V2V Overview

- Wireless exchange of anonymous safety relevant data (precise location$^1$, heading, speed$^2$) between nearby vehicles.
- Uses DSRC (5.9 GHz) to sense threats with a 360 degree “view” to issue driver warnings.
- In some cases, the driver is not able to see the potential threat.
- Each vehicle communicates with other vehicles to support a new generation of safety applications.
- Can supplement existing sensing technology (radar, camera)
- Provides a building block for automation

1) Relative position accuracy of about 1.5 m. Represents “lane level” accuracy.
2) Also called basic safety message, or BSM
In-Vehicle Components of a V2V System

Security system
Provides and verifies V2V security certificates to ensure trust between vehicles

GPS, DSRC antennae

In-vehicle components

Dedicated Short Range Communications (DSRC) radio
Receives and transmits data through antennae

GPS receiver
- Provides vehicle position and time to DSRC radio
- Provides timekeeping signal for applications

Driver-vehicle interface
Generates warning issued to driver

Memory
Stores security certificates, application data, and other information

Safety application electronic control unit
Runs safety applications

Vehicle’s internal communications network
Existing network that interconnects components

This in-vehicle equipment can consist of either a single, integrated unit or a discrete set of components

Sources: Crash Avoidance Metrics Partnership and GAO.
U.S. DOT V2V Research Activities/Milestones

- **ITS Joint Program Office (JPO)** - The JPO has been coordinating intelligent vehicle safety research with NHTSA since 1998.

- **2009 NHTSA V2V Research Plan** - Included identifying the crash problem, interoperability needs, application testing; driver acceptance, and estimation of V2V benefits.

- **Safety Pilot Driver Clinics** - Conducted across the U.S. on controlled test track environments to understand driver acceptance of the V2V safety technology on light and heavy vehicles.

- **Safety Pilot Model Deployment** – 2,800 V2V equipped vehicles operated by regular drivers in Ann Arbor, MI to collected data on V2V crash avoidance warnings in support of benefit estimation.


- **NHTSA V2V Readiness Report** – Comprehensive presentation of NHTSA research on V2V technology, testing, and implementation considerations. Released to public August, 2014

- **Request for Information (RFI)** for security system published on October 15, 2014
Technical Practicability—Issues Addressed in V2V Readiness Report

- GPS Availability
- Relative Position
- Message Congestion
- Device Installation
- Device Updates

Technological Readiness

- Vehicle Base
- Non-Vehicle Based
- Hardware
- Security
- Software
- DSRC
- Safety Applications
- Interoperability

- Communications
- Message Sets
- 5.9 GHz spectrum
- Standards
- Performance Measures

System Limitations
V2V Warning Scenarios

- V2V communications technology can address approximately 2.5 M annual light and heavy vehicle crashes.
- Key types of crashes addressed by V2V include:
  - Rear-end and head-on
  - Intersection related
  - Turning across path (left hand turns)
  - Lane change related (blind spot warning)
### 37 Pre-Crash Scenarios

All Heavy-Truck (HT) Crashes (384,000)  
Unimpaired HT Crashes (375,000)

### 22 V2V Pre-Crash Scenarios

266,000 HT Crashes  
(69% of All HT Crashes, 71% of Unimpaired HT Crashes)

<table>
<thead>
<tr>
<th>Scenario Type</th>
<th>Number of Scenarios</th>
<th>HT Crashes</th>
<th>Percentage of All HT Crashes</th>
<th>Percentage of Unimpaired HT Crashes</th>
</tr>
</thead>
<tbody>
<tr>
<td>17 Target V2V Pre-Crash Scenarios</td>
<td>224,000</td>
<td>58%</td>
<td>60%</td>
<td></td>
</tr>
<tr>
<td>5 V2V Pre-Crash Scenarios</td>
<td>11%</td>
<td>Not Used</td>
<td></td>
<td></td>
</tr>
<tr>
<td>5 V2V Pre-Crash Scenarios</td>
<td>2 - Control Loss</td>
<td></td>
<td></td>
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<tr>
<td>5 V2V Pre-Crash Scenarios</td>
<td>1 - Backing</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>5 V2V Pre-Crash Scenarios</td>
<td>1 - Parking</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>5 V2V Pre-Crash Scenarios</td>
<td>1 - Other</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>10 Priority Pre-Crash Scenarios</td>
<td>201,000</td>
<td>52%</td>
<td>54%</td>
<td></td>
</tr>
<tr>
<td>10 Priority Pre-Crash Scenarios</td>
<td>3 - Rear-End</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>10 Priority Pre-Crash Scenarios</td>
<td>3 - Lane Change</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>10 Priority Pre-Crash Scenarios</td>
<td>2 - Opposite Direction</td>
<td></td>
<td></td>
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</tr>
<tr>
<td>10 Priority Pre-Crash Scenarios</td>
<td>1 - LTAP/OD (combined)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>10 Priority Pre-Crash Scenarios</td>
<td>1 - Junction Crossing</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*Note that the numbers preceding the pre-crash scenarios refer to the total number of scenarios.

### Safety Need Heavy Vehicles (HV)
Heavy Vehicle Crash Scenario Analysis

  - DOT HS 812 023, June 2014

Challenge - Need for Security

Trust
Message Validity

Defense Against Attacks
Proposed V2V Security System

- Variation of common/mature machine-to-machine Public Key Infrastructure (PKI)
- Approved system participants granted a bundle of trusted, encrypted certificates by central authority – an entity managed outside government
  - Devices receive certificate updates and “do not trust” or certificate revocation lists from central authority.
  - Devices exchange trusted basic safety messages (BSMs) by attaching certificates to each message.
  - Device-to-device messages contain no personally identifiable information (PII)
  - Devices report observed anomalous conditions in BSMs (or “misbehavior”)

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Plan for Maturing and Implementing an SCMS

- Early, limited functionality, version tested in Safety Pilot (Complete)
- Finalize Design (Complete)
- Build and Test a Prototype
  - In process: led by CAMP with support from telecommunication industry partners.
  - End-to-End testing to be completed by late 2015
- Operate a fully functional SCMS to service Connected Vehicle Pilot environments being established by USDOT.
- Issued a Request for Interest to build/operate an SCMS
  - Over 20 responses from variety of auto, telecom and IT industry stakeholders and suppliers.
Key Cost Elements

- **Vehicle equipment**
  - DSRC radio(s)
  - GPS
  - Operating system
  - Antennas and wiring

- **Security system**
  - Capital (IT equipment; facilities; land; etc.)
  - Operating (labor, rents, utilities, etc.)

- **Communications**
  - Between SCMS and vehicles
  - DSRC, cellular, or other (baseline costs to be estimated on DSRC network)
Safety Benefits Estimation

- Crash Data
  - Pre-Crash Scenarios
  - Number of Crashes

- Field Data
  - Driving Conflicts
  - Exposure Factor

- Modeling
  - Crash Probability
  - Prevention Factor

- Map
  - Derive

Safety Benefits
Primary Data Sources For Benefits Estimation

- **Heavy Truck - Driver Acceptance Clinics**
  - Experience of approximately 100 truck drivers using V2V in realistic driving scenarios in a closed course environment

- **Safety Pilot - Model Deployment**
  - Data from 19 equipped V2V trucks driven by participating fleets in an 18-month naturalistic field study

- **Heavy Truck V2V Performance Testing**
  - VRTC test track evaluation of heavy truck V2V systems

- **National Advanced Driving Simulator Heavy Truck V2V Study**
  - Simulator study to measure truck drivers’ reactions to V2V warnings in crash imminent driving scenarios

- **IVBSS**
  - Field data on truck driver’s reaction to safety warnings
Research on General V2V Issues

- Additional research continues through 2015
  - Specifications and objective test procedures for mandatory DSRC devices
  - Finalize security system design and end-to-end testing
  - Mitigating communications congestion
  - Detailed privacy risk assessment and security review
  - Public Acceptance Research
  - Performance metrics for safety applications

- Spectrum: to share or not to share?
- Security system: who will operate?
Heavy Vehicle Specific V2V Research

- Basic Safety Message for Truck Trailers
  - Develop changes to the BSM to accommodate articulated trailers
  - Demonstrate this fall on prototype tractor-trailer and submit to SAE technical committees for standards review

- Objective test procedures for heavy vehicle applications for V2V systems

- Complete safety benefits for heavy vehicles
  - Estimates of crash, fatality, and injury reductions
  - System costs
Basic Safety Message (BSM) for Articulated Vehicles

- Current BSM reflects only single-bodied vehicle
- Special considerations for articulated vehicles in BSM
- Need more accurate vehicle position and vehicle type information for trailers
  - On a straight path, a single, simple BSM adequately describes the vehicle
  - On a highway curve or ramp at low to moderate speed, the trailer tracks inside the tractor
- Recommendations for SAE J2735 and J2945 committees to update standards
ANPRM on Light Vehicle V2V Communications

- NHTSA released an Advance Notice of Proposed Rulemaking (ANPRM) in August 2014
  - Require V2V communication capability for light vehicles (passenger cars and light truck vehicles (LTVs))
  - Create minimum performance requirements for V2V devices and messages for new vehicles in a future year.
- ANPRM will includes an analysis of research findings in a report: *Vehicle-to-Vehicle Communications: Readiness of V2V Technology for Application*
  - Technical feasibility
  - Privacy and security
  - Preliminary estimates on costs and safety benefits.
Next Steps

- Continue research on heavy vehicle specific V2V issues
- Prepare heavy vehicle decision document
- Announce NHTSA Heavy Vehicle V2V Decision by early 2015
- Issue a request for expressions of interest in establishing and running the security system
- Complete research for proposed LV rule
- Draft NPRM for LV in 2016
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For more information on the U.S. DOT Connected Vehicles Program, visit the websites:


http://www.its.dot.gov