

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

#### 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

#### 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

#### 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

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**U.S. Department of Transportation**
AASHTO CV Footprint Analysis

- Conduct analysis leading to a *preliminary, general concept* of a national connected vehicle field infrastructure footprint.
- Tool for analyzing needs for infrastructure and extent of investment.
- Set of generic design concepts with actions needed for deployment.
AAHSTO CV Vision

Vision for Connected Vehicle Infrastructure Footprint - 2040

- 80% of traffic signals are V2I connected with DSRC
- 25,000 other local safety V2I connected devices
- Accurate real-time localized information on 90+% of roadway miles*
- Next-generation, multimodal, information-driven active traffic management deployed system-wide*

*enabled by both cellular and DSRC communications
Applications Assessment

Application Packages

- V2I Safety
- Mobility/Environment
- Road Weather
- Smart Roadside
- Int. Border Crossings
- Fee Payments
- Agency Operations

Application Requirements

- Data from Vehicles and Infrastructure
  - Basic Safety Message
  - Probe Message
  - Signal Phase and Timing
- Communication Modes
  - DSRC, Cellular
- Backhaul Options
- Back Office
Urban Intersection Example

Urban Intersection Deployment Concept

NATIONAL CONNECTED VEHICLE FIELD INFRASTRUCTURE FOOTPRINT ANALYSIS

Typical Setting Features:
- Urban intersections are junctions of two or more roads within a city setting which typically includes curbing, designated lane markings, and pedestrian crossings.

Concept Example:
- DSRC antennas communicate towards all approaches of the intersection and at a mid-block location to communicate with vehicles on the roadway.

Other Example Applications:
- Red Light Violation Warning and Stop Sign Violation
- Driver Gap Assist at Signalized Intersections and Stop Signs
- Multimodal Intelligent Traffic Signal Systems
- Advanced Arterial Management and Operations
- Advanced Signal Operations

Legend:
- Existing Mast Arm
- Existing Cabinets
- DSRC Radio
- DSRC Comm.

NOT FOR CONSTRUCTION
## Potential Intersection Sites

### Signalized intersections (311,000 total)

<table>
<thead>
<tr>
<th>Deployment Fraction</th>
<th>Objective</th>
<th>Number of Deployment Sites</th>
</tr>
</thead>
<tbody>
<tr>
<td>20%</td>
<td>Deploy only at highest volume intersections (50% of intersection crashes)</td>
<td>62,200</td>
</tr>
<tr>
<td>50%</td>
<td>Deploy at half of all intersections (80% of intersection crashes)</td>
<td>155,500</td>
</tr>
<tr>
<td>80%</td>
<td>Deploy at all intersections where warranted</td>
<td>248,800</td>
</tr>
</tbody>
</table>
**DSRC Unit Deployment Costs**

- DSRC RSU deployment costs were surveyed from existing and planned deployments

<table>
<thead>
<tr>
<th>Deployment Site</th>
<th>Michigan</th>
<th>Arizona</th>
<th>Virginia</th>
<th>TFHRC</th>
<th>Average</th>
</tr>
</thead>
<tbody>
<tr>
<td>Connected Vehicle DSRC Hardware</td>
<td>$9,850.00</td>
<td>$4,200</td>
<td>$8,400</td>
<td>$6,100</td>
<td>$7,450</td>
</tr>
<tr>
<td>Installation Labor</td>
<td>$4,000</td>
<td>$3,000</td>
<td>$3,800</td>
<td>$3,400</td>
<td>$3,550</td>
</tr>
<tr>
<td>Design and Planning</td>
<td>$7,300</td>
<td>$5,900</td>
<td>$6,900</td>
<td>$6,400</td>
<td>$6,600</td>
</tr>
<tr>
<td>Total Direct Connected Vehicle Costs</td>
<td>$21,150</td>
<td>$13,100</td>
<td>$19,100</td>
<td>$15,900</td>
<td><strong>$17,600</strong></td>
</tr>
</tbody>
</table>

Compared to $150K to upgrade an intersection, DSRC deployment would add 10-15%
# National Deployment Unit Cost and O&M Cost

<table>
<thead>
<tr>
<th>Cost Element</th>
<th>Total Unit Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of Sites</td>
<td>87,200</td>
</tr>
<tr>
<td>(DSRC) Equipment and Site Deployment</td>
<td>$17,600</td>
</tr>
<tr>
<td>Backhaul Upgrades and Deployment</td>
<td>$26,800</td>
</tr>
<tr>
<td>Traffic Signal Controller Upgrades</td>
<td>$3,200</td>
</tr>
<tr>
<td><strong>Total Unit Cost (2013$)</strong>*</td>
<td><strong>$47,600</strong></td>
</tr>
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</table>

<table>
<thead>
<tr>
<th>Cost Element</th>
<th>Per Site Cost per year</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of Sites</td>
<td>1</td>
</tr>
<tr>
<td>Power</td>
<td>$100</td>
</tr>
<tr>
<td>Regular Maintenance and Replacement</td>
<td>$2,950</td>
</tr>
<tr>
<td><strong>Total O&amp;M per year</strong></td>
<td><strong>$3,050</strong></td>
</tr>
</tbody>
</table>
Timeline

Equipped Vehicle Population over Time

- 5 Year Mandate (green)
- 1 Year Mandate (red)
- 15 Year Organic (blue)

Fraction of Fleet Equipped vs. Years
Connected Work Zone

- Application of the USDOT FRATIS
- Freight corridor optimization with work zone lane closure information
- In-vehicle warnings of lane closures, delay, and end-of-queue
- Cellular, DSRC
Automated Transportation
Connected vs. Automated

- **Automated**
  - Sensors (cameras, radar, lidar or combination) used to guide vehicle
  - Problems with unexpected conditions
    - Work zones, incidents, inclement weather

- **Connected-Automated**
  - Connected information represents another sensor
  - Issues of reliability, quality, timeliness
## SAE Levels of Automation

<table>
<thead>
<tr>
<th>NHTSA Automation Level</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Zero</td>
<td>No Automation</td>
</tr>
<tr>
<td></td>
<td>Human performs all functions</td>
</tr>
<tr>
<td>One</td>
<td>Driver Assistance</td>
</tr>
<tr>
<td></td>
<td>Single function automation</td>
</tr>
<tr>
<td>Two</td>
<td>Partial Automation</td>
</tr>
<tr>
<td></td>
<td>Lateral and longitudinal driver assist</td>
</tr>
<tr>
<td>Three</td>
<td>Conditional Automation</td>
</tr>
<tr>
<td></td>
<td>Automation with request for driver to intervene</td>
</tr>
<tr>
<td>Four</td>
<td>High Automation</td>
</tr>
<tr>
<td></td>
<td>Automation even if driver does not respond to intervene</td>
</tr>
<tr>
<td>Five</td>
<td>Full Automation</td>
</tr>
<tr>
<td></td>
<td>Full performance by automated driving system</td>
</tr>
</tbody>
</table>
## NHTSA Levels of Automation

<table>
<thead>
<tr>
<th>NHTSA Automation Level</th>
<th>Forecasted Range</th>
</tr>
</thead>
<tbody>
<tr>
<td>One</td>
<td>Function-Specific</td>
</tr>
<tr>
<td>Two</td>
<td>Combined Function</td>
</tr>
<tr>
<td>Three</td>
<td>Limited Self-Driving</td>
</tr>
<tr>
<td>Four</td>
<td>Full Self-Driving</td>
</tr>
</tbody>
</table>
Early Deployments

- Automated valet parking
- Truck platooning
- Controlled environments
  - Military bases
  - Special events
  - Gated communities
Looking Ahead
How will Agencies be Engaged?

- Deployments may start with active agencies
  - AASHTO Deployment Coalition
  - CTS Pooled Fund Study
- Agencies must see a “value proposition” – greater savings or more efficiency
- Agencies looking to improve safety, mobility, environment, border crossings, operations
- Meeting political and public expectations
Issues for Consideration

- Infrastructure Investment
- Data Management / Storage
- Staffing Skills and Abilities
- New business models
Questions?

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