

# AAA AUTOMOTIVE ENGINEERING

*Evaluation of Lane Departure Warning and Lane Keeping Assist Technologies*

2014



AAA conducted research on **lane-departure warning systems** in the third quarter of 2014. The research was conducted in partnership with the Automobile Club of Southern California's Automotive Research Center. The intent of the testing was to better understand how lane-departure systems work and respond to various traffic scenarios.



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# BACKGROUND

## LANE DEPARTURE WARNING SYSTEMS

Lane Departure Warning (LDW) systems have the ability to detect standard lane markings including intermittent stripes, continuous stripes and even raised pavement markers (Bott's dots). Lane Departure Warning systems utilize a computer vision camera that captures road boundary information and uses this information with a proprietary software algorithm to estimate the geometry of the lane and predict the position of the vehicle within the lane. All of these measurements and calculations are performed in real-time, several hundred times a second.



FIGURE 1: LANE DEPARTURE WARNING CAMERAS MOUNTED TO THE WINDSHIELD OF THE CAR. SUBARU USES TWO (STEREO) CAMERAS IN THEIR EYESIGHT SYSTEM (LEFT). OTHER MANUFACTURERS USE A SINGLE CAMERA SUCH AS THE INFINITI (RIGHT).



FIGURE 2: LANE DEPARTURE CAMERA ANALYZING LANE MARKINGS. (IMAGE COURTESY OF KIA)

Since LDW and LKA systems are a camera based, visual measurement technology, their accuracy and reliability can be greatly affected by the ambient conditions such as snow, rain and fog. Road conditions such as worn pavement markers, construction zones and intersections can also cause the LDW system to lose track of the lane geometry. Once the system loses track of the lane geometry, the system will temporarily deactivate until the system can pick up the road markings once again.

## LANE DEPARTURE WARNING

When the system detects the vehicle drifting out of the lane, a visual, audible or haptic (vibration) warning is given to notify the driver of the potential issue. The visual warning is typically displayed within the dash cluster or on the windshield for vehicles equipped with a head-up-display.



FIGURE 3: LANE DEPARTURE WARNING SHOWN ON MERCEDES CLS DASH.

Some vehicles, such as the Acura RLX momentarily mute the radio and provide an audible alert to notify the driver of a potential lane departure event. On vehicles equipped with haptic feedback, the steering wheel or seat will vibrate to alert the driver of an impending lane departure event.

## LANE KEEPING ASSIST

On vehicles equipped with Lane Keeping Assist (LKA) systems, the vehicle can attempt to correct the lane departure event by *steering* the vehicle back into the intended lane. Currently, there are two LKA methods utilized by vehicle manufactures.

Mercedes and Infiniti use the rear wheel braking to steer the vehicle back into the intended lane should a lane departure event occur. If the vehicle is drifting outside of the intended lane, the vehicle applies brake pressure to the outside rear wheel, which causes the car to pull the vehicle back into the intended lane.

Other manufacturers such as Ford and Acura use steering torque to direct the vehicle back into the intended lane during a lane departure event. Many newer vehicles are equipped with electric power steering systems so it is relatively easy using this system to apply steering torque in a specific direction as needed. The intent of applying steering torque is to alert the driver of a potential lane departure event, it isn't intended to be a replacement for safe driving practices. In the event of an impending accident, it is possible for the driver to override the steering

input since it only applies light corrective steering torque. The steering torque provides a slight *nudge* to alert the driver and to being the process of re-centering the vehicle in the travel lane.

*Lane Departure Warning system implementation can vary greatly from manufacturer to manufacturer so it is suggested that you consult the vehicle owner's manual to determine how the system works in your car.*

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## PROCEDURE

AAA analyzed National Highway Traffic Safety Administration (NHTSA) test methods related to Lane Departure Warning tests. The test methods used by AAA are a derivation of the NHTSA testing methods based upon the goals of the organization, available testing time and resources.

### NHTSA TEST DOCUMENTS:

- LANE DEPARTURE WARNING SYSTEM CONFIRMATION TEST and Lane Keeping Support Performance Documentation<sup>1</sup>

### AAA'S EVALUATION WAS DESIGNED TO:

- Define the activation criteria and system limitations for lane-departure warning systems available on a sample of current production vehicles.
- Lane-departure warning systems were tested to demonstrate the system response to various road marking types.

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## TEST METHODS

### LANE-DEPARTURE WARNING TESTS

Lane-departure warning systems were evaluated on a variety of street types and lane markings. Testing occurred on streets with different pavement markings, on the freeway, in traffic and construction areas. Road markings tested included solid yellow stripes, discontinuous stripes, worn pavement markers and raised Botts' Dots.



*Botts' Dots raised pavement markers were invented by Elbert D. Botts in the 1950s. The dots were invented so drivers could see lane stripes in the rain or at night. Photo courtesy of the Sacramento County Department of Transportation website.*

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<sup>1</sup> PDF download available from [www.safercar.gov](http://www.safercar.gov)

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## RESULTS

### EVALUATION OUTCOMES:

The tests were conducted at the Auto Club Speedway of California and on public road ways to ensure a good mix of lane marking types and pavement conditions. A dedicated safety vehicle was driven behind the vehicle under test as an additional safety precaution.

The lane departure warning test was intended to be a subjective evaluation comparing the system implementation of lane departure warning systems. Videos of the test were recorded to enable the research team to review the vehicle response to the test conditions.



FIGURE 4: LANE DEPARTURE WARNING TEST VIDEO

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## TEST VEHICLES

A matrix of measurement technologies for the LDW tests identifies categories for measurement technology, alert type (haptic, visual or audible) and active intervention.

The test vehicles for this evaluation were chosen based upon system alert type, intervention type and car availability at the time of testing.

*The variety of test vehicles included within this report is not intended to represent every vehicle with Lane Departure Warning technology, but rather to compare and contrast vehicles with different measurement systems and alert types.*

Lane Departure Vehicle Selection			
Safety System	Test Vehicles		
	Acura RLX	Cadillac Escalade	Mercedes CLS
Lane Departure Warning	Audible	Haptic-Seat	Haptic-Steering
		Visual Display	
Lane Keeping Assist	Steering-Torque	NA	Wheel-Braking
	Visual Dash	NA	Visual Dash

FIGURE 5: LDW WARNING TYPE AND FEEDBACK

The vehicles selected for testing from left-to-right; 2015 Cadillac Escalade, 2014 Acura RLX and 2014 Mercedes CLS.



FIGURE 6: LANE DEPARTURE WARNING TEST VEHICLES.

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## TEST EQUIPMENT

The test vehicles were instrumented with a Racelogic VideoVbox<sup>2</sup> system that utilizes 4 camera inputs and has GPS and vehicle data overlay.



FIGURE 7: RACELOGIC VIDEO VBOX WITH GPS AND DATA OVERLAY

A technical support engineer from Racelogic U.S.A was onsite during testing to assist with vehicle instrumentation and data collection.

GoPro cameras were also setup on the test vehicle to enable high-definition video of the test scenarios. The GoPro cameras were time synchronized to enable picture-in-picture videos of the test.



FIGURE 8: VISUAL DISTANCE REFERENCE ADDED TO VIDEO BY USING TAPE MEASURE.

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<sup>2</sup> <http://www.vboxmotorsport.com/index.php/us/products/video-loggers/video-vbox-pro>

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## OBSERVATIONS

- Feedback from the AAA test personnel regarding lane-departure warning systems
  - The annoyance potential for both the Lane Departure Warning and Lane Keeping systems tested was high, but the urgency of the driving situation needs to be quickly conveyed to the driver. It is understood that an alert balance of *Urgency* versus *Annoyance*, more annoyance may be acceptable for Lane Departure Warning and Lane Keeping systems compared to other systems such as Navigation or parking sonar. A safety-system with high annoyance potential, such as the LDW / LKA system could motivate drivers to disable the safety-system due to the high annoyance potential of the alerts.
  - Haptic feedback (vibration) for lane departure warning was preferred by most test personnel, although there were individual preferences on seat and steering wheel haptic feedback methods.
  - Steering wheel haptic feedback was difficult to discern when driving over raised pavement markers. While it was not tested, it might be difficult to feel the steering wheel vibration while wearing gloves; this could be an important aspect for colder weather climates.
  - Lane keeping assist (LKA) using rear-wheel braking worked well at moderate speeds, but caused a noticeable deceleration of the vehicle at higher speeds as the brake was applied to actively steer the vehicle back into the lane. This sensation might make the passenger or driver feel un-easy. When the LKA system is activated, the vehicle brake lights turn on as the rear-wheel brake is applied, even though the driver does not depress the brake pedal.
  - In most cases, the testing group had to review the vehicle owner's manual to understand how to activate or de-activate the lane departure warning systems.
  - The AAA Foundation for Traffic Safety has also provided an assessment of lane-departure warning systems, along with six other advanced technologies, in the August 2014 [report \*Evaluating Technologies Relevant to the Enhancement of Driver Safety\*](#). Conducted by the Massachusetts Institute of Technology Age Lab, the study details a data-driven system for rating the effectiveness of new in-vehicle technologies intended to improve driver safety. Motorists can review the AAA Foundation's rating for new in-vehicle technologies, along with extensive informational material, at <https://www.aaafoundation.org/ratings-vehicle-safety-technology>.

### VEHICLES CURRENTLY EQUIPPED WITH LANE-DEPARTURE WARNING SYSTEMS:

- AAA's review of manufacturer vehicle data – from the Insurance Institute for Highway Safety (IIHS) website<sup>3</sup> – it was determined that of the 415 vehicles lane-departure warning systems are offered as optional on 226 models (54%) and as standard equipment on 9 models (2%).
- Lane-keeping assist is a similar technology that will attempt to guide the vehicle back into the lane through corrective steering or rear-wheel braking. This technology is offered as optional equipment on 74 vehicles (18%).
- IHS Automotive, a Detroit research firm, projects that sales of anti-crash sensors will total \$9.90 billion in 2020 – up from \$3.94 billion in 2014. The majority of sales volume will come from radar and cameras, followed by ultrasound and lidar. Automakers are outfitting less expensive mass-market models with anti-collision systems, leveraging radar and cameras to increase safety.

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<sup>3</sup> <http://www.iihs.org/iihs/ratings/crash-avoidance-features>



- A report by Smithers Apex forecasts possible sensor market growth of more than 50 percent annually through 2018. Automaker designs are driving the growth: advanced driver assistance features were once \$3,000+ options on high-end vehicles and now are \$395 options on mainstream vehicles.

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## CONCLUSION

### AAA'S MESSAGE:

- Lane departure warning systems worked well in most traffic conditions, but there were instances in every evaluation where an alert driver needed to take corrective action. These systems are not a substitute for an engaged driver.
- The implementation of lane departure warning systems varies greatly among manufacturers; motorists should consult the vehicle's owner's manual to determine how the systems work before driving the vehicle.

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