Vehicle-Vehicle and Vehicle-Infrastructure Communications based Safety Applications

Michael Maile
Mercedes-Benz R&D North America
Past Projects

- Collaborative effort between 5 OEMs (Daimler, Ford, GM, Honda & Toyota) and US DOT

- Cooperative Intersection Collision Avoidance Systems-Violations (CICAS-V) project
  - Development of an intersection collision avoidance system to address crashes caused by violations of traffic signals and stop signs

- Vehicle Safety Communications – Applications project
  - Strong emphasis on resolving current communication and vehicle positioning issues so that interoperable future deployment of DSRC+Positioning based safety systems will be enabled
V2I communications based safety applications

Information is transmitted from the infrastructure to a vehicle
Infrastructure uses Roadside Equipment (RSE) that includes a DSRC radio
Examples are
- Cooperative Intersection Collision Avoidance Systems
- Road departure warning
- Danger zones
- Speed limits
- Weather based hazards
CICAS application will be described in more detail
## SPaT message

Sends signal phase and timing information to the vehicle  
Vehicle uses SPaT and GID to determine which traffic signal applies  
Message can include pedestrian signals and other information about intersection

<table>
<thead>
<tr>
<th>Field</th>
<th>Type</th>
</tr>
</thead>
<tbody>
<tr>
<td>Object ID</td>
<td>unsigned 8-bit integer</td>
</tr>
<tr>
<td>Object Size</td>
<td>unsigned 8-bit integer</td>
</tr>
<tr>
<td>Approach ID</td>
<td>unsigned 8-bit integer</td>
</tr>
<tr>
<td>Signal Phase Indications</td>
<td>32-bit bitmask</td>
</tr>
<tr>
<td>Countdown Timer</td>
<td>2 x unsigned 4-bit integer (two nibbles)</td>
</tr>
<tr>
<td>Yellow Duration</td>
<td>unsigned 16-bit integer</td>
</tr>
<tr>
<td>Time until next signal phase change (in hundredths of a second) aka Countdown Timer</td>
<td>unsigned 16-bit integer</td>
</tr>
<tr>
<td>Yellow Duration</td>
<td>unsigned 8-bit integer</td>
</tr>
</tbody>
</table>
Geometric Intersection Description (GID)

GID is a small map that describes the intersection geometry accurately (30 cm or better)

GID elements
- Stop bar location for all lanes
- Lane geometry
- Starting point for new lanes
- Correspondence between Lanes
- Signal Phases

Intersections in the project were mapped using aerial photography

Intersection RSEs broadcast the GID for their associated signalized intersection as well as the stop-controlled intersections in the local area

IRP: Intersection Reference Point
Positioning Corrections

GPS system in intersection sends correction message to RSE

RSE formats the message and sends it to vehicle

Vehicle GPS uses correction message to calculate exact position

- Requirement for error: <1m
- Actual performance: <50 cm

The corrections enable lane-level accurate positioning for any intersection with clear view of the sky
CICAS-V Warning Indications

Icon during Intersection Ahead

Flashing Icon during Warning

Stoplight Warning Audio File

Stop Sign Warning Audio File

Brake Pulse Indication or Automated Braking (ITSWC 2008)
V2V-Communications based Safety Applications

Information is transmitted between vehicles
Enables vehicles to know where the vehicles in its vicinity are and what they are doing

Applications include
- Forward Collision Warning
- Emergency Electronic Brake Light
- Blind Spot/Lane Change Warning
- Intersection Movement Assist
- Do Not Pass Warning
- Control Loss Warning

<Position>
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<Yaw Rate>
<Path History>
<Acceleration>
<GPS corrections>
VSC-A Main Objectives

- Develop scalable, common vehicle safety communication architecture, protocols, and messaging framework necessary to achieve interoperability and cohesiveness among different vehicle manufacturers
  - Standardize this messaging framework and the communication protocols (including message sets) to facilitate future deployment

- Develop accurate and commercially feasible relative vehicle positioning technology needed, in conjunction with the 5.9 GHz DSRC, to support most of the safety applications with high potential benefits

- Develop and verify (on VSC-A system test bed) a set of objective test procedures for the selected vehicle safety communications applications
# VSC-A Test Bed System Development

## Mapping of applications to crash scenarios

<table>
<thead>
<tr>
<th>Crash Scenarios</th>
<th>EEBL</th>
<th>FCW</th>
<th>BSW</th>
<th>LCW</th>
<th>DNPW</th>
<th>IMA</th>
<th>CLW</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lead Vehicle Stopped</td>
<td></td>
<td>✓</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Control Loss without Prior Vehicle Action</td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>✓</td>
</tr>
<tr>
<td>Vehicle(s) Turning at Non-Signalized Junctions</td>
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<td></td>
<td></td>
<td></td>
<td>✓</td>
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<tr>
<td>Straight Crossing Paths at Non-Signalized Junctions</td>
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<td></td>
<td></td>
<td>✓</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lead Vehicle Decelerating</td>
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<td>✓</td>
<td></td>
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<tr>
<td>Vehicle(s) Not Making a Maneuver – Opposite Direction</td>
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<td>Vehicle(s) Changing Lanes – Same Direction</td>
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<tr>
<td>LTAP/OD at Non-Signalized Junctions</td>
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<td></td>
<td></td>
<td></td>
<td>✓</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>


**Abbreviations:**
- EEBL: Emergency Electronic Brake Lights
- FCW: Forward Collision Warning
- BSW: Blind Spot Warning
- LCW: Lane Change Warning
- IMA: Intersection Movement Assist
- DNPW: Do Not Pass Warning
VSC-A System Test Bed

Is a trigger to request verification of the security credentials, from the security module, of the selected threat(s)

Is a trigger to the Engineering DVI to notify the driver of a potential threat
Basic Safety Message validated in VSC-A Test Bed

VSC-A focus:
Part I: ensure that each element is:
- Needed in each BSM
- Defined with adequate range and minimal bandwidth

Part II:
- Defined “Extension” data structure with information essential for V-V safety
- Ensured each element is correctly and efficiently defined

SAE J2735 Basic Safety Message

Part I
- Basic Vehicle State
  \[(\text{Veh. ID, Seq. #, time, position, motion, control, veh. size})\]

Part I is mandatory in Basic Safety message

Part II
- Vehicle Safety Extension
  - Event Flags
  - Path History
  - Path Prediction
  - RTCM Corrections

Required for V-V safety applications, but not in every message

Other optional safety-related data
Objective Test Procedures (OTP)

Task 9 of the VSC-A project involved the development of the objective test plan and conducting the objective tests.

The test procedures were defined by the respective application owners and agreed upon by the USDOT and the VSC-A Team.

The test plan included the procedures together with the validation criteria and setup details to ensure the tests were repeatable.
Objective Test Procedures (OTP) - continued

The OTP contained 33 individual tests: 22 true positive tests and 11 false positive tests.

The OTP demonstrated that the test bed implementation developed in the VSC-A project:
- Fulfilled the performance requirements
- Could support any warning timing chosen for a particular application
- Supported repeatable warning results
Next Steps

Moving vehicle communications to market requires work in

- Security
- Interoperability
- Communications Scalability

Vehicle-to-Vehicle Interoperability project conducted by the VSC3 Consortium under CAMP addresses these issues