AAA AUTOMOTIVE ENGINEERING

Evaluation of Blind Spot Monitoring and Blind Spot Intervention Technologies

2014

AAA conducted research on **blind-spot monitoring 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 blind-spot monitoring systems work and respond to various traffic scenarios.

BACKGROUND

BLIND SPOT MONITORING SYSTEMS

Blind spot monitoring systems utilize radar based technology that is either mounted below side mirrors or in the rear bumper of the vehicle. The radar sensors emit and receive electromagnetic waves that are tuned to a specific frequency and distance by the system suppliers. When an approaching vehicle is within the range of the electromagnetic wave, it is reflected off of the approaching vehicle and sent back to the primary vehicle. This information is then processed by the Blind Spot Monitoring (BSM) controller to determine whether or not an alert condition exists. If an alert condition exists, the warning lights in the A-pillar or side mirror will be illuminated.

FIGURE 1: HELLA BLIND SPOT MONITORING RADAR SENSOR (LEFT).
THE CADILLAC ESCALADE USES TWO OF THESE SENSORS MOUNTED BEHIND THE REAR BUMPER COVER (RIGHT).

Most radar based blind spot monitoring systems utilize a short range pulse that has a potential range of approximately 100ft. While the sensors have the ability to measure up to the maximum distance their detection range is tuned by the manufacturer to a distance that is determined to provide adequate response yet not too far to create an annoying alert when vehicles are driven in typical traffic conditions.

The Cadillac Escalade utilizes a blind spot monitoring radar sensor manufactured by HELLA which is capable of measuring in *multiple modes* depending on the application. When configured for the lane change assist function, the sensor can detect vehicles up to 200ft away in the adjacent lane. When the Hella radar sensor is configured for standard blind spot monitoring, the sensors can detect vehicles approximately 10ft behind the vehicle in the adjacent lane.

AUDIO / VISUAL DISPLAY:

The BSM systems typically notify the driver with a visual alert in either in the A-pillar of the car or in the side view mirror as shown below. Most manufacturers do not use an audible alert for blind spot warning systems due to the annoyance potential of an audible alarm in traffic conditions. If a driver attempts to make a lane change towards a vehicle in their blind spot, the system may issue an audible alarm or flash the BSM warning light to indicate a potential collision.

FIGURE 2: LEXUS BLIND SPOT INDICATOR IN MIRROR (LEFT) AND VOLVO BLIND SPOT INFORMATION SYSTEM ON THE A-PILLAR (RIGHT).

BLIND SPOT INTERVENTION:

Blind Spot Intervention is available on some vehicles as an addition to the standard blind spot monitoring system. The technology is capable steering the vehicle away from a potential collision if the system determines that a collision is imminent. Mercedes and Infiniti use selective rear-wheel braking to steer the vehicle away from a potential accident. The Blind Spot Intervention system is only activated when a potential collision scenario is detected.

Blind Spot Monitoring 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.

PROCEDURE

AAA analyzed National Highway Traffic Safety Administration (NHTSA) test methods related to Blind Spot Monitoring. 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:

- Blind Spot Monitoring in Light Vehicles – System Performance (DOT HS 812 045) [1]

AAA'S EVALUATION WAS DESIGNED TO:

- Define the activation criteria and system limitations for blind-spot monitoring systems available on a sample of current production vehicles.
- Measure the blind spot monitoring system response time and vehicle detection distance in a variety of scenarios. These tests were conducted with either a car or motorcycle in the side blind spots (left and right side) of the test vehicle.

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[1] PDF download available from www.safercar.gov

TEST METHODS

BLIND SPOT MONITORING TESTS

The target vehicles were driven according to the test plan in the lane adjacent to the vehicle-under-test. In certain test scenarios, the target vehicle will approach the subject vehicle in the same lane to simulate a last minute passing maneuver by the target vehicle. To ensure consistency and repeatability between test runs, both vehicles were driven at a constant velocity at the point of detection to minimize the driver influence on the test results. The detection distance and response time for the data table within the *results section* is an average of the five test runs.

				Target Vehicle	
Blind Spot Monitoring Test Scenarios	**Vehicle Side**	**Subject Vehicle**	**Target Vehicle**	**Full-size Sedan**	**Motorcycle**
Minimum Activation Speeds	**Right**	Slow Accel	Slow Accel	**X**	
Lateral Activation Distance	**Right**	40	40	**X**	
Longitudinal Activation Distance	**Right**	40	40	**X**	
Small Speed Differential	**Left**	55	70	**X**	**X**
Large Speed Differential	**Left**	25	75	**X**	**X**
Pass from Behind	**Left**	60	75	**X**	**X**
Small Speed Differential	**Right**	55	70	**X**	**X**
Large Speed Differential	**Right**	25	75	**X**	**X**
Pass from Behind	**Right**	60	75	**X**	**X**
Two Vehicle Passing	**Both**	55	70	**X**	

Note: Each test scenario was performed 5 times to create an average for each vehicle / test condition.

FIGURE 4: BLIND SPOT MONITORING TEST WITH MOTORCYCLE TARGET VEHICLE. THIS SCENARIO IS ILLUSTRATING THE PASS-FROM-BEHIND TEST

FIGURE 3: DOUBLE PASS TEST AT THE AUTO CLUB SPEEDWAY OF CALIFORNIA.

RESULTS

EVALUATION OUTCOMES:

The tests were conducted on a closed course test track at the Auto Club Speedway of California in an effort to maintain consistent vehicle speeds and to ensure safety of the test personnel and vehicles. The test vehicles were driven at the speeds and conditions defined within the Test Method section of this report.

The test results were post-processed by a Racelogic support engineer and organized in an Excel document so the data could be analyzed by AAA Automotive Engineering and the Auto Club of Southern California Automotive Research Center.

For each test scenario, test runs were repeated five times in order to obtain a running average of the system response time and vehicle separation distance. The data shown within the table below is the result of the average system response times and vehicle separation distances captured during the on-track testing.

		Vehicle #1	**Vehicle #2**	**Vehicle #3**
Target Vehicle (Full-Size Sedan)				
Small Speed Differential (Left)	**Ft.**	23.27	84.35	19.56
	Sec	1.74	4.27	1.4
Small Speed Differential (Right)	**Ft.**	23.05	82.53	14.81
	Sec	1.73	4.07	1.25
Large Speed Differential (Left)	**Ft.**	14.21	233.23	17.87
	Sec	0.48	3.69	0.21
	Misses	3.00	0.00	1.00
Large Speed Differential (Right)	**Ft.**	17.35	188.39	4.13
	Sec	0.48	3.15	0.28
	Misses	2.00	0.00	3.00
Pass From Behind (Left)	**Ft.**	20.98	21.29	17.11
	Sec	1.37	1.76	1.28
Pass From Behind (Right)	**Ft.**	21.09	19.76	15.23
	Sec	1.62	1.59	1.40

FIGURE 5: BLIND-SPOT MONITORING SYSTEM RESPONSE TIME AND VEHICLE SEPARATION DISTANCE AT ALARM ONSET.

		Vehicle #1	Vehicle #2	Vehicle #3
Target Vehicle (Motorcycle)				
Small Speed Differential (Left)	**Ft.**	18.37	74.53	18.58
	Sec	0.91	3.61	1.30
Small Speed Differential (Right)	**Ft.**	19.68	54.18	15.12
	Sec	0.94	3.25	1.02
Large Speed Differential (Left)	**Ft.**	18.33	200.37	11.15
	Sec	0.47	3.30	0.26
	Misses	3.00	0.00	0.00
Large Speed Differential (Right)	**Ft.**	12.71	229.30	1.42
	Sec	0.45	3.65	0.25
	Misses	1.00	0.00	2.00
Pass From Behind (Left)	**Ft.**	19.31	20.53	16.59
	Sec	1.14	1.61	1.42
Pass From Behind (Right)	**Ft.**	20.08	18.31	12.63
	Sec	1.15	1.22	1.29

FIGURE 6: BLIND-SPOT MONITORING SYSTEM RESPONSE TIME AND VEHICLE SEPARATION DISTANCE AT ALARM ONSET.

A motorcycle was included in the blind spot monitoring tests to illustrate the detection differences when compared to a standard full-size sedan. California currently allows a motorcycle to “lane-split” which enables motorcycles to pass between cars in adjacent lanes. While there are potential safety benefits to a motorcycle by lane splitting, the practice does make it harder for a driver to detect an approaching motorcycle.

FIGURE 7: MOTORCYCLE LANE SPLITTING SIGN.[2]

When comparing the baseline pass-by tests with the target vehicle versus the target motorcycle, the motorcycle was detected on average *26% later* than the target full-size sedan. As a result, the average separation distance of the vehicle test vs. the motorcycle also resulted in a *reduced distance of 14%* on average.

The BSM system activation speed was found through test and evaluation. The minimum activation speed is the lowest speed at which the BSM system will detect a vehicle in the blind spot of the test vehicle. The lateral (side-

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[2] Image source: http://lanesplittingislegal.com

to-side) and longitudinal (front-to-back) activation distance is the separation distance of the two test vehicles when the BSM warning light was activated.

Blind Spot Monitoring Detection Parameters		Vehicle #1	Vehicle #2	Vehicle #3
Minimum Activation Speeds	**Mph**	20.5	0.0	18.1
Lateral Activation Distance	**Ft.**	10.8	7.7	10.0
Longitudinal Activation Distance	**Ft.**	23.2	83.4	17.2
BSM Effective Area	**Ft²**	250.1	642.5	171.9

FIGURE 8: BLIND-SPOT MONITORING SYSTEM ACTIVATION CONDITIONS AND MAXIMUM DETECTION DISTANCES.

TEST VEHICLES

A matrix of measurement technologies for the BSM 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 Blind Spot Monitoring, but rather to compare and contrast vehicles with different measurement systems and alert types.

Blind Spot / Lane Departure Vehicle Selection			
Safety System	**Test Vehicles**		
	Acura RLX	Cadillac Escalade	Mercedes CLS
Blind Spot Warning	Visual- Pillar	Visual-Mirror	Visual-Mirror
Blind Spot Intervention	NA	NA	Wheel-Braking

FIGURE 9: BSM ALERT LOCATION AND INTERVENTION TECHNOLOGY

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

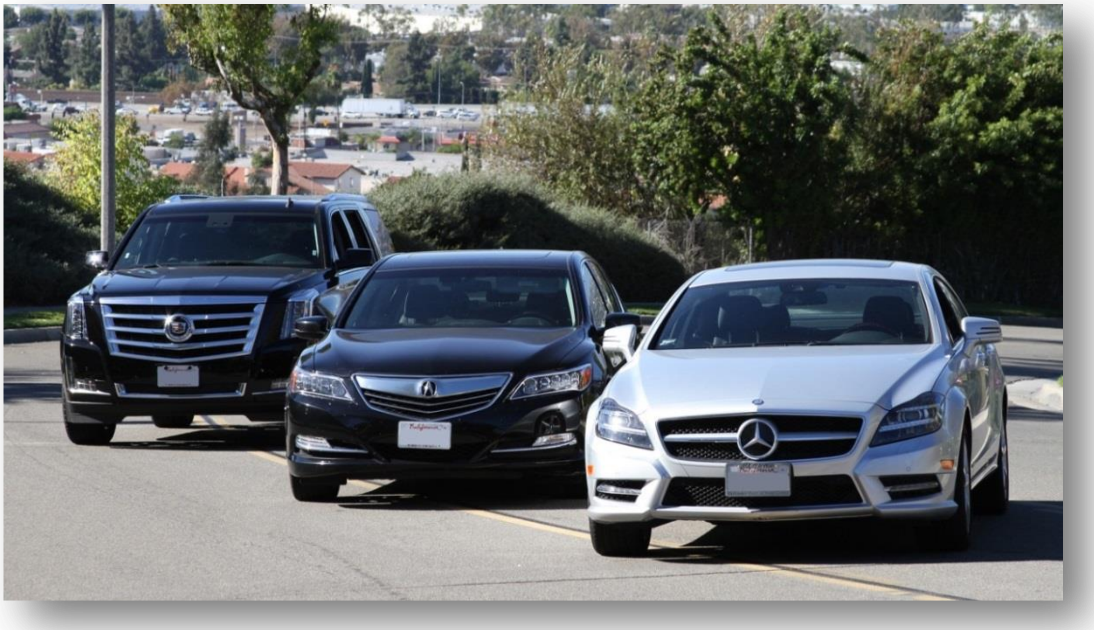

FIGURE 10: BLIND SPOT MONITORING TEST VEHICLES.

A dedicated *"target"* car (the vehicle approaching the blind spot) was used for all of the blind spot monitoring evaluations, with the exception of the motorcycle. A 2014 Cadillac ATS was selected as a target car because the frontal area of the car represented an average mid-size sedan.

FIGURE 11: THE TARGET CAR (CADILLAC ATS) WITH TEST CAR MERCEDES CLS.

A Ducati Hypermotard was selected as the *"target"* vehicle for the motorcycle portion of the blind spot evaluations. This is a fast accelerating motorcycle that features a small frontal area that potentially makes it harder for the blind spot monitoring system radar to detect.

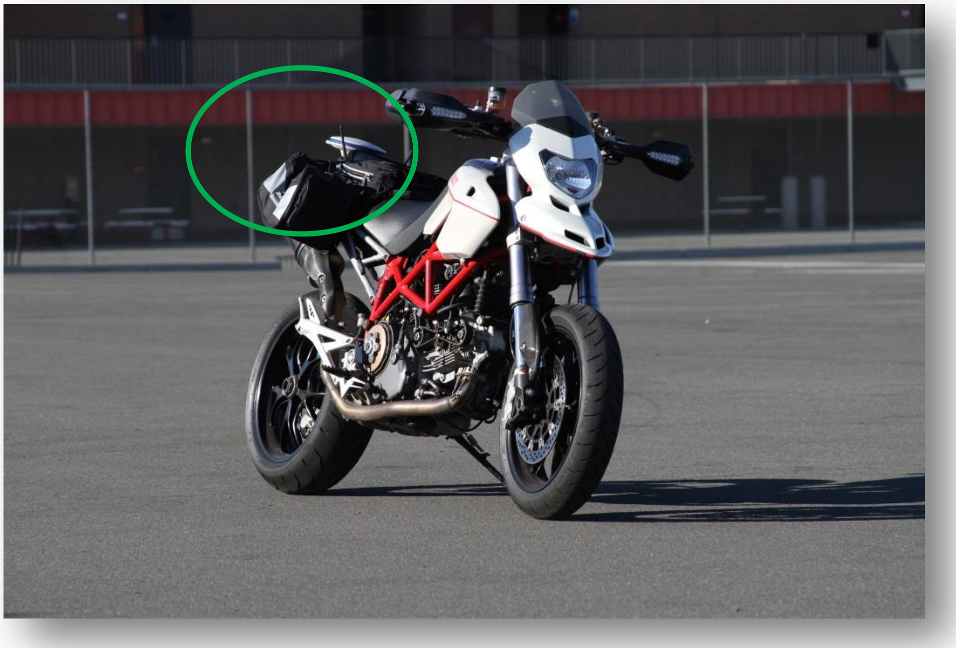

FIGURE 12: BSM TARGET MOTORCYCLE SHOWN WITH RACELOGIC VEHICLE SEPARATION GPS SYSTEM.

TEST EQUIPMENT

The test vehicles were instrumented with a Racelogic vehicle separation system that consisted of two Vbox 3i data loggers configured as a moving base station with a position accuracy of ± 20cm. The test data is transferred from the secondary vehicle real-time via telemetry system.

FIGURE 13: RACELOGIC ADAS TEST SYSTEM

The Racelogic system allows measurements of separation distance *lateral* (side-to-side measurement between vehicles) and *longitudinal* (front-to-back), separation angle, vehicle speed and heading of both test vehicles.

http://www.velocitybox.co.uk/index.php/en/adas-validation

The vehicle separation data was recorded on a Racelogic Video Vbox system to enable time-synch videos of the test with data overlay. Each test pass was recorded using this system so the results could be reviewed after the test.

A technical support engineer from Racelogic U.S.A was onsite during testing to assist with vehicle instrumentation and data collection. The raw test files were post processed by Racelogic and provided to AAA at the completion of testing.

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 14: HIGH DEFINITION PICTURE-IN-PICTURE VIDEO OF BSM TEST.

OBSERVATIONS

- Feedback from the test personnel regarding both blind-spot monitoring systems
  - In most cases, the testing group had to review the vehicle owner's manual to understand how to activate or de-activate the blind spot monitoring system.

VEHICLES CURRENTLY EQUIPPED WITH BLIND-SPOT MONITORING SYSTEMS:

- AAA's review of manufacturer vehicle data – from the Insurance Institute for Highway Safety (IIHS) website[3] – determined that blind-spot monitoring systems were the most widely offered crash-avoidance technology for the 2014 model year.
- Of the 415 vehicles listed, 288 (69%) offer blind-spot warning technology as optional equipment, while only 20 (5%) offer it as standard equipment.

HOW AUTOMAKERS ARE ENHANCING THEIR DESIGNS:

Automakers are continuously working to improve the design of advanced driver assistance systems and reduce instances of false detection or missed alerts.

- To create a seamless integration of advanced safety features, General Motors has deployed *sensor fusion*, which enables integration of a broad range of sensing and positioning technologies that can alert drivers to road hazards and help them avoid crashes. The outcome is a group of sensors and equipment that function as one advanced sensor system that doesn't rely on only one sensor for critical measurements. GM considers sensor fusion a building block in the development of semi-autonomous and fully autonomous vehicles.

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[3] http://www.iihs.org/iihs/ratings/crash-avoidance-features

- GM engineers also used driving on the Brooklyn Bridge to refine radar sensors to be able to tell the difference between stationary objects – like guard rails and bridge structure – and vehicle traffic. Nearly 2,000 scenarios were identified by GM to test the sensors and radar, including variables such as weather, traffic volume, lighting and radar reflections, all of which can impact radar systems or other sensors in the car.
- 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.
- 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.

CONCLUSION

AAA'S MESSAGE:

- The blind spot monitoring system worked well, but there were instances where an alert driver needed to take corrective action. These systems are not a substitute for an engaged driver.
- The blind spot monitoring system performance can vary greatly; motorists should consult the vehicle's owner's manual to determine how the systems work before driving the vehicle.

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