Active Driving Assistance Systems:

Test Results and Design Recommendations

November 2020

CR Consumer Reports | Data Intelligence

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ABOUT CONSUMER REPORTS

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ABOUT THIS REPORT

Objectives

In line with Consumer Reports' mission to create a fair, safe, and consumer-driven marketplace, this report has been written for the industry to provide more explanation and guidance on the state of Active Driving Assistance systems based on our recent evaluation. While the systems are not equally capable, and may be designed with different usage intentions, CR's evaluation focused on real-world driving experience of consumers, keeping safety at the forefront. Our goals:

- Support the creation of government policies and company practices to ensure that innovation and safety go hand-in-hand
- Use consumer data to inform the industry of best-practices to aid in development
- Influence the safe design, testing, and deployment of systems consumers will like and use
- Advocate for transparency and clarity in marketing and consumer education of systems

Background

In October 2020, Consumer Reports published ratings of Active Driving Assistance Systems, defined as systems that allow the driver to use Adaptive Cruise Control (ACC) and Lane Keeping Assistance (LKA) to simultaneously control both the speed and steering of the vehicle. An industry webinar was also held.

Glossary of terms:

Adaptive Cruise Control Assists with acceleration and/or braking to maintain a prescribed distance between it and a vehicle in front. Some systems can come to a stop and continue.

Lane Keeping Assistance Assists with steering to maintain vehicle within driving lane.

Active Driving Assistance Assists with vehicle acceleration, braking, and steering. Some systems are limited to specific driving conditions. Driver is responsible for primary task of driving.

See *Clearing the Confusion: Recommended Common Naming for Advanced Driver Assistance Technologies*

Since CR's first-ever ratings of four of these systems in 2018, testing has been expanded to include 18 systems currently available to consumers, including one after-market device. CR's testing program has grown to 36 tests with input from several sources. The new 2020 ratings consider information from the recent CR Member surveys (2018 and 2019, *Consumer Perceptions of ADAS*), which provides a better understanding of how the systems are being used, and how they should be designed to maximize consumer satisfaction. CR also works with other organizations to test ADAS systems, such as the MIT AVT (Advanced Vehicle Technology) consortium where data has been collected in naturalistic studies from hundreds of thousands of miles of real-world driving. Collaborative relationships with global testing organizations regarding specifics in metrics and scoring ensure CR's testing program is robust and aligned in terms of capabilities as well as driver safety.

What did we test?

This industry report includes 18 Active Driving Assistance Systems representing the different brands available for consumer purchase in the United States. Seventeen of the tested systems were native systems purchased on vehicles in the Consumer Reports test fleet; the additional system tested was an after-market device, called the Comma Two, installed on a test vehicle.

This analysis examined systems that assist with vehicle acceleration, braking, and steering. These two features of ACC and LKA which, when active simultaneously, control both the speed and steering of the vehicle, make up Active Driving Assistance systems. Other features such as automated parking assist, automated lane change assist, and active safety systems were out of scope.

All LKA systems, *regardless of design intent,* were subject to the same testing protocol. Based on our research of consumer preferences and expectations, any system that provides steering should try to keep the vehicle in the center of the lane. Drivers who experience LKA systems that are designed to only intervene as the vehicle departs the lane report undesirable, inconsistent, and unexpected steering behavior that may ping-pong them between lane lines. Vehicles with multiple LKA features were evaluated on the higher scoring feature. Only vehicles with ACC that had stop and go functionality were included.

A determination was made to include the Comma Two Open Pilot system manufactured by Comma.ai. Although Consumer Reports does not endorse after-market modifications to all consumers, we feel that it is important to include the test results in this report to the industry. The direct comparison of this system to the other OEM systems will hopefully provide insight on this alternative approach and highlight the areas across the industry that have room for improvement.

All vehicles tested were anonymously purchased by Consumer Reports. Testers had experience with the systems on multiple vehicles by the same automaker. When there were multiple vehicles with the same system equipped on vehicles in our test fleet, the vehicle with the highest score was selected for inclusion. All efforts were made to represent the performance of the system at a brand-level with the latest software updates. Discrepancies in performance among different vehicles, trims, and packages do exist. Scores are based on the performance of the system at the time of testing, as a comparative analysis of the state of the marketplace. (See Appendix for a full list of Vehicles Tested.)

Is this testing part of CR's Overall Score?

At this time, the testing of Active Driving Assistance Systems is not included in the vehicle's Overall Score, but CR is considering adding or removing points for these systems in the future. Any changes to CR's methodology and ratings will be communicated to the industry in advance.

Is testing data available?

Some additional data is available for licensing through the CR Data Intelligence program. Please direct inquiries to dataintelligence@cr.consumer.org.

RATINGS OVERVIEW

The ratings methodology includes a total of 36 tests, each of which is given a rating on a scale of 1 to 10, from worse to better performing. Tests ratings include objective and expert judgment scores. (See Appendix for details regarding Test Methods.)

Advanced Driver Assistance Testing Hierarchy

OVERALL SCORE 100 POINTS

CAPABILITIES AND PERFORMANCE	LKA	13 TESTS	• Lane Departures - *Track - 35 MPH* • Lane Departures - *Track - 55 MPH* • Obstacles - *Track (4 tests)* • Standby Frequency • Centerline Deviation - *Road* • Lane Departures - *Road - 45 MPH* • Lane Departures - *Road - 65 MPH* • Obstacles - *Road (3 tests)*
	ACC	7 TESTS	• Speed Range • Stop & Go • Acceleration and Deceleration • Cut-ins / Cut-outs • Modes • Range Comfort • Override
KEEPING THE DRIVER ENGAGED	DRIVER MONITORING	2 TESTS	• Type • Performance
	USER-SELECTED ENGAGEMENT	1 TEST	• Collaborative Steering
	SYSTEM-SELECTED DISENGAGEMENT	1 TEST	• Modes
EASE OF USE	CONTROLS	4 TESTS	• Standalone • Taxonomy • Set, adjust, cancel • LKA System
	DISPLAYS	3 TESTS	• ACC lead car • LKA lane lines • Surrounding traffic
CLEAR WHEN SAFE TO USE	ODD SAFE	1 TEST	• Low risk
	ODD CLEAR	2 TESTS	• Owner's manual • In-vehicle communication
UNRESPONSIVE DRIVER	INATTENTIVE DRIVER	1 TEST	• Time to first warning - audible
	SYSTEM FALLBACK	1 TEST	• Warning escalation

CR | Data Intelligence

Overall Ratings Results

SYSTEM NAME	SCORE	CAPAB. & PERF.	KEEPING DRIVER ENGAGED	EASE OF USE	CLEAR WHEN SAFE TO USE	UNRE-SPONSIVE DRIVER
Comma Two Open Pilot	78	8	9	8	6	8
Cadillac Super Cruise	69	8	7	3	8	9
Tesla Autopilot	57	9	3	7	2	6
Ford/Lincoln Co-Pilot 360	52	8	4	3	4	5
Audi Driver Assistance Plus	48	8	3	3	2	6
Mercedes-Benz Driver Assistance	46	6	4	4	2	5
Subaru Eyesight	46	7	4	3	4	5
Hyundai Smart Sense, **Kia** Drive Wise	46	5	4	5	4	4
BMW Active Driving Assistance Pro	44	7	3	3	2	6
Porsche Active Safe	41	4	3	6	2	5
Volvo Pilot Assist	41	6	3	3	2	5
Toyota/Lexus Safety Sense 2.0	40	5	4	2	4	5
Honda/Acura Sensing	40	6	4	2	4	4
Nissan/Infiniti ProPILOT Assist	40	5	3	3	4	7
Volkswagen Driver Assistance	39	4	3	6	2	5
Land Rover Driver Assist	38	4	3	6	2	4
Buick/Chevy Driver Confidence	36	3	3	5	2	6
Mazda i-ACTIVSENSE	27	3	2	5	2	1

Key Recommendations

As these systems continue to develop and become ubiquitous on the roadways, it is more important than ever to have clear expectations for performance and ensuring safety. This report includes specific design recommendations and details of the performance of these systems in our testing. The following summarizes CR’s recommendations for manufacturers. These high-level recommendations are intended to provide guidance on designing active driver assistance systems that drivers want, will use, and have safeguards in place.

- ✓ **Direct driver monitoring and management is essential.** Hands on wheel warnings are not sufficient. Camera-based (vision and/or infrared) systems are more effective.
- ✓ **Systems should not penalize the driver for engagement.** The driver should always maintain control of mode selection. There should be no system-initiated standby mode in which the system controls when it does and does not provide steering assistance.
- ✓ **Lane keeping systems should keep the vehicle in the center of the lane.** Our experience, and the results from CR member surveys, indicate that drivers expect the systems to hold the vehicle in the center of the lane—and if it doesn't do so, they will likely simply stop using the system. Multiple LKA systems, regardless of design intent or other rationale, cause confusion.
- ✓ **Systems should know the driver’s state and keep drivers safe when they need it most**. The system should stay on and not penalize the driver for not responding. If the driver does not respond to warnings, the system should try to do everything possible to safely bring the vehicle to a stop then call for help.

DEEP DIVE: SCORES, TEST INSIGHTS, DESIGN RECOMMENDATIONS

1. Capability & Performance

Scores

SYSTEM NAME	CAPABILITY & PERFORMANCE	
	LKA	ACC
Audi Driver Assistance Plus	8	9
BMW Active Driving Assistance Pro	7	7
Buick/Chevy Driver Confidence	2	5
Cadillac Super Cruise	8	8
Comma Two Open Pilot	9	3
Ford/Lincoln Co-Pilot 360	8	7
Honda/Acura Sensing	6	5
Hyundai Smart Sense, **Kia** Drive Wise	5	7
Land Rover Driver Assist	4	4
Mazda i-ACTIVSENSE	2	6
Mercedes-Benz Driver Assistance	6	9
Nissan/Infiniti ProPILOT Assist	4	5
Porsche Active Safe	3	9
Subaru Eyesight	7	7
Tesla Autopilot	9	7
Toyota/Lexus Safety Sense 2.0	5	6
Volkswagen Driver Assistance	3	7
Volvo Pilot Assist	6	6

1 2 3 4 5 6 7 8 9 10

WORSE ← → BETTER

Test Insights

> **Our experience, and the results from CR member surveys, indicate that drivers expect the systems to hold the vehicle in the center of the lane—and if it doesn't do so, they will likely simply stop using the system.**

Favorable Implementations: The systems that were able to maintain placement near the center of the lane were **Tesla, Comma Two, Audi, Cadillac**, and **Lincoln**. Unsurprisingly, the systems that keep the vehicle well within the lane boundaries remain active and able to continually provide steering assistance. Those top performing vehicles were **Comma Two, Tesla, Lincoln, Cadillac, BMW**, and **Audi**. **Tesla** performed the best in our tests of obstacles, such as merges and splits, on both the road and our track followed closely by **Comma Two** and **Audi**.

Most of the systems tested performed well at quickly and smoothly adapting to a change of speed when following or approaching another vehicle. **Mercedes-Benz** excelled when evaluating the responsiveness to a cut-in or cut-out of a lead vehicle. Systems that scored the best at moderating the car's speed were those from **Audi, Mercedes-Benz**, and **Porsche**, which have options in the menu for drivers to select how quickly the ACC speeds up and slows down. The ACC can be set in the **Toyota** while the vehicle is stopped.

Opportunities to Improve: Regardless of design intent or improper use of LKA systems, those that only assist the driver as a lane departure occurs were vehicles that have a single LKA system, such as those from **Buick** and **Mazda**. The **Volkswagen, Porsche, Buick**, and **Mazda** systems were unable to successfully complete the lane line obstacles on the track while the **Porsche** also struggled with the road obstacles. When the driver presses the accelerator to temporarily override ACC, there is no salient indicator to the driver in the **Toyota** that ACC is still engaged.

The **Buick** also had inadequate following distances—the nearest setting was too far away and there was little noticeable difference between the other distance settings. **Comma Two**'s Open Pilot system has a few disadvantages; it designates a single following distance setting that cannot be changed by the driver which may not be desirable to all drivers, it also disengages the system if the driver presses the accelerator, and it has harsh acceleration and braking while attempting to maintain a constant speed.

Design Recommendations

- ★ **LKA should keep the vehicle in the center of the lane**. Drivers expect the automated steering to consistently and reliably keep the vehicle within the lane lines and maintain lane placement that mimics natural human driving behavior. To drivers, systems that are designed to only react to lane departures and systems that keep the vehicles in the center of the lane both have the same intent. Our research shows that the design intent and nuance is not important. Additionally, inconsistency in performance is not desirable to drivers—drivers are likely to turn off or disable these systems, eliminating any potential benefit.

- ★ **ACC with stop and go is essential.** Drivers should be able to set the speed while stopped. When ACC is actively modulating the speed based on a lead car, the system should only disengage via driver intervention. Brakes should stay engaged and bring the car to a full stop and automatically accelerate when the lead car begins to move. Immediate deactivation of ACC when coming to a full stop negates the benefits of this feature. However, too long of a stop should require input from the driver before re-accelerating.

- ★ **Systems should be adept and reactive** to the changing dynamics of surrounding traffic. There should be an adequate range of following distances and behavioral characteristics for acceleration and deceleration that are customizable to appease most drivers.

Future Design Ideal

- ➔ **The LKA system would steer around obstacles when hard braking isn't safe.**

2. Keeping the Driver Engaged

Scores

SYSTEM NAME	KEEPING DRIVER ENGAGED		
	DRIVER MONITORING	USER-SELECTED ENGAGEMENT	SYSTEM-SELECTED DISENGAGEMENT
Audi Driver Assistance Plus	2	9	6
BMW Active Driving Assistance Pro	2	6	6
Buick/Chevy Driver Confidence	2	5	5
Cadillac Super Cruise	8	2	10
Comma Two Open Pilot	8	10	10
Ford/Lincoln Co-Pilot 360	2	10	8
Honda/Acura Sensing	2	8	5
Hyundai Smart Sense, **Kia** Drive Wise	2	8	6
Land Rover Driver Assist	2	6	4
Mazda i-ACTIVSENSE	1	5	1
Mercedes-Benz Driver Assistance	2	9	5
Nissan/Infiniti ProPILOT Assist	2	7	4
Porsche Active Safe	2	6	4
Subaru Eyesight	2	8	6
Tesla Autopilot	2	1	10
Toyota/Lexus Safety Sense 2.0	2	8	6
Volkswagen Driver Assistance	2	4	4
Volvo Pilot Assist	2	8	4

Test Insights

> **Systems need to work with drivers, not against them. The system should encourage drivers to provide their own steering inputs by keeping the system active rather than going into standby mode.**

Favorable Implementations: The infrared camera in **Cadillac**'s Super Cruise and **Comma Two**'s Open Pilot are the best driver monitors. They ensure the driver's eyes are open and looking forward.

Comma Two, Lincoln, Audi, and **Mercedes-Benz** systems stayed active during all of the steering interventions from the driver when attempting to steer around a pothole or reposition within the lane. The **Comma Two** and **Lincoln** even stayed active during lane departures, attempting to immediately re-center the vehicle in the lane after the driver completed the steering intervention.

Tesla and **Comma Two** are the only systems with clear-cut modes of either on or off, which keeps the driver in control of engaging the system. They both have immediate audible warnings when the mode changes from active to off, andthe system then remains off until the driver re-engages it. Uniquely, in some situations, the **Cadillac** system can alert the driver in advance that they are leaving the ODD and will need to take over. While using the LKA in the **Lincoln**, the driver experiences an optimal balance of steering wheel torque and resistance that both informs the driver that the system is actively steering the vehicle but also allows for the driver to work with the system, not against it. There is a clear, audible chime when the LKA turns off in the **Nissan**.

Opportunities to Improve: Although the **BMW** and **Subaru** vehicles have an infrared camera, it is not used to continually monitor the driver while the active driver assistance is engaged. Steering wheel input is not a sufficient substitute for direct driver monitoring. Systems that solely implement steering wheel input as a substitute for direct driver monitoring may only be slightly better than systems with no mechanism at all.

The amount of force required to override the LKA system in the **Tesla** dissuades drivers from intervening. **Cadillac**'s system goes into a standby mode as soon as the driver applies any amount of steering input, then it's finicky to get the system to re-engage even when you are well within the lane lines. Both of these types of systems discourage driver collaboration and engagement.

Other than **Comma Two** and **Tesla**, all systems have a standby mode in which the system (not the driver) has control of re-engaging the LKA at will. Additionally, systems that have a standby mode rarely notify the driver that the LKA is no longer steering, other than a subtle change to a steering wheel icon in the instrument cluster.

Design Recommendations

- ★ **Systems should promote driver engagement and collaboration** rather than penalizing drivers who try to manually adjust the vehicles position in the lane. Drivers should know they are in control and can intervene even when the system is active. Too much steering wheel torque may have unintended consequences, but a small amount of torque resistance can give the driver more information, visual and physical, that the system is engaged.

- ★ **Drivers should determine whether the system is on or off.** The driver should always maintain control of mode selection. There should be no system-initiated standby mode in which the system controls when it does and does not provide steering assistance. Systems should immediately help re-center the vehicle after driver intervention. If the system works well, it will gently nudge the car back to the center of the lane after the driver stops providing steering input. If a system-initiated mode change occurs, it should immediately warn the driver then remain off until the driver re-engages the feature.

- ★ **Direct driver monitoring and management is essential.** Driver monitoring systems (DMS) that indirectly monitor the driver, such as using information from cameras about swaying within a lane or steering wheel input, are not sufficient.

- ★ **Hands on wheel warnings are not sufficient** to ensure the driver is paying attention. Steering wheel torque and capacitive warning systems are inadequate to ensure the driver's eyes are on the road, and they can be "tricked" with a small amount of pressure on the steering wheel. Some visual warnings may distract drivers and draw attention to the interior displays rather than on the outside roadway.

- ★ **Camera-based (vision and/or infrared) systems are more effective.** At a minimum, systems need to be active while LKA and ACC are being used, but should be available to the driver at all times, not limited to use with Active Driving Assistance Systems. Glance location and fixation duration should be taken into account to satisfy the warning system.

- ★ **Data privacy and security is paramount.** Information obtained through DMS should be used solely to make the system work correctly. Minimum amounts of data should be collected and protected, destroyed after use, and not shared or transmitted.

Future Design Ideal

- → **DMS would be able to monitor and ensure both visual and cognitive attention using more precise psychometrics, e.g., glance patterns and object detection.**

3. Ease of Use

Scores

SYSTEM NAME	EASE OF USE	
	CONTROLS	DISPLAYS
Audi Driver Assistance Plus	4	2
BMW Active Driving Assistance Pro	4	2
Buick/Chevy Driver Confidence	8	2
Cadillac Super Cruise	4	2
Comma Two Open Pilot	7	8
Ford/Lincoln Co-Pilot 360	4	2
Honda/Acura Sensing	3	2
Hyundai Smart Sense, **Kia** Drive Wise	7	4
Land Rover Driver Assist	9	4
Mazda i-ACTIVSENSE	8	2
Mercedes-Benz Driver Assistance	6	3
Nissan/Infiniti ProPILOT Assist	4	1
Porsche Active Safe	8	4
Subaru Eyesight	3	2
Tesla Autopilot	6	8
Toyota/Lexus Safety Sense 2.0	2	2
Volkswagen Driver Assistance	8	4
Volvo Pilot Assist	4	2

Test Insights

> **Controls and displays should be intuitive and not require extensive training. They should be easily identifiable and distinct from other features.**

Favorable Implementations: Drivers are able to activate the steering and speed control independently in the **Hyundai**, so that drivers can decide exactly how much assistance they want to use. **Buick, Land Rover, Mazda, Nissan, Porsche**, and **Volkswagen** all had a single LKA system and ACC that could be engaged separately or simultaneously.

Although there were no systems that maintained perfect consistency in naming conventions and iconology among in-vehicle controls and displays, **Audi, Hyundai, Mercedes-Benz, Volkswagen**, and **Volvo** had adequate descriptions of the functionality and close adherence to industry standards. (See *Clearing the Confusion*.)

Tesla and **Comma Two** stand out for their dynamic displays. The **Tesla** display provides information about lane line detection and proximity to surrounding traffic in all directions. The comprehensive display gives drivers the ability to match the sensor information with their own experience and detection, particularly due to the accuracy of detecting solid and dashed lane lines. The **Comma Two** uses a unique augmented reality display to overlay indicators for identifying the leader vehicle, the lane lines, and the projected pathway. This provides information to the driver to rationalize the decision-making and behavior of the system.

Opportunities to Improve: Both **Subaru** and **Volvo** systems change the ACC set speed by 5 MPH increments when the driver presses the control. A long-press is required to adjust by 1 MPH, which is counterintuitive. **Audi** and **Porsche** both utilize an additional stalk on the steering wheel to control the ACC. The lack of illumination and obstruction by the steering wheel make using the controls difficult. **Honda** and **Lincoln** require unnecessary steps to turn on the controls before being able to activate features of the system. The **Comma Two** display, when mounted according to manufacturer instruction, is physically located between the rear-view mirror and screen containing the backup camera. This location in the center of the vehicle is commonly associated with the rear view of the vehicle which may cause disorientation. Similarly, the sole display in the **Tesla** is located in the center stack of the vehicle, not in direct view of the driver when looking at the forward roadway. All systems could benefit from providing the most important information to the driver in their direct field of view without taking their eyes off the road or causing distraction.

Design Recommendations

- ★ **Multiple LKA systems, regardless of design intent or other rationale, cause confusion to drivers.** The overall value of a system that does not keep the car centered as drivers expect is questionable. There should be a single feature within the system that controls steering.

- ★ **Controls and displays should be simple and intuitive.** Drivers should be able to operate LKA and ACC independently and not only with a single button to activate both simultaneously. Drivers need to be able to easily turn systems on, off, or adjust settings while driving without taking eyes off the road. Drivers should not have to go through a menu. Adjustments should be intuitive such as 1 MPH increments for adjusting the ACC.

- ★ **Displays should clearly show which system is on and the current settings** when drivers are using the system. There should be clear and adequate feedback on the system availability, status, and mode.

- ★ **Systems need to provide ample information about what the system sees** in front, to the side, and behind the vehicle. It should effectively communicate information to the driver about why it is behaving in a certain way so that the driver can determine if it is performing correctly. This, and other important system information, should be in the direct view of the driver without taking their eyes off the road.

Future Design Ideal

- ➔ **Visual information would be displayed in an augmented reality or HUD (Head Up Display) and would always be in view of the driver.**

4. Clear When Safe to Use

Scores

SYSTEM NAME	CLEAR WHEN SAFE TO USE	
	ODD SAFE	ODD CLEAR
Audi Driver Assistance Plus	2	2
BMW Active Driving Assistance Pro	2	3
Buick/Chevy Driver Confidence	2	2
Cadillac Super Cruise	10	4
Comma Two Open Pilot	7	5
Ford/Lincoln Co-Pilot 360	5	3
Honda/Acura Sensing	5	2
Hyundai Smart Sense, **Kia** Drive Wise	5	3
Land Rover Driver Assist	2	2
Mazda i-ACTIVSENSE	2	2
Mercedes-Benz Driver Assistance	2	3
Nissan/Infiniti ProPILOT Assist	5	3
Porsche Active Safe	2	3
Subaru Eyesight	5	3
Tesla Autopilot	2	3
Toyota/Lexus Safety Sense 2.0	5	3
Volkswagen Driver Assistance	2	3
Volvo Pilot Assist	2	3

Test Insights

> **Systems that automate steering and/or speed should only be available in low-risk situations. Ensuring the driver's eyes are on the road and that the driver is able to take control at any time can increase the ODD.**

Favorable Features: **Cadillac** is the only vehicle that restricts use of the system to a prescribed ODD. Super Cruise can only be used on pre-mapped, divided highways and it warns the driver in advance of an upcoming lane-merge or complex situation that requires driver intervention. It also informs drivers when and where it is available, even when it's not active. Both the **Cadillac** and **Comma Two** use direct driver monitoring which expands the scenarios in which the system can be safely used. They also provide ample information to the driver about the availability of the system.

Opportunities to Improve: Systems from **Audi, BMW, Tesla**, and **Volvo** were capable of being operated during test drives through residential areas when the road had only a single, center lane line. These systems, that lack effective direct driver monitoring, should restrict use in less-than-ideal situations. All of the systems we tested could improve information regarding safe ODD in the owner's manual, but more importantly, to the driver inside the vehicle.

Design Recommendations

★ **Systems should tell the driver when it is not appropriate to use,** by providing information about availability to the driver while they are using the system. This information is not sufficient in the owner's manual alone. If the vehicle is outside of the ODD, the system should not be available to the driver.

★ **Systems should warn drivers if the vehicle is approaching, or operating outside of the ODD**, the system should warn the driver and shut off with clear indication of system status. When possible, the system should attempt to warn the driver in advance of disengagement. It should then remain unavailable until the vehicle is again within the ODD.

★ **Systems should only be able to be available in low-risk driving environments** such as straight, divided, limited-access highways, void of pedestrians and tricky situations, such as intersections and complicated traffic patterns. Systems must enforce the ODD and not leave this responsibility to the driver.

Future Design Ideal

➔ **The system would inform the driver of necessary re-calibration of the sensors and be able to recalibrate themselves.**

5. Unresponsive Driver

Scores

SYSTEM NAME	UNRESPONSIVE DRIVER	
	INATTENTIVE DRIVER	SYSTEM FALLBACK
Audi Driver Assistance Plus	4	8
BMW Active Driving Assistance Pro	4	8
Buick/Chevy Driver Confidence	8	4
Cadillac Super Cruise	10	8
Comma Two Open Pilot	10	6
Ford/Lincoln Co-Pilot 360	4	6
Honda/Acura Sensing	4	4
Hyundai Smart Sense, **Kia** Drive Wise	4	4
Land Rover Driver Assist	4	4
Mazda i-ACTIVSENSE	1	1
Mercedes-Benz Driver Assistance	2	8
Nissan/Infiniti ProPILOT Assist	6	8
Porsche Active Safe	4	6
Subaru Eyesight	4	6
Tesla Autopilot	3	8
Toyota/Lexus Safety Sense 2.0	6	4
Volkswagen Driver Assistance	6	4
Volvo Pilot Assist	6	4

Test Insights

> **Drivers want systems to help them if they become incapacitated, regardless of whether they are using the active driving assistance features.**

Favorable Features: Due to the infrared driver monitoring camera, **Super Cruise** and **Open Pilot** monitor the driver's eyes and will provide warnings when inattention is detected. Although most other vehicles tested do not have the capability of monitoring the drivers' eyes like Super Cruise, most do have a system that will alert if the car judges the driver to be inattentive for a significant period and then bring the car to a stop with the hazard lights on, and even make a phone call for help via the in-car telematics system or the driver's paired smartphone. **Nissan**'s system applies rapid hard braking in an attempt to wake the driver if warnings are disregarded.

Opportunities to Improve: **Mazda** completely lacked safeguards for keeping the system engaged or providing an escalation process when drivers ignore system warnings. Too much time to the first audible warning caused several systems to score low in this category, such as **Mercedes-Benz** and **Tesla**. Vehicles with frequent system-initiated standby mode changes also contributed to lower scores for **Mazda** and **Buick**.

Design Recommendations

- ★ **Systems should ensure the driver is attentive** and able to take control of the vehicle at all times. Detecting driver attention and inattention is achieved most effectively using direct driver monitoring systems. Vehicles should have a mechanism to assess the driver's state and warn if inattention is detected.

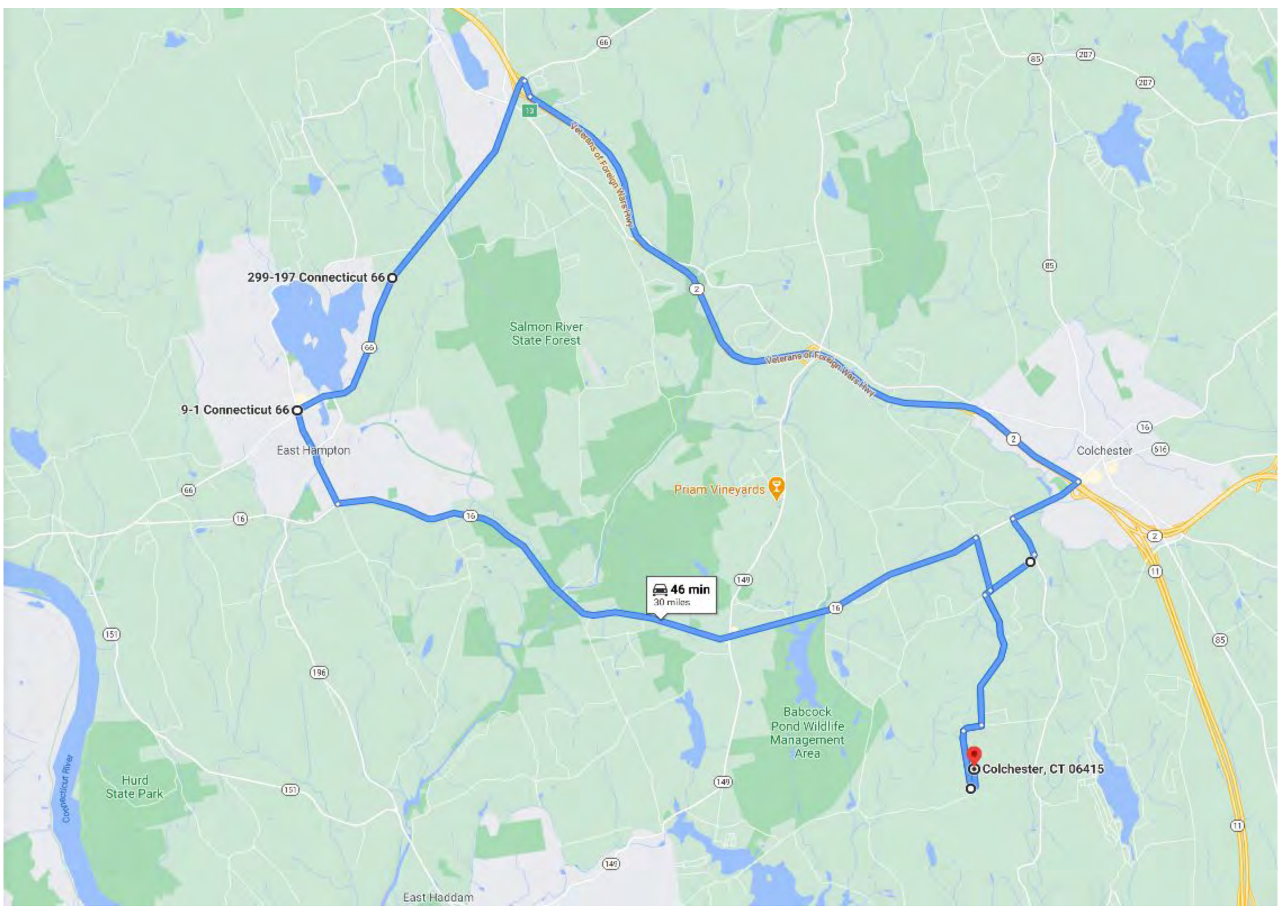
- ★ **Systems should keep drivers safe when they need it most.** Systems should alert the driver using a series of multi-modal escalating warnings (visual, audible, and haptic) in a timely manner if inattention is detected. If there is no response, the system should stay on and not penalize the driver for not responding. The system should try to do everything possible to safely bring the vehicle to a stop then call for help.

Future Design Ideal

- ➔ **The best systems would be able to pull the vehicle off the road or to the shoulder safely, and to detect the driver's state even when the system is not in use.**

How We Test

As with every vehicle CR anonymously purchases for our test program, testers familiarize themselves with the vehicle and the systems prior to testing by driving hundreds of miles on the road, and on the Auto Test Center track in East Haddam, Connecticut. For the evaluation of the Active Driver Assistance systems, the lane lines on our test track were recently updated to create obstacles and scenarios that are representative of real roads. Using these obstacles, testers are able to safely evaluate how each system reacts during repeated exposure to the same scenarios. In addition to these evaluations, testers also drive a 30-mile loop near the testing facility. This route includes neighborhood streets, limited access freeways, and combinations of lane types and speed ranges. Due to the randomness that can be experienced during real-world driving, this route is driven several times to ensure consistency in the data.



1. Capability & Performance Test Methods

LANE KEEPING ASSISTANCE (LKA), 13 TESTS

TEST	METHODOLOGY
Lane Departures, Track (35 MPH)	Count of touching lane line and crossing lane line at 35 MPH
Lane Departures, Track (55 MPH)	Count of touching lane line and crossing lane line at 55 MPH
Obstacles, Track	Performance and consistency (4 tests)
Standby Frequency	Time system was in standby or off during tests
Centerline Deviation, Road	Deviation from lane center, consistency
Lane Departures, Road (45 MPH)	Frequency touching lane line and crossing lane line 45 MPH
Lane Departures , Road (65 MPH)	Frequency touching lane line and crossing lane line 65 MPH
Obstacles , Road	Performance and consistency (3 tests)

ADAPTIVE CRUISE CONTROL (ACC), 7 TESTS

TEST	METHODOLOGY
Speed Range	At what speed can you set the ACC? What is the minimum speed ACC can be set to?
Stop & Go	Does the vehicle come to a stop? How long does the car hold the brake at a stop before the system “times out”?
Acceleration and Deceleration	How smooth is the acceleration at low speeds? High speeds? How smooth is the deceleration at low speeds? High speeds?
Cut-ins / Cut-outs	How reactive is the ACC braking during a vehicle cut-in from an adjacent lane? How reactive is the ACC acceleration during a vehicle cut-out to an adjacent lane?
Modes	Are there personalizable settings for ACC acceleration and deceleration? How well do the default acceleration and deceleration behaviors perform?
Range Comfort	How many following distance (gaps) options are there? Is the closest following distance adequate? Is the farthest following distance adequate?
Collaborative Speed (Speed Override)	What happens when the driver presses the accelerator while ACC is active?

2. Keeping the Driver Engaged Test Methods

DRIVER MONITORING, 2 TESTS

TEST	METHODOLOGY
Type	How is inattention measured? Direct or indirect driver monitoring system? Warning type, location, frequency Elicited response to satisfy warning Where is the driver's attention when responding to the warning? (In-vehicle display, roadway, etc.)
Performance	DMS sensitivity and responsiveness How quickly does the system ensure the driver's eyes are on the road? Does the DMS measure attention? Can the DMS be "tricked" or disabled by the driver?

USER-SELECTED ENGAGEMENT, 1 TEST

TEST	METHODOLOGY
Collaborative Steering (Steering Override)	Is the driver always in control of mode selection? Does the system stay active while the driver steers within the lane? Does the system stay active when the driver steers over a lane line? Are there penalties for the driver steering while the system is active?

SYSTEM-SELECTED DISENGAGEMENT, 1 TEST

TEST	METHODOLOGY
Modes	Framework and circumstances (active, standby, off; speed, lines) Does the system provide too little or too much torque while the driver is steering? What causes a system-initiated mode change? (incl. Active, standby, off) Does the system warn the driver of a system-initiated mode change in advance? How does the system inform the driver of a system-initiated mode change?

3. Ease of Use Test Methods

CONTROLS, 4 TESTS

TEST	METHODOLOGY
Standalone	Can the LKA and ACC be used independently? Is there a single control or are there multiple controls to activate both ACC and LKA simultaneously?
Taxonomy	Consistency of controls, symbols, menus, displays etc throughout the vehicle Adequate *descriptions* of the functionality of features in menus Taxonomy adherence to industry standards i.e., “Clearing the Confusion”
Set, Adjust, Cancel (ACC)	Controls and displays location and labels Adequate *representation* of the functionality of features Intuitive controls (i.e., 1 MPH increments in speed, bidirectional) Ease of driver engagement/disengagement
LKA System	Controls and displays location and labels Adequate *representation* of the functionality of features Intuitive controls (i.e., more than one LKA system?) Ease of driver engagement/disengagement

DISPLAYS, 3 TESTS

TEST	METHODOLOGY
ACC lead car	Lead car display: static or dynamic; location (cluster, HUD, other) Always-on display while using ACC Driver confidence: what information is given to drivers to match the display with the sensor information, and how can the driver check or recalculate the performance by the system?
LKA lane lines	Lane lines display: static or dynamic; location (cluster, HUD, other) Always-on display while using LKA Driver confidence: what information is given to drivers to match the display with the sensor information, and how can the driver check or recalculate the performance by the system?
Surrounding Traffic	Surrounding traffic display: static or dynamic; location (cluster, HUD, other) Always-on display while using LKA + ACC Driver confidence: what information is given to drivers to match the display with the sensor information, and how can the driver check or recalculate the performance by the system?

4. Clear When Safe to Use Test Methods

ODD SAFE, 1 TEST

TEST	METHODOLOGY
Low Risk	Does the system enforce a safe ODD? Does the system enforce its own ODD? Advanced warnings of system disengagement

ODD CLEAR, 2 TESTS

TEST	METHODOLOGY
Owner's Manual	What information is contained in the owner's manual for safe and appropriate use of each feature?
In-Vehicle Communication	How does the driver know the system is available for use? How does the driver know if the system should not be used?

5. Unresponsive Driver Test Methods

INATTENTIVE DRIVER, 1 TEST

TEST	METHODOLOGY
Time to First Warning (Audible)	Average time to first audible warning when driver ignores visual warning(s) (Time-based, Speed-based measures)

SYSTEM FALLBACK, 1 TEST

TEST	METHODOLOGY
Warning Escalation	Frequency of system-initiated standby mode Timing/order of escalation process including visual, audible, haptic warnings Other warnings such as seat belt tension, hard braking, other Does the vehicle slow to a stop? Are hazard lights used? Does the vehicle stay in its lane? Is an SOS or eCall initiated? Does the vehicle pull to the shoulder?

Vehicles Tested

SYSTEM NAME	VEHICLE TESTED
Audi Driver Assistance Plus	2019 Audi eTron
BMW Active Driving Assistance Pro	2019 BMW 330i xDrive
Buick/Chevy Driver Confidence	2020 Buick Encore GX Select
Cadillac Super Cruise	2018 Cadillac CT6
Comma Two Open Pilot	2020 Toyota Corolla LE equipped with the Comma Two device
Ford/Lincoln Co-Pilot 360	2020 Lincoln Corsair Reserve
Honda/**Acura** Sensing	2020 Honda CR-V Hybrid
Hyundai Smart Sense, **Kia** Drive Wise	2020 Hyundai Palisade SEL
Land Rover Driver Assist	2020 Land Rover Range Rover Evoque
Mazda i-ACTIVSENSE	2020 Mazda CX-30
Mercedes-Benz Driver Assistance	2020 Mercedes-Benz GLS450
Nissan/Infiniti ProPILOT Assist	2019 Nissan Leaf Plus
Porsche Active Safe	2020 Porsche Taycan 4S
Subaru Eyesight	2020 Subaru Outback Limited
Tesla Autopilot	2020 Tesla Model Y
Toyota/Lexus Safety Sense 2.0	2020 Toyota Corolla LE
Volkswagen Driver Assistance	2020 VW Passat SE
Volvo Pilot Assist	2019 Volvo S60