Vehicle-Vehicle and Vehicle-Infrastructure Communications based Safety Applications

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CAMP

Vehicle Safety Communications 2

Mercedes-Benz Research & Development North America, Inc.

GM

TOYOTA

HONDA

Honda R&D Americas, Inc.

Ford

Intelligent Transportation Systems

SAE®

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

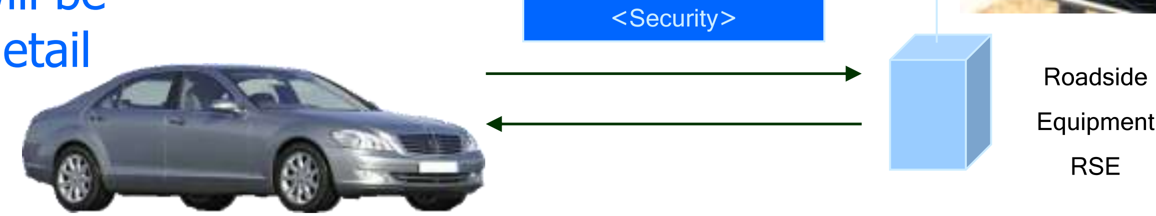
Information is transmitted from the infrastructure to a vehicle

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>
<tr><td colspan="2">Object ID</td><td>unsigned 8-bit integer</td></tr>
<tr><td colspan="2">Object Size</td><td>unsigned 8-bit integer</td></tr>
<tr><td colspan="2">Approach ID</td><td>unsigned 8-bit integer</td></tr>
<tr><td colspan="2">Signal Phase Indications</td><td>32-bit bitmask</td></tr>
<tr><td>Countdown Timer Confidence</td><td>Yellow Duration Confidence</td><td>2 x unsigned 4-bit integer
(two nibbles)</td></tr>
<tr><td colspan="2">Time until next signal phase change
(in hundredths of a second)
aka Countdown Timer</td><td>unsigned 16-bit integer</td></tr>
<tr><td colspan="2">Yellow Duration</td><td>unsigned 8-bit integer</td></tr>
</table>

Geometric Intersection Description (GID)

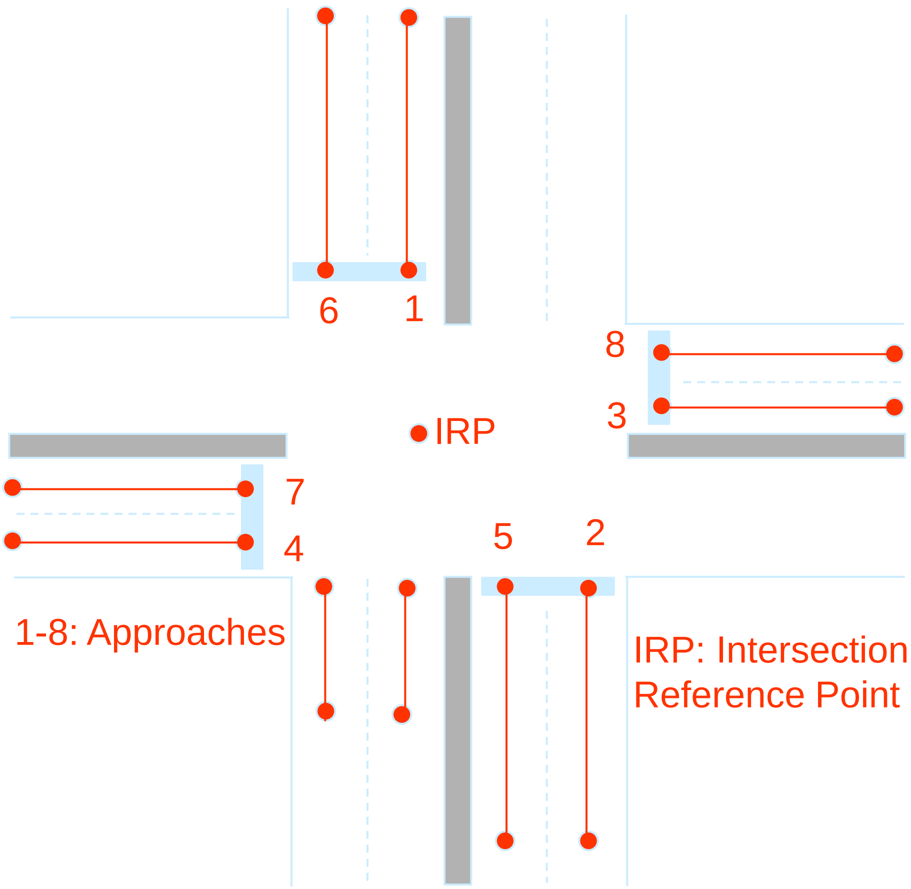
GID is a small map that describes the intersection geometry accurately (30 cm or better)

GID elements

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

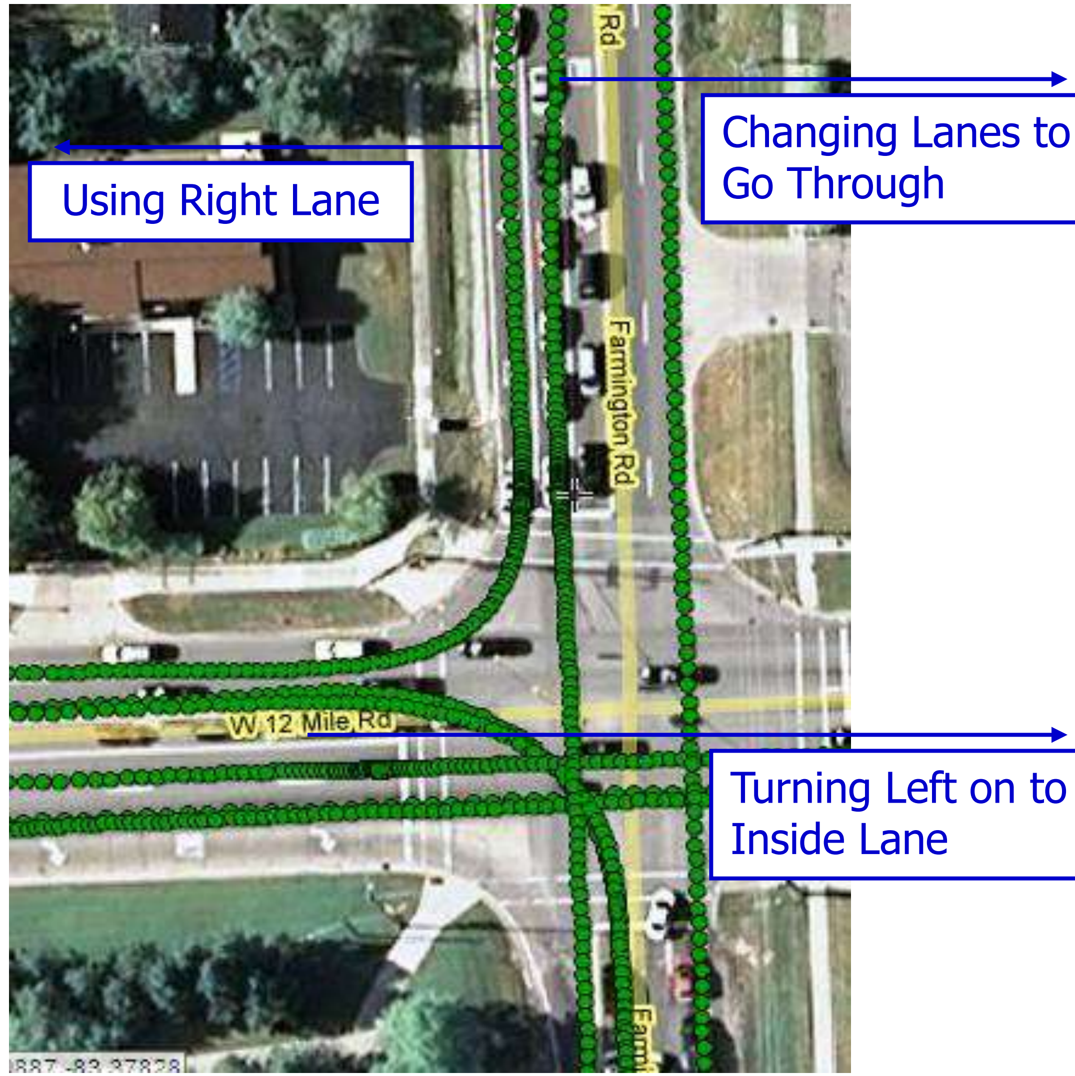
Intersections in the project were mapped using aerial photography

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



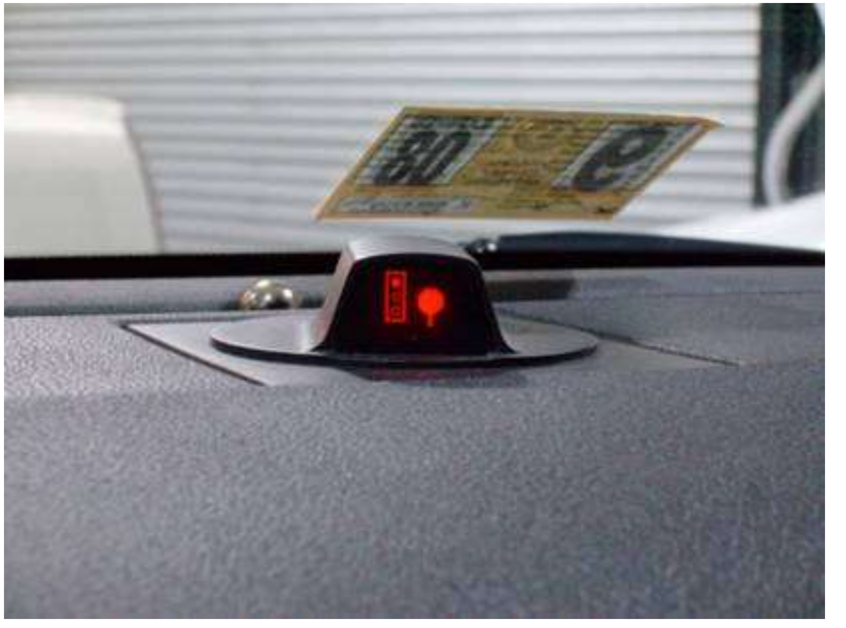
Positioning Corrections

- 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

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

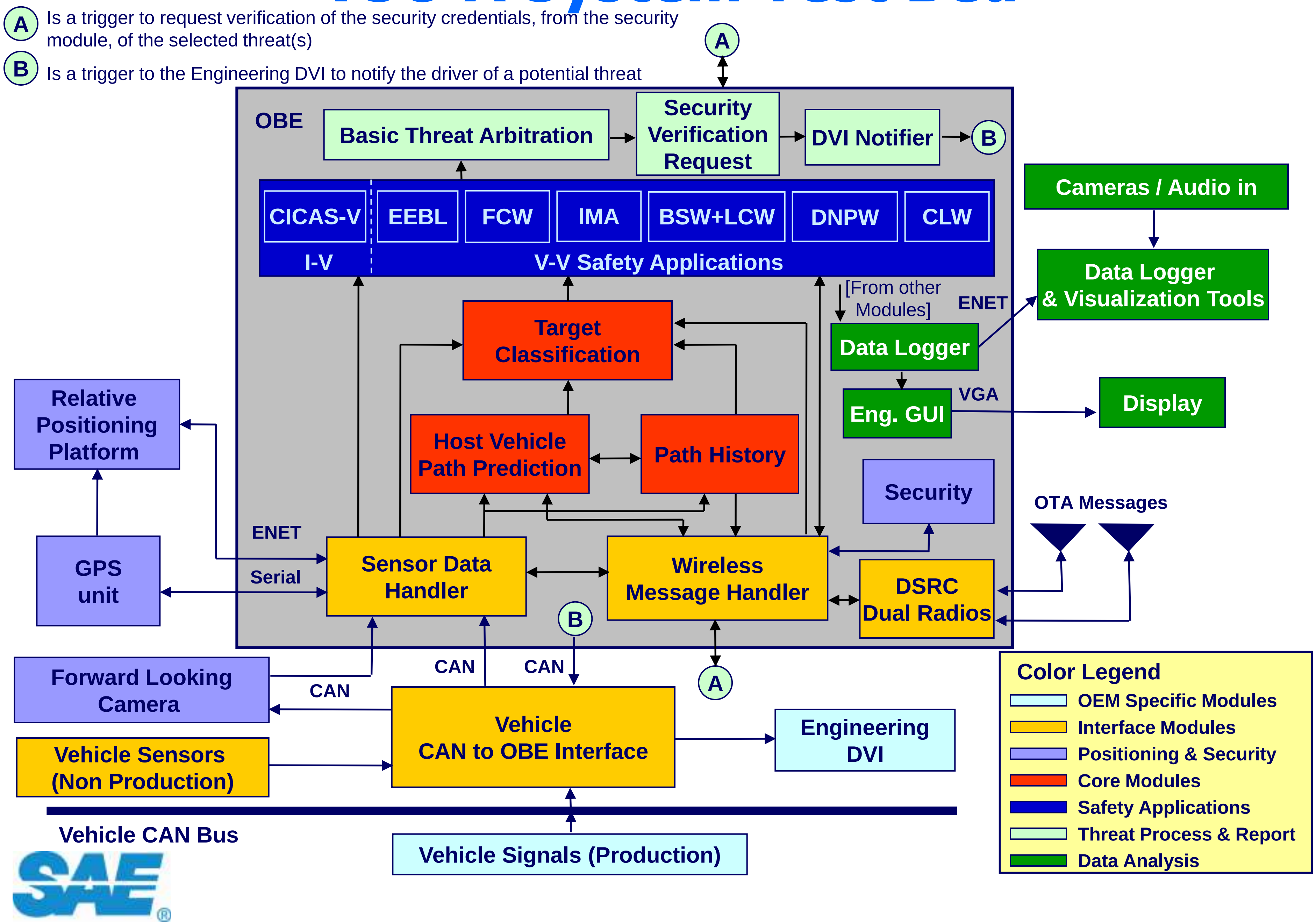
VSC-A Test Bed System Development
Mapping of applications to crash scenarios

	Crash Scenarios ↓ / V2V Safety Applications →	EEBL	FCW	BSW	LCW	DNPW	IMA	CLW
1	Lead Vehicle Stopped		✓					
2	Control Loss without Prior Vehicle Action							✓
3	Vehicle(s) Turning at Non-Signalized Junctions						✓	
4	Straight Crossing Paths at Non-Signalized Junctions						✓	
5	Lead Vehicle Decelerating	✓	✓					
6	Vehicle(s) Not Making a Maneuver – Opposite Direction					✓		
7	Vehicle(s) Changing Lanes – Same Direction			✓	✓			
8	LTAP/OD at Non-Signalized Junctions						✓	

Note: Crash Scenario reference: "VSC-A Applications_NHTSA-CAMP Comparison v2" document, USDOT, May 2 2007. Selected based on 2004 General Estimates System (GES) data and Top Composite Ranking (High Freq., High Cost and High Functional Years lost).

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



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

(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