

Safeguards For Partial Driving Automation Test Protocol and Rating Guidelines

Version I

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Note. DMS = driver monitoring system.

SUMMARY

This protocol describes the test and rating procedures used for the Insurance Institute for Highway Safety (IIHS) Safeguards for partial driving automation vehicle ratings program.

The program evaluates the user safeguards that vehicles with partial driving automation (also known as Level 2 systems; SAE International, 2021) employ to help drivers use the technology appropriately. The systems eligible for testing are those that can simultaneously support control of the vehicle's longitudinal motion with adaptive cruise control (ACC) and control of its lateral motion with sustained lane centering under highway driving conditions.

This protocol is available on the *Partial automation safeguard ratings* section of the IIHS website.

Core rating principles:

- Partially automated systems need to ensure that the driver's eyes are directed at the road and their hands are either on the steering wheel or ready to grab it. Escalating alerts and appropriate emergency procedures are required when the driver does not meet those conditions.
- All automated lane changes should be initiated or confirmed by the driver.
- When traffic ahead causes ACC to bring the vehicle to a complete stop, it should not automatically resume if the driver is not looking at the road or if the vehicle has been stopped for too long.
- The sustained lane centering function should encourage the driver to share control of the steering rather than switch off automatically whenever the driver adjusts the wheel. Switching off risks disincentivizing drivers from staying physically engaged in the driving task.
- Partial driving automation should be designed to prevent drivers from using it when their seat belt is unfastened or when forward collision warning (FCW)/automatic emergency braking (AEB) or lane departure warning (LDW)/lane departure prevention (LDP) is disabled.

Ratings are based on a test vehicle's ability to meet these requirements. A selection of the IIHS research on partial driving automation is provided in the *References* section.

TEST ENVIRONMENT

Testing is conducted on flat, straight roads with clearly delineated lane lines. Testing is not conducted during periods of inclement weather. The term "inclement weather" refers to, but is not limited to, rain, snow, hail, fog, smoke, and/or ash. Peak wind speeds must be below 22.4 mph (10 m/s) to minimize test vehicle disturbance.

Testing is completed during daylight hours when ambient illumination is greater than 2,000 lux. To prevent sun glare issues with camera-based vehicle sensors, the sun position must be at least 15 degrees above the horizon if the test vehicle is driving into the sun.

Whenever possible, for systems that only operate in certain driving conditions (i.e., geofenced systems that operate on specific sections of certain highways/interstates), tests are conducted within the vehicle's specified conditions.

TEST VEHICLE PREPARATION

General

Prior to testing, IIHS ensures that:

- The tires are in good condition and inflated to the manufacturer's recommended cold-inflation pressure. If more than one recommendation is provided, the tires are inflated to the lightly loaded condition.
- The windshield and area around the radar are clean of debris with no visible damage.
- The vehicle's software is the most up-to-date version available for the test vehicle.
- The system is initialized based on manufacturer feedback (i.e., for a given ignition/power cycle, the vehicle has been driven for 1 minute or 1 mile (1.6 km) prior to testing).
- The vehicle has no fault codes visible to the driver that may affect the testing.

Vehicle settings

At the start of each trial for each test procedure, except for Test 10c, FCW/AEB is on and set to the earliest warning/braking setting.

At the start of each trial for each test procedure, except for Test 10d, LDW/LDP is on and set to the latest/least sensitive setting.

ACC is set to the longest headway setting possible.

Drive and suspension settings, if available, are set to the "normal" or "default" settings.

Steering wheel and driver seat positions are set so that the driver can see the instrument panel and turn the steering wheel without hindrance. Steering wheel and seat settings are also checked to ensure that the vehicle's driver monitoring cameras (if available) have a clear line of sight to the driver so that the driver monitoring system can perform as intended.

Instrumentation and equipment

Multiple cameras record synchronized video footage. The combination of cameras record views of the forward roadway; the location(s) where visual alerts are presented (i.e., the instrument panel and/or center console); the steering wheel; and the driver's face, head, hands, and torso.

The cameras' microphones record audible alerts and are used by the driver to audibly document relevant test events (driver actions, vehicle behavior, system activity, etc.) to help facilitate post-test analysis.

The following equipment is used during testing:

- Black Cinefoil (Figure 1a) with thin black felt fabric applied to the back to protect the vehicle's camera hardware (Figure 1b),
- Baseball cap (Figures 2a and 2b),
- Grade 90 cheesecloth (Figure 2b),
- A 5-lb (2.7-kg) adjustable ankle weight, which contains five individual 1-lb (0.5-kg) weights (Figures 3a and 3b), and
- A black foam block with similar dimensions to a smartphone (height: 1.5 cm, length: 16 cm, width: 8 cm; Figure 4).

Figure 1a

Black Cinefoil for Tests 1a and 1b



Figure 1b

Thin black felt fabric and fabric adhesive



Note. Thin black felt fabric is glued to the back of the Cinefoil using a flexible permanent fabric adhesive. Fabric density is similar to that of a handkerchief or t-shirt so as not to impede Cinefoil moldability.

Figure 2a

Baseball cap for Tests 2a and 2b



Note. The brim dimensions of the hat are 18.5 cm across and 7 cm long.

Figure 2b

Driver wearing a grade 90 cheesecloth draped over a baseball cap for Tests 2a and 2b.



Note. This grade of cheesecloth does not interfere with driver's view of the road.

Figure 3a

Ankle weight holder for Test 5b, with the individual 1-lb (0.5-kg) weights shown below the holder



Figure 3b

Steering wheel with the ankle weight attached for Test 5b



Figure 4

Foam block (on left) for Tests 5a, 5b, and 6



Note. A smartphone is shown on right to demonstrate its general physical similarity to the foam block.

DOCUMENTATION

Before testing, IIHS documents the following information:

- Vehicle year, make, and model
- Partial automation system information (e.g., system name, availability, trim/package, geofencing, software version, and hardware version)
- Capabilities of the driver monitoring camera(s) (e.g., none, eye gaze, head position, hands, other)
- Driver monitoring capabilities through the steering wheel (e.g., none, torque, capacitive touch, other)
- Emergency notification system information (e.g., none, cellular, subscription, Bluetooth, manufacturer-assisted calling, other)

The timing of changes in the system status during each trial and any alerts, warnings, or countermeasures performed by the vehicle are documented via video analysis.

As mentioned in the *Instrumentation and equipment* section, to facilitate the review, the driver of the test vehicle verbalizes each step of the procedure; for example, the driver will say aloud "driver removing hands from the steering wheel" as they remove their hands from the steering wheel. If the vehicle initiates nonaudible or nonvisual alerts that are not easily detectable through the video review (e.g., haptic communication), the driver will verbalize those events as soon as they occur during the drive.

TESTS

A vehicle's partial driving automation may have multiple states that operate with unique capabilities and user requirements. For instance, a system that provides sustained lane centering and ACC support simultaneously may allow hands-free operation with certain driver monitoring strategies under specific conditions (e.g., within geofenced areas), but it may have different driver monitoring strategies and system capabilities when the driver's hands are required to be on the wheel.

These different states of the partial driving automation may be subject to independent evaluations and separate ratings as specified by this protocol.

Tests 1a to 4 apply to vehicles with a camera-based driver monitoring system (DMS) that tracks the eyes, face, and/or hands. Tests 1a to 4 are conducted only on partially automated states that use the camera-based DMS.

Tests 5a and Tests 6 to 10 apply to all vehicles equipped with partial driving automation.

Test 5b applies to any vehicle that monitors the driver through the steering wheel.

Tests 3, 4, and 6 include another occupant in the front passenger seat (herein called a "safety monitor"). The safety monitor watches the driving environment and the partial driving automation's activity to ensure each test is conducted safely.

If the vehicle's partial driving automation or one of its automation states is geofenced, manufacturer verification is required to capture performance for Tests 6, 8a, 8b, 10a, and 10b.

The driver must not wear sunglasses during any test that involves tracking the driver's eyes (i.e., Tests 4, 6, and 8b).

For every test that requires the driver to put their hands on the wheel, the driver must keep their hands on the wheel once instructed to do so until the end of the trial. If the driver removes their hand(s) for some reason during the hands-on-wheel phase of the test, the trial must be redone.

Likewise, if a test requires the driver to remove their hands from the wheel, they must keep both hands off the wheel until instructed. If the driver returns hands to the wheel before the test is complete, the trial must be redone.

Test trials

Each test is conducted three times (these test replications are known as trials or runs) except for Test 7, which documents the type of automated lane change functionality equipped in the vehicle.

Resetting the vehicle

At the end of each trial, the driver resets the vehicle using the following procedure:

1. The driver exits the vehicle,
2. Locks the vehicle,
3. Unlocks the vehicle,
4. Reenters the vehicle,
5. Powers it back on,
6. Performs initialization (if necessary),
7. Verifies vehicle settings (see the *Vehicle settings* section), and then
8. Begins the next trial.

All test procedures except Tests 7 and 9 require the vehicle to be reset between trials.

Tests 1a and 1b: DMS camera occlusion

Test 1a: DMS camera occlusion — covering the camera(s) before activating the partial driving automation

This test documents whether the partial driving automation can be activated while the DMS camera(s) is occluded.

1. Before the test, the driver-facing camera(s) are completely covered with the Cinefoil while the vehicle is parked.
2. The vehicle is brought to the test speed (posted speed limit or 45 mph [72 km/h] for a test track).
3. The driver keeps both hands on the steering wheel, head facing forward, and eyes on the road.
4. After at least 5 seconds at speed, the driver makes repeated attempts to switch on the partial driving automation (at least three attempts) within 30 seconds or until the end of the test.
5. The test ends if one of the following occurs:
 - a. The system activates and does not initiate an alert within 10 seconds,
 - b. The system activates and initiates an alert within 10 seconds,
 - c. The system activates and then deactivates within 10 seconds (it might give an alert prior to deactivating), or
 - d. The system does not activate within 30 seconds.

Test 1b: DMS camera occlusion — covering the camera(s) after activating the partial driving automation

This test documents whether the partial driving automation remains active if the DMS camera is occluded. The safety monitor may be present to cover the camera(s) if the camera(s) location is out of reach of the driver.

1. The vehicle is brought to the test speed (posted speed limit or 45 mph [72 km/h] for a test track).
2. The driver activates the partial driving automation.
3. The driver keeps both hands on the steering wheel, head facing forward, and eyes on the road.
4. The partial driving automation is on for at least 5 seconds.
5. While maintaining their forward-facing head and body position, the driver uses one hand to completely cover the driver-facing camera(s) with the Cinefoil. If the driver is unable to do this because of the camera's location within the vehicle cabin, the test must be performed with the safety monitor in the front passenger seat who will cover the camera at this stage.
6. The driver returns both hands to the steering wheel and keeps their head facing forward, eyes on the road, and feet near the pedals.
7. The test ends if one of the following occurs:
 - a. The system deactivates (it might give an alert prior to deactivating),
 - b. The system remains active for 10 seconds without an alert, or
 - c. The system remains active and initiates an alert within 10 seconds.

Tests 2a and 2b: DMS driver obscuration

Test 2a: DMS driver obscuration — covering the driver's face before activating the partial driving automation

This test documents whether the partial driving automation can be activated if the driver's face is obscured.

1. The driver puts on a baseball cap before beginning the test.
2. The vehicle is brought to the test speed (posted speed limit or 45 mph [72 km/h] for a test track).
3. The driver drapes the cheesecloth loosely over the baseball cap on their head and shoulders, ensuring their face is completely covered, and continue driving for 5 seconds.
4. The driver keeps both hands on the steering wheel, head facing forward, and eyes on the road.
5. The driver makes repeated attempts to switch on the partial driving automation (at least three attempts) within 30 seconds or until the end of the test.
6. The test ends if one of the following criteria are met:
 - a. The system activates and does not initiate an alert within 10 seconds,
 - b. The system activates and initiates an alert within 10 seconds,
 - c. The system activates and then deactivates within 10 seconds (it might give an alert prior to deactivating), or
 - d. The system does not activate within 30 seconds.

Test 2b: DMS driver obscuration — covering the driver's face after activating the partial driving automation

This test documents whether the partial driving automation remains active if the driver's face becomes obscured.

1. The driver wears a baseball cap before beginning the test.
2. The vehicle is brought to the test speed (posted speed limit or 45 mph [72 km/h] for a test track).
3. The driver activates the partial driving automation.
4. The driver keeps both hands on the steering wheel, head facing forward, and eyes on the road.
5. The partial driving automation is on for at least 5 seconds.
6. The driver drapes the cheesecloth loosely over the baseball cap on their head and shoulders, ensuring their face is completely covered.
7. The test ends if one of the following occurs:
 - a. The system deactivates (it might give an alert prior to deactivating),
 - b. The system remains active for 10 seconds without an alert, or
 - c. The system remains active and initiates an alert within 10 seconds.

Test 3: DMS eye tracking — driver's eyes away from the road with the partial driving automation activated

This test documents whether the partial driving automation can detect if the driver's eyes are looking away from the road while the head is facing forward. This test requires a safety monitor in the front passenger seat. The driver must not wear sunglasses for this test.

1. The vehicle is brought to the test speed (posted speed limit or 45 mph [72 km/h] for a test track).
2. The driver activates the partial driving automation.
3. The driver keeps both hands on the steering wheel, head facing forward, eyes on the road, and feet near the pedals.
4. The partial driving automation is on for at least 5 seconds.
5. The driver keeps both hands on the wheel and head facing forward while they direct their eyes to look at the center of the steering wheel until end of test.
6. The test ends if one of the following occurs:
 - a. The system deactivates (it might give an alert prior to deactivating),
 - b. The system remains active for 15 seconds without an alert after the driver glances downward, or
 - c. The system remains active and initiates an alert within 15 seconds after the driver glances downward.

Test 4: DMS head tracking — driver's head and eyes looking away from the road with the partial driving automation activated

This test documents whether the partial driving automation can detect if the driver's head and eyes are directed away from the road. This test requires a safety monitor in the front passenger seat.

1. The vehicle is brought to the test speed (posted speed limit or 45 mph [72 km/h] for a test track).
2. The driver activates the partial driving automation.
3. The driver keeps both hands on the steering wheel, head facing forward, eyes on the road, and feet near the pedals.
4. The partial driving automation is on for at least 5 seconds.
5. The driver keeps both hands on the wheel while they move their head downward, so their head and eyes are directed to look at the center of the steering wheel until the end of the test.
6. The test ends if one of the following occurs:
 - a. The system deactivates (it might give an alert prior to deactivating),
 - b. The system remains active for 15 seconds without an alert after the driver looks down, or
 - c. The system remains active and initiates an alert within 15 seconds after the driver looks down.

Tests 5a and 5b: DMS hand tracking/monitoring

Test 5a: DMS hand tracking/monitoring — driver's hands off the steering wheel holding the block

This test documents whether the partial driving automation can detect when the driver's hands become occupied, even in hands-free driving mode, as drivers must be immediately ready and able to perform their role in the dynamic driving task.

1. The vehicle is brought to the test speed (posted speed limit or 45 mph [72 km/h] for a test track).
2. The driver activates the partial driving automation.
3. The driver keeps both hands on the steering wheel, head facing forward, eyes on the road, and feet near the pedals.
4. The partial driving automation is on for at least 5 seconds.
5. The driver keeps their eyes and head facing forward.
6. With their right hand, the driver picks up the block from the center console area and then holds the block in both hands, hovering in front of the center of the steering wheel. The driver will be careful not to touch the steering wheel and to make sure that the block does not interfere with the driver monitoring camera's line of sight to the driver.
7. The test ends if one of the following occurs:
 - a. The system deactivates (it might give an alert prior to deactivating),
 - b. The system remains active for 15 seconds without an alert after the driver removes their hands from the steering wheel, or
 - c. The system remains active and initiates an alert within 15 seconds after the driver removes their hands from the steering wheel.

Test 5b: DMS hand tracking/monitoring — driver's hands off the steering wheel holding the block, ankle weight on the steering wheel

This test documents whether the partial driving automation can detect if the driver is trying to fool the system while their hands are occupied.

1. Before the test, the driver attaches the ankle weight to either side of the steering wheel (see Figure 3b).

The driver ensures that the ankle weight location does not interfere with steering wheel controls and that the weight and location of the ankle weight do not deactivate the system. If the ankle weight deactivates the system, the driver adjusts the location of the weight and/or removes some of the weight.

2. The vehicle is brought to the test speed (posted speed limit or 45 mph [72 km/h] for a test track).
3. The driver activates the partial driving automation.
4. The driver keeps both hands on the steering wheel, head facing forward, eyes on the road, and feet near the pedals.
5. The partial driving automation is on for at least 5 seconds.
6. With their right hand, the driver picks up the block from the center console area and then holds the block in both hands, hovering in front of the center of the steering wheel. The driver will be careful not to touch the steering wheel and to make sure that the block does not interfere with the driver monitoring camera's line of sight to the driver.
7. The test ends if one of the following occurs:
 - a. The system deactivates (it might give an alert prior to deactivating),
 - b. The system remains active for 15 seconds without an alert after the driver removes their hands from the steering wheel, or
 - c. The system remains active and initiates an alert within 15 seconds after the driver removes their hands from the steering wheel.

Test 6: Attention reminders, emergency escalation countermeasures, and lockout confirmation

This test documents the attention reminder process and the start of the emergency escalation when the driver is looking away from the road and their hands are off the steering wheel and occupied. This test requires a safety monitor in the front passenger seat. The driver must not wear sunglasses for this test.

1. The vehicle is brought to the test speed (posted speed limit or 45 mph [72 km/h] for a test track).
2. The driver activates the partial driving automation.
3. The driver keeps both hands on the steering wheel, head facing forward, eyes on the road, and feet near the pedals.
4. The partial driving automation is on for at least 5 seconds.
5. The driver moves their head downward, so their head and eyes are directed to look at the center of the steering wheel until the end of the test.
6. With their right hand, the driver picks up the block from the center console area and then holds the block in both hands, hovering in front of the center of the steering wheel. The driver will be careful not to touch the steering wheel and to make sure that the block does not interfere with the driver monitoring camera's line of sight to the driver.
7. The test ends if one of the following occurs:
 - a. The partial driving automation's lane centering support disengages at any point within 35 seconds (it might give an alert prior to disengaging support),
 - b. The partial driving automation remains active for 35 seconds without the vehicle slowing down,
 - c. The vehicle begins to slow down within 35 seconds. If it does, the driver will allow the vehicle to slow by 10 mph (16 km/h) and then end the test.

Note. The slowdown must not occur in response to a slower moving lead vehicle. If another vehicle causes the test vehicle to slow down, the trial must be redone.
8. If the partial driving automation remained on without any response within the 35 seconds, then the test ends.
9. After the test, obtain manufacturer verification about whether and how the partial driving automation performs SOS calling and/or a system lockout.

Test 7: Automated lane change

This test documents if the vehicle automatically changes lanes without driver input.

The owner's manual and/or manufacturer verification is used to determine if the vehicle is capable of automatically changing lanes without driver input or confirmation. What defines "driver-initiated" or "driver-confirmed" functionality is the system's requirement that the driver must perform a deliberate action that is specific to the maneuver (and cannot be confused with normal operation of the vehicle) before the system change lanes. Deliberate actions include, but are not limited to, activating a turn signal, pressing a button, or a driver's head turning to glance over their shoulder.

Driver-initiated auto lane changes occur when the driver performs a deliberate action to begin the maneuver.

Driver-confirmed auto lane changes occur when the system offers to make a lane change, but the driver must perform a deliberate action before the maneuver will begin.

Vehicle-initiated or autonomously performed auto lane changes occur without any response from the driver.

Tests 8a and 8b: ACC auto-resume

Test 8a: ACC auto-resume — timeout

This test documents if the ACC automatically resumes after 2 minutes.

Note. If the partial driving automation or one of its states is geofenced, manufacturer verification is required for this test.

1. The test vehicle and lead vehicle are brought up to the minimum speed required to activate the test vehicle's ACC.
2. The driver of the test vehicle activates the partial driving automation.
3. The driver of the test vehicle keeps both hands on the steering wheel, head facing forward, eyes on the road, and feet near the pedals.
4. The lead vehicle begins to decelerate to a complete stop in a controlled manner (and not exceed 0.5 g while decelerating).
5. After the test vehicle has been stopped for 2 minutes, the lead vehicle starts to pull away.
6. The test ends if one of the following occurs:
 - a. The test vehicle begins to move forward, or
 - b. The test vehicle remains stationary.

Test 8b: ACC auto-resume — driver monitoring

This test documents if the ACC auto-resume requires the driver to be looking at the forward roadway before the test vehicle starts moving forward or if it times out after 10 seconds of being at a standstill. If the partial driving automation or one of its states is geofenced, manufacturer verification is required for this test.

The driver must not wear sunglasses for this test.

1. The test vehicle and lead vehicle are brought up to the minimum speed required to activate the test vehicle's ACC.
2. The driver of the test vehicle activates the partial driving automation.
3. The driver of the test vehicle keeps both hands on the steering wheel, head facing forward, eyes on the road, and feet near the pedals.
4. The lead vehicle begins to decelerate to a complete stop in a controlled manner (and not exceed 0.5 g while decelerating).
5. After the test vehicle comes to a complete stop, while keeping both hands on the wheel, the driver moves their head downward, so their head and eyes are directed to look at the center of the steering wheel until the end of the test.
6. After both vehicles have been stopped for at least 10 seconds, the lead vehicle starts to pull away.
7. The test ends if one of the following occurs:
 - a. The test vehicle begins to move forward while the driver is looking down, or
 - b. The test vehicle remains stationary.

Test 9: Cooperative steering

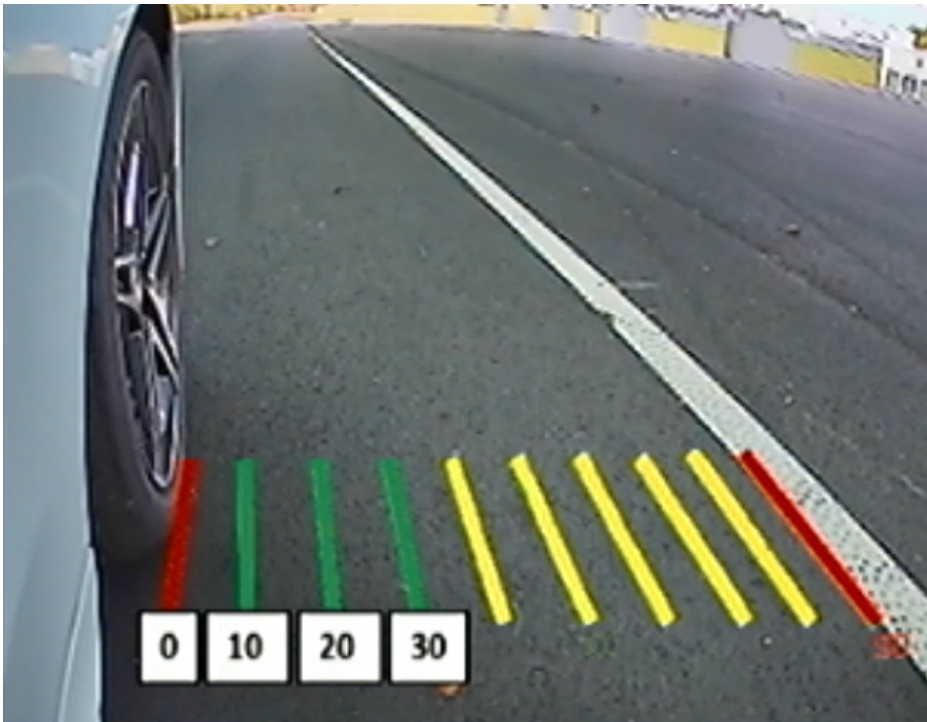
This test documents whether the partial driving automation allows the driver to steer the vehicle within the lane without disengaging the system. This test mimics a "lane hugging" maneuver, which is when the driver moves the vehicle closer to one side of the lane, typically to avoid another road user or debris or a pothole in the road.

Note. This test must be conducted on a straight roadway where there are no curves. The roadway must have visible and clear lane markings on both sides of the vehicle for the entire test duration.

1. The vehicle is to the test speed (posted speed limit or 45 mph [72 km/h] for a test track).
2. The driver activates the partial driving automation.
3. The driver keeps both hands on the steering wheel, head facing forward, eyes on the road, and feet near the pedals.
4. The partial driving automation is on for at least 5 seconds with the lane centering function keeping the vehicle centered within the lane. See Figure 5.

Figure 5

Still frame of video capturing the vehicle centered within the lane.



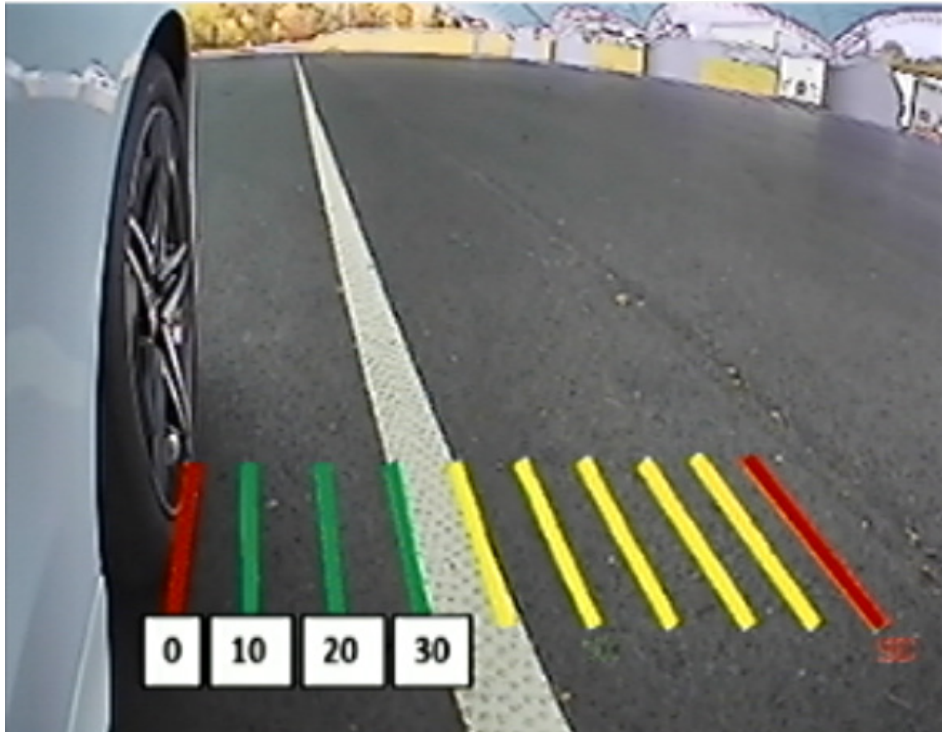
Note. This image illustrates the vehicle's position within the lane based on the distance of its front wheel to inside edge of the lane line prior to the driver's steering maneuver.

The distance between each overlaid marking represents 10 cm.

5. The driver gently steers the vehicle to the right (or left) side of the lane so that the wheel is positioned between 0 and 30 cm from the inside edge of the lane—without the vehicle's right (or left) wheel touching the lane line—for 5 seconds or more. See Figure 6. The vehicle's lateral acceleration must not exceed 0.75 m/s during the maneuver.

Figure 6

Still frame of video capturing the vehicle "hugging" one side of the lane.



Note. This image illustrates the vehicle's position within the lane based on the distance of its front wheel to inside edge of the lane line during the driver's steering maneuver.

The distance between each overlaid marking represents 10 cm. During the driver's steering maneuver, the vehicle must cross the space marked by the yellow markings until the inside edge of the lane line reaches the green markings.

6. After 5 seconds, the driver lets go of the wheel (while keeping hands at the ready to rapidly resume control if needed) and allows the partial driving automation to either maintain the offset or steer the vehicle back to the center of the lane.

7. The test ends if one of the following occurs:
 - a. The partial driving automation (or just the lane centering function) disengages completely at any point during or after the driver's steering maneuver,
 - b. The partial driving automation (or just the lane centering function) disengages temporarily during the driver's steering input and then, upon the driver input ceasing, the partial driving automation system automatically reactivates within 3 seconds.

By automatically reactivating, this means that the partial driving automation provides sustained steering support by either maintaining the offset position or re-centering the vehicle within the lane, or
 - c. The partial driving automation remains active during and after the driver's steering maneuver.

This means that the partial driving automation continuously provides sustained steering support to maintain the offset position or re-center the vehicle within the lane once the driver's steering input stops.

Note. The intensity of the lane centering's steering support may decrease while the driver steers; however, the lane centering system never disengages.

Tests 10a to 10f: Safety features

Test 10a: Safety features — activating the partial driving automation with an unbelted driver

This test documents whether the partial driving automation activates with an unbelted driver. Note, if the partial driving automation or one of its states is geofenced, manufacturer verification is required for this test.

1. On a closed course, the vehicle is brought to the test speed (posted speed limit or 45 mph [72 km/h] for a test track).
2. The driver keeps both hands on the steering wheel, head facing forward, eyes on the road, and feet near the pedals.
3. The driver unbuckles the seat belt.
4. The driver makes repeated attempts to switch on the partial driving automation (at least three attempts) within 10 seconds or until the end of the test.
5. The test ends if one of the following occurs:
 - a. The partial driving automation activates and does not initiate an alert within 10 seconds,
 - b. The partial driving automation activates and initiates an alert within 10 seconds, or
 - c. The partial driving automation does not activate within 10 seconds.

Test 10b: Safety features — unbuckling the seat belt with the partial driving automation active

This test documents whether the partial driving automation remains active if a driver unbuckles. If the partial driving automation or one of its states is geofenced, manufacturer verification is required for this test.

1. On a closed course, the vehicle is brought to the test speed (posted speed limit or 45 mph [72 km/h] for a test track).
2. The driver keeps both hands on the steering wheel, head facing forward, eyes on the road, and feet near the pedals.
3. The driver activates the partial driving automation.
4. Wait up to five seconds and then the driver unbuckles the seat belt.
5. The test ends if one of the following occurs:
 - a. The partial driving automation deactivates within 5 seconds (it might give an alert prior to deactivating),
 - b. The partial driving automation remains active and does not initiate an alert within 5 seconds, or
 - c. The partial driving automation remains active and initiates an alert within 5 seconds.

Test 10c: Safety features — activating the partial driving automation with AEB deactivated

This test documents whether the partial driving automation can be activated with AEB deactivated. This test is not performed if AEB cannot be deactivated.

1. Before the test, the driver deactivates AEB.
2. The vehicle is brought to the test speed (posted speed limit or 45 mph [72 km/h] for a test track).
3. The driver keeps both hands on the steering wheel, head facing forward, eyes on the road, and feet near the pedals.
4. The driver attempts to switch on the partial driving automation three times within 10 seconds or until the end of the test.
5. The test ends if one of the following occurs:
 - a. The partial driving automation activates while AEB is off,
 - b. The partial driving automation does not activate within 10 seconds, or
 - c. AEB automatically reactivated with the partial driving automation's activation.

Test 10d: Safety features — activating the partial driving automation with LDP deactivated

This test documents whether the partial driving automation can be activated with LDP deactivated. This test is not performed if LDP cannot be deactivated.

1. Before the test, the driver deactivates LDP.
2. The vehicle is brought to the test speed (posted speed limit or 45 mph [72 km/h] for a test track).
3. The driver keeps both hands on the steering wheel, head facing forward, eyes on the road, and feet near the pedals.
4. The driver attempts to switch on the partial driving automation three times within 10 seconds or until the end of the test.
5. The test ends if one of the following occurs:
 - a. The partial driving automation activates while LDP is off,
 - b. The partial driving automation does not activate, or
 - c. LDP automatically reactivated with the partial driving automation's activation.

Test 10e: Safety features — deactivating AEB with the partial driving automation active

This test documents whether the partial driving automation remains engaged if AEB is deactivated. This test is not performed if AEB cannot be deactivated.

1. The vehicle is brought to the test speed (posted speed limit or 45 mph [72 km/h] for a test track).
2. The driver keeps both hands on the steering wheel, head facing forward, eyes on the road, and feet near the pedals.
3. The driver activates the partial driving automation.
4. After 5 seconds, the driver attempts to switch off AEB.
5. The test ends if one of the following occurs:
 - a. The partial driving automation deactivates (it might give an alert prior to deactivating),
 - b. The test vehicle does not allow AEB to be switched off, or
 - c. There is no response from the partial driving automation within 5 seconds.

Test 10f: Safety features — deactivating LDP with the partial driving automation active

This test documents whether the partial driving automation remains engaged if LDP is deactivated. This test does not need to be performed if LDP cannot be deactivated.

1. The vehicle is brought to the test speed (posted speed limit or 45 mph [72 km/h] for a test track).
2. The driver keeps both hands on the steering wheel, head facing forward, eyes on the road, and feet near the pedals.
3. The driver activates the partial driving automation.
4. After 5 seconds, the driver attempts to switch off LDP.
5. The test ends if one of the following occurs:
 - a. The partial driving automation deactivates (it might give an alert prior to deactivating),
 - b. The test vehicle does not allow LDP to be switched off, or
 - c. There is no response from the partial driving automation within 5 seconds.

RATING GUIDELINES

The ratings are based on the vehicle system performance in Tests 1 to 10.

The ratings program is based on demerits in seven individual categories. The overall rating is based on the sum of the demerits in these individual categories. The demerits and overall ratings are shown in Table 1 at the end of this document.

A vehicle may have multiple partially automated states that operate with unique capabilities and user requirements. These different states will be subject to independent evaluations and separate ratings.

Many of the test procedures require three trials to capture system performance. When evaluating performance, the trial with the worst performance will be used.

RATING CATEGORIES

Driver monitoring

Partially automated systems should monitor three aspects of the driver's body: the head, eyes, and hands. The driver monitoring rating is based on the system's ability to monitor these aspects and pass Tests 1a, 1b, 2a, 2b, 3, 4, 5a, and 5b. If the system does not monitor the driver, it will receive an overall rating of poor for the program.

To pass Test 1a, the partial driving automation must not activate while the camera is covered. If it does activate, it must initiate an alert to signal the start of escalation within 5 seconds of activation. To pass Test 1b, the system must give an alert to signal the start of escalation within 10 seconds of the driver monitoring camera(s) being covered.

To pass Test 2a, the partial driving automation must not activate while the driver's face is covered. If it does activate, it must initiate an alert to signal the start of escalation within 5 seconds of activation. To pass Test 2b, the system must give an alert to signal the start of escalation within 10 seconds of the driver's face being covered.

To pass Tests 3, 4, and 5, the system must be able to detect when the driver's eyes glance downward (Test 3), their head is tilted downward (Test 4), and hands are off the wheel (Tests 5a and 5b) and initiate alerts within 15 seconds of the driver performing those behaviors. For a system to receive credit for Tests 3 and 4, the vehicle must also pass Tests 1a, Test 1b, and either Test 2a or 2b.

A system will receive a good rating in the driver monitoring category if it monitors the driver's eyes (receives credit for Test 3), monitors the driver's head (receives credit for Test 4), and monitors the driver's hands (passes Tests 5a and 5b). A system that monitors two of these three aspects will receive an acceptable rating. If a system only monitors one of these aspects, it will only receive a marginal rating. A system that does not adequately monitor any of the three aspects will receive a poor rating.

Attention reminders

Partial automated systems should quickly provide attention reminders in multiple modes when they detect the driver is not paying attention (Test 6). Eligible attention reminder modalities include visual, haptic or tactile, auditory, seat belt tugging, pulse braking, ACC coasting, etc. If the partial driving automation does not initiate alerts at all in response to the driver's behind-the-wheel behavior, it will receive an overall poor rating for the program.

If there are visual cues for the attention reminder process provided in multiple locations within the vehicle cabin, they will only be considered if they occur concurrently with those in the instrument panel. The instrument panel communication is considered the default location for visual information in the attention reminder process. The visual alert sequence will be counted as beginning based on when it is shown in the instrument panel, regardless of when it is shown elsewhere in the cabin.

To receive a good rating in the attention reminders category, the system must initiate a bimodal alert within 10 seconds from the start of the driver disengaging and escalate to either a trimodal alert or the emergency escalation slowdown (described in the next section) within 20 seconds from start.

For an acceptable rating, the system must initiate a bimodal alert within 15 seconds from the start and escalate to either a trimodal alert or the emergency escalation slowdown within 30 seconds from start.

The system will receive a marginal rating, if it initiates a bimodal alert within 15 seconds from the start, but it does not initiate a third alert modality or start the emergency escalation slowdown within 30 seconds from start.

Systems that don't initiate bimodal alerts within 15 seconds from the start will receive a poor rating.

Emergency escalation and countermeasures

Partial automated systems must provide the driver with appropriate emergency escalation. The rating protocol considers three emergency escalation countermeasures.

- 1. Emergency escalation slowdown.** The partial driving automation must begin an emergency escalation slowdown within 35 seconds from the start. The slowdown may either bring the vehicle to a physical stop or reduce its speed to a maximum of 10 mph (16 km/h).
- 2. SOS notification.** The partial driving automation must send an SOS notification. This notification can be placed through cellular, manufacturer subscription, or vehicle Bluetooth means to either a vehicle concierge service or to local emergency services. The SOS notification may be sent at any time during the emergency escalation procedure.
- 3. System lockout.** The partial driving automation must engage a system lockout that prevents the driver from reactivating the automation for the remainder of the drive. The lockout countermeasure must occur once the vehicle slowdown procedure has begun. However, the system must not cease lateral and longitudinal support until the driver has resumed control of the vehicle. Only after the driver has resumed control should the lockout countermeasure be activated. Driver access to the partial driving automation can only be reestablished once the vehicle's ignition has been recycled or powered back on.

To receive a good rating, the system must provide all three emergency escalation countermeasures. Systems that provide two of the three countermeasures will receive an acceptable rating. If the system

only provides one of the three countermeasures it will receive a marginal rating. Systems that do not provide any of the countermeasures will receive a poor rating.

Automated lane change

Partially automated systems should only allow driver-initiated or driver-confirmed automated lane changes. Driver-initiated automated lane changes make the lane change once it has received a deliberate action from the driver instructing the system to perform the maneuver. In a driver-confirmed lane change, the system offers the opportunity to make the lane change but requires the driver to take deliberate action to confirm before the lane change will occur. A system should not make a lane change without driver involvement.

Vehicles that do not make automated lane changes or that require driver involvement before making a lane change will receive a good rating. Vehicles that can make a vehicle-initiated lane change will receive a poor rating.

ACC auto-resume

The adaptive cruise control auto-resume rating will be based on Tests 8a and 8b. To pass Test 8a, systems that have ACC auto-resume capability must timeout when the vehicle has been at a standstill for 2 minutes or longer. A deliberate action from the driver is required before ACC will reengage. To pass Test 8b, the system must be able to verify the driver is looking forward at the roadway before the vehicle will move or the auto resume must timeout within 10 seconds of coming to a standstill.

Systems that do not have ACC auto-resume or that pass both Tests 8a and 8b will earn a good rating. Systems that only pass Test 8b will receive an acceptable rating. A system will receive a marginal rating if it only passes Test 8a. Systems that do not pass Tests 8a or 8b will receive a poor rating.

Cooperative steering

Partially automated systems should encourage cooperative steering between the driver and vehicle. The cooperative steering rating is based on the system performance in Test 9.

The systems will receive a good rating if lane centering support remains active during the entire steering maneuver.

If the lane centering support temporarily suspends while the driver steers, automatically reengages within 3 seconds after the driver has stopped steering, and the system clearly communicates the change, the partial driving automation will receive an acceptable rating.

Vehicles will receive a marginal rating if the lane centering support temporarily suspends while the driver steers and automatically reengages within 3 seconds after the driver has stopped steering, but the change in lane centering support is not clearly communicated.

A system will receive a poor rating if the lane centering support disengages when the driver steers, requiring the driver to manually reactivate the lane centering support after the maneuver.

Safety features

Partially automated systems should require safety features to remain on during the use of the system. The safety features rating is based on the system performance in Tests 10a–10f.

Systems must prevent activation by unbelted drivers (Test 10a). If the system is on and the driver unbuckles (Test 10b), the system must immediately initiate the attention reminder process.

AEB must be on while the partially automated system is on. For test 10c, systems should not activate when AEB is off or AEB must automatically reactivate when partially automated systems are turned on. When the partially automated system is on, the driver cannot deactivate AEB (Test 10e).

Also, while the partially automated system is on, lane keeping systems must provide a similar level of performance to when the partially automated system is off. For test 10d, partially automated systems should not activate when LDW/LDP are off or should reactivate LDW/LDP with similar levels of performance (i.e., still provide lane departure warnings). When the partially automated system is on, the driver cannot deactivate LDW/LDP (Test 10f).

For a system to receive a good rating, it must pass all six safety feature tests. Systems that pass five out of the six tests will earn an acceptable rating. A marginal rating will be for systems that pass four out of the six tests. Vehicles that pass less than four of the tests will receive a poor rating.

WEIGHTING PRINCIPLES FOR OVERALL RATINGS

Table 1

Weighting principles for partial automation safeguards

	Good	Acceptable	Marginal	Poor
Driver monitoring	0	5	15	30
Attention reminders	0	5	15	30
Emergency escalation and countermeasures	0	5	15	30
Automated lane change	0	n/a	n/a	5
ACC auto-resume	0	1	3	5
Cooperative steering	0	3	6	10
Safety features	0	10	30	50
Total score	0–9	10–29	30–49	> 49

Note. n/a = not applicable.

REFERENCES

SAE International. (2021). *Taxonomy and definitions for terms related to driving automation systems for on-road motor vehicles* (SAE Standard J3016, Report No. J3016_202104). https://doi.org/10.4271/J3016_202104

IIHS research on partial driving automation

Hu, W., Cicchino, J. B., Reagan, I. J., Monfort, S., Gershon, P., Mehler, B., & Reimer, B. (2022). Use of Level 1 and 2 driving automation on horizontal curves on interstates and freeways. *Transportation Research Part F: Traffic Psychology and Behaviour*, 89, 64–71. <https://doi.org/10.1016/j.trf.2022.06.008>

Kidd, D. G., Cicchino, J. B., Reagan, I. J., & Kerfoot, L. B. (2017). Driver trust in five driver assistance technologies following real-world use in four production vehicles. *Traffic Injury Prevention*, 18, S44–S50. <https://doi.org/10.1080/15389588.2017.1297532>

Kidd, D. G., & Reagan, I. J. (2019). System attributes that influence reported improvement in drivers' experiences with adaptive cruise control and active lane keeping after daily use in five production vehicles. *International Journal of Human-Computer Interaction*, 35, 972–979. <https://doi.org/10.1080/10447318.2018.1561786>

Montfort, S. S., Reagan, I. J., Cicchino, J. B., Hu, W., Gershon, P., Mehler, B., & Reimer, B. (2022). Speeding behavior while using adaptive cruise control and lane centering in free flow traffic. *Traffic Injury Prevention*, 23, 85–90. <https://doi.org/10.1080/15389588.2021.2013476>

Mueller, A. S., Cicchino, J. B., & Calvanelli, Jr, J. (2023). Consumer demand for partial driving automation and hands-free driving capability. *Journal of Safety Research*, 84, 371–383. <https://doi.org/10.1016/j.jsr.2022.11.012>

Mueller, A. S., Cicchino, J. B., & Calvanelli, Jr., J. V. (in press). Habits, attitudes, and expectations of regular users of partial driving automation systems. *Journal of Safety Research*. <https://doi.org/10.1016/j.jsr.2023.10.015>

Mueller, A. S., Cicchino, J. B., Benedick, A., De Leonardis, D., & Huey, R. (2022). Bears in our midst: Familiarity with Level 2 driving automation and attending to surprise on-road events. *Transportation Research Part F: Traffic Psychology and Behaviour*, 90, 500–511. <https://doi.org/10.1016/j.trf.2022.09.016>

Mueller, A. S., Cicchino, J. B., Singer, J., & Jenness, J. W. (2020). Effects of training and display content on Level 2 driving automation interface usability. *Transportation Research Part F: Traffic Psychology and Behaviour*, 69, 61–71. <https://doi.org/10.1016/j.trf.2019.12.010>

- Mueller, A. S., Reagan, I. J., & Cicchino, J. B. (2021). Addressing driver disengagement and proper system use: Human factors recommendations for Level 2 driving automation design. *Journal of Cognitive Engineering and Decision Making*, 15, 3–27.
<https://doi.org/10.1177/1555343420983126>
- Reagan, I. J., Cicchino, J. B., & Kidd, D. G. (2020). Driver acceptance of partial automation after a brief exposure. *Transportation Research Part F: Traffic Psychology and Behaviour*, 68, 1–14.
<https://doi.org/10.1016/j.trf.2019.11.015>
- Reagan, I. J., Hu, W., Cicchino, J. B., Seppelt, B., Fridman, L., & Glazer, M. (2019). Measuring adult drivers' use of Level 1 and 2 driving automation by roadway functional class. *Proceedings of the Human Factors and Ergonomics Society 2019 Annual Meeting*, 2093–2097.
<https://doi.org/10.1177/1071181319631225>
- Reagan, I. J., Kidd, D. G., & Cicchino, J. B. (2017). Driver acceptance of adaptive cruise control and active lane keeping in five production vehicles. *Proceedings of the Human Factors and Ergonomics Society 2017 Annual Meeting*, 1949–1953.
<https://doi.org/10.1177/1541931213601966>
- Reagan, I. J., Teoh, E. R., Cicchino, J. B., Gershon, P., Reimer, B., Mehler, B., & Seppelt, B. (2021). Disengagement from driving when using automation during a 4-week field trial. *Transportation Research Part F: Traffic Psychology and Behaviour*, 82, 400–411.
<https://doi.org/10.1016/j.trf.2021.09.010>
- Teoh, E. R. (2020). What's in a name? Drivers' perceptions of the use of five SAE Level 2 driving automation systems. *Journal of Safety Research*, 72, 145–151.
<https://doi.org/10.1016/j.jsr.2019.11.005>