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16. Abstract

This draft test procedure provides specifications used by the National Highway Traffic Safety Administration to research blind spot intervention (BSI) system performance on light vehicles with gross vehicle weight ratings (GVWR) of up to 10,000 lbs (4,536 kg). The expected operating domain for BSI includes roadways supporting moderate- to high-speed traffic. This draft research test procedure is an update to that dated April 2018. The updates were made to improve test performability.

In the first two scenarios, a subject vehicle (SV) initiates, or attempts to initiate, a lane change into an adjacent lane while a single principal other vehicle (POV) is within the SV blind zone. A third scenario is used to evaluate the propensity of a BSI system to inappropriately activate in a non-critical driving scenario that does not present a safety risk to the SV occupants. For all tests described in this document, the POV is a strikeable object with the characteristics of a compact passenger car.

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BLIND SPOT INTERVENTION SYSTEM CONFIRMATION TEST

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GLOSSARY

ACC	adaptive cruise control
ASTM	formerly known as the American Society for Testing and Materials, and as ASTM International since 2001
BSD	blind spot detection
BSI	blind spot intervention
FHWA	Federal Highway Administration
GVT	Global Vehicle Target
GVWR	gross vehicle weight rating
lidar	light detection and ranging
POV	principal other vehicle
SAE	formerly known as the Society of Automotive Engineers, and as SAE International since 2006
SV	subject vehicle
V2V	vehicle-to-vehicle communication

REVISION HISTORY

Date	Revision
04/09/2018	Original draft
03/05/2019	• Minor typographical corrections • The ACC headway specified in in S5.3.2 has been changed to the farthest setting (i.e., that which would provide the longest following distance when a lead vehicle is present ahead of the SV in its travel lane). • POV yaw rate tolerances have been removed. Extensive testing has demonstrated that satisfying a ±1 deg/s criteria with the GST does not appear to be possible. Since the POV must still satisfy a lateral tolerance of ±0.8 ft (0.25 m) during the test validity period, this change is not expected to confound the test results or affect the test outcome. • The lateral distance between the right side of the POV and the inboard edge of the lane line immediately to its right has been reduced from 4.9 ± 0.8 ft (1.5 ± 0.25 m) to 3.3 ± 0.8 ft (1.0 ± 0.25 m). • The test condition where the SV is initially operated in L2, but transitions to L1 just before being manually steered towards the line separating the SV travel lane from the adjacent lane immediately to the left has been removed from each of the three test scenarios. If the SV begins at or very near the center of its travel lane, it may not be possible to consistently (i.e., for all light vehicles) achieve the desired lateral velocity of 2.3 ft/s (0.7 m/s) before a BSI intervention occurs. Should this situation occur, the SV steering input would be in the opposite direction to the heading correction requested by the BSI intervention. This conflict is expected confound the ability to accurately assess BSI system performance. • With exception to the baseline trials performed for the SV Lane Change With Constant Headway, False Positive Assessment test, the number of repeated trials per test condition has been reduced from three to one to lower the overall test burden. • Steady-state timing used throughout the test procedure has been reduced from 5 to 3 seconds • The time between the onset of the validity period and SV turn signal activation has been reduced from 5 to 3 seconds for the SV Lane Change With Constant Headway tests. • The SV turn signal activation timing has been increased from 3.7 to 4.9 seconds during the SV Lane Change With Closing Headway tests.

1.0 PURPOSE AND APPLICATION

This draft test procedure provides specifications used by the National Highway Traffic Safety Administration to research blind spot intervention (BSI) system performance on light vehicles with gross vehicle weight ratings of up to 10,000 lbs (4,536 kg). The expected operating domain for BSI includes roadways supporting moderate-to-high speed traffic. Examples include multiple lane highways and interstates.

The tests contained in this document are intended for evaluation of SAE automation level 0, 1, 2, or 3 vehicles that use sensors such as radar, cameras, and/or lidar to detect nearby objects. Although it is impossible to predict what technologies could be used by future BSI systems (e.g., vehicle-to-vehicle communication), it is believed that modifications to these procedures, when deemed appropriate, could be used to accommodate the evaluation of (1) alternative or more advanced BSI systems, and/or (2) higher level automated vehicles.

Note: *The subject vehicle (SV) driver shall not provide manual[1] inputs to the accelerator pedal, brake pedal, or steering wheel when the tests described in this document are performed with the SV operating in SAE automation level 2 or 3 within the applicable validity periods. This provision is intended to eliminate the potential for BSI operation from being unintentionally affected by the SV driver while tests are being safely performed within the controlled confines of a test track, and does not constitute an endorsement by NHTSA for drivers to remove their hands from the steering wheel while operating their vehicle on public roads.*

2.0 GENERAL REQUIREMENTS

This document describes the methods used by NHTSA to assess BSI operation on the test track. In the first two scenarios, an SV initiates, or attempts to initiate, a lane change into an adjacent lane while a single principal other vehicle (POV) is within the SV's blind zone. A third scenario is used to evaluate the propensity of a BSI system to inappropriately activate in a non-critical driving scenario that does not present a safety risk to the SV occupants. For all tests described in this document, the POV is a strikeable object with the characteristics of a compact passenger car[2]. At no time shall the SV contact the POV during the conduct of any trial described in this document.

3.0 DEFINITIONS

There are presently two commercially available crash avoidance technologies designed to directly address the "changing lanes/same direction" pre-crash scenario: blind spot detection (BSD) and blind spot intervention. Although they both apply to the same target population, BSD is a passive technology, whereas BSI is active.

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[1] In the context of this document, manual inputs are those not automatically controlled by the SV itself. Manual steering, throttle, and brake applications may be input by the SV driver, a robotic controller, etc.

[2] POV specifications are described in S4.5.

Blind Spot Detection: A warning-based technology designed to help the driver recognize that another vehicle is approaching, or being operated within, the blind spot of their vehicle in an adjacent lane. Should the driver initiate a lane change towards this other vehicle, the BSD presents an alert before a collision is expected to occur. Depending on the implementation, BSD activation may or may not require the driver to operate their turn signal indicator during their lane change.

Blind Spot Intervention: A system designed to actively help the driver avoid a collision with another vehicle that is approaching, or being operated within, the blind spot of their vehicle in an adjacent lane. Depending on the implementation, BSI activation may or may not require the driver to operate their turn signal indicator during their lane change. It is anticipated that some BSI systems may only operate if the vehicle's BSD is also enabled.

4.0 PRETEST AND FACILITY REQUIREMENTS

4.1 Road Test Surface

The road test surface used for the tests described in this document shall be dry (without visible moisture on the surface), straight, and flat, with a consistent slope between level and one percent. The road surface shall be constructed from asphalt or concrete and shall be free of irregularities, undulations, and/or cracks that could cause the SV to pitch excessively. The surface shall be free of excessive tire skid marks, pavement seam sealer, and/or other high-contrast surface markings that could potentially confound lane line identification and/or tracking.

The road test surface must produce a peak friction coefficient (PFC) of at least 0.9 when measured using an American Society for Testing and Materials E1136 standard reference test tire, in accordance with ASTM Method E 1337-90, at a speed of 64.4 km/h (40 mph), without water delivery [1]. The test track PFC shall be documented.

4.2 Line Markings

The tests described in this document are comprised of three scenarios. The SV Lane Change With Constant Headway and SV Lane Change With Closing Headway scenarios require two straight travel lanes. Performing the SV Lane Change With Constant Headway, False Positive Assessment test requires an additional lane to the left of the two lanes used for the other scenarios. The lines used to delineate each lane shall meet Federal Highway Administration specifications as required by the Manual on Uniform Traffic Control Devices (MUTCD) and be considered in "very good condition" [2].

4.2.1 Lane Line Styles

The tests described in this document use a combination of discontinuous dashed white and solid white lane lines. Details about which lines to use within a given scenario, and where they should be located, are shown in Figures 1, 4, and 5 provided in S5.3.5, S5.3.6, and S5.3.7, respectively.

4.2.2 Line Marking Color and Reflectivity

Lane line marker color and reflectivity shall meet all applicable standards. These standards include those from the International Commission of Illumination for color and the ASTM on lane marker reflectance. Methods for determining lane marker characteristics are discussed in the Road Departure Crash Warning Systems (RDCWS) Field Operational Test (FOT) by the National Institute of Standards and Technology (NIST) [3].

4.2.3 Line Marker Width

The width of the edge line marker shall be 4 to 6 in (10 to 15 cm). This is a normal width for longitudinal pavement markings under Section 3A.05 of the MUTCD [2].

4.3 Lane Width

Each lane required by this test procedure shall be delineated with two lane lines. Measured from inside edge to inside edge, these lines shall be spaced 12 to 14 ft (3.7 to 4.3 m) apart.

4.4 Ambient Conditions

4.4.1 Ambient Temperature

The ambient temperature shall be between 45°F (7°C) and 104°F (40°C).

4.4.2 Wind Speed

The maximum wind speed shall be no greater than 22 mph (35 km/h).

4.4.3 Inclement Weather

Tests should not be performed during periods of inclement weather. This includes, but is not limited to, rain, snow, hail, fog, smoke, or ash.

4.4.4 Visibility

The tests shall be conducted during daylight hours with good atmospheric visibility defined as an absence of fog and the ability to see clearly for more than 3 miles (4.8 km). Tests shall not be conducted with the SV oriented into the sun during very low sun angle conditions, where the sun is oriented 15 degrees or less from horizontal and potential camera "washout" or system inoperability could result.

4.5 Principal Other Vehicle Specifications

To safely perform tests where the POV remains in a travel lane adjacent to the SV for the duration of the test trial (the scenarios described in S5.3.5 and S5.3.6), the POV shall be a realistic surrogate vehicle. For the trials where the POV is initially driven in a travel lane two lanes from that of the SV (the scenario described in S5.3.7), the POV may be either (1) a realistic surrogate vehicle, or (2) an actual (i.e., real) passenger car that satisfies the specifications described in S4.5.2.

4.5.1 Surrogate Vehicle

A surrogate vehicle suitable for the tests described in this document shall have the characteristics of a compact passenger car. This is intended to maximize the ability of the SV to detect the POV in the most realistic manner possible without compromising SV driver safety and minimizing the potential for SV damage. An appropriate surrogate vehicle must possess the following attributes:

A. Accurate physical characteristics (e.g., visual, dimensional) when viewed from any approach angle.

   i. Body panels and rear bumper shall be white in color.

   ii. Simulated body panel gaps shall be present.

   iii. The simulated rear glass and tires shall be dark gray or black.

   iv. A rear-mounted United States specification license plate, or reflective simulation thereof, shall be installed.

B. Reflective properties representative of a high-volume passenger car when viewed from any approach angle by radar (using the 24 GHz and 76-77 GHz bands) and lidar-based sensors.

C. Remains consistently shaped (e.g., visually, dimensionally, internally, and from a radar sensing perspective) within each test series.

D. Resistant to damage resulting from repeated SV-to-POV impacts.

E. Inflicts minimal to no damage to the SV, even in the event of multiple impacts.

The test conductor shall present documentation that objectively qualifies how the surrogate vehicle used to perform the tests described in this document satisfies the requirements of S4.5.1.

Note: *NHTSA intends to use the Global Vehicle Target (GVT) as the POV for the tests described in this document [4]. The GVT is a full-sized artificial vehicle designed to appear realistic to the sensors used by automotive safety systems and automated vehicles: radar (24 and 76-77 GHz), camera, and lidar. Appropriate radar characteristics are achieved by using a combination of radar-reflective and radar-absorbing material is enclosed within the GVT's vinyl covers. The GVT is dimensionally similar to a 2013 Ford Fiesta hatchback and is secured to a robotic platform using Velcro attachment points. Internally, the GVT consists of a vinyl-covered foam structure. If a test vehicle impacts the GVT at low speed, it is typically pushed off and away from the platform, which is then pushed against the ground and stops as the test vehicle is driven over it. At higher impact speeds, the GVT breaks apart as the SV essentially drives through it. The GVT can be repeatedly struck from any approach angle without harm to those performing the tests or the vehicles being* *evaluated. Reassembly of the GVT occurs on top of the robotic platform and takes a team of 3 to 5 people approximately 7 to 10 minutes to complete. The robotic platform that supports the GVT is preprogrammed, and allows the GVT's movement to be accurately and repeatedly choreographed with the test vehicle and/or other test equipment required by a pre-crash scenario using closed-loop control.*

4.5.2 Actual Vehicle

If the test conductor uses an actual vehicle as the POV for the tests described in S5.3.7, it shall be a high-production, mid-sized passenger car between 175 to 197 in (445 to 500 cm) long, and 70 to 76 in (178 to 193 cm) wide measured at the widest part of the vehicle. The color of the actual vehicle used as the POV is unrestricted.

4.6 Instrumentation Required

4.6.1 Sensors and Sensor Locations

An overview of the sensors used for the tests described in this document is provided in Table 1.

4.6.1.1 Vehicle Position

The position of the SV and POV relative to their respective travel lanes, and the position of the SV relative to the POV shall be measured within the test validity period. The sensors used for these measurements are not constrained provided they meet the range, resolution, and accuracy specifications provided in Table 1.

4.6.1.2 Vehicle Speed

The lateral and longitudinal velocities of the SV and POV (where applicable) shall be measured within the test validity period. The sensors used for this measurement are not constrained provided they meet the range, resolution, and accuracy specifications provided in Table 1.

4.6.1.3 Yaw Rate

SV yaw rate shall be measured. Alternatively, differentially-corrected GPS data may be used to calculate yaw rate in lieu of direct measurement, provided the resulting accuracy is comparable.

4.6.1.4 Vehicle Acceleration

Lateral and longitudinal accelerations of the SV and POV shall be measured within the test validity period, and shall meet the range, resolution, and accuracy specifications provided in Table 1.

Table 1 – Recommended Measurements and Measurement Specifications

Type	Output	Range	Resolution	Accuracy
Various	Lateral and longitudinal position of SV and POV	650 ft (200 m)	2 in (5 cm)	At least 3.9 in (10 cm) absolute
Speed Sensors	SV and POV lateral and longitudinal velocity	0.1 – 62 mph (0.1 -100 km/h)	0.1 mph (0.2 km/h)	+/- 0.25% of full scale range
Rate Sensor	SV and POV yaw rate	+/- 100 deg/s	0.01 deg/s	+/- 0.25% of full scale range
Accelerometers	SV and POV lateral and longitudinal accelerations	+/- 2g	0.001g	+/- 0.01% of full scale range
Position Sensor	SV throttle and brake pedal positions	0 – 100 percent (normalized)	0.1 percent	0.1 percent
Load Cell	SV brake pedal force	0 – 300 lbf (1.3 kN)	0.1 lbf (0.4 N)	+/- 0.05% of full scale range
Steering Wheel Angle Sensor	SV steering wheel angle	±360 degrees	1 degree	2 degrees
Steering Wheel Torque Sensor	SV steering wheel torque	±500 in. lbf (56 Nm)	5 in. lbf (0.6 Nm)	5 in. lbf (0.6 Nm)
Data Flag	Turn signal indicator status	0 – 10 VDC (nominally)	N/A	Output response ≤ 10 ms
Video recorded messages	Visual/audible vehicle instructions, notifications, and/or alerts presented to the driver	N/A	At least 720p	N/A
Vehicle Dimensional Measurements	Location of SV and POV GPS antennas; SV and POV centerlines; front-most SV bumper position; and rear-most POV and SV bumper positions.	N/A	0.04 in (1 mm)	0.04 in (1 mm)
SV-to-POV Static Range	Distance to POV reference point (typically the longitudinal center of gravity (CG)) and rear-most POV bumper position.	N/A	2 in (5 cm)	At least 3.9 in (10 cm) absolute

4.6.1.5 SV Brake Pedal Force

To ensure that the SV driver did not manually apply the foundation brakes during the test validity period, brake pedal force shall be measured with a single-axis load cell securely attached to the SV brake pedal. If the SV driver manually applies force to the brake pedal within the validity period, the test trial is not valid and shall be repeated.

4.6.1.6 SV Accelerator Pedal Position

SV accelerator pedal position shall be measured to ensure that the driver did not manually apply an input within the validity period during tests performed with cruise control enabled (conventional or adaptive). If the driver manually applies an accelerator pedal input within the validity period, the test trial is not valid and shall be repeated. SV throttle pedal position shall be expressed as a percentage of the wide-open throttle (WOT) pedal position.

4.6.1.7 SV Instructions, Notifications, and/or Alerts

The data acquisition system shall record any visual/audible vehicle instructions, notifications, and/or alerts presented to the SV driver. Use of a high resolution digital video camera synchronized with the other recorded data channels is recommended for this purpose.

5.0 TEST EXECUTION AND TEST REQUIREMENTS

All tests performed in this document shall be performed with the SV operating in either SAE automation level 0, 1, 2, or 3 and the SV transmission in “drive.” For safety reasons, and to ensure the SV is properly initialized before each trial is initiated, it is anticipated a test driver will be present in the SV driver’s seat. BSI system performance shall be evaluated in accordance with the test procedures described in S5.3.5, S5.3.6, and S5.3.7.

5.1 Pre-Test Initialization and Calibration

5.1.1 Instrumentation Initialization

All instrumentation shall be secure and properly configured. With all instrumentation off, the SV and POV shall be driven to an outdoor location unobstructed by buildings, overpasses, or other structures capable of interfering with the ability of the GPS equipment to acquire satellite-based position information and real-time base station corrections (where applicable). At this location, the instrumentation shall be turned on, and static and dynamic GPS initializations shall be performed.

1. Static initialization

   A. Where applicable, the transmissions of the SV and POV shall be placed in park or with the system brake enabled (robotic platforms).

B. The SV and POV shall remain at rest until transmissions from least six (6) GPS satellites have been obtained and indicated by the vehicle's respective instrumentation.

2. Dynamic initialization

   A. The SV and POV shall be driven in a straight line, at a speed of at least 35 mph (56.3 km/h) for at least 350 ft (107 m).

   B. The SV and POV shall be driven in 3 figure eight patterns. The radii of the turns shall be approximately 20 ft (6 m).

   C. Steps 5.1.1.2.A and 5.1.1.2.B shall be repeated until the respective instrumentation indicates that the required accuracies for position and heading have been achieved.

5.1.2 Static Instrumentation Calibration

Calibration data shall be collected prior to the tests specified in S5.3.5, S5.3.6, and S5.3.7 to assist in resolving uncertain test data.

1. The SV and POV shall be centered in the same travel lane with the same orientation (i.e., each must face the same direction).

2. The front-most location of the SV shall be positioned such that it just contacts a vertical plane that defines the rearmost location of the POV. This is the "zero position."

3. The zero position shall be documented prior to, and immediately after, conduct of a test series.

   A. If the zero-position reported by the data acquisition system differs by more than ±2 in (±5 cm) from that measured during collection of the pre-test static calibration data file, the pre-test longitudinal offset shall be adjusted to output zero and another pre-test static calibration data file shall be collected.

   B. **If the zero-position reported by the data acquisition system differs by more than ±2 in (±5 cm) from that measured during collection of the post-test static calibration data file, the tests performed between collection of that post-test static calibration data file and the last valid pre-test static calibration data file shall be repeated.**

4. Static data files shall be collected prior to, and immediately after, conduct of the test series described in S5.3.5, S5.3.6, and S5.3.7. The pre-test static files shall be reviewed

prior to test conduct to confirm that all data channels are operational and have been properly configured.

5.2 BSI Pre-Test System Initialization

Some SVs may require a brief period of initialization (e.g., verification of sensor alignment and detection readiness) before their respective BSI system performance can be properly assessed. If a manufacturer-specific initialization procedure is required, NHTSA will obtain the appropriate procedure from the respective vehicle manufacturer, and provide it to the contractor. The contractor shall perform any NHTSA-provided initialization schedule prior to performing the tests described in this test document.

5.3 Test Scenarios

5.3.1 General Test Requirements

For tests described in S5.3.5, S5.3.6, and S5.3.7 of this document, the following requirements shall be satisfied during the respective validity periods:

1. The SV driver seat belt must be latched.

2. If any load has been placed on the SV front passenger seat (e.g., for instrumentation), the vehicle's front passenger seat belt must be latched.

3. When operating the SV in automation level 0 within the validity period, SV speed shall be maintained by (1) the SV driver manually modulating the SV accelerator pedal, or (2) use of conventional cruise control unless the SV BSI system automatically terminates its operation[3].

4. Operating the SV in automation level 1 requires SV ACC (i.e., not the vehicle's lane centering system) be enabled and in operation unless the SV BSI system automatically terminates its operation[4].

5. Operating the SV in automation level 2 or 3 requires ACC and lane centering systems both be enabled and in operation.

6. The SV driver shall not provide manual inputs to the SV accelerator or brake pedals while the SV is being operated in automation level 1 (i.e., while ACC is actively modulating the SV speed), 2, or 3.

7. The POV shall be driven at constant speed.

[3] Where applicable. A BSI system intervention may not terminate cruise control operation for all vehicles.

[4] Where applicable. A BSI system intervention may not terminate ACC operation for all vehicles.

8. The lateral distance between the right side of the POV and the inboard edge of the lane line immediately to its right shall be 3.3 ± 0.8 ft (1.0 ± 0.25 m).

9. When the SV is being operated in automation level 0 or 1, the SV yaw rate must not exceed ±1.0 deg/s from the onset of the validity period until the initiation of the SV lane change.

5.3.2 Adaptive Cruise Control Settings

ACC systems typically provide the operator with a range of settings to incrementally adjust the following distance from the front of the SV to the rear of the vehicle ahead of it. Since none of the scenarios described in this document begin with the SV following a lead vehicle, the ACC headway setting is not expected to effect the initial conditions of any test trial. However, for the sake of test consistency, each test scenario/condition combination described in this document shall be performed with the SV ACC set to its farthest setting (i.e., that which would provide the longest following distance when a lead vehicle is present ahead of the SV in its travel lane).

5.3.3 Lane Centering Control Settings

In the context of this document, a lane centering control (LCC) system continuously provides the steering inputs needed to keep the SV centered in its travel lane. Unlike ACC (where applicable), it is not anticipated the vehicles evaluated with the tests described in this document will be equipped with an LCC system that provide operator-selectable settings, modes, etc. other than on, off, and standby.

Note: *LCC system functionality differs from that provided by Lane Keeping Support (LKS) or Lane Keeping Assist (LKA) systems, as the latter are only intended to provide the brief heading corrections needed to bring the vehicle away from a lane line after it has been crossed or if a crossing has been deemed imminent.*

5.3.4 Data Collection Interval

Data collection for all trials described in this document shall be initiated at the onset of the validity period, and end at least 5 seconds after completion of any termination condition.

5.3.5 SV Lane Change With Constant Headway Scenario (SVLC_Constant_HW)

The objective of the SVLC_Constant_HW test is to evaluate the BSI system's ability to detect and respond to a POV residing in the SV blind spot. For these tests, the POV is driven in a lane adjacent to that of the SV with a constant longitudinal offset from the rear of the SV. During the tests performed with the SV operating in automation level 0 or 1, the SV driver engages the turn signal indicator and initiates a manual lane change into the POV travel lane (see Figure 1). If the SV is equipped with a system that supports automatic lane changes while the vehicle is operated in automation level 2 or 3, a series of tests where the SV driver engages the turn signal indicator to initiate an automatic lane change into the POV travel lane shall also be performed.

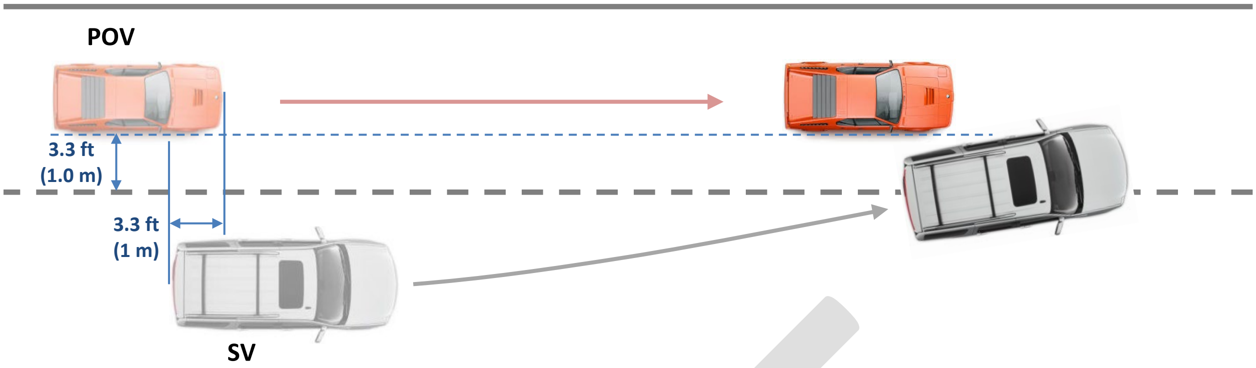

Figure 1. SV Lane Change With Constant Headway scenario.

5.3.5.1 Scenario-Specific Validity Requirements

In addition to the general test requirements described in S5.3.1, the following requirements must also hold true throughout each SVLC_Constant_HW trial:

1. Using closed loop control, the front most center position of the POV shall be 3.3 ± 1.6 ft (1 ± 0.5 m) ahead of a vertical plane defined by the rear of the SV and perpendicular to the SV travel lane, as shown in Figure 1, from the onset of the validity period defined in S5.3.5.5 to the instant when the SV lane change begins.

2. After initiation of the SV lane change, the POV shall use open loop control to maintain the constant speed specified in Table 2.

5.3.5.2 Test Overview

Specific details of how the SVLC_Constant_HW scenario tests are performed depend on the level of automation the SV is being operated in. Tests performed in automation level 0 begin with the SV driven in its travel lane at the desired speed. For these tests, SV speed is achieved either manually or after the SV cruise control has been enabled and initialized. Tests performed in automation level 1 begin with enabling and initialization of the SV ACC while the SV is driven at the desired speed in its travel lane. Tests performed in automation level 2 or 3 begin with enabling and initialization of the SV ACC and LCC while the SV is driven at the desired speed in its travel lane. The POV is then driven toward the rear of the SV in an adjacent lane to the left of the SV and establishes a constant longitudinal position. Shortly thereafter, the SV driver engages the left turn signal indicator and initiates a lane change into the POV travel lane using one of the methods described in Table 3 and either S5.3.5.3 or S5.3.5.4. In response to this, the BSI system is expected to intervene and prevent the left rear of the SV from contacting with the right front of the POV. Table 2 presents an overview of the SV and POV speeds, positions, and timing used to perform the SVLC_Constant_HW tests.

Table 2. SV Lane Change With Constant Headway Test Specifications.

<table>
<tr><th rowspan="2">SV Automation Condition</th><th colspan="2">Initial Speed</th><th colspan="2">Lateral Lane Position</th><th rowspan="2">SV-to-POV Longitudinal Orientation</th><th rowspan="2">SV Left Turn Signal Activation</th><th colspan="3">SV Lane Change</th><th rowspan="2">SV Path Tolerance</th><th rowspan="2">Number of Trials</th></tr>
<tr><th>SV</th><th>POV</th><th>SV</th><th>POV</th><th>Initiation Timing</th><th>Steering Release Timing</th><th>Lateral Velocity</th></tr>
<tr><td>Manual speed control,
LCC off
(Level 0)</td><td rowspan="4">45 ± 1 mph
(72.4 ± 1.6 km/h)</td><td rowspan="4">45 ± 1 mph
(72.4 ± 1.6 km/h)</td><td rowspan="3">Manually offset within travel lane, then manual lane change towards left adjacent lane</td><td rowspan="4">Constant;
3.3 ± 0.8 ft (1.0 ± 0.25 m) from the right side of the POV to the inboard edge of the lane line immediately to its right</td><td rowspan="4">Constant;
POV front located 3.3 ± 1.6 ft (1 ± 0.5 m) ahead of the SV rear</td><td rowspan="4">At least3 seconds after the onset of the validity period</td><td rowspan="3">1.0 ± 0.5 s after the SV turn signal is activated</td><td rowspan="3">Within 250 ms of achieving desired SV heading angle</td><td rowspan="3">2.3 ± 0.3 ft/s
(0.7 ± 0.1 m/s)</td><td rowspan="3">±0.8 ft (0.25 m) until SV steering wheel is released</td><td>1</td></tr>
<tr><td>Cruise control,
LCC off
(Level 0)</td><td>1</td></tr>
<tr><td>ACC on,
LCC off
(Level 1)</td><td>1</td></tr>
<tr><td>ACC on,
LCC on (initially); automatic SV lane change
(Level 2 or 3)</td><td>Automatically centered, then automatic lane change towards left adjacent lane</td><td>N/A; timing is vehicle-dependent</td><td>N/A; SV driver does not touch the steering wheel during the validity period</td><td>N/A; lane change lateral velocity is vehicle-dependent</td><td>N/A; SV path is vehicle-dependent</td><td>1</td></tr>
</table>

5.3.5.3 SV Lane Changes During Automated Vehicle Level 0 or 1 Operation

Tests performed with the SV operating in automation level 0 or 1 require manual steering be used to establish the desired SV heading angle towards the line separating the SV and POV travel lanes. To achieve this, the input parameters described Figure 2 are used.

The test begins with the SV laterally offet from the center of its travel lane[5]. The offset magnitude is calculated by adding one half of the SV width and a short period of steady state driving at a constant lateral velocity of 2.3 ± 0.3 ft/s (0.7 ± 0.1 m/s) before the SV reaches the left lane line. The SV lateral position shall not deviate more than 1.6 ft (0.5 m) from the onset of the validity period defined in S5.3.5.5 until the initiation of the SV lane change.

After at least 3 seconds from the onset of the validity period defined in S5.3.5.5, the SV driver shall activate the left turn signal indicator. Within 1 ± 0.5 seconds after the turn signal has been activated, the SV driver shall begin the lane change shown in Figure 2.

The SV driver shall release the steering wheel[6] within 250 ms of the SV exiting the 2,625 ft (800 m) radius curve during the lane change.

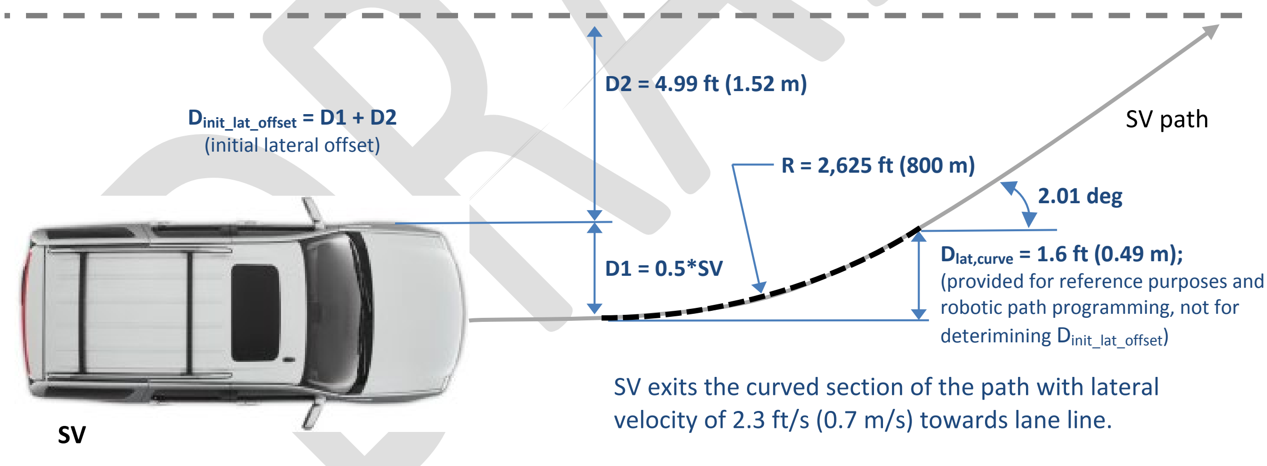

Figure 2. Input parameters used to define the SV path during the SV Lane Change With Constant Headway scenario.

5.3.5.4 SV Lane Changes During Automated Vehicle Level 2 or 3 Operation

In automation level 2 or 3, the longitudinal and lateral position of the vehicle is automatically controlled by the SV, not by the driver. Therefore, evaluation of the SV's BSI system while the

[5] Specification of a lateral offset is intended to insure the SV is being operated at the desired lateral velocity before its BSI system intervenes. This eliminates the likelihood of the SV BSI system attempting to apply a correction away from the POV at the same time the SV is being steered towards it.

[6] When performing the tests with a robotic steering machine that does not completely decouple from the SV steering wheel during the test trial, it is important the equipment have negligible-to-no effect on the torque required to turn the steering wheel (i.e., low inertia and low drag) to best emulate the situation where a human driver is operating the vehicle with their hands removed from the steering wheel.

vehicle is operating in automation level 2 or 3 requires that the SV be equipped with an automatic lane change system. For vehicle's so-equipped, the SV driver shall operate the vehicle in automation level 2 or 3 for the duration of the validity period defined in S5.3.5.5. Without touching the steering wheel, the SV driver activates the left turn signal indicator at least 3 seconds after the onset of this validity period.

If the SV is equipped with automation level 2 or 3 capability, but does not have the ability to automatically change lanes in response to activation of the SV turn signal indicator, the SV shall be evaluated with the vehicle operating in automation level 1 using the process (i.e., the timing and inputs) described in S5.3.5.3 and shown in Figure 2.

5.3.5.5 Validity Period

1. The valid test interval begins 3 seconds before the SV driver activates the left turn signal indicator.

2. For trials where BSI intervenes, the valid test interval ends:

    A. When the SV impacts the POV; or

    B. Five seconds after the SV has established a heading away from the POV and is completely within its original travel lane; or

    C. One second after the SV travels ≥ 1 ft (0.3 m) beyond the inboard edge of the lane line separating the SV travel lane from one adjacent and to the right of it (see Figure 3).

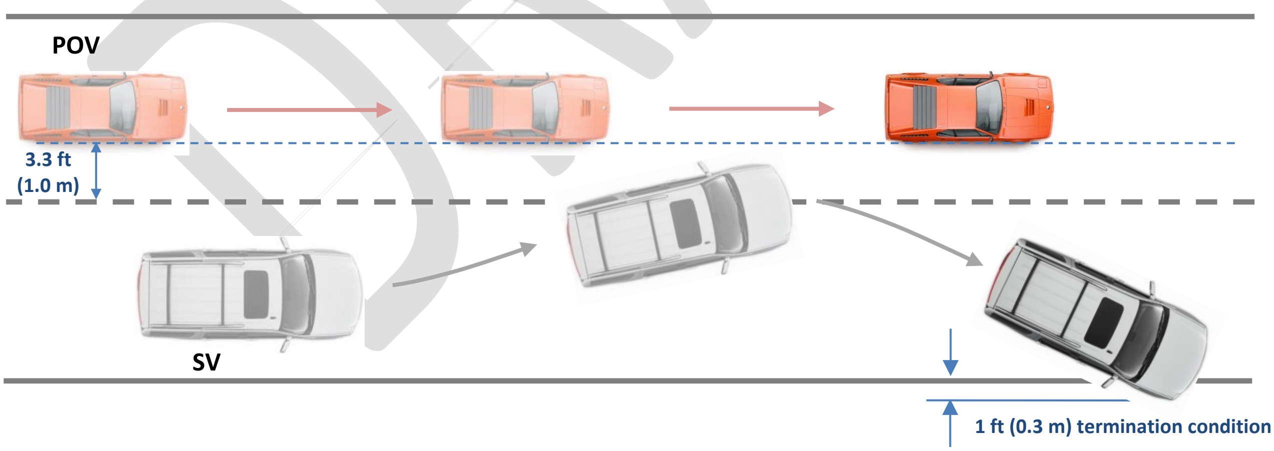

Figure 3. Valid test interval conclusion condition described in S5.3.5.6.2.C and S5.3.6.5.2.C (for the SV Lane Change With Constant and Closing Headway assessments, respectively).

3. For trials where BSI does not intervene, the valid test interval ends when the SV impacts the POV.

5.3.5.6 End-of-Test Instructions

1. After the validity period defined in S5.3.5.5 is complete, the SV driver shall manually apply force to the brake pedal, bring the vehicle to a stop (if necessary), and place the transmission in park.

2. The SVLC_Constant_HW test trial is complete.

5.3.5.7 Evaluation Criteria

The evaluation criteria used to assess the SV BSI performance during an SVLC_Constant_HW trial depends on what level of automation the SV was being operating in during that trial.

1. The SV shall not impact the POV during any valid test performed in automation level 0 or 1 (i.e., those performed with the timing and inputs described in S5.3.5.3).

2. The SV shall not initiate the lane change commanded by the turn signal indicator during any valid test performed with automation level 2 or 3 (i.e., those described in S5.3.5.4).

3. The SV BSI intervention shall not cause the SV to travel ≥ 1 ft (0.3 m) beyond the inboard edge of the lane line separating the SV travel lane from one adjacent and to the right of it within the validity period defined in S5.3.5.5 during any valid test (i.e., with automation level 1, 2, or 3).

5.3.6 SV Lane Change With Closing Headway Scenario (SVLC_Closing_HW)

The objective of the SVLC_Closing_HW test is to evaluate the BSI system's ability to detect and respond to a POV approaching the SV blind spot from the rear (see Figure 4). For these tests, the POV is driven at a constant speed 5 mph (8 km/h) greater than that of the SV in an adjacent lane.

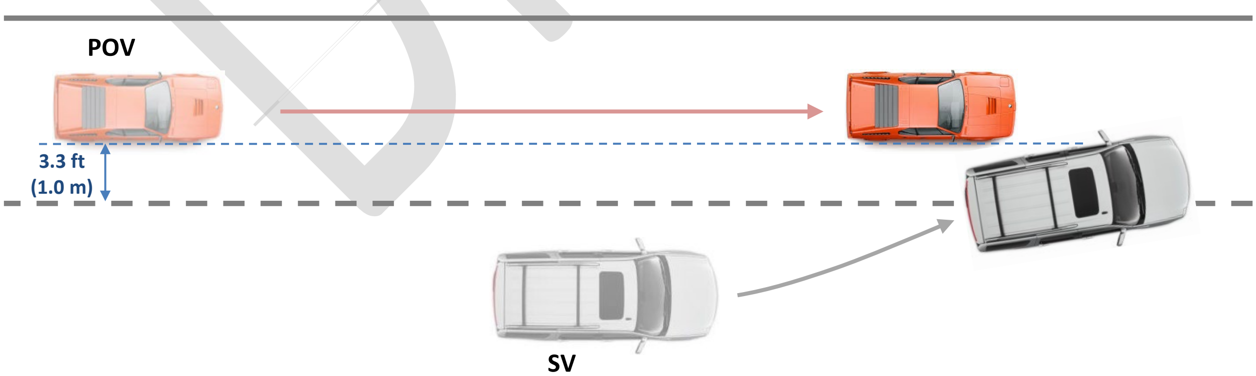

Figure 4. SV Lane Change With Closing Headway scenario.

During the tests performed with the SV operating in automation level 0 or 1, the SV driver engages the turn signal indicator and initiates a manual lane change into the POV travel lane. If the SV is equipped with a system that supports automatic lane changes while the vehicle is operated in automation level 2 or 3, a series of tests where the SV driver engages the turn signal indicator to initiate an automatic lane change into the POV travel lane shall also be performed.

5.3.6.1 Test Overview

Specific details of how the SVLC_Closing_HW scenario tests are performed depend on the level of automation the SV is being operated in. Tests performed in automation level 0 begin with the SV driven in its travel lane at the desired speed. For these tests, SV speed is achieved either manually or after the SV cruise control has been enabled and initialized. Tests performed in automation level 1 begin with enabling and initialization of the SV ACC while the SV is driven at the desired speed in its travel lane. Tests performed in automation level 2 or 3 begin with enabling and initialization of the SV ACC and LCC while the SV is driven at the desired speed in its travel lane. The POV is then driven toward the rear of the SV in an adjacent lane to the left of the SV, and shall be at a constant speed no later than 3 seconds before reaching a vertical plane defined by the rear of the SV and perpendicular to the SV travel lane. Using the timing and inputs described in Table 3 and either S5.3.6.2 or S5.3.6.3, the SV driver engages the left turn signal indicator and initiates a lane change into the POV travel lane. In response to this, the BSI system is expected to intervene and prevent the left rear of the SV from contacting with the right front of the POV. Table 3 presents an overview of the SV and POV speeds, positions, and timing used to perform the SVLC_Closing_HW tests.

5.3.6.2 SV Lane Changes During Automated Vehicle Level 0 or 1 Operation

Tests performed with the SV operating in automation level 0 or 1 require manual steering be used to establish the desired SV heading angle towards the line separating the SV and POV travel lanes. To achieve this, SV lane change path definition previously shown in Figure 2 and described in S5.3.5.3 are used. However, since the longitudinal position of the POV relative to the SV changes during the SVLC_Closing_HW scenario, the SV lane change timing differs.

The test begins with the SV laterally offet from the center of its travel lane with the offset magnitude specified in Figure 2. The SV lateral position shall not deviate more than 1.6 ft (0.5 m) from the onset of the validity period defined in S5.3.6.4 until the initiation of the SV lane change. The SV driver shall activate the left SV turn signal indicator when the POV is 4.9 ± 0.5 seconds[7] from a vertical plane defined by the rear of the SV and perpendicular to the SV travel lane. Within 1 ± 0.5 seconds[8] after the turn signal has been activated, the SV driver shall begin the lane change shown in Figure 4 using the SV lane change path definition previously described Figure 2. The SV driver shall release the steering wheel within 250 ms of the SV exiting the 2,625 ft (800 m) radius curve shown in Figure 2.

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[7] With a 5 mph (8 km/h) speed differential the longitudinal SV-to-POV headway is nominally 35.6 ft (10.8 m) when the vehicles are 4.9 seconds apart.

[8] With a 5 mph (8 km/h) speed differential the longitudinal SV-to-POV headway is nominally 28.2 ft (8.6 m) when the vehicles are 3.9 seconds apart.

Table 3. SV Lane Change With Closing Headway Test Specifications.

<table>
<tr><th rowspan="2">Automation Condition</th><th colspan="2">Initial Speed</th><th colspan="2">Lateral Lane Position</th><th rowspan="2">SV-to-POV Longitudinal Orientation</th><th rowspan="2">SV Left Turn Signal Activation</th><th colspan="3">SV Lane Change</th><th rowspan="2">SV Path Tolerance</th><th rowspan="2">Number of Trials</th></tr>
<tr><th>SV</th><th>POV</th><th>SV</th><th>POV</th><th>Initiation Timing</th><th>Steering Release Timing</th><th>Lateral Velocity</th></tr>
<tr><td>Manual speed control,
LCC off
(Level 0)</td><td rowspan="4">45 ± 1 mph
(72.4 ± 1.6 km/h)</td><td rowspan="4">50 ± 1 mph
(80.5 ± 1.6 km/h)</td><td rowspan="3">Manually offset within travel lane, then manual lane change towards left adjacent lane</td><td rowspan="4">Constant;
3.3 ± 0.8 ft
(1.0 ± 0.25 m) from the right side of the POV to the inboard edge of the lane line immediately to its right</td><td rowspan="4">POV approaches rear of the SV with a constant relative velocity</td><td rowspan="4">When the POV is 4.9 ± 0.5 seconds from a vertical plane defined by the SV rear and perpendicular to the SV travel lane</td><td rowspan="3">1.0 ± 0.5 s after the SV turn signal is activated</td><td rowspan="3">Within 250 ms of achieving desired SV heading angle</td><td rowspan="3">2.3 ± 0.3 ft/s
(0.7 ± 0.1 m/s)</td><td rowspan="3">±0.8 ft (0.25 m) until SV steering wheel is released</td><td>1</td></tr>
<tr><td>Cruise control,
LCC off
(Level 0)</td><td>1</td></tr>
<tr><td>ACC <u>on</u>,
LCC off
(Level 1)</td><td>1</td></tr>
<tr><td>ACC <u>on</u>,
LCC <u>on</u>
(initially);
automatic
SV lane change
(Level 2 or 3)</td><td>Automatically centered, then automatic lane change towards left adjacent lane</td><td>N/A; timing is vehicle-dependent</td><td>N/A; SV driver does not touch the steering wheel during the validity period</td><td>N/A; lane change lateral velocity is vehicle-dependent</td><td>N/A; SV path is vehicle-dependent</td><td>1</td></tr>
</table>

5.3.6.3 SV Lane Changes During Automated Vehicle Level 2 or 3 Operation

Evaluation of the SV's BSI system while the vehicle is operating in automation level 2 or 3 requires that the SV be equipped with an automatic lane change system. For vehicle's so-equipped, the SV driver shall activate the left SV turn signal indicator, without touching the steering wheel, when the POV is 4.9 ± 0.5 seconds from a vertical plane defined by the rear of the SV and perpendicular to the SV travel lane.

If the SV is equipped with automation level 2 or 3 capability, but does not have the ability to automatically change lanes in response to activation of the SV turn signal indicator, the SV shall be evaluated with the vehicle operating in automation level 0 or 1 using the process (i.e., the timing and inputs) described in S5.3.6.2.

5.3.6.4 Validity Period

1. The valid test interval begins 3 seconds before the SV driver activates the left turn signal indicator.

2. For trials where BSI intervenes, the valid test interval ends:

   A. When the SV impacts the POV; or

   B. Five seconds after the SV has established a heading away from the POV and is completely within its original travel lane; or

   C. One second after the SV travels ≥ 1 ft (0.3 m) beyond the inboard edge of the lane line separating the SV travel lane from one adjacent and to the right of it (previously shown in Figure 3).

3. For trials where BSI does not intervene, the valid test interval ends when the SV impacts the POV .

5.3.6.5 End-of-Test Instructions

1. After the validity period defined in S5.3.6.4 is complete, the SV driver shall manually apply force to the brake pedal, bring the vehicle to a stop (if necessary), and place the transmission in park.

2. The SVLC_Closing_HW test trial is complete.

5.3.6.6 Evaluation Criteria

The evaluation criteria used to assess the SV BSI performance during an SVLC_Closing_HW trial depends on what level of automation the SV was being operating in during that trial.

1. The SV shall not impact the POV during any valid test performed in automation level 0 or 1 (i.e., those performed with the timing and inputs described in S5.3.6.2).

2. The SV shall not initiate the lane change commanded by the turn signal indicator during any valid test performed with automation level 2 or 3 (i.e., those described in S5.3.6.3).

3. The SV BSI intervention shall not cause the SV to travel ≥ 1 ft (0.3 m) beyond the inboard edge of the lane line separating the SV travel lane from one adjacent and to the right of it within the validity period defined in S5.3.6.4 during any valid test (i.e., with automation level 1, 2, or 3).

5.3.7 SV Lane Change With Constant Headway, False Positive Assessment (SVLC_Constant_HW_FP)

The objective of the SVLC_Constant_HW_FP test is to assess whether the BSI system detects and responds to a non-threatening POV during a single lane change. For these tests, the POV is driven in a lane two lanes to the left of the SV's initial travel lane with a constant longitudinal offset from the rear of the SV. During the tests performed with the SV operating in automation level 0 or 1, the SV driver engages the turn signal indicator and initiates a manual lane change into the left adjacent lane (see Figure 5). If the SV is equipped with a system that supports automatic lane changes while the vehicle is operated in automation level 2 or 3, a series of tests where the SV driver engages the turn signal indicator to initiate an automatic lane change into the left adjacent lane shall also be performed.

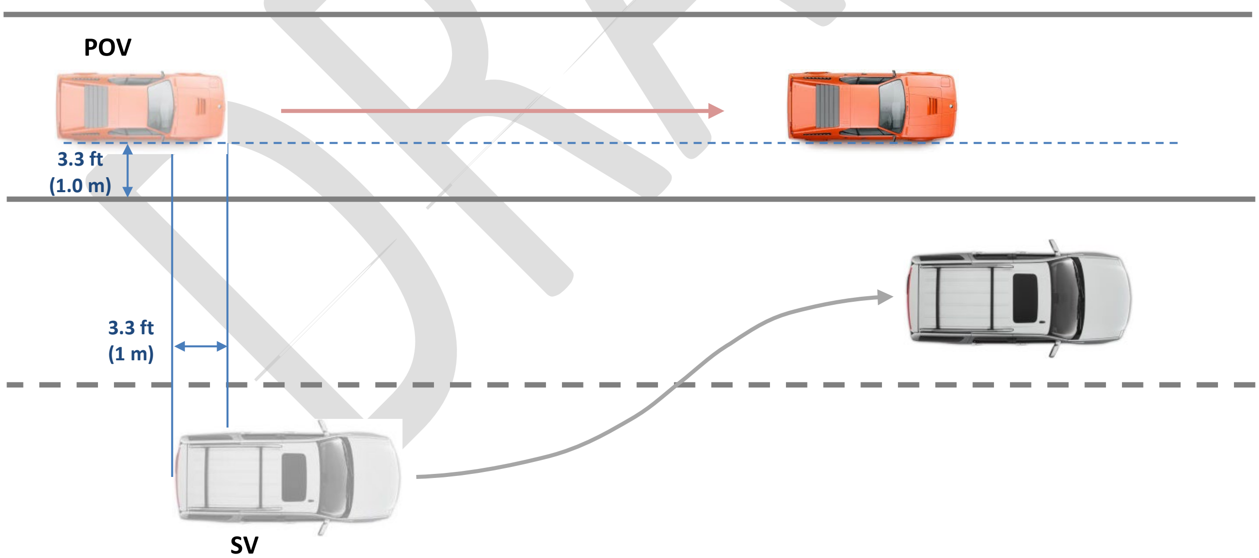

Figure 5. SV Lane Change With Constant Headway, False Positive scenario

5.3.7.1 Scenario-Specific Validity Requirements

Unlike the SVLC_Constant_HW and SVLC_Closing_HW tests described in S5.3.5 and S5.3.6, the SVLC_Constant_HW_FP scenario is performed as a two-part test series comprised of "baseline" and "evaluation" trials. Baseline trials are performed first, and are comprised of an SV lane change being performed without a POV. Next, identical trials are performed with the POV located two lanes to the left of the SV's initial travel lane. Specific details pertaining to the baseline and evaluation phases of the respective false positive tests defined in this document are available in S5.3.7.3 or S5.3.7.4.

The general SV-related test requirements described in S5.3.1 apply to the SVLC_Constant_HW_FP baseline trials. Additionally, the following requirements must also hold true throughout each SVLC_Constant_HW_FP evaluation trial performed with a POV:

1. Using closed loop control, the front most center position of the POV shall be 3.3 ± 1.6 ft (1 ± 0.5 m) from a vertical plane defined by the rear of the SV and perpendicular to the SV travel lane as shown in Figure 5, from the onset of the validity period defined in S5.3.7.5 to the instant when the SV lane change begins.

2. After initiation of the SV lane change, the POV shall use open loop control to maintain the constant speed specified in Tables 4a and 4b.

5.3.7.2 Test Overview

The specific details of how the SVLC_Constant_HW_FP scenario tests are performed depend on the level of automation the SV is being operated in. However, all tests begin with the SV is driven at the desired speed in its travel lane. During the evaluation phase of these tests (i.e., not the baseline trials), the POV is then driven toward the rear of the SV in a lane two lanes to the left of the SV and establishes a constant longitudinal position. Shortly thereafter, the SV driver engages the left turn signal indicator and initiates a single lane change into the left adjacent lane (i.e., the one between the SV and POV) using one of the methods described in Tables 4a and 4b and either S5.3.7.3 or S5.3.7.4. Since the lane change will not result in an SV-to-POV collision, the BSI system is not expected to intervene at any time during this scenario.

Tables 4a and 4b present an overview of the SV and POV speeds, positions, and timing used to perform the SVLC_Constant_HW_FP the baseline and evaluation tests, respectively.

5.3.7.3 SV Lane Changes During Automated Vehicle Level 0 or 1 Operation

Tests performed with the SV operating in automation level 0 or 1 require manual steering to perform the lane changes used during the SVLC_Constant_HW_FP baseline and evaluation trials. In each test phase, the input parameters described Figure 6 are used. Unlike the SVLC_Constant_HW and SVLC_Closing_HW tests performed in automation level 0 or 1, at no time during conduct of the automation level 0 or 1 SVLC_Constant_HW_FP tests does the SV driver release the steering wheel.

Table 4a. SV Lane Change With Constant Headway, False Positive Assessment Test Specifications (Baseline Trials).

<table>
<tr><th rowspan="2">Automation Condition</th><th colspan="2">Initial Speed</th><th colspan="2">Lateral Lane Position</th><th rowspan="2">SV-to-POV Longitudinal Orientation</th><th rowspan="2">SV Left Turn Signal Activation</th><th colspan="3">SV Lane Change</th><th rowspan="2">SV Path Tolerance</th><th rowspan="2">Number of Trials</th></tr>
<tr><th>SV</th><th>POV</th><th>SV</th><th>POV</th><th>Initiation Timing</th><th>Steering Release Timing</th><th>Lateral Velocity</th></tr>
<tr><td>Manual speed control, LCC off (Level 0)</td><td rowspan="4">45 ± 1 mph (72.4 ± 1.6 km/h)</td><td rowspan="4">N/A</td><td rowspan="3">Manually offset within travel lane, then manual lane change into a lane left and adjacent to that of the SV</td><td rowspan="4">N/A</td><td rowspan="4">N/A</td><td rowspan="4">At least 3 seconds after the onset of the validity period</td><td rowspan="3">1.0 ± 0.5 s after the SV turn signal is activated</td><td rowspan="3">N/A; the SV driver does not release the steering wheel</td><td rowspan="3">2.3 ± 0.3 ft/s (0.7 ± 0.1 m/s)</td><td rowspan="3">± 0.8 ft (± 0.5 m)</td><td>3</td></tr>
<tr><td>Cruise control, LCC off (Level 0)</td><td>3</td></tr>
<tr><td>ACC <u>on</u>, LCC off (Level 1)</td><td>3</td></tr>
<tr><td>ACC <u>on</u>, LCC <u>on</u> (initially); automatic SV lane change (Level 2 or 3)</td><td>Automatically centered, then automatic lane change into a lane left and adjacent to that of the SV</td><td>N/A; timing is vehicle-dependent</td><td>N/A; the SV driver does not touch the steering wheel during the validity period</td><td>N/A; lane change lateral velocity is vehicle-dependent</td><td>N/A; SV path is vehicle-dependent</td><td>3</td></tr>
</table>

Table 4b. SV Lane Change With Constant Headway, False Positive Assessment Test Specifications (Evaluation Trials).

<table>
<tr><th rowspan="2">Automation Condition</th><th colspan="2">Initial Speed</th><th colspan="2">Lateral Lane Position</th><th rowspan="2">SV-to-POV Longitudinal Orientation</th><th rowspan="2">SV Left Turn Signal Activation</th><th colspan="3">SV Lane Change</th><th rowspan="2">SV Path Tolerance</th><th rowspan="2">Number of Trials</th></tr>
<tr><th>SV</th><th>POV</th><th>SV</th><th>POV</th><th>Initiation Timing</th><th>Steering Release Timing</th><th>Lateral Velocity</th></tr>
<tr><td>Manual speed control, LCC off (Level 0)</td><td rowspan="4">45 ± 1 mph (72.4 ± 1.6 km/h)</td><td rowspan="4">45 ± 1 mph (72.4 ± 1.6 km/h)</td><td rowspan="3">Manually offset within travel lane, then manual lane change into a lane left and adjacent to that of the SV</td><td rowspan="4">Constant; 3.3 ± 0.8 ft (1.0 ± 0.25 m) from the right side of the POV to the inboard edge of the lane line immediately to its right[1]</td><td rowspan="4">Constant; POV front located 3.3 ± 1.6 ft (1 ± 0.5 m) ahead of the SV rear</td><td rowspan="4">At least 3 seconds after the onset of the validity period</td><td rowspan="3">1.0 ± 0.5 s after the SV turn signal is activated</td><td rowspan="3">N/A; the SV driver does not release the steering wheel</td><td rowspan="3">2.3 ± 0.3 ft/s (0.7 ± 0.1 m/s)</td><td rowspan="3">± 0.8 ft (± 0.5 m) unless a BSI intervention occurs</td><td>1</td></tr>
<tr><td>Cruise control, LCC off (Level 0)</td><td>1</td></tr>
<tr><td>ACC <u>on</u>, LCC off (Level 1)</td><td>1</td></tr>
<tr><td>ACC <u>on</u>, LCC <u>on</u> (initially); automatic SV lane change (Level 2 or 3)</td><td>Automatically centered, then automatic lane change into a lane left and adjacent to that of the SV</td><td>N/A; timing is vehicle-dependent</td><td>N/A; the SV driver does not touch the steering wheel during the validity period</td><td>N/A; lane change lateral velocity is vehicle-dependent</td><td>N/A; SV path is vehicle-dependent</td><td>1</td></tr>
</table>

[1] The POV travel lane is two lanes to the left of the SV travel lane

(a) Performing SVLC_Constant_HW_FP Baseline Trials (automation level 0 or 1)

Baseline tests performed in automation level 0 or 1 begin with the SV driven in the center of its travel lane at the desired speed. For these tests, SV speed is achieved either manually or after the SV cruise control has been enabled and initialized. Tests performed in automation level 1 begin with enabling and initialization of the SV ACC while the SV is driven at the desired speed in its travel lane. After 3 seconds, the SV driver shall engage the left turn signal indicator and initiate a single lane change into the left adjacent lane using the path shown in Figure 6. Since no POV is present during conduct of the baseline trials, no BSI system interventions are expected.

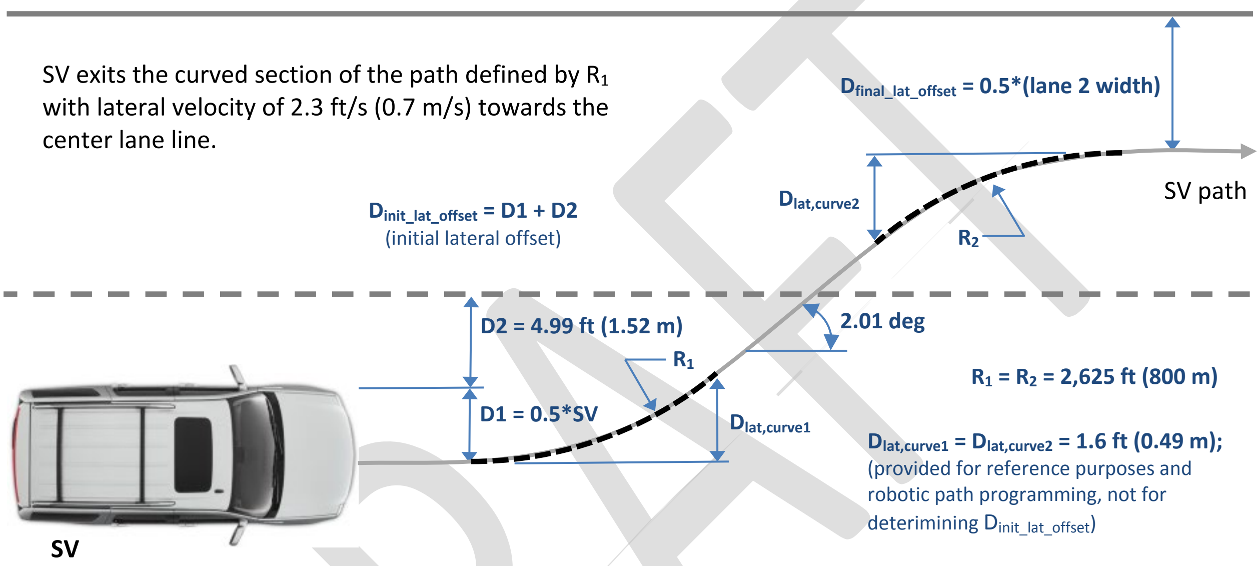

Figure 6. SV Lane Change With Constant Headway, false positive scenario.

The SV lateral position shall not deviate more than 1.6 ft (0.5 m) during the following baseline trial intervals:

- From the onset of the validity period defined in S5.3.7.5 to initiation of the SV lane change.
- During the lane change described in Figure 6.
- From completion of the lane change until the end of the validity period defined in S5.3.7.5.

Subject vehicle yaw rate data from each of the three baseline trials shall be synchronized in time and averaged to generate a composite data trace. Using this composite, two additional data traces shall be created, with values ±1 deg/s than the composite at each instant in time to define the upper and lower bounds, respectively, of an “acceptability corridor.” A description of how the acceptability corridor, shown in Figure 7, is used to determine whether a BSI false positive intervention occurred during a given evaluation trial (described in S5.3.7.3.b) is provided in 5.3.7.3.c.

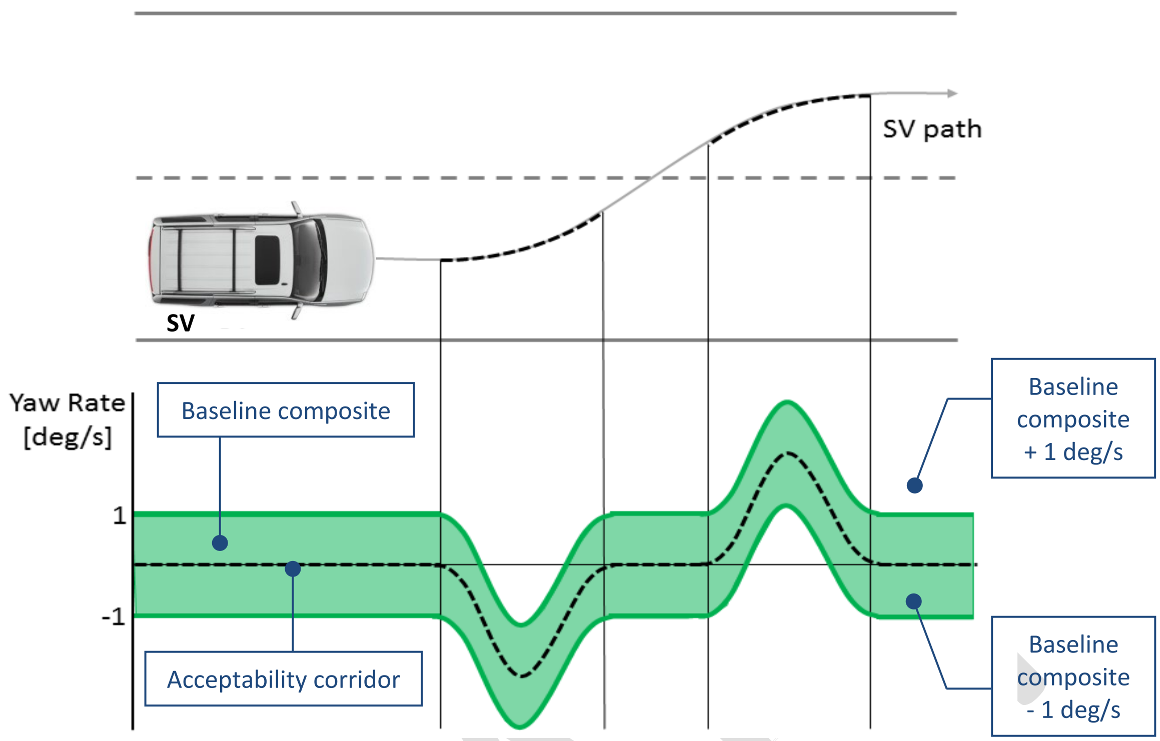

Figure 7. Definition of a yaw rate acceptability corridor.

(b) Performing SVLC_Constant_HW_FP Evaluation Trials (automation level 0 or 1)

Tests performed in automation level 0 or 1 begin with the SV driven in the center of its travel lane at the desired speed. For these tests, SV speed is achieved either manually or after the SV cruise control has been enabled and initialized. Tests performed in automation level 1 begin with enabling and initialization of the SV ACC while the SV is driven at the desired speed in its travel lane. The POV shall then be driven toward the rear of the SV in a lane two lanes to the left of the SV and shall establish the longitudinal position shown in Figure 5 and defined in Table 4b. After remaining in this formation for 3 seconds, the SV driver shall engage the left turn signal indicator and manually initiate a single lane change into the left adjacent lane (i.e., the one between the SV and POV) using the path shown in Figure 6. Since the lane change will not result in an SV-to-POV collision, the BSI system is not expected to intervene at any time during this scenario.

Provided no BSI intervention occurs, the SV lateral position shall not deviate more than 1.6 ft (0.5 m) during the following evaluation trial intervals:

- From the onset of the validity period defined in S5.3.7.5 to initiation of the SV lane change.
- During the lane change shown in Figure 6.
- From completion of the lane change until the end of the validity period defined in S5.3.7.5.

The method used to assess whether a BSI intervention occurred during an SVLC_Constant_HW_FP Evaluation trial performed in automation level 1 is defined in S5.3.7.3.c.

(c) Comparison of Baseline and Evaluation Trials (automation level 0 or 1)

Determination of whether a false positive BSI intervention occurred during an SVLC_Constant_HW_FP Evaluation trial requires comparison of the SV yaw rate data collected during that trial with the acceptability corridor defined by the corresponding baseline data composite using the following steps:

1. Synchronization of the evaluation trial with the baseline composite so that the onsets of the respective lane changes occur with 20 ms of each other.
2. Comparison of the SV yaw rate data collected during the evaluation trial with that defined by acceptability corridor. The SV yaw rate data collected during the evaluation trial shall not exceed the boundaries of the baseline acceptability corridor within the applicable validity period defined in S5.3.7.5.

An example of the comparison used to assess the occurrence of a BSI false positive intervention is shown in Figure 8.

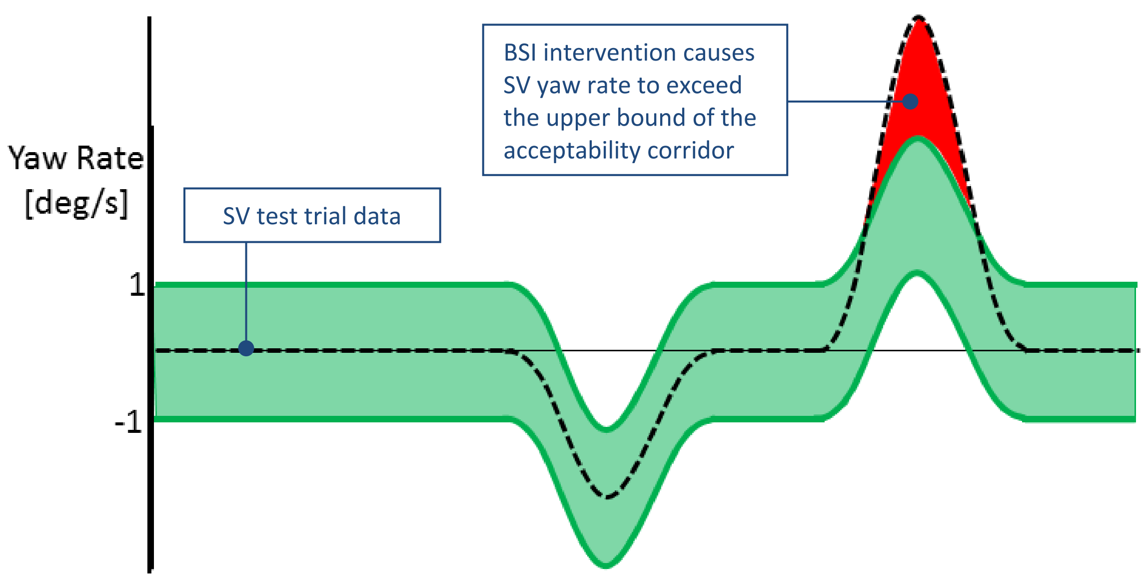

Figure 8. BSI false positive example.

5.3.7.4 SV Lane Changes During Automated Vehicle Level 2 or 3 Operation

Evaluation of the SV BSI system false positive propensity while the vehicle is operating in automation level 2 or 3 requires that the SV be equipped with an automatic lane change system. For vehicle's so-equipped, the SV driver shall operate the vehicle in automation level 2 or 3 for the duration of the validity period defined in S5.3.7.5.

Note: The tests described in this document assume the SV will only provide one single lane change within the validity period defined in S5.3.7.5 when the SV driver activates the turn signal.

If the SV is equipped with automation level 2 or 3 capability, but does not have the ability to automatically change lanes in response to activation of the SV turn signal indicator, the SV shall be evaluated with the vehicle operating in automation level 1 using the process described in S5.3.7.3, including use of the baseline, evaluation, and comparison phases.

(a) Performing SVLC_Constant_HW_FP Baseline Trials (automation level 2 or 3)

Baseline tests shall begin with enabling and initialization of the SV LCC and/or ACC while the SV is driven at the desired speed in the center of the SV travel lane. After 3 seconds, and without touching the steering wheel, the SV driver shall engage the left turn signal indicator and initiate an automatic lane change into the left adjacent lane. Since no POV is present during conduct of the baseline trials, no BSI system interventions are expected.

Using the same process described in S5.3.7.3.a, the yaw rate data from each of the three baseline trials shall be synchronized in time, averaged to generate a composite data trace, and used to define a yaw rate-based acceptability corridor.

(b) Performing SVLC_Constant_HW_FP Evaluation Trials (automation level 2 or 3)

Evaluation tests shall begin with enabling and initialization of the SV LCC and/or ACC while the SV is driven at the desired speed in the center of the SV travel lane. The POV shall then be driven toward the rear of the SV in a lane two lanes to the left of the SV and shall establish the longitudinal position shown in Figure 5 and defined in Table 4b. After remaining in this formation for 3 seconds, and without touching the steering wheel, the SV driver shall engage the left turn signal indicator and initiate an automatic lane change into the left adjacent lane. Since the lane change will not result in an SV-to-POV collision, the BSI system is not expected to intervene at any time during this scenario.

The method used to assess whether a BSI intervention occurred during an SVLC_Constant_HW_FP Evaluation trial performed in automation level 2 or 3 is defined in S5.3.7.4.c.

(c) Comparison of Baseline and Evaluation Trials (automation level 2 or 3)

Determining whether a BSI intervention occurred during an SVLC_Constant_HW_FP evaluation trial performed in automation level 2 or 3 requires comparison of that trial to baseline data. The steps required for this comparison shall be identical to those defined in S5.3.7.3.c.

5.3.7.5 Validity Period

1. The valid test interval begins 3 seconds before the onset of the SV lane change.

2. The valid test interval ends:

    A. When the SV impacts the POV; or

    B. Five seconds after the SV has completed the single lane change into the left lane adjacent to the SV's original travel lane without a BSI intervention; or

    C. One second after a BSI intervention causes the SV to travel ≥ 1 ft (0.3 m) beyond the inboard edge of the lane line separating the post lane change SV travel lane and one adjacent and to the right of it (see Figure 9).

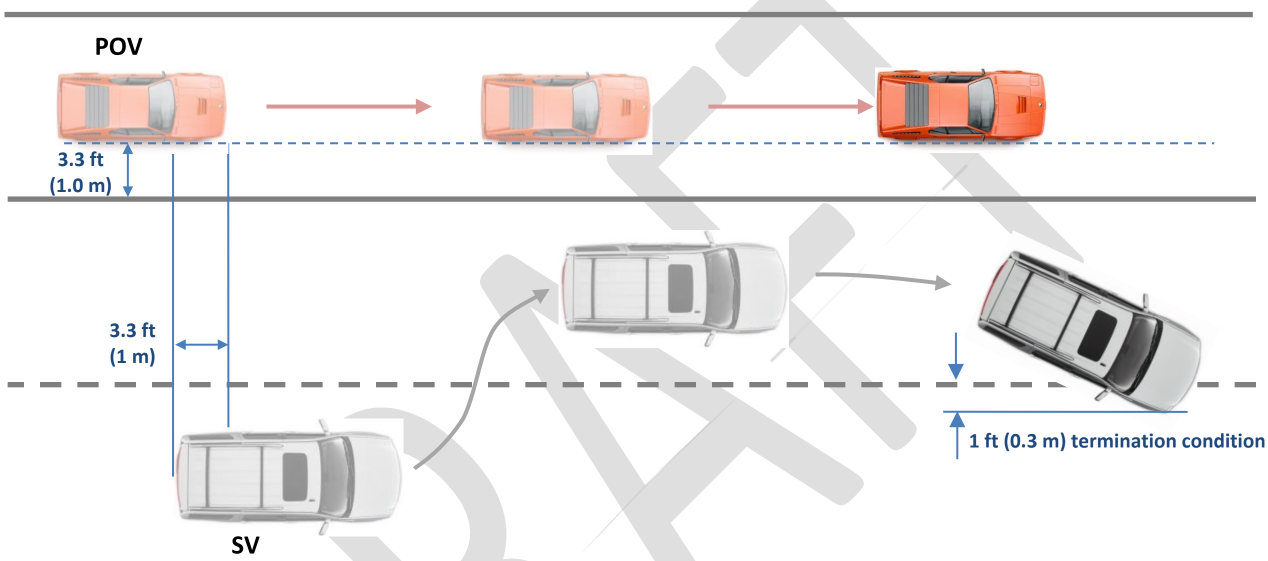

Figure 9. Valid test interval conclusion condition described in S5.3.7.6.2.C (used for the SV Lane Change With Constant Headway, False Positive assessment).

5.3.7.6 End-of-Test Instructions

1. After the validity period defined in S5.3.7.5 is complete, the SV driver shall manually apply force to the brake pedal, bring the vehicle to a stop (if necessary), and place the transmission in park.

2. The SVLC_Constant_HW, FP test trial is complete.

5.3.7.7 Evaluation Criteria

Since the lane change will not result in an SV-to-POV collision, the SV BSI system shall not intervene during any valid SVLC_Constant_HW_FP test trial, regardless of what level of automation the trial was performed with.

6.0 REFERENCES

1. ASTM International. (2011). *ASTM Standard E 1337-90 (2008) Standard Test Method for Determining Longitudinal Peak Braking Coefficient of Paved Surfaces Using a Standard Reference Test Tire.* West Conshohocken, PA: Author.

2. Federal Highway Administration. (2012, May). *Manual on Uniform Traffic Control Devices for Streets and Highways, 2009 Edition*. Washington, DC: Author. Available at https://mutcd.fhwa.dot.gov/pdfs/2009r1r2/pdf_index.htm

3. Szabo, S., & Norcross, R. (2006, February). *Recommendations for objective test procedures for road departure crash warning systems.* (Report No. NISTIR 7288). Gaithersburg, MD: Department of Commerce.

4. Forkenbrock, G. J., Snyder, A. C., Davis, I. J., & O'Harra, B. C. (in press). *A test track comparison of the global vehicle target and NHTSA's strikeable surrogate vehicle*. Washington, DC: National Highway Traffic Safety Administration.

7.0 DATA SHEETS

SUBJECT VEHICLE (SV) INFORMATION			
NHTSA Vehicle No.		Vehicle Identification Number (VIN)	
Vehicle Make/Model/Body Style		Date of Manufacture	
Vehicle Width (in. or mm)		Vehicle Length (in. or mm)	
Vehicle Test Weight (lbs or kg)	GVWR (lbs or kg)	Front GAWR (lbs or kg)	Rear GAWR (lbs or kg)

Driver Seatbelt Buckled?	Front Passenger Seatbelt Buckled?	Airbags Disabled?

Cruise Control (conventional)	
Operational Speed Range (mph or km/h)	Method to Engage (stalk, button, etc.)

Adaptive Cruise Control (ACC)		
Operational Speed Range (mph or km/h)	Method to Engage (stalk, button, etc.)	Number of Headway Settings

Lane Centering Control (LCC)	
Operational Speed Range (mph or km/h)	Method to Engage (stalk, button, etc.)

SAE Automation Level 2 or 3 Driving
Process to engage automation level 2 or 3 driving

PRINCIPAL OTHER VEHICLE (POV) INFORMATION	
POV Description (e.g., surrogate design)	POV Construction Type / Materials (e.g., carbon fiber shell)
POV Moving Platform Description (if applicable)	POV Moving Platform Material (if applicable)

GENERAL TEST FACILITY INFORMATION		
Facility Designation (e.g., “VDA west edge”)	Test Surface (e.g., asphalt, concrete)	Surface Condition
Lane Line Description		
Vehicle Orientation During **SVLC_Constant_HW** tests (e.g., “North”)	Vehicle Orientation During **SVLC_Closing_HW** tests	
Vehicle Orientation During **SVLC_Constant_HW_FP baseline** tests	Vehicle Orientation During **SVLC_Constant_HW_FP evaluation** tests	

PRETEST CONDITIONS (complete before each test scenario is evaluated)			
Time	Ambient Temperature (°F or °C)	Wind Speed (mph or km/h)	Wind Direction
Ambient Condition Description (e.g., “overcast”)			
Test Vehicle-to-POV Distance During Static Cal, Measured (in. or mm)		Test Vehicle-to-POV Distance During Static Cal, Displayed (in. or mm)	

POST-TEST CONDITIONS (complete after each test scenario is evaluated)			
Time	Ambient Temperature (°F or °C)	Wind Speed (mph or km/h)	Wind Direction
Ambient Condition Description (e.g., “overcast”)			
Test Vehicle-to-POV Distance During Static Cal, Measured (in. or mm)		Test Vehicle-to-POV Distance During Static Cal, Displayed (in. or mm)	

Table 5a. SVLC_Constant_HW Test Performance Summary (Level 0 or 1)

Trial #	Manual Speed Control, LCC Off (Automation Level 0)			Cruise Control On, LCC Off (Automation Level 0)			ACC On, LCC Off (Automation Level 1)		
	Lane Deviation? [1]	Crash Avoidance?	Secondary Departure? [2]	Lane Deviation? [1]	Crash Avoidance?	Secondary Departure? [2]	Lane Deviation? [1]	Crash Avoidance?	Secondary Departure? [2]
1									
2									
3									

[1]Lane Deviation = Maximum SV incursion into the POV travel lane, measured from the left inboard edge of the SV travel lane line.

[2]Secondary Departure = Maximum SV incursion into a lane adjacent and to the right of the SV travel lane, measured from the right inboard edge of the SV travel lane line.

Table 5b. SVLC_Constant_HW Test Performance Summary (Level 2 or 3)

Trial #	ACC On, LCC On; Automatic SV Lane Change (Automation Level 2 or 3)		
	Lane Deviation? [1]	Crash Avoidance?	Secondary Departure? [2]
1			
2			
3			

[1]Lane Deviation = Maximum SV incursion into the POV travel lane, measured from the left inboard edge of the SV travel lane line.

[2]Secondary Departure = Maximum SV incursion into a lane adjacent and to the right of the SV travel lane, measured from the right inboard edge of the SV travel lane line.

Table 5a. SVLC_Closing_HW Test Performance Summary (Level 0 or 1)

Trial #	Manual Speed Control, LCC Off (Automation Level 0)			Cruise Control On, LCC Off (Automation Level 0)			ACC On, LCC Off (Automation Level 1)		
	Lane Deviation? [1]	Crash Avoidance?	Secondary Departure? [2]	Lane Deviation? [1]	Crash Avoidance?	Secondary Departure? [2]	Lane Deviation? [1]	Crash Avoidance?	Secondary Departure? [2]
1									
2									
3									

[1]Lane Deviation = Maximum SV incursion into the POV travel lane, measured from the left inboard edge of the SV travel lane line.

[2]Secondary Departure = Maximum SV incursion into a lane adjacent and to the right of the SV travel lane, measured from the right inboard edge of the SV travel lane line.

Table 5b. SVLC_ Closing_HW Test Performance Summary (Level 2 or 3)

Trial #	ACC On, LCC On; Automatic SV Lane Change (Automation Level 2 or 3)		
	Lane Deviation? [1]	Crash Avoidance?	Secondary Departure? [2]
1			
2			
3			

[1]Lane Deviation = Maximum SV incursion into the POV travel lane, measured from the left inboard edge of the SV travel lane line.

[2]Secondary Departure = Maximum SV incursion into a lane adjacent and to the right of the SV travel lane, measured from the right inboard edge of the SV travel lane line.

Table 7a. SVLC_Constant_HW_FP Test Performance Summary (Level 0 or 1)

Trial #	Manual Speed Control, LCC Off (Automation Level 0)		Cruise Control On, LCC Off (Automation Level 0)		ACC On, LCC Off (Automation Level 1)	
	BSI Intervention?	Secondary Departure? [1]	BSI Intervention?	Secondary Departure? [1]	BSI Intervention?	Secondary Departure? [1]
1						
2						
3						

[1] Secondary Departure = Maximum SV incursion into a lane adjacent and to the right of the SV travel lane, measured from the right inboard edge of the SV travel lane line.

Table 7b. SVLC_Constant_HW_FP Test Performance Summary (Level 2 or 3)

Trial #	ACC on, LCC on Automatic SV lane change (Automation Level 2 or 3)	
	BSI Intervention?	Secondary Departure? [1]
1		
2		
3		

[1] Secondary Departure = Maximum SV incursion into a lane adjacent and to the right of the SV travel lane, measured from the right inboard edge of the SV travel lane line.

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