Commercial Vehicle V2V Communications for Safety Research

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National Highway Traffic Safety Administration

Connected Vehicle Truck Safety Meeting
Chicago, IL
August 4, 2011
Vehicle Safety Communications

Connected Vehicle Environment
Vehicle Safety Communications

Greater situational awareness
• Your vehicle can “see” nearby vehicles and knows roadway conditions you can’t see.

Vehicle-to-Vehicle (V2V) can reduce or mitigate crashes
• Driver advisories
• Driver warnings
• Vehicle control

Vehicle safety communications have the potential to address approximately 80% of crash scenarios for unimpaired drivers
Commercial Vehicle V2V Research Plan

**Objective** – Resolve technical issues necessary for deployment of Vehicle-to-Vehicle (V2V) systems on commercial vehicles (CV) and conduct research on areas of policy concerns.

**Key Tasks**

- Identify priority CV crash scenarios.
- Select priority safety applications / determine performance requirements.
- Identify CV specific interoperability issues.
- Identify CV specific human factors / DVI issues.
- Build prototype vehicles and develop objective test procedures.
- Conduct Driver Acceptance Clinics.
- Participate in Safety Pilot to gain “real world” experience.
- Estimate safety benefits.
- Identify CV policy issues and coordinate with overall program.
- Support NHTSA Agency decision in 2014 for heavy vehicles.
## Research Completed to Date
- Driver Vehicle Interface Needs Identification
- Development of Performance Requirements for Safety Applications
- Identify CV Interoperability Issues

## Upcoming Research
- Build Prototype Truck Tractors with Integrated V2V Applications
- Participate in Safety Pilot
  - Conduct CV Driver Acceptance Clinics
  - Model Deployment

### Commercial Vehicle V2V and Safety Pilot Roadmap

<table>
<thead>
<tr>
<th>Safety Pilot</th>
<th>Vehicle to Vehicle Safety</th>
</tr>
</thead>
<tbody>
<tr>
<td>V2V LV Benefits Assessment</td>
<td>HIA Device</td>
</tr>
<tr>
<td>Safety Pilot DVI Criteria</td>
<td>2011 ITS World Congress Demo</td>
</tr>
<tr>
<td>V2V LV Benefits Assessment</td>
<td>Pre-Model Deployment</td>
</tr>
<tr>
<td>NHTSA Agency Decision (LV)</td>
<td>Model Deployment</td>
</tr>
</tbody>
</table>

### Research Completed to Date
- Driver Vehicle Interface Needs Identification
- Development of Performance Requirements for Safety Applications
- Identify CV Interoperability Issues

### Upcoming Research
- Build Prototype Truck Tractors with Integrated V2V Applications
- Participate in Safety Pilot
  - Conduct CV Driver Acceptance Clinics
  - Model Deployment

### Research Timeline

<table>
<thead>
<tr>
<th>Year</th>
<th>Q1</th>
<th>Q2</th>
<th>Q3</th>
<th>Q4</th>
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</thead>
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<tr>
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<tr>
<td>2014</td>
<td></td>
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</table>
Commercial Vehicle V2V Results To Date

Connected Vehicle Truck Safety Meeting
Chicago, IL
August 4, 2011
Commercial Vehicle V2V Research

Completed CV V2V Research Projects initiated in 2010

- University of Michigan Transportation Research Institute
- Virginia Tech Transportation Institute
- Battelle Center for Human Performance and Safety

Answer the Fundamental Questions for CV Deployment

- Interoperability Issues
- Performance Requirements For Applications
- Driver-Vehicle Interface (DVI) Needs
CV Driver-Vehicle Interface Needs

Battelle identified specific CV DVI needs. Prepared a reference document to be used for the future development of DVI guidelines.

Unique to CV Driver:
- Cab environment
- Workload
- Duration
CV Driver-Vehicle Interface Needs

Guidance for DVI Design

- Format, modality, location, and timing of messages, alerts, and warnings
- Strategies for minimizing false and nuisance alerts
- Integrating multiple subsystems
  - Prioritizing messages presented to driver
- Status, particularly as it relates to automated vehicle control functions
- Mitigating driver distraction
- Maintaining compatibility between message design and the desired driver response
- Special requirements of CV drivers
CV V2V Safety Applications

VTTI developed performance requirements for CV V2V and V2I safety applications that map to real-world crash scenarios for heavy vehicles.
CV Safety Applications

VTTI summarized performance requirements for the following CV safety applications:

- Cooperative Forward Collision Warning (FCW)
- Emergency Electronic Brake Light (EEBL)
- Blind Spot Warning (BSW) / Lane Change Warning (LCM)
- Control Loss Warning (CLW)
- Wrong Way Direction Warning (WWDW)
- Do Not Pass Warning (DNPW)
- Cooperative Stop Sign Violation Warning (CSSVW)
- Intersection Movement Assist (IMA)
- Left Turn Assist (LTA)
- Cooperative Traffic Signal Violation Warning (CTSVW)
# Pre-Crash Scenarios and Safety Applications

<table>
<thead>
<tr>
<th>Pre-crash Scenarios</th>
<th>Safety Applications</th>
<th>V2V</th>
<th>V2V and V2I</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Cooperative FCW</td>
<td>EEBL ERS</td>
<td>BSW/LCW</td>
</tr>
<tr>
<td><strong>Rear-end</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lead vehicle stopped</td>
<td>•</td>
<td>•</td>
<td></td>
</tr>
<tr>
<td>Lead vehicle decelerating</td>
<td>•</td>
<td>•</td>
<td></td>
</tr>
<tr>
<td>Lead vehicle moving</td>
<td>•</td>
<td>•</td>
<td></td>
</tr>
<tr>
<td>Striking maneuver</td>
<td>•</td>
<td>•</td>
<td></td>
</tr>
<tr>
<td>Lead vehicle accelerating</td>
<td>•</td>
<td>•</td>
<td></td>
</tr>
<tr>
<td><strong>Lane change</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Changing lanes/same direction</td>
<td></td>
<td>•</td>
<td></td>
</tr>
<tr>
<td>Turning/same direction</td>
<td>•</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Drifting/same direction</td>
<td>•</td>
<td>•</td>
<td></td>
</tr>
<tr>
<td><strong>Opposite direction</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>No maneuver</td>
<td>•</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Maneuver</td>
<td>•</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>LTAP/OD</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Non-signal</td>
<td>•</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Signal</td>
<td>•</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Junction Crossing</strong></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>SCP at non-signal</td>
<td>•</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Turn at non-signal</td>
<td>•</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Turn right at signal</td>
<td>•</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>TCD Violation</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Running red light</td>
<td>•</td>
<td>•</td>
<td></td>
</tr>
<tr>
<td>Running stop sign</td>
<td>•</td>
<td>•</td>
<td></td>
</tr>
</tbody>
</table>
## Annual CV Crashes Addressable by V2V

<table>
<thead>
<tr>
<th>Pre-crash Scenario</th>
<th>Crash Count</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rear-end/lead vehicle stopped</td>
<td>31,598</td>
</tr>
<tr>
<td>Rear-end/lead vehicle decelerating</td>
<td>17,568</td>
</tr>
<tr>
<td>Rear-end/lead vehicle moving</td>
<td>14,251</td>
</tr>
<tr>
<td>Rear-end/striking maneuver</td>
<td>4,687</td>
</tr>
<tr>
<td>Rear-end/lead vehicle accelerating</td>
<td>1,222</td>
</tr>
<tr>
<td>Turning/same direction</td>
<td>27,922</td>
</tr>
<tr>
<td>Opposite direction/no maneuver</td>
<td>13,352</td>
</tr>
<tr>
<td>Opposite direction/maneuver</td>
<td>978</td>
</tr>
<tr>
<td>LTAP/OD at non-signal</td>
<td>5,257</td>
</tr>
<tr>
<td>LTAP/OD at signal</td>
<td>5,430</td>
</tr>
<tr>
<td>Straight crossing paths (SCP) at non-signal</td>
<td>22,452</td>
</tr>
<tr>
<td>Turn at non-signal</td>
<td>4,299</td>
</tr>
<tr>
<td>Turn right at signal</td>
<td>2,782</td>
</tr>
<tr>
<td>Running red light</td>
<td>9,404</td>
</tr>
<tr>
<td>Running stop sign</td>
<td>1,441</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>185,095</strong></td>
</tr>
</tbody>
</table>

2005-2008 GES
Crash Scenario – Rear End Collisions

Crashes that could be addressed by V2V safety applications

<table>
<thead>
<tr>
<th>Pre-crash Scenario</th>
<th>Count</th>
<th>Percent</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rear-end/lead vehicle stopped</td>
<td>31,598</td>
<td>45.6</td>
</tr>
<tr>
<td>Rear-end/lead vehicle decelerating</td>
<td>17,568</td>
<td>25.3</td>
</tr>
<tr>
<td>Rear-end/lead vehicle moving</td>
<td>14,251</td>
<td>20.6</td>
</tr>
<tr>
<td>Rear-end/striking maneuver</td>
<td>4,687</td>
<td>6.8</td>
</tr>
<tr>
<td>Rear-end/lead vehicle accelerating</td>
<td>1,222</td>
<td>1.8</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>69,326</strong></td>
<td><strong>100.0</strong></td>
</tr>
</tbody>
</table>

2005-2008 GES
Rear-End with Lead Vehicle Crashes

Subject vehicle that is proceeding straight closes in on a lead vehicle

Variations:
• Lead Vehicle Stopped
• Lead Vehicle Moving at a Slower Constant Speed

Applications: FCW, EEBL
Rear-End – Striking Maneuver

Subject vehicle that is changing lanes or passing, and then closes in on a lead vehicle

Applications: FCW, EEBL, CLW
Rear-End / Lead Vehicle Accelerating

Subject vehicle proceeding straight closes in on an accelerating lead vehicle

Applications: FCW, EEBL
Lane Change Crash Scenarios

Crashes that could be addressed by V2V safety applications

<table>
<thead>
<tr>
<th>Pre-crash Scenario</th>
<th>Count</th>
<th>Percent</th>
</tr>
</thead>
<tbody>
<tr>
<td>Changing lanes/same direction</td>
<td>50,690</td>
<td>51.6</td>
</tr>
<tr>
<td>Turning/same direction</td>
<td>27,922</td>
<td>28.4</td>
</tr>
<tr>
<td>Drifting/same direction</td>
<td>19,703</td>
<td>20.0</td>
</tr>
<tr>
<td>Total</td>
<td>98,315</td>
<td>100.0</td>
</tr>
</tbody>
</table>

2005-2008 GES

Subject vehicle changing lanes then encroaching into another vehicle traveling in the same direction

Applications: BSW/LCW
Turning / Same Direction

Subject vehicle turning left at an intersection cuts across the path of another vehicle initially traveling in the same direction

Applications: FCW, LTA
Subject vehicle proceeding straight drifts into an adjacent vehicle traveling in the same direction

Applications: BSW/LCW, CLW
Opposite Direction Crashes

Crashes that could be addressed by V2V safety applications

<table>
<thead>
<tr>
<th>Pre-crash Scenario</th>
<th>Count</th>
<th>Percent</th>
</tr>
</thead>
<tbody>
<tr>
<td>Opposite direction/no maneuver</td>
<td>13,352</td>
<td>93.2</td>
</tr>
<tr>
<td>Opposite direction/maneuver</td>
<td>978</td>
<td>6.8</td>
</tr>
<tr>
<td>Total</td>
<td>14,330</td>
<td>100.0</td>
</tr>
</tbody>
</table>

2005-2008 GES

**No Maneuver**

Applications: FCW, CLW, WWDW

Subject vehicle traveling straight drifts into another vehicle traveling in the opposite direction

**Maneuver**

Applications: FCW, DNPW
# Left Turn Across Path Opposite Direction

Crashes that could be addressed by V2V safety applications

<table>
<thead>
<tr>
<th>Pre-crash Scenario</th>
<th>Count</th>
<th>Percent</th>
</tr>
</thead>
<tbody>
<tr>
<td>LTAP/OD at non-signal</td>
<td>5,257</td>
<td>49.2</td>
</tr>
<tr>
<td>LTAP/OD at signal</td>
<td>5,430</td>
<td>50.8</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>10,687</td>
<td>100.0</td>
</tr>
</tbody>
</table>

2005-2008 GES

Subject vehicle turning left at an intersection cuts across the path of another vehicle crossing from an opposite direction.

Variations:
- Traffic signal controlled intersection

Applications: FCW, IMA, LTA
## Junction Crossing Crashes

Crashes that could be addressed by V2V safety applications

<table>
<thead>
<tr>
<th>Pre-crash Scenario</th>
<th>Count</th>
<th>Percent</th>
</tr>
</thead>
<tbody>
<tr>
<td>SCP at non-signal</td>
<td>22,452</td>
<td>76.0</td>
</tr>
<tr>
<td>Turn at non-signal</td>
<td>4,299</td>
<td>14.6</td>
</tr>
<tr>
<td>Turn right at signal</td>
<td>2,782</td>
<td>9.4</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>29,533</td>
<td>100.0</td>
</tr>
</tbody>
</table>

2005-2008 GES

Stopped Crossing Path (SCP) subject vehicle stopping at a road junction then proceeding against lateral crossing traffic

Applications: FCW, IMA
Turn at Non-Signal

Subject vehicle stops at a road junction and then proceeds to turn left against lateral crossing traffic

Applications: FCW, IMA
Right Turn at Signal

Subject vehicle stops at a signalized intersection then proceeds to turn right into the path of another vehicle crossing laterally from the subject vehicle’s initial stop position

Applications: FCW, IMA
## Traffic Control Device (TCD) Violation

### Crashes that could be addressed by V2V/ V2I safety applications

<table>
<thead>
<tr>
<th>Pre-crash Scenario</th>
<th>Count</th>
<th>Percent</th>
</tr>
</thead>
<tbody>
<tr>
<td>Running red light</td>
<td>9,404</td>
<td>86.7</td>
</tr>
<tr>
<td>Running stop sign</td>
<td>1,441</td>
<td>13.3</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>10,845</td>
<td>100.0</td>
</tr>
</tbody>
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2005-2008 GES

Subject vehicle proceeding through a red light, through the intersection, and colliding with another straight-crossing vehicle from a lateral direction.

Applications: FCW, BSW/LCW, IMA, CTSVW, CSSVW
**Ranking of Priority CV V2V Crash Scenarios**

<table>
<thead>
<tr>
<th>Scenario</th>
<th>Comprehensive Costs</th>
<th>Functional Years Lost</th>
</tr>
</thead>
<tbody>
<tr>
<td>Opposite direction/no maneuver</td>
<td>25.0%</td>
<td>25.0%</td>
</tr>
<tr>
<td>SCP @ non-signal</td>
<td>20.0%</td>
<td>20.0%</td>
</tr>
<tr>
<td>Rear-end/LVS</td>
<td>15.0%</td>
<td>15.0%</td>
</tr>
<tr>
<td>Rear-end/LVM</td>
<td>10.0%</td>
<td>10.0%</td>
</tr>
<tr>
<td>Changing lanes/same direction</td>
<td>5.0%</td>
<td>5.0%</td>
</tr>
<tr>
<td>LTAP/OD</td>
<td>5.0%</td>
<td>5.0%</td>
</tr>
<tr>
<td>Rear-end/LVD</td>
<td>2.5%</td>
<td>2.5%</td>
</tr>
<tr>
<td>Turning/same direction</td>
<td>2.5%</td>
<td>2.5%</td>
</tr>
<tr>
<td>Drifting/same direction</td>
<td>2.5%</td>
<td>2.5%</td>
</tr>
<tr>
<td>Opposite direction/move</td>
<td>2.5%</td>
<td>2.5%</td>
</tr>
</tbody>
</table>

CV Interoperability Issues

UMTRI was tasked with identifying priority CV interoperability issues that need to be addressed for successful deployment of vehicle safety communications.

High Priority
- DSRC performance and CV physical factors
- SAE J2735 basic safety messages (BSM) and articulated vehicles

Mid-Level Priority
- Aftermarket/retrofit safety devices and J1939 issues
- Scalability: performance in areas of dense DSRC
- Impact of CVs on relative positioning accuracies
- Power unit OBEs knowing trailer parameters
- Certification of onboard equipment
- Engagement of commercial industry in discussions
- Using CVs in objective testing
DSRC Performance and CV Physical factors

Impact on GPS signals received by a small vehicle adjacent to a large vehicle

Blockage scenarios
SAE J2735 BSM and Articulated Vehicles

SAE J2735 message set does not allow for combination (articulated) vehicles. All data is associated with a single “rigid body” vehicle which could have impacts for safety application performance.
ITS Safety Pilot Roadmap

CY 2010
Q1
Vehicle Builds & Driver Clinics
Integrated LV Builds
LV Driver Clinics

Q2
Integrated HV Builds
HV Driver Clinics

Q3
HIA Device

Q4
Update

Device QPL

Safety Pilot DVI Criteria

Device QPL

A/M Safety Device - LV

Device QPL

HV Retrofit Safety Device - LV

Controller interface defined

Roadside Equipment

Device QPL

RSE QPL

Real World Testing
Pre-Model Deployment

Model Deployment

World Congress

Evaluation & Benefits
Independent Evaluation of Testing Activities

CY 2011
Q1
Q2
Q3
Q4

CY 2012
Q1
Q2
Q3
Q4

CY 2013
Q1
Q2
Q3
Q4

NHTSA Agency Decision (LV)

NHTSA Agency Decision (HV)

LV – Light Vehicle
HV – Heavy Vehicle
TV – Transit Vehicle
HIA – “Here I Am”
A/M - Aftermarket
QPL – Qualified Product List
RSE – Roadside Equipment
V2V – Vehicle-to-Vehicle
Current CV V2V Research – Safety Pilot

• **Connected CV Safety Applications Development**
  - U.S. DOT awarded a contract in April to team led by Battelle to build heavy vehicles with integrated V2V applications
  - 4 - Class 8 tractors (3 sleepers, 1 day cab) and 7 trailers

• **CV Driver Acceptance Clinics**
  - Conduct tests in 2-4 locations in the U.S. to gauge driver acceptance and collect data on systems and applications
  - Select CDL-licensed drivers to participate from local trucking fleets and independents
  - Tests run in a controlled environment with in-cab experimenter
  - On-board data collection and driver surveys
Safety Pilot

• **Model Deployment**
  • Full scale test of approximately 3000 vehicles (all types)
  • 2-3 Integrated CVs – with safety applications
    • Naturalistic, recruiting “real” truck drivers
  • 8 - Retrofit – fleet vehicles
    • Devices same functionality as integrated CVs
  • 50 – CVs with basic functionality
  • Field test runs from July 2012 – June 2013
Safety Pilot

• Retrofit Safety Device (RSD) Development
  • Project begins in fall of 2011 – contract to be awarded
  • Supplemental to Connected CV Activities
  • Develop RSD kits with V2V safety applications
  • Increase the number of fully functional CVs in the Model Deployment
  • RSD kits installed in Safety Pilot participating fleet CVs
    • Articulated vehicles and straight trucks (Classes 6, 7, and 8) that feature J1939 CAN
    • Provide additional CV test data
    • Establish a platform for future research
Contact Information

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http://www.its.dot.gov/