V2V RESEARCH
CRASH, PERFORMANCE, AND TESTS

ITS Workshop on Connected Vehicles:
Moving from Research Towards Implementation

September 25, 2012
V2V Safety Framework

- Maturing the V2V Research
  - Initial Crash Problems
  - Performance Measures
  - Testing Procedures
  - Interoperability Requirements
  - Initial Security Models
  - Driver Vehicle Interface Guidance

- Model Deployment
  - Benefits Framework
  - Driver Clinics
  - Performance Testing
  - Model Deployment
  - Experimental Design

- Evaluation
  - Evaluation Plan
  - Data
  - Conduct Evaluation
  - Run Simulations

- Supporting Policy Elements
  - Implementation
  - Technical
  - Legal

- Moving Towards a Decision
  - Safety Benefits
  - Performance Requirements
  - Test Procedures
  - Driver Acceptance

Moving Towards an Operation Model
- Data Collection
- Data Evaluation & Analysis
- Establishing an Operational Environment
- Results
Pre-Crash Scenario Framework

Step 1 • Identify target pre-crash scenarios for V2V-based safety applications

Step 2 • Describe target pre-crash scenarios based on national crash statistics

Step 3 • Prioritize and rank target pre-crash scenarios by frequency and severity

Step 4 • Depict priority pre-crash scenarios and determine crash avoidance needs and countermeasure profiles

Step 5 • Highlight V2V-based countermeasures for priority pre-crash scenarios
Target V2V Crashes

37 Pre-Crash Scenarios
All Light-Vehicle (LV) Crashes (5,726,000) Unimpaired LV Crashes (5,355,000)

22 V2V Pre-Crash Scenarios
4,336,000 LV Crashes
(76% of All LV Crashes, 81% of Unimpaired LV Crashes)

17 Target V2V Scenarios
3,662,000 LV Crashes
(64% of All, 68% of Unimpaired)
5 Rear-End  2 Opposite Direction
3 Lane Change  3 Junction Crossing
2 LTAP/OD (all intersections)
2 Traffic Control Device Violation

10 Priority Scenarios
3,224,000 LV Crashes
(56% of All, 60% of Unimpaired)
3 Rear-End  3 Lane Change
2 Opposite Direction  1 LTAP/OD
1 Junction Crossing

5 V2V Pre-Crash Scenarios
12% of All LV Crashes
13% of Unimpaired LV Crashes
Not Used
2 Control Loss
1 Backing
1 Parking
1 Other

15 V2I or Single Vehicle Pre-Crash Scenarios
24% of All LV Crashes
19% of Unimpaired LV Crashes
Not Used

Target V2V Scenario Groups by Safety Application

Opposite Direction: 3%
- Do Not Pass Warning (DNPW) & BSW/LCW

Turn Across Path: 10%
- Left Turn Assist (LTA)

Lane Change: 17%
- Blind Spot/Lane Change Warning (BSW/LCW)

Junction Crossing: 26%
- Intersection Crash Avoidance (IMA + ICA)

Rear-End: 43%
- Forward Collision Warning/Avoidance & Emergency Electronic Brake Lights (FCW/A & EEBL)

% of Target Crashes
Preliminary Performance Measures

Crash Avoidance Groups

- Rear-End
- Lane Change
- Opposite Direction
- Junction Crossing
- LTAP/OD

Methodology

- Related Literature
- Supporting Data
- Analysis & Assumptions

Recommended Performance Measures and Requirements
Three Crash Avoidance Action Categories

- Normal Driving
- Advisory Systems
- Driver Warning Systems
- Automatic Control Intervention

Crash Unavoidable
Crash Threat Imminent
Initial Threat
Time
Increasing Intensity of Action
Crash
Performance Metrics

**Driver Reaction Time**
Depends on:
- age
- gender
- physical & psychological state
- etc.

**Braking Level**
Depends on:
- speed
- range
- closing rate
- ttc
- etc.

**Braking Level**
Braking level known plus additional considerations:
- brake subsystem delay
- hydraulic pressure or deceleration build-up
- maximum level of braking
- brake characteristics
- etc.
• **Purpose**
  – Forward Crash Warning (FCW) system detects vehicles in the path of the host vehicle, determines the likelihood of collision, and warns the driver of impending collisions.
  – Forward Crash Avoidance (FCA) system automatically applies the brakes in addition to the FCW function.
  – Comprises LVS, LVM, and LVD scenarios

• **Literature Study**
  – Crash Avoidance Metrics Partnership (CAMP)
  – International Standards Organization (ISO)
  – Integrated Vehicle-Based Safety System (IVBSS)
  – New Car Assessment Program (NCAP)

• **Crash Databases**
  – National Automotive Sampling System (GES)
  – Event Data Recorder (EDR)

• **Field Operational Test (FOT)**
  – IVBSS
### REAR END – FCW and FCA Input Performance Measures Variables

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Source</th>
</tr>
</thead>
<tbody>
<tr>
<td>Instantaneous host vehicle speed</td>
<td>In-Vehicle and/or GPS</td>
</tr>
<tr>
<td>Instantaneous host vehicle acceleration</td>
<td>In-Vehicle, GPS, or computed</td>
</tr>
<tr>
<td>Predicted average acceleration (braking) by driver due to warning</td>
<td>FCW - Estimated by system</td>
</tr>
<tr>
<td>FCA - System Based</td>
<td></td>
</tr>
<tr>
<td>Driver reaction time to warning</td>
<td>FCW - Estimated by system</td>
</tr>
<tr>
<td>FCA - Zero</td>
<td></td>
</tr>
<tr>
<td>Total system delay including computation and attaining average acceleration (brake level)</td>
<td>System Based</td>
</tr>
<tr>
<td>Instantaneous remote vehicle speed</td>
<td>In-Vehicle and/or GPS</td>
</tr>
<tr>
<td>Instantaneous remote vehicle acceleration</td>
<td>In-Vehicle, GPS, or computed</td>
</tr>
<tr>
<td>Median expected (braking – measured by FOT’s) remote vehicle acceleration</td>
<td>Estimated by system designer</td>
</tr>
<tr>
<td>Instantaneous range between host and remote vehicles</td>
<td>GPS</td>
</tr>
<tr>
<td>Instantaneous range rate (relative speed) between host and remote vehicles</td>
<td>GPS</td>
</tr>
<tr>
<td>Instantaneous relative speed rate (relative acceleration) between host and remote vehicles</td>
<td>GPS</td>
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</tbody>
</table>
REAR END – FCW and FCA Output Performance Measures

- Time-to-collision and Range for Advisory Warning
- Time-to-collision and Range for Imminent Warning
- Time-to-collision and Range for Automatic Braking
Testing Procedures

Device Certification

• Interoperability
  – Ensures devices can communicate with other devices
  – Form, transmit, receive, and process BSM
  – Assess compliance with device specifications

Safety Application Performance (Objective Tests)

• Measure performance of crash avoidance applications
  – Does application operate as prototype design intent
    • Acceptable for Model Deployment (Warning)
  – Characterize performance for simulation
    • Warning and extended prototype to support benefit estimation
      – Forward Crash Avoidance and Intersection Crash Avoidance
Objective Test Procedures

• Procedure Requirements
  – Testing Approach
  – Countermeasure Modality Requirements
  – Objective Test Run Validity Criteria
  – Instrumentation, Equipment Installation, Calibration
  – Data Collection Requirements
  – Environmental, Ambient, and Standard Test Conditions
  – Suspension Criteria
  – Safety Protocols
  – Crash Imminent Test Scenarios
  – No-Action Test Scenarios
Connected Vehicles Testing

Rear End Forward Collision Avoidance
October 2012 – February 2013

Junction Crossing Intersection Collision Avoidance
March 2013 – July 2013

Diagram of vehicles and traffic signals indicating collision avoidance scenarios.
Safety Application Characterization Tests

**Initial Conditions**
Host vehicle is traveling at constant speed, $V_H$. Remote vehicle is traveling at the same constant speed, at specified range, $R_{\text{Initial}}$.

**Transition**
Remote vehicle begins to decelerate at a steady rate that is less than $2.0 \text{ m/sec}^2$. 
**Safety Application Characterization Tests**

**Countermeasure Action**
The countermeasure action is issued per the system specifications.

![Diagram of Countermeasure Action]

**Resolution**
After a countermeasure action or the host vehicle driver senses an imminent crash, the host vehicle shall brake and/or change lanes to avoid a collision.

![Diagram of Resolution]
FCA Offset RV

- Position displacement
- Offset strike-able ‘boom’
Intersection Surrogate Vehicle

- Examining use of a surrogate remote vehicles for use in Intersection Collision Avoidance testing.