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Characterization Testing of Crash Imminent Braking in Rear-End and Oncoming Crash Scenarios

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16. Abstract

This project aimed to answer the following questions:
1) How do the crash imminent braking (CIB) systems equipped on a variety of makes/models respond to rear-end crash scenarios involving relative velocities higher than 40 km/h?
2) How do CIB systems from a variety of makes/models respond to a head-on crash imminent scenario?
3) What test procedure development is needed for head-on crash CIB testing?
Seven vehicles of varying makes/models were evaluated in three rear-end crash scenarios and one head-on crash scenario. In CIB testing, notable performance differences were observed as the relative velocities between the subject vehicle and principal other vehicle increased. Although one vehicle did provide alerts for two test trials, no vehicle tested provided an intervention in the head-on crash scenario.

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List of Acronyms

ABS	antilock braking system
ADAS	advanced driver assistance system
AEB	automatic emergency braking
BSI	blind spot intervention
CAN	controller area network
CG	center of gravity
CIB	crash imminent braking
DBS	dynamic brake support
FCW	forward collision warning
GPS	global positioning system
GST	Guided Soft Target
GVT	global vehicle target
IBT	initial brake temperature
IMU	inertial measurement unit
LVD	lead vehicle decelerating
LVM	lead vehicle moving
LVS	lead vehicle stopped
MY	model year
NCAP	New Car Assessment Program
PFC	peak friction coefficient
POV	principal other vehicle
SAE	SAE International, formerly the Society of Automotive Engineers
SV	subject vehicle
TTC	Time-to-collision

Executive Summary

According to the report *Statistics of Light-Vehicle Pre-crash Scenarios Based on 2011-2015 National Crash Data* (Swanson et al., 2019), light-vehicle rear-end crashes accounted for an annual average of 1,709,717 crashes and 1,245 fatalities when the light vehicle was making the critical action pre-crash. Head-on crashes, on the other hand, are low-frequency events and accounted for an annual average of 100,786 crashes when a light vehicle was making the critical action. A substantial number of these crashes, 3,258 from 2011 to 2015, had fatalities.

The objective of this project was to examine the performance of automatic emergency braking systems in rear-end and head-on driving situations. Specifically, the following primary research questions were evaluated.

1. How do the crash imminent braking systems equipped on a variety of makes/models respond to rear-end crash scenarios involving relative velocities higher than 40 km/h?
2. How do CIB systems from a variety of makes/models respond to a head-on crash imminent scenario?
3. What test procedure development is needed for head-on crash CIB testing?

Three rear-end crash scenarios and one head-on crash scenario were used for this project. Two additional head-on scenarios were evaluated with one vehicle; however, no alerts or intervention occurred, and no further testing was done. Seven vehicles of varying makes/models were selected in conjunction with NHTSA. All tests were performed with a surrogate passenger vehicle as the principal other vehicle in the scenario.

With respect to the first research question, we observed notable performance differences as the relative velocities between the subject vehicle and POV were increased. As testing exceeded 40 km/h relative velocity, the average relative impact speeds for most vehicles tested ranged from less than 1 km/h to 32.3 km/h depending on the magnitude of the relative velocity.

Although one vehicle presented FCW alerts during two trials, no vehicle tested provided a CIB intervention during the head-on crash testing regardless of which relative velocity was used.

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Introduction

AEB is a technology comprised of forward collision warning, crash imminent braking, and dynamic brake support that is designed to help a driver avoid or mitigate a collision with another vehicle in front of their vehicle. In this project the Transportation Research Center Inc., executed the following test plan to perform characterization testing of CIB system performance at speeds over 40 km/h and in crash scenarios involving an oncoming vehicle. The detailed study plan supported this effort by addressing these primary research questions.

1. How do the CIB systems implemented in a variety of makes/models respond to rear-end crash scenarios involving relative velocities higher than 40 km/h?
2. How do CIB systems from a variety of makes/models respond to a head-on crash imminent scenario?
3. What is needed in terms of test procedure development for head-on crash CIB testing?

Background

According to the report *Statistics of Light-Vehicle Pre-crash Scenarios Based on 2011-2015 National Crash Data (Swanson et al., 2019)*, light-vehicle rear-end crashes accounted for an annual average of 1,709,717 crashes and 1,245 fatalities when the light vehicle was making the critical action pre-crash. Head-on crashes accounted for an annual average of 100,786 crashes when a light vehicle was making the critical action. A substantial number of these crashes, 3,258 from 2011 to 2015, were fatal. From these statistics, this research sought to evaluate rear-end test speeds with relative velocities between the SV and the POV higher than 40 km/h, SV speeds exceeding 72 km/h, and head-on tests to gain a better understanding of how vehicles equipped with modern crash avoidance technology perform and their ability to reduce crash severity. A speed of 40 km/h was chosen for this research because it was the maximum test speed outlined in the 2015 New Car Assessment Program test procedure.

We reviewed model year 2021 and 2022 vehicle user manuals to determine CIB system reported capabilities in both rear-end and head-on crash-imminent driving situations. Depending on the vehicle manufacturer and trim level, these CIB systems were either standard or optional features. Of the 260 vehicle models explored, 90 percent had rear-end collision CIB available. Maximum CIB operation speeds were typically noted by the manufacturer along with details clarifying scenarios where the vehicle would activate the CIB system. Not all vehicles provided maximum CIB operational speeds in the user manuals. Some vehicles provided a range of relative velocities that they worked at instead. Several vehicle manufacturers noted maximum operating speeds up to 250 km/h for CIB, but some also specified the maximum relative velocity between vehicles, in addition to that maximum operating speed.

Vehicles capable of head-on CIB were difficult to identify through the initial review due to lack of detail in the user manuals regarding capabilities related to oncoming traffic. In MY 2021 and 2022 vehicles, head-on CIB capability was mentioned in the user manuals of only three vehicle manufactures during initial review. They were Volvo, Lexus, and Honda. It is unclear if other vehicles were capable of head-on CIB, but the manufacturers did not directly address it in their user manuals.

Numerous test procedures from around the world include provisions to perform CIB evaluations. These test procedures commonly include three rear-end test scenarios: lead vehicle stopped, lead vehicle moving, and lead vehicle decelerating.

Execution

The following sections outline the test procedures, vehicle selection, equipment, facility, and weather conditions used for the execution of this project.

Test Procedures

Test scenarios were developed to characterize rear-end collisions at the tested speeds and relative velocities as well as head-on collisions. The governing document used for all additional information not specifically mentioned below is the NHTSA CIB Performance Evaluation test procedure from October 2015.

Rear-End Collision Test Procedures

Three scenarios were used to characterize CIB performance in rear-end crash scenarios.

Lead Vehicle Stopped – evaluates the ability of the SV's CIB system to detect and respond to a stopped POV immediately in the forward path of the SV.

Lead Vehicle Moving – evaluates the ability of the SV's CIB system to detect and respond to a POV traveling at a constant slower speed immediately in the forward path of the SV.

Lead Vehicle Decelerating – evaluates the ability of the SV's CIB system to detect and respond to a POV slowing with a constant deceleration immediately in the forward path of the SV.

Each scenario involved the SV approaching the rear of the POV as shown in Figure 1.



Figure 1. Vehicle Approach for Rear-End Collision Scenarios

Table 1 and Table 2, below, outline the SV speeds, POV speeds, deceleration (if applicable), headway (if applicable), and number of unique speed combinations for each of the rear-end collision scenarios. For each of the unique speed combinations, one valid test run was completed. If a vehicle was not capable of head-on collision testing, additional contingency test runs of the rear-end collision scenarios were completed. The contingency test runs are noted by an asterisk in Table 2.

Table 1. Nominal LVS and LVM Test Matrix

Base NHTSA Test Procedure	SV Speed (km/h) 10 km/h Increments	POV Speed (km/h) 10 km/h Increments	# of Unique Speed Combinations	# of Test Runs Each Speed Combination
NCAP CIB LVS	40-80	0	5	1
NCAP CIB LVM	70	10-30	3	1
	80	10-70	7	1
	90	10-70	7	1
	100	20-70	6	1
	110	30-70	5	1

Base NHTSA Test Procedure	SV Speed (km/h) 10 km/h Increments	POV Speed (km/h) 10 km/h Increments	# of Unique Speed Combinations	# of Test Runs Each Speed Combination
	120	40-70	4	1

Table 2. Nominal LVD Test Matrix

Base NHTSA Test Procedure	SV Speed (km/h)	POV Speed (km/h)	POV Decel Rate (g)	Initial Headway (m)	# of Unique Speed Combinations	# of Test Runs Each Speed Combination
NCAP CIB LVD	60	60	0.5	40	1	1
				12	1	1
			0.6*	40	1	1
				12	1	1
	70	70	0.5	40	1	1
				12	1	1
			0.6*	40	1	1
				12	1	1
	80	80	0.5	40	1	1
				12	1	1
			0.6*	40	1	1
				12	1	1

*Denotes planned contingency test runs based on vehicle performance.

Rear-end collision testing for a particular SV speed and relative velocity was stopped when one of the following conditions occurred in an effort to mitigate significant damage to the test equipment and the SV.

- The SV did not present an FCW alert.
- The SV deceleration did not exceed 5.0 m/s^2 and it struck the target.

Rear-End Collision Test Validity

Each test trial meets the initial validation as outlined in the test procedures section of this report. The validity period for each test started at a time-to-collision of 3.0 seconds and ended either when the SV came to a speed less than or equal to the POV for 1 second or a collision occurred. The following list details other validity requirements for each test run.

- SV yaw rate does not exceed ±1.0 deg/s from the onset of the validity period until the SV has reached 0.25 g deceleration.
- Lateral distance of SV and POV does not vary more than 0.3 m from the center of the lane and in reference to one another.
- The SV driver shall not apply the brake pedal during any portion of the validity period.
- Speeds of both the SV and POV shall be within ±1.6 km/h.

- The SV driver shall release the throttle pedal within 500 ms after the initial FCW alert.
- The SV brakes shall be kept at an initial brake temperature from 65°C to 100°C.
- Average POV deceleration ±0.03 g from 1.5 seconds after POV deceleration onset until: 1) impact or, 2) up to 250 ms prior to coming to a stop.

Head-On Collision Test Procedure

The **Head-On Collision POV Lane Change** scenario evaluates the ability of the CIB system in the vehicle to detect and respond to a POV changing lanes into the oncoming path of the SV. For this scenario, the approach for the SV and POV are shown in Figure 2. This scenario was developed and provided by NHTSA at the start of the project.

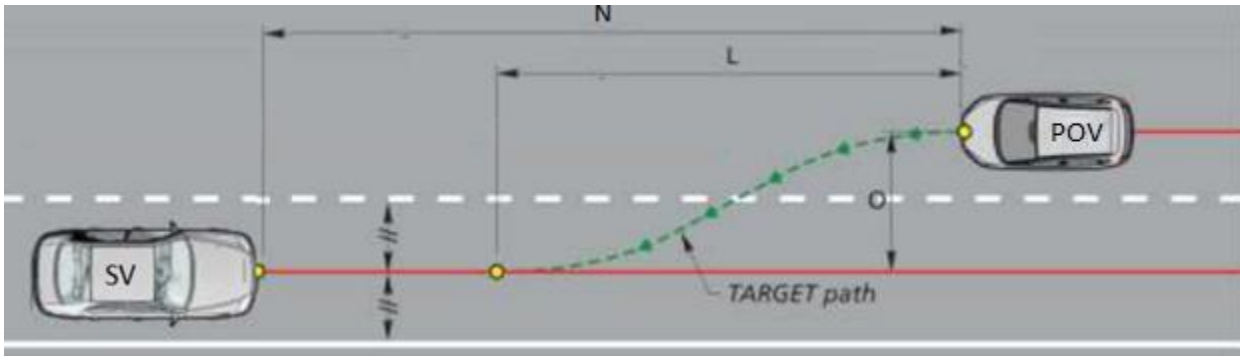


Figure 2. Vehicle Approach for Head-On Collision Scenarios

Table 3 outlines the vehicle speeds, lane change parameters, timing of lane change, distance between vehicles at lane change initiation, and maximum lateral acceleration for the lane change.

Table 3. Nominal Head-On Collision Test Matrix

SV Speed (km/h)	POV Speed (km/h)	Lane Change Offset (m) "O"	Lane Change Length (m) "L"	Time Required for POV to Complete Lane Change (sec)	TTC at Start of Lane Change (sec)	Distance Between SV and POV at Start of Lane Change (m) "N"	Max Lateral Acceleration (m/s^2)
30	10	3.65	8.3	3.34	3.0	33.3	1.5
	15	3.65	13.0	3.27	3.0	37.5	1.5
	20	3.65	17.6	3.25	3.0	41.7	1.5
	25	3.65	22.1	3.24	3.0	45.8	1.5
	30	3.65	26.6	3.23	3.0	50.0	1.5
40	10	3.65	8.3	3.34	3.0	41.7	1.5
	15	3.65	13.0	3.27	3.0	45.8	1.5
	20	3.65	17.6	3.25	3.0	50.0	1.5
	25	3.65	22.1	3.24	3.0	54.2	1.5
	30	3.65	26.6	3.23	3.0	58.3	1.5
50	10	3.65	8.3	3.34	3.0	50.0	1.5

SV Speed (km/h)	POV Speed (km/h)	Lane Change Offset (m) "O"	Lane Change Length (m) "L"	Time Required for POV to Complete Lane Change (sec)	TTC at Start of Lane Change (sec)	Distance Between SV and POV at Start of Lane Change (m) "N"	Max Lateral Acceleration (m/s^2)
	15	3.65	13.0	3.27	3.0	54.2	1.5
	20	3.65	17.6	3.25	3.0	58.3	1.5
60	10	3.65	8.3	3.34	3.0	58.3	1.5

Additional Head-On Collision Test Scenarios

Two additional head-on scenarios were completed for the Lexus NX 250 to gather performance data. Both scenarios came from the Euro NCAP Test Protocol AEB Car-to-Car Systems (2023a). The same validity criteria specified in the Head-On Collision Test Validity section were used; however, speeds and manuever details were taken from the Euro NCAP Test Protocol. The scenarios were:

- **Car-to-Car Front Head-On Straight (CCFhos)** – evaluates the ability of the CIB system in the SV to detect and respond to an oncoming vehicle in its own lane, as shown in Figure 3. This scenario was tested at two SV-POV speed combinations. In the first test, the SV and POV speeds were both 50 km/h and in the second test, the SV and POV speeds were both 70 km/h.
- **Car-to-Car Front Head-On Lane Change (CCFhol)** – evaluates the ability of the CIB system in the SV to detect and respond to a vehicle changing lanes into the path of the SV, as shown in Figure 4. This scenario was tested at two SV-POV speed combinations. In the first test, the SV and POV speeds were both 50 km/h and in the second test the SV and POV speeds were both 70 km/h. This scenario was added to understand if vehicles performed better at set speeds and specifications specified in the Euro NCAP Test Protocol.



Figure 3. Euro NCAP CCFhos Scenario Diagram

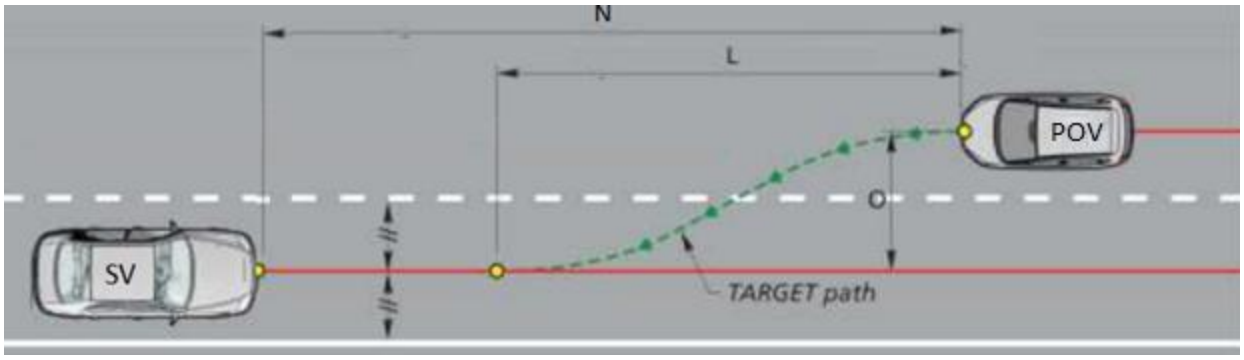


Figure 4. Euro NCAP CCFhol Scenario Diagram

Table 4 outlines the vehicle speeds, lane change parameters, timing of lane change, distance between vehicles at lane change initiation, and maximum lateral acceleration for the lane change.

Table 4. Euro NCAP CCFhol Scenario Details

POV Speed (km/h)	POV Speed (km/h)	Lane Change Offset (m) "O"	Lane Change Length (m) "L"	Following Distance (m) "F"	TTC at End of Lane Change (s)	Max Lateral Acceleration (m/s^2)
50	50	3.5	44	13.9	1.5	1.5
70	50	3.5	60	19.4	1.5	1.5

Head-On Collision Test Validity

Validation of each test had to meet the requirements listed in the sections above. The validity period for these tests started at a TTC of 5.0 seconds and ended when the SV and POV had a collision. Some metrics observed for test validation are listed below.

- SV Yaw rate does not exceed ±1.0 deg/s from the onset of the validity period until the SV has reached 0.25g deceleration.
- Lateral distance of the SV does not vary more than ±0.3 m from the lane center.
- Lateral distance of the POV does not vary more than ±0.3 m from the lane center until the POV lane change starts.
- The SV driver shall not apply the brake pedal during any portion of the validity period.
- Speeds of both the SV and POV shall be within ±1.6 km/h.
- The SV driver shall release the throttle pedal within 500 ms after the initial FCW alert.
- The SV brakes shall be kept at an IBT from 65°C to 100°C.

Test Vehicle Selection

Vehicle user manuals of MY 2021 and 2022 vehicles were reviewed to determine if they had higher-speed rear-end and head-on CIB. Depending on the vehicle manufacturer and trim level, these systems were either standard or optional features. During the vehicle selection process, with the help of NHTSA, a variety of vehicles were selected with particular consideration given

to sensor type and body style. An electric vehicle, the Tesla Model 3, was also selected to better understand if performance differences resulted from regenerative braking. All new or used vehicles were inspected for like-new tire and brake conditions as well as functioning ADAS systems without malfunction indicator lamps on. No calibrations were done to the sensors prior to the test start, so all were assumed to have "factory calibration" during testing. All were tested in their "normal or default" drive mode setting. Table 5 outlines the details for the vehicles used in this study. Additional vehicle information is included in Appendix A.

Table 5. Test Vehicles

Year & Make	2022 Honda	2021 Ford	2021 Volvo	2022 Lexus	2018 Tesla[1]	2022 Toyota	2023 Hyundai
Model & Trim	Civic Sport	Bronco Outer Banks	S60 Momentum	NX 250	Model 3 Dual Motor	Prius Prime	Palisade Limited
Body Style	4-door sedan	SUV	4-door sedan	SUV	4-door sedan	5-door hatchback	SUV
Trade Name	collision mitigation braking system	pre-collision assist	city safety	pre-collision system	collision avoidance assist	pre-collision system	forward collision-avoidance assist
Forward-Facing Sensors (qty)	Camera (1)	Camera (1)	Camera (1) and radar (1)	Camera (1) and radar (1)	Camera (1) and radar (1)	Camera (1) and radar (1)	Camera (1) and radar (1)
Sensor Location(s)	Behind windshield near rear view mirror	Behind windshield near rear view mirror	Camera and radar - behind windshield near rear view mirror	Camera - behind windshield near rear view mirror; radar - behind vehicle grill	Camera - behind windshield near rear view mirror; radar - behind vehicle grill	Camera - behind windshield near rear view mirror; radar - behind vehicle grill	Camera - behind windshield near rear view mirror; radar - behind vehicle grill
AEB Alert Icon							
Icon Description	Orange “Brake” alert across instrument panel	Red flashing “Pre-Collision Assist” alert on instrument panel	Orange vehicle flash on instrument panel	Red “Pre-Collision System” alert on instrument panel	Vehicle on center screen turns red once crash is imminent	Red “Brake!” alert across instrument panel	Red “Emergency Braking” alert across instrument panel
Audible Warning	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Min – Max AEB Activation Speeds	5 – 100 km/h	5 – 120 km/h	5 – 115 km/h	5 – 180 km/h	5 – 150 km/h	10 – 180 km/h	10 – 200 km/h
Oncoming AEB Capability	Yes	No	Yes	Yes	No	No	No

[1]The Tesla Model 3 software version at the time of testing was v11.0 (2022.16.2 86e60d9a2bcf). This was not updated or changed until all runs of the Tesla Model 3 were complete.

Principal Other Vehicle

The POV used throughout testing was the AB Dynamics GVT Revision G Soft Car 360.[1] Specifications for this test target are detailed in Table 6. The Soft Car 360 is shown in Figure 5. Due to the likelihood of impacts, special attention was given to the wear and tear of the target vehicle throughout testing. It was unclear what level of visual degradation would affect CIB system performance for each SV so out of caution, pieces were replaced any time a tear occurred or if scuffs occurred that caused body lines to be blurred. An example of a piece that was replaced due to an impact that resulted in significant visual defects can be seen in Figure 6.

Table 6. POV Specifications

Target	Vehicle Type	Revision	Length (mm)	Width (mm)	Height (mm)	Weight (kg)
Soft Car 360	Hatchback	G	4023	1712	1427	108



Figure 5. Revision G Soft Car 360



Figure 6. Example Soft Car 360 Damage that Required Replacement

To accurately and repeatedly move the POV, and to position it in the travel lane, a Guided Soft Target[2] from AB Dynamics was used (see Figure 6). The GST is a low-profile robotic platform

[1] AB Dynamics, also known as Anthony Best Dynamics Limited. Bradford on Avon, United Kingdom. www.abdynamics.com/en/products/track-testing/adas-targets/soft-car-360

[2] AB Dynamics, www.abdynamics.com/en/products/track-testing/adas-targets/guided-soft-target

that allows for accurate path-following control and can also be driven over, if intervention by the SV is not sufficient to avoid a collision. The specifications of the GST used for the work described in this report are detailed in Table 7.



Figure 7. Guided Soft Target

Table 7. Guided Soft Target Specifications

Movement System Model	GST100
Maximum Acceleration	0.22g
Maximum Deceleration	0.8g
Maximum Lateral Acceleration	0.4-0.5g
Length	2950 mm
Width	1680 mm
Height	100 mm
Overall Weight	315 kg
Overrun Capacity	1000 kg per wheel

One challenge discovered during testing was consistently and repeatedly achieving the nominal deceleration rates of 5.0 m/s^2 and 6.0 m/s^2 as specified in the test matrix. Daily tuning of the brake system was required to allow for the validity requirements to be met. The GST capable of 100 km/h (GST100) does not have an antilock braking system, so the condition of consumable parts, such as tires and brakes, had a greater impact on braking performance at these higher deceleration rates.

Data Acquisition

The test equipment in Table 8 was used to accurately and repeatedly complete each scenario in this study. All equipment is commonly used in ADAS testing. With proper calibration tracking and specifications, the data acquisition system met all requirements specified in the NHTSA CIB test procedure for range, resolution, and accuracy.

Table 8. Data Acquisition System

Test Equipment	Manufacturer/Model	Notes
Integrated inertial measurements unit and GPS	OXTS/RT 3003	Main GPS/IMU system used for position, speed, yaw rate, and acceleration data
Data acquisition system	Dewesoft/DEWE43	Collection of all signals from each individual data source
Vehicle-to-vehicle range transmitter	AB Dynamics/ Control Box OR OXTS/ RT Range S	For LVS tests, the RT Range S system was used, and for LVM and LVD tests, the vehicle-to-vehicle data from the AB Dynamics system was used
Thermocouples	Not specified	K type thermocouples to monitor brake temperatures at all four tires throughout testing
FCW data flag measurement system	TRC/V&A Detection System	Camera and microphone system to capture FCW alerts in real time and act upon them
Thermocouple reader	Peak Systems/ Thermocouple1 CAN	CAN output of thermocouple data to the data acquisition system
RTK corrections	Freewave/FGR3-CE-U	Onsite permanent base station providing differentially corrected GPS data
Video recording via webcams	Logitech/ Brio	Used to monitor and review scenario. Dash-facing and forward-facing cameras
Power box	TRC/PBSys35	Battery power for all equipment that was independent of vehicle power
Robotic platform	AB Dynamics/ GST100	Movement platform for targets
Target vehicle (POV)	DRI Soft Car 360	Latest Revision G used
Coordinate measurement machine	Faro/Quantum E	Millimeter precision measurements of GPS position, antenna position, and front bumper location
Tire pressure gauge	Intercomp/360045	Tire pressures checked each test day
Weight scales	Mettler Toledo/ B8033	Vehicle corner weights

Test Facility and Weather Conditions

All testing in this report was conducted at TRC Inc.'s SMARTCenter, a 540-acre facility dedicated to automated and connected vehicle testing. For this project specifically, the North Leg of the High-Speed Intersection was used. See Figure 8.



Figure 8. SMARTCenter North Leg

This test facility has the following characteristics.

- Six lanes wide
- 610 m long, with 460 m of white solid/dashed/solid lane markings
- All lanes were 3.5 to 3.8 m wide
- Slope of 0.25 percent
- Free of cracks, bumps, and other irregularities
- Pavement friction coefficient greater than 1.02

Based on both 2015 NHTSA confirmation test procedures, the following execution details for weather and facility conditions were used.

- All tests were completed with the following weather conditions: ambient temperature between 32°F (0°C) and 104°F (40°C), maximum wind speed no greater than 22 mph (10 m/s).
- Tests were not performed during inclement weather (rain, snow, hail, fog, smoke, and/or ash).
- Tests were conducted during daylight with good atmospheric visibility, defined as an absence of fog and the ability to see clearly for at least 3.1 mi (5.0 km).
- Tests were not conducted with the SV and POV oriented into the sun during very low sun angle conditions (where the sun is oriented 15° or less from horizontal) to maintain consistency in testing and mitigate potential risk of camera "washout" or system inoperability. All test runs were completed traveling with a heading of 327°.
- The road test surface was dry (without visible moisture on the surface), straight, and flat, with a consistent slope between level and 0.25 percent. The road surface was asphalt or concrete and was free of irregularities, undulations, and/or cracks that could cause the SV to pitch excessively. The road test surface produced a peak friction coefficient of at least 0.9 at a speed of 64.4 km/h without water delivery.
- Each trial was conducted with no other vehicles (except the POV), obstructions, or stationary objects within one lane width on either side of the SV's lane of travel. This

single lane of travel was used for the CIB test and was delineated with two white lane lines (a white dashed line left of the SV and a white solid line right of the SV).

Data Summary

The following sections provide summary data for each of the test scenarios performed for each vehicle. Table header descriptions are provided below.

- **SV Speed (km/h)** – speed the SV was driven during the test.
- **POV Speed (km/h)** – speed the POV was driven during the test.
- **FCW TTC (s)** – TTC when the FCW alert (either visual or audible) first appeared to the driver.
- **Minimum Distance (m)** – minimum distance between the SV and POV. A minimum distance of 0.00 m denotes an impact with the POV.
- **Speed Reduction (km/h)** – speed reduced by the SV at time of impact with the POV. Calculations for speed reduction are described in the NHTSA CIB Test Procedure.
- **Relative Impact Speed (km/h)** – speed difference between SV and POV at time of impact. A speed difference of 0.00 km/h denotes no impact.
- **TTC of CIB Activation (s)** – TTC when the SV first reached 5.0 m/s^2 braking.
- **Peak Decel (m/s^2)** – maximum amount of deceleration from the SV during the braking event. This acceleration data was filtered with a low-pass 6th order Butterworth filter with cutoff corner frequency of 3 Hz.

In the data summary tables, any rows that are grey with dashed lines were not completed due to reaching the end of the test criteria.

CIB LVS

Table 9 details the individual vehicle results for the LVS scenario. Generally, as the relative velocity increased, the test vehicles began to present their FCW alert to the driver at an increasingly earlier TTC. At speeds at which impacts began to occur with the POV, the timing of the FCW alert timing did not continue to occur increasingly earlier in the event.[3] The Honda Civic and Ford Bronco began striking the target at speeds above 40 km/h. The Volvo S60, Tesla Model 3, and Toyota Prius Prime all began striking the target at test speeds above 60 km/h. The Hyundai Palisade began striking the target at test speeds above 70 km/h. The Lexus NX 250 was able to complete all LVS trials without an impact, including performing from the maximum test speed of 80 km/h. The speed at which an impact with the target occurred demonstrated the upper bounds of the CIB's capabilities. That is, any further increase in SV speed also resulted in an increase in the relative impact speed with the target vehicle.

[3] The Tesla Model 3 was the one exception, having a longer FCW TTC at 50 km/h (3.11 s) compared to 60 km/h (3.03 s).

Table 9. CIB LVS

Scenario	Vehicle	SV Speed km/h	POV Speed km/h	FCW TTC (s)	Minimum Distance (m)	Speed Reduction (km/h)	Relative Impact Speed (km/h)	TTC of CIB Activation (s)	Peak Decel (m/s^2)
Lead Vehicle Stopped (LVS)	2022 Honda Civic	40	0	2.23	1.53	40.10	0.00	0.81	9.59
		50		2.38	0.00	47.38	2.38	0.83	9.91
		60		2.52	0.00	49.25	11.05	0.96	9.46
		70		2.55	0.00	34.09	34.88	0.93	9.50
		80		2.50	0.00	25.92	53.06	0.83	9.45
	2021 Ford Bronco	40	0	1.86	1.68	39.82	0.00	0.81	9.43
		50		2.04	0.00	39.42	9.94	0.76	9.28
		60		2.13	0.00	30.67	28.76	0.72	9.35
		70		2.26	0.00	29.95	39.71	0.71	10.32
		80		1.50	0.00	22.68	56.41	0.56	9.42
	2021 Volvo S60	40	0	2.10	0.77	38.81	0.00	0.91	9.95
		50		2.35	0.90	50.04	0.00	0.90	9.62
		60		2.80	0.83	60.16	0.00	0.97	9.56
		70		2.96	0.00	51.80	17.86	0.96	9.45
		80		2.97	0.00	40.61	39.53	0.84	9.63
	2018 Tesla Model 3	40	0	2.63	1.04	39.17	0.00	0.74	9.51
		50		3.11	1.40	50.15	0.00	0.90	8.78
		60		3.03	0.93	59.69	0.00	1.06	8.84
		70		2.98	0.00	50.90	19.12	1.03	8.92
		80		2.94	0.00	47.79	32.58	1.10	9.59
	2022 Lexus NX 250	40	0	2.29	1.00	39.89	0.00	1.02	8.42
		50		2.39	0.99	49.93	0.00	1.21	8.81
		60		2.45	0.98	60.01	0.00	1.26	9.69
		70		2.62	0.98	69.05	0.00	1.32	8.02
		80		2.73	1.17	80.64	0.00	1.27	9.85
	2022 Toyota Prius Prime	40	0	2.15	0.96	39.60	0.00	0.91	9.68
		50		2.48	0.80	49.86	0.00	1.01	9.25
		60		2.73	0.32	60.23	0.00	0.99	11.30
		70		2.13	0.00	41.80	28.22	0.82	10.27
		80		2.67	0.00	35.75	43.88	0.75	11.04
	2023 Hyundai Palisade	40	0	2.25	3.14	38.66	0.00	0.95	10.25
		50		2.47	2.88	48.78	0.00	1.03	10.34
		60		2.55	2.83	59.87	0.00	1.19	10.03
		70		2.86	3.71	69.98	0.00	1.33	10.68
		80		2.94	0.00	65.03	14.94	1.19	10.14

CIB LVM

Table 10 outlines the individual vehicle results for the CIB LVM scenario when the nominal relative velocity was 10 km/h. The only scenario when the relative velocity was 10 km/h was when the SV speed was 80 km/h and POV speed was 70 km/h. No impacts occurred for this scenario at this speed for the seven vehicles tested. A notable effect of the Tesla Model 3 regenerative braking is evident in the data. The FCW alert occurred at 2.00 seconds TTC, which resulted in the driver releasing the throttle pedal and the regenerative braking was able to reduce vehicle speed enough to avoid an impact without initiation of a CIB-based brake application. During all tests the Tesla Model 3 had regenerative braking mode set to standard.

Table 10. CIB LVM With 10 km/h Relative Velocity, 80 km/h Subject Vehicle Speed and 70 km/h POV Speed

Scenario	Relative Velocity	Vehicle	SV Speed (km/h)	POV Speed (km/h)	FCW TTC (s)	Minimum Distance (m)	Speed Reduction (km/h)	Relative Impact Speed (km/h)	TTC of CIB Activation (s)	Peak Decel (m/s^2)
Lead Vehicle Moving (LVM)	**10 km/h**	2022 Honda Civic	80	70	2.10	1.22	9.04	0.00	0.72	7.83
		2021 Ford Bronco	80	70	2.49	1.02	10.15	0.00	0.68	8.74
		2021 Volvo S60	80	70	2.17	0.76	8.53	0.00	0.59	7.29
		2018 Tesla Model 3	80	70	2.00	0.80	7.63	0.00	0.00	4.39
		2022 Lexus NX 250	80	70	1.85	1.23	9.14	0.00	0.71	6.10
		2022 Toyota Prius Prime	80	70	2.34	1.09	9.68	0.00	0.75	5.32
		2023 Hyundai Palisade	80	70	3.20	2.92	10.69	0.00	2.37	5.63

For the CIB LVM scenario with a nominal relative velocity of 20 km/h, only one impact occurred with the target vehicle: with the Ford Bronco at an SV speed of 90 km/h and the POV speed at 70 km/h. The peak deceleration only reached 3.78 m/s^2, so the Ford Bronco's test series was terminated at this point and the 100_70 km/h test scenario was not completed. The results for the 20 km/h and 30 km/h relative velocity test runs can be seen in Table 11 and Table 12, respectively. All other vehicles' CIB LVM tests with a relative velocity of 30 km/h did not result in contact.

Table 11. CIB LVM With 20 km/h Relative Velocity

Scenario	Relative Velocity	Vehicle	SV Speed (km/h)	POV Speed (km/h)	FCW TTC (s)	Minimum Distance (m)	Speed Reduction (km/h)	Relative Impact Speed (km/h)	TTC of CIB Activation (s)	Peak Decel (m/s^2)
Lead Vehicle Moving	**20 km/h**	2022 Honda Civic	80	60	2.20	1.73	19.66	0.00	0.74	8.04
			90	70	2.39	1.78	19.44	0.00	0.76	8.47
		2021 Ford Bronco	80	60	2.07	0.55	17.89	0.00	0.50	8.99
			90	70	2.28	0.00	9.04	10.30	0.49	3.78
		2021 Volvo S60	80	60	1.67	1.60	29.52	0.00	0.79	8.40
			90	70	1.66	1.72	20.48	0.00	0.77	8.91
		2018 Tesla Model 3	80	60	2.90	0.95	18.61	0.00	0.55	8.66
			90	70	3.16	0.87	20.30	0.00	0.51	8.72
		2022 Lexus NX 250	80	60	1.99	1.03	20.66	0.00	0.74	5.72
			90	70	1.98	1.10	18.76	0.00	0.68	6.10
		2022 Toyota Prius Prime	80	60	2.38	1.32	19.69	0.00	0.78	7.05
			90	70	2.33	1.47	19.01	0.00	0.70	8.91
		2023 Hyundai Palisade	80	60	2.26	3.55	20.59	0.00	1.10	9.74
			90	70	2.52	3.74	19.04	0.00	1.20	10.00

Table 12. CIB LVM With 30 km/h Relative Velocity

Scenario	Relative Velocity	Vehicle	SV Speed (km/h)	POV Speed (km/h)	FCW TTC (s)	Minimum Distance (m)	Speed Reduction (km/h)	Relative Impact Speed (km/h)	TTC of CIB Activation (s)	Peak Decel (m/s^2)
Lead Vehicle Moving	**30 km/h**	2022 Honda Civic	80	50	2.25	1.72	28.12	0.00	0.84	7.79
			90	60	2.30	1.88	30.35	0.00	0.84	8.34
			100	70	2.13	2.18	28.51	0.00	0.86	8.40
		2021 Ford Bronco	80	50	2.28	0.48	29.56	0.00	0.65	9.13
			90	60	2.34	0.37	30.02	0.00	0.78	9.28
			100	70	-	-	-	-	-	-
		2021 Volvo S60	80	50	2.08	1.98	28.26	0.00	0.91	8.92
			90	60	1.77	1.84	29.34	0.00	0.91	8.91
			100	70	1.73	2.11	30.24	0.00	0.96	8.63
		2018 Tesla Model 3	80	50	2.91	1.12	30.24	0.00	0.61	9.49
			90	60	3.06	1.47	28.69	0.00	0.65	9.16
			100	70	3.05	1.06	30.60	0.00	0.60	9.77
		2022 Lexus NX 250	80	50	2.15	0.98	28.87	0.00	0.86	5.90
			90	60	2.02	0.82	29.20	0.00	0.85	8.40
			100	70	2.06	0.99	27.90	0.00	0.80	6.17
		2022 Toyota Prius Prime	80	50	2.44	1.56	28.94	0.00	0.88	9.24
			90	60	1.23	1.36	27.61	0.00	0.68	9.82
			100	70	2.48	0.68	30.17	0.00	0.59	9.79
		2023 Hyundai Palisade	80	50	2.68	4.87	29.48	0.00	1.12	10.24
			90	60	2.39	5.00	28.84	0.00	1.12	9.76
			100	70	2.41	5.15	28.58	0.00	1.14	10.15

At a nominal relative velocity of 40 km/h for CIB LVM scenario, CIB interventions provided full avoidance for all vehicle and speed combinations except for the Ford Bronco. The Ford Bronco experienced impacts at both 90_50 km/h and 100_60 km/h. The Volvo S60 presented alerts that were much later than typical for both the 100_60 km/h and 110_70 km/h SV/POV speed scenarios, but the vehicle still intervened and stopped at distances comparable to those recorded for the other 40 km/h relative velocity test scenarios. This trend continued throughout the testing with the Volvo S60 having FCW alerts with less than 2 seconds TTC on test runs with complete avoidance when the SV speed was greater than 100 km/h and relative velocity was greater than 40 km/h.

Table 13. CIB LVM With 40 km/h Relative Velocity

Scenario	Relative Velocity	Vehicle	SV Speed (km/h)	POV Speed (km/h)	FCW TTC (s)	Minimum Distance (m)	Speed Reduction (km/h)	Relative Impact Speed (km/h)	TTC of CIB Activation (s)	Peak Decel (m/s^2)
Lead Vehicle Moving	**40 km/h**	2022 Honda Civic	70	30	2.46	1.66	38.12	0.00	0.90	9.07
			80	40	2.21	1.12	40.25	0.00	0.90	8.19
			90	50	2.09	1.66	39.06	0.00	0.90	8.70
			100	60	2.29	2.03	38.84	0.00	0.98	8.07
			110	70	2.36	1.86	38.52	0.00	0.92	8.47
		2021 Ford Bronco	70	30	2.31	1.70	39.17	0.00	0.90	9.67
			80	40	2.27	1.87	39.64	0.00	0.90	9.86
			90	50	2.15	0.00	31.61	7.81	0.86	9.61
			100	60	2.11	0.00	17.46	22.18	1.00	7.96
			110	70	-	-	-	-	-	-
		2021 Volvo S60	70	30	2.28	1.28	38.95	0.00	1.18	9.72
			80	40	2.27	1.34	38.92	0.00	1.17	9.20
			90	50	2.27	1.36	40.75	0.00	1.19	9.15
			100	60	1.44	1.83	38.74	0.00	0.99	9.05
			110	70	1.70	1.54	39.13	0.00	1.15	9.45
		2018 Tesla Model 3	70	30	3.02	0.93	38.81	0.00	0.69	8.85
			80	40	2.79	1.77	38.52	0.00	0.76	9.93
			90	50	2.27	1.78	38.99	0.00	0.79	9.36

Scenario	Relative Velocity	Vehicle	SV Speed (km/h)	POV Speed (km/h)	FCW TTC (s)	Minimum Distance (m)	Speed Reduction (km/h)	Relative Impact Speed (km/h)	TTC of CIB Activation (s)	Peak Decel (m/s^2)
			100	60	3.07	1.82	38.56	0.00	0.77	9.29
			110	70	2.53	2.11	40.18	0.00	0.83	9.58
		2022 Lexus NX 250	70	30	2.35	0.86	38.88	0.00	1.04	9.39
			80	40	2.34	0.89	38.56	0.00	1.05	9.53
			90	50	2.36	0.92	37.51	0.00	1.05	9.57
			100	60	2.25	0.72	39.96	0.00	1.05	8.84
			110	70	2.27	0.76	38.20	0.00	1.05	9.23
		2022 Toyota Prius Prime	70	30	2.03	1.26	39.02	0.00	1.00	9.36
			80	40	2.57	1.94	39.64	0.00	1.05	8.41
			90	50	2.61	1.43	39.89	0.00	1.03	9.30
			100	60	2.50	1.82	38.09	0.00	0.87	9.82
			110	70	2.60	1.04	39.42	0.00	0.97	10.25
		2023 Hyundai Palisade	70	30	2.41	3.61	39.78	0.00	1.00	9.45
			80	40	2.70	4.60	38.95	0.00	1.08	9.65
			90	50	2.54	4.74	39.17	0.00	1.07	10.16
			100	60	2.54	5.91	39.92	0.00	1.17	10.12
			110	70	2.41	5.57	41.47	0.00	1.12	10.40

For CIB LVM scenarios with nominal relative velocities of 50 km/h and 60 km/h, the two camera-only based AEB vehicles, the Honda Civic and Ford Bronco, began to experience more impacts with the target. In the 50 km/h relative velocity CIB LVM scenario, the Ford Bronco struck the target in the 90_40 km/h and 100_50 km/h SV/POV speed tests. In the 60 km/h relative velocity CIB LVM scenario, the Ford Bronco struck on every test run with relative impact speeds exceeding 20 km/h and the end of test criteria was met on the 90_30 km/h SV/POV speed test run. The Honda Civic had some inconsistency in performance when the relative velocity was 50 km/h and 60 km/h. The Honda Civic only struck on the 80_30 km/h scenario when the relative velocity was 50 km/h, but when the relative velocity was 60 km/h, the vehicle was only able to avoid a collision on the 120_60 km/h test run. The Toyota Prius Prime struck the target when the relative velocity was 60 km/h during the 70_10 km/h SV/POV speed scenario. In this test, the alert occurred

very late during this trial, and a collision occurred with a relative impact speed of 55.30 km/h. The results for the 50 km/h and 60 km/h relative velocity test runs can be seen in Table 14 and Table 15.

Table 14. CIB LVM With 50 km/h Relative Velocity

Scenario	Relative Velocity	Vehicle	SV Speed (km/h)	POV Speed (km/h)	FCW TTC (s)	Minimum Distance (m)	Speed Reduction (km/h)	Relative Impact Speed (km/h)	TTC of CIB Activation (s)	Peak Decel (m/s^2)
Lead Vehicle Moving	**50 km/h**	2022 Honda Civic	70	20	2.56	0.18	49.25	0.00	1.00	8.26
			80	30	2.10	0.00	27.95	21.78	0.88	8.29
			90	40	2.52	1.78	49.82	0.00	1.04	9.25
			100	50	2.55	0.48	48.78	0.00	1.00	8.37
			110	60	2.78	0.60	50.00	0.00	0.91	8.76
			120	70	2.35	1.11	48.96	0.00	0.95	8.78
		2021 Ford Bronco	70	20	2.35	0.54	48.96	0.00	0.92	9.81
			80	30	4.60	0.02	48.67	0.00	0.89	9.76
			90	40	2.16	0.00	32.47	17.24	0.96	9.64
			100	50	2.21	0.00	17.41	31.79	0.93	9.11
			110	60	-	-	-	-	-	-
			120	70	-	-	-	-	-	-
		2021 Volvo S60	70	20	2.56	1.17	49.25	0.00	1.29	9.59
			80	30	2.47	1.39	49.00	0.00	1.30	9.52
			90	40	2.45	1.06	49.03	0.00	1.18	8.71
			100	50	1.41	1.71	48.96	0.00	0.96	9.58
			110	60	1.46	1.33	48.02	0.00	1.01	9.46
			120	70	1.47	1.57	48.28	0.00	1.15	8.95
		2018 Tesla Model 3	70	20	3.06	1.33	49.72	0.00	0.91	8.59
			80	30	3.02	1.02	49.10	0.00	0.86	8.57
			90	40	2.76	2.48	49.90	0.00	0.98	9.41
			100	50	2.96	2.34	48.38	0.00	0.95	9.18

Scenario	Relative Velocity	Vehicle	SV Speed (km/h)	POV Speed (km/h)	FCW TTC (s)	Minimum Distance (m)	Speed Reduction (km/h)	Relative Impact Speed (km/h)	TTC of CIB Activation (s)	Peak Decel (m/s^2)
			110	60	2.17	2.72	49.82	0.00	1.06	9.34
			120	70	2.34	2.64	49.57	0.00	1.02	9.28
		2022 Lexus NX 250	70	20	2.35	0.84	48.28	0.00	1.23	9.38
			80	30	2.39	0.84	47.59	0.00	1.24	9.48
			90	40	2.38	0.89	48.49	0.00	1.16	9.70
			100	50	2.39	0.87	49.25	0.00	1.20	9.56
			110	60	2.52	0.63	50.65	0.00	1.25	9.38
			120	70	2.44	0.75	49.72	0.00	1.19	9.76
		2022 Toyota Prius Prime	70	20	2.74	0.59	49.90	0.00	1.16	9.78
			80	30	2.70	1.39	49.39	0.00	1.11	9.34
			90	40	2.72	0.37	48.17	0.00	1.10	7.59
			100	50	2.68	1.04	44.86	0.00	1.15	8.13
			110	60	2.63	1.84	48.31	0.00	1.02	9.75
			120	70	2.65	0.52	49.43	0.00	0.79	10.36
		2023 Hyundai Palisade	70	20	2.62	3.91	47.74	0.00	1.08	9.72
			80	30	2.52	3.79	47.27	0.00	1.10	9.78
			90	40	2.54	4.78	49.79	0.00	1.15	10.12
			100	50	2.57	5.41	49.36	0.00	1.19	9.96
			110	60	2.78	6.00	49.54	0.00	1.22	10.43
			120	70	2.72	6.76	51.26	0.00	1.28	10.26

Table 15. CIB LVM With 60 km/h Relative Velocity

Scenario	Relative Velocity	Vehicle	SV Speed (km/h)	POV Speed (km/h)	FCW TTC (s)	Minimum Distance (m)	Speed Reduction (km/h)	Relative Impact Speed (km/h)	TTC of CIB Activation (s)	Peak Decel (m/s^2)
Lead Vehicle Moving	**60 km/h**	2022 Honda Civic	70	10	2.55	0.00	44.53	15.52	1.09	8.56
			80	20	2.57	0.00	35.03	24.84	1.03	8.44
			90	30	1.63	0.00	37.91	22.25	1.04	8.96
			100	40	2.59	0.00	41.29	18.58	1.09	9.01
			110	50	2.27	0.00	38.45	21.02	1.03	9.43
			120	60	2.52	0.79	59.22	0.00	1.07	8.80
		2021 Ford Bronco	70	10	2.35	0.00	33.35	27.32	0.88	10.45
			80	20	2.34	0.00	39.19	20.12	0.92	10.10
			90	30	2.38	0.00	23.90	36.54	0.91	9.68
			100	40	-	-	-	-	-	-
			110	50	-	-	-	-	-	-
			120	60	-	-	-	-	-	-
		2021 Volvo S60	70	10	2.72	1.39	59.51	0.00	1.34	10.57
			80	20	2.62	1.27	58.68	0.00	1.29	10.02
			90	30	1.91	0.77	58.54	0.00	1.24	9.48
			100	40	1.93	1.10	60.48	0.00	1.30	9.71
			110	50	1.62	1.51	59.04	0.00	1.26	9.42
			120	60	1.62	0.92	57.82	0.00	1.26	10.16
		2018 Tesla Model 3	70	10	2.99	0.47	60.05	0.00	1.04	8.64
			80	20	3.00	0.65	59.87	0.00	1.05	8.75
			90	30	3.03	2.57	59.62	0.00	1.16	9.21
			100	40	2.93	2.61	59.33	0.00	1.13	9.48
			110	50	3.00	2.14	59.22	0.00	1.12	9.13
			120	60	2.77	1.44	60.44	0.00	1.12	9.00

Scenario	Relative Velocity	Vehicle	SV Speed (km/h)	POV Speed (km/h)	FCW TTC (s)	Minimum Distance (m)	Speed Reduction (km/h)	Relative Impact Speed (km/h)	TTC of CIB Activation (s)	Peak Decel (m/s^2)
		2022 Lexus NX 250	70	10	2.45	0.91	59.00	0.00	1.27	10.59
			80	20	2.47	0.77	58.03	0.00	1.32	9.26
			90	30	2.53	0.86	59.72	0.00	1.33	9.66
			100	40	2.51	0.63	58.28	0.00	1.33	9.30
			110	50	2.59	0.77	59.33	0.00	1.31	9.42
			120	60	2.51	0.78	59.33	0.00	1.31	9.70
		2022 Toyota Prius Prime	70	10	0.81	0.00	1.13	55.30	0.00	2.06
			80	20	1.27	1.41	56.12	0.00	1.13	9.18
			90	30	2.83	0.19	59.76	0.00	1.09	9.43
			100	40	2.35	0.68	59.83	0.00	1.14	9.55
			110	50	2.80	0.72	58.50	0.00	1.11	9.82
			120	60	2.45	0.62	58.72	0.00	1.15	9.62
		2023 Hyundai Palisade	70	10	2.72	3.72	59.51	0.00	1.21	10.03
			80	20	2.72	4.09	57.78	0.00	1.25	9.29
			90	30	2.82	4.50	58.64	0.00	1.26	9.71
			100	40	2.83	5.20	58.43	0.00	1.27	9.72
			110	50	3.07	5.80	59.44	0.00	1.30	10.22
			120	60	2.68	6.19	57.31	0.00	1.30	10.43

As the relative velocity increased to 70 km/h, vehicle impacts with the target occurred more frequently across several vehicles including the Toyota Prius Prime, Hyundai Palisade, Honda Civic, and Ford Bronco. The Tesla Model 3 also experienced one impact during the 90_20 km/h SV/POV speed test scenario. During that test run, CIB activation occurred at a TTC of 1.06 seconds which was later compared to its average TTC of 1.14 seconds. The Lexus NX 250 and Volvo S60 avoided a collision on all test runs at 70 km/h relative velocity. Table 16 details the vehicle performance for the 70 km/h relative velocity test runs.

Table 16. CIB LVM With 70 km/h Relative Velocity

Scenario	Relative Velocity	Vehicle	SV Speed (km/h)	POV Speed (km/h)	FCW TTC (s)	Minimum Distance (m)	Speed Reduction (km/h)	Relative Impact Speed (km/h)	TTC of CIB Activation (s)	Peak Decel (m/s^2)
Lead Vehicle Moving	**70 km/h**	2022 Honda Civic	80	10	2.46	0.00	30.89	38.48	0.94	9.55
			90	20	2.21	0.00	32.33	37.12	1.03	9.06
			100	30	2.54	0.00	37.39	32.94	1.12	9.39
			110	40	2.61	0.00	31.97	38.45	0.96	9.43
			120	50	2.23	0.00	38.00	30.64	1.04	9.47
		2021 Ford Bronco	80	10	2.38	0.00	29.43	39.92	0.81	9.79
			90	20	2.31	0.00	25.94	43.45	0.90	9.70
			100	30	-	-	-	-	-	-
			110	40	-	-	-	-	-	-
			120	50	-	-	-	-	-	-
		2021 Volvo S60	80	10	2.90	1.36	68.54	0.00	1.24	10.03
			90	20	2.02	1.41	70.34	0.00	1.17	9.93
			100	30	2.07	0.74	68.98	0.00	1.26	9.62
			110	40	1.82	0.71	76.07	0.00	1.26	9.50
			120	50	1.97	0.77	69.77	0.00	1.25	9.82
		2018 Tesla Model 3	80	10	2.87	0.09	69.91	0.00	1.13	9.95
			90	20	2.84	0.00	56.74	13.10	1.06	9.98
			100	30	3.04	0.05	69.77	0.00	1.16	9.73
			110	40	2.96	0.32	68.58	0.00	1.14	9.38
			120	50	3.05	0.06	71.17	0.00	1.13	9.75
		2022 Lexus NX 250	80	10	2.68	0.78	69.66	0.00	1.40	10.48
			90	20	2.64	0.61	68.51	0.00	1.40	9.31
			100	30	2.73	0.76	69.52	0.00	1.39	9.41
			110	40	2.71	0.76	69.05	0.00	1.39	10.17

Scenario	Relative Velocity	Vehicle	SV Speed (km/h)	POV Speed (km/h)	FCW TTC (s)	Minimum Distance (m)	Speed Reduction (km/h)	Relative Impact Speed (km/h)	TTC of CIB Activation (s)	Peak Decel (m/s^2)
			120	50	2.74	0.55	68.47	0.00	1.36	9.76
		2022 Toyota Prius Prime	80	10	-	-	-	-	-	-
			90	20	2.89	0.00	47.36	21.82	1.01	10.05
			100	30	2.95	0.00	50.35	19.01	1.01	9.88
			110	40	2.11	0.30	67.79	0.00	1.06	10.14
			120	50	2.90	0.00	47.45	22.93	0.98	10.09
		2023 Hyundai Palisade	80	10	1.03	0.00	52.29	4.93	1.08	10.10
			90	20	2.43	0.00	62.86	7.96	1.30	10.10
			100	30	2.13	0.00	61.27	7.88	1.36	9.33
			110	40	2.59	0.00	62.33	7.06	1.33	10.01
			120	50	2.88	1.87	68.54	0.00	1.42	10.44

When the nominal relative velocity was 80 km/h, impacts occurred on every test run except for those performed with the Lexus NX 250, which was able to complete the entire LVM matrix without an impact. There was variability across the vehicles in many of the key data metrics including CIB activation timing and FCW alert TTC. For example, the Volvo S60 had FCW alerts at as early as 2.95 seconds TTC and as late as 2.03 seconds TTC for runs with the same relative velocity. The Toyota Prius Prime had CIB activations as early as 1.20 seconds but also as late as 0.90 seconds. For those vehicles exhibiting impacts, relative impact speeds ranged from a low of 8.5 km/h to a high of 64 km/h. For each test run, the vehicles all alerted prior to 2 seconds TTC. The Hyundai Palisade had FCW TTC timings earlier than the Lexus NX 250, but on average, applied the brakes at a TTC of 0.3 seconds later than the Lexus NX 250, which resulted in impacts with the target. Table 17 details the vehicle performance for the 80 km/h relative velocity test runs.

Table 17. CIB LVM With 80 km/h Relative Velocity

Scenario	Relative Velocity	Vehicle	SV Speed (km/h)	POV Speed (km/h)	FCW TTC (s)	Minimum Distance (m)	Speed Reduction (km/h)	Relative Impact Speed (km/h)	TTC of CIB Activation (s)	Peak Decel (m/s^2)
Lead Vehicle Moving	**80 km/h**	2022 Honda Civic	90	10	2.55	0.00	28.84	50.62	0.99	9.63
			100	20	2.58	0.00	32.33	47.95	1.02	9.86
			110	30	2.19	0.00	25.06	54.68	0.82	10.26
			120	40	2.58	0.00	30.98	49.00	0.96	9.61
		2021 Ford Bronco	90	10	2.33	0.00	15.43	63.90	0.68	11.12
			100	20	-	-	-	-	-	-
			110	30	-	-	-	-	-	-
			120	40	-	-	-	-	-	-
		2021 Volvo S60	90	10	2.03	0.00	55.66	24.52	1.29	10.33
			100	20	2.95	0.00	71.68	8.50	1.23	9.99
			110	30	2.22	0.00	48.60	30.53	1.33	10.86
			120	40	2.10	0.00	64.01	15.91	1.20	10.71
		2018 Tesla Model 3	90	10	2.63	0.00	61.52	18.61	1.14	10.14
			100	20	2.41	0.00	55.24	24.52	1.12	10.67
			110	30	2.11	0.00	52.78	26.10	1.10	10.15
			120	40	2.88	0.00	55.42	22.32	1.15	10.05
		2022 Lexus NX 250	90	10	2.68	0.79	78.41	0.00	1.56	10.77
			100	20	2.73	1.57	79.09	0.00	1.54	9.55
			110	30	2.78	0.85	78.55	0.00	1.54	9.82
			120	40	2.60	0.48	78.91	0.00	1.56	10.26
		2022 Toyota Prius Prime	90	10	-	-	-	-	-	-
			100	20	2.95	0.00	37.85	41.44	0.90	10.97
			110	30	2.92	0.00	39.20	40.14	0.93	10.85
			120	40	2.10	0.00	64.01	15.91	1.20	10.71

Scenario	Relative Velocity	Vehicle	SV Speed (km/h)	POV Speed (km/h)	FCW TTC (s)	Minimum Distance (m)	Speed Reduction (km/h)	Relative Impact Speed (km/h)	TTC of CIB Activation (s)	Peak Decel (m/s^2)
		2023 Hyundai Palisade	90	10	2.70	0.00	44.37	34.70	1.13	10.66
			100	20	2.93	0.00	64.37	15.12	1.15	10.13
			110	30	2.93	0.00	65.16	13.75	1.15	10.44
			120	40	2.95	0.00	66.01	13.68	1.25	10.54

CIB LVD

Table 18 outlines the results of the CIB LVD scenario. The Honda Civic and Ford Bronco struck on every run with relative impact speeds ranging from 6.9 km/h to 44.3 km/h. The Volvo S60 experienced two impacts for the 70_70 km/h SV/POV speed scenarios and three impacts for the 80_80 km/h scenarios. The Tesla Model 3 and Toyota Prius Prime only experienced impacts when the vehicle speeds were 80 km/h. The Hyundai Palisade only experienced impacts for speeds of 70 km/h and 80 km/h when the headway was 40 meters. The Lexus NX 250 experienced impacts when the headway was 12 meters at both 70 km/h and 80 km/h, but the relative impact speed for both test runs was below 5 km/h. Generally, vehicle performance was worse when the POV to SV headway was 40 meters rather than 12 meters. We noted during testing that the 40-meter headway test runs closely resembled LVS tests in feel to the driver of the SV. In particular, the 60 km/h test runs at 0.6g braking the SV was still traveling more than 50 km/h when the POV was at zero velocity for all vehicles.

Table 18. CIB LVD

Vehicle	SV Speed (km/h)	POV Speed (km/h)	Headway (m)	POV Decel Rate (g)	FCW TTC (s)	Minimum Distance (m)	Speed Reduction (km/h)	Relative Impact Speed (km/h)	TTC of CIB Activation (s)	Peak Decel (m/s^2)
2022 Honda Civic	60	60	12	0.5	2.14	0.00	25.71	17.78	0.84	9.98
				0.6	1.97	0.00	44.02	9.94	1.23	11.35
			40	0.5	4.30	0.00	41.29	19.04	1.08	10.03
				0.6	3.59	0.00	52.63	6.91	1.08	10.21
	70	70	12	0.5	2.68	0.00	26.53	19.33	0.91	9.86
				0.6	1.64	0.00	24.80	20.74	1.07	11.48
			40	0.5	4.47	0.00	31.18	38.95	1.18	9.89
				0.6	2.70	0.00	31.06	39.74	1.15	10.31
	80	80	12	0.5	1.78	0.00	20.94	20.99	0.88	8.66
				0.6	-	-	-	-	-	-
			40	0.5	4.52	0.00	29.45	44.32	1.22	10.84
				0.6	-	-	-	-	-	-
	60	60	12	0.5	2.33	0.00	16.52	21.60	0.65	10.01
				0.6	1.72	0.00	18.00	27.50	0.66	10.25

Vehicle	SV Speed (km/h)	POV Speed (km/h)	Headway (m)	POV Decel Rate (g)	FCW TTC (s)	Minimum Distance (m)	Speed Reduction (km/h)	Relative Impact Speed (km/h)	TTC of CIB Activation (s)	Peak Decel (m/s^2)
2021 Ford Bronco			40	0.5	2.42	0.00	31.86	27.25	0.92	10.54
				0.6	2.65	0.00	31.60	27.68	0.84	10.86
	70	70	12	0.5	1.78	0.00	11.92	25.60	0.48	10.46
				0.6	1.34	0.00	16.19	26.93	0.67	10.36
			40	0.5	3.65	0.00	27.13	42.88	0.91	10.21
				0.6	2.82	0.00	32.32	37.40	0.99	9.85
	80	80	12	0.5	1.85	0.00	16.59	25.27	0.62	10.52
				0.6	1.55	0.00	14.18	27.47	0.60	10.29
			40	0.5	4.20	0.00	36.04	40.25	1.13	10.69
				0.6	3.97	0.00	32.32	44.10	1.07	9.95
2021 Volvo S60	60	60	12	0.5	1.93	0.69	59.36	0.00	1.11	10.89
				0.6	3.22	1.06	59.00	0.00	1.53	11.41
			40	0.5	4.85	0.87	59.72	0.00	0.93	9.79
				0.6	5.03	0.87	59.40	0.00	0.97	10.28
	70	70	12	0.5	2.33	0.00	64.57	4.46	1.46	9.82
				0.6	3.11	0.00	64.75	4.68	1.49	10.15
			40	0.5	5.20	0.62	68.72	0.00	1.80	10.38
				0.6	5.73	0.92	69.08	0.00	1.79	10.99
	80	80	12	0.5	2.70	0.00	71.64	8.57	1.23	11.40
				0.6	2.42	0.00	71.15	9.90	1.22	11.89
			40	0.5	4.96	0.00	62.99	17.10	1.42	11.06
				0.6	5.82	0.78	79.82	0.00	1.83	10.61
2018 Tesla Model 3	60	60	12	0.5	1.73	2.59	53.24	0.00	1.09	10.69
				0.6	3.42	1.54	59.44	0.00	1.43	9.86
			40	0.5	2.83	4.50	58.36	0.00	1.12	10.17

Vehicle	SV Speed (km/h)	POV Speed (km/h)	Headway (m)	POV Decel Rate (g)	FCW TTC (s)	Minimum Distance (m)	Speed Reduction (km/h)	Relative Impact Speed (km/h)	TTC of CIB Activation (s)	Peak Decel (m/s^2)
				0.6	3.83	4.70	59.04	0.00	1.29	9.78
	70	70	12	0.5	1.81	0.01	69.77	0.00	1.29	9.65
				0.6	1.65	0.60	68.22	0.00	1.32	10.35
			40	0.5	2.81	0.36	70.2	0.00	1.10	10.31
				0.6	2.94	2.42	69.01	0.00	1.38	10.74
	80	80	12	0.5	1.74	0.00	80.03	0.00	1.17	9.77
				0.6	1.62	0.00	54.80	5.47	1.18	11.00
			40	0.5	2.53	0.00	53.16	27.18	0.74	11.30
				0.6	2.58	0.00	54.57	26.03	0.99	11.74
2022 Lexus NX 250	60	60	12	0.5	3.41	0.13	57.71	0.00	1.85	10.85
				0.6	-	-	-	-	-	-
			40	0.5	3.84	0.88	58.25	0.00	1.37	11.59
				0.6	-	-	-	-	-	-
	70	70	12	0.5	3.29	0.00	66.74	3.10	1.92	10.32
				0.6	-	-	-	-	-	-
			40	0.5	3.72	0.95	69.73	0.00	1.46	10.31
				0.6	-	-	-	-	-	-
	80	80	12	0.5	3.03	0.00	74.37	4.18	1.85	10.18
				0.6	-	-	-	-	-	-
			40	0.5	3.81	0.59	77.90	0.00	1.45	10.54
				0.6	-	-	-	-	-	-
2022 Toyota Prius Prime	60	60	12	0.5	4.10	0.60	58.97	0.00	1.55	8.82
				0.6	3.67	0.24	58.43	0.00	1.41	10.60
			40	0.5	3.09	0.71	58.90	0.00	1.39	9.20
				0.6	2.13	0.42	57.64	0.00	1.04	10.92

Vehicle	SV Speed (km/h)	POV Speed (km/h)	Headway (m)	POV Decel Rate (g)	FCW TTC (s)	Minimum Distance (m)	Speed Reduction (km/h)	Relative Impact Speed (km/h)	TTC of CIB Activation (s)	Peak Decel (m/s^2)
	70	70	12	0.5	3.12	1.33	61.70	0.00	1.74	10.79
				0.6	3.39	0.68	67.32	0.00	1.65	10.13
			40	0.5	3.68	0.52	69.80	0.00	1.54	10.92
				0.6	4.16	0.60	69.66	0.00	1.62	9.89
	80	80	12	0.5	3.43	0.32	79.20	0.00	1.39	10.76
				0.6	2.00	1.24	76.50	0.00	1.55	10.50
			40	0.5	3.28	0.81	79.16	0.00	1.58	10.94
				0.6	3.56	0.00	69.92	9.22	1.64	10.83
2023 Hyundai Palisade	60	60	12	0.5	3.60	0.92	59.80	0.00	1.52	9.71
				0.6	3.56	2.60	56.34	0.00	1.50	10.45
			40	0.5	4.31	1.29	59.83	0.00	1.14	9.86
				0.6	4.36	2.58	59.44	0.00	1.16	10.20
	70	70	12	0.5	3.86	4.22	48.10	0.00	1.81	9.99
				0.6	3.19	3.43	50.83	0.00	1.67	10.57
			40	0.5	4.32	0.00	43.39	25.99	1.06	11.29
				0.6	4.47	0.00	52.07	17.30	1.15	11.40
	80	80	12	0.5	3.32	3.73	41.26	0.00	1.49	10.50
				0.6	3.30	1.68	80.24	0.00	1.49	10.19
			40	0.5	4.28	0.00	49.67	29.56	1.20	12.38
				0.6	4.25	0.00	49.93	29.70	1.24	11.23

Head-On Collision Testing

FCW activations were minimal in the head-on collision scenarios and CIB activation did not occur in any test. Only the Honda Civic presented FCW alerts, albeit very late in the precrash timeline; at TTC = 0.11 seconds for the 30_15 SV/POV speed scenario and at TTC = 0.12 seconds for the 40_15 scenario. The LVD test results are provided in Table 19. Cells that are grey with dashed lines were not completed due to previous run performance.

As mentioned earlier, two additional unique scenarios were completed for the Lexus NX 250 to gather performance data (CCFhos and CCFhol). Both of these scenarios came from the Euro NCAP Test Protocol AEB Car-to-Car Systems Version 4.1.1. In the tests conducted with the Lexus NX 250, neither the FCW nor CIB were activated.

Table 19. Head-On Collision

Scenario	Vehicle	SV Speed (km/h)	POV Speed (km/h)	FCW TTC (s)	Minimum Distance (m)	Speed Reduction (km/h)	Relative Impact Speed (km/h)	TTC of CIB Activation (s)	Peak Decel (m/s^2)
Head-On Collision (HOC)	2022 Honda Civic	30	10	0.00	0.00	0.00	40.60	0.00	0.00
			15	0.11	0.00	0.04	44.80	0.00	0.08
			20	0.00	0.00	0.00	49.20	0.00	0.00
			25	0.00	0.00	0.00	54.40	0.00	0.00
			30	0.00	0.00	0.00	57.80	0.00	0.00
		40	10	0.00	0.00	0.00	49.60	0.00	0.00
			15	0.12	0.00	0.06	54.10	0.00	0.09
			20	-	-	-	-	-	-
			25	-	-	-	-	-	-
			30	-	-	-	-	-	-
		50	10	-	-	-	-	-	-
			15	-	-	-	-	-	-
			20	-	-	-	-	-	-
		60	10	-	-	-	-	-	-
	2021 Volvo S60	30	10	0.00	0.00	0.00	40.40	0.00	0.00
			15	0.00	0.00	0.00	44.70	0.00	0.00
			20	0.00	0.00	0.00	50.80	0.00	0.00
			25	0.00	0.00	0.00	53.20	0.00	0.00
			30	0.00	0.00	0.00	59.80	0.00	0.00
		40	10	0.00	0.00	0.00	48.80	0.00	0.00
			15	-	-	-	-	-	-
			20	-	-	-	-	-	-
			25	-	-	-	-	-	-
			30	-	-	-	-	-	-
		50	10	-	-	-	-	-	-
			15	-	-	-	-	-	-

Scenario	Vehicle	SV Speed (km/h)	POV Speed (km/h)	FCW TTC (s)	Minimum Distance (m)	Speed Reduction (km/h)	Relative Impact Speed (km/h)	TTC of CIB Activation (s)	Peak Decel (m/s^2)
			20	-	-	-	-	-	-
		60	10	-	-	-	-	-	-
	2022 Lexus NX 250	30	10	0.00	0.00	0.00	40.10	0.00	0.00
			15	0.00	0.00	0.00	45.40	0.00	0.00
			20	0.00	0.00	0.00	49.90	0.00	0.00
			25	0.00	0.00	0.00	54.70	0.00	0.00
			30	0.00	0.00	0.00	60.20	0.00	0.00
		40	10	0.00	0.00	0.00	50.30	0.00	0.00
			15	0.00	0.00	0.00	54.90	0.00	0.00
			20	-	-	-	-	-	-
			25	-	-	-	-	-	-
			30	-	-	-	-	-	-
		50	10	-	-	-	-	-	-
			15	-	-	-	-	-	-
			20	-	-	-	-	-	-
		60	10	-	-	-	-	-	-
CCFhos		50	50	0.00	0.00	0.00	None[1]	0.00	0.00
		70	70	0.00	0.00	0.00	None[1]	0.00	0.00
CCFhol		50	50	0.00	0.00	0.00	None[1]	0.00	0.00
		70	70	0.00	0.00	0.00	None[1]	0.00	0.00

[1]Steered away at TTC 0.8 seconds to mitigate damage.

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Observations

Primary Research Question 1 Observations

Table 20 displays aggregated LVS and LVM results and the average relative impact speed for all vehicles, and also separately for each AEB sensor type, as the nominal relative velocity increases.

Table 20. Average Relative Impact Speed as Nominal Relative Velocity Increases

Nominal Relative Velocity (km/h)	Average Relative Impact Speed (km/h) All Vehicles	Average Relative Impact Speed (km/h) Radar + Camera	Average Relative Impact Speed (km/h) Camera-Only
10	0.0	0.0	0.0
20	0.7	0.0	2.6
30	0.0	0.0	0.0
40	0.9	0.0	2.7
50	2.2	0.0	6.9
60	7.5	1.6	20.6
70	15.5	6.3	37.3
80	32.3	22.8	54.1

All testing with a nominal relative velocity of 40 km/h or below resulted in average relative impact speeds of less than 3 km/h, with complete collision avoidance achieved for most relative velocities. As the nominal relative velocity was increased past 40 km/h, the average relative impact speed increased, approximately doubling (or more) with each 10 km/h increase in relative velocity.

There is also a difference observed in the performance for camera-only AEB systems compared to those with both camera and radar. The relative impact speed of camera-only vehicles increased linearly with nominal relative velocity above 50 km/h. Average relative impact speeds for vehicles having both camera and radar systems were less than 2 km/h until nominal relative velocities reached 70 km/h at which point they started increasing following a polynomial trendline. Figure 9 shows those observations in more detail.

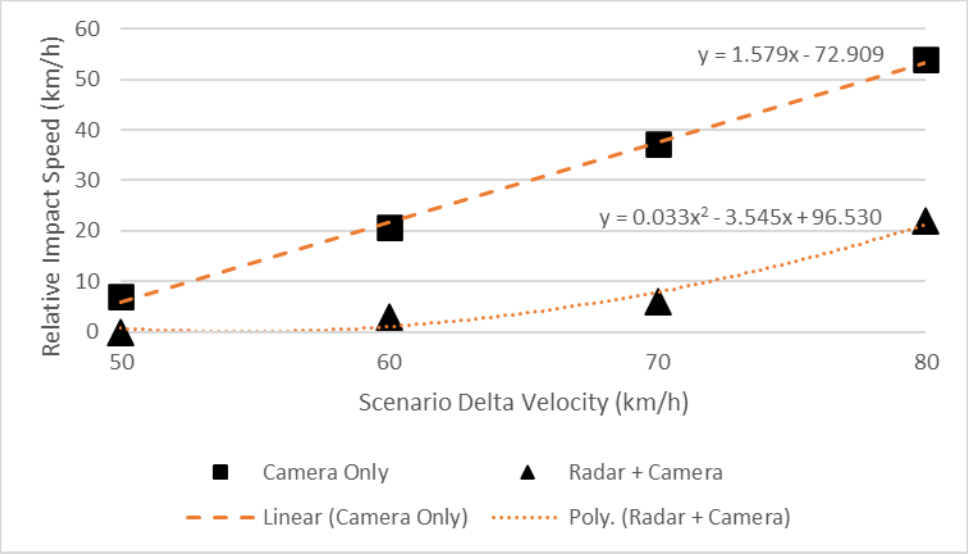


Figure 9. Differences Noted in Sensor Systems

For LVD test results specifically, there was very little difference in the average relative impact speed when the POV deceleration rate was 0.5 g versus 0.6 g. The largest performance drop-off occurred in the camera-only vehicles for higher SV speeds in the LVD scenario. While only two of the seven vehicles tested had camera-only AEB systems, in most scenarios, the average relative impact speed for the camera-only vehicles was much greater than that for vehicles equipped with both camera and radar, with differences ranging from a minimum of 16.9 km/h to a maximum of 35.6 km/h.

Table 21. LVD Average Relative Impact Speed Comparison

SV Speed (km/h)	POV Speed (km/h)	POV Decel Rate (g)	Initial Headway (m)	Average Relative Impact Speed (km/h)	Average Relative Impact Speed (km/h) Radar + Camera	Average Relative Impact Speed (km/h) Camera-Only
60	60	0.5	40	6.6	0.0	23.0
			12	5.5	0.0	19.4
		0.6	40	5.6	0.0	16.9
			12	6.3	0.0	18.8
70	70	0.5	40	15.3	5.1	40.7
			12	8.3	2.6	22.5
		0.6	40	15.9	4.4	38.8
			12	8.6	1.2	23.4
80	80	0.5	40	21.9	13.8	42.1
			12	9.2	3.5	23.6
		0.6	40	22.3	16.7	44.7
			12	8.6	3.9	27.5

Relative impact speeds continued to increase as SV and POV speeds increased in the LVD test scenarios. When the SV and POV speeds were 60 km/h, the vehicles equipped with camera and radar systems were able to avoid contact, whereas vehicles equipped with camera-only systems produced average relative impact speeds from 16.9 km/h to 23.0 km/h. At 70 km/h and 80 km/h the average relative impact speed increased no matter the sensor type. The increase in average relative impact speed was particularly noticeable in the 40 m headway compared to the 12 m headway. With the 12 m headway, the average relative impact speed was, in most cases, lower than the comparable 40 m headway test run. When the SV and POV speeds were 70 km/h and 80 km/h, the average relative impact speed was almost half when tested at 12 m headway compared to 40 m headway In the case of the camera-only vehicles, when reviewing video data and data traces, it was common for no speed reduction to occur until after the POV had already stopped, which did not allow enough time for the CIB system to reduce vehicle speed prior to an impact. Vehicles that are equipped with AEB systems enabled by both camera and radar began alerting and typically applying some speed reduction prior to the POV coming to a complete stop.

Primary Research Question 2 Observations

When evaluating the second research question, very few conclusions can be drawn from the head-on data gathered in this study. As previously discussed and shown in Table 19, no vehicles activated CIB during any of these test runs. Although the Honda Civic presented FCW alerts during two trials, both alerts occurred at a TTC less than 0.2 seconds, which is very late in the pre-crash timeline. Even during the Euro NCAP CCFhos and CCFhol tests performed with the Lexus NX 250, the vehicle did not provide any alerts during either scenario. Due to the lack of access to internal vehicle controller area network data for the test vehicles, it was not possible to determine if the POV was seen, if POV was seen but CIB classification confidence level was low, or if activating CIB in head-on crash situations (a capability that while mentioned in the user manual) can only occur under different, specific, conditions.

Primary Research Question 3 Observations

Regarding the third research question related to what is needed in terms of test procedure development for head-on crash CIB testing, Euro NCAP helps to provide some insights into head-on collision test performance assessment. The details of the scoring are located in the Assessment Protocol-Safety Assist Collision Avoidance document version 10.2 (Euro NCAP, 2023b). Based on this document, Euro NCAP has decided to award points to the vehicle based on the speed reduction of the SV. The highest number of points are given if the vehicle is able to reduce its speed greater than or equal to 20 km/h. No points are awarded if the speed reduction does not reach 10 km/h. Based on the number of points awarded, Euro NCAP appears to be expecting limited intervention from the vehicle, and that a collision with the POV, while reduced in severity, will still occur.

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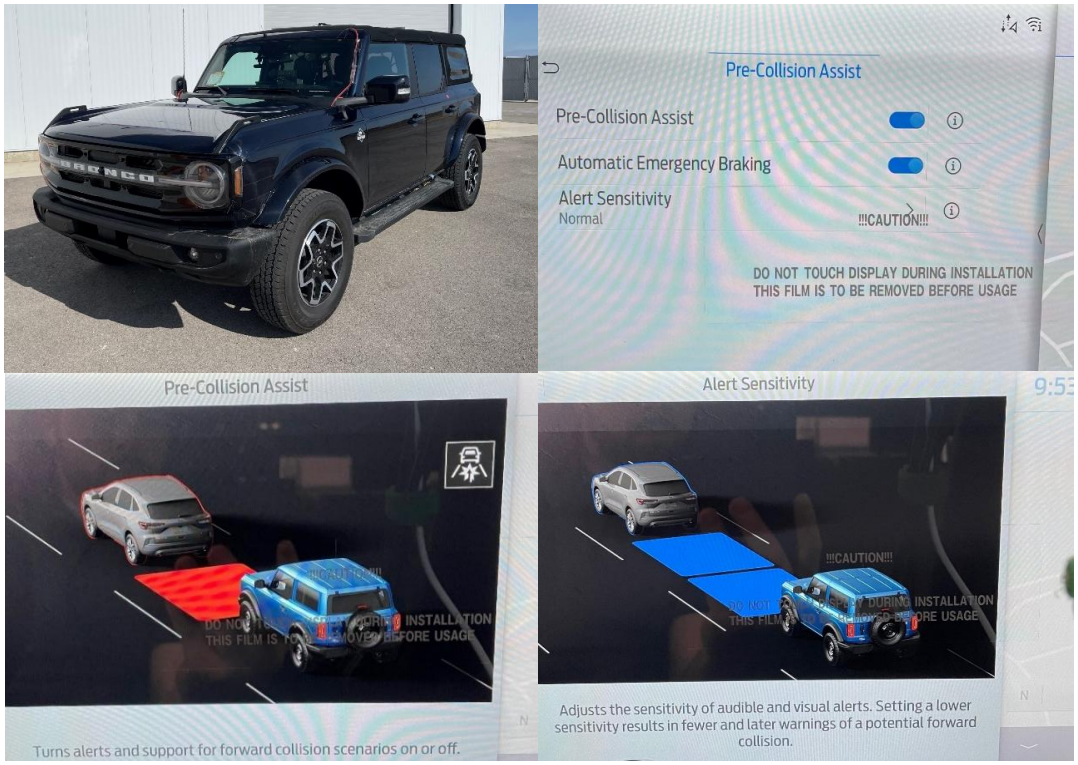
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Appendix A: Vehicle Information Sheets

Vehicle Information					
Make	Ford				
Model / Trim	Bronco / Outer Banks				
Body Style	Sport Utility Vehicle				
VIN	1FMDE5BH0MLB05883				
Date of Manufacture	012/21				
Exterior Color	Blue				
Pre-test Odometer Reading	399 Miles				
Date Vehicle Received	02/07/22				
Engine Type/Displacement	2.3L Inline 4 Cylinder Turbo EcoBoost				
Fuel Type	Unleaded 87				
Transmission Type	10 Speed Automatic				
Driveline Type (Rear, Front, or 4 Wheel Drive)	4 Wheel Drive				
Tire Size	255/70R18				
Manufacturer / Tire Name	Bridgestone / Dueler A/T				
Vehicle Weights (kg) from Placard	GVWR: 2685		Tire Pressure Recommendation from Placard (PSI)	LF: 35	RF: 35
	GAWR(Front): 1402	GAWR(Rear): 1393		LR: 35	RR: 35



Vehicle Information					
Make	Honda				
Model / Trim	Civic / Sport				
Body Style	4-door Sedan				
VIN	2HGFE2F57NH565294				
Date of Manufacture	01/22				
Exterior Color	Red				
Pre-test Odometer Reading	22 Miles				
Date Vehicle Received	02/11/22				
Engine Type/Displacement	2.0L 4 Cylinder				
Fuel Type	Unleaded 87				
Transmission Type	CVT				
Driveline Type (Rear, Front, or 4 Wheel Drive)	Front Wheel Drive				
Tire Size	235/40R18				
Manufacturer / Tire Name	Goodyear / Eagle Sport				
Vehicle Weights (kg) from Placard	GVWR: 1760		Tire Pressure Recommendation from Placard (PSI)	LF: 33	RF: 33
	GAWR(Front): 940	GAWR(Rear): 835		LR: 32	RR: 32



Vehicle Information					
Make	Hyundai				
Model / Trim	Palisade / Limited				
Body Style	Sport Utility Vehicle				
VIN	KM8R54GEXPU514521				
Date of Manufacture	07/22				
Exterior Color	Dark Gray				
Pre-test Odometer Reading	413 Miles				
Date Vehicle Received	09/27/22				
Engine Type/Displacement	3.8L V6				
Fuel Type	Unleaded 87				
Transmission Type	8 Speed Automatic				
Driveline Type (Rear, Front, or 4 Wheel Drive)	Front Wheel Drive				
Tire Size	245/50R20				
Manufacturer / Tire Name	Hankook / Ventus S1 noble2				
Vehicle Weights (kg) from Placard	GVWR: 2600		Tire Pressure Recommendation from Placard (PSI)	LF: 35	RF: 35
	GAWR(Front): 1340	GAWR(Rear): 1450		LR: 35	RR: 35





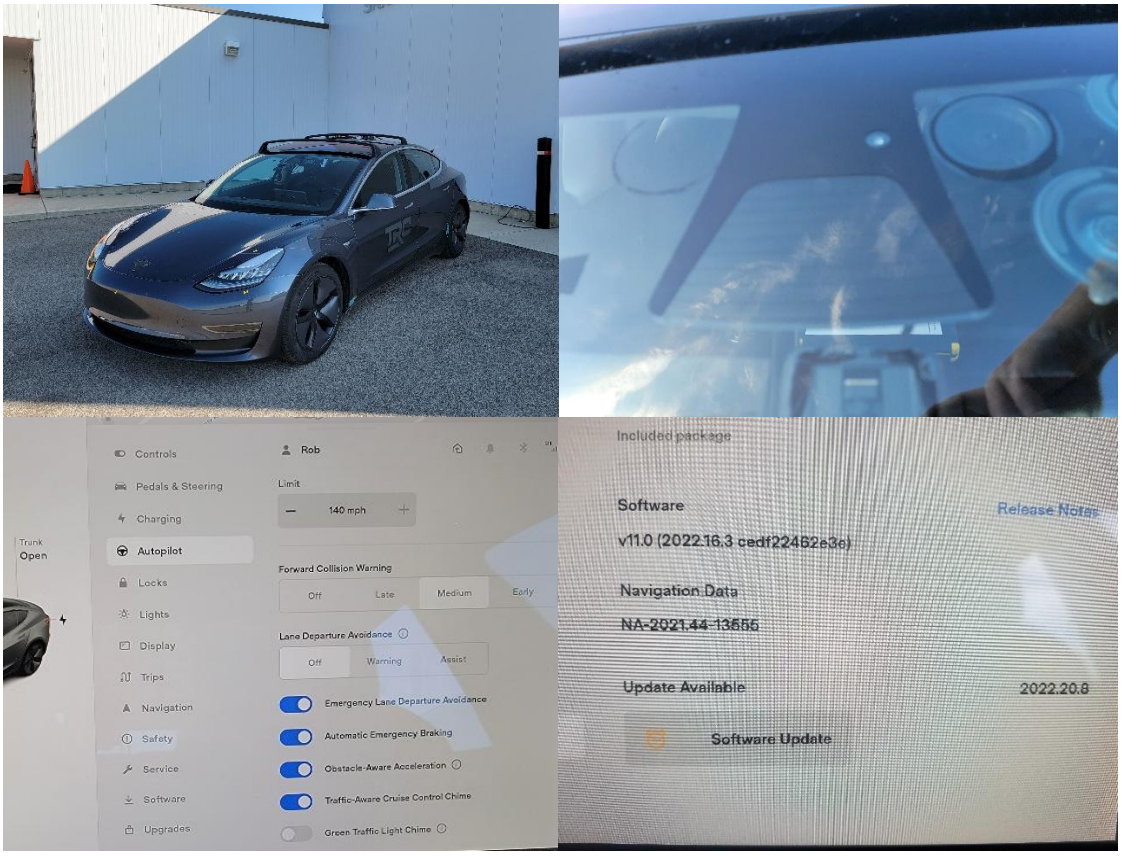




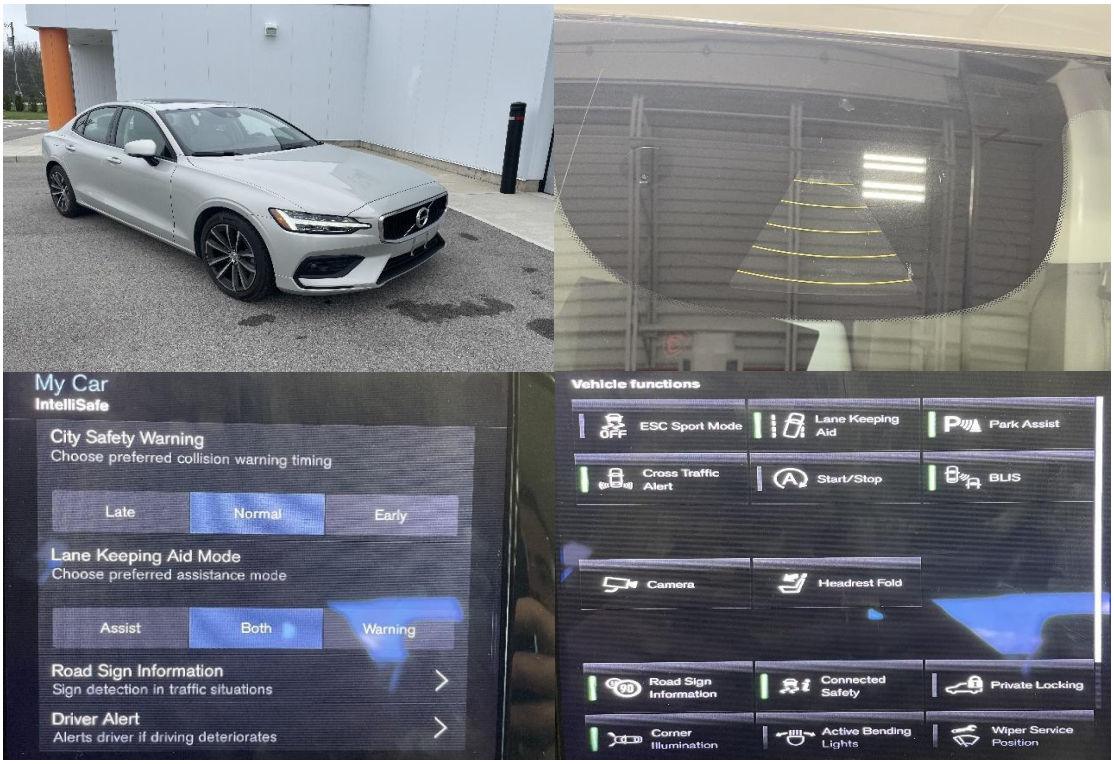
Vehicle Information					
Make	Toyota				
Model / Trim	Prius / Prime				
Body Style	5-door Hatchback				
VIN	JTDKAMFP9N3209177				
Date of Manufacture	12/21				
Exterior Color	Silver				
Pre-test Odometer Reading	3406 Miles				
Date Vehicle Received	09/22/22				
Engine Type/Displacement	Gasoline Hybrid 1.8L Inline 4 Cylinder Turbo				
Fuel Type	Unleaded 87 / Electricity				
Transmission Type	CVT				
Driveline Type (Rear, Front, or 4 Wheel Drive)	Front Wheel Drive				
Tire Size	195/65R15				
Manufacturer / Tire Name	Toyo / NanoEnergy				
Vehicle Weights (kg) from Placard	GVWR: 1930		Tire Pressure Recommendation from Placard (PSI)	LF: 36	RF: 36
	GAWR(Front): 1057	GAWR(Rear): 1016		LR: 35	RR: 35



Vehicle Information					
Make	Tesla				
Model / Trim	Model 3 / Dual Motor				
Body Style	4-door Sedan				
VIN	5YJ3E1EBXJF181304				
Date of Manufacture	12/18				
Exterior Color	Dark Gray				
Pre-test Odometer Reading	18848 Miles				
Date Vehicle Received	07/11/22				
Engine Type/Displacement	Dual Electric Motors				
Fuel Type	Electricity				
Transmission Type	1 Speed Fixed Gear				
Driveline Type (Rear, Front, or 4 Wheel Drive)	All Wheel Drive				
Tire Size	235/45R18				
Manufacturer / Tire Name	Michelin / Primacy MXM4				
Vehicle Weights (kg) from Placard	GVWR: 2265		Tire Pressure Recommendation from Placard (PSI)	LF: 42	RF: 42
	GAWR(Front): 1110	GAWR(Rear): 1257		LR: 42	RR: 42



Vehicle Information					
Make	Volvo				
Model / Trim	S60 / Momentum				
Body Style	4-door Sedan				
VIN	7JRA22TK8MG080346				
Date of Manufacture	08/20				
Exterior Color	Silver				
Pre-test Odometer Reading	27,236 Miles				
Date Vehicle Received	05/09/22				
Engine Type/Displacement	2.0L Inline 4 Cylinder Turbo				
Fuel Type	Unleaded Premium				
Transmission Type	8 Speed Automatic				
Driveline Type (Rear, Front, or 4 Wheel Drive)	All Wheel Drive				
Tire Size	235/45R18				
Manufacturer / Tire Name	Continental / ProContact				
Vehicle Weights (kg) from Placard	GVWR: 2281		Tire Pressure Recommendation from Placard (PSI)	LF: 36	RF: 36
	GAWR(Front): 1150	GAWR(Rear): 1159		LR: 36	RR: 36



Vehicle Information					
Make	Lexus				
Model / Trim	NX250				
Body Style	Sport Utility Vehicle				
VIN	JTJADCAZ1N2001478				
Date of Manufacture	01/22				
Exterior Color	Dark Green				
Pre-test Odometer Reading	600 Miles				
Date Vehicle Received	05/16/22				
Engine Type/Displacement	2.5L Inline 4 Cylinder				
Fuel Type	Unleaded 87				
Transmission Type	8 Speed Automatic				
Driveline Type (Rear, Front, or 4 Wheel Drive)	Front Wheel Drive				
Tire Size	235/60R18				
Manufacturer / Tire Name	Bridgestone / Alenza A/S				
Vehicle Weights (kg) from Placard	GVWR: 2660		Tire Pressure Recommendation from Placard (PSI)	LF: 35	RF: 35
	GAWR(Front): 1270	GAWR(Rear): 1270		LR: 35	RR: 35



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