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Rear Automatic Braking Feature Confirmation Test – Draft Test Procedure Assessment

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16. Abstract
This report describes the assessment of a draft test procedure for confirming the presence of a rear automatic braking feature, defined as installed vehicle equipment that has the ability to sense the presence of objects behind a reversing vehicle, alert the driver of the presence of the objects via auditory and visual alerts, and automatically engage the available braking systems to stop the vehicle. The test procedure assesses the performance of such a feature in detecting a child mannequin test object behind a backing vehicle. The child mannequin is placed 20 feet rearward of the stationary test vehicle at one of three lateral locations on a grid (along the vehicle centerline and 2 feet left and right of center). The vehicle's transmission is shifted into reverse gear and the brake pedal is released allowing the vehicle to roll rearward without accelerator pedal application. The system must detect the test object and automatically apply the vehicle's brakes to bring the vehicle safely to a stop without contacting the test object. Contact between the vehicle and test object must be avoided for all three test object locations to pass the test.

To assess the test procedure, three vehicles with rear automatic braking features were tested. None of the three vehicle systems tested in this effort were able to consistently detect and avoid striking the test object in each of the three locations over multiple repetitions of the procedure. Each system had at least one collision with the test object at the grid location that was 2 feet left (i.e., driver's side) of the vehicle's centerline over the multiple trial repetitions.

Overall, the test procedure was found to be repeatable, reproducible, and effective in evaluating the ability of a rear automatic braking feature to alert the driver to the presence of a rear obstacle and automatically engage the brake system attempting to avoid striking the object. Some test outcome variability was observed and may be related to factors such as environmental conditions impacting sensor performance, vehicle backing speed variability, or inconsistent rear automatic braking feature performance. Analysis of video data from testing showed that average backing speeds for the tested vehicles differed only slightly (SD <=0.13) under the conditions of this test procedure for the three vehicles tested. Regardless of the source of any outcome differences, conducting multiple repetitions of the three-trial test procedure could be considered as a means to improve the confidence level associated with test results and ensure consistent system performance. For example, three repetitions of the test procedure in which the rear automatic braking feature is required to detect and avoid the test object in each of the three locations could be performed.

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EXECUTIVE SUMMARY

This report describes the assessment of a draft test procedure for confirming the presence of a rear automatic braking feature. A “rear automatic braking feature” is defined as installed vehicle equipment that has the ability to sense the presence of objects behind a reversing vehicle, alert the driver of the presence of the objects via auditory and visual alerts, and automatically engage the available braking system to stop the vehicle. The test procedure assesses the performance of such a feature in detecting a child mannequin test object behind a backing vehicle. The child mannequin is placed 20 feet rearward of the stationary test vehicle at one of three lateral locations on a grid (along the vehicle centerline and 2 feet left and right of center). The test driver initiates a test trial by depressing the vehicle’s brake pedal, shifting the vehicle’s automatic transmission from park to reverse gear, and then quickly fully releasing the brake pedal to allow the vehicle to roll rearward. As stated in the test procedure, the accelerator pedal was not applied during trials. The vehicle was allowed to roll rearward without accelerator pedal application until either the rear automatic braking feature intervened by automatically engaging the vehicle’s brakes to bring the vehicle to a stop or until the vehicle struck the test object. Once either of these two outcomes occurred (automatic braking stopped the vehicle or the test object was struck), the driver depressed the vehicle’s brake pedal to ensure the vehicle came safely to a stop and the test trial ended. This procedure was repeated for each of three test object positions. Contact between the vehicle and test object must be avoided for all three test object locations to pass the test.

To assess the test procedure, three vehicles with rear automatic braking features were tested. None of the three vehicle systems tested in this effort were able to consistently detect and avoid striking the test object in each of the three locations over multiple repetitions of the procedure. Each system had at least one collision with the test object at the grid location that was 2 feet left (i.e., driver’s side) of the vehicle’s centerline over the multiple trial repetitions.

Overall, the test procedure was found to be repeatable, reproducible, and effective in evaluating the ability of a rear automatic braking feature to alert the driver to the presence of a rear obstacle and automatically engage the brake system attempting to avoid striking the object. Some test outcome variability was observed and may be related to factors such as environmental conditions impacting sensor performance, vehicle backing speed variability, or inconsistent rear automatic braking feature performance. Analysis of video data from testing showed that average backing speeds for the tested vehicles differed only slightly (SD <=0.13) under the conditions of this test procedure for the three vehicles tested. Regardless of the source of any outcome differences, conducting multiple repetitions of the three-trial test procedure could be considered as a means to improve the confidence level associated with test results and ensure consistent system performance. For example, three repetitions of the test procedure in which the rear automatic braking feature is required to detect and avoid the test object in each of the three locations could be performed.

1. INTRODUCTION

Backover crashes involve a person being struck by a vehicle moving in reverse. The victims of backing crashes are frequently young children and elderly persons. Due to their short stature, children can be difficult for drivers to detect in vehicle rear blind zones (the area behind a vehicle that a driver cannot see due to structural design aspects of the vehicle, such as vehicle height and length, pillar width, and rear window dimensions). Poor rear visibility contributes to the likelihood of unseen obstacles, which includes pedestrians.

NHTSA has been evaluating rear object detection system performance in detecting pedestrians and other objects since the early 1990s. The evaluations have been iterative, as new original equipment and aftermarket technologies have become available. Testing of sensor-based systems to date has found their performance in detecting small children to be poor and inconsistent [1, 2]. For this reason, the December 2010 FMVSS No. 111 Notice of Proposed Rulemaking (NPRM) [3] proposed a visual-image based countermeasure for improving rear visibility rather than a sensor-based warning system. A final rule issued on April 7, 2014 [4], required that all vehicles under 10,000 pounds, including buses and trucks, manufactured on or after May 1, 2018, must display to a driver a rearview image showing the 10-foot wide by 20-foot long zone directly behind the vehicle. The system must also meet other requirements including image size, linger time, response time, durability, and deactivation.

In model year 2013, two manufacturers released vehicles equipped with sensor-based rear automatic braking systems. These systems were not marketed as pedestrian detection systems; however, they may have some ability to detect pedestrians. They use multiple sensor technologies working together to detect rear obstacles, alert the driver, and automatically initiate braking. Both vehicles were also equipped with rearview video systems.

A September 2012 GM press release [5] titled, "Cadillac 'Virtual Bumpers' Can Help Avoid Crashes," stated that "Automatic Front and Rear Braking is part of the new optional Driver Assist Package on the 2013 ATS sport sedan, XTS luxury sedan and SRX crossover." The system uses "Radars, vision, and ultrasonic sensors …working together to determine if a crash may be imminent." Based on calculations, "the vehicle can automatically brake to avoid a crash or reduce impact speed, and if necessary, can apply the vehicle's maximum braking capability." If the driver fails to respond to the provided alerts and "a potential collision is imminent, the automatic braking is designed to apply the brakes and stop the vehicle. If the system brings the car to a stop, the electronic parking brake will hold the car in place until the driver presses the accelerator pedal."

The Infiniti Backup Collision Intervention (BCI) system debuted on the 2013 Infiniti JX. An Infiniti USA press kit overview for the vehicle [6] said, "when the transmission is in reverse, the JX will help the driver detect crossing vehicles and objects behind the JX, and, if necessary, the system can automatically engage the brakes to help avoid a collision." The owner's manual [7] for the 2013 Infiniti JX describes the system as follows:

> "If the radar detects a vehicle approaching from the side or the sonar detects close objects in the rear, the system gives visual and audible warnings, and applies the brake for a moment when the vehicle is moving backwards. After the automatic brake application, the driver must depress the brake pedal to maintain brake pressure. If the driver's foot is on the accelerator pedal, the system pushes the accelerator upward before applying the brake."

This system differed from the Cadillac system in that the driver must apply pressure to the brake pedal to bring the vehicle to a stop.

With the release of this type of system as a commercial product in 2013, NHTSA sought to reevaluate available systems to assess whether technology improved since NHTSA's last examination of the performance of sensor-based systems.

This report documents an effort to evaluate a draft "Rear Automatic Braking Feature Confirmation Test Procedure" by testing three different original equipment vehicle systems. A copy of the draft test procedure is Appendix 8.1 of this report. The goal was to assess whether the test procedure is effective in evaluating the ability of a rear automatic braking feature to alert the driver to the presence of a rear obstacle and automatically engage the brake system in an attempt to avoid striking the object. Effectiveness of a rear automatic braking feature in this context was defined in terms of ability to detect the presence of a test object simulating a 6-year-old child and automatically applying the vehicle's brakes and stopping the vehicle before striking the test object.

2. METHOD

This section describes the equipment used and methods used in this effort to assess the draft test procedure.

2.1. Test Location

Testing was conducted primarily indoors in an open area with dimensions of approximately 20 feet by 60 feet. The test surface was a smooth and nearly level concrete floor. The test surface was marked with a dimensioned floor grid.

A portion of testing was conducted outdoors to permit comparison of indoor versus outdoor test outcomes. The outdoor testing was conducted on a large, open paved area having a generally level surface with the appropriate dimensioned lines and markings on the surface for testing.

Prior to running test trials at each location, preliminary testing without any test object was conducted to ensure that nothing in the test environment would trigger a response from the vehicle's rear object detection systems or reflect sensor signals.

2.2. Lasers for Vehicle Path Guidance

Two pen lasers were mounted on the vehicle to help with vehicle alignment prior to beginning each dynamic test trial, as well as to aid the driver in guiding the vehicle rearward in a straight line during the trial. One laser was mounted on the vehicle's hood along its longitudinal centerline and was pointed at a vertical post forward of the vehicle and at the test grid's centerline. A second laser was mounted below the test vehicle's rear bumper and pointed downward to highlight the vehicle's lateral position with respect to the grid's centerline. To ensure a consistent, straight backing path across tests, trials were repeated if the laser on the rear bumper showed the vehicle's lateral position straying by more than 1 inch from the grid centerline at any time during the 20-foot backing path.

2.3. Video Cameras

The draft test procedure specifies that both still photos of the test vehicle and video data of test trials be obtained. A digital camera was used to capture photographs of each test vehicle prior to testing. All dynamic test trials were recorded in digital video format to document the dynamic test scenario. Sound was also recorded.

The draft test procedure specifies that three cameras shall be used to videograph the dynamic test scenario: one overhead view, one full-frame view of the vehicle's rearview image, and an image of any visual alerts presented separately from the rearview image. These video data documented the test object's position with respect to the vehicle as well as the system's response to the object's presence (if any). One video camera was mounted up above the test object to capture an overhead view of the vehicle approaching the test object. Two cameras and a microphone were located inside the vehicle to capture any visual and/or auditory warnings produced by the systems.

One additional camera was used in this test effort but not specified in the test procedure. The camera was mounted on the vehicle's trunk lid and pointed downward to capture a view of the floor grid as well as the rear-mounted laser beam used to guide the vehicle along a straight rearward path.

Also used in this effort but not noted in the test procedure was an auxiliary video display positioned in the front passenger seat to provide the driver with a view of the trunk-mounted downward-pointed camera view and laser beam. The driver used this view to help maintain a straight rearward path during test trials.

Example camera views and photos of some of the equipment can be found in Appendix 8.2. Still photos of the test vehicles can be found in Appendix 8.3.

2.4. Test Object

The test object used in this program was the 4active Systems EuroNCAP pedestrian child posable mannequin, a 46.5-inch tall radar-representative child surrogate simulating a 6-year-old child. The child mannequin test object is shown in Figure 1.

Figure 1. Child Mannequin Test Object, Side View and Front View

2.5. Vehicle Preparation

Each test vehicle must be a purchased or leased new vehicle. Each test vehicle's tires were set to the pressure value(s) recommended by the vehicle manufacturer, and the fuel tank was filled so as to achieve a standard vehicle pitch. All other vehicle fluids were ensured to be properly filled. The vehicle's battery level was confirmed to be within normal operating range. During testing, all vehicle doors, hatches, hood, and trunk lid (as appropriate) were closed. System sensors were wiped to ensure they were free of dirt or other substance that might impact sensor performance.

Also as per the draft test procedure, up to five 45 kg weights were placed on the seat pans of the available seating positions and five 23 kg weights were place on the floorboards of the corresponding seating positions. The test required a driver seated in the driver's seat to operate the vehicle.

2.6. Test Procedure

Tests were performed as appropriate, given the particular operating conditions of each system being tested, with the test vehicle moving to assess system performance in detection of a stationary test object, and system detection performance repeatability.

This section describes the test procedure used for assessing system performance in this effort. The dynamic test scenario specified in the draft test procedure was conducted for each vehicle three times indoors and a fourth time outdoors. The purpose of the outdoor test set was to permit assessment of whether any environmentally based performance differences might be observable.

The systems were tested to measure their performance in detecting the test object in a scenario in which the vehicle was moving and the test object was stationary. The test surface was marked with a dimensioned floor grid of 1-foot squares. Prior to each test trial, the test object was placed at one of three grid locations in the travel path of the backing test vehicle. The three grid locations correlated to the number of feet laterally from the centerline of the vehicle's intended backing path, labeled as grid locations -2 ft, 0 ft, and 2 ft from left to right. The test object was oriented in an upright (vertical) position, facing perpendicular to the vehicle's centerline for all three grid locations and in an appropriate direction as if the object was crossing behind the vehicle from right to left (as shown in Figure 2, with the object positioned at grid location 0).

Figure 2. Child Mannequin Test Object at Grid Location 0 Behind Backing Test Vehicle

The test vehicle was initially positioned 20 feet away from the test object located at the 0-foot line of the floor grid. The test vehicle was moved in reverse the test object located at one of three locations on a grid on the floor, as depicted in Figure 3.

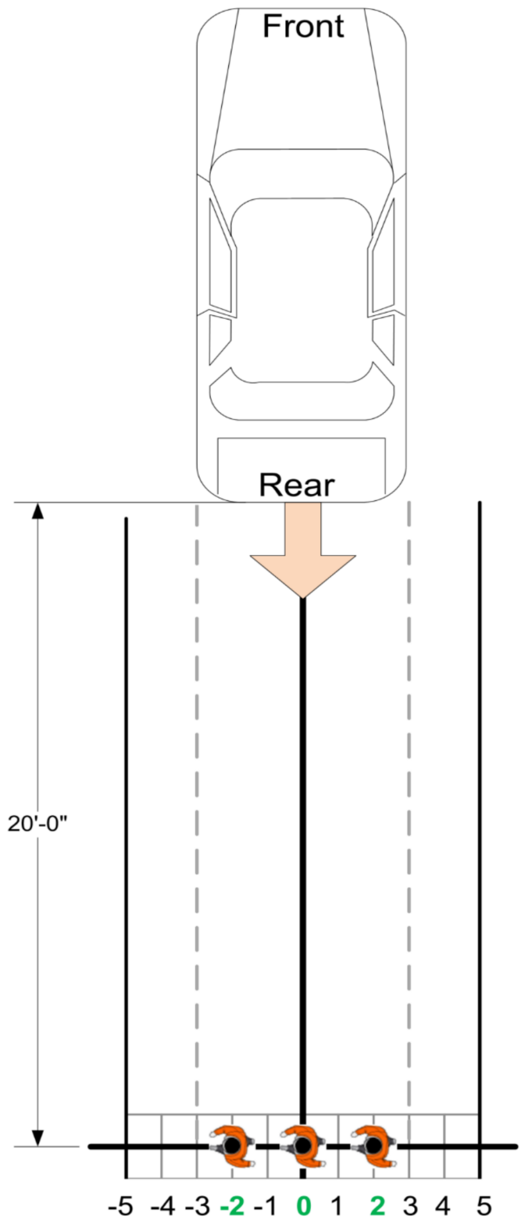

Figure 3. Test Procedure Layout, Object Grid Locations and Vehicle Start Position

For this effort the test vehicle was running for some period of time before each trial. Prior to each test trial, the vehicle was accurately positioned along the grid centerline using the alignment lasers to guide the positioning. The test driver initiated the trial by starting the video data recording, depressing the brake pedal, shifting the vehicle's automatic transmission from park to reverse gear, and then fully releasing pressure on the brake pedal to allow the vehicle to roll rearward. As stated in the test procedure, the accelerator pedal was not applied during trials. The vehicle was allowed to roll rearward without accelerator application until either the rear automatic braking feature intervened by automatically engaging the vehicle's brakes to bring the vehicle to a stop or until the vehicle struck the test object. Once either of these two outcomes occurred (automatic braking stopped the vehicle or the test object was struck), the driver would depress the vehicle's brake pedal to ensure the vehicle came to a stop and the test trial ended.

The test driver's only potential impact on test trial conduct was through their method of removing his or her foot from the brake pedal. The test drivers were instructed to release the pedal quickly, since this is much easier to relate and implement than any slower type of release that could be subject to individual differences.

This procedure was repeated for each of three test object positions. Only one set of three test trials was run per vehicle per day.

For each location at which the test object was placed, a data point was manually recorded to reflect whether the system did or did not detect the presence of the object, whether or not the vehicle stopped automatically, and whether or not the vehicle contacted the test object. A positive test outcome would involve the vehicle coming to a stop before it reaches the location of the test object and with no physical contact with the test object for each of the three test object locations assessed. Thus, a positive test outcome was when the system prevented the test vehicle from crashing into the test object.

3. VEHICLES/SYSTEMS

Three vehicles, each with a different system for backing support, were tested using the rear automatic braking feature confirmation test procedure. Descriptions of those vehicle systems are provided below using excerpts from each vehicle's owner manual. Additional owner manual excerpts pertaining to the backing support systems can be found in Appendix 8.4. The three vehicles tested are as follows:

- 2014 Cadillac ATS
- 2014 Infiniti Q50
- 2015 Chrysler 200C

Images of each vehicle are shown in Appendix 8.3.

3.1. "Rear Automatic Braking" on a 2014 Cadillac ATS

With regard to the "Rear Vision Camera" feature, the owner manual [8] states the following points (excerpted):

> "When the vehicle is shifted into R (Reverse), the RVC displays an image of the area behind the vehicle in the center stack display. When the vehicle is shifted out of R (Reverse), the screen returns to the previous content, after a short delay."
>
> "The RVC system does not display children, pedestrians, bicyclists, animals, or any other object located outside the camera's field of view, below the bumper, or under the vehicle. Perceived distances may be different from actual distances. Do not back the vehicle using only the RVC screen, during longer, higher speed backing maneuvers, or where there could be cross traffic. Failure to use proper care before backing may result in injury, death, or vehicle damage. Always check behind and around the vehicle before backing."
>
> "With URPA [Ultrasonic Rear Park Assist], as the vehicle backs up at speeds of less than 8 km/h (5 mph), the sensors on the rear bumper detect objects up to 2.5 m (8ft) behind the vehicle that are within a zone 25 cm (10 in) high off the ground and below bumper level."
>
> "The Backing Warning System will beep once from the rear when a potential object threat is first detected, or pulse twice on both sides of the Safety Alert Seat. When the system detects a potential imminent crash, beeps will be heard from the rear, or five pulses will be felt on both sides of the Safety Alert Seat. There may also be a brief sharp application of the brakes."
>
> "Vehicles with Adaptive cruise Control (ACC) have the Backing Warning System, which is designed to help avoid backing crashes. The system can warn of rear objects when backing up at speeds greater than 8 km/h (5 mph). The Backing Warning System will beep once from the rear when a potential object threat is first detected, or pulse twice on both sides of the Safety Alert Seat. When the system detects a potential imminent crash, beeps will be heard from the rear, or five pulses will be felt on both sides of the Safety Alert Seat. There may also be a brief sharp application of the brakes."
>
> "Pressing the brake pedal after the vehicle comes to a stop will release the Rear Automatic Braking. If the brake pedal is not pressed within two seconds after the stop, the electric parking brake is set.
>
> Release the electric parking brake. When it is safe, pressing the accelerator pedal firmly at any time will override the Rear Automatic Braking."

3.2. “Back-Up Collision Intervention” on a 2014 Infiniti Q50

With regard to the “Back-Up Collision Intervention System” feature, the owner manual [9] states:

> “The Back-up Collision Intervention (BCI) system can help alert the driver of approaching vehicles or rear objects when the driver is backing out of a parking space.”
>
> “When the shift lever is in the R (Reverse) position and the vehicle speed is less than approximately 5 MPH (8 km/h), the BCI system operates.”
>
> “The BCI system uses radar sensors (1) installed on both sides near the rear bumper to detect an approaching vehicle and sonar sensors (2) to detect objects in the rear.”
>
> “The radar sensors (1) detect the approaching vehicle from up to approximately 49 ft (15 m) away. The sonar sensors (2) detect a rear obstacle at up to approximately 4.9 ft (1.5 m) from the bumper.”
>
> “If the radar detects a vehicle approaching from the side or the sonar detects close objects in the rear, the system gives visual and audible warnings, and then applies the brake for a moment when the vehicle is moving backwards. After the automatic brake application, the driver must depress the brake pedal to maintain brake pressure. If the driver's foot is on the accelerator pedal, the system pushes the accelerator upward before applying the brake. If you continue to press the accelerator, the system will not engage the brake.”
>
> “**BCI System Operation**
>
> When the shift lever is placed in the R (Reverse) position, the indicator on the BCI system key (1) illuminates on the upper display. The BCI system operates by detecting the vehicles and/or objects using either the radar or sonar sensors.”
>
> “A close object behind the vehicle:
>
> If the sonar detects a close object behind the vehicle when your vehicle is backing up, the system chimes a sound (three times) and red rectangular frame 0 appears on the upper display. The system applies the brake for a moment. After the automatic brake application, the driver must depress the brake pedal to maintain brake pressure. If the driver's foot is on the accelerator pedal, the system pushes the accelerator pedal upward before applying the brake. If you continue to press the accelerator pedal, the system will not engage the brake.”

3.3. “Rear Cross Path & ParkSense Rear Park Assist” on a 2015 Chrysler 200C

With regard to the “Rear Cross Path” feature, the owner’s manual [10] states:

> “The Rear Cross Path (RCP) feature is intended to aid the drivers when backing out of parking spaces where their vision of oncoming vehicles may be blocked. Proceed slowly and cautiously out of the parking space until the rear end of the vehicle is exposed. The RCP system will then have a clear view of the cross traffic and if an oncoming vehicle is detected, alert the driver.”
>
> “RCP monitors the rear detection zones on both sides of the vehicle, for objects that are moving toward the side of the vehicle with a minimum speed of approximately 3 mph (5 km/h), to objects moving a maximum of approximately 20 mph (32 km/h), such as in parking lot situations.”
>
> “When RCP is on and the vehicle is in REVERSE, the driver is alerted using both the visual and audible alarms, including reducing the radio volume.”

With regard to the “ParkSense Rear Park Assist system” feature, the owner manual [10] states:

> “The ParkSense Rear Park Assist system provides visual and audible indications of the distance between the rear fascia and a detected obstacle when backing up, e.g., during a parking maneuver.”
>
> “If your vehicle is equipped with an Automatic Transmission, the vehicle brakes may be automatically applied and released when performing a reverse parking maneuver if the system detects a possible collision with an obstacle.”
>
> “ParkSense can be active only when the shift lever/gear selector is in REVERSE. If ParkSense is enabled at this shift lever/gear selector position, the system will remain active until the vehicle speed is increased to approximately 7 mph (11 km/h) or above. When in REVERSE and above the system’s operating speed, a warning will appear within the Electronic Vehicle Information Center (EVIC) or Driver Information Display (DID) indicating the vehicle speed is too fast. The system will become active again if the vehicle speed is decreased to speeds less than approximately 6 mph (9 km/h).”
>
> “The four ParkSense sensors, located in the rear fascia/bumper, monitor the area behind the vehicle that is within the sensors’ field of view. The sensors can detect obstacles from approximately 12 in (30 cm) up to 79 in (200 cm) from the rear fascia/bumper in the horizontal direction, depending on the location, type and orientation of the obstacle.”
>
> “The ParkSense Warning screen is located within the EVIC/DID. It provides visual warnings to indicate the distance between the rear fascia/bumper and the detected obstacle.”
>
> **“**When the vehicle is in REVERSE, the EVIC/DID will display the park assist ready system status. The system will indicate a detected obstacle by showing a single arc in one or more regions based on the obstacle’s distance and location relative to the vehicle. If an obstacle is detected in the center rear region, the display will show a single solid arc in the center rear region and will produce a one-half second tone. As the vehicle moves closer to the obstacle, the display will show the single arc moving closer to the vehicle and the sound tone will change from slow, to fast, to continuous. If an obstacle is detected in the left and/or right rear region, the display will show a single flashing arc in the left and/or right rear region and will produce a fast sound tone. As the vehicle moves closer to the obstacle, the display will show the single arc moving closer to the vehicle and the tone will change from fast to continuous. The vehicle is close to the obstacle when the warning display shows one flashing arc and sounds a continuous tone. The following chart shows the warning alert operation when the system is detecting an obstacle:

WARNING ALERTS							
Rear Distance (in/cm)	Greater than 79 in (200 cm)	79-59 in (200-150 cm)	59-47 in (150-120 cm)	47-39 in (120-100 cm)	39-25 in (100-65 cm)	25-12 in (65-30 cm)	Less than 12 in (30 cm)
Arcs — Left	None	None	None	None	None	2nd Flashing	1st Flashing
Arcs — Center	None	6th Solid	5th Solid	4th Solid	3rd Flashing	2nd Flashing	1st Flashing
Arcs — Right	None	None	None	None	None	2nd Flashing	1st Flashing
Audible Alert Chime	None	Single 1/2-Second Tone (for rear center only)	Slow (for rear center only)	Slow (for rear center only)	Fast (for rear center only)	Fast	Continuous
Radio Volume Reduced	No	Yes	Yes	Yes	Yes	Yes	Yes

NOTE: ParkSense will reduce the volume of the radio, if on, when the system is sounding an audio tone.

4. RESULTS

This section summarizes the results of testing three vehicles per the draft "Rear Automatic Braking Feature Confirmation Test Procedure."

Additional descriptive information about the systems' responses during each trial is provided. Such information includes whether an auditory or visual warning was presented to the driver. Since it is possible for the systems to automatically apply the brakes and yet fail to avoid a collision with a test object, braking response was noted separately from crash outcome for each trial.

4.1. Cadillac ATS

Four test set repetitions were performed with the 2014 Cadillac ATS in the controlled indoor test environment and a single trial set was conducted outdoors for comparison. The results of those tests are shown in Table 1.

Table 1. Test Results, Cadillac ATS

Test Environment:	**INDOORS**			**OUTDOORS**		
Lateral Position of Object on Grid (Feet)	**-2**	**0**	**2**	**-2**	**0**	**2**
N	4	4	4	1	1	1
% Object Detected	100%	100%	100%	100%	100%	100%
% Auditory Warning	100%	100%	100%	100%	100%	100%
% Visual Warning	75%	100%	100%	100%	100%	100%
% Automatic Braking	100%	100%	100%	100%	100%	100%
% Crashes Avoided	**25%**	**100%**	**100%**	**0%**	**100%**	**100%**

As shown in Table 1, the Cadillac system detected the object, provided at least one mode of warning, and applied the brakes automatically in 100 percent of trials conducted. For two test object locations, centerline and 2 feet toward the passenger side of the vehicle, the system detected and avoided a crash with the test object in all trials. In 1 of the 4 trials for the -2 test object location, no visual warning was provided. In 3 of 4 indoor trials and the one outdoor trial for the -2 test object location, the Cadillac's system failed to bring the vehicle to a complete stop before it contacted the test object. As crash outcome for a single set of trials covering the three test object locations is the only factor considered in this test, this system would have passed the test in 1 of the 5 test set repetitions.

4.2. Infiniti Q50

Four test set repetitions of the 2014 Infiniti Q50 were completed in the controlled indoor test environment and a single trial set was conducted outdoors for comparison. The results of those tests are shown in Table 2.

Table 2. Test Results, Infiniti Q50

Test Environment:	**INDOORS**			**OUTDOORS**		
Lateral Position of Object on Grid (Feet)	**-2**	**0**	**2**	**-2**	**0**	**2**
N	4	4	4	1	1	1
% Object Detected	100%	100%	100%	100%	100%	100%
% Auditory Warning	75%	100%	100%	100%	100%	100%
% Visual Warning	100%	100%	100%	100%	100%	100%
% Automatic Braking	100%	100%	100%	100%	100%	100%
% Crashes Avoided	**50%**	**100%**	**100%**	**100%**	**100%**	**100%**

As shown in Table 2, the Infiniti system detected the object, provided at least one mode of warning, and applied the brakes automatically in 100 percent of trials conducted. For two test object locations, centerline and 2 feet toward the passenger side of the vehicle, the Infiniti system detected and avoided a crash with the test object in all trials. In 1 of the 4 indoor trials for the -2 test object location, no auditory warning was provided. In 2 of the 4 indoor trials for the -2 test object location, the Infiniti's system failed to bring the vehicle to a complete stop before it contacted the test object. As crash outcome for a single set of trials covering the three test object positions is the only factor considered in this test, this system would have passed the test in 3 of the 5 test set repetitions.

4.3. Chrysler 200C

Only one indoor and one outdoor test set repetition was completed for the 2015 Chrysler 200C. This was due to project time constraints but also because in completing the first indoor and outdoor test sets, the system was observed to be unable to brake to a stop before contacting the test object. The results of tests conducted are shown in Table 3.

Table 3. Test Results, Chrysler 200C

Test Environment:	**INDOORS**			**OUTDOORS**		
Lateral Position of Object on Grid (Feet)	**-2**	**0**	**2**	**-2**	**0**	**2**
N	1	1	1	1	1	1
% Object Detected	100%	100%	100%	100%	100%	100%
% Auditory Warning	100%	100%	100%	100%	100%	100%
% Visual Warning	100%	100%	100%	100%	100%	100%
% Automatic Braking	100%	100%	0%	100%	100%	100%
% Crashes Avoided	**0%**	**0%**	**0%**	**0%**	**0%**	**0%**

As shown in Table 3, the Chrysler's system detected the object and provided both an auditory and visual warning in all trials conducted. The system also consistently applied the brakes automatically in all but one test trial (indoor trial, test object location 2 feet from centerline toward passenger side), but failed to avoid a crash in all cases.

5. DISCUSSION

The “Rear Automatic Braking Feature Confirmation Test Procedure” called for one set of three trials to be performed in order to determine whether a vehicle was able to successfully detect a test object and brake automatically to avoid crashing into the object. For the purpose of this research, to assess the repeatability and effectiveness of the test procedure, each vehicle was subjected to the test procedure three times.

5.1. Consistency of Test Outcomes

The results showed different outcomes across sets of trials, in which none of the systems consistently avoided crashing into the test object. As a result, in nearly all cases the tested vehicles would not have passed the test procedure for a rear automatic braking system feature. Both the Cadillac and Infiniti systems showed different results across the five sets of trials at the -2 test object location (2 feet from the vehicle centerline toward the driver’s side) in which some trials had a positive test outcome while other trials had a negative test outcome at that location.

Possible contributing factors to the outcome differences across repeated trials include variability in the speed with which the test driver removed his or her foot from the brake pedal, vehicle backing speed, and in rear automatic braking feature performance, as well as possible effects of environmental conditions. Environmental conditions, such as wind, can impact ultrasonic sensor performance and potentially could have impacted the results of testing conducted outdoors.

To determine whether the test vehicles’ backing speeds may have been variable enough to affect system performance and test outcomes, trials were run to measure each vehicle’s typical backing speed when rolling rearward on a level surface without accelerator pedal application. Trials were run that were identical to the specified test procedure except that no test object was present. Average backing speed across all speed trials was calculated for points representing 5, 10, and 20 feet of travel. Figure 4 presents average backing speed data. The data show that average backing speeds for the tested vehicles differed only slightly under the conditions of this test procedure. At 20 feet, the average backing speed was 2.14 mph (n=44, SD=0.13) for the Cadillac, 2.20 mph (n=68, SD=0.13) for the Infiniti, and 2.29 for the Chrysler 200C (n=23, SD=0.06). Given that the observed variability in backing speed for the vehicles involved in this testing was quite small, it is unlikely that backing speed differences would have been a contributing factor to any failing test outcome.

While the Chrysler had slightly less time (approximately 0.3 – 0.5 seconds less time) than did the other two vehicles to detect and avoid the test object based on its average backing speed, this small time difference was not likely to be the primary reason that the Chrysler was less successful in passing this test procedure.

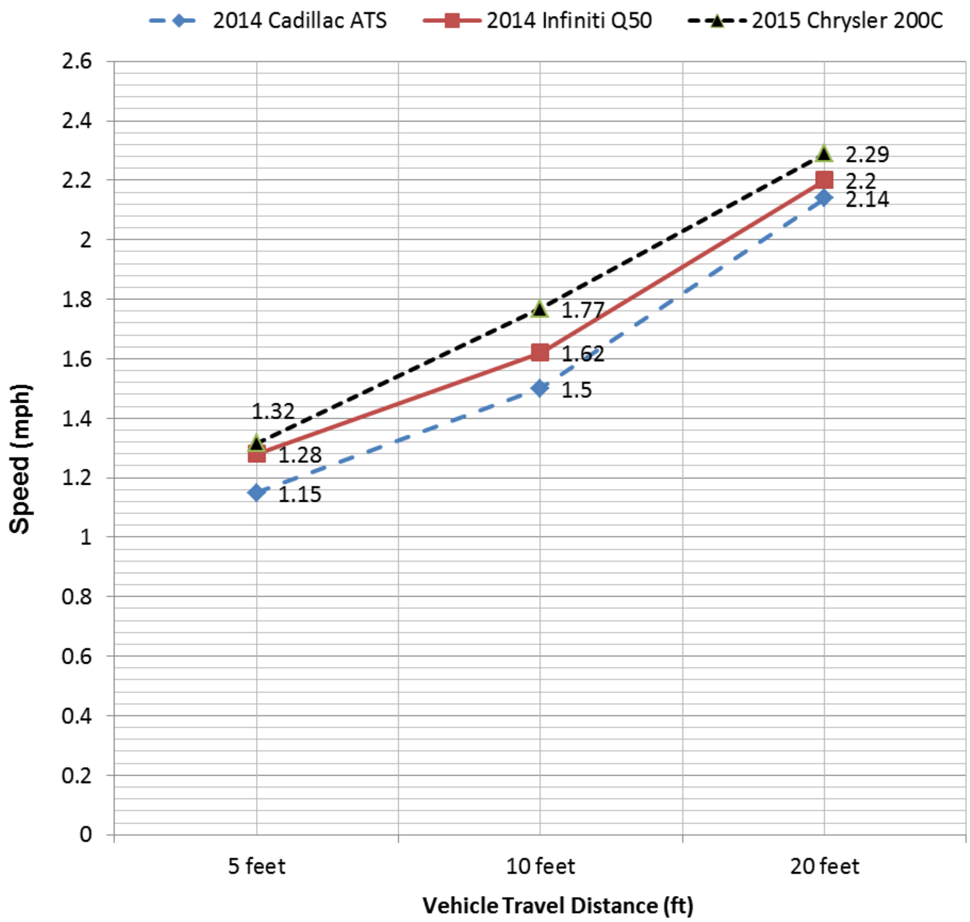

Figure 4. Average Backing Speed Over 20-Foot Distance for Vehicles Tested

Additional examination of aspects of the test vehicles' dynamics during trials is discussed in a related research report.

Regardless of the source of any outcome differences, conducting multiple repetitions of the three-trial test procedure could be considered as a means to improve the confidence level associated with test results and ensure consistent system performance. For example, three repetitions of the test procedure in which the rear automatic braking feature is required to detect and avoid the test object in each of the three locations could be performed.

5.2. Test Procedure Comments

In general, the test procedure presented no difficulties to execute. Thus, it should not be much of a burden to include additional sets of trials when testing a backing support system in this manner. In fact, one of the most difficult components of the test procedure was to properly align the test vehicle for the next trial, and subsequently back it in a straight line towards the test object along the grid centerline. Adding the front and rear lasers to the test vehicle for vehicle alignment and path guidance was very helpful for obtaining test efficiency and accuracy. Lasers or similar path guidance tools should be considered when performing such tests.

This test procedure is written for vehicles with automatic transmissions. Vehicles with a manual transmission would not roll backward on a level surface without some degree of accelerator pedal application. As a result, testing a vehicle with a manual transmission would require some accelerator pedal input by the driver to initiate the maneuver. This accelerator pedal input would be difficult to perform in a repeatable manner that would achieve a travel speed comparable to that which would be obtained in testing a vehicle with an automatic transmission. The fact that this test procedure cannot be performed with a manual transmission is not problematic, however. All contemporary U.S.-sold light passenger vehicle models have at least one trim level available with an automatic transmission. If a particular vehicle model is selected for testing, the automatic transmission version should be used. Alternatively, speed control equipment could be employed that would allow the vehicle to be accelerated to set speed or to simulate the speed of approach of a light vehicle.

6. SUMMARY

This report describes an effort to assess the adequacy of a draft “Rear Automatic Braking Feature Confirmation Test Procedure by examining three late-model test vehicles using that procedure.

The dynamic test procedure using a child mannequin test object was effective in demonstrating system performance and assessing systems’ ability to stop the vehicle before reaching the test object. Results of this test effort show that each vehicle had a rear automatic braking feature that could effectively detect the test object, provide visual and auditory alerts to the driver, and apply the brakes in response to object detection. However, none of the systems were 100 percent effective at meeting the test procedure’s performance criteria requiring the vehicle to stop before it reaches the location of the test object and with no physical contact with the test object for each of the three test object locations assessed. In particular, trials involving the test object location which was 2 feet left of the vehicle’s centerline (i.e., on the driver’s side) had crash outcomes for all three vehicle systems.

The test procedure was found to be effective for evaluating the ability of each vehicle’s rear automatic braking feature to alert the driver to the presence of a rear obstacle and automatically engage the brake system in an attempt to avoid striking the object. The test procedure appears to work well for confirming the existence and performance of a rear automatic braking system. Conducting multiple repetitions of the three-trial test procedure could be considered as a means to compensate for any test outcome variability related to factors such as variation in test conditions, vehicle path accuracy, vehicle backing speed, or rear automatic braking feature performance that may impact test outcome. For example, three repetitions of the test procedure in which the rear automatic braking feature is required to detect and avoid the test object in each of the three locations could be performed.

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APPENDIX A: Rear Automatic Braking Feature Confirmation Test (December 2015, draft) [6]

[Non-relevant sections omitted.]

1.0 PURPOSE AND APPLICATION

This laboratory test procedure provides specifications for conducting tests to confirm the existence of a Rear Automatic Braking Feature on a passenger vehicle with a gross vehicle weight rating (GVWR) of under 10,000 pounds. Current Rear Automatic Braking technology consists of a sensor-based system that detects obstacles behind a reversing vehicle, alerts the driver using auditory and visual signals, and engages the brake system in an attempt to avoid striking the obstacle.

2.0 DEFINITIONS

Rear Automatic Braking Feature means installed vehicle equipment that has the ability to sense the presence of objects behind a reversing vehicle, alert the driver of the presence of the object(s) via auditory and visual alerts, and automatically engage the service brake system to stop the vehicle.

3.0 GENERAL REQUIREMENTS

This test evaluates the ability of a vehicle's rear automatic braking feature to alert the driver of a reversing vehicle to the presence of a rear obstacle and automatically engage the brake system in an attempt to avoid striking the obstacle. The test consists of placing the vehicle's direction selector into reverse, releasing the brake pedal allowing the vehicle to coast rearward, and confirming that the appropriately located test objects are detected and the vehicle's brakes are automatically applied in time to avoid striking the test objects.

6.0 PRE-TEST AND FACILITY REQUIREMENTS

6.2 Facility Requirements

Test course or proving ground facilities shall have straight, level road sections of length at least 12 m (39 ft). Road surfaces shall be well-maintained, smooth and without bumps, creases, or potholes.

Testing should be performed in a wide-open area to ensure that the system is detecting the test object and not another object in the vicinity. If the area is not clear, then testing needs to be performed to ensure that nothing in the environment will trigger a response from the vehicle or reflect sensor signals.

9.0 INSTRUMENTATION AND CALIBRATION

9.1 Instrumentation

A. Portable tire pressure gauge with an operating pressure of at least 700kPa (100 psi), graduated increments of 1.0 kPa (0.1 psi) and an accuracy of at least ± 2.0% of the applied pressure.

B. Digital video cameras for recording the following:

(a) Overhead view via camera suspended above point of vehicle intersection with the test object

(b) Full-frame image of vehicle's rearview image

(c) Image (zoomed as needed) of any feature-related visual alerts not presented via the rearview image

C. A thermometer to measure and record the ambient temperature of the inside of the vehicle. A digital thermometer is recommended to photographically document the ambient temperature during the test.

9.2 Test Equipment

A. Up to five (5) 45 kg weights to be placed on the seat pans of the available seating positions and five (5) 23 kg weights to be place on the floorboards of the corresponding seating positions. These weights may be subdivided for ease of installation.

B. Test object(s).

(a) The 4active Systems EuroNCAP pedestrian child posable mannequin (46.5 inch height, simulating a 6-year-old child) developed by 4a Engineering GmbH, Traboch, Austria.

This is a posable mannequin developed for testing vehicles equipped with advanced pedestrian avoidance technologies. The mannequin is tuned for RADAR, IR, and optical features.

9.3 Calibration

Before the Contractor initiates the test program, a test instrumentation calibration system must be implemented and maintained in accordance with established calibration practices. Guidelines for setting up and maintaining such calibration systems are described in “International Organization for Standards (ISO) 100 12- 1, "Quality Assurance Requirements for Measuring Equipment," Part 1 : "Meteorological Confirmation System for Measuring Equipment;" American National Standards Institute (ANSI)/National Conference of Standards Laboratories (NCSL) 2540-1, "General Requirements for Calibration Laboratories and Measuring and Test Equipment;" or comparable alternative standards to MIL-C-45662A approved by the NHTSA COR. The calibration system shall be set up and maintained as follows:

A. Standards for calibrating the measuring and test equipment will be stored and used under appropriate environmental conditions to assure their accuracy and stability.

B. All measuring instruments and standards shall be calibrated by the Contractor, or a commercial facility, against a higher order standard at periodic intervals not exceeding twelve (12) months. Records, showing the calibration traceability to the National Institute of Standards and Technology (NIST), shall be maintained for all measuring and test equipment. The calibration frequency can be increased if deemed necessary by NHTSA.

C. All measuring and test equipment and measuring standards will be labeled with the following information:

1. Date of calibration

2. Date of next scheduled calibration

3. Name of the organization and the technician who calibrated the equipment

D. A written calibration procedure shall be provided by the Contractor which includes as a minimum the following information for all measurement and test equipment:

1. Type of equipment, manufacturer model number, etc.

2. Measurement range

3. Accuracy

4. Calibration interval

5. Type of standard used to calibrate the equipment (calibration traceability of the standard must be evident)

6. The actual procedures and forms used to perform the calibrations.

E. Records of calibration for all test instrumentation shall be kept by the Contractor in a manner that assures the maintenance of established calibration schedules. All such records shall be readily available for inspection when requested by the COR and shall be included in the final test report. The calibration system will need the acceptance of the COR before testing commences.

F. Test equipment shall receive a pre- and post-test zero and calibration check. This check shall be recorded by the test technician(s) and submitted with the final report.

NOTE: In the event of a failure to meet the standard's minimum performance requirements additional calibration checks of some critically sensitive test equipment and instrumentation may be required for verification of accuracy. The necessity for the calibration will be at the COR's discretion and will be performed without additional cost the OCAS.

10.0 TEST REQUIREMENTS

10.1 Ambient Conditions

A. Ambient Temperature

The temperature outside the vehicle shall be between 32° F (0° C) and 100° F (38° C).

B. Wind Speed

The maximum wind speed shall be no greater than 10 mph (16 km/h).

C. Inclement Weather

Tests should not be performed during periods of inclement weather. This includes, but is not limited to, rain, snow, hail, fog, smoke, and/or ash.

D. Visibility

Prior to the test, the test area ambient illumination condition measured at the center of the vehicle roof rearmost exterior surface shall be recorded. The ambient illumination conditions, in which testing can be conducted, as measured by the illuminance meter with the test vehicle lighting systems turned off, shall be no less than 16.0 lux.

11.0 TEST VEHICLE PREPARATION AND MEASUREMENT

11.1 Test Vehicle Preparation

A. The vehicle’s tires are set to the vehicle manufacturer’s recommended cold inflation pressure.

B. The fuel tank and all fluids are full.

C. The vehicle is loaded to simulate the weight of the driver and four passengers or the designated occupant capacity, if less. The weight of each occupant is represented by 45 kg resting on the seat pan and 23 kg resting on the vehicle floorboard placed in the driver's designated seating position and any other available designated seating position.

D. All vehicle doors should be closed.

E. If the vehicle is equipped with a rear hatch or a trunk lid, this vehicle component should be closed and latched in its normal vehicle operating condition.

F. Steering wheel adjustment. The steering wheel is adjusted to the position where the longitudinal centerlines of all vehicle tires are parallel to the longitudinal centerline of the vehicle.

G. The battery power must be within the nominal operating range for the type of vehicle being tested.

11.2 Test Vehicle Measurement

A. The temperature inside the vehicle at the beginning of the test is any temperature between 60° F (15° C) and 80° F (27° C).

B. Measure the vehicle's battery power level at the beginning of the test.

12.0 PHOTOGRAPHIC DOCUMENTATION

Each vehicle shall be documented in digital images (minimum size 4 x 6 inches), with minimum resolution of 300 dpi. The color images must be sufficiently clear to be reproducible in black and white using standard office equipment. Light glare and shadows must be minimized so that views of the test are visible for visual analysis.

12.1 Cameras Required

CAMERA 1: A still camera to document the vehicle.

VIDEO CAMERA(S): synchronized high-definition, digital video camera(s) to document the activity and performance of the rear automatic braking feature:

(a) Overhead view via camera suspended above point of vehicle intersection with the test object

(b) Full-frame image of vehicle's rearview image

(c) Image (zoomed as needed) of any feature-related visual alerts not presented via the rearview image

12.2 Vehicle Photographs

The following still photographs (8 x 10 inch or 8 ½ x 11 inch color prints properly focused for clear images) are required for the test:

Pretest photographs:

A. Using CAMERA 1, non-instrumented pictures of the test vehicles (front, rear, and four three-quarter pictures)

B. Using CAMERA 1, instrumented pictures of the test vehicles (driver side with the door open, and pictures of the instrumentation)

C. Using CAMERA 1, document the steering wheel position immediately prior to the start of the test.

Test photograph:

E. Using CAMERA 1, follow test procedure described in S12.0 and photograph the image of the visual display.

Test video:

F. Using CAMERA 2, follow test procedure described in S13.0 and videograph the dynamic test scenario.

13.0 TEST EXECUTION

13.1 Test Procedure

1. Position the vehicle on a flat, level surface marked with a line on the test roadway surface indicating the longitudinal centerline of the vehicle and extending at least 20 ft rearward.

2. Position the test object such that it is:

a) Longitudinally centered along a line perpendicular to the vehicle's centerline and 20 ft from the rearmost point on the vehicle's rear bumper.

b) 2 ft from the centerline toward the vehicle passenger's side

3. Place the direction selector in reverse while maintaining full pressure on the brake pedal.

4. Confirm the vehicle's position is 20 ft from the line on which the test object is positioned.

5. Initiate video data recording.

6. Release the vehicle's brake pedal and allow the vehicle to coast backward while maintaining the vehicle's centerline within +/- 1 inch of the longitudinal line marked on the ground.

7. Allow the vehicle to coast until the rear automatic braking feature intervenes by automatically engaging the service brakes bring the vehicle to a stop or until the vehicle strikes the test object. Once either of these two outcomes occurs, the vehicle's brake pedal should be depressed to end the test trial. Every effort must be made to safely conduct this test. If testing indoors, proper ventilation must be provided. No personnel shall be located to the rear of a test vehicle at any time during the test trial.

8. Stop video data recording.

9. Repeat Steps 1 through 8 with the test object positioned such that it is:

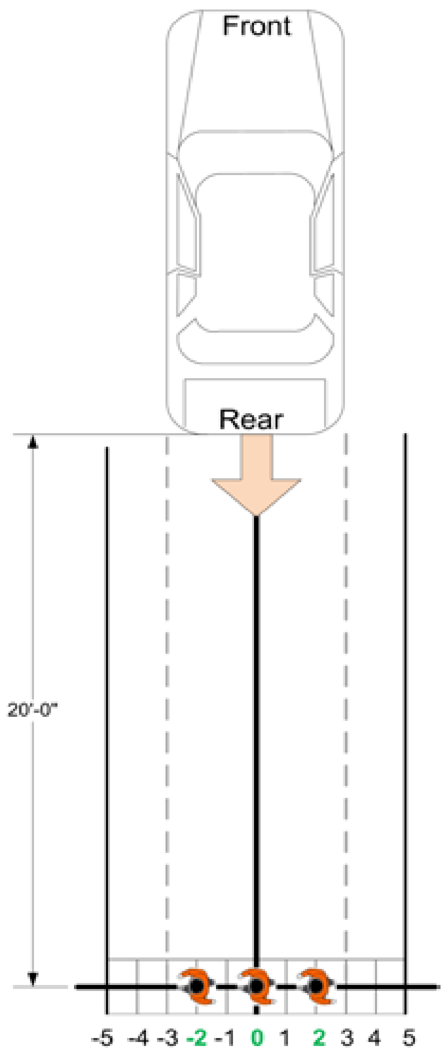
a) Longitudinally centered along a line perpendicular to the vehicle's centerline and 20 ft from the rearmost point on the vehicle's rear bumper.

b) Along a line extrapolated from the vehicle's centerline

10. Repeat Steps 1 through 8 with the test object positioned such that it is:

a) Longitudinally centered along a line perpendicular to the vehicle's centerline and 20 ft from the rearmost point on the vehicle's rear bumper.

b) 2 ft from the centerline toward the vehicle driver's side



A positive test outcome would involve the vehicle coming to a stop before it reaches the location of the test object and with no physical contact with the test object for each of the three test object locations assessed.

[Remaining non-relevant sections omitted.]

APPENDIX B: Instrumentation/Equipment

The following figure is an example image from the overhead camera. The image captures the vehicle approaching the object during the last several feet of travel. In the image, one can see whether the vehicle is properly aligned (green laser dot on floor), whether the brake lights activate, and whether or not a collision occurs (or where the vehicle stops before striking the object).

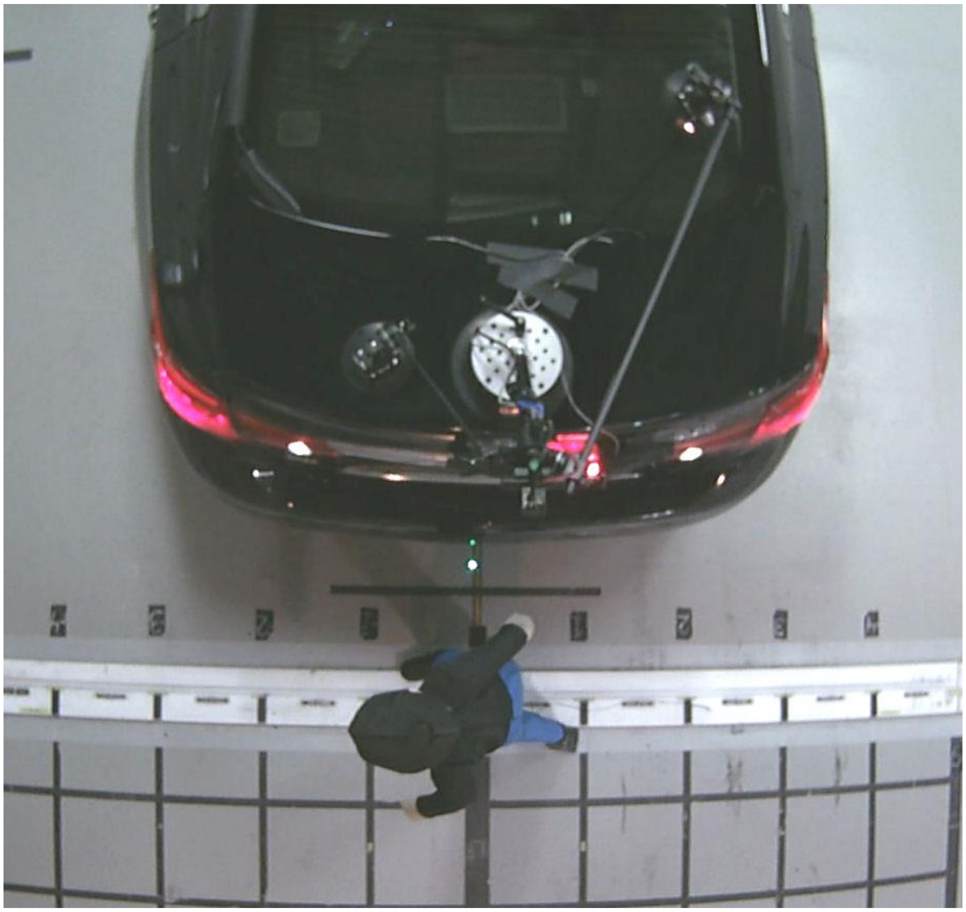


Figure 5. Overhead Camera View of Object and Test Vehicle

Figure 6. Image of Camera, Capturing Vehicle's Rearview Video Display

Figure 7. Image of Camera and Equipment, Capturing Instrument Panel Warnings and Vehicle Speed

Figure 8. Image of Green Laser Installed on Vehicle Bumper for Alignment Purposes

Figure 9. Image of Camera Mounted to Rear Trunk Lid of Vehicle

APPENDIX C: Images of Test Vehicles, Systems and Equipment

2014 Cadillac ATS

Figure 10. Cadillac ATS, Front and Rear Views

Figure 11. Cadillac ATS, Four Three-Quarter Views

2014 Infiniti Q50

Figure 12. Infiniti Q50, Front and Rear Views

Figure 13. Infiniti Q50, Four Three-Quarter Views

2015 Chrysler 200C

Figure 14. Chrysler 200C, Front and Rear Views

Figure 15. Chrysler 200C, Four Three-Quarter Views

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