V2V Target Crash Scenarios, Research Performance Measures, and Prototype Objective Testing

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Moving From Research Toward Implementation
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Outline

• Crash Scenarios
• Performance Measures
• Objective Tests
Crash Analysis 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
V2V Light-Vehicle Target 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)

15 V2I or Single Vehicle Pre-Crash Scenarios

24% of All LV Crashes

19% of Unimpaired LV Crashes

Not Used

17 Target V2V Scenarios

3,662,000 Crashes

(64% of All, 68% of Unimpaired)

5 V2V Pre-Crash Scenarios

12% of All LV Crashes

13% of Unimpaired LV Crashes

Not Used

10 Priority Scenarios

3,224,000 Crashes

(56% of All, 60% of Unimpaired)
Target Scenarios for Forward Crash Warning (FCW) & Lane Change Warning (LCW)

**FCW**
- Lead Vehicle Stopped
- Lead Vehicle Slower
- Lead Vehicle Decelerating

**LCW**
- Changing Lanes/Same Direction
- Drifting/Same Direction
- Turning/Same Direction
Target Scenarios for Intersection Movement Assist (IMA)

- **Straight Crossing Paths**
- **Right Turn Into Path**
- **Left Turn Into Path**
- **Left Turn Across Path**
Target Scenarios for Left Turn Assist (LTA) & Do Not Pass Warning (DNPW)
# Annual Crash Frequency of V2V Target Pre-Crash Scenarios

Based on 2004-2008 GES Statistics
Crash Analysis Framework for V2V

• Publish following documents:
  – Description of Light Vehicle Pre-Crash Scenarios for Safety Applications Based on Vehicle-to-Vehicle Communications
  – Depiction of Priority Light Vehicle Pre-Crash Scenarios for Safety Applications Based on Vehicle-to-Vehicle Communications
  – Light Vehicle Crash Avoidance Needs and Countermeasure Profiles for Safety Applications Based on Vehicle-to-Vehicle Communications
V2V Application Performance Measures

• Identify measures of performance for target V2V safety applications
  – Consider additional performance measures for sensing/communication needs and crash avoidance decisions

• Develop preliminary performance requirements at the system level
  – Use empirical data from Model Deployment, field operational tests, objective tests, and controlled HF experiments
Key Performance Measure Categories

- Performance variables about host vehicle (HV), remote vehicle (RV), and driver of HV
- HV state at warning*
- RV state at warning
- RV relative to HV at warning

* Transition from normal driving to advisory or warning, or change from advisory to warning
## Safety Application Critical Performance Variables

<table>
<thead>
<tr>
<th>Safety Application/Performance Variables</th>
<th>Forward Collision Warning (FCW)</th>
<th>Intersection Movement Assist (IMA)</th>
<th>Lane Change Warning (LCW)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Remote Vehicle</td>
<td>Deceleration</td>
<td>Information about RV motion</td>
<td>Information about RV motion</td>
</tr>
<tr>
<td>Host Vehicle (HV)</td>
<td>Lag between brake application and deceleration</td>
<td>Lag between brake application and deceleration</td>
<td>Lag between steering and change in lateral speed</td>
</tr>
<tr>
<td>Host Vehicle Driver</td>
<td>• Brake reaction time</td>
<td>Brake reaction time</td>
<td>Steering reaction time</td>
</tr>
<tr>
<td></td>
<td>• Braking level</td>
<td>Braking level</td>
<td>Lateral speed response level</td>
</tr>
</tbody>
</table>
Objective Testing

• Perform characterization tests to provide accurate ground truth data for use in safety benefits estimation:
  – Test scenarios and initial conditions driven by crash statistics
  – Large sample size (Multiple scenarios, initial conditions, and trials) used to improve statistical significance of the data
  – Combination of countermeasure “Action” and “No Action” scenarios used to assess how well the system distinguishes between crash-imminent and benign driving scenarios
Connected Vehicle Track 4 Testing

Track 4A – Rear End Forward Collision Avoidance
October 2012 – February 2013

Track 4B – Junction Crossing Intersection Collision Avoidance
April 2013 – July 2013
## Forward Collision Avoidance Scenarios

<table>
<thead>
<tr>
<th>Type</th>
<th>No</th>
<th>Test Description</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Countermeasure</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Action Required</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>1</td>
<td>Stopped RV on a straight road (3 sets of initial conditions)</td>
</tr>
<tr>
<td>2</td>
<td>2</td>
<td>Slower RV on a straight road (3 sets of initial conditions)</td>
</tr>
<tr>
<td>3</td>
<td>3</td>
<td>Slowing RV on a straight road (3 sets of initial conditions)</td>
</tr>
<tr>
<td>4</td>
<td>4</td>
<td>Stopped RV in a curve</td>
</tr>
<tr>
<td>5</td>
<td>5</td>
<td>Slower RV in a curve</td>
</tr>
<tr>
<td>6</td>
<td>6</td>
<td>Slower RV after a lane change by the HV</td>
</tr>
<tr>
<td>7</td>
<td>7</td>
<td>Slower RV after a cut-in by the RV</td>
</tr>
<tr>
<td><strong>No-Action</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>8</td>
<td>8</td>
<td>HV in a curve passes a stopped RV in the adjacent lane</td>
</tr>
<tr>
<td>9</td>
<td>9</td>
<td>HV closely follows RV</td>
</tr>
<tr>
<td>10</td>
<td>10</td>
<td>Faster moving RV cuts in front of HV at very close headway gap</td>
</tr>
</tbody>
</table>
### Intersection Collision Avoidance Scenarios

<table>
<thead>
<tr>
<th>Type</th>
<th>No</th>
<th>Test Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Countermeasure</td>
<td>1</td>
<td>Straight Crossing Paths (SCP), Five combinations of HV and RV speeds, 0 to 45 MPH.</td>
</tr>
<tr>
<td>Action Required</td>
<td>2</td>
<td>Right Turn into Path (RTIP)</td>
</tr>
<tr>
<td></td>
<td>3</td>
<td>Left Turn into Path (LTIP)</td>
</tr>
<tr>
<td></td>
<td>4</td>
<td>Left Turn across Path/Lateral Direction (LTAP/LD)</td>
</tr>
<tr>
<td></td>
<td>5</td>
<td>Left Turn across Path/Opposite Direction (LTAP/OD)</td>
</tr>
<tr>
<td>No-Action</td>
<td>6</td>
<td>Straight Crossing Paths (SCP) with stopping RV</td>
</tr>
<tr>
<td></td>
<td>7</td>
<td>SCP with stopping HV</td>
</tr>
<tr>
<td></td>
<td>8</td>
<td>Left Turn across Path/Opposite Direction (LTAP/OD) with stopping RV</td>
</tr>
<tr>
<td></td>
<td>9</td>
<td>HV and RV Turning Right</td>
</tr>
<tr>
<td></td>
<td>10</td>
<td>HV Turning Right, RV Continuing Straight</td>
</tr>
</tbody>
</table>
Host Vehicle Independent Measurement System & Data Acquisition System
Conclusion

• V2V target crashes
  – Published 3 reports: description of target crashes and crash avoidance needs

• Performance measures
  – Completed draft report: to be revised based on empirical data from Model Deployment and Track 4 objective tests

• Objective tests
  – Completed testing of FCW, IMA, and LTA applications: OEMs and aftermarket safety devices
  – Will publish objective test procedures for FCW and IMA+LTA applications