Background

• In 2012 USDOT requested AASHTO to form a team to conduct a national connected vehicle field infrastructure footprint analysis
  ▪ Consider broad range of CV apps and scenarios
  ▪ Include safety, mobility and environmental apps
  ▪ Include light vehicles, transit, commercial vehicle and pedestrian apps
  ▪ Include urban, rural, freeway, arterial, and freight/intermodal facilities, and land border crossings
Footprint Development Process

- Develop a **Tech Memo** to initiate engagement with State and local agencies (Task 3)
- Assess the range of **applications** and their **enabling requirements** such as data & communication needs (Task 4)
- Develop **deployment concepts** (Task 5)
- Develop **deployment scenarios**, a preliminary **national footprint**, and **cost estimates** (Task 6)
Tech Memo

“This is a major undertaking for AASHTO, Transport Canada, and the United States as we prepare for a safer and more productive transportation environment.”

**Mike Lewis**, AASHTO President and Director, Rhode Island DOT

“We are proud to invest in innovation and new opportunities to improve transportation safety and efficiency. By working together now we can lay the groundwork to align standards and regulations in North America and prevent barriers to cross-border travel and trade.”

**Susan Spencer**, Director of ITS Programs, Transport Canada
Footprint 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
Deployment Concepts

• Selected to represent settings into which an agency might want to deploy CV applications
• Documented with conceptual plan sheets and supporting descriptions
• Include variations and alternatives to enable broader range of applications
• Identify example applications appropriate to that setting and concept
Urban Intersection Example

Urban Intersection Deployment Concept

NATIONAL CONNECTED VEHICLE FIELD INFRASTRUCTURE FOOTPRINT ANALYSIS

NOT FOR CONSTRUCTION

LEGEND
- Existing Mast Arm
- Existing Cabinets
- DSRC Radio
- DSRC Comm.

TYPICAL SETTING FEATURES
urban intersections are junctions of two or more roads within a city setting which typically include 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
Ten Sample Deployment Concepts

• Urban Intersection
• Urban Highway
• Urban Corridor
• Rural Roadway
• International Border Crossings
  ▪ Canada & Mexico

• Smart Roadside
• DOT Operations
• Fee Payments
• Freight Facility
• Cellular Concept
Deployment Scenarios

• Discussions with selected agencies using application assessment and deployment concepts
• Ask how they would proceed with implementation and acquire funding
• Results were used to describe
  1. National launch footprint for infrastructure ~ 2020?
  2. A typical agency deployment process
  3. A national deployment progression
Deployment Scenarios

• Urban deployment
• Rural deployment
• Multi-state corridor
• DOT system management & operations
• Commercial vehicle & freight systems
• International border crossing
• Fee payment
Deployment Objectives

• The CV infrastructure will be deployed by state and local agencies in pursuit of specific operational objectives
  ▪ Improving safety
  ▪ Improving personal mobility and environmental impacts
  ▪ Improving freight efficiency
  ▪ Improving border crossing operations
  ▪ Improving internal agency operations
<table>
<thead>
<tr>
<th>Objective</th>
<th>Scenarios</th>
<th>Apps Focus</th>
<th>Example Applications</th>
<th>Enabling Tech</th>
<th>Priority Deployments</th>
</tr>
</thead>
<tbody>
<tr>
<td>Improve Safety</td>
<td>Urban</td>
<td>V2I safety</td>
<td>Red Light Violation Warning Speed Zone and other safety warning</td>
<td>DSRC</td>
<td>High crash rate intersections High volume intersections</td>
</tr>
<tr>
<td></td>
<td>Rural</td>
<td></td>
<td></td>
<td></td>
<td>High crash rate curves High consequence weather sites: bridges, fog areas</td>
</tr>
<tr>
<td>Improve Mobility and Environmental Impact</td>
<td>Urban</td>
<td>Arterial Management</td>
<td>Intelligent Traffic Signal Systems with Prioritization and Preemption Eco-Drive</td>
<td>DSRC</td>
<td>High volume corridors</td>
</tr>
<tr>
<td></td>
<td>Rural</td>
<td>Traveler Information</td>
<td>Next-generation Traveler Information, including local weather alerts</td>
<td>Cellular</td>
<td>High volume corridors High consequence weather sites: bridges, fog areas</td>
</tr>
<tr>
<td>Improve Freight Mobility</td>
<td>Urban, Rural, Freight, Corridor</td>
<td>Traveler Information</td>
<td>Next-generation Traveler Information</td>
<td>Cellular</td>
<td>Primary Freight Network</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Enforcement</td>
<td>Smart Roadside</td>
<td>DSRC or Cellular</td>
<td>Primary Freight Network</td>
</tr>
<tr>
<td>Improve Border Crossings</td>
<td>IBCs</td>
<td>Traveler Information</td>
<td>Next-generation Traveler Information</td>
<td>Cellular</td>
<td>Border Crossings</td>
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<tr>
<td></td>
<td></td>
<td>Enforcement</td>
<td>Similar to Smart Roadside</td>
<td>DSRC or Cellular</td>
<td>Border Crossings</td>
</tr>
<tr>
<td>Improve Agency Operations</td>
<td>DOT Ops and Maintenance DSS, Road Weather</td>
<td>Enhanced Maintenance Decision Support Maintenance and Fleet Management Systems</td>
<td>Cellular</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Building up to National Deployment

• The CV environment emerges over time from the mix of applications deployed in pursuit of specific operational objectives

• Deployment is likely to follow the same pattern seen in other infrastructure and ITS innovations
511 Deployment Experience

511 Launches

(Source: USDOT FHWA)

511 DEPLOYMENT

(Source: http://www.fhwa.dot.gov/trafficinfo/511.htm)
Electronic Screening Participation

- PrePass (423,000+ vehicles)
- NORPASS (97,000+ vehicles)
- State operated/developed (41,000 + vehicles Oregon Green Light)

Source: Federal Motor Carrier Safety Administration

October 2008
Deployment Progression
Infrastructure Timelines


Safety
- NHTSA Light V2V Decision
- Plan
- Pilot
- Evaluate
- Deploy
- Expand
- 1st DSRC on signals
- DSRC for Other Local Safety Apps
- DSRC on 20% of signals
- DSRC on up to 80% of signals

Mobility
- 1st CV-enabled ATM
- Traveler Info on 90+% of Roadways
- System-wide Active Traffic Mgmt
- Plan
- Pilot
- Evaluate
- Deploy
- Expand

Freight Mobility
- NHTSA Heavy V2V Decision
- Plan
- Pilot
- Evaluate
- Deploy
- Expand

Border Crossings
- Plan
- Pilot
- Evaluate
- Deploy
- Expand

Agency Operations
- MN/NV/MI Integrated Mobile Observations
- Plan
- Pilot
- Evaluate
- Deploy
- Expand

With financial contribution from:
Transport Canada
Transports Canada

AASHTO
The Voice of Transportation
• Up to 80% of traffic signal locations are V2I-enabled
• 25,000 other roadside locations are V2I-enabled
• Accurate real-time localized information is available on 90+% of roadway miles
• Next-generation, multimodal, information-driven active traffic management is available system-wide
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>
Infrastructure Cost Estimation

• Deployment Costs
  ▪ DSRC RSUs
  ▪ Backhaul
  ▪ Signal Controller Replacement
  ▪ Total Deployment

• Other Costs
  ▪ Operations and Maintenance
  ▪ Backend Systems
  ▪ OBU on Fleets
  ▪ Cellular Data Costs
  ▪ Probe Data from Third Parties
DSRC Deployment Experience

- 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><strong>Total Direct Connected Vehicle Costs</strong></td>
<td><strong>$21,150</strong></td>
<td><strong>$13,100</strong></td>
<td><strong>$19,100</strong></td>
<td><strong>$15,900</strong></td>
<td><strong>$17,600</strong></td>
</tr>
</tbody>
</table>

Compared to $150K to upgrade an intersection, DSRC deployment would add 10-15%
## Backhaul Experience

<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>Reported Backhaul Cost Planning</td>
<td>$31,100</td>
<td>$1,700</td>
<td>$2,000</td>
<td>$18,900</td>
<td>$13,400</td>
</tr>
<tr>
<td>Design</td>
<td>$4,700</td>
<td>$300</td>
<td>$300</td>
<td>$2,800</td>
<td>$2,000</td>
</tr>
<tr>
<td>Construction</td>
<td>$6,200</td>
<td>$300</td>
<td>$400</td>
<td>$3,800</td>
<td>$2,700</td>
</tr>
<tr>
<td>System Integration &amp; License</td>
<td>$4,700</td>
<td>$300</td>
<td>$300</td>
<td>$2,800</td>
<td>$2,100</td>
</tr>
<tr>
<td>Traffic Control</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total Backhaul Cost</td>
<td>$48,200</td>
<td>$4,100</td>
<td>$4,500</td>
<td>$29,800</td>
<td>$21,700</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Type of Location/Backhaul</th>
<th>Number of Sites</th>
<th>Cost Per Site (2013$)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Signalized Locations</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Integration of Existing Equipment (10%)</td>
<td>24,880</td>
<td>$3,000</td>
</tr>
<tr>
<td>“Easy” Upgrade (20%)</td>
<td>49,760</td>
<td>$22,000</td>
</tr>
<tr>
<td>“Hard” Upgrade (30%)</td>
<td>74,640</td>
<td>$40,000</td>
</tr>
<tr>
<td>Installation of New Backhaul (40%)</td>
<td>99,520</td>
<td>$40,000</td>
</tr>
<tr>
<td><strong>Freeway Locations</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Integration of Existing Equipment (75%)</td>
<td>18,750</td>
<td>$3,000</td>
</tr>
<tr>
<td>“Hard” Upgrade or Installation of New Equipment (25%)</td>
<td>6,250</td>
<td>$40,000</td>
</tr>
</tbody>
</table>

*with financial contribution from: Transport Canada, Transports Canada, AASHO*
## Signal Controller Upgrades

<table>
<thead>
<tr>
<th>Controller Type</th>
<th>Number to be Replaced</th>
</tr>
</thead>
<tbody>
<tr>
<td>ATC 5.2b</td>
<td>0</td>
</tr>
<tr>
<td>Model 2070L</td>
<td>0</td>
</tr>
<tr>
<td>NEMA Modern:</td>
<td>0</td>
</tr>
<tr>
<td>Standard OS (33%)</td>
<td></td>
</tr>
<tr>
<td>Non-Standard OS (67%)</td>
<td></td>
</tr>
<tr>
<td>NEMA Legacy (Shelf)</td>
<td>91,000</td>
</tr>
<tr>
<td>Type 170 Modern</td>
<td>0</td>
</tr>
<tr>
<td>Type 170 Legacy (Rack)</td>
<td>102,000</td>
</tr>
<tr>
<td>Electromechanical Controllers</td>
<td>6,000</td>
</tr>
<tr>
<td>Total Number of Controllers</td>
<td>199,000</td>
</tr>
</tbody>
</table>

### Cost Element (per Site) Cost (2013$)

<table>
<thead>
<tr>
<th>Cost Element (per Site)</th>
<th>Cost (2013$)</th>
</tr>
</thead>
<tbody>
<tr>
<td>New Controller Equipment</td>
<td>$2,200</td>
</tr>
<tr>
<td>Labor to Install/Program Controller</td>
<td>$1,000</td>
</tr>
<tr>
<td>Total Cost Per Controller</td>
<td>$3,200</td>
</tr>
</tbody>
</table>
## Estimated DSRC Unit O&M Costs

<table>
<thead>
<tr>
<th>Cost Element</th>
<th>Per Device Cost per Year (2013$)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Power</td>
<td>$100</td>
</tr>
<tr>
<td>Traditional Maintenance</td>
<td>$500</td>
</tr>
<tr>
<td>License/Maintenance Agreements</td>
<td>$200</td>
</tr>
<tr>
<td>SCMS Certificate License</td>
<td>$50</td>
</tr>
<tr>
<td>Annualized Replacement Cost (every five to ten years)</td>
<td>$1100 - $2200</td>
</tr>
<tr>
<td>Total</td>
<td>$1950 - $3050</td>
</tr>
</tbody>
</table>
Back-End Cost Elements

• Not enough detail in most application design descriptions to estimate back-end costs, so the footprint is limited to identifying cost elements
• All elements could be in-house or outsourced, potentially to “cloud” services
• Software development, licensing, and operations support
• Staffing for system monitoring and upgrades
• Staff training
• Computer hardware
• Facilities for hardware
• Facilities for staff
# Probe Vehicle Cost Elements

<table>
<thead>
<tr>
<th>DSRC Equipment Component</th>
<th>Unit Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>DSRC After-market Safety Device</td>
<td>$1,000</td>
</tr>
<tr>
<td>Cabling Management/Installation Kits</td>
<td>$150</td>
</tr>
<tr>
<td>Installation Labor</td>
<td>$3,000</td>
</tr>
<tr>
<td>Video Data Collection System (optional)</td>
<td>$5,050</td>
</tr>
<tr>
<td><strong>Total Cost Per Vehicle (with video)</strong></td>
<td><strong>$9,200</strong></td>
</tr>
</tbody>
</table>

## Cellular Source & Service

<table>
<thead>
<tr>
<th>Source &amp; Service</th>
<th>Monthly Rate</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sprint Gov’t Quote, January 2014, Unlimited Data, Free Modem</td>
<td>$35</td>
</tr>
<tr>
<td>Sprint Consumer Price, 12GB data, 3G/4G modem ($0 to $50)</td>
<td>$80</td>
</tr>
<tr>
<td>Sprint Consumer Price, unlimited data, smart phone</td>
<td>$110</td>
</tr>
<tr>
<td>AT&amp;T Consumer Price, 10GB data, data modem</td>
<td>$60</td>
</tr>
<tr>
<td>AT&amp;T Consumer Price, 10GB data, unlimited voice, smart phone</td>
<td>$100</td>
</tr>
<tr>
<td>Verizon Consumer Price, 10GB data, unlimited voice, smart phone</td>
<td>$100</td>
</tr>
</tbody>
</table>
## Traffic Data Costs

<table>
<thead>
<tr>
<th></th>
<th>Infrastructure Based/Typical</th>
<th>Probe Based (e.g., I-95 Corridor)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Initial capital cost (per centerline mile)</strong></td>
<td>$26,000</td>
<td>$900</td>
</tr>
<tr>
<td><strong>Annual Recurring Cost</strong></td>
<td>$150</td>
<td>$750</td>
</tr>
<tr>
<td><strong>5-year Est. Cost</strong></td>
<td>$26,600</td>
<td>$3,900</td>
</tr>
<tr>
<td><strong>10-year Est. Cost</strong></td>
<td>$27,350</td>
<td>$7,650</td>
</tr>
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</table>
What’s Next for the Footprint?

• Outreach
  ▪ May 6th AASHTO SSOM
  ▪ May 22nd Open T3 webinar
  ▪ May 29th States & OEM webinar

• Complete Report
  ▪ Publish Final Report by June 30
  ▪ Documents posted at AASHTO & USDOT
Website for Documents

- Footprint Documents for Tasks 3, 4 & 5 are on the AASHTO SSOM Web Site: [http://ssom.transportation.org/Pages/Connected-Vehicles.aspx](http://ssom.transportation.org/Pages/Connected-Vehicles.aspx)
- JPO web site for Final Report (after 6/30) [http://www.its.dot.gov/connected_vehicle/connected_vehicle.htm](http://www.its.dot.gov/connected_vehicle/connected_vehicle.htm)
- JWright@aashto.org
- Ben.McKeever@dot.gov
- Kyle.Garrett@synesis-partners.com