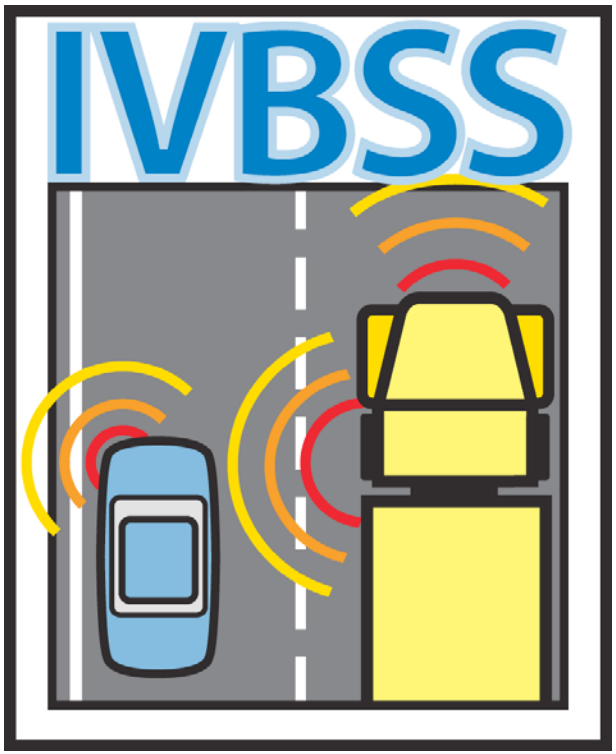


Light Vehicle Platform Update

Debby Bezzina

IVBSS 2008 Public Meeting

April 10-11, 2008

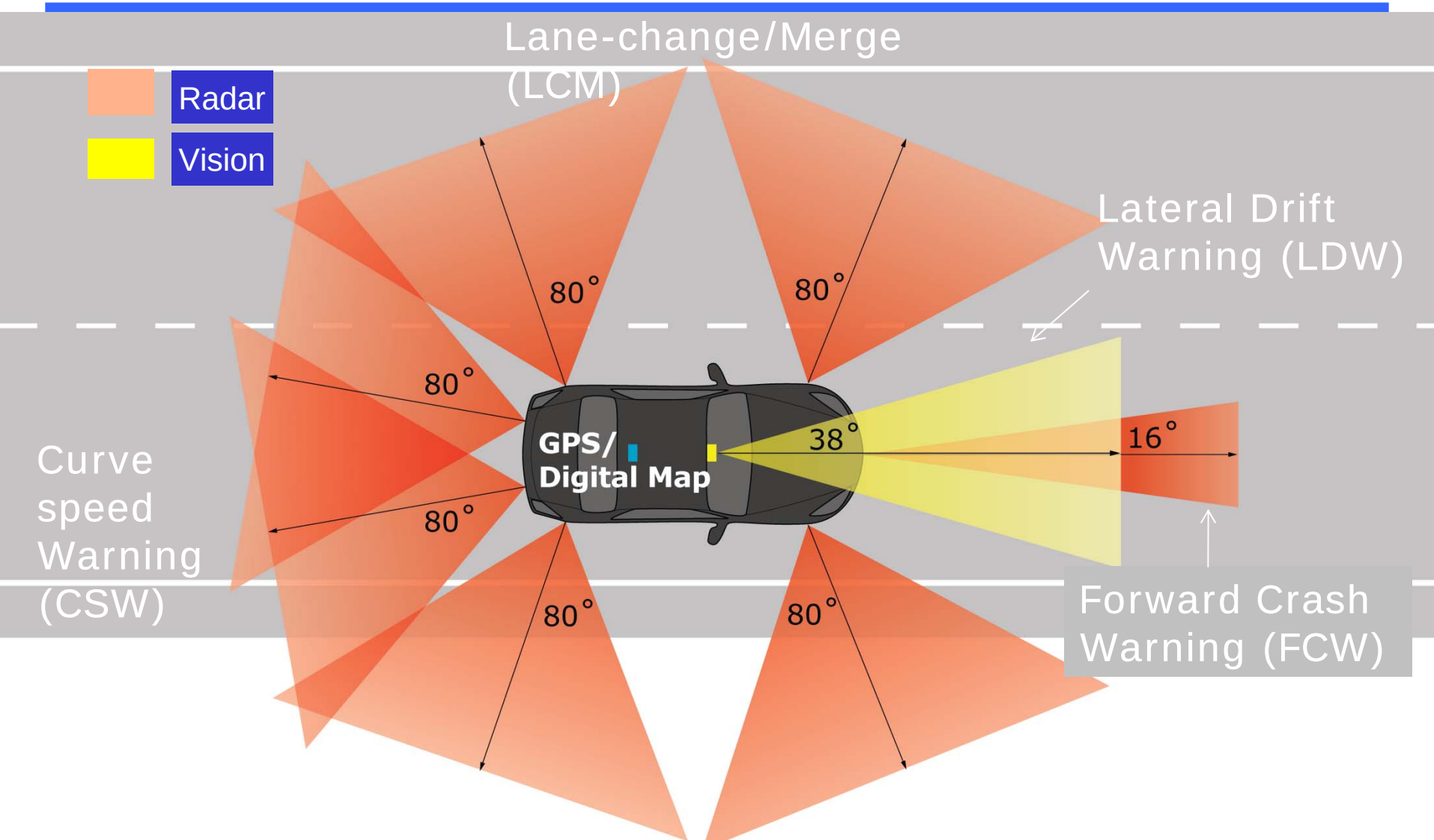
Eagle Crest Resort & Conference Center

Ypsilanti, MI

Outline

- System Overview
- Year 2 Progress Summary
- Systems Engineering Process
- Key Subsystem Developments
- Subsystem Integration
- Change Control and Release Process
- Phase 1 Extension
- Phase 2 Development Plan
- FOT Readiness

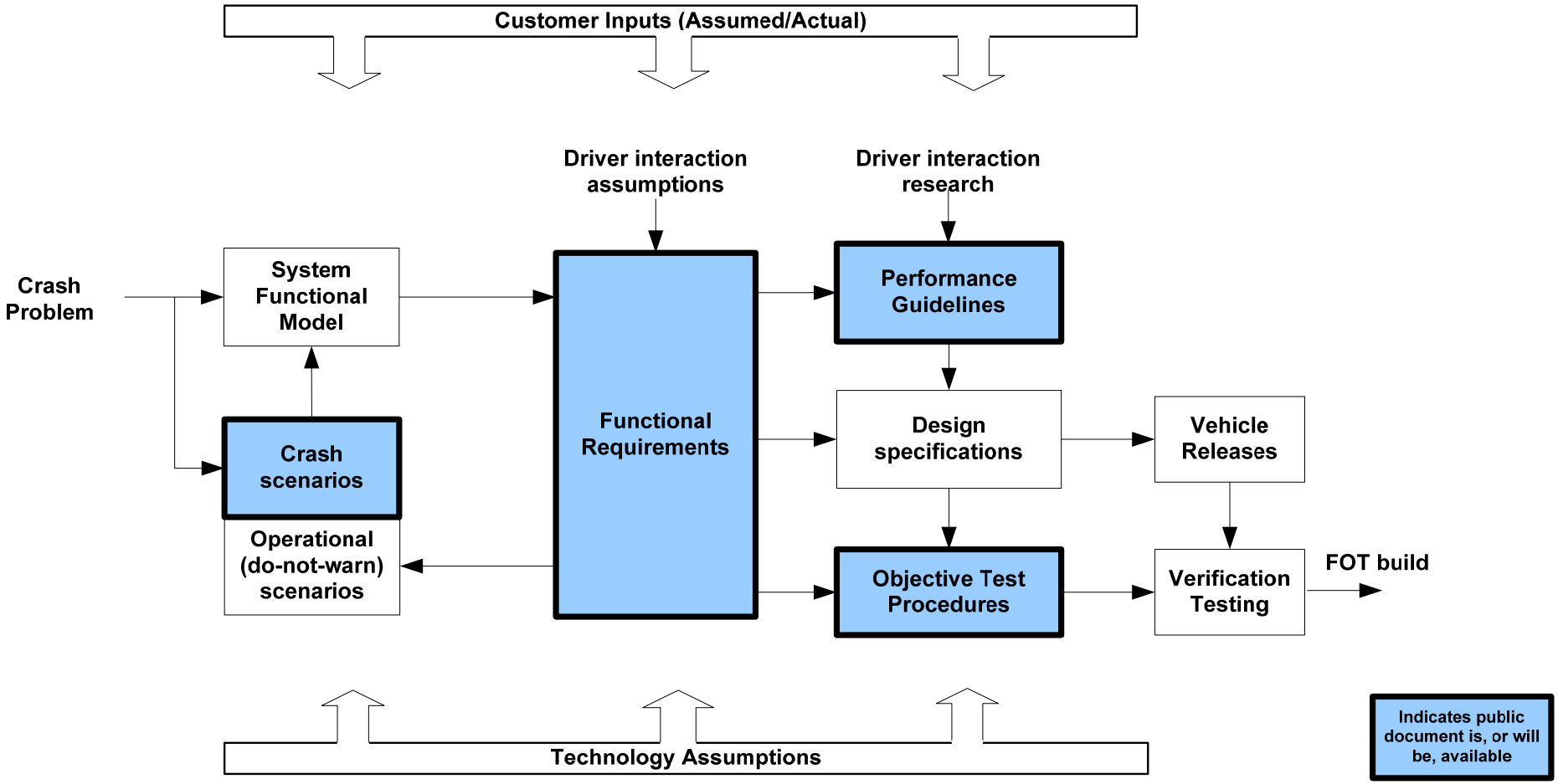
Integrated Safety System



Year 2 Summary of Progress

- Deliverables
  - Functional Requirements
  - Performance Guidelines
  - Verification Test Procedures
- Activities
  - IVBSS Light Vehicle Development complete
  - Six prototype vehicles fabricated
  - Jury drives completed and results incorporated into Light Vehicle IVBSS design
  - Stage 1 Testing (accompanied pilot) complete and results incorporated into Light Vehicle IVBSS design
  - Completed verification testing at Transportation Research Center (TRC) and Dana
  - Light Vehicle IVBSS issues identified and prioritized for Phase 2
  - Phase 1 Extension

Systems Engineering Process for Light Vehicle



Key Functional Elements

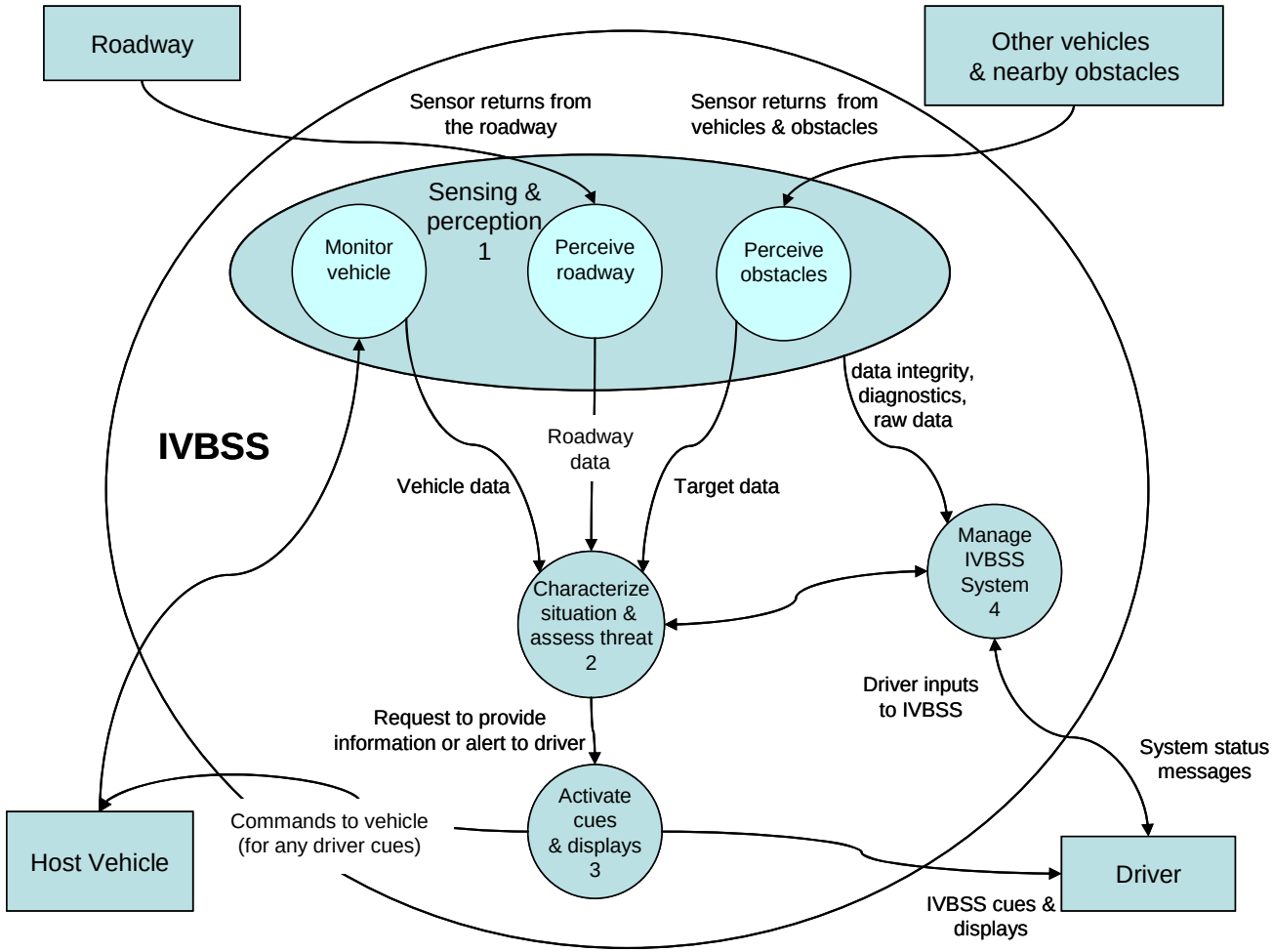


Figure shows only the interactions directly with or within IVBSS.

Functional Requirements Example

- The following functional requirements apply to the curve-speed warning function:
  - The threshold for issuing alerts shall be less than the tire-road friction limits associated with dry pavement
  - The threat assessment shall adjust its crash alert timing to provide earlier alerts when there is evidence that the road condition may be slippery

LCM Warning Zones

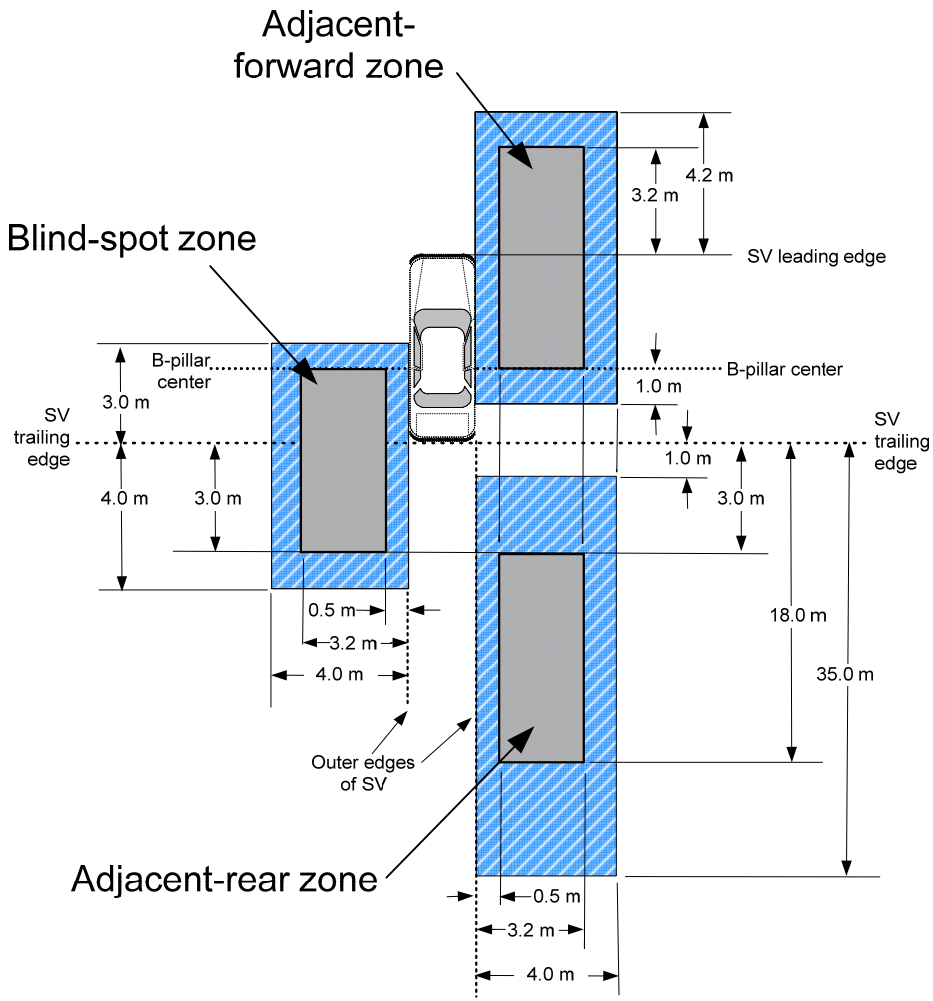


Figure not to scale

All three zones exist on both the left and right size; each zone is shown only on one side here for clarity.

Must-inform regions

May-inform regions

When all other conditions are satisfied - particularly crash alert timing specifications - an LCM crash alert shall be provided when the POV is within the must-inform region. Crash alerts are allowable when the POV is within the may-inform regions.

The POV is considered to be within these regions when:

a) the nearest rear corner of the POV is within the region (for adjacent-forward zone), or
b) the nearest front corner of the POV is within the region (adjacent-rear and blind-spot zones).

LDW Warning Zone

Lateral Drift Crash Alert Thresholds and Zones

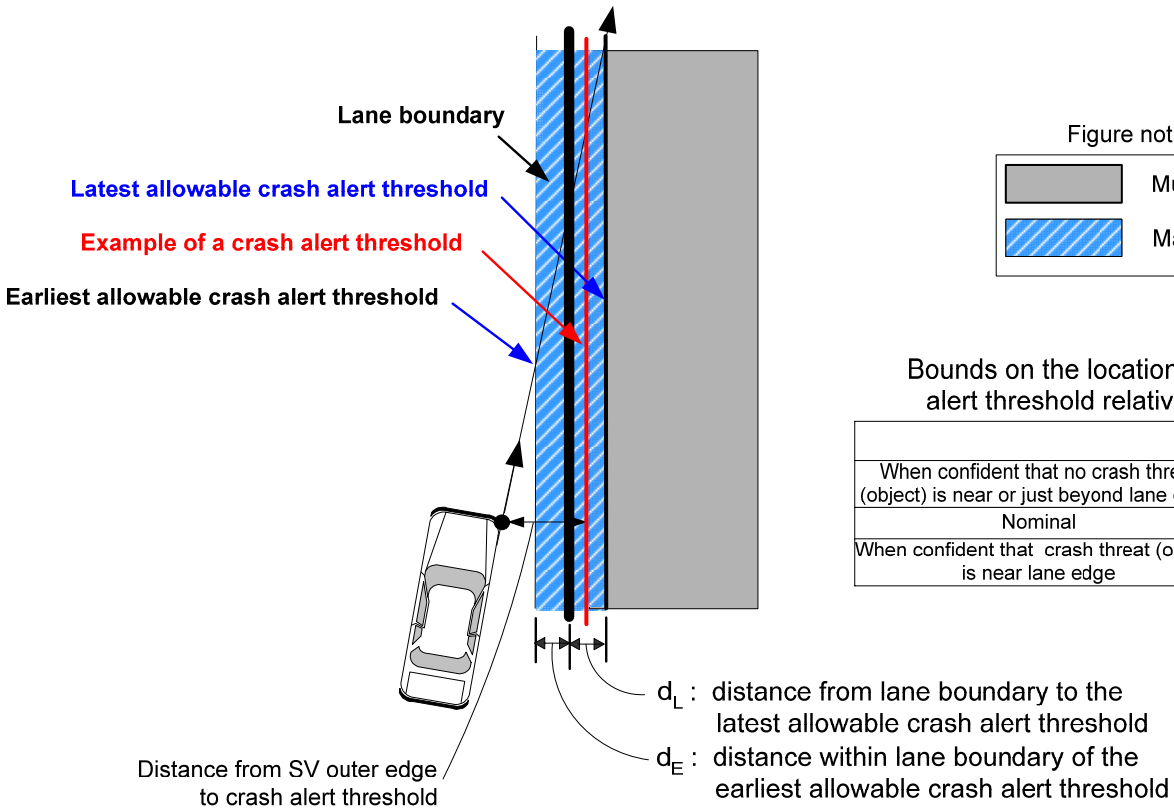


Figure not to scale.

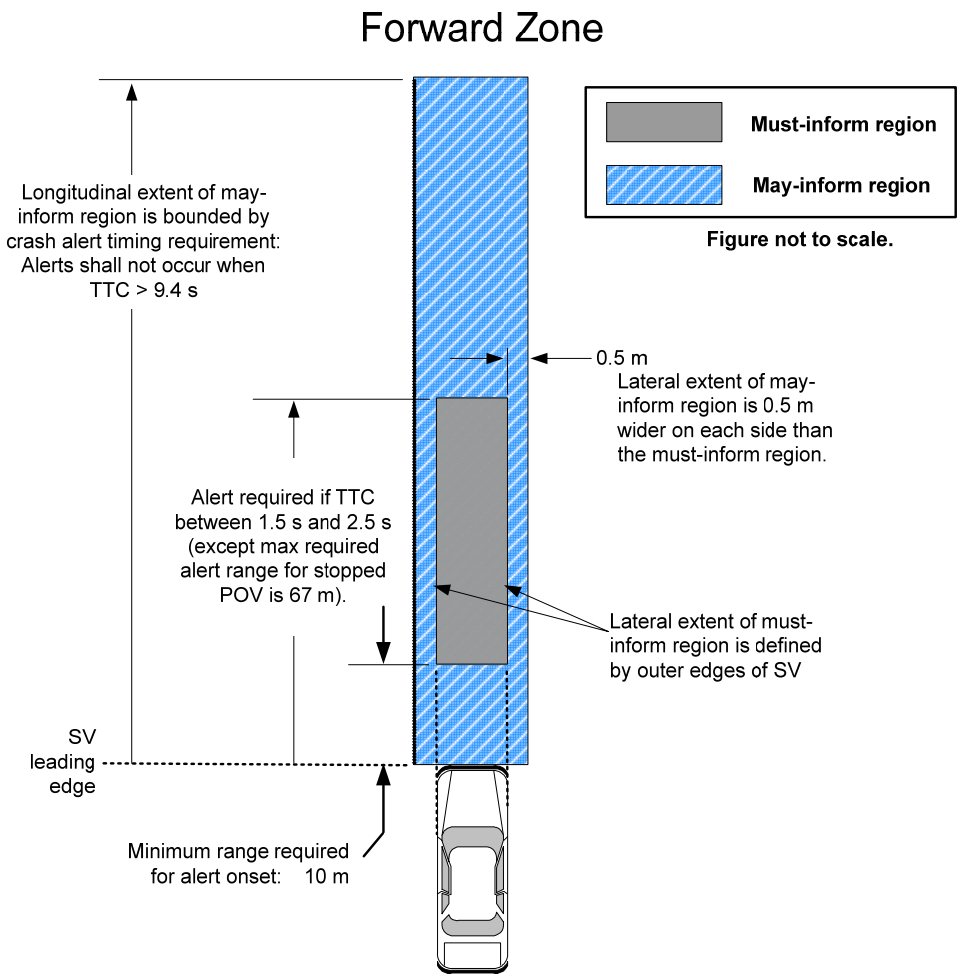
Must-inform region

May-inform region

Bounds on the location of the lateral drift crash alert threshold relative to the lane boundary

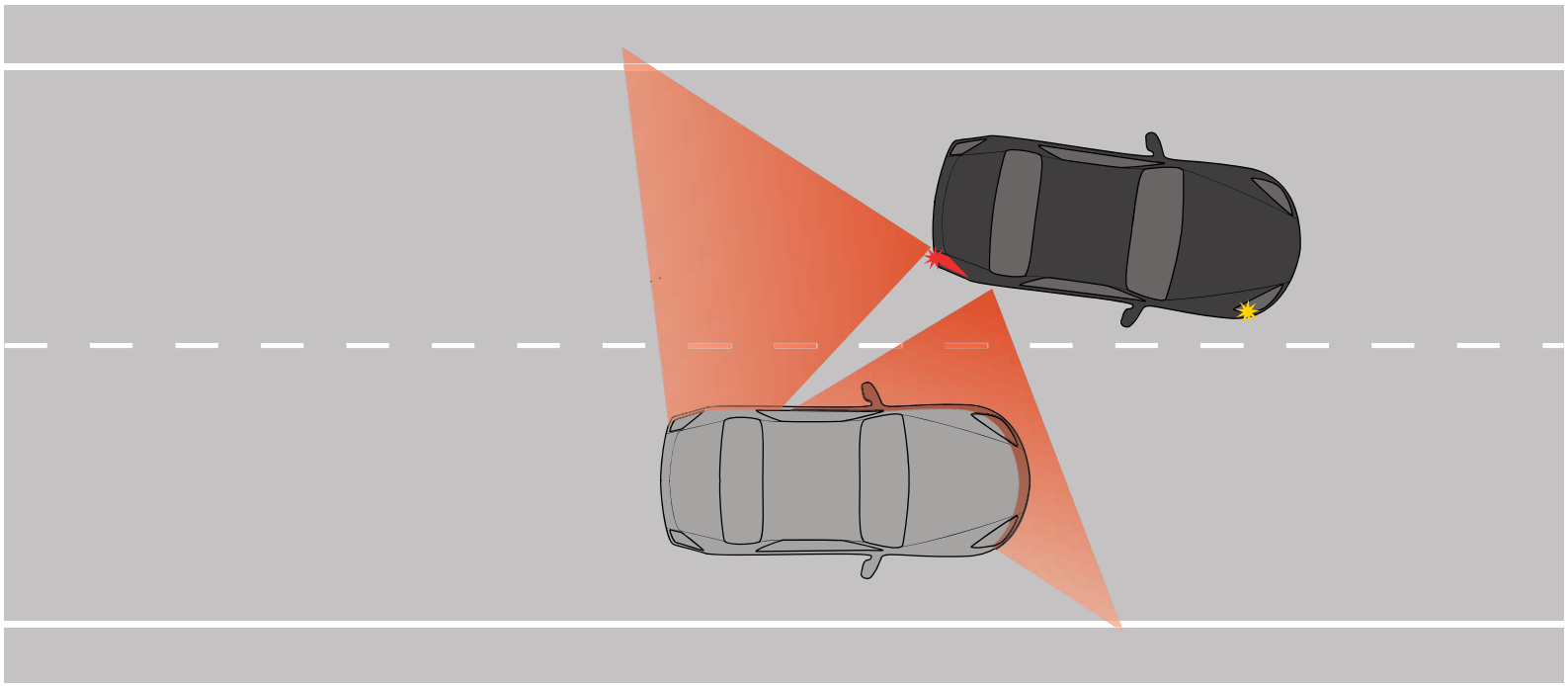
	d_E	d_L
When confident that no crash threat (object) is near or just beyond lane edge	0.5 m	0.75 m
Nominal	0.5 m	0.5 m
When confident that crash threat (object) is near lane edge	0.75 m	0.5 m

FCW Warning Zone



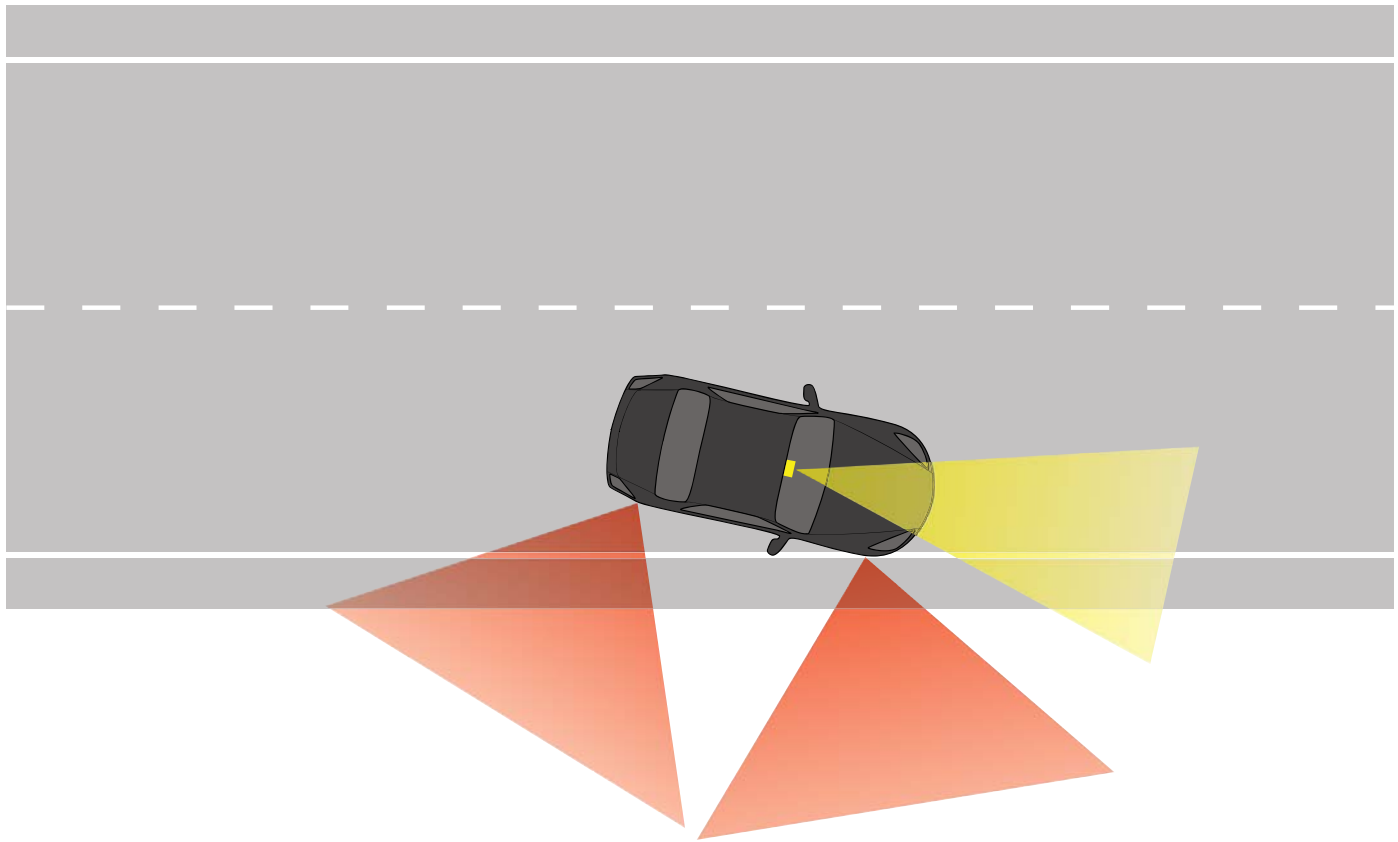
Key Subsystem Developments
LCM/LDW

- LCM incorporated Time-to-Collision algorithm



Key Subsystem Developments
LCM/LDW

- LDW incorporated Time-to-Line-Crossing



Key Subsystem Developments
LCM/LDW

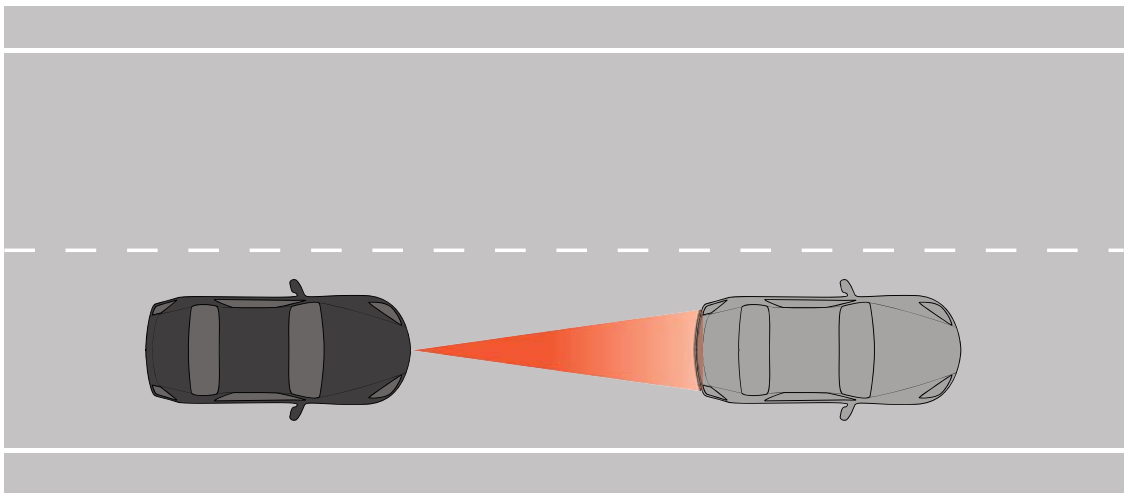
- Works together by sharing radar and vision information
  - LCM calculates Available Maneuvering Room and shares with LDW
    - Six short-range radar sensors
    - Side vision deleted
  - LDW shares position in lane with LCM
    - Forward CMOS camera
- Same warning for LCM and LDW imminent
  - Directional auditory cue
  - LDW cautionary directional haptic cue in seat

Key Subsystem Developments LCM/LDW

- Other Subsystem Interactions
  - LDW uses information from FCW to:
    - Adjust the warning threshold while traversing a curve
    - Better track the lane boundaries (better predictor of where to look in the field of view)
    - Disable the system if too close the vehicle ahead
  - LDW uses road class from the map data from CSW to determine the appropriate default Available Maneuvering Room (AMR) value and to potentially adjust the AMR value being reported by LCM

Key Subsystem Developments
FCW

- Uses long-range radar sensor, yaw rate sensor and map information from CSW
- Improved radar processing techniques to improve object detection and rejection
  - Better stopped object performance/ maintain low false alarm rate
  - Allows deletion of additional vision system to augment radar data

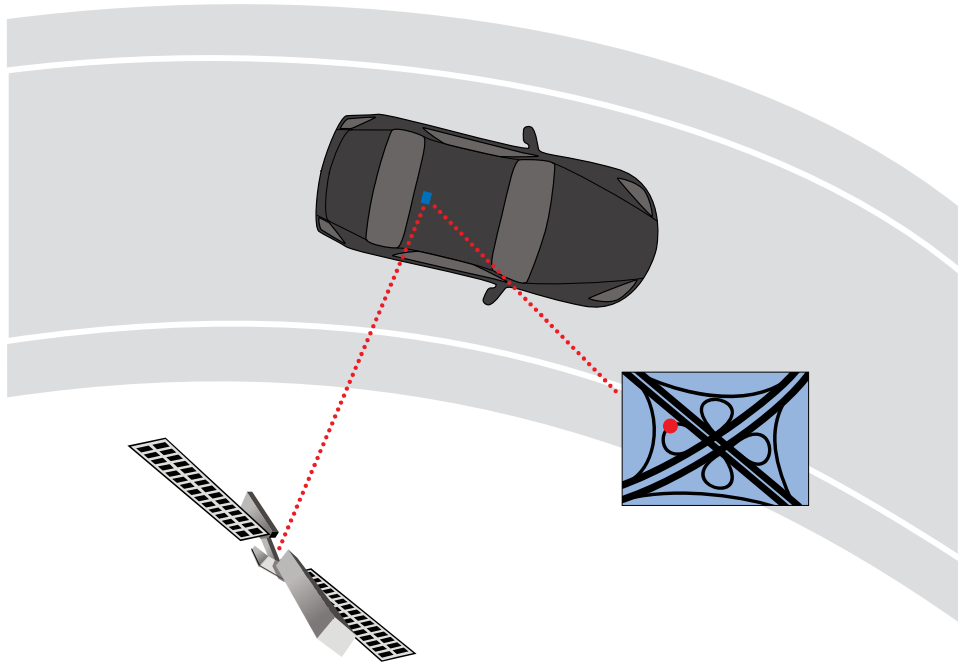


Key Subsystem Developments
FCW

- FCW uses map database attributes and Most-Likely Path attributes from CSW for path prediction and primary target selection
- FCW calculates and sends the following data for use by other subsystem:
  - Refined curvature based on scene tracking and CSW curvature values
  - Primary target information, such as headway

Key Subsystem Developments
CSW

- Uses digital map combined with vehicle state signals
- Developed and implement a False Alarm Database (FADB)



Key Subsystem Developments
CSW

- Interaction with other subsystems
  - Provides the GPS latitude and longitude information
  - Provides the road geometry and road attributes to the other subsystems
  - Uses lane boundary type from LDW as an input for the Most-Likely Path calculation

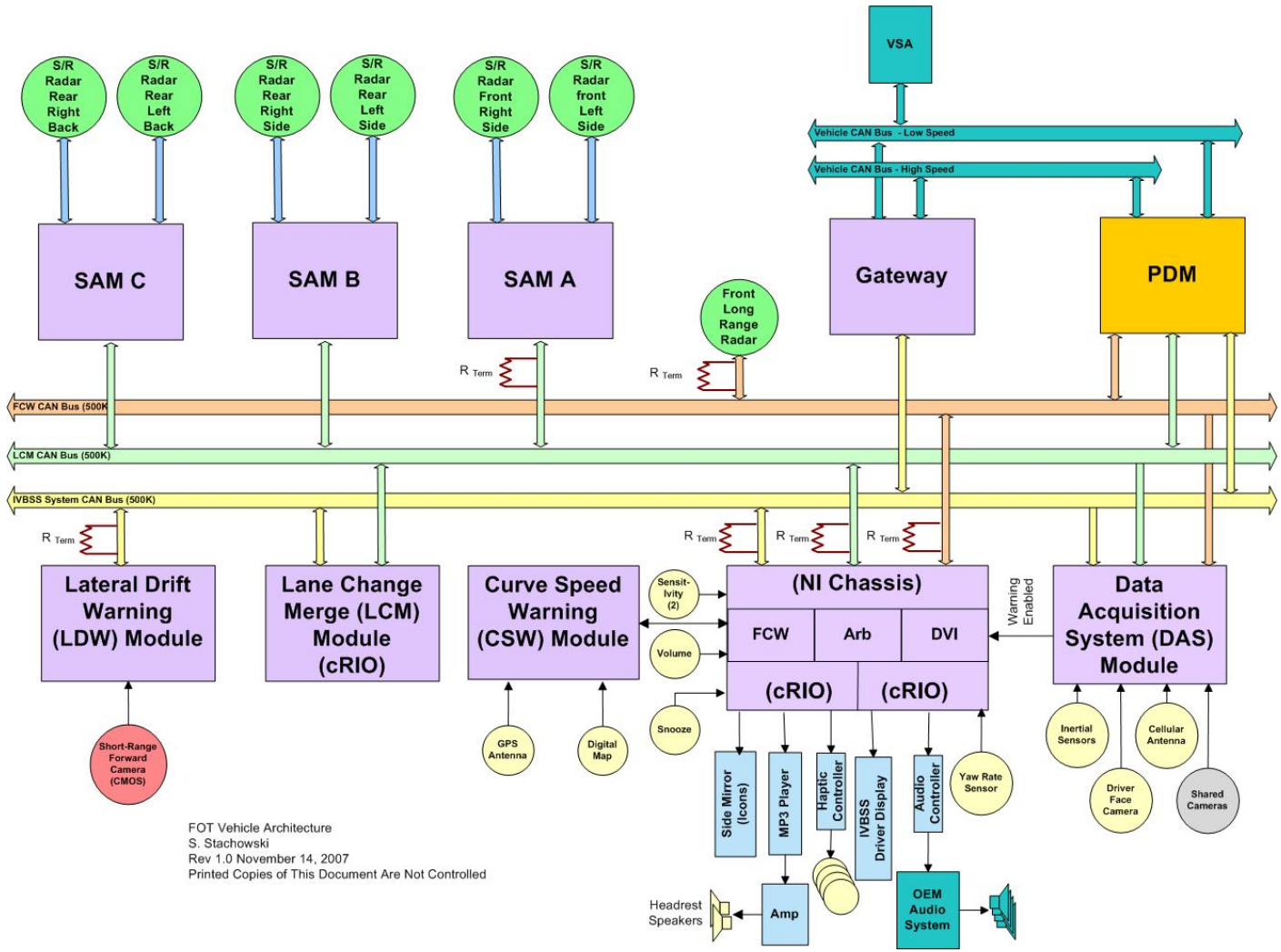
Key Subsystem Developments

- Arbitration Subsystem
  - Developed rule-based for multiple threat scenarios
    - Do not repeat warnings within 3 seconds (15 seconds for CSW)
    - Give competing warnings immediately after 1st warning is complete (710 ms)
    - Ignore lower priority warnings
    - Only 2 warnings maximum for any given multiple-threat scenario
- DVI Subsystem
  - Designed and integrated a 3-warning strategy
  - Designed and integrated BSD function

DVI Warnings

Type of crash conflict	Crash alert		Crash alert visual indicator
	Auditory component	Haptic component	
Striking rear-end of vehicle ahead	Audible cue A 	Brake pulse	Text: “Hazard Ahead”
Curve-overspeed crash	Audible cue (same as above) 	Brake pulse (optional, same pulse as above)	Text: “Sharp Curve”
Drifting off road – no object identified as crash threat or Drifting out of lane– no object identified as crash threat (optional)	None	Haptic vibration in seat (directional)	Text: “Drift Left/Right”
Drifting off road or out of lane–object identified as crash threat or Lane-change crash or merging crash	Audible cue B – (directional) 	None	Text: “Left/Right Hazard”

Subsystem Integration

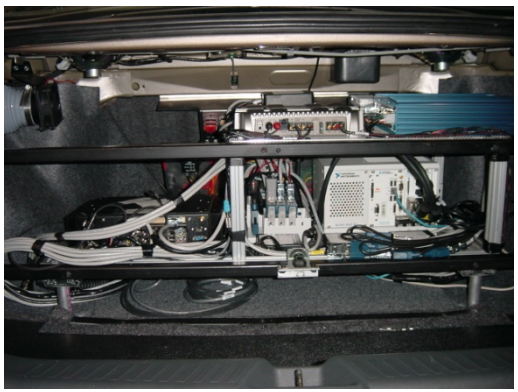


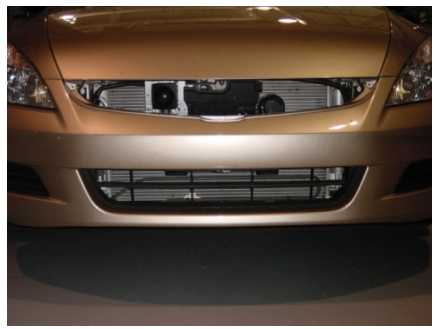
FOT Vehicle Architecture
S. Stachowski
Rev 1.0 November 14, 2007
Printed Copies of This Document Are Not Controlled

Changes to Light Vehicle Subsystem Integration in Year 2

- Migrated to Visteon Gateway Module
- Deleted forward long-range vision for radar-based Forward Collision Warning augmentation
- Deleted side vision for radar-based Lane Change/Merge augmentation
- Ported the LCM algorithms to separate rapid prototype module (cRIO)
- Migrated to the CAN-based SafeTRAC 2 w/ integrated CMOS camera
- Migrated from the Prolificx TrakPod to the IVXP navigation platform for Curve Speed Warning

Prototype Vehicles





Change Control Process

- All issues discovered during development or verification testing are documented.
  - Root cause analysis performed
  - Corrective action identified
  - Implementation plan defined
  - Verification plan created and implemented
  - A Change Request is issued as appropriate
- Preliminary approval required by Visteon, Cognex and UMTRI
- Final approval required by U.S. DOT

Release Process

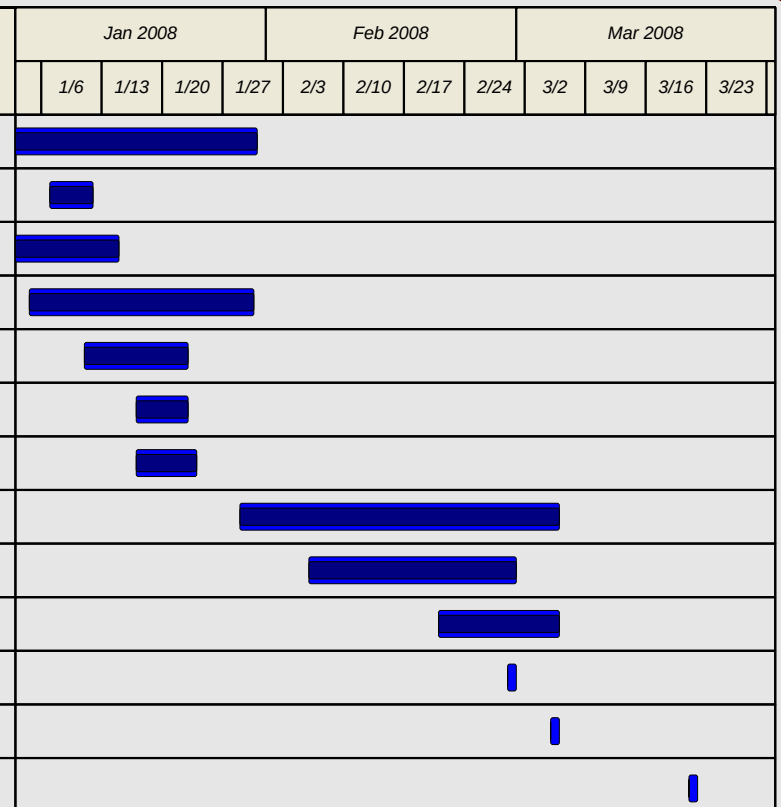
- Five scheduled releases during Phase 1
  - Alpha: Initial release for vehicle level development (NOV272006)
  - Beta: Release for preliminary verification and Jury Drives (18MAY2007)
  - Gamma: Release for Pilot Testing (03JUL2007)
  - Delta: Release for Phase 1 Verification dress rehearsals (06SEP2007)
  - Epsilon: Release for Phase 1 Final Verification (24SEP2007)
- Zeta release for Phase 1 Extension (23JAN2008)
- All approved Change Requests are incorporated into the release

Phase 1 Extension

- December 31, 2007 – April 30, 2008
- Light Vehicle did not meet all performance requirements as tested at the track during Phase 1
  - Failed all Lane Change/Merge tests including the multiple threat scenario
    - Warnings were too early
    - Three of the tests were 7/10 (8/10 is passing)
- Modified LCM algorithm to improve performance
  - Updated driver intent signal processing algorithm parameters for faster response
  - Integrated additional inputs to weigh lane position as part of the threat assessment

Phase 1 Extension Schedule

ID	Task Name	Start	Finish	Duration
1	Change History	1/3/2008	1/30/2008	20d
2	Visteon Data Collection System	1/7/2008	1/11/2008	5d
3	Performance Testing	1/3/2008	1/14/2008	8d
4	Verification Agreement	1/4/2008	1/30/2008	18d
5	Preliminary Track Testing with IMS	1/11/2008	1/22/2008	8d
6	Analyze data	1/17/2008	1/22/2008	4d
7	Zeta Release	1/17/2008	1/23/2008	5d
8	Final Verification with IMS	1/29/2008	3/5/2008	27d
9	Analyze track data	2/6/2008	2/29/2008	18d
10	Analyze on-road data	2/21/2008	3/5/2008	10d
11	Submit Track Test Report	2/29/2008	2/29/2008	1d
12	Submit On-Road Test Report	3/5/2008	3/5/2008	1d
13	Release final Test Procedure Document	3/21/2008	3/21/2008	1d



Phase 1 Extension Testing

- Track Testing conducted at TRC
  - 15JAN2008: Preliminary track testing (with the Independent Measurement System) to very algorithm changes and updated test procedures
    - Dana track had closed, affecting several tests
    - Test repeatability improvements (when to start maneuver, etc.)
  - 04FEB2008: Final Phase 1 Ext track testing
- On-road testing in Metro-Detroit by USDOT
  - 19FEB2008: Night route completed
  - 20FEB2008: Day route completed
- Test Results to be presented by Volpe Center

Phase II Development Plans

- Final System Tuning (warning onset timing)
- System Diagnostics
- Safety Testing
- Optimize DVI for extended pilot
- Populate CSW FADB to FOT intent
- Turn on LDW false alarm suppression algorithm
- Migrate to production level Blind Spot Detection algorithms
- Investigate increasing FCW stopped object detection range without increasing false alarms
- Optimize FCW reaction to cut-ins

FOT Readiness

- Winter testing of brake pulse plausibility (simulated at TRC)
- Update 4 development vehicles for extended pilot
- Extended pilot verification
- Extended pilot testing
- Build 12 additional vehicles and update 4 development vehicles for a 16 vehicle FOT fleet
  - Vehicles are on hand
  - Bids sent out and supplier selected for vehicle builds
  - Major design elements completed
- FOT Deployment Release