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16. Abstract

This test procedure provides specifications used by the National Highway Traffic Safety Administration (NHTSA) to research Active Park Assist (APA) 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 APA includes low-speed object rich environments such as parking lots and high-density residential, commercial, and industrial areas.

The test procedures described in this document use a series of low speed parking and crash-imminent driving scenarios to assess APA operation. In this assessment, the SV shall identify a parking spaces capable of accommodating a driver's vehicle and, with minimal-to-no input from the driver, automatically provide the driver with control input assistance to maneuver the vehicle into the space without colliding into other objects or pedestrians.

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ACTIVE PARK ASSIST TEST TRACK PERFORMANCE EVALUATION

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GLOSSARY

ADA	Americans with Disability Act
APA	Active Park Assist
Euro NCAP	European New Car Assessment Programme
FHWA	Federal Highway Administration
GVT	Global Vehicle Target
GVWR	Gross Vehicle Weight Rating
lidar	Light Detection and Ranging
MUTCD	Manual on Uniform Traffic Control Devices
NHTSA	National Highway Traffic Safety Administration
PED	Surrogate Pedestrian (Test Mannequin)
PV	Parked Vehicle
radar	Radio Detection and Ranging
SV	Subject Vehicle

REVISION HISTORY

Date	Revision
04/09/2018	• Original draft
04/02/2019	• Minor figure formatting changes. • The distance to the centerline was increased from 13 ft to 14 ft in Figure 2. • The distance of the pedestrian platform to the inboard longitudinal edge was increased from 4 ft to 4.5 ft in Figure 5. • Lowered the steady state timing requirements on the approach to the parking space to be consistent with the timing criteria for the start of the validity period. • The termination boundary for the perpendicular parking maneuver has been increased to 4 spaces (36 ft, or 11 m) past the desired space to be in better agreement with that used during parallel parking. • In Section 5.4.1, the time from when SV driver first receives the parking space detection notification (or the time when the rearmost part of the SV crosses the termination boundary) to the time they must release the accelerator pedal and stop the vehicle has been changed to 5 seconds. The previous specification was deceleration-based. • Clarification on how to evaluate a vehicle equipped with an active parking assist system comprised of automated steering, brake pedal, and accelerator pedal inputs, but manual gear selection, was added to Section 5.4.2. • In Section 5.5.1, the time needed for the pedestrian mannequin to operate at a constant speed of 3.5 mph (5.6 km/h) has been corrected (reduced by 0.1 seconds). • In Section 5.5.1, the initial distance of the pedestrian mannequin to the desired space edge line has been reduced to 1 ft (0.3 m). • In Section 5.5.1, the pedestrian mannequin incursion into the desired space has been increased to 4 ft (1.2 m) and 9 ft (2.7 m) for the parallel and perpendicular parking maneuvers, respectively. • The Perpendicular Parking with Vehicle Obstruction test scenario has been removed from Section 5.5.2. • Manual override assessments now occur within 500 ms after the parking maneuver's initial (clockwise) steering input is initiated.

1.0 PURPOSE AND APPLICATION

This test procedure provides specifications used by the National Highway Traffic Safety Administration (NHTSA) to research active park assist system performance on light vehicles with gross vehicle weight ratings (GVWR) of up to 10,000 lbs (4536 kg). The expected operating domain for active park assist includes low speed, object rich environments such as parking lots and high-density residential, commercial, and industrial areas.

Current active park assist technology relies on sensors such as cameras, ultrasonic proximity detectors, and radar(s) to recognize a potential parking space. As such, the test procedures described in the document rely on test courses defined by pavement markings (painted or taped lines), other traffic vehicles (real and artificial), and simulated pedestrians on the test course to emulate the real-world driving environment. Although it is impossible to predict what technologies could be used by future active park assist systems (e.g., magnetic markers, infrared, vehicle-to-vehicle (V2V) communication), it is believed that modifications to these procedures, when deemed appropriate, could be used to accommodate the evaluation of alternative or more advanced active park assist systems.

2.0 GENERAL REQUIREMENTS

The test procedure described in this document was developed to evaluate the ability of an active park assist system to automatically, safely, and efficiently identify an available parking space and maneuver a light vehicle into that space. Functional capability is assessed using parking scenarios with perpendicular and parallel space orientations. System operation in response to stationary and moving obstructions (including pedestrians), and the vehicle's response to accelerator pedal, brake pedal, and steering wheel overrides, shall also be assessed. Repeated trials per test condition are used to evaluate system consistency.

3.0 DEFINITIONS

Active park assist is an automated driver assistance system that identifies parking spaces capable of accommodating a driver's vehicle and, with minimal-to-no input from the driver, automatically provides the driver with control input assistance to maneuver the vehicle into the space without colliding into other objects or pedestrians.

The active park assist system shall, at a minimum, provide automated control of the steering. Additional capabilities may include automated control of acceleration, foundation brakes, and/or gear selector. Regardless of the system configuration, the subject vehicle (SV) driver shall be able to terminate any and all automated control utilized during the parking maneuver via manual override.

The test procedure described in this document is designed to evaluate active park assist system operation while a driver is seated in the SV driver's seat.

4.0 PRETEST AND FACILITY REQUIREMENTS

4.1 Road Test Surface

The tests described in this document shall be performed using a dry, uniform, smooth, level, solid-paved test surface. Surfaces with irregularities, such as dips and large cracks, are unsuitable, as they may confound the test results.

4.2 Line Markings

The lines used to delineate the approach lane and parking spaces described in this document (including the perpendicular edge and inboard longitudinal lines shown in Figures 1 and 2) shall meet Federal Highway Administration (FHWA) standards and guidelines specified in the Manual on Uniform Traffic Control Devices (MUTCD) and be considered in "very good condition" [1].

4.2.1 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 (CIE) for color and the American Society for Testing and Materials (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) [2]. Parking space markings shall be white.

4.2.2 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.06 – Functions, Widths, and Patterns of Longitudinal Pavement Markings" of the MUTCD [1].

4.3 Test Courses

The perpendicular and parallel parking spaces used for the tests described in this test procedure shall be located on the right side of the SV. The parking spaces[1] shall be delineated with pavement markings only; the use of curbs is not specified. Allowable dimensions for the parked vehicles shown in the respective test layout descriptions are provided in Section 4.5.1.

[1] Parking space dimensions are compliant with the Americans with Disability Act (ADA) Standard for Accessible Design [3]. The minimum width of a parking space defined by this document is 8 ft (2.4 m). However, it does not define the length of a parking space, which is often defined by a locality.

4.3.1 Perpendicular Parking Test Layout

The desired SV parking space, shown in Figure 1, shall be 9 ft (2.4 m) wide from inside edge line to the parallel inside edge line and 18 feet (5.5 m) long from inside of the front edge line to the end of the perpendicular side lines.

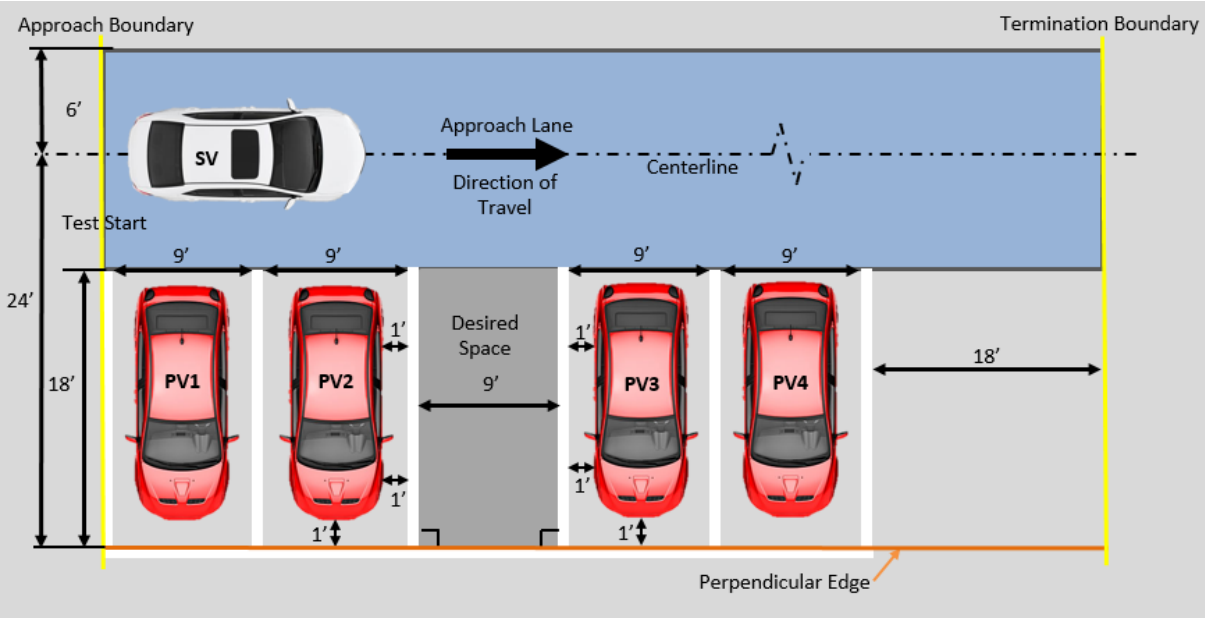

Figure 1. Perpendicular active park assist test layout.

The approach lane shall be perpendicular to the desired SV parking space. The left side of the approach lane shall be delineated with a line whose inboard edge is located 6 ft (1.8 m) from the center of the lane. The composition of this line (solid, dashed, color, etc.) is not restricted.

As shown in Figure 1, four parked vehicles (PVs) shall be positioned within the spaces on either side of the desired SV parking space. Each PV shall face the perpendicular edge line. The dimensions of these spaces shall be equivalent and parallel to the desired SV parking space. If additional parking spaces are present on the test track, they shall have no traffic vehicles in them.

The front most location of the four PVs shall be 12 ± 2 inches (305 ± 51 mm) away from the perpendicular edge line defining the depth of each parking space. The front and rear PV tires closest to the desired SV parking space (i.e., those of PV2 and PV3) shall be 12 ± 2 inches (305 ± 51 mm) away from the inboard edge of each PV's respective parking space.

4.3.2 Parallel Parking Test Layout

The desired SV parallel parking space, shown in Figure 2 shall be delineated with white lines. This parking space shall be 22 ft (6.7 m) long from the inside edge line to the parallel inside edge line, and 8 ft (2.4 m) wide from inside of the longitudinal edge line to the end of the perpendicular side lines.

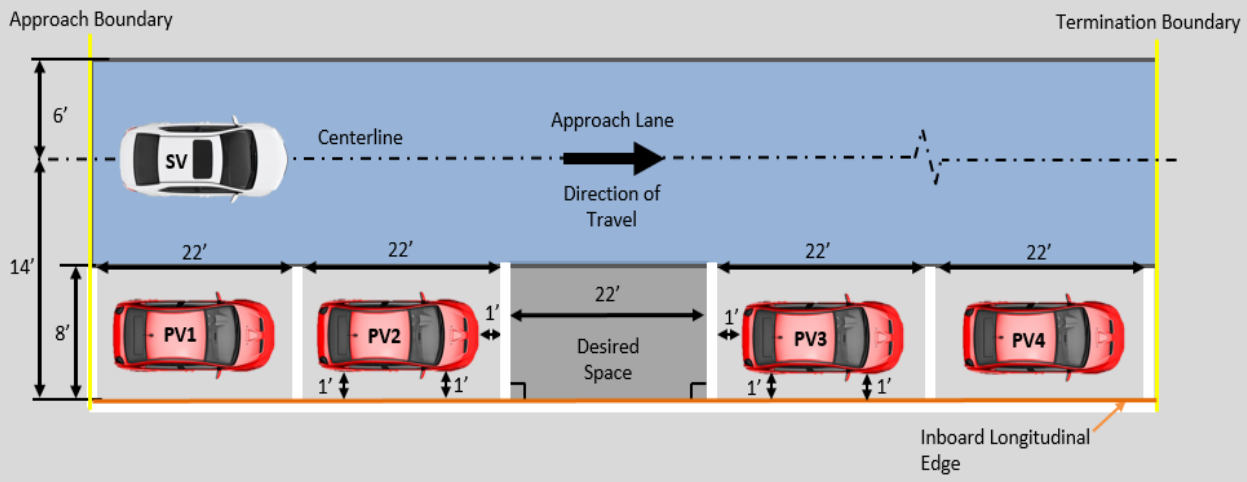

Figure 2. Parallel active park assist test layout.

The approach lane shall be parallel to the desired SV parking space. The left side of the approach lane shall be delineated with a line whose inboard edge is located 6 ft from the center of the lane. The composition of this line (solid, dashed, color, etc.) is not restricted.

Four PVs shall be positioned within spaces on either side of the desired SV parking space as shown in Figure 2. Each PV shall face the same direction of travel as the SV. If additional parking spaces are on the test track, they shall have no traffic vehicles in them. For each PV, the outboard edge right-side tires shall be 12 ± 2 inches (305 ± 51 mm) away from the inboard longitudinal edge line. The front-most and rear-most location of the PVs closest to the desired SV parking space (i.e., those of PV2 and PV3) shall be 12 ± 2 inches (305 ± 51 mm) behind the inboard edge of its respective parking space delineation.

4.4 Ambient Conditions

The ambient conditions described in this section apply to all tests described in this document.

4.4.1 Wind Speed

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

4.4.2 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.

4.4.3 Visibility

Unless specified otherwise, 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 vehicle 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 Test Equipment Specifications

4.5.1 Actual Vehicle(s)

If the test conductor uses an actual vehicle as a PV for the tests described in this document, it shall be a high-production 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 PV is unrestricted. Alternatively, one or more of the PVs may be a realistic surrogate vehicle with specifications described in Section 4.5.2.

4.5.2 Surrogate Vehicle(s)

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 PV in the most realistic manner possible without compromising SV driver safety and minimizing the potential for SV damage. An appropriate surrogate vehicle shall 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 windows 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-PV 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 test conditions of Section 4.5.2.

Note: *NHTSA intends to use the Global Vehicle Target (GVT) as the encroaching PV (PV5) for the tests described in Section 5.5.2 [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. 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.*

4.5.3 Surrogate Pedestrian (Test Mannequin)

A realistic-appearing surrogate pedestrian test mannequin (subsequently referred to as the "PED") shall be used for the tests described in Section 5.5.1. A suitable PED shall have the characteristics representative of a 50th percentile adult male. This is intended to maximize the chance of the SV to detect the PED in the most realistic manner possible without compromising the safety of those performing the tests and to minimize the potential for SV damage. An appropriate PED shall possess the following attributes:

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

    i. Must include a head, torso, two arms, and two legs.

    ii. Must be clothed with a black long-sleeved shirt and blue long pants.

    iii. Must be posable with adjustable but non-articulating leg and arm spacing

B. Representative reflective properties 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-PED 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 PED used to perform the tests described in this document satisfies the test conditions of Section 4.5.3.

Note: *The PED NHTSA intends to use for the evaluations described in this document satisfies the specifications defined in the European New Car Assessment Programme (Euro NCAP) Automatic Emergency Braking for Vulnerable Road User (AEM VRU) systems test procedure [5]. This static (non-articulating) posable mannequin is a 50th percentile adult male-sized surrogate pedestrian 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 reflective characteristics are achieved by using specific treatments to the PED skin surfaces, clothing, and test apparatus. The PED is secured to a shallow platform (using magnets), which is accurately pulled along a pre-programmed path using closed loop control. If hit by the SV, the PED 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. The PED can be repeatedly struck from any approach angle without harm to those performing the tests or the vehicles being evaluated. Reassembly and securing the PED back to top of the platform takes one person approximately 1 minute to complete.*

4.6 Instrumentation

4.6.1 Sensors and Sensor Locations

A brief description of the sensors used for the tests described in this document is provided in Table 1.

4.6.1.1 SV Speed

Subject vehicle longitudinal velocity shall be measured. The sensor(s) used for this measurement is (are) not constrained provided they meet the range, resolution, and accuracy specifications provided in Table 1.

4.6.1.2 SV and Test Object Positions

Subject vehicle position relative to the parking spot shall be measured. The sensor(s) used for this measurement is (are) not constrained provided they meet the range, resolution, and accuracy specifications provided in Table 1.

While conducting the tests described in Section 5.5.1, the position of the PED shall be measured and recorded during the data collection interval. The sensor(s) used for this measurement is (are) not constrained provided they meet the range, resolution, and accuracy specifications provided in Table 1.

Table 1 – Recommended Sensors and Sensor Specifications

Sensor Type	Output	Range	Resolution	Accuracy
Longitudinal Speed Sensor	Vehicle speed	0.1 – 20 mph (0.1 – 100 km/h)	0.1 mph (0.2 km/h)	± 0.25% of full scale
Various Position	Position relative to parking space edge(s)	0 – 4.0 ft (0 – 1.2m)	0.25 in (6 mm)	0.25 in (6 mm)
Accelerator Pedal Position Sensor	Percent full stroke	0-100%	1%	1%
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 Torque Sensor	Driver Input steering torque	±500 in. lbs.	5 in. lbs.	5 in. lbs.
Steering Angle Sensor	Hand wheel steering angle	±360 degrees	1 degree	2 degrees
Parking Space Detection Data Flag	Signal from park assist system indicating a suitable parking space has been detected	Output assessed via video/audio data reduction		Output response ≤10 ms
Park Assist Operation Data Flag	Signal from park assist system indicating if the park assist system is in operation	Output assessed via video/audio data reduction		Output response ≤10 ms
Parking Maneuver Completion Data Flag	Signal from park assist system indicating if the parking maneuver is complete	Output assessed via video/audio data reduction		Output response ≤10 ms
Override Initiation Data Flag	Signal from park assist system indicating that a manual override has interrupted the automated parking m	Output assessed via video/audio data reduction		Output response ≤10 ms
Override Completion Data Flag	Signal from park assist system indicating manual control of SV acceleration, braking, steering, and gear selection has been fully restored.	Output assessed via video/audio data reduction		Output response ≤10 ms
Driver Input	Driver input time	Output assessed via video data reduction		Output response ≤10 ms

While conducting the tests described in Section 5.5.2, the position of PV2 and PV3 shall be measured and recorded during the data collection interval. The sensor(s) used for this measurement is (are) not constrained provided they meet the range, resolution, and accuracy specifications provided in Table 1.

4.6.1.3 Vehicle Instructions/Display Notifications

A data acquisition system shall be used to record any vehicle instructions and/or notification presented to the driver. The sensor(s) used for this measurement is (are) not constrained provided they meet the range, resolution, and accuracy specifications provided in Table 1.

4.6.1.4 Driver Input

A data acquisition system to record any driver input to the vehicle shall be used. The sensor(s) used for this measurement is (are) not constrained provided they meet the range, resolution, and accuracy specifications provided in Table 1.

5.0 TEST EXECUTION AND TEST REQUIREMENTS

5.1 Pre-Test System Initialization

Some vehicles may require a brief period of initialization (e.g., verification of sensor alignment and detection readiness) before their active park assist system performance can be properly assessed. If a manufacturer-specific initialization procedure is required by a park assist system, 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 procedure.

5.2 Data Collection Interval

Data collection for all trials described in this document shall be initiated at least 2 seconds before the front most part of the SV crosses a plane perpendicular to the approach lane, located at the approach boundary, to the longer of the following:

- 5 seconds after the park assist system has notified the SV driver that the automated parking process is complete.
- 5 seconds after completion of any termination condition.

5.3 Test Validity Conditions

5.3.1 Validity Period

The validity period for the tests described in this test procedure begins 1 second before the front most part of the SV crosses a plane perpendicular to the approach lane, located at the approach boundary, and concludes at the onset of the SV driver's braking in response to receiving the parking space detection notification described in Section 5.4.1. If this notification does not occur,

the validity period concludes 1 second after the rearmost part of the SV crosses a plane perpendicular to the approach lane, located at the termination boundary.

5.3.2 Vehicle Speed

The SV longitudinal velocity shall be 6 ± 1 mph (9.7 ± 1.6 km/h) during the validity period.

5.3.3 Vehicle Path

The SV lateral position shall be within 1 ft (0.3 m) of the center of the approach lane during the validity period.

5.3.4 SV Driver Response Times

The driver response times needed to perform valid test trials are specified within Sections 5.4, 5.5, and 5.6.

5.4 Active Park Assist Performance Assessment

The tests described in this section are designed to objectively evaluate the SV's ability to successfully perform automated parking into spaces with fixed dimensions. The tests are comprised of two parking space configurations (perpendicular and parallel, as previously shown in Figure 1 and Figure 2, respectively) and one approach direction. Each test condition shall be repeated five (5) times.

Sections 5.4.1 to 5.4.4 define the four stages needed to objectively and consistently perform active parking assist (APA) evaluations. Each stage is defined in a manner intended to ensure the proper system operation regardless of what driver-vehicle interaction is required by the respective system design. Table 2 provides an overview of the related test matrix.

Table 2 – Active Park Assist Test Matrix

Parking Orientation	Parking Space Location	SV Approach		Number of Trials
		Speed	Lateral Distance from Lane Center	
Parallel	Right side of SV	6 ± 1 mph (9.7 ± 1.6 km/h)	± 1 ft (0.3 m)	5
Perpendicular	Right side of SV	6 ± 1 mph (9.7 ± 1.6 km/h)	± 1 ft (0.3 m)	5

To mitigate driver confusion, the active park assist system shall provide the SV driver with clear instructions as to what their role is throughout the automated parking process. These instructions shall be recorded during the collection interval described in Section 5.2. The modality of the notifications described in Sections 5.4.1 to 5.4.4 is not restricted; however, each notification shall be unambiguously presented to the SV driver through verbal auditory and/or visual means.

Note: If the active park assist system is inoperable and/or unable to present the notifications described in Sections 5.4.1 to 5.4.4 (e.g., due to environmental, mechanical, or software-related reasons), the system shall suppress all active parking functions, notify the driver of the active park assist system unavailability, and restore manual control of the SV's longitudinal and lateral movement to the driver.

5.4.1 Stage 1: Parking Space Detection

Before each test trial is initiated, the SV driver shall confirm the active park assist system has been enabled. Each test trial begins with the SV being driven in the center ±12 inches (0.3 m) of the travel lane shown in Figure 1 (perpendicular parking) or Figure 2 (parallel parking) at a constant speed of 6 ± 1 mph (9.7 ± 1.6 km/h) for 1 second prior to crossing the respective approach boundary.

The SV shall be driven towards, and beyond if necessary, the desired SV parking space until the park assist system notifies the driver it has identified a space with dimensions large enough to accommodate the SV.

The SV driver shall release the accelerator pedal and brake the SV to a complete stop within 5 seconds of receiving the parking space detection notification or before the rearmost part of the SV crosses the termination boundary. The brake pedal shall be held until the steps described in Section 5.4.2 are initiated.

The SV shall present a parking space detection notification by the time the rearmost part of the SV traverses a plane defined by the termination boundary shown in Figure 1 (perpendicular parking) or Figure 2 (parallel parking). If this notification does not occur, or occurs after the rearmost part of the SV traverses a plane defined by the termination boundary (shown in Figure 1 or 2), the result of that test trial shall be recorded as "failure."

5.4.2 Stage 2: Automated Parking Initiation

After bringing the SV to a complete stop, the driver shall initiate the automated parking function in accordance with the in-vehicle instructions presented by the system within 5 seconds.

At a minimum, the system shall clearly indicate to the driver through verbal auditory and/or visual means whether the SV driver must manually operate the transmission gear selector, accelerator and/or brake pedal during the automated parking maneuver, and the extent to which they must do so throughout the automated parking process.

- For systems that automatically perform the parking maneuver using automated gear selector, steering, brake pedal, and accelerator pedal inputs, the SV driver shall fully release manual control of the steering wheel and brake pedal within 5 seconds of being prompted to do so.

- For systems that perform the parking maneuver using automated steering, brake pedal, and accelerator pedal inputs, but require manual gear selection, the SV driver shall fully release

manual control of the steering wheel and brake pedal within 5 seconds or being prompted to do so.

- For systems that perform the parking maneuver using automated steering with manual gear selector, brake pedal, and accelerator pedal inputs, the SV driver shall fully release manual control of the steering wheel within 5 seconds of being prompted to do so.

The SV shall present in-vehicle instructions within 5 seconds after the SV driver has initiated the automated parking function. If this notification does not occur, or occurs later than 5 seconds after the SV driver has initiated the automated parking function, the result of that test trial shall be recorded as "failure."

5.4.3 Stage 3: Automated Parking Execution

The automated parking process shall be efficiently executed. The parking phase of the maneuver shall be taken to begin at the instant the SV driver fully releases the brake pedal (i.e., as described in Section 5.4.1). Completion of the parking stage occurs when the park assist system first notifies the driver that the parking maneuver is complete.

- For systems that automatically perform the parking maneuver using only automated inputs (gear selector, steering, brake pedal, and accelerator pedal inputs), a test trial is terminated if the system cannot complete the parking maneuver within 45 seconds.
- For systems that perform the parking maneuver using automated steering in conjunction with manual gear selector, brake pedal, and/or accelerator pedal inputs, the SV driver must respond to any accelerator pedal and/or brake pedal application requests presented by the APA system within 2 second. Changes to the gear selector position shall be completed within 3 seconds of a request, when applicable. Provided that the SV driver satisfies their response time requirements, a test trial is terminated if the system cannot complete the parking maneuver within 60 seconds.

5.4.4 Stage 4: Automated Parking Completion

The park assist system shall notify the SV driver through verbal auditory and/or visual means when the automated parking process is complete. At that time, the system shall move the gear selector to park. If the system is unable to automatically complete this function, it shall notify the driver to do so. The park assist system shall also recommend that the vehicle be turned off and that the driver checks their surroundings before exiting the vehicle.

If the system does not present in-vehicle instructions within 5 seconds after completion of the parking maneuver, the SV shall receive a fail rating for that test trial.

For the perpendicular parking test maneuver, the SV position shall also satisfy three performance criteria at completion of each test trial:

- The rear-most part of the SV shall be ≤12 in (0.3 m) from the inboard perpendicular edge defining the rear of the desired SV space (as defined in Figure 1).

- The left-most part of the SV shall be ≥12 in (0.3 m) away from a vertical plane defined by the right-most part of PV2. This plane shall be perpendicular to the approach lane.
- The right-most part of the SV shall be ≥12 in (0.3 m) away from a vertical plane defined by the left-most part of PV3. This plane shall be perpendicular to the approach lane.

Note: At no point during the automated parking maneuver shall any part of the SV cross the inboard perpendicular edge of the desired SV parking space.

For the parallel parking test maneuver, the SV position shall satisfy three performance criteria at completion of each test trial:

- The outboard edge of the SV's right-side tires shall be ≤12 in (0.3 m) from the inboard longitudinal edge of the desired SV parking space (as defined in Figure 2).
- The front-most part of the SV shall be ≥12 in (0.3 m) away from a vertical plane defined by the rear-most part of PV3. This plane shall be perpendicular to the approach lane.
- The rear-most part of the SV shall be ≥12 in (0.3 m) away from a vertical plane defined by the front-most part of PV2. This plane shall be perpendicular to the approach lane.

Note: At no point during the automated parking maneuver shall any part of the SV cross the inboard longitudinal edge (i.e., during parallel parking) of the desired SV parking space by more than 12 in (0.3 m).

5.5 Encroaching Pedestrian and Obstructing Vehicle Recognition Assessments

The tests described in this section are designed to objectively evaluate how an SV responds to a [simulated] pedestrian (Section 5.5.1) or obstructing vehicle (Section 5.5.2) introduced while the parking maneuvers described in Section 5.4 are being performed. Each test condition, shown in Table 3 shall be repeated five (5) times.

Table 3 – Active Park Assist Encroaching Pedestrian and Vehicle Recognition Test Matrix

Parking Orientation	Parking Space Location	Encroaching Pedestrian (number of trials)		Obstructing Vehicle (number of trials)	
		SV Front	SV Rear	SV Front	SV Rear
Parallel	Right side of SV	5	5	n/a	5
Perpendicular	Right side of SV	n/a	5	n/a	5

5.5.1 Encroaching Pedestrian Detection Assessment

The following test criteria shall be applicable during each encroaching pedestrian test described in Sections 5.5.1.1 and 5.5.1.2:

- The SV driver shall initiate the automated parking maneuver using the procedure previously described in Section 5.4.
- The path travelled by the PED shall be from 1 ft (0.3 m) outside of the desired SV space to a location:
  - 4 ft (1.2 m) from the inboard longitudinal edge line for parallel parking, or
  - 9 ft (2.7 m) from the inboard perpendicular edge line for perpendicular parking.
- The lateral and longitudinal path tolerances of the PED shall be ±6 in (15 cm).
- The PED shall use the following nominal displacement profile: accelerate from rest to 3.5 mph (5.6 km/h) in 0.5 seconds, remain at a constant 3.5 mph (5.6 km/h), then decelerate to a stop in 0.5 seconds. The constant PED speed shall be maintained for:
  - 0.47 seconds for parallel parking, or
  - 1.45 seconds for perpendicular parking
- The overall time tolerance to achieve total longitudinal displacement of the PED shall be ±0.5 seconds.

The performance criteria for the encroaching pedestrian tests are described in Section 5.5.1.3.

5.5.1.1 Parallel Parking with Pedestrian

The parallel parking with pedestrian tests are comprised of rear and front encroaching trials. Except for where the PED enters desired SV parking space, these tests are equivalent.

(a) Rear Encroaching Pedestrian Test

For the rear encroaching trials, the PED path shall be perpendicular to the inboard longitudinal edge shown in Figure 3, and 8 ft (1.2 m) ahead of the front most part of PV2. The PED shall begin moving into the desired SV space within 1 second after the SV first begins to move backwards during Stage 3 of the parking maneuver (i.e., when the SV first begins to approach PV2).

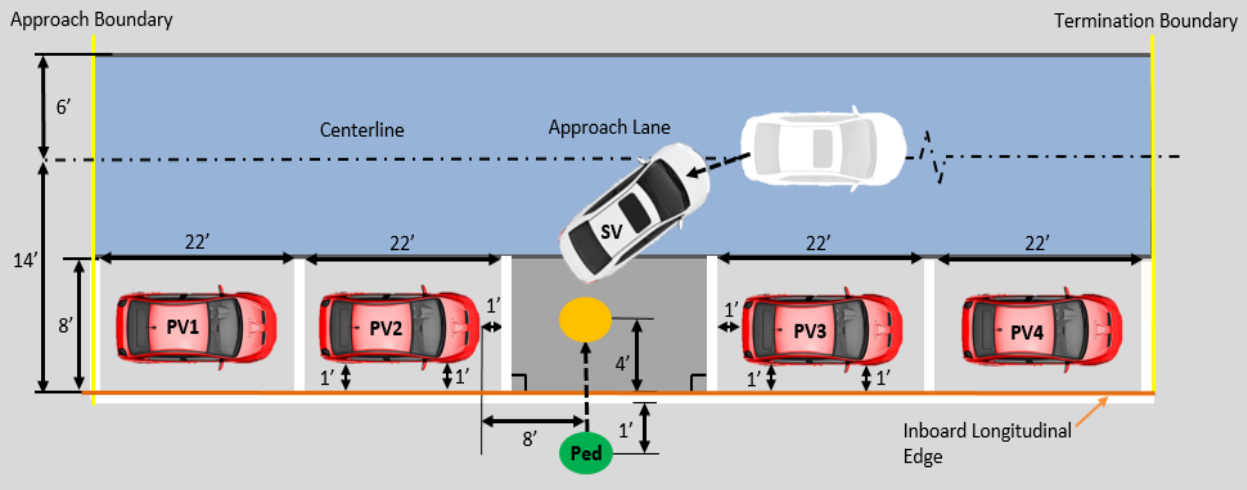

Figure 3. Encroaching pedestrian while parallel parking test layout (rear approach).

(b) Front Encroaching Pedestrian Test

For the front encroaching trials, the PED path shall be perpendicular to the inboard longitudinal edge shown in Figure 4, and 8 ft (1.2 m) behind the rear most part of PV3. The PED shall begin moving into the desired SV space within 1 second after the SV first begins to move backwards during Stage 3 of the parking maneuver.

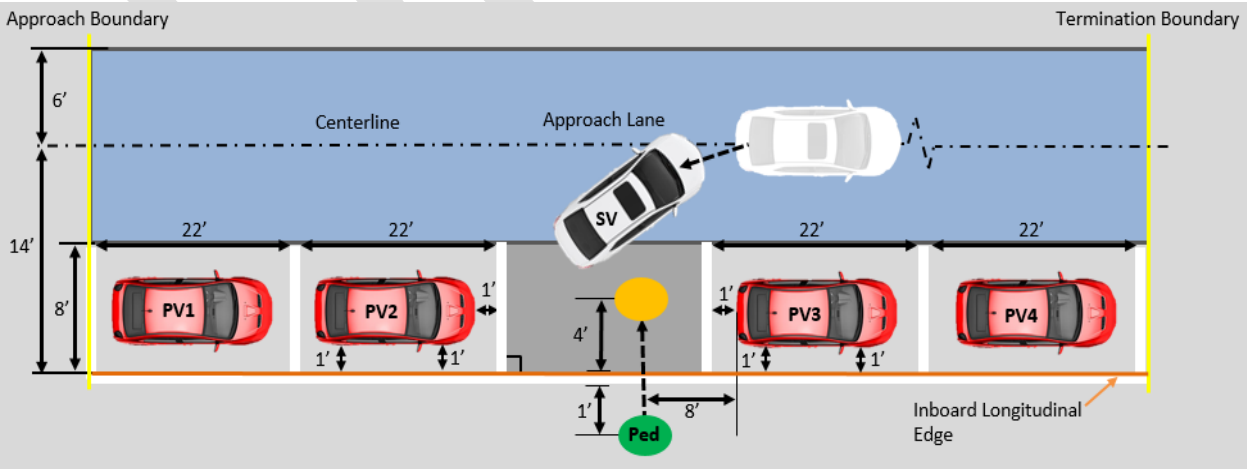

Figure 4. Encroaching pedestrian while parallel parking test layout (front approach).

5.5.1.3 Perpendicular Parking with Pedestrian

The perpendicular parking with pedestrian tests are comprised of rear encroaching trials. The PED path shall be perpendicular to the front edge line shown in Figure 5, and laterally centered within the desired SV space. The PED shall begin moving into the desired SV space within 1 second after the SV first begins to move backwards during Stage 3 of the parking maneuver.

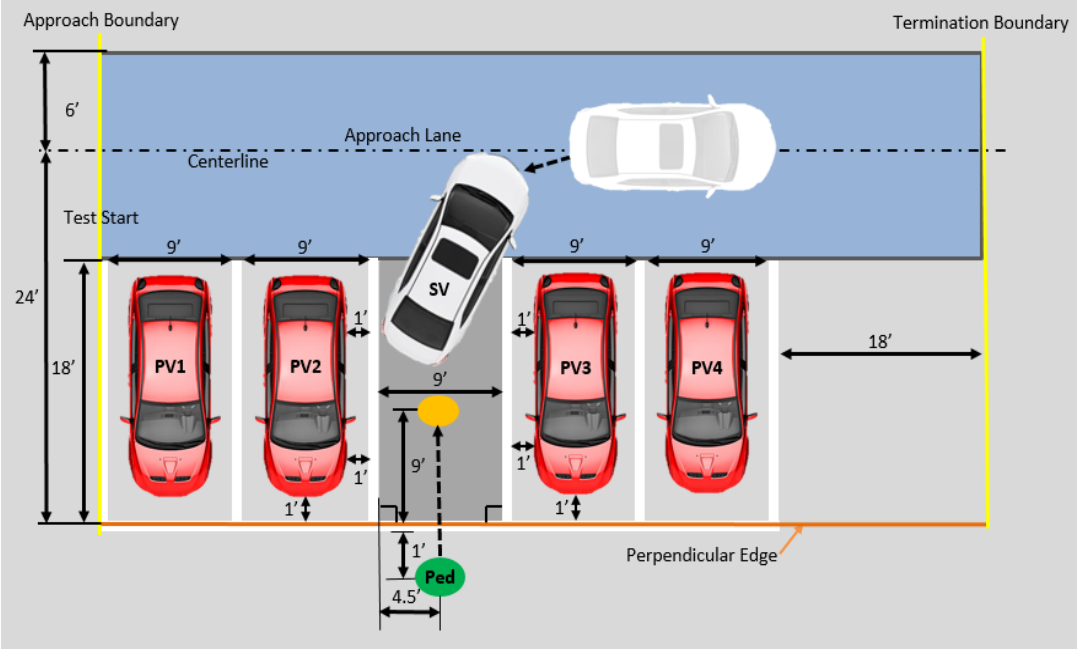

Figure 5. Encroaching pedestrian while perpendicular parking test layout.

5.5.1.4 Encroaching Pedestrian Detection Performance

For systems that use only automated inputs, the APA system shall not allow the SV to impact the encroaching pedestrian at any time during the parking maneuver. If the system cannot park the SV within the desired SV space due to the presence of the PED, the SV shall terminate the automated parking maneuver and restore full manual control of the SV to the SV driver.

For systems that perform the parking maneuver using automated steering in conjunction with manual gear selector, brake pedal, and/or accelerator pedal inputs, the system shall instruct the SV driver how to avoid the PED during the parking maneuver. Provided the SV driver responds to the active park assist system as requested, and within 2 seconds, the SV shall not impact PV2 or PV3 at any time during the parking maneuver. If the system cannot park the SV within the desired SV space due to the presence of the test PED, the SV shall terminate the automated parking maneuver and restore full manual control of the SV to the SV driver.

5.5.2 Obstructing Vehicle Detection Assessment

The following test criteria shall be applicable during each obstructing vehicle detection test described in Section 5.5.2.1:

- The SV driver shall initiate the automated parking maneuver using the procedure previously described in Section 5.4. However, from the onset of Stage 1 to the onset of Stage 3 of the maneuver, PV5 shall follow the SV with a constant longitudinal headway of 6 ft (1.8 m) and a lateral offset of 3 ft (0.9 m) to the left of the SV travel lane center. The lateral and longitudinal path tolerances of PV5 shall be ±6 in (15 cm) and ±1 ft (0.3 m), respectively.

- PV5 shall remain stationary while the SV performs Stages 3 and 4 of the parking maneuver.

The performance criteria for the obstructing vehicle tests are described in Section 5.5.2.2.

5.5.2.1 Parallel Parking with Vehicle Obstruction

Using the procedure described in Section 5.4, the SV driver shall initiate the automated parallel parking maneuver, but with the SV-to-PV5 orientation described in Section 5.5.2 and shown in Figure 7. The test shall conclude at the end of the data collection interval (see Section 5.2).

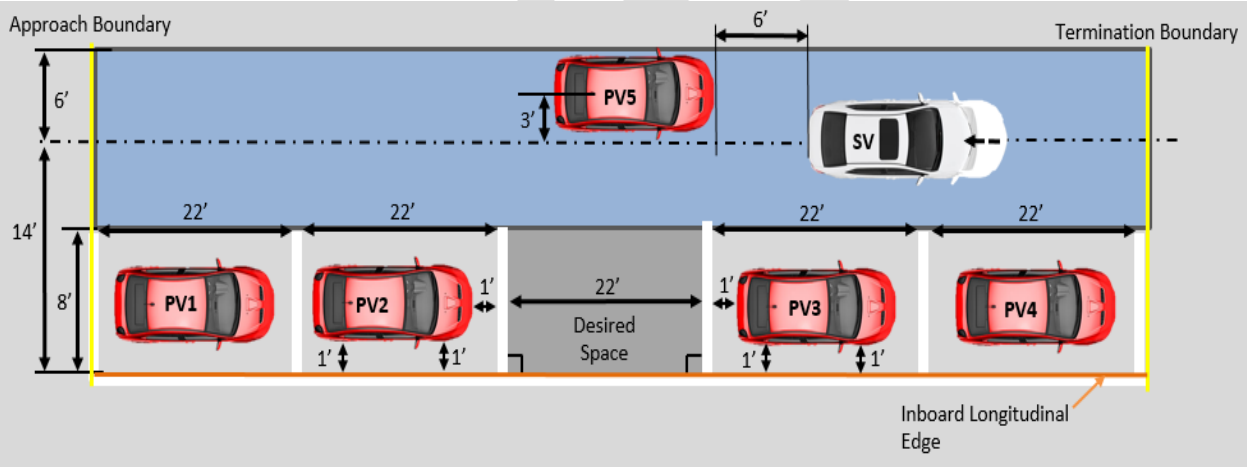

Figure 6. Parallel Parking with Vehicle Obstruction test layout.

5.5.2.2 Obstructing Vehicle Detection Performance

For systems that use only automated inputs, the APA system shall not allow the SV to impact any PV at any time during the parking maneuver. If the system cannot park the SV within the desired SV space due to the presence of PV5, the SV shall terminate the automated parking maneuver and restore full manual control of the SV to the SV driver.
For systems that perform the parking maneuver using automated steering in conjunction with manual gear selector, brake pedal, and/or accelerator pedal inputs, the system shall instruct the SV driver how to avoid the PVs during the parking maneuver. Provided the SV driver responds to the

active park assist system as requested, and within 2 seconds, the SV shall not impact any PV at any time during the parking maneuver. If the system cannot park the SV within the desired SV space due to the presence of PV5, the SV shall terminate the automated parking maneuver and restore full manual control of the SV to the SV driver.

5.6 System Override Assessment

The driver shall be able to manually override any control function automated by the active park assist system while it is in operation, during any stage of the parking maneuver. Here, the term "control function" includes, but is not limited to, the SV acceleration, foundation brakes, steering, and gear selection. The term "override" is taken to occur when a manual input terminates the automated parking maneuver, causing the SV to automatically come to a stop. Specifically, when any manual override occurs, the sequence described in Figure 8 shall occur.

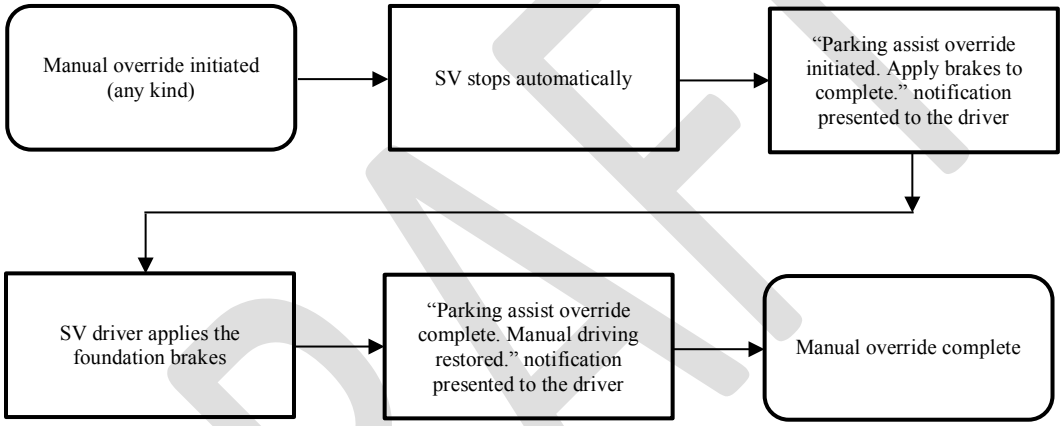

Figure 7. Active park assist system override sequence.

The tests described in Section 5.6 are based on perpendicular and parallel parking maneuvers previously described in Section 5.4. Each test condition shall be repeated five (5) times. Table 4 provides an overview of the override assessment test matrix. Section 5.6.1, 5.6.2, and 5.6.3.1 describe the procedures used to perform the steering, accelerator pedal, and brake pedal overrides, respectively. Section 5.6.3.2 describes the procedure used for manual timeout assessment.

Table 4 – Active Park Assist System Override Test Matrix

Parking Orientation	Parking Space Location	Override Assessment (number of trials indicated, where applicable)			
		Steering	Accelerator Pedal	Brake Pedal	Timeout
Parallel	Right	5	5	5	5
Perpendicular	Right	5	5	5	5

5.6.1 Steering Override Assessment

The steering torque required to manually override the automated parking maneuver shall be assessed within 500 ms after the initial clockwise (CW) steering cut-in is initiated.

The steering wheel torque required to manually override system operation, at any time during the automated parking maneuver, shall be ≤ 20 ft·lbf (27 N·m). Although these criteria are assessed during the predefined specific interval, they shall be applicable at any time during the automated parking maneuver.

5.6.2 Accelerator Pedal Override Assessment

If the active park assist system automatically controls the SV acceleration during the automated parking maneuver, the accelerator pedal position required to manually override the automated parking maneuver shall be assessed within 500 ms after the first clockwise steering reversal is initiated.

The accelerator pedal position required to manually override system operation, at any time during the automated parking maneuver, shall be ≤ 5 percent of the wide-open accelerator pedal position, where 100 percent wide open accelerator pedal position occurs when the accelerator pedal is fully applied. Although this criterion is assessed during the predefined specific interval, it shall be applicable at any time during the automated parking maneuver.

5.6.3 Brake Pedal Override and Manual Timeout Assessment

5.6.3.1 Brake Pedal Override Assessment

If the active park assist system automatically controls the SV braking during the automated parking maneuver, the brake pedal position required to manually override the automated parking maneuver shall be assessed within 500 ms after the first clockwise steering reversal is initiated.

The brake pedal position required to manually override system operation at any time during the automated parking maneuver shall be ≤5 percent of the fully applied brake pedal position. In the context of this document, the fully applied brake pedal position occurs when a force of 112 lbf (500 N) is applied to the brake pedal. Although this criterion is assessed during the specific predefined interval, it shall be applicable at any time during the automated parking maneuver.

5.6.3.2 Manual Timeout Assessment

If the active park assist system does not automatically control the SV braking during the automated parking maneuver, the driver manually brakes the SV to a stop, and the SV remains at rest for at least 5 seconds, a manual timeout condition shall be considered to have occurred.

The brake application used to assess the presence of a brake pedal-based manual timeout shall be applied within 500 ms after the first clockwise steering reversal is initiated. The force and application rate are not restricted; however, the combination of brake pedal force and application

rate must be great enough to stop the SV within two (2) seconds, measured from the onset of the brake application to the instant when the SV speed reaches zero.

Once the SV has remained stopped for > 5 seconds, the SV must automatically terminate the active park assist maneuver and restore full manual control of the vehicle to the SV driver.

6.0 REFERENCES

1. Federal Highway Administration. (2012, May). *Manual on Uniform Traffic Control Devices for Streets and Highways, 2009 Edition*. Washington, DC: US Department of Transportation. https://mutcd.fhwa.dot.gov/pdfs/2009r1r2/pdf_index.htm.

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3. *2010 ADA Standards for Accessible Design.* (2010, September). 28 CFR Part 36. Washington, DC: US Department of Justice. https://www.ada.gov/restripe.pdf

4. Forkenbrock, G.J., Snyder, A.C., Davis, I.J., O'Harra, B.C. (2017, December). *A Test Track Comparison of the Global Vehicle Target (GVT) and NHTSA's Strikeable Surrogate Vehicle (SSV)*. (Report No. DOT HS TBD TBD). Washington, DC: US Department of Transportation.

5. *European New Car Assessment Programme (Euro NCAP) Test Protocol -- AEB VRU systems*; version 1.0.1, June 2015.

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 (mm)	Vehicle Length (mm)

ACTIVE PARKING ASSIST CONFIGURATION (check all that apply):	
Fully Automated; Vehicle Selects Parking Space	Fully Automated; Driver Selects Parking Space
Automated Steering	Automated Acceleration
Automated Braking	Automated Shifter

GENERAL TEST FACILITY INFORMATION		
Facility Designation (e.g., "VDA west edge")	Test Surface (e.g., asphalt, concrete)	Surface Condition
Parallel Parking Space Orientation (e.g., "North")	Perpendicular Parking Space Orientation (e.g., "East")	

PRETEST CONDITIONS (complete before each test scenario is evaluated)				
Time	Ambient Temperature (°F or °C)	Ambient Conditions (e.g., "overcast")	Wind Speed (mph or km/h)	Wind Direction

POST-TEST CONDITIONS (complete after each test scenario is evaluated)				
Time	Ambient Temperature (°F or °C)	Ambient Conditions (e.g., "overcast")	Wind Speed (mph or km/h)	Wind Direction

Category	Assessment	Evaluation Criteria				
Parallel Parking	Stage 1: Parking Space Detection	Notification presented by the termination boundary? **(Y/N)**				
		Trial 1	Trial 2	Trial 3	Trial 4	Trial 5
	Stage 2: Automated Parking Initiation	In-vehicle instructions presented within 5 seconds after the SV driver has initiated the automated parking function? **(Y/N)**				
		Trial 1	Trial 2	Trial 3	Trial 4	Trial 5
	Stage 3: Automated Parking Execution	Time to complete parking maneuver; from SV driver's release of brake pedal at the end of Stage 2 to completion of the automatic parking maneuver? **(seconds)**				
		Trial 1	Trial 2	Trial 3	Trial 4	Trial 5
	Stage 4: Automated Parking Completion	**SVs with fully automated parking:** SV automatically shifted into park at the end of the parking maneuver? **(Y/N)** **Other SVs:** Driver instructed to shift SV into park at the end of the parking maneuver? **(Y/N)**				
		Trial 1	Trial 2	Trial 3	Trial 4	Trial 5
		SV position within allowable specifications throughout the entire parking maneuver? **(Y/N)**				
		Trial 1	Trial 2	Trial 3	Trial 4	Trial 5

Category	Assessment	Evaluation Criteria				
Perpendicular Parking	Stage 1: Parking Space Detection	Notification presented by the termination boundary? **(Y/N)**				
		Trial 1	Trial 2	Trial 3	Trial 4	Trial 5
	Stage 2: Automated Parking Initiation	In-vehicle instructions presented within 5 seconds after the SV driver has initiated the automated parking function? **(Y/N)**				
		Trial 1	Trial 2	Trial 3	Trial 4	Trial 5
	Stage 3: Automated Parking Execution	Time to complete parking maneuver; from SV driver's release of brake pedal at the end of Stage 2 to completion of the automatic parking maneuver? **(seconds)**				
		Trial 1	Trial 2	Trial 3	Trial 4	Trial 5
	Stage 4: Automated Parking Completion	**SVs with fully automated parking:** SV automatically shifted into park at the end of the parking maneuver? **(Y/N)** **Other SVs:** Driver instructed to shift SV into park at the end of the parking maneuver? **(Y/N)**				
		Trial 1	Trial 2	Trial 3	Trial 4	Trial 5
		SV position within allowable specifications throughout the entire parking maneuver? **(Y/N)**				
		Trial 1	Trial 2	Trial 3	Trial 4	Trial 5

Category	Assessment	Evaluation Criteria				
Encroaching Pedestrian, Parallel Parking	Front encroachment during automated parking stage 3	Test mannequin impact? **(Y/N)**				
		Trial 1	Trial 2	Trial 3	Trial 4	Trial 5
		Automated parking automatically terminated due to presence of the test mannequin? **(Y/N)**				
		Trial 1	Trial 2	Trial 3	Trial 4	Trial 5
	Rear encroachment during automated parking stage 3	Test mannequin impact? **(Y/N)**				
		Trial 1	Trial 2	Trial 3	Trial 4	Trial 5
		Automated parking automatically terminated due to presence of the test mannequin? **(Y/N)**				
		Trial 1	Trial 2	Trial 3	Trial 4	Trial 5

Category	Assessment	Evaluation Criteria				
Encroaching Pedestrian, Perpendicular Parking	Rear encroachment during automated parking stage 3	Test mannequin impact? **(Y/N)**				
		Trial 1	Trial 2	Trial 3	Trial 4	Trial 5
		Automated parking automatically terminated due to presence of the test mannequin? **(Y/N)**				
		Trial 1	Trial 2	Trial 3	Trial 4	Trial 5

Category	Assessment	Evaluation Criteria				
Obstructing Vehicle, Parallel Parking	Rear vehicle obstruction during automated parking stage 3	PV5 impact? **(Y/N)**				
		Trial 1	Trial 2	Trial 3	Trial 4	Trial 5
		Automated parking automatically terminated due to presence of PV5? **(Y/N)**				
		Trial 1	Trial 2	Trial 3	Trial 4	Trial 5

Category	Assessment	Evaluation Criteria				
Obstructing Vehicle, Perpendicular Parking	Rear vehicle obstruction during automated parking stage 3	PV5 impact? **(Y/N)**				
		Trial 1	Trial 2	Trial 3	Trial 4	Trial 5
		Automated parking automatically terminated due to presence of PV5? **(Y/N)**				
		Trial 1	Trial 2	Trial 3	Trial 4	Trial 5

Category	Assessment	Evaluation Criteria				
System Override	Steering Override (assessed within 500 ms after initiation of the first CW steering cut-in)	The steering wheel torque required to manually override system operation shall be ≤ 20 ft·lbf (27 N·m). Did the complete override sequence described in Figure 8 occur within the assessment window? **(Y/N)**				
		Trial 1	Trial 2	Trial 3	Trial 4	Trial 5
	Accelerator Pedal (assessed within 500 ms after initiation of the first CW steering cut-in)	If the active park assist system automatically controls the SV acceleration during the automated parking maneuver, the accelerator pedal position required to manually override system operation shall be ≤ 5 percent of wide open accelerator pedal position. Did the complete override sequence described in Figure 8 occur within the assessment window? **(Y/N)**				
		Trial 1	Trial 2	Trial 3	Trial 4	Trial 5
	Brake Pedal (assessed within 500 ms after initiation of the first CW steering cut-in)	If the active park assist system automatically controls the SV braking during the automated parking maneuver, the brake pedal position required to manually override system operation shall be ≤5 percent of fully suppressed brake pedal position. Did the complete override sequence described in Figure 8 occur within the assessment window? **(Y/N)**				
		Trial 1	Trial 2	Trial 3	Trial 4	Trial 5
	Manual Timeout (assessed within 500 ms after initiation of the first CW steering cut-in)	If the active park assist system doesn't automatically control the SV braking during the automated parking maneuver, and the driver manually brakes the SV to a stop, once the SV has remained stopped for > 5 seconds, the SV must automatically terminate the active park assist maneuver and restore full manual control of the vehicle to the SV driver. Did the complete override sequence described in Figure 8 occur within the assessment window? **(Y/N)**				
		Trial 1	Trial 2	Trial 3	Trial 4	Trial 5

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