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Evaluation of CIB System Susceptibility to Non-Threatening Driving Scenarios on the Test Track

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16. Abstract

The objectives of the research described in this report were twofold: evaluate whether crash imminent braking (CIB) false positives can be consistently observed on the test track using maneuvers representative of real-world driving scenarios, and to assess the practicality of accurately and repeatably performing these maneuvers.

To satisfy these objectives, five later model light vehicles were evaluated using eight test maneuvers performed at two test speeds. Six of the scenarios were identified during CIB research conducted by the Crash Avoidance Metrics Partnership (CAMP) Crash-Imminent Braking Consortium. The remaining scenarios originated from an ISO 22839 draft that provides recommendations for test methods and requirements necessary for validating forward collision warning (FCW) and CIB system performance.

Generally speaking, CIB false positives were not consistently observed on the test track. Of the eight maneuvers used in this study, only "Object in Roadway – Steel Trench Plate" tests produced CIB false positives, and only for one vehicle (although they were present during each test trial for this vehicle). Whether the corresponding reduction in vehicle speed would create a real-world safety problem is not known. FCW alerts always preceded the CIB activations for this vehicle.

Three maneuvers produced FCW alerts but no CIB false activations: the Stationary Vehicle at Curve Entrance, Stationary Roadside Vehicles, and Decelerating Vehicle in an Adjacent Lane (Curve) scenarios. Alert frequency varied considerably by vehicle and maneuver; some vehicles consistently issued alerts while others did not respond at all.

Four maneuvers failed to elicit either FCW or CIB activation: The Decelerating Vehicle in an Adjacent Lane (Straight), Driving Under an Overhead Bridge, Objects in Roadway – Botts' Dots, and Stationary Vehicle at Curve Exit scenarios.

With regards to practicality, the only maneuver found to produce CIB false positives, the Object in Roadway – Steel Trench Plate scenario, was very straightforward to perform. The large plate used for the tests was easily procured, and was simply positioned on the test surface. Maintaining vehicle speed during test conduct was performed consistently by the driver without issue. Test repeatability was excellent. Incorporating this maneuver into an objective procedure intended to evaluate CIB false positive activations on the test track would be feasible.

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CONVERSION FACTORS

Approximate Conversions to Metric Measures

Symbol	When You Know	Multiply by	To Find	Symbol
		LENGTH		
in	inches	25.4	millimeters	mm
in	inches	2.54	centimeters	cm
ft	feet	30.48	centimeters	cm
mi	miles	1.61	kilometers	km
		AREA		
in^2	square inches	6.45	square centimeters	cm^2
ft^2	square feet	0.09	square meters	m^2
mi^2	square miles	2.59	square kilometers	km^2
		MASS (weight)		
oz	ounces	28.35	grams	g
lb	pounds	0.45	kilograms	kg
		PRESSURE		
psi	pounds per $inch^2$	0.07	bar	bar
psi	pounds per $inch^2$	6.89	kilopascals	kPa
		VELOCITY		
mph	miles per hour	1.61	kilometers per hour	km/h
		ACCELERATION		
ft/s^2	feet per $second^2$	0.30	meters per $second^2$	m/s^2
		TEMPERATURE (exact)		
°F	Fahrenheit	5/9 (Fahrenheit) - 32°C	Celsius	°C

Approximate Conversions to English Measures

Symbol	When You Know	Multiply by	To Find	Symbol
		LENGTH		
mm	millimeters	0.04	inches	in
cm	centimeters	0.39	inches	in
m	meters	3.3	feet	ft
km	kilometers	0.62	miles	mi
		AREA		
cm^2	square centimeters	0.16	square inches	in^2
m^2	square meters	10.76	square feet	ft^2
km^2	square kilometers	0.39	square miles	mi^2
		MASS (weight)		
g	grams	0.035	ounces	oz
kg	kilograms	2.2	pounds	lb
		PRESSURE		
bar	bar	14.50	pounds per $inch^2$	psi
kPa	kilopascals	0.145	pounds per $inch^2$	psi
		VELOCITY		
km/h	kilometers per hour	0.62	miles per hour	mph
		ACCELERATION		
m/s^2	meters per $second^2$	3.28	feet per $second^2$	ft/s^2
		TEMPERATURE (exact)		
°C	Celsius	9/5 (Celsius) + 32°F	Fahrenheit	°F

NOTE REGARDING COMPLIANCE WITH AMERICANS WITH DISABILITIES ACT SECTION 508

For the convenience of visually impaired readers of this report using text-to-speech software, additional descriptive text has been provided for graphical images contained in this report to satisfy Section 508 of the Americans with Disabilities Act (ADA).

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EXECUTIVE SUMMARY

Forward collision warning (FCW) and crash Imminent braking (CIB) are advanced technologies designed to mitigate rear-end collisions. From 2007 to 2010, research by the Crash Avoidance Metrics Partnership (CAMP) Crash Imminent Braking (CIB) Consortium endeavored to define minimum performance requirements and objective tests for vehicles equipped with CIB systems [1]. While assessing the performance of various system configurations and capabilities, the CAMP Consortium also identified real-world scenarios capable of eliciting an inappropriate CIB activation; a particularly undesirable and potentially dangerous situation known as a CIB "false positive."

Six of the CAMP-identified scenarios were included in the test matrix used in this report. Additionally, two scenarios from an ISO 22839 draft [2] were used, a recommended practice that describes test methods and requirements for validating FCW and CIB system performance. Using this matrix, five contemporary light-vehicle CIB systems were evaluated to determine whether a CIB false-positive problem could be identified on the test track. The scenarios were also evaluated for practicality (e.g., ease of conduct and suitability for potential use in a New Car Assessment Program [NCAP] or regulatory test procedure). Test speeds of 25 mph and 45 mph were used.

All FCW alerts presently known by NHTSA either precede, or are coincident with, CIB activation. For this reason, scenarios that failed to elicit an FCW alert were not expected to cause CIB to activate, making them unsuitable for creating the potential for a CIB false-positive event. Of the maneuvers used in this study, FCW activations were observed during the conduct of four: Object in Roadway – Steel Trench Plate, Stationary Vehicle at Curve Entrance, Stationary Roadside Vehicles, and Decelerating Vehicle in an Adjacent Lane (Curve). Considering all vehicles collectively, FCW alerts were observed in 43.6, 41.6, 15.8, and 0.4 percent of all tests per maneuver, respectively. However these alerts were more prevalent for some vehicles than for others.

Of the maneuvers capable of producing an FCW alert, CIB false positives were observed only during certain Object in Roadway – Steel Trench Plate tests, and for only one vehicle. Importantly, the vehicle producing the CIB false-positives did so for 100 percent of the Object in Roadway – Steel Trench Plate tests trials, albeit with low deceleration. Whether the corresponding reduction in speed would create a real-world safety problem is not known.

No FCW or CIB activations were observed in four of the eight test scenarios used in this study: the Decelerating Vehicle in an Adjacent Lane (Straight), Driving Under an Overhead Bridge, Objects in Roadway – Botts' Dots, and Stationary Vehicle at Curve Exit maneuvers.

1.0 BACKGROUND

1.1 The Rear-End-Crash Problem

Using General Estimates System (GES) statistics from 2004, a data summary assembled by the Volpe Center[1] indicated that approximately 6,170,000 police-reported crashes of all vehicle types, involving 10,945,000 vehicles, occurred in the United States [3]. Many of these crashes involved rear-end collisions, with the most common pre-crash scenarios being the Lead Vehicle Stopped, Lead Vehicle Decelerating, and Lead Vehicle Moving at Lower Constant Speed. Table 1.1 presents a summary of the frequency, cost, and harm (expressed as functional years lost) for these crash types. For each parameter, the percentage with respect to the overall crash problem is provided in parentheses.

Table 1.1. Crash Rankings by Frequency (2004 GES data)

Pre-Crash Scenario	Frequency	Cost ($)	Years Lost
Lead Vehicle Stopped	975,000 *(16.4%)*	15,388,000,000 *(12.8%)*	240,000 *(8.7%)*
Lead Vehicle Decelerating	428,000 *(7.2%)*	6,390,000,000 *(5.3%)*	100,000 *(3.6%)*
Lead Vehicle Moving at Lower Constant Speed	210,000 *(3.5%)*	3,910,000,000 *(3.3%)*	78,000 *(2.8%)*

1.2 Forward Collision Warning

NHTSA defines a forward collision warning (FCW) system as one intended to passively assist the driver in avoiding or mitigating a rear-end collision. These systems have forward-looking vehicle detection capability provided by sensing technologies such as radar, lidar (laser), and cameras. Using the information from these sensors, an FCW system alerts the driver of an impending collision with a vehicle or object in its forward path based on relative closing speed and current trajectory. Contemporary FCW systems typically include various combinations of audible, visual, and/or haptic warnings, presented together as a single concurrent alert or as part of a cascaded presentation.

1.3 Crash Imminent Braking

Crash imminent braking (CIB) is an active safety system that mitigates forward crashes by using autonomous pre-crash braking late in the pre-crash timeline, often when a collision is no longer avoidable by braking and/or steering. CIB systems typically rely on the same forward-looking sensors used by FCW. NHTSA testing indicates CIB interventions generally occur after the FCW alert has been issued, although some interventions have been shown to be coincident. The

[1] The Volpe Center is part of the U.S. Department of Transportation's Research and Innovative Technology Administration (RITA).

amount of braking authority varies among manufacturers, with several systems achieving maximum vehicle deceleration just prior to impact.

Although the intent of their interventions differs, both FCW and CIB contain control logic designed to circumvent nuisance alarms and unnecessary brake activations, respectively. This is done to avoid unnecessary braking (which could create crashes) and to promote (and maintain) driver acceptance of the technology. Inappropriate CIB activations are particularly undesirable since the vehicle's brakes are automatically applied in a non-critical situation. In the context of this report, such activations are referred to as "CIB false positives."

1.4 Crash Avoidance Metrics Partnership (CAMP) Research

As part of a larger CAMP research program designed to evaluate CIB functionality and operation (September 2007 – August 2010), two instrumented vehicles were driven approximately 22,000 miles over a variety of United States roads. Sensor data were processed through software simulations representative of different sensor combinations and sensitivity levels to identify real-world scenarios where CIB may have unnecessarily activated had it been able to do so [1]. These scenarios were then categorized into frequency distributions based on sensor combination and sensitivity level. Using these data, a series of eleven operational tests to "examine the propensity of a CIB system for undesirable false CIB activation" was defined [1]. Six of these tests were included in the test matrix used for the work described in this report, selected on the basis of whether the tests could be practically performed using facilities at the Transportation Research Center, Inc. (TRC).

1.5 Objectives

The objectives of the research described in this report were twofold:

1. Evaluate whether CIB false positives can be consistently observed on the test track using maneuvers representing eight[2] real-world driving scenarios believed to be capable of eliciting such activations.
2. Assess the practicality of accurately and repeatably performing these maneuvers.

[2] "Two additional scenarios from an ISO 22839 draft [2] were added to the six CAMP scenarios.

2.0 TEST METHODOLOGY

This chapter provides a general description of the test vehicles, instrumentation, scenarios, and course layouts used for the study discussed in this report.

2.1 Test Vehicles

Table 2.1 lists the test vehicles used in this study, a description of the forward-looking sensors, and whether the vehicles were equipped with an FCW or CIB system. Five other light vehicles (not listed) were used in supporting roles as principal other vehicles (POV).

Table 2.1. Vehicles Tested

Vehicle			Forward-Looking Sensor(s)	Implementation	
Model Year	Make	Model		FCW	CIB
2011	Acura	MDX	Single Radar	x	x
2011	Ford	Explorer	Single Radar	x	-
2010	Mercedes	E350	Multiple Radars	x	x
2010	Subaru	Outback[3]	Stereo Cameras	x	x
2008	Volvo	S80	Fused Single Radar and Mono Camera	x	x

2.2 Instrumentation

Of the vehicles listed in Table 2.1, only the Mercedes E350, Subaru Outback, and Volvo S80 were equipped with instrumentation and a data acquisition system (DAS). Key data channels for these vehicles are highlighted in Table 2.2.

Due to test time constraints, the Acura MDX and Ford Explorer were equipped with only a GPS-based vehicle speed display (to assist the driver with maintaining the desired velocities) and a video camera secured between the front seats, positioned to record the vehicles' instrument clusters and a view through the windshield.

2.2.1 Subject Vehicle (SV) Instrumentation

Analog measurements recorded by the subject vehicle (SV) DAS included brake pedal force, brake line pressure, throttle position, and the FCW-alert data flag. A load cell was attached to the front surface of the brake pedal to verify that the driver had not applied force to the brake pedal during any test trial. Four pressure transducers were installed, one at each brake caliper

[3] This vehicle was a prototype equipped with equipment believed to be representative of that available on model year 2012 and later Subaru Outback and Legacy models

bleeder screw, to detect any automatic pressure changes indicative of system pre-charge and/or CIB activation.

Table 2.2. Data Channels

Data Measured	Type	Range	Accuracy	Manufacturer and Model
Brake Pedal Force (at the brake pedal)	Load Cell	0 – 300 lbf	0.5% of full scale (or 1.5 lbf)	GSE 3100A
Brake Line Pressure	Millivolt Output Pressure Transducer	0 – 2000 psi	0.25% of full scale	Transducers Direct TDG03
Throttle Position Sensor	Throttle Pedal Tap or CAN based	0 – 100 percent	0.1 percent resolution	Unknown supplier per OEM specifications.
FCW Alert Signal (issued at threshold conditions)	CAN based or directly measured	0 – 10 volts	N/A	N/A
X, Y, Z Accelerations	IMU	100 m/s^2	0.01 m/s^2	Oxford Technical Solutions' RT3002
X,Y, Z Angular Rates	IMU	100 deg/s	0.01 deg/s	Oxford Technical Solutions' RT3002
Pitch and Roll (calculated)	IMU	0-90 deg	0.03 deg	Oxford Technical Solutions' RT3002
Vehicle Heading (calculated)	IMU / GPS	0-360 deg	0.1 deg	Oxford Technical Solutions' RT3002
GPS Position (Lat., Long., Alt.)	IMU / GPS	extensive[4]	2 cm	Oxford Technical Solutions' RT3002
Velocities (North, East, Down)	IMU / GPS	0.05km/h and higher	0.05 km/h	Oxford Technical Solutions' RT3002
Vehicle Speed (calculated)	IMU / GPS	practically unlimited[5]	0.05 km/h	Oxford Technical Solutions' RT3002

Throttle position data were collected to insure the driver used smooth inputs throughout each maneuver (a requirement for all tests), and was recorded from a direct tap of the vehicle's throttle position sensor (TPS) or from its CAN bus. Monitoring the state of the FCW alert provided a way to identify test series for which a particular vehicle may have been more prone to CIB false activations. The agency's testing experience indicates the likelihood for a CIB false activation to occur without being preceded by an FCW alert is very low.

[4] Anywhere on or near the Earth with an unobstructed view of four or more GPS satellites.

[5] While the exact upper limit is not known, it exceeds the top speed of the test vehicle.

2.2.2 Moving and Decelerating Lead Vehicle Instrumentation

As described in Sections 2.4.1 and 2.4.2, two maneuvers required the use of moving lead vehicles. For one of these tests, a lead vehicle maintained a constant speed ahead of the SV (subsequently referred to as the moving lead vehicle, or MLV). For the other test the lead vehicle was slowed in an adjacent lane (subsequently referred to as the decelerating lead vehicle, or DLV). Both lead vehicles were equipped with a GPS-enhanced inertial platform to provide real-time SV-to-MLV and SV-to-DLV range. To assist the MLV and DLV drivers with maintaining the desired velocities, speed displays were secured to the inside of the windshields just above the dashboards. The DLV was equipped with a programmable brake controller to insure that accurate and consistent deceleration was achieved for each test trial.

2.3 Factors That Can Result in Suppression of CIB

For each SV, the operator's manual was reviewed for known system limitations, including factors stated to be capable of suppressing CIB operation. These factors helped guide the design and conduct of the maneuvers used in this study. Where applicable, these factors were consolidated across vehicles, and are summarized in Sections 2.3.1 and 2.3.2. The precise wording found in each manual is provided in Appendix A. The Subaru Outback was a leased prototype and was not provided with an owner's manual.

2.3.1 Environmental Conditions

Certain environmental conditions can interfere with a sensor's ability to provide reliable information, thus affecting CIB operation. Such conditions include:

- Vision-based systems may have limited to no capability when the windshield ahead of the camera is covered by snow or dirt, or when directly exposed to shallow sun angles.
- Vision-based systems may have reduced performance when the forward view is obscured by heavy rain, road spray, and/or fog.
- Radar-based system performance may be reduced when the sensor is covered by snow or dirt.
- Heavy rain, road spray, snow, and/or fog can interfere with the radar's signals, as can standing water, snow, or ice on the surface of the road.
- Radar-based systems can be negatively affected by other radar sources, an overly strong radar return, or not enough radar return such as with small or absorptive objects.

2.3.2 Other Factors

CIB operation can also be affected by factors not related to the sensor itself, including the driver, vehicle, and terrain.

Driver

- Certain steering and/or throttle inputs from the driver. In some instances, the CIB system may interpret these actions as an intentional crash avoidance attempt. Should this occur, the CIB system may be temporarily disabled so as to not interfere with the driver's avoidance strategy.
- When the driver is using a "very active" driving style.

Vehicle

- Vehicle speed falls below an operational threshold. This is often between 5 – 10 mph, but varies by vehicle.
- When a flat tire is detected.
- When the vehicle is driven with the parking brake applied.

Terrain

- During extended off-road or mountainous driving.
- While approaching or driving on a curve in the road with a tight radius.

2.4 Test Scenarios and Conduct

The following sections describe the eight individual test scenarios used in this research. For all testing, the drivers were instructed to maintain vehicle speeds within ±1 mph of the nominal values while using the least amount of steering necessary to maintain lane position.[6] Each test facility was located at TRC, located in East Liberty, OH.

Table 2.3. Test Scenario Details

Maneuver	Nominal Speed	Source Material for Maneuver Design	Test Facility
Decelerating Vehicle in an Adjacent Lane - Straight Road	25 and 45 mph	ISO 22839	Skid Pad
Decelerating Vehicle in an Adjacent Lane - Curved Road	25 and 45 mph	ISO 22839	VDA
Driving Under an Overhead Bridge	25 and 45 mph	CAMP	Skid Pad
Driving Over Objects in Roadway - Botts' Dots	25 and 45 mph	CAMP	WRC
Driving Over Objects in Roadway - Steel Trench Plate	25 and 45 mph	CAMP	VDA
Stationary Vehicle at Curve Entrance	25 and 45 mph	CAMP	WRC
Stationary Vehicle at Curve Exit	25 and 45 mph	CAMP	WRC
Stationary Roadside Vehicles	25 and 45 mph	CAMP	WRC

[6] Not applicable to tests requiring lane changes.

2.4.1 Decelerating Vehicle in an Adjacent Lane

The two Decelerating Vehicle in an Adjacent Lane maneuvers were based on tests described in an ISO 22839 working draft. Both included three vehicles driven in formation, in the same direction, within the confines of two lanes. For all tests, the MLV was a 2008 Buick Lucerne and the DLV was a 2010 Ford Taurus. The intent of the maneuvers was to evaluate whether the SV misinterprets a vehicle slowing in an adjacent lane as presenting a genuine crash imminent situation.

2.4.1.1 Straight Road

To begin the maneuver, the MLV was driven at a constant test speed of either 25 or 45 mph. In an adjacent lane, a second vehicle (the DLV) was driven directly beside the MLV. When the MLV was driven at 25 mph, the SV followed the MLV in the same lane with a headway of 49 ± 4 ft. When the MLV speed was 45 mph, the SV-to-MLV headway was increased to 98 ± 8 ft. In both cases, headway was calculated as the resultant range between the centers of the SV front bumper and the MLV rear bumper. Laterally, all three vehicles maintained a distance to the shared lane boundary of approximately 3 ft. After the nominal test speed and headway conditions had been satisfied for 3 seconds, the DLV was braked with a deceleration of 0.3 ± 0.03g. The brake pedal application rate for the DLV was set such that the DLV satisfied the deceleration target quickly while avoiding the unintentional activation of brake assist. The maneuver concluded when the SV was driven past the DLV. The functional layout of this test maneuver is shown in Figure 2.1.

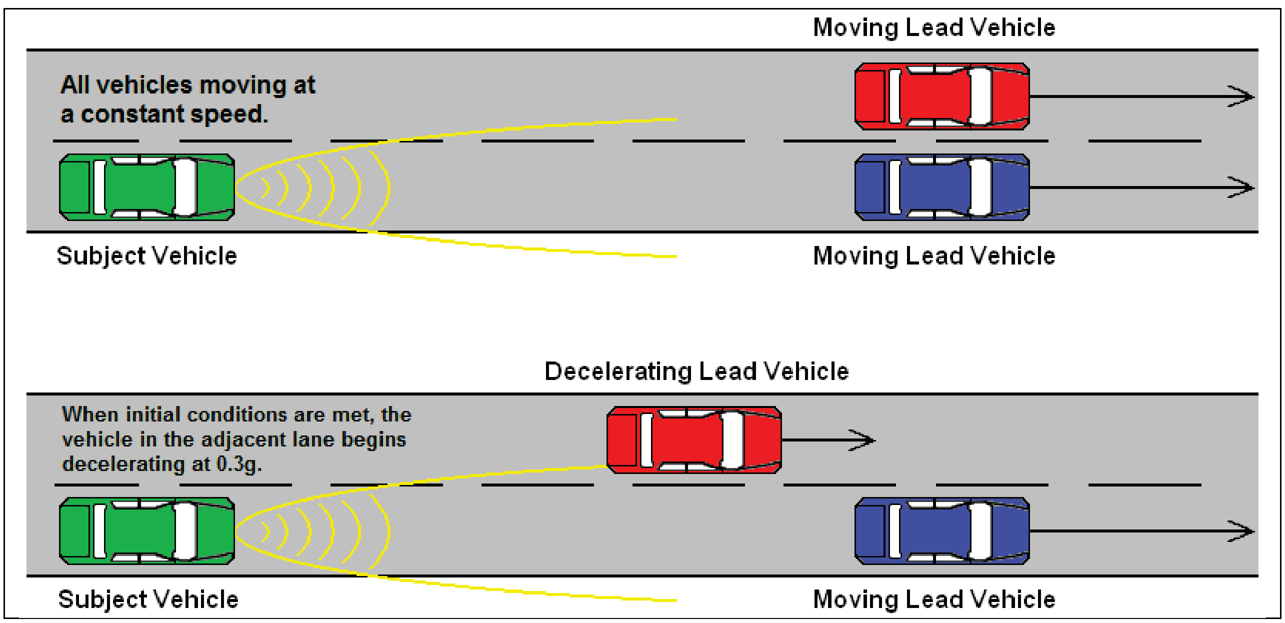

Figure 2.1. Functional Layout of the Decelerating Vehicle in an Adjacent Lane Maneuver (Straight Road)

For the straight road scenarios, the Decelerating Vehicle in an Adjacent Lane tests were performed on the TRC Skid Pad. Tests were performed with the vehicles being driven to the north and south using the same travel lanes. In other words, when the vehicles changed their direction of travel between each test trial, they maintained their lane assignments so that the DLV would alternate from one side of the MLV to the other. Figure 2.2 shows the SV, MLV, and DLV in a formation representative of that used for the 45 mph tests, where the SV-to-MLV headway was 49 ft.

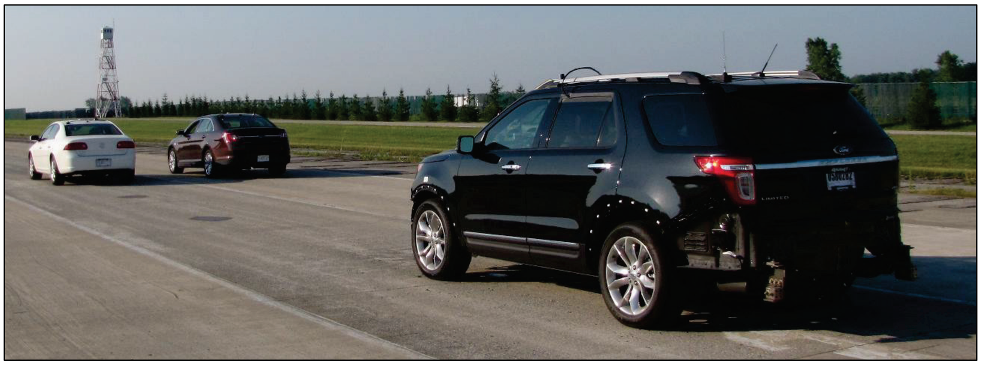

Figure 2.2. Ford Explorer Test Vehicle With the MLV and DLV on the TRC Skid Pad (Facing South)

2.4.1.2 Curved Road

This test was performed in manner nearly equivalent to that previously described in S2.4.1.1, with the biggest difference being that it was performed in a curve. As before, the intent of this maneuver was to evaluate whether the SV misinterprets a vehicle slowing in an adjacent lane as presenting a genuine crash-imminent threat.

All Decelerating Vehicle in an Adjacent Lane tests were performed in the north loop of the TRC Vehicle Dynamics Area (VDA), a shallowly banked curve with a radius of approximately 630 ft. To begin the maneuver, the MLV was driven at a constant test speed of either 25 or 45 mph. In an adjacent (and outermost) lane, the DLV was driven directly beside the MLV. To maintain its position in the three vehicle formation, the DLV was driven at a speed slightly higher than that used for the MLV before the brakes were applied. Laterally, all three vehicles maintained a distance to the shared lane boundary of approximately 3 ft.

To insure that the DLV would pass through the SV's forward path as it was braking (i.e., creating the potential for a false positive event), the initial SV-to-MLV resultant range was 196 ± 8 ft. for both MLV speed conditions. After the nominal test speed and headway conditions had been satisfied for 3 seconds, the DLV was braked at 0.3 ± 0.03g. The maneuver concluded when the SV was driven past the DLV. The functional layout of this test maneuver is shown in Figure 2.3.

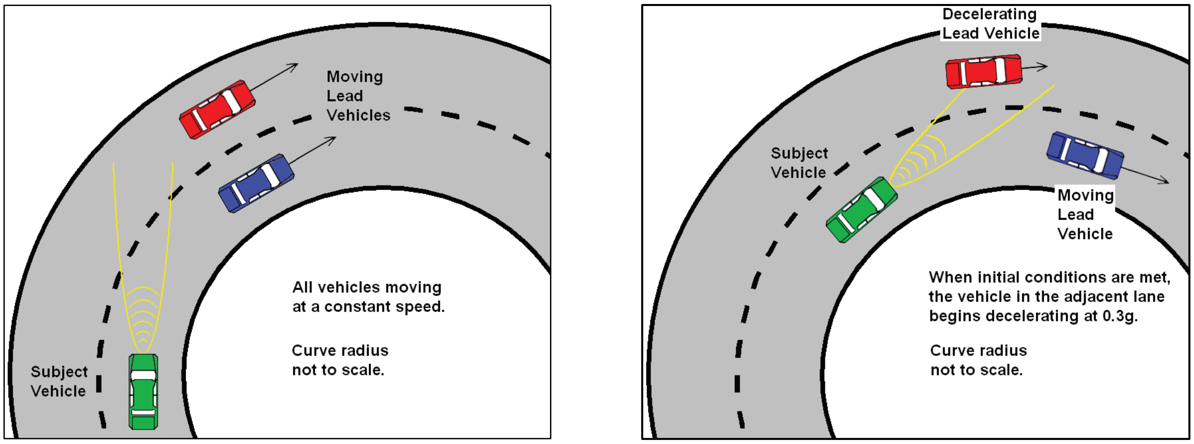

Figure 2.3. Functional Layout of the Decelerating Vehicle in an Adjacent Lane Maneuver (Curve Road)

Figure 2.4 shows the SV, MLV, and DLV in a formation representative of that used for tests performed in a clockwise direction. The SV can be seen in the background with a SV-to-MLV resultant range of 196 ft. Similar tests were performed with the vehicles being driven in a counter-clockwise direction.

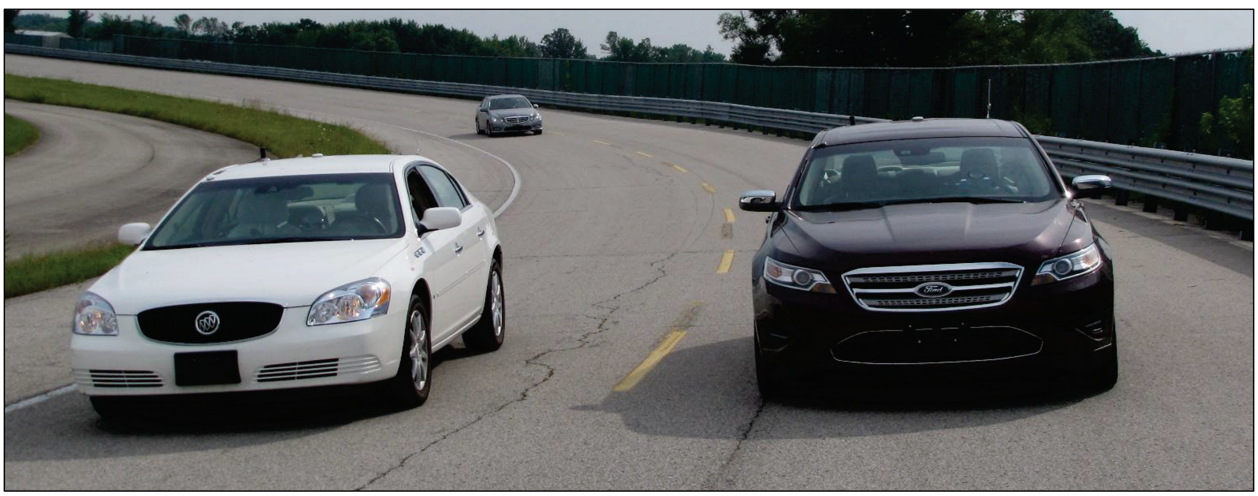

Figure 2.4. SV (Mercedes E350), MLV (Buick Lucerne), and DLV (Ford Taurus) in the VDA North Loop

2.4.2 Driving Under an Overhead Bridge

If a CIB-equipped vehicle inappropriately classifies an Overhead Sign or Overhead Bridge as being an object in the SV's immediate path, a false positive can occur. To emulate this scenario, the SV was driven on a straight road under a metal bridge. The bridge was approximately perpendicular to the travel lane (actual orientation was 86.5 degrees), and the vertical distance from the center of the SV travel lane to the bottom of the bridge was 18.5 feet. Tests were performed at speeds of 25 and 45 mph. Figure 2.5 provides the functional layout of this test maneuver.

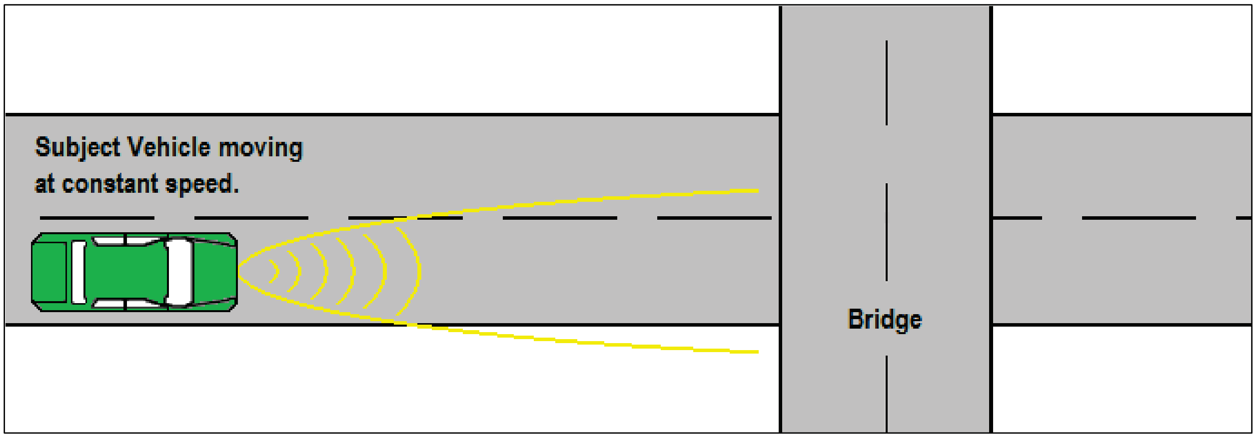

Figure 2.5. Functional Layout of the Overhead Bridge Maneuver

Figure 2.6 shows how the test scenario appeared from the driver's perspective. The bridge was located at the south end of the TRC Skid Pad. All tests were performed with the SV being driven north under the bridge.

Figure 2.6. A Driver's View of the Overhead Bridge.

2.4.3 Driving Over Objects in Roadway

In some situations, a vehicle may be intentionally driven over a non-threatening object present on the roadway. If a CIB-equipped vehicle misclassifies driving over the object as a crash-imminent event, a false positive can occur. In this study, two objects were placed on the test course: a series of Botts' Dots and a steel trench plate. For both test series, the SV was driven on a straight and level road at a constant forward velocity of either 25 or 45 mph.

2.4.3.1 Botts' Dots

In this scenario, the SV was driven toward a single row of Botts' Dots and reflectors positioned along the center of a 26.25 ft wide lane using dimensions specified in California Standard Plan

A20A, Detail 4 (see Figure 2.7). This pattern was repeated seven times to create a course 336 ft long on the TRC Winding Road Course (WRC).

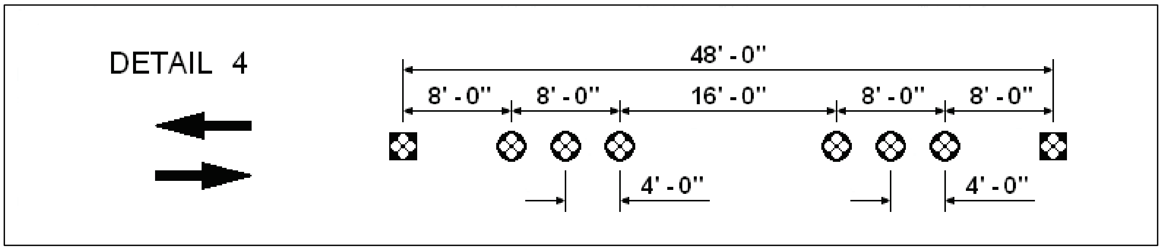

Figure 2.7. California Standard Plan A20A, Detail 4 Specifications

To perform the tests, the SV was driven in the center of the travel lane at the nominal test speed for at least three seconds prior to crossing the first reflector of the test course. While continuing to maintain a constant speed, the SV was driven over the course such that the Botts' Dots passed directly under the middle of the car. The test ended after the SV entirely cleared the last reflector in the series. Figures 2.8 and 2.9 provide the functional and actual layouts of this test maneuver, respectively.

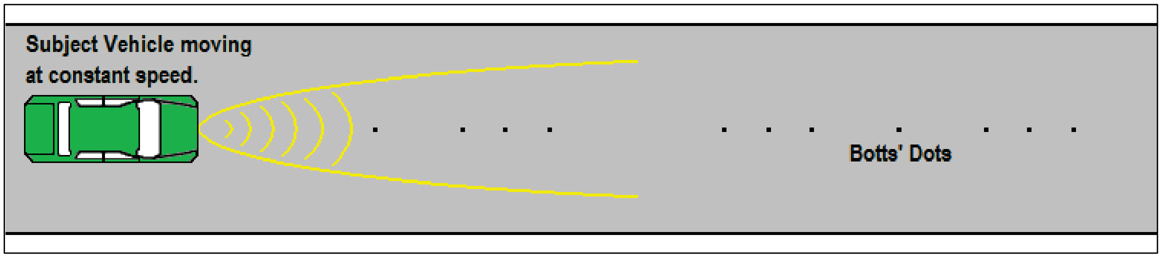

Figure 2.8. Functional Layout of the Objects in Roadway Maneuver (Botts' Dots)

Figure 2.9. A Southwest Facing View of the Botts' Dots Course on the Front Stretch of the WRC

2.4.3.2 Steel Trench Plate

In this scenario, the SV was driven toward, and over, a large ASTM A36 steel trench plate centered in a 12 ft wide lane. The lane was located on the TRC Skid Pad and delineated by two solid white lane lines, as shown in Figure 2.10. The plate, which was leased from a road-construction equipment supplier, had dimensions of approximately 8 ft × 12 ft x 1 in. Trench plates like that used in this study are often used in construction to temporarily cover sections of pavement unsafe to drive over directly (typically during repair).

Figure 2.10. Steel Trench Plate Positioned on the TRC Skid Pad

To perform the tests, the SV was driven in the center of the travel lane at the nominal test speed for at least three seconds prior to crossing the leading edge of the test plate. While continuing to maintain a constant speed, the SV was driven over the plate. The test ended after the SV had entirely cleared the far edge of the plate. Figure 2.11 provides the functional layout of this test maneuver.

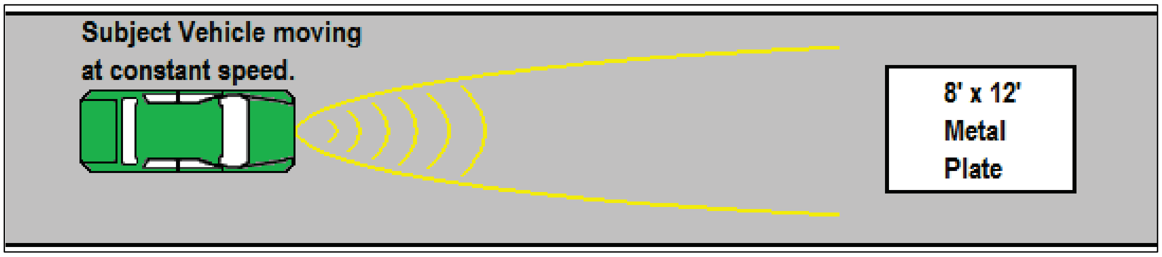

Figure 2.11. Functional Layout of the Object in Roadway Maneuver (Steel Trench Plate)

2.4.4 Curved-Lane Test Scenarios

Two curved-lane test scenarios were used in this study: Stationary Vehicle at Curve Entrance (Curve-Entry tests) and Stationary Vehicle at Curve Exit (Curve-Exit tests). To perform the tests as efficiently as possible, conduct of both maneuvers were performed within a common test trial. The Curve-Entry tests were performed first, as the SV entered a curve in the travel lane.

Before exiting the curve, the Curve-Exit evaluations were performed. Figure 2.13 shows the relative location of the two test maneuvers on the TRC Winding Road Course (WRC). For both test series, the SV was driven at a constant forward velocity of either 25 or 45 mph. Note: the stationary roadside vehicles indicated on Figure 2.13 were used during the maneuver described in S2.4.4.1, which was performed separately from the combined Curved-Lane test series.

Figure 2.13. Relative Locations of the Two Stationary Vehicle-in-Curve Maneuvers (WRC)

2.4.4.1 Stationary Vehicle at Curve Entrance

A Curve-Entry false positive event can occur when the SV correctly identifies another vehicle in the driver's forward path, but does not anticipate the driver may steer around it by virtue of simply maintaining lane position while driving in a curve.

To emulate this scenario, the SV was driven on a straight section of road approaching a curve. A Stationary Lead Vehicle (SLV) was placed on the side of the road just after the curve began, such that if the SV continued in a straight line its path would have intersected the SLV, as shown in Figure 2.14. Test speeds of 25 and 45 mph were maintained for at least five seconds before the SV crossed a plane established by the rear of the SLV. The curve radius was 300 ft. All Curve-Entry tests performed in this study were in a clockwise manner, where the road turned away from the SLV to the right.

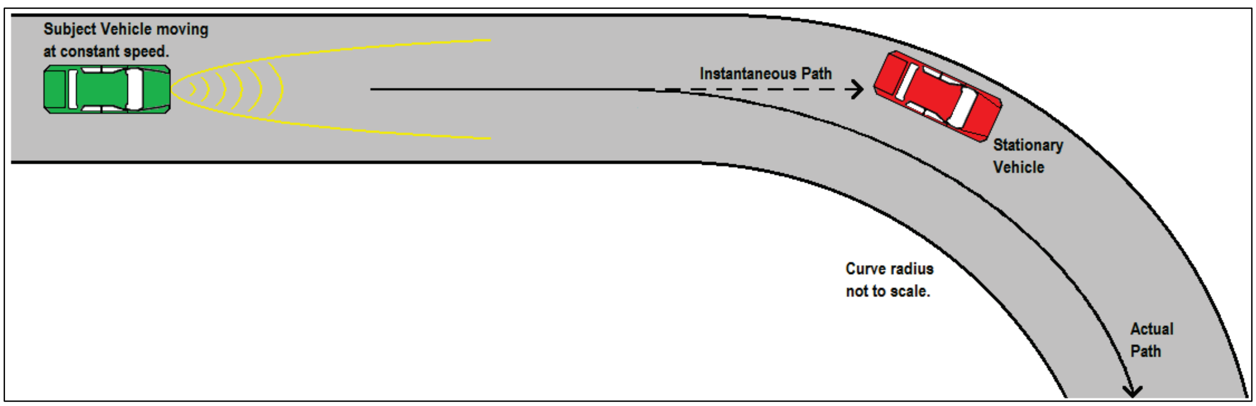

Figure 2.14. Functional Layout of the Stationary Vehicle at Curve Entrance Maneuver

Figure 2.15 shows the SLV position in the curved road from the perspective of the SV driver. The SLV's right front and right rear wheels were approximately 12 inches from the leftmost side of the SV's lane of travel, allowing 0.4 to 3.9 ft[7] between the two vehicles as the SV was driven by the SLV. The SLV used for this maneuver was a 2008 BMW 528i.

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[7] Descriptive statistics that detail how close each of the three instrumented vehicles came to the stationary vehicle positioned at the curve entrance can be found in Appendix C.

Figure 2.15. The Stationary Vehicle at Curve Entrance Maneuver was performed on the WRC

2.4.4.2 Stationary Vehicle at Curve Exit

A Curve-Exit false positive event can occur while the vehicle is being driven in a curve and experiences a path-prediction error. Here, the SV correctly identifies an SLV vehicle is ahead of the SV, but incorrectly assumes the SV operator will continue driving in the curved lane rather than steering out of it.

To create the potential for a Curve-Exit false positive event, the SV was driven on a curved section of roadway that transitioned to a straight, as shown in Figure 2.16. A SLV was placed just past the curve exit such that continuation of the curve would have intersected the SLV (shown in Figure 2.16 below). Test speeds of 25 and 45 mph were maintained for at least 5 seconds before the SV crossed a plane established by the rear of the SLV. The curve radius was 360 ft. All Curve-Exit tests performed in this study were in a clockwise manner, with the SLV present to the right of the SV.

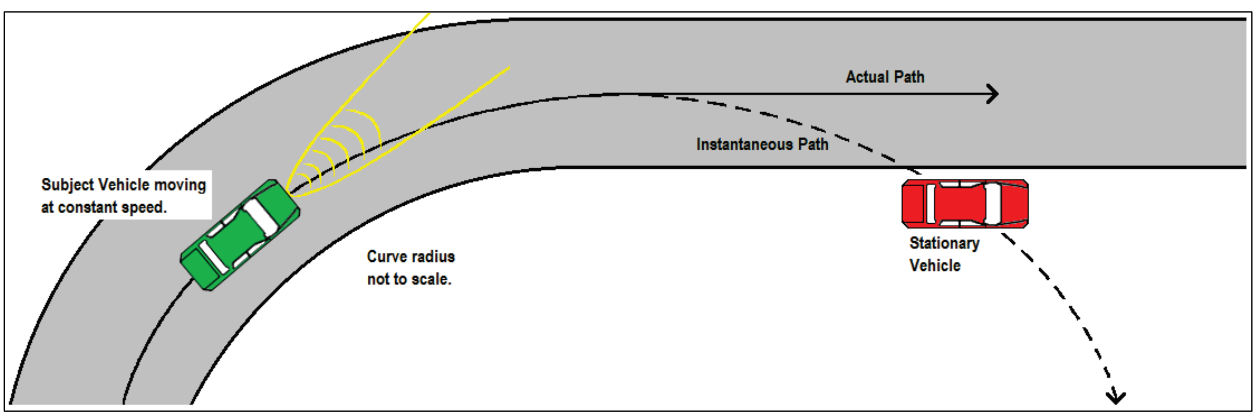

Figure 2.16. Functional Layout of the Stationary Vehicle at Curve Exit Maneuver

Figure 2.17 shows the SLV position relative to the curved road from the perspective of the SV driver. The SLV's left front and left rear wheels were approximately 12 inches from the rightmost side of the roadway, approximately 2.6 to 9.9 ft[8] from the SV as it was driven by to the left of the SLV. The SLV used for this maneuver was a 2005 Chrysler 300C.

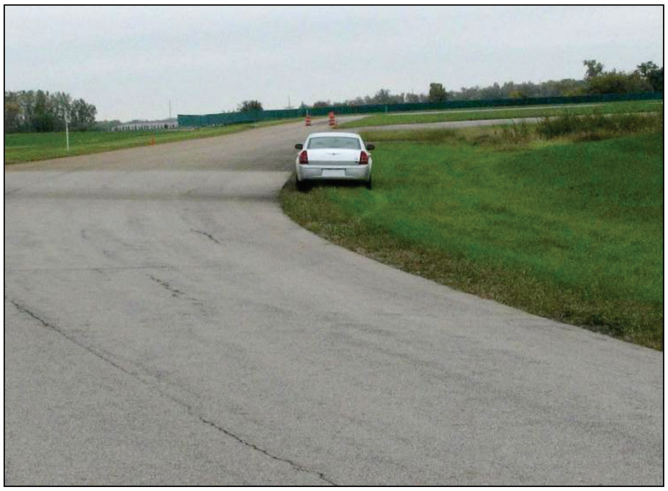

Figure 2.17. The Stationary Vehicle at Curve Exit Maneuver was performed on the WRC

2.4.5 Stationary Roadside Vehicles

During periods of normal operation, a vehicle may be driven toward other vehicles or objects present along the side of the road. These events generally are non-threating, as they occur only for a short time, and the driver takes corrective action before a collision is imminent. A Roadside Object false positive event can occur when the CIB system intervenes before an attentive driver has had an opportunity to initiate their predetermined corrective action. In other words, the SV correctly identifies one or more parked vehicles ahead of the SV, in its instantaneous forward path, but incorrectly assumes the SV operator will continue driving toward the parked vehicles rather than steering way from them.

To create the potential for a Roadside Object false positive event, the SV was driven at constant speed of 25 or 45 mph, on a straight two-lane roadway, parallel to the formation of four parked cars shown in Figures 2.13 and 2.17. As the SV approached the parked vehicles, the SV driver performed a mild lane change toward the center of the four-vehicle formation using a lateral velocity target of approximately 3 ft per second.[9] Orange pylons were used to provide a visual marker for the SV driver to initiate the maneuver. Test speeds of 25 and 45 mph were maintained for at least three seconds before the SV driver initiated the lane change. Tests were performed in both directions so that the SV approached the parked vehicles from the left and right. The parked vehicles were always oriented in the same direction of the SV (i.e., the SV

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[8] Descriptive statistics that detail how close each of the three instrumented vehicles came to the stationary vehicle positioned at the curve entrance can be found in Appendix C.

[9] To accomplish this, the faster test speed approached the vehicle formation at a shallower angle than the slower test speed. A total of four pylons were used, one for each test speed and direction of travel.

always approached the rear of the parked vehicles). The design of this maneuver was based largely on Appendix O of [1].

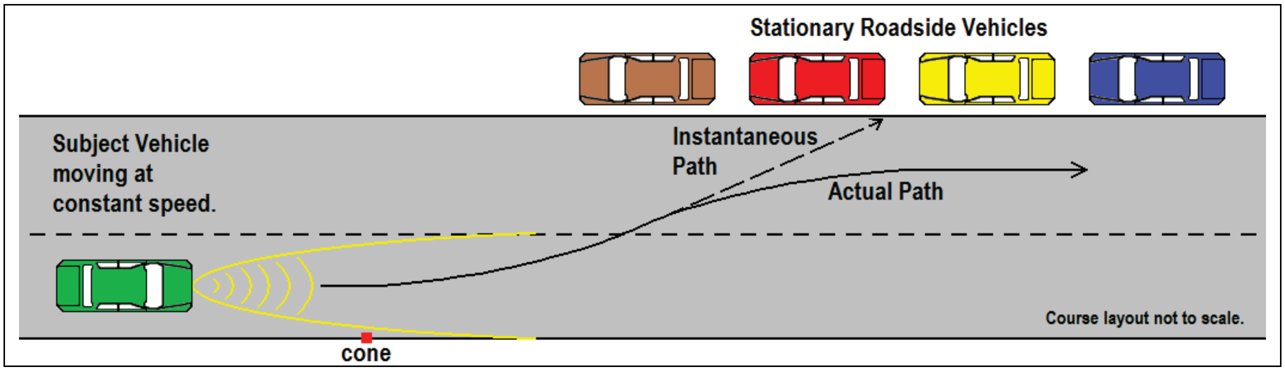

Figure 2.18. Functional Layout of the Stationary Roadside Vehicles Maneuver

Figure 2.18 shows the four roadside vehicles from the perspective of the SV driver. From nearest to farthest, the parked vehicles were a 2005 Chrysler 300C, a 2008 BMW 528i, a 2004 Volvo XC90, and a 2008 Buick Lucerne. Each parked car was centered within a 24 ft long parking space, and positioned with its inboard[10] tires 18 in from the lane boundary.

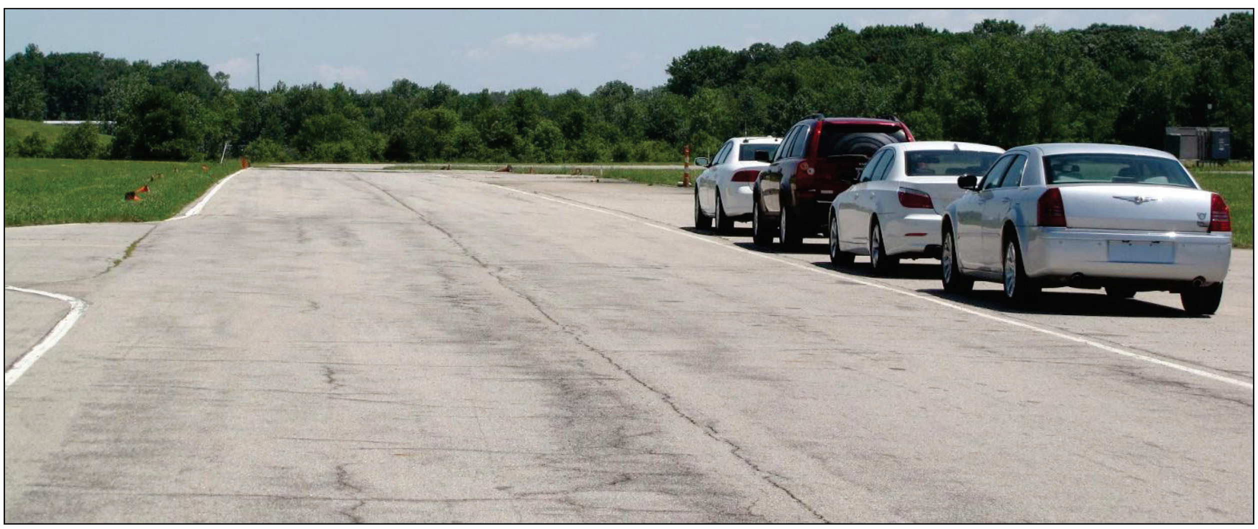

Figure 2.19. Four Roadside Vehicles Parked Beside Two 12-ft Lanes

[10] Inboard tires are those closest to the SV travel lanes (e.g., if the SV approached the left side of the parked cars, the left front and left rear tires of the parked cars were 18 inches from the lane boundary).

3.0 RESULTS

3.1 Analysis Approach

Since one objective of this study was simply to assess whether CIB false positives could be consistently observed on the test track, analyses beyond whether an FCW alert and/or CIB activation occurred were limited. If a maneuver did not elicit any response from the vehicle, the finding was documented (see S3.2), but not discussed. However, for tests where FCW alerts and/or CIB activations were observed, and the vehicle was equipped with in-vehicle instrumentation, the variability of test input conditions (e.g., vehicle speed, yaw rate, throttle position, etc.) were quantified for all test trials performed within the respective series. When considering these results, it is important to recognize NHTSA researchers did not have a way to explicitly monitor the state of each vehicle's respective CIB/FCW systems beyond whether they had been activated or not. Due to the proprietary nature of their control algorithms, directly monitoring elements such as object classification (or misclassification), confidence levels, or whether a suppression algorithm had been activated was not possible.

3.2 CIB and FCW Activation Summary

The FCW activations observed in this study were divided into two categories, true positive and false positive, and were assigned by considering the scenario and whether issuance of an FCW alert could help prevent a potential vehicle-to-vehicle collision. In the context of this study, FCW activation is relevant since it is unlikely a CIB false positive would be activated by a maneuver incapable of producing an FCW alert.

Tables 3.1 and 3.2 summarize the number of FCW alerts per vehicle, per test condition. Table 3.1 summarizes results for the tests performed with a nominal speed of 25 mph, while Table 3.2 summarizes the 45 mph tests.

Table 3.1. Summary of FCW Activations at 25 mph

Test Condition	Vehicle					Overall
	Outback	E350	S80	MDX	Explorer	
Decelerating Vehicle Adjacent Lane Straight	0/40	0/24	0/22	0/24	0/20	**0/130**
Decelerating Vehicle Adjacent Lane Curve	0/32	0/21	0/20	0/25	0/20	**0/118**
Driving Under an Overhead Bridge	0/10	0/10	0/10	0/10	0/10	**0/50**
Objects in Roadway – Botts' Dots	0/10	0/10	0/10	0/10	0/10	**0/50**
Object in Roadway – Steel Trench Plate	0/10	1/10	0/10	10/10	10/10	**21/50**
Stationary Vehicle at Curve Entrance	1/10	0/10	9/10	1/11	0/10	**11/51**
Stationary Vehicle at Curve Exit	0/10	0/10	0/10	0/11	0/10	**0/51**
Stationary Roadside Vehicles	0/20	8/21	0/21	11/20	6/20	**25/102**
Total	**1/142**	**9/116**	**9/113**	**22/121**	**16/110**	**57/602**

Table 3.2. Summary of FCW Activations at 45 mph

Test Condition	Vehicle					Overall
	Outback	E350	S80	MDX	Explorer	
Decelerating Vehicle Adjacent Lane Straight	0/36	0/21	0/21	0/23	0/20	**0/121**
Decelerating Vehicle Adjacent Lane Curve	0/30	0/20	1/20	0/23	0/24	**1/117**
Driving Under an Overhead Bridge	0/10	0/10	0/10	0/10	0/10	**0/50**
Objects in Roadway – Botts' Dots	0/11	0/10	0/10	0/10	0/10	**0/51**
Object in Roadway – Steel Trench Plate	0/10	1/10	0/9	12/12	10/10	**23/51**
Stationary Vehicle at Curve Entrance	0/10	7/10	10/10	4/10	10/10	**31/50**
Stationary Vehicle at Curve Exit	0/10	0/10	0/10	0/10	0/10	**0/50**
Stationary Roadside Vehicles	0/20	1/20	1/20	0/20	5/20	**7/100**
Total	**0/137**	**9/111**	**12/110**	**16/118**	**25/114**	**62/590**

Of the maneuvers shown in Tables 3.1 and 3.2, the Object in Roadway – Steel Trench Plate was the only test condition for which FCW and CIB activations were observed. This is in contrast to the Stationary Vehicle at Curve Entrance, Stationary Roadside Vehicles, and Decelerating Vehicle Adjacent Lane Curve maneuvers, which produced FCW alerts without CIB activations. These overall results are summarized in Table 3.3, and are discussed in greater detail in Sections 3.3 through S3.6.

Table 3.3. FCW and CIB Activations by Maneuver – 25 and 45 mph Tests Combined, Collapsed Across Vehicle

Test Condition	Number of FCW Alerts	Percent of FCW Alerts Per Maneuver	Number of CIB False Activations	Percent of CIB False Activations
Object in Roadway – Steel Trench Plate	44/101	43.6%	22/101	21.8%
Stationary Vehicle at Curve Entrance	42/101	41.6%	0/101	0.0%
Stationary Roadside Vehicles	32/202	15.8%	0/202	0.0%
Decelerating Vehicle Adjacent Lane Curve	1/235	0.4%	0/235	0.0%

The Decelerating Vehicle in an Adjacent Lane Straight, Driving Under an Overhead Bridge, Objects in Roadway – Botts' Dots, and Stationary Vehicle at Curve Exit test conditions did not elicit FCW or CIB activations for any of the five vehicles evaluated in this study. With the notable caveat that the environmental conditions present during test conduct were idealized (e.g., good weather with no other vehicles or roadside clutter present), the results suggest that the FCW/CIB systems installed in the test vehicles were capable of correctly assessing the traffic situations presented in those maneuvers (i.e., no need to intervene, as there was no threat of an impending rear-end crash).

From a vehicle perspective, the stereo camera-based system found in the Subaru Outback produced the fewest number of FCW alerts, and no CIB false activations. Conversely, the single radar-based systems found in the Acura MDX and the Ford Explorer[11] produced the greatest number of FCW alerts, and in the case of the Acura MDX, consistent CIB false positives during the Object in Roadway – Steel Trench Plate tests. Table 3.4 presents the test vehicles sorted by frequency of FCW alerts in ascending order, collapsed across maneuver and nominal vehicle speed. In addition to these occurrences, numerous FCW activations were observed while the Acura MDX and Ford Explorer were being driven to or from the various facilities described in Sections 3.3 to 3.6. For the sake of documentation, the driving environs associated with these activations are provided in Appendix B of this report but are not discussed.

Table 3.4. FCW and CIB Activations by Vehicle – 25 and 45 mph Tests Combined, Collapsed Across Maneuver

Vehicle	Type of Sensor	Number of FCW Alerts	Percent of FCW Alerts	Number of CIB False Activations	Percent of CIB False Activations
Subaru Outback	Stereo Cameras	1/279	0.4%	0/279	0.0%
Mercedes E350	Multiple Radars	18/227	7.9%	0/227	0.0%
Volvo S80	Fused Single Radar and Mono Camera	21/223	9.4%	0/223	0.0%
Acura MDX	Single Radar	38/239	15.9%	22/239	9.2%
Ford Explorer	Single Radar	41/224	18.3%	n/a	n/a

3.3 Object in Roadway – Steel Trench Plate

Of the four test conditions that produced an FCW alert, driving over a steel trench plate was the easiest to set up, the least complex to perform, and highly valid since the scenario is encountered during real world driving. While the CAMP CIB report [1] doesn't specifically mention steel trench plates being represented in their data set, it does mention a metal grate, like that used as a bridge surface. The trench plate used in this study was believed to impose similar demands on the system functionality, albeit with better test track practicality (i.e., cost, expediency, and availability).

The Acura MDX presented a CIB false positive during 100 percent of the Object in Roadway – Steel Trench Plate test trials used to evaluate its performance. This maneuver also produced FCW false positive activations during 100 percent of the test trials for the Acura MDX and Ford Explorer. Since these vehicles were instrumented with only speed displays and video cameras to document test conduct, detailed summaries of the input conditions for these tests are not available.

Twenty Object in Roadway – Steel Trench Plate trials were performed with the Mercedes E350. FCW false positive alerts were observed during two of these tests, once during each of the two

[11] The Ford Explorer was not equipped with CIB; therefore no assessment of CIB false positive propensity was made.

test speed conditions (i.e., during 10 percent of tests). Although an equipment malfunction prevented determination of the range, speed, and therefore time-to-"collision" of when the FCW activated, analysis of the test input conditions was still possible to assess variability by considering data collected for five seconds prior to the vehicle being driven over the trench plate[12]. This interval was long enough to demonstrate the vehicle had been driven in a stable manner prior to reaching the trench plate, but concise enough to make the tests simple to consistently perform.

Table 3.5 presents the throttle position, longitudinal speed, yaw rate, and longitudinal acceleration data collected during the Object in Roadway – Steel Trench Plate performed with the Mercedes E350 using a min, max format. In this table, lateral deviation from the lane centerline is the furthest distance that the vehicle's centerline went to either the right or left of the lane centerline, whichever was greater. The test validity summarized in the last column of Table 3.5 refers to whether the driver applied force to the brake pedal during the five seconds before reaching the trench plate; a valid test was one in which no brake application was observed.

The data shown in Table 3.5 demonstrate that the tests within each test speed condition were consistently performed, and do not indicate why FCW false positive occurred during some, but not all, tests

[12] This interval was defined by subtracting five seconds from the instant the front-most part of the vehicle's front bumper crossed a plane defined by the leading edge of the trench plate.

Table 3.5. Mercedes E350 Test Input Conditions – Object in Roadway (Steel Trench Plate)

Test Information			Test Input Conditions					
Vehicle	Test Speed (mph)	Test Number	Throttle Position (% of WOT) (min, max)	Longitudinal Speed (mph) (min, max)	Longitudinal Acceleration (g) (min, max)	Yaw Rate (deg/sec) (min, max)	Lateral Deviation from Lane Centerline (in)	Valid Test? (y/n)
Mercedes E350	25	227	16.3, 18.4	25.3, 25.3	-0.01, 0.01	-0.63, 0.45	1.0	Y
		228	14.0, 15.6	25.0, 25.4	-0.02, 0.01	-0.58, 0.35	0.9	Y
		229	13.1, 18.8	25.1, 25.3	-0.01, 0.02	-0.36, 0.41	0.8	Y
		230	11.1, 19.6	25.0, 25.1	-0.01, 0.01	-0.39, 0.33	2.8	Y
		231	8.0, 18.0	25.0, 25.4	-0.02, 0.01	-0.45, 0.54	2.2	Y
		232	12.3, 18.4	25.0, 25.2	-0.01, 0.01	-0.73, 0.44	2.7	Y
		233[1]	10.7, 17.6	25.1, 25.2	-0.01, 0.01	-0.75, 0.40	2.1	Y
		234	8.3, 20.4	24.9, 25.3	-0.01, 0.01	-0.47, 0.47	1.2	Y
		235	12.4, 17.2	25.2, 25.4	-0.01, 0.01	-0.37, 0.25	1.2	Y
		236	8.4, 16.1	24.9, 25.5	-0.02, 0.01	-0.48, 0.40	0.8	Y
	45	238	22.0, 31.6	44.8, 45.4	-0.01, 0.02	-0.18, 0.42	3.5	Y
		239	17.5, 27.2	45.1, 45.3	-0.02, 0.01	-0.34, 0.53	4.8	Y
		240	19.9, 27.3	45.1, 45.3	-0.02, 0.02	-0.49, 0.54	2.3	Y
		241	18.3, 31.2	45.0, 45.4	-0.02, 0.02	-0.53, 0.66	6.4	Y
		242[1]	21.1, 27.7	45.2, 45.4	-0.02, 0.01	-0.35, 0.35	2.5	Y
		243	19.9, 27.6	45.3, 45.5	-0.02, 0.01	-0.29, 0.69	5.5	Y
		244	19.9, 26.8	45.2, 45.4	-0.02, 0.02	-0.31, 0.34	2.9	Y
		245	15.9, 29.6	45.0, 45.4	-0.02, 0.02	-0.28, 0.54	4.7	Y
		246	17.6, 29.3	45.1, 45.3	-0.02, 0.01	-0.39, 0.26	2.2	Y
		247	17.9, 26.8	45.2, 45.4	-0.02, 0.02	-0.51, 0.60	2.6	Y

[1] Test produced an FCW false activation.

3.4 Stationary Vehicle at Curve Entrance

The Stationary Vehicle at Curve Entrance maneuver was simple to set up, but due to differences in steering input timing (i.e., when the steering used to initiate curve entry was applied), it was less consistently performed than the Object in Roadway – Steel Trench Plate scenario. The maneuver has real-world relevance and was mentioned in the CAMP CIB report as a scenario capable of producing false positive events [1].

The POV was accurately and repeatably positioned 12 in from the subject vehicle's travel lane via use of pavement marking paint. To provide the data necessary for evaluation of test repeatability, GPS surveys of the stationary POV and subject vehicle travel lane (i.e., the straight lane approaching the curve as well as the curve itself) were collected.

As was the case for the Object in Roadway – Steel Trench Plate tests, a five second window was used to verify the subject vehicles were driven in a stable manner before reaching the POV. Specifically, this interval was defined from when the subject vehicle's front bumper first crossed the plane created by the POV's rear bumper backwards 5 seconds in time. Throttle position, longitudinal speed, yaw rate, and longitudinal acceleration are presented in the min, max format used previously. Similarly, no brake pedal force applied was the validity criterion. Tests where an FCW alert was issued are indicated.

Each of the five test vehicles used in this study issued at least one FCW alert during conduct of the Stationary Vehicle at Curve Entrance maneuver. Overall, some key findings for this maneuver include:

- Subject vehicle speed was strongly related to FCW activation frequency. 73.8 percent of the alerts were issued during tests performed at 45 mph.
- The Volvo S80 issued FCW alerts during 90 percent of the vehicle's 25 mph tests, and during all of the 45 mph trials.
- The Ford Explorer presented FCW alerts during each 45 mph test, but during none of the trials performed at 25 mph.
- The Mercedes E350 issued FCW alerts during 70 percent of the vehicle's 45 mph tests, but during none of the 25 mph trials.
- The Acura MDX presented FCW alerts during 9 percent of the tests performed from 25 mph, and during 40 percent of the trials performed at 45 mph.
- The Subaru Outback issued one FCW alert during the 25 mph tests, 10 percent of the vehicle's trials performed at that speed, but during none of the 45 mph tests.

An additional test input condition for this scenario was range at steering onset. Test outputs include range to POV, subject vehicle speed, and the TTC when the FCW alert was issued (i.e., for applicable tests performed with the Volvo S80, Mercedes E350, and Subaru Outback). To calculate the SV-to-POV range, the right-rear bumper corner of the POV was considered; the location it would have been first hit at had the subject vehicle been driven straight ahead. Steering onset was taken to be the moment when subject vehicle yaw rate first exceeded 1 deg/s (i.e., at onset of a right-hand turn). Time-to-Collision (TTC) was derived by dividing the range at FCW onset by the subject vehicle's speed at that instant. Tables 3.6 through 3.8 contain the same basic set of information for each of the three instrumented test vehicles.

In the upcoming analyses, whenever a test series includes what appears to be anomalous data, an attempt to identify its origin is made. Since a way of directly monitoring the state of each vehicle's respective CIB/FCW systems was not available, these assessments are limited to high-level discussions of how the input conditions may have affected system operation.

3.4.1 Volvo S80

Of the ten 25 mph tests performed with the Volvo S80 (shown in Table 3.6), there was one where the vehicle did not issue an FCW alert (Test 135). While it is not possible to identify specifically why no alert occurred during this test, the 167.4 ft range at steering onset is suspect. This value is further than that used for all other tests in the series for this vehicle.

In addition to range at steering onset, yaw rates and path data from the 25 mph tests were compared to identify any obvious differences in curve entry. Plots of the yaw rate data in Figure 3.1 present the 5-second time interval used to calculate the 25 mph test data in Table 3.6. The yaw rate trace for Test 135 is shown in blue and follows the general trend of the other nine tests.

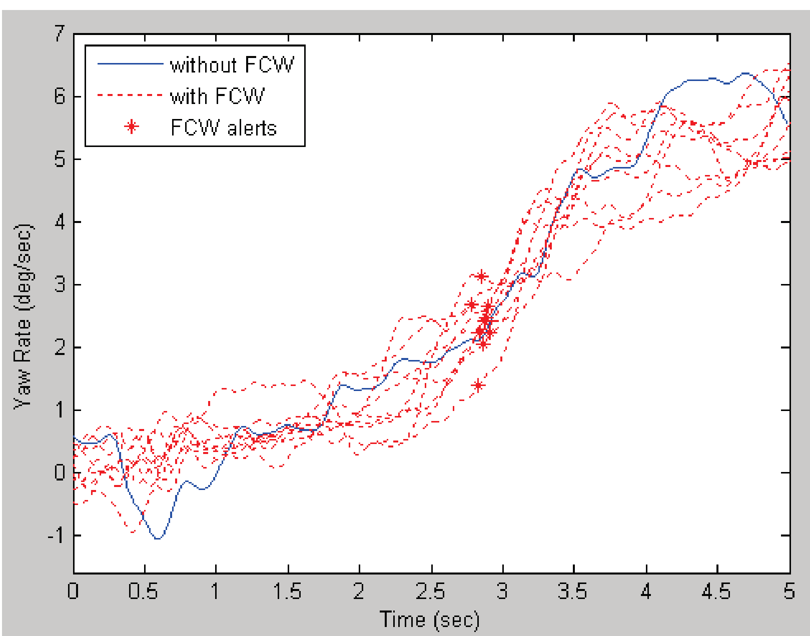

Figure 3.1. Volvo S80 Yaw Rate – Stationary Vehicle at Curve Entrance (25 mph)

Table 3.6. Volvo S80 Test Input Conditions and Results – Stationary Vehicle at Curve Entrance

Test Information			Test Input Conditions						Test Output		
Vehicle	Test Speed (mph)	Test Number	Throttle Position (% of WOT) (min, max)	Longitudinal Speed (mph) (min, max)	Longitudinal Acceleration (g) (min, max)	Yaw Rate (deg/sec) (min, max)	Range at Steering Onset (ft)	Valid Test? (y/n)	FCW Onset		
									Range (ft)	Speed (mph)	TTC (sec)
Volvo S80 (7-5-11)	25	127	5.8, 6.2	25.0, 25.6	-0.02, 0.00	-0.23, 5.12	120.4	Y	79.2	25.4	2.1
		128	5.6, 8.2	24.7, 25.2	-0.01, 0.01	0.07, 5.44	96.6	Y	79.2	24.9	2.2
		129	5.6, 10.7	25.6, 26.0	-0.01, 0.02	-0.13, 5.97	102.5	Y	80.3	25.6	2.1
		130	3.7, 10.9	25.0, 25.6	-0.04, 0.02	-0.23, 5.90	110.6	Y	77.9	25.1	2.1
		131	8.4, 9.4	25.4, 26.3	0.00, 0.01	-0.29, 6.32	102.8	Y	83.0	26.0	2.2
		132	7.2, 7.6	25.2, 25.6	-0.01, 0.01	-0.51, 5.89	152.9	Y	82.2	25.5	2.2
		133	3.5, 8.7	25.1, 25.9	-0.02, 0.02	0.17, 6.08	120.5	Y	79.9	25.6	2.1
		134	7.5, 7.9	25.7, 26.2	0.00, 0.01	-0.17, 6.41	99.9	Y	83.4	26.1	2.2
		135[1]	1.8, 10.8	25.3, 25.9	-0.03, 0.02	-1.07, 6.36	167.4	Y	–	–	–
		136	3.1, 9.5	25.4, 26.3	-0.02, 0.04	-0.95, 6.53	126.6	Y	84.5	26.2	2.2
	45	117	9.7, 17.5	45.0, 45.5	-0.01, 0.03	-0.72, 11.58	174.3	Y	151.4	45.3	2.3
		118	7.4, 14.4	45.5, 45.7	-0.03, 0.02	-0.75, 12.61	159.0	Y	165.7	45.7	2.5
		119	10.3, 16.2	45.3, 45.7	-0.01, 0.03	-0.57, 12.14	133.6	Y	111.5	45.6	1.7
		120	6.3, 13.7	44.6, 46.0	-0.03, 0.01	-0.71, 10.81	139.9	Y	161.7	45.7	2.4
		121	9.7, 13.3	45.2, 45.7	-0.02, 0.01	-0.80, 9.40	157.2	Y	135.4	45.7	2.0
		122	8.6, 15.0	44.9, 45.6	-0.03, 0.02	-0.24, 11.33	157.3	Y	176.7	45.6	2.6
		123	11.1, 11.6	45.2, 45.4	-0.02, 0.01	-0.38, 13.90	144.5	Y	82.6	45.4	1.2
		124	11.4, 15.5	44.8, 45.4	-0.01, 0.01	-0.13, 9.93	140.1	Y	162.0	45.3	2.4
		125	12.1, 14.4	44.5, 45.7	-0.01, 0.02	-0.78, 10.69	149.6	Y	171.1	45.1	2.6
		126	11.5, 18.6	44.8, 45.6	0.00, 0.03	-0.78, 10.02	130.1	Y	178.2	44.9	2.7

[1] Test did not produce an FCW activation. All other Stationary Vehicle at Curve Entrance tests performed with the Volvo S80 did.

Figure 3.2 plots the path the S80 took during the ten tests performed at 25 mph. The tight cluster of red dots visually indicates the consistency of the FCW alerts when issued. The x- and y-axes have been labeled in "Northings" and "Eastings" but in reality have been modified for plotting purposes[13]. In Figure 3.2, the right-rear bumper of the POV has been fixed at 30 m on the north axis and 50 m on the east axis.

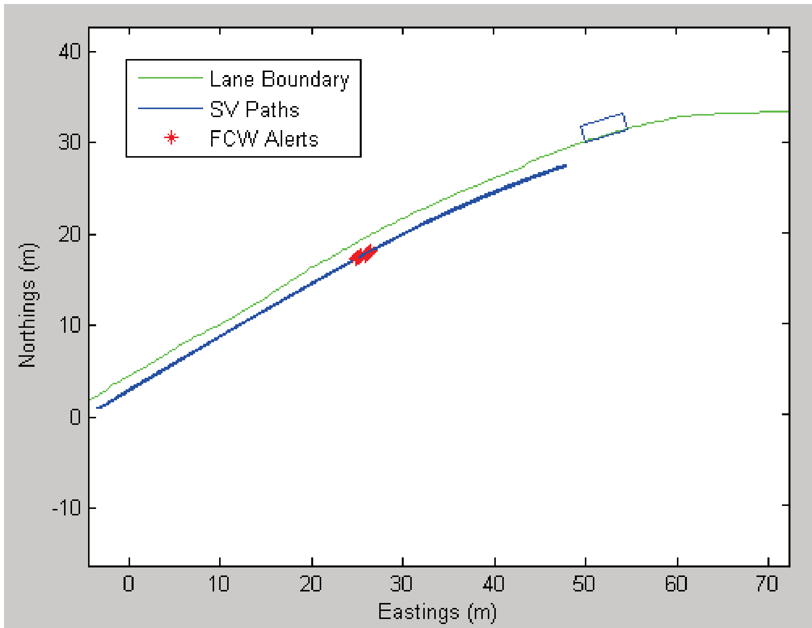

Figure 3.2. Volvo S80 Paths and FCW Alert Locations – Stationary Vehicle at Curve Entrance (25 mph)

Figure 3.3 and Figure 3.4 plot the yaw rates and vehicle paths for each Stationary Vehicle at Curve Entrance test performed at 45 mph with the Volvo S80. An FCW alert was present during each of these tests; however the location where the FCW alert was issued was more variable.

[13] The test vehicle instrumentation logs positions as longitude and latitude 200 times each second. Since longitude and latitude coordinates are often not useful for quick and easy geometric evaluations, the logged longitude and latitude coordinates are converted to coordinates in the Universal Transverse Mercator coordinate system (UTM). The UTM system approximates locations on the Earth as orthogonal distances on a plane often described as "northings" and "eastings." The UTM system divides the Earth into multiple zones such that the inherent approximation of describing the Earth's surface as a plane is minimized.

For example, on one of TRC's test facilities (north loop of the VDA), the logged latitude and longitude pair (40.312010787973378,-83.546266063392864) becomes an easting, northing pair (283632.2224732623, 4465499.784350083) in UTM zone 17. This particular easting, northing pair implies that the location we are referring to is about 4465 km north of the Earth's equator and about 217 km to the west of zone 17's central line of longitude.

Since UTM pairs tend to consist of fairly large values, the x and y, map-type plots contained within this report have been offset such that the scale values are reasonably small and readable numbers.

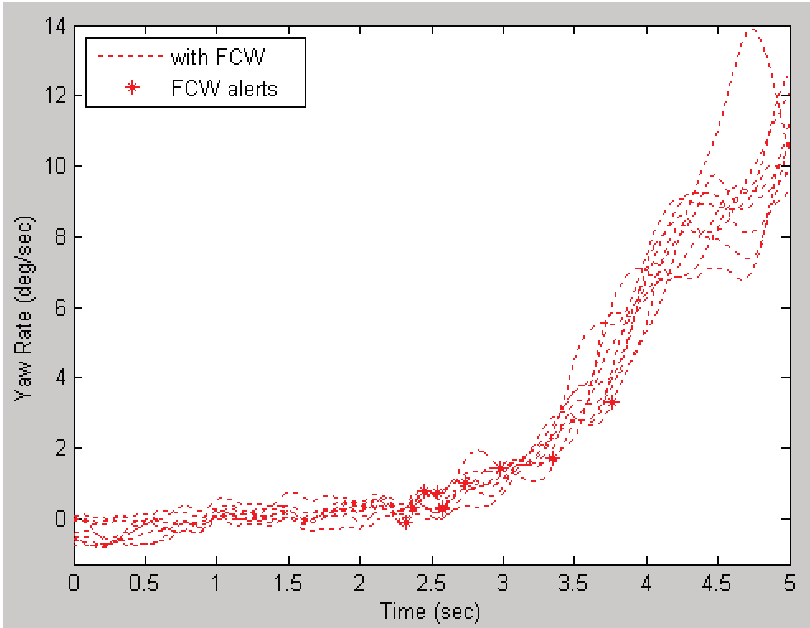

Figure 3.3. Volvo S80 Yaw Rate – Stationary Vehicle at Curve Entrance (45 mph)

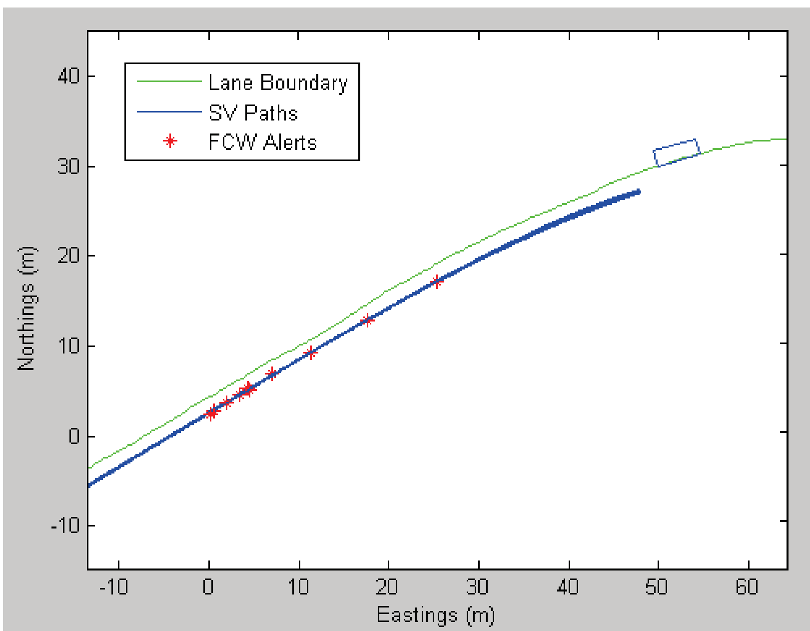

Figure 3.4. Volvo S80 Paths and FCW Alert Locations – Stationary Vehicle at Curve Entrance (45 mph)

3.4.2 Mercedes E350

Of the ten 45 mph tests performed with the Mercedes E350 (shown in Table 3.7), there were three where the vehicle did not issue an FCW alert (Tests 205, 207, and 208). From an input perspective, the tests for which an FCW was realized were not markedly different from those where an alert was not produced. Table 3.7 presents a summary of the Stationary Vehicle at

Curve Entrance tests performed at 45 mph with the Mercedes E350. Figures 3.5 and 3.6 plot the yaw rates and vehicle paths for these tests, respectively.

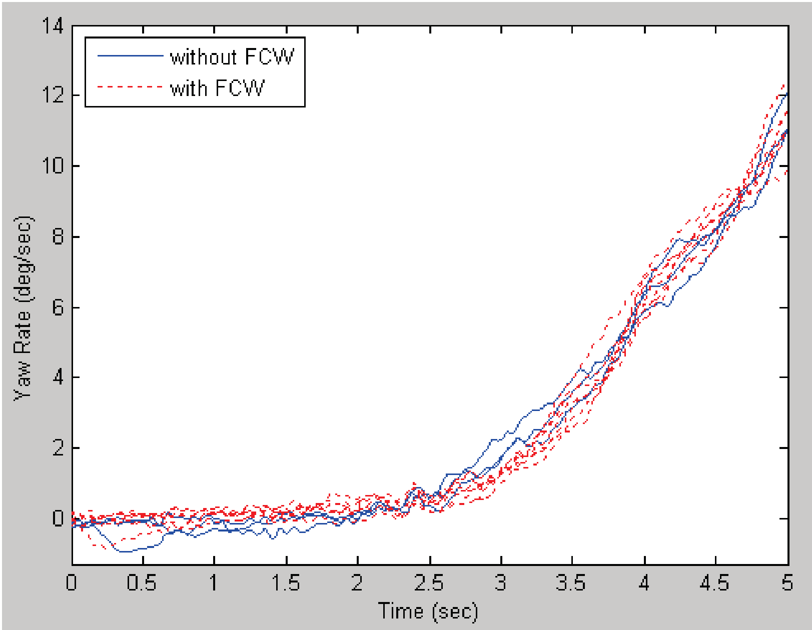

Figure 3.5. Mercedes E350 Yaw Rate – Stationary Vehicle at Curve Entrance (45 mph)

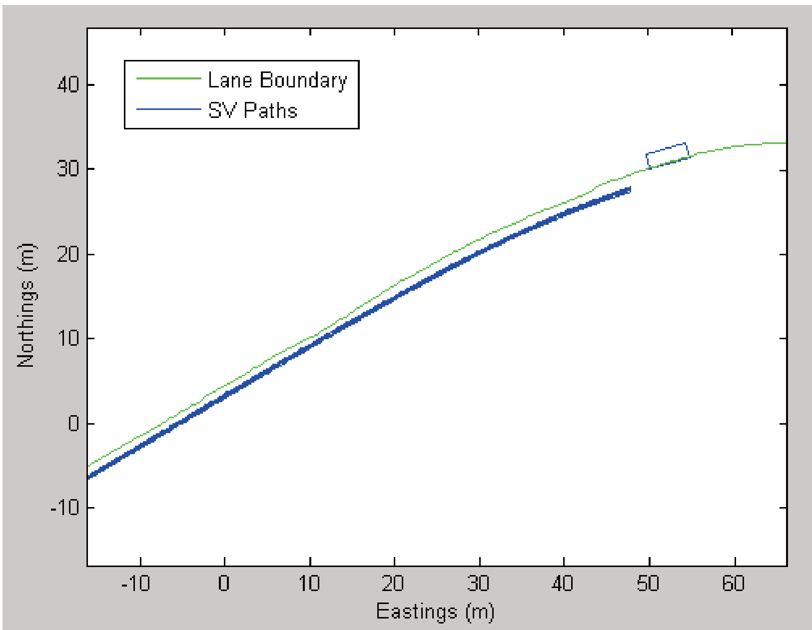

Figure 3.6. Mercedes E350 Paths – Stationary Vehicle at Curve Entrance (45 mph). FCW alert status was not available for these tests due to an instrumentation malfunction.

Table 3.7. Mercedes E350 Test Input Conditions and Results – Stationary Vehicle at Curve Entrance

Test Information			Test Input Conditions						Test Output		
Vehicle	Test Speed (mph)	Test Number	Throttle Position (% of WOT) (min, max)	Longitudinal Speed (mph) (min, max)	Longitudinal Acceleration (g) (min, max)	Yaw Rate (deg/sec) (min, max)	Range at Steering Onset (ft)	Valid Test? (y/n)	FCW Onset		
									Range (ft)	Speed (mph)	TTC (sec)
Mercedes E350 (7-5-11)	45	205	5.3, 26.8	45.0, 45.7	-0.02, 0.03	-0.58, 12.10	157.0	Y	n/a	n/a	n/a
		206[1]	11.0, 20.0	45.3, 45.5	-0.02, 0.01	-0.21, 9.84	140.2	Y	n/a	n/a	n/a
		207	1.6, 21.6	45.3, 45.6	-0.02, 0.02	-0.51, 11.01	152.3	Y	n/a	n/a	n/a
		208	0, 20.5	44.7, 45.4	-0.03, 0.02	-0.94, 11.05	158.8	Y	n/a	n/a	n/a
		209[1]	4.2, 24.4	45.2, 45.5	-0.01, 0.03	-0.31, 11.53	154.6	Y	n/a	n/a	n/a
		210[1]	4.4, 20.8	44.8, 45.6	-0.03, 0.01	-0.01, 10.59	132.5	Y	n/a	n/a	n/a
		211[1]	3.5, 21.2	45.0, 45.4	-0.03, 0.02	-0.15, 10.91	153.0	Y	n/a	n/a	n/a
		212[1]	7.2, 23.0	45.0, 45.3	-0.02, 0.02	-0.21, 11.06	138.7	Y	n/a	n/a	n/a
		213[1]	0, 22.0	44.8, 45.6	-0.02, 0.02	-0.85, 11.51	172.6	Y	n/a	n/a	n/a
		214[1]	12.9, 24.0	44.9, 45.5	-0.01, 0.02	-0.12, 12.39	135.8	Y	n/a	n/a	n/a

[1]Test produced an FCW activation.

3.4.3 Subaru Outback

The 25 mph Stationary Vehicle at Curve Entrance was the only test condition to produce an FCW alert with the Subaru Outback. For this test series, the inputs that produced the FCW alert were not markedly different from those used when it did not (i.e., while the test generating an alert was at the extreme of the observed trajectories, it only differed from tests that did not generate alerts by a few inches.) Table 3.8 presents a summary of the Stationary Vehicle at Curve Entrance tests performed at 25 mph with the Subaru Outback. Figures 3.7 and 3.8 plot the yaw rates and vehicle paths for these tests, respectively.

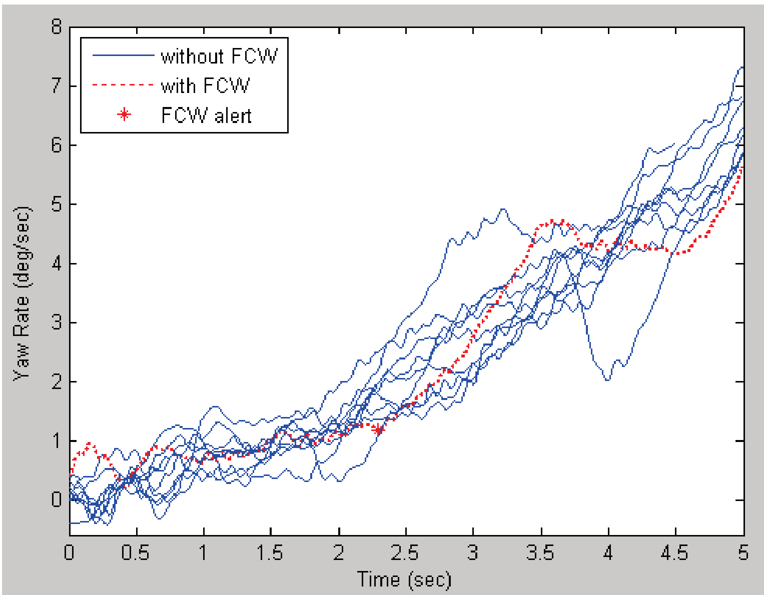

Figure 3.7. Subaru Outback Yaw Rate – Stationary Vehicle at Curve Entrance (25 mph)

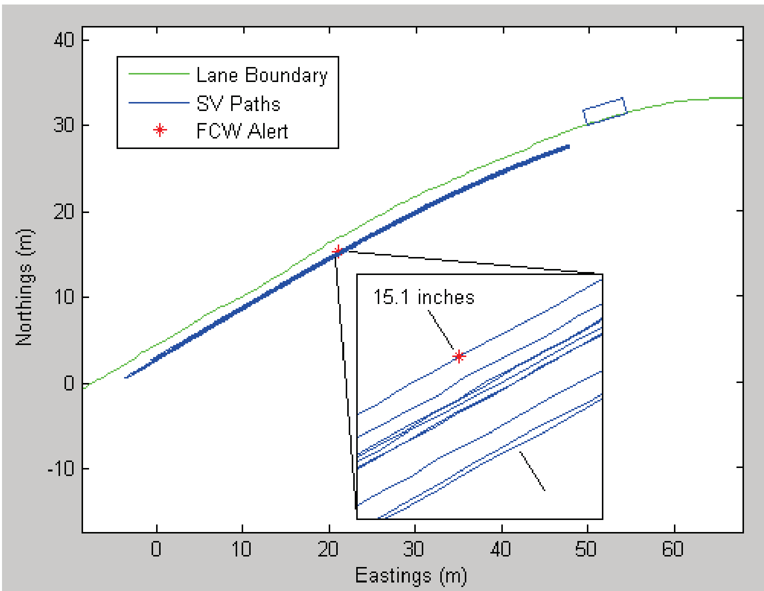

Figure 3.8. Subaru Outback Paths and FCW Alert Location – Stationary Vehicle at Curve Entrance (25 mph)

Table 3.8. Subaru Outback Test Input Conditions and Results – Stationary Vehicle at Curve Entrance

Test Information			Test Input Conditions						Test Output		
									FCW Onset		
Vehicle	Test Speed (mph)	Test Number	Throttle Position (% of WOT) (min, max)	Longitudinal Speed (mph) (min, max)	Longitudinal Acceleration (g) (min, max)	Yaw Rate (deg/sec) (min, max)	Range at Steering Onset (ft)	Valid Test? (y/n)	Range (ft)	Speed (mph)	TTC (sec)
Subaru Outback (6-30-11)	25	210[1]	0, 8.6	24.1, 25.0	-0.04, 0.01	0.20, 5.66	126.0	Y	97.6	24.9	2.7
		211	2.3, 6.7	25.1, 25.5	-0.01, 0.02	0.23, 5.90	162.0	Y	–	–	–
		212	0, 16.0	25.7, 26.6	-0.05, 0.04	-0.27, 6.21	156.6	Y	–	–	–
		213	0, 8.3	25.1, 25.8	-0.05, 0.02	-0.33, 6.77	134.6	Y	–	–	–
		214	2.0, 7.1	25.6, 26.2	-0.02, 0.02	-0.43, 6.82	134.6	Y	–	–	–
		215	0, 5.5	25.5, 26.4	-0.04, 0.01	-0.25, 5.89	132.6	Y	–	–	–
		216	0, 7.9	24.9, 25.7	-0.05, 0.01	-0.06, 6.07	133.5	Y	–	–	–
		217	0, 7.5	25.6, 26.1	-0.03, 0.02	-0.10, 5.85	115.1	Y	–	–	–
		218	0.7, 6.3	25.4, 25.9	-0.01, 0.02	-0.41, 7.31	123.8	Y	–	–	–
		219	0, 7.1	25.1, 25.7	-0.04, 0.01	-0.42, 6.28	157.2	Y	–	–	–

[1]Tests produced an FCW activation.

3.5 Stationary Roadside Vehicles

Although it was not difficult, the Stationary Roadside Vehicles maneuver did require more time to set up and configure than the Stationary Vehicle at Curve Entrance or Object in Roadway – Steel Trench Plate scenarios. Each of the four roadside vehicles had to be centered within their respective 24 ft long parking spaces with both inboard-side tires 18 in from the lane line. A GPS survey of the four parking spaces was collected. Two sets of pylon-based gates were used to assist the subject vehicle driver in establishing the desired lateral velocity toward the center of the roadside vehicle group for both test speeds from either direction.

Performing the Stationary Roadside Vehicle tests consistently was challenging since it was not possible for the driver to initiate the single lane change toward, and near-limit avoidance input away from, the parked vehicles at exactly the same locations. For this reason, the opportunity for run-to-run differences between individual tests was much higher than for some of the other tests used in this study.

To analyze the input conditions recorded during the Stationary Roadside Vehicle tests, a six second window was used. This interval began when the subject vehicle's front bumper crossed a vertical plane defined by the end of the last parking space[14] backwards six seconds in time. As with earlier analyses, throttle position, longitudinal speed, yaw rate, and longitudinal acceleration are presented in the min, max format (see Tables 3.8 through 3.10). No brake pedal force applied was the validity criterion. Tests where an FCW alert was issued are indicated in the summary tables.

In Tables 3.8 through 3.10, Range at Steering Onset describes how far away the subject vehicle was when the driver first turned toward the formation of parked vehicles. It is provided to describe the consistency of test conduct within and between directions of travel. Here, range is the resultant distance between the center of the subject vehicle's front bumper and the lane line closest to the roadside vehicle formation at the longitudinal center of the four parking spaces. Steering onset was taken to be the instant when yaw rate magnitude first exceeded 1 deg/sec in a direction toward the roadside vehicles. Finally, the Minimum Approach Distance column describes how close the nearest front wheel of the subject vehicle came to the formation of parked vehicles.

Graphical analyses provided for this scenario include yaw rate, vehicle path, and lateral velocity toward the formation, and are presented in Figures 3.9 through 3.26. In these figures, the plane of reference is the formation of stationary roadside vehicles. Movement toward the formation is in the positive direction, regardless of the subject vehicle's direction of travel. Where applicable, the green line adjacent to the parking spaces depicts a distance of 18 inches from the lane line previously shown in Figure 2.18 (i.e., where the stationary vehicles' inboard wheels

[14] The last parking space was defined as the furthest space from the subject vehicle as it approached the line of roadside vehicles.

were located). For plotting purposes, the center of the roadside vehicle formation has been fixed at 0 m on the north axis and 0 m on the east axis.

Four of the five test vehicle used in this study issued at least one FCW alert during conduct of the Stationary Roadside Vehicle tests. The Subaru Outback was the only vehicle that did not issue an FCW alert in this scenario, regardless of test speed or direction of approach. Overall, some key findings for this maneuver include:

- Subject vehicle speed was strongly related to FCW activation frequency (albeit in a manner contrary to the Object in Roadway – Steel Trench Plate tests). 78.1 percent of the alerts were issued during tests performed at 25 mph.
- The Volvo S80 presented one FCW alert during the 45 mph tests, 5 percent of the vehicle's trials performed at that speed, but during none of the 25 mph tests.
- The Ford Explorer issued FCW alerts during 30 percent of the vehicle's trials performed at 25 mph, and during 25 percent of the 45 mph tests.
- The Mercedes E350 presented FCW alerts during 38 percent of the vehicle's test trials performed at 25 mph, but only once during the 45 mph tests, 5 percent of the vehicle's trials performed at that speed.
- The Acura MDX issued FCW alerts during 55 percent of the vehicle's 25 mph tests, but during none of the 45 mph trials.

3.5.1 Volvo S80

The only FCW alert observed during the Volvo S80 evaluation occurred during the conduct of Test 65, as highlighted in Table 3.9. As shown in this table, and in Figures 3.9 through 3.14, the inputs associated with this test were not markedly different from those of the no-alert tests performed in the series

3.5.2 Mercedes E350

As shown in Table 3.10, the Mercedes E350 produced eight alerts during the tests performed at 25 mph; four for each direction of approach. The 25 mph test series is presented graphically in Figures 3.15 through 3.20. Although the test inputs shown in Table 3.10 are unrevealing, Figures 3.15 through 3.20 suggests run-to-run variability could have influenced test outcome.

The Mercedes E350 produced one FCW activation during the tests performed at 45 mph, Test 147, as highlighted in Table 3.11. As shown in this table, and in Figures 3.21 through 3.26, none of the input conditions associated with this test were markedly different from those of the tests not producing alerts.

Table 3.9. Volvo S80 Test Input Conditions – Stationary Roadside Vehicles (45 mph)

Test Information				Test Input Conditions						
Vehicle	Test Speed (mph)	Initial Direction of Steer	Test Number	Throttle Position (% of WOT) (min, max)	Longitudinal Speed (mph) (min, max)	Longitudinal Acceleration (g) (min, max)	Yaw Rate (deg/sec) (min, max)	Range at Steering Onset (ft)	Minimum Approach Distance (ft)	Valid Test? (y/n)
Volvo S80 (6-28-11)	45	Right	51	8.0, 16.8	44.3, 45.8	-0.01, 0.04	-3.78, 3.37	233.7	4.2	Y
			53	8.6, 12.2	44.8, 45.3	-0.01, 0.01	-4.38, 2.38	216.0	4.6	Y
			55	9.7, 11.8	45.2, 45.8	0.00, 0.01	-4.27, 2.33	226.1	3.5	Y
			57	8.8, 10.7	45.1, 45.3	-0.01, 0.01	-3.94, 2.35	228.3	4.5	Y
			59	4.7, 10.6	44.8, 45.5	-0.02, 0.01	-3.75, 2.98	245.4	5.3	Y
			61	7.7, 10.5	45.0, 45.3	-0.01, 0.01	-4.56, 2.34	229.4	4.5	Y
			63	7.8, 9.9	45.1, 45.4	-0.01, 0.00	-4.67, 2.17	228.3	3.8	Y
			65[1]	6.7, 9.9	44.6, 45.1	-0.01, 0.00	-3.87, 2.27	227.8	4.5	Y
			67	3.2, 14.9	45.2, 46.0	-0.03, 0.03	-4.36, 2.70	243.9	4.8	Y
			69	8.0, 12.8	45.2, 46.0	-0.01, 0.02	-4.14, 3.24	219.9	4.1	Y
		Left	52	7.4, 11.6	44.7, 45.4	-0.01, 0.02	-2.88, 4.05	229.8	3.8	Y
			54	10.6, 12.4	45.1, 45.8	0.00, 0.01	-2.43, 3.79	223.2	5.0	Y
			56	5.9, 11.5	44.0, 44.8	-0.02, 0.01	-2.91, 4.25	218.5	6.1	Y
			58	3.8, 14.1	43.7, 45.0	-0.02, 0.02	-2.40, 4.09	220.1	5.1	Y
			60	7.4, 13.7	45.3, 45.6	-0.01, 0.02	-3.10, 4.06	231.1	5.0	Y
			62	8.5, 9.9	45.1, 45.5	-0.02, 0.01	-2.53, 3.56	223.0	4.8	Y
			64	6.1, 8.9	44.2, 45.2	-0.02, 0.00	-3.06, 4.95	217.6	4.7	Y
			66	5.2, 10.5	45.0, 45.6	-0.02, 0.01	-3.23, 4.64	217.6	5.5	Y
			68	10.1, 11.4	45.5, 46.2	-0.01, 0.01	-3.36, 4.69	218.7	5.2	Y
			70	8.8, 11.6	45.5, 46.2	-0.01, 0.01	-2.87, 3.49	228.6	4.5	Y

[1]Test produced an FCW activation.

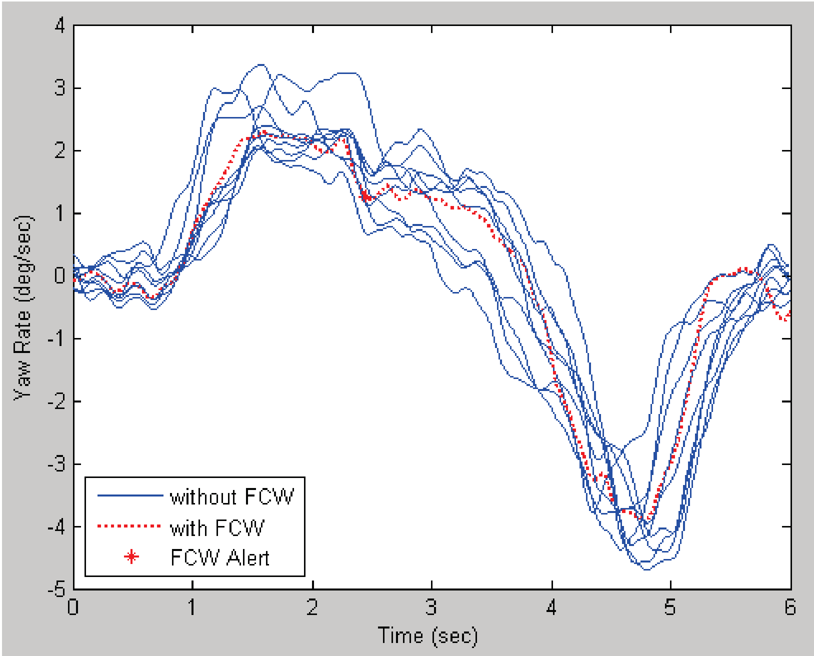

Figure 3.9. Volvo S80 Yaw Rate – Stationary Roadside Vehicles on the Right (45 mph)

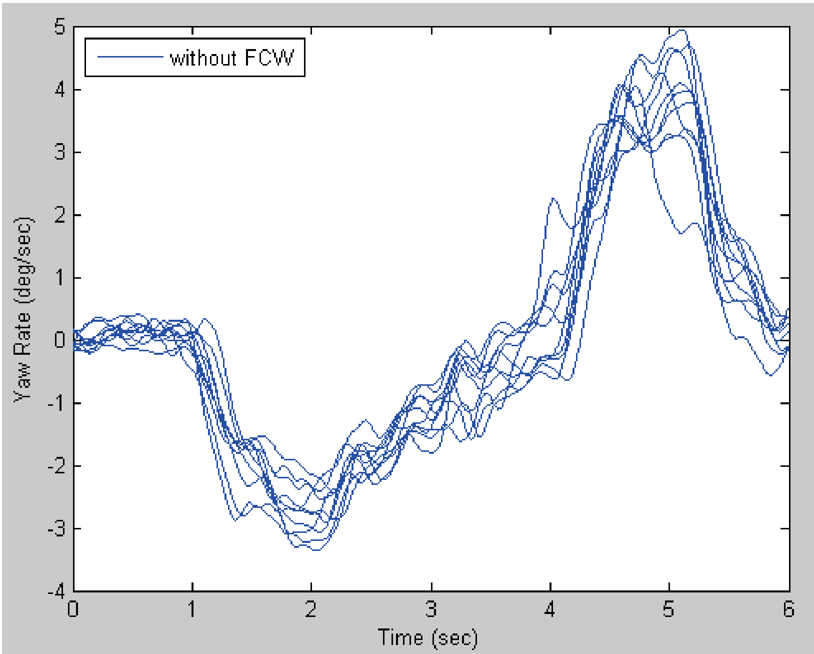

Figure 3.10. Volvo S80 Yaw Rate – Stationary Roadside Vehicles on the Left (45 mph)

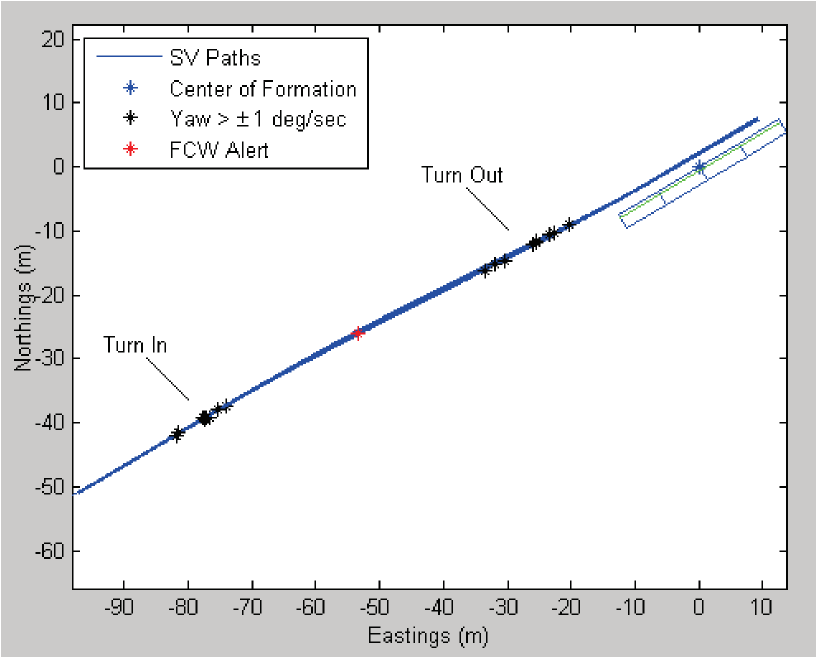

Figure 3.11. Volvo S80 Paths and FCW Alert Location – Stationary Roadside Vehicles on the Right (45 mph)

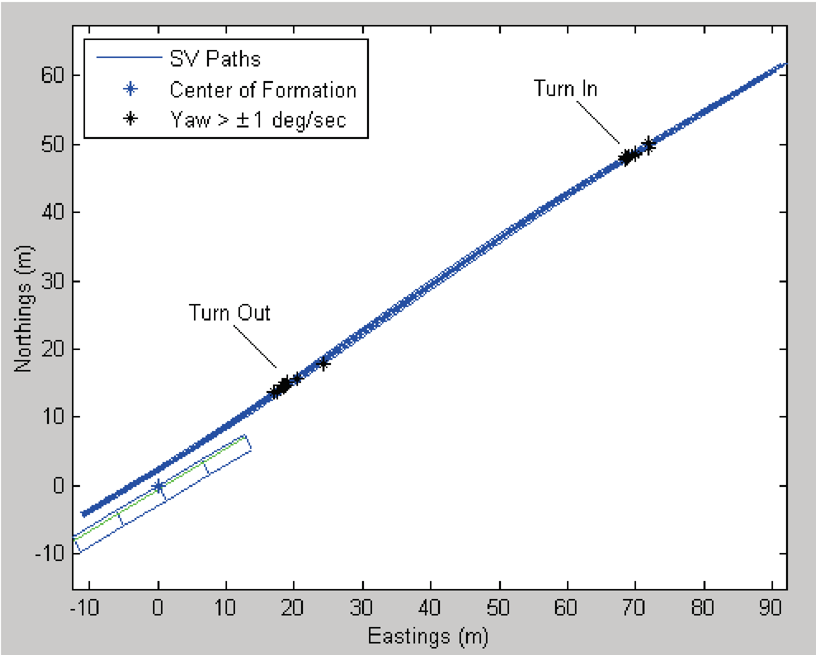

Figure 3.12. Volvo S80 Paths – Stationary Roadside Vehicles on the Left (45 mph)

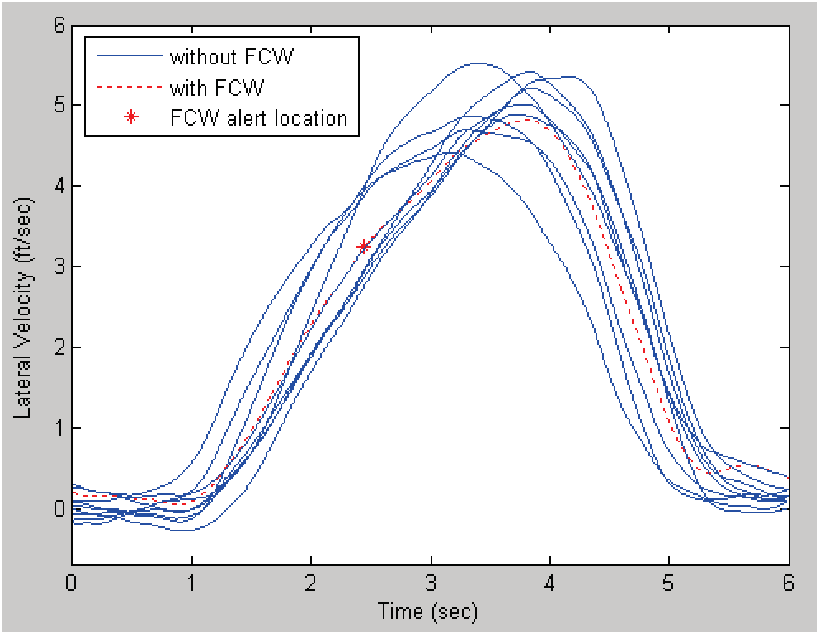

Figure 3.13. Volvo S80 Lateral Velocity Toward Formation – Stationary Roadside Vehicles on the Right (45 mph)

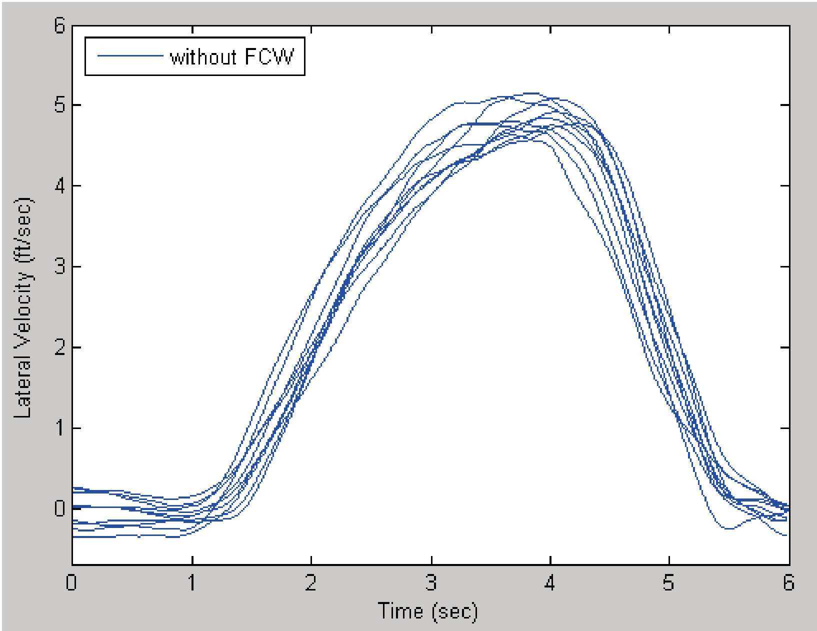

Figure 3.14. Volvo S80 Lateral Velocity Toward Formation – Stationary Roadside Vehicles on the Left (45 mph)

Table 3.10. Mercedes E350 Test Input Conditions – Stationary Roadside Vehicles (25 mph)

Test Information				Test Input Conditions						
Vehicle	Test Speed (mph)	Initial Direction of Steer	Test Number	Throttle Position (% of WOT[1]) (min, max)	Longitudinal Speed (mph) (min, max)	Longitudinal Acceleration (g) (min, max)	Yaw Rate (deg/sec) (min, max)	Range at Steering Onset (ft)	Minimum Approach Distance (ft)	Valid Test? (y/n)
Mercedes E350 (6-28-11)	25	Right	155	n/a	25.8, 26.5	-0.01, 0.02	-7.03, 4.64	107.5	3.9	Y
			157[2]	n/a	25.0, 25.3	-0.01, 0.01	-6.92, 4.52	106.6	3.9	Y
			159	n/a	25.3, 26.1	-0.01, 0.02	-6.15, 4.09	109.3	3.9	Y
			161	n/a	25.4, 26.4	-0.01, 0.02	-6.59, 4.05	108.9	4.6	Y
			163[2]	n/a	25.0, 25.2	-0.02, 0.01	-6.42, 3.66	110.4	3.8	Y
			165	n/a	25.1, 25.2	-0.02, 0.01	-6.42, 3.81	113.6	4.6	Y
			167[2]	n/a	25.3, 26.4	-0.01, 0.02	-7.10, 3.78	101.0	4.0	Y
			169	n/a	25.4, 26.1	-0.01, 0.02	-6.77, 4.23	111.0	3.8	Y
			171[2]	n/a	25.6, 26.1	-0.01, 0.01	-5.86, 3.97	115.0	5.0	Y
			173	n/a	25.3, 25.9	-0.01, 0.01	-6.85, 3.98	110.3	4.2	Y
			175	n/a	25.3, 26.0	-0.01, 0.02	-6.84, 4.23	108.7	3.6	Y
		Left	158	n/a	24.0, 24.8	-0.02, 0.00	-4.16, 6.09	113.7	5.5	Y
			160	n/a	24.8, 25.4	-0.02, 0.00	-4.16, 6.01	108.7	4.8	Y
			162[2]	n/a	25.6, 26.3	-0.01, 0.02	-3.76, 6.68	106.8	5.6	Y
			164[2]	n/a	25.4, 25.7	-0.01, 0.01	-4.13, 7.11	105.0	6.0	Y
			166	n/a	25.8, 26.3	-0.01, 0.01	-4.25, 6.57	111.0	5.4	Y
			168	n/a	24.6, 25.4	-0.02, 0.01	-3.78, 6.41	109.1	3.9	Y
			170	n/a	25.5, 25.6	-0.01, 0.01	-4.19, 6.92	108.5	2.7	Y
			172	n/a	25.3, 25.9	0.00, 0.02	-4.14, 6.73	113.4	3.7	Y
			174[2]	n/a	25.5, 25.5	-0.01, 0.01	-4.31, 6.32	99.5	5.4	Y
			176[2]	n/a	25.0, 26.6	0.00, 0.02	-4.09, 6.47	104.5	4.9	Y

[1] For unknown reasons, the TPS channel was not working on this day of testing.
[2]Test produced an FCW activation

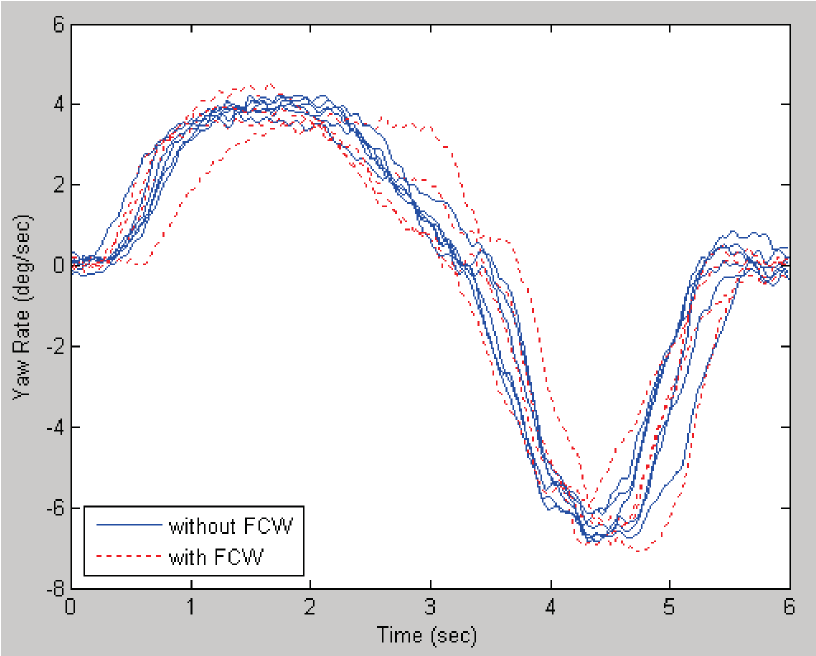

Figure 3.15. Mercedes E350 Yaw Rate – Stationary Roadside Vehicles on the Right (25 mph)

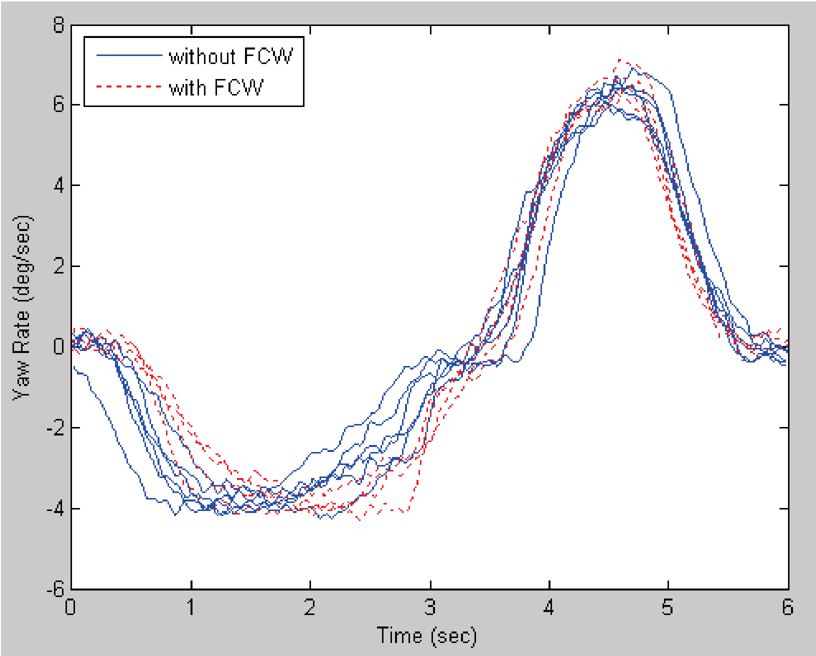

Figure 3.16. Mercedes E350 Yaw Rate – Stationary Roadside Vehicles on the Left (25 mph)

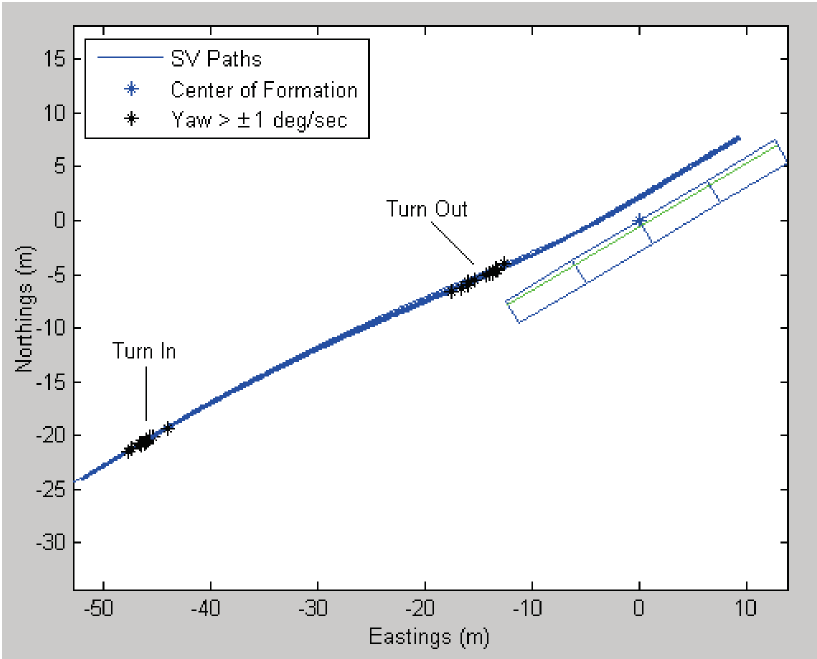

Figure 3.17. Mercedes E350 Paths – Stationary Roadside Vehicles on the Right (25 mph)

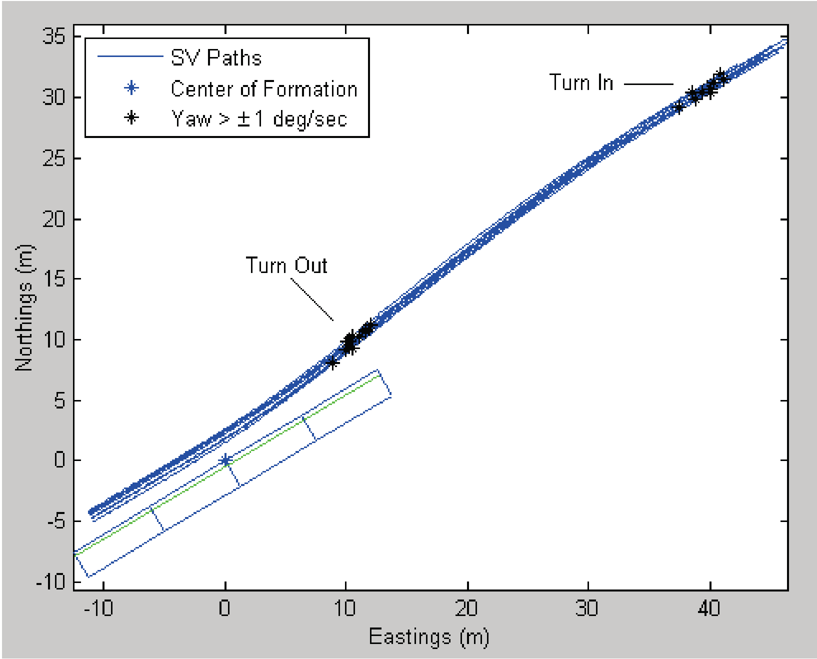

Figure 3.18. Mercedes E350 Paths – Stationary Roadside Vehicles on the Left (25 mph)

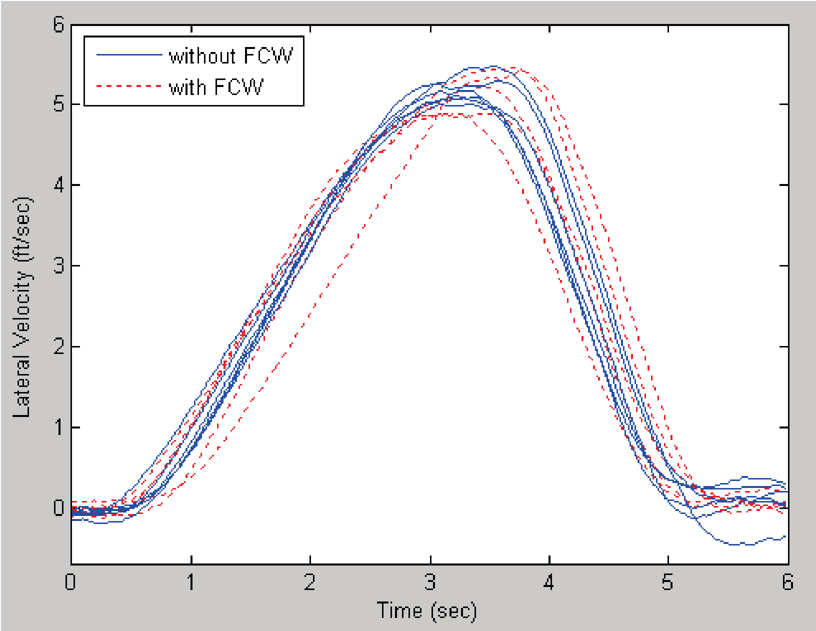

Figure 3.19. Mercedes E350 Lateral Velocity Toward Formation – Stationary Roadside Vehicles on the Right (25 mph)

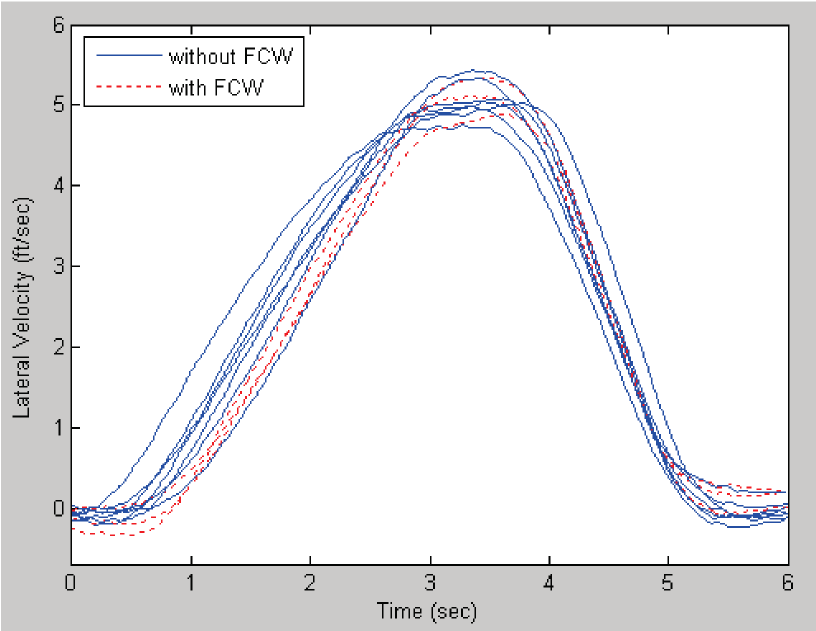

Figure 3.20. Mercedes E350 Lateral Velocity Toward Formation – Stationary Roadside Vehicles on the Left (25 mph)

Table 3.11. Mercedes E350 Test Input Conditions – Stationary Roadside Vehicles (45 mph)

Test Information				Test Input Conditions						
Vehicle	Test Speed (mph)	Initial Direction of Steer	Test Number	Throttle Position (% of WOT[1]) (min, max)	Longitudinal Speed (mph) (min, max)	Longitudinal Acceleration (g) (min, max)	Yaw Rate (deg/sec) (min, max)	Range at Steering Onset (ft)	Minimum Approach Distance (ft)	Valid Test? (y/n)
Mercedes E350 (6-28-11)	45	Right	135	n/a	44.9, 45.1	-0.02, 0.01	-3.51, 2.34	211.8	4.5	Y
			137	n/a	44.8, 45.5	-0.02, 0.02	-3.88, 2.81	213.9	4.4	Y
			139	n/a	45.5, 45.8	-0.02, 0.01	-4.69, 2.52	211.6	3.8	Y
			141	n/a	43.9, 45.4	-0.03, 0.00	-5.47, 2.55	210.6	4.3	Y
			143	n/a	44.7, 45.8	-0.01, 0.02	-3.64, 3.59	241.5	4.7	Y
			145	n/a	45.3, 45.9	-0.02, 0.01	-4.92, 2.74	209.8	4.3	Y
			147[2]	n/a	45.3, 45.8	-0.02, 0.02	-5.35, 2.57	224.5	3.9	Y
			149	n/a	45.1, 45.3	-0.01, 0.01	-5.83, 2.93	219.5	4.7	Y
			151	n/a	44.3, 45.3	-0.02, 0.03	-4.59, 3.07	227.9	4.3	Y
			153	n/a	45.6, 47.3	0.00, 0.02	-4.39, 2.78	232.8	4.4	Y
		Left	136	n/a	44.9, 45.7	-0.02, 0.00	-2.98, 3.91	225.5	3.5	Y
			138	n/a	45.5, 46.1	-0.02, 0.02	-3.40, 4.00	231.4	5.3	Y
			140	n/a	45.5, 45.8	-0.01, 0.01	-3.01, 4.31	226.6	5.5	Y
			142	n/a	45.2, 46.0	-0.03, 0.02	-2.70, 4.42	220.2	4.2	Y
			144	n/a	45.4, 45.7	-0.02, 0.01	-2.28, 4.09	218.2	4.4	Y
			146	n/a	44.3, 45.4	-0.03, 0.02	-2.61, 4.30	228.6	3.6	Y
			148	n/a	45.6, 45.7	-0.01, 0.01	-2.68, 4.47	227.2	3.3	Y
			150	n/a	45.2, 45.5	-0.01, 0.01	-3.02, 4.81	223.6	3.4	Y
			152	n/a	45.2, 45.6	-0.02, 0.01	-3.03, 4.07	201.0	4.3	Y
			154	n/a	45.4, 45.7	-0.03, 0.01	-3.31, 4.45	196.6	4.8	Y

[1]For unknown reasons, the TPS channel was not working on this day of testing.
[2]Test produced an FCW activation.

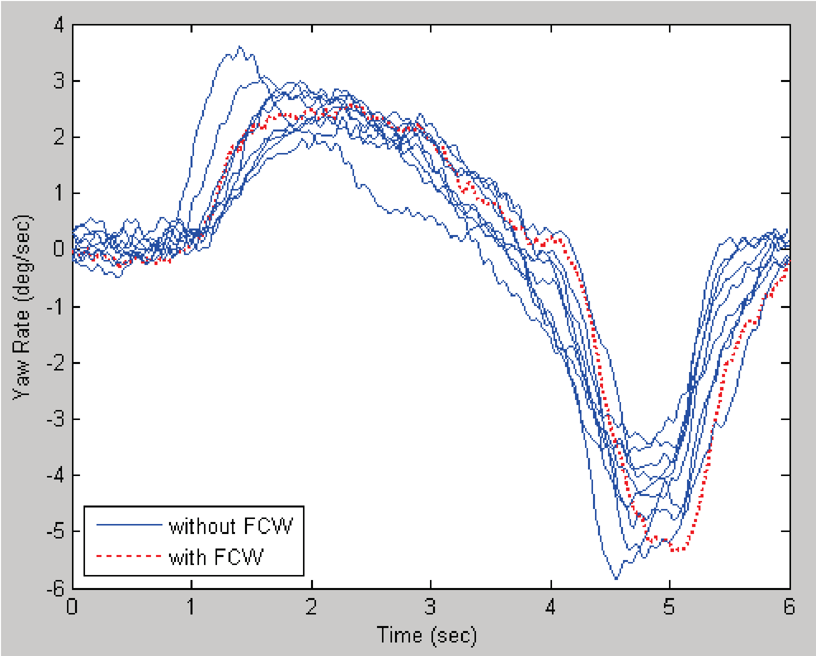

Figure 3.21. Mercedes E350 Yaw Rate – Stationary Roadside Vehicles on the Right (45 mph)

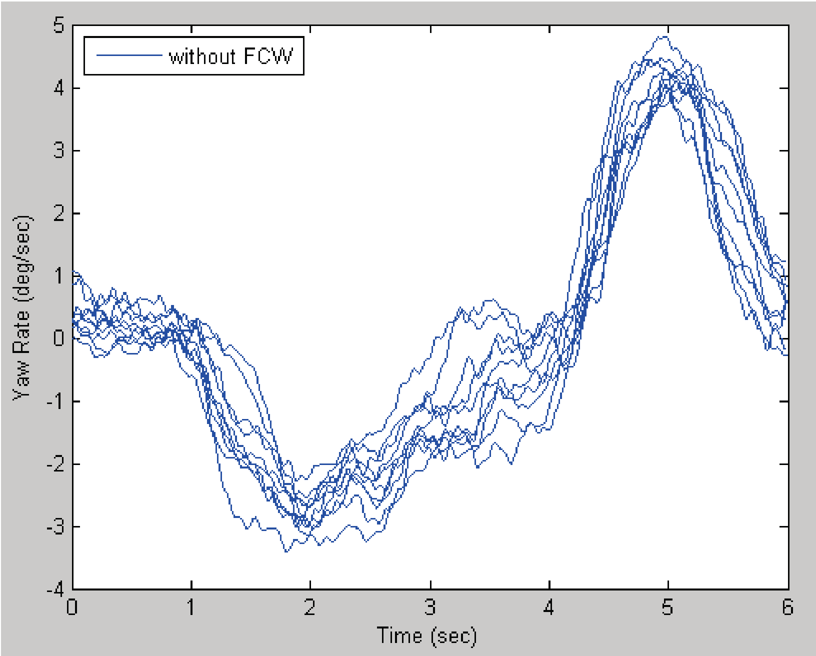

Figure 3.22. Mercedes E350 Yaw Rate – Stationary Roadside Vehicles on the Left (45 mph)

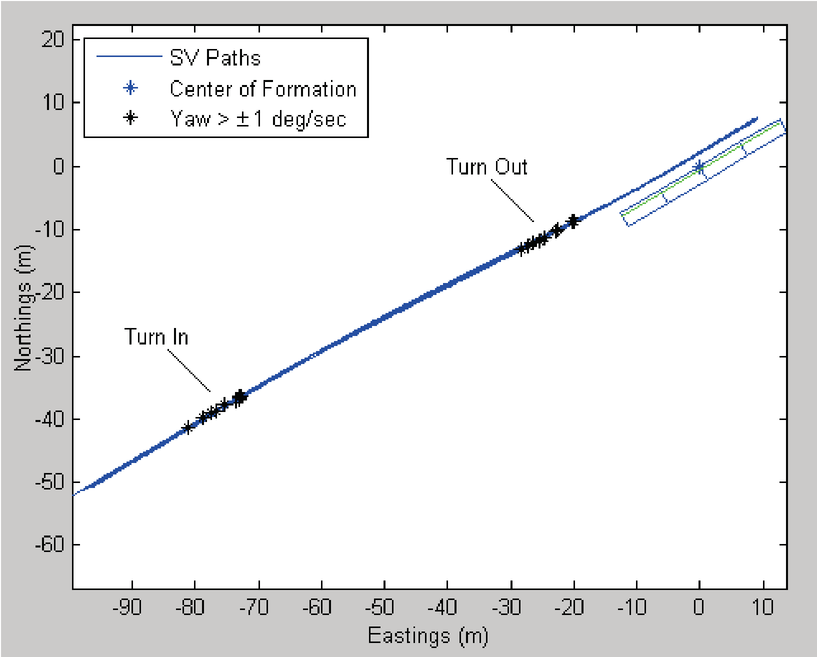

Figure 3.23. Mercedes E350 Paths – Stationary Roadside Vehicles on the Right (45 mph)

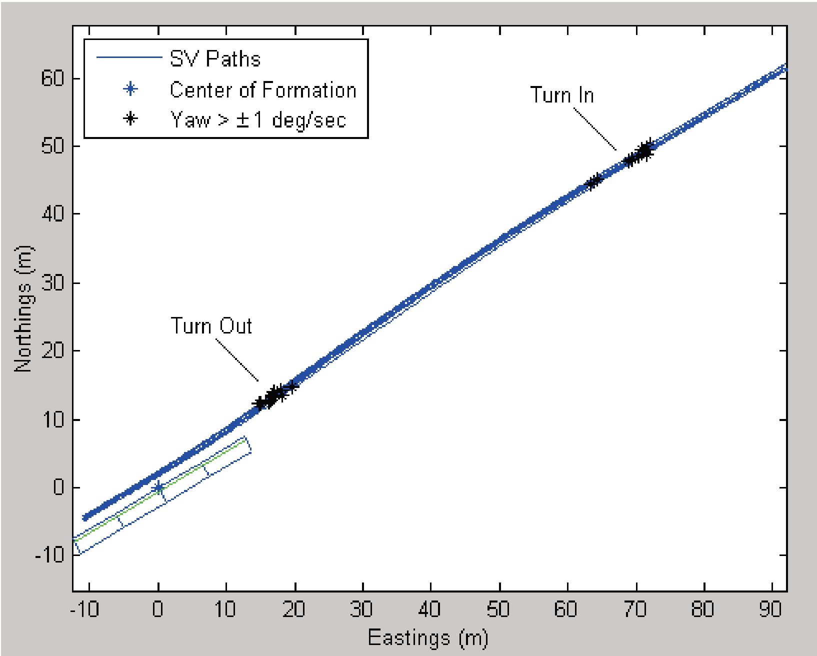

Figure 3.24. Mercedes E350 Paths – Stationary Roadside Vehicles on the Left (45 mph)

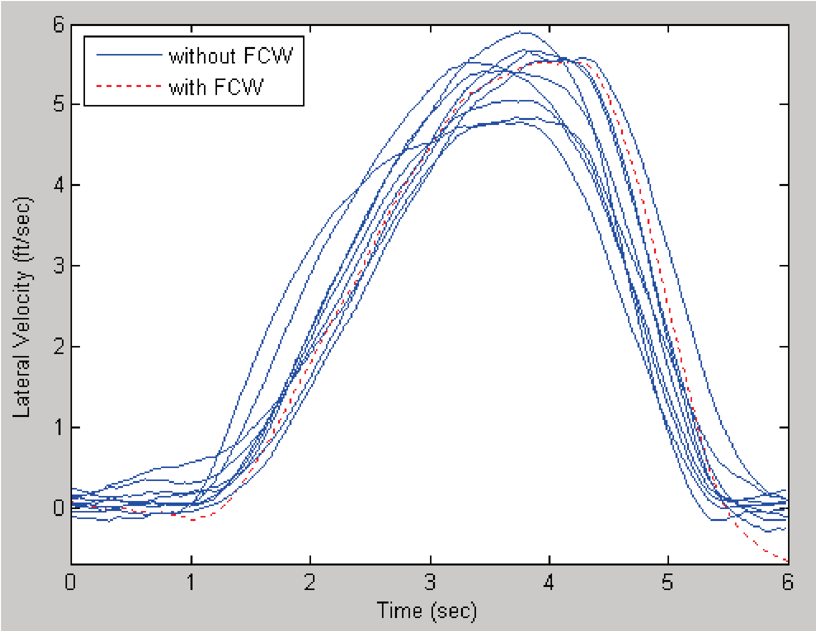

Figure 3.25. Mercedes E350 Lateral Velocity Toward Formation – Stationary Roadside Vehicles on the Right (45 mph)

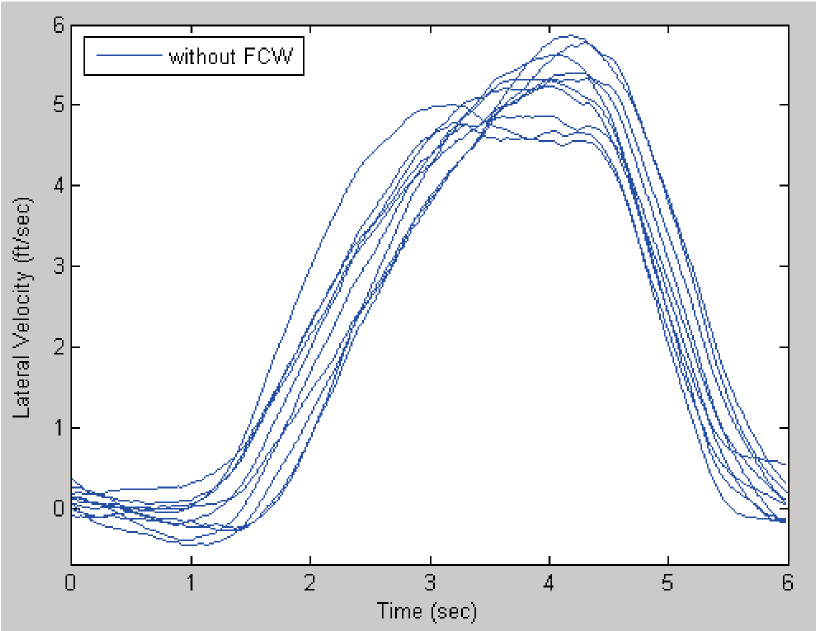

Figure 3.26. Mercedes E350 Lateral Velocity Toward Formation – Stationary Roadside Vehicles on the Left (45 mph)

3.6 Decelerating Vehicle in an Adjacent Lane (Curved Road)

Since Decelerating Vehicle in an Adjacent Lane (Curved Road) tests were performed on an existing facility with line-delineated lanes, and since each vehicle was initially moving, conduct of the maneuver required no set-up time or course measurement beyond GPS surveying. However, of all the maneuvers used in this study, it was the most difficult one to perform. To ensure stable initial conditions, the vehicles had to be kept in a tight formation for three seconds before each test began. Once the decelerating vehicle began braking, the subject vehicle-to-POV headway was maintained for approximately 6 additional seconds. Due to facility size limitations, the 630 ft radius of the TRC VDA north loop provided a 30-second window of opportunity to complete each 45 mph test run. Approximately 20 percent of all tests run were not within the specified range, speed, and/or lane position. In addition, there were also one or two trials per vehicle where the maneuver was initiated but aborted because the initial conditions were not satisfied.

To begin the evaluation process, a reference in the time domain was established. This was taken to be the instant when the decelerating lead vehicle first satisfied a deceleration threshold of 0.27g (recall the test protocol specified a target deceleration of 0.3g ± 0.03g (±10%) be used during the test). The vehicles' test input conditions were analyzed from three seconds prior to satisfying the deceleration threshold to when the front bumper of the subject vehicle reached a plane defined by the decelerating lead vehicle's rear bumper.

Of the five evaluated in this study, the Volvo S80 was the only vehicle to issue an FCW false positive alert in the Decelerating Vehicle in an Adjacent Lane (Curved Road) scenario, and it did so only once.

As with previous analyses, throttle position, longitudinal speed, yaw rate, and longitudinal acceleration are presented in the min, max format, and no brake pedal force applied by the subject vehicle driver was the validity criterion. Additionally, average longitudinal acceleration of the DLV and the resultant range between the subject vehicle and the POV were analyzed and are presented in the min, max format. Test outputs were subject vehicle-to-DLV range, subject vehicle speed, and the TTC when the FCW alert was issued (using the right-rear corner of the decelerating lead vehicle bumper as the basis for calculating range from).

As shown in Table 3.12, Volvo S80 Test 254 was the only trial performed at 45 mph to produce an FCW false positive. Consideration of the data summary shown in Table 3.12, as well as the yaw rate and path data presented in Figures 3.27 – 3.30, do not indicate Test 254 was performed in a manner markedly different than the other 23 tests that did not produce an FCW alert in this condition.

Note: Due to the challenges associated with establishing and maintaining the three-vehicle formation used for the Decelerating Vehicle in an Adjacent Lane (Curved Road) scenario, the individual test trials began at different places within the test lanes. Therefore, to facilitate a direct comparison of the vehicle paths, a coordinate transformation was used to create a consistent subject vehicle position at the beginning of each trial (i.e., when the decelerating vehicle first reached -0.27 g). This point corresponds to (0, 0) on the 'normalized' axes used in Figures 3.29 and 3.30. The other vehicles' paths were then plotted relative to the path of the subject vehicle until the test concluded. As with earlier graphical analyses, it was important to know the state of the vehicle when the FCW alert was issued and to note any distinguishing characteristics between the tests that did, and did not, include an FCW activation.

Table 3.12. Volvo S80 Test Input Conditions and Results – Decelerating Vehicle in an Adjacent Lane (Curved Road) (45 mph)

Test Information				Test Input Conditions							Test Output		
Vehicle	Test Speed (mph)	Direction of Travel	Test Number	Throttle Position (% of WOT) (min, max)	Longitudinal Speed (mph) (min, max)	Longitudinal Acceleration (g) (min, max)	Yaw Rate (deg/sec) (min, max)	Valid Test? (y/n)	Average Long. Acceleration (g) - Taurus	Volvo-Buick Range (ft) (min, max)	FCW Onset		
											Range (ft)	Speed (mph)	TTC (sec)
Volvo S80 (8-2-11)	45	West to East	249	9.6, 17.8	45.6, 46.2	-0.02, 0.03	5.02, 6.89	Y	-0.299	197.7, 201.2	–	–	–
			250	11.0, 15.4	45.6, 46.2	-0.01, 0.01	5.11, 7.15	Y	-0.326	198.8, 200.2	–	–	–
			251	4.8, 15.4	46.0, 46.4	-0.02, 0.02	5.20, 6.93	Y	-0.363	190.3, 194.5	–	–	–
			252	8.0, 14.6	45.6, 46.1	-0.01, 0.01	5.38, 7.08	Y	-0.295	191.2, 195.1	–	–	–
			253	9.9, 17.0	45.6, 46.2	-0.02, 0.02	4.43, 6.51	Y	-0.306	191.8, 192.3	–	–	–
			254[1]	9.6, 17.8	45.4, 45.9	-0.02, 0.03	5.47, 6.63	Y	-0.317	198.4, 202.0	159.0	45.9	2.4
			255	9.1, 14.6	45.5, 46.0	-0.02, 0.01	4.97, 7.03	Y	-0.313	189.6, 195.3	–	–	–
			257	5.4, 13.5	45.6, 45.9	-0.02, 0.01	5.08, 6.98	Y	-0.320	201.5, 202.8	–	–	–
			259	3.8, 13.7	45.2, 45.9	-0.03, 0.01	5.32, 6.88	Y	-0.317	195.6, 199.6	–	–	–
			260	8.5, 16.7	45.4, 46.0	-0.02, 0.02	5.05, 6.47	Y	-0.321	197.0, 199.0	–	–	–
		East to West	221	8.4, 17.2	45.4, 46.2	-0.02, 0.03	-6.65, -5.37	Y	-0.368	193.2, 196.9	–	–	–
			222	9.1, 15.4	45.1, 46.0	-0.02, 0.01	-6.77, -4.78	Y	-0.343	195.3, 200.4	–	–	–
			223	9.5, 15.6	45.3, 45.8	-0.01, 0.02	-6.76, -5.17	Y	-0.327	194.2, 199.4	–	–	–
			225	6.6, 16.0	45.6, 45.9	-0.02, 0.02	-7.00, -5.02	Y	-0.299	194.3, 197.1	–	–	–
			226	8.8, 17.0	45.3, 45.9	-0.02, 0.03	-7.10, -4.98	Y	-0.304	196.9, 201.8	–	–	–
			227	8.9, 14.7	45.3, 45.8	-0.02, 0.01	-6.72, -5.06	Y	-0.311	196.5, 200.6	–	–	–
			228	9.7, 15.1	45.3, 45.8	-0.02, 0.01	-6.83, -5.13	Y	-0.315	192.8, 194.4	–	–	–
			231	3.7, 15.0	45.2, 45.7	-0.03, 0.02	-7.27, -5.19	Y	-0.309	193.5, 200.4	–	–	–
			232	7.3, 15.8	45.2, 46.0	-0.03, 0.02	-6.85, -5.00	Y	-0.298	188.9, 203.0	–	–	–
			233	9.4, 14.0	45.1, 45.5	-0.02, 0.01	-6.82, -4.84	Y	-0.302	194.5, 203.1	–	–	–

[1]Test produced an FCW activation.

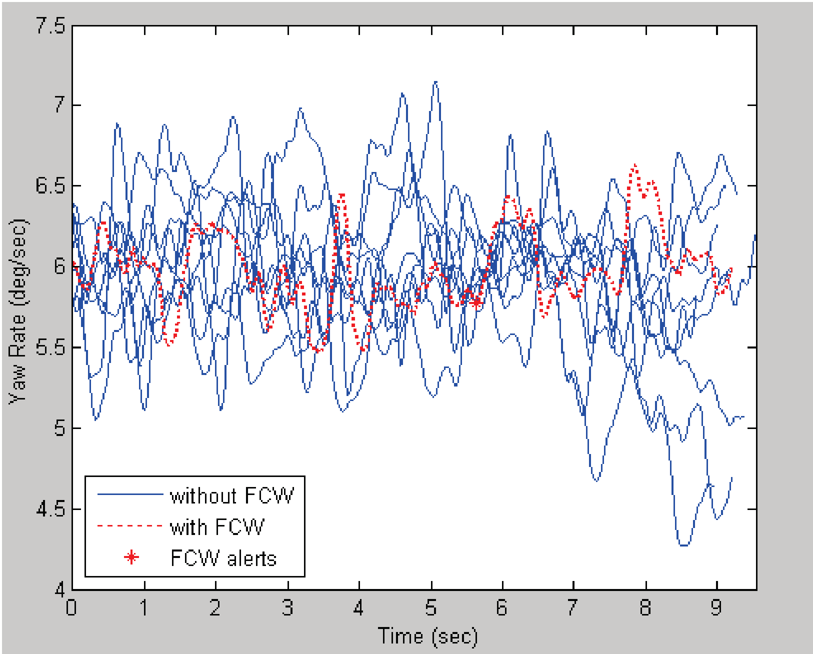

Figure 3.27. Volvo S80 Yaw Rate – Decelerating Vehicle in Left Lane (Curved Road) (45 mph)

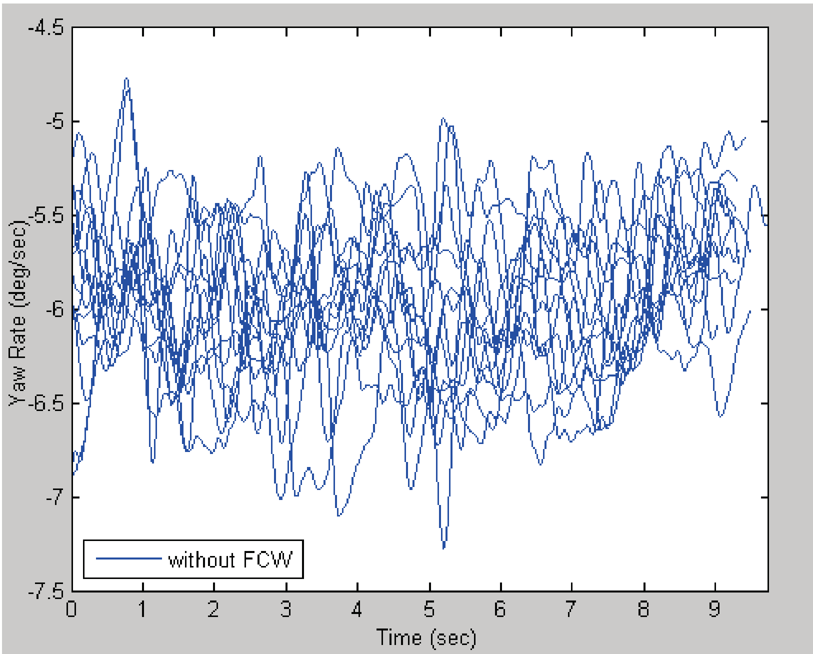

Figure 3.28. Volvo S80 Yaw Rate – Decelerating Vehicle in Right Lane (Curved Road) (45 mph)

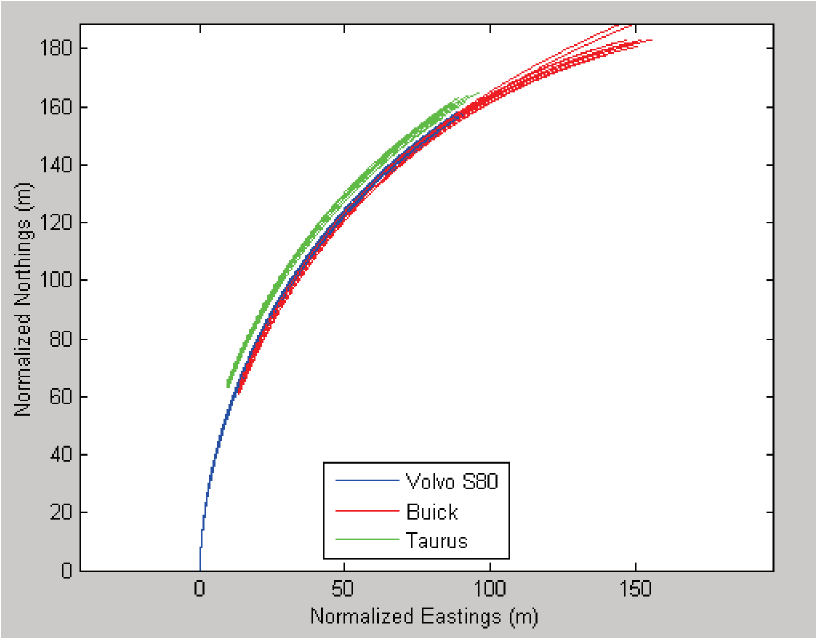

Figure 3.29. Vehicle Paths – Decelerating Vehicle in Left Lane (Curved Road) (45 mph)

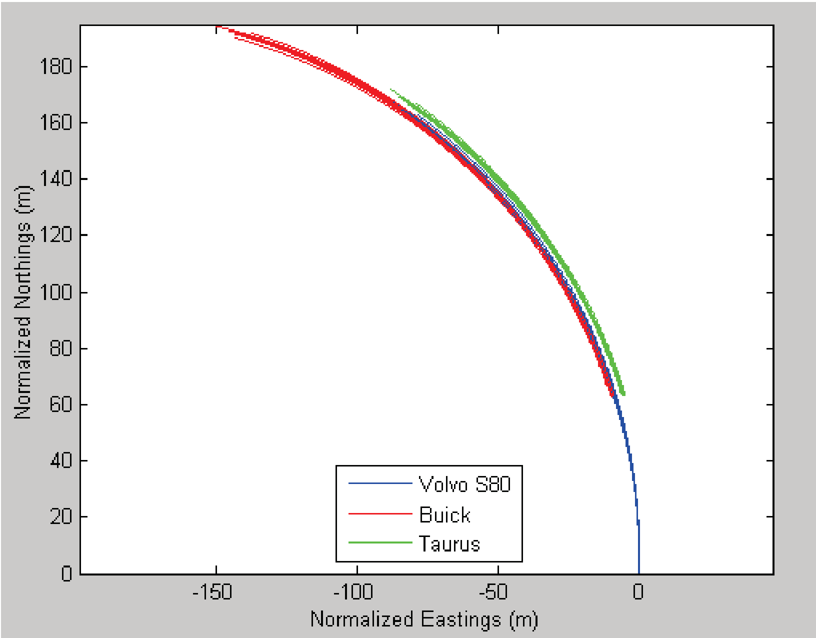

Figure 3.30. Vehicle Paths – Decelerating Vehicle in Right Lane (Curved Road) (45 mph)

To further examine Volvo S80 Test 254, the only trial performed at 45 mph to produce an FCW false positive, several additional plots were created. The speed and range data of the vehicles observed throughout the maneuver are shown in Figure 3.31. In agreement with the previously presented data, the data from Test 254 (red line) was not found to be markedly different than from that associated with the tests that did not produce an FCW alert.

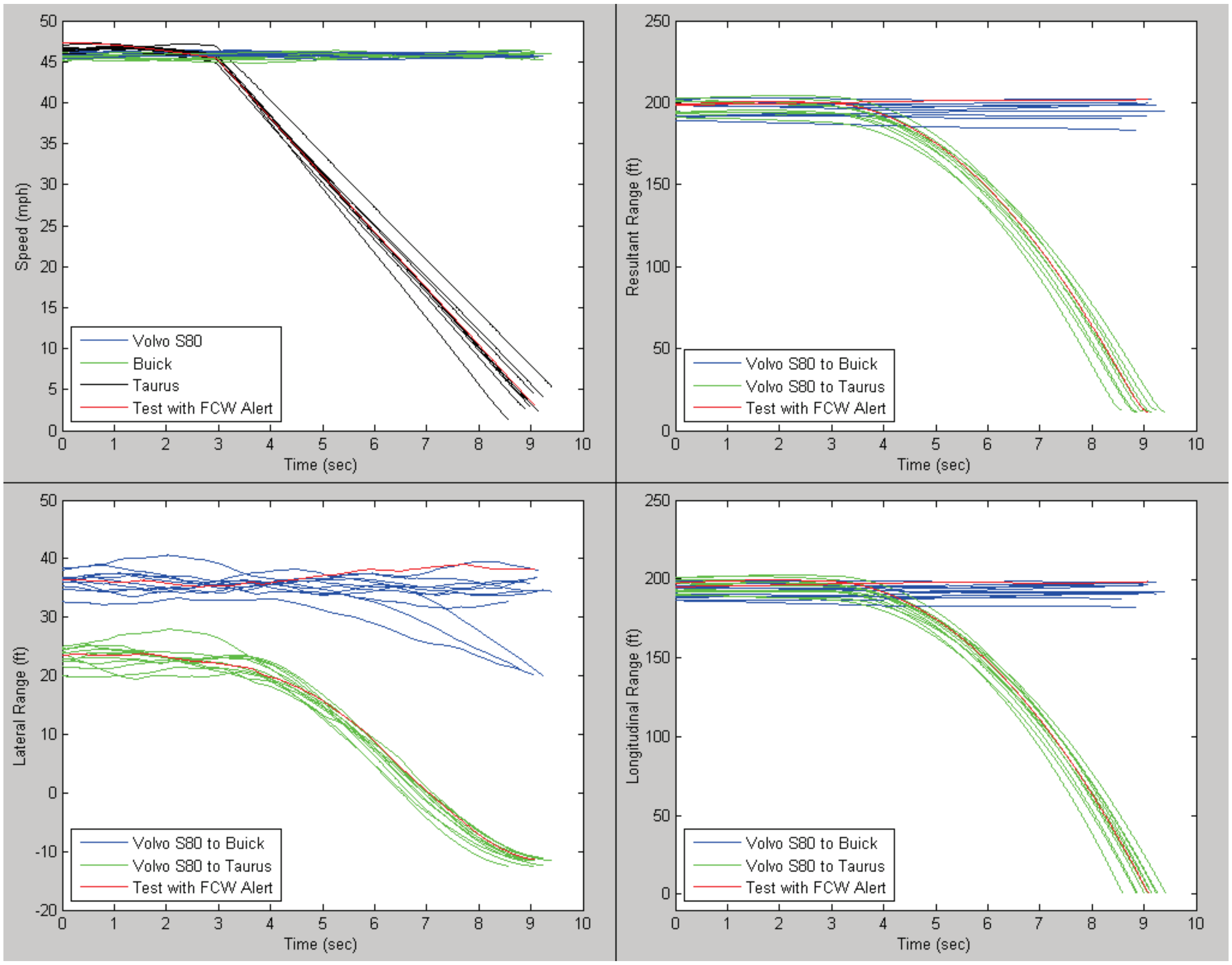

Figure 3.31. Vehicle Velocities and Range Data – Decelerating Vehicle in Left Lane (Curved Road) (45 mph)

Figures 3.32 and 3.33 present a final comparative summary for clockwise tests performed at 45 mph with the Volvo S80 (the test series that produced the FCW false positive event). Here, the orientation of the subject and decelerating vehicle at a common headway were compared. The headway selected was 159 feet, which was the distance when the FCW alert was issued for Test 254 (see Range at FCW Onset, Table 3.12). The right-rear corner of the Taurus' bumper was used for graphical analysis since it was closer to the Volvo bumper than the center was, although the difference was only found to be 0.24 in.

Figure 3.32 shows the actual vehicle positions on the test track at the beginning of each trial without having the coordinate transformation process used in Figures 3.29 and 3.30 applied to the data; the axes are in true Northings and Eastings (i.e., different from what was used previously in this report). For each trial, the resultant headway of the subject vehicle to the decelerating vehicle was 159 ft. Figure 3.33 presents the same data shown in Figure 3.32, but with a common subject vehicle position and orientation. In other words, the position of the subject vehicle at a common reference point (represented as (0,0) in the top pane of Figure 3.33) and heading angle were identical for each of the ten trials shown. This allowed for the yaw angle, lateral position, and longitudinal position of the decelerating vehicle relative to the subject vehicle to be directly compared. As was the case for the other comparisons made in this section, the comparison made in Figure 3.33 offers no explanation as to why one test had an FCW alert and the others did not.

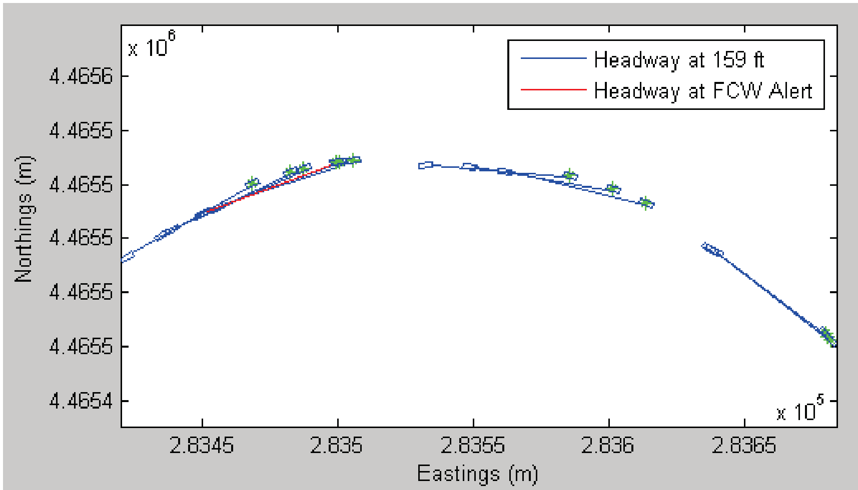

Figure 3.32. Vehicle Positions – Decelerating Vehicle in Left Lane (Curved Road) (45 mph)

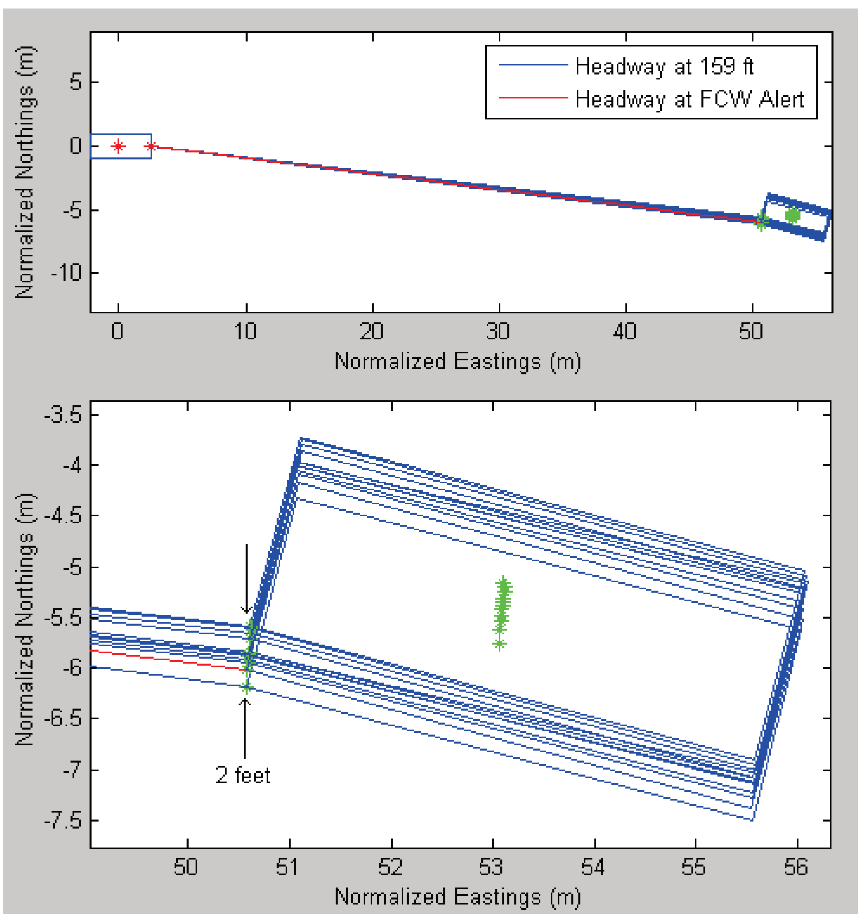

Figure 3.33. Overlaid Vehicle Positions – Decelerating Vehicle in Left Lane (Curved Road) (45 mph)

4.0 CONCLUSIONS

The objectives of the research described in this report were twofold: to evaluate whether CIB false positives can be consistently observed on the test track using maneuvers representative of eight real-world driving scenarios, and to assess the practicality of accurately and repeatably performing these maneuvers. To satisfy these objectives, five later model light vehicles were evaluated using eight test maneuvers performed at two test speeds.

Were CIB False Positives Consistently Observed on the Test Track?

Generally speaking, this was not the case. CIB false positive activations were observed only during Object in Roadway – Steel Trench Plate tests performed with the Acura MDX. However, the vehicle's response was very repeatable, as these activations occurred during 100 percent of the tests performed in this condition for both test speeds. All CIB false activations observed during evaluation of the Acura MDX produced only low vehicle deceleration and mild speed reductions. For this reason, it is unknown whether these activations alone present a real-world safety problem. As expected, FCW alerts always preceded the CIB activations for this vehicle.

Far more common than CIB false positives in this study were FCW activations. For the vehicles evaluated in this study, FCW activations were passive; they had no direct effect on the state of the vehicle since automatic braking was not coincident with issuance of the FCW alert. FCW activations were present during the conduct of four maneuvers:

- Object in Roadway – Steel Trench Plate;
- Stationary Vehicle at Curve Entrance;
- Stationary Roadside Vehicles; and
- Decelerating Vehicle in an Adjacent Lane – Curve.

When contemplating these results, it is important to consider the fundamental differences in FCW versus CIB design that is apparent in most contemporary implementations. For CIB, effectiveness is quantified in terms of speed reduction before impact. For an FCW alert to be effective, it must be issued early enough for the driver to detect, comprehend, and respond to the alert effectively. However, these activations must balance potential effectiveness with customer acceptance (i.e., if issued too early, the driver could question why the alert was presented and become annoyed).

The FCW activations observed in this study can be divided into two categories: true positive and false positive. Since the experimenters did not have a way of directly monitoring the classification or control algorithms present in each test vehicle, or a way of objectively assessing whether they were operating correctly, subjective categorization was assigned by considering the scenario and whether issuance of an FCW alert could help prevent a potential vehicle-to-vehicle collision. In the context of this study, FCW activation is relevant since it is unlikely a CIB false positive would have occurred during a maneuver incapable of activating the FCW.

Object in Roadway – Steel Trench Plate Scenario

The Object in Roadway – Steel Trench Plate scenario was capable of activating the FCW of each test vehicle equipped with a radar-only system, and since there was no actual threat presented to the subject vehicle, each activation was categorized as an FCW false positive. Ten percent of the trials per test speed performed with the Mercedes E350 (multiple radars) produced an FCW false positive. For the Ford Explorer and Acura MDX, 100 percent of the test trials produced FCW false positives regardless of test speed. Both of these vehicles were equipped with single radar-based systems.

Stationary Vehicle at Curve Entrance and Stationary Roadside Vehicles Scenarios

Each FCW activation observed during the Stationary Vehicle at Curve Entrance tests was categorized as a true positive, not as a false positive. With a nominal speed of 25 mph, FCW activations occurred during 9, 10, and 90 percent of the tests performed with the Acura MDX (single radar), Subaru Outback (stereo vision), and Volvo S80 (fused mono camera plus radar), respectively. This combination of vehicle speed and test scenario was the only one that produced an FCW alert with the stereo-vision-equipped Subaru Outback (during one of the 279 overall trials performed with the vehicle).

When the Stationary Vehicle at Curve Entrance test speed was increased to 45 mph, the number of FCW activations increased, and with the exception of the Subaru Outback, they were observed for each vehicle. FCW activations occurred during 40 and 70 percent of the tests performed with the Acura MDX and Mercedes E350, respectively, and for 100 percent of the Ford Explorer and Volvo S80 tests.

Each FCW activation observed during the Stationary Roadside Vehicle tests was categorized as a true positive, not as a false positive. With a nominal speed of 25 mph, FCW activations occurred during 30, 38, and 55 percent of the tests performed with the Ford Explorer, Mercedes E350, and Acura MDX, respectively.

When the Stationary Roadside Vehicle test speed was increased to 45 mph, the number of FCW activations generally decreased (with the Volvo S80 being the sole exception). FCW activations occurred during 5 percent of tests performed with the Mercedes E350 and Volvo S80, and during 25 percent of the tests performed with the Ford Explorer.

Although the Stationary Vehicle at Curve Entrance and Stationary Roadside Vehicles tests were able to produce true positive FCW activations, their value as tools for evaluating CIB false positive activations may be limited. The combination of subject vehicle speed, heading, range and range rate to the other vehicles was, by design, configured to present an impending crash-imminent scenario. During conduct of these maneuvers, the subject vehicle had no way of knowing the driver was intentionally suppressing their avoidance steer until the last possible instant in an attempt to intentionally elicit CIB activation (i.e., atypical driving behavior). So in this context, the FCW activations observed were not surprising; in these scenarios, the parked vehicles were correctly classified as genuine threats and the driver was notified that unless corrective action was taken, a crash would likely occur. Despite the presence of these classifications, neither maneuver was capable of eliciting CIB activation from any of the subject vehicles, implying the subject vehicle drivers may not have driven closely enough to the parked cars used in each maneuver. Since the subject vehicle drivers were aggressively avoiding the parked cars during these maneuvers, reducing the time-to-collision from when they initiated their avoidance maneuvers would unacceptability reduce driver safety and contribute to test variability (some test drivers may be willing to approach the parked vehicles closer than others).

A second reason Stationary Vehicle at Curve Entrance and Stationary Roadside Vehicles tests may ultimately be of limited utility for CIB false positive evaluation has to do with the control algorithms used in a particular vehicle's implementation. Not all CIB-equipped vehicles are configured to respond to stationary lead vehicles with automatic braking, regardless of crash likelihood. If such operation is intentionally suppressed, it is unlikely <u>any</u> CIB activations would occur, whether appropriate or otherwise. For these vehicles, it may be difficult to impossible to assess whether a vehicle is able to "pass" a test intended to evaluate false positive propensity due to system tuning or simply because of limited functionality.

<u>Decelerating Vehicle in an Adjacent Lane – Curve Scenario</u>

As was the case for the Object in Roadway – Steel Trench Plate tests, the decelerating vehicle present in the Decelerating Vehicle in an Adjacent Lane – Curve tests posed no actual threat to the subject vehicle. Therefore, any FCW activation observed in this condition would be categorized as a false positive.

However, of the 235 tests performed in this condition, only one such event occurred: during a 45 mph test performed with the Volvo S80. Why the other within-series tests performed with this vehicle did not produce the same outcome is not known. Therefore, given the inability of the Decelerating Vehicle in an Adjacent Lane – Curve condition to consistently elicit FCW false positives, the potential for this maneuver to be an effective way to evaluate CIB false positive propensity appears to be very low.

<u>Scenarios Unable to Activate CIB or FCW</u>

Since an FCW alert is, by design, expected to precede CIB activation, scenarios that failed to elicit at least one FCW alert are unlikely to repeatably induce CIB false positive events on the test track. FCW or CIB activations were <u>not</u> observed during the conduct of four maneuvers, for any test vehicle:

- Decelerating Vehicle in an Adjacent Lane – Straight
- Driving Under an Overhead Bridge
- Objects in Roadway – Botts' Dots
- Stationary Vehicle at Curve Exit

While these four maneuvers may provide vehicle manufacturers and suppliers with a way to insure system robustness, results from this study imply they may not be the best candidates for NHTSA to research CIB false positive propensity.

Can Maneuvers Capable of Triggering CIB False Positives Be Practically Performed?

Eight test scenarios were used in this study, however only the Object in Roadway – Steel Trench Plate tests were observed to produce CIB false positives. Object in Roadway – Steel Trench Plate and Decelerating Vehicle in an Adjacent Lane – Curve scenarios were observed to produce FCW false positives. The study's other scenarios either did not activate FCW or CIB, or the FCW activations produced were categorized as true positives. Therefore, only the performability of the maneuvers capable of producing, at a minimum, FCW false activations are discussed.

<u>Object in Roadway – Steel Trench Plate</u>

The Object in Roadway – Steel Trench Plate tests were straightforward to perform. The large plate used for the tests was easily procured and was simply positioned on the test course (although care must be taken to make sure the leading edge is perpendicular to the lane of travel). Maintaining vehicle speed during test conduct was performed consistently by the driver without issue. Test repeatability was excellent. Incorporating this maneuver into an objective procedure intended to evaluate CIB false positive activations on the test track would be feasible.

<u>Decelerating Vehicle in an Adjacent Lane – Curve</u>

Of all the scenarios used in this study, the Decelerating Vehicle in an Adjacent Lane – Curve was the most complicated. Three moving vehicles being driven on a curved road were used. Respecting the vehicle-to-vehicle choreography and lane position (lateral and longitudinal) imposed by these tests was difficult for the drivers to perform consistently. Although a programmable brake controller was used to facilitate the adjacent vehicle braking, brake output variability of more than 10 percent from the desired 0.3g target was observed during some individual trials. In short, if tight test tolerances are imposed (e.g., like those in the Forward Collision Warning test presently used by the Advanced Technology New Car Assessment Program [NCAP]), conduct of the Decelerating Vehicle in an Adjacent Lane – Curve is expected to require many tests beyond the number specified in the respective procedure to ensure the desired test conditions have been acceptably satisfied.

Given that this complex maneuver did not produce any CIB false positive activations, and only one FCW false activation for one vehicle, incorporating this maneuver into an objective procedure intended to evaluate CIB false positive activations on the test track does not appear feasible at this time.

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6.0 APPENDICES

Appendix A. Operator Manual Excerpts Relevant to CIB Operation and Suppression

Volvo S80

1.1.1. Adaptive Cruise Control-ACC – p160

The radar sensor and its limitations

The radar sensor is used by both Adaptive Cruise Control and the Collision Warning System with Auto-brake (see page 166). It is designed to detect cars or larger vehicles driving in the same direction as your vehicle.

⚠ WARNING

Accessories or other objects must not be installed in front of the grille.

Modification of the radar sensor could make its use illegal.

The radar sensor's capacity to detect vehicles ahead is impeded:

if the radar sensor is obstructed and cannot detect other vehicles, for example in heavy rain, or if snow or other objects are obscuring the radar sensor.

Notes

Keep the area in front of the radar sensor clean.

if the speed of vehicles ahead is significantly different from your own speed.

The radar sensor has a limited field of vision. In some situations it may detect a vehicle later than expected or not detect vehicles at all.

❶ In certain situations, the radar sensor cannot detect vehicles at close quarters, for example a vehicle that suddenly enters the lanes between your vehicle and the one that the system has already detected.

❷ Small vehicles, such as motorcycles, or vehicles not driving in the center of the lane may remain undetected.

In curves, the radar sensor may detect the wrong vehicle or lose a detected vehicle from view.

Collision Warning with Auto-brake (option) – p168

Warnings may not appear if the distance to the vehicle ahead is very small or if steering wheel and pedal movements are great, for example, due to a very active driving style.

WARNING

- In certain situations, the system cannot provide warnings or warning may be delayed if traffic conditions or other external factors make it impossible for the radar sensor or camera to detect the vehicle ahead.
- Warnings may not be provided if the distance to the vehicle ahead is short, or if movements of the steering wheel/brake pedal are great, such as during active driving.
- The sensor system has a limited range for stationary or slow-moving vehicles and may therefore give delayed or no warnings if your vehicle's speed is above approximately 45 mph (70 km/h).
- Warnings for stationary or slow-moving vehicles may not be provided in dark conditions.

The Collision Warning system uses the same radar sensors as Adaptive Cruise Control. For more information on the radar sensor and its limitations, see page 160.

If no warning is given, or if a warning is delayed, Auto-brake will also not be provided or will be delayed.

Ford Explorer

COLLISION WARNING SYSTEM (IF EQUIPPED)

The collision warning with brake support is designed to alert the driver of certain collision risks with a red warning light located above the dashboard and an audible warning chime. The brake support assists the driver in reducing the collision speed, by pre-charging the brakes.

WARNING: This system is designed to be a supplementary driving aid. It is not intended to replace the driver's attention, and judgment, or the need to apply the brakes. This system does NOT activate the brakes automatically. Failure to press the brake pedal to activate the brakes may result in a collision.

WARNING: The collision warning system with brake support cannot help prevent all collisions. Do not rely on this system to replace driver judgment and the need to maintain distance and speed.

Note: The collision warning with brake support will not detect, warn, or respond to potential collisions with vehicles to the rear or sides of the vehicle.

Operation

The radar sensor detects vehicles ahead that are moving in the same direction as your vehicle. If the radar detects that your vehicle is rapidly closing on another vehicle a red warning light will illuminate and an audible warning chime will sound. After that, if the risk of collision further increases after the warning light, the brake support prepares the brake system for rapid braking. This may be apparent to the driver. However, the system will not automatically activate the brakes. The vehicle will not stop unless the driver presses the brake pedal. If the brake pedal is pressed then braking is implemented with full brake function, even if the force on the brake pedal is light. The collision warning system is active at speeds above approximately 5 mph (8 km/h).

Collision warning system limitations

Due to the nature of radar technology, there may be certain instances where vehicles will not provide a collision warning. These include:

• Stationary or slow moving vehicles below 6 mph (10 km/h).

• Pedestrians or objects in the roadway.

• Oncoming vehicles in the same lane.

• Severe weather conditions (see also blocked sensor section).

• Debris build-up on the grille near the headlamps (see block sensor section).

• Small distance to vehicle ahead.

• Steering wheel and pedal movements are large (very active driving style).

• High interior temperatures, which may deactivate the illumination or the warning lamps until the interior temperature reduces (audible warning will alert the driver). In addition, sun load and sunglasses may reduce the visibility of the warning lamps. Therefore, it is recommended to keep the audible warning on.

Mercedes E350

PRE-SAFE Brake – p68
The PRE-SAFE Brake is available in vehicles equipped with DISTRONIC PLUS. The PRE- SAFE Brake can assist you in minimizing the risk of a rear-end collision with a vehicle in front of you. The PRE-SAFE Brake may also reduce the severity of an accident. At speeds above approximately 20 mph (30 km/h) it will issue a warning when your vehicle is approaching the preceding vehicle very quickly. An intermittent acoustic warning sounds and the distance warning lamp [&] in the instrument cluster comes on.

Due to the system characteristics, warnings could be issued without cause in complex driving situations.

Warning! – p70

The PRE-SAFE Brake will only respond with brake assistance if it has clearly detected an object. Detection can be impeded by

- dirty or covered sensors
- snowfall or heavy rain
- disturbance from other radar sources
- strong radar reflection such as in parking garages

The PRE-SAFE Brake uses radar signals that are not reflected well by narrow objects and absorptive materials. For this reason the PRE- SAFE Brake will not react to persons, animals, and approaching traffic or cross- traffic.

The PRE-SAFE Brake may not detect narrow vehicles driving in front of you, such as motorcycles and vehicles driving offset from your vehicle center.

…

The PRE-SAFE Brake maneuver is terminated immediately when

- you avoid the obstacle by evasive steering
- you drive less than 9 mph (15 km/h)
- an obstacle can no longer be identified ahead of you
- the system no longer senses the risk of a collision

Acura MDX

Overview – Pg. 459

• The CMBS does not activate if the speed difference between the two vehicles is less than 10 mph (15 km/h). CMBS may also not activate if you turn the steering wheel to avoid the collision. When the CMBS activates, the brake lights also come on.

Pg. 460

• The radar sensor is located under the Acura emblem in the front grille. If the radar sensor cover is covered with mud, dirt, dead leaves, wet snow, etc., or if you put a sticker on it, the CMBS will automatically shut off, and the CMBS indicator on the instrument panel will come on. You will also see a "CHECK CMBS RADAR SENSOR" message on the multi-information display for about 5 seconds. Always keep the radar sensor cover clean. If it gets dirty, clean it with water or a mild detergent. Never use chemical solvents or polishing powder. There are three bolts on the sides of the radar sensor. Do not tamper with these bolts, or you may cause the system to malfunction. Do not allow anything to impact the radar sensor or the radar sensor cover. If either of these parts receives a strong impact, turn off the system by pressing the CMBS off switch, and have your vehicle checked by a dealer. If the front grille ever needs to be repaired, consult a dealer first. Notice: When the CMBS is on, the radar sensor constantly scans for vehicles ahead of you. This means that driving on a road with a few or no vehicles could cause a CHECK CMBS RADAR SENSOR message to appear on the multi-information display. This is normal and not a cause for concern.

Pg. 461

• The radar sensor may not always scan as intended. Here are two examples: •Your vehicle is tilted because of a heavy load in the rear or from modifications to the suspension. •The tires are not correctly maintained.

Pg. 465

• Limitations: The CMBS may not activate under some conditions. Here are a few examples:

• The distance between your vehicle and the vehicle ahead of you is too short. • A vehicle cuts in front of you at a slow speed. • A vehicle cuts in front of you and brakes suddenly. • When you accelerate rapidly and approach the vehicle ahead of you at high speed. • Immediately after you drive off.

Pg. 466

• Driving in heavy, stop-and-go traffic. • The vehicle ahead of you is a motorcycle or other small vehicle. • A vehicle suddenly crosses in front of you. Notice: The CMBS is not designed to detect pedestrians.

• Even with little or no chance of a collision, the CMBS may activate under these conditions:

• When you change lanes quickly, then overtake the vehicle ahead of you.

Pg. 467

• When you approach or pass a vehicle ahead of you that is turning left or right in an intersection. • When you pass a low bridge at high speed. • When you go over a sharp-edged speed bump at high speed. • When you go over areas of construction on the road surface. • When you approach train tracks at the bottom of a hill and you do not apply the brakes.

Appendix B. Driving Environs Associated with Non-Testing Related FCW Activations

Figure B.1. Directional Sign at the South End of the Skid Pad

Figure B.2. Tree Going to the Mobility Gate

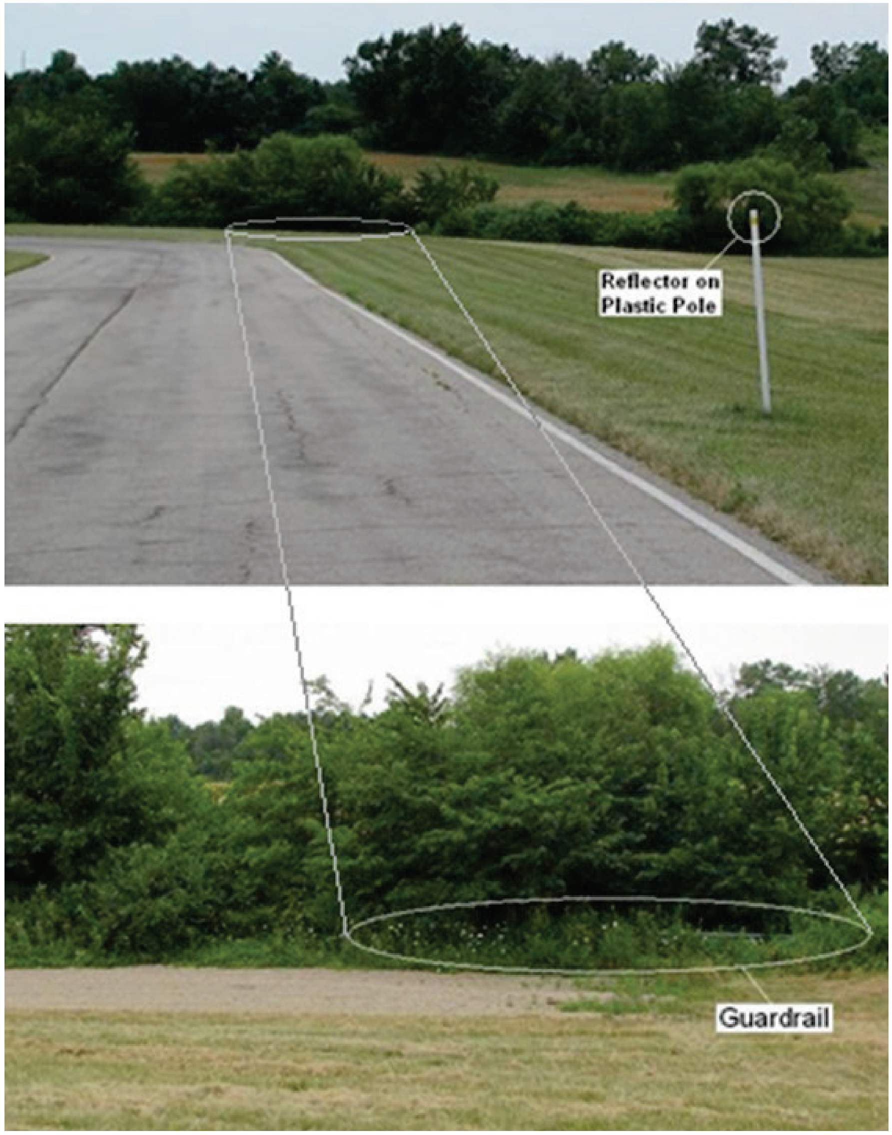

Figure B.3. Objects Near the WRC's Front Straightaway

Figure B.4. Orange Construction Barrel Going Toward the WRC

Appendix C. Curved-Lane Test Input Repeatability – Closest Approach to Stationary Vehicle

The following tables contain descriptive statistics regarding how close each of the three instrumented test vehicles came to the two stationary vehicles used in the Curved-Lane Test scenarios. The measurements shown below were taken when the front bumper of the test vehicle passed the rear bumper of the stationary vehicle. They are the lateral distance between the test vehicle's front wheel (nearest the stationary vehicle) and the plane created by the stationary vehicle's front and rear wheels (nearest the test vehicle).

Table C.1. Closest Approach to the BMW 528i (Stationary Vehicle at Curve Entrance)

Vehicle	Initial Velocity	Average Distance (ft.)	St. Dev.	Min	Max
E350	45	2.0	0.57	1.4	3.2
E350	25	1.2	0.42	0.4	1.7
Outback	45	3.1	0.40	2.4	3.5
Outback	25	2.1	0.44	1.5	2.7
S80	45	3.3	0.48	2.6	3.9
S80	25	2.6	0.26	2.1	3.0

Table C.2. Closest Approach to the Chrysler 300C (Stationary Vehicle at Curve Exit)

Vehicle	Initial Velocity	Average Distance (ft.)	St. Dev.	Min	Max
E350	45	6.0	0.63	4.6	6.6
E350	25	5.0	0.38	4.6	5.8
Outback	45	8.6	0.99	6.8	9.9
Outback	25	6.2	0.93	4.4	7.6
S80	45	6.3	1.37	4.9	8.6
S80	25	3.2	0.49	2.6	3.9

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