DEPARTMENT OF TRANSPORTATION

National Highway Traffic Safety Administration

[Docket No. NHTSA–2024–0077]

New Car Assessment Program Final Decision Notice—Advanced Driver Assistance Systems and Roadmap

AGENCY: National Highway Traffic Safety Administration (NHTSA or the Agency), Department of Transportation (DOT).

ACTION: Final decision notice.

SUMMARY: This final decision notice adds four new advanced driver assistance systems (ADAS) technologies—blind spot warning (BSW), blind spot intervention (BSI), lane keeping assist (LKA), and pedestrian automatic emergency braking (PAEB)—to the New Car Assessment Program (NCAP) and enhances the performance evaluation of ADAS technologies currently in NCAP. The notice also finalizes a 10-year roadmap for updating NCAP through multiple phases for the period 2024 through 2033. This notice responds in part to the provisions in section 24213 of the Infrastructure, Investment, and Jobs Act.

DATES: Decisions on planned changes to the New Car Assessment Program are effective for the 2026 model year.

FOR FURTHER INFORMATION CONTACT: For technical issues, you may contact Ms. Taryn E. Rockwell, New Car Assessment Program, Office of Crashworthiness Standards (Telephone: (202) 366–1810). For legal issues, you may contact Ms. Sara R. Bennett, or Ms. Natasha D. Reed, Office of Chief Counsel (Telephone: (202) 366–2992). You may send mail to these officials at the National Highway Traffic Safety Administration, 1200 New Jersey Avenue SE, West Building, Washington, DC 20590–0001.

SUPPLEMENTARY INFORMATION:

Table of Contents

I. Executive Summary

Since its launch in 1978, NHTSA's New Car Assessment Program (NCAP) has supported NHTSA's mission to reduce the number of fatalities and injuries that occur on U.S. roadways. NCAP, like many other NHTSA programs, has contributed to significant reductions in motor vehicle related crashes, fatalities, and injuries, with passenger vehicle occupant fatalities decreasing from 32,043 to 26,325 from 2001 to 2021.[1] Unfortunately, this reduction was not universal, with pedestrian fatalities increasing by 51 percent during the same timeframe, from 4,901 to 7,388.[2] Despite improvements in automotive safety since NCAP's implementation, far more work must be done to reduce the continued high toll to human life on our nation's roads. In response to this need, on March 9, 2022, NHTSA published a Request for Comments (RFC) notice outlining proposed NCAP updates.[3]

After careful consideration of all comments received and applicable regulatory considerations, this notice announces the Agency's decision to update NCAP with the enhanced evaluation of advanced driver assistance systems (ADAS) technologies currently in NCAP[4] and to add four new ADAS technologies to NCAP: blind spot warning (BSW), blind spot intervention (BSI), lane keeping assist (LKA),[5] and pedestrian automatic emergency braking (PAEB). This notice also establishes a 10-year roadmap for updating NCAP through a multi-phased approach, with RFC notices planned over the next several years. NHTSA will address comments received on program elements outside the scope of the March 2022 RFC notice in subsequent final decision notices as part of the multi-phase efforts to update NCAP over the next several years.

A. Legal and Policy Considerations

In finalizing its decisions for this notice, in addition to comments received, the Agency sought to address requirements from the 2015 Fixing America's Surface Transportation (FAST) Act,[6] the 2021 Bipartisan Infrastructure Law (BIL), enacted as the Infrastructure Investment and Jobs Act,[7] and the U.S. Department of Transportation's National Roadway Safety Strategy. The Agency also took into consideration its May 9, 2024, final rule for FMVSS No. 127, "Automatic Emergency Braking for Light Vehicles."[8] These considerations are described below.

1. 2015 Fixing America's Surface Transportation Act

This final decision notice serves as NHTSA's initial step in fulfilling section 24322 of the FAST Act, which directs the Agency to promulgate a rule ensuring the display of crash avoidance information next to crashworthiness information on window stickers that manufacturers place on motor vehicles.[9] The Agency is currently working to develop a crash avoidance rating system based on comments received in response to several rating system concepts discussed in the March 2022 RFC, and this notice finalizes additional crash avoidance technologies that will be included in the future crash avoidance rating system.

2. 2021 Bipartisan Infrastructure Law

This notice also fulfills in part several mandates in section 24213 of the BIL, enacted on November 15, 2021 as the Infrastructure Investment and Jobs Act.[10] First, section 24213(a) requires NHTSA to "finalize the proceeding for which comments were requested" on December 16, 2015.[11] This final decision notice does so by adopting four new ADAS technologies discussed in the Agency's December 16, 2015 RFC notice,[12] thus finalizing that proceeding and notice.[13]

Second, this notice addresses the Advanced Crash-Avoidance Technologies portion of section 24213(b) of the BIL, which directs the Secretary of the Department of

[1] Traffic Safety Facts 2021 "*A Compilation of Motor Vehicle Crash Data.*" U.S. Department of Transportation. National Highway Traffic Safety Administration. NHTSA acknowledges a recent increase in passenger vehicle occupant fatalities occurring during the COVID–19 pandemic. In 2019, 22,372 passenger vehicle occupants were killed in traffic crashes.

[2] Traffic Safety Facts 2021 "*A Compilation of Motor Vehicle Crash Data.*" U.S. Department of Transportation. National Highway Traffic Safety Administration.

[3] Docket No. NHTSA–2021–0002. 87 FR 13452 (March 9, 2022).

[4] The ADAS technologies currently evaluated in NCAP are forward collision warning (FCW), lane departure warning (LDW), dynamic brake support (DBS), and crash imminent braking (CIB).

[5] "LKS" was used for this technology in the March 2022 RFC. However, in this final decision notice, "LKA" is used instead to maintain consistency with other agency initiatives.

[6] Public Law 114–94.

[7] Public Law 117–58.

[8] Docket No. NHTSA–2023–0021. 89 FR 39686 (May. 9, 2024).

[9] Section 24322 of the FAST Act, otherwise known as the "Safety Through Informed Consumers Act of 2015."

[10] Public Law 117–58.

[11] *Id.* at Section 24213(a); the notice referred to in the Bipartisan Infrastructure Law is 80 FR 78522 (Dec. 16, 2015).

[12] Docket No. NHTSA–2015–0119. 80 FR 78591 (Dec. 16, 2015).

[13] As communicated in the March 2022 RFC, while NHTSA is adopting a roadmap that includes aspects of the 2015 RFC, this notice is not an extension of the December 2015 notice.

Transportation to ''publish a notice, for the purposes of public comment, to establish a means for providing consumer information relating to advanced crash-avoidance technologies'' within one year of enactment that includes an appropriate methodology for: (1) determining which advanced crash avoidance technologies should be included in the information, (2) developing performance test criteria for use by manufacturers in evaluating those technologies, (3) determining a distinct rating system involving each crash avoidance technology, and (4) updating overall vehicle ratings to incorporate the advanced crash avoidance technology ratings. This notice satisfies two of these four requirements by (1) adopting established criteria for determining which advanced crash avoidance technology [14] should be included as referenced and discussed in the March 9, 2022 RFC notice, and (2) finalizing test procedures and criteria to evaluate performance for each of these advanced crash avoidance technologies. Although the Agency is not yet implementing a rating system for individual crash avoidance technologies, it has sought comments in this regard and has detailed plans in its roadmap to finalize such ratings, along with an updated overall (*i.e.,* crashworthiness and crash avoidance) rating, in the near future.

Third, this notice addresses the Vulnerable Road User Safety portion of section 24213(b), which directs the Secretary to publish a notice meeting similar requirements to those mandated for advanced crash avoidance technologies ''to establish a means for providing to consumers information relating to pedestrian, bicyclist, or other vulnerable road user safety technologies'' within one year of enactment. By applying the established inclusion criteria in the adoption of PAEB technology and the applicable test procedures and evaluation criteria included in this notice, two of the four requirements for the Vulnerable Road User Safety portion of section 24213(b) will be met. NHTSA will fulfill the remaining requirements when it proposes and finalizes a new rating system for the crash avoidance technologies in NCAP.

Fourth, this final decision notice fulfills the requirements in section 24213(c) of the BIL. This section states that, within one year of the law's enactment, the Secretary of the Department of Transportation shall establish a roadmap, vetted through the public comment process, identifying and prioritizing safety opportunities and technologies that could be used in future roadmaps, establishing a plan for implementation of NCAP changes, and considering the benefits of consistency with other U.S. and international rating systems. Section 24213(c) further specifies that the roadmap shall span a term of ten years, with five-year mid-term and five-year long-term components. Further, it requires updates to the roadmap at least once every four years to reflect new Agency interests and diverse stakeholder input (garnered annually), and in consideration of opportunities to benefit from collaboration and/or harmonization with third-party safety rating programs. As will be discussed herein, the Agency is taking steps to harmonize with existing consumer information rating programs, where possible and when appropriate, both for this NCAP update and future initiatives included in the program's roadmap. The Agency's proposed roadmap includes phased updates, as mandated, and was made available for public comment as part of the March 2022 RFC notice. As all relevant comments received have been considered prior to this notice's finalization, the Agency has fulfilled the requirements of section 24213(c). Additional details for the mid-term and long-term five-year spans are available in the NCAP Roadmap section of this notice.

3. 2022 U.S. Department of Transportation National Roadway Safety Strategy (NRSS)

The U.S. Department of Transportation published the National Roadway Safety Strategy (NRSS) in January 2022.[15] The NRSS announced key planned departmental actions aimed at significantly reducing serious roadway injuries and deaths to reach the Department's long-term zero roadway fatalities goal. At the core of the NRSS is the Department-wide adoption of the Safe Systems Approach,[16] which focuses on building layers of protection to both prevent crashes from happening and minimize harm when crashes do occur.

With respect to NCAP, the NRSS supports program updates emphasizing safety features that protect people both inside and outside the vehicle. These safety features may incorporate consideration of pedestrian protection systems, better understanding of impacts to pedestrians (*e.g.,* specific considerations for children), and may include automatic emergency braking and lane keeping assistance to benefit bicyclists and pedestrians. The NCAP program also works to identify the most promising vehicle technologies to help achieve NRSS's safety goals, such as alcohol detection systems and driver distraction mitigation systems. In addition, the NRSS includes a 10-year roadmap for the program and lists as a key departmental action the initiation of rulemaking to update the vehicle Monroney label. As part of that process, the Agency may also consider including information on features that mitigate safety risks for people outside of the vehicle.

This final decision notice presents NHTSA's initial actions towards the implementation of this broad, multi-faceted safety strategy for NCAP that includes improved road safety for both motor vehicle occupants and people outside of the vehicle, including pedestrians and other vulnerable road users. Additionally, the 10-year roadmap for the program presents a plan for the incorporation of future safety technologies and provides a projected timeline for updating the Monroney label to include crash avoidance information.

Relatedly, NRSS lists the initiation of a new rulemaking to require automatic emergency braking and pedestrian automatic emergency braking on passenger vehicles as a key departmental action. In response to this action, NHTSA published a final rule on May 9, 2024, establishing a new Federal motor vehicle safety standard, FMVSS No. 127, ''Automatic Emergency Braking for Light Vehicles.'' Similar to the changes adopted by NCAP in this notice, this final rule aims to reduce the frequency and associated injury and fatalities of rear-end and pedestrian crashes. Manufacturers must comply with the final rule by September 1, 2029.[17] This final decision notice will upgrade NCAP to provide consumers with additional vehicle safety information on AEB and PAEB technologies to help them make more informed purchasing decisions. NHTSA will identify vehicles that are equipped with these recommended technologies and pass NHTSA's performance criteria by way of check marks on the NHTSA website starting with model year 2026

[14] This notice refers to advanced crash avoidance technology as ADAS technology.

[15] U.S. Department of Transportation. (2020). ''National Roadway Safety Strategy, Version 1.1.'' *https://www.transportation.gov/sites/dot.gov/files/2022-02/USDOT-National-Roadway-Safety-Strategy.pdf.*

[16] *https://www.transportation.gov/NRSS/SafeSystem.*

[17] Vehicles produced by small-volume manufacturers, final-stage manufacturers, and alterers must be equipped with a compliant AEB system by September 1, 2030.

vehicles, as discussed in the following sections. Although the final rule and this decision on NCAP rely on the agency's separate authorities, NHTSA has sought to ensure that the revised test procedures for NCAP and the AEB final rule are compatible with one another, such that a manufacturer would be able to design a system that both received NCAP credit and would meet the requirements contained in the final rule.[18] NHTSA believes these collective efforts will lead to more rapid and complete market penetration of AEB and PAEB technologies.

II. Summary of Updates to NCAP and Roadmap for Future Updates

A brief summary of the updates to NCAP included in this final decision notice is provided below, along with the finalized 10-year roadmap for future updates to NCAP.

Updates To Crash Imminent Braking (CIB), Dynamic Brake Support (DBS), and Forward Collision Warning (FCW) Evaluations

This notice modifies the existing test conditions, evaluation procedure, and performance criteria for crash imminent braking (CIB) and dynamic brake support (DBS) systems, subject to the same test scenarios currently used in NCAP.[19] An overview of the amended test scenarios (Lead Vehicle Stopped (LVS), Lead Vehicle Moving (LVM), and Lead Vehicle Decelerating (LVD)) and test conditions (subject vehicle (SV) speed, principal other vehicle (POV) speed, POV headway, and POV deceleration) required to receive passing credit for AEB systems (*i.e.,* CIB and DBS collectively) in NCAP is shown in Tables 1 and 2. NHTSA will test vehicles starting with the lowest test speed for a test scenario and incrementally increase test speed according to the test matrix in Tables 1 and 2, with only one trial[20] conducted per test condition. The passing criterion for a test trial is no contact between the subject vehicle and principal other vehicle. If the subject vehicle contacts the principal other vehicle during a test trial, the vehicle fails the assessed test condition and the AEB test overall, whether CIB or DBS. In the event of subject vehicle-to-principal other vehicle contact, testing will cease for the test condition, respective test scenario, the AEB test being performed (*i.e.,* CIB or DBS), and the AEB assessment overall.[21] NHTSA will also continue to conduct the false positive[22] test scenario currently used in NCAP, but has modified the test conditions and requirements for passing performance. This test scenario evaluates the propensity of a vehicle's DBS system to activate inappropriately in a non-critical driving scenario that would not present a safety risk to the vehicle's occupants. A vehicle must pass each of the 19 required CIB test conditions to obtain credit for CIB and must also separately pass each of the 17 required DBS test conditions to obtain credit for DBS.

NHTSA is consolidating forward collision warning (FCW) testing to assess and evaluate FCW functionality during CIB and DBS testing in all test scenarios except NHTSA's false positive tests. For evaluations during CIB and DBS testing, the test vehicle must issue an FCW prior to the onset of automatic braking (as defined by the instant the subject vehicle deceleration reaches at least 0.15g) for the vehicle to pass each test trial run conducted as part of NCAP's CIB and DBS testing. If the required FCW is not issued prior to the onset of automatic braking imparted by CIB, the vehicle will fail the test trial and CIB/DBS assessment overall. NHTSA will conduct the AEB evaluation by (1) fully releasing the subject vehicle's accelerator pedal (at any rate) within 500 milliseconds (ms) after an FCW is issued (during CIB and DBS evaluations, and whether before or after automatic braking has begun), and (2) initiating manual (robotic) brake application at a time that corresponds to 1.0 ± 0.1 seconds after issuance of the required FCW signals (during DBS evaluations). A FCW must be presented to the vehicle operator via a minimum of two sensory modalities to receive credit in each of NCAP's CIB and DBS tests (except for the false positive test). A vehicle must present, at a minimum, an FCW comprised of visual and auditory signals. Finally, Revision G of the AB Dynamics (ABD) Global Vehicle Target (GVT) will be used as the principal other vehicle in NCAP testing instead of the currently used Strikable Surrogate Vehicle (SSV) test device. Other details of the test conditions and response to comments on updating CIB, DBS, and FCW evaluations are provided in relevant sections in this notice.

TABLE 1—ADOPTED CIB TEST SCENARIOS AND CONDITIONS

Test no.	Test scenario	SV speed (kph (mph))	POV speed (kph (mph))	POV headway (m (ft.))	POV deceleration (g)	Requirement to pass
1	LVS	40 (24.9)	0	n/a	n/a	No SV-to-POV contact during any test trial.
2		50 (31.1)	0	n/a	n/a	
3		60 (37.3)	0	n/a	n/a	
4		70 (43.5)	0	n/a	n/a	
5		80 (49.7)	0	n/a	n/a	
6	LVM	40 (24.9)	20 (12.4)	n/a	n/a	
7		50 (31.1)	20 (12.4)	n/a	n/a	
8		60 (37.3)	20 (12.4)	n/a	n/a	
9		70 (43.5)	20 (12.4)	n/a	n/a	
10		80 (49.7)	20 (12.4)	n/a	n/a	
11	LVD	50 (31.1)	50 (31.1)	40 (131.2)	0.3	
12		50 (31.1)	50 (31.1)	12 (39.4)	0.3	
13		80 (49.7)	80 (49.7)	40 (131.2)	0.3	
14		80 (49.7)	80 (49.7)	12 (39.4)	0.3	
15		50 (31.1)	50 (31.1)	40 (131.2)	0.5	
16		50 (31.1)	50 (31.1)	12 (39.4)	0.5	
17		80 (49.7)	80 (49.7)	40 (131.2)	0.5	

[18] See Appendix.

[19] CIB and DBS systems are collectively known as automatic emergency braking (AEB).

[20] Trial or test trial is a test among a set of tests conducted under the same test conditions (including test speed) with the same subject vehicle.

[21] In essence, because the Agency will provide an overall assessment for AEB performance, if a vehicle fails a trial run in the DBS test, testing will cease for the DBS assessment, and CIB assessments will not be conducted because the vehicle will have failed the AEB assessment overall.

[22] For purposes of this document, NHTSA uses ''false positive'' and ''false activation'' interchangeably, and the Agency intends for them to refer to the same situations.

TABLE 1—ADOPTED CIB TEST SCENARIOS AND CONDITIONS—Continued

Test no.	Test scenario	SV speed (kph (mph))	POV speed (kph (mph))	POV headway (m (ft.))	POV deceleration (g)	Requirement to pass
18		80 (49.7)	80 (49.7)	12 (39.4)	0.5	
19	False Positive (STP)	80 (49.7)	n/a	n/a	n/a	SV peak deceleration <0.25g

TABLE 2—ADOPTED DBS TEST SCENARIOS AND CONDITIONS

Test no.	Test scenario	SV speed (kph (mph))	POV speed (kph (mph))	POV headway (m (ft.))	POV deceleration (g)	Requirement to pass
1	LVS	70 (43.5)	0	n/a	n/a	No SV-to-POV contact during any test trial.
2		80 (49.7)	0	n/a	n/a	
3		90 (55.9)	0	n/a	n/a	
4		100 (62.1)	0	n/a	n/a	
5	LVM	70 (43.5)	20 (12.4)	n/a	n/a	
6		80 (49.7)	20 (12.4)	n/a	n/a	
7		90 (55.9)	20 (12.4)	n/a	n/a	
8		100 (62.1)	20 (12.4)	n/a	n/a	
9	LVD	50 (31.1)	50 (31.1)	40 (131.2)	0.3	
10		50 (31.1)	50 (31.1)	12 (39.4)	0.3	
11		80 (49.7)	80 (49.7)	40 (131.2)	0.3	
12		80 (49.7)	80 (49.7)	12 (39.4)	0.3	
13		50 (31.1)	50 (31.1)	40 (131.2)	0.5	
14		50 (31.1)	50 (31.1)	12 (39.4)	0.5	
15		80 (49.7)	80 (49.7)	40 (131.2)	0.5	
16		80 (49.7)	80 (49.7)	12 (39.4)	0.5	
17	False Positive (STP)	80 (49.7)	n/a	n/a	n/a	SV peak deceleration <0.25g over the baseline peak imparted by manual braking.

Adding Pedestrian Automatic Emergency Braking Evaluation

NHTSA is adding the evaluation of pedestrian automatic emergency braking (PAEB) to NCAP using four crossing test scenarios and two in-path test scenarios to evaluate PAEB in daylight and darkness lighting conditions with no overhead lights. For the crossing scenarios (S1), a walking adult or running child pedestrian mannequin crosses perpendicular to the vehicle's line of travel from either the driver's left or right side. For the in-path scenarios (S4), an adult pedestrian mannequin is slightly overlapped with the front of the vehicle and is either facing away while standing in front of the vehicle, or walking away from the vehicle, parallel to the flow of traffic.

The subject vehicle's lower beam headlamps will be used during all NCAP PAEB testing in dark lighting conditions, and the upper beam headlamps will not be engaged either manually or automatically by way of an advanced lighting system, such as adaptive driving beams, unless such a system cannot be deactivated. This requirement will apply even to those systems that are active by default when low beam headlamps are first engaged. The performance criterion for NCAP's PAEB tests will be no contact with the pedestrian mannequin. The 4activePA Adult and 4activePA Child pedestrian test mannequins (articulating mannequins) will be used for NCAP's PAEB evaluation.

NHTSA will test for each of the adopted PAEB test conditions at a minimum subject vehicle speed threshold of 10 kph (6.2 mph), increasing the subject vehicle speed in 10 kph (6.2 mph) increments until the maximum speed threshold is reached, so long as the test vehicle does not contact the pedestrian mannequin during each progressive speed tested. For test conditions S1a, S1b, S1e, S4a, and S4c, the Agency is adopting a maximum subject vehicle speed threshold of 60 kph (37.3 mph) for both daylight and darkness testing. For test condition S1d, NHTSA is adopting a maximum subject vehicle speed threshold of 60 kph (37.3 mph) for daylight testing and 40 kph (24.9 mph) for darkness testing. Should the subject vehicle contact the pedestrian mannequin during the initial run for any test speed, testing will cease for the test condition, respective test scenario, and PAEB testing overall for the particular lighting condition. Only one trial will be conducted per test condition and vehicles must pass all required tests (*i.e.,* no contact with pedestrian mannequin) to receive PAEB credit for the relevant lighting condition.

An overview of test scenarios and test parameters (pedestrian size, test speed, pedestrian motion, overlap, and obstruction) is provided in Tables 3 and 4.

TABLE 3—ADOPTED NCAP PAEB DAYLIGHT TEST CONDITIONS AND VARIANTS

Test condition	Size	Movement classification	Path origin	Overlap (%)	Obstruction	Test no.	Test speeds (kph (mph))	
							SV	Pedestrian
S4c	Adult (Facing Away).	Walk	Right	25	No	1	10 (6.2)	5 (3.1)

TABLE 3—ADOPTED NCAP PAEB DAYLIGHT TEST CONDITIONS AND VARIANTS—Continued

Test condition	Size	Movement classification	Path origin	Overlap (%)	Obstruction	Test no.	Test speeds (kph (mph))	
							SV	Pedestrian
						2	20 (12.4)	5 (3.1)
						3	30 (18.6)	5 (3.1)
						4	40 (24.9)	5 (3.1)
						5	50 (31.1)	5 (3.1)
						6	60 (37.3)	5 (3.1)
S4a	Adult (Facing Away).	Stationary	Right	25	No	7	10 (6.2)	0
						8	20 (12.4)	0
						9	30 (18.6)	0
						10	40 (24.9)	0
						11	50 (31.1)	0
						12	60 (37.3)	0
S1b	Adult	Walk	Right	50	No	13	10 (6.2)	5 (3.1)
						14	20 (12.4)	5 (3.1)
						15	30 (18.6)	5 (3.1)
						16	40 (24.9)	5 (3.1)
						17	50 (31.1)	5 (3.1)
						18	60 (37.3)	5 (3.1)
S1a	Adult	Walk	Right	25	No	19	10 (6.2)	5 (3.1)
						20	20 (12.4)	5 (3.1)
						21	30 (18.6)	5 (3.1)
						22	40 (24.9)	5 (3.1)
						23	50 (31.1)	5 (3.1)
						24	60 (37.3)	5 (3.1)
S1e	Adult	Run	Left	50	No	25	10 (6.2)	8 (5.0)
						26	20 (12.4)	8 (5.0)
						27	30 (18.6)	8 (5.0)
						28	40 (24.9)	8 (5.0)
						29	50 (31.1)	8 (5.0)
						30	60 (37.3)	8 (5.0)
S1d	Child	Run	Right	50	Yes	31	10 (6.2)	5 (3.1)
						32	20 (12.4)	5 (3.1)
						33	30 (18.6)	5 (3.1)
						34	40 (24.9)	5 (3.1)
						35	50 (31.1)	5 (3.1)
						36	60 (37.3)	5 (3.1)

TABLE 4—ADOPTED NCAP PAEB DARKNESS TEST CONDITIONS AND VARIANTS

Test condition	Size	Movement classification	Path origin	Overlap (%)	Obstruction	Test no.	Test speeds (kph (mph))	
							SV	Pedestrian
S4c	Adult (Facing Away).	Walk	Right	25	No	1	10 (6.2)	5 (3.1)
						2	20 (12.4)	5 (3.1)
						3	30 (18.6)	5 (3.1)
						4	40 (24.9)	5 (3.1)
						5	50 (31.1)	5 (3.1)
						6	60 (37.3)	5 (3.1)
S4a	Adult (Facing Away).	Stationary	Right	25	No	7	10 (6.2)	0
						8	20 (12.4)	0
						9	30 (18.6)	0
						10	40 (24.9)	0
						11	50 (31.1)	0
						12	60 (37.3)	0
S1b	Adult	Walk	Right	50%	No	13	10 (6.2)	5 (3.1)
						14	20 (12.4)	5 (3.1)
						15	30 (18.6)	5 (3.1)
						16	40 (24.9)	5 (3.1)
						17	50 (31.1)	5 (3.1)
						18	60 (37.3)	5 (3.1)
S1a	Adult	Walk	Right	25	No	19	10 (6.2)	5 (3.1)
						20	20 (12.4)	5 (3.1)
						21	30 (18.6)	5 (3.1)
						22	40 (24.9)	5 (3.1)
						23	50 (31.1)	5 (3.1)
						24	60 (37.3)	5 (3.1)

TABLE 4—ADOPTED NCAP PAEB DARKNESS TEST CONDITIONS AND VARIANTS—Continued

Test condition	Size	Movement classification	Path origin	Overlap (%)	Obstruction	Test no.	Test speeds (kph (mph))	
							SV	Pedestrian
S1e	Adult	Run	Left	50	No	25	10 (6.2)	8 (5.0)
						26	20 (12.4)	8 (5.0)
						27	30 (18.6)	8 (5.0)
						28	40 (24.9)	8 (5.0)
						29	50 (31.1)	8 (5.0)
						30	60 (37.3)	8 (5.0)
S1d	Child	Run	Right	50	Yes	31	10 (6.2)	5 (3.1)
						32	20 (12.4)	5 (3.1)
						33	30 (18.6)	5 (3.1)
						34	40 (24.9)	5 (3.1)

* All darkness testing to occur without the use of overhead artificial lighting.

Adding Blind Spot Warning (BSW) and Blind Spot Intervention (BSI) Evaluation

This notice adds assessments for two blind spot technologies, BSW and BSI, to NCAP's crash avoidance program. Blind spot warning (BSW) and blind spot intervention (BSI) will be evaluated separately in individual tests conducted in daylight with the principal other vehicle on the left and right side of the subject vehicle, with the subject vehicle turn signal indicator activated and not activated. BSW will be evaluated using tests representing the Straight Lane Converge and Diverge and Straight Lane Pass-by scenarios,[23] using an actual vehicle (representing a high production mid-size passenger car) as the principal other vehicle. For tests where the turn signal is not activated, a visual warning signal in the side mirror or the A-pillar must be issued within a specified time as detailed in the BSW test procedure. For tests where the turn signal is activated, an additional warning modality (*i.e.,* a dual-modality warning) or an escalating visual warning signal (*e.g.,* switches from steady-burning to flashing) is required within the time specified in the BSW test procedure.

For the BSW Straight Lane Converge and Diverge scenario, the test speed for both the subject vehicle and principal other vehicle will be 72.4 kph (45.0 mph). For the BSW Straight Lane Pass-by scenario, NHTSA will conduct the lowest speed differential condition (subject vehicle/principal other vehicle speeds of 72.4/80.5 kph (45.0/50.0 mph)) first. If the subject vehicle issues a passing BSW during the run, the principal other vehicle speed will be incrementally increased by 8.0 kph (5.0 mph) and testing will continue with one run conducted per speed differential condition until a principal other vehicle speed of 104.6 kph (65.0 mph) is reached. Testing will then be repeated following a similar methodology for principal other vehicle movement on the opposite side of the subject vehicle. If, for any speed differential condition, the subject vehicle does not issue a passing BSW, NHTSA will discontinue BSW testing for that vehicle model. Only one trial per BSW test condition will be conducted. An overview of the test scenarios and test parameters for the BSW tests is presented in Table 5. To obtain credit for BSW, the vehicle must pass all 20 tests for BSW.

TABLE 5—BLIND SPOT WARNING (BSW) ADOPTED TEST CONDITIONS

Test scenario	SV speed (kph (mph))	POV speed (kph (mph))	POV direction of approach	Turn signal
Straight Lane Converge and Diverge	72.4 (45)	72.4 (45)	Right	Enabled
				Disabled
			Left	Enabled
				Disabled
Straight Lane Pass-by	72.4 (45)	80.5 (50)	Right	Enabled
				Disabled
			Left	Enabled
				Disabled
		88.5 (55)	Right	Enabled
				Disabled
			Left	Enabled
				Disabled
		96.6 (60)	Right	Enabled
				Disabled
			Left	Enabled
				Disabled
		104.6 (65)	Right	Enabled
				Disabled
			Left	Enabled
				Disabled

[23] The two scenarios for assessing BSW were proposed in the March 2022 RFC notice and are described in a later section of this notice.

BSI will be evaluated using tests representing two lane change scenarios (Subject Vehicle Lane Change with Constant Headway and Subject Vehicle Lane Change with Closing Headway) and one false positive scenario (Subject Vehicle Lane Change with Constant Headway False Positive Assessment),[24] using Revision G of the ABD GVT as the principal other vehicle. All BSI evaluations will be conducted with adaptive cruise control (ACC), lane centering assistance (LCA), and/or lane keeping assist (LKA) technologies (if equipped and if the systems can be disengaged) turned off.

For the BSI Subject Vehicle Lane Change with Constant Headway and the False Positive tests, the test speed for both the subject vehicle and principal other vehicle will be 72.4 kph (45.0 mph). For the BSI Subject Vehicle Lane Change with Closing Headway tests, the subject vehicle test speed will be 72.4 kph (45.0 mph) and the principal other vehicle speed will be 80.5 kph (50 mph). In these tests, after a short period of steady-state driving, the subject vehicle driver (*i.e.,* robot) initiates a lane change and follows an 800 m (2,625 ft.) radius curved path towards the principal other vehicles' travel lane. The subject vehicle driver then releases the steering wheel upon the subject vehicle exiting the curve so as to achieve a steady state lateral velocity of 0.7 ± 0.1 m/s (2.3 ± 0.3 ft./s) relative to the line separating the subject vehicle and principal other vehicle travel lanes. Each test scenario is conducted with turn signal enabled and disabled and for both left and right lane change directions.

To pass the Subject Vehicle Lane Change with Constant Headway and the Subject Vehicle Lane Change with Closing Headway tests, the BSI system must prevent any contact between the subject vehicle and the principal other vehicle. The subject vehicle BSI intervention must not cause a secondary departure on the opposite side of the lane. To pass a false positive test, the BSI system must not intervene. Only one trial per BSI test condition will be conducted. An overview of the test scenarios and test parameters for the BSI tests is presented in Table 6. To obtain credit for BSI, the vehicle must pass all 12 tests.

TABLE 6—BLIND SPOT INTERVENTION (BSI) ADOPTED TEST CONDITIONS

Test scenario	SV speed (kph (mph))	POV speed (kph (mph))	Lane change direction	Turn signal
SV Lane Change with Constant Headway	72.4 (45)	72.4 (45)	Left	Enabled.
				Disabled.
			Right	Enabled.
				Disabled.
SV Lane Change with Closing Headway	72.4 (45)	80.5 (50)	Left	Enabled.
				Disabled.
			Right	Enabled.
				Disabled.
SV Lane Change with Constant Headway, False Positive Assessment.	72.4 (45)	72.4 (45)	Left	Enabled.
				Disabled.
			Right	Enabled.
				Disabled.

Adding Lane Keeping Assist (LKA) and Enhancing Lane Departure Warning (LDW) Evaluation

NHTSA is adding the assessment of lane keeping assist (LKA) into NCAP and integrating the evaluation of lane departure warning (LDW) with the LKA evaluation. To evaluate a vehicle's LDW sensitivity and LKA intervention capabilities, NHTSA's testing includes the use of a single solid white lane line, dashed yellow lane line, or Botts' dots (raised pavement markers) on either the right or left side of the vehicle's travel lane, depending on testing direction. Additional tests will be conducted with two lane lines (solid yellow and dashed white lines, and dashed white and solid white lines) to evaluate a vehicle's ability to properly correct its heading to prevent a secondary lane departure after the initial intervention. For the LDW/LKA tests, the subject vehicle, traveling at a speed of 72.4 kph (45 mph), heads towards the lane line using an initial path defined by a 1,200 m (3,937 ft.) radius curve. Tests will be conducted by incrementing the lateral velocity of the subject vehicle's approach toward the lane line from 0.2 to 0.6 m/s (0.7 to 2.0 ft./s) in 0.1 m/s (0.3 ft./s) increments.

To pass the criteria of the LDW/LKA evaluation test, the subject vehicle must issue a visual signal when the lateral position of the vehicle, represented by a two-dimensional polygon, is within 0.75 m (2.5 ft.) of the inboard edge of the lane line and before the lane departure exceeds 0.3 m (1 ft.). The LKA intervention itself will serve as a secondary haptic alert component. Neither an LDW nor LKA intervention shall occur when a vehicle has not departed its lane and is farther than 0.75 m (2.5 ft.) from the inboard edge of the lane line. In addition, the visual warning signal and LKA intervention must be issued before the lane departure exceeds 0.3 m (1 ft.), and the visual alert must be issued prior to, or concurrent with, the start of the LKA intervention. Only one trial per test condition is conducted. An overview of the test scenarios and test parameters for the LDW/LKA tests is presented in Table 7. To obtain credit for LDW and LKA, the vehicle must pass all 50 tests performed during the LDW/LKA performance assessment.

[24] These three scenarios for assessing BSI were proposed in the March 2022 RFC notice and are described in a later section of the notice.

TABLE 7—LANE DEPARTURE WARNING (LDW)/LANE KEEPING ASSIST (LKA) ADOPTED TEST CONDITIONS

Test scenario	Line type	Departure direction	Lateral velocity (m/s (ft./s))	Passing criteria	
				Maximum SV excursion (m (ft.))	LDW alert issued (m (ft.))
Primary Departure (Single Straight Lane Line)	Solid White	Left	0.2 (0.7)	−0.3 (−1.0)	0.75 to −0.3 (2.5 to −1.0).
			0.3 (1.0)		
			0.4 (1.3)		
			0.5 (1.6)		
			0.6 (2.0)		
	Solid White	Right	0.2 (0.7)		
			0.3 (1.0)		
			0.4 (1.3)		
			0.5 (1.6)		
			0.6 (2.0)		
	Dashed Yellow	Left	0.2 (0.7)		
			0.3 (1.0)		
			0.4 (1.3)		
			0.5 (1.6)		
			0.6 (2.0)		
	Dashed Yellow	Right	0.2 (0.7)		
			0.3 (1.0)		
			0.4 (1.3)		
			0.5 (1.6)		
			0.6 (2.0)		
	Raised Pavement Markers.	Left	0.2 (0.7)		
			0.3 (1.0)		
			0.4 (1.3)		
			0.5 (1.6)		
			0.6 (2.0)		
	Raised Pavement Markers.	Right	0.2 (0.7)		
			0.3 (1.0)		
			0.4 (1.3)		
			0.5 (1.6)		
			0.6 (2.0)		
Secondary Departure (Dual Straight Lane Line)	Solid Yellow (L)/ Dashed White (R).	Left	0.2 (0.7)	−0.3 (−1.0)	0.75 to −0.3 (2.5 to −1.0).
			0.3 (1.0)		
			0.4 (1.3)		
			0.5 (1.6)		
			0.6 (2.0)		
	Solid Yellow (L)/ Dashed White (R).	Right	0.2 (0.7)		
			0.3 (1.0)		
			0.4 (1.3)		
			0.5 (1.6)		
			0.6 (2.0)		
	Dashed White (L)/Solid White (R).	Left	0.2 (0.7)		
			0.3 (1.0)		
			0.4 (1.3)		
			0.5 (1.6)		
			0.6 (2.0)		
	Dashed White (L)/Solid White (R).	Right	0.2 (0.7)		
			0.3 (1.0)		
			0.4 (1.3)		
			0.5 (1.6)		
			0.6 (2.0)		

NCAP Roadmap 2024–2033

NHTSA has developed a final roadmap to update NCAP through multiple phases from 2024 through 2033, with mid-term roadmap items spanning the period 2024–2028, and long-term items spanning the period 2024–2033. The NCAP roadmap includes four phases for each NCAP initiative, along with a completion milestone for each phase. The four phases are: (1) Research phase, if applicable, (2) Request for comment (RFC) phase, (3) Final decision phase, and (4) Implementation phase. NHTSA plans updates to NCAP in the following three safety programs: crashworthiness, crash avoidance, and vulnerable road user safety. A summary of the mid-term and long-term actions for this roadmap is presented in Tables 8 and 9, respectively. The timeframe shown for the research, RFC, and final decision phases is in calendar years. The start of the implementation phase is in the fourth quarter of the calendar year shown in the two tables. Note that the implementation phase starts with vehicle models of the following calendar year shown in Tables 8 and 9. NHTSA plans to update the NCAP roadmap approximately every four years, with timelines updated accordingly. Details of the NCAP roadmap are provided in the roadmap section of this notice.

TABLE 8—ROADMAP FOR MID-TERM UPGRADES TO NCAP

[In calendar years]

Potential updates to NCAP evaluations	Research phase	RFC phase	Final decision phase	Implementation phase start in 4th quarter
Crash Avoidance Program:				
Enhanced FCW, CIB, DBS			2023–2024	2025
LDW+LKA and BSW+BSI			2023–2024	2025
Rear Automatic Braking	2024	2025	2025–2026	2027
Crashworthiness Program:				
THOR–50M in Frontal Crash Tests and HIII–05F * in Driver Position in Frontal Rigid Barrier Crash Test	2024	2024–2025	2025–2026	2027
Frontal Oblique Crash Test with THOR–50M	2024	2024–2025	2025–2026	2027
WorldSID–50M in Side Impact Tests, and SID–IIs ** Rib Deflections for Injury Risk Assessment	2024	2024–2025	2025–2026	2027
Vulnerable Road User (VRU) Safety Program:				
PAEB (day and night-time)			2023–2024	2025
Crashworthiness Pedestrian Protection			2023–2024	2025
Unattended Child Alert System (Availability of Direct Sensing Technologies Noted in Safety Features Section on Ratings Webpage)				2024
Bicyclist and Motorcyclist AEB (along path scenarios)	2024–2025	2025	2025–2026	2027
Vehicle Safety Rating:				
Rating System for Crash Avoidance Technologies			2024–2025	2027
Rating Systems for Crashworthiness, VRU Safety, and Overall Safety		2024–2025	2025–2026	2027
Monroney Label Rulemaking—Crash Avoidance, Crashworthiness, VRU Safety, and Overall Safety Ratings	2023–2024	2025	2025–2026	2027

* The advanced 5th percentile female frontal impact test dummy, THOR–05F, is currently under evaluation/refinement and is included in the long-term NCAP update in this roadmap. Until THOR–05F is completed and included in NCAP, NHTSA will use the current HIII–05F dummy in frontal crash tests.

** The advanced 5th percentile female side impact test dummy, WorldSID–05F, is currently under development and its use in NCAP will be considered in the long-term section of this roadmap. Until WorldSID–05F is included in NCAP, the SID–IIs will be used in NCAP along with thoracic and abdominal deflection measurements.

TABLE 9—ROADMAP FOR LONG-TERM UPGRADES TO NCAP

[In calendar years]

Potential updates to NCAP Evaluations	Research phase	RFC phase	Final decision phase	Implementation phase start in 4th quarter
Crash Avoidance Program:				
Headlighting System (Advanced Driving Beam, Semi-Automatic Beam Switching, and Lower Beam Headlamp)	2024–2026	2026–2027	2028	2030
AEB for Intersection Crash Scenarios	2025–2027	2028	2029	2031
Enhanced LKA (Higher Speed, Curved Road and/or Road Edge Detection Scenarios)	2024–2026	2027	2028	2030
Enhanced AEB (Speed and Additional Scenarios)	2026–2028	2029	2030	2032
Driver Monitoring Systems—Distracted/Drowsy Driving	2023–2027	2028	2029	2031
Intelligent Speed Assist	2024–2028			
Crashworthiness Program:				
THOR–05F in Frontal Crash Tests in Front and Rear Seating Positions	2023–2027	2027–2028	2028–2029	2031
WorldSID–05F in Side Impact Crash Tests	2023–2029	2029–2030	2030–2031	2033
VRU Safety Program:				
Enhanced AEB for Bicyclists and Motorcyclists in Intersection Crashes	2025–2026	2027	2028	2030
BSW and BSI Evaluation for Bicyclists and Motorcyclists Crash Protection	2025–2026	2027	2028	2030
Crashworthiness Pedestrian Protection using aPLI *	2024–2025	2026	2027	2029
Enhanced PAEB (Speed and Additional Scenarios)	2026–2028	2029	2030	2032
Driver Visibility	2023–2027			

* aPLI is the advanced pedestrian legform impactor. It assesses pedestrian injuries to the knee, upper leg, and lower leg in impacts with the front of vehicles.

III. Background

The National Highway Traffic Safety Administration's (NHTSA's) New Car Assessment Program (NCAP) supports the Agency's mission to reduce the number of fatalities and injuries that occur on U.S. roadways by providing important vehicle safety information to consumers to inform their purchasing decisions. The last major NCAP upgrade occurred on July 11, 2008, and took effect with model year 2011 vehicles.[25] That program update included the Agency's adoption of new frontal and side anthropomorphic test devices (crash test dummies) and associated injury criteria, a new oblique side pole test, and a new overall rating system combining the individual frontal, side, and rollover ratings. NHTSA also expanded NCAP to include assessment of three advanced driver assistance systems (ADAS) technologies: forward collision warning (FCW), lane departure warning (LDW), and electronic stability

[25] 73 FR 40016 (July 11, 2008).

control (ESC).[26] Through that expansion, the Agency began to identify which vehicles were equipped with these technologies and met specified performance requirements, making this information available on the NHTSA website. In November 2015, NHTSA also added crash imminent braking (CIB) and dynamic brake support (DBS) technologies (also known as automatic emergency braking, or AEB technology) to its ADAS assessments, with implementation beginning with model year 2018 vehicles.[27]

In December 2015, the Agency published a Request for Comments (RFC) notice with planned changes to the overall NCAP program. The notice sought comment on NCAP's potential use of enhanced tools and techniques to evaluate the safety of vehicles, generate star ratings, and encourage further vehicle safety developments.[28] The RFC notice also outlined planned changes for the crashworthiness, crash avoidance, and ratings categories. Many commenters responding to the December 2015 RFC notice stated it lacked sufficient detail and supporting information to allow for thorough review and comment. Commenters also expressed concern over test procedure repeatability and reproducibility based on the RFC notice's lack of detail, performance criteria, and non-standardized test devices. NHTSA hosted a public meeting in October 2018 to re-engage stakeholders and seek up-to-date input to help the Agency plan the future of NCAP.

On March 9, 2022, NHTSA published an RFC notice proposing changes to NCAP in response to the comments received from the 2015 RFC and public meetings, which partially fulfills the Agency's obligations under the 2015 Fixing America's Surface Transportation (FAST) Act directive and recent mandates included in section 24213 of the November 2021 Bipartisan Infrastructure Law (BIL). The proposed changes include:

- Changes to test procedures and performance criteria, including an increase in stringency, for the four currently recommended ADAS technologies in NCAP (FCW, LDW, DBS, and CIB) to enhance evaluation of the systems' capabilities in current vehicle models, reduce test burden, and promote harmonization with other consumer information programs.
- The addition of four new ADAS technologies—blind spot warning (BSW), blind spot intervention (BSI), lane keeping assist (LKA), and pedestrian automatic emergency braking (PAEB)—to those currently recommended by NCAP and highlighted on the Agency's website. The Agency proposed to incorporate these four new ADAS technologies into NCAP because data indicates they satisfy NHTSA's four prerequisites for inclusion in the program: (1) a known safety need exists; (2) system designs (countermeasures) exist that can mitigate the safety problem; (3) existing or new system designs have the potential to improve safety; and (4) a performance-based objective test procedure exists that can assess system performance.[29]
- A ''roadmap'' of the Agency's plans to update NCAP in phases over the next ten years, setting forth NHTSA's mid-term and long-term strategies for upgrading the program using a phased approach. The roadmap presents an *estimated* timeframe for the issuance of phased request for comment notices to incorporate various potential program components. However, NHTSA would only issue proposals to update the program as technologies mature and are considered ready for inclusion such that they meet the program's four prerequisites. Following each proposal, NHTSA will issue a final decision notice responding to the comments received and providing the Agency's decisions for that particular program update, as well as the lead time for implementation.

In addition to these proposed changes, the RFC notice proposed operational changes to streamline the information provided to consumers. Specifically, the Agency proposed a process for updating ADAS-related information provided to consumers to reflect changes made to vehicles during the middle of a model year. Further, although not explicitly proposed in the RFC notice, the Agency sought comment on the following topics to help guide future proposals:

- The Agency's plan to develop a new ADAS rating system for NCAP to provide consumers with improved data to compare and shop for vehicles and spur improved ADAS performance. NCAP currently assigns ratings to vehicles based on their performance in crashworthiness (*i.e.,* frontal and side impact) and rollover tests, but the program has no complementary rating system to differentiate performance among vehicles' crash avoidance systems. Instead, NCAP only recommends certain ADAS technologies to shoppers and identifies vehicles that offer the recommended technologies that pass the program's system performance criteria.
- Steps to include crash avoidance rating information on a vehicle's window sticker (*i.e.,* the Monroney label) at the point of sale, consistent with the 2015 FAST Act. The Agency noted that it is currently conducting consumer research to determine how best to present such information to maximize its effectiveness in informing vehicle purchasing decisions. NHTSA stated that it would consider the information gained from this research in conjunction with related comments received in response to the 2022 RFC to develop a proposal for a revised label, which will be detailed in a separate RFC notice.
- Expanding NCAP to include safety technologies that promote NHTSA's continuing efforts to combat unsafe driving or riding behaviors, such as speeding and drowsy, impaired, distracted, and unbelted driving, as well as safety technologies that may prevent unintentional human behavior that may result in injury or death, such as vehicular heatstroke.
- The Agency's ideas for updating several programmatic aspects of NCAP, including adding new crash test dummies, updating the rollover risk curve, and enhancing the presentation and dissemination of safety information provided to consumers to improve the program. More specifically, NHTSA requested comment on several potential ways to revise the 5-star safety ratings system, including adopting a points-based rating system concept, revising the baseline risk, and incorporating decimal or half-star ratings.
- Additional considerations that would allow NCAP to remain effective and relevant to improve vehicle safety, such as proposed updates to the NCAP website and the development of an NCAP database to modernize the operational aspects of the program, including a new vehicle information submission process for vehicle manufacturers.

Following publication of the March 2022 RFC notice, NHTSA received comments generally supportive of the Agency's proposal to adopt additional crash avoidance elements. Additional details of NHTSA's proposal for each of

[26] ESC was removed from the Agency's list of recommended ADAS technologies through NCAP beginning in model year 2014 when the technology became mandated under Federal motor vehicle safety standard (FMVSS) No. 126, ''Electronic stability control.'' NHTSA also included rear video systems in its list of recommended technologies under NCAP from model years 2014 to 2017 and removed that technology from its list when it became mandated under FMVSS No. 111, ''Rear visibility.''

[27] 80 FR 68604 (Nov. 5, 2015).

[28] 80 FR 78521 (Dec. 16, 2015).

[29] See NCAP Rating FAQ No. 07, *http://nhtsa.gov/ratings.*

the items listed above is provided in later sections.

Summary of General Comments on Proposed Updates to NCAP

NHTSA received over 4,000 comments in response to the March 2022 RFC notice.[30] The Agency received comments from a wide variety of commenters including safety advocacy groups, trade associations, vehicle manufacturers, suppliers and developers, government agencies and associations, test laboratories, an insurance company, a research/consulting firm, and individual members of the public. A summary of the commenters to the March 2022 RFC notice is provided in Table 10.

TABLE 10—COMMENTERS TO THE MARCH 2022 NCAP RFC NOTICE

Category	Commenters
Safety Advocacy Groups	AAA Inc. (AAA), AARP, Advanced Mobility Group, Advocates for Highway and Auto Safety (Advocates), American Motorcyclist Association (AMA), Center for Auto Safety (CAS), Consortium for Constituents with Disabilities Transportation Task Force (CCD Transportation Task Force), Consumer Reports (CR), Insurance Institute for Highway Safety (IIHS), Kids and Car Safety (KAC), Families for Safe Streets (FSS), Intelligent Transportation Society of America (ITS America), Massachusetts Vision Zero Coalition, The League of American Bicyclists (The League), Vision Zero Network (VZN), and ZF Group.
Industry Trade Associations	Alliance for Automotive Innovation (Auto Innovators), Automotive Safety Council (ASC), Motor & Equipment Manufacturers Association (MEMA), Motorcycle Industry Council and Motorcycle Safety Foundation (MIC/MSF), National Automobile Dealers Association (NADA), Specialty Equipment Market Association (SEMA), The Lidar Coalition.
Vehicle Manufacturers	American Honda Motor Co., Inc. (Honda), BMW of North America, LLC (BMW), FCA US LLC (FCA), Ford Motor Company (Ford), General Motors (GM), Hyundai America Technical Center, Inc. (HATCI), Hyundai Motor North America (Hyundai), Mercedes-Benz, LLC, a division of Mercedes-Benz Automotive Group (Mercedes-Benz), North American Subaru, Inc. (Subaru), Rivian Automotive, LLC (Rivian), Tesla, Inc. (Tesla), Toyota Motor North America (Toyota).
Suppliers and Developers	Aptiv PLC (Aptiv), Bosch LLC (Bosch), DENSO Corporation (DENSO), Intel Corporation (Intel), Robert Vayyar, Velodyne Lidar, Inc. (Velodyne).
Government Agencies and Associations	American Association of State Highway and Transportation Officials (AASHTO), National Association of City Transportation Officials (NACTO), National Transportation Safety Board (NTSB), New York City Department of Transportation & New York City Department of Citywide Administrative Services, Vision Zero Task Force (NYC DOT/NYC DCAS, Vision Zero Task Force).
Test Laboratories	Applus IDIADA (IDIADA), Dynamic Research Inc. (DRI), Transportation Research Center, Inc. (TRC).
Insurance Companies	State Farm Insurance Companies (State Farm).
Research/Consulting Companies	Safe Streets Research & Consulting (Safe Streets).
General Public	Individuals.

Many commenters stated they support NHTSA's goal of providing comparative safety information to consumers through NCAP but encouraged the Agency to further leverage NCAP to ensure consumers have a comprehensive understanding of vehicle safety. Commenters also stated that more testing, rating, and information-sharing with consumers about the functionalities of advanced safety technologies via NCAP will promote the technologies' use in future vehicles and advance vehicle safety. The Alliance for Automotive Innovation (Auto Innovators) stated it supports NHTSA's efforts to modernize NCAP, noting that a key benefit of a well-developed and technically robust NCAP is the introduction of advanced safety technologies and performance evaluation through market incentives (objective ratings) in a structured and predictable manner via the development of testing procedures, evaluation metrics, and safety benefits. Auto Innovators stated that doing so will lead to more vehicles being equipped with new ADAS technologies, ultimately decreasing technology costs, and bolstering the case for potential regulation.

Many commenters, including those who have lost loved ones in automotive accidents, expressed support for the proposed NCAP changes but stated they do not go far enough, noting the U.S. program is behind other countries' NCAP programs in updating, implementing, and ''standardizing'' NCAP with proven safety technologies to save more lives. The Advocates for Highway and Auto Safety (Advocates), the Consumer Federation of America, and many others expressed concern that the approach described in the March 2022 RFC is not sufficiently specific and lacks firm commitments on key updates to the program. Further, the National Safety Council (NSC) stated that its data continues to suggest NHTSA is not doing enough to address roadway safety, with thousands of people dying in preventable crashes each year.

Several commenters pointed out that fatalities involving pedestrians and cyclists have been increasing at alarming rates and urged NHTSA to consider the safety of those outside of the vehicle. Many cyclist organizations stated that any NCAP updates should include cyclist AEB testing and tests aimed at increasing cyclist safety. One individual noted the more than 50 percent increase in annual pedestrian fatalities in the past decade, stating that safety innovations are benefiting those inside, not outside, of the vehicle. Many other individual commenters expressed concern for the safety of pedestrians, mobility device users, and cyclists amidst rising fatalities from increasingly large vehicles, suggesting that NHTSA should consider promoting technologies and performing tests to protect them.

Many commenters expressed support for the Agency's proposed inclusion of the four new ADAS technologies and for enhancing the evaluation of ADAS technologies currently in NCAP. However, some commenters argued the proposal did not go far enough, suggesting that ADAS technologies (including PAEB) should not just be part of the voluntary NCAP program but should be mandatory on new vehicles to reduce fatalities, especially in urban areas. Many commenters also requested that NHTSA harmonize test procedures and evaluations with other existing testing protocols like Euro NCAP. While commenters generally supported the proposed roadmap, some noted that it

[30] The March 2022 RFC notice requested comment on a number of topics, including emerging technologies, and potential future updates to NCAP, that have not been proposed, and thus are not addressed, in the present notice. Details of the comments received and the Agency's response to these comments will be provided in future RFC notices relevant to those topics.

lacked sufficient specificity on future timelines, dates, and required actions. Commenters requested periodic stakeholder engagement and collaboration for developing future NCAP roadmaps.

Several commenters also provided detailed responses to questions NHTSA posed in the March 2022 RFC notice to help guide its decisions. The following sections discuss in detail: (1) NHTSA's proposal for each technology, (2) the Agency's response to the comments received to the questions posed, and (3) final decisions on the proposed changes to NCAP specific to the technology.

IV. Updating Forward Collision Prevention Technologies

NHTSA is updating assessments for FCW and AEB technologies (*i.e.,* CIB and DBS) in NCAP's crash avoidance program. As discussed in NHTSA's March 2022 RFC notice, these technologies, designed to address forward collisions (rear-end crashes), have the potential to help prevent or mitigate rear-end pre-crash scenarios representing approximately 1.7 million crashes annually, or 29 percent of all crashes that currently occur on U.S. roadways.[31] These crashes result in 1,275 fatalities, on average, and 883,386 MAIS 1–5 injuries annually, representing 3.8 percent of all fatalities and 32 percent of all injuries, respectively.[32] FCW and AEB technologies have proven effective in reducing crashes, fatalities, and injuries. For instance, as discussed in the March 2022 RFC notice, the University of Michigan Transportation Research Institute (UMTRI) found that for 3.8 million model year 2013–2017 GM vehicles, camera-based FCW systems produced an estimated 21 percent reduction in rear-end striking crashes, while the AEB systems studied (which included a combination of camera-only, radar-only, and fused camera-radar systems) produced an estimated 46 percent reduction in the same crash type.[33] These findings align with a 2017 Insurance Institute for Highway Safety (IIHS) study,[34] which concluded that vehicles equipped with FCW and AEB showed a 50 percent reduction for the same crash type.[35]

Until these technologies are standard equipment on all passenger vehicles, it is important for NCAP to continue to recommend FCW and AEB technologies to consumers and to inform them which vehicles have FCW and AEB technologies meeting NHTSA's performance criteria. Further, given recent increases in the penetration of FCW and AEB technologies in the vehicle fleet and improvements to sensors, now is an opportune time to increase the stringency of the current NCAP performance requirements for these technologies.

A. Forward Collision Warning (FCW)

FCW systems use forward-looking sensors (*e.g.,* radar, lidar, camera systems, or a combination thereof) that detect objects (*e.g.,* vehicles, pedestrians) in front of vehicles and issue an alert to the driver. An FCW system uses the sensors' input to determine the speed of the object in front of it and the distance between the vehicle and the object. If the sensing system determines that the closing distance and velocity[36] between the driver's vehicle and the object in front of it is such that a collision may be imminent, the warning system is designed to induce an immediate crash avoidance response by the vehicle operator. Warning systems in use today provide drivers with a visual display, such as an illuminated telltale on or near the instrument panel, an auditory signal (*e.g.,* buzzer or chime), and/or a haptic signal that provides tactile feedback (*e.g.,* rapid vibrations of the seat pan or steering wheel). These signals warn the driver of an impending collision so the driver may then manually intervene (*e.g.,* apply the vehicle's brakes or make an evasive steering maneuver) to avoid or mitigate a crash. FCW systems alone do not brake the vehicle.

NHTSA added FCW systems to its NCAP ADAS evaluations in 2008 (with performance evaluations beginning with model year 2011 vehicles) because these systems met the Agency's four prerequisites for inclusion at the time.[37] In its March 2022 RFC notice, the Agency proposed to continue to include FCW assessments in NCAP, as it found FCW systems to be effective, well-accepted by consumers, and widely available in the current vehicle fleet. For example, in its 2017 study, IIHS[38] found that FCW systems reduced rear-end crashes by 27 percent. Further, in a 2019 survey of more than 57,000 Consumer Reports subscribers, 69 percent of vehicle owners reported they were satisfied with their vehicle's FCW technology.[39] Currently, manufacturer-submitted data collected by NHTSA indicates 91 percent of model year 2023 vehicles are equipped with FCW systems as standard equipment.

NCAP's Current Forward Collision Warning Test Procedure

The Agency included FCW as a recommended technology in NCAP and conducted performance evaluations beginning with model year 2011 vehicles. The FCW test procedure adopted at that time is still in use in the Agency's testing today.[40]

Currently, NCAP's FCW test procedure[41] consists of three scenarios that simulate the most frequent types of rear-end crashes. These include lead vehicle stopped (LVS), lead vehicle decelerating (LVD), and lead vehicle moving (LVM) scenarios. In each scenario, the vehicle being evaluated is called the subject vehicle (SV). The SV is driven by a professional driver who provides the necessary acceleration, braking, and steering inputs during the test. A production mid-size passenger car, designated as the principal other vehicle (POV) during testing, is positioned directly in front of the SV and is also driven by a professional driver. Time-to-collision (TTC) criteria are prescribed for each FCW scenario. The TTC for each scenario is calculated by considering the speed of the SV relative to the POV at the time of the FCW. If the FCW system fails to issue a warning within the required time during testing, the SV's professional test

[31] Wang, J.-S. (2019, March), *Target crash population for crash avoidance technologies in passenger vehicles* (Report No. DOT HS 812 653). Washington, DC: National Highway Traffic Safety Administration.

[32] The Abbreviated Injury Scale (AIS) is a classification system for assessing impact injury severity. AIS ranks individual injuries by body region on a scale of 1 to 6 where 1=minor, 2=moderate, 3=serious, 4=severe, 5=critical, and 6=maximum (untreatable). MAIS represents the maximum injury severity, or AIS level, recorded for an occupant (*i.e.,* the highest single AIS for a person with one or more injuries).

[33] Leslie, A.J., Kiefer, R.J., Meitzner, M.R., & Flannagan, C.A. (2019), *Analysis of the field effectiveness of General Motors production active safety and advanced headlighting systems,* The University of Michigan Transportation Research Institute and General Motors LLC. UMTRI–2019–6.

[34] Cicchino, J.B. (2017, February), Effectiveness of forward collision warning and autonomous emergency braking systems in reducing front-to-rear crash rates, *Accident Analysis and Prevention,* 2017 Feb;99(Pt A):142–152. *https://doi.org/10.1016/j.aap.2016.11.009.*

[35] Low-speed AEB showed a 43% reduction.

[36] Closing velocity is the rate at which two objects are getting closer to each other.

[37] 73 FR 40033 (July 11, 2008).

[38] Cicchino, J.B. (2017, February), Effectiveness of forward collision warning and autonomous emergency braking systems in reducing front-to-rear crash rates, *Accident Analysis and Prevention,* 2017 Feb;99(Pt A):142–152. *https://doi.org/10.1016/j.aap.2016.11.009.*

[39] Consumer Reports (2019, November), *Consumer Perception of ADAS, https://data.consumerreports.org/reports/consumer-perceptions-of-adas/.*

[40] 73 FR 40016 (July 11, 2008).

[41] National Highway Traffic Safety Administration. (2013, February). *Forward collision warning system confirmation test. https://www.regulations.gov.* Docket No. NHTSA–2006–26555–0134.

driver brakes, or steers away, to avoid a collision with the POV. A short description of each test scenario and the requirements for a passing result based on the prescribed TTC is provided below:

• LVS—The SV encounters a stopped POV directly in front of it on a straight road. The SV is moving at 72.4 kph (45 mph), and the POV is stationary. To pass this test, the SV must issue an FCW when the TTC is at least 2.1 s. See Figure 1 (below) for a scenario diagram.

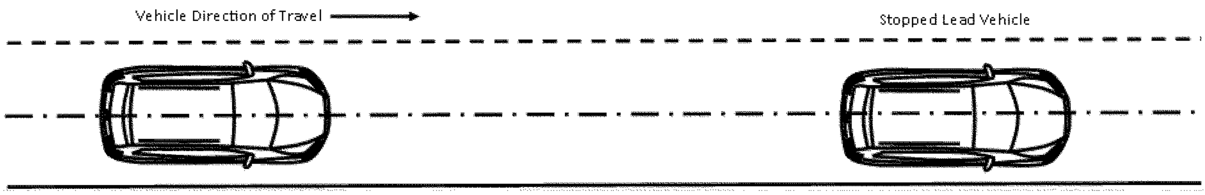


Figure 1: Lead Vehicle Stopped Scenario

• LVD—The SV encounters a POV slowing with constant deceleration directly in front of it on a straight road. The SV and POV are both driven at 72.4 kph (45 mph) with an initial headway of 30.0 m (98.4 ft.). The POV then decelerates, braking at a constant deceleration of 0.3g in front of the SV. To pass this test, the SV must issue an FCW when the TTC is at least 2.4 s. See Figure 2 (below) for a scenario diagram.

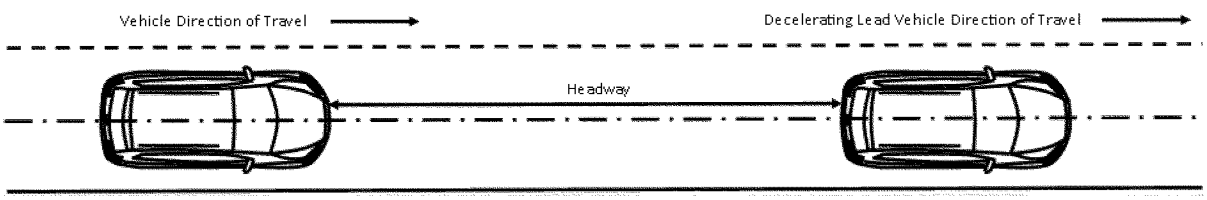


Figure 2: Lead Vehicle Decelerating Scenario

• LVM—The SV encounters a slower-moving POV directly in front of it on a straight road. The SV and POV are driven at constant speeds of 72.4 kph (45 mph) and 32.2 kph (20 mph), respectively. To pass this test, the SV must issue an FCW when the TTC is at least 2.0 s. See Figure 3 (below) for a scenario diagram.

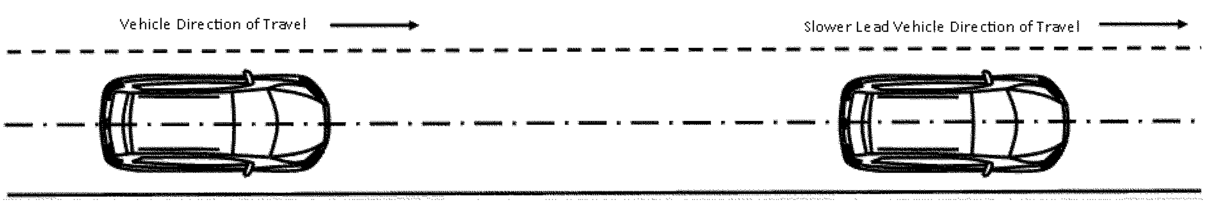


Figure 3: Lead Vehicle Moving Scenario

Each of these three scenarios is conducted up to seven times. To pass the NCAP FCW system performance tests, the SV must satisfy the respective TTC-based performance criteria for at least five out of seven trials [42] for each of the three test scenarios.

B. Automatic Emergency Braking (AEB)

One limitation of FCW systems is that, although designed to warn the driver of an impending rear-end crash, they do not actively and automatically assist drivers with avoiding rear-end crashes or mitigating their severity. To address this, CIB and DBS (known collectively as AEB) both provide significant automatic braking of the vehicle.[43] DBS systems provide supplemental braking when sensors determine that driver-applied braking is insufficient to avoid an imminent crash. CIB systems provide automatic braking when forward-looking sensors indicate that a crash is imminent, and the driver has not braked.

Research has shown that active safety systems such as AEB provide greater safety benefits than the corresponding warning systems alone, such as FCW. In its 2019 study, UMTRI [44] found that

[42] As noted in the Agency's 2015 AEB final decision notice (80 FR 68618 (Nov. 5, 2015)), a pass rate of five out of seven tests per scenario was adopted for NCAP's current FCW test protocol to provide the Agency with a way to encourage system robustness without precluding the proliferation of emerging technologies offering the potential for significant safety benefits.

[43] Some FCW systems use haptic brake pulses to alert the driver of a crash-imminent driving situation, but they are not intended to effectively slow the vehicle.

[44] Leslie, A.J., Kiefer, R.J., Meitzner, M.R., & Flannagan, C.A. (2019, September), *Analysis of the field effectiveness of General Motors production*

AEB systems produced an estimated 46 percent reduction in applicable rear-end crashes when combined with a forward collision warning, which alone showed only a 21 percent reduction.[45] Like FCW systems, AEB systems are also well-accepted by consumers and widely available in the current vehicle fleet. In Consumer Reports' 2019 subscriber survey, 81 percent of owners of vehicles equipped with AEB reported they were satisfied with AEB technology.[46] Currently, manufacturer-submitted data collected by NHTSA indicates approximately 91 percent of model year 2023 vehicles are equipped with AEB systems as standard equipment. For these reasons, in 2015, NHTSA added CIB and DBS technologies to its ADAS assessments starting with model year 2018 vehicles, and why the Agency also proposed to continue to include AEB assessments in NCAP in its March 2022 RFC notice.[47]

1. *Dynamic Brake Support (DBS)*

Like FCW (and CIB) systems, DBS systems employ forward-looking sensors to detect vehicles in the path directly ahead while simultaneously monitoring the operational state of the driver's vehicle (*e.g.,* speed, the relative speed of and distance to the lead vehicle, driver inputs of steering and braking). In response to an FCW or an imminent crash, a driver may initiate braking to avoid a rear-end crash. However, research suggests that a driver's brake application may not take full advantage of the vehicle's foundation braking system in cases where the driver is inattentive, receives an FCW, and re-engages in the driving task prior to automatic braking (*i.e.,* CIB) taking place. In situations where the driver's braking is insufficient to prevent a collision, DBS can automatically supplement the driver's braking action to prevent or mitigate the crash.[48] The NCAP DBS performance evaluations serve to ensure that the vehicle's supplemental braking is sufficient to augment the driver's manual brake application and avoid a collision with the lead vehicle in the tested driving situations. DBS testing also endeavors to ensure that a vehicle's automatic brake application (*i.e.,* CIB) is not suppressed in the event of a driver's manual brake application.

NCAP's Current Dynamic Brake Support Test Procedure

NCAP's current DBS test procedure[49] consists of the same three rear-end pre-crash scenarios specified in the FCW system performance test procedure: LVS, LVD, and LVM. However, most of the test speed combinations specified in the DBS test procedure differ. The single exception is that the FCW and DBS test procedures both use an LVM test performed with SV and POV speeds of 72.4 and 32.2 kph (45 and 20 mph), respectively. The DBS performance assessment also includes a Steel Trench Plate (STP) false positive suppression test conducted at two test speeds. The false positive suppression test series evaluates the ability of a DBS system to differentiate a steel trench plate, often found on roadways, from an object presenting a genuine safety risk to the SV. Although STPs are large and metallic, they are designed to be driven over without risk of injury to drivers or vehicles. This fourth test scenario is used to evaluate the propensity of a vehicle's DBS system to activate inappropriately in this non-critical driving scenario that would not present a safety risk to the vehicle's occupants.

Like NCAP's FCW tests, the vehicle subjected to the DBS test scenarios is termed the SV. However, unlike NCAP's FCW tests, the DBS test procedure uses a surrogate vehicle (*i.e.,* a realistic looking artificial vehicle) as the POV instead of an actual vehicle to limit the potential for damage to the SV and/or the test equipment in the event of a collision. Additionally, instead of driver- (human-) based inputs, like those required in NCAP's FCW tests, a programmable (robotic) brake controller is used to provide all SV brake pedal applications made during the DBS system performance evaluations.

The Strikeable Surrogate Vehicle (SSV) is the surrogate vehicle presently used as the POV by NCAP for the Agency's DBS testing. The SSV, developed by NHTSA for the purpose of track testing, appears as a "real" vehicle to the camera, radar, and lidar sensors used by existing AEB systems. The SSV system is comprised of (a) a shell,[50] which is a visually and dimensionally accurate representation of a compact passenger car; (b) a slider and load frame assembly to which the shell is attached, (c) a two-rail track on which the slider operates, (d) a road-based lateral restraint track, and (e) a tow vehicle, which pulls the SSV and its peripherals down the test track during the test where the POV (*i.e.,* SSV) must be in motion.

For the three test scenarios where braking is expected, the SV must provide enough supplemental braking to completely avoid contact with the SSV (*i.e.,* POV) to pass a trial run. In the case of the DBS false positive test scenario, the performance criterion is minimal to no activation for both test speeds.[51] [52] A short description of each DBS system performance test scenario, and the requirements for a passing result, is provided below:

• Lead Vehicle Stopped (LVS)—The SV encounters a stopped POV directly in front of it on a straight road. The SV is moving at 40.2 kph (25 mph) and the POV is stationary. The SV throttle is released within 500 ms after the SV issues an FCW, and the SV brake pedal is manually applied at a TTC of 1.1 s (*i.e.,* at a nominal headway of 12.2 m (40 ft.)). To pass this test, the SV must not contact the POV. See Figure 1 for a scenario diagram.

• Lead Vehicle Decelerating (LVD)—The SV encounters a POV slowing with constant deceleration directly in front of it on a straight road. The SV and POV are both driven at 56.3 kph (35 mph) with an initial headway of 13.8 m (45.3 ft.). The POV brakes are then applied to achieve a constant deceleration of 0.3g in front of the SV. The SV throttle is released within 500 ms after the SV issues an FCW, and the SV brake pedal

active safety and advanced headlighting systems, The University of Michigan Transportation Research Institute and General Motors LLC, UMTRI–2019–6.

[45] The AEB systems studied by UMTRI consisted of camera-only, radar-only, and fused camera-radar AEB systems, the latter two systems of which also included adaptive cruise control functionality.

[46] Consumer Reports, (2019, November), *Consumer Perceptions of ADAS, https://data.consumerreports.org/reports/consumer-perceptions-of-adas/.*

[47] Docket No. NHTSA–2021–0002. 87 FR 13452. March 9, 2022.

[48] DBS systems differ from traditional brake assist systems used with the vehicle's foundation brakes. Whereas both systems rely on brake pedal application rate to determine whether supplemental braking is required, DBS has a lower activation threshold since it also uses information from forward-looking sensors to verify that more braking is needed.

[49] National Highway Traffic Safety Administration (2015, October), *Dynamic brake support performance evaluation confirmation test for the New Car Assessment Program, http://www.regulations.gov,* Docket No. NHTSA–2015–0006–0026.

[50] The shell is constructed from lightweight composite materials with favorable strength-to-weight characteristics, including carbon fiber, Kevlar®, phenolic, and Nomex honeycomb. It is also wrapped with a commercially available vinyl material to simulate paint on the body panels, rear bumper, and a tinted glass rear window. A foam bumper having a neoprene cover is attached to the rear of the SSV to reduce the peak forces realized immediately after an impact from a test vehicle occurs.

[51] Minimal activation is defined as a peak SV deceleration attributable to DBS intervention that is less than or equal to 1.5 times the average of the deceleration recorded for the vehicle's foundation brake system alone during its approach to the STP. The 1.5 multiplier serves to provide some system flexibility, meaning a mild DBS intervention is acceptable, but one where the vehicle thinks it must respond to the STP as if it was a real vehicle is not.

[52] Note that the March 2022 notice specified a multiplier of 1.25. This specification was in error.

is manually applied at a TTC of 1.4 s (*i.e.,* at a nominal headway of 9.6 m (31.5 ft.)). To pass this test, the SV must not contact the POV. See Figure 2 for a scenario diagram.

• Lead Vehicle Moving (LVM)—The SV encounters a slower-moving POV directly in front of it on a straight road. In the first test, the SV and POV are driven on a straight road at a constant speed of 40.2 kph (25 mph) and 16.1 kph (10 mph), respectively. In the second test, the SV and POV are driven at a constant speed of 72.4 kph (45 mph) and 32.2 kph (20 mph), respectively. In both tests, the SV throttle is released within 500 ms after the SV issues an FCW, and the SV brake pedal is manually applied at a TTC of 1 s (*i.e.,* at a nominal headway of 6.7 m (22 ft.) in the first test, and 11.3 m (37 ft.) in the second test). To pass these tests, the SV must not contact the POV. See Figure 3 for a scenario diagram.

• Steel Trench Plate (STP) false positive suppression test—The SV is driven over a 2.4 m × 3.7 m × 25.4 mm (8 ft. × 12 ft. × 1 in.) steel trench plate at 40.2 kph (25 mph) and 72.4 kph (45 mph). If an FCW is issued, the SV throttle is released within 500 ms of the alert. If no FCW is issued by a TTC of 2.1 s, the SV throttle is released within 500 ms of a TTC of 2.1 s. In both instances, the SV brakes are applied at a TTC of 1.1 s (*i.e.,* at a nominal distance of 12.3 m (40 ft.) from the edge of the STP at 40.2 kph (25 mph), or 22.3 m (73 ft.) at 72.4 kph (45 mph)). To pass this test, the performance criterion is minimal to no activation, as defined previously. See Figure 4 (below) for a scenario diagram.

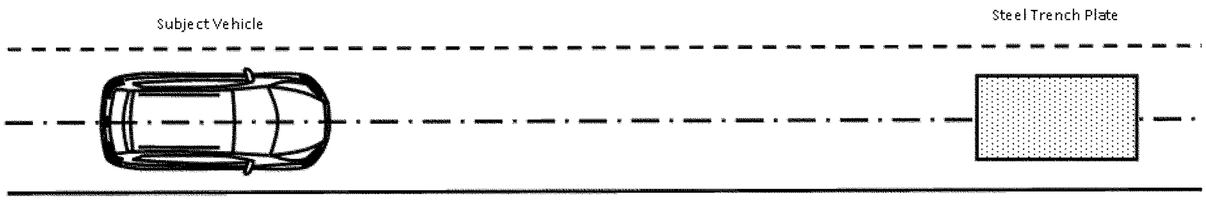


Figure 4: Steel Trench Plate (STP) False Positive Scenario

Currently, to pass NCAP's DBS system performance criteria, the SV must pass at least five out of seven trials for each of the six test conditions.

2. Crash Imminent Braking (CIB)

If a driver does not manually apply the vehicle's brakes when a rear-end crash is imminent, CIB systems, using the same forward-looking sensors as DBS systems, apply the vehicle's brakes automatically to slow or stop the vehicle. Unlike DBS systems, which provide additional braking to supplement the driver's brake input, CIB systems activate when the driver has not applied the brake pedal.

NCAP's Current Crash Imminent Braking (CIB) Test Procedure

The Agency's current CIB test procedure[53] is comprised of the same four test scenarios (LVS, LVD, LVM, and the STP false positive suppression test) and test speeds specified in the DBS test procedure. However, the performance criteria vary slightly. Whereas collision avoidance is the performance requirement stipulated for all DBS test scenarios except the false positive scenario, only the LVM 40.2 kph/16.1 kph (25 mph/10 mph) CIB test condition requires that the SV not contact the POV. The LVS, LVD, and the LVM 72.4 kph/32.2 kph (45 mph/20 mph) test conditions permit SV-to-POV contact but require minimum SV speed reductions prior to the contact being made. For the CIB false positive tests, the performance criterion is little-to-no activation, like the comparable DBS tests. Also, like NCAP's DBS tests, the SSV is the POV presently used in the program's CIB testing. A short description of each test scenario and the requirements for a passing result are provided below:

• LVS—The SV encounters a stopped POV directly in front of it on a straight road. The SV is moving at 40.2 kph (25 mph) and the POV (*i.e.,* the SSV) is stationary. The SV throttle is released within 500 ms after the SV issues an FCW. To pass this test, the SV speed reduction attributable to CIB intervention must be ≥ 15.8 kph (9.8 mph). See Figure 1 for a scenario diagram.

• LVD—The SV encounters a POV slowing with constant deceleration directly in front of it on a straight road. The SV and POV are both driven at 56.3 kph (35 mph) with an initial headway of 13.8 m (45.3 ft.). The POV then decelerates, braking at a constant deceleration of 0.3g in front of the SV, after which the SV throttle is released within 500 ms after the SV issues an FCW. To pass this test, the SV speed reduction attributable to CIB intervention must be ≥ 16.9 kph (10.5 mph). See Figure 2 for a scenario diagram.

• LVM—The SV encounters a slower-moving POV directly in front of it on a straight road. In the first test, the SV and POV are driven on a straight road at a constant speed of 40.2 kph (25 mph) and 16.1 kph (10 mph), respectively. In the second test, the SV and POV are driven at a constant speed of 72.4 kph (45 mph) and 32.2 kph (20 mph), respectively. In both tests, the SV throttle is released within 500 ms after the SV issues an FCW. To pass the first test, the SV must not contact the POV. To pass the second test, the SV speed reduction attributable to CIB intervention must be ≥ 15.8 kph (9.8 mph). See Figure 3 for a scenario diagram.

• STP test (to assess false positive suppression)—The SV is driven towards a steel trench plate at 40.2 kph (25 mph) in one test and 72.4 kph (45 mph) in the other test. If an FCW is issued, the SV throttle is released within 500 ms of the alert. If no FCW is issued, the throttle is not released until the test's validity period (the time when all test specifications and tolerances must be satisfied) has passed. To pass these tests, the SV must not achieve a peak deceleration equal to or greater than 0.5g at any time during its approach to the steel trench plate. See Figure 4 for a scenario diagram.

To pass NCAP's CIB system performance criteria, the SV must pass at least five out of seven trials for each of the six test conditions.

[53] National Highway Traffic Safety Administration. (2015, October). *Crash imminent brake system performance evaluation for the New Car Assessment Program. http://www.regulations.gov.* Docket No. NHTSA–2015–0006–0025.

C. Linking Current FCW and AEB Test Scenarios With Real-World Crashes

NCAP's FCW and AEB test scenarios are directly related to real-world crash data. From its analysis of 2011 to 2015 Fatality Analysis Reporting System (FARS) and National Automotive Sampling System General Estimate System (GES) data, the Agency found that crashes analogous to the LVS test scenario, where a struck vehicle was stopped at the time of impact, occurred in 65 percent of the rear-end crashes studied.[54] [55] The LVD scenario, in which the struck vehicle was decelerating at the time of impact, occurred in 22 percent of the rear-end crashes, and the LVM scenario, in which the struck vehicle was moving at a constant, but slower, speed compared to the striking vehicle at impact, occurred in 10 percent of the rear-end crashes. Collectively, these test scenarios represented 97 percent of rear-end crashes.

With respect to test speed, in its independent review of the 2011–2015 FARS and GES data sets, the John A. Volpe National Transportation Systems Center (Volpe) concluded that, when posted speed limit was known, 2 percent of fatal rear-end crashes and 6 percent of all rear-end crashes occurred on roadways with posted speed limits of 40.2 kph (25 mph) or less.[56] [57] [58] Eleven percent of fatal rear-end crashes and 33 percent of all rear-end crashes where posted speed limit was known occurred on roads with posted speeds of 56.3 kph (35 mph) or less. For posted speeds of 72.4 kph (45 mph) or less, Volpe found the comparable statistics to be 29 percent and 70 percent, respectively.

Roadway alignment and grade for the current FCW and AEB test scenarios are also comparable to those found where real-world rear-end crashes occur. NHTSA's LVS, LVD, and LVM procedures are to be performed on straight, level roads. In its review of 2011–2015 FARS and GES data sets, for rear-end crashes where roadway alignment was known, Volpe found that 95 percent of both fatal and injurious crashes occurred on a straight roadway.[59] For rear-end crashes where roadway grade was known, 77 percent of fatal crashes and 84 percent of crashes with injuries occurred on level roads.[60]

1. *AEB Installation Rates, Effectiveness, and Research Tests*

a. AEB Installation Rates

When NHTSA's CIB test scenarios were developed, relatively few vehicles were equipped with this technology; those that were equipped had systems with limited capabilities. Since then, fitment rates for CIB systems have increased significantly due in part to a voluntary industry commitment made in March 2016.[61] Per this commitment, 20 vehicle manufacturers, representing more than 99 percent of light motor vehicle sales in the U.S., voluntarily committed to make FCW and CIB standard on virtually all light-duty vehicles with a gross vehicle weight rating (GVWR) of 3,855.5 kg (8,500 pounds) or less beginning no later than September 1, 2022, and all trucks with a GVWR between 3,856.0 and 4,535.9 kg (8,501 and 10,000 pounds) beginning no later than September 1, 2025.[62] Conforming vehicles were required to be equipped with (1) an AEB system that earned at least an ''advanced'' rating from IIHS in its then-current front crash prevention track LVS tests and (2) an FCW system that met the performance requirements specified in two of NCAP's current three FCW test scenarios, LVD and LVM.[63] By 2019, participating manufacturers had equipped 75 percent of their new vehicle fleet with AEB,[64] and for model year 2023 vehicles, approximately 91 percent of the fleet was equipped with FCW and AEB systems as standard equipment.

As fitment increased, the sensor technology for CIB systems also advanced significantly. In 2017, many systems were not designed to meet the voluntary commitment thresholds, whereas by 2021, most vehicles with FCW and CIB systems could pass all relevant NCAP test scenarios, most of which are more stringent than those included in the voluntary agreement.[65] In its RFC, NHTSA noted that the original equipment manufacturer (OEM)-reported pass rate for NCAP's FCW and CIB tests for model year 2021 vehicles[66] equipped with these technologies, and for which manufacturers submitted data, was 89 percent and 70 percent, respectively.[67] Furthermore, NHTSA mentioned that only 63 percent of model year 2017 vehicles avoided contacting the POV for at least five out of seven of the required runs in the LVS CIB scenario during the Agency's testing, whereas 100 percent of model year 2021 vehicles were able to repeatedly avoid contact when tested.[68] It should be noted that a speed reduction of 15.8 kph (9.8 mph) for at least five out of seven trial runs is currently required to pass NCAP's CIB LVS test, not complete crash avoidance. For the model year 2023 vehicle fleet, the OEM-reported pass rate for the Agency's FCW test was 98 percent of equipped vehicles, and 86 percent for

[54] Wang, J.-S. (2019, March), *Target crash population for crash avoidance technologies in passenger vehicles* (Report No. DOT HS 812 653), Washington, DC: National Highway Traffic Safety Administration.

[55] NHTSA notes that the target crash populations reported for the LVS, LVD, and LVM scenarios encompass all related real-world rear-end crashes (where the light vehicle is making a critical action) that could potentially be addressed by a DBS system. As such, the target crash populations for each crash scenario reflect crashes exhibiting variations in vehicle overlap, roadway curvature, environmental conditions, etc.; target crash populations were not reduced to align exactly with those represented by NCAP's LVS, LVD, and LVM test scenarios.

[56] Swanson, E., Foderaro, F., Yanagisawa, M., Najm, W.G., & Azeredo, P. (2019, August), *Statistics of light-vehicle pre-crash scenarios based on 2011–2015 national crash data* (Report No. DOT HS 812 745), Washington, DC: National Highway Traffic Safety Administration.

[57] NHTSA notes that throughout this notice, all crash statistics cited from Report No. DOT HS 812 745 encompass those where the light vehicle made the critical action (*e.g.,* losing control, departing road, changing lanes, striking, maneuvering, etc.).

[58] For rear-end crashes, posted speed limit was unknown or not reported for 2 percent of fatal crashes and 11 percent of injurious crashes.

[59] For rear-end crashes, roadway alignment was unknown or not reported for 1 percent of fatal crashes and 3 percent of injurious crashes.

[60] For rear-end crashes, roadway grade was unknown or not reported for 4 percent of fatal crashes and 18 percent of injurious crashes.

[61] The Agency also asserts that its recommendation of AEB systems (*i.e.,* CIB and DBS) that meet NCAP performance criteria on its website since the 2018 model year has further encouraged adoption of these technologies.

[62] Insurance Institute for Highway Safety (2016, March 17), *U.S. DOT and IIHS announce historic commitment of 20 automakers to make automatic emergency braking standard on new vehicles, https://www.iihs.org/news/detail/u-s-dot-and-iihs-announce-historic-commitment-of-20-automakers-to-make-automatic-emergency-braking-standard-on-new-vehicles.*

[63] To achieve an advanced rating in IIHS' front crash prevention track tests, a vehicle's AEB system must show a speed reduction of at least 16.1 kph (10 mph) in either IIHS's 19.3 or 40.2 kph (12 or 25 mph) tests, or a speed reduction of 8.0 kph (5 mph) in both tests. *https://www.iihs.org/news/detail/u-s-dot-and-iihs-announce-historic-commitment-of-20-automakers-to-make-automatic-emergency-braking-standard-on-new-vehicles.*

[64] National Highway Traffic Safety Administration (2019, December 17), *NHTSA announces update to historic AEB commitment by 20 automakers, https://www.nhtsa.gov/press-releases/nhtsa-announces-update-historic-aeb-commitment-20-automakers.*

[65] NCAP's CIB test protocol requires a speed reduction of at least 15.8 kph (9.8 mph) in the program's 40 kph (24.9 mph) LVS test. However, the voluntary commitment allows a vehicle to comply with the memorandum for a speed reduction of 8.0 kph (5 mph) in IIHS's 19.3 and 40.2 kph (12 and 25 mph) LVS tests.

[66] In this instance, ''vehicles'' refers to the total number of vehicles in the 2021 fleet, and not the total number of vehicle models for that year.

[67] These values assume a 50 percent take rate for vehicles having optional equipment.

[68] No contact was assumed if the test vehicle did not contact the POV in five or more of the seven required trial runs.

the CIB test. In the Agency's model year 2023 CIB testing, all vehicles avoided contacting the POV test device for at least five out of seven runs, and thus received credit for passing performance. For the FCW assessments, only one vehicle model failed to provide a passing performance for the LVS and LVD scenarios.

b. Model Year 2019 and 2020 Research Testing

As NHTSA noted in its March 2022 RFC, research testing conducted for a sample of model year 2019 and 2020 vehicles from various manufacturers also confirmed advancement of CIB system capabilities in recent years. The goal of this testing was to characterize the performance of then-current CIB systems and evaluate the technology's future potential for the new model years' vehicle fleet. For this purpose, the Agency chose to focus testing on NCAP's LVS and LVD test scenarios, as its review of the 2011–2015 FARS and GES rear-end crash data sets showed that LVS and LVD rear-end scenarios resulted in the highest number of crashes and MAIS 1–5 injuries.[69] NHTSA conducted testing for each scenario in accordance with NCAP's current CIB test procedure. These tests were then repeated using an ABD GVT as the surrogate vehicle in lieu of the SSV to verify that little to no change in performance would result.[70] The Agency also performed additional tests for each scenario using the GVT to assess how specific procedural changes (*i.e.,* increases in test speed and POV deceleration magnitude) affected CIB system performance.[71]

For the additional LVS tests, the Agency incrementally increased the vehicle speed from 40.2 to 72.4 kph (25 to 45 mph) in 8.0 kph (5 mph) increments to identify when or if the vehicle reached its operational limits and/or did not react to the POV ahead. When the vehicle's intervention was insufficient (*i.e.,* the SV's maximum (peak) deceleration was less than 0.5g), the Agency repeated the test scenario at a test speed that was 4.0 kph (2.5 mph) lower. This reduced speed was used to define the system's upper capabilities for the LVS scenario.

For the additional LVD tests, the Agency evaluated how changes made to either the SV and POV speed (72.4 kph versus 56.3 kph (45 mph versus 35 mph)) or POV deceleration magnitude (0.5g versus 0.3g) affected CIB performance. No changes were made to the SV-to-POV headway; it was retained at 13.8 m (45.3 ft.).

The Agency chose to increase the test speeds for the scenarios included in its CIB characterization study because, in its independent analysis of the 2011–2015 FARS data set, Volpe found that, when the posted speed limit was known, approximately 29 percent of fatalities and 70 percent of injuries in rear-end crashes occurred when the posted speed on roadways was 72.4 kph (45 mph) or less.[72] The additional change to increase the POV deceleration in the LVD scenario was intended to create a more stringent test to address situations where the driver of a lead vehicle brakes aggressively, causing the driver of the following vehicle to have even less time to avoid or mitigate the crash than had the lead vehicle braking been at the 0.3g level presently specified in the Agency's test procedure. Based on previous Agency research, when drivers need to apply the brakes in a non-emergency situation, they do so by decelerating up to approximately 0.306g, while drivers encountering an unexpected obstacle apply the brakes at 0.48g.[73] Further, NHTSA noted that a deceleration of 0.5g falls within the range of deceleration magnitudes prescribed by Euro NCAP in its AEB Car-to-Car systems test protocol, Version 3.0.3, dated April 2021 for the Car-to-Car rear braking CCRb scenario. In its CCRb test, Euro NCAP specifies POV deceleration magnitudes of 2 m/s^2 and 6 m/s^2 (approximately 0.2 to 0.6 g) for an SV-to-POV headway of 12 m (39.4 ft.) and SV test speed of 50 kph (31.1 mph).

The Agency's characterization testing showed that many vehicles were able to repeatedly provide complete crash avoidance at higher test speeds and generally more aggressive conditions than those specified in NCAP's current CIB test procedure. For the 56.3 kph (35.0 mph) LVS tests conducted with a POV deceleration of 0.3g, seven out of the eleven vehicles avoided contact with the lead vehicle in every test trial. One of the remaining vehicles avoided contact in six out of seven test trials and the other three vehicles demonstrated an average speed reduction that exceeded 30.6 kph (19 mph). For the 72.4 kph (45.0 mph) LVS tests conducted with a POV deceleration of 0.3g, four out of the eleven vehicles avoided contact in every test trial and two other vehicles avoided contact in all but one test trial. Three of the remaining vehicles avoided contact in one or two test trials, while the two other vehicles could not avoid contact but both demonstrated an average 21 kph (13 mph) speed reduction. For the 56.3 kph (35.0 mph) LVD tests conducted at 0.5g rather than 0.3g, as specified in NCAP's current CIB test procedure, eight vehicles demonstrated the ability to avoid contact with the lead vehicle in at least one trial and three vehicles avoided contact in all trials, despite having less time to avoid the crash.[74] Similarly, when the speed of the SV and lead vehicle was increased to 72.4 kph (45 mph), nine vehicles demonstrated the ability to avoid contact with the lead vehicle in at least one test while four vehicles avoided contact in all tests. One vehicle avoided contact in all lead vehicle decelerating trials, including both increased speeds and increased lead vehicle deceleration.

Given these findings, the Agency concluded that current CIB systems are capable of significantly exceeding NCAP's current testing requirements. Thus, it is feasible to update the program's CIB test conditions to further safety improvements and address a greater number of rear-end crashes, particularly those which cause a greater number of injuries and fatalities in the real world.

c. AEB Effectiveness

In its March 2022 RFC notice, NHTSA discussed findings from several studies suggesting that AEB systems (*i.e.,* CIB and DBS) have collectively been effective in reducing rear-end crashes. As noted in the introductory section, UMTRI[75] found that AEB systems

[69] Per Wang, J.-S. (2019, March), *Target crash population for crash avoidance technologies in passenger vehicles* (Report No. DOT HS 812 653), Washington, DC: National Highway Traffic Safety Administration, there were 1,099,868 LVS, 374,624 LVD, and 174,217 LVM crashes annually. Furthermore, there were 561,842 MAIS 1–5 injuries resulting from the LVS crash scenario, 196,731 for LVD, and 97,402 for LVM. The LVS scenario also had the second highest number of fatalities.

[70] The Agency desired to use the GVT in lieu of the SSV for its higher speed testing because, given its material properties, the GVT significantly reduced the potential for damage to the testing equipment and test vehicles.

[71] Test reports related to NHTSA's CIB characterization testing can be found in the docket for the March 2022 RFC notice.

[72] Swanson, E., Foderaro, F., Yanagisawa, M., Najm, W.G., & Azeredo, P. (2019, August), *Statistics of light-vehicle pre-crash scenarios based on 2011–2015 national crash data* (Report No. DOT HS 812 745), Washington, DC: National Highway Traffic Safety Administration.

[73] Gregory M. Fitch, Myra Blanco, Justin F. Morgan, Jeanne C. Rice, Amy Wharton, Walter W. Wierwille, and Richard J. Hanowski (2010, April) Human Performance Evaluation of Light Vehicle Brake Assist Systems: Final Report (Report No. DOT HS 811 251) Washington, DC: National Highway Traffic Safety Administration, p. 13 and p. 101.

[74] Two vehicles avoided contact with the POV in four out of five trials.

[75] Leslie, A.J., Kiefer, R.J., Meitzner, M.R., & Flannagan, C.A. (2019, September), *Analysis of the field effectiveness of General Motors production active safety and advanced headlighting systems,* The University of Michigan Transportation

produced an estimated 46 percent reduction in applicable rear-end crashes when combined with a forward collision alert, which alone showed only a 21 percent reduction.[76] Similarly, in a 2017 study, IIHS found that rear-end collisions decreased by 50 percent for vehicles equipped with AEB and FCW.[77] Furthermore, a 2019 study conducted by IIHS [78] suggested that the increasing effectiveness of AEB technology in certain crash situations, particularly those evaluated by NCAP and other consumer information programs, is changing the rear-end crash problem.

While these studies suggest that AEB systems (*i.e.,* CIB and DBS) have collectively been effective in reducing rear-end crashes, NHTSA stated in its March 2022 notice that it was not clear how effective each of these systems is independently, or whether their individual effectiveness may change for certain crash scenarios, environmental conditions, or driver factors (*e.g.,* poor judgement, distraction, etc.). The Agency also stated it is not aware of any studies of current-generation AEB systems that have determined the extent to which CIB and DBS individually contribute to crash reduction. Since NHTSA could not differentiate between the individual effectiveness of CIB and DBS systems, it tentatively concluded that NCAP should continue to assess CIB and DBS system performance individually and therefore retain DBS assessments. NHTSA explained that this approach would ensure vehicles would not suppress AEB operation in situations where the driver applies the vehicle's foundation brakes.[79] However, as discussed later, the Agency also sought comment on removing the DBS test conditions from NCAP entirely in an effort to reduce test burden.

The Agency did not perform DBS testing as part of its characterization study to evaluate system performance capabilities beyond what is currently required in NCAP's respective test procedure. However, DBS systems have historically been shown to impart additional braking beyond that afforded by CIB systems. NHTSA has observed complete crash avoidance in DBS tests but only speed reduction in the equivalent CIB tests conducted for the same vehicle models. Therefore, it was expected that DBS performance should typically be as good as, if not better than, CIB performance. NHTSA believed that it was fitting to align the proposed CIB and DBS evaluations for the assessed situations, since doing so would allow the Agency to evaluate whether a vehicle's DBS system would provide sufficient supplemental braking if the driver brakes but additional braking is warranted. To verify that equivalent performance requirements and criteria proposed for CIB would also be appropriate for DBS, NHTSA planned research tests for model year 2021 and 2022 vehicles.

d. Model Year 2021 and 2022 Research Testing

In accordance with its plans expressed in the March 2022 RFC, NHTSA conducted a series of AEB research tests in 2022 to further analyze current fleet performance.[80] This testing, which involved 12 model year 2021 and 2022 light vehicles, included CIB and DBS testing in a variety of CIB and DBS test conditions. The goal of this research was to evaluate NHTSA's AEB proposals (found in subsequent sections) and to gain further knowledge regarding the capabilities of the current vehicle fleet.

Both CIB and DBS tests were conducted in the LVS, LVM, LVD, and STP false positive scenarios. Additionally, NHTSA conducted two other false positive test scenarios as part of this research: a ''Pass Through'' test, in which the SV approaches two stationary lead vehicles located to the left and right of the SV forward path, and ''Pass Through + STP'' test, which is a combination of the STP and Pass Through scenarios.[81] See Table 11 for the nominal test parameters used in this series of research tests. The ABD GVT Revision G, secured to a GST robotic platform (or carrier), was used as the POV for the model year 2021 and 2022 research testing.

TABLE 11—NOMINAL TEST PARAMETERS FOR MODEL YEAR 2021 AND 2022 RESEARCH TESTING

Test scenario	Test speeds (kph (mph))		Headway (m (ft.))	POV decel. (g)	CIB	DBS
	SV	POV				
Lead Vehicle Stopped (LVS)	10, 40, 50, 60, 70, 80 (6.2, 24.9, 31.1, 37.3, 43.5, 49.7).	0			✓	
	70, 80, 90, 100 (43.5, 49.7, 55.9, 62.1).	0				✓
Lead Vehicle Moving (LVM)	40, 50, 60, 70, 80 (24.9, 31.1, 37.3, 43.5, 49.7).	20 (12.4)			✓	
	70, 80, 90, 100 (43.5, 49.7, 55.9, 62.1).	20 (12.4)				✓
Lead Vehicle Decelerating (LVD)	50 (31.1)	50 (31.1)	12, 40 (39.4, 131.2)	0.4, 0.5	✓	✓
	80 (49.7)	80 (49.7)	12, 40 (39.4, 131.2)	0.4, 0.5	✓	✓
Steel Trench Plate (STP)	80 (49.7)				✓	✓
Pass Through	80 (49.7)	0			✓	✓
Pass Through + Steel Trench Plate	80 (49.7)	0			✓	✓

For the LVS and LVM test series, SV speed was increased from lowest to highest. One initial trial was conducted per test speed. If no SV-to-POV contact was observed, the next highest SV speed was run. However, if SV-to-POV contact

Research Institute and General Motors LLC, UMTRI–2019–6.

[76] The AEB systems studied by UMTRI consisted of camera-only, radar-only, and fused camera-radar AEB systems, the latter two systems of which also included adaptive cruise control functionality.

[77] Cicchino, J.B. (2017, February), Effectiveness of forward collision warning and autonomous emergency braking systems in reducing front-to-rear crash rates, *Accident Analysis and Prevention,* 2017 Feb;99(Pt A):142–152, *https://doi.org/10.1016/j.aap.2016.11.009.*

[78] Cicchino, J.B. & Zuby, D.S. (2019, August), Characteristics of rear-end crashes involving passenger vehicles with automatic emergency braking, *Traffic Injury Prevention,* 2019, VOL. 20, NO. S1, S112–S118 *https://doi.org/10.1080/15389588.2019.1576172.*

[79] Foundation brake system means all components of the service braking system of a motor vehicle intended for the transfer of braking application force from the operator to the wheels of a vehicle. *See* 49 CFR 579.4.

[80] *https://www.regulations.gov/document/NHTSA-2023-0021-0005.*

[81] In the Pass Through + STP test, the SV approaches a large steel plate positioned longitudinally on the test surface in the forward path of the SV. Two stationary lead vehicles are located to the left and right of the STP in the SV forward path. The SV is driven over the STP, between the two lead vehicles.

occurred and the SV speed at the time of impact was less than or equal to 50 percent of the initial SV speed, up to four additional (repeated) trials were performed at the same SV speed. If two additional SV-to-POV impacts were observed during the repeat sequence, the test series was terminated. Furthermore, if the SV speed at the time of impact was greater than 50 percent of the initial SV speed during the initial trial, no repeat runs were performed; testing for that scenario was terminated. For the LVD test series, testing proceeded in a similar manner. The SV speed was increased from lowest to highest, and POV deceleration was iteratively increased from 0.4g to 0.5g for a given speed combination and headway. Relevant outcomes of this research are detailed throughout the applicable sections of this notice.

D. NHTSA's Proposals, Summary of Comments, Response to Comments, and Agency Decisions

1. AEB

a. Forward Collision Prevention Technologies Inclusion in General

Many commenters, including the NTSB, Bosch, HMNA, and NADA, expressed support for the Agency's proposed updates for NCAP's AEB testing. Additional proponents, such as the Advocates and QuantivRisk, Inc., cited the need for increased test stringency to realize additional safety benefits. In this vein, NTSB specifically asked NHTSA to ''strive for the performance we want the systems to be able to reach, not merely evaluate the current capabilities of the systems.'' Auto Innovators expressed a need for consistency between changes to NCAP and those planned for AEB standards. Other respondents, such as MEMA, appreciated the Agency's attempts to focus resources on emerging trends and harmonize its AEB test procedures with those used by European New Car Assessment Programme (Euro NCAP) and other consumer information programs. Toyota also supported the Agency's attempts at shared global assessments but recommended that NHTSA select (1) tests that can adequately ensure performance across a range of conditions to improve overall test efficiency and (2) performance criteria that reflect real-world benefits. Citing rising fatalities, several commenters requested that the Agency consider AEB test additions for cyclists and motorcyclists, while others mentioned current AEB system limitations, such as systems' inability to detect cyclists and other vulnerable road users (VRUs) at higher speeds and in low light and inclement weather.

b. AEB Test Procedure Changes, Including Higher Speeds and POV Deceleration Magnitude for LVD Test; and Removal of DBS Tests and Only High-Speed DBS Assessments

NHTSA proposed harmonizing many aspects of changes to NCAP's CIB and DBS procedures with Euro NCAP's AEB Car-to-Car systems test protocol. The Agency reasoned this approach was most appropriate based on requirements of the BIL. The Agency also argued that it would be beneficial to standardize the current AEB test specifications with other consumer information programs, as doing so would allow the Agency and vehicle manufacturers to focus resources on emerging trends for rear-end crashes as AEB-equipped vehicles become more abundant in the fleet.[82] NHTSA also noted it would consider making additional updates to its AEB test evaluation as the rear-end crash problem evolves.

The updated CIB and DBS tests proposed in the 2022 RFC are detailed below for each test scenario. Tables 12 and 13 summarize the proposed test scenarios and conditions.

TABLE 12—CIB TEST SCENARIOS AND CONDITIONS PROPOSED IN THE 2022 RFC

Test scenario	SV speed (kph (mph))	POV speed (kph (mph))	POV headway (m (ft.))	POV deceleration (g)	Requirement to pass
LVS	40 (24.9)	0	n/a	n/a	(1) No SV-to-POV contact on first trial;
	50 (31.1)	0	n/a	n/a	OR
	60 (37.3)	0	n/a	n/a	(2) Any SV-to-POV contact where the relative velocity between the SV and POV is ≤ 50% of initial SV speed
	70 (43.5)	0	n/a	n/a	AND
	80 (49.7)	0	n/a	n/a	No SV-to-POV contact in 3 out of 5 total trials.
LVM	40 (24.9)	20 (12.4)	n/a	n/a	
	50 (31.1)	20 (12.4)	n/a	n/a	
	60 (37.3)	20 (12.4)	n/a	n/a	
	70 (43.5)	20 (12.4)	n/a	n/a	
	80 (49.7)	20 (12.4)	n/a	n/a	
LVD*	50 (31.1)	50 (31.1)	12 (39.4)	0.5	
	60 (37.3)	60 (37.3)	12 (39.4)	0.5	
	70 (43.5)	70 (43.5)	12 (39.4)	0.5	
	80 (49.7)	80 (49.7)	12 (39.4)	0.5	

* For LVD, NHTSA requested comment on whether at least five of seven trials should be required for vehicles whose contact velocity is ≤50 percent of the initial velocity, whether a 40 m headway should be included, and whether NHTSA should employ a 0.6g POV deceleration in lieu of 0.5g.

TABLE 13—DBS TEST SCENARIOS AND CONDITIONS* PROPOSED IN THE 2022 RFC

Test scenario	SV speed (kph (mph))	POV speed (kph (mph))	POV headway (m (ft.))	POV deceleration (g)	Requirement to pass
LVS**	70 (43.5)	0	n/a	n/a	(1) No SV-to-POV contact on first trial;
	80 (49.7)	0	n/a	n/a	OR
					(2) Any SV-to-POV contact where the relative velocity between the SV and POV is ≤50% of initial SV speed
					AND
					No SV-to-POV contact in 3 out of 5 total trials.
LVM**	70 (43.5)	20 (12.4)	n/a	n/a	
	80 (49.7)	20 (12.4)	n/a	n/a	

[82] Cicchino, J.B., & Zuby, D.S. (2019, August), Characteristics of rear-end crashes involving passenger vehicles with automatic emergency braking, *Traffic Injury Prevention,* 2019, VOL. 20, NO. S1, S112–S118, *https://doi.org/10.1080/15389588.2019.1576172*.

TABLE 13—DBS TEST SCENARIOS AND CONDITIONS* PROPOSED IN THE 2022 RFC—Continued

Test scenario	SV speed (kph (mph))	POV speed (kph (mph))	POV headway (m (ft.))	POV deceleration (g)	Requirement to pass
LVD ***	70 (43.5) 80 (49.7)	70 (43.5) 80 (49.7)	12 (39.4) 12 (39.4)	0.5 0.5	

* For all DBS conditions, NHTSA requested comment on removal of all DBS test conditions.
** For LVS and LVM, NHTSA requested comment on the additional inclusion of 40, 50, and 60 kph (24.9, 31.1, and 37.3 mph).
*** For LVD, NHTSA requested comment on the additional inclusion of 50 and/or 60 kph (31.1 and/or 37.3 mph) SV/POV speeds or only 70 and 80 kph (43.5 and 49.7 mph) (if they were adopted for CIB as well). NHTSA also requested comment on whether at least five of seven trials should be required to satisfy the performance requirement for vehicles whose relative velocity at contact is ≤50 percent of the initial SV speed, whether 40 m headway should be included, and whether NHTSA should employ 0.6g POV deceleration in lieu of 0.5g.

Crash Imminent Braking (CIB)

Lead Vehicle Stopped (LVS)

Currently, NCAP's CIB LVS test is conducted at a speed of 40.2 kph (25 mph). In its upgrade proposal, the Agency recommended assessing CIB system performance over a range of test speeds for this test scenario. Specifically, NHTSA proposed a minimum SV test speed of 40 kph (24.9 mph) (similar to that currently specified in NHTSA's CIB test procedure) and a maximum SV test speed of 80 kph (49.7 mph). NHTSA also proposed increasing the SV test speed in 10 kph (6.2 mph) increments from the minimum test speed to the maximum test speed for the LVS assessment, performing one trial per speed. To achieve a passing result for each speed, NHTSA proposed that the test trial must be valid (all test specifications and tolerances satisfied), and the SV must not contact the POV. Further, the Agency proposed that it would conduct four additional trials for any specific test speed that resulted in a test failure (*i.e.,* contact) as long as the SV relative velocity at impact was less than or equal to 50 percent of the initial SV speed. For these five trials (*i.e.,* one failed trial and four additional trials), NHTSA proposed that the SV must avoid contact with the POV for at least three trials to pass the test condition (*i.e.,* combination of test scenario and test speed).

In justifying its recommendation to incorporate higher test speeds for the LVS scenario, in addition to Volpe's real-world data analysis, which illustrated the safety need, the Agency indicated its CIB characterization testing demonstrated that several vehicles repeatedly afforded full crash avoidance (*i.e.,* no contact) at speeds up to 72.4 kph (45 mph) when subjected to this test. Further, NHTSA recognized that Euro NCAP's Car-to-Car Rear stationary (CCRs) scenario, which is comparable to the Agency's LVS test, is conducted at speeds as high as 80 kph (49.7 mph) in the ''AEB only'' test condition. NHTSA reasoned that Euro NCAP's use of higher test speeds suggests higher test speeds are, from the perspective of test conduct, practicable for NCAP's LVS test as well.[83] The Agency believed it was appropriate to harmonize with Euro NCAP on the maximum LVS test speed of 80 kph (49.7 mph), as this should better address the higher severity, high-speed crash problem and, in turn, further reduce fatalities and serious injuries. However, NHTSA did not propose to harmonize with Euro NCAP's protocol on the minimum SV test speed. Euro NCAP's CCRs scenario specifies a minimum SV speed of 10 kph (6.2 mph) for AEB systems, but the Agency stated it did not see the need to conduct its updated LVS testing at a speed less than that which is specified in its existing test procedure (40.2 kph (25 mph)). As such, a minimum test speed of 40 kph (24.9 mph) was proposed instead.

The Agency sought comment on whether the proposed speeds and overall assessment approach were appropriate for LVS or whether alternatives should be considered.

Lead Vehicle Moving (LVM)

As mentioned previously, NCAP's CIB test procedure currently includes two LVM test conditions: a lower speed assessment that specifies an SV speed of 40.2 kph (25 mph) and POV speed of 16.1 kph (10 mph), and a higher speed assessment that prescribes an SV speed of 72.4 kph (45 mph) and POV speed of 32.2 kph (20 mph). For this NCAP update, NHTSA proposed to assess CIB system performance over a range of SV test speeds for the LVM scenario. Similar to its proposal for the LVS scenario, NHTSA proposed to implement a ''no contact'' performance criterion for the LVM scenario and to increase the SV test speed for the LVM assessment in 10 kph (6.2 mph) increments from a minimum speed of 40 kph (24.9 mph) to a maximum speed of 80 kph (49.7 mph), with a POV speed of 20 kph (12.4 mph) for every SV test speed. The Agency also proposed to perform one trial run per speed and four additional trials for any specific test speed that resulted in a test failure for initial runs where the SV had a relative velocity at impact less than or equal to 50 percent of the initial SV speed. Similar to its proposal for LVS, the Agency proposed that the SV must not contact the POV for at least three out of the five test trials performed at that same speed to pass the LVM test condition.

The Agency noted that the proposed minimum SV test speed of 40 kph (24.9 mph) is nearly equivalent to the speed currently specified for its lower speed LVM assessment, 40.2 kph (25 mph), and the proposed maximum SV test speed of 80 kph (49.7 mph) is only slightly higher than the speed specified for its higher speed LVM assessment, 72.4 kph (45 mph). Since NCAP's higher speed CIB LVM assessment (conducted at an SV speed of 72.4 kph (45 mph) and POV speed of 32.2 kph (20 mph)) showed that many vehicles were able to stop without contacting the POV test device for each of the required test trials, NHTSA believed it was reasonable to raise the SV speed in NCAP's LVM test even though it had not performed additional LVM testing as part of its characterization study. The Agency also noted that Euro NCAP performs its Car-to-Car Rear moving (CCRm) scenario (which is comparable to NCAP's LVM tests) at speeds as high as 80 kph (49.7 mph), further suggesting that higher SV test speeds are practicable.[84] Given this, NHTSA believed it was appropriate to harmonize with Euro NCAP on the maximum SV test speed of 80 kph (49.7 mph) for the Agency's LVM test. NHTSA reasoned that adopting a higher maximum SV test speed than that which is currently required in the Agency's CIB procedure should encourage improved CIB system performance at higher speeds, and thus further reduce fatalities and serious injuries.

Although it proposed to harmonize with Euro NCAP's protocol with respect to the maximum SV speed adopted for

[83] European New Car Assessment Programme (Euro NCAP) (April 2021), *Test Protocol—AEB Car-to-Car systems, Version 3.0.3.* See section 8.2.3.

[84] European New Car Assessment Programme (Euro NCAP) (April 2021), *Test Protocol—AEB Car-to-Car systems, Version 3.0.3.* See section 8.2.4.

its LVM test, the Agency did not suggest harmonizing with Euro NCAP with respect to the minimum required SV test speed. Euro NCAP's CCRm scenario specifies a minimum SV test speed of 30 kph (18.6 mph) for AEB-equipped vehicles; however, the Agency did not believe there was not a compelling reason to perform its updated LVM test at a speed that is less than the current required test speed (*i.e.,* 40.2 kph (25 mph)) since most vehicles have been able to meet NCAP's current LVM test requirements at 40.2 kph (25 mph) to date with a similar POV test speed. Accordingly, NHTSA proposed a minimum SV test speed of 40 kph (24.9 mph).

NHTSA proposed to adopt a POV test speed of 20 kph (12.4 mph). The Agency noted this POV speed is specified in Euro NCAP's CCRm protocol, and therefore adopting this speed for NHTSA's LVM testing seemed appropriate since it would further support harmonization efforts.

Comments were requested on whether the SV/POV speeds and assessment approach proposed for NCAP's CIB LVM tests were appropriate or whether alternative speeds or approaches should be considered instead.

Lead Vehicle Decelerating (LVD)

For the LVD scenario, NHTSA proposed to reduce the minimum nominal SV and POV test speeds from 56 kph (34.8 mph), as specified in NCAP's test procedure, to 50 kph (31.1 mph), as stated in Euro NCAP's AEB Car-to-Car systems test protocol, Version 3.0.3, dated April 2021 for the Car-to-Car rear braking (CCRb) scenario.[85] The Agency stated that, given additional changes proposed for the SV-to-POV headway and deceleration magnitude for the LVD scenario, the proposed reduction in test speed would not lead to an overall reduction in test stringency or loss of safety benefits. NHTSA requested comment on whether this proposed test speed change was appropriate for NCAP's LVD testing.

The Agency also sought comment on whether it would be appropriate to incorporate additional SV and POV test speeds for the LVD test scenario: 60, 70, and 80 kph (37.3, 43.5, and 49.7 mph, respectively). Similar to the proposed CIB LVS and LVM test scenarios, NHTSA proposed to concurrently increase the SV and POV test speeds in 10 kph (6.2 mph) increments from the minimum test speed to the maximum test speed for NCAP's LVD assessment if multiple speeds were adopted. The Agency also proposed, as discussed in a later section, to perform one trial run per speed and four additional trials for any specific test speed that resulted in a test failure (*i.e.,* SV-to-POV contact) where the SV had a relative velocity at impact less than or equal to 50 percent of the initial SV speed. Like the other two CIB test scenarios, the Agency proposed the SV must not contact the POV for at least three out of the five test trials performed at that same speed to pass the test condition. Alternatively, the Agency sought comment on whether testing at only 50 kph (31.1 mph) and 80 kph (49.7 mph) would be acceptable.

NHTSA acknowledged in its proposal that it had not yet performed LVD testing at 80 kph (49.7 mph), mainly due to equipment and test track length limitations, as this test scenario requires that both the SV and POV be travelling at the same speed at the onset of the test validity period. However, the Agency recognized that higher speed tests may be warranted. For instance, Volpe's analysis of the 2011–2015 FARS data set showed that, when posted speed limit was known, the majority of fatal rear-end crashes (71 percent) occurred on roads with posted speeds exceeding 72.4 kph (45 mph). Considering the braking performance observed during the high-speed LVS tests conducted as part of its characterization study, the Agency noted current vehicles may perform well in LVD tests conducted at even higher speeds. Additionally, NHTSA believed that CIB systems may be able to classify POVs more confidently in the LVD test compared to the LVS test due to the POV's detected motion (*i.e.,* path history). Accordingly, NHTSA conducted research to assess vehicles' CIB system performance in the LVD test at SV and POV speeds ranging from 50 kph (31.1 mph) to 80 kph (49.7 mph) to determine the feasibility of adopting one or more of these speeds for this test scenario.[86]

In its March 2022 RFC notice, NHTSA also proposed to reduce the minimum nominal SV-to-POV headway of 13.8 m (45.3 ft.), currently specified for the LVD scenario, to 12 m (39.4 ft.) for the proposed test speed of 50 kph (31.1 mph). Although not assessed as part of its CIB characterization testing, the Agency asserted this change would not only harmonize with Euro NCAP's CCRb scenario with respect to test conduct, but also maintain similar stringency to NCAP's current LVD test scenario, given the proposed test speed reduction from 56 kph (34.8 mph) to 50 kph (31.1 mph). Euro NCAP also specifies an additional SV-to-POV headway of 40 m (131.2 ft.); however, the Agency did not propose to conduct this assessment as part of the RFC, as NHTSA suggested there would not be a safety benefit in adopting 40 m (131.2 ft.) as an additional, and presumably less stringent, headway. Therefore, the Agency did not want to increase the test burden unnecessarily. However, the Agency indicated that it would assess vehicle performance at both 12 and 40 m (39.4 and 131.2 ft.) headways as part of its future research for each of the test speeds to be evaluated. The Agency also sought public comment on which SV-to-POV headway(s) may be appropriate for adoption not only for the proposed test speed (*i.e.,* 50 kph (31.1 mph)), but also for each of the additional test speeds (ranging from 60 kph (37.3 mph) to 80 kph (49.7 mph)) it planned to evaluate and possibly incorporate.

The last change the Agency proposed for the LVD test scenario was increasing the POV deceleration magnitude currently specified in its CIB test procedure from 0.3g to 0.5g. In the Agency's CIB characterization study, three vehicles repeatedly afforded full crash avoidance (*i.e.,* no contact) for all trials when the POV executed a 0.5g braking maneuver in the LVD condition with an SV test speed of 56.3 kph (35 mph) and SV-to-POV headway of 13.8 m (45.3 ft.), demonstrating that the change to POV deceleration for the revised LVD test conditions (which also includes a slightly lower test speed and slightly shorter SV-to-POV headway) is likely feasible. The Agency also noted that, in Euro NCAP's AEB Car-to-Car systems test protocol, the organization specifies POV deceleration magnitudes of 2 m/s^2 and 6 m/s^2 (approximately 0.2 and 0.6g) for its CCRb scenario.[87] As such, NHTSA reasoned that adopting a 0.5g POV deceleration magnitude would be practicable. To verify this assumption, as part of its research study, NHTSA committed to evaluating POV deceleration magnitudes of both 0.4 and 0.5g for the range of test speeds considered (*i.e.,* 60, 70, and/or 80 kph (37.3, 43.5, and/or 49.7 mph)) for future LVD testing.[88] The Agency also sought comment on what deceleration magnitude(s) would be appropriate for the proposed test speed (*i.e.,* 50 kph

[85] European New Car Assessment Programme (Euro NCAP) (April 2021), *Test Protocol—AEB Car-to-Car systems, Version 3.0.3.* See section 8.2.5.

[86] The Agency proposed these speeds would each be assessed for both 12 and 40 m (39.4 and 131.2 ft.) headways and POV deceleration magnitudes of 0.4g and 0.5g.

[87] European New Car Assessment Programme (Euro NCAP) (), *Test Protocol—AEB Car-to-Car systems, Version 3.0.3.* See section 8.2.5.

[88] NHTSA notes that the LVD research tests were conducted only for 50 and 80 kph (31.1 and 49.7 mph) test speeds.

(31.1 mph)), as well as each of these additional test speeds.

NHTSA did not propose a 0.6g POV deceleration magnitude for use in its LVD test, even though Euro NCAP specifies 0.6g as the maximum POV deceleration for its CCRb scenario. In proposing 0.5g as the maximum POV deceleration in lieu of 0.6g, the Agency stated a lower POV deceleration may reduce equipment wear, particularly for the tires and braking components of the POV propulsion system, thus improving test efficiency. Specifically, NHTSA explained it has observed instances where the tires of the low-profile robotic vehicle (LPRV) platform [89] used to move the GVT developed flat spots while performing a braking maneuver similar to that specified in the Agency's CIB LVD test [90] but with higher POV decelerations. During this testing, NHTSA also found it was more difficult to achieve and accurately control POV deceleration within prescribed tolerances when braking maneuvers higher than 0.5g were used, even with extensive LPRV tuning efforts.[91] The Agency noted that a deceleration of 0.6g is not only very close to the maximum braking capability of the LPRV, but also very close to the default magnitude used by the LPRV during an emergency stop (maximum deceleration). However, NHTSA acknowledged that newer robotic platforms (*i.e.,* robotic carriers) offering greater capabilities are now becoming available, and they may resolve the issues observed in the Agency's testing. Accordingly, NHTSA requested comment on whether it may now be feasible to adopt a POV deceleration magnitude of 0.6g in lieu of 0.5g, as proposed.

Dynamic Brake Support (DBS)

With respect to DBS, the Agency proposed to align all test conditions (*e.g.,* SV and POV test speed(s), headway(s), POV deceleration magnitude(s), etc.) for the comparable LVD, LVM, and LVS test scenarios with those proposed for CIB. Likewise, NHTSA proposed a similar performance criterion (*i.e.,* no contact) and assessment approach as well; when applicable, speeds would be increased in 10 kph (6.2 mph) increments from the minimum test speed to the maximum test speed, with one trial performed per speed, and four additional trials conducted for any specific test speed that resulted in a test failure (*i.e.,* contact) as long as the SV had a relative velocity at impact less than or equal to 50 percent of the initial SV speed. Similar to CIB, the Agency proposed that the SV must avoid contact with the POV for at least three out of the five test trials performed at that same speed to pass the test condition (if the vehicle fails the initial trial at a given test speed).

Although the Agency had not conducted DBS testing as part of its characterization study to evaluate system performance capabilities beyond what is currently required in NCAP's DBS test procedure, NHTSA believed it was nonetheless fitting to align the proposed CIB and DBS evaluations, as it would allow NHTSA to assess whether a vehicle's DBS system will provide supplemental braking if the driver manually applies a brake pedal input but additional braking is warranted to afford crash avoidance. Further, the Agency noted its CIB and DBS test procedures are currently aligned with respect to test scenarios, test speeds, headways, etc. Differences exist only with respect to the use of manual brake application (*i.e.,* for the SV in DBS testing) and (most) performance criteria.[92] Therefore, the Agency reasoned it would be appropriate to adopt the CIB test conditions (*i.e.,* test speeds, headways, etc.) for the comparable DBS test conditions for future testing as well. NHTSA requested comments on whether this proposal for future DBS testing, including the assessment method, was appropriate.

The Agency also sought comment on removing the LVD, LVM, and LVS DBS test conditions from NCAP entirely (in addition to the false positive test conditions, discussed later) to reduce test burden and associated costs given findings from Volpe's analysis of the 2011–2015 FARS and GES data sets and other changes NHTSA proposed for its CIB assessments.

Specifically, Volpe found that the driver braked in just 8 percent of rear-end crashes involving fatalities and in 20 percent of those crashes involving injuries. The study also showed that the driver made no attempt to avoid the crash (*e.g.,* no braking, steering, accelerating) for 56 percent of crashes involving fatalities and for 21 percent of those involving injuries.[93] These findings were contrary to those documented by NHTSA during a review of 2003–2009 National Automotive Sampling System Crashworthiness Data System data to define the target population for rear-end crashes.[94] For that analysis, the Agency concluded that the driver braked in approximately half of the crashes and did not brake in the other half, which lends merit to performing both CIB and DBS tests. The Agency believed it was possible the brake application rates differed in the two studies because of (1) target crash population refinements made for NHTSA's original analysis and (2) differences in data collection methods between the crash databases. For instance, high-speed crashes were excluded from NHTSA's target crash population review because the AEB systems tested at the time had limited speed reduction capabilities.

As previously mentioned, NHTSA proposed to adopt a more stringent ''no contact'' performance criterion for each of NCAP's CIB test conditions. The Agency's existing CIB test procedure requires a specified speed reduction for each of the CIB test conditions (with the exception of the lower speed LVM condition, which requires ''no contact''), whereas the DBS test procedure currently specifies ''no contact'' as the performance criterion for all DBS test conditions. The proposed change for CIB would effectively align the CIB performance requirements with those currently specified for DBS, and NHTSA questioned whether it was necessary to continue performing DBS tests in NCAP given public comments previously

[89] The GVT is secured to the top of the LPRV. The LPRV is responsible for any movement of the GVT during test conduct.

[90] Fogle, E. E., Arquette, T. E. (TRC), and Forkenbrock, G. J. (NHTSA), (2021, May), *Traffic Jam Assist Draft Test Procedure Performability Validation* (Report No. DOT HS 812 987), Washington, DC: National Highway Traffic Safety Administration.

[91] From Section 4.1 of DOT HS 812 987: ''POV deceleration validity check failures occurred during six trials of the eight LVDAD trials performed. Four of the seven 0.6 g failures were because the POV was unable to achieve the minimum deceleration threshold of 0.55 g. The remaining three 0.6 g failures were because the POV was unable to maintain a minimum average deceleration of at least 0.55 g.'' Here, LVDAD refers to ''Lead Vehicle Accelerates, Decelerates, then Decelerates.'' The LVDAD test is a more complex variant of the LVD test and was used by NHTSA to perform traffic jam assist research.

[92] NHTSA's DBS test procedure currently specifies ''no contact'' as the performance criterion for all DBS test conditions, whereas the Agency's CIB test procedure currently requires a specified speed reduction for each of the CIB test conditions (with the exception of the lower speed LVM condition where the POV speed is 16.1 kph (10 mph) and the SV speed is 40.2 kph (25 mph), which requires ''no contact.''

[93] The Agency notes that for the rear-end pre-crash scenario group, the driver avoidance maneuver was unknown in 25 percent and 54 percent of the FARS and GES crashes, respectively. When excluding cases where a driver avoidance maneuver was unknown, the driver made no attempt to avoid the crash in 75 percent and 48 percent of the FARS and GES crashes, respectively. Likewise, when a driver's avoidance maneuver was known, the driver braked in 11 percent of FARS crashes and 45 percent of GES crashes.

[94] National Highway Traffic Safety Administration (2012, June), *Forward-looking advanced braking technologies research report, https://www.regulations.gov/document?D=NHTSA-2012-0057-0001.*

received. For example, in its comments to NCAP's December 2015 notice, the Alliance [95] stated that since crash avoidance (*i.e.,* no SV-to-POV contact) is the desired outcome for all imminent rear-end crash events, if an SV avoids contact with the POV in all CIB tests, DBS testing should not be necessary. The Agency agreed with the Alliance's rationale in principle but questioned whether there would be merit to ensuring both AEB systems perform as designed and help the driver to mitigate or prevent the crash. NHTSA hypothesized that it may be possible for the driver to apply the brakes but with a magnitude that does not result in achieving the vehicle's maximum crash avoidance potential (*i.e.,* deceleration). Further, the Agency explained that, in the past, some manufacturers had assumed the driver was in control when the brake pedal was depressed, and designed CIB systems such that automatic braking was overridden by the driver's input, even when the driver's braking was insufficient to avoid a crash. Based on this reasoning, NHTSA explained it was hesitant to assume that if a vehicle's CIB system works effectively during testing, its DBS system would automatically do so as well.

Thus, as an alternative to removing the DBS performance evaluations from NCAP entirely (or retaining the LVD, LVM, and LVS DBS tests in NCAP, as proposed), the Agency concluded that it might be more reasonable to conduct only LVS and LVM DBS tests in NCAP at the highest two test speeds proposed for CIB—70 and 80 kph (43.5 and 49.7 mph, respectively)—to ensure (1) the DBS system functions properly at these speeds and (2) the SV will not suppress AEB operation when the driver applies the vehicle's foundation brakes. The Agency further noted that it would also consider conducting the DBS LVD test at only 70 and 80 kph (43.5 and 49.7 mph, respectively) if it decided to adopt those same higher test speeds for the CIB LVD test. Comments were requested on this alternative proposal and whether an alternative assessment method would be more appropriate if any or all of the DBS test scenarios were conducted only at the two highest test speeds.

[95] Alliance of Automobile Manufacturers (The Alliance) merged with Global Automakers in January 2020 to create the Alliance for Automotive Innovation (Auto Innovators). Both automotive industry groups separately submitted comments to the December 2015 notice.

Summary of Comments

Regarding NHTSA's AEB Proposal, In General

Several commenters, including BMW, FCA, and Honda, supported the Agency's proposal for CIB and DBS with respect to SV and POV speeds, headway distances, and POV deceleration magnitudes. FCA stated that the proposal was appropriate because it reflects current system capabilities and real-world crashes. With the exception of suggested changes for the LVD scenario, discussed later, Tesla also generally agreed with the Agency's proposal with respect to test speeds, headway, and deceleration magnitudes for CIB testing and the general intent to harmonize with Euro NCAP test protocols. Specifically, Tesla supported conducting LVS and LVM scenarios at test speeds ranging from 40 to 80 kph (24.9 and 49.7 mph) with 10 kph (6.2 mph) increments, as proposed. Auto Innovators also generally agreed with the proposed test requirements but suggested the Agency harmonize with Euro NCAP and conduct CIB testing up to 50 kph (31.1 mph) and DBS testing at speeds over 50 kph (31.1 mph).

Like Tesla, Advocates and Bosch also supported generally harmonizing the Agency's CIB testing with that performed by Euro NCAP, but with small variations. Advocates supported aligning the LVM and LVS POV and SV speeds with those used by Euro NCAP but did not support the Agency's justification for not aligning minimum test speeds for these two scenarios with those prescribed by Euro NCAP (10 kph, or 6.2 mph) as being sufficient. Bosch also mentioned harmonization with respect to test speeds but suggested the Agency should further investigate whether there is merit to increasing test speeds to assess AEB systems.

Conversely, GM opposed any change to the test conditions prescribed in the Agency's current CIB test procedure. The automaker stated that the current AEB test speeds show significant real-world safety benefits [96] and, as documented in DOT HS 811 521A, ''Objective Tests for Automatic Crash Imminent Braking (CIB) Systems,'' the current test parameters are ''well-supported by field crash scenarios most relevant to these features and associated with the highest societal harm, as measured by Functional Years Lost.''

Other commenters suggested that the Agency remove certain test conditions. Auto Innovators suggested that the Agency remove one of the two original LVM scenarios, preferably the lower speed condition (*i.e.,* SV and POV speeds of 40 and 16 kph (25 and 10 mph), respectively), since real-world data shows only 2 percent of fatalities and 6 percent of injuries occur on roads having posted speed limits of 40 kph (25 mph) or less. Similarly, Toyota stated that the Agency should adopt only the number of test conditions sufficient to communicate accurate performance information to consumers. The automaker suggested that, if testing only at a certain speed would ensure performance for a large speed range, then that approach was acceptable for testing.

[96] See GM Appendix 1.

With respect to other procedural considerations, Subaru recommended that NHTSA adopt a speed increment of 20 kph (12.4 mph) in lieu of 10 kph (6.2 mph) for LVM testing. A few other respondents also generally supported the test parameters, but suggested slight modifications, which are addressed later in this section.

Adopt Higher AEB Test Speeds Than Those Proposed

State Farm, IIHS, and Uhnder supported CIB and DBS testing at higher speeds, stating that such speeds better reflect real-world driving conditions. Uhnder supported adoption of test speeds that exceed 88.5 kph (55 mph), citing a May 2022 study from IIHS finding nearly 70 percent of fatal rear-end crashes occurred when the speed limit was 88.5 kph (55 mph) or higher.[97] Similarly, IIHS noted that nearly 80 percent of police-reported rear-end crashes occurred on roads having speed limits ranging from 48.3 to 104.6 kph (30 to 65 mph),[98] and the speed of the striking vehicle was more than 40 kph (24.9 mph), even on roads with speed limits of 40.2 kph (25 mph).[99]

Adasky, NTSB, and CAS also favored higher speed AEB assessments than those proposed. CAS asserted that NHTSA should conduct CIB tests at the highest speeds possible to still afford safe testing so that consumers may identify vehicles offering superior CIB performance at each test speed. Similarly, NTSB encouraged NHTSA to consider more challenging test speeds to drive desired (*i.e.,* ideal) system performance instead of testing to current system capabilities. Finally, Rivian also suggested adopting higher speeds for DBS tests than those proposed if the Agency continued DBS testing in the future.

[97] See footnote 11 of Uhnder response.

[98] Kidd, 2022a.

[99] Kidd, 2022b.

Test Speeds and Headway for the LVD Test Scenario Specifically

Several commenters favored adopting AEB test speeds up to 80 kph (49.7 mph) for the LVD test scenario, with BMW and Honda stating that these test speeds were appropriate since they were supported by crash data.

Tesla, along with Subaru, recommended conducting LVD scenarios at 50 kph (31.1 mph), as proposed (similar to Euro NCAP), and also at 80 kph (49.7 mph), as suggested by NHTSA. Subaru added that, if a test failure occurs at 80 kph (49.7 mph), the test speed should then be reduced by 10 kph (6.2 mph). Advocates favored harmonization with Euro NCAP with respect to test speed, headway, and deceleration for the LVD scenario, but preferred NHTSA's alternative proposal of adopting multiple higher test speeds (above 50 kph (31.1 mph)), suggesting NHTSA should also include a ''range of test speeds'' based on crash data and the Agency's testing.

Toyota encouraged NHTSA to conduct additional feasibility studies and research, particularly for the LVD test scenario, to: (1) resolve possible GVT stability issues; (2) study the possible conflict with human driver steering avoidance maneuver timing; and (3) research the effectiveness of FCW and DBS based on the physical limitations imposed by the proposed LVD DBS test condition, and, considering driver reaction times, determine whether such higher-speed testing is feasible and appropriate before modifying the AEB test conditions. With respect to the first request, Toyota noted the Agency's statement that it has not conducted CIB/DBS LVD testing at 80 kph (49.7 mph) because of equipment and test track length limitations. Regarding its second point, the automaker asserted that the time required to steer to avoid a collision at higher speeds is less than the time required to brake, and that by imposing the suggested high speed CIB test conditions, the Agency may create a challenging 'braking' situation that could interfere with a driver's ability to avoid the crash by steering instead. Lastly, Toyota voiced concern that the SV and POV dynamics for DBS LVD testing at higher speeds may pose physical limitations.[100] More specifically, for speeds of 50 kph (31.1 mph) and greater, the manufacturer asserted that, given the (constant) headway prescribed, the time (*i.e.,* TTC) required to activate the brake to avoid impact, and the proposed brake application timing of 1.0 s after issuance of the FCW, it is possible the FCW would have to be issued before the POV test device begins to decelerate in the DBS test for the SV to avoid contact with the POV. Toyota was supportive of DBS testing at higher speeds for the LVS test scenario.

Intel shared Toyota's concerns about the LVD DBS tests, explaining the proposed headway (12 m (39.4 ft.)) may be too small given a POV deceleration of 0.5 to 0.6g, such that it may not be possible to issue the FCW early enough to achieve brake activation one second after the issuance of the FCW as NHTSA proposed for the test procedure. Intel also cautioned the Agency that it should ensure it is feasible for test labs to conduct LVD tests at the proposed higher speeds considering the GVT platform experiences performance degradation at high speeds. Intel further noted many automakers limit speed reductions to approximately 60 kph (37.3 mph) per Automotive Safety Integrity Level (ASIL) considerations.

Auto Innovators did not support the Agency's adoption of test speeds exceeding the capabilities afforded by current systems for the LVD test condition because it may induce false positives under real-world driving conditions, which may in turn discourage AEB use. The group, like Toyota, also cautioned that the proposed high-speed testing may cause unexpected interactions between the SV and POV during testing. Auto Innovators recommended that the Agency consider the proposed changes for CIB and DBS for future program updates to (1) allow additional time to investigate the field relevance of the proposed changes for both technologies and (2) provide sufficient time for system capabilities to improve.

To better align with Euro NCAP testing, Intel suggested that LVD testing should be limited to 50 kph (31.1 mph) and should be performed only for vehicles equipped with both AEB and FCW. HATCI recommended that the Agency harmonize with the test speeds prescribed in Euro NCAP's protocol for the LVD test scenario if it ultimately adopts higher test speeds, and asked that the SV-to-POV headway be increased for each higher speed test condition based on field-representative distances or TTCs. Subaru recommended that the Agency maintain vehicle headway in LVD testing at a spacing equivalent to 1.0 second (instead of 12 m (39.4 ft.), as proposed) regardless of test speed. FCA also favored higher speed assessments for the LVD test scenario. However, FCA stated that the SV-to-POV headway should be adjusted for each speed to reflect a 0.9 second following distance, asserting this following distance is typical of real-world driving.

POV Deceleration Magnitude for LVD Test Scenario

Most commenters addressing this issue favored a 0.5g POV deceleration for the LVD CIB test instead of 0.6g, with TRC citing issues with repeatability when attempting to tune the GVT braking system to operate at a deceleration greater than 0.5g. Although it acknowledged that new robotic platforms make tuning easier, TRC also suggested that they are expensive and require modification of existing equipment before they can be utilized. BMW also cited robotic platform operational limits and tire wear as reasons not to adopt a 0.6g POV deceleration requirement. HATCI favored a 0.5g deceleration magnitude because of proven repeatability and minimal equipment damage. The commenter recommended that the Agency increase the vehicle headway if it chooses to adopt a 0.6g POV deceleration instead.

GM and Auto Innovators supported a 0.5g deceleration, asserting that this is a ''common'' deceleration level (based on crash data reviewed by NHTSA) and therefore ''realistic.'' Both commenters mentioned that a 0.6g deceleration has not been shown to induce differences in vehicle performance, but can cause problems with test equipment (based on experience in conducting Euro NCAP tests at 6 m/s^2). In a similar vein to the repeatability concerns mentioned by others, GM also noted that China NCAP no longer generally performs LVD tests (and other consumer groups are expected to follow suit) because they are difficult to conduct and test results for a given vehicle model are often widely variable.

A few commenters expressed conditional support for the higher POV deceleration. Specifically, Honda and Auto Innovators offered support for adoption of a 0.6g deceleration if crash data indicates such a limit is more representative of driver braking in real-world crashes. Auto Innovators added that the Agency must also ensure testing tolerances. FCA suggested that a 0.6g deceleration may be acceptable if NHTSA wanted to ''reduce validation effort.''

Intel expressed support for adopting a 0.6g deceleration criterion for the LVD CIB test to harmonize with other entities and regulations and thus reduce test burden. The company stated that, considering the tolerance currently prescribed for the POV deceleration, the

[100] See case study included in Toyota's comments.

difference between 0.5g and 0.6g is small. Bosch also supported adoption of a 0.6g deceleration magnitude, as did Tesla. However, Tesla suggested that in lieu of a single POV deceleration of 0.5 or 0.6g, as proposed, the Agency should adopt deceleration magnitudes of –2 m/s² and –6 m/s² (approximately 0.2 and 0.6g), respectively, for each test speed to harmonize with Euro NCAP. Advocates shared this opinion.

Agree With Removal of DBS Tests

MEMA, Subaru, and HATCI agreed with the Agency's proposal to remove the DBS test scenarios from NCAP's AEB test matrix, with the latter commenter suggesting that CIB and DBS functionality may overlap at certain speeds such that DBS functionality would be redundant when CIB is activated. HATCI therefore suggested that, if the Agency decided to continue conducting separate DBS assessments in NCAP, such tests should only be performed when a vehicle exhibits a test failure during CIB testing for that condition, as this would reduce test burden. Rivian remarked that the DBS testing was unnecessary because a vehicle's CIB system will activate and slow the vehicle when the braking imparted by DBS is insufficient. Subaru recommended removal or replacement of any ADAS test that currently has a high rate of passing results if adoption rates for the related ADAS technology are also high.

Retain Some or All DBS Tests

Several commenters expressed that the Agency should continue to conduct DBS assessments in NCAP because DBS affords additional safety benefits compared to CIB. ZF Group favored retaining the DBS tests to ensure that vehicles continue to be equipped with DBS, noting that DBS systems ''can react earlier in critical situations.'' Similarly, CAS asserted that DBS ''can provide additional safety margin.''

Other commenters recommended that NHTSA continue DBS testing to ensure system functionality. Advocates, GM, and Auto Innovators suggested the Agency should (Advocates and GM), or could (Auto Innovators), continue to conduct DBS tests to ensure that brake pedal application does not override AEB system functionality in general. NTSB also agreed that DBS functionality should be verified and supported NHTSA's alternative proposal to retain DBS testing in NCAP and conduct LVM and LVS testing at higher speeds (70 and 80 kph (43.5 and 49.7 mph)).

GM and Auto Innovators also recommended other options centered on performing DBS tests only at certain speeds that NHTSA could adopt to reduce the burden of DBS testing. GM noted that China NCAP performs CIB tests at lower speeds and DBS tests at higher speeds. The automaker suggested that for speeds higher than 40 kph (24.9 mph) the Agency could alternate between CIB and DBS testing. Auto Innovators stated that DBS testing would be unnecessary in situations where the CIB system provides complete avoidance in all tests, noting that the Agency could simply assume DBS performance and apply points for both systems equally. Auto Innovators also stated that each assessed test speed should afford equal weighting for both CIB and DBS, noting it should not be the case that one test speed carries twice the weight simply because both systems are assessed at that speed, whereas another test speed carries less weight because only one of the two systems is assessed at that speed. Both GM and Auto Innovators noted, similar to HATCI, that NHTSA could conduct CIB tests until the system can no longer provide full avoidance and then begin DBS testing for the next subsequent higher test speed. If the CIB system was able to provide complete avoidance at all test speeds, then the commenters suggested that DBS testing could be repeated for only the maximum test speed to ensure system functionality. GM also noted that for 2023 Euro NCAP removed the DBS tests for LVM and LVD from their assessment and going forward it will only perform the DBS test for the LVS scenario. Finally, Auto Innovators encouraged the Agency to reduce the number of test scenarios and evaluate FCW during DBS testing (*i.e.,* record the time of the FCW) to further reduce test burden.

Like other commenters' suggestions, FCA and Intel recommended that the Agency continue to perform DBS tests in NCAP for higher test speeds where the CIB system does not afford full crash avoidance, with Intel suggesting that it may be appropriate to start the DBS tests at 60 kph (37.3 mph) to harmonize with Euro NCAP. IDIADA also suggested that the Agency only perform higher speed DBS tests. Similarly, Toyota, like the NTSB, was supportive of the Agency conducting LVS and LVM DBS tests at only the highest test speeds proposed for CIB—70 and 80 kph (43.5 and 49.7 mph), respectfully. However, Toyota did not support conducting the LVD DBS test at 80 kph (49.7 mph) since NHTSA stated that it had not conducted testing at this speed due to equipment and test track limitations. Intel expressed similar concerns, stating that manufacturers may not be able to issue the FCW early enough to achieve brake activation one second after the issuance of the FCW as NHTSA proposed for the LVD tests.

Unlike those commenters who expressed that it was sufficient for the Agency to only conduct high-speed DBS assessments or alternate CIB and DBS assessments for incremental speeds, Honda stated that it is most appropriate to conduct CIB and DBS tests at the same test speeds. Honda asserted that evaluating DBS performance only at higher test speeds may skew performance ratings (similar to what Auto Innovators stated) and not accurately convey the real-world safety benefits DBS provides at lower test speeds. Since CIB and DBS address different safety needs (*i.e.,* the driver is either not responsive, or responsive, respectively, to an imminent collision), the automaker indicated that it is imperative to ensure ratings reflect the benefits afforded by both technologies. Accordingly, Honda, like Auto Innovators, suggested that if the Agency moves forward with such an approach, vehicles should be awarded credit for lower speed DBS tests as well (even though they would only be tested for CIB and not DBS) if the vehicle received passing results for the CIB system at the lower test speeds. Honda asserted this credit would be appropriate, noting that DBS systems should afford equivalent or higher performance than CIB systems when tested at the same speeds. Bosch similarly responded that it would be appropriate to cover the entire speed range by performing one test per scenario and incrementing speeds for each separate scenario by 10 kph (6.2 mph) if NHTSA decided to continue to perform separate DBS assessments and if there are benefits to increasing both CIB and DBS test speeds. CAS also noted that if the Agency imposed higher test speeds for LVD CIB assessments, those same test speeds should be used to assess DBS. The group stated that DBS activation was highly likely for the LVD scenario and all technologies that may contribute to a given scenario/crash outcome should be assessed. Likewise, Tesla asserted that DBS testing should not be reserved only for higher-speed assessments and should be conducted using the same test specifications (speed, headway, and POV deceleration) as the corresponding CIB tests.

Advocates encouraged NHTSA to select the appropriate number of tests and test speeds to ensure acceptable performance across a range of conditions, including those that would be expected during real-world driving.

Response to Comments and Agency Decisions

NHTSA's decision regarding CIB and DBS testing specifics can be found in the following sections as well as in Tables 12 and 13.

CIB Test Speeds for the LVS Test Scenario

NHTSA will proceed with assessing CIB performance in NCAP's LVS scenario using the proposed SV test speeds and increments. The Agency will initiate the LVS test series at the lowest vehicle test speed, 40 kph (24.9 mph), and test speeds will increase in increments of 10 kph (6.2 mph) as each test condition's criteria are met (*i.e.,* no SV-to-POV contact is observed), up to and including the 80 kph (49.7 mph) test condition.

Although several commenters, including Advocates, recommended that the Agency set the minimum LVS test speed to 10 kph (6.2 mph) to harmonize with Euro NCAP, the Agency asserts a 40 kph (24.9 mph) minimum LVS test speed is appropriate for NCAP testing. As noted in Auto Innovators' comments to the March 2022 RFC notice, Volpe's review of 2011–2015 crash data sets showed that, for rear-end crashes, only 2 percent of fatalities and 6 percent of injuries occurred on roadways with posted speed limits of 40.2 kph (25 mph) or less.[101] [102] It is most appropriate, at this time, to allocate resources for the flagship consumer information program to performing tests representing rear-end crashes that are more likely to induce injuries or fatalities instead of those that are more likely to cause only property damage.

NHTSA has chosen to set the uppermost SV test speed for CIB LVS testing at 80 kph (49.7 mph). A few commenters, such as GM, requested that the Agency not make any changes to the current AEB test conditions, including the test speeds, stating that the current conditions already provide significant real-world safety benefits. However, most commenters supported NHTSA's proposal to increase test speeds, including for the LVS test scenario, and several commenters even suggested adopting higher test speeds, with recommended maximums ranging from 88.5 to 104.6 kph (55 to 65 mph). The Agency notes that its recent research testing showed CIB tests up to 80 kph (49.7 mph) are practicable; however, there is a particular need for improvement in CIB performance at vehicle test speeds above 60 kph (37.3 mph). In NHTSA's model year 2021–2022 CIB LVS research test series, out of 12 test vehicles, only three achieved full avoidance at 70 kph (43.5 mph) and two achieved full avoidance at 80 kph (49.7 mph). Given these results, establishing a maximum test speed of 80 kph (49.7 mph) for NHTSA's CIB LVS testing is currently appropriate. Further, as NHTSA recognized in its 2022 RFC notice, by adopting a maximum LVS test speed of 80 kph (49.7 mph), the Agency will harmonize with Euro NCAP's upper test speed limit for its CCRs scenario, which is analogous to NHTSA's LVS test scenario. Ensuring robust AEB system performance at 80 kph (49.7 mph) also allows the Agency to better target the high severity, high-speed crash problem identified in Volpe's real-world data analysis, further mitigating serious injuries and fatalities. For future iterations of the testing program, the Agency may choose to increase this upper test speed, as several commenters suggested, based on further real-world data collection and analysis, future research, the assurance of test practicability, and other factors.

As vehicles meet the criteria (*i.e.,* no SV-to-POV contact is observed) for passing each LVS test condition, SV test speeds will increase in 10 kph (6.2 mph) increments. Thus, LVS tests may be conducted for SV test speeds of 40 kph, 50 kph, 60 kph, 70 kph, and 80 kph (24.9 mph, 31.1 mph, 37.3 mph, 43.5 mph, and 49.7 mph), respectively, depending on the vehicle's performance at each speed. Should a test failure occur at any of these speeds, defined as SV-to-POV contact during the single trial performed at that respective speed, the test laboratory will discontinue the LVS test series. By using 10 kph (6.2 mph) increments, the Agency can minimize potential damage to the test vehicle and vehicle test device as test speeds and potential impact energy increase.

CIB Test Speeds for the LVM Test Scenario

NHTSA will adopt the same SV test speeds for LVM testing that it is adopting for LVS testing: a minimum speed of 40 kph (24.9 mph) with speed increases in increments of 10 kph (6.2 mph), up to and including 80 kph (49.7 mph), as test vehicles meet criteria (*i.e.,* no contact) for passing each LVM condition. This approach results in potential SV test speeds of 40 kph, 50 kph, 60 kph, 70 kph, and 80 kph (24.9 mph, 31.1 mph, 37.3 mph, 43.5 mph, and 49.7 mph), respectively, depending on vehicle performance at each speed. For the lead vehicle, the POV speed will be 20 kph (12.4 mph) regardless of SV test speed.

NHTSA's rationale for adopting the LVS minimum and maximum SV test speeds and speed increments also pertains to LVM testing. The Agency asserts the selected speeds relate well to the rear-end crash problem and should thus improve real-world safety. Also, LVM testing at the selected speeds is possible. Not only are the SV speeds selected already assessed by Euro NCAP in its CCRm test,[103] but also, during model year 2021–2022 research testing, NHTSA found that vehicle models performed more favorably throughout the battery of test speeds in its CIB LVM test series than in its LVS test series. Only one vehicle did not achieve full avoidance in the 70 kph (43.5 mph) condition, and an additional three did not fully avoid the POV in the 80 kph (49.7 mph) condition. The rest of the vehicles were able to fully avoid SV-to-POV impact in every CIB LVM test condition. Because the lead vehicle is moving in LVM tests, the SV's speed relative to the POV is lower than in the LVS scenario for any given test speed. Further, the current NCAP protocol specifies similar minimum SV speeds and slightly lower maximum SV speeds (40.2 kph (25 mph) and 72.4 kph (45 mph)), so it is possible manufacturers have already designed their vehicles' CIB systems to mitigate such crashes.

Adopting a POV speed of 20 kph (12.4 mph) is appropriate for the LVM tests. As noted in the March 2022 RFC notice, Euro NCAP's CCRm protocol specifies this POV speed, offering another opportunity for NCAP to harmonize with other consumer information programs.

Although Subaru recommended that the Agency adopt a speed increment of 20 kph (12.4 mph) in lieu of 10 kph (6.2 mph) for NCAP's LVM testing, explaining that this speed increment would be ''adequate for system evaluation,'' conducting an additional two test runs at 50 and 70 kph (31.1 and 43.5 mph) in addition to 40, 60, and 80 kph (24.9, 37.3, and 49.7 mph) should not add significantly to the test burden. Therefore, the Agency does not see a reason to deviate for the LVM test scenario from the 10 kph (6.2 mph) speed increment adopted for the other AEB test scenarios.

[101] Swanson, E., Foderaro, F., Yanagisawa, M., Najm, W.G., & Azeredo, P. (2019, August), *Statistics of light-vehicle pre-crash scenarios based on 2011–2015 national crash data* (Report No. DOT HS 812 745), Washington, DC: National Highway Traffic Safety Administration.

[102] Data provided is from all rear-end FARS and GES crashes, including cases where posted speed limit was unknown.

[103] European New Car Assessment Programme (Euro NCAP) (December 2023), *Test Protocol—AEB Car-to-Car systems, Version 4.3.* See section 8.2.2.2.

CIB Test Speeds for the LVD Test Scenario

For the LVD CIB test scenario, the Agency will conduct tests using two SV/POV test speeds only: 50 kph (31.1 mph) and 80 kph (49.7 mph). NHTSA chose these speeds for several reasons. First, Euro NCAP specifies a 50 kph (31.1 mph) test speed for its CCRb scenario,[104] and adopting this speed allows the Agency to harmonize its testing in this regard. Adopting an 80 kph (49.7 mph) uppermost test speed also aligns with the highest speed NHTSA is adopting for NCAP's LVM and LVS test scenarios.

Second, in NHTSA's model year 2021–2022 research testing series, vehicles performed reasonably well for the 50 kph (31.1 mph) LVD test conditions. Half of the tested models met all the requirements for every test condition (*i.e.,* varying headways and POV decelerations). However, the 80 kph (49.7 mph) LVD test conditions proved more difficult, with SV-to-POV contact observed in most vehicle trials. Varying responses in vehicle braking systems and/or AEB algorithms may have contributed to the performance differences seen at 50 kph (31.1 mph) versus 80 kph (49.7 mph). However, one vehicle was able to pass all test criteria for the 80 kph (49.7 mph) LVD test condition, thus proving that robust AEB performance at this higher test speed is feasible. This vehicle was a popular model with a high sales volume, and the Agency has not observed an increase in reports of false activations in the field. Thus, it is NHTSA's view that Auto Innovators' concern that encouraging swift innovation will result in many false positive activations is unfounded, at least up to the maximum speed the Agency has chosen to adopt at this time.

Third, NHTSA has confirmed that its initial concern (which was also expressed by Toyota) regarding safety considerations and equipment limitations when running higher-speed LVD tests was unwarranted for speeds up to 80 kph (49.7 mph). The Agency's recent research for model year 2021–2022 vehicles showed that it is feasible to conduct CIB LVD testing at 80 kph (49.7 mph) safely. Further, neither test track limitations nor achieving the higher GVT speeds were found to be problematic during this testing.

Finally, as mentioned previously, NHTSA notes that real-world fatality and injury data highlights a safety need for testing at higher speeds, further suggesting that adopting an 80 kph (49.7 mph) upper test speed for the LVD test scenario is warranted. While Euro NCAP's CCRb test scenario specifies a single test speed of 50 kph (31.1 mph), and Intel requested that NHTSA adopt only this speed for the LVD scenario, adopting 80 kph (49.7 mph) in addition to 50 kph (31.1 mph) is appropriate. This decision also aligns with the recommendation made by other commenters, including Tesla and Subaru.

NHTSA acknowledges Subaru's recommendation that the Agency should perform an additional test at 70 kph (43.5 mph) if the SV contacted the POV during the 80 kph (49.7 mph) test to identify the vehicle's CIB performance threshold. Other commenters stated that NHTSA should test a range of speeds for the LVD tests, like the range being adopted for LVM and LVS scenarios. However, the initial speed conditions for the LVD scenario are not as critical to the outcome as other test parameters, such as headway and POV deceleration, since the SV and POV speeds are initially the same. Therefore, the Agency has decided to use two discrete speeds to evaluate LVD performance instead of speed increments but, as detailed in the next sub-section, will vary the headway and POV deceleration magnitude assessed for each speed. The use of two speeds is expected to ensure system robustness while limiting test burden.

NHTSA also acknowledges Toyota's comments that, in some high-speed cases, steering away from the impending crash may be preferable to remaining in the same travel lane and fully braking, since the time required to steer away would be less than the time required to fully stop.[105] That said, the timing necessary to steer away from a crash rather than brake is not the only factor that should be considered; vehicle dynamics, traffic conditions, and other traffic participants all influence the possibility and advisability of a steering avoidance maneuver. Steering to avoid a crash with a lead vehicle could cause the subject vehicle to either depart the road, collide with a vehicle in the adjacent lane, or on an undivided two-lane road, causing a head-on frontal crash. As such, the situations in which an evasive steering maneuver to avoid a crash would likely be the preferable response would be under limited circumstances, since there must be sufficient space in a lane or on the shoulder adjacent to the subject vehicle's lane that the subject vehicle may move to, and the driver must have the ability to safely maneuver a vehicle at such a high speed. Further, it is unreasonable to assume that a driver who is inattentive until moments before a crash will reengage and be able to perform a safe steering maneuver that would not jeopardize the safety of others in the surrounding area or themselves.

Research also shows drivers are not prone to initiate steering alone to avoid a surprise obstacle in front of them in the roadway in an emergency situation.[106] Instead, they either brake, or brake and steer. When drivers were presented with a surprise obstacle catapulted from the side (which typically would invoke a steering response) at a TTC of 1.5 seconds, with the adjacent lane free of obstacles such that the drivers had the opportunity to avoid a collision by steering alone, 43 percent of research participants attempted to avoid the obstacle by braking alone. The other 57 percent of participants tried to avoid a collision by braking and steering, while no participant tried to avoid contact by steering alone. Only as the TTC increased (*i.e.,* above 2.0 seconds) did drivers feel comfortable attempting to avoid the obstacle by steering alone. At a TTC of 2.0 seconds, 46 percent of participants tried to avoid by braking alone, 38 percent tried to avoid by braking and steering, and 15 percent tried to avoid by steering alone, while at a TTC of 2.5 seconds, 72 percent of participants tried to avoid by braking only, 14 percent tried to avoid by braking and steering, and 14 percent tried to avoid by steering alone. These findings further reinforce the Agency's assertion that braking in lane is appropriate at the speeds NCAP will test.

The Agency also notes that in its data analysis, for those rear-end crashes where the driver's avoidance maneuver was known, Volpe found the driver made no attempt to avoid the crash for 75 percent of crashes involving fatalities and 48 percent of crashes involving injuries.[107] [108] Therefore, initiating

[104] European New Car Assessment Programme (Euro NCAP) (December 2023), *Test Protocol—AEB Car-to-Car systems, Version 4.3.* See section 8.2.2.3.

[105] The Agency additionally notes that Euro NCAP awards points for vehicles equipped with Emergency Steering Support (ESS) systems that assist a driver in safely maneuvering around an obstacle in select scenarios. See TB037, *https://cdn.euroncap.com/media/68587/tb-037-ess-assessment-v10.pdf.*

[106] Emergency Steer and Brake Assist—A Systematic Approach for System Integration of Two Complementary Driver Assistance Systems (Eckert, Continental AG, Paper Number 11–0111), *https://www-hesv.nhtsa.dot.gov/Proceedings/22/files/22ESV-000111.pdf.*

[107] Swanson, E., Foderaro, F., Yanagisawa, M., Najm, W.G., & Azeredo, P. (2019, August), *Statistics of light-vehicle pre-crash scenarios based on 2011–2015 national crash data* (Report No. DOT HS 812 745), Washington, DC: National Highway Traffic Safety Administration.

steering (which would require driver engagement) during an AEB test would not address this large portion of crashes resulting in injuries and fatalities. Given the findings from these studies, the Agency's current AEB test requirement for braking in the absence of steering is appropriate. However, this is not to say that steering must be suppressed in crash-imminent situations.

CIB Headway for the LVD Test Scenario

NHTSA plans to adopt the 12 m (39.4 ft.) and 40 m (131.2 ft.) headway conditions proposed for both the 50 kph (31.1 mph) and 80 kph (49.7 mph) LVD CIB tests. The Agency's model year 2021–2022 testing demonstrated that no contact performance is practicable for both headways, even at the highest test speed (*i.e.,* 80 kph (49.7 mph)) and most stringent POV deceleration proposed (*i.e.,* 0.5g). One of the twelve test vehicles was able to achieve no contact performance at 80 kph (49.7 mph) with an initial headway of 12 m and lead vehicle deceleration of 0.5g. This same vehicle, in addition to a second model, was also able to meet the test requirements at the same test speed for a headway of 40 m and POV deceleration of 0.5g. For an SV test speed of 50 kph (31.1 mph) and 0.5g POV deceleration, all but one of the twelve vehicles tested avoided contact with the POV for the 40 m headway and six of the twelve vehicles provided passing performance for the 12 m headway.

NHTSA previously stated that adopting multiple headways in the LVD CIB test to assess CIB system performance would unnecessarily increase test burden because longer headways should result in less stringent test conditions compared to shorter headways. However, the Agency's recent model year 2021–2022 research test findings contradicted this assertion. Specifically, greater relative speed reduction was not always observed for the longer assessed headway (40 m (131.2 ft.)) compared to the shorter headway (12 m (39.4 ft.)), as the Agency had expected. When assessing vehicles at 50 kph (31.1 mph) with a POV deceleration of 0.5g, one vehicle experienced greater relative speed reduction during the shorter headway (12 m (39.4 ft.)) test than during the longer headway (40 m (131.2 ft.) test. For LVD CIB tests completed at 80 kph (49.7 mph) and 0.4g POV deceleration, six vehicle models performed better in the shorter headway test compared to the longer headway test.[109] Thus, the Agency now reasons that assessments using both headways—the 12 m (39.4 ft.) condition proposed by NHTSA and the 40 m (131.2 ft.) condition required by Euro NCAP in its CCRb test—are necessary for NCAP testing (in addition to the two adopted test speeds) to assess CIB performance in the LVD test scenario.

The Agency notes that HATCI requested NHTSA increase headways for higher-speed testing based on field-representative distances. Alternatively, it and other commenters recommended that NHTSA adjust headways based on test speed to achieve specific times-to-collision, suggesting these would be more representative of real-world driving. Such changes are not necessary, since results from NHTSA's recent research demonstrate it is possible to achieve full avoidance across both short and long headways, even at the highest speed and highest POV deceleration for the CIB LVD tests. Further, while maintaining a 12 m (39.4 ft.) headway at an 80 kph (49.7 mph) travelling speed is uncomfortably close and more likely to result in a crash imminent situation, it is reflective of the real-world driving habits of some individuals. In such situations, it will be difficult, even for an attentive driver, to react quickly enough to avoid a crash, especially with a lead vehicle braking above 0.3g. As such, it is imperative to ensure vehicles respond quickly and appropriately in such instances. Performing CIB tests in NCAP with an 80 kph (49.7 mph) test speed and 12 m (39.4 ft.) headway can provide this assurance.

Based on the results of NHTSA's recent model year 2021–2022 research testing, and in an effort to harmonize test procedures as much as possible with other consumer information programs per the BIL mandate, NHTSA will conduct tests using both 12 m (39.4 ft.) and 40 m (131.2 ft.) headways for both test speeds selected for CIB LVD testing.

CIB POV Deceleration Magnitude for the LVD Test Scenario

With respect to NHTSA's proposal to increase the POV deceleration magnitude currently specified in NCAP's CIB LVD test procedure from 0.3g to 0.5g or 0.6g for this upgrade of NCAP, the Agency has decided to retain a 0.3g POV deceleration in its CIB LVD tests and adopt a 0.5g POV deceleration specification.[110]

While NHTSA sought comments on adopting a 0.6g POV deceleration for LVD testing and received some supportive feedback regarding this idea due in part to Euro NCAP's use of a similar test specification (6 m/s^2), the Agency reasons that adopting a maximum 0.6g POV deceleration is not appropriate at this time. Although harmonization is generally desired, Euro NCAP requires only a 50 kph (31.1 mph) test speed for its CCRb test and provides partial credit for speed reduction, while NHTSA has also adopted an 80 kph (49.7 mph) test speed and is moving forward with a no contact passing criterion for its CIB testing (as discussed later). Additionally, as mentioned in its March 2022 RFC notice, NHTSA observed excessive wear on the GVT's tires (*i.e.,* flat-stopping due to wheel lockup) while conducting research testing during braking maneuvers where the POV deceleration was near 0.6g, and found it was more difficult to achieve and accurately control deceleration within the prescribed tolerances when braking maneuvers were performed with decelerations higher than 0.5g, even with extensive tuning efforts. Commenters also suggested that a 0.5g deceleration was less likely than a 0.6g deceleration to introduce repeatability issues or cause damage to test equipment. To limit potential testing challenges, NHTSA is adopting a 0.5g maximum POV deceleration for NCAP's updated LVD test requirements at this time but may consider incorporating a 0.6g deceleration as part of future program updates if testing concerns can be alleviated.

The Agency notes that many commenters asserted a 0.5g deceleration was representative of real-world driving. NHTSA's previous research suggests that drivers decelerate up to approximately 0.3g in a non-emergency situation and up to approximately 0.5g when encountering an unexpected obstacle.[111] Additionally, past NHTSA research analysis of rear-end crash event data recorder data showed that drivers applied the brakes at approximately 0.4g

[108] The SV driver's avoidance maneuver was unknown for 25 percent of fatal rear-end crashes and 54 percent of rear-end crashes with police-reported injuries.

[109] Note that most of the vehicles in this test series did not undergo CIB LVD testing at 80 kph (49.7 mph) and 0.5g POV deceleration. Thus, 0.4g POV deceleration data was used.

[110] The Agency notes that testing with a 12 m (39.4 ft.) headway and a POV deceleration of 0.5g roughly corresponds to the deceleration necessary to comply with the minimum stopping distance required in FMVSS No. 135, ''Light vehicle brake systems.''

[111] Fitch, G.M., Blanco, M., Morgan, J.F., Rice, J.C., Wharton, A., Wierwille, W.W., & Hanowski, R.J. (2010, April) Human Performance Evaluation of Light Vehicle Brake Assist Systems: Final Report (Report No. DOT HS 811 251) Washington, DC: National Highway Traffic Safety Administration, p. 13 and p. 101.

in rear-end crash scenarios.[112] Therefore, a POV deceleration of 0.5g seems reasonable to adopt (*i.e.,* compared to 0.6g) when real-world driving data are considered.

Given these data, there is also reason to retain the 0.3g POV deceleration currently specified in the Agency's CIB test procedure. Adopting this lower deceleration magnitude in addition to 0.5g will ensure vehicles continue to perform as expected in situations where the lead vehicle decelerates at a more moderate rate. The Agency reasons that CIB systems should function whether the lead vehicle is engaged in an emergency maneuver or not. AEB systems that perform well in a test with higher lead vehicle deceleration may not necessarily offer comparable or better performance in tests with lower lead vehicle decelerations. The Agency also notes Euro NCAP takes a similar approach to testing in its CCRb scenario. In addition to the previously mentioned 6 m/s^2 (19.7 ft./s^2) deceleration, Euro NCAP prescribes a lower POV deceleration of 2 m/s^2 (6.6 ft./s^2). Tesla and Advocates also agreed with such a testing approach. By adopting two POV deceleration rates for NHTSA's NCAP testing, manufacturers will need to demonstrate that their vehicles offer consistent performance by effectively recognizing and responding to lead vehicles that are braking at various rates.

While much of the Agency's recent model year 2021–2022 research testing was conducted using a 0.4g POV deceleration in addition to a 0.5g POV deceleration at each headway and test speed, NHTSA is not adopting a POV deceleration of 0.4g for its future NCAP testing. At the lower test speed of 50 kph (31.1 mph) and longer headway of 40 m (39.4 ft.), all vehicles achieved full avoidance when the POV decelerated at 0.4g and all but one vehicle met the no-contact requirements at a POV deceleration of 0.5g. Reducing the headway to 12 m (39.4 ft.) made this test condition more challenging, with half the vehicles tested achieving full avoidance when subjected to POV decelerations of 0.4g and 0.5g.[113] As noted earlier in this notice, higher-speed LVD testing (*i.e.,* 80 kph (49.7 mph)) was more rigorous, and few vehicles offered full avoidance for either headway. However, for the 80 kph (49.7 mph) conditions, vehicles that achieved full avoidance in a given 0.4g POV deceleration test condition also achieved full avoidance when subjected to the same condition but with a POV deceleration of 0.5g. While the Agency has noted (above) that vehicles may not always provide comparable or better performance for lower POV decelerations, NHTSA's test data shows they often do, thus suggesting it may be appropriate for NCAP, in consideration of limiting test burden, to adopt one of these decelerations (*i.e.,* 0.4 or 0.5g) without sacrificing the program's efforts to ensure robust CIB system performance. This decision seems especially reasonable since NHTSA has decided to retain a 0.3g POV deceleration while adding a 0.5g deceleration.

For the LVD CIB scenario, NHTSA will impose a similar testing assessment process to that adopted for the LVS and LVM CIB scenarios. The Agency will perform the LVD CIB test conditions in a manner consistent with increasing stringency. The first LVD trial will be performed at the minimum test speed (50 kph (31.1 mph)), maximum headway (40 m (131.2 ft.)), and minimum deceleration (0.3g). If the initial trial run is valid (*i.e.,* all test specifications and tolerances are satisfied) and the SV does not contact the POV, the Agency will proceed with conducting the next trial run at the same test speed (50 kph (31.1 mph)) and deceleration (0.3g) but will adjust the headway to the minimum specified distance, 12 m (39.4 ft.). If the vehicle does not contact the POV for this test condition and the trial run is determined to be valid, NHTSA will then increment the test speed to the maximum LVD test speed, 80 kph (49.7 mph), and perform one trial run at the maximum headway (40 m (131.2 ft.)) and minimum deceleration (0.3g), followed by one trial run at 80 kph (49.7 mph), minimum headway (12 m (39.4 ft.)), and minimum deceleration (0.3g). If no vehicle-to-POV contact is observed and all 80 kph (49.7 mph) trials are considered valid, the Agency will repeat the LVD test sequence utilizing a POV deceleration of 0.5g. See Table 14 for the sequence of CIB LVD tests.

DBS Testing in NCAP

After consideration of the most recent research data and comments received from the public in response to the March 2022 RFC notice, the Agency has decided to retain DBS testing in NCAP.

For the LVS and LVM scenarios, NHTSA will perform DBS assessments at the two highest test speeds adopted for the complementary CIB test scenarios—70 kph (43.5 mph) and 80 kph (49.7 mph)—as well as two additional speeds, 90 kph (55.9 mph) and 100 kph (62.1 mph). The performance criterion for each assessment will be ''no contact,'' and the POV speeds adopted for DBS will align with those adopted for CIB evaluation (*i.e.,* 0 kph (0 mph) for the LVS scenario and 20 kph (12.4 mph) for the LVM scenario). For the LVD scenario, the Agency will perform DBS assessments in all eight test conditions covered by CIB: 50 kph (31.1 mph) and 80 kph (49.7 mph), each at 12 m (39.4 ft.) and 40 m (131.2 ft.) headways and each with 0.3g and 0.5g POV deceleration. Like the LVS and LVM DBS tests, the performance criterion adopted for the LVD DBS assessment will be ''no contact.''

NHTSA notes that commenter suggestions on appropriate DBS test speeds varied. Some suggested that the Agency conduct CIB and DBS tests at the same speeds or alternate between CIB and DBS testing above certain speeds. Others recommended that NHTSA perform CIB tests at lower speeds and DBS tests at higher speeds, albeit sometimes with slight deviations (*e.g.,* conducting DBS testing at the next highest speed once the CIB system fails to provide complete avoidance.) Several commenters also stated that NHTSA should conduct AEB assessments, in general, at speeds higher than those proposed, citing the need to better reflect real-world driving conditions and foster ideal system performance. There is merit to these commenters' recommendations for NCAP's DBS tests. In its real-world data analysis, Volpe found that, for rear-end crashes where posted speed was known, over 37 percent of fatalities and 21 percent of injuries occurred on roadways having posted speeds between 80 kph (49.7 mph) and 100 kph (62.1 mph).[114] [115]

By adopting two additional higher test speeds for NCAP's LVS and LVM test scenarios (*i.e.,* 90 kph (55.9 mph) and 100 kph (62.1 mph)) in addition to those proposed (*i.e.,* 70 kph (43.5 mph) and 80 kph (49.7 mph)), the program's DBS tests would represent the posted speeds at which more than 65 percent of fatalities and 91 percent of injuries occurring in rear-end crashes.[116]

[112] Automatic Emergency Braking System (AEB) Research Report, NHTSA, August 2014, pg. 47. *https://www.regulations.gov/document/NHTSA-2012-0057-0037*.

[113] If a vehicle did not achieve full avoidance during the 0.4g POV deceleration test condition, the 0.5g POV deceleration test condition was not assessed.

[114] Swanson, E., Foderaro, F., Yanagisawa, M., Najm, W.G., & Azeredo, P. (2019, August), *Statistics of light-vehicle pre-crash scenarios based on 2011–2015 national crash data* (Report No. DOT HS 812 745), Washington, DC: National Highway Traffic Safety Administration.

[115] Posted speed limit was unknown or not reported in 2 percent of fatal rear-end crashes and 11 percent of rear-end crashes with injuries.

[116] Swanson, E., Foderaro, F., Yanagisawa, M., Najm, W.G., & Azeredo, P. (2019, August), *Statistics*

NHTSA's testing has shown such test speeds to be practicable with respect to both testing feasibility and current AEB system capabilities. In its model year 2021–2022 research testing, one vehicle was able to provide complete crash avoidance up to 100 kph (62.1 mph) for all LVM and LVS test conditions.[117] This is likely because a speed differential of 80 kph (49.7 mph) in the Agency's LVS CIB test, where no manual braking is imparted, affords similar stringency to the Agency's LVS DBS test scenario for a test speed of 100 kph (62.1 mph), where manual braking at a constant average deceleration of 0.4g is required. The Agency also maintains that a 100 kph (62.1 mph) LVS DBS test would require braking that is no harsher than that currently demonstrated by vehicles compliant with FMVSS No. 135, ''Light vehicle brake systems.'' In addition, a maximum subject vehicle test speed of 100 kph (62.1 mph) in the Agency's DBS LVM test affords similar stringency as a test speed of 80 kph (49.7 mph) in its DBS LVS test since the POV speed in the LVM test is 20 kph (12.4 mph), and thus, the relative speed between the subject vehicle and POV is 80 kph (49.7 mph).

While NHTSA is adopting a 100 kph (62.1 mph) maximum speed for its DBS LVS and LVM assessments, NHTSA's proposed maximum speed of 80 kph is appropriate for its DBS LVD assessment. As mentioned for the CIB LVD test, there was some concern regarding the ability to perform LVD testing reliably at 80 kph (49.7 mph). While research data has shown that testing at this speed is feasible and practicable, LVD research testing has not been conducted at speeds higher than 80 kph (49.7 mph). As such, the Agency hesitates to raise the DBS LVD test speeds to match those for LVS and LVM. Another concern raised in response to the March 2022 RFC was related to the LVD scenario and FCW timing for higher test speeds, with Toyota and Intel both noting there may not be sufficient time to: (1) issue the FCW, (2) wait for the prescribed amount of time between FCW and brake activation (*i.e.,* 1.0 second, as proposed), and (3) initiate braking during an LVD assessment where POV deceleration is 0.5g and headway is 12 m (39.4 ft.). In fact, Toyota stipulated that the POV may not have even begun decelerating at the time at which the FCW would need to be issued. However, during its research testing, NHTSA found many vehicle models are currently available to meet this criterion.[118] In the 12 m (39.4 ft.) headway LVD tests with 0.5g POV deceleration, for a 50 kph (31.1 mph) test speed, eight vehicle models were able to fully avoid the POV. For the 80 kph (49.7 mph) test speed, four were able to achieve full avoidance.[119] These results confirm that the requirements adopted for the LVD test conditions are feasible for current DBS systems. The Agency's decision (discussed later) to explicitly allow automatic braking resulting from CIB activation after issuance of the FCW but prior to manual brake application during DBS testing is also an important consideration, as it ensures the SV is provided with the best overall opportunity to avoid the POV regardless of whether a manual brake application is being used.

Although there was overall support for retaining DBS testing in NCAP, NHTSA also recognizes that a few commenters suggested that continued testing for this technology was unnecessary. For example, Subaru stated that NHTSA remove DBS assessments from NCAP because DBS systems have a record of good performance. The automaker reasoned that mature ADAS technologies with high adoption rates could be removed and replaced with other emerging technologies. In general, NHTSA agrees with this approach, but it does not agree there are no further gains to be made regarding DBS performance. Model year 2021–2022 research testing showed that, at test speeds greater than 80 kph (49.7 mph), vehicle models offered a range of DBS performance in the LVM test. Of the 12 models, four did not offer full avoidance at 90 kph (55.9 mph) and an additional five did not offer full avoidance at 100 kph (62.1 mph). For the DBS LVS condition, five did not offer full avoidance at 70 kph (43.5 mph), three did not offer full avoidance at 80 kph (49.7 mph), two did not offer full avoidance at 90 kph (55.9 mph), and another one did not offer full avoidance at 100 kph (62.1 mph). Further, one vehicle was able to fully avoid contact through 80 kph (49.7 mph) in the CIB LVS tests but did not avoid contact in the 90 kph (55.9 mph) DBS LVS test, which would be expected to be less challenging based on the additional manual braking imparted by the driver.

DBS LVD assessments at 80 kph (49.7 mph) also demonstrated room for improvement in the same study. When the POV deceleration was 0.4g, only five of the total 12 vehicles tested were able to fully avoid the POV for the 40 m (131.2 ft.) headway test condition, while six of the total 12 were able to fully avoid the POV in the 12 m (39.4 ft.) headway test condition. When the POV deceleration was increased to 0.5g, only three of five vehicle models tested for the 80 kph (49.7 mph), 40 m (131.2 ft.) headway test condition provided full avoidance and four of the six vehicle models achieved this performance for the 12 m (39.4 ft.) headway test condition. Several commenters also stated that continuing to perform DBS testing for each of the test conditions adopted for CIB would be redundant and only serve to increase test burden. The Agency's decision to adopt additional higher test speeds than those adopted for CIB (*i.e.,* 90 kph (55.9 mph) and 100 kph (62.1 mph)) for its LVS and LVM tests, in addition to a ''no contact'' performance criterion, effectively ensures that the majority of NCAP's DBS tests will be as stringent as the program's CIB tests. Thus, it is not necessary at this time to require a higher level of stringency in NCAP's DBS tests compared to its CIB tests to justify the need to retain DBS testing in NCAP. Rather, the Agency agrees with those commenters who suggested that DBS testing in NCAP is necessary to ensure that brake pedal application does not adversely affect overall AEB functionality or suppress CIB operation. If a driver attempts to brake but does so with an input that is insufficient to avoid a crash, the vehicle's DBS system must support the driver's action and intention to stop the vehicle.

With respect to the assessment approach to be used for NCAP's DBS tests, the Agency plans to align its approach for the LVS and LVM DBS tests with those finalized for CIB; however, the first and last SV speed in the respective test series will be higher. NHTSA will initiate the DBS test sequence for each of the LVS and LVM scenarios by performing a trial run at the minimum DBS test speed in the sequence (*i.e.,* 70 kph (43.5 mph)) and will then incrementally increase the test speed by 10 kph (6.2 mph) to assess the next test condition in the sequence (*i.e.,* 80 kph (49.7 mph)), as long as the initial trial run is valid (*i.e.,* all test specifications and tolerances satisfied) and the SV does not contact the POV. This incremental process will continue

of light-vehicle pre-crash scenarios based on 2011–2015 national crash data (Report No. DOT HS 812 745), Washington, DC: National Highway Traffic Safety Administration.

[117] This same vehicle, when tested for the LVD scenario with the more stringent headway and POV deceleration (*i.e.,* a 12 m headway and 0.5g POV deceleration), was also able to avoid collision when tested at 50 kph (31.1 mph) and 80 kph (49.7 mph).

[118] The time between FCW onset and braking initiation for this testing was set at 1.0 second, which is the timing being adopted in this final notice (see later section).

[119] *https://www.regulations.gov/document/NHTSA-2023-0021-0005.*

until the maximum test speed of 100 kph (62.1 mph) is assessed.

For the LVD scenario, NHTSA will impose a DBS testing assessment process that is identical to that adopted for the LVD CIB tests. The Agency will conduct the first LVD trial at the minimum test speed (50 kph (31.1 mph)), maximum headway (40 m (131.2 ft.)), and minimum deceleration (0.3g). If the initial trial run is valid (*i.e.,* all test specifications and tolerances satisfied) and the SV does not contact the POV, the next trial run will be conducted at the same test speed (50 kph (31.1 mph)) and deceleration (0.3g) but the headway will be adjusted to the minimum specified distance, 12 m (39.4 ft.). If the vehicle fully avoids contacting the POV for this test condition and the trial run is determined to be valid, NHTSA will then increment the test speed to the maximum LVD test speed, 80 kph (49.7 mph), and will perform one trial run at the maximum headway (40 m (131.2 ft.)) and minimum deceleration (0.3g), followed by one trial run at 80 kph (49.7 mph), minimum headway (12 m (39.4 ft.)), and minimum deceleration (0.3g). If no vehicle-to-POV contact is observed and all 80 kph (49.7 mph) trials are considered valid, the Agency will repeat the LVD DBS test sequence utilizing a POV deceleration of 0.5g. See Table 15 for the sequence of LVD DBS tests.

The test conditions, performance criteria, and assessment approaches adopted for the LVS, LVM, and LVD DBS test scenarios will allow NHTSA to keep test burden to a minimum while confirming functionality of DBS systems and ensuring acceptable system performance across a range of real-world driving conditions, as Advocates requested.

c. Removal of False Positive Assessments

When the STP test was initially developed, many AEB systems relied solely on radar for lead vehicle detection. Today, most vehicles utilize a camera-only or fused system that relies on both camera and radar. While some radar-only systems have had difficulty classifying the STP correctly (*i.e.,* responding to the STP as if it was a vehicle), camera-only and fused systems have not exhibited this issue.[120] Since its AEB testing began in NCAP for model year 2017 vehicles, the Agency has observed no instances of false positive test failures during CIB and DBS NCAP evaluations performed for camera-only and fused AEB systems.

Since fused camera-radar forward-looking AEB systems are becoming more prevalent in the fleet, NHTSA suggested it might be appropriate to remove the false positive STP assessments from NCAP's AEB (*i.e.,* CIB and DBS) evaluation matrix as part of this NCAP update and sought comment in that regard.

Summary of Comments

Approximately two-thirds of commenters stated that NHTSA could remove the STP false positive assessment from NCAP's AEB test matrix. The remaining one-third urged the Agency to continue to conduct false positive tests.

Remove False Positive Tests

The following commenters supported removal of the STP false positive tests from NCAP's AEB test matrix: Auto Innovators, BMW, Bosch, GM, HATCI, Honda, IDIADA, IIHS, Intel, MEMA, Rivian, Toyota, and TRC.

Toyota and HATCI cited improved performance of the latest technologies, as demonstrated by NCAP test results, as a reason to remove the STP tests. Likewise, TRC mentioned that vehicles may occasionally issue an alert when driven over the steel trench plate during testing, but they no longer activate AEB.

Bosch supported removal of the STP assessments from both CIB and DBS test procedures due to concerns about the tests' repeatability and representation of all real-world driving situations. Along the same lines, GM mentioned that the Agency's current STP false positive tests address only a very limited number of potential conditions that vehicle manufacturers and suppliers must assess as part of their due diligence to ensure sensors and systems respond appropriately (*i.e.,* without issuing false activations) when driven in a myriad of driving environments and conditions. Auto Innovators and BMW agreed that NCAP's false positive tests are inadequate to address all potential conditions that may incite a false positive event for all AEB systems. As such, the commenters asserted that they only serve to unnecessarily increase test burden without providing appreciable safety benefit.

Both GM and Auto Innovators suggested that, in lieu of conducting false activation tests, NHTSA should monitor customer complaints about frequent false activation events. Both commenters stated that this information would be more useful to NHTSA. IIHS also favored such an approach to addressing false-positive braking problems. IIHS remarked that NHTSA has received customer complaints and opened investigations for false positive activations for both radar-only and camera-based AEB systems despite currently performing false positive tests and only witnessing failures for radar-only systems. Accordingly, the commenter concluded that not only are the current tests insufficient to address all instances of real-world false activations, but also the Agency could use its authority through a recall process to address false positive braking problems as they arise. IIHS further mentioned that vehicle manufacturers are sufficiently motivated to minimize false-positive interventions by customer feedback such that false positive AEB tests are not necessary.

Honda and HATCI also stated that the current false positive tests no longer address a safety need, particularly since, as Honda added, cameras are now a fundamental component of AEB, and their performance should continue to improve. Rivian agreed that most vehicles rely on fused data (*i.e.,* involving cameras) for FCW and CIB activations but also cautioned that ''some manufacturers still rely on radar confidence and allow low deceleration radar-only braking.'' As such, the manufacturer recommended that the Agency should incorporate scenarios that could trigger radar-only braking if it wants to evaluate a vehicle's propensity to issue false positive braking. Similarly, FCA commented that it would be appropriate for the Agency to remove the STP assessment for vehicles equipped with camera-based systems, but NHTSA should continue those assessments for vehicles using radar-only systems. Intel stated that false positive STP evaluations were now ''redundant'' for CIB and DBS because the Agency has relaxed the allowable deceleration threshold.

Continue To Perform False Positive Tests

Some commenters (including Adasky, Advocates, CAS, Tesla, Vayyar, and ZF Group) stated that NHTSA should continue to conduct false positive assessments as part of NCAP's AEB test evaluations.

Adasky stated that NHTSA should retain the false positive AEB tests in NCAP because ''they serve as an indication of the lack of robustness of RGB cameras and radars.'' [121] The supplier also suggested that thermal cameras should be encouraged (or required) because they may address ''phantom braking'' in real-world cases.

[120] This is not to suggest that camera systems are superior to radar systems in all tests.

[121] RGB cameras are cameras that can capture light in red, green, and blue (hence, RGB) wavelengths.

Adasky noted that thermal cameras offer more robust detection and provide the redundancy necessary to overcome RGB camera and radar deficiencies. Vayyar explained that removal of false positive assessments from NCAP would serve to foster development of ''suboptimal technologies'' and drive an increase in real-world false positive events. ZF Group reasoned that current and future AEB systems would not necessarily be prone to false positive activations, but in the interest of safety, the group recommended retaining STP false positive tests in NCAP to ensure systems continue to work as expected. Tesla commented that false positive activations may become more common as vehicle sensing technologies continue to evolve. Accordingly, the automaker recommended that NHTSA continue to conduct the current false positive STP assessments since they may help provide nuanced distinctions in AEB performance among vehicles relying on different sensing technologies in the future. Tesla stated this would permit a more comprehensive rating.

CAS also stated that NHTSA should continue performing false positive STP assessments for AEB. The commenter noted that it would be inappropriate to assume system capabilities without test verification, especially since false positive activations have been reported for production vehicles, and there are many reasons for system failures, including supply chain disruptions, design or production issues, and manufacturing defects. Advocates opposed eliminating the false positive AEB assessments from NCAP until they were adopted into regulations.

Response to Comments and Agency Decisions

The Agency will retain the STP false positive test in NCAP's AEB evaluation matrix. The test scenario will be conducted as part of both CIB and DBS system assessments as is done currently in NCAP. However, instead of performing the STP test at the currently prescribed test speeds, 40.2 and 72.4 kph (25 and 45 mph), the Agency is adopting only a test speed of 80 kph (49.7 mph) to mirror the highest test speed adopted for CIB testing.

NHTSA reasons it is no longer necessary to conduct AEB STP tests at 40.2 kph (25 mph) because the Agency has observed no instances of false positive test failures during CIB and DBS NCAP evaluations performed since the tests were added to the program for model year 2017 vehicles. Requiring only one test speed instead of two for NCAP's CIB and DBS STP assessments should also help to offset any added test burden imposed by the 90 and 100 kph (55.9 and 62.1 mph) assessments adopted for the program's LVM and LVS DBS test scenarios. The slight increase in test speed (from 72.4 kph (45 mph), as currently prescribed for NCAP's STP tests, to 80 kph (49.7 mph), as adopted) for the higher speed test condition is reasonable and justifiable to complement the performance requirements adopted for the Agency's other AEB tests. During NHTSA's AEB research testing for model year 2021–2022 vehicles, no AEB false positives (*i.e.,* unnecessary system activations) were observed for any of the twelve vehicles evaluated during the conduct of valid CIB and DBS trials for the STP scenario at a test speed of 80 kph (49.7 mph).

Although some commenters supported removal of the false positive tests, others encouraged the Agency to continue to conduct such tests in NCAP. Adasky, Tesla, and Vayyar expressed concerns surrounding a lack of sensor robustness and an increase in false activations with system evolution if NHTSA was to stop performing false positive tests in NCAP. While the Agency has not observed false positive test failures in CIB or DBS testing since NHTSA added these ADAS technologies to NCAP, and similarly did not observe failures in NHTSA's research tests for model year 2021–2022 vehicles, it agrees with these commenters that it should exercise due diligence given the anticipated system changes that will be necessary to ensure current system functionality is maintained as sensing technologies evolve and as CIB test speeds increase. The Agency remains concerned that false activation events may introduce hard braking situations when such actions are not warranted, potentially causing rear-end crashes instead of mitigating them. Since the consequences of unintended braking can be more significant at higher vehicle travel speeds, retaining the highest proposed test speed (*i.e.,* 80 kph (49.7 mph) is most appropriate. It is not appropriate at this time to adopt a test speed higher than 80 kph (49.7 mph) for the program's CIB and DBS STP test assessments, such as the maximum test speed adopted for NCAP's DBS tests (*i.e.,* 100 kph (62.1 mph)), since, to date, NHTSA has not performed research testing at speeds higher than 80 kph (49.7 mph) for the STP test.

Of those commenters that suggested the Agency should remove the false positive test conditions from NCAP's AEB test matrix, some, like Honda and HATCI, stated the current STP test no longer addresses a safety need. However, NHTSA contends that if NCAP's STP test provides even limited coverage of real-world false positive conditions, it is still beneficial. Along these lines, continuing false positive testing in NCAP should lessen Auto Innovators' concern that an increase in false positives during real-world driving may discourage AEB use.

Some commenters asserted that performing false positive tests in NCAP should be unnecessary since vehicle manufacturers have an incentive to maintain high customer satisfaction; therefore, they will design AEB systems to thoroughly address the potential for unwarranted braking in real-world driving scenarios. GM asserted that it is the vehicle manufacturers' responsibility to ensure systems respond appropriately. NHTSA agrees with these commenters in theory and expects vehicle manufacturers to design AEB systems to thoroughly address the potential for false activations in a myriad of possible real-world situations so that vehicles do not pose an unreasonable risk to safety. However, the Agency also recognizes that it has received customer complaints and opened investigations for false positive activations for AEB systems. This suggests that the motivation of positive consumer feedback and accountability alone may be insufficient to fully eliminate false positive activations. Therefore, it is appropriate to retain false positive testing in NCAP's AEB test matrix. The Agency maintains this position while acknowledging that current false positive tests are neither comprehensive nor sufficient to eliminate susceptibility to all false activations. The false activation tests serve to provide a baseline for system functionality and to establish a minimum expected performance level.

To address real-world conditions not covered by NCAP's false positive test, NHTSA will continue to monitor customer complaints to look for reports of frequent false activations as part of its oversight. The Agency will conduct investigations, as necessary, to determine whether vehicles experiencing excessive false positive activations have a safety-related defect and thus pose an unreasonable risk to safety. The Agency will continue to handle such cases appropriately as they arise. NHTSA also plans to amend or supplement the STP test with other false positive activation tests or criteria as needed based on real-world data.

Peak Additional Deceleration in DBS False Positive Test

Currently, in NCAP's STP DBS test, a vehicle's DBS system must not engage the brakes to create a peak deceleration that is greater than 1.5 times the average of the peak decelerations imparted by manual brake application during ''baseline'' tests, which are conducted to simulate the magnitude of brake application needed to produce 0.4g deceleration using the vehicle's foundation brakes. For the Agency's future DBS STP tests, the DBS system must not engage the brakes to create a peak deceleration of more than 0.25g additional deceleration beyond the average of the peak decelerations recorded during the DBS STP ''baseline'' runs. NHTSA is making this change because the lower braking threshold, which equates to a maximum combined braking level of 0.65g (*i.e.,* combining the 0.4g from the foundation's brakes with a possible 0.25g additional deceleration), is more appropriate for the false positive test, which offers no real crash threat.

The Agency will also make a similar change for its CIB false positive test. Instead of stipulating that a vehicle cannot impart braking that exceeds 0.5g in NCAP's CIB STP test, NHTSA is amending the criterion to reflect a maximum peak braking of 0.25g. Effectively, the vehicle's CIB system must not engage the brakes to create a peak deceleration of more than 0.25g during the CIB STP test.

In imposing these modified requirements, a mild DBS intervention, such as that stemming from a haptic brake pulse, is deemed acceptable, but one where the vehicle thinks it must respond to the STP as if it was a real vehicle is not.

Brake Pedal Application Rate in DBS False Positive Test

Since the Agency has decided to retain the false positive test scenarios for its AEB tests, it plans to retain the current brake pedal application rate of 254 ± 25.4 mm/s (10 ± 1 in./s) for the DBS test, as discussed in the March 2022 RFC notice.

In response to NHTSA's December 2015 RFC notice, BMW had suggested that the Agency should allow manufacturers to specify a brake pedal application rate limit up to 400 mm/s (16 in./s) for the false positive DBS test scenario to harmonize with Euro NCAP requirements. BMW asserted that limiting the rate to a lower threshold could increase a DBS system's sensitivity and thereby increase the likelihood of additional false activation events in the real world.

As the Agency mentioned in its RFC notice, the current application rate value is not only well within the brake application rate range of 200 to 400 mm/s (8 to 16 in./s) specified by Euro NCAP,[122] but also has been shown to provide the input characteristics needed to satisfy DBS activation thresholds during NHTSA NCAP testing. To reduce the potential for an unintended intervention, activation of conventional brake assist systems typically requires higher brake pedal application rates than those required for DBS. This is because conventional brake assist systems assume that if the driver applies the brakes quickly (*i.e.,* with a brake pedal velocity profile used by drivers in an emergency/panic situation), supplemental braking is appropriate, whereas DBS systems consider data from forward-looking sensors and how the driver is applying the brakes. The additional data used by DBS allows the brake pedal velocity threshold to be lower than that of conventional brake assist systems. Thus, retaining the brake application rate of 254 ± 25.4 mm/s (10 ± 1 in./s) in the DBS system performance test enables NHTSA to focus on evaluating DBS system performance instead of conventional brake technology.

d. No Contact Versus Speed Reduction Performance Criterion

In its March 2022 RFC notice, NHTSA proposed to adopt a performance criterion of ''no contact'' for both CIB and DBS tests. Although NHTSA's DBS test procedure currently specifies ''no contact'' as the performance criterion for all DBS test conditions, the Agency's CIB test procedure specifies speed reduction as the passing requirement for all but one CIB test condition.[123] Under the Agency's proposal, the SV would have to avoid contacting the POV test device to pass CIB and DBS test trials. NHTSA reasoned that this approach would limit damage to the SV and POV test device during testing, thus maintaining test repeatability and vehicle test device usability. However, as alternatives to this proposal, NHTSA also asked if it would be more appropriate to require minimum speed reductions or specify a maximum allowable SV-to-POV impact speed for any or all of the proposed AEB test conditions (*i.e.,* test scenario and test speed combinations).

Summary of Comments

Speed Reduction is Appropriate

Most respondents (Auto Innovators, BMW, DENSO, GM, HATCI, Honda, IIHS, Intel, Subaru, Tesla, and Toyota) favored a speed reduction performance criterion in lieu of ''no contact'' because of its implication for safety benefits. BMW, DENSO, IIHS, and Subaru stated that speed reduction was appropriate for all AEB test scenarios because it mitigates crash severity, thus reducing vehicle damage, the risk of injury, and injury severity. Similarly, GM voiced that, under many conditions (*e.g.,* speeds above 40 kph (24.9 mph) for the tested scenarios), current systems do not have the capability to completely avoid a crash, and as such, speed reduction provides the ''most relevant measurable safety benefit'' for AEB systems because it directly correlates to injury risk. Therefore, the automaker suggested the Agency should assess speed reduction at test speeds ranging from 40 to 60 kph (24.9 to 37.3 mph). IIHS objected to a ''no contact'' criterion whether the Agency proceeds with single trials, multiple trials, or single trials with follow-up trials. Like GM, Honda and Auto Innovators also asserted that many current AEB systems will not be able to achieve complete crash avoidance at higher speeds but will still provide a significant speed reduction. Honda and Auto Innovators, in addition to HATCI, stated that they were opposed to a ''no contact'' criterion because such an approach (*i.e.,* pass/fail) does not accurately reflect the safety benefits inherent to speed reductions. Auto Innovators cited DOT HS 813 194 to highlight the influence speed reduction can have on crash severity.[124]

Auto Innovators and HATCI recommended NHTSA adopt a sliding scale with points awarded to systems that successfully avoid a crash and also those that provide speed reduction (at least for ''the most challenging situations'' (Auto Innovators)), with the former receiving full points and the latter receiving partial credit to better differentiate performance among the fleet.[125] This approach is similar to that of Euro NCAP. Auto Innovators added points should be determined based on the corresponding injury risk gleaned from real-world data, and HATCI mentioned points should progressively decrease with decreasing speed reduction until the speed reduction does not provide statistically significant safety benefits. BMW mentioned that basing AEB performance assessments on speed reduction instead of pass/fail criteria would ''more accurately'' rate AEB systems and allow ratings to be

[122] 80 FR 68608 (Nov. 5, 2015).

[123] A performance criterion of ''no contact'' is currently specified for the lower speed LVM scenario (*i.e.,* SV speed of 40.2 kph (25 mph) and POV speed of 16.1 kph (10 mph)).

[124] NHTSA Traffic Safety Facts: Speeding 2019 Data, DOT HS 813 194 (Published October 2021).

[125] European New Car Assessment Programme (Euro NCAP) (November 2022), *Assessment Protocol—Safety Assist—Collision Avoidance, Version 10.2.*

more easily adjusted in the future. Honda and Auto Innovators recommended the Agency adopt maximum allowable collision speed as a performance criterion for higher-speed test conditions (*i.e.,* SV speeds of 70 and 80 kph (43.5 and 49.7 mph) per Auto Innovators). Although HATCI favored a scoring approach based on speed reduction like that used by Euro NCAP, it noted that specifying a maximum allowable impact speed for all test conditions in lieu of ''no contact'' would also be acceptable.

Adopting performance-based criteria (*i.e.,* speed reduction) in lieu of pass/fail criteria (*i.e.,* ''no contact'') was also preferred by Toyota for similar reasons to those already mentioned. Specifically, the manufacturer stated that performance-based criteria, such as speed reduction, can be associated with reducing injuries and fatalities to better represent real-world ADAS performance. The commenter also stated that adopting a speed reduction performance criterion could reduce the number of trials that are necessary (due to system variations) for vehicle assessments, which would ultimately reduce test burden. Therefore, like Auto Innovators, the automaker recommended assigning points for both crash mitigation and avoidance.

Intel and Subaru suggested NHTSA adopt Euro NCAP's speed reduction approach for the Agency's CIB and DBS tests, with the latter commenter referencing Euro NCAP Assessment Protocol—Safety Assist Collision Avoidance v10.0.[126] Intel suggested that it is important for NHTSA to distinguish between those systems that afford at least partial speed reduction and those that offer no speed reduction, especially at higher initial test speeds.

Like Auto Innovators and HATCI, Rivian suggested that the Agency award points for speed reduction (at least for certain scenarios) in addition to having a ''no contact'' criterion to encourage manufacturers to continuously improve system performance for those scenarios. FCA, Bosch, and GM shared a similar sentiment. FCA suggested it may be appropriate to require ''no contact'' for LVS tests with speeds up to 30 kph (18.6 mph), but speed reduction should generally be required for higher test speeds since the ''prediction time increases'' for such conditions. The commenter stated a requirement of ''no contact'' may cause higher false positive rates, resulting in system deactivation in the real world. Bosch opined that ''no contact'' is an appropriate performance criterion for test speeds up to 60 kph (37.3 mph) but stated that points should be awarded for speed reductions as low as 10 kph (6.2 mph) for higher speed test conditions.

No Contact Is Appropriate

A few commenters asserted a performance criterion of ''no contact'' was appropriate for the Agency to adopt for its NCAP AEB testing. CAS expressed that ''no contact'' is the most appropriate performance criterion for the Agency's AEB tests since the desired outcome of any CIB or DBS activation is to avoid contact. CAS also asserted that ''no contact'' serves as a useful criterion for consumers when comparing vehicles, especially as speeds are increased. Finally, it stated that if the Agency found that a vehicle exhibited contact as test speeds were progressively incremented, then it should ''regressively test at lower speeds'' to determine ''the maximum 'no contact' speed,'' which could then be used as the baseline to compare vehicles.

Adasky commented that AEB systems should afford ''no contact'' even at higher test speeds and at night since thermal cameras are available and can help systems perform well under these conditions. Advocates stated that a ''no contact'' requirement is ''essential,'' but also suggested that the Agency consider assigning credit to systems that offer ''meaningful'' speed reductions for tested speeds that fall outside of the range of performance afforded by current systems—both lower and higher.

Response to Comments and Agency Decisions

The Agency is proceeding with adopting a ''no contact'' criterion for NCAP's AEB performance test requirements. Such a criterion is feasible to achieve, consistent with the safety need, and necessary to ensure test repeatability, among other reasons.

Recent AEB testing has shown that several vehicles from the modern fleet were able to avoid contacting the vehicle test device for most of the test conditions adopted herein. For instance, one vehicle model provided complete avoidance in most of the adopted test conditions. This model did not provide full avoidance when tested using a 12 m (39.4 ft.) headway and 0.4g POV deceleration, so the more stringent 0.5g deceleration NCAP test condition using the same 12 m (39.4 ft.) headway was not performed. However, the vehicle's relative impact speed for the 0.4g deceleration condition was relatively low, at 9.5 kph (5.9 mph) during the first trial. Consequently, it is reasonable to expect that minor changes could be made to the vehicle model's AEB system such that it would be able to pass the CIB LVD, 12 m (39.4 ft.) headway and 0.5g POV deceleration condition in the near future. Another vehicle model provided full avoidance in nearly every test condition, failing to completely avoid contact with the POV in only the CIB LVS test scenario. For this test scenario, the vehicle provided complete avoidance at test speeds through 60 kph (37.3 mph), and at 70 kph (43.5 mph), the vehicle provided partial speed reduction. Since full avoidance was not observed at 70 kph (43.5 mph), the vehicle was not subsequently tested at 80 kph (49.7 mph). Thus, while several commenters mentioned that tested vehicles may currently have difficulty with completely avoiding contact with the vehicle test device, the aforementioned results suggest that the test requirements are practical for vehicles to achieve in the near future. Furthermore, manufacturers of these vehicles have shown that a ''no contact'' performance criterion can be met with no increase to false positive rates, even at higher test speeds, which was a concern expressed by FCA. To date, NHTSA has not received an increased number of false positive reports for either vehicle.

In response to Rivian and FCA's statements that adopting speed reduction as a performance criterion would encourage manufacturers to continuously improve system performance, particularly at higher test speeds, applying a ''no contact'' performance criterion should achieve the same goal. Vehicle manufacturers that wish to obtain NCAP credit for AEB must have vehicles that offer exceptional, robust system performance. Although it may be true that there are inherent safety benefits to adopting a maximum allowable impact speed or speed reduction performance criterion, as numerous commenters asserted, there are more profound safety benefits afforded by systems that offer complete crash avoidance. By promoting development of more robust AEB systems capable of much higher speed reductions and complete crash avoidance, AEB systems may effectively address a larger percentage of crashes that cause serious injuries and/or fatalities.

It would be most advantageous to establish a ''no contact'' performance criterion for several other reasons. From a testing logistics perspective, the Agency has observed that it is possible for even relatively low-speed collisions with the lead vehicle test device to

[126] See figure provided by Intel and Euro NCAP Assessment Protocol—Safety Assist Collision Avoidance v10.0 for Subaru.

damage the SV during testing. In such instances, camera or radar sensors on the vehicle may become misaligned such that subsequent runs might not be representative of the vehicle condition at the time of first sale. Further, striking the vehicle test device might prematurely degrade the appearance of the device and modify its specifications, including in ways not immediately observable. As mentioned previously, damage to the test device might affect the radar cross section and may require a lengthy verification procedure to discover. As such, vehicle contact which does not result in immediate test failure may introduce repeatability concerns, time-consuming interruptions to testing, and higher costs.

As mentioned in the March 2022 RFC notice, the Agency is not proposing a full-scale rating system for crash avoidance technologies at this time. NHTSA plans to continue to use check marks to give credit to vehicles that are equipped with the recommended ADAS technologies and pass the applicable system performance test requirements for each ADAS technology included in NCAP until it issues a final decision notice announcing the new ADAS rating system. Therefore, at this time, the Agency cannot adopt a points-based system for speed reductions, as Auto Innovators, HATCI, Toyota, and Rivian suggested.

Regarding Toyota's comment that adopting a speed reduction performance criterion could reduce the number of trials necessary for vehicle assessments and therefore reduce test burden, the Agency's planned testing approach (discussed in the next section) will effectively address this concern.

Finally, the Agency agrees with CAS that it will be easier to communicate test results to consumers if the passing criterion is straightforward (''no contact'') compared to a passing criterion based on speed reduction or maximum allowable impact speed. NHTSA also recognizes, as the respondent suggested, that full avoidance is likely the result that most consumers desire from an AEB system.

e. Number of Trials

Currently, NHTSA's AEB test procedure requires that a vehicle meet performance criteria (*i.e.,* a specified speed reduction) for five out of seven trials. In its March 2022 proposal, however, the Agency suggested that a new testing approach may be more appropriate given the changes proposed for its AEB tests.

Per NHTSA's March 2022 RFC, only one valid test trial (*i.e.,* a trial in which all test specifications and tolerances are satisfied) would be conducted per each incremented test speed (*i.e.,* 40, 50, 60, 70, and 80 kph or 24.9, 31.1, 37.3, 43.5, and 49.7 mph (as applicable for each test scenario)) [127] as long as the SV did not contact the POV test device. If the SV were to contact the POV during a test trial, and the relative longitudinal velocity between the SV and POV was less than or equal to 50 percent of the initial speed of the SV, NHTSA proposed that it would then perform four additional (repeated) test trials at the same speed for which the impact occurred. The Agency proposed that the SV could not contact the POV for at least three out of the five test trials performed at that same speed to pass that specific combination of test scenario and test speed (*i.e.,* test condition).[128] If the SV contacted the POV during a valid trial of a test condition (whether it be the first test performed at a particular test speed or a subsequent test trial at that same speed), and the relative impact velocity exceeded 50 percent of the initial speed of the SV, no additional test trials would be conducted at the given test speed (or for the test scenario) and the SV would fail the test condition.

Because the Agency had proposed additional test speeds (compared to its current assessments) for the various AEB test scenarios, NHTSA asserted this assessment approach would reduce test burden while continuing to ensure that passing AEB systems represent robust designs that offer a high level of performance and safety. In its March 2022 RFC, the Agency sought comment on whether this proposed assessment method was appropriate or whether an alternative method, such as subjecting the vehicle to multiple trials, should be adopted instead. For respondents preferring multiple trials, NHTSA asked how many trials would be appropriate and what an acceptable pass rate would be. Further, for those respondents who favored the proposed assessment method, NHTSA asked whether such a method would also be acceptable in instances where only one or two test speeds were selected for inclusion, such as for the LVD test scenario,[129] or whether it would be more appropriate in such instances to alternatively require seven trials for each test speed and additionally require that five out of the seven trials conducted pass the ''no contact'' performance criterion.

Summary of Comments

A few commenters generally agreed with the Agency's proposal to conduct one trial per test speed with speed increments of 10 kph (6.2 mph) and to only perform repeated trials in the event of POV contact. Rivian was one such commenter, stating that the proposed AEB test method was ''practical,'' as 10 kph (6.2 mph) test speed increments should sufficiently highlight performance degradations such that multiple trials at a given speed should not be necessary, thus reducing test burden. Likewise, IDIADA commented that performing one trial per test speed across many different speeds was sufficient to ensure system robustness. DRI also supported the Agency's proposal for AEB testing, explaining that their experience has shown that CIB and DBS systems typically do not have difficulty detecting lead vehicles and are able to do so repeatedly such that inconsistent results generally stem from poor system performance rather than detection capabilities.

HATCI and Honda also generally agreed with the Agency's proposal. The manufacturers were in favor of completing an additional four runs after the first failed (*i.e.,* contact) run and supported the proposed pass rate of three out of five total runs. However, Honda commented that additional trials should be conducted even if the AEB system does not impart a 50 percent relative speed reduction in the first trial run. The automaker expressed that stopping the test after one failed run may be ''overly strict'' and ''premature'' given potential variations in test conditions.

BMW supported test speed increments of 10 kph (6.2 mph) and the Agency's proposal to conduct four additional runs in the event of contact if NHTSA ultimately adopted a ''no contact'' (*i.e.,* pass/fail) criterion. Having noted this, the automaker, along

[127] NHTSA's proposal included several assessment alternatives for the LVD test scenario. These included testing one speed, 50 kph (31.1 mph); two speeds, 50 kph (31.1 mph) and 80 kph (49.7 mph); or four speeds, 50, 60, 70, and 80 kph (31.1, 37.3, 43.5, and 49.7 mph).

[128] The Agency notes that a similar pass/fail criterion (*i.e.,* a vehicle must meet performance requirements for three out of five trials for a particular test condition to pass the test condition) is included in its current LDW test procedure, as referenced later in this document.

[129] For the LVD test scenario, NHTSA proposed to adopt an SV and POV test speed of 50 kph (31.1 mph) (*i.e.,* one test condition) but also sought comment on whether it would be appropriate to incorporate additional SV and POV test speeds of 60, 70, and 80 kph (37.3, 43.5, and 49.7 mph, respectively). Furthermore, for DBS specifically, the Agency sought comment on whether it was reasonable to only conduct LVS and LVM tests at only the highest two test speeds proposed for CIB—70 and 80 kph (43.5 and 49.7 mph) (*i.e.,* two test conditions). A similar comment request was made for the LVD DBS test, if NHTSA decided to adopt those same higher test speeds (*i.e.,* 70 and 80 kph (43.5 and 49.7 mph)) for the CIB LVD test.

with several other commenters, expressed strong support for adopting assessment criteria based on speed reduction instead. With speed reduction as the assessment criterion (instead of ''no contact''), BMW supported conducting two additional trials after the first run failure (*i.e.,* contact) and then using the median speed for all three trial runs as the true impact speed for rating purposes.

Auto Innovators and FCA also generally supported the Agency's proposal for AEB testing (*i.e.,* one trial per test speed) but suggested that a pass rate of two out of three would be acceptable in instances of contact during the first trial run for a test condition to reduce test burden. However, like BMW, both groups also stated that the Agency should recognize the inherent safety benefits afforded by crash mitigation (*i.e.,* speed reduction) in addition to complete crash avoidance. In the same vein, Auto Innovators asserted that the Agency's current proposal, which would prohibit test conduct for higher speeds if lower speeds did not result in crash avoidance, ''may unintentionally penalize systems that have robust higher-speed performance.'' Accordingly, the group suggested that (1) conducting higher-speed trial runs should not be contingent on a 50 percent relative speed reduction for lower speed runs and/or (2) testing for a scenario should continue regardless of whether the relative speed reduction in one trial is less than 50 percent. Instead, Auto Innovators suggested the Agency consider assigning ''partial credit'' to systems that perform worse at lower speeds. Whereas BMW recommended using the median speed of all three trials to assign vehicles' AEB performance ratings, FCA suggested NHTSA average the impact speed for the trials conducted when impact occurs. FCA further noted it would prefer ''further definition'' for LVD tests at test speeds greater than 60 kph (37.3 mph) before settling on an assessment method for these test conditions.

In general, GM favored optimizing the number of test conditions rather than reducing the number of test runs. The manufacturer noted the former does more to reduce overall test burden and the latter leads to a diminished understanding of system performance variation. However, in this instance, the automaker reasoned that the Agency's proposal would ''speed up the test, and only repeat trials when necessary,'' so they were supportive of the proposed three out of five pass rate if the Agency adopted a ''no contact'' performance criterion. However, the automaker, like many others, favored speed reduction as the performance criterion for higher speeds in lieu of ''no contact.'' More specifically, GM recommended the Agency adopt a 30 kph (18.6 mph) relative impact speed (instead of full avoidance) as the minimum performance criterion for SV speeds above 50 kph (31.1 mph). The manufacturer suggested that additional trials should be performed for those vehicles having a relative impact speed of 30 kph (18.6 mph) or less, and either the mean or median of the resulting velocity reductions should be used for scoring.

While Rivian stated that the Agency's proposal of testing across multiple speeds instead of multiple trials at the same speed would ensure system robustness, Intel stated that conducting multiple trials was ''more robust.'' However, to limit test burden, Intel suggested, like others, that a pass rate of two out of three trials was appropriate for a given test condition. The company also agreed in sentiment with others' recommendation that the Agency recognize the safety benefits inherent to speed reductions, and Honda's assertion that stopping a test because of one run at a lower speed that doesn't produce at least a 50 percent speed reduction may be too extreme. As such, Intel also proposed an alternative test procedure to further reduce test burden.

For its proposed procedure, Intel suggested that instead of performing the entire AEB test matrix, NHTSA should select a random subset of tests (*i.e.,* test conditions) to be performed based on test results for the complete matrix provided by vehicle manufacturers. The first trial of the first selected test condition would then be performed. If the speed reduction for that trial meets a ''predicted'' speed reduction, points applicable to the actual speed reduction would be awarded and the first trial of the next randomly selected test condition would then be performed. If the speed reduction for the first trial was insufficient (*i.e.,* did not achieve the ''predicted'' speed reduction), an additional two trials would be conducted (as mentioned previously). If both of those trial runs achieved the ''predicted speed reduction,'' points applicable to the actual speed reduction would be awarded and testing would continue with the next randomly selected test condition. If the ''predicted'' speed reduction was not met for at least two of the three trials conducted for a given test condition, then the test would cease, and partial points would be awarded based on the average speed reduction recorded for the three trials. Intel also suggested the Agency should apply a penalty, as is done by Euro NCAP, for instances where the actual speed reduction is less than the ''predicted'' speed reduction.

Tesla also stated it supported adopting performance criteria based on speed reduction in lieu of a ''no contact'' pass/fail criterion (for both CIB and DBS). Unlike the other commenters who expressed a similar sentiment and proposed that three trials should be conducted upon impact, Tesla supported the Agency's original proposal of requiring that an additional four runs be conducted after the initial trial run (for five runs total). For those additional four runs, Tesla asserted the vehicle should have to achieve a speed reduction of 75 percent or more of the initial SV speed to obtain a passing result for that test condition. If the vehicle was to achieve passing results for that test condition, then the speed would be incremented to the next test speed and the process would repeat until the vehicle either could not exceed a 75 percent speed reduction, or the 80 kph (49.7 mph) test condition was passed, whichever came first.

CAS stated that NHTSA's assessments should be based on objective reliability and confidence criteria, noting that passing 7 out of 7 trials at any speed provides 91 percent reliability of the AEB system with only 50 percent confidence. Therefore, CAS contended that no fewer than 7 successful trials and no failures should be acceptable at any speed.

As previously mentioned, Auto Innovators did not favor a pass rate of five out of seven runs since this pass rate would not optimize test resources. Notwithstanding, the group remarked that if the Agency did impose a five out of seven requirement and the first five runs produced passing results (*i.e.,* no contact), then the last two runs should not be conducted in order to reduce test burden.

Other commenters provided general comments on this topic. For example, Toyota stated the Agency should conduct the number of trials that were sufficient to communicate accurate performance information to consumers, without recommending a specific number. Advocates asserted that the Agency should justify how the number of trials and pass/fail criteria adopted will assure that evaluated systems will perform as expected and address the safety need, especially since NHTSA's testing is conducted under controlled conditions.

Response to Comments and Agency Decisions

The Agency sought feedback on the proposed number of trials within each test variant. The Agency also asked commenters to consider a potential ADAS rating system that would allow flexibilities for continuous improvements to the program and cross-model year comparisons. Based on comments received on the appropriate number of trials for each test variant, NHTSA has decided that instead of performing multiple trials for each assessed test condition for a given test scenario, as is currently done for NCAP testing, it will conduct one trial per test condition (*e.g.,* at a prescribed test speed for a given test condition/scenario) for future AEB NCAP tests. In the event the SV contacts the POV during a trial, testing will cease for the test condition, respective test scenario, and the AEB test being performed (*i.e.,* CIB or DBS). Effectively, the vehicle will fail the individual test condition/scenario being assessed, and it will not receive NCAP credit for the ADAS system being evaluated, whether it be CIB or DBS.

Number of Trials Required for Each Test Condition

Since the Agency will run only one valid trial per test condition, per NHTSA's finalized CIB testing approach, the Agency will conduct, at most, five LVS tests, five LVM tests, eight LVD tests, and one false positive test. For DBS, NHTSA will conduct, at most: four LVS tests, four LVM tests, eight LVD tests, and one false positive test. This results in a maximum total of 19 CIB test trials and 17 DBS test trials, or 36 total AEB trials.

Although several commenters, like Intel and CAS, stated the Agency should or must continue to conduct multiple trials per test condition, many other commenters (Auto Innovators, FCA, GM, HATCI, Honda, and BMW) asserted that NHTSA's planned testing approach was appropriate. There are several reasons that a testing approach requiring one trial run per test condition, instead of multiple runs, is appropriate for the Agency's AEB testing in NCAP. First, NHTSA notes that DRI attested that, from its own experience with AEB testing, systems exhibiting better performance tend to do so repeatably. DRI's observation for superior AEB systems partially counters CAS's assertion that conducting a single trial for a given test condition would be insufficient. With respect to less robust AEB systems, the Agency acknowledges that, occasionally, a vehicle may pass the first trial for a given speed even though it may fail subsequent trials if additional trials were to be conducted at that same speed. However, NHTSA also asserts that the system's poor performance could alternatively be exposed in single trials conducted for progressively higher speeds, which is the approach the Agency has adopted for its LVS and LVM tests.[130] As such, the Agency agrees not only with IDIADA, which stated that an approach that requires one trial per test speed across many different speeds should effectively assure system robustness, but also with Rivian, which noted that such an approach should effectively identify changes in system performance without the need to conduct multiple runs for each test condition. Further, NHTSA asserts its planned testing approach of incrementing test speeds should also reduce the risk of damage to the SV and POV.

Performing one trial run per test condition is also reasonable for NCAP's LVD tests. Although NHTSA plans to assess only two discrete test speeds for the LVD scenario rather than a range of speeds as planned for the LVS and LVM scenarios, NHTSA reasons this approach should still ensure system robustness for the LVD AEB tests. As mentioned earlier, since the SV and POV speeds are initially the same in the LVD tests, the initial speed conditions for the decelerating lead vehicle scenario are not as critical to the outcome of the test as the other main parameters, headway and POV deceleration. It should be noted, though, that a higher initial test speed inherently requires additional braking to achieve a complete stop compared to a lower initial test speed. Thus, by adopting two discrete test speeds, two different headways, and two POV deceleration magnitudes, as well as structuring testing such that it progresses from generally the least challenging to the most challenging parameters, it will still ensure AEB systems receiving NCAP credit for passing test results represent robust designs offering a high level of performance and safety without increasing test burden unnecessarily.

Second, NHTSA's testing approach is reasonable for NCAP because it best manages test burden. Per CAS' comments, the Agency can only be 50 percent confident that AEB systems will be 91 percent reliable when seven runs are conducted for each test condition. This means that NHTSA would have to perform a far greater number of runs for each test condition to have a reasonably high confidence that the observed system performance is representative of the system's true capability.[131] Alternatively, the Agency could consider conducting a large number of runs at only the highest test speed for each test scenario. However, it would risk imparting additional damage to the test vehicle and test equipment in addition to test delays due to repairs if it were to take such an approach.[132]

Third, permitting some number of failures, which would be inherent to repeated trials, would be detrimental to real-world safety. Considering NCAP testing will be limited to only certain conditions in a controlled testing environment, allowing no test failures is the most acceptable approach and will best ensure consistency in real world AEB system performance and safety improvement in rear-end crashes.

The aforementioned considerations make the Agency's planned testing approach the most appropriate for NCAP testing. Because NHTSA has decided to adopt an approach requiring only one trial per test condition, it is not necessary to evaluate a random subset of test conditions to limit test burden, as Intel suggested.

Repeat Trials in the Event of Contact

NHTSA's RFC notice proposed performing four additional (repeated) test trials at the same test speed if the SV contacted the POV during the first test trial for a given AEB test condition and the relative longitudinal velocity between the SV and POV was less than or equal to 50 percent of the initial speed of the SV. To pass the test condition, NHTSA proposed that the SV could not contact the POV for at least three out of the five total trials conducted. The Agency also proposed that if the SV contacted the POV during a valid trial of a test condition (whether it be the first test performed at a particular test speed or a subsequent repeat run conducted at that same speed), and the relative longitudinal impact velocity exceeded 50 percent of the initial speed of the SV, no additional test trials would be conducted at the given test speed (or for the test scenario) and the SV would fail the test condition.

[130] The Agency will increment test speeds by 10 kph (6.2 mph) from a minimum to a maximum speed.

[131] Three hundred trials would be needed for 99 percent reliability with 95 percent confidence. Similarly, 59 trials would be needed for 95 percent reliability with a 95 percent confidence, and 29 trials would be needed for 90 percent reliability with 95 percent confidence.

[132] Since the vehicle tested is randomly purchased or leased from dealerships, its performance in the AEB tests is based on the performance and manufacturing reliability set by the manufacturer.

The Agency has decided not to finalize this part of its proposal and will thus not conduct repeat trials in the event of SV-to-POV contact, regardless of the relative longitudinal impact velocity recorded between the two vehicles at the time of impact.

Many commenters (Auto Innovators, BMW, FCA, GM, HATCI, Honda, Rivian, and Tesla) agreed, at least in part (some differed on the pass rate), with the Agency's proposal to conduct additional trials if an initial trial run resulted in contact, and most of these commenters (Auto Innovators, BMW, FCA, GM, Honda, and Rivian) stated that NHTSA should consider conducting multiple trials regardless of whether a 50 percent speed reduction was observed in the first or subsequent trial runs. However, based on other comments received and laboratory testing experience, NHTSA reasons it is no longer appropriate to conduct repeat trials in the event of contact.

Specifically, the Agency's underlying objective in updating NCAP is to adopt AEB tests that are representative of real-world rear-end crashes and maximize safety. To achieve these goals, NHTSA must establish performance criteria for testing that will ensure AEB system response is consistent and repeatable. Similar to DRI's observations during AEB testing, the Agency has observed that if a vehicle contacts the vehicle test device during the first trial run for a test condition, it is also likely to contact the vehicle test device during subsequent runs conducted.[133] In the Agency's testing, if an impact occurred and additional tests were performed for that test condition, at least one more impact was observed 97 percent of the time (32 of 33 applicable test conditions) for CIB tests, and for 100 percent of the DBS tests (27 of 27 of the applicable test conditions). Considering all CIB and DBS trials, the total was 98 percent (59 of 60 total trials). Therefore, the Agency disagrees with commenters who stated that discontinuing testing after a single-run failure is ''overly strict.''

Encouraging robust system performance that limits contact will lead to a reduction of harm and costs associated with crashes, and result in fewer testing delays and costs caused by SV-to-POV contact, benefiting both the public and the Agency. Based on this, NHTSA does not agree with concerns raised by several commenters who expressed that discontinuing testing after failures at low speeds may be ''premature'' or may unfairly penalize vehicles that offer more robust AEB system performance at higher test speeds. Specifically, NHTSA notes that a lower speed rear-end crash resulting in an injury still causes an unnecessary injury, and still imposes an economic cost. As such, requiring crash avoidance performance across the range of speeds and test conditions defined in the NCAP AEB test matrix is imperative to maximize safety.

The Agency also agrees with Toyota that it should only conduct the number of test trials necessary to provide consumers with accurate information pertaining to AEB system performance. Allowing repeated trials in the event of SV-to-POV contact may mislead consumers, potentially causing them to assume that a vehicle's AEB system provides more repeatable, robust crash avoidance performance than it does. As such, it is most appropriate to provide consumers with an assessment of system performance using a single, representative sample rather than an assessment based on the average or median impact speed across several runs, as some commenters suggested. Manufacturers must design their vehicles to meet the adopted performance criteria every time. By proceeding in this manner, the Agency is responding to Advocates' request to best ensure the number of trial and performance criteria adopted will assure that evaluated systems will perform as expected and best address the safety need.

f. Pass Rate

The Agency sought comment on an appropriate minimum pass rate to evaluate AEB performance based on the adjustments it proposed for its AEB assessments. The proposal included plans to (1) consolidate its FCW and CIB tests such that the CIB tests would also serve as an indicant of FCW operation, (2) assess up to 14 test speeds for CIB (*i.e.,* five for LVS, five for LVM, and potentially four for LVD), and (3) assess up to six test speeds for DBS (two for LVS, two for LVM, and potentially two for LVD), which would result in a total of up to 20 unique combinations of test conditions to be evaluated for AEB. As an example, the Agency suggested that a vehicle could be considered to meet the AEB performance if it passes two-thirds of the 20 unique combinations of test conditions (*i.e.,* passes 14 unique combinations of test conditions).

Summary of Comments

Bosch favored a pass rate of two-thirds of the 20 unique combinations but stated that any vehicles not able to meet this criterion should be awarded partial credit. BMW, Honda, and Auto Innovators also commented that a pass rate of two-thirds is reasonable. However, to ensure that both CIB and DBS performance is weighted equally, Honda suggested (as mentioned earlier) that the Agency should add DBS tests at lower speeds (40, 50, and 60 kph) to align with CIB performance evaluations that are also conducted at those speeds.

Tesla favored a pass rate of 70 percent for CIB and DBS tests overall (*i.e.,* 70 percent of all test conditions assessed for the specified test scenarios) since this would generally be consistent with current NCAP test procedures, which require a pass rate of five out of seven trials.

CAS asserted that the only appropriate pass rate is 100 percent, stating that the number of trials proposed by the Agency was ''insufficient to establish high confidence in safe performance even with no failures.''

Response to Comments and Agency Decisions

NHTSA has decided to adopt a 100 percent pass rate for CIB and DBS system testing and will provide consumers with an overall assessment of AEB performance, as proposed. This means AEB systems must achieve passing results (*i.e.,* no POV-to-SV contact) in all adopted test conditions for both CIB and DBS (*i.e.,* 19 test conditions for CIB—five for LVS, five for LVM, eight for LVD, and one false positive; and 17 test conditions for DBS—four for LVS, four for LVM, eight for LVD, and one false positive) to receive credit for AEB technology. The Agency will not provide separate credit for CIB and DBS passing performance; only those vehicles achieving passing performance for all 36 AEB test conditions will receive NCAP credit for passing AEB performance.

The Agency's decision to adopt a pass rate of 100 percent and combine CIB and DBS performance into an overall assessment for AEB is appropriate for several reasons. First, NHTSA agrees with CAS that no test failures should be allowed for any test scenarios/conditions. This is the best way to ensure that only the most robust AEB systems obtain AEB credit on the Agency's website. Adopting a pass rate of two-thirds or seventy percent, as some commenters suggested, or awarding partial credit, as Bosch requested, does not best serve the motoring public. As mentioned previously, the only way to ensure AEB systems afford meaningful safety is to require vehicles to avoid contact for every test condition assessed. Further, since the goal of NCAP is to provide

[133] *https://downloads.regulations.gov/NHTSA-2023-0021-0006/attachment_2.pdf.*

consumers with information to inform their vehicle buying choices, communicating information on the functionality of a vehicle's entire AEB system, rather than its individual system components, would be more beneficial at this time. The Agency reasons that consumers' new vehicle selection criteria will not include a consideration of whether they anticipate braking or not when faced with a crash-imminent situation. Rather, they will want to purchase a vehicle that responds appropriately to prevent the crash regardless of their action(s) or inaction. As such, providing separate ratings for CIB and DBS performance would be unhelpful in this regard. NHTSA also does not want to mislead consumers in assuming AEB system performance is better than it is by assigning credit to a vehicle for passing DBS performance when its CIB performance was lackluster. This is particularly concerning since, as mentioned, NHTSA found in its analysis of 2003–2009 NASS–CDS data that drivers of an SV involved in a rear-end crash tended to brake at about the same rate as those who did not brake, thus making performance for both system components equally important.[134] Yet, the Agency's research testing for model year 2021–2022 vehicles suggested that no vehicle exhibited passing performance for both AEB technologies, although one vehicle achieved passing results for one technology, DBS.[135] Nonetheless, NHTSA believes that achieving a pass rate of 100 percent for CIB and DBS testing is feasible. The Agency notes that the vehicle which provided passing performance for all DBS tests also achieved no contact performance for 16 of the 18 assessed CIB test conditions. While contact was observed for the 12 m headway, 0.4g deceleration LVD CIB test condition (such that the 12 m headway, 0.5g deceleration LVD CIB test condition was not subsequently performed), the vehicle exhibited a relative impact speed of less than 10 kph during all runs performed. Considering the vehicle's robust performance overall for the overwhelming majority of the AEB tests conducted, NHTSA believes that minor changes to the system's software should afford a perfect pass rate overall.

Since the number of tests adopted for NCAP's CIB assessments is nearly identical to the number adopted for the program's DBS assessments (*i.e.,* 19 tests for CIB versus 17 for DBS), there is no need to weight either set of assessments (*i.e.,* those for CIB or DBS), as Honda requested, especially since vehicles must achieve a pass rate of 100 percent for each of the two AEB technologies to receive credit for both.

An overview of test scenarios and conditions that will be required to receive passing credit for AEB systems in NCAP is shown in Tables 14 and 15.

TABLE 14—ADOPTED CIB TEST SCENARIOS AND CONDITIONS

Test No.	Test scenario	SV speed (kph (mph))	POV speed (kph (mph))	POV headway (m (ft.))	POV deceleration (g)	Requirement to pass
1	LVS	40 (24.9)	0	n/a	n/a	No SV-to-POV contact during any trial.
2		50 (31.1)	0	n/a	n/a	
3		60 (37.3)	0	n/a	n/a	
4		70 (43.5)	0	n/a	n/a	
5		80 (49.7)	0	n/a	n/a	
6	LVM	40 (24.9)	20 (12.4)	n/a	n/a	
7		50 (31.1)	20 (12.4)	n/a	n/a	
8		60 (37.3)	20 (12.4)	n/a	n/a	
9		70 (43.5)	20 (12.4)	n/a	n/a	
10		80 (49.7)	20 (12.4)	n/a	n/a	
11	LVD	50 (31.1)	50 (31.1)	40 (131.2)	0.3	
12		50 (31.1)	50 (31.1)	12 (39.4)	0.3	
13		80 (49.7)	80 (49.7)	40 (131.2)	0.3	
14		80 (49.7)	80 (49.7)	12 (39.4)	0.3	
15		50 (31.1)	50 (31.1)	40 (131.2)	0.5	
16		50 (31.1)	50 (31.1)	12 (39.4)	0.5	
17		80 (49.7)	80 (49.7)	40 (131.2)	0.5	
18		80 (49.7)	80 (49.7)	12 (39.4)	0.5	
19	False Positive (STP)	80 (49.7)	n/a	n/a	n/a	SV peak deceleration <0.25g.

TABLE 15—ADOPTED DBS TEST SCENARIOS AND CONDITIONS

Test No.	Test scenario	SV speed (kph (mph))	POV speed (kph (mph))	POV headway (m (ft.))	POV deceleration (g)	Requirement to pass
1	LVS	70 (43.5)	0	n/a	n/a	No SV-to-POV contact during any trial.
2		80 (49.7)	0	n/a	n/a	
3		90 (55.9)	0	n/a	n/a	
4		100 (62.1)	0	n/a	n/a	
5	LVM	70 (43.5)	20 (12.4)	n/a	n/a	
6		80 (49.7)	20 (12.4)	n/a	n/a	
7		90 (55.9)	20 (12.4)	n/a	n/a	
8		100 (62.1)	20 (12.4)	n/a	n/a	
9	LVD	50 (31.1)	50 (31.1)	40 (131.2)	0.3	

[134] National Highway Traffic Safety Administration (2012, June), *Forward-looking advanced braking technologies research report, https://www.regulations.gov/document?D=NHTSA-2012-0057-0001.*

[135] National Highway Traffic Safety Administration. (2023, February). *NHTSA's 2022 Light Vehicle Automatic Emergency Braking Research Test Summary. http://www.regulations.gov.* Docket No. NHTSA–2023–0021–0005. This statement is based on the results of the Agency's model year 2021–2022 research test data, which did not include the LVD test conditions that require a 0.3g POV deceleration.

TABLE 15—ADOPTED DBS TEST SCENARIOS AND CONDITIONS—Continued

Test No.	Test scenario	SV speed (kph (mph))	POV speed (kph (mph))	POV headway (m (ft.))	POV deceleration (g)	Requirement to pass
10		50 (31.1)	50 (31.1)	12 (39.4)	0.3	
11		80 (49.7)	80 (49.7)	40 (131.2)	0.3	
12		80 (49.7)	80 (49.7)	12 (39.4)	0.3	
13		50 (31.1)	50 (31.1)	40 (131.2)	0.5	
14		50 (31.1)	50 (31.1)	12 (39.4)	0.5	
15		80 (49.7)	80 (49.7)	40 (131.2)	0.5	
16		80 (49.7)	80 (49.7)	12 (39.4)	0.5	
17	False Positive (STP)	80 (49.7)	n/a	n/a	n/a	SV peak deceleration <0.25g over the baseline peak imparted by manual braking.

g. Use of the ABD GVT and Appropriate Revision(s)

Currently, NHTSA uses the SSV as the POV in NCAP testing of DBS and CIB systems. The SSV, modeled after a small hatchback passenger car, is fabricated from light-weight composite materials including carbon fiber and Kevlar®.[136] To maximize visual realism, the SSV shell is wrapped with a vinyl material that simulates paint on the body panels and rear bumper and a tinted glass rear window. Given the combination of a design that emphasizes being lightweight, use of a towed track to support movement, and its material properties, the SSV has certain limitations during testing; namely, the maximum speed at which it can operate (*i.e.,* ≤56 kph (35 mph)) and maximum relative speed at which the SV can strike it (*i.e.,* 40 kph (25 mph) and lower speed). When operated outside of its intended operational constraints, the SSV can inflict damage to other vehicles and/or be damaged itself. The monorail used to laterally constrain the SSV is visible and secured to the test surface, which could potentially confound camera-based AEB systems. Considering these complications and constraints for testing, NHTSA proposed in its March 2022 RFC notice to use a GVT, mounted to a robotic platform, in lieu of the SSV in future AEB testing because GVTs do not have the same testing limitations.

A GVT, which also resembles a white hatchback passenger car, is meant to represent a vehicle in the subcompact to compact car class. A specific description of the required GVT characteristics is defined in International Organization for Standardization (ISO) 19206–3:2021, and at the time of this notice, there were two companies that produced a GVT as a commercially available product: AB Dynamics, Inc (ABD) and 4activeSystems (4a).[137] Both versions use an internal foam-based frame covered by multiple vinyl outer ''skin'' sections designed to provide the dimensional, optical, and radar characteristics of a real vehicle that can be recognized as such by camera and radar sensors.[138] In contrast to the SSV, the available GVTs are secured using hook and loop fasteners to the top of a programmable robotic platform which facilitates their movement. When either version of the GVT is impacted at low speed, it is typically pushed off the robotic platform but remains assembled. At higher impact speeds, the ABD GVT breaks apart, as the SV essentially drives through it.[139] At similar impact speeds, the 4a GVT is designed to remain more intact after being pushed off the robotic platform. Both GVT variants are designed to be reconstructed/reset back on top of the robotic platform after an SV-to-POV impact occurs. NHTSA reasoned that a GVT is therefore less likely than the SSV to impart damage to other vehicles, particularly at higher impact speeds.

In its March 2022 RFC notice, NHTSA proposed to use the [ABD] GVT Revision G for its future AEB assessments. This vehicle test device was proposed at the time because it is currently used by other consumer vehicle safety organizations that provide consumer information, including Euro NCAP,[140] as well as many vehicle manufacturers in their internal testing conducted per NCAP test specifications.[141] As such, by adopting ABD GVT Revision G for NCAP's AEB testing, NHTSA would embrace another opportunity to harmonize with other consumer information safety rating programs, as mandated by the BIL. The Agency also noted that the ABD GVT would be an appropriate replacement for the SSV in NCAP's future AEB testing because the test device (1) afforded similar AEB system performance to that of the SSV in comparison testing,[142] and (2) was found to be physically stable and durable when evaluated using straight line and curved path maneuvers for various speeds and lateral accelerations.[143] Accordingly, the Agency reasoned that the ABD GVT Revision G could be used to evaluate more challenging crash scenarios in future NCAP upgrades as well, such as those required for other ADAS technologies (intersection safety assist (intersection AEB) and Opposing Traffic Safety Assist (OTSA)), which would allow harmonization across the program areas. NHTSA did not similarly propose adoption of the 4a GVT because it had not yet evaluated the in-use characteristics of the device as part of its AEB research.

The Agency, recognizing that there have been ongoing revisions to the ABD GVT to address its performance in other crash modes that exercise different ADAS applications, proposed to adopt the latest revision of the test device, Revision G, for NCAP's AEB testing.

[136] 80 FR 68604 (Nov. 5, 2015).

[137] ABD refers to their GVT product as the ''Soft Car 360'' and 4activeSystems refers to their GVT product as the ''4activeC2.''

[138] Snyder, A.C., Forkenbrock, G.J., Davis, I.J., O'Harra, B.C., & Schnelle, S.C., *A test track comparison of the global vehicle target and NHTSA's strikeable surrogate vehicle,* (Report No. DOT HS 812 698), July 2019, *https://rosap.ntl.bts.gov/view/dot/41936.*

[139] Id.

[140] *https://www.euroncap.com/en/for-engineers/supporting-information/technical-bulletins/.* See Appendices I & II.

[141] Currently, manufacturers use test results from their internal testing and submit them to NHTSA for NCAP's recommendation of vehicles that pass its performance testing requirements.

[142] FCW and CIB onset timings for a given vehicle model were found to be highly comparable in the Agency's CIB characterization testing regardless of whether the SSV or ABD GVT vehicle test device was used. NHTSA notes that ABD GVT Revision E was used for these assessments.

[143] Snyder, A.C., Forkenbrock, G.J., Davis, I.J., O'Harra, B.C., & Schnelle, S.C., *A test track comparison of the global vehicle target and NHTSA's strikeable surrogate vehicle,* (Report No. DOT HS 812 698), July 2019, *https://rosap.ntl.bts.gov/view/dot/41936.*

NHTSA reasoned that this latest revision could be utilized for other ADAS technologies proposed for adoption as part of this NCAP upgrade, such as blind spot intervention (BSI), as well as future technologies, such as intersection safety assist (ISA) and opposing traffic safety assist (OTSA). For AEB testing purposes only, NHTSA proposed to accept manufacturer verification data for AEB tests conducted using ABD GVT Revision F as well. It is the Agency's understanding that modifications to the front, side, and oblique aspects of ABD GVT Revision F were incorporated into the company's GVT Revision G. NHTSA reasoned that these changes should not alter the physical characteristics of the rear of the vehicle test device such that a vehicle's performance in the rear-end crash mode (*i.e.,* AEB testing) would be impacted.[144]

Though the Agency used ABD GVT Revision E in its comparison testing with the SSV, it is unclear if/how the small changes made to Revision E to create Revision F may have affected the test track AEB performance.[145] For this reason, NHTSA did not propose to similarly accept manufacturer data for AEB test results derived using ABD GVT Revision E since this revision is no longer in production. Further, NHTSA also did not propose to accept vehicle manufacturer test data derived from alternative vehicle test devices other than that which is specified in NCAP's test procedures, though this was requested in response to NHTSA's November 2015 AEB final decision notice.[146] [147] The Agency explained that during its system performance verification testing it has observed several test failures that may be attributed to differences in vehicle test device designs. Therefore, NHTSA proposed to only accept manufacturer self-reported data obtained using tests conducted in accordance with NHTSA test procedures.

Comments were sought on the adoption of the ABD GVT Revision G in lieu of the SSV for AEB testing in NCAP regardless of whether modifications were made to test speeds, deceleration, test scenarios, combining test procedures, et cetera. The Agency also requested comment on whether ABD GVT Revision G was the most appropriate for adoption, and whether ABD GVT Revisions F and G should be considered equivalent for AEB testing.

Summary of Comments

Use of the ABD GVT Revision G in Lieu of the SSV

Commenters who supported replacing the SSV with the ABD GVT Revision G[148] in NCAP testing included AAA, Adasky, Auto Innovators, BMW, Bosch, CAS, GM, HATCI, Honda, IDIADA, MEMA, Rivian, Subaru, Toyota, and ZF Group.

ZF Group stated it supported adoption of the GVT because it was developed through coordinated efforts. Several commenters, including ZF Group, HATCI, Honda, and GM, stated the GVT more reasonably simulates the characteristics (*e.g.,* appearance, camera/radar detection, etc.) of actual vehicles. Auto Innovators noted that NHTSA participated in the GVT's development and 360-degree correlation to real-world vehicles but has yet to adopt it for use in its testing.

Toyota, GM, and Auto Innovators approved the use of the GVT because of its design and inherent durability. The commenters mentioned that the GVT is both less susceptible to damage compared to the SSV and less likely to induce damage to the SV, which naturally improves test efficiency and lowers testing costs. HATCI agreed that the GVT would limit damage to the SV and, along with Auto Innovators, asserted that it would promote a safer testing environment.

Intel encouraged NHTSA to adopt the GVT because the Agency showed that performance differences between the two vehicle test devices were ''negligible'' and real-world data has not revealed negative consequences due to its use. Furthermore, the company, along with Auto Innovators, Rivian, HATCI, Honda, and Adasky, favored the GVT's adoption because it would harmonize with Euro NCAP and other consumer programs, which Rivian specifically asserted would permit consistency in testing and reduce overall test burden and costs. Bosch supported adopting the GVT because it is specified in International Organization for Standardization Approved Work Item (ISO/AWI) 19206–3:2021.[149] Auto Innovators further added that the GVT would improve repeatability for LVD tests. IDIADA suggested that the SSV was ''obsolete,'' and GM and Auto Innovators mentioned that it had limited functionality (*i.e.,* it is acceptable only for rear-end tests with no offset or angular requirements). CAS agreed with the sentiment expressed by these last two commenters and asserted that the GVT should replace the SSV because it will allow the Agency to perform higher speed tests and additional crash scenarios, as well as accommodate testing for other ADAS technologies, which will promote more safety.

DRI mentioned that the GVT should be used in rear-end tests with 100 percent overlap when closing speeds exceed 40.2 kph (25 mph); however, the laboratory asserted that the SSV remains appropriate for testing (and offers equivalent results to the GVT) at closing speeds of 40.2 kph (25 mph) or less. TRC expressed similar sentiments. HATCI also recognized the SSV's viability for lower speed rear-end testing but argued that since it is limited to low speed rear-end tests, whereas the GVT can accommodate higher speeds and additional AEB and other ADAS technology test scenarios, the SSV should ideally be replaced with the GVT in NHTSA testing. Auto Innovators and GM agreed with HATCI but suggested it would be appropriate to ''adopt a phase-in approach'' for replacement of the SSV with the GVT since some manufacturers may currently be using the SSV for testing. Both Auto Innovators and GM suggested that NHTSA accept test data derived using either vehicle test device for a period of time.

In addition to their recommendation that the Agency adopt the GVT, Subaru and Auto Innovators requested that NHTSA harmonize with Euro NCAP with respect to the GVT moving platform, a GST100/120 or 4activeFB-Large, manufactured by ABD and 4a, respectively, in addition to adopting the related version of the GVT, to limit the cost burden to manufacturers.

---

[144] To improve the real-world characteristics from the front and side of the vehicle test device, several changes to the radar treatment were integrated into the components of the body for ABD GVT Revision G compared to ABD GVT Revision F, including changes to the skin and wheel treatment. There were also some minor shape changes to the front of the GVT body to improve front radar return and to the side to improve the ability to hold its shape. *http://www.dynres.com/2020/02/25/the-new-global-vehicle-target-gvt-has-arrived/.*

[145] It is the Agency's understanding that the modifications made to the rear of ABD GVT Revision E consisted of adding additional radar-absorbing material to the bottom skirt of the vehicle test device to attenuate internal reflections and reducing the slope of the simulated rear hatchback glass to increase the power of the radar return from the rear aspect.

[146] 80 FR 68604 (Nov. 5, 2015).

[147] Mercedes-Benz requested that NHTSA consider several vehicle test devices and allow manufacturers the option to choose which test device is used for testing.

[148] While not specifically mentioned in most comments, NHTSA assumes (unless otherwise indicated) responses to this topic pertained to the ABD GVT Revision G, as proposed.

[149] ISO/AWI 19206–3:2021, ''Road vehicles—Test devices for target vehicles, vulnerable road users and other objects, for assessment of active safety functions—Part 3: Requirements for passenger vehicle 3D targets.''

Consideration of Other ABD GVT Revisions and Alternative GVTs

Some commenters supported only adoption of Revision G of the ABD GVT at this time, including BMW, Bosch, MEMA, Toyota, and ZF Group. BMW recommended use of the ABD GVT Revision G to harmonize with other consumer testing programs, including Euro NCAP. As mentioned previously, Intel also supported efforts to harmonize where possible. IDIADA was another commenter to support using ABD GVT Revision G for NCAP's AEB testing. IDIADA opined that ABD GVT Revision G is the current standard version and ''offers more stable detection.'' Similar to its prior comments for use of the GVT in general, Bosch stated that ABD GVT Revision G was appropriate to incorporate because it fulfills ISO/AWI 19206–3:2021 requirements; however, the commenter also suggested that NHTSA refer to the ISO standard for incorporation rather than a GVT revision to allow for more flexibility in market participation.

Several commenters expressed support for ABD GVT Revision G in addition to ''lower'' ABD GVT revisions (*i.e.,* E, F) at this time. Auto Innovators, CAS, DENSO, DRI, FCA, GM, HATCI, Honda, Subaru, and TRC all opined that ABD GVT Revisions F and G should be considered equivalent for the purpose of AEB testing covering the current NCAP test scenarios. DENSO and Honda (which expressed a preference for ABD GVT Revision G) mentioned that since the rear components of both ABD GVT Revisions F and G have ''equivalent physical characteristics,'' they would be expected to perform the same in scenarios simulating rear-end crashes. However, a few of the commenters who supported adopting ''lower'' ABD GVT revisions for the proposed AEB test matrix, including Auto Innovators and GM, remarked that they would recommend use of only ''higher'' ABD GVT revisions (*e.g.,* ABD GVT Revision G and newer) in the future to improve correlation if additional test conditions with different approach angles and/or directions are added to Agency testing.

Some commenters, such as GM, supported adoption of ABD GVT Revision E in addition to ABD GVT Revisions F and G. Auto Innovators and HATCI preferred ABD GVT Revision G but additionally supported the inclusion of both ABD GVT Revisions E and F for use in current NHTSA NCAP test conditions. HATCI suggested that the Agency allow use of ABD GVT Revisions E and F in case of damage or supply shortages. CAS did not agree that the Agency should accept data from tests utilizing ABD GVT Revision E if that version is ''obsolete'' and ABD GVT Revisions F and G are now available.

Regarding the timeline and preparation for inclusion, HATCI requested that manufacturers be given a two-year lead-time to align with product development cycles if the Agency was to adopt an alternative GVT revision in the future. Auto Innovators requested that NHTSA work with other NCAPs to harmonize development of future versions of a global vehicle test device suitable for testing.

Response to Comments and Agency Decisions

Use of the ABD GVT Revision G in Lieu of the SSV

Commenters overwhelmingly supported replacing the SSV with the ABD GVT Revision G in NCAP testing, with many echoing points expressed by NHTSA in its March 2022 RFC notice. Most notably, commenters stated that adoption of the ABD GVT Revision G permits harmonization with other consumer information programs, including Euro NCAP, and allows the Agency to incorporate higher speed tests and additional test scenarios, including those for other ADAS technologies. The ABD GVT Revision G is an appropriate surrogate for use in NCAP testing given its physical characteristics, material properties, and durability, especially when compared to the SSV. The vehicle test device complies with ISO/AWI 19206–3:2021, ''Road vehicles—Test devices for target vehicles, vulnerable road users and other objects, for assessment of active safety functions—Part 3: Requirements for passenger vehicle 3D targets'' [150] with respect to the specifications outlined for radar cross section, reflectivity, color, and physical dimensions. As such, it is considered to be representative of a real vehicle. Further, in the Agency's most recent high-speed AEB research tests, the ABD GVT Revision G was found capable of operation at higher speeds and durable enough to receive impacts at higher relative speed than possible with the SSV. Accordingly, NHTSA plans to use the ABD GVT Revision G to conduct NCAP testing to measure the performance of AEB systems beginning with model year 2026 vehicles.

Although the Agency did not specify in its RFC notice a specific robotic platform to be used with the GVT, a few commenters recommended that NHTSA harmonize its platform(s) with Euro NCAP's to decrease burden. Because the GVT's movement will be subjected to specifications (speed, deceleration magnitude, etc.), the Agency does not see a substantial need to specify which platform must be used to achieve the appropriate POV kinematics.

Consideration of Other ABD GVT Revisions and Alternative GVTs

The Agency notes that several commenters favored adoption of ABD GVT Revision E and/or F in addition to Revision G, or desired a phase-in period for adoption of ABD GVT Revision G. Since ABD GVT Revision G only includes changes to the front and sides of Revision F, it is reasonable to continue to accept data using ABD GVT Revision F for LVS, LVD, and LVM AEB test scenarios for a period of time. NHTSA will accept manufacturers' AEB self-reported data for tests that use either ABD GVT Revisions F or G for the first two model years under the new ADAS testing program (*i.e.,* for model year 2026 and model year 2027). For model year 2028 and beyond, the Agency will only accept AEB data generated using the ABD GVT Revision G vehicle test device. This two-year period allows sufficient lead-time for vehicle manufacturers to procure the required GVT and complete testing for model year 2028 models. Since the Agency is making extensive changes to the AEB test procedures, including integrating FCW evaluations (as will be discussed in a later section), no test data collected for model year 2025 vehicles will carry over to model year 2026. Therefore, it is expected that vehicle manufacturers will have to conduct the updated AEB tests for all vehicle models in their model year 2026 fleet to claim AEB NCAP credit. Although the Agency anticipates that most manufacturers will utilize ABD GVT Revision G during testing conducted for their model year 2026 models, the Agency recognizes that manufacturers may experience procurement delays when obtaining ABD GVT Revision G such that only the Revision F version of the test device may be available for testing. Therefore, providing a short lead-time to account for this possibility is appropriate. For its own testing, NHTSA will utilize ABD GVT Revision G to validate AEB system performance beginning with model year 2026 vehicles.

NHTSA has decided it will not accept data obtained from tests utilizing ABD GVT Revision E for the 2026 model year and beyond. The Agency agrees with CAS that this version should be considered ''obsolete'' since it is no longer in production. Further, data gathered from testing conducted with the SSV will also not be eligible for credit starting in model year 2026. As

[150] *https://www.iso.org/standard/70133.html.* May 2021.

mentioned in the March 2022 RFC notice, NHTSA plans to only accept self-reported manufacturer data from tests conducted in accordance with its test procedures to uphold NCAP's credibility. This requirement includes use of the prescribed test device, when applicable. Vehicles failing to provide passing performance during the Agency's assessments will not receive credit for AEB technology, regardless of whether passing results were provided by the vehicle manufacturer in response to NCAP's annual data information request.

Although nearly all commenters supported adoption of Revision G of the ABD GVT, the Agency recognizes that Bosch recommended NHTSA incorporate by reference ISO/AWI 19206–3:2021 in NCAP, rather than stipulate a specific vehicle test device for use in the program's AEB tests. The Agency has not conducted thorough evaluations of alternative test devices, such as the 4a GVT, to ensure they invoke equivalent vehicle/system performance as the ABD GVT Revision G in the Agency's AEB tests. Therefore, at this time, the Agency is specifying use of the ABD GVT Revision G in the NCAP AEB tests to mitigate variability between the Agency's test results and those submitted by the manufacturer. As noted earlier, the ABD GVT Revision G meets the ISO 19206–3:2021 specifications.

Vehicle Test Device Specifications

Since AEB systems currently on the market may utilize camera-, radar-, and/or lidar-based sensors (or some combination thereof) to provide automatic emergency braking, the vehicle test device adopted for NCAP's AEB testing must meet certain specifications to ensure the SV recognizes the target as a real-world vehicle to ensure real-world benefit and assure test repeatability and reproducibility. These specifications include (1) physical dimensions, such as vehicle width; (2) features that are identifiable on the rear of a typical passenger vehicle, such as tail lamps, reflex reflectors, windows, and the rear license plate; (3) those addressing visual and near infrared specifications, such as for the exterior of the vehicle and also for various surface features, including tires, windows, and reflex reflectors; and (4) radar reflectivity, since many AEB systems rely on radar sensors in some capacity to identify the presence of other vehicles. Specifications for acceptable vehicle test devices are defined in ISO 19206–3:2021, and as mentioned, ABD states that the GVT Revision G meets these requirements as manufactured. Given this, it is unnecessary to prescribe additional specifications for the ABD GVT Revision G for NCAP testing, as compliance with the ISO standard in its entirety should be inherent. That said, the Agency will reference ISO 19206–3:2021 in NCAP's AEB test procedures to ensure any device utilized for Agency testing complies with the standard's specifications.

h. DBS Brake Application Timing

The Agency proposed that, should it decide to continue to perform DBS testing in NCAP, in lieu of the current procedure of initiating manual braking at prescribed TTCs for each test scenario,[151] brake application for all LVD, LVS, and LVM DBS test scenario and speed combinations would occur at a time corresponding to 1.0 second after the FCW is issued. NHTSA proposed this change would apply regardless of whether automatic braking occurs after the FCW but before initiation of the manual brake application. The Agency reasoned this procedural modification would better represent real-world use and driving conditions while also being in basic agreement with the approach specified for FCW performance evaluations in Euro NCAP's AEB Car-to-Car systems test protocol.[152] Euro NCAP requires that brake application begin 1.2 seconds after issuance of the FCW. As an alternative to this proposal, NHTSA also requested comment on appropriate TTCs for the modified test conditions.

Summary of Comments

Many commenters, including Toyota, Honda, GM, and Tesla, agreed with the Agency's proposal to trigger manual brake application 1.0 second after the FCW is issued in DBS testing. GM supported the proposed changes for the Agency's DBS test procedure, stating that such modifications would better align with protocols used by other NCAPs and ''provide a more comprehensive assessment of overall system performance.'' GM, Honda, and ZF Group commented that the proposed time of 1.0 second after issuance of an FCW would reasonably simulate the time it might take a driver to depress the vehicle's brake after an FCW is issued. Tesla agreed that this was a reasonable method of replicating human behavior but cautioned the Agency to use factory default settings for configurable FCW timing settings to ensure consistency across vehicle models.

Auto Innovators, Bosch, IDIADA, and Intel agreed with the Agency's proposal of applying the brake 1.0 second after the FCW was issued in DBS tests but suggested that a brake application timing of 1.2 seconds after the FCW, as used by Euro NCAP, would also be reasonable. Like other commenters, Auto Innovators stated that triggering a brake application at a prescribed time after issuance of an FCW in the Agency's DBS tests rather than at a fixed TTC is more appropriate since the intent of an FCW is to compel the driver to react; thus, it should be more representative of the driver's behavior under real-world conditions. The group added that aligning with Euro NCAP's brake activation timing would reduce test burden.

Rivian stated the Agency should adopt a ''lower time gap'' between the FCW and manual brake application because CIB will often activate and move the brake pedal before DBS activation, (as the Agency acknowledged in its 2022 RFC notice), such that not all DBS systems may be effectively assessed if the Agency were to adopt the proposed test procedure modifications. Similarly, in agreement with its recommendation to conduct integrated assessments for FCW, CIB, and DBS collectively ''to better assess the total safety benefit,'' BMW stated that once CIB activates, ''any DBS influence is irrelevant.''

CAS recommended that the Agency should base brake application timing for DBS testing on actual human driver responses to an FCW.

Response to Comments and Agency Decisions

To provide a comprehensive assessment of AEB system performance, the Agency has decided to initiate manual (robotic) brake application in NCAP's LVS, LVD, and LVM DBS tests at a time that corresponds to 1.0 ± 0.1 seconds after issuance of the required FCW signals (*i.e.,* both signals for any bimodal warning, as will be discussed later) instead of at prescribed TTCs, as is done currently. The prescribed 1.0-second delay is based on the time it takes a driver to react when presented with an obstacle.[153] If the FCW (*i.e.,* one or more of the required two signals) is *not* issued in an LVS, LVD, or LVM DBS

[151] The TTCs prescribed for actuator braking in NCAP's DBS test procedure are 1.1 seconds, 1.0 second, and 1.4 seconds, respectively, for the LVS, LVM, and LVD scenarios.

[152] European New Car Assessment Programme (Euro NCAP) (November 2022), *Test Protocol—AEB Car-to-Car systems, Version 4.1.1.* See Annex A.

[153] Fitch, G.M., Blanco, M., Morgan, J.F., Rice, J.C., Wharton, A., Wierwille, W.W., & Hanowski, R.J. (2010, April) *Human Performance Evaluation of Light Vehicle Brake Assist Systems: Final Report* (Report No. DOT HS 811 251) Washington, DC: National Highway Traffic Safety Administration, p. 101.

test, the SV accelerator pedal will not be released, and the brake will not be manually applied prior to impact with the vehicle test device (*i.e.,* POV).[154] This planned procedural change will not apply to the false positive DBS assessment since an FCW is not expected during this assessment (though it may occur). For the false positive DBS test, the SV brakes will be applied (after throttle release)[155] at a TTC of 1.1 seconds, corresponding to a nominal distance of 24.4 m (80.2 ft.) from the edge of the STP.

NHTSA notes that commenters were generally supportive of this proposed change and agreed that such an approach better represents human behavior during real-world driving. Several respondents also noted this approach aligns well with Euro NCAP's AEB Car-to-Car systems test protocol, which specifies that braking is applied 1.2 seconds after the FCW is issued. Though some commenters requested that the Agency harmonize precisely with Euro NCAP's specification, the Agency's requirement is reasonable, and NHTSA has no data showing that a reaction time of 1.2 seconds is more appropriate. Previous NHTSA research has shown it takes drivers 1.04 seconds, on average, to begin applying the brake when presented with an unexpected obstacle, and 0.8 seconds when presented with an anticipated obstacle.[156] For similar reasons, NHTSA reasons it is inappropriate to adopt a lower time gap between the FCW and manual brake application, as requested by Rivian.

Regarding Rivian's concern that CIB may activate and move the brake pedal after the time of the FCW but before the brake pedal is manually applied one second later during DBS testing, the Agency has observed this phenomenon and does not consider it problematic for several reasons. First, although the presence of CIB braking may negate the need for DBS activation (*i.e.,* the supplemental braking typically associated with DBS is not required since the CIB system may already be braking the vehicle at its maximum capability), the manual brake application timing relative to the FCW is not changed and the crash avoidance performance requirement remains in place, so the test severity is fully retained. Second, tests where the brakes are manually applied after a CIB intervention has been initiated provide an opportunity not only to demonstrate the vehicle can avoid the POV, but also to ensure that the driver's input does not override the CIB system such that it reverts to the braking level input by the driver alone (*i.e.,* without any braking contribution from AEB), since doing so would be expected to result in contact with the POV, and therefore a test failure. Third, the Agency defines the onset of SV manual brake application as when the force applied to the brake pedal is ≥11 N (2.5 lbf), not when the brake pedal physically moves. This is a consideration for both CIB and DBS tests when assessing whether a given test trial is valid (*i.e.,* performed properly). For CIB testing, the Agency's test procedure prohibits the driver from applying force to the brake pedal during the test's validity period. For DBS testing, the onset of SV manual braking is important when assessing manual brake application timing relative to the onset of the FCW.

Given the Agency's decision to initiate manual (robotic) brake application in NCAP's LVD, LVS, and LVM DBS tests at a time that corresponds to 1.0 ± 0.1 seconds after issuance of the required FCW signals, the Agency has also tried to limit the effect of different FCW timing settings (*e.g.,* early vs. late) on AEB testing outcomes to best ensure consistency across vehicle models, as Tesla suggested. As discussed later in this final notice, NHTSA has decided to specify use of the middle (or next latest) FCW setting in lieu of the default setting (as Tesla requested) or the latest alert setting for NCAP testing. This is because the warning setting most preferred by drivers will likely correspond to the default setting and should generally fall in the middle of the range of driver setting preferences that span either earlier or later alert settings.

i. SV Throttle and Brake Application Overlap in DBS Tests

The Agency's existing DBS test procedure states that the accelerator pedal must be fully released within 500 ms after an FCW is issued but prior to the onset of the manual SV brake application by a robotic brake controller, a timing currently dictated in the test procedure (as prescribed TTCs) for each test condition. As mentioned previously, if the Agency decided to continue to perform DBS testing in NCAP, it proposed to revise the time when the manual (robotic) brake application is initiated during testing to a time that corresponds to 1.0 second after the FCW is issued, even in instances where automatic braking (*i.e.,* CIB) occurs after the FCW but before initiation of the manual brake application. However, as an alternative to this proposed procedural change, NHTSA also requested comment on appropriate revised TTCs for the modified DBS test conditions. In the event the Agency decided to proceed with this alternative proposal to adopt revised TTCs, NHTSA proposed that the current test specifications for pedal release timing (*i.e.,* within 500 ms after an FCW is issued, but prior to the onset of the prescribed manual SV brake application by a robotic brake controller) would be maintained.

In its March 2022 RFC notice, the Agency recognized that the current test requirements for pedal release timing can be problematic if no FCW is issued or if the alert happens very close to the prescribed brake activation timing, because the throttle may still be depressed (since no warning was issued, or it was issued late) while the SV brakes are applied by the robot at the prescribed TTC. The Agency documented this possibility (*i.e.,* where the SV throttle and brake pedals are applied at the same time) during track testing and provided a recommendation that up to a 250 ms overlap be allowed.[157] In other words, once the SV driver detects that the robot has applied the brakes, the driver will have 250 ms (instead of 500 ms) to fully release the accelerator. A test run would not be valid unless this criterion is met.

Given the Agency's findings and recommendation, NHTSA sought comment on whether it would be acceptable to modify NCAP's DBS test procedure (in the event it adopted revised TTCs for the modified DBS test conditions) to allow a 250 ms overlap of SV throttle and brake pedal application in instances where no FCW has been issued by the prescribed TTC in a DBS test, or where the FCW is issued very close to brake activation.

Summary of Comments

Several commenters, including Auto Innovators, FCA, GM, and Rivian, stated that a 250 ms overlap for SV throttle and brake pedal application was acceptable. Rivian added that it appropriately

[154] In this instance, the vehicle will also fail the trial run.

[155] For the false positive DBS tests, the subject vehicle accelerator pedal will be released at any rate, such that it is fully released within 500 milliseconds, either when a forward collision warning is given or at a headway that corresponds to a time-to-collision of 2.1 seconds, whichever occurs earlier.

[156] Fitch, G.M., Blanco, M., Morgan, J.F., Rice, J.C., Wharton, A., Wierwille, W.W., & Hanowski, R.J. (2010, April) *Human Performance Evaluation of Light Vehicle Brake Assist Systems: Final Report* (Report No. DOT HS 811 251) Washington, DC: National Highway Traffic Safety Administration, p. 101.

[157] Forkenbrock, G.J., & Snyder, A.S. (2015, June), *NHTSA's 2014 automatic emergency braking test track evaluations* (Report No. DOT HS 812 166), Washington, DC: National Highway Traffic Safety Administration.

simulates panic braking within 250 ms of an FCW in real-world driving situations. Honda also agreed that such an overlap was unobjectionable ''as long as the application of SV throttle is not excessive'' since this could possibly affect braking performance.

In contrast, IDIADA and Intel did not support any amount of throttle and brake overlap. IDIADA commented that the DBS test procedure is intended to simulate a driver's normal response in situations represented by the test scenarios. As such, the laboratory asserted there should be no overlap between brake and throttle application since the driver would normally be operating both pedals with one foot, and therefore could not depress both simultaneously. Intel expressed a similar sentiment.

TRC noted that, as not all throttle robots permit application of both the brake and throttle at once, some test entities may have to purchase new equipment if NHTSA was to adopt this test procedural change.

Response to Comments and Agency Decisions

NHTSA has decided not to adopt a 250 ms overlap for testing scenarios, despite several commenters stating that such an overlap is acceptable. The 250 ms overlap is unnecessary because it has implemented requirements in NCAP's LVD, LVS, and LVM DBS tests to (1) fully release the SV's accelerator pedal (at any rate) within 500 ms after an FCW is issued (whether it be before or after automatic braking has begun), and (2) initiate manual (robotic) brake application at a time that corresponds to 1.0 ± 0.1 seconds after issuance of the required FCW signals (*i.e.,* any dual-modality alert, as discussed later) instead of at currently prescribed TTCs.

In any situation, the throttle should be fully released for a minimum of 500 ms prior to manual brake application. This manual (robotic) braking procedure aligns with comments received from IDIADA and Intel, both of which stated it was inappropriate for throttle depression to overlap with brake application. The Agency agrees with IDIADA that NCAP's DBS test procedure should simulate real-world driving conditions, where the driver's foot would be removed from the throttle prior to depressing the brake. The changes NHTSA has made to throttle release and robotic brake application timing requirements reflect that intention.

NHTSA also asserts the possibility of SV throttle and brake application overlap does not exist for the false positive DBS assessment. In the false positive DBS test, issuance of an FCW is not expected (though it may occur). As such, the SV throttle is to be released within 500 ms of the prescribed TTC (2.1 seconds) if no FCW is issued by the specified time. If an FCW is issued, the SV throttle is released within 500 ms of the warning. In both situations, the SV brakes are then to be applied at a TTC of 1.1 s, which corresponds to a nominal distance of 24.4 m (80.2 ft.) from the edge of the STP. Like the LVD, LVS, and LVM DBS tests, the SV accelerator should always be fully released for a minimum of 500 ms prior to brake application in the false positive DBS test, regardless of whether an FCW is issued. NHTSA notes that no commenters suggested revised TTCs for the false positive test condition. As such, the Agency will maintain the current TTC requirement for the 80 kph (49.7 mph) false positive test condition. This is reasonable given the same TTC requirements are currently specified for both the 40.2 kph (25 mph) and 72.4 kph (45 mph) test speeds.

Finally, TRC's contention that some braking robots are not able to apply both the brake and accelerate at the same time is no longer a concern, because overlap between the SV throttle and manual brake application is now avoidable for all DBS tests due to the adopted throttle release and brake application timing requirements.

j. Addition of Manual Brake Application Controller Option

To achieve accurate, repeatable, and reproducible SV brake pedal inputs during NCAP's DBS tests, NHTSA uses a programmable brake controller, set to one of two closed-loop control modes—constant pedal displacement or hybrid feedback—to command the necessary brake force.[158]

The Agency is incorporating a third manual brake application controller option, a force-only feedback controller, which will provide another useful method of brake application. The force feedback controller is substantially similar to the hybrid controller with the commanded brake pedal position omitted, leaving only the commanded brake pedal force application.

For the force feedback procedure, the commanded brake pedal application is the brake pedal force that results in a mean deceleration of 0.4g in the absence of AEB system activation. The mean deceleration is the deceleration over the time from when the commanded brake pedal force is first achieved to 250 ms before the vehicle comes to a stop. The force controller applies a force of at least 11.1 N (at an unrestricted rate) to the brake pedal to achieve the commanded brake pedal force within 250 ms. The force controller may overshoot the commanded force by any amount up to 20 percent. If such an overshoot occurs, it must be corrected within 250 ms from when the commanded force is first achieved. The average pedal force must be maintained within 10 percent of the commanded brake pedal force from 250 ms after the commanded pedal force occurs until test completion.

k. Regenerative Braking

In its March 2022 RFC notice, the Agency noted that regenerative braking[159] may influence vehicle performance during its AEB tests and create complications for DBS testing.

Regenerative braking, which has become more common as electric vehicles have begun to proliferate the fleet, slows a vehicle when the accelerator pedal is released. As such, a vehicle that has regenerative braking may exhibit a significant speed reduction prior to the onset of AEB-induced braking during the Agency's CIB and DBS testing, particularly in instances where the FCW is issued early, since the vehicle's accelerator pedal is to be fully released upon the issuance of the FCW. Furthermore, a relatively high deceleration resulting from regenerative braking can introduce complications during DBS testing, as only a relatively small increase in braking from the braking actuator would be required to provide the necessary combined 0.4g deceleration.[160]

To limit the influence of regenerative braking during AEB testing, NHTSA proposed to select the ''off'' setting, or the setting that provides the lowest deceleration when the accelerator is fully released for those vehicles offering multiple regenerative braking settings (*e.g.,* less aggressive, nominal, more aggressive). The Agency proposed to test with the least aggressive setting (or the ''off'' setting) over the ''nominal'' setting for two reasons. First, NHTSA believed

[158] National Highway Traffic Safety Administration (2015, October), *Dynamic brake support performance evaluation confirmation test for the New Car Assessment Program, http://www.regulations.gov,* Docket No. NHTSA–2015–0006–0026.

[159] Regenerative braking slows a vehicle down when the accelerator pedal is released, which helps traditional brakes. It also recovers kinetic energy that would otherwise turn into heat by converting it into electrical energy for storage in onboard propulsion batteries. Regenerative braking is a common feature in electric-powered vehicles.

[160] For instance, if the regenerative braking from simply releasing the accelerator pedal results in 0.3g braking, the additional braking required from the actuator to achieve a total deceleration of 0.4g would be a very low force and/or brake pedal displacement.

that the least aggressive (or ''off'') regenerative braking setting would be the setting most likely to produce comparable performance to vehicles that are not equipped with a regenerative braking feature. Second, the Agency reasoned that the least aggressive setting would likely afford ''worst case'' performance during testing, since it should generate the lowest deceleration and thus allow the vehicle to travel faster at the onset of AEB braking. The Agency did not propose to make any procedural modifications for vehicles that have regenerative braking that cannot be switched off or adjusted, since those vehicles should operate similarly during testing as compared to real-world driving.

Comments were requested on whether the proposed setting selection was appropriate. NHTSA also requested comment on whether regenerative braking could introduce additional testing issues for the Agency's AEB testing, such as those described, along with recommendations for test procedural changes to best address them.

Summary of Comments

Most commenters agreed with the Agency's proposal to select the ''off'' setting during AEB NCAP testing. However, a few respondents favored the ''Default'' setting or letting manufacturers choose the setting they preferred.

Choose ''Off'' or the Lowest Setting

Commenters who favored turning regenerative braking ''off'' and/or selecting the lowest regenerative braking setting for AEB testing included Advocates, BMW, CAS, FCA, GM, Honda, Intel, and TRC. Intel commented that choosing the regenerative braking setting that is considered ''worst case'' (*i.e.,* ''off'') is ''reasonable,'' while CAS remarked that NHTSA should evaluate ADAS systems in ''the least favorable foreseeable circumstances.'' GM remarked that it was most appropriate to conduct a worst-case performance assessment for electric vehicles (*i.e.,* regenerative braking ''off'') since it is currently unknown what percentage of drivers release the accelerator pedal prior to, or during, AEB activation (such that regenerative braking would engage). BMW asserted that selecting the ''off'' or lowest setting for regenerative braking is appropriate because choosing a setting that induces high regenerative braking may unfairly skew AEB test results. Advocates agreed that the regenerative braking setting should be set to ''off'' unless there is no way to disable it, and Honda commented that NHTSA's approach seems ''reasonable for most vehicles'' for AEB and FCW assessments.

A few commenters favored the ''off'' or lowest setting for regenerative braking because alternative settings may cause complications for testing. TRC and GM mentioned that the ''off'' or lowest settings simplify test execution. TRC added that they have seen instances where a test cannot be properly conducted per the applicable procedure to create a crash-imminent situation because of early FCWs coupled with high regenerative braking. FCA noted that disabling regenerative braking improves test repeatability, particularly for DBS tests, due to ''different brake pedal behavior when transitioning from regeneration to braking.'' For this reason, the automaker recommended that the Agency select the ''off'' setting in the near-term and switch to an alternative setting (resulting in a ''more complicated test'') if real-world data supports this change. GM agreed that selecting the ''off'' setting for regenerative braking would lead to more consistent testing for electric vehicles.

Choose the ''Default'' Setting

In lieu of turning regenerative braking ''off'' or to the lowest setting for AEB testing, Rivian, Tesla, and HATCI stated that NHTSA should use the factory default setting, as this setting is more consistent with real-world driving. HATCI commented that an internal study of Hyundai and Kia owners revealed that most owners do not change the ADAS settings from the factory default settings after purchasing a vehicle.[161] As such, the commenter stated the Agency should only deviate from default settings for testing purposes if there is a need to do so to ensure safe test conduct. Given these findings for ADAS settings, HATCI encouraged NHTSA to conduct a similar fleet-wide study of customer-selected regenerative braking settings before incorporating related test procedure changes. Similarly, Tesla mentioned that the company's fleet data has shown that over 80 percent of Tesla vehicles on the road use the default setting for regenerative braking. Like other commenters above, the manufacturer acknowledged that different regenerative braking settings will generate different AEB performance. Similar to TRC, Tesla mentioned that, depending on the regenerative braking setting selected, a vehicle may not even need to activate AEB in some test scenarios because regenerative braking effectively slows the vehicle to a stop and prevents it from making contact with the vehicle test device.

Let Manufacturers Specify the Setting

Auto Innovators explained that they were not opposed to turning regenerative braking ''off'' for electric vehicles but requested that NHTSA allow vehicle manufacturers to specify the regenerative braking setting they want to be tested (''off'' or otherwise) for each vehicle/test.

Single-Pedal Operation Considerations

Honda and Auto Innovators requested that NHTSA amend the AEB test procedures, where appropriate for electric vehicles, to clarify what it means for the throttle to be ''fully released'' in vehicles that use one pedal for both acceleration and braking. To accommodate vehicles using one pedal operation, the commenters suggested that ''fully released'' should translate to ''an accelerator position that provides deceleration equivalent to that of engine braking, about 0 to 0.1 g.'' BMW expressed a similar sentiment.

Response to Comments and Agency Decisions

NHTSA has decided that, for NCAP's AEB tests, it will adopt its initial proposal to select the ''off'' setting for regenerative braking, or the setting that provides the lowest deceleration when the accelerator is fully released for those vehicles offering multiple regenerative braking settings (*e.g.,* less aggressive, nominal, more aggressive). Although some commenters shared the assertion that this setting is not reflective of real-world use, it is prudent to perform testing to represent the worst reasonable case scenario, a sentiment shared by multiple respondents. By taking such an approach, the vehicle's speed just prior to either manual (robotic) or automatic braking will be retained to the greatest extent possible, which should allow the Agency to most objectively evaluate the vehicle's ability to avoid a crash without introducing confounding factors caused by early FCWs or significant braking prior to the onset of AEB. In a similar vein, selecting the ''off,'' or least aggressive regenerative braking setting, should improve test execution, and thus test repeatability, and allow the Agency to evaluate actual system performance more effectively, as several commenters mentioned. Also, selecting the ''off'' setting promotes a level of fairness. This is particularly important for a consumer information program in which comparisons may be made between

[161] *https://www.regulations.gov/comment/NHTSA-2021-0002-3862.* HATCI's internal research covered nine focus groups of Hyundai and Kia vehicle owners from 2017–2019 from the Chicago, IL area (N=24) and an online survey.

vehicle model test results. If the Agency instead allowed vehicle manufacturers to specify any regenerative braking setting that they prefer, as Auto Innovators suggested, this could result in AEB performance that is not comparable to other tested vehicles in the fleet, and thus, not necessarily consistent in a way consumers might expect.

With respect to accelerator pedal input and release for vehicles equipped with a one pedal operation mode, by setting regenerative braking to ''off,'' one pedal operation will also effectively be disabled in most instances. However, in agreement with the decision made above to select settings that provide the lowest deceleration in order to represent the worst reasonable case scenario, the Agency will also select the ''off'' setting for one pedal operation, for those vehicles offering selectable settings for modes of operation. If one pedal operation cannot be disabled (*i.e.,* regenerative braking is always enabled and one pedal operation cannot be switched ''off''), the vehicle will be tested with the moderate deceleration level ensuing from accelerator pedal release. At this time, accelerator pedal release need not be defined beyond the definition applicable to vehicles that do not permit one pedal operation. The Agency will require the accelerator pedal to be fully released within 500 ms after the FCW is presented for all vehicles, including those equipped with a one pedal operation mode.

For electric vehicles, propulsion batteries will be charged at 80 percent or higher capacity during NCAP's AEB testing. This decision aligns well with the Agency's decision to select the setting for regenerative braking that provides the lower deceleration when the accelerator is fully released. Performing AEB assessments with a higher SOC should limit regenerative braking.

l. Refinement and Clarification of Test Procedures

In addition to the changes discussed herein for NCAP's AEB test procedures, the Agency also sought public comment on whether there are any aspects of NCAP's current FCW, CIB, and/or DBS test procedure(s) that need further refinement or clarification. Commenters responded with recommendations for general test procedure clarifications, additions, and refinements. These recommendations tended to fall into three general categories: the use of robotic test equipment, tolerances currently used, and general test procedure changes to either increase the applicability of results or to increase repeatability.

Summary of Comments

Robotic Test Equipment

Auto Innovators requested that driver braking be implemented in a ''more realistic manner.'' The group asserted that, in general, a brake robot ''adds a degree of reliability to the test operation.'' Accordingly, the organization suggested that the Agency eliminate human operation to the extent possible for all AEB tests and specify use of a robot-controlled POV test device. Toyota also asserted that the Agency should require the SV to be controlled by a steering robot controller since vehicle test devices can be controlled by a GST system.

GM and Auto Innovators requested that NHTSA harmonize the robotic test equipment and settings used in NCAP's tests with other equipment used by industry and other NCAPs globally. However, at a minimum, Auto Innovators requested NHTSA refine the brake robot procedure to add more detailed instructions about calibration and setup. Both commenters mentioned that one of NHTSA's test contractors uses different robotic test equipment than that which is commonly used, and the robot parameters are applied slightly differently in NCAP's tests. Per GM, troubleshooting performance issues may be difficult when differences arise because of various equipment and settings.

TRC asked for NHTSA to clarify the meaning of the test procedure phrase ''smooth throttle inputs.'' The commenter mentioned that data from brake and throttle robots, which are helpful to maintain speed tolerances, may appear ''noisy'' even with tuning. As such, they requested clarification on NHTSA's definition of ''smooth'' in such instances. Auto Innovators requested that accelerator pedal release rates be defined in general.

IDIADA noted that regenerative braking may affect the speed control during testing when regenerative braking is activated, such that the throttle robot may ''over-throttle and result in an override action.'' To prevent the occurrence of a system override, the commenter suggested that NHTSA ''ensure that [the] throttle robot is kept on [the] hold position prior to AEB activation.''

Changes to Tolerances

Honda and Auto Innovators asserted that the tolerances for POV and SV deceleration, POV and SV speed, and headways in the Agency's CIB and DBS test procedures are currently too wide. The commenters noted the combined tolerance variation ''have a significant influence on collision closing speed and timing,'' and Honda added that certain tolerance combinations can prevent a possible SV and POV collision. As such, both commenters recommended that NHTSA adopt the tolerances Euro NCAP uses for these test variables to (as Honda stated) improve test objectivity and uphold program credibility.[162] Toyota also recommended that NHTSA adopt Euro NCAP tolerances if the Agency ultimately decides to incorporate higher test speeds and higher decelerations for the lead vehicle with shorter headways. Toyota asserted that if test procedures allow for wide variation, then system design will need to cover the variation, potentially causing real-world false positive cases to increase. Intel suggested certain tolerances should be tightened, noting that if the headway and braking force of the braking robot are at the higher end of the tolerance range, ''the brake robot itself is almost enough to avoid the collision,'' making it difficult to assess what is supposed to be a crash-imminent event.

General Test Procedure Additions/ Clarifications

To improve test repeatability and reproducibility, Tesla suggested NHTSA should better define the ''end-of-the-event'' in the test procedures.

Additionally, CAS suggested that the Agency should conduct testing to ensure vehicles provide effective warnings when ''safe operating limits are exceeded,'' such as for certain environmental conditions (*e.g.,* ice, snow), maximum speed conditions for ADAS operation, or upon violation of minimum following distances.

Response to Comments and Agency Decisions

Robotic Test Equipment

Proper test conduct is vital to the credibility of NCAP, and the Agency seeks to maximize testing consistency wherever possible. NHTSA agrees with commenters that eliminating human operation as much as is practicable might be helpful in maintaining test repeatability. However, NCAP CIB and DBS testing currently utilizes a human driver to maintain SV lane position and speed, and NHTSA has not encountered problems with achieving valid tests using human inputs to satisfy the test tolerances associated with these parameters. Therefore, NHTSA is not

[162] See Appendix A of Honda's submission for detailed proposed revisions.

requiring robotic control of all SV inputs used to perform the Agency's AEB tests. However, there are some inputs where robotic control is beneficial, namely those associated with the SV brake pedal inputs (*e.g.,* force, velocity, and displacement) used during DBS testing. For instance, the test tolerances associated with these inputs must be accurately achieved and maintained throughout the brake application. Also, some vehicles require a precise transition from brake pedal inputs based on position control to those based on applied force. Such brake inputs are difficult to reproduce with a human driver. In the future, NHTSA may consider performing AEB tests using robotic control of all SV inputs.

Along these lines, NHTSA will not harmonize the robotic test equipment and/or settings used with those used commonly in industry. The Agency has specified steering, throttle, and brake input requirements that must be met. Therefore, it is not warranted to specify particular equipment.

With respect to the POV, the Agency's decision to use the ABD GVT Revision G during NCAP's AEB tests necessarily requires that the test device be secured to a robotic platform to facilitate movement during conduct of the LVM and LVD tests. For the sake of scenario-to-scenario consistency, the ABD GVT Revision G will also be secured to an LPRV during conduct of the LVS tests. NHTSA notes that the movement of a robotic platform is accurately and repeatably controlled and can be safely achieved, monitored, and terminated, if necessary, by laboratory personnel at any time during a test trial. Given the demanding test conditions of the CIB and DBS tests described in this notice, these are all important considerations.

NHTSA received general comments regarding throttle and brake inputs. Pertaining to the test procedure phrase ''smooth throttle inputs,'' there is no current definition of this phrase. The intent underlying this description is that the manner in which the accelerator pedal inputs are applied must not confound AEB operation or affect the test outcome. As described in the previous section, further definition of accelerator pedal release rates, as Auto Innovators requested, is unnecessary. Finally, NHTSA has not encountered the over-throttling problem that IDIADA has described; therefore, no changes will be made to the test procedure at this time to alter throttle robot inputs. However, the Agency will make refinements to the procedures in the future to clarify additional details if the need arises.

Changes to Tolerances

NHTSA acknowledges that several commenters to the March 2022 RFC notice reasoned that many tolerances in the Agency's CIB and DBS test procedures should be revised. Specifically, commenters remarked that tolerances were too wide. Honda noted that wide tolerances in NHTSA's DBS LVD test procedure may compound and allow for a vehicle with borderline performance to either make contact or not, depending on test parameters. NHTSA does not expect Honda's concern to be relevant for the updated NCAP AEB tests. Specifically, the wide assortment of test conditions being evaluated (*e.g.,* POV speed combinations, SV-to-POV headways and POV decelerations (for LVD tests)), along with a no-contact criterion, contributes to greater test stringency overall. A vehicle achieving marginal performance will likely have difficulty passing the suite of tests performed by NCAP. Further, the Agency's current test tolerances balance the desire to perform the tests as accurately and consistently as possible with the ability to practically perform them. NHTSA has demonstrated the practicability of using its AEB test tolerances during NCAP and research testing; thus, it is appropriate to retain their use during conduct of the updated NCAP CIB and DBS tests.

Regarding comments on SV speed, NHTSA's experience is that test vehicle speed can be reliably controlled within the proposed tolerance, and that speed variation within the tolerance yields consistent results. A smaller speed tolerance would be unnecessarily burdensome, as it may result in a higher rate of invalid test runs without any greater assurance of test accuracy. Therefore, the Agency will proceed with a speed tolerance of ±1.6 kph (±1.0 mph) for both the SV as well as for the POV in NCAP's CIB and DBS testing.

General Test Procedure Additions/Clarifications

Regarding comments relating to the definition of the end of the validity or test period, for the AEB LVS and LVD scenarios, NHTSA considers a test run complete when either of the following occurs: (1) the SV contacts the POV; or (2) the SV comes to a complete stop without making contact with the POV. For the AEB LVM test scenario, a test run is considered complete when either of the following occurs: (1) the SV contacts the POV; or (2) the SV speed becomes less than or equal to the POV speed without contacting the POV. For the false positive STP test, the test is complete when either (1) the SV comes to a stop prior to crossing over the leading edge of the steel trench plate, or (2) when the frontmost part of the SV crosses over the leading edge of the STP.

NHTSA acknowledges that some vehicles are equipped with telltales that alert the driver that an ADAS system is not functional. These cases may include manual system deactivation or detection of system malfunction, which may result from sensor obstruction or saturation due to accumulated snow or debris, sunlight glare, fog, and other environmental conditions. These warnings serve as an indication to the driver that assistance with the driving task is not available. While NHTSA agrees that these warnings are useful to the driver, stipulating the type, function, and performance of a system malfunction warning is out of scope of an NCAP evaluation and is more suitable for rulemaking.

2. FCW

a. NHTSA's Proposal for FCW Testing, Including Alternatives

NCAP's current FCW requirements were developed at a time when FCW and AEB functionality were not integrated as part of one frontal crash prevention system. Consequently, when FCW was selected for inclusion in the program in 2008, the Agency adopted a test procedure and performance requirements that served only to evaluate the performance of FCW systems. However, in recent years, there has been a shift towards FCW and AEB system integration to improve real-world safety performance and consumer acceptance. It may be reasonable to combine FCW testing with AEB (and PAEB) testing such that FCW operation is evaluated as part of NCAP's AEB (and PAEB) tests. NHTSA also expects this change would reduce test burden since there will not be an additional suite of tests to conduct solely for the purpose of verifying FCW performance.

NHTSA's Proposal for FCW Testing—Integrating FCW Assessments Into CIB Testing

In its March 2022 RFC Notice, NHTSA proposed that the Agency's CIB (and PAEB) tests could be used as an indicant of FCW functionality. Essentially, the Agency would evaluate the functionality of a vehicle's FCW system during the CIB system evaluation by requiring the SV's accelerator pedal to be fully released within 500 ms after the FCW is issued. If no FCW were issued during a CIB test, the SV accelerator pedal would be fully released within 500 ms after the onset of CIB system braking (as defined in the Agency's proposal as the instant SV deceleration reached at least 0.5g).[163] If no FCW were issued and the vehicle's CIB system did not offer any braking, release of the SV accelerator pedal would not be required prior to impact with the POV (*i.e.,* the GVT). Comments were requested on whether this proposed approach was reasonable to assess FCW operation.

NHTSA asserted that it was appropriate to assess the presence of an FCW within CIB (and PAEB) tests because the operation of FCW and AEB/PAEB systems are complementary and fundamentally intertwined in the test scenarios currently assessed by NCAP. Therefore, it seemed appropriate to the Agency to begin to assess FCW timing relative to the intended onset of CIB activation instead of relative to an ''absolute TTC,'' as in NCAP's current FCW tests, since the former would be at the discretion of the vehicle manufacturer, which would have explicit knowledge of how the operation of their vehicles' CIB systems affect the FCW TTC. The Agency proposed to integrate FCW performance assessments into its CIB tests rather than DBS tests because, as mentioned previously, the Agency had considered removing DBS testing from NCAP entirely, and alternatively, weighed performing DBS testing at only a limited number of higher speeds. As such, evaluating FCW functionality during DBS testing did not seem like a viable option at the time.

Alternative 1—Conduct Multiple Separate FCW Assessments

As an alternative to integrating FCW and CIB tests, NHTSA also mentioned that it could maintain the FCW test scenarios currently included in its FCW test procedure if commenters suggested the current testing approach was more appropriate than its consolidation proposal. If the Agency maintained separate FCW and CIB assessments, it proposed to align the corresponding *maximum* SV test speeds, POV speeds, headway, POV deceleration magnitude, etc., as applicable, for the FCW tests with the included CIB tests (which will be discussed later). More specifically, it proposed to adopt the following for NCAP's FCW assessments:

- LVS—SV speed of 80 kph (49.7 mph); POV is stationary.
- LVD—SV and POV speed of 50 kph (31.1 mph) or up to 80 kph (49.7 mph), depending on the final test speed adopted for the CIB LVD scenario; a 12 m (39.4 ft.) SV-to-POV headway; and a POV deceleration magnitude of 0.5g.
- LVM—SV speed of 80 kph (49.7 mph); POV speed of 20 kph (12.4 mph).

If the Agency continued to conduct separate FCW assessments that aligned procedurally with those required for CIB, NHTSA also reasoned it would be necessary to revise the prescribed TTCs currently used to assess FCW performance to reflect the revised test scenario and speed combinations.[164] As such, NHTSA sought comment on what TTC would be appropriate for each test scenario.

The Agency also proposed a revised assessment approach for FCW (in lieu of requiring a pass rate of at least five out of seven runs for each FCW test scenario, as is done currently) if FCW assessments were not integrated into those for CIB. The Agency proposed to conduct one test trial per test speed for each FCW test scenario and to increase test speeds in 10 kph (6.2 mph) increments from the minimum test speed to the maximum test speed. In the event of a test failure for instances where the SV has a relative velocity at impact that is equal to or less than 50 percent of the initial SV speed, NHTSA proposed that up to four repeat trials would be performed.

Alternative 2—Perform One Indicant FCW Assessment

Given that most FCW systems are currently able to pass all relevant NCAP test scenarios, the Agency also suggested that as an alternative to retaining *three* separate FCW test scenarios (to be conducted per the test conditions prescribed for the related CIB tests), it may be feasible for NCAP to perform *one* FCW test (to be conducted per the test conditions prescribed for the comparable CIB test) that could serve as an indicant of FCW system performance. NHTSA reasoned that taking this approach for FCW testing would also reduce test burden, similar to its proposal to integrate FCW and CIB testing. For this alternative proposal, the Agency sought comment on which one of the proposed CIB test scenarios would be most appropriate to adopt for an FCW test to assess the performance of FCW systems.

Assessment Method, Number of Trials, and Pass Rate (for Separate FCW Assessments)

NHTSA also requested comment on whether an alternative assessment method would be appropriate if the decision was made to retain one or more FCW scenarios that would be performed at only a single test speed, such as for the LVS and LVM test conditions. In such instances, the Agency sought comment on whether it should require one trial per test condition (*i.e.,* align with the assessment method proposed for the AEB test conditions) or conduct multiple trials instead, similar to the approach currently prescribed in NCAP's FCW and AEB tests. If commenters preferred that the Agency adopt multiple trials in such instances, NHTSA asked how many trials would be appropriate, and what would be an acceptable pass rate.

The changes NHTSA proposed for its FCW test procedure as well as possible alternatives are shown in Table 16.

TABLE 16—FCW TEST SCENARIOS AND CONDITIONS—PROPOSALS AND ALTERNATIVES

	Test scenario	SV Speed (kph (mph))	POV Speed (kph (mph))	POV Headway (m (ft.))	POV deceleration (g)
Proposal	Evaluate FCW during all CIB testing (release throttle within 500 ms after FCW).				
Alternative 1	LVS	80 (49.7)	0	n/a	n/a
	LVM	80 (49.7)	20 (12.4)	n/a	n/a
	LVD *	80 (49.7)	80 (49.7)	12 (39.4)	0.5
Alternative 2	Evaluate FCW in one CIB test condition only.				

* For LVD, NHTSA proposed adoption of the highest CIB SV/POV speed for the FCW assessment.

[163] The Agency proposed these test procedural changes for its PAEB tests as well.

[164] To pass a test trial, the vehicle must issue the FCW on or prior to the prescribed time-to-collision (TTC) specified for each of the three FCW test scenarios.

Summary of Comments

Integrating FCW Assessments Into CIB Testing

The majority of commenters (BMW, MEMA, DENSO, GM, HATCI, Intel, Auto Innovators, Rivian, and TRC) supported the consolidation of FCW and CIB tests into a single evaluation. Rivian expressed that combining FCW and CIB is appropriate because FCW and AEB rely on the same inputs, and FCW is designed to work in a sequential manner with AEB. The automaker also mentioned that consolidation of FCW and AEB testing would reduce overall test burden, an assertion also expressed by Auto Innovators, GM, and TRC. Additionally, TRC mentioned that combining assessments for FCW and CIB functionality seemed logical since the timing of FCWs is already collected during the Agency's CIB tests. IDIADA also articulated this assertion.

DENSO also noted that it was appropriate to integrate FCW and CIB testing since voluntary agreements have helped to standardize CIB. The company asserted that this was even more fitting if the Agency was considering higher-speed CIB assessments, since Euro NCAP's AEB Car-to-Car test protocol stipulates assessment of FCW functionality within the CIB assessments at even higher speeds than those utilized to evaluate CIB functionality. NTSB supported harmonizing NHTSA's FCW test protocol with those used by other NCAPs, and consolidating FCW and AEB testing, but expressed concern that the proposed maximum SV test speed of 80 kph (49.7 mph) is inadequate, as it is only slightly higher than the SV speed currently specified in NCAP's FCW test procedure (72.4 kph (45 mph)).

Bosch also supported harmonization with Euro NCAP, suggesting that NHTSA combine assessments for FCW, CIB, *and* DBS, as they maintained it would be difficult to define acceptable TTCs for FCW alone. Thus, instead of specifying prescribed TTCs for FCW, Bosch favored stipulating when FCWs should be issued prior to AEB braking. Like Bosch, BMW and Auto Innovators stated consolidation of FCW, CIB, *and* DBS testing was appropriate, since all three systems are designed to work together to achieve the same goal of rear-end crash avoidance or crash mitigation through speed reduction.[165] The commenters recommended that the Agency combine FCW, CIB, and DBS assessments into one test series consisting of multiple test scenarios since this would better assess the safety rendered by the systems collectively and align with other NCAPs globally. They also noted that FCW system requirements were determined at a time when FCW and AEB functionalities were not necessarily integrated with one another, as they often are currently. GM also supported consolidating FCW and CIB/DBS testing like that employed in test protocols used in other global NCAPs. The automaker expressed that FCW should be assessed as part of the overall system performance since AEB systems are now widely available in current vehicles and provide additional safety benefits compared to FCWs alone.[166]

Both GM and Auto Innovators mentioned two potential ways the Agency could integrate FCW performance assessments into AEB tests, with both affording an overall assessment of system performance. The commenters stated the Agency could trigger activation of the brake robot during DBS testing based on the timing of the FCW, as is done by Euro NCAP. Alternatively, they stated NHTSA could directly assess FCW timing during CIB tests if the Agency's FCW and CIB protocols included the same test conditions, as is the case currently for the LVM 45_20 condition. The commenters expressed that appropriate FCW TTCs for the other CIB scenarios/conditions could be similarly calculated using the same approach NHTSA used to establish criteria for the LVM 45_20 condition. Although the respondents suggested the latter option may provide a simpler test method, they preferred that the Agency adopt the methodology employed by Euro NCAP, stating that this method would also provide the best indication of appropriate timing for brake pedal application. The commenters favored combining FCW and CIB assessments over NCAP's current evaluation method, which stipulates separate assessments for each technology. This is because the commenters supported evaluations for the same test scenarios but over a varying range of speeds. If the Agency ultimately chose not to combine FCW and AEB assessments, Auto Innovators suggested that it should continue to conduct all three of the current FCW test scenarios.

Advocates stated they supported consolidating FCW and CIB testing if NHTSA provided data and analysis to support such a decision, and if the Agency was able to ensure the adopted test procedure could adequately assess the functionality for each system independently.

A few commenters, including Honda, Toyota, FCA, and CAS, did not support consolidating FCW and CIB testing. Honda stated that it was more appropriate to instead consolidate FCW and DBS tests, since the two technologies are designed to work in tandem to mitigate or avoid a rear-end collision (*i.e.,* the driver is aware of the impending collision and responds to the FCW by braking), and CIB is designed to operate alone (*i.e.,* the driver is not aware of the impending threat and therefore does not apply the vehicle's brakes in response to an FCW, and as such, is also unlikely to have released the accelerator pedal). FCA and Toyota also supported consolidating FCW and DBS testing for similar reasons. FCA stated that CIB can be executed differently when the attentiveness of the driver is present, and that automatic braking from CIB is more effective at low speeds than manual braking resulting from the combination of FCW and DBS, such that FCW would not necessarily be issued in such situations. Toyota also supported combined FCW and DBS testing because such an approach would be like that used by Euro NCAP. Furthermore, in the case of combined FCW and CIB testing, the automaker relayed that simply releasing the accelerator pedal after FCW activation would not discern the actual effectiveness of the FCW system to alert the driver to brake, since there would be no large deceleration observed by the time the pedal was released. Instead, Toyota asserted that such an approach only serves to demonstrate CIB performance regardless of FCW activation.

CAS asserted that it would only be appropriate to consolidate FCW and CIB testing if FCW is a part of the underlying CIB system (such that it utilizes identical physical components (*e.g.,* sensors and brakes)), if it is provided every time CIB is activated (*i.e.,* uses the same logic and parameters for system execution), and if capabilities for both systems can be ''separately appreciated and evaluated'' by users.

Alternative 1—Conduct Multiple Separate FCW Assessments

Honda favored combining FCW and DBS tests but stated if the Agency chose to keep FCW tests separate, it did not support any adjustment to the current FCW tests, unless other commenters suggested differently. Intel proposed to consolidate FCW and CIB testing but asserted TTCs should be revised and ''carefully selected'' to limit nuisance activations if the Agency chooses to continue to conduct separate FCW assessments. Intel stated this was

[165] Also see Auto Innovators Appendix 1.

[166] See GM Attached A and Table 1.

particularly important for low SV speeds where a high TTC may be particularly annoying since a late reaction from the driver could still be reasonable and practicable.

Like Honda and Intel, Bosch also did not support separate FCW assessments. As mentioned earlier, the company stated it would be challenging to define appropriate TTCs and other performance criteria for FCW only, and specifically requested that the current TTC for the LVD scenario (*i.e.,* 2.4 seconds) be revised because they considered it too difficult for current technology.

Other commenters expressed that test criteria would have to change if the Agency opted to continue with separate FCW assessments. Auto Innovators, which supported the conduct of all three of the current FCW test scenarios if FCW assessments were not consolidated with those for AEB, mentioned that the SV headway should be increased if the current FCW tests were to be conducted at higher speeds. FCA opined that NHTSA should adjust the TTC criteria if it chooses to amend the test speed for the SV, but the automaker did not suggest appropriate TTC values. Likewise, Advocates generally mentioned that the Agency would have to specify TTCs, test speed, headway, etc. and present the data to support its selections to ensure FCW systems continue to elicit the intended driver response.

Alternative 2—Perform One Indicant FCW Assessment

If the Agency were to retain separate FCW assessments, FCA and CAS supported retaining all three current FCW test scenarios. CAS added that NHTSA should not reduce the number of test scenarios unless it could prove that doing so would not negatively affect safety. Advocates agreed that any reduction to the number of required tests should be supported by data. Furthermore, the group cautioned the Agency not to ''seek convenience or expediency over the promotion of safety.'' Instead, Advocates commented that NHTSA should test the range of conditions necessary to ensure FCW systems address the safety need and offer robust performance during real-world driving. They recommended the Agency establish minimum test criteria to ensure a baseline level of safety and use supplemental test criteria (*e.g.,* assessments at higher or lower speeds, shorter headways, etc.) to assign additional credit to higher-performing systems.

GM and Auto Innovators favored consolidating FCW, CIB, and DBS testing, as is done by other consumer programs, to permit assessment of FCW and AEB systems simultaneously and thus minimize test burden. However, if the Agency opted to assess FCW separately, the commenters favored retaining all three test scenarios (*i.e.,* LVD, LVM, and LVS), as FCA and CAS proposed, to ensure (1) consistency with other NCAPs and that (2) FCW performance continues to align with the rear-end crash problem in the real world.

Similar to GM and Auto Innovators, Honda supported consolidation of FCW and DBS tests. However, the manufacturer also acknowledged not all DBS systems may perform well at certain higher test speeds, such as 80 kph (49.7 mph). Therefore, the manufacturer commented it may be necessary to perform one FCW test scenario independently at the maximum SV speed to appropriately evaluate FCW performance.

Intel suggested the Agency should choose either the LVS or LVM test scenarios if NHTSA decides to require one test for FCW assessment. The company envisioned that procedural changes proposed for the CIB LVD test may be especially challenging for FCW systems as the prescribed headway (12 m (39.4 ft.)) and POV deceleration (0.5g) will shorten the TTC substantially compared to that afforded currently in the FCW LVD test (*i.e.,* 30 m (98.4 ft.) and 0.3 g POV deceleration). BMW also stated that the proposed LVS test scenario was the most appropriate scenario to select to evaluate FCW systems.

Assessment Method, Number of Trials, and Pass Rate (for Separate FCW Assessments)

Auto Innovators and FCA recommended that NHTSA should continue to conduct seven trials per scenario and maintain the pass rate of five out of seven trials if the Agency retains separate FCW tests. Intel also supported retaining multiple trials, stating that conducting three trials and adopting a pass rate of two out of three would limit test burden while still ensuring robust assessments. For the assessment method in general, the company proposed an approach that aligned with their comments to PAEB and AEB.

Stating that FCW is not as important as AEB, IDIADA expressed that the Agency should award fewer points for FCW if separate assessments will be conducted for this technology.

Accelerator Release Timing (Applicable for FCW Integration)

With respect to the Agency's proposal for release of the accelerator pedal if it was to integrate FCW and AEB tests, FCA stated a release time of 500 ms after the issuance of the FCW was appropriate. IDIADA also mentioned that a 500 ms pedal release time could be acceptable, as FCWs would ''ideally'' be issued 1.2 seconds prior to braking. However, Toyota did not agree with releasing the accelerator pedal 500 ms after issuance of the FCW if FCW and CIB testing was combined since, as mentioned previously, the commenter noted this approach would not assess the actual effectiveness of FCW, but rather, would just show the effectiveness of CIB.

Intel suggested an alternative approach to validate FCW functionality. The company suggested NHTSA pursue a similar approach to that used by the General Safety Regulation (GSR), whereby the Agency would require an FCW be issued 0.8 seconds prior to the start of autonomous braking (as measured by the deceleration reaching a certain level).

Auto Innovators suggested that NHTSA study drivers' reaction times to determine whether releasing the accelerator pedal 500 ms after an FCW is issued is appropriate. The organization also opined that specifying 0.5g as the threshold indicative of CIB braking in instances where no FCW is issued may be too high, such that the release of the accelerator pedal should potentially occur at a lower deceleration level.

Response to Comments and Agency Decisions

Based on the comments received, NHTSA has decided to consolidate FCW and AEB testing such that an assessment of FCW functionality will be assessed during NCAP's CIB and DBS evaluations using LVD, LVS, and LVM test scenarios. During these evaluations, the SV must issue an FCW prior to the onset of automatic braking (as defined by the instant SV deceleration reaches at least 0.15g) for each trial run performed. If an FCW is issued, the SV's accelerator pedal will be fully released (at any rate) within 500 ms. For DBS testing, manual (*i.e.,* robotic) braking will then be imparted 1.0 ± 0.1 seconds after issuance of the FCW. If no FCW is issued during a test trial, release of the SV accelerator pedal would not be required prior to impact with the POV (regardless of whether the vehicle's AEB system offers automatic braking), and the SV will fail the trial run. See Figure

5 for sequence of FCW, throttle release, and brake application in the CIB and DBS evaluation tests.

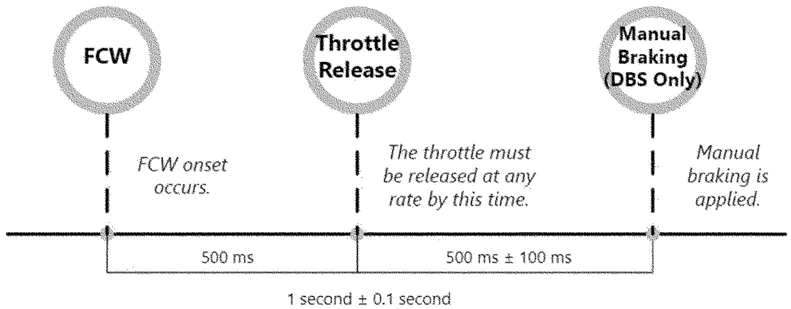


Figure 5: FCW, Throttle Release, and Brake Application Sequence in the CIB and DBS Tests

NHTSA notes that the requirement that an FCW be issued prior to the onset of automatic braking (as defined by the instant SV deceleration reaches at least 0.15g) will not apply to the AEB false positive tests since issuance of an FCW and activation of automatic braking is not expected in these tests. If an FCW *is* issued in the CIB false positive test, the SV throttle will also be released within 500 ms, as this is an existing requirement for this test scenario. Likewise, per the existing CIB test procedure, if no FCW is issued during the CIB false positive test, the throttle will not be released until the test's validity period (the time when all test specifications and tolerances must be satisfied) has passed. The Agency is also making no changes to throttle release timing or brake application for the DBS false positive test. As currently specified for this test, the SV throttle will be released within 500 ms of the currently prescribed TTC (2.1 seconds) if no FCW is issued by the specified time. If an FCW *is* issued, the SV throttle will be released within 500 ms of the alert. For both situations in the DBS test, the SV brakes will then be applied at a TTC of 1.1 s, which corresponds to a nominal distance of 24.4 m (80.2 ft.).

Integrating FCW Assessments Into AEB Testing

The decision to evaluate FCW functionality during CIB and DBS evaluations using NCAP's LVD, LVS, and LVM test scenarios differs slightly from the Agency's March 2022 proposal. As mentioned earlier, NHTSA had proposed to integrate FCW into CIB testing in NCAP. At the time, the proposed combination of tests appeared to be the only viable option, (if the Agency was to consolidate FCW and AEB testing), since NHTSA had considered removing DBS testing from NCAP entirely or performing DBS testing at only a limited number of higher speeds. However, since the Agency has decided to retain DBS assessments in NCAP and will continue to perform DBS tests at multiple speeds, as discussed previously, evaluating FCW within DBS testing is also appropriate. NHTSA notes that FCA, Honda, and Toyota supported integrating FCW and DBS testing, suggesting that such an approach was more appropriate than integrating FCW and CIB testing. As Honda stated, FCW and DBS are designed to be complementary systems that operate sequentially to assist a driver in responding appropriately to prevent a rear-end collision. The FCWs the driver to the impending collision, the driver responds by braking, and the DBS system offers additional braking in instances where the driver's braking alone is insufficient to avoid the crash. Therefore, it seems reasonable to evaluate FCW functionality (*i.e.,* notification and timing) during NCAP's DBS testing.

Although CIB systems are designed to operate when the driver is unaware or unresponsive to an impending rear-end crash (*i.e.,* the driver either does not respond to an FCW by braking or does not have time to brake after an FCW is issued), a vehicle should still issue an FCW in such situations. First, the vehicle cannot anticipate what actions the driver will take. Second, the warning serves to warn the driver not only of the crash threat but also of the onset of sudden profound braking, which can be alarming in itself. For these reasons the Agency has also decided to require the FCW be issued prior to automatic braking during NCAP's CIB assessments. While the Agency acknowledges Toyota's assertion that integrating FCW and CIB assessments ''only serves to demonstrate CIB performance regardless of FCW activation,'' the consolidation of FCW and CIB assessments permits an overall assessment of FCW functionality in situations where the driver may still find an alert to be beneficial.

The requirement that an FCW be issued prior to the onset of automatic braking (as defined by the instant SV deceleration reaches at least 0.15g) will apply for all test speed and scenario combinations used during the conduct of the NCAP's CIB and DBS evaluations, except for the false positive scenarios. By adopting this requirement, it is not necessary to calculate appropriate FCW TTCs for all AEB test conditions, as Auto Innovators and GM suggested. Rather, the presence of FCW will simply be assessed in the context of the AEB system as a whole.

Although FCA expressed that automatic braking from CIB may be more effective at low speeds compared to driver braking and subsequent DBS intervention, NHTSA does not agree with the manufacturer that an FCW is not needed at lower speeds for a particular intervention method (*i.e.,* automatic braking from CIB compared to driver braking and subsequent DBS engagement). For the reasons mentioned previously, an FCW should always be issued prior to automatic braking in the real-world situations represented by the Agency's AEB testing. Additionally, well-designed FCWs can provide significant safety benefits in crash-imminent rear-end crash scenarios. NHTSA encourages vehicle manufacturers to present them so that the driver may be able to respond with sufficient time to avoid a crash (*i.e.,* not to solely rely on CIB activation for crash avoidance). That being said, the Agency is not prescribing that the FCW be issued at a specific time prior to braking in each test, as several commenters recommended. NHTSA should afford manufacturers with flexibility in this regard so they may design systems that are most appropriate for the complexities of various crash situations, some of which may provide very little time for a driver to take action to avoid a crash. Although the Agency reasons a requirement that an FCW be issued prior to automatic braking is appropriate for pre-defined scenarios during track testing, it does not want to be overly prescriptive such that automatic braking is suppressed in certain situations during real-world driving, such as when a lead vehicle cuts immediately in front of an AEB-equipped vehicle, where it may not be appropriate to delay immediate automatic braking in anticipation of a driver warning.

NHTSA acknowledges BMW's and Auto Innovators' recommendation that the Agency combine FCW, CIB, and DBS assessments into one test series consisting of multiple test scenarios to assess the total safety provided by the systems collectively; however, this is not feasible given the Agency's desire to provide assurance of both CIB and DBS system functionality. Driver-imparted manual braking may not be provided in all real-world situations; thus, it is beneficial to evaluate the performance of CIB systems devoid of DBS intervention. Further, the Agency agrees with FCA's assertion that manufacturers may choose to execute CIB differently when the driver is attentive and responsive (*i.e.,* situations represented by DBS testing) compared to when they are not (*i.e.,* situations represented by CIB testing). The Agency aims to ensure system effectiveness in both situations.

Conducting Separate FCW Assessments

The Agency has decided not to conduct separate FCW assessments. NHTSA's decision to expand upon its proposal to evaluate FCW functionality in both CIB and DBS assessments aligns well with recommendations made by many commenters, including Auto Innovators, Bosch, BMW, and GM. Respondents supported integration of FCW, CIB, *and* DBS testing for various reasons, including harmonization and a reduction in test burden. As mentioned by commenters, FCW is designed to work in a sequential manner with AEB, and AEB provides additional safety benefits compared to FCWs alone. Therefore, NHTSA reasons it is no longer necessary to assess FCW independent of AEB. Although Honda supported FCW and AEB consolidation, the commenter also asserted it may be necessary to perform one separate FCW test to assess system functionality at higher speeds (*i.e.,* 80 kph (49.7 mph)) since not all DBS systems may perform well when tested. Similarly, NTSB suggested that NHTSA pursue FCW assessments at test speeds in excess of 80 kph (49.7 mph). Since the Agency will perform LVS and LVM DBS assessments for test speeds of 80, 90, and 100 kph (49.7, 55.9, and 62.1 mph), and vehicles will be required to issue an FCW prior to automatic braking for all AEB test conditions to be evaluated (except for the false positive test conditions), it is unnecessary to conduct a separate high-speed assessment specifically to evaluate FCW functionality. Vehicles unable to meet the Agency's FCW requirement will fail an AEB test trial.

Accelerator Release Timing

The Agency has decided to proceed with adopting its proposal for accelerator release timing. The SV's accelerator pedal will be fully released at any rate within 500 ms after an FCW is issued during all CIB and DBS evaluations using LVD, LVS, and LVM test scenarios. This timing is consistent with that specified in NCAP's current CIB and DBS test procedures, and the approach (*i.e.,* releasing the throttle after the FCW is issued) matches that prescribed in Euro NCAP's AEB Car-to-Car systems test protocol. The Agency notes Euro NCAP specifies the pedal be released 1.0 second after issuance of the FCW during manual braking tests. Since NHTSA's test laboratories have not experienced difficulties with releasing the accelerator pedal within 500 ms, as currently specified in the current test procedure, the Agency sees no reason to adopt Euro NCAP's requirement instead. Loosening the requirement would only serve to increase the likelihood that an accelerator pedal application may interfere with AEB engagement.

Although NHTSA had also proposed that the SV accelerator pedal would be fully released within 500 ms after the onset of automatic braking (as defined in the Agency's proposal as the instant SV deceleration reaches at least 0.5g)[167] for CIB and DBS tests if no FCW is issued, this additional requirement is seemingly unnecessary since the Agency has decided that a vehicle would fail a trial in such instances. As such, if no FCW is issued during a CIB or DBS evaluations using LVD, LVS, or LVM test scenarios, release of the SV accelerator pedal would not be required prior to impact with the POV.

For false positive testing, as stated earlier, the SV accelerator pedal will be released within 500 ms of an FCW if one is issued in the CIB false positive test; however, if no FCW is issued, the accelerator pedal will not be released until the test's validity period has passed. For the DBS false positive test, the SV accelerator pedal will be released within 500 ms of the currently prescribed TTC (2.1 seconds) if no FCW is issued by the specified time; if an FCW *is* issued, the SV throttle will be released within 500 ms of the alert.

Defining the Onset of Automatic Braking

While there is no need to define the term ''onset of automatic braking'' for the purpose of releasing the accelerator pedal (given the decisions made herein), a definition of the term is needed to determine whether a vehicle's FCW timing meets the adopted requirements for passing performance. Instead of defining the onset of automatic braking as 0.5g, as proposed, the Agency has decided to define the onset of automatic braking as a deceleration of 0.15g. NHTSA agrees with Auto Innovators that a 0.5g threshold may be too high. The Agency now reasons a 0.15g threshold is appropriate based on its experience conducting AEB testing for NCAP. This value has proven to be a reliable marker for AEB onset during the program's track testing.[168] As will be discussed, a vehicle cannot pass an NCAP AEB LVS, LVM, or LVD test trial unless the required FCW is presented prior to the onset of automatic braking (*i.e.,* CIB), as defined by the instant SV deceleration reaches at least 0.15g.

Since NHTSA has decided to integrate FCW and AEB testing rather than conduct separate FCW assessments, the Agency does not see the need to address comments received in this regard that are specific to an appropriate assessment method, number of trials, and pass rate solely for FCW.

b. FCW Signal Modalities

Currently, NHTSA gives credit to vehicles having FCW systems that send visual, auditory and/or haptic warning signals that meet the TTC requirements outlined in NCAP's FCW test procedure. The Agency's research has provided mixed results surrounding warning signal effectiveness. In one study, the Agency found that presenting drivers with an auditory warning in medium or

[167] NHTSA notes that, pursuant to other changes made in this notice, the onset of automatic braking will be defined as 0.15g instead of 0.5g for NCAP's future AEB tests.

[168] *https://www.regulations.gov/document/NHTSA-2021-0002-0002.*

high urgency situations significantly reduced crash severity relative to visual and tactile (or haptic) warnings.[169] However, in other research studying the response of distracted human subjects to FCWs in forward collision crash scenarios on a test track, NHTSA found that 15 of the 17 total crashes that were successfully avoided (88 percent) occurred during trials performed with a seat belt pretensioner-based haptic alert. Only one crash was avoided during a trial performed with a beep-based auditory-only alert.[170] Research conducted by other entities has also suggested that haptic warning signals may increase consumer acceptance of FCW technologies compared to auditory alerts.[171]

Based on these findings, the Agency sought comment on whether it should give credit to vehicles equipped with FCW systems that only provide a passing auditory warning or whether it should also give credit to those FCW systems that only provide passing haptic signals (if it chose to retain one or more separate FCW tests).[172] NHTSA questioned whether haptic warning signals can be accurately and objectively assessed, and if so, whether certain haptic signal types should be excluded from consideration (if the Agency was to award credit to vehicles with haptic warnings that pass NCAP tests) because they may be a nuisance to drivers such that they would be more likely to disable them. NHTSA further questioned whether, for separate FCW evaluations, it should no longer give credit to FCW-equipped vehicles that offer only visual FCW signals. Finally, the Agency sought comment on what type(s) of FCW signal(s) would be acceptable for use in defining the timing of the release of the SV accelerator pedal if the Agency decided to assess the sufficiency of an FCW in the context of CIB (and PAEB) tests in lieu of separate FCW assessments.

Summary of Comments

Allow All Warning Signal Modalities

Those in favor of not restricting the type of FCW signal modality permitted during Agency testing included CAS, HATCI, and Intel. HATCI stressed the importance that NHTSA be flexible with respect to warning signal type(s), contending that ''[current] flexibilities allow industry to optimize and adjust the alerts based on the multitude of ADAS technology installed, the interaction between the technologies, and research and development findings.'' The manufacturer warned that restricting system warning signals to specific modalities may limit future alert strategies (*e.g.,* combinations, locations) and have unintended consequences (*e.g.,* reduced alert effectiveness) as ADAS technology evolves and other systems are introduced. Instead of prescribing alert types, HATCI suggested that NHTSA work with industry and/or established standards bodies (*e.g.,* Society of Automotive Engineers, or SAE) to define process-based and/or performance-based methods to assess alert effectiveness.

Intel mentioned that modality should not be restricted since credit should be based on warning effectiveness (*i.e.,* a warning resulting in passing performance is effective, regardless of the signal modality). CAS agreed that any effective implementation of warning signal type(s) should be considered acceptable since FCW activation during real-world driving should rarely occur.

Restrict Warning Signal Modalities

A few commenters recommended the Agency award credit only to certain FCW signal modalities. MEMA, FCA, Bosch, and Subaru stated that credit should be awarded for only auditory or haptic warnings. Although Bosch supported awarding credit for both auditory and haptic warnings and considered itself to be ''technology agnostic'' in general, the company also reasoned that haptic warnings are more likely to seize the attention of the driver. If a specific haptic warning (*e.g.,* steering wheel vibration) is implemented for a specific technology (*e.g.,* FCW), Bosch asserted strongly that the same haptic warning (*e.g.,* steering wheel vibration) should not also be paired to a different technology (*e.g.,* BSW) to avoid confusing the driver.

Subaru stated that credit should be awarded to auditory and haptic FCW signals since they are the most effective. The company cited the Agency's research findings pertaining to the effectiveness of auditory warnings versus visual and haptic warnings referenced in its March 9, 2022, RFC Notice [173] (and above) as justification to award credit to auditory warnings.

NTSB supported awarding credit to vehicles offering auditory unimodal FCW or bimodal FCWs that include an auditory component. In general, the commenter did not support awarding credit to vehicles offering haptic FCW signals as the group noted that there is large variation in the implementation of haptic warnings (*e.g.,* seat, steering wheel, seat belt); therefore, it would not be prudent to assume equivalent effectiveness without supporting research. Finally, ZF Group suggested the Agency should award credit to haptic seatbelt warnings when considering approved warning signal modalities, as their research has shown them to be highly effective.

Add Requirements to Visual Warning Signals or Require Multiple Modalities

Several commenters, including NTSB and DRI, remarked that visual-only warnings should not be considered acceptable to earn FCW credit. NTSB cited the low effectiveness of visual-only warnings as the reason not to award credit to visual FCWs.[174] The group also referenced several crash investigations where visual warnings failed to capture drivers' attention when the vehicle was operating in partial automation mode at the time of the crash.[175]

DRI also suggested the Agency discontinue the acceptance of visual warnings or ''alternatively prescribe minimum characteristics of the alerts (size, color, brightness, location)'' to gain the driver's attention. The test laboratory stated that in many FCW systems, the visual warning signal, which is typically a telltale in the instrument panel that changes color, is ''too small,'' appears in ''non-attention-capturing colors (*e.g.,* white),'' or is otherwise inconspicuous. The company also reasoned that a distracted driver's gaze would likely not be forward-looking, such that a visual warning located in the instrument panel would

[169] Lerner, N., Robinson, E., Singer, J., Jenness, J., Huey, R., Baldwin, C., & Fitch, G. (2014, September), *Human factors for connected vehicles: Effective warning interface research findings* (Report No. DOT HS 812 068), Washington, DC: National Highway Traffic Safety Administration.

[170] Forkenbrock, G., Snyder, A., Heitz, M., Hoover, R. L., O'Harra, B., Vasko, S., and Smith, L. (2011, July), *A Test Track Protocol for Assessing Forward Collision Warning Driver-Vehicle Interface Effectiveness* (Report No. DOT HS 811 501), Washington, DC: National Highway Traffic Safety Administration.

[171] Flannagan, C., LeBlanc, D., Bogard, S., Nobukawa, K., Narayanaswamy, P., Leslie, A., Kiefer, R., Marchione, M., Beck, C., and Lobes, K. (2016, February), *Large-scale field test of forward collision alert and lane departure warning systems* (Report No. DOT HS 812 247), Washington, DC: National Highway Traffic Safety Administration.

[172] NHTSA proposed that it would give credit to FCW systems that have both passing auditory and haptic alerts if both alert types were available. However, if a vehicle with such a system provided only a passing haptic alert and the Agency decided only to give credit to systems that provided passing auditory alerts, then the vehicle would not receive credit as having met the Agency's FCW test requirements.

[173] 87 FR 13477.

[174] *https://www.regulations.gov/comment/NHTSA-2021-0002-1530.* See footnote 15.

[175] *https://www.regulations.gov/comment/NHTSA-2021-0002-1530.* See footnote 16.

not capture the driver's attention as well as an auditory or haptic warning. However, DRI suggested that a large, bright visual warning in an attention-capturing color, such as red, may suffice. DRI further surmised that a visual FCW is often intended to be an indicator to a driver regarding the ''real'' alert, which may be auditory or haptic, such that it serves to ''communicate visually to the driver why they are hearing a warning beeping, rather than [the visual alert] being a warning in and of itself.'' As such, the laboratory, along with an anonymous commenter, opined that visual FCWs are not effective at warning the driver unless they are combined with an auditory or haptic warning signal. IDIADA agreed that visual warnings alone are insufficient to capture the driver's attention since they may not be looking at the instrument panel, and as such, recommended the Agency award credit to vehicles offering a combination of visual and auditory warnings.

GM stated that multimodal (*e.g.,* visual plus directional auditory or directional haptic) warnings are necessary for ''imminent'' crash warnings, but visual-only signals are acceptable for ''cautionary'' crash alerts. The manufacturer suggested that multimodal warnings may increase consumer acceptance and limit instances of drivers turning off FCW systems due to annoyance. However, GM opined that NHTSA should only provide credit to vehicles in NCAP testing offering multimodal FCWs that include both a visual and haptic or auditory signals. Like DRI, GM also suggested the Agency impose additional requirements for visual warning signals, recommending that visual alerts should explain the nature of the warning and should be located such that they ''draw the driver's attention to the general direction of the crash threat.'' This directional requirement, referenced previously, was also suggested for haptic and auditory components of multimodal warnings. The manufacturer suggested that acceptable visual FCWs should include a ''red flashing imminent alert and be placed in the lower, center portion of the driver's forward field-of-view,'' like a translucent red flashing alert reflected on the lower part of the vehicle's windshield, to draw the driver's attention forward, in the direction of the crash threat, stating this may facilitate a rapid, appropriate response by the driver.

With respect to haptic warnings, GM suggested the Agency should award additional credit to their Safety Alert Seat (SAS) vibration alerts, and to other haptic alerts shown to support equivalent rationale.[176] According to GM, SAS vibration alerts are triggered simultaneously with an auditory alert by the same ADAS signal and can be detected by various means during testing (*e.g.,* voltage readings, vibration sensors, auditory microphone, etc.). GM explained they allow non-visual crash alerts to be detected by hearing-impaired drivers, thus improving accessibility. GM further stated a large-scale telematics-based study funded by NHTSA found that, compared to auditory warnings, SAS warnings produced braking at the same time after issuance of an FCW, were preferred by drivers, and increased usage of not just the FCW system overall, but also the most conservative alert timing setting (*i.e.,* ''Far'').[177]

Several other commenters (BMW, Subaru, Rivian, and Auto Innovators) also favored systems offering multimodal warning strategies, specifically auditory or haptic warning signals in combination with visual signals. Auto Innovators suggested that vehicles having haptic or auditory warnings could receive a greater number of points than those offering only visual warnings if the Agency was to implement a rating system for FCWs. Similarly, Subaru supported awarding more points to FCW systems that provide a combination of warning signal modalities. Rivian suggested that drivers could be given the option to turn off either the auditory or haptic warning to suit their preference. To limit driver nuisance, the commenter stated NHTSA should provide a recommended decibel level for auditory warnings and a recommended type and location for haptic warning signal presentation, but not restrict system designs. As stated previously, NTSB also implied that bimodal auditory warnings (*i.e.,* auditory plus visual) would be preferred.

Other Related Comments

Auto Innovators requested that the Agency clarify what constitutes an alert. Specifically, the group asked whether alerts at the steering wheel, driver's seat, and pedal qualify as haptic alerts, in addition to system-induced vehicle braking at low deceleration levels (*i.e.,* partial braking). The commenter mentioned that, per Euro NCAP's 2023 update, the organization now considers partial braking to be an approved haptic warning. DRI posed a similar question. The commenter cited section 11.5.2.4 of the Agency's FCW test procedure, which states, ''The FCW system shall provide a warning to the driver by presenting an auditory alert, visual alert, haptic vibration, haptic vehicle cue (*e.g.,* braking vibration, steering vibration, or seat vibration),'' and asked whether the Agency intended to include ''a brake tug,'' defined as a short (0.3 seconds) system-supplied braking at a low, 0.2 g deceleration, as a valid warning modality. DRI stated it considers ''a brake tug'' to be an effective FCW that should be accepted.

Advocates recommended that the Agency conduct research to identify which FCW warning signal modalities will increase use, reduce dissatisfaction, and be most effective at reengaging the driver and eliciting a safe, timely, and appropriate response. The organization also suggested there may be further benefit realized from standardizing warnings, especially for drivers that use multiple vehicles.

Response to Comments and Agency Decisions

FCWs Must Include Auditory and Visual Signals

Based on the comments received and the general support for use of a multimodal FCW strategy, the Agency has decided that a vehicle must present a forward collision warning consisting of auditory and visual warning signals to the vehicle operator to receive credit in each of NCAP's LVD, LVM, and LVS AEB tests.

Use of a multimodal FCW will ensure most drivers will perceive the warning as soon as it is presented, allowing the most time for the driver to take evasive action to mitigate or, if possible, avoid a crash. Further, a multimodal FCW strategy is consistent with the recommendations of multiple U.S. and international organizations, including Euro NCAP, the ISO, and SAE International. ISO recommends a multimodal approach in both ISO 15623, ''Forward vehicle collision warning systems—Performance requirements and test procedures,'' and ISO 22839, ''Forward vehicle collision mitigation systems—Operation, performance, and verification requirements'' (which applies to light and heavy vehicles). SAE addresses the topic of a multimodal FCW strategy in both information report J2400 2003–08, ''Human Factors in Forward Collision Warning Systems: Operating Characteristics and User Interface Requirements,'' and J3029, ''Forward Collision Warning and Mitigation Vehicle Test Procedure and Minimum

[176] *https://www.regulations.gov/comment/NHTSA-2021-0002-3856.* See Appendix 2 for rationale and supporting data.

[177] DOT HS 812 247.

Performance Requirements—Truck and Bus (2015–10; Work in Progress currently).''

While no one signal combination was preferred by commenters, NHTSA's decision to impose a standardized auditory plus visual alert strategy for NCAP is appropriate given most of these organizations' recommendations specify an FCW consisting of auditory and visual signals, though ISO 15623 specifies that an FCW include a visual warning as well as an auditory or haptic signal. Euro NCAP also defines an FCW as an audio-visual warning.[178] The Agency's decision to adopt a combined auditory/visual bimodal alert aligns well with its ''Human factors design guidance for driver-vehicle interfaces'' report,[179] which contains best practice information for implementation of various alerts, including those for FCW. Based on cited research, the report suggests ''collision avoidance performance for both forward and side object collisions may be best when a bimodal auditory/visual warning system is used, which extends across driving scenarios, types of collisions, and driver populations.'' Requiring a bimodal auditory/visual alert also seems reasonable considering FCWs comprised of auditory and visual signals are prevalent in current U.S. vehicle models, thus limiting manufacturer burden.

The Agency recognizes that multiple commenters sought flexibility for automakers to use an FCW of their own preference in lieu of one prescribed by NHTSA to optimize warning strategies for other technologies in the future. However, as Advocates suggested, standardizing FCW signal modalities may simplify a consumer's understanding of these warnings while hastening a driver's recognition, and thus, response, to them. As commenters provided no data concerning consumers' degree of understanding of the wide variety of FCW implementations currently—they simply made generalized statements about consumer familiarity—NHTSA does not view these arguments as sufficient to overcome the value of standardization as a means of ensuring consumer familiarity with FCWs. FCW components that differ by manufacturer and across models may cause confusion for drivers, especially when driving new, unfamiliar, or rental vehicles. Consistency of alerts to the extent possible should improve a driver's ability to quickly comprehend the nature of the alert and the reason behind any AEB intervention. Although NHTSA acknowledges that studies exist which suggest that, depending on design, alternative warning types (*i.e.,* visual and haptic, auditory and haptic, or haptic-only) can also be effective, without overwhelming data to suggest that one of these alert types/combinations is more effective than a combined auditory/visual FCW, ensuring standardization of a familiar alert option would best serve consumers.

Option To Include Supplementary Haptic Signal

Although the Agency will require a combined auditory/visual FCW, a vehicle may additionally present a haptic signal to warn of an impending collision without penalty. As several commenters noted, some vehicle manufacturers incorporate a haptic component into their products' FCWs. These may include vibrations in the steering wheel, driver's seat, and/or pedal, ''tugs'' on the driver's seat belt, or system-induced vehicle braking at low deceleration levels (*i.e.,* partial braking), including ''brake tugs.'' [180] There is no current evidence to show that haptic FCW signals themselves are detrimental to safety. In fact, Euro NCAP awards extra human machine interface (HMI) credit to systems offering supplementary haptic alerts that meet certain criteria.[181] Thus, the Agency does not want to discourage manufacturers from incorporating haptic alerts as an optional addition if they so choose. That said, NHTSA advises vehicle manufacturers to carefully implement haptic signals such that they will not be confused with those currently used for other crash avoidance technologies, such as those related to lane keeping or blind spot detection. The issuance of an FCW will not be considered complete during NCAP tests until both auditory and visual components are provided.

Warning Signal Timing

During DBS tests performed with LVD, LVM, and LVS scenarios, release of the SV's accelerator pedal will not be initiated (and thus, the brake will not be applied) until after issuance of the required auditory and visual signals. However, a vehicle cannot pass a DBS test trial unless the two required FCW signals are presented prior to the onset of automatic braking (*i.e.,* CIB), as defined by the instant SV deceleration reaches at least 0.15g.[182] In other words, if automatic braking stemming from CIB occurs prior to the issuance of either signal (auditory or visual) from the required bimodal FCW, the vehicle will fail a test trial even if it does not make contact with the vehicle test device. However, if automatic braking from CIB occurs prior to the application of manual braking used to assess DBS but after the required FCW signals are presented, the vehicle can pass a test trial if it does not contact the POV. NHTSA reasons that this procedural requirement not only aligns with the intent of DBS tests (*i.e.,* for an inattentive driver to respond to the FCW by braking prior to CIB system intervention), but it should also make certain that the driver is presented with a warning with sufficient time to react to an impending rear-end crash even if CIB intervention begins relatively soon after the FCW is issued. In addition, it should ensure a vehicle's FCW affords real-world effectiveness. If one or more of the required components of the bimodal FCW are not issued, release of the SV accelerator pedal would not be required prior to impact with the vehicle test device (*i.e.,* POV).

NHTSA is requiring that both FCW signals be issued before the accelerator pedal is released in DBS tests because, as DRI asserted with respect to visual cues, for bimodal alerts, one FCW signal often serves as a secondary, confirmatory indication that explains to the driver what the primary signal is intended to communicate (*i.e.,* a forward crash-imminent situation). Therefore, it seems reasonable to require both signals be issued to provide a timely response so the driver can recognize the purpose of the FCW, release the accelerator, and brake.

While the Agency's CIB test represents a different real-world situation compared to its DBS test, adopting a similar test approach for CIB is reasonable. As mentioned, NHTSA's DBS tests represent situations where an inattentive driver re-engages in the driving task in response to an FCW (or simply in response to noticing a crash-imminent situation) and applies the brakes to avoid or mitigate a rear-end

[178] T_{FCW} is determined by the auditory portion of the warning in Euro NCAP's test procedure.

[179] Campbell, J.L., Brown, J.L., Graving, J.S., Richard, C.M., Lichty, M.G., Sanquist, T., . . . & Morgan, J.L. (2016, December). Human factors design guidance for driver-vehicle interfaces (Report No. DOT HS 812 360). Washington, DC: National Highway Traffic Safety Administration.

[180] These examples of ''haptic vehicle cues'' are currently permitted under Section 11.5.2.4 of NCAP's current FCW test procedure. See Docket No. NHTSA–2006–26555–0134.

[181] Euro NCAP Assessment Protocol—Safety Assist, Collision Avoidance, Version 10.4. December 2023.

[182] NHTSA clarifies that FCW onset would be determined via measurement of the FCW auditory signal sound output within the vehicle cabin and the illumination of the FCW visual signal. CAN bus information would not be used to assess FCW onset.

crash. On the other hand, the Agency's CIB tests are designed to represent situations in which the driver does not brake. For instance, the driver may respond to the FCW by releasing the throttle but still fail to manually apply the brake pedal. Since the vehicle cannot anticipate what actions the driver will or will not take in a crash-imminent situation, the Agency expects that an FCW would/should always be issued. In situations where the driver does not respond by braking (such as those represented by NHTSA's CIB tests), the alert serves to inform the driver that the vehicle is going to intervene. As such, for NHTSA's LVD, LVM, and LVS CIB testing, like for its DBS tests, the Agency will release the SV's accelerator pedal after the issuance of *both* FCW components (*i.e.,* the visual and auditory signal), and a vehicle will fail a CIB test trial (even if it does not contact the vehicle test device) if both FCW signals are not issued prior to the onset of automatic braking (*i.e.,* CIB), as defined by the instant SV deceleration reaches at least 0.15g. Furthermore, if one or more of the two required alert signals from the bimodal FCW are not issued, release of the SV accelerator pedal would not be required prior to impact with the vehicle test device (*i.e.,* POV).

Additional Requirements for Specific Warning Signal Types

At this time, the Agency is not prescribing additional requirements for visual or auditory warning signals (*e.g.,* color, location, decibel level, type, etc.) as some commenters suggested, and it is not standardizing FCW beyond defining signal types, as requested by Advocates. It is outside the scope of NCAP (a consumer information program) to be prescriptive in this regard.

c. Adjustable Setting for FCW/AEB

NCAP's current FCW test procedure states that if an FCW system provides a warning timing adjustment setting for the driver, at least one timing setting must meet the TTC warning criteria specified in the procedure. Therefore, if a vehicle is equipped with a warning timing adjustment, only the most conservative (*i.e.,* earliest) warning setting is presently tested. However, in its March 2022 RFC notice, the Agency acknowledged that while selecting the most conservative setting is beneficial for track testing where the driver of the SV must steer and/or brake to avoid a crash with the POV after the FCW is issued, another setting may be more appropriate for NCAP evaluation.

NHTSA recognized that many consumers may not adjust the warning timing setting for FCWs, and those that do may be unlikely to select the earliest setting since this setting is most likely to result in false positive warnings (*i.e.,* nuisance warnings) during real-world operation.[183] The Agency also expressed that selecting the earliest (*i.e.,* most conservative) FCW setting may allow a vehicle to pass NCAP's FCW test, whereas later warning settings may not earn NCAP credit. Accordingly, NHTSA voiced concern that its FCW test results for such vehicles may not accurately represent drivers' real-world experiences.

Based on these considerations, the Agency proposed to test the middle (or next latest) FCW system setting when performing FCW (and AEB/PAEB) NCAP tests on vehicles that offer multiple FCW timing adjustment settings. Selection of the middle or next latest warning setting for testing would harmonize with Euro NCAP's AEB Car-to-Car systems test protocol, thus potentially driving costs down for manufacturers and attempting to ensure that consumers in both the U.S. and European markets benefit from similar FCW system settings.[184] The Agency noted that the proposed procedural change would uphold the mandate in the BIL that NHTSA consider harmonization with third-party safety rating programs when practicable. NHTSA requested comments on whether testing the middle (or next latest) FCW system setting was acceptable or whether another setting would be more appropriate.

Summary of Comments

Middle or Next Latest Timing Setting

Many commenters (FCA, Honda, Bosch, NTSB, Advocates, and NYC DOT/NYC DCAS, Vision Zero Task Force) suggested that the middle (or next latest) FCW system setting should be utilized for testing. Honda stated this setting was ''the best compromise'' to evaluate system capabilities. AAA also asserted the middle setting was most appropriate because it should be less likely to ''bias system response relative to endpoint settings.'' That said, the commenter also opined that if the system automatically reverts to a certain setting with each key cycle, that setting should be utilized for testing instead.

[183] Nodine, E., Fisher, D., Golembiewski, G., Armstrong, C., Lam, A., Jeffers, M.A., Najm, W., Miller, S., Jackson, S., and Kehoe, N. (2019, May), *Indicators of driver adaptation to forward collision warnings: A naturalistic driving evaluation* (Report No. DOT HS 812 611), Washington, DC: National Highway Traffic Safety Administration.

[184] European New Car Assessment Programme (Euro NCAP) (December 2023), *Test Protocol—AEB Car-to-Car systems, Version 4.3.* See section 7.4.1.1.

NYC DOT/NYC DCAS, Vision Zero Task Force favored the middle (or next latest) FCW setting to ''eliminate grade inflation'' and ensure systems perform well under conditions consumers would expect them to. Advocates favored the middle or next latest setting to harmonize with Euro NCAP test protocols if such an approach did not negatively affect FCW safety benefits, such as if the vehicle exhibited a significant degradation in performance when an alternative alert setting was chosen, particularly if that setting was favored by the majority of consumers.

Some commenters did not favor assessments that utilized the middle FCW setting. Intel stated that by choosing the middle setting, TTC thresholds may increase, which may be perceived as a nuisance by many drivers such that they would turn off the FCW system. The commenter suggested that the Agency could utilize the middle setting if it reduced the TTC requirements for the FCW tests. GM contended that if NHTSA was to select the middle setting for testing, automakers would alter FCW system designs accordingly to align current default settings to the test settings (*i.e.,* middle) to limit the possibility of unexpected performance differences.

If NHTSA was to choose the middle setting for testing, HATCI asked for clarification on what setting would be used if the vehicle has only two settings.

Factory Default Timing Setting

Several commenters stated that the Agency should select the factory default setting for testing purposes when driver configuration is available. BMW and Rivian mentioned that such system settings are rarely changed and therefore the default setting is most likely to be the one enabled. BMW commented that vehicle manufacturers should inform NHTSA of the default setting, and if such information is not provided, the Agency should utilize the middle (or next latest) setting during testing. As mentioned previously, Tesla also favored testing with the factory default setting (for any configurable FCW or AEB setting), contending that the default setting is the most-used setting by drivers, ''best represents the vehicle manufacturer's intended system performance,'' and would best ensure consistency across vehicle models. The automaker mentioned that different settings may result in a 1.0 second variation (earlier or later compared to other settings) which would have varying impacts on performance.

HATCI also proposed that NHTSA utilize the default system settings during testing. HATCI noted their research has shown that most Hyundai and Kia customers do not change ADAS settings after purchasing a new vehicle, and that changing the settings for testing purposes would likely not be most representative of most real-world driving situations.[185] The automaker recommended that the Agency conduct a comparable fleet-wide study and use those findings for system settings to guide future test procedural changes.

Similar to HATCI, GM asserted that testing with a setting other than the factory default setting would not best represent real-world customer selection. In a 2016 study of FCWs, the automaker found their default setting (*i.e.,* ''Far'') was utilized 59 percent of the time compared to 17 percent for the ''Medium'' setting and 15 percent for the ''Near'' setting.[186] In 9 percent of cases, customers had turned the FCW system off even though a range of alert settings was available. From this, GM gleaned that the default setting aligns well with their customer preferences, and if customers had not been provided with a range of alert settings, more would have likely turned the FCW system off. Based on these findings, GM opined that utilizing the factory default setting for NCAP testing would challenge vehicle manufacturers to provide NCAP levels of performance at the setting choice most likely to be used by consumers while also limiting nuisance alerts.

Alternative Timing Settings

Some respondents, like CAS, mentioned that selecting the setting that is ''least sensitive'' is most appropriate since it would provide consumers with a sense of the ''worst-case'' protection offered by the system, while Auto Innovators recommended that the Agency allow the manufacturer to decide the setting to be tested to promote flexibility with respect to system design. Like Intel, the group asserted that requiring a specific setting may impact the upper and lower bounds of system performance and sensitivity and thus affect customer satisfaction. Auto Innovators stated that by allowing automakers to specify the test setting, consumer acceptance would not be affected, and the Agency could still be assured that at least one setting meets system performance requirements.

Response to Comments and Agency Decisions

The Agency has decided to adopt its March 2022 proposal for FCW timing settings in NCAP testing and will set FCW presentation timing to the middle (or next latest) setting during its AEB evaluations (see Figure 6). For FCW systems that have only two settings, as HATCI mentioned, the Agency will select the later setting for NCAP testing. NHTSA will apply a similar requirement to vehicles separately offering adjustments for AEB (*e.g.,* early versus late intervention).

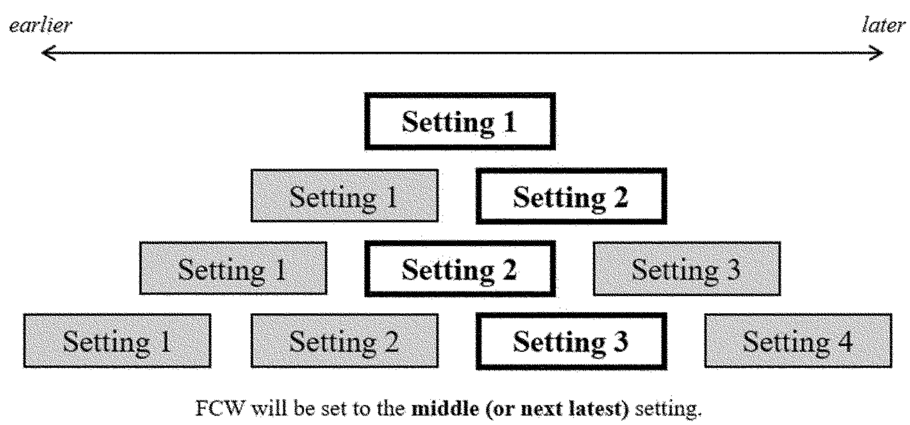


Figure 6: Forward Collision Warning (FCW) Settings Used for NCAP Testing

Although many commenters recommended that the Agency select the default setting for its AEB tests, generally citing that it is the setting most likely to be utilized in real-world driving, selecting the middle (or next latest) setting is most appropriate for NCAP's AEB testing program for several reasons. First, while there may be merit in selecting default settings for test evaluations, as noted in the Agency's initial proposal, harmonization with other third-party safety rating protocols, most notably Euro NCAP, is desirable whenever practicable. Also, it is a reasonable expectation that the setting most preferred or often used by consumers would (or rather should) be the default setting and that this setting should generally fall in the middle of the range of driver setting preferences that span either earlier or later alert settings. In essence, the default setting for FCW systems is expected to correspond to the middle alert setting. As such, NHTSA is not concerned that vehicle manufacturers may choose to alter FCW system designs to align current default settings to the test settings (*i.e.,* middle), as GM asserted. In fact, the Agency encourages this. As AAA mentioned, this should limit designs that bias system response toward either earlier or later settings. Along these lines, the Agency has decided against choosing the latest setting for NCAP's AEB testing, as CAS suggested, even though it may identify worst-case performance. NHTSA does not want to encourage acceptable performance for only more aggressive settings that may be preferred by a limited number of drivers. Similarly, it has not opted to retain the most

[185] In a 2017–2019 study of nine focus groups involving 24 participants (58 percent female and 42 percent male) from the Chicago, IL area, market research, and an online review focused on consumer perception of ADAS technologies, HATCI found that approximately 62 percent of consumers did not access or make changes to ADAS settings.

[186] DOT HS 812 247, ''Large-Scale Field Test of Forward Collision Alert and Lane Departure Warning Systems,'' 2016.

conservative (or earliest) setting for NCAP's tests.

This is not to suggest that manufacturers should provide other FCW or AEB system settings which will afford little to no benefit, nor should any other setting negatively impact the performance of FCW and/or AEB. However, as NCAP is a consumer information program, NHTSA must provide comparable results in order for consumers to make informed purchasing decisions. Accordingly, it is selecting one timing setting for FCW and AEB systems, the middle (or next latest) setting, for NCAP's AEB testing. Also, for vehicles that have an ESC off switch, NHTSA will keep ESC engaged for the duration of the test.

As previously mentioned, NHTSA has decided to evaluate FCW in tandem with CIB and DBS. To pass a test trial in the Agency's CIB or DBS evaluations that use LVD, LVM, and LVS scenarios, the SV must issue the required FCW signals (*i.e.,* auditory and visual) prior to the onset of automatic braking (as defined by the instant SV deceleration reaches at least 0.15g). After the required FCW signals are issued, the SV's accelerator pedal will be fully released (at any rate) within 500 ms. Additionally, for DBS test conditions, manual braking will be imparted 1.0 ± 0.1 seconds after the complete, bimodal FCW is presented. Effectively, to perform well in the Agency's AEB evaluations, the vehicle must issue the FCW in a timely manner so that the accelerator pedal can be released, and the brake can be applied (either automatically or manually), with sufficient time to allow the vehicle to avoid contacting the POV. By integrating FCW assessments in this way, NHTSA expects, as GM opined with respect to default settings, that vehicle manufacturers will inherently strive to limit nuisance alerts during real-world driving for the FCW timing setting preferred by most drivers while also performing well in NCAP's AEB tests at this preferred setting. In essence, the Agency's effort to integrate testing should help to eliminate the concern expressed by Intel that TTC thresholds (and inherently nuisance alerts) may increase if the middle timing setting is selected for testing. Since the functionality of FCW and AEB will be assessed holistically, manufacturers should ultimately be afforded more flexibility with respect to system design. They may establish the upper and lower bounds of the FCW system's performance, deciding whether to either increase or reduce FCW TTCs to address customer satisfaction, and thus will effectively set the timing for the FCW setting to be tested (albeit the middle setting), as Auto Innovators requested. The resultant FCW and AEB system performance is markedly at their discretion.

NHTSA also notes that, to receive credit for AEB, forward collision warning and automatic emergency braking technologies (*i.e.,* FCW and AEB systems) must appear 'Default ON' during each ignition/key cycle. While the Agency is not prohibiting a disabling function for these technologies in its NCAP evaluation, it does not expect that the testing requirements imposed herein should result in reduced consumer satisfaction. Instead, NHTSA expects drivers will adjust their vehicle's FCW and AEB system settings to meet their personal preferences instead of disengaging the systems altogether.

3. Additional FCW and AEB Test Scenarios and Conditions

a. Other FCW Scenarios or Test Conditions

In its March 2022 RFC notice, NHTSA also requested comment on whether there were additional or alternative test scenarios or test conditions that it should consider incorporating into an updated FCW test procedure for NCAP. More specifically, the Agency sought comment on whether it should adopt tests for FCW that were more complex or at higher speeds compared to those tests/conditions proposed for CIB evaluations, and if so, whether or how NHTSA should amend the current FCW performance criteria (*i.e.,* TTCs) and/or test scenario specifications.

Summary of Comments

Intel, Honda, Auto Innovators, and GM recommended that the Agency not adopt any additional or alternative test scenarios or conditions for NCAP's FCW assessments. GM and Auto Innovators asserted that adding more complicated tests would increase test variation without providing meaningful performance distinctions, thus hampering consumers' ability to use results to compare performance across vehicles. Auto Innovators further stated that the current scenarios align well with crash data and other NCAPs. FCA also suggested that NHTSA retain the current test scenarios and did not offer suggested changes.

In contrast, some respondents stated that the current FCW test conditions are not sufficient. Specifically, Adasky supported adopting tests for FCW (and CIB/DBS) that would assess system performance at higher speeds, at nighttime, and while turning. The commenter further stated that thermal cameras are currently available and can perform well under such conditions. NTSB also recommended incorporation of other test scenarios, including those involving cross traffic, vehicle cut-in situations, and additional targets (*e.g.,* different types or orientations of vehicles, roadway hardware, such as crash attenuators, etc.).[187] CAS encouraged the Agency to aim to optimize safety rather than simply encourage compliance.

Response to Comments and Agency Decisions

As NHTSA has decided to integrate FCW testing into its AEB assessments as part of this upgrade to NCAP, and commenters were generally not supportive of retaining separate FCW assessments, the Agency will not incorporate any additional FCW test scenarios or test conditions at this time. However, the Agency currently has plans to conduct research that aligns with some of the commenters' recommendations, including nighttime AEB assessments and AEB testing with motorcycles and bicycles. NHTSA will continue to add scenarios to NCAP's roadmap in the future as research data becomes available, as detailed, objective test procedures are drafted, and as technologies mature to address the safety need.

b. Additional AEB Test Scenarios and Test Surrogates

As mentioned previously, in its March 2022 RFC notice, NHTSA discussed findings from a 2019 IIHS study[188] of 2009–2016 crash data from 23 states which suggested that the increasing effectiveness of AEB technology in certain crash situations is changing the rear-end crash problem. The study identified types of rear-end crashes in which striking vehicles involved in rear-end crashes were more likely to be equipped with AEB.[189] These included rear-end crashes: (1) where the striking vehicle was turning relative to when it was moving straight; (2) when the struck vehicle was turning or changing lanes relative to when it was slowing or stopped; (3) when the struck vehicle was not a passenger

[187] *https://www.regulations.gov/comment/NHTSA-2021-0002-1530.* See footnote 14.

[188] Cicchino, J.B. & Zuby, D.S. (2019, August), Characteristics of rear-end crashes involving passenger vehicles with automatic emergency braking, *Traffic Injury Prevention,* 2019, VOL. 20, NO. S1, S112–S118, *https://doi.org/10.1080/15389588.2019.1576172.*

[189] In this instance, over-represented means a higher frequency as a percentage for AEB-equipped vehicles versus non-AEB-equipped vehicles on a normalized basis.

vehicle or was a special use vehicle relative to a passenger car; (4) on snowy or icy roads; or (5) on roads with speed limits of 112.7 kph (70 mph) relative to those with 64.4 to 72.4 kph (40 to 45 mph) speed limits.

Findings from the study suggested that tests used to evaluate the performance of AEB systems by the Agency's NCAP and other consumer information programs are influencing the development of countermeasures capable of minimizing the crash problems they were intended to address. However, the results also implied that, while current AEB systems are effective at addressing the most common rear-end crashes, they have not yet been optimized to address more atypical crashes where the SV is the striking vehicle.

Given IIHS's findings, NHTSA requested comment on if (and how) it should alter its current AEB tests to not only address the ''changing'' rear-end crash problem, but also discourage system performance degradation in more typical crash situations, create unintended safety consequences, or adversely affect AEB use due to nuisance activations. The Agency also sought comment on future suggestions for AEB generally (*i.e.,* beyond any near-term upgrade), including the adoption of additional AEB tests.

Summary of Comments

Capture Front Impact Events

Rivian and NTSB stated the Agency should add ''cut-in'' scenarios, while CAS expressed that NHTSA should add ''lead vehicle maneuvers.'' Similar to Rivian and CAS, and in line with findings from its 2019 study, IIHS suggested adding scenarios to capture lead vehicles that were changing lanes or turning, and tests where the lead vehicle is a non-passenger vehicle (*e.g.,* medium- or heavy-duty truck) or motorcycle in order to improve the real-world effectiveness of AEB systems. Further, the organization suggested incorporating tests where the SV is turning (*i.e.,* cross traffic) or travelling on roads with speed limits of 112.7 kph (70 mph) or more. IIHS explained, as the Agency acknowledged in its March 2022 RFC notice, that these situations were over-represented in real-world rear-end crashes involving an AEB-equipped striking vehicle.[190] Although the group acknowledged that the majority of the crash types mentioned were ''rare,'' those where an AEB-equipped vehicle struck a large truck or motorcycle accounted for approximately 40 percent of fatal rear-end crashes, thus suggesting that a test scenario simulating this crash type should be given thoughtful consideration for adoption. Adasky also supported AEB testing for turning scenarios.

Other commenters also favored incorporation of certain scenarios recommended by IIHS. Intel, for example, expressed support for including oncoming and crossing traffic test scenarios, similar to those recently adopted by Euro NCAP. IDIADA, along with several public commenters, mentioned the need for higher-speed assessments. Since testing becomes more difficult at higher speeds, the test laboratory suggested the Agency should incorporate a requirement that AEB systems must be operational up to 120 kph (74.6 mph). NTSB also favored the addition of cross-traffic scenarios, assessments for various vehicle types and orientations, and assessments for ''common roadway obstacles'' like ''roadway hardware'' (*e.g.,* crash attenuators, concrete median barriers, etc.) that many vehicles do not currently detect.[191]

Finally, ZF Group supported adding an Emergency Steering Support (ESS) test, which it stated would assure vehicles provide steering (or added steering, in the case that the driver is already steering) to avoid a collision with the vehicle in front of it if there is not enough time for CIB to intervene effectively before a crash occurs. Examples of these scenarios include situations where vehicles are travelling at a high rate of speed and ''scenarios with low overlap.''

Capture Backing Events

There were commenters, including TRC and Consumer Reports, who mentioned that the Agency should add rear automatic emergency braking (RAB). Consumer Reports suggested that the Agency adopt a rear cross-traffic warning (RCTW) test.

Add Motorcycle or Other Powered 2-Wheeled Test Device

Some commenters stated, like IIHS, that the Agency should adopt AEB test scenarios for motorcycle test devices. DRI proposed AEB testing with a motorcycle and/or scooter test device because: (1) ''motorcycle fatalities reached an all-time high'' in 2020,[192] (2) the number of registered on-road motorcycles has been steadily increasing,[193] and (3) NHTSA data shows that more than a quarter of motorcycle accidents involve rear-end crashes. FCW testing involving a motorcycle test device that was conducted by DRI showed that motorcycle detection rates varied widely compared to vehicle detection rates. The laboratory remarked that in many cases the SV either did not detect the motorcycle test device or detected it much later compared to the vehicle test device.

NTSB also supported AEB (and FCW) test assessments using a motorcycle test device.[194] Similarly, Intel suggested the Agency consider incorporation of the test device used in Euro NCAP's powered two-wheeler (PTW) tests.

Add Additional AEB Test Scenarios Based on Real-World Data

Several commenters (Auto Innovators, BMW, FCA, and GM) specifically stated the Agency should not adopt any additional AEB test scenarios for NCAP unless real-world data supports their inclusion. FCA, GM, and Auto Innovators commented that current AEB systems have shown significant safety benefits in reducing rear-end crashes, such that according to GM and Auto Innovators, it is expected that adopting additional rear-end AEB test scenarios would likely offer little additional benefit.[195] The two commenters stated that any additional AEB performance assessments should be centered around new crash types (depending on system capabilities) and supported by crash data trends. In addition, Auto Innovators asserted that potential new scenarios, such as those involving turning by an SV or lead vehicle, a lead vehicle lane change, or alternative test targets, may require vehicles to have cameras offering a larger field of view, additional radars (such as on the vehicle front corners), and algorithm changes to permit detection of the added targets. As such, the organization reiterated their opinion that crash data should dictate the need for these tests, which should be harmonized with Euro NCAP. CAS also mentioned that crash statistics should be considered when considering new tests for NCAP and suggested that market penetration of the various

[190] Cicchino & Zuby, 2019.

[191] Safety Recommendation H–20–1, currently classified ''Open—Acceptable Response.''

[192] According to DRI, there were 5,579 motorcycle fatalities in 2020 compared to 1,260 cyclist fatalities.

[193] IIHS data showed 4.2 million registrants in 2002 compared to 8.3 million in 2018.

[194] Safety Recommendation H–18–29, currently classified ''Open—Acceptable Response.''

[195] GM cited Leslie, A.J., Kiefer, R.J., Flannagan, C.A., Owen, S.H, & Schoettle, B.A. (2022). Analysis of the Field Effectiveness of General Motors Model Year 2013–2020 Advanced Driver Assistance System Features. UMTRI–2022–2 as a source of data considered for its conclusion.

system types (*e.g.,* camera, radar) should guide priority for future testing.

MEMA did not offer explicit suggestions for NHTSA to consider with respect to additional test scenarios that may be viable for inclusion, but the commenter did express support for the Agency's decision to ''focus resources on emerging trends with the potential for future updates as the crash problem evolves.'' NTSB recommended that the Agency add tests (for all technologies) that assess higher speeds and increased complexities to evaluate ''advanced capabilities.'' State Farm and NYC DOT/NYC DCAS, Vision Zero Task Force also expressed support for higher test speeds in general and tests to reflect real-world driving conditions and crashes.

Response to Comments and Agency Decisions

Capture Front Impact Events

While the LVS, LVM, and LVD scenarios cover a substantial number of frontal impact events, there are other frontal impact scenarios that will not be directly assessed by NHTSA's NCAP testing as adopted in this final notice.

Several commenters to the March 2022 RFC requested the addition of various intersection crash scenarios. The Agency agrees that, while the scenarios adopted for NCAP's AEB testing cover a large portion of crashes, there is a safety need for scenarios which cover intersection-specific interactions, such as left turn across path and straight crossing path conditions. As mentioned in the NCAP Roadmap section, NHTSA plans to consider the inclusion of these scenarios in the future. Pending necessary research, the Agency may implement these additional scenarios for model year 2032 vehicles.

Regarding AEB testing at higher speeds, NHTSA acknowledges that there is further safety potential to be realized by assessing CIB and DBS performance at speeds greater than those adopted for NCAP in this final notice. Indeed, NHTSA is aware, from a review of owner's manuals, that many vehicle manufacturers have equipped their vehicles with AEB systems that function at speeds much higher than those which will be evaluated by NCAP. Given the practical limitations of testing (*e.g.,* safety of test personnel, vehicle and test equipment damage, etc.), test speeds are currently restricted. That said, the Agency expects that, with further evolution of test methods, vehicle systems, and equipment, test speeds could be increased in the future. The NCAP Roadmap currently incorporates a plan for further enhancement to the adopted AEB tests with evaluations beginning with model year 2033 vehicles.

At this time, NHTSA is not incorporating ESS testing as ZF Group suggested. The Agency must further study the capabilities and limitations of systems meant to support the driver during these maneuvers prior to incorporating assessments in its NCAP testing. The Agency may decide to include an evaluation of ESS systems in the future, particularly if it moves to evaluating performance at higher speeds than those adopted in this final decision notice.

Additional recommendations included assessments using a variety of other objects as targets, such as crash attenuators, median barriers, and other roadway hardware. Large trucks were also proposed as possible impact targets for AEB evaluation. NHTSA does not have current research planned to evaluate these scenarios, but it may consider these, and other, assessments for the future.

Capture Backing Events

The Agency will not include backing scenarios, such as those mitigated by RAB or RCTW, in NCAP's AEB testing at this time. As noted in the March 2022 notice, NHTSA is currently amending its RAB test procedure to account for earlier comments received. Once this work is completed, NHTSA hopes to add the related assessments to NCAP. As noted in the NCAP Roadmap section, NHTSA's plan is to evaluate RAB systems starting with model year 2028 vehicles.

Add Motorcycle or Other Powered 2-Wheeled Target

In the March 2022 RFC notice, NHTSA stated that it was conducting additional research to evaluate vehicle AEB performance when approaching cyclists and motorcyclists. The Agency acknowledges, as did DRI, that motorcyclist fatalities have risen in recent years. Euro NCAP performs car-to-motorcyclist AEB testing under its AEB/Lane Support System (LSS) VRU Test Protocol.[196] Specifications for the motorcyclist test device used in Euro NCAP's testing can be found in Motorbike Users Safety Enhancement (MUSE) Deliverable 2.1, Motorcyclist Target Specifications.[197] [198] The test device represents an average human adult motorcyclist on a motorcycle with dimensions based on average values of most registered motorcycles in Europe with a cylinder capacity of greater than 500 cc. Euro NCAP's AEB testing includes several scenarios, including rear stationary, rear braking, and front turn across path scenarios, all in daylight conditions.

Preliminary results of NHTSA's motorcycle research testing using five vehicles have shown that many factors, such as lane position of the test device, lighting condition, and speed may influence vehicle braking performance, and there was no discernable pattern across the five vehicles tested. Further, some concerns were noted with the motorcyclist surrogate design used. Thus, NHTSA has further research underway and planned. A report summarizing this initial research, which was conducted in both daylight and darkness conditions, is expected to be available in 2024.

NHTSA has expedited its follow-on research on AEB for other VRUs, namely bicyclists and motorcyclists. The Agency's research to develop and evaluate test procedures and surrogate targets for certain crash scenarios to address bicyclist and motorcyclist injuries in crashes with light vehicles is expected to be completed in 2024. As noted in the mid-term updates to NCAP in the NCAP roadmap finalized in this notice, NHTSA has included evaluation of AEB for mitigating crashes with bicyclists and motorcyclists starting with model year 2028 vehicles.

c. Additional AEB Environmental Test Conditions

In its March 2022 RFC notice, NHTSA noted that 51 percent of fatalities and 80 percent of MAIS 1–5 injuries caused by rear-end crashes occurred under daylight conditions. Further, nearly 92 percent of fatalities and 88 percent of injuries caused by such crashes occurred in clear weather.[199] However, IIHS's rear-end crash study concluded that AEB-equipped vehicles are over-represented for crashes occurring in certain weather conditions, such as

[196] European New Car Assessment Programme (Euro NCAP) Test Protocol—AEB/LSS VRU systems, Implementation 2023. Version 4.5, December 2023.

[197] *https://www.utac.com/wp-content/uploads/2023/04/MUSE-d2-1-motorcyclist-target-specifications.pdf.*

[198] When published, Euro NCAP will replace the specifications provided with those in ISO/AWI 19206–5, ''Road vehicles—Test devices for target vehicles, vulnerable road users and other objects, for assessment of active safety functions—Part 5: Requirements for Powered Two-Wheeler targets''. At the time of this publication, ISO/AWI 19206–5 is Under Development in Stage 20.00 (Preparatory, New project registered in TC/SC work programme).

[199] Swanson, E., Foderaro, F., Yanagisawa, M., Najm, W.G., & Azeredo, P. (2019, August), *Statistics of light-vehicle pre-crash scenarios based on 2011–2015 national crash data* (Report No. DOT HS 812 745), Washington, DC: National Highway Traffic Safety Administration.

snow and ice.[200] Given these findings and the fact that the Agency's proposal for PAEB systems encompassed testing under less-than-ideal environmental conditions (specifically in darkness), NHTSA sought comment on whether it should pursue research to assess AEB system performance under less-than-ideal environmental conditions, and if so, what environmental conditions would be appropriate. This research would subsequently inform further updates to NCAP testing.

Summary of Comments

Commenters were generally in favor of the Agency conducting research to support inclusion of evaluations for different environmental conditions to encourage improved AEB performance. However, responses were varied, with suggestions spanning lighting conditions, road surface conditions, atmospheric conditions, etc. There were also a few commenters who did not support additional research into alternative environmental test conditions.

Lighting Conditions

Several respondents, including ASC, Rivian, State Farm, and TRC, suggested that NHTSA add test scenarios that include different lighting conditions. ASC, CAS, Consumer Reports, and Uhnder favored assessments for dark, nighttime conditions as well as conditions that may cause glare or temporary driver blindness, such as those resulting from travelling directly toward the sun at dawn or dusk.

Bosch, Adasky, and The Lidar Coalition commented that they support testing in low light conditions. Similar assertions were expressed by public commenters who mentioned that current AEB systems are problematic because they do not perform well in low light. The Lidar Coalition commented that testing in low light (with no overhead lighting and use of only the lower beam headlamps) is necessary because of performance differences observed for various sensor types. The commenter asserted that: cameras have high resolution but do not work well (*i.e.,* cannot ''see'') in low light conditions; radar works well (*i.e.,* can ''see'') in such conditions but lacks the resolution to detect slow-moving or stationary objects and to distinguish between objects that are close together; and lidar can both ''see'' in low light conditions and has high resolution, thus affording advantages where the other sensors independently cannot. Adasky stated that thermal cameras can perform well in dark conditions.

Although Auto Innovators, in general, did not support the consideration of alternative environmental conditions to assess AEB systems currently, they did express modest support for adding low light evaluations in the near-term. However, the group, in addition to TRC, cautioned that the GVT would likely have to be modified to permit taillight illumination (TRC) and ''replicate the vehicle lighting or light reflection characteristics of real vehicles at night'' (Auto Innovators).

Road Surface Conditions

Other commenters, including Rivian and CAS, recommended the Agency add test scenarios that evaluate performance on wet surfaces. CAS and Consumer Reports stated that assessments for icy conditions may also be appropriate, and IIHS suggested adding evaluations for ''surfaces with reduced friction.'' IIHS stated that crash data shows that AEB-equipped vehicles are over-represented in rear-end crashes on ''slippery roads'' such that encouraging AEB systems through testing to adjust brake force and intervene earlier on slippery roads compared to dry roads should promote improved AEB performance in the real world. IIHS further mentioned that their testing has shown that ''AEB systems initiate automated braking with the same force and time on 'slippery' roads as on snowy roads,'' suggesting that only one test condition would be necessary. Advocates also supported incorporating testing for various roadway conditions.

Atmospheric Conditions

Other respondents encouraged pursuing research to assess AEB performance in various atmospheric conditions that cause reduced driver visibility such as fog, smoke, ash, rain, hail, and snow (ASC and Uhnder). Uhnder remarked that fog alone causes more than 600 fatalities and over 16,300 injuries per year in the U.S.[201] and yet digital radar, which is ''agnostic to lighting conditions'' and functions in ''degraded visibility environments,'' is available and could provide safety benefits.

Honda stated that NHTSA should first test in ''normal'' rain followed by fog, ''heavy'' rain, and snow. Although the automaker acknowledged that AEB performance may be limited in heavy rain and snow conditions due to tire traction, the company stated that assuring effective AEB functionality in conditions representing ''normal'' rain was reasonable and appropriate. State Farm also supported testing in snow and over a range of fog and rain conditions since sensors are known to operate differently. Likewise, Consumer Reports supported testing in heavy rain and snow as well as in low-visibility conditions, such as those found in fog and smoke, and Adasky supported assessments for heavy rain, snow, fog, and sleet. Adasky asserted that such conditions are ''typical and predictable;'' therefore, AEB systems should function reliably. Conversely, Auto Innovators explicitly stated that they did not support testing in heavy rain and snow because of the loss of tire traction previously mentioned by Honda.

Several public commenters also expressed support for testing in inclement weather in general, stating current AEB systems are less reliable in such conditions. Additionally, Advocates stated that evaluating system performance under different weather and temperature conditions seems appropriate, since these are normal vehicle operating conditions. The group also stated that this testing will be essential to address inadequacies in system performance to assure the success of automated vehicles (AVs), as many of these technologies will serve as the building blocks for future AV development. Advocates, along with The League, suggested that NHTSA adopt those conditions that prove to be the most ''problematic'' for technologies during Agency research.

Use Real-World Data

BMW, FCA, Auto Innovators, and GM stated that NHTSA should use real-world crash data to guide development of future test conditions.

With respect to environmental conditions, Auto Innovators asserted that, if the Agency decides to pursue future research to assess AEB performance for varying environmental conditions, it should prioritize those conditions that occur more frequently in the real world before proceeding with assessments that simulate less frequently encountered conditions. The group cautioned that, at this time, the Agency should add only those conditions that are justifiable (*i.e.,* will result in large safety benefits) because adding ''complex . . . variations in environmental conditions may require more sophisticated sensors and/or research and development that can

[200] Cicchino, J.B. & Zuby, D.S. (2019, August), Characteristics of rear-end crashes involving passenger vehicles with automatic emergency braking, *Traffic Injury Prevention.* 2019, VOL. 20, NO. S1, S112–S118, *https://doi.org/10.1080/15389588.2019.1576172.*

[201] ''Low visibility.'' *Low Visibility—FHWA Road Weather Management. https://ops.fhwa.dot.gov/weather/weather_events/low_visibility.htm.*

ultimately affect affordability.'' Likewise, BMW added that NHTSA should consider incorporating those environmental conditions that contribute to a higher percentage of accidents, critical injuries, and fatalities. That said, the manufacturer also stated they were not currently aware of any environmental condition that would be appropriate for inclusion. Similarly, GM remarked that real-world data shows that for those crashes with the highest Functional Years Lost that are relevant to the ADAS technologies the Agency is considering adopting in NCAP, the environmental conditions were typically clear and dry, such that there is not a strong need to include alternative assessments.

Repeatability and Reproducibility Concerns

Several commenters (Auto Innovators, Bosch, GM, Intel, and TRC) cautioned NHTSA that repeatability and reproducibility is a concern for assessments involving environmental conditions. In fact, Intel, GM, and Auto Innovators stated they did not support the inclusion of less-than-ideal environmental conditions in NCAP assessments for this reason. GM added that testing additional environmental conditions would be ''inherently difficult and expensive to precisely control,'' and Auto Innovators stated that, except for possible low light conditions, it would add ''unnecessary test complexity.'' Both commenters further stated that the limited assessments conducted by NCAP would pale in comparison to the vast range of conditions and overall performance considerations that must be factored in during product design and development.

Add Changes to Test Conditions to NCAP Roadmap

Some commenters (Auto Innovators, BMW, Bosch, and Consumer Reports) requested that NHTSA include any planned research into environmental conditions, along with expected completion dates, in the NCAP roadmap so that industry would have time to prepare for such changes.

Response to Comments and Agency Decisions

At the moment, the Agency has decided to continue its research on AEB technologies. Further enhancements to AEB with additional scenarios and test conditions will be considered in the long-term updates to NCAP for the period 2029 to 2033.

V. Adding Pedestrian Automatic Emergency Braking (PAEB) Technology

NHTSA is committed to improving the safety of VRUs and acknowledges the rapidly growing safety risk to pedestrians, with 7,388 pedestrians killed in 2021 and 60,577 injured in traffic crashes in the U.S.[202] NHTSA notes that between 2012 and 2021, pedestrian fatalities rose from 14 to 17 percent of all traffic fatalities. From 2020 to 2021 alone, pedestrian fatalities increased 13 percent, and pedestrian injuries increased 11 percent. PAEB has the potential to mitigate this risk, with a recent Swedish study finding that in daylight and twilight conditions, the presence of PAEB reduced pedestrian crash risk by 18 percent.[203] Given this substantial safety need, NHTSA is adopting PAEB evaluation as part of this NCAP upgrade.

By way of background, PAEB systems function like AEB systems but detect pedestrians instead of vehicles. PAEB systems use information from forward-looking sensors to warn the driver and actively apply the vehicle's brakes when a pedestrian (or, sometimes, cyclist, scooter-rider, motorcyclist) is in the path of the vehicle and the driver has not acted to avoid the crash. Current PAEB systems typically use cameras to determine whether a pedestrian is in imminent danger of being struck by the vehicle. However, some systems use a combination of cameras, radars, and/or possibly lidar sensors.

A. Proposed Pedestrian Automatic Emergency Braking Test Procedures

Most pedestrian crashes occur when a pedestrian is in the forward path of a driver's vehicle. Four common pedestrian crash scenarios include when the vehicle is:

1. Heading straight and a pedestrian is crossing the road;

2. Turning right and a pedestrian is crossing the road;

3. Turning left and a pedestrian is crossing the road; and

4. Heading straight and a pedestrian is walking along or against traffic.

These four crash scenarios are defined as Scenarios S1–S4, respectively, by the Crash Avoidance Metrics Partnership (CAMP) Crash Imminent Braking (CIB) Consortium.[204]

NHTSA's draft research PAEB test procedure, published on November 21, 2019, and referenced herein as the 2019 PAEB test procedure, included two scenarios, S1 and S4, which were identified when combined as the two most frequent, injurious, and fatal crash scenarios involving pedestrians in the U.S.[205] [206] Scenario S1 represents a pedestrian crossing the road in front of the vehicle, and the S4 scenario represents a pedestrian moving with or against traffic along the side of the road in the path of the vehicle. Both test scenarios are expanded into multiple test conditions representing multiple pedestrian impact locations. A short description of each test condition (*e.g.,* S1a, S4b) described in the 2019 PAEB test procedure is presented below for each test scenario (S1 and S4):

- S1
  - S1a—The SV travels in a straight, forward direction at 16 kph (9.9 mph) or 40 kph (24.9 mph). An adult pedestrian mannequin crosses perpendicular to the vehicle's line of travel at 5 kph (3.1 mph). The SV encounters the mannequin walking from the right (*i.e.,* the passenger's side of the vehicle) with 25 percent overlap of the vehicle.[207] See Figure 7(a) for a scenario diagram.
  - S1b—The SV travels in a straight, forward direction at 16 kph (9.9 mph) or 40 kph (24.9 mph). An adult pedestrian mannequin crosses perpendicular to the vehicle's line of travel at 5 kph (3.1 mph). The SV encounters the mannequin walking from the right with 50 percent overlap of the vehicle. See Figure 7(b) for a scenario diagram.
  - S1c—The SV travels in a straight, forward direction at 16 kph (9.9 mph) or 40 kph (24.9 mph). An adult pedestrian mannequin crosses perpendicular to the vehicle's line of travel at 5 kph (3.1 mph). The SV encounters the mannequin walking from the right with 75 percent overlap

[202] National Center for Statistics and Analysis. (2023, June), *Pedestrians.* (Traffic Safety Facts, 2021 Data. Report No. DOT HS 813 458), Washington, DC: National Highway Traffic Safety Administration.

[203] Kullgren, A., Amin, K, & Tingvall, C. (2023) Effects on crash risk of automatic emergency braking systems for pedestrians and bicyclists, Traffic Injury Prevention, 24:sup1, S111–S115, DOI: 10.1080/15389588.2022.2131403.

[204] Carpenter, M.G., Moury, M.T., Skvarce, J.R., Struck, M. Zwicky, T.D., & Kiger, S.M. (2014, June), *Objective tests for forward looking pedestrian crash avoidance/mitigation systems: Final report* (Report No. DOT HS 812 040), Washington, DC: National Highway Traffic Safety Administration.

[205] Yanagisawa, M., Swanson, E., Azeredo, P., & Najm, W.G. (2017, April). Estimation of potential safety benefits for pedestrian crash avoidance/mitigation systems. (Report No. DOT HS 812 400). Washington, DC: National Highway Traffic Safety Administration.

[206] 84 FR 64405 (Nov. 21, 2019).

[207] Overlap is defined as the percent of the vehicle's width that the pedestrian would traverse prior to impact if the vehicle's speed and pedestrian's speed remain constant.

of the vehicle. See Figure 7(c) for a diagram.

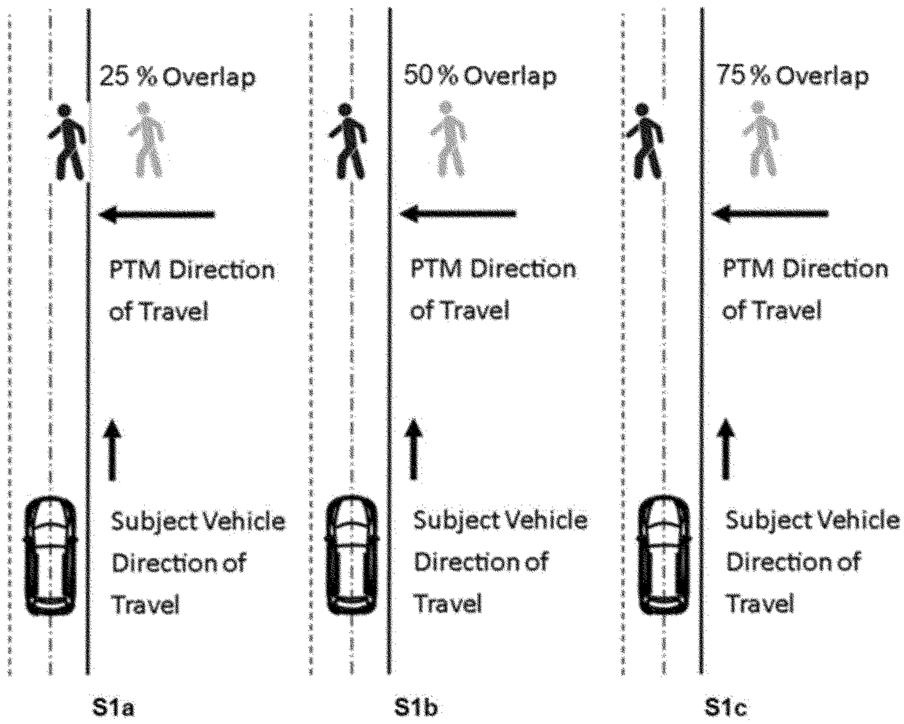


Figure 7: Adult Pedestrian Crossing Path Conditions S1a (a), S1b (b), and S1c (c)

○ S1d—The SV travels in a straight, forward direction at 16 kph (9.9 mph) or 40 kph (24.9 mph). A child pedestrian mannequin crosses perpendicular to the vehicle's line of travel at 5 kph (3.1 mph). The SV encounters the child mannequin running from behind parked cars on the right with 50 percent overlap of the vehicle. See Figure 8 for a diagram.

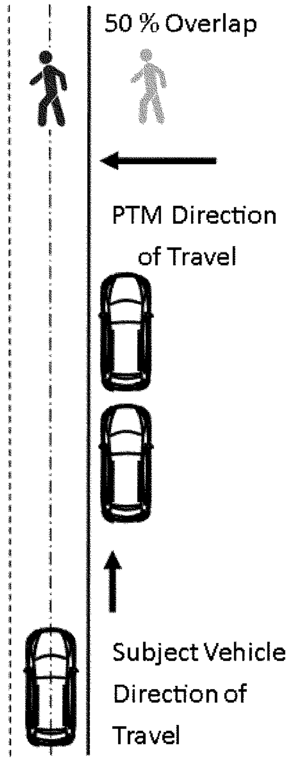


Figure 8: Child Pedestrian (Obstructed) Crossing Path Condition S1d

○ S1e—The SV travels in a straight, forward direction at 40 kph (24.9 mph). An adult pedestrian mannequin crosses perpendicular to the vehicle's line of travel at 8 kph (5.0 mph). The SV encounters the mannequin walking from the left (*i.e.,* the driver's side of the vehicle) with 50 percent overlap of the vehicle. See Figure 9 for a diagram.

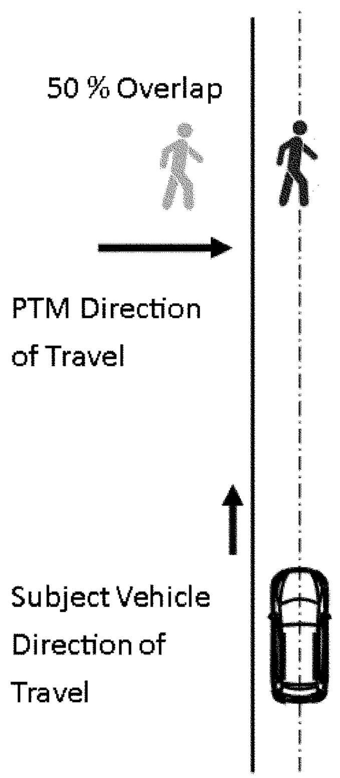


Figure 9: Adult Pedestrian Crossing Path Condition S1e

○ S1f—The SV travels in a straight, forward direction at 40 kph (24.9 mph). An adult pedestrian mannequin moves perpendicular to the vehicle's line of travel toward the vehicle's right at 5 kph (3.1 mph), but it stops short (−25 percent overlap) of the SV's path. See Figure 10(a) for a diagram.

○ S1g—The SV travels in a straight, forward direction at 40 kph (24.9 mph). An adult pedestrian mannequin crosses perpendicular to the vehicle's line of travel toward the vehicle's right at 5 kph (3.1 mph). The mannequin clears the SV's path (125 percent overlap). See Figure 10(b) for a diagram.

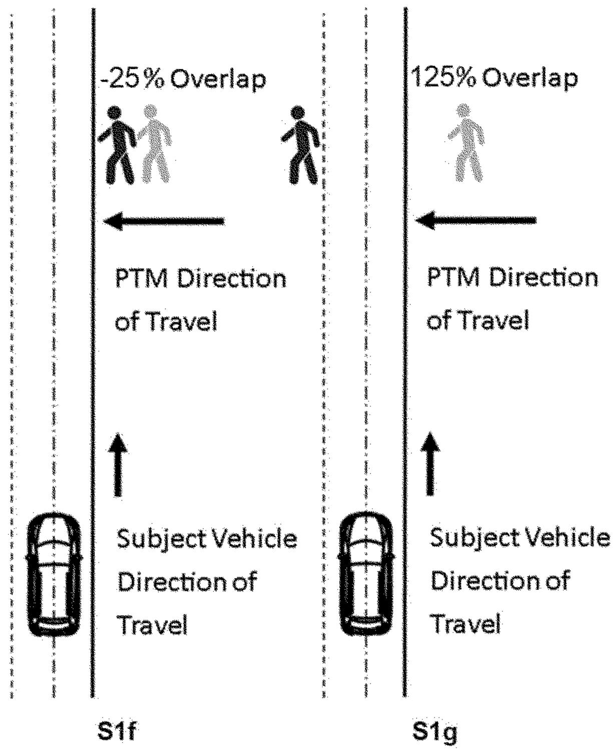


Figure 10: Adult Pedestrian False Positive Crossing Path Conditions S1f (a) and S1g (b)

- S4

○ S4a—The SV travels in a straight, forward direction at 16 kph (9.9 mph) or 40 kph (24.9 mph). An adult pedestrian mannequin is stationary in front of the SV at 25 percent overlap. The mannequin is facing away from the SV on the right hand side of the road. See Figure 11 for a diagram.

○ S4b—The SV travels in a straight, forward direction at 16 kph (9.9 mph) or 40 kph (24.9 mph). An adult pedestrian mannequin is stationary in front of the SV at 25 percent overlap. The mannequin is facing toward the SV on the right hand side of the road. See Figure 11 for a diagram.

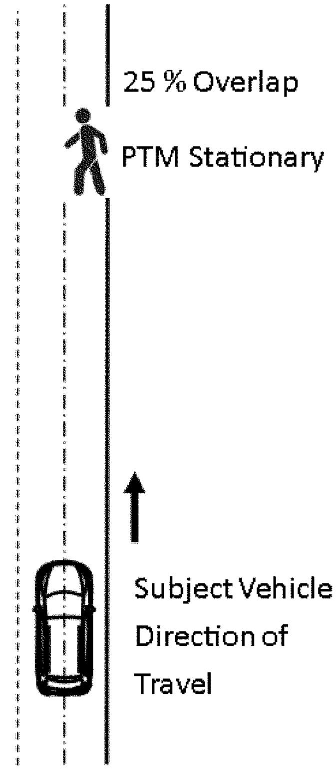


Figure 11: Adult Pedestrian Stationary In-Path Conditions S4a (Pedestrian Facing Away from SV) and S4b (Pedestrian Facing Toward SV)

○ S4c—The SV travels in a straight, forward direction at 40 kph (24.9 mph). An adult pedestrian mannequin is walking away from the approaching SV at 5 kph (3.1 mph), parallel to the flow of traffic. The mannequin is located on the right hand side of the road at 25 percent overlap. See Figure 12 for a diagram.

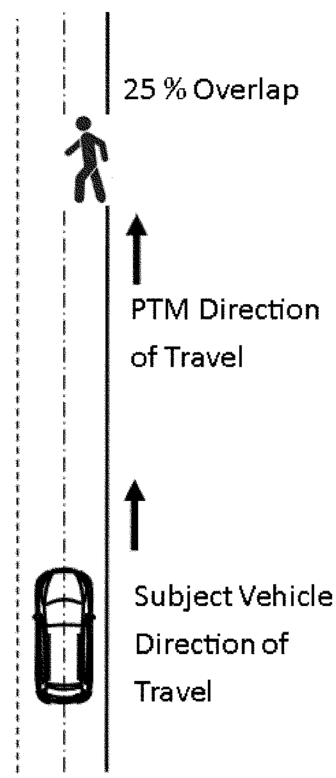


Figure 12: Adult Pedestrian Moving In-Path Condition S4c

The proposed 2019 PAEB test procedure required that all testing take place during daylight hours with good atmospheric visibility and the use of posable pedestrian mannequins.

As detailed in the March 2022 RFC Notice, the Agency proposed several changes to the 2019 PAEB test procedure involving the pedestrian mannequins, test conditions, test variants for SV speed, specified lighting conditions, and the number of test trials required to be conducted for each test variant. The RFC included the following:

1. Use of articulated pedestrian mannequins with moving legs, instead of the posable child and adult pedestrian mannequins;
2. SV test speeds from 10 kph (6.2 mph) to 60 kph (37.3 mph) in increments of 10 kph (6.2 mph) for each test condition (S1a, S1b, S1c, S1d, S1e, S4a, S4b, and S4c)
3. PAEB evaluation in darkness lighting conditions with the vehicle's lower beam headlamps switched on, in addition to daylight conditions.

The test matrix of the proposed PAEB evaluations is summarized in Table 17.

TABLE 17—TEST MATRIX OF PROPOSED PAEB EVALUATIONS IN THE MARCH 2022 RFC NOTICE

Test cond.	Size	Test speeds (kph (mph))		Movement classification	Path origin	Overlap (%)	Obstruction	Light condition
		SV	Pedestrian					
S1a	Adult	10, 20, 30, 40, 50, 60 (6.2, 12.4, 18.6, 24.9, 31.1, 37.3).	5 (3.1)	Walk	Right	25	No	Daylight Darkness—Lower Beam.
S1b	Adult	10, 20, 30, 40, 50, 60 (6.2, 12.4, 18.6, 24.9, 31.1, 37.3).	5 (3.1)	Walk	Right	50	No	Daylight Darkness—Lower Beam.
S1c	Adult	10, 20, 30, 40, 50, 60 (6.2, 12.4, 18.6, 24.9, 31.1, 37.3).	5 (3.1)	Walk	Right	75	No	Daylight Darkness—Lower Beam.
S1d	Child	10, 20, 30, 40, 50, 60 (6.2, 12.4, 18.6, 24.9, 31.1, 37.3).	5 (3.1)	Run	Right	50	Yes	Daylight Darkness—Lower Beam.
S1e	Adult	10, 20, 30, 40, 50, 60 (6.2, 12.4, 18.6, 24.9, 31.1, 37.3).	8 (5.0)	Run	Left	50	No	Daylight Darkness—Lower Beam.
S4a	Adult (Facing Away).	10, 20, 30, 40, 50, 60 (6.2, 12.4, 18.6, 24.9, 31.1, 37.3).	0	Stationary	Right	25	No	Daylight Darkness—Lower Beam.
S4b	Adult (Facing Toward).	10, 20, 30, 40, 50, 60 (6.2, 12.4, 18.6, 24.9, 31.1, 37.3).	0	Stationary	Right	25	No	Daylight Darkness—Lower Beam.
S4c	Adult (Facing Away).	10, 20, 30, 40, 50, 60 (6.2, 12.4, 18.6, 24.9, 31.1, 37.3).	5 (3.1)	Walk	Right	25	No	Daylight Darkness—Lower Beam.

B. Linking Proposed PAEB Test Scenarios With Real-World Crashes

A review of pedestrian crashes from the 2011–2012 GES and FARS data sets where a light vehicle's front struck the pedestrian as the first event and there was no avoidance maneuver[208] found that, on average, the S1 and S4 pre-crash scenarios represent approximately 10,431 (17 percent) of the 62,917 real-world crashes involving pedestrians annually. The two pre-crash scenarios also account for 3,889 (30 percent) of the 13,058 MAIS 2+ and 2,739 (40 percent) of the 6,770 MAIS 3+ injured pedestrians. In these real-world crashes represented by S1 and S4 scenarios, there were, on average, 2,016 fatal vehicle-to-pedestrian crashes annually, representing 60 percent of the 3,337 fatal vehicle-pedestrian crashes.

More specifically, the researchers from the study found that for the S1 scenario, approximately 7,481 (12 percent) and 1,396 (42 percent) real-world crashes involving pedestrian injuries and fatalities occurred annually, respectively. These resulted in, on average, 2,682 (21 percent) of MAIS 2+ injured pedestrians and 1,879 (28 percent) of MAIS 3+ injured pedestrians yearly. For the S4 scenario, approximately 2,950 (5 percent) and 620 (19 percent) of real-world crashes involving pedestrian injuries and fatalities occurred annually, respectively. These resulted in, on average, 1,207 (9 percent) of MAIS 2+ injured pedestrians and 860 (13 percent) of MAIS 3+ injured pedestrians yearly.

The above figures include both daytime and nighttime crashes. Though the 2019 PAEB test procedure specified daylight conditions, there is a demonstrated safety need for the Agency and industry to jointly address nighttime pedestrian crashes in addition to those crashes that occur in the daytime. The Volpe study of 2011–2015 FARS and GES crash data showed that 75 percent of pedestrian fatalities and 38 percent of pedestrian injuries occurred in dark conditions, including darkness illuminated by overhead lighting.[209] A study of California, North Carolina, and Texas crash data revealed that pedestrians struck in the dark were five times more likely to be killed than those struck during the day.[210] Various factors make low-light driving inherently more dangerous for pedestrians than driving during daylight hours, including a reduction in pedestrian visibility, night vision deterioration as an individual ages,[211] an increased likelihood of driver drowsiness at nighttime,[212] and an increased likelihood that both pedestrians and drivers are under the influence of drugs or alcohol in darkness compared to daylight.[213] Furthermore, both IIHS and AAA have shown performance issues with current PAEB systems in dark conditions.[214]

With regard to SV speeds, a review of 2011–2015 FARS and GES crash data sets showed that, for crashes where posted speed limit was known, 8 percent of pedestrian fatalities and 36 percent of pedestrian injuries resulted from crashes that occurred on roadways with posted speeds of 40.2 kph (25 mph) and less (*i.e.,* at speeds equivalent

[208] Yanagisawa, M., Swanson, E., Azeredo, P., & Najm, W.G. (2017, April), *Estimation of potential safety benefits for pedestrian crash avoidance/mitigation systems* (Report No. DOT HS 812 400), Washington, DC: National Highway Traffic Safety Administration.

[209] Yanagisawa, M., Swanson, E., Azeredo, P., & Najm, W.G. (2017, April), *Estimation of potential safety benefits for pedestrian crash avoidance/mitigation systems* (Report No. DOT HS 812 400), Washington, DC: National Highway Traffic Safety Administration.

[210] Ferenchak, Nicholas N., Gutierrez, Risa E., & Singleton, Patrick A. (2022), *Shedding light on the pedestrian safety crisis: An analysis across the injury severity spectrum by lighting condition,* Traffic Injury Prevention, 23:7, 434–439, DOI: 10.1080/15389588.2022.2100362.

[211] *https://www.nsc.org/road/safety-topics/driving-at-night.*

[212] *https://www.nhtsa.gov/sites/nhtsa.gov/files/808707.pdf.*

[213] *https://deepblue.lib.umich.edu/bitstream/handle/2027.42/58726/99831.pdf?sequence=1&isAllowed=y.*

[214] Cicchino, J.B (2022, February), *Effects of automatic emergency braking systems on pedestrian crash risk,* Insurance Institute for Highway Safety, *https://www.iihs.org/api/datastoredocument/bibliography/2243.*

to those covered by NHTSA's 2019 PAEB test procedure), whereas 38 percent of fatalities and 76 percent of injuries occurred as a result of crashes on roadways with posted speeds of 56.3 kph (35 mph) and less.[215] [216] By adopting a higher maximum test speed than the one in the 2019 draft PAEB procedure, the Agency could address an additional 30 percent of fatalities and 40 percent of injuries. Since speeding was a reported factor in only 5 percent of the fatal pedestrian crashes and 2 percent of the injurious pedestrian crashes, NHTSA reasoned that the posted speed may correlate closely with the travel speed of the vehicle prior to impact with the pedestrian.[217] [218]

Finally, roadway alignment and grade for real-world pedestrian crashes in Volpe's 2011–2015 data set were found to be comparable to those prescribed in the Agency's 2019 PAEB test procedures. Of those pedestrian crashes where roadway alignment was known, 94 percent of both fatal and injurious crashes occurred on a straight roadway, and 84 percent and 88 percent of fatal and injurious pedestrian crashes, respectively, occurred on a level roadway.

C. PAEB Installation Rates and Research Tests

1. PAEB Installation Rates

New vehicles equipped with PAEB systems, like those equipped with AEB systems, are currently broadly available. In the five years between model years 2018 and 2023, the percentage of the fleet fitted with standard PAEB systems rose from 19 percent to 91 percent. Not only has the presence of PAEB increased, but system performance has improved substantially. In model year 2019, 21 percent of vehicles tested by IIHS for PAEB performance received a ''Superior'' score, 27 percent received ''Advanced,'' 5 percent received ''Basic,'' and 4 percent received no credit. The remaining 44 percent did not have the technology available. By contrast, in model year 2022, only 12 percent of vehicles did not have PAEB available; 54 percent received ''Superior'' ratings and 30 percent received ''Advanced'' ratings.[219] [220] The Agency has observed similar improvements in PAEB performance over this period during its research testing, as discussed in the sections to follow.

2. Model Year 2019 and 2020 Research Testing

As described in the March 2022 RFC notice, the Agency conducted a series of tests on the same 11 model year 2019 and 2020 vehicles used in the CIB testing series to assess the operational range and performance of then-current PAEB systems. For the purpose of this study, the Agency used the 2019 PAEB test procedure but employed the articulating mannequins in lieu of posable mannequins and expanded the test procedure specifications to include higher vehicle test speeds of 60 kph (37.2 mph) for the S1b, S1d, and S1e test conditions and 80 kph (49.7 mph) for the S4a and S4c conditions.[221] For each test, the SV speed was incrementally increased to identify when each SV reached its operational limits and did not respond to the pedestrian mannequin. When no or late intervention occurred for a vehicle and test condition (*i.e.,* combination of test scenario and speed), NHTSA repeated the test condition at a test speed that was 5 kph (3.1 mph) lower. This reduced speed defined the system's upper capabilities. NHTSA also chose to alter the lighting conditions from the 2019 PAEB test procedure specifications and conducted tests in both daylight and dark conditions using the vehicles' lower or upper beam headlamps as the only light source to illuminate the pedestrian mannequin. For most of the darkness tests, no overhead ambient light source was provided in either condition; however, for two of the model year 2020 vehicles, limited testing was also conducted using the vehicles' lower beam headlamps and overhead lights to investigate possible performance differences when using overhead lighting. These vehicles were subjected to PAEB conditions S1b, S1d, S1e, S4a, and S4c at test speeds of 16 kph (9.9 mph) and 40 kph (24.9 mph).

The Agency's characterization testing showed that many model year 2019 and 2020 vehicles were able to repeatedly avoid impacting the pedestrian mannequins at higher test speeds for S1 and S4 than those specified in the 2019 PAEB test procedure, and several vehicles repeatably achieved full crash avoidance at speeds up to 60 kph (37.3 mph) or higher.[222] These findings suggested that PAEB system performance at the time exceeded most of the testing requirements outlined in NHTSA's 2019 PAEB test procedure. Specific to testing in dark lighting conditions, PAEB system performance generally degraded in dark conditions compared to daylight conditions, results which align well with IIHS's system effectiveness study for 2017–2020 model year vehicles. IIHS found that although PAEB systems were associated with a 32 percent reduction in pedestrian crashes occurring during daylight and a 33 percent reduction in pedestrian crashes for areas with artificial lighting during dawn, dusk, or at night, there was no evidence that PAEB systems were effective at nighttime without street lighting.[223] With regard to overhead lighting, NHTSA's data suggested that a vehicle's PAEB system performs only slightly better with overhead lighting versus no overhead lighting.

3. Model Year 2021 and 2022 Research Testing

Subsequently, NHTSA conducted a series of PAEB research tests to further assess current fleet performance.[224] This testing, which generally aligned well with NHTSA's proposal for NCAP PAEB assessments, involved 12 model year 2021 and 2022 light vehicles and included PAEB testing for the following PAEB test conditions: S1a, S1b, S1c, S1d, S1e, S4a, S4b, and S4c. Testing was conducted under both daylight and darkness lighting conditions. For darkness conditions, NHTSA evaluated

[215] Swanson, E., Foderaro, F., Yanagisawa, M., Najm, W.G., & Azeredo, P. (2019, August), *Statistics of light-vehicle pre-crash scenarios based on 2011–2015 national crash data* (Report No. DOT HS 812 745), Washington, DC: National Highway Traffic Safety Administration.

[216] The posted speed limit was either not reported or was unknown in 4 percent of fatal pedestrian crashes and 29 percent of pedestrian crashes that resulted in injuries.

[217] Swanson, E., Foderaro, F., Yanagisawa, M., Najm, W.G., & Azeredo, P. (2019, August), *Statistics of light-vehicle pre-crash scenarios based on 2011–2015 national crash data* (Report No. DOT HS 812 745), Washington, DC: National Highway Traffic Safety Administration.

[218] In 4 percent of fatal and 11 percent of injurious pedestrian crashes, it was unknown or not reported whether speeding was a factor.

[219] IIHS's vehicle-to-pedestrian rating is a points-based assessment. A maximum of six points is possible, and points are assigned based on average amount of speed reduction afforded in each of three test scenarios, with bonus points awarded for vehicles that warn a driver at least 2.1 seconds prior to impact in a test condition similar to NHTSA's S1a.

[220] *https://iihs.org/ratings/.*

[221] These test speeds represent the maximum test speeds potentially utilized for a given test condition. The actual speeds used for a given vehicle and test condition depended on observed PAEB system performance.

[222] See Docket No. NHTSA–2021–0002–0002. There are embedded reports titled, ''PEDESTRIAN AUTOMATIC EMERGENCY BRAKING SYSTEM RESEARCH TEST'' for each of the 11 vehicle make/models.

[223] Cicchino, J.B (2022, February), *Effects of automatic emergency braking systems on pedestrian crash risk,* Insurance Institute for Highway Safety, *https://www.iihs.org/api/datastoredocument/bibliography/2243.*

[224] National Highway Traffic Safety Administration (2023, March). 2022 Light Vehicle Pedestrian Automatic Emergency Braking Test Summary. Washington, DC: National Highway Traffic Safety Administration.

the PAEB systems using lower beam headlamps, but for select conditions (S1b, S4a, and S4c), NHTSA also evaluated systems using upper beam headlamps. NHTSA utilized both adult and child articulated mannequins for this series. The goal of this research was to assess NHTSA's PAEB proposals (outlined in subsequent sections) and to gain further knowledge regarding capabilities of the current vehicle fleet. See Table 18 below for nominal test parameters used in this series of research tests.

TABLE 18—NOMINAL TEST PARAMETERS FOR MODEL YEAR 2021–2022 PAEB RESEARCH TESTING

Test condition	Size	Test speeds (kph (mph))		Movement classification	Path origin	Overlap (%)	Obstruction	Light condition
		SV	Pedestrian					
S1a	Adult	10, 20, 30, 40, 50, 60 (6.2, 12.4, 18.6, 24.9, 31.1, 37.3).	5 (3.1)	Walk	Right	25	No	Daylight. Darkness—Lower Beam.
S1b	Adult	10, 20, 30, 40, 50, 60 (6.2, 12.4, 18.6, 24.9, 31.1, 37.3).	5 (3.1)	Walk	Right	50	No	Daylight. Darkness—Lower Beam. Darkness—Upper Beam.
S1c	Adult	10, 20, 30, 40, 50, 60 (6.2, 12.4, 18.6, 24.9, 31.1, 37.3).	5 (3.1)	Walk	Right	75	No	Daylight. Darkness—Lower Beam.
S1d	Child	10, 20, 30, 40, 50, 60 (6.2, 12.4, 18.6, 24.9, 31.1, 37.3).	5 (3.1)	Run	Right	50	Yes	Daylight. Darkness—Lower Beam.
S1e	Adult	10, 20, 30, 40, 50, 60 (6.2, 12.4, 18.6, 24.9, 31.1, 37.3).	8 (5.0)	Run	Left	50	No	Daylight. Darkness—Lower Beam.
S4a	Adult (Facing Away).	10, 20, 30, 40, 50, 60 (6.2, 12.4, 18.6, 24.9, 31.1, 37.3).	0	Stationary	Right	25	No	Daylight. Darkness—Lower Beam. Darkness—Upper Beam.
S4b	Adult (Facing Toward).	10, 20, 30, 40, 50, 60 (6.2, 12.4, 18.6, 24.9, 31.1, 37.3).	0	Stationary	Right	25	No	Daylight. Darkness—Lower Beam.
S4c	Adult (Facing Away).	10, 20, 30, 40, 50, 60, 65 (6.2, 12.4, 18.6, 24.9, 31.1, 37.3, 40.4).	5 (3.1)	Walk	Right	25	No	Daylight. Darkness—Lower Beam. Darkness—Upper Beam.

Like the Agency's AEB characterization research, testing for each PAEB scenario advanced from the lowest SV speed to the highest, with one initial trial conducted per test speed. If the SV did not contact the pedestrian mannequin during the initial trial for a given speed, the SV speed was increased by 10 kph (6.2 mph) and the next trial was conducted. This iterative process continued until the maximum test speed was reached.[225] However, if the SV contacted the pedestrian mannequin for the initial trial conducted for test speeds of 20 kph (12.4 mph) or greater, and the SV speed at the time of impact was at least 50 percent less than the initial SV speed, the Agency performed up to four additional trials at the same SV speed.[226] If the SV speed at the time of impact was 50 percent or greater than the initial SV speed, testing for that scenario ended. Relevant outcomes of this research are detailed throughout the applicable sections of this notice. Overall, vehicle performance in this test series was shown to have improved from the already relatively strong model year 2019–2020 research test series.

D. Summary of Comments, Response to Comments, and Agency Decisions Pedestrian Automatic Emergency Braking Technology Inclusion in General

Broadly, commenters were in favor of evaluating PAEB systems on new vehicle models. Many noted that pedestrian and cyclist fatalities are rising quickly relative to vehicle occupant fatalities. NSC presented data to show that in 2020, an estimated 6,721 pedestrians were killed, a 33-year high. On a local level, several city governments, transportation departments, and advocacy groups submitted pedestrian crash data from their own cities to support inclusion of PAEB evaluations in NCAP (Portland, OR; Minneapolis, MN; Boston, MA; Philadelphia, PA; New York, NY; and Bike Anchorage, among others). Data supplied by Bosch showed that an estimated 21,300 crashes with injuries and/or fatalities could be eliminated each year assuming full fleet penetration of PAEB.[227] Bosch also presented data from IIHS that showed the presence of a PAEB system results in a 25 to 27 percent reduction in the risk of overall pedestrian crashes and a 29 to 30 percent reduction in risk of injurious pedestrian crashes.[228] Advocates stated that the research, analyses, and justification laid forth in the March 2022 RFC notice were detailed and sound, and CR suggested that the Agency should take action as quickly as possible given the rapid rise in crashes involving VRUs.

NSC also noted that VRU protection is one of the ''largest gaps'' in the current NCAP. In general, commenters strongly favored a paradigm shift in NHTSA's vehicle ratings program. NCAP ratings currently address safety of the vehicle occupants only; however, many wished to see the safety information provided expand beyond the vehicle and extend to VRUs in the wider community. Some individuals indicated that they do not feel safe as a VRU. Commenters often stated that only vehicle purchasers (*i.e.,* not VRUs) can choose vehicles that are designed to protect VRUs. Aptiv stated that vehicle-to-VRU scenarios should be treated with greater stringency than vehicle-to-vehicle scenarios because of the risk of severe injury and/or fatality to those outside of the vehicle. NTSB stated it has previously called on NHTSA to implement performance tests for evaluating PAEB systems[229] and to incorporate them into NCAP,[230] noting that these actions might incentivize vehicle manufacturers to include and improve PAEB systems.

[225] For S4 scenarios, after 60 kph (37.3 mph), the next, and final, test speed was 65 kph (40.4 mph).

[226] Vehicle-to-pedestrian contact at the lowest test speed of 10 kph (6.2 mph) was noted but did not result in a cessation of testing at the next highest test speed.

[227] *https://www.regulations.gov/comment/NHTSA-2021-0002-3613.* See attachment 4.

[228] Cicchino, J.B. (2022, February), *Effects of automatic emergency braking systems on pedestrian crash risk,* Insurance Institute for Highway Safety, *https://www.iihs.org/api/datastoredocument/bibliography/2243.*

[229] Safety Recommendation H–18–42.

[230] Safety Recommendation H–18–43.

Comments received in response to NHTSA's proposal are summarized below, along with the corresponding Agency decision.

1. Test Conditions for S1 and S4, Including False Positive Assessments S1f and S1g and Varying Lighting Conditions

Because the Agency is committed to reducing test burden whenever appropriate, NHTSA proposed to include Scenarios S1a–e and S4a–c in its upcoming NCAP assessment but sought comments on the necessity of running each test condition to adequately address the safety problem. Further, NHTSA did not propose to include PAEB false positive test conditions (*i.e.,* S1f and S1g) in NCAP in its March 2022 notice. However, it requested comment on whether the omission of these test conditions is acceptable.

In addition to performing PAEB testing in daylight conditions, NHTSA's proposal for PAEB in NCAP included executing scenarios S1a–e and S4a–c in dark lighting conditions to simulate nighttime pedestrian encounters. As detailed in the RFC notice and by many commenters, nighttime travel is risky for VRUs.[231] In 2021, most pedestrian fatalities occurred in the dark (77 percent).[232] NHTSA sought comment on this approach.

Summary of Comments

Several commenters stated that the Agency should move forward with the proposed PAEB test conditions. Specifically, Uhnder, CAS, FCA, AAA, ASC, Intel, and one individual submitted comments in support of moving forward with test conditions S1a–e and S4a–c. CAS and the individual commenter noted that reducing test burden without empirical evidence supporting this decision will not adequately address the safety problem. AAA asserted that inclusion of the proposed test plan would ''characterize system response to variations of kinematic characteristics realistically encountered in the naturalistic environment.'' To reduce test burden while maintaining real-world relevance and test stringency, Intel reasoned that, since these test conditions are all well-known to industry and have been defined in existing international regulations, NHTSA could require OEMs to self-report predicted performance data and the Agency could ''spot-check'' results, reflecting Euro NCAP's methodology. As an alternative approach to reduce burden, Toyota posed that NHTSA could determine a subgroup of certain scenarios (and/or test speeds) that will ensure adequate performance across a range of conditions/speeds and run this subgroup of tests rather than the full battery. Instead of reducing the test matrix at this time, Uhnder and ASC suggested NHTSA could re-evaluate the necessity for each test condition on a regular basis; at that time, tests could be reduced if there is no longer a need.

Several other commenters provided general input on which test conditions should be selected for inclusion. Mercedes-Benz and Advocates noted that test conditions selected should reflect real-world conditions and needs, and those needs should be supported by statistically significant data. Advocates added that NHTSA should select test conditions which give the Agency confidence that the system will operate as intended by the manufacturer.

Some commenters recommended specific reductions for the proposed test conditions. Pertinent comments are summarized below.

S1 Test Conditions

Many commenters requested the Agency reduce the test plan proposed for the S1 scenario. HATCI, Honda, Auto Innovators, MEMA, GM, and BMW supported removal of S1b, a test condition involving an adult-sized pedestrian mannequin entering the roadway from the nearside with 50 percent overlap of the vehicle at point of contact. HATCI's rationale for removal of S1b was that the 25 percent (S1a) and 75 percent (S1c) overlap conditions address the 50 percent condition adequately; therefore, the S1b test condition would be redundant. Bosch, Honda, MEMA, BMW, and Auto Innovators agreed with HATCI's sentiments. GM supported this rationale for a pass/fail scoring system; however, the manufacturer recommended that the Agency adopt a wider range of test conditions if NCAP ratings would be assigned according to a points-based system. Some of the same commenters supporting a reduction in the test matrix for the S1 scenario (Honda, Auto Innovators, BMW) asserted that S1c should also be removed because they considered the S1a (25 percent overlap) condition to be the most stringent test case. TRC also stated that S1c was redundant and could be removed for similar reasons; the laboratory did not mention removal of S1b. Mercedes-Benz supported harmonization with international test protocols for the PAEB crossing conditions whenever possible. Similarly, Bosch recommended harmonization with Euro NCAP's PAEB evaluation.

S4 Test Conditions

For the S4 scenarios, Mercedes-Benz, Auto Innovators, Subaru, and BMW recommended NHTSA remove both S4a and S4b from its test plan. S4a and S4b both involve the use of a stationary pedestrian mannequin situated on the nearside of the road at a 25 percent overlap facing away from (S4a) or towards (S4b) the SV. Mercedes-Benz was unsupportive of the use of stationary targets, citing data from three resources: a Volpe study, which did not identify any stationary scenarios;[233] an ISO standard, which does not prescribe the use of any stationary pedestrian tests due to low occurrence;[234] and a Mercedes-Benz study of German In Depth Accident Study (GIDAS) data, which revealed that only 4 percent of pedestrians struck were stationary.[235] Subaru recommended that NHTSA focus on the S4c test condition, showing FARS data from 2016–2020 that indicated 61% of pedestrians struck alongside a roadway were walking in the direction of traffic. Auto Innovators, Honda, GM, and BMW reasoned that S4b is redundant with S4a since the only difference is the direction of the pedestrian, but Auto Innovators and BMW went on to state, similar to Subaru, that S4a and S4b may both be eliminated since S4c scenarios are more common in the real world. MEMA, Bosch, and Toyota were in favor of including either S4a or S4b, but not both, with Bosch encouraging the Agency to harmonize with the corresponding PAEB test procedures used by Euro NCAP. NACTO did not offer support for specific in-path condition, but the group noted that it is important for PAEB systems to detect stationary pedestrians.

Removal of Select Test Conditions

IIHS took a different approach in its comments, stating that its consumer information program includes scenarios S1a, S1d, and S4c. S1d is a test scenario in which a child-sized pedestrian

[231] As detailed in the March 2022 RFC notice, Volpe's 2011–2015 FARS data set showed that 36 percent of pedestrian fatalities occurred in the dark with no overhead lights.

[232] National Center for Statistics and Analysis. (2023, June), *Pedestrians.* (Traffic Safety Facts, 2021 Data. Report No. DOT HS 813 458), Washington, DC: National Highway Traffic Safety Administration.

[233] Carpenter, M.G., Moury, M.T., Skvarce, J.R., Struck, M. Zwicky, T.D., & Kiger, S.M. (2014, June), *Objective tests for forward looking pedestrian crash avoidance/mitigation systems: Final report* (Report No. DOT HS 812 040), Washington, DC: National Highway Traffic Safety Administration.

[234] ISO/CD 19237:2017.

[235] NHTSA–2021–0002–3847.

mannequin enters the roadway from the nearside behind parked vehicles with 50 percent overlap of the vehicle. IIHS recommended that NHTSA focus on expediting rulemaking efforts for AEB/PAEB, stating that model year 2021 vehicles examined by the group performed exceedingly well.[236] Should the Agency pursue PAEB rating in NCAP, the group suggested removal of the three tests that it currently conducts (S1a, S1d, and S4c) to reduce unnecessary test burden, indicating that any consumer confusion could be mitigated by explaining that the two programs are meant to be complementary.

False Positive Test Conditions (S1f and S1g)

Regarding false positive test conditions S1f and S1g, most commenters suggested that false positive tests should not be conducted in NCAP for PAEB. Bosch, Toyota, Honda, FCA, AAA, GM, Auto Innovators, BMW, and IIHS were not in favor of including S1f and S1g. Toyota submitted data to show that, due to tolerance overlap between the ''off'' and ''on'' conditions, there is a risk of leaving PAEB off when it should remain on. Bosch, Auto Innovators, Honda, and BMW echoed this sentiment. For instance, Bosch noted the unpredictability of pedestrians and suggested that it is safer for a vehicle to stop if there is a chance that the pedestrian will enter the vehicle's path. Bosch suggested that NHTSA should be cautious not to incorporate scenarios that may prompt a vehicle to continue driving when a pedestrian may continue into the vehicle's path, as this may erode consumer confidence and trust in PAEB systems. Similarly, AAA stated that automakers should not be ''pressured to minimize false positives at the possible expense of reduced system efficacy.'' Along these lines, FCA asserted that designing for S1f and S1g conditions may negatively affect tuning and calibration. IIHS and GM both noted that stakeholders could collect data on false activations by monitoring real-world field performance data. They claimed that this will be more useful since the test conditions outlined by the Agency will not address the full variety of situations in which false activations may occur in the field. They also noted that manufacturers have a vested interest in minimizing false positives to improve customer satisfaction.

Conversely, a few commenters were in favor of adding false positive test conditions S1f and S1g to the battery of NCAP PAEB tests. TRC noted that vehicles still brake during these false positive tests, and thus reasoned that manufacturers may continue to increase system robustness if included in NCAP. Rivian stated that false positive conditions should be included since these situations occur in the field and braking unnecessarily and on short notice can contribute to the rear-end crash problem. CAS cited concern for various groups of VRUs, such as children, compromised adults, and animals, in its support for false positive testing. Like Bosch (above), CAS mentioned that these VRUs may first stop at the edge of the roadway but then continue crossing or reverse direction. Unlike Bosch, however, CAS suggested that the Agency should conduct false positive testing to ensure PAEB systems include additional safety margins and provide adequate protection. Adasky stated that false positive results serve as an indication of a lack of system robustness and are therefore important to include. Aptiv also noted that fused sensor technology should minimize false positive activation. Intel was not opposed to the inclusion of scenarios S1f and S1g, but it also suggested that test parameters and criteria should be reviewed carefully. In Intel's opinion, warnings or short braking intervals may be acceptable to the driver since the miss distance for the false positive scenarios is relatively small. The group noted that this especially holds true for cases where the SV speed is high and the pedestrian is crossing the path, as the driver may not be sure that there is enough time for the pedestrian to cross safely. Intel stated it would like to see the miss distance reviewed and road markings considered.

Overall Need for PAEB Testing in Darkness Lighting Conditions

Respondents from a variety of backgrounds approved of NHTSA's decision to conduct PAEB testing in dark lighting conditions. Many suggested that PAEB testing in dark lighting conditions was critical given the real-world safety problem. Generally, commenters were concerned about the current effectiveness of PAEB systems, citing studies that showed PAEB systems do not work as well in low light as they do in daylight. These groups and individuals reasoned that NHTSA must evaluate PAEB systems in dark conditions to encourage improvements in system performance.

Auto Innovators and HATCI requested more information from NHTSA regarding PAEB test procedures in dark lighting conditions and real-world nighttime crash conditions. Auto Innovators asked that NHTSA more clearly define nighttime parameters in its test procedure so that test repeatability could be guaranteed. Should NHTSA decide not to harmonize with Euro NCAP nighttime test procedures, HATCI reasoned that NHTSA should study U.S. areas prone to nighttime crash events to determine precise lux levels and other environmental conditions which might be representative of these high-incident areas. These specifications should then be incorporated into NCAP's test procedures, increasing test repeatability. The automaker provided pedestrian-related crash data gathered from Ann Arbor, MI, including recorded lux measurements for areas with the highest pedestrian crash risk. Similarly, Advocates suggested that NHTSA evaluate real-world data to determine which kinds of crashes are occurring most frequently in low light and dark conditions. The group mentioned that this data could help inform testing practices and may also suggest that other technologies, including LDW/LKA and BSW/BSI, should be evaluated under nighttime conditions as well.

Two commenters, Toyota and Auto Innovators, asserted there was not a need for the Agency to conduct condition S1d runs at night. Both groups referred to an accident analysis that showed the percentage of pedestrian impacts with vehicle obstacles present is low and therefore suggested that NHTSA eliminate the nighttime assessment of this scenario.

Response to Comments and Agency Decisions

The Agency plans to adopt specific test conditions from the S1 and S4 test scenarios included in its 2019 PAEB test procedure for NCAP's PAEB assessments. In particular, the Agency is adopting S1a, S1b, S1d, and S1e for crossing path conditions and S4a and S4c for in-path conditions. NHTSA will perform assessments for each of these test conditions in both daylight and darkness.

The Agency recognizes that this decision conflicts with IIHS's request that NHTSA consider removal of select test conditions, notably S1a, S1d, and S4c, because they are performed by IIHS. While NHTSA suggests that consumers review all available,

[236] *https://www.regulations.gov/comment/NHTSA-2021-0002-4068.* ''Of 186 systems on vehicles from 29 automakers that we examined in 2021, 46% were superior, 34% were advanced, 5% were basic, 1% received no credit, and 13% were not available with pedestrian detection. Of those rated advanced or superior, 68% were standard equipment rather than optional features. Systems receiving a superior rating can avoid or substantially reduce the impact speed in almost all, if not all, three scenarios.''

reputable safety information to make purchasing decisions, the Agency's safety information program should be informative enough to stand alone. Since NHTSA cannot guarantee that any information currently available from other entities will remain available in the same capacity indefinitely, the Agency should not omit certain test conditions simply because comparable ratings information is currently provided by another consumer program. However, NHTSA has decided to omit a few of the test conditions it proposed in its RFC from NCAP's final PAEB test matrix based on comments received and recent Agency research.

S1 Test Conditions

As noted earlier, in 12 percent of pedestrian crashes involving injuries and 42 percent of crashes involving pedestrian fatalities, a light vehicle is traveling straight while a pedestrian enters the vehicle's path from either the left or right side.[237] These real-world crashes can be represented by the S1 crossing path scenario. More specifically, the S1a–c test conditions involve an adult pedestrian walking into the roadway and into the SV's path from the right side. For each of these three S1 test conditions, S1a, S1b, and S1c, the pedestrian mannequin begins its crossing maneuver at different times prior to collision, thus resulting in 25, 50, and 75 percent overlap, respectively, with the vehicle's front end.

Several commenters suggested that NHTSA include the 25 and 75 percent overlap assessments only (*i.e.,* S1a and c, respectively). Euro NCAP assesses vehicles in these two test conditions, represented by their Car-to-Pedestrian Nearside Adult 25 percent (CPNA–25) and Car-to-Pedestrian Nearside Adult 75 percent (CPNA–75) conditions, and does not perform a CPNA test at 50 percent overlap. Commenters stated that the 25 and 75 percent overlap conditions sufficiently cover the 50 percent overlap condition, making the S1b assessment superfluous. However, this assertion was not found to be accurate in the Agency's model year 2021–2022 research testing. One vehicle contacted the pedestrian mannequin in the S1b test at 60 kph (37.3 mph) but did not contact the mannequin for any of the other test speeds included for either the S1a or S1c conditions during daylight testing. Thus, if the Agency had not conducted S1b for this vehicle, the failure would not have been captured. Additionally, for a second vehicle, contact was observed at 50 kph (31.1 mph) in the S1b test conducted during daylight but was not observed until 60 kph (37.3 mph) in the S1a test. Similarly, during darkness testing with lower beam headlamps, three vehicles subjected to the S1b test condition contacted the pedestrian mannequin at 50 kph (31.1 mph), whereas contact was not observed for the S1a test condition until 60 kph (37.3 mph). Given these findings, it is beneficial to adopt the S1b test condition.

The Agency is also retaining the S1a condition from its proposal because doing so should ensure the system has an adequate operational field of view and is able to identify pedestrians that are not at the center of the travel path. In addition, this test condition was generally found to be more stringent, as several commenters suggested, with the only exceptions observed being the two vehicles previously mentioned for the S1b test. Although IIHS also performs tests that correspond to NHTSA's S1a test, adopting this test condition for NCAP would be advantageous at this time given the results observed during the Agency's model year 2021–2022 research testing. Specifically, only four of the twelve vehicles tested were able to avoid contacting the pedestrian mannequin for every test speed assessed for the S1a test condition in daylight. This number was reduced to two during darkness testing with lower beam headlamps, with performance degradation generally beginning around 40 kph (24.9 mph). While these results show this condition may be challenging for current PAEB systems, they also show that passing performance is practicable for all adopted test speeds.

Although NHTSA has decided to retain the S1a and S1b test conditions for NCAP PAEB testing, it does not plan to adopt the S1c test condition (*i.e.,* Euro NCAP's CPNA–75 test). Because of the larger amount of overlap at the point of impact (75 percent) for the S1c condition, the vehicle is afforded an increased amount of time for the PAEB system to sense and react to the crossing pedestrian. NHTSA's model year 2021–2022 research testing showed that vehicles which contacted the pedestrian mannequin in the S1c test condition also contacted the mannequin in either S1a or S1b at the same speed or at a lower speed for both daylight and darkness testing. Therefore, the Agency agrees with those commenters that stated that S1c is the least stringent of the S1a–c crossing path test conditions. The Agency also acknowledges Toyota's recommendation that it should seek to reduce test burden in situations where it can remove a test condition and still ensure adequate performance across a range of conditions. Since system performance observed for the 75 percent overlap condition appears to be sufficiently addressed by the 25 percent and 50 percent overlap conditions, NCAP sees no need to also adopt the S1c test condition.

The Agency has also decided to adopt the S1d test condition, which was particularly challenging for vehicles in the Agency's recent testing series. Because the child mannequin emerges from behind an obstruction (parked vehicle along the SV's path), the SV's PAEB system has less time to detect and react to the pedestrian. No vehicle out of the 12 tested in the model year 2021–2022 test series achieved full avoidance for every test speed assessed for this test condition in either daylight or dark lighting condition. For daylight testing, four vehicles contacted the pedestrian mannequin in the first trial for the 60 kph (37.3 mph) test at a speed less than 50 percent of the initial speed (less than 30 kph, or 18.7 mph), but none demonstrated full avoidance in at least three of the four retrials. However, three vehicles were able to repeatedly avoid contact up to and including 50 kph (31.1 mph). An additional vehicle contacted the pedestrian mannequin at 10 kph (6.1 mph) in daylight but avoided contacting again until the 60 kph (37.3 mph) test was conducted. Most often, for the other vehicles in the test series, performance degradation at higher speeds began occurring around 40 kph (24.9 mph) during the daylight runs. During darkness testing, no vehicle was able to achieve full avoidance for three or more trials at test speeds of 40 kph (24.9 mph) or greater. Five vehicles exhibited contact with the pedestrian mannequin at the lowest test speed of 10 kph (6.1 mph). For the remaining seven vehicles, four contacted the mannequin with speed reductions of less than 50 percent at an SV initial speed of 40 kph (24.9 mph), two models contacted at 30 kph (18.6 mph), and one model contacted at 20 kph (12.4 mph).

While subpar performance was observed for the S1d test condition, there is merit in including it in NCAP's final PAEB test matrix for both daylight and dark lighting conditions. Several commenters mentioned that the real-world occurrence rate of this condition is relatively low in comparison to some of the other adopted test conditions, particularly with respect to the darkness variant. However, NHTSA notes that because of the shorter daylight time in fall and winter, it is possible for

[237] Yanagisawa, M., Swanson, E., Azeredo, P., & Najm, W.G. (2017, April), *Estimation of potential safety benefits for pedestrian crash avoidance/mitigation systems* (Report No. DOT HS 812 400), Washington, DC: National Highway Traffic Safety Administration.

children to be walking after events, such as an evening soccer practice, in relatively dark lighting conditions. It is important to adopt the S1d condition for NCAP testing since it involves a child pedestrian and is one with which current vehicles especially struggle. NHTSA received a substantial number of comments in response to the RFC regarding child safety.

Finally, NHTSA will adopt the test scenario S1e, which represents an adult pedestrian running into the vehicle's path from the far, or left-hand, side. NHTSA received few comments regarding the applicability of this test condition. During the Agency's model year 2021–2022 daylight testing series, two vehicles achieved full crash avoidance at all test speeds in the S1e condition, and an additional two only contacted the pedestrian mannequin during the 60 kph (37.3 mph) test speed. Nearly the same observations were made for the Agency's lower beam headlamp darkness testing; two vehicle models avoided contact with the pedestrian mannequin at all assessed test speeds, and one additional model only contacted the mannequin at the 60 kph (37.3 mph) test speed. Several vehicles that only experienced contact at higher test speeds during the S1b condition (where the pedestrian mannequin approaches the test vehicle from the right side at 50 percent overlap) did not perform as well for S1e, when the pedestrian entered at a faster speed from the left-hand side with the same overlap at the point of impact (50 percent). This was true for both daylight and darkness testing with lower beams.

It is critical to assess PAEB performance when the pedestrian is crossing from the left side as well as from the right, and while both walking and jogging. As several vehicles were able to perform well when subjected to the S1e condition in daylight, and two vehicles were able to provide complete avoidance for all test speeds in darkness with lower beams, NHTSA will include the S1e condition in NCAP at this time.

S4 Test Conditions

NHTSA has decided to include scenarios S4a and S4c in NCAP's updated test matrix for both lighting variants. The in-path scenario, S4, which includes test conditions S4a, S4b, and S4c, represents a pedestrian standing alongside the roadway facing away from the vehicle (S4a) or towards the vehicle (S4b), or walking along with traffic away from the vehicle on the side of the roadway with a 25 percent overlap (S4c). Overall, the S4 scenario comprises 5 percent of pedestrian crashes involving injuries and 19 percent of pedestrian fatalities.[238]

Regarding commenters' concerns surrounding redundancy between the proposed stationary mannequin conditions (*i.e.,* S4a and S4b), in its model year 2021–2022 research tests, NHTSA found that, when comparing daylight results for each vehicle, the S4a test condition, where the stationary mannequin was facing away from the SV, resulted in more frequent vehicle-to-pedestrian contact across the incremented test trials compared to the S4b test condition, where the stationary mannequin was facing toward the SV. This same trend was observed for the Agency's darkness testing. Given these findings, NHTSA agrees with commenters that adding both S4a and S4b test conditions is not necessary to achieve improved PAEB performance. Thus, the Agency has chosen not to adopt the seemingly less stringent test condition for the stationary mannequin, S4b, for NCAP to reduce testing burden.

While the Agency is removing one of the in-path stationary mannequin tests from NCAP's PAEB test matrix (*i.e.,* S4b), it will not remove both stationary mannequin conditions, as some commenters requested. The Agency agrees with NACTO that stationary pedestrians should be accounted for when conducting PAEB testing; consumers expect PAEB systems to operate regardless of the pedestrian's movement, or lack thereof. Testing using a stationary pedestrian may also help to mitigate crashes in which a law enforcement officer or other first responder is standing in the roadway. Based on the results of the Agency's model year 2021–2022 research testing, in-path assessments for both stationary and moving pedestrian mannequins are necessary to ensure robust PAEB system performance. When comparing daylight results from the S4a tests to those for S4c, five vehicles contacted the mannequin at the uppermost test speed (60 kph (37.3 mph)) when the pedestrian was stationary (S4a), but not when it was moving (S4c). Furthermore, four vehicle models contacted the mannequin at the lowest test speed (10 kph (6.2 mph)) for the moving mannequin test (S4c) but not for either stationary test (S4a or S4b). Similar findings were observed during the Agency's darkness testing. Results for the S4a stationary mannequin condition with lower beam headlamps showed contact at 60 kph (37.3 mph) for three vehicles which was not similarly observed for the moving pedestrian condition. Furthermore, at 10 kph (6.2 mph), seven vehicles contacted the moving mannequin target during the S4c darkness tests but did not contact the stationary mannequin target at this same test speed in the S4a tests. In addition, five of these seven vehicles exhibited no reduction in speed. This is concerning because, as the Agency has mentioned previously, even low-speed pedestrian crashes can be fatal. Further, as Subaru and others suggested, recent FARS data shows that the S4c test condition is representative of a common, fatal real-world crash. This is unsurprising since the pedestrian is facing away from the vehicle in these crashes and therefore may be unaware that a vehicle is approaching; if the driver of the vehicle is inattentive, it is even more likely that the vehicle may collide with the pedestrian. These results show that at very low and high speeds, PAEB systems may have trouble properly classifying moving and stationary pedestrians, respectively. Therefore, both stationary and moving targets should be assessed in NCAP's PAEB tests in daylight and dark lighting conditions and will proceed with adopting the S4a and S4c test scenarios accordingly.

Although many vehicles exhibited contact at higher and/or lower speeds for the S4a and S4c test conditions, three vehicles offered complete crash avoidance for all test speeds, up to and including 60 kph (37.3 mph) for both conditions during the Agency's daylight assessments, thus showing that robust performance is practicable. Further, although no vehicles were able to completely avoid contact with the pedestrian mannequin for all test speeds during darkness testing for the NCAP-adopted S4a and S4c scenarios, one vehicle only contacted the pedestrian mannequin at 10 kph (6.2 mph) for both conditions (*i.e.,* S4a and S4c). In fact, of the 10 vehicles exhibiting contact at 10 kph (6.2 mph) in at least one of the two S4 test conditions in dark lighting being adopted, four avoided contacting the mannequin again completely during higher-speed tests in the scenario and three avoided contact until 60 kph (37.3 mph). These results demonstrate the achievability of future iterations of PAEB systems to fully avoid pedestrians for in-path stationary and moving pedestrian test conditions during assessments in both daylight and dark lighting conditions, making adoption of scenarios S4a and S4c in NCAP's

[238] Yanagisawa, M., Swanson, E., Azeredo, P., & Najm, W. G. (2017, April), *Estimation of potential safety benefits for pedestrian crash avoidance/mitigation systems* (Report No. DOT HS 812 400), Washington, DC: National Highway Traffic Safety Administration.

updated test matrix reasonable for both lighting variants.

False Positive Test Conditions (S1f and S1g)

Regarding the false positive test conditions S1f and S1g, the Agency will not adopt these test conditions for NCAP's PAEB testing at this time. Despite the risk of drivers disabling PAEB if too many unnecessary activations occur, comments received regarding NCAP's inclusion of false positive testing negatively affecting system efficacy is also of concern, especially given the inherently vulnerable nature of those outside the vehicle. Data submitted by Toyota demonstrated that there is a potential overlap in the S1b and S1f cases up to 0.8 seconds TTC. As a result, systems may either falsely activate when it is not appropriate, or they may not activate when it is necessary to do so. Fewer false positive activations should not come at the expense of increased false negatives. Further, pedestrian behavior can be unpredictable, as Bosch noted. If there is a reasonable chance that the pedestrian will enter the vehicle's path, the vehicle's PAEB system should be prepared to react accordingly. The Agency reasons, as Intel suggested, that drivers will accept false activations in cases where the miss distance is small, especially at higher vehicle speeds, since the driver may not be certain that the individual will indeed avoid the vehicle's path. Additionally, NHTSA agrees that manufacturers have an interest in maintaining customer satisfaction. The lack of false positive testing does not prevent a manufacturer from optimizing its designs and improving sensor technology and system robustness. Nevertheless, the Agency plans to monitor real-world performance data to ensure that nuisance activations do not become problematic, especially given the numerous situations that may occur in the field. As mentioned for AEB, vehicles that have excessive false positive activations may pose an unreasonable risk to safety and, as such, may be considered to have a safety-related defect.

The Agency acknowledges that its decision not to add false positive tests for PAEB is a departure from its treatment of false positive testing for AEB. NHTSA expects that a vehicle should encounter near-miss pedestrians relatively less frequently than it encounters near-miss situations with other vehicles. Therefore, a deficient PAEB system design should produce fewer unnecessary activations than a deficient AEB system. However, it is the Agency's intent to periodically revisit its review of the crash problem and adjust scenarios and test conditions accordingly, not only for false positive testing and PAEB assessments but for all ADAS testing.

Need for PAEB Assessments in Daylight and Dark Lighting Conditions

Given the significant safety need described earlier in this notice, the proven feasibility of conducting PAEB testing in dark lighting conditions, and the ability for current systems to meet requirements, assessments in both daylight and dark lighting conditions are suitable for the adopted NCAP PAEB test conditions.

For the adopted S1 crossing path test conditions (*i.e.,* S1a, S1b, S1d, and S1e), one vehicle in the Agency's model year 2021–2022 research testing was able to achieve full crash avoidance from 10 kph to 60 kph (6.2 mph to 37.3 mph) in all but one test condition, S1d, during testing in both daylight and dark lighting conditions using the vehicle's lower beam headlamps. For the S1d dark lighting test condition, the vehicle afforded full crash avoidance up to and including 30 kph (18.6 mph). Additionally, although eight of the 12 vehicles contacted the pedestrian mannequin in each of the four crossing path conditions being adopted for NCAP's assessments in dark lighting conditions, three of these eight were able to achieve full avoidance in at least one crossing path test condition during daylight testing. These results show that excellent PAEB response in S1 dark lighting test conditions can be achieved, like those observed for testing in daylight, but for many vehicle models, there are further gains to be made specifically for PAEB performance under dark lighting conditions.

For the adopted S4 in-path conditions and test speeds (*i.e.,* S4a and S4c), five of the 12 models were able to fully avoid the mannequin target during daylight testing for at least one in-path condition; three of these five afforded full crash avoidance for both S4a and S4c test conditions. While none of the vehicles achieved full crash avoidance in either of the two adopted in-path test conditions during testing in the dark lighting condition using the vehicle's lower beam headlamps, many performed well between 20 kph and 50 kph (12.4 mph and 31.1 mph) for both S4 test conditions. Furthermore, although eight out of 12 vehicle models failed to avoid the pedestrian mannequin in the S4c test condition at 10 kph (6.2 mph) in the dark lighting condition (with lower beam headlamps), only five of these same models failed this test condition variant during the corresponding tests in daylight. These results suggest that robust performance is achievable in both daylight and darkness assessments for the selected in-path test conditions; however, performance in one lighting condition does not necessarily translate to the other lighting condition.

While the Agency acknowledges that its model year 2021–2022 PAEB testing demonstrated that current systems provided wide-ranging system capabilities during darkness testing for the adopted test conditions, it sees no reason to reduce the test matrix for testing in dark lighting condition, other than for the speed maximum speed to be assessed for the S1d condition, as will be discussed in the next section. NHTSA's research test results suggest that installation of improved sensing capabilities should allow for improved nighttime PAEB performance that more closely mirrors the performance observed during daylight. Further, the Agency reasons there is no reason to conduct only testing in darkness and forgo testing in daylight. As mentioned earlier, a significant number of pedestrian crashes occur in both lighting conditions. As such, the Agency must ensure system changes made to improve performance in darkness do not affect performance in daylight, and vice versa. In addition, because of the vast differences in current PAEB system capabilities, it is most reasonable to offer PAEB credit for performance in daylight separate from that of performance in darkness. By proceeding in this manner, the Agency expects it can more quickly award partial PAEB credit to current systems that may require relatively minor changes (*i.e.,* to software) to perform successfully for all test variants in daylight.

2. Test Speeds

Like its plan for AEB, NHTSA proposed to assess PAEB system performance over a range of test speeds for each of the test scenarios considered for inclusion. Specifically, NHTSA proposed to increase the SV test speed in 10 kph (6.2 mph) increments from a minimum test speed of 10 kph (6.2 mph) to a maximum test speed of 60 kph (37.3 mph) for each test condition, performing one trial per speed. To achieve a passing result for each speed, the Agency stipulated that the test trial must be valid (all test specifications and tolerances satisfied), and the SV must not contact the pedestrian mannequin. As will be discussed later, similar to its research testing of model year 2021 and 2022 vehicles, the Agency further suggested that it would conduct up to four additional trials for any specific test speed that resulted in a test failure (*i.e.,* contact) as long as the SV had a relative velocity at impact equal to or less than 50 percent of the initial SV test speed. In such instances, NHTSA proposed that the SV must not contact the pedestrian mannequin for at least three out of the five total trials conducted to pass the test condition (*i.e.,* combination of test scenario and test speed).

The Agency believed it was appropriate to increase the maximum SV test speed from the 40 kph (24.9 mph) specified in its 2019 PAEB test procedure to 60 kph (37.3 mph) for all PAEB test conditions proposed for inclusion in NCAP for several reasons. First, as detailed in the real-world data section earlier, NHTSA reasoned that adopting a higher maximum PAEB test speed was necessary to drive improved PAEB system performance and address a larger portion of real world injuries and fatalities.[239] Second, the Agency found that performing PAEB testing at 60 kph (37.3 mph) was reasonable, as NHTSA's model year 2019–2020 (and subsequent model year 2021–2022) research testing showed that robust PAEB system performance across various test conditions was achievable at this higher test speed. Further, Euro NCAP prescribes a maximum vehicle speed of 60 kph (37.3 mph) in its PAEB testing for test conditions similar or identical to those proposed; in particular, S1a, S1c, S1d, S1e and S4c. Harmonizing test speeds with Euro NCAP should reduce manufacturer burden while also fulfilling mandates stipulated in the Bipartisan Infrastructure Law, which requires that the Agency take steps to harmonize with existing consumer information rating programs where possible and when appropriate.

The Agency's reasons for proposing the minimum test speed of 10 kph (6.2 mph) for the planned PAEB test conditions were similar to those used to justify the proposed maximum test speed: harmonization and real-world relevance. Although the minimum test speed proposed is lower than the minimum speed prescribed in NHTSA's 2019 PAEB test procedure and in its characterization testing (*i.e.,* 16 kph (9.9 mph)), the Agency noted that it aligns with the minimum test speed specified in Euro NCAP's pedestrian tests, except for Euro NCAP's Car-to-Pedestrian Longitudinal Adult (CPLA) scenario. The minimum vehicle test speed for the CPLA scenario, which is similar to the Agency's PAEB S4c test condition, is 20 kph (12.4 mph). NHTSA also believed that reducing the minimum test speed to 10 kph (6.2 mph) would ensure PAEB system functionality for very low speed crashes that may still cause injuries. Such injuries incurred from low-speed pedestrian collisions often result from secondary impacts with the ground.

NHTSA also proposed to adopt Euro NCAP's approach to assessing vehicles' PAEB system performance by incrementally increasing the SV speed from the minimum test speed for a given scenario to the maximum. The Agency reasoned that such an approach would (1) harmonize with other consumer information programs on vehicle safety, (2) address comments received in response to NHTSA's December 2015 notice to expand the applicability of PAEB tests to include a broader range of test speeds, thus addressing a broader range of crash speeds driving pedestrian injuries and fatalities, and (3) ensure future PAEB systems effectively manage the inherent trade-off between a wider field-of-view needed for lower speed impacts and a narrower field-of-view necessary for distance detection in higher speed crashes. The Agency proposed 10 kph (6.2 mph) increments for the test speed progression.

The Agency sought comment on whether the proposed speeds and overall assessment approach were appropriate or whether alternatives should be considered.

Summary of Comments

Many commenters agreed with the Agency's plan to set lower and upper bounds for SV test speed in PAEB testing to 10 kph (6.2 mph) and 60 kph (37.3 mph), respectively. Toyota, Advocates, MEMA, NYC DOT/NYC DCAS Vision Zero Task Force, IDIADA, AAA, ASC, FCA, Rivian, Uhnder, BMW, Intel, HATCI, and ZF Group stated that this range of speed was appropriate. Some of those in favor mentioned that this speed range is representative of urban driving conditions to which pedestrians are typically exposed (roads with speed limits of 35 mph or less) (NYC DOT/NYC DCAS Vision Zero Task Force, IDIADA, ASC, Uhnder, and Intel). Others (FCA and Rivian) noted that this speed range would lessen the testing burden for manufacturers because it aligns with Euro NCAP's PAEB speed range. Advocates, AAA, and Rivian cited the need to ensure that the technology works across a spectrum of vehicle speeds to address both lower- and higher-speed pre-impact scenarios, but Advocates added that NHTSA should continue to evaluate whether the proposed speed ranges will be adequate to protect all VRUs.

Although Toyota agreed with the test speed range proposed by the Agency, it noted that physical intervention at higher speeds may interfere with a driver's ability to intentionally maneuver to avoid the collision since the vehicle must begin braking earlier. In addition, Toyota suggested that if there is a test speed (or subgroup of speeds) at which system performance is most representative of the entire speed spectrum, testing at that speed would be the most preferable solution as it would be the most efficient method to disseminate information to the public. Auto Innovators and GM also remarked that tests with SV speeds higher than 60 kph (37.3 mph) are more likely to damage test equipment. State Farm was generally supportive of higher vehicle speeds and conditions representative of real-world cases.

Minimum Test Speed Changes

A few commenters disagreed with the lower boundary of NHTSA's proposed speed range. GM requested that the Agency begin testing PAEB S1 and S4 scenarios at 20 kph (12.4 mph). The automaker noted that the speed range of 20 kph (12.4 mph) to 60 kph (37.3 mph) is supported by other global consumer metrics and is referenced in a NHTSA-supported project.[240] Auto Innovators and Honda requested that NHTSA allow vehicle manufacturers to select the minimum speed for PAEB testing, reasoning that modern AEB sensors are designed to prioritize functionality at higher, more injurious speeds. Since the speed differential between the SV and the pedestrian is lower at lower speeds, the pedestrian enters the AEB sensor field-of-view at a wider angle than at higher speeds. IDIADA also echoed this sentiment. Both groups noted that Euro NCAP and Japan New Car Assessment

[239] The Agency hesitated to draw conclusions based solely on the travel speed data due to its significant limitations. The travel speed was either not reported or was unknown in 59 percent of fatal pedestrian crashes and 72 percent of pedestrian crashes that resulted in injuries. That being said, this data did show similar trends to that observed for posted speeds. For crashes that occurred on roadways where the travel speed was known, 14 percent of pedestrian fatalities and 70 percent of pedestrian injuries were reported for travel speeds of 40.2 kph (25 mph) and less, whereas 36 percent of fatalities and 85 percent of injuries occurred for travel speeds of 60 kph (37.3 mph) and less. Like the posted speed data, the known travel speed data, although limited, also showed that adopting the higher maximum test speed of 60 kph (37.3 mph) would allow the Agency to capture additional fatalities and injuries, 21 percent and 15 percent, respectively.

[240] Carpenter, M.G., Moury, M.T., Skvarce, J.R., Struck, M. Zwicky, T.D., & Kiger, S.M. (2014, June), *Objective tests for forward looking pedestrian crash avoidance/mitigation systems: Final report* (Report No. DOT HS 812 040), Washington, DC: National Highway Traffic Safety Administration.

Program (JNCAP) allows manufacturers to select the minimum speed.

Maximum Test Speed Changes

The upper speed range was also questioned by several commenters. Vision Zero Network, NTSB, CAS, League of American Bicyclists, and a number of individuals commented that they would like the Agency to run PAEB testing at speeds higher than 60 kph (37.3 mph). NTSB disagreed with NHTSA regarding its logic for selecting the upper test speed, stating that test specifications should not be based on current system capabilities but instead should drive systems toward ideal performance. CAS suggested that NHTSA determine the upper limits for each model's PAEB system to discourage designing to the test and to allow consumers to identify vehicles with superior performance. Vision Zero Network cited an IIHS study which found that PAEB is not efficient in areas with speed limits of 80.5 kph (50 mph) or greater. The League of American Bicyclists did not provide a preferred upper speed limit; however, the advocacy group did provide pedestrian fatality data to support upper speeds anywhere from 56.3 kph (35 mph) to 88.5 kph (55 mph). Advocates, while supporting the speed range overall, also suggested that NHTSA evaluate whether the upper test speed limit is sufficient to capture the full range of real-world incidents. ZF Group supported increasing the test speed for test scenario S4c up to 80 kph (49.7 mph), as it could evaluate system capability in a pre-crash scenario involving a pedestrian walking along a rural road or highway with a higher speed limit. Comments from individuals were mostly in favor of increasing the speed range to anywhere from 64.3 kph (40 mph) to 120.7 kph (75 mph).

Incremental Speed Changes

Regarding speed intervals between the minimum and the maximum, some (HATCI, ZF Group, and one individual) specifically offered support for 10 kph (6.2 mph) speed intervals. ASC recommended that NHTSA use three test speeds to evaluate the range of performance more efficiently: 10 kph (6.2 mph), 35 kph (21.7 mph), and 60 kph (37.3 mph). Adasky suggested that NHTSA drop to three test speed increments instead of six to allow resources to test a wider range of scenarios.

Response to Comments and Agency Decisions

NHTSA will begin testing for each of the adopted PAEB test conditions at a minimum SV speed threshold of 10 kph (6.2 mph) and will increase the SV speed in 10 kph (6.2 mph) increments until a maximum speed threshold is reached, as long as the test vehicle does not make contact with the pedestrian mannequin during each progressive speed tested. For test conditions S1a, S1b, S1e, S4a, and S4c, the Agency is adopting a maximum SV speed threshold of 60 kph (37.3 mph) for both daylight and dark testing. For test condition S1d, the Agency is adopting a maximum SV speed threshold of 60 kph (37.3 mph) for daylight testing and 40 kph (24.9 mph) for dark testing. Travel speeds adopted for the pedestrian mannequins align with those proposed—5 kph (3.1 mph) for the walking adult test conditions (S1a, S1b, and S4c) and the running child test condition (S1d), 8 kph (4.9 mph) for the running adult test condition (S1e), and 0 kph (0 mph) for the standing adult test condition (S4a). Should vehicle-to-mannequin contact occur at any speed, the test laboratory will discontinue the PAEB test series for the relevant lighting condition.

Citing real-world relevance, testing feasibility, and reduced test burden due to harmonization, commenters generally favored the lower speed threshold (*i.e.,* 10 kph (6.2 mph)) proposed by NHTSA. A few commenters, however, requested that NHTSA adopt an alternative minimum speed threshold, either one dictated by vehicle manufacturers' preference or 20 kph (12.4 mph) to align with other consumer testing programs. NHTSA reasons it is inappropriate to allow vehicle manufacturers to select the minimum speed for testing simply because some vehicles may currently prioritize functionality at higher, more injurious speeds, as Honda and Auto Innovators asserted. A vehicle striking a pedestrian at low speeds, such as 10 kph (6.2 mph), can still result in serious injuries or a fatality. Also, the minimum PAEB test speed of 10 kph (6.2 mph) is acceptable for NCAP's test matrix because it aligns with the lower-most test speed utilized by Euro NCAP for its CPNA, CPNCO, and CPFA tests, which are comparable to the Agency's S1a and S1c, S1d, and S1e tests, respectively.[241] Adopting a minimum speed threshold of 10 kph (6.2 mph) allows the Agency to best achieve its goal to pursue harmonization, where reasonable, to reduce manufacturer burden and better fulfill the BIL's mandate that NHTSA consider the benefits of consistency with other U.S. and international rating systems.

The Agency is also selecting 10 kph (6.2 mph) as the minimum speed threshold because system performance at speeds below 10 kph (6.2 mph) does not appear to be practical at this time. The Agency's recent research testing for model year 2021 and 2022 vehicles showed that many vehicles were unable to prevent contact with the SV at 10 kph (6.2 mph), even though these same models achieved acceptable performance at incrementally higher test speeds (*i.e.,* 20, 30, 40 kph (12.4, 18.6, 24.9 mph), etc.). This was observed for each of the various test conditions and lighting specifications.

NHTSA is establishing a maximum speed threshold of 60 kph (37.3 mph), as proposed, for nearly all of the test conditions adopted herein, with the exception of S1d testing conducted in darkness. A 60 kph (37.3 mph) upper speed limit is generally appropriate for several reasons. Adopting this speed for the upper limit of the test speed range would permit safe test conduct and repeatability, as the pedestrian surrogates the Agency plans to use for testing allow impact speeds of 60 kph (37.3 mph). As mentioned above, a 60 kph (37.3 mph) SV speed is also consistent with that prescribed in Euro NCAP's AEB/LSS VRU systems test protocol for the comparable AEB test conditions (*i.e.,* CPFA, CPNA, CPNCO, and CPLA).[242] In addition, adopting a 60 kph (37.3 mph) upper limit for the SV speed range allows the Agency to mitigate a large portion of the safety problem involving pedestrians. Recall that nearly 40 percent of all pedestrian fatalities and approximately three out of four pedestrian injuries occur in areas where the posted speed limit is 60 kph (37.3 mph) or lower.[243]

A 60 kph (37.3 mph) maximum speed threshold has also proven practical for most of the PAEB test condition variants. The Agency's recent model year 2021–2022 research testing showed that while PAEB performance was generally inconsistent across the tested fleet, particularly for higher test speeds and dark conditions, at least one vehicle was able to completely avoid contacting the pedestrian mannequin at all test speeds from 10 kph (6.2 mph) up to and including 50 kph (31.1 mph) *and* exhibited a speed reduction greater than 50 percent at 60 kph (37.3 mph) for all but one of the adopted test condition

[241] Euro NCAP prescribes a 20 kph (12.4 mph) lower speed threshold for its CPLA scenario, which is comparable to NHTSA's S4c test.

[242] European New Car Assessment Programme (Euro NCAP) (December 2023), *Test Protocol—AEB/LSS VRU systems, Version 4.5.*

[243] See ''Linking Proposed PAEB Test Scenarios with Real-World Crashes'' section of this notice.

variants, S1d in darkness. For the S1d dark lighting variant, four vehicles were able to prevent contact with the test vehicle at all test speeds from the minimum test speed of 10 kph (6.2 mph) up to and including 30 kph (18.6 mph); however, when tested in darkness at 40 kph (24.9 mph), only two of these four vehicle models offered a speed reduction greater than 50 percent. As such, the next incremental test speed, 50 kph (31.1 mph), was not assessed to prevent damage to the test vehicle and equipment.

Given these findings, a 60 kph (37.3 mph) upper speed limit is practical for current NCAP evaluation for all test condition variants except for the S1d darkness variant. By adopting 60 kph (37.3 mph) for the upper bound of the SV speed range, the Agency reasons it will mitigate as much of the safety problem as possible while not compromising test repeatability and safe test conduct. While NHTSA acknowledges that no one vehicle was able to provide complete crash avoidance for each of the test variants adopted herein, test vehicles' aggregate performance for available production PAEB systems is not indicative of shortcomings in the overall capability of PAEB technology. Instead, current systems are simply designed to meet a lower level of performance. It is noteworthy that IIHS's analogous testing for the S1d condition, the perpendicular child scenario, is currently conducted at 20 kph and 40 kph (12.4 mph and 24.9 mph), whereas the Agency is adopting test speeds for daylight testing ranging from 10 to 60 kph (6.2 to 37.3 mph) for this test condition.[244] As such, the Agency reasons further improvements in PAEB system performance are possible as manufacturers optimize perception system hardware and software to meet the requirements stated in this notice. NHTSA observed a similar trend with the deployment of AEB technology approximately six years ago, when performance was inconsistent in NCAP for its AEB scenarios. AEB systems failed to meet all performance levels established for NCAP at that time, but AEB performance quickly improved as manufacturers updated and improved system software.

For the S1d darkness variant, it is appropriate to adopt an upper speed threshold of 40 kph (24.9 mph) at this time. While no vehicle was able to prevent contact with the pedestrian mannequin for this test variant during NHTSA's recent research testing at this test speed, two vehicle models provided a significant speed reduction (*i.e.,* a speed reduction greater than 50 percent of the initial SV speed). Furthermore, the Agency recognizes, as mentioned earlier, that this test condition is performed by Euro NCAP at 60 kph (37.3 mph) at night, albeit with overhead lights in addition to the vehicle's lower beam headlamps. Therefore, it is practical, given minor software changes to improve system performance, for future iterations of existing systems to prevent contact with the pedestrian mannequin at a 40 kph (24.9 mph) test speed during S1d assessments in dark lighting conditions that utilize only vehicles' lower beam headlamps. As systems exhibit improved performance during testing, the Agency may then consider increasing the upper test speed for this test variant as part of future updates to the program.

NHTSA acknowledges that there were a fair number of commenters who asserted that it should perform PAEB testing at speeds exceeding 60 kph (37.3 mph) (*i.e.,* at speeds ranging from 80 kph (49.7 mph) to 120.7 kph (75 mph)). These commenters cited the ineffectiveness of current PAEB systems at higher speeds as well as pedestrian injury and fatality data that shows a safety need to curtail pedestrian-involved crashes at speeds exceeding the upper limit proposed by NHTSA. As mentioned, NTSB and CAS also encouraged NHTSA not to limit assessments to lower maximum speed thresholds dictated by current (NTSB) or average (CAS) system capabilities. Instead, these commenters suggested that NHTSA set upper test speed limits to drive system capabilities to meet ideal performance expectations or to identify superior performing systems.

While there is merit to these suggestions and underlying rationale, NHTSA reasons that, given other decisions it is making to increase the stringency of its proposal, adopting a maximum speed of 60 kph (37.3 mph) for the selected PAEB test scenarios is appropriate at this time. As detailed later, NHTSA has decided to implement a testing approach that requires (1) no contact with the pedestrian mannequin to prevent real-world injuries and (2) no repeated trials at a given test speed to ensure system robustness. Furthermore, a vehicle will not receive credit for passing NHTSA's PAEB test protocol unless it is able to meet these performance requirements for all test speeds across all test conditions for a given lighting condition. As evidenced in NHTSA's recent research testing, few PAEB systems were able to meet these requirements; therefore, it is expected that many may not receive PAEB credit for several years after the program changes take effect. Yet, it is important that NCAP provides consumers with useful information to guide their purchasing decisions. Steps taken to further increase the stringency of PAEB testing at this time will likely thwart this goal. Furthermore, the Agency should assess the implications of the anticipated changes on overall fleet performance to limit the effect of any unintended consequences before adopting more rigorous requirements. For instance, as Toyota noted, system intervention at high speeds may impede the driver's response to an impending collision. In addition, the Agency recognizes that, given PAEB system capabilities for the current vehicle fleet, increasing test stringency too quickly may spur an increase in false positives and thus consumer dissatisfaction. NHTSA expects that future system designs may include the use of long range lidar or other technology, which should improve overall system performance. As the state of technology advances, the Agency may consider raising the maximum test speed for one or more of the PAEB test condition variants (*e.g.,* S4c in darkness) as part of future program enhancements upon conducting additional research to assess test feasibility, system advancements, and re-evaluation of the safety problem.

The Agency also recognizes it is not feasible to proceed as Toyota suggested and select one test speed (or a subgroup of speeds, which other respondents also suggested) that would be most representative of system performance. While these alternative approaches may improve testing efficiency in one regard, since fewer runs would be required, they may also hinder it in another. If the Agency were to select one ''representative'' speed for testing, it would choose the highest speed since it would generally be expected to be the most stringent and the one most likely to discern system performance for more injurious and fatal pedestrian crashes. However, evaluating system performance at only the highest test speed instead of at an incremental progression of speeds places both test equipment and the SV at greater risk for damage. Damage to test equipment or test vehicles not only introduces costly repairs but also delays testing. On the other hand, incrementally increasing speeds should often, though not always, reveal performance degeneration at more moderate speeds, thus limiting overall risk during testing and improving test efficiency. NHTSA also

[244] Insurance Institute for Highway Safety (IIHS) (January 2024), *Pedestrian Autonomous Emergency Braking Test Protocol, Version IV.*

reasons that conducting several additional runs for each test condition will have little impact on overall test efficiency or burden and seems inconsequential when considering the benefits ensuing from ensuring system robustness. An incremental testing approach should adequately ensure that PAEB systems which receive NCAP credit for passing requirements offer equivalent performance (*i.e.,* no contact) across a range of speeds, as several commenters suggested. This is particularly important since pedestrians, who lack inherent protection from an impacting vehicle, may incur injuries and fatalities even at low vehicle speeds. However, NHTSA's latest research testing showed that not all PAEB systems that provide passing performance at higher speeds also perform well at lower speeds. As mentioned, some vehicles' systems failed to activate at speeds of 10 kph (6.2 mph) but prevented SV-to-pedestrian mannequin contact at many higher test speeds, including the highest test speed assessed for a particular condition. The Agency also asserts that an incremental testing approach is appropriate for NCAP's PAEB assessments because it aligns with that adopted for the program's AEB tests and the testing methodology employed by Euro NCAP for its comparable VRU testing. Notwithstanding, NHTSA may also consider a reduction in the number of speed increments in the future, as Adasky suggested, if it looks to add test scenarios or conditions to the PAEB test matrix and fleet performance for PAEB systems has generally improved.

As the Agency did not receive comments on the proposed walking and running speeds of the pedestrian mannequins stipulated for each test condition, it will adopt the speeds proposed. For the walking adult test conditions (S1a, S1b, and S4c) and the running child test condition (S1d), NHTSA is adopting a pedestrian mannequin speed of 5 kph (3.1 mph). For the running adult test condition (S1e), the pedestrian mannequin speed will be 8 kph (4.9 mph), and for the standing adult test condition (S4a), the pedestrian mannequin will be stationary (*i.e.,* 0 kph (0 mph)). These speeds are consistent with those used in NHTSA's PAEB characterization study, the 2019 draft NHTSA PAEB test procedures, and Euro NCAP's AEB/LSS VRU systems test protocol for the comparable test conditions.[245] They were also determined to be appropriate for PAEB testing based on research conducted by Directorate-General for Research and Innovation and published in 2014.[246]

3. PAEB Testing in Darkness—With Lower Beams and Use of Advanced Lighting Systems; With Upper Beams, in Lieu of or in Addition to Lower Beams, and With Overhead Lights; Other Technologies To Evaluate in Dark Lighting Conditions

To evaluate PAEB performance in darkness, NHTSA planned to perform all proposed scenarios with the lower beam headlamps as the only source of illumination. However, if the vehicle is equipped with advanced lighting features, such as semiautomatic headlamp beam switching, adaptive driving beam (ADB), and/or high beam assist (HBA) headlighting systems, the Agency noted that these features would be engaged to function during the test as well. NHTSA requested comment on whether such a testing approach (*i.e.,* a lower beam assessment that only allows automatic engagement of advanced lighting systems) was appropriate or whether it should additionally, or alternatively, consider testing in darkness that would allow manual activation of a vehicle's upper beams. In seeking comment on upper beam headlamp assessments, NHTSA noted that it is not guaranteed that upper beam headlamps will be used during real-world nighttime driving since the driver may need to manually activate them.

NHTSA also asked whether it should utilize a secondary overhead lighting source, such as overhead streetlights, during PAEB testing. Overhead lighting is common in urban and suburban areas but scarcer along rural roads and highways. NHTSA notes that Euro NCAP's nighttime PAEB protocol specifies the use of overhead lighting for scenarios CPNA–25, CPNA–75, CPNCO–50, and CPFA–50 (which are similar to U.S. NCAP's S1a, S1c, S1d, and S1e, respectively) with the SV's lower beams activated. Euro NCAP's nighttime in-path scenario, the CPLA scenario (25 and 50 percent overlaps), which is similar to U.S. NCAP's S4c test, is performed with no overhead lighting and with the SV's upper beams engaged. As previously mentioned, NHTSA performed limited PAEB testing in darkness using lower beam headlamps and overhead streetlights, and the resulting data indicated only a slight improvement in PAEB system performance with overhead lighting compared to no overhead lighting.

In devising its proposal, NHTSA reasoned that testing with the SV's lower beams engaged without overhead lights represents the presumed worst-case, real-world scenario, particularly at higher test speeds. Conditions such as these represented 36 percent of pedestrian fatalities, with 39 percent of fatalities in pedestrian crashes associated with low light conditions with overhead lights per FARS data from 2011–2015.[247] The Agency reasoned that PAEB systems that meet the performance test specifications under dark lighting conditions with no overhead lights are likely to meet the performance specifications under dark lighting conditions with overhead lights, effectively addressing both conditions. NHTSA believed that assessing vehicles in the proposed manner (*i.e.,* under dark conditions with no overhead lights and with the vehicle's lower beams) would encourage vehicle manufacturers to make design improvements to address a significant portion of crashes that currently result in pedestrian fatalities.

Beyond its current and proposed procedures, the Agency also sought further comment on (1) other technologies in development which may mitigate the significant nighttime pedestrian crash problem and (2) information available for evaluation under dark lighting conditions.

Summary of Comments

Use of High Beam, Low Beam, and/or ADB/Advanced Lighting Features

Some respondents favored testing vehicles in dark lighting conditions utilizing lower beams only (*i.e.,* with no advanced lighting system enabled), regardless of the scenario. Lidar Coalition, Velodyne, NYC DOT/NYC DCAS, Aptiv, and one individual suggested that the theoretical worst-case scenario would be the one with the least illumination. Lidar Coalition stated that this test procedure specification was ''critical'' because each technology used for detecting pedestrians has its own advantages and limitations. The group said that these procedures would drive the need for updated sensor types that achieve good performance across all driving conditions, particularly ones in which the human eye fails to identify a pedestrian. Velodyne provided data to support the Agency's accounting for scenarios where current systems

[245] European New Car Assessment Programme (Euro NCAP) (December 2023), *Test Protocol—AEB/LSS VRU systems, Version 4.5.*

[246] *https://cordis.europa.eu/docs/results/285/285106/final1-aspecss-publishable-final-report-2014-10-14-final.pdf* at pg. 19.

[247] Swanson, E., Foderaro, F., Yanagisawa, M., Najm, W. G., & Azeredo, P. (2019, August), *Statistics of light-vehicle pre-crash scenarios based on 2011–2015 national crash data* (Report No. DOT HS 812 745), Washington, DC: National Highway Traffic Safety Administration.

underperform; the Governor's Highway Safety Association (GHSA) found that 75 percent of pedestrian fatalities occur at night. NYC DOT/NYC DCAS noted that in NHTSA's testing, vehicles were repeatedly able to avoid crashing into the pedestrian mannequin while utilizing only the vehicle's lower beams, indicating that it is possible to achieve this level of performance. Aptiv suggested that vehicles should not be tested with any advanced lighting features enabled because they can be disabled by the consumer. In light of this, the commenter deduced that vehicles would be evaluated on a level playing field if no advanced lighting systems are enabled. One commenter, Vayyar, suggested that NHTSA run a test with no headlamp illumination at all, stating this will allow NHTSA to evaluate how well PAEB sensors work in total darkness.

There were also commenters, however, that recommended testing vehicles using the vehicle's lower beams along with advanced lighting systems in certain instances. Some reasoned that advanced lighting systems should only be used when they are enabled by default or enabled at key-on. CAS, Advocates, Tesla, AAA, Uhnder, Adasky, and IDIADA suggested this approach as a possibility. HATCI mentioned that vehicles should be tested in their default configurations during ADAS testing and that advanced lighting systems should be enabled during PAEB testing under dark lighting conditions. However, the automaker did not specifically state that advanced lighting systems must be on by default to be included in the test protocol. CAS, Uhnder, and Adasky stated that advanced lighting systems should be enabled only if they cannot be disabled by the user. They reasoned that it is important to evaluate the worst-case scenario, which in their opinion is use of lower beams with the adaptive driving beam/advanced lighting features disabled, where possible. Uhnder added that drivers often turn off advanced features when they can and that drivers often do not utilize upper beams appropriately while driving. ZF Group also shared this assertion.

Many commenters stated that advanced lighting systems should always be enabled, regardless of whether they are standard or automatically enabled by default. Advocates, Intel, FCA, BMW, Honda, Toyota, ASC, Rivian, Bosch, Subaru, Auto Innovators, The League, Vayyar, ZF Group, GM, and several individuals supported the use of advanced lighting systems during PAEB testing in dark conditions. BMW suggested that separate tests should be conducted with lower beams and with the advanced lighting systems enabled, adding that NHTSA should weight one over the other. Alternatively, BMW stated that only testing with advanced lighting systems for those vehicles equipped could lower the testing burden. Honda noted that advanced lighting systems are meant to work with PAEB systems at night and should be enabled to capture the system's intended performance. Rivian echoed Honda's sentiment. Subaru and Auto Innovators pointed out that ADB is not required to function below 32.2 kph (20 mph), so tests should begin at this speed.

Advocates, Tesla, Toyota, Bosch, Subaru, Auto Innovators, The League, and GM stated that manufacturers may be encouraged to include advanced lighting systems in their vehicles if they are able to be used during PAEB testing in dark lighting conditions. Subaru suggested that NHTSA offer extra credit for vehicles equipped with advanced lighting capabilities. IIHS and one individual requested that NHTSA focus on adding an advanced lighting requirement to all new vehicles, citing safety benefits.

For vehicles not equipped with ADB, HBA, or other advanced lighting technologies, Honda, Rivian, Subaru, FCA, and The League expressed that NHTSA should assess at least some scenarios with the SV's high beams manually activated. Rivian specified that high beams should only be engaged in dark driving conditions as it is unlikely that an SV would be traveling in an area without ambient lighting or oncoming vehicles with lower beam headlamps only. The League and Subaru agreed with this reasoning. Subaru also mentioned that high beam usage more closely compares to HBA or ADB activation. FCA suggested that a vehicle's upper beams should be used in scenario S4 testing to lessen test burden. A few respondents noted that tests should be run both with lower and upper beams, with IIHS, CAS, and a few individuals favoring this strategy. However, CAS clarified that only the worst-case, lowest-illumination results should factor into capability ratings. IIHS stated it plans to give higher weight to high beam results in vehicles with HBA capability for tests in which the speed is over the threshold for activating HBA. Intel stated that vehicles should achieve partial credit if they pass with manual high beam engagement, thus motivating manufacturers to include advanced lighting features in their vehicles. ASC did not support the use of any manually-activated high beams, and AAA requested additional data to show that drivers use high beam lighting frequently before allowing manual high beam activation.

NHTSA also received comments regarding headlighting features, specifically advanced headlighting systems. GM sated that there is an opportunity for the Agency to list advanced lighting features on NHTSA's website as a method of promoting the technology, therefore driving adoption into the vehicle fleet. The automaker reasoned that there are safety benefits associated with "Auto High Beam," noting that the benefits found are at least as great as those for LDW, another feature that NHTSA has listed for new vehicles on its website. GM also noted that far-infrared cameras do not have associated field effectiveness data at this time due to low penetration rate but suggested that they still be added to a listing of safety features. Honda, Auto Innovators, BMW, FSS, TI, and Intel agreed that adoption of advanced lighting features such as Auto High Beam should be incentivized. FSS noted that advanced lighting features not only improve PAEB performance but also eliminate glare from oncoming vehicles, improving visibility for other drivers in the surrounding area. FSS also referred to IIHS's vehicle lighting ratings and the positive effect on nighttime crash rates for vehicles earning the group's "good" rating versus a "poor" rating. To encourage installation of advanced lighting features in the U.S. vehicle fleet, BMW and Auto Innovators suggested NHTSA provide additional credits for vehicles equipped with an advanced lighting feature. Texas Instruments (TI) recommended that advanced lighting features be added to NCAP ratings in some capacity but did not specify how this should be accomplished. MEMA, CR, HMNA, and NTSB were among other respondents in favor of incorporating lighting for improved nighttime pedestrian visibility.

Overhead Lighting

NHTSA also requested comments on overhead lighting for PAEB testing under dark lighting conditions. NHTSA notes that rural environments tend to be darker and without ambient overhead lighting, while urban and suburban environments are typically more well-lit from overhead lights, surrounding vehicle headlamp illumination, and other various light sources. Some commenters reasoned that the lighting should match the environment of the scenario approximated. MEMA, BMW, HATCI, Subaru, and Auto Innovators were in favor of having overhead lighting for urban and suburban scenarios but no overhead lighting for scenarios which more closely reflect rural encounters. Subaru specified that urban/suburban scenarios should have overhead lighting of 15 lux to simulate street lighting and that lower beams should be acceptable in these scenarios. In scenarios with no supplemental lighting, ADB or HBA would be expected to engage if the vehicle was equipped with advanced lighting features. If the SV does not have advanced lighting features, then some commenters (MEMA, BMW, HATCI, Auto Innovators, and Intel) asserted that high beams should be engaged. BMW also suggested that high beams should be engaged in higher-speed testing scenarios (tests with initial test speed at 50 kph (31.1 mph) or greater). HATCI mentioned that high beams should be allowed in dark conditions with no overhead lighting if high beam usage is shown to be common in the field in these situations.

GM suggested that scenarios be performed in two conditions: with overhead lighting and the use of low beams, and without overhead lighting and upper beam headlamps or advanced lighting features. The automaker reasoned that these two conditions represent a large portion of real-world driving conditions. Bosch, ZF Group, AARP, Intel, State Farm, The League, and one anonymous individual agreed that testing should be performed both with overhead lighting as well as in dark lighting conditions. The League also noted that if overhead lighting is shown to improve PAEB performance, then street lighting should be more widely deployed with the assistance of Congress, the U.S. Department of Transportation (USDOT), and the Federal Highway Administration (FHWA).

Many commenters expressed particular interest in the opportunity to harmonize with other global consumer information programs, with many responding to the proposed PAEB protocol noting that overhead lighting is used in Euro NCAP's protocol for crossing path tests in low ambient light conditions.[248] Bosch, TI, MEMA, GM, HATCI, Auto Innovators, and NSC were in favor of harmonizing NHTSA's NCAP PAEB test procedures under dark lighting conditions with Euro NCAP's. Tesla supported harmonization with IIHS's then-upcoming PAEB protocol, which does not involve the use of overhead lighting. IIHS plans to test using both lower beam and upper beam headlamps.

One commenter, FCA, only supported conducting tests with overhead lighting as part of this upgrade. The group stated that current PAEB camera technology requires illumination to the sides of the vehicle and that regulatory restrictions prevent headlighting systems from achieving this level of illumination on their own. It also noted that this condition is more severe than Euro NCAP's current protocol. The group suggested that the Agency could add tests without overhead lighting at a future time when technology advances.

There were also many respondents (Lidar Coalition, Velodyne, NACTO, Advocates, CAS, Adasky, AAA, IIHS, ASC, and three individuals) who commented that no overhead lighting should be used in PAEB testing. As mentioned previously, Lidar Coalition supported testing in the darkest realistic conditions possible, comments also supplied by Velodyne, CAS, and an anonymous individual. Further, both Velodyne and Lidar Coalition stated that testing without supplemental lighting would highlight the need for new sensors and technologies that will ''achieve optimal detection'' of VRUs in all road conditions. NACTO urged NHTSA to consider the known shortcomings of PAEB systems when deciding which scenarios and test conditions to include in its NCAP test procedures, citing an IIHS study showing that PAEB systems are less effective in dark conditions.[249] One individual noted that pedestrians are often fatally struck by vehicles while walking in areas without streetlights and suggested that the Agency evaluate performance in commonly encountered dangerous situations to achieve NCAP's safety goals. Advocates stated it was in favor of testing without overhead lighting because of the wide array of street light types and brightness in the U.S., and the increased stringency that testing in dark conditions would present. Because of the abundance of rural and highway roads without overhead street lighting, Adasky stated that testing should be conducted in zero lux conditions. AAA expressed that testing with overhead lighting does not challenge a PAEB system as much as the use of advanced lighting or low beam headlamp use does in isolation and therefore suggested that the Agency conduct tests without supplemental lighting, also noting that many pedestrians are struck in areas without overhead lighting.

Additional Information Supplied

Regarding available technology and other information, several commenters suggested that NHTSA should evaluate each technology type currently available and, in some cases, investigate the effectiveness of each. ASC noted that high resolution imaging radar, lidar, and thermal imaging cameras are available to address nighttime scenarios. NSC requested that NHTSA compare camera-based systems with lidar and other technologies in both light and dark conditions. Rivian acknowledged that there are limitations on FCW and PAEB technology's performance currently, specifically noting performance during dark lighting conditions. The automaker advocated for consideration of current system capabilities when determining NCAP test speeds and scenarios.

Other commenters offered information regarding specific sensor types. Tesla noted that infrared cameras may aid in pedestrian and animal detection in nighttime conditions. Vayyar mentioned that these enhanced attributes help the system provide robust monitoring. Thermal cameras were also specifically recommended by Adasky and one individual, with both respondents touting thermal cameras' abilities to perform in varied lighting situations, including nighttime, rain, snow, and fog. Both commenters claimed that this is because thermal cameras do not depend on ambient light to operate effectively. The individual commenter expressed that they were therefore in favor of more challenging test conditions since technology exists to address them. Adasky also added that thermal cameras have a wide field-of-view and longer range, and since even high beam lighting can only currently illuminate 120 m (393.7 ft.) to 150 m (492.1 ft.) ahead of the vehicle, high rates of speed require the system to be able to identify objects 200 m (656.2 ft.) ahead to reduce false positives. Lidar Coalition and Velodyne Lidar disagreed, opining that thermal cameras have limitations of their own: low resolution, placement restrictions, and potential to miss objects due to blending of separate objects' head characteristics. Instead, both groups stated that lidar systems are more capable of addressing nighttime scenarios because they rely on their own light source and have a higher resolution than radar. In addition to thermal cameras and lidar, Uhnder responded that imaging radar is also of higher resolution than most radar systems used in PAEB applications currently and is a promising technology.

[248] European New Car Assessment Programme (Euro NCAP) (December 2023), *Test Protocol—AEB/LSS VRU systems, Version 4.5.* See Annex B.

[249] Cicchino, J. B (2022, February), *Effects of automatic emergency braking systems on pedestrian crash risk,* Insurance Institute for Highway Safety, *https://www.iihs.org/api/datastoredocument/bibliography/2243.*

TI and Vayyar suggested that four-dimensional (4D) radar systems may increase system effectiveness. With regard to 4D systems, TI stated that ''cascading multiple radar sensors provides a wider field of view, an extended range, and enhanced angle resolution to detect static objects.''

ITS suggested that night view assist, a system using infrared headlamps, is already available in certain vehicle models. The vehicle displays a view of upcoming obstacles in the instrument cluster to give the driver advanced notice. ITS favored including the technology in safety ratings but also reasoned that including this technology in NHTSA's ''recommended technologies'' section would be appropriate.

Response to Comments and Agency Decisions

Details regarding lighting specifics for each condition to be tested are included in the sections that follow.

Vehicle Lighting Specifications, Including Advanced Lighting Systems

NHTSA proposed to use the SV's lower beam headlamps during all NCAP PAEB testing conducted in the dark and to refrain from manually engaging the upper beam headlamps. After considering comments, this notice adopts this plan. NHTSA will also prohibit automatic engagement of a vehicle's upper beams by way of advanced lighting systems, such as ADB, unless such systems cannot be deactivated.

NHTSA acknowledges that, as mentioned in the March 2022 RFC notice and above, Euro NCAP performs its CPLA scenario, which is analogous to the Agency's S4c scenario, using upper beam headlamps. FCA supported this test specification to lessen test burden on manufacturers. Additionally, BMW requested that NHTSA manually engage upper beam headlamps during higher-speed (50 and 60 kph, or 31.1 and 37.3 mph) PAEB testing conducted in the dark. However, previous studies have suggested that drivers may not manually engage high beam headlamps each time they are warranted,[250] and NHTSA is not aware of definitive data available at this time to suggest that drivers use them appropriately in the field, as Rivian and other commenters had suggested. IIHS found that, for 3,200 isolated vehicles (where other vehicles were at least 10 or more seconds away), only 18 percent had their upper beam headlamps engaged.[251] At one unlit urban location, IIHS data showed that upper beam use was less than 1 percent. IIHS also found that even on rural roads, drivers used their upper beams less than half of the time they should have for maximum safety, on average. Accordingly, it is inappropriate to tie PAEB to a vehicle feature that a driver may or may not use on a trip. NHTSA agrees with several respondents that supporting data would be necessary to allow manual high beam headlamp usage.

Similarly, the Agency has also decided that advanced lighting systems, including ADB, will be disabled during NCAP PAEB testing conducted in the dark, unless the advanced lighting system cannot be deactivated. This decision will apply even to those systems that are active by default when low beam headlamps are first engaged. Furthermore, for lighting systems with adjustable settings, the vehicle will be tested in dark conditions utilizing the beam/lighting configuration that is most similar to a traditional low beam setting, unless the beam/lighting configuration is automatically adjusted.

While NHTSA amended its lighting standard, FMVSS No. 108, ''Lamps, reflective devices, and associated equipment,'' in 2022 to allow installation of ADB headlamps, citing the potential to provide safety benefits in preventing collisions with pedestrians when other vehicles are present,[252] such systems are not required by this Standard, unlike lower beam and upper beam headlamps. Therefore, NHTSA reasons, as several commenters mentioned, that even if an ADB system or other advanced lighting system were installed on a vehicle, the driver may opt not to use it. Accordingly, it is most desirable from a safety standpoint for NCAP to assess those conditions that represent, as Aptiv suggested, a theoretical worst-case scenario—testing in dark conditions with only the vehicle's lower beam engaged. Several commenters expressed concern that vehicles will not be evaluated equally if advanced lighting features are enabled, stating that they are akin to upper beam headlamps. In the same vein, others suggested that NHTSA evaluate PAEB performance with upper beam headlamps if advanced lighting systems are enabled for use in the lower beam tests. The Agency recognizes that ADB works by automatically switching from the lower beam to the upper beam when it is deemed appropriate. As such, testing PAEB in the dark with ADB (or other advanced lighting systems) enabled may amount to NHTSA only evaluating system performance when the vehicle's upper beam is active. Finally, because ADB and other advanced lighting systems will not be enabled for NCAP's PAEB testing, commenters' concerns regarding ADB activation speeds are no longer applicable.

Although NHTSA received suggestions to conduct testing using upper beam headlamps in addition to testing using lower beam headlamps, the Agency does not see the need to increase NCAP test burden at this time. A vehicle which performs well in the lower-illumination case would be expected to also perform well when there is more illumination. Notably, more vehicle-to-target contact was observed during the lower beam PAEB research tests than the upper beam tests. However, NHTSA also recognizes that, in rare cases, vehicles may perform better in PAEB testing with the lower beams illuminated versus the upper beams. The Agency plans to monitor PAEB performance under various circumstances and will address any further needs for additional testing as they become apparent.

While the Agency acknowledges Vayyar's suggestion that NHTSA conduct testing with no headlighting system illumination under the assumption that this would best test the sensing system and provide a true worst-case evaluation, this is not a reasonable use case. In areas synonymous with NHTSA's lighting test conditions (*i.e.,* darkness with no overhead lighting), failure to turn on one's headlamps should yield such limited visibility that the Agency reasons drivers will almost certainly realize they are not utilizing their lights and turn them on. Driving in dark conditions without headlamps also constitutes a significant and dangerous misuse situation. While NHTSA agrees there is merit to assessing worst-case conditions in many circumstances, the Agency also sees benefit in ensuring that test cases are also field-representative use cases.

Several commenters suggested that NHTSA promote the installation of advanced lighting systems not only to mitigate nighttime pedestrian crashes but to improve nighttime visibility in general by eliminating glare. GM submitted data to show an estimated 22 percent field benefit from Auto High

[250] Sullivan, John M., Adachi, G., Mefford, Mary Lynn, Flannagan, Michael J. (2003, February). *High-Beam Headlamp Usage on Unlighted Rural Roadways.* The University of Michigan Transportation Research Institute. *https://deepblue.lib.umich.edu/bitstream/handle/2027.42/55182/UMTRI-2003-2.pdf.*

[251] *https://www.iihs.org/news/detail/few-drivers-use-their-high-beams-study-finds* (last accessed 11/18/2023).

[252] 87 FR 9916.

Beam systems, mitigating nighttime pedestrian, cyclist, and animal crashes.[253] However, as there will be no method for assigning extra credit for vehicles with added safety features at this time, NHTSA will not implement multiple commenters' suggestions to offer additional points or credit to vehicles equipped with advanced lighting systems, nor will the Agency allow vehicles to receive partial credit for passing with manual upper beam usage as suggested by Intel. More research is needed to ascertain safety benefits associated with night view systems. While it is out of scope for NHTSA to require advanced lighting features on new vehicle models as part of this final notice as some commenters requested, the Agency has added advanced headlighting assessments to its long-term NCAP roadmap.

Overhead Lighting

NHTSA agrees that unlit roads are treacherous for pedestrians. As both AAA and an individual commenter noted, pedestrians are often fatally struck while walking in areas without supplemental lighting. For example, IIHS found that in 2019, 35 percent of pedestrian fatalities occurred in the dark with no supplemental lighting present,[254] which is nearly the same as that found by Volpe in its 2011–2015 data set (36 percent).[255] Further, a study of California, North Carolina, and Texas crashes from 2010–2019 found that pedestrians struck in areas without street lights were 2.4 times more likely to be fatally injured than those struck in areas with street lights.[256]

Based on this, the Agency has decided it will conduct all testing under dark lighting conditions with no overhead lighting present. As previously mentioned, the Agency's testing showed only slightly improved performance when conducting PAEB tests with overhead lighting present versus no overhead lighting. Given these findings, the Agency asserts it is also least burdensome to conduct testing in the darkest environmental scenario only.

NHTSA acknowledges that some commenters suggested it match the environmental lighting conditions for each test to the analogous real-world scenario, with overhead lighting used for S1 crossing path scenarios, while no overhead lighting would be used for S4 in-path scenarios. Commenters noted that Euro NCAP performs its PAEB tests in this manner. However, the Agency concludes there are several reasons its planned testing approach is the most appropriate at this time.

First, environmental lighting conditions vary across the U.S. Light color (*i.e.,* color temperature), uniformity, luminance level, and other parameters may differ, even along different stretches of the same roadway. As Advocates noted, there are also a wide variety of streetlight types in use on U.S. roadways, making it difficult for the Agency to choose one streetlight specification that is representative of all or most overhead lighting conditions. Instead, it is most practical to conduct PAEB testing in dark conditions which can be more easily replicated. Such testing would align with Adasky's assertion that many American roads are not lit.

In addition, the Agency reasons that conducting NCAP's PAEB tests under dark lighting conditions may not only mitigate pedestrian involvement in crashes at night, but also encourage the development of more robust sensing and detection technologies. Specifically, although there are natural limits to the human eye's vision capabilities in dark conditions, several commenters described various technologies that substantially augment a driver's ability to detect objects and pedestrians. The commenters noted the benefits of these technologies in different conditions, including darkness, rain, snow, and fog. While the Agency agrees there are technologies available to fulfill this need, it is inappropriate to promote or mandate one sensor technology over another, particularly since there are advantages and limitations to each, as Lidar Coalition stated. Instead, NHTSA intends to test the capabilities of the system as a whole. This should allow vehicle manufacturers the ability to address each nighttime scenario as they wish and may in turn spur innovation.

In response to FCA's suggestion that overhead lighting is necessary based on the concern that regulatory barriers may prevent manufacturers from designing headlamps providing sufficient illumination to the sides of the vehicle so as to perform well in PAEB testing under dark lighting conditions, the Agency found this not to be the case during its research testing series. As described earlier, some vehicles were able to perform well in most of the adopted PAEB tests conducted under dark lighting conditions, proving that regulations do not restrict system designs which are effective. Based on this, the knowledge that PAEB is generally less effective when driving in dark conditions, and the substantial percentage of pedestrian fatalities that occur in conjunction with a lack of street lighting overhead, NHTSA concludes it is most appropriate at this time to move forward with testing without the use of supplemental lighting.

Finally, NHTSA notes that although Euro NCAP uses overhead lighting for its CPNA, CPNCO, and CPFA testing, IIHS does not utilize supplemental lighting for any of its nighttime PAEB testing. Instead, IIHS requires that test site illumination must be below 1 lux.[257]

4. Number of Required Trials To Pass and Repeat Trials in the Event of Contact

In its March 2022 notice, the Agency proposed an evaluation method for PAEB similar to that proposed for AEB. NHTSA presented a plan to perform one trial per test speed, beginning at a 10 kph (6.2 mph) minimum SV speed. If the SV did not contact the pedestrian mannequin during this initial trial, the test speed would be raised incrementally by 10 kph (6.2 mph) until a maximum test speed of 60 kph (37.3 mph) was achieved and evaluated. If the SV contacted the pedestrian mannequin during an initial trial for a given test condition and test speed combination, the resulting next steps would depend on the relative longitudinal velocity of the SV at impact. If the SV's relative longitudinal velocity at impact was less than or equal to 50 percent of the SV's initial test speed, then up to four more confirmatory tests at the same SV speed would be performed. The SV could not contact the pedestrian mannequin in three or more of the five total tests. However, if the SV contacted the pedestrian mannequin at a relative longitudinal velocity greater than 50 percent of the SV's initial speed, testing would be discontinued. This is because the vehicle would be considered to have failed the PAEB test evaluation at this test speed and, consequently, the PAEB test overall. Noting that 50 percent of the minimum test speed (10 kph, or 6.2

[253] *https://www.regulations.gov/comment/NHTSA-2021-0002-3856.*

[254] Cicchino, J.B. (2022, February), *Effects of automatic emergency braking systems on pedestrian crash risk,* Insurance Institute for Highway Safety, *https://www.iihs.org/api/datastoredocument/bibliography/2243.*

[255] Swanson, E., Foderaro, F., Yanagisawa, M., Najm, W.G., & Azeredo, P. (2019, August), *Statistics of light-vehicle pre-crash scenarios based on 2011–2015 national crash data* (Report No. DOT HS 812 745), Washington, DC: National Highway Traffic Safety Administration.

[256] Ferenchak, N.N., Gutierrez, R.E., & Singleton, P.A. (2022), *Shedding light on the pedestrian safety crisis: An analysis across the injury severity spectrum by lighting condition,* Traffic Injury Prevention, 23:7, 434–439, DOI: 10.1080/15389588.2022.2100362.

[257] Insurance Institute for Highway Safety (IIHS) (January 2024), *Pedestrian Autonomous Emergency Braking Test Protocol, Version IV.*

mph) is 5 kph (3.1 mph) and 50 percent of the maximum speed possible (60 kph, or 37.3 mph) is 30 kph (18.6 mph), NHTSA requested comments on whether a 50 percent limit on the maximum relative impact velocity was an appropriate threshold to establish at which additional testing (*i.e.,* repeat trials) would be conducted for the proposed range of test speeds.

Given the large number of PAEB test conditions proposed for adoption (*i.e.,* eight conditions covering multiple test speeds and lighting specifications), NHTSA noted that its proposed approach to reduce the number of test trials required at a given test speed from those specified in the original draft 2019 PAEB test procedure was a reasonable attempt to reduce test burden. The Agency believed that assessing PAEB system performance over subsequent incremental trials and for multiple repeated trials in instances where a vehicle is unable to meet the ''no contact'' performance requirement in the initial valid trial for a particular combination of test condition and speed would best integrate program efficiency while still ensuring system robustness.

In addition to seeking comments on its proposed assessment approach, NHTSA also sought comment on whether it should instead pursue an alternative approach, such as conducting multiple trials for each test condition and speed combination regardless of whether the ''no contact'' performance criterion was met. The Agency collected a wide variety of comments in response to these questions.

Summary of Comments

A few commenters, including AAA and ASC, agreed with NHTSA's proposed testing approach in its totality. Another commenter, Adasky, relayed that NHTSA's plan was sufficient if information about any potential test failures is made clear to the public. However, several commenters suggested NHTSA adopt an entirely different testing approach. Specifically, MEMA, HATCI, Auto Innovators, and Intel recommended the Agency employ the evaluation method currently utilized by Euro NCAP, whereby the Agency would accept self-reported performance predictions from manufacturers and then randomly select scenarios and test speeds to verify vehicle performance. Intel further commented that if the results of a spot-check test match the manufacturer's results, then the test would be accepted (and points could be awarded based on performance), but if the results differed between the manufacturer's data and NHTSA's, then two additional tests would be performed. If two of the three trials did not produce the manufacturer's predicted results, the company suggested partial credit could be given, and a correction factor could be applied. The commenters noted this method of evaluation would achieve the desired result of reducing the test burden on NHTSA labs.

One commenter, CAS, stated the performance criteria proposed by the Agency could be more stringent. The organization explained that systems offering no contact performance for five of five tests ''provide only 86% reliability with 50% confidence.'' Accordingly, CAS opined additional tests should only be allowed after pedestrian mannequin contact if the manufacturer changed the vehicle's configuration in response to the impact. Under CAS's plan, follow-up tests would be conducted, and the configuration would be retrofitted to previously assembled units and applied to all new units moving forward, similar to the process for a running change in crashworthiness NCAP.

Overall, most commenters agreed with the Agency's approach, in part, but suggested an alternative number of trials or maximum speed threshold would be more appropriate.

Number of Test Trials/Repeat Trials

In relation to number of test trial and repeat trials, several commenters stated the Agency should adopt an alternative number of test trials to assess each test speed. DRI and Subaru were two such commenters, with both stating at least two trials should always be completed. DRI stated if the first trial ended in a contact with an SV impact speed of 50 percent of the initial speed or greater, a full set of five trials would be completed. However, if the SV avoided the pedestrian mannequin or impacted at less than 50 percent of the initial speed, one confirmatory repeat trial would be conducted. DRI explained if the results of the confirmatory trial were the same as the initial trial, then that scenario/speed would be complete. However, if the results differed, then three more trials would be conducted for a total of five trials. DRI explained this approach may potentially identify vehicles that inconsistently detect pedestrians and would eliminate ''luck of the draw'' results. The laboratory also noted anecdotal evidence from its testing experience suggesting there may be vehicles which cannot reliably detect pedestrians, but they perform very well otherwise. Subaru suggested that NHTSA harmonize with JNCAP's method of testing, which entails running three trials for each vehicle speed. Subaru stated trials at a given SV speed could be stopped at two if the vehicle avoided contact twice in a row or if the speed reduction rate was the same twice in a row.[258]

Honda agreed with DRI that five trials should be performed if the SV contacts the pedestrian mannequin at 50 percent or greater of the initial speed. TRC expressed that three total trials would be sufficient, with only one failed run permitted. Auto Innovators opined multiple trials (*i.e.,* for a three-out-of-five passing criterion) would be needed if a no-contact criterion is established since the Agency's research data showed that several vehicles had contact for one run but were able to avoid making contact for three out of five runs. An individual commenter expressed that seven trials would be more appropriate to ensure the systems work reliably and to harmonize with other ADAS test protocols proposed by NHTSA for NCAP.

Two respondents, Toyota and Advocates, suggested that an alternative number of trials may be more appropriate for PAEB evaluations, without providing a specific number. Advocates suggested a greater number of trials may be appropriate, with the consumer group advising NHTSA to set stringent pass/fail criteria since real-world situations may vary and are not ideal. Advocates urged the Agency to take this into account when selecting the number of trials for each scenario, asserting that NHTSA must be confident that the technologies will operate as tested. Conversely, Toyota suggested that a reduced number of trials may be sufficient. The automaker emphasized the importance of minimizing the amount of testing wherever possible to provide timely information to consumers. It recommended carefully selecting the number of test trials (and test conditions) to ensure that enough relevant performance information is conveyed to interested parties.

IDIADA reasoned the Agency's approach provided sufficient assurance, stating it was a ''good strategy'' to perform one run per test speed for multiple speeds and a range of scenarios since PAEB systems are robust. However, the laboratory did not support NHTSA's testing approach in its entirety. As discussed later, IDIADA commented that vehicles should completely avoid making contact with the mannequin target at initial test

[258] Japan New Car Assessment Program (JNCAP) (Revised March 23, 2022), *Autonomous Emergency Braking System [For Pedestrian Daytime] Performance Test Procedure.*

speeds up to 40 kph (24.9 mph) and offer speed reductions of greater than 50 percent for initial test speeds greater than 40 kph (24.9 mph). Like IDIADA, HATCI also found NHTSA's proposed approach of one run per speed appropriate; however, they opined that vehicles should get credit for any passed runs up to the point of failure and for the speed reduction at failure. GM stated the Agency could conduct one trial per test speed up to 40 kph (24.9 mph) or until contact occurs. BMW also supported the Agency's approach of performing one run per test condition and four additional trials in the case of impact if NHTSA employed a no-contact criterion; however, the manufacturer preferred an assessment approach based on speed reduction. For this approach, BMW asserted that any impact should be followed by two confirmatory trials, with the median impact speed of the three trials being selected as the true impact speed for that scenario/speed. Conversely, Auto Innovators suggested that the Agency may only have to conduct one trial run per test speed if a speed reduction approach was adopted. However, Auto Innovators seemingly preferred an assessment approach requiring three out of five passing runs in such instances, like it advocated for in the event NHTSA adopted a no contact criterion (discussed prior).

Appropriate Maximum Allowable Impact Speed for Repeat Trials

Three groups agreed with NHTSA's proposed allowable maximum impact velocity for additional testing: AAA, ASC, and HATCI. AAA noted testing experience suggests insufficient speed reduction in the first trial indicates a vehicle is unlikely to perform well in subsequent testing. ASC specifically stated its support of the 50 percent reduction in speed value, because at the upper end of the testing range (60 kph (37.3 mph)), the maximum allowable impact speed for additional test trials would be 30 kph (18.6 mph), which is lower than the pedestrian impact test speeds for crashworthiness pedestrian protection tests in Global Technical Regulation (GTR) No. 9 (40 kph (24.9 mph)).

Other commenters, like Mercedes-Benz, Honda, Intel, IDIADA, Auto Innovators, and GM, objected to an assessment approach that discontinued testing based on a vehicle's inability to achieve complete crash avoidance for a specified test speed. These respondents suggested that the full battery of required test trials should be conducted for the entire speed range regardless of complete crash avoidance. More specifically, Honda and Intel expressed it would be overly stringent to discontinue testing when impact speed is greater than 50 percent of the initial test speed, as was proposed. Honda stated that four additional trials should be conducted in such instances, and Intel recommended that, if an incremental approach was adopted, NHTSA should continue to run trials at least one SV initial speed increment higher beyond the speed at which the vehicle is considered to fail, as long as the vehicle achieves full avoidance in at least one trial. Although Subaru generally agreed with the upper impact speed limit threshold, the automaker recommended that instead of discontinuing testing for impact speeds over 50 percent of the initial test speed, NHTSA should review in-house manufacturer data to determine whether this was an expected outcome. If the manufacturer data indicates that different performance was expected, then Subaru suggested additional trials should be executed.

Auto Innovators also supported allowing testing to proceed in the event of contact and/or a speed reduction of less than 50 percent, suggesting the Agency utilize a three-out-of-five passing criterion in such instances and assign partial credit for vehicles that perform well at higher speeds. For lower initial test speeds (*i.e.,* less than 40 kph (24.9 mph)), the group, along with Honda, suggested incremental testing should proceed regardless of impact speed. Honda expressed this would limit the influence of potential variation in test conditions and would be consistent with approaches used by other global NCAPs to determine the maximum allowable impact speed. The manufacturer explained that Euro NCAP discontinues testing when the SV impact speed reduction is less than 15 kph (9.3 mph) for initial test speeds over 40 kph (24.9 mph), and JNCAP discontinues testing if impact speed exceeds 40 kph (24.9 mph) over two test runs. Auto Innovators asserted some vehicles may not achieve full avoidance at lower speeds due to sensor viewing angles and suggested that NHTSA's proposed method of discontinuing the test in this case would unfairly penalize a vehicle manufacturer and might not convey the system's full capability. Subaru also stated that poor performance at lower speeds should not automatically disqualify a vehicle from earning partial credit for better performance at higher speeds.

Like other commenters, GM supported continued testing upon contact. The manufacturer cautioned that a single failure should not result in the full penalty of no credit when there is potential test variation introduced at higher speeds or with obstructions present. GM stated that the pass/fail penalty should be applied over the entire set of test runs instead of individual runs. Alternatively, the manufacturer suggested the Agency could adopt pass/fail criteria based on a minimum nominal speed reduction, an approach also supported by Tesla, FCA, and Aptiv. FCA and Aptiv noted that a 50 percent reduction when the initial test speed is 40 kph (24.9 mph) or greater would be too stringent and instead suggested that a more appropriate speed reduction to accept for these higher initial speeds would be 20 kph (12.4 mph) since the ensuing impact speed would fall below the GTR No. 9 crashworthiness test speeds, (40 kph (24.9 mph)). Aptiv stated their comment was based on statistics showing pedestrian fatalities and injuries are "greatly reduced" below 40 kph. Along similar lines, assuming contact was allowed, the League advocated for a maximum impact speed of 25.7 kph (16 mph) based on a study by the AAA showing the average risk of severe injury for a pedestrian struck at this speed is 10 percent.[259]

As with other aspects of the PAEB testing protocol, Advocates requested NHTSA provide data and analyses to support its decisions for test specifications, noting the information the Agency provides must be sufficient for consumers to accurately and reliably compare vehicle performance.

Response to Comments and Agency Decisions

As mentioned previously, NHTSA has decided to proceed with adopting a testing approach for PAEB that is similar to, but not identical to, that which the Agency proposed. For each test condition, the Agency will increase test speeds in 10 kph (6.2 mph) increments from the minimum test speed to the maximum, conducting one trial for each required speed. In the event the SV contacts the pedestrian mannequin during the initial run for any test speed, testing will cease for the test condition, respective test scenario, and PAEB testing for the particular lighting condition overall. Vehicles must pass all required trial runs (*i.e.,* one per test speed) to receive PAEB credit for the relevant lighting condition on NHTSA's website.

[259] Tefft, B.C. (2011). Impact Speed and a Pedestrian's Risk of Severe Injury or Death (Technical Report). Washington, DC: AAA Foundation for Traffic Safety.

Number of Test Trials/Repeat Trials

Although several commenters recommended the Agency perform multiple trials (*e.g.,* two, three, five, seven, etc.) for each test condition, often with the number of recommended trials varying based on the initial test speed, impact speed, or prior results, NHTSA has made the decision to run only one valid trial per test condition. This decision, which aligns with that adopted for AEB testing, is appropriate for several reasons.

First, a testing approach that requires one trial run per test condition instead of multiple runs allows the Agency to limit test burden while also performing tests for a greater number of conditions that represent real-world crashes involving pedestrians. Under the Agency's final PAEB test matrix, NHTSA will conduct (at most) 36 test trials for testing in daylight conditions and 34 trials for the testing in dark lighting conditions, for 70 trials total. This is far fewer than the number of trials that would be required if the Agency were to adopt an approach that required multiple trials for each of the six adopted PAEB test conditions as is prescribed for NCAP ADAS testing currently. For instance, NCAP's current AEB test procedure requires a minimum of five passing trials out of seven conducted to pass a given test condition, for a total of up to 42 trials for a CIB test and up to 56 trials for a DBS test. Adopting a similar approach for PAEB, as one commenter suggested, would require that up to 350 total trials be conducted, resulting in a significant burden to both vehicle manufacturers and NHTSA. Choosing instead to conduct one trial per test condition creates a test burden more comparable to NCAP's current AEB testing.

Given this decision, it is not necessary to proceed as several commenters suggested and select only certain scenarios and/or test speeds, whether pre-selected or chosen at random, to verify system performance. Such an approach may limit burden, but it would not best ensure system functionality or robustness. Likewise, it is unnecessary to accept manufacturer data and spot-check system performance for only certain test condition/speed combinations, as several commenters suggested. NHTSA reasons that its reduced testing approach should ensure acceptable system performance across a range of real-world conditions without sacrificing program integrity. This finalized test method of limited trials should also allow NHTSA to communicate valuable information more quickly to consumers, as Toyota requested.

The Agency's decision to conduct one trial per test condition/speed combination should also limit consumer confusion and better instill confidence and reliability in a vehicle's PAEB system. As mentioned earlier for AEB, allowing repeated trials in the event of contact may mislead consumers into thinking that a vehicle's AEB system provides more repeatable, robust performance than it does. Providing consumers with an assessment of system performance that is a single, representative sample rather than an assessment based on a best three out of five approach therefore seems most appropriate. And, while Auto Innovators contended that vehicle performance in the Agency's research tests suggests that multiple runs (*i.e.,* for a three-out-of-five passing criterion) are necessary if a no-contact criterion is adopted, NHTSA disagrees with this assertion. Although several vehicles made contact in many runs, one vehicle afforded complete crash avoidance in 63 out of the 70 total adopted test condition/speed combinations. This suggests that consistent, repeatable performance is possible for more robust PAEB systems, and that any poorer performance was something manufacturers could remedy. To best address the safety need, the Agency concludes it should devise passing performance thresholds that encourage design improvements to match the system performance afforded by the best fleet performers (*i.e.,* those that provide no contact during the first trial run for a large number of test conditions) rather than to establish a performance threshold based on the average or worst performers.

While some commenters expressed that the Agency should perform multiple trials for each test condition to ensure system reliability (albeit often with contact permitted), the Agency asserts, as it conveyed for AEB, that requiring one trial run per test condition instead of multiple runs is appropriate given its decisions to increment test speeds by 10 kph (6.2 mph) from a minimum speed to a maximum speed (as discussed earlier) and to disallow contact (as discussed next) for the PAEB tests. NHTSA reasons this approach will effectively identify system inconsistency and adequately address DRI's concern regarding ''luck of the draw'' results. The Agency's planned incremental testing approach, which uses relatively small speed intervals, is inherently designed to expose unreliable systems and ensure system reliability without the need for confirmatory runs, as the test laboratory suggested. If an inferior system happens to succeed at one speed, it will likely not continue to be ''lucky'' for the entire test series for a test condition (or for subsequent test conditions) as speeds are increased and test stringency increases. Since a failure of any one run at any given speed for any one test condition will result in an overall test failure for the tested PAEB system in that particular lighting condition, this approach is sufficient to serve as an acceptable gauge of system robustness. Furthermore, the slight increase in test speed from one trial to the next effectively provides the same benefit of assuring reliability as multiple runs conducted at the same speed. By adopting this testing method, consumers should feel confident that a vehicle that receives PAEB credit on NHTSA's website for a given lighting condition will operate consistently during a myriad of real-world driving situations in which consumers will likely be involved, as Advocates had requested.

Adopting the testing approach of conducting one run per test condition is viable even though CAS asserted that ''passing five of five tests provides only 86% reliability with 50% confidence.'' The Agency notes that while its final testing approach may be limited in that it does not ensure absolute reliability of system performance with 100 percent confidence, it is also unreasonable to impose the number of runs for each PAEB test speed that would be required to achieve this level of certainty. The test burden for NHTSA would increase exponentially.[260] While NHTSA could alternatively consider conducting a significant number of runs (*i.e.,* more than 20) at only the highest test speed for each test condition (*i.e.,* 40 kph (24.9 mph) for S1d testing in darkness and 60 kph (37.3 mph) for all other PAEB test conditions in daylight and darkness), as the Agency mentioned prior for AEB, it would risk imparting additional damage to the test vehicle and test equipment in addition to test delays if it was to take such an approach. As such, NHTSA's planned test method affords the most balanced approach to ensure system reliability with an acceptable degree of

[260] Using the binomial distribution to determine sample size for a given reliability and confidence level, 300 trials would be needed for 99 percent reliability with 95 percent confidence. See *https://reliabilityanalyticstoolkit.appspot.com/sample_size.* Similarly, 59 trials would be needed for 95 percent reliability with a 95 percent confidence, and 29 trials would be needed for 90 percent reliability with 95 percent confidence. Since the vehicle tested is randomly purchased or leased from dealerships, its performance in the AEB tests is based on the performance and manufacturing reliability set by the manufacturer.

confidence. Furthermore, as will be discussed later, the Agency has adopted a criterion of ''no contact,'' like CAS requested, which should further help to address the organization's concerns.

Maximum Allowable Impact Speed for Repeat Trials

NHTSA originally proposed conducting multiple trials and requiring a three-out-of-five pass rate for instances where the relative longitudinal velocity between the SV and pedestrian mannequin was less than or equal to 50 percent of the initial speed of the SV during an initial trial at any one test speed. However, based on the results from the Agency's recent model year 2021–2022 PAEB research tests, it is now unacceptable to award credit to PAEB systems with inferior performance that may allow impact with pedestrians at some frequency when other systems are able to avoid contact for most test conditions. To maximize safety impact, NHTSA must establish performance criteria for testing that will ensure AEB system response is consistent and repeatable. As such, like decisions made for AEB NCAP testing, NHTSA will not conduct repeat PAEB trials in the event of SV-to-pedestrian mannequin contact regardless of the relative longitudinal impact velocity recorded between the vehicle and the pedestrian mannequin at the time of impact. Instead, PAEB testing for a given lighting condition will cease at the first instance of contact. The Agency is making this decision while, at the same time, acknowledging that many commenters supported conducting additional PAEB test trials when a 50 percent speed reduction or less is observed in the first trial run or subsequent trial runs for a particular test speed.

For example, ASC expressed that a 50 percent reduction in speed was acceptable since the maximum allowable impact speed at the highest PAEB test speed (60 kph (37.3 mph)) would be 30 kph (18.6 mph), and this speed is lower than the 40 kph (24.9 mph) pedestrian impact test speed specified for crashworthiness pedestrian protection tests in GTR No. 9. However, the Agency would be remiss to tolerate any amount of vehicle-to-pedestrian contact in the PAEB NCAP tests given the possibility of serious injury or death resulting from low-speed crashes. Furthermore, NHTSA agrees with AAA's concerns that vehicles that cannot provide complete crash avoidance in one trial are unlikely to avoid contact in subsequent, higher-speed trials, with the exception of trials initiated at 10 kph (6.2 mph). Discontinuing follow-up testing for these vehicles should limit potential damage to the vehicle, pedestrian mannequin, and test equipment, thus avoiding expensive or time-consuming interruptions or repairs during NCAP assessments and limiting repeatability concerns. For these reasons, the Agency also does not see a need to proceed as Subaru suggested and conduct repeat trials for impact speeds over 50 percent of the initial test speed for those vehicles exhibiting performance that differs from manufacturer data.

For similar reasons, it is not appropriate to adopt an alternative, and essentially less stringent, speed reduction, like 20 kph (12.4 mph), for speeds greater than 40 kph (24.9 mph), as suggested by FCA and Aptiv. While it is true that the resultant maximum impact speed (40 kph (24.9 mph)) resulting from the maximum initial test speed (60 kph (37.3 mph)) is equivalent to the GTR No. 9 crashworthiness test speed and the likelihood of being killed or seriously injured at impact speeds below 40 kph (24.9 mph) is reduced, it is not negated; injuries and fatalities still occur at impact speeds ranging from 20 kph (12.4 mph) to 40 kph (24.9 mph). NHTSA's crash data shows that, on average, 22 percent of pedestrian injuries and 8 percent of pedestrian fatalities occur yearly on roads with posted speeds 40 kph (24.9 mph) and under.[261] Likewise, NHTSA does not agree with adopting a pass/fail criterion based on a minimum nominal speed reduction, as GM and several others suggested, or a maximum impact speed, as the League submitted. Adopting a testing approach which accepts a 10 percent chance a pedestrian may incur a severe injury, as the League suggested for a 27.5 kph (16 mph) maximum impact speed, is objectionable when systems capable of producing no injuries in the scenarios examined exist in today's fleet.

The Agency disagrees with the assertions of many commenters that it would be overly stringent or incomplete to discontinue testing upon contact in a single run and/or when a specific speed reduction was not achieved instead of proceeding with incremental testing through the full battery of required test trials. NHTSA's main objectives—to promote robust PAEB system designs, maximize safety potential, and prevent damage during testing—are best met by implementing a no contact criterion for each trial run, as CAS and Adasky asserted. This applies even to those runs conducted at low initial test speeds. NHTSA recognizes that Subaru and Auto Innovators objected to discontinuing testing when poor performance was observed at low initial test speeds, with the latter commenter contending that such an approach would unfairly penalize a vehicle and not convey the system's full capability. However, assuring robust performance across all speeds is imperative to maximize safety, especially considering a large number of pedestrian crashes occur at similar speeds to those adopted. The Agency's planned testing approach (*i.e.,* conducting one trial per test condition across a wide range of test speeds and scenarios and adopting a no contact performance requirement) provides a more complete assessment of system capability and is the most appropriate method to ensure system reliability and confidence. Since vehicles will not be given multiple opportunities to provide passing performance but will instead be required to perform well on the first try, the Agency's approach should allow consumers to feel confident that a vehicle that receives PAEB credit for a given lighting condition on NHTSA's website will operate consistently in the real-world driving situations they will likely encounter, as Advocates requested.

The Agency also does not concur with GM's assertion that test variations introduced at higher speeds or with obstructions present may result in questionable test conduct such that it would unfairly penalize a vehicle to discontinue testing based on a single run failure. NHTSA imposes tolerances on vehicle and target speeds, accelerations, positions, etc. to eliminate such concerns. Furthermore, it expects that PAEB systems that pass the selected tests should offer robust overall performance such that slight deviations from exact test specifications, which will likely be encountered during real-world driving, should not result in vastly different system performance. For this reason, it is appropriate that failure in a single trial will result in an overall test failure for a given lighting condition. Robust system performance is needed to ensure safety potential is realized.

NHTSA will conduct PAEB tests in a prescribed order for its NCAP testing, generally moving from least stringent to most stringent, based on the Agency's experience gained during research testing. For a given lighting condition, PAEB testing will proceed as follows: S4c, S4a, S1b, S1a, S1e, S1d. For each

[261] Swanson, E., Foderaro, F., Yanagisawa, M., Najm, W.G., & Azeredo, P. (2019, August), *Statistics of light-vehicle pre-crash scenarios based on 2011–2015 national crash data* (Report No. DOT HS 812 745), Washington, DC: National Highway Traffic Safety Administration.

condition, testing will begin with an SV speed of 10 kph (6.2 mph) and will increase incrementally by 10 kph (6.2 mph) until either (1) the SV fails to fully avoid the pedestrian mannequin or (2) the SV reaches the maximum test speed for that condition. If the SV successfully avoids the pedestrian mannequin for a full battery of tests under one condition, testing will move to the next test condition. However, if the SV contacts the pedestrian mannequin, testing for that condition (as well as all subsequent testing for the applicable lighting condition) will cease. The Agency expects that, by using this approach, damage to both the pedestrian mannequins as well as to the SVs will be minimized, thus limiting costly and time-consuming repairs and delays.

Since NHTSA is proceeding with a pass/fail approach designed to provide a comprehensive assessment across a range of test speeds and multiple test conditions with no contact, it does not see a need to finalize Intel's request to conduct at least one trial for the subsequent speed increment beyond the speed at which a vehicle first fails in instances where the vehicle achieves full avoidance in at least one of the prior trials. Such vehicles would fail the Agency's PAEB test for the given lighting condition at the first instance of contact. This test plan, including the order in which test conditions are carried out, may be amended should the Agency's assessment method change in the future.

5. No Contact Versus Speed Reduction

For PAEB performance criteria, NHTSA proposed that a vehicle must achieve complete crash avoidance (*i.e.,* have no contact with the pedestrian mannequin) to receive credit for a test trial conducted at each specified test speed (*i.e.,* 10, 20, 30, 40, 50, and 60 kph (6.2, 12.4, 18.6, 24.9, 31.1, and 37.3 mph)) for each test condition (S1a-e and S4a-c). NHTSA believed that this approach, used in conjunction with an incremental increase in SV speed (as discussed earlier), would limit damage to the pedestrian mannequin and the SV during testing. As an alternative, however, the Agency sought comment on whether it should require minimum speed reductions or specify a maximum allowable SV-to-mannequin impact speed for any or all proposed test conditions (*i.e.,* test condition and variant/test speed combination).

Summary of Comments

No Contact

Some commenters agreed with the Agency that the no contact criterion was appropriate for the proposed PAEB test conditions. AAA found the no contact criterion unambiguous and straightforward, qualities that would be helpful in evaluating performance, a sentiment echoed by Adasky. The League commented that avoiding contact is the only way to ensure that death or serious injury does not occur. The remaining commenters that shared this viewpoint commented that, by requiring no contact, the Agency would insure against real-world, challenging situations that are not as controlled as NHTSA's test protocol. CAS, Uhnder, ASC, and Adasky mentioned that pedestrians in the field are diverse, and it would be impossible to ensure the public at large's safety without a no contact criterion. As mentioned earlier, CAS also asserted that a no contact criterion is necessary because ''passing five of five tests provides only 86% reliability with 50% confidence.'' From a logistical standpoint, TRC noted that this would be a welcomed approach since the test mannequins and equipment could receive significant damage during pedestrian testing. Specifically, a no-contact criterion would alleviate concerns about equipment durability, particularly for higher-speed (greater than 60 kph (37.3 mph)) testing.

No Contact at Low Speeds, Speed Reduction at Higher Speeds

A few groups favored requiring no contact for tests with initial test speeds of 40 kph (24.9 mph) or less and allowing speed reduction for tests with initial test speeds above 40 kph (24.9 mph). These included Aptiv, Advocates, IDIADA, GM, and Intel. GM stated that the current state of technology does not support full avoidance at all speeds but that it is currently possible in the proposed test conditions up to 40 kph (24.9 mph). Beyond 40 kph (24.9 mph), GM suggested that the vehicle should be evaluated based on the amount of speed reduction achieved. Advocates acknowledged that no-contact results are preferable but noted that speed reduction offers meaningful safety benefits and should be encouraged at higher speeds. The group did not offer a speed at which to require speed reduction versus no contact but encouraged NHTSA to determine an appropriate threshold. Advocates further stated that vehicles which offer a speed reduction benefit should be given credit in some form. Aptiv suggested that full avoidance could be required for more simple conditions (*e.g.,* non-obstructed adult crossing), but not for more difficult ones (*e.g.,* S1d, child obstructed by parked vehicles). Intel had similar comments regarding test condition S1d, since the child becomes visible only 1.4 seconds pre-collision. The company suggested that NHTSA should offer full credit for a 40 kph (24.9 mph) speed reduction from a 60 kph (37.3 mph) initial test speed for this condition. Further, Intel stated that there is a clear safety benefit in reducing impact speed by 20 kph (12.4 mph) to 30 kph (18.6 mph) at initial test speeds above 40 kph (24.9 mph). Finally, from a logistical standpoint, IDIADA mentioned that pedestrian mannequins can withstand impacts up to 40 kph (24.9 mph) with minimal damage.

Many commenters reiterated the safety benefit that speed reduction can offer, with Toyota, BMW, Bosch, Honda, IIHS, Mercedes-Benz, GM, Rivian, DENSO, Auto Innovators, HATCI, and Subaru highlighting the advantages of speed reduction in their comments. Toyota suggested that NHTSA move away from a pass/fail criterion to a performance-based metric, which the manufacturer suggested may allow NHTSA to reduce the number of test trials required to evaluate vehicles. The automaker also noted that reduction in impact speed would be a suitable measure of performance to distinguish one vehicle from another and corresponds to real-world performance and injury risk. Toyota noted this performance-based metric could also drive improvements in system capabilities. These sentiments were echoed by most of the commenters mentioned above. For example, IIHS asserted if the Agency requires no contact, manufacturers may not equip their vehicles with systems that can offer injury-mitigating speed reduction, or it may lead to more false-positive activations. Tesla also echoed IIHS's concern regarding increased false positive interventions which pose risks of their own as manufacturers attempt to identify applicable situations as early as possible. The manufacturer went on to state that a ''fine-tuned'' speed reduction requirement strikes a balance between injury mitigation and reduction of false positives in the field. Rivian mentioned that by providing credit for impact speed reduction, NHTSA may encourage manufacturers to invest in technologies over time rather than abandoning them upfront if they cannot achieve the no contact requirement. Many others, including Auto Innovators, Honda, Mercedes-Benz, and Bosch, asserted that any speed reduction should be rewarded with partial credit. Like Rivian, these commenters referred to Euro NCAP's sliding scale method of issuing points for reduced impact speeds. GM also backed a sliding scale assessment approach based on speed reduction for test speeds over 40 kph (24.9 mph), and HATCI supported assigning partial credit when a vehicle can meet the imposed performance requirements for *only* certain test speeds, as well as when a vehicle fails to meet the performance requirements (*i.e.,* greater than 50 percent speed reduction) at a specific test speed as long as it provides some degree of crash mitigation. HATCI requested that NHTSA harmonize with Euro NCAP's performance evaluation method to the extent possible. DENSO suggested that speed reduction be tested in a range of conditions and referred specifically to evaluations in both Euro NCAP and U.N. Regulation No. 152, ''Uniform provisions concerning the approval of motor vehicles with regard to the Advanced Emergency Braking System (AEBS) for M1 and N1 vehicles.''

Other Suggestions

Two commenters offered an alternative to speed reduction or no-contact: crash avoidance via steering. ZF Group and Intel suggested that the Agency should allow manufacturers to pass scenarios 4a–c by using avoidance maneuvers instead of deceleration. ZF Group noted that ESS systems can support crash avoidance in various longitudinal scenarios.

Two other commenters, Bosch and MEMA, specifically discussed Euro NCAP's method of determining contact and impact speed, indicating their support for the use of a virtual box around the articulated pedestrian mannequin to account for the movement of the mannequin's arms and legs, similar to that specified in Euro NCAP's AEB VRU test protocol. Both groups stated that SV contact or impact speed, if any, should be determined based on this virtual box.

Finally, two individuals responded to this topic with suggestions to take individual vehicle design into account when determining contact or speed reduction criteria. Specifically, these individuals suggested that the Agency take vehicle mass into account since heavier vehicles traveling at a given speed will impart more force to a pedestrian than a lighter vehicle would at the same speed.

Response to Comments and Agency Decisions

NHTSA is adopting a ''no contact'' criterion for NCAP's PAEB performance test requirements. The Agency recognizes that this decision conflicts with the recommendations made by a number of commenters, many of which supported the benefits of a performance criterion based on speed reduction. Notably, the respondents reasoned that a speed reduction criterion, along with a sliding scale method of assessment like that used by Euro NCAP, would be a more suitable metric to permit performance comparisons among vehicles and encourage improved system capabilities. The Agency, however, agrees with respondents (including as AAA and Adasky) who stated that consumers can more easily understand a pass/fail metric like ''no contact'' compared to a criterion based on speed reduction. Thus, NHTSA reasons this criterion should simplify vehicle performance evaluations. NHTSA is also of the opinion that complete avoidance is likely the result that most consumers expect from PAEB systems. Further, restricting assignment of PAEB credit to only those vehicles that offer superior system performance will also best assure that future designs offer meaningful improvements.

The Agency does not agree with IIHS that vehicle manufacturers may not equip their vehicles with PAEB systems if NHTSA chooses to adopt a no contact performance requirement. For the model year 2024 light vehicle fleet, 94 percent of vehicles are equipped with standard PAEB systems. Based on this, the probability that manufacturers of these models will remove existing sensors used for pedestrian detection or fail to improve PAEB system capabilities simply because the Agency has adopted a stringent performance requirement for its voluntary consumer information program (*i.e.,* NCAP) seems unlikely. Today's consumers expect technological advancements, whether they be related to infotainment, safety, autonomous driving, or otherwise. Because of this, the Agency also doubts other manufacturers would abandon pursuit of PAEB technology because they are unable to achieve a no contact performance threshold upfront, as Rivian suggested. Instead, as other commenters contended, adoption of a no contact performance metric will likely encourage development of superior systems that provide robust performance in NHTSA's testing, a feat that is reasonably attainable for vehicles in the near future using existing technology. In the Agency's 2021–2022 research, one vehicle model afforded complete crash avoidance in all but seven of the test conditions adopted herein, and four of the failed trials stemmed from failure of the vehicle to respond to the mannequin at 10 kph (6.2 mph).

Several commenters cited the safety benefits inherent to speed reduction as a reason to adopt a speed reduction performance metric. While there are benefits to crash mitigation, there are more profound safety benefits afforded by PAEB systems that offer complete crash avoidance. Specifically, NHTSA agrees with the League that requiring vehicles to avoid contact with pedestrians is the only way to ensure that death or serious injury does not occur. Additionally, it would not be appropriate to adopt a no contact criterion for vehicle-to-vehicle testing (*i.e.,* AEB) and allow contact for vehicle-to-pedestrian testing. A no contact requirement is especially important for pedestrian impacts since the consequences are more likely to be fatal. By promoting development of more robust PAEB systems capable of much higher speed reductions and complete crash avoidance, future systems may effectively address a larger percentage of crashes that cause serious injuries and/or fatalities.

Like the related discussion earlier for AEB, a no contact performance metric has implicit benefits for NHTSA and manufacturer testing as well. As TRC asserted, imposing a no contact criterion in lieu of speed reduction better limits damage to the test vehicle, pedestrian mannequin, and test equipment during testing. Although the Agency acknowledges IDIADA's comments that mannequins may see ''minimal damage'' at impacts up to 40 kph (24.9 mph), contact between the pedestrian mannequin and test vehicle at low speeds can still cause sensor misalignment or test device degradation. Since such damage can influence test results and generate expensive or time-consuming delays or repairs to ensure repeatable testing, adoption of a no contact performance criterion better ensures the Agency is able to accurately verify manufacturer performance assessments in a timely manner.

A few commenters suggested that a no contact performance criterion was unreasonable for current vehicles to meet, especially at higher test speeds. Others suggested that the Agency could require full avoidance for certain scenarios that they considered simpler (*e.g.,* S1a–c and S1e) but not others (S1d) that they considered more difficult. Some respondents preferred that NHTSA adopt a speed reduction criterion in lieu of no contact and assign partial credit using a sliding scale (similar to Euro NCAP) for mitigation observed at higher initial test speeds. However, as mentioned, several vehicles from the current vehicle fleet were able to avoid contacting the pedestrian mannequin for most of the test conditions adopted herein. For instance, one vehicle model provided complete avoidance in all crossing path scenarios except for the S1d test condition in both daylight and dark lighting assessments, and two vehicle models afforded complete avoidance in all daylight in-path scenarios. With minor system changes to improve performance, future versions of these vehicles would be able to pass the failed test conditions, thus proving a pass/fail metric is practical. Therefore, the Agency sees no need to condone inferior system performance by allowing contact when it can encourage the design and development of robust PAEB systems instead. As the referenced vehicle models have not received an increased number of false positive reports compared to other models, the Agency further reasons that its recent data also show that a no contact performance metric can be met at higher initial test speeds with no increase in false positive rates, which was a concern expressed by IIHS and Tesla. As mentioned previously for AEB, NHTSA plans to continue to use check marks to assign credit to vehicles that pass the performance test requirements adopted for each ADAS technology until such time as it publishes a notice to finalize a rating system for crash avoidance technologies. Therefore, it cannot award partial credit for speed reductions at this time, as a few commenters requested.

As requested by Bosch and MEMA, NHTSA is adopting the ''virtual box'' specified in section 3.4.2 of Euro NCAP's AEB VRU test protocol [262] to clearly define the area that accounts for the movement of the articulating pedestrian mannequin's arms and legs when determining contact. This virtual box is necessary to enable a fair assessment for all tested vehicles. At this time, however, NHTSA will not permit vehicles to pass NCAP's PAEB testing by utilizing steering to avoid impact instead of braking for S4a–c, as ZF Group and Intel recommended, or any of the other PAEB test conditions being adopted. Previously-cited Volpe data showed that, for cases where driver avoidance maneuver was known, the driver made no attempt to avoid the crash (*e.g.,* no braking, steering, accelerating) for 76 percent of pedestrian crashes involving fatalities and 70 percent of crashes involving injuries.[263] [264] Accordingly, adopting PAEB test requirements that require the vehicle to automatically brake in the absence of driver input, such as steering, is appropriate. This decision also aligns with that which the Agency has made in response to comments received surrounding evasive steering for NCAP's AEB tests. As thoroughly discussed previously, such factors as vehicle dynamics, traffic conditions, and traffic participants all influence the safety benefit of a steering avoidance maneuver. Steering, when used as an avoidance maneuver, may not be as safe as in-lane braking, particularly in an urban environment. Furthermore, allowing vehicles to use ESS during NCAP's PAEB assessments to avoid contact with the pedestrian mannequin would require the Agency to adopt additional tests to assess the functionality of ESS itself to prevent unintended consequences. While this may be considered as part of a later update, it will not be incorporated at this time. The Agency must first study the capabilities and limitations of systems meant to support the driver during these evasive maneuvers prior to incorporating such assessments in its NCAP testing. As such, NCAP will disable ESS systems prior to PAEB testing for those vehicles equipped with such systems, thus ensuring fairness for all vehicles, as only braking performance will be evaluated for all.

Since NHTSA has decided to impose a no-contact performance criterion for NCAP's PAEB testing, it does not see a need to create more stringent requirements for heavier vehicles compared to lighter ones, as two respondents recommended. Regardless of the vehicle's mass, all vehicles will be required to completely avoid impact with the pedestrian mannequin. Therefore, the potential difference in the imparting force created at impact for vehicles of different weights is inconsequential.

Finally, regarding Toyota's comment that adopting a speed reduction performance criterion could reduce the number of trials necessary for vehicle assessments and therefore reduce test burden, the Agency's planned testing approach, as previously discussed, effectively addresses this concern.

6. Appropriate Minimum Overall Pass Rate for PAEB

NHTSA proposed to denote vehicles that are equipped with a given ADAS technology and which meet the Agency's applicable minimum ADAS performance requirements with a check mark instead of a more detailed sliding scale assessment until the publication of the final notice for the new ADAS rating system. NHTSA requested comments on the appropriate number of test conditions a vehicle must pass to be granted a check mark for PAEB, suggesting two-thirds of the total unique combinations of test scenarios and test speeds (*i.e.,* test conditions) as a possible benchmark.

Summary of Comments

Several commenters agreed with NHTSA's proposed benchmark. BMW, Honda, IDIADA, Intel, Uhnder, and Bosch stated that passing results for two-thirds of unique combinations should be required to attain a check mark, but some commenters added caveats to their comments. Specifically, BMW, Honda, and Bosch preferred assessments that took speed reduction into account in some manner. BMW stated this would allow for a more accurate rating of a system and would set the Agency up for easier tuning of rating scales in the future. Honda stated it only agreed to a two-thirds passing rate if each individual scenario/speed combination took speed reduction into account. As mentioned earlier, the automaker reasoned that a no-contact criterion would be too stringent and not give credit to products that offer safety benefits. In a similar vein, Bosch suggested that any amount of mitigation should be rewarded and that vehicles should receive partial credit even if they do not meet the two-thirds minimum for a check mark.

Auto Innovators did not support the two-thirds minimum for credit. However, like those mentioned previously, the group suggested that vehicles offering speed reduction should be given credit since they still provide a ''reasonable safety benefit.'' Auto Innovators also recommended that speed reduction should be used to determine pass/fail criteria, or alternatively, a sliding scale should be used as part of an overall PAEB rating. Adasky also referred to a rating system in its response to this topic, mentioning that the Euro NCAP method of weighting each category according to real-world factors would be preferred since some tests will have a larger target population than others. Rivian also mentioned it preferred a points-based

[262] European New Car Assessment Programme (Euro NCAP) (December 2023), *Test Protocol—AEB/LSS VRU systems, Version 4.5.*

[263] Swanson, E., Foderaro, F., Yanagisawa, M., Najm, W.G., & Azeredo, P. (2019, August), *Statistics of light-vehicle pre-crash scenarios based on 2011–2015 national crash data* (Report No. DOT HS 812 745), Washington, DC: National Highway Traffic Safety Administration.

[264] Driver avoidance maneuver was either unknown or not reported for 24 percent of fatal pedestrian crashes and 52 percent of passenger crashes with injuries.

PAEB rating system requiring a minimum number of points to pass. However, Rivian stated if NHTSA were to move forward with a scenario-based approach, the pass rate should be determined based on the complexity of each test. The automaker also suggested that NHTSA should require a greater passing percentage for simpler scenarios and a smaller passing percentage for more complicated or difficult scenarios.

Citing the variety of real-world encounters that occur between vehicles and VRUs, CAS stated the pass rate for NHTSA's PAEB system testing should be 100 percent. However, the group mentioned that NHTSA could enhance the program by adding optional PAEB tests or by assessing test performance metrics like distance between the stopped vehicle and the test target. CAS explained this would allow consumers to identify strengths in vehicle performance rather than lowering the bar to give credit to vehicles that cannot pass all of NHTSA's tests.

Three other groups (Toyota, Advocates, and GM) commented on this topic but did not provide specific acceptable pass rates. As mentioned earlier, Toyota urged NHTSA to use performance-based criteria wherever possible, instead of pass/fail criteria. Advocates suggested that the Agency set stringent pass/fail criteria given that the variety of on-road conditions found in the field are not always represented in the ideal testing environment. Finally, GM noted that NHTSA should strike a balance between current PAEB system limitations and criteria informed by real-world pedestrian crash data to maximize potential safety benefit.

Response to Comments and Agency Decisions

Since the Agency has opted to impose a no contact performance criterion for PAEB testing, it will not adopt a rating system based on speed reduction, as many commenters requested. Although BMW contended that such a rating system would be ''more accurate'' and allow NHTSA to make changes more easily to reflect future updates, the Agency reasons, as previously mentioned, that an assessment based on no contact can be more easily understood by consumers. Until a crash avoidance rating system is developed and finalized, those vehicles receiving a check mark will have met NHTSA's minimum level of performance, and those that do not display a check mark will have not.

In the same vein, NHTSA has decided to adopt a pass rate of 100 percent for NCAP's PAEB testing instead of the suggested two-thirds (*i.e.,* 67 percent) benchmark. This decision aligns with the Agency's choice for AEB testing. PAEB systems must achieve passing results (*i.e.,* no SV-to-pedestrian mannequin contact) in all adopted test conditions (*i.e.,* 24 tests in daylight conditions and 22 in dark lighting conditions for S1—S1a, S1b, S1d, S1e, spanning speeds from 10 to 60 kph (6.2 to 37.3 mph),[265] and 12 daylight and darkness test conditions (*i.e.,* 24 total) for scenario S4—S4a and S4c, spanning speeds from 10 to 60 kph (6.2 to 37.3 mph)) to receive credit for PAEB technology for each lighting condition. By requiring a 100 percent pass rate, the Agency concludes consumers will be able to quickly recognize which vehicles offer robust, repeatable PAEB system performance.

At this time, as mentioned, the Agency has decided to assign credit separately for PAEB system performance in daylight and dark lighting conditions; vehicles will not have to achieve passing performance for all 70 tests in daylight and dark lighting conditions collectively to obtain credit for PAEB overall. A vehicle must pass the 36 required test conditions in daylight to obtain credit for PAEB performance in daylight and must separately pass the 34 prescribed test conditions in dark lighting conditions to obtain credit for PAEB performance in darkness. The Agency has decided to evaluate PAEB performance in daylight and dark lighting conditions separately because no one vehicle tested as part of NHTSA's model year 2021–2022 research passed all test conditions (*i.e.,* did not contact the pedestrian mannequin) for both daylight and dark lighting conditions. However, as mentioned, one vehicle exhibited nearly passing performance for each of the two lighting conditions.[266]

By assigning credit separately for each of the two lighting conditions, the Agency's planned approach offers a compromise between the pass rate endorsed by several commenters (*i.e.,* two-thirds or 67 percent, albeit often with a speed reduction performance criterion instead of no contact) compared to that suggested by CAS (*i.e.,* 100 percent) for the proposed 70 unique PAEB test combinations. A vehicle that contacts the pedestrian mannequin for any of the required 34 PAEB test conditions when tested in the dark will not receive credit for PAEB performance in darkness; however, that same vehicle may still receive credit for PAEB performance in daylight if it offers complete crash avoidance for the required 36 PAEB test conditions when tested in the daylight. A vehicle could technically fail all 34 test conditions required for testing in darkness and still receive credit for PAEB in daylight, thus permitting an overall effective PAEB pass rate of just over 50 percent. Therefore, this approach aligns with Bosch's request to award partial credit for those vehicles that are not able to meet a two-thirds pass rate overall. It also provides additional useful information to certain groups of consumers that may not have otherwise been conveyed if the Agency had chosen to instead adopt a pass rate of 100 percent for PAEB testing in both daylight and dark lighting, collectively. For instance, certain groups of consumers that drive primarily at night may find separate lighting-specific PAEB ratings particularly helpful. Likewise, consumers that rarely drive at night may not be deterred from purchasing a vehicle that does not perform well during NCAP's PAEB assessments in darkness. This decision also aligns with CAS's comment that the Agency should reward superior performance instead of lowering the bar so that more vehicles may receive credit. Although NHTSA has decided to require passing performance in only one lighting condition for this NCAP upgrade to receive partial credit for PAEB, this approach currently seems challenging for most vehicles given the results of its most recent PAEB research, even when considering a reduction in test speed for the S1d in dark lighting condition.

Several commenters suggested alternative pass rates. Rivian opined that, if NHTSA adopted a pass-fail performance threshold, the pass rate for PAEB systems should be based on test complexity (*i.e.,* a vehicle should be required to achieve passing performance for a greater percentage of test conditions for simpler scenarios compared to more complicated/difficult scenarios). Further, Adasky recommended that target populations for real-world crashes should dictate the weight assigned to each test scenario/condition. GM also suggested that real-world crash data should be considered, in addition to current system limitations. Although there is merit to these suggestions, the Agency agrees with Advocates that it should establish stringent pass/fail criteria to ensure that

[265] S1d will be assessed in the nighttime lighting condition from 10 to 40 kph (6.2 to 24.9 mph).

[266] For daylight conditions, the aforementioned vehicle failed only S1d at test speeds greater than 50 kph (31.1 mph) and S4a and c at 10 kph (6.2 mph). Similarly, for dark conditions, the vehicle failed only the S1d condition at test speeds greater than 40 kph (24.9 mph) and S4a and c at 10 kph (6.2 mph).

PAEB systems are robust and perform well during variations of the Agency's tested conditions, since the situations encountered during real-world driving will not always mirror the ideal testing environment. As such, only a 100 percent pass rate for each lighting condition ensures the development of optimal PAEB system designs. While capabilities may be limited for many current PAEB systems, as GM suggested, the results for one vehicle in the Agency's research testing exemplified system potential for future system iterations.

Finally, at this time, the Agency will not adopt additional optional PAEB tests for extra credit, as CAS requested. NHTSA is considering the inclusion of other PAEB test scenarios in NCAP at some point in the future, such as turning scenarios and scenarios for bicyclists. These potential scenarios are discussed in a later PAEB section of this notice. However, the Agency is not considering program additions that align with CAS' second request—adding performance assessments based on the distance between the stopped vehicle and the test target. Because manufacturers must design PAEB systems that perform well in *all* real-world conditions, not just those assessed by NHTSA, the finalized NCAP test conditions should not be unduly prescriptive. Whether a vehicle stops several inches or several feet behind a pedestrian mannequin when tested seems irrelevant considering the outcome (*i.e.,* complete crash avoidance) is the same. The Agency prefers to encourage manufacturers to expend additional resources into perfecting performance in all PAEB test conditions, both daylight and dark lighting conditions, as well as for the wide variety of other crash scenarios/conditions that may occur during real-world driving.

7. PAEB Warning, Including Signal Modality and Timing

NHTSA is adopting the same FCW modalities outlined for NCAP's AEB test conditions for the program's PAEB test conditions. Specifically, a vehicle must present a forward collision warning to the vehicle operator via two sensory modalities—auditory and visual—to receive credit in each of NCAP's PAEB tests. Similar to AEB, while the Agency is requiring a an auditory/visual FCW, a vehicle may additionally present a haptic signal to warn of an impending collision without penalty. Adopting the same bimodal alert strategy for PAEB as NHTSA adopted for AEB is appropriate since standardization should ensure consumer familiarity and limit confusion. Drivers will be more likely to associate a dual-modality FCW with any sort of crash-imminent forward collision and, as such, should be more likely to respond with a timely and evasive action to mitigate or, if possible, avoid a crash altogether. This is especially important for crash-imminent situations involving pedestrians since they have no intrinsic protection.

While the Agency will require the same dual-modality alert type for NCAP's PAEB tests as it's requiring for the program's AEB tests, it is making a distinction for the timing of the FCW. For PAEB testing, the FCW need not be issued prior to the onset of automatic braking, like was specified for AEB; the warning may be issued at any time before or during the automatic braking event. The Agency is making this distinction for PAEB because it recognizes the dynamics of some pedestrian crashes inherently result in a quick succession of events. For these crashes, it may be problematic to require the warning be followed sequentially by automatic braking. This was evidenced in the Agency's 2020 research testing, particularly for certain test conditions, such as S1d. The Agency's data showed automatic braking occurred nearly concurrent with, or prior to, the FCW for several of the Agency's test vehicles.[267] Yet, many of these vehicles avoided contact with the pedestrian mannequin. Therefore, NHTSA hesitates to require sequential warning and braking functionality in order to not hinder system response time or alter system effectiveness. The Agency also does not want to encourage requirements that would drive forward collision warnings to be issued too early in response to potential pedestrian impacts since pedestrian movements can be unpredictable. Early warnings may have unintended consequences and lead to an increase in false positive activations. While FCWs issued prior to the onset of automatic braking are most desirable since they will serve to warn the driver of an impending crash and solicit a response, those issued after the onset of automatic braking can also be beneficial since they should serve to inform the driver that automatic braking is ongoing.

During NCAP's PAEB tests, NHTSA will release the SV's accelerator (at any rate) within 500 ms after (1) issuance of the two required FCW signals (*i.e.,* auditory and visual), or (2) the onset of automatic braking (as defined by the instant SV deceleration reaches at least 0.15g), whichever is sooner.[268] In either instance, the vehicle can pass a test trial if it does not make contact with the pedestrian mannequin and both signals for the bimodal alert are issued at some point prior to or during the braking event. While neither modality signal will be required prior to the onset of PAEB braking, both will be required prior to the end of the test for a vehicle to receive a passing result. If one or both of the signals required for the dual-modality FCW are *not* issued and the vehicle's PAEB system does *not* offer any automatic braking (as defined by the instant SV deceleration reaches at least 0.15g), in a PAEB test, release of the SV accelerator pedal will not be required prior to impact with the pedestrian mannequin and the vehicle will fail the trial run. The driver (or throttle robot) will modulate the accelerator to maintain a constant speed until the end of the test occurs.

It is reasonable to require that both FCW signals be issued before the end of the event in the Agency's PAEB tests because, as explained earlier, one of the two FCW signals which comprise a bimodal alert often serves as a secondary, confirmatory indication that explains to the driver what the primary signal is intended to communicate (*i.e.,* a forward crash-imminent situation). Therefore, it seems prudent to assume these signals would be provided nearly concurrently, particularly given the dynamics of many pedestrian crashes and the limited time for intervention.

The Agency is aligning other decisions for PAEB with those made for NCAP's AEB tests with respect to the FCW. NHTSA is not prescribing additional requirements for visual or auditory warnings (*e.g.,* color, location, decibel level, type, etc.) and it is not standardizing PAEB warnings at this time.

8. User-Configurable Settings for PAEB Tests

In its March 2022 RFC notice, the Agency proposed to test the middle (or next latest) FCW and PAEB system settings when assessing FCW and PAEB

[267] As an example, when the S1d test condition was conducted for a model year 2020 Subaru Outback traveling at 16 kph, the onset of the FCW occurred at 0.92 sec. (FCW on time history plot) and automatic braking occurred essentially at the same time, at 0.91 sec. (PAEB on time history plot). ''Final Report of Pedestrian Automatic Emergency Braking System Research Testing of a 2020 Subaru Outback Premium/LDD,'' *https://www.regulations.gov/document/NHTSA-2021-0002-0002,* See: Figure D66. Time History for PAEB Run 180, S1d, Daytime, 16 kph.

[268] The accelerator pedal will be released in a timely manner in either instance so as to not interfere with, and potentially override, the PAEB system, as this could affect test repeatability.

as part of NCAP's PAEB tests for those vehicles that offer multiple timing adjustment settings.

Since NHTSA has decided to evaluate FCW in tandem with PAEB (essentially, the SV must issue the required FCW signals at some point during the braking event), and the vehicle must not contact the pedestrian mannequin during testing, the tested FCW and PAEB system settings are important test variables. Effectively, to perform well in the Agency's PAEB evaluations, the vehicle must issue the FCW and brake automatically with sufficient time to allow the vehicle to avoid contacting the POV. As it decided for NCAP's AEB tests, the Agency will set the timing for the FCW and PAEB intervention to the middle (or next latest) setting (if adjustable) during its PAEB evaluations, like that previously shown in Figure 2. For FCW or PAEB systems having only two settings, the Agency will select the later of the two settings and this test setting will meet NHTSA's middle (or next latest) FCW/PAEB setting requirement. These system setting configurations align with Euro NCAP's AEB/LSS VRU systems test protocol. By integrating FCW assessments and adopting the middle (or next latest) system settings, NHTSA expects that vehicle manufacturers will inherently strive to limit nuisance alerts and PAEB activations during real-world driving for the timing settings preferred by most drivers while also performing well in NCAP's PAEB tests at this preferred setting.

NHTSA is also imposing requirements for other system settings during NCAP's PAEB tests. For vehicles that have an ESC off switch, NHTSA will keep ESC engaged for the duration of the test. For vehicles offering regenerative braking, the Agency will select the ''off'' setting, or the setting that provides the lowest deceleration when the accelerator pedal is fully released for those vehicles offering multiple regenerative braking settings (*e.g.,* less aggressive, nominal, more aggressive). This decision, which was also made for NCAP's AEB tests, should promote fairness and improve test execution, and thus test repeatability. NHTSA will also select the ''off'' setting for vehicles equipped with a one pedal operation mode in instances where those vehicles offer selectable settings for modes of operation. If one pedal operation cannot be disabled (*i.e.,* regenerative braking is always enabled and one pedal operation cannot be switched ''off''), the vehicle will be tested with the moderate deceleration level ensuing from accelerator pedal release. For these vehicles, like all other vehicles, the accelerator pedal will still be fully released within 500 ms after the FCW is presented or automatic braking (as defined earlier) occurs. In line with these decisions (and that made previously for NCAP's AEB tests), propulsion batteries will be charged at 80 percent or higher capacity during PAEB testing for electric vehicles, as performing assessments with a higher SOC should limit regenerative braking, and thus vehicle deceleration, when the accelerator is fully released.

To receive credit for PAEB, forward collision warning and pedestrian automatic emergency braking technologies (*i.e.,* FCW and PAEB systems) must appear 'Default ON' during each ignition/key cycle. While the Agency is not prohibiting a disabling function for these technologies in its NCAP evaluation, it does not expect that the testing requirements imposed herein should result in reduced consumer satisfaction. Instead, NHTSA expects drivers will adjust their vehicle's FCW and PAEB system settings to meet their personal preferences instead of disengaging the system altogether.

9. Articulated Pedestrian Mannequins

NHTSA proposed, and sought comment on, utilizing modern mannequins with moving legs instead of the posable pedestrian mannequins specified in its 2019 PAEB test procedure. The Agency explained that the articulating pedestrian mannequins are more representative of walking pedestrians and expected that more realistic targets would encourage development of PAEB systems that detect, classify, and respond to real-world pedestrians more effectively and accurately. NHTSA's adoption of the articulating mannequin would also harmonize with Euro NCAP and IIHS, fulfilling the BIL's mandate that NHTSA ''benefit from harmonization with third-party safety rating programs.''

Summary of Comments

Adoption of the Articulating Mannequin

Several commenters responding to the December 2015 notice favored the adoption of the articulating pedestrian mannequin, and most of the comments received in response to the March 2022 also favored its adoption and use in PAEB testing. Those in favor included TRC, MEMA, CAS, GM, The League, BMW, Bosch, FCA, Honda, Toyota, AAA, ASC, CCD Transportation Task Force, Rivian, Auto Innovators, Intel, HATCI, ZF Group, IDIADA, and one individual. Most of these commenters stated that articulating pedestrian mannequins are more representative of pedestrian gait and should be used. TRC noted that articulating pedestrian mannequins are the industry standard, a sentiment echoed by GM, BMW, FCA, Toyota, ASC, Auto Innovators, Intel, The League, and HATCI. GM added that ''the only means of measuring the potential added capabilities of [camera/radar] fusion systems, especially in low-light conditions, is to use the articulated pedestrian mannequin.'' Bosch, Auto Innovators, and HATCI noted that articulating pedestrian mannequins are preferable due to their Doppler spread and radar reflectivity characteristics and stated the performance measured with the static mannequins may not translate to real-world benefit. IDIADA also specified that radar-based systems monitor Doppler frequencies from leg movement. Some groups cited PAEB systems' algorithms (AAA) and artificial intelligence (FCA) as reason to utilize articulated mannequins. Honda added the ability to quickly identify a pedestrian and react accordingly is valuable, especially in situations with limited visibility or short reveal times. Intel agreed it is necessary for a PAEB system to identify pedestrians quickly and accurately. Rivian offered that accurate identification of pedestrians may reduce false positive activations. Finally, the League stated there is no benefit to adopting an unharmonized, fixed mannequin that is less lifelike.

Though both BMW and Auto Innovators agreed that articulating pedestrian mannequins should be used in PAEB testing, they further requested that NHTSA use a black cover for the center tube for any PAEB assessments in dark lighting conditions the Agency may perform. The groups reasoned this change will further improve the mannequin's resemblance to an actual pedestrian in the dark. TRC also favored adoption of the articulating mannequins but requested detailed information on acceptable pedestrian target movement systems. The laboratory specifically noted there are currently belt and robotic platform systems available.

Other commenters stated it is premature to include the articulated mannequins in NCAP and that other VRUs should be taken into account. Lidar Coalition, Velodyne, and two individuals urged NHTSA to account for all road users who are not walking, such as those in a wheelchair or scooter; those standing, pausing, or bending down; or those wearing clothing that obscures ambulation, such as a dress or robe. These commenters raised concern that PAEB systems may begin to over rely on leg movement as a VRU indicator. CCD Transportation Task

Force agreed that NHTSA should consider a variety of VRUs when choosing targets, adding that other groups may not be accurately represented by the pedestrian mannequin, such as women, shorter adults, and those with darker skin tones. Lidar Coalition, Advocates, and Velodyne stated that more data is needed to ensure the use of the articulating pedestrian mannequin will not have an adverse effect on these, or any other, VRU populations.

Response to Comments and Agency Decisions

The Agency is adopting the 4activePA Adult and 4activePA Child pedestrian mannequins for NCAP testing.[269] Commenters overwhelmingly favored the adoption of articulating, rather than static, mannequins for PAEB testing. In support of this stance, commenters cited harmonization, radar reflectivity characteristics, and realistic, lifelike movement, among other reasons. These pedestrian mannequins, used in NHTSA's research testing and utilized by Euro NCAP as part of testing conducted per its AEB/LSS VRU Systems test protocol,[270] provide an accurate representation of real-life pedestrians, as commenters requested. The 4activePA Adult and Child mannequins have physical dimensions (*i.e.,* size and shape) representative of a 50th percentile adult male and 7-year-old child, respectively, and are designed to produce a realistic response from radar, lidar, and camera sensors. Both mannequins have features representing hair, facial skin, hands, a long-sleeve black shirt, long blue pants, and black shoes. They also have articulating legs synchronized to the forward motion of the mannequin, replicate a human-like gait, and produce a realistic Micro Doppler effect. Unlike the legs of the pedestrian mannequin, the arms of the mannequins do not move, but are posable, and will be posed during testing. The 4activePA mannequins are also appropriate for NCAP testing because they are lightweight with a soft exterior to prevent vehicle damage upon impact.

NHTSA will utilize the 4activePA Adult mannequin for all PAEB test conditions that specify an adult test mannequin—S1a, S1b, S1e, S4a, and S4c; the 4activePA Child mannequin will be utilized for the S1d PAEB test condition. While the Agency recognizes it could utilize a posable pedestrian mannequin for the S4a test condition since the mannequin is stationary in those tests, NHTSA is adopting instead the articulating mannequin for S4a testing to promote test efficiency. As described later in this section, the 4activePA Adult mannequin will be confined to a standing posture position, with the legs at rest (*i.e.,* static), for S4a tests. For all other test scenarios prescribing the adult mannequin (*i.e.,* S1a, S1b, S1e, and S4c), the legs of the mannequin will articulate to simulate a walking or running motion, as appropriate. Similarly, for the S1d scenario, the legs of the child mannequin will be configured to articulate to simulate a running child.

Since PAEB systems currently on the market may utilize camera-, radar-, and/or lidar-based sensors (or some combination thereof) to provide automatic emergency braking and prevent impact with pedestrians, the pedestrian test mannequins adopted for NCAP's PAEB testing must meet certain specifications to ensure the SV recognizes the targets, similar to real-world pedestrians, thus offering real-world benefit. These specifications will also help assure test repeatability and reproducibility. Accordingly, NHTSA is adopting in its test procedures, certain specifications provided in several ISO standards for color (for camera-based sensors), physical dimensions (for camera- and lidar-based sensors), infrared reflectivity (for lidar-based sensors), and radar cross section and leg articulation (for radar-based sensors). The ISO standards are appropriate because they contain a large body of research testing to support the test devices. In most respects, these specifications also harmonize with those outlined by Euro NCAP in its ''Articulated Pedestrian Target Specifications'' document.[271] The 4activePA pedestrian mannequins, as manufactured, meet these specifications.

First, the Agency is referencing many, but not all, of the specifications in ISO 19206–2:2018, ''Road vehicles—Test devices for target vehicles, vulnerable road users and other objects, for assessment of active safety functions—Part 2: Requirements for pedestrian targets.'' This standard addresses specifications for a test mannequin, including basic postures and body dimensions as well as leg articulation, infrared, and radar properties.

Second, NHTSA is referencing sections of ISO 19206–4:2020, ''Road vehicles—Test devices for target vehicles, vulnerable road users and other objects, for assessment of active safety functions—Part 4: Requirements for bicyclists targets'' in NCAP's PAEB test procedures. This standard describes specifications for bicycle test devices representative of adult and child sizes. Although NHTSA will not use a bicycle test device during NCAP's PAEB testing at this time, this standard is being referenced solely because it contains sufficient specifications for color (*i.e.,* the color of the mannequins' hair, clothes, skin, etc.) for the pedestrian test mannequins.

NHTSA is also referencing in NCAP's PAEB test procedures sections of ISO 19206–3:2021, ''Test devices for target vehicles, vulnerable road users and other objects, for assessment of active safety functions—Part 3: Requirements for passenger vehicle 3D targets.'' This document provides measurement procedures for assessing radar cross-section.

Lastly, NHTSA is referencing ISO 3668:2017, ''Paints and varnishes—Visual comparison of colour of paints,'' in NCAP's PAEB test procedures. This standard, which specifies a method to allow the visual comparison of the color of paints against a standard, will ensure the color of the pedestrian mannequins' hair, torso, arms, and feet are black, the color of the legs is blue, etc., as prescribed by ISO 19206–4:2020.

In addition to these requirements, the Agency will also require the placement of a black cover over the pedestrian mannequins' center vertical pole during PAEB assessments in dark lighting conditions, as Auto Innovators and BMW requested. NHTSA agrees that this should further improve the mannequin's resemblance to a real pedestrian. This modification should minimize contrast with the background and limit reflectivity to light sources (*e.g.,* headlamps) during testing in dark lighting conditions. The radar reflectivity requirements prescribed in ISO 19206–2:2018 must be met both with and without the black cover present on the pole.

Similar to its decision for the GVT, NHTSA is not adopting separate specifications for the pedestrian mannequin carrier system. The carrier system controls the speed (where applicable) and position (*e.g.,* lateral overlap relative to the front of the SV and desired contact points) of the pedestrian test device. Since these variables will be subject to

[269] Both pedestrian mannequins are manufactured by 4activeSystems.

[270] In Euro NCAP's AEB/LSS VRU Systems test protocol, the adult pedestrian mannequin is termed the Euro NCAP Pedestrian Target (EPTa) and the child pedestrian mannequin is termed the Euro NCAP Child Target (EPTc).

[271] European Automobile Manufacturers' Association (ACEA), February 2016, ''Articulated Pedestrian Target Specification Document,'' Version 1.0, available at *https://www.acea.auto/publication/articulated-pedestrian-target-acea-specifications/.*

specifications and tolerances prescribed for the pedestrian mannequins for each test scenario, NHTSA does not see a substantial need to specify which carrier system must be used to achieve the appropriate mannequin kinematics during testing. Further, the pedestrian mannequins will be assessed while mounted on the carrier system per ISO 19206–2:2018, thus assuring the carrier system has a minimal radar cross-section and minimal optical features based on the test environment. The Agency also notes that, at this time, it anticipates using the 4activeSB robotic platform for NCAP testing.

While NHTSA acknowledges the stance of a few commenters that the Agency should consider adding VRUs with different positioning/posture or clothing to not overly rely on leg movement to prompt system intervention, or different dimensions or skin tones to offer equivalent protection for all pedestrians, the Agency concludes the 4activa-PA Adult and Child pedestrian mannequins are acceptable for this NCAP upgrade. Although the Agency reasons it is important for PAEB performance requirements to ensure real-world safety benefits across a broad spectrum of pedestrian crash scenarios, it also recognizes that, for practical reasons, performance requirements cannot address every pedestrian crash scenario. Notwithstanding, the Agency is adopting test scenarios representing a walking, running, and standing adult. Further, NHTSA is incorporating a test scenario designed to simulate real-world pedestrian impacts involving children. Given this, the Agency expects future PAEB systems will effectively address pedestrians of various sizes and not rely solely on leg articulation for functionality. NHTSA will also continue to monitor real-world pedestrian crash data to ensure the adopted mannequins are reasonably sufficient to address the crash risks for pedestrians of other sizes, such as small adult women, and those having alternative postures. This data analysis should also allow the Agency to determine whether additional VRU surrogates or scenarios should be added to the Agency's PAEB test matrix in the future as representative test devices become available and research proves such devices to be robust and reliable during testing. Further, as discussed later in this notice, the Agency is considering adding additional test scenarios for bicyclists, motorcyclists, etc. in future updates to NCAP. NHTSA is also conducting research to assess the affect that variations in skin tone and/or clothing may have on PAEB system performance. NHTSA will compare these results to the referenced ISO standard specifications and may consider additions or modifications to improve the relevance of the Agency's PAEB tests once the research is complete.

10. Additional Test Procedure Refinements, Clarifications, and Feedback

NHTSA requested comments on any areas of the proposed PAEB test procedure that needed clarification or further refinement before the Agency adopted it for use in NCAP. Various comments were received.

Summary of Comments

Publication of Draft Test Procedures

Auto Innovators noted the draft test procedures have not been republished with changes suggested in response to a 2019 RFC notice.[272] The group recommended that NHTSA republish the latest version of the procedures for comment and review.

Pedestrian Mannequin Target

Some commenters stated the characteristics of pedestrian mannequin target movement, like speed and acceleration of the mannequin as it moves across the test site, should be addressed. One individual stated the maximum pedestrian speed did not represent runners, as they may approach a vehicle's path more quickly. This commenter also noted the Agency could factor in safety for the variety of speeds at which VRUs travel by also varying the target speed. One individual commenter noted that seniors tend to move at a slower pace and are less likely to recover from injuries sustained in a vehicle impact, stating that seniors over the age of 65 are 35 percent more likely to be killed as pedestrians. NSC stated that older adults (those 65 and older) account for 20 percent of pedestrian fatalities.

For target acceleration, vehicle manufacturers expressed logistical concerns. Honda, Toyota, and Auto Innovators requested the Agency ensure the pedestrian mannequin start and acceleration distances are adjusted to ensure the mannequins move smoothly across the surface. Commenters noted if the pedestrian mannequin is subject to sudden accelerations, it may ''shake,'' and its location and speed may not be detected accurately by PAEB systems. Toyota provided data to demonstrate that for S1b and S1e, a greater mannequin acceleration distance is needed to achieve a stable velocity.

[272] NHTSA–2019–0102–0011.

Honda recommended S1a-d test conditions should have ''PTM Start Distance'' increased from 3.5 m to 4.0 m and ''PTM Acceleration Distance'' increased from 0.5 m to 1.0 m. For test condition S1e, the manufacturer suggested that ''PTM Start Distance'' should be increased from 5.5 m to 6.0 m and ''PTM Acceleration Distance'' should be increased from 1.0 m to 1.5 m. Honda and Auto Innovators mentioned that this has already been addressed in the Euro NCAP and JNCAP test procedures. Auto Innovators added that pedestrian mannequin motion tolerances can accumulate, resulting in the target's final location being farther away from its intended location. Accordingly, the group stated that the pedestrian mannequin motion tolerances should be reduced to ensure test repeatability, stating that if the highest test speed of 60 kph (37.3 mph) is adopted, tolerances should align with Euro NCAP's. IDIADA and Honda also recommended that NHTSA ensure the pedestrian and vehicle travel paths intersect at the intended location. Regarding false positive testing, GM requested clarity on deceleration distance in test condition S1f.

Auto Innovators stated that controllability of the freeboard should be further investigated. For in-path test conditions S4a–c, Auto Innovators stated that NHTSA should ensure the pedestrian mannequin is properly mounted on the pole if the Agency intends to test conditions with the pedestrian mannequin facing both away from and towards the SV.

Subject Vehicle

Regarding the movement of the SV, Honda suggested that the Agency use an accelerator/brake robot to increase the robustness of the test procedure. The automaker noted that changes like these would uphold NCAP's credibility and ensure well-defined safety performance information is gathered should the Agency collect self-reported data. Auto Innovators agreed, requesting that the SV be controlled by a steering robot.

For PAEB testing in dark conditions, TRC commented that the ''aimed location'' of the SV's headlamps may need to be documented, further noting that IIHS currently records headlight aim for some of its work. Advocates stated the Agency should verify that the advanced headlighting system operates automatically. Additionally, Intel and ZF Group suggested the test should allow sufficient time for the headlighting systems to engage and switch to upper beams before the test begins (or at least 4 seconds TTC).

Finally, SEMA stated that NHTSA should also test modified vehicles, defining modified as ''lifted and lowered.'' SEMA also requested that data, including mechanical and electronic tolerances, be published by the OEM so that modified vehicles' PAEB systems may achieve the same performance as a non-modified vehicle's performance. The group stated that such vehicle modifications are legal and should be accounted for.

Scenario and Test Condition Specifications

Auto Innovators and GM stressed the importance of eliminating other artificial light sources that do not represent on-road conditions. The groups suggested the presence of such light may interfere with the intended operation of the PAEB system. If the artificial light sources cannot be removed, GM suggested that tests take place in the opposing direction, or, if this is not possible, vehicle high beams should be engaged to replicate the expected driving conditions. These commenters also requested alterations specific to certain test conditions. Auto Innovators stated the Agency should align the parked obstacle vehicle location in scenario S1d to the Euro NCAP condition, and GM requested clarity on definitions for pass/fail criteria for both false positive (S1f and S1g) conditions.

Velodyne expressed concerns that the current test procedures do not include enough of the elements of real-world driving to effectively evaluate a vehicle's true PAEB performance. The company listed ''shadows, unclear or unmarked lane lines or road edges, curved roadways, irregular route geometries, [. . .] irregularities in the roadway, cluttered or low contrast scenes, overhead objects, or irregular object shapes'' as potential confounding factors. Velodyne went on to state the shortcomings of cameras and radar in effectively informing PAEB systems, noting that adding more cameras and radar sensors will not be enough to address this issue. Velodyne suggested lidar will be necessary to address challenging real-world conditions such as those mentioned above.

Response to Comments and Agency Decisions

Publication of Draft Test Procedures

NHTSA acknowledges the prior receipt of comments from Auto Innovators detailing feedback regarding the Agency's draft PAEB test procedures. The Agency has considered all comments received and has made changes to its PAEB test procedures accordingly. These revised PAEB test procedures are being published and docketed along with this final decision notice for use in NCAP testing.

Pedestrian Mannequin Target

The Agency is adopting the pedestrian speeds proposed in the March 2022 RFC notice. NHTSA acknowledges requests by respondents to make changes to the characteristics of the pedestrian mannequin target, including accounting for different pedestrian speeds based on walking or running speed. However, because the Agency must be mindful of the test burden created by adding additional test conditions, it is choosing to keep the proposed pedestrian speeds at this time. NHTSA notes the pedestrian mannequin speeds chosen for NCAP's PAEB test conditions align with those selected by Euro NCAP, and thus seem reasonable for inclusion in U.S. NCAP. Given the variations in test conditions adopted, including those for the pedestrian mannequin speed (*i.e.,* walking, running, and stationary), the Agency expects that the prescribed pedestrian mannequin target speeds will mitigate crashes for pedestrians travelling faster or slower than the target speed. Real-world pedestrian crashes that PAEB does not completely prevent may also be further mitigated by NCAP's forthcoming crashworthiness pedestrian protection testing program.[273]

Further, NHTSA shares similar concerns as those expressed by commenters relating to pedestrian target acceleration, such as potential mannequin instability caused by inadequate starting and acceleration distances already observed and addressed by other global testing entities. Specifically, the Agency has observed that when the pedestrian mannequin begins to move, the mannequin tends to sway and oscillate for some time before gaining stability. Additionally, the Agency has found that sudden acceleration results in inconsistent pedestrian mannequin motion. Based on these concerns and observations, NHTSA will adopt amended starting and acceleration distances for its NCAP PAEB test procedures. For test conditions S1a–d, the pedestrian mannequin's starting distance will be 4.0 ± 0.1 m (13.1 ± 0.3 ft.) from the SV's intended travel path. For test condition S1e, the pedestrian mannequin's starting distance will be 6.0 ± 0.1 m (19.7 ± 0.3 ft.) from the intended travel path. For all conditions, the pedestrian mannequin's acceleration distance will be 1.5 m (4.9 ft.). These changes should increase repeatability and accuracy of PAEB system testing. Apart from the crossing path acceleration distance specification, these specifications also promote harmonization, as they are aligned with Euro NCAP's pedestrian mannequin starting and acceleration distances. NHTSA will also provide additional clarity on the deceleration distance for condition S1f if and when it chooses to adopt this test condition for NCAP.

NHTSA will adopt a pedestrian mannequin target speed tolerance of 0.4 kph (± 0.2 mph) for pedestrian mannequin motion tolerance. Despite commenter concern regarding tolerances being too wide and the pedestrian target's final location being inconsistent, particularly at higher speeds, the Agency's experience through its research testing to date is that this amount of tolerance is consistently achievable and provides a high-level of repeatability.

Finally, because the Agency plans to adopt only the S4a and S4c test conditions, which both specify that the dummy face away from the vehicle instead of towards the vehicle as is required for the S4b condition, there is a decreased likelihood that the pedestrian mannequin will be improperly installed on the pole since there will be no need to switch the orientation of the pole during testing. Having said this, test laboratories will be expected to inspect their equipment prior to performing evaluations and to verify that the test setup is valid.

Subject Vehicle

Repeatability of the SV's movements throughout the testing series was of concern to some commenters. A few suggested that either accelerator/brake (Honda) or steering (Auto Innovators) robots should be utilized. As with the AEB tests described earlier, steering and throttle requirements are specified; a test will be considered valid if these requirements are met. Thus, the Agency declines to require the use of throttle or steering robots at this time to conduct testing according to NCAP protocol. However, they may be used by laboratories or manufacturers if desired.

NHTSA agrees with Intel and ZF Group's concern that the PAEB testing procedure for testing in dark conditions should allow time for any advanced lighting feature(s) that cannot be disabled to engage prior to the official start of the test. NHTSA will ensure that advanced lighting feature(s) engage automatically, if appropriate, and will

[273] 88 FR 34366. The final decision notice for the NCAP crashworthiness pedestrian protection testing program is forthcoming.

allow sufficient time prior to the vehicle's encounter with the pedestrian mannequin for the automatic engagement to occur. It is also reasonable to measure vehicles' headlamp aim angles and record these prior to testing, as TRC requested. However, the Agency will not alter the aim of vehicles' headlamps to align with manufacturer instructions prior to conducting PAEB tests. NHTSA asserts vehicle headlamps should be tested as received from the dealer for NCAP testing, since it is unlikely vehicle owners will adjust the aim of their headlamps prior to driving. Thus, maintaining factory settings should ensure more realistic testing.

The Agency is not adopting the testing of modified vehicles at this time, as suggested by SEMA. NCAP's test methodology involves the evaluation of production-level vehicles available directly from the manufacturer, and any modified vehicle may not receive similar NCAP results, whether tested for crashworthiness or crash avoidance. Given the variety of legal modifications that may be completed in an aftermarket setting, it is not practicable to evaluate vehicles with modifications. Further, generating this information would be a significant burden to vehicle manufacturers.

Scenario and Test Condition Specifications

NHTSA finds validity in the unspecified artificial light source concerns raised by GM and Auto Innovators. As the Agency seeks to replicate challenging real-world scenarios while also offering repeatable test conditions, it has decided that the test procedure for darkness PAEB testing will specify the ambient illumination at the test site must be no greater than 0.2 lux. This value approximates roadway lighting in dark conditions without direct overhead lighting with moonlight and low levels of indirect light from other sources, such as reflected light from buildings and signage. Additionally, an illumination level of 0.2 lux mirrors the level specified in the test procedures for the recently issued final rule for adaptive driving beams.[274] This darkness level accounts for the effect ambient light has on AEB performance, particularly for camera-based systems, and should ensure robust performance of all AEB systems, regardless of sensor type. Also, NHTSA will not perform tests where the SV is driving toward the moon such that the horizontal angle between the moon and a vertical plane containing the centerline of the SV is less than 25 degrees and the lunar elevation angle is less than 15 degrees. By incorporating these specifications, the Agency sees no need to allow manual high beam usage, as GM requested.

Auto Innovators suggested the Agency align the parked obstacle vehicle location in test condition S1d to the applicable specifications prescribed for Euro NCAP's comparable CPNCO test condition. The Agency confirms that NHTSA's S1d parked obstacle vehicle location aligns with Euro NCAP's CPNCO specification.

In response to GM's request that the Agency clarify the pass/fail criteria for both false positive (S1f and S1g) test conditions, appropriate specification will be provided if and when the Agency chooses to adopt these test conditions for NCAP.

Finally, while NHTSA acknowledges Velodyne's assertion that its current PAEB test procedures do not encompass all aspects of real-world driving, given the number of test conditions and variants included in NCAP's PAEB test matrix, the Agency concludes the published test procedures are sufficient to gauge overall PAEB system performance. NHTSA notes it must balance attempts to ensure system robustness with increased test burden. NHTSA may consider adopting additional test conditions or variants in the future encompassing one or more of the elements the commenter mentioned if real-world data identifies a significant need.

11. Adding Test Scenarios S2 and S3

The Agency's 2019 PAEB test procedure does not include CAMP scenario S2 (vehicle turning right and a pedestrian crossing the road) or CAMP scenario S3 (vehicle turning left and a pedestrian crossing the road), both of which are defined earlier in this final notice. In response to the December 2015 RFC notice, several commenters stated that addressing these scenarios with available technology may generate a significant number of false positive detections. These false detections could have the unintended consequences of causing hazardous situations (*e.g.,* unexpected sudden braking while turning in traffic) that could lead drivers to disable their PAEB systems or possibly lead to an increase in rear-end collisions. The commenters explained that the S2 and S3 test scenarios require more sophisticated algorithms as well as more robust test methodologies than those required for scenarios S1 and S4. However, ZF Group mentioned that ADAS sensors designed to meet Euro NCAP's Vulnerable Road Users test procedures would have increased fields-of-view, which should improve their effectiveness in turning scenarios. Other commenters stated that the articulating mannequins may not be representative of a real human for all sensing technologies in turning scenarios. Most commenters found it more appropriate to focus on the scenarios affording the most significant safety benefits first—S1 and S4, and stated that adding the S2 and S3 scenarios would be more practical when the technology matures. NHTSA committed to continuing PAEB system evaluations in its March 2022 RFC notice to determine the feasibility of including S2 or S3 scenarios as technological advancements are made.

Earlier in this notice, the Agency stated it did not conduct the S2 and S3 test scenarios as part of its PAEB characterization study and did not propose these test scenarios for inclusion in its current proposal to update NCAP. NHTSA agreed with the comments mentioned previously that most vehicles in the U.S. fleet are not currently equipped with sensing systems capable of detecting pedestrians while a vehicle is turning (*i.e.,* those situations represented by S2 and S3 test scenarios), as they do not have the necessary field-of-view. AAA conducted PAEB tests, including an S2 scenario where the vehicle is turning right with an adult pedestrian crossing.[275] In AAA's testing, the PAEB systems for four tested model year 2019 vehicles did not react to the test targets during a testing scenario similar to NHTSA's S2 scenario described above, resulting in all test vehicles colliding with the pedestrian mannequin target. These systems performed better in a scenario similar to NHTSA's S1 scenario, however. In that testing, the vehicles avoided a collision with the pedestrian mannequin target 40 percent of the time at a 32.2 kph (20 mph) test speed and nearly all the time at a 48.3 kph (30 mph) test speed. Further, in its recent study on PAEB system effectiveness, IIHS found that while AEB with pedestrian detection was associated with significant reductions in pedestrian crash risk (approximately 27 percent) and pedestrian injury crash risk (approximately 30 percent), no evidence suggested that existing systems were effective while the PAEB-equipped vehicle was turning.[276] Thus, it was

[274] 87 FR 9916.

[275] American Automobile Association (2019, October), *Automatic emergency braking with pedestrian detection, https://www.aaa.com/AAA/common/aar/files/Research-Report-Pedestrian-Detection.pdf.*

[276] Cicchino, J. B. (2022, February), *Effects of automatic emergency braking systems on*

more beneficial to focus current efforts on performing PAEB testing at higher speeds and with various lighting conditions using the S1 and S4 test scenarios. However, NHTSA's March 2022 RFC sought comment on an appropriate timeframe for including S2 and S3 scenarios in NCAP and requested information from vehicle manufacturers on any vehicle models designed to address, and ideally achieve crash avoidance, during conduct of the S2 and S3 scenarios to support Agency evaluation as part of a future program upgrade.

Summary of Comments

Include Turning Scenarios Now

Commenters seeking the inclusion of turning scenarios into PAEB evaluations either immediately or as soon as possible (Bosch, Lidar Coalition, Aptiv, CAS, NTSB, MEMA, Adasky, Advocates, The League, ZF Group, IIHS, ASC, Intel, CR, AARP, Velodyne, Tesla, and a number of individual commenters), noted that including turning scenarios would align with Euro NCAP's test protocol and promote harmonization. NTSB did not provide a timeline for including turning PAEB scenarios in NCAP but stressed the importance of testing the upper limits of vehicle capabilities to drive innovation and advancement. Advocates and The League echoed NTSB's opinion, with Advocates noting that manufacturers are already able to meet expectations internationally. The League also questioned why NHTSA did not acknowledge or adopt the Euro NCAP CPTA protocol. Velodyne noted Euro NCAP's Roadmap for 2025, already highlights turning conditions as a priority for inclusion.

Some commenters cited real-world injury data to support the prompt inclusion of turning scenarios, with Lidar Coalition reiterating nearly half of vehicle-to-pedestrian collisions occur at an intersection while the vehicle is turning. Although NHTSA's data has previously shown intersection crashes involving a crossing pedestrian and turning vehicle are generally of lower severity, Lidar Coalition noted vehicles have grown larger since this data analysis, a sentiment echoed by Velodyne. IIHS cited its 2022 study which found that at intersections, the odds that a crash that killed a crossing pedestrian involved a left turn by the vehicle versus no turn were about twice as high for SUVs, nearly three times as high for vans and minivans and nearly four times as high for pickups as they were for passenger cars.[277] The group suggested that NHTSA begin evaluating S2 scenarios as a complementary approach to its consumer information program. Lidar Coalition and another individual acknowledged the same study and noted that a similar trend could be seen for crashes involving vehicles turning right. Therefore, Lidar Coalition requested that NHTSA perform a follow-up study to investigate more current severity trends with respect to pedestrians involved in turning pre-crash scenarios. NACTO also stated vehicles are three to four times more likely to fatally injure pedestrians while turning.

Commenters also noted the evolution of vehicle sensors and equipment. Specifically, Lidar Coalition stated that field-of-view limitations are of less concern when vehicles are equipped with a variety of sensors intended to monitor the sides of a vehicle, such as with BSW/BSI, and that consumers will expect the vehicle to be able to warn them of an impending crash with a pedestrian while turning because of "rotational" sensors monitoring their vehicles. ZF Group noted the field-of-view of current sensors has improved since prior consideration of the S2 and S3 scenarios, and vehicles would show improved performance at this time. Adasky stated that thermal cameras are also adequate to address S2 and S3 scenarios and have become more affordable and smaller in size. Adasky also discussed the capability of fusion sensors (thermal/RGB cameras/radar) and object detection software to perform well in these scenarios, particularly emphasizing the performance improvement that thermal cameras offer over RGB camera/radar fusion systems. ASC, Intel, Velodyne, Aptiv, and others also noted that improved perception technology is currently available.

Lidar Coalition and Velodyne stated that NHTSA should balance the risk of an increased numbers of false positives (and, therefore, rear-end collisions) with the benefit to VRUs that may be afforded by including turning scenarios in PAEB evaluations. Both groups noted it is preferable for a driver to encounter a false positive activation and have time to react or override the intervention than to experience a false negative situation. Adasky recommended NHTSA evaluate false positive rates, as doing so may indicate system robustness and offer insight into possible areas of improvement.

The Agency also received comments from NYC DOT/NYC DCAS, which expressed concern regarding consumer understanding of PAEB performance if S2 and S3 are not included in NHTSA's evaluations. The group stated the Agency needs to clearly convey that PAEB systems may not be as effective while turning as they are when the vehicle is driving straight.

In relation to timing, some commenters mentioned that a phased approach may be appropriate. Aptiv advocated for a timeline similar to Euro NCAP's, with immediate inclusion of S2 and S3 when the pedestrian is oncoming with respect to the SV before the turn is initiated, and later inclusion of S2 and S3 scenarios with the pedestrian receding (possibly with two- or three-years lead-time between oncoming and receding). Aptiv justified this timing by noting oncoming pedestrian scenarios are less challenging to meet than receding pedestrian scenarios.

Wait To Include Turning Scenarios

Some commenters recommended that NHTSA should wait to include S2 and S3 pre-crash scenarios in NCAP. Specifically, BMW, GM, Honda, Auto Innovators, Toyota, FCA, and HATCI agreed that the S1 and S4 scenarios should be introduced first with turning pre-crash scenarios added at a later time. Toyota did not have a specific recommendation regarding a timeline for S2 and S3 scenario inclusion but did note the frequency of pedestrian crashes in which the striking vehicle was turning was very low (8 percent) compared to scenarios S1 and S4.[278] HATCI also noted the higher relative frequency of S1 and S4 pre-crash scenarios in real-world data. FCA stated there should be a demonstrated need and robust test procedure prior to the incorporation of any new technology assessment into NCAP. BMW suggested the latter half of this decade would be appropriate timing because of the possibility of increased false positive activations. Auto Innovators, FCA, and HATCI stated turning scenarios should be included in the Agency's future roadmap, with Auto Innovators specifically noting this item should be targeted for the mid- to long-term range. GM stated the S2 and S3 scenarios should be phased in later as part of a

pedestrian crash risk, Insurance Institute for Highway Safety, *https://www.iihs.org/api/datastoredocument/bibliography/2243.*

[277] Hu, W. and J.B. Cicchino. (2022, July), *Relationship of pedestrian crash types and passenger vehicle types,* Insurance Institute for Highway Safety.

[278] Carpenter, M.G., Moury, M.T., Skvarce, J.R., Struck, M. Zwicky, T.D., & Kiger, S.M. (2014, June), *Objective tests for forward looking pedestrian crash avoidance/mitigation systems: Final report* (Report No. DOT HS 812 040), Washington, DC: National Highway Traffic Safety Administration.

mid-term update to allow time for planned system and sensor enhancements to enter the fleet. Honda suggested NHTSA evaluate the current vehicle fleet using the Euro NCAP CPTA protocol to determine whether current systems could meet requirements. The automaker did not give a timeframe for inclusion of S2 and S3 but noted S1 and S4 should be given priority.

Other Suggestions

Commenters also provided specific suggestions for the S2 and S3 scenario test procedures in the event that NHTSA chose to adopt them with its final decision notice. Bosch recommended NHTSA amend the test procedure to have the SV perform a clothoid maneuver [279] instead of the constant-radius maneuver currently specified. The group stated the clothoid path more closely resembles a real-world left turn maneuver and is more easily repeated in a test setting than is a constant-radius maneuver. ASC suggested adopting S2 with a 10 kph (6.2 mph) SV speed and conducting S3 at 10 kph (6.2 mph) and 20 kph (12.4 mph), since this would be in alignment with Euro NCAP's protocol.

Commenters also expressed opinions on how to best convey PAEB system performance information for S2 and S3 pre-crash scenarios if these scenarios were adopted in NCAP. Rivian stated NHTSA should phase in levels of intervention by first giving credit to auditory warnings and then, at a later point in time, checking for speed reduction. Auto Innovators suggested that the Agency give credit for S2 and S3 performance as a ''Recommended Technology'' rather than integrating these pre-crash scenarios into an overall rating. Conversely, Advocates stated it would like to see PAEB included in the rating itself rather than simply listed as a ''Recommended Technology,'' as it would allow consumers to differentiate between vehicle safety system performance.

Response to Comments and Agency Decisions

While the Agency agrees with those commenters asserting there are inherent safety benefits in adopting S2 and S3 turning scenarios to assess PAEB systems, it will not incorporate these additional test scenarios as part of this NCAP upgrade.

NHTSA acknowledges the many reasons commenters cited for adding turning scenarios to PAEB evaluations as soon as possible, including: harmonization with Euro NCAP's CPTA scenarios, anticipated real-world benefits and their potential to nullify the risk of a potential increase in false positives, the recent increase in vehicle size leading to more fatal crashes, recent sensor additions and advancements, and potential consumer confusion if such scenarios are omitted. Other commenters supported phasing in the turning PAEB test scenarios over time, with many agreeing with the Agency's proposal to adopt S1 and S4 scenarios as part of this upgrade to NCAP and S2 and S3 scenarios as part of a future update. These commenters, many of which suggested that an appropriate timeline for S2 and S3 adoption would be approximately five to seven years, cited limited real-world benefits compared to those afforded by adoption of the S1 and S4 scenarios, and the need for test procedure development and Agency research. Aptiv also supported a phased approach to adoption of the S2 and S3 test scenarios but explained that certain turning scenarios could be added as part of the current program update (which also includes the adoption of S1 and S4) and others could be included two to three years later to allow time for PAEB systems to mature.

Given the comments received, NHTSA reasons several actions must take place prior to the adoption of additional PAEB tests. Specifically, the Agency should first analyze recent crash data to further characterize scenarios for pedestrians involved in crashes with a turning vehicle. This analysis should allow the Agency to refine existing testing procedures to best address the safety need. Following this, NHTSA should conduct research testing to validate these test procedures and assess the capabilities of the current fleet. As part of the Agency's research effort, it will consider Bosch's suggestion to adopt a clothoid maneuver for the SV in lieu of a constant-radius maneuver to improve test repeatability, along with ASC's recommendation to align test speeds to those prescribed by Euro NCAP. In the event the Agency develops a proposal to add the S2 and S3 PAEB tests to NCAP in the future, as many respondents suggested, the Agency will also consider the comments received from Rivian, Auto Innovators, and Advocates pertaining to performance requirements and incorporating the associated test results for the turning scenarios for ratings purposes. In the meantime, NHTSA will communicate on its website test specifics for the PAEB scenarios the Agency is adopting so the public may understand NCAP's assessments are limited to only those situations reflected by the tests conducted and do not encompass all situations involving pedestrians that a driver may encounter, as NYC DOT/NYC DCAS requested.

12. Future Safety Areas for Pedestrian Protection

NHTSA requested comments on other safety areas that should be considered as part of a pedestrian protection NCAP strategy for this program update or the future. NHTSA received many comments on this topic, summarized below.

Summary of Comments

Pedestrian Crashworthiness

An overwhelming number of commenters responded in favor of incorporating a crashworthiness pedestrian protection component to the NCAP ratings. Commenters expressed concerns about the increasing size (both in height and weight) of vehicles in the U.S., noting that consumers often purchase larger vehicles to protect their own families while inadvertently placing VRUs at a disadvantage. Those in favor of a pedestrian crashworthiness component reasoned that its incorporation would help balance the risk between those inside and outside of the vehicle. Many commenters also mentioned that ADAS technologies will not be effective in every scenario and requested that NHTSA take a multi-pronged approach in addressing pedestrian injuries and fatalities. These individuals suggested manufacturers design their vehicles to be more pedestrian-friendly, rather than relying on technology that may not be completely effective to avoid the crash. Many commenters noted Euro NCAP currently performs this testing.[280] [281]

The League specifically requested NHTSA evaluate vehicles for crashworthiness protection for cyclists, those in wheelchairs, and other VRUs sharing the roadway with motor vehicles. It stated that if this evaluation cannot be included in NCAP, it should at least be undertaken as research to allow all parties (consumers, researchers, and vehicle manufacturers) to better understand how vehicle design influences injury in these populations.

[279] A clothoid is a curve whose curvature changes linearly with its curve length. It is often used as a transition curve in highway design.

[280] European New Car Assessment Programme (Euro NCAP) (December 2023), *Vulnerable Road User Testing Protocol, Version 9.1.*

[281] In Euro NCAP's VRU protection protocol, head impactors and leg impactors are used to evaluate a pedestrian's injury risk after an impact with the test vehicle.

Direct Visibility

Commenters also expressed concerns relating to direct driver visibility, with many stating that ADAS technologies involving cameras and sensors should not be the first solution to increase the field of view of a driver. Instead, they preferred manufacturers consider vehicle designs which eliminate or greatly reduce blind zones at early stages of development. Commenters noted that minimized blind zones may improve a driver's ability to see and respond to VRUs who use assisted mobility devices, such as wheelchairs, walkers, or scooters, and may already be closer to the ground. One individual also suggested that visibility of a pedestrian or other VRU after an initial PAEB intervention has taken place should be accounted for, allowing the driver to physically see why the vehicle intervened and take appropriate actions.

Pedestrian Mannequin Target

Many commenters requested changes to the pedestrian mannequin target and/or additional targets to represent a wider variety of VRUs more closely. Of particular concern was the ability of PAEB systems to accurately detect people of color. NACTO cited a 2019 study from the Georgia Institute of Technology [282] that demonstrated automated vehicles cannot detect darker skin as well as lighter skin. The group further stated that ''people of color, particularly Black and Indigenous people, are disproportionately killed while walking and are more likely to live in communities with unsafe, inadequate infrastructure for walking and biking.'' NSC added that although pedestrian deaths represent about 14% of all traffic deaths among white, non-Hispanics, they represent more than 20% of pedestrian fatalities among Hispanics, Black non-Hispanics, and Native Americans. NSC further noted that, compared to white non-Hispanics, the pedestrian fatality rate for Native Americans is almost four times as high, and the pedestrian fatality rate for the Black community is nearly twice as high. These sentiments were detailed by safety advocates, local government organizations, and individuals alike.

Commenters also expressed concerns with the height of the pedestrian mannequin target, particularly for shorter individuals, including children. An individual commenter stated that children are vulnerable to pedestrian impacts not only because of their size relative to a modern vehicle's size, but also because of the behavioral differences between adults and children. Specifically, the commenter noted that children are less likely to use the same judgment around vehicles as adults, citing evidence to support this claim.[283] NSC stated that, in 2017, one in every five children killed in a crash were pedestrians. Several individuals and one group (Bikemore) stated the pedestrian mannequin should be representative of a 2-year-old child. MEMA noted there are currently 2-year-old and 7-year-old pedestrian mannequins available, adding they should also be included in a future NCAP upgrade. Auto Innovators supported the use of a 7-year-old child target in the future. Uhnder stated child targets should be used in all testing, noting that all VRUs should be equally represented. ASC also stated all VRUs should be represented equally, adding that NHTSA should consider using them beyond scenario S1d.

Commenters also noted several other areas of potential interest for characteristics of the pedestrian target, including: gender, clothing type and color, carried or pushed objects (such as a stroller), and the use of assistive mobility devices like wheelchairs and scooters. For example, AARP suggested that PAEB systems should be able to recognize pedestrians carrying shopping bags or walking a bicycle across a road. Advocates cited the NTSB's findings that a 2018 crash involving a vehicle equipped with ADAS technologies occurred because the vehicle did not properly identify the pedestrian walking her bicycle across the road.[284] One commenter who uses a wheelchair stated those using assistive mobility devices like wheelchairs are already more difficult to see while traveling because their head is lower to the ground, including sometimes below the hoods of vehicles. Likewise, one individual commenter noted wheelchair users are 36 percent more likely to be killed as pedestrians than the overall population. Uhnder and another individual stated that darker clothing is more difficult for the human eye to distinguish from surroundings in the dark, particularly for pedestrians traveling at night. It would be imperative for a PAEB system to recognize and respond to a pedestrian wearing such clothing.

Finally, Auto Innovators and GM stressed the need for field pedestrian crash data to support any additional safety areas addressed by NCAP.

Inclement/Challenging Weather

Many comments addressed PAEB performance in poor weather conditions and in a variety of environments. As discussed in previous sections of this notice, many respondents expressed concerns over performance degradation in rain, snow, and fog. Walk and Roll Bellingham stated that a system that will not work in these conditions would not be useful to them, as inclement weather is common.

One individual commented that many crashes occur during dawn and dusk, which are mid-level lighting conditions. The commenter stated this may be due to sun glare or to more individuals traveling at these times of day, noting it should be a targeted scenario due to frequency of occurrence.

Other Scenarios To Consider

Commenters also suggested other PAEB scenarios and variations the Agency should consider, with Uhnder, ASC, and one individual recommending the addition of a test simulating a pedestrian crossing the road with another vehicle approaching in oncoming traffic, both in daylight and dark lighting conditions. Uhnder also suggested including a test with a pedestrian crossing under a bridge or walkway. Uhnder stated that these scenarios, which had once been difficult for the SV to pass because sensors could not properly resolve the pedestrian, are now less challenging for modern sensors. Vayyar recommended including a parking lot scenario in which a vehicle enters and exits a parking space. CAS noted that highway signage, crosswalk painting, and construction should be accounted for in NHTSA's testing.

One individual pointed out there is currently no provision to mitigate a crash with a pedestrian that may be lying in the road, and that such a case might apply to a pedestrian that has already been struck.

TRC, AARP, and one individual pointed out this proposal does not address backovers. TRC and the individual commenter noted Euro NCAP has developed and approved a protocol for reverse pedestrian braking. Accordingly, TRC asserted the Agency could readily adopt this test as part of its PAEB test procedures. Similarly, the individual commenter expressed that it was unacceptable NHTSA did not plan

[282] *https://arxiv.org/pdf/1902.11097.pdf.*

[283] Elizabeth E. O'Neal et al., Changes in Perception-Action Tuning Over Long Time Scales: How Children and Adults Perceive and Act on Dynamic Affordances When Crossing Roads, 44 JOURNAL OF EXPERIMENTAL PSYCHOLOGY: HUMAN PERCEPTION AND PERFORMANCE 18 (2018).

[284] *https://www.ntsb.gov/investigations/accidentreports/reports/har1903.pdf.*

to include reverse and turning scenarios until the 2025–2031 timeframe. AARP suggested that including a reverse pedestrian test will improve PAEB technology more rapidly.

Finally, Vision Zero Network and NACTO expressed concerns with a PAEB system's ability to distinguish pedestrians traveling in a crowd.

Vehicle to Everything (V2X)

Several commenters expressed that V2X technology could help drivers and VRUs avoid potential hazards, especially as vehicles increasingly share roads with pedestrians, bicyclists, etc. 5G Automotive Association noted that V2X technology developed under the 3rd Generation Partnership Project already supports vehicle-to-pedestrian communications. Two additional commenters stated V2X technology could be used specifically to help address the nighttime pedestrian crash problem. ASC and one individual commenter stated that vehicles could assess nearby smartphone location data to locate and track VRUs. ASC suggested NHTSA perform testing with location data enabled smartphones attached to the pedestrian mannequin for vehicles equipped with this technology.

Other Comments

ZF Group commented that pedal misapplication is a concern and that as the country ages, incidents could increase. Additionally, the group noted JNCAP has developed a protocol to evaluate acceleration suppression technologies to mitigate the risk and suggested NHTSA investigate this further.

Another individual stated NHTSA should require vehicles to make sound at low speeds to warn pedestrians that a vehicle is in motion nearby.

Response to Comments and Agency Decisions

Many commenters stated the Agency should pursue multiple paths beyond those specifically proposed in the March 2022 notice to fully mitigate pedestrian crashes. NHTSA's response to these comments follows.

Pedestrian Crashworthiness

Many commenters expressed that vehicle manufacturers should take pedestrian crashworthiness into account when designing vehicles. As noted previously, NHTSA intends to develop a pedestrian crashworthiness FMVSS to address pedestrian head impacts to vehicle hoods and has also proposed a separate testing program for NCAP.[285] [286] Comments will be considered independently in the context of those actions. The Agency hopes that, if implemented, these efforts may help to address the need to balance risk to occupants in the vehicle with those outside of the vehicle.

Direct Visibility

The Agency is looking into this further to determine the best approach to address these issues and has included driver visibility in the 10-year roadmap for consideration in future NCAP updates.

Pedestrian Mannequin Target

NHTSA notes the proposed 4activePA adult and child articulated mannequins represent a 50th percentile male adult and a 7-year-old child. Both pedestrian mannequin targets have the same clothing and skin/hair color. Many commenters suggested alternative pedestrian targets, noting that a variety of VRUs should be accounted for. This included people of color; VRUs of differing heights, ages, and clothing styles; those who use assistive mobility devices; or those carrying objects which may impede proper detection.

Because the Agency is not currently aware of alternative pedestrian targets proven to be reliable, including those representing a toddler-aged child, those using mobility aids, or those with alternative clothing, the proposed 4active targets will be adopted for this NCAP update. As noted previously, these are the pedestrian targets adopted for use by Euro NCAP. However, NHTSA is currently conducting research to evaluate vehicle response to various pedestrian characteristics, such as clothing color and type. This research will inform next steps for the Agency.

Regarding children in particular, the Agency notes that, while there are likely behavioral differences between adults and children, as one commenter claimed, crash data show that child pedestrian involvement is relatively low. In 2021, less than one-sixth (15 percent) of children aged 14 and younger killed in traffic crashes were pedestrians, and the age group with the fewest pedestrian fatalities was ages five to nine years, followed by the less than five-year-old age group.[287] That said, for this NCAP update, the Agency will utilize the seven-year-old 4activePA mannequin for S1d. Use of this pedestrian target in at least one condition should ensure that vehicle manufacturers account for smaller pedestrians in their PAEB system designs while still targeting the largest population of pedestrians for the majority of adopted conditions. The Agency may revisit this decision in the future if additional mannequins are found to be reliable during testing, sensing technology improves, and/or the real-world crash problem changes.

Inclement/Challenging Weather Conditions

NHTSA has decided that all NCAP PAEB testing will occur in dry, clear conditions free of fog, smoke, ash, or other airborne particulate matter with the minimum visibility range stated. Doing so should ensure that each vehicle is evaluated under the same circumstances and maintain a reasonable test burden.

NHTSA acknowledges that pedestrian crashes occur in various weather conditions. According to Volpe data from 2011–2015, approximately 10 percent of fatal pedestrian crashes and 13 percent of injurious pedestrian crashes occurred during adverse weather annually.[288] PAEB systems should be functional in a variety of weather conditions. This especially holds true for areas of the country subject to frequent inclement weather.

However, for an NCAP testing program to be useful to consumers, repeatability and reproducibility of test results is imperative. The presence of precipitation could influence the outcome of the tests, as pavement covered in precipitation may have a lower coefficient of friction than dry pavement and falling precipitation may interfere with sensing systems such that vehicles are not independently subjected to the same conditions. The same logic applies to visibility at the test site. A current industry standard specifies the horizontal visibility at ground level must be greater than 1 km (0.62 miles), a standard also adopted by Euro NCAP for its AEB/LSS protocol.[289] Thus, NHTSA will conduct all NCAP PAEB tests in dry, clear conditions free of fog, smoke, ash, or other airborne particulate matter with the minimum visibility range stated. However, similar to that which the Agency indicated for

[285] *https://www.reginfo.gov,* RIN 2127–AK98.

[286] 88 FR 34366 (May 26, 2023).

[287] National Center for Statistics and Analysis. (2023, June), *Pedestrians.* (Traffic Safety Facts, 2021 Data. Report No. DOT HS 813 458), Washington, DC: National Highway Traffic Safety Administration.

[288] Swanson, E., Foderaro, F., Yanagisawa, M., Najm, W.G., & Azeredo, P. (2019, August), *Statistics of light-vehicle pre-crash scenarios based on 2011–2015 national crash data* (Report No. DOT HS 812 745), Washington, DC: National Highway Traffic Safety Administration.

[289] European New Car Assessment Programme (Euro NCAP) (December 2023), *Test Protocol—AEB/LSS VRU systems, Version 4.5.*

turning scenarios S2 and S3, NHTSA may communicate on its website possible system limitations pertaining to environmental conditions not assessed by NCAP to lessen consumer confusion relating to expectations for system functionality. Further, notwithstanding the adopted test specificity, NHTSA encourages manufacturers to continue working toward delivering PAEB systems that are robust and that function in as many real-world environments as possible.

Other Scenarios To Consider

NHTSA acknowledges that real-world driving involves a variety of situations. Commenters noted that the proposed testing conditions do not address such scenarios as: parking lots; cases where an oncoming vehicle is also present; situations where a pedestrian is crossing under a structure such as a bridge; backover incidents; or other surroundings such as signs, roadway markings, and other visual clutter, such as that found in construction zones.

The Agency agrees that each of these situations represents a possible real-world case in which PAEB is expected to function. However, it would not be possible to test every permutation, as the resources required for this endeavor would make such a testing program prohibitive. As mentioned in previous sections, NHTSA plans to monitor real-world cases and has the authority to investigate situations which prove increasingly problematic.

Several commenters expressed concern that a specific mitigation plan for backover pedestrian crashes was not included in the Agency's March 2022 proposal, beyond inclusion in a short-term roadmap. At that time, NHTSA referred to data which showed NHTSA backing data from 2021 in-traffic pedestrian crashes shows that most pedestrian fatalities where the first harmful event was a collision with the vehicle are a result of initial contact with the front of the vehicle. As detailed in the March 2022 RFC notice, more time is required for NHTSA to review real-world data and the effects of FMVSS No. 111, ''Rear visibility.'' This information will also help inform changes to the rear automatic braking (RAB) test procedure, which remains under further development. Thus, NHTSA concludes that while Euro NCAP has developed an RAB protocol for use in its testing, it would be premature for the Agency to incorporate RAB as a U.S. NCAP ADAS technology at this time.

NHTSA will also not perform PAEB testing for a lying, stationary pedestrian at this time. These cases are likely rare and would not represent a large portion of the pedestrian crash problem. Further, there is not a test procedure developed at this time to address such a scenario. Similarly, there is not a test procedure currently developed to assess a PAEB system's response to multiple pedestrians in a group, so this scenario will also not be incorporated into NCAP testing at this time.

Vehicle to Everything (V2X)

NHTSA also received a suggestion to incorporate V2X support into its PAEB test procedures for dark lighting conditions. This would allow vehicles to utilize smartphone location data to locate the pedestrian target and map its movement. As a result, V2X technology could help to mitigate cases in which a VRU is not visible due to obstruction, lack of lighting, or other environmental factors. However, because the Agency has not conducted testing of a smartphone-enabled test target, it would be premature to incorporate this additional specification into PAEB testing at this time. Further, DOT research has not yet determined whether cellular-based V2X would be able to support safety-critical crash avoidance technologies, although it may have benefits for weather, traffic, and infrastructure-related alerts. NHTSA may consider the inclusion of this technology in NCAP in the future.

Other Comments Related to Pedestrian Safety

As part of NHTSA's AEB research to further assess the rear-end safety problem, characterize current vehicles, and identify potential countermeasures, the Agency will study pedal misapplication. AEB/PAEB test procedure modifications it deems necessary as a result of that effort may be adopted as part of subsequent updates to NCAP.

NHTSA notes all electric and hybrid vehicles manufactured on or after March 1, 2021, are required to produce a sound at low speeds per FMVSS No. 141, ''Minimum sound requirements for hybrid and electric vehicles.'' This standard should address concerns related to quiet vehicles and pedestrian crash risk.

13. Acceptable Timeframe To Add Bicyclist Testing and Test Procedures Other Than Euro NCAP's To Address Bicyclist Crashes

In its March 2022 RFC notice, the Agency committed to conducting additional research to address injuries and fatalities for other VRUs, specifically bicyclists and motorcyclists. NHTSA's current PAEB test procedure does not include a specific bicyclist component, although PAEB systems capable of detecting bicyclists may exist. The rising number of bicyclists killed on U.S. roads [290] prompted the Agency to study and determine the viability of Euro NCAP's AEB bicyclist tests.[291]

Acknowledging the current state of bicyclist PAEB testing in the U.S., NHTSA requested comments detailing when it would be acceptable to add bicyclist PAEB testing to its suite of ADAS tests, and whether there are other test procedures available beyond Euro NCAP's to evaluate. The Agency also requested information from vehicle manufacturers on any currently available models with the capability to validate the bicyclist target and test procedures used by Euro NCAP to support evaluation for a future NCAP program upgrade.

Summary of Comments

An overwhelming majority of commenters who addressed the issue urged NHTSA to move forward with a bicyclist component as soon as possible. Somerville Bicycle Safety noted that according to NSC, bicyclist fatalities increased 44 percent from 2011 to 2020.[292] The League stated that other NHTSA FARS data shows that in 2020, 276 bicyclists were killed by the grouped crash type, ''motorist overtaking bicyclist,'' which was more than three times the number of those killed in the next crash type, ''parallel paths—other circumstances,'' and noted that these crash types could be addressed by AEB.

Vision Zero Network, the League, and Bike Cleveland noted that rising cyclist deaths are cited as a targeted issue in USDOT's National Roadway Safety Strategy (NRSS). Further, the BIL's requirement to consider benefits of harmonization with domestic and international ratings systems was cited by PeopleForBikes and Ride New Orleans. Advocates also noted there is an increased interest from the U.S. DOT and other transportation organizations in the use of bicycles in urban transportation programs to travel to school and work.

Respondents also cited the availability of a bicyclist target and Euro

[290] National Center for Statistics and Analysis (2019, June), *Bicyclists and other cyclists: 2017 data* (Traffic Safety Facts. Report No. DOT HS 812 765), Washington, DC: National Highway Traffic Safety Administration.

[291] European New Car Assessment Programme (Euro NCAP) (December 2023), *Test Protocol—AEB/LSS VRU systems, Version 4.5.*

[292] *https://injuryfacts.nsc.org/home-and-community/safety-topics/bicycle-deaths/.*

NCAP's protocol in support of NHTSA's adoption of a bicyclist component for PAEB. Intel, Vision Zero Network, Safe Roads Alliance, Aptiv, Somerville Bicycle Safety, PeopleForBikes, AARP, The League, NACTO, Ride New Orleans, Advocates, CAS, ITS America, Bike Cleveland, KAC, ASC, FSS, and Vayyar all referred to Euro NCAP's readily available protocol as a reason to move urgently. Intel specifically noted that bicyclist AEB should be included in the 2023–2024 timeframe of NCAP's roadmap because of this readily available and updated protocol. Lidar Coalition noted that NHTSA's plan to not include bicyclist AEB until a future NCAP upgrade appears out of step with the Agency's stated goals to address areas of substantial safety need and to harmonize with Euro NCAP wherever possible. The League noted inconsistencies in NHTSA's justifications for including other ADAS technologies for this NCAP upgrade, including BSI and CIB, to encourage proliferation and development of capabilities in the vehicle fleet, while not also including bicyclist AEB. Other commenters stated that NHTSA, and therefore the U.S., will lag behind European countries by a decade should NHTSA decide to delay inclusion of bicyclist detection as shown in the draft NCAP roadmap. Several commenters stated that Australasian NCAP, JNCAP, and IIHS, in addition to Euro NCAP, already take bicyclists into account in their PAEB/AEB testing.

The NTSB submitted a comment referring to its 2019 recommendation that NHTSA incorporate vehicle-to-bicyclist crash avoidance capabilities in NCAP as a mechanism to incentivize incorporation of the technology in vehicles.[293] The accompanying study showed that vehicle ADAS could reduce the frequency of bicyclist crashes.

Some commenters stated that the Agency should wait until a future NCAP upgrade to include bicyclist detection in PAEB/AEB testing. These included Auto Innovators, HMNA, GM, Honda, and HATCI. GM and Auto Innovators stated the Agency should take more time for NCAP to evolve and should adopt Euro NCAP procedures when NHTSA eventually adopts bicyclist detection protocols. Honda acknowledged that bicyclist detection is an important feature that should be included but suggested that it be included at a future time, as Scenarios S1 and S4 should be prioritized. HATCI suggested that if NHTSA plans to harmonize with Euro NCAP, NHTSA could move forward as part of a future upgrade, but if the Agency is going to make changes to the protocol, then HATCI recommended that NHTSA publish the amended test procedure for review and comment. Finally, DRI mentioned that, in its experience, the current bicyclist targets available on the market lack the durability for continuous testing during which impacts may occur.

Several commenters stated more research would be useful to inform decisions regarding appropriate test scenarios and conditions. Auto Innovators, GM, Tesla, FCA, and the League suggested that NHTSA review U.S. crash data to determine any necessary adaptations to Euro NCAP test scenarios for the U.S. market. The groups suggested the Agency should take into consideration variables such as specific crash scenarios commonly seen in fatal crashes, SV and bicyclist speeds, and road features and markings specific to the U.S. market. The League also stated that door opening crashes, in which a vehicle occupant opens their door into the path of an approaching bicyclist, are likely underrepresented in FARS data, as other sources estimate that 7 percent to 20 percent of all cyclist crashes involve this crash type. Uhnder also supported continued studies to determine which scenarios are most likely to be found on U.S. roadways. Uhnder and ASC also suggested that NHTSA undertake a characterization study of bicyclist targets[294] to include radar cross section (RCS), like the study completed for pedestrian targets, prior to incorporation of a bicyclist component.[295]

The League stated when bicyclist AEB testing begins, it should be conducted in both daylight and dark lighting conditions. The group stated it is relevant to include these test conditions because NHTSA FARS data showed between 2016 and 2020, about 50 percent of bicyclist fatalities occurred during dark lighting conditions.[296]

In addition to bicycles, commenters stated other signatures, such as scooters and wheelchairs, should also be detected by vehicle AEB systems. MIC/MSF specifically recommended NHTSA also ensure the inclusion of motorcyclist tests. One individual stressed the importance of bicycle infrastructure, requesting safer spaces for cyclists to travel on the roadway.

Response to Comments and Agency Decisions

NHTSA recognizes many of the commenters supported the inclusion of bicyclist testing in NCAP and wanted the Agency to take such action immediately. Two of the main reasons cited for this inclusion were the need to fulfill initiatives established in the NRSS and BIL mandates, as well as incentivizing the proliferation and development of system capabilities in the vehicle fleet. These commenters referenced several existing test procedures and test targets that could be utilized to assess system performance to mitigate light vehicle crashes with bicyclists.

However, the Agency agrees with those commenters who suggested it should conduct additional research prior to adoption of a bicyclist component into NCAP. Existing test procedures, such as that in Euro NCAP, for evaluating crash avoidance technologies for bicyclist and motorcyclist protection need further evaluation for their effectiveness, objectivity, and suitability for vehicles sold in the U.S. Additional assessment is also needed on the durability and suitability of the targets used in the tests.

NHTSA has expedited its research on AEB for other VRUs, namely bicyclists and motorcyclists. Initial research has been performed on surrogate bicycle and motorcycle targets for testing and global test procedures to evaluate their effectiveness and suitability for use in performance tests. Further crash data analysis will be performed to better characterize the critical safety scenarios that account for bicycle and motorcycle injuries and fatalities. Collectively, this information will lead to test procedures that can be used to assess safety performance of vehicles sold in the U.S. This research effort is expected to be completed in 2025. As noted in the mid-term updates to NCAP in the NCAP roadmap finalized in this notice, NHTSA has included evaluation of AEB for mitigating crashes with bicyclists and motorcyclists starting with model year 2028 vehicles.

E. Summary of Adopted Tests for Pedestrian Automatic Emergency Braking

Tabular summaries of the adopted test conditions and variants for PAEB are provided in Tables 19 and 20.

[293] NTSB Safety Recommendation H–19–36.

[294] Including ISO19206–2, ISO19206–4, and ISO19206–5 (under development) targets.

[295] Albrecht, H. (2015, November 5). ''Pedestrian Test Mannequins Objective Criteria for Evaluating Repeatability and Accuracy of PCAM Systems.'' SAE Active Safety Symposium. Plymouth, MI.

[296] National Highway Traffic Safety Administration. Fatality and Injury Reporting System Tool (FIRST), Version 6. Fatality Analysis Reporting System (FARS): 2016–2020 Final File.

TABLE 19—ADOPTED NCAP PAEB DAYLIGHT TEST CONDITIONS AND VARIANTS

Test condition	Size	Movement classification	Path origin	Overlap (%)	Obstruction	Test No.	Test speeds (kph (mph))	
							SV	Pedestrian
S4c	Adult (Facing Away).	Walk	Right	25	No	1	10 (6.2)	5 (3.1).
						2	20 (12.4)	5 (3.1).
						3	30 (18.6)	5 (3.1).
						4	40 (24.9)	5 (3.1).
						5	50 (31.1)	5 (3.1).
						6	60 (37.3)	5 (3.1).
S4a	Adult (Facing Away).	Stationary	Right	25	No	7	10 (6.2)	0.
						8	20 (12.4)	0.
						9	30 (18.6)	0.
						10	40 (24.9)	0.
						11	50 (31.1)	0.
						12	60 (37.3)	0.
S1b	Adult	Walk	Right	50	No	13	10 (6.2)	5 (3.1).
						14	20 (12.4)	5 (3.1).
						15	30 (18.6)	5 (3.1).
						16	40 (24.9)	5 (3.1).
						17	50 (31.1)	5 (3.1).
						18	60 (37.3)	5 (3.1).
S1a	Adult	Walk	Right	25	No	19	10 (6.2)	5 (3.1).
						20	20 (12.4)	5 (3.1).
						21	30 (18.6)	5 (3.1).
						22	40 (24.9)	5 (3.1).
						23	50 (31.1)	5 (3.1).
						24	60 (37.3)	5 (3.1).
S1e	Adult	Run	Left	50	No	25	10 (6.2)	8 (5.0).
						26	20 (12.4)	8 (5.0).
						27	30 (18.6)	8 (5.0).
						28	40 (24.9)	8 (5.0).
						29	50 (31.1)	8 (5.0).
						30	60 (37.3)	8 (5.0).
S1d	Child	Run	Right	50	Yes	31	10 (6.2)	5 (3.1).
						32	20 (12.4)	5 (3.1).
						33	30 (18.6)	5 (3.1).
						34	40 (24.9)	5 (3.1).
						35	50 (31.1)	5 (3.1).
						36	60 (37.3)	5 (3.1).

TABLE 20—ADOPTED NCAP PAEB DARKNESS TEST CONDITIONS AND VARIANTS

Test condition	Size	Movement classification	Path origin	Overlap (%)	Obstruction	Test No.	Test speeds (kph (mph))	
							SV	Pedestrian
S4c	Adult (Facing Away).	Walk	Right	25	No	1	10 (6.2)	5 (3.1).
						2	20 (12.4)	5 (3.1).
						3	30 (18.6)	5 (3.1).
						4	40 (24.9)	5 (3.1).
						5	50 (31.1)	5 (3.1).
						6	60 (37.3)	5 (3.1).
S4a	Adult (Facing Away).	Stationary	Right	25	No	7	10 (6.2)	0.
						8	20 (12.4)	0.
						9	30 (18.6)	0.
						10	40 (24.9)	0.
						11	50 (31.1)	0.
						12	60 (37.3)	0.
S1b	Adult	Walk	Right	50	No	13	10 (6.2)	5 (3.1).
						14	20 (12.4)	5 (3.1).
						15	30 (18.6)	5 (3.1).
						16	40 (24.9)	5 (3.1).
						17	50 (31.1)	5 (3.1).
						18	60 (37.3)	5 (3.1).
S1a	Adult	Walk	Right	25	No	19	10 (6.2)	5 (3.1).
						20	20 (12.4)	5 (3.1).
						21	30 (18.6)	5 (3.1).
						22	40 (24.9)	5 (3.1).
						23	50 (31.1)	5 (3.1).
						24	60 (37.3)	5 (3.1).
S1e	Adult	Run	Left	50	No	25	10 (6.2)	8 (5.0).
						26	20 (12.4)	8 (5.0).
						27	30 (18.6)	8 (5.0).
						28	40 (24.9)	8 (5.0).
						29	50 (31.1)	8 (5.0).
						30	60 (37.3)	8 (5.0).

TABLE 20—ADOPTED NCAP PAEB DARKNESS TEST CONDITIONS AND VARIANTS—Continued

Test condition	Size	Movement classification	Path origin	Overlap (%)	Obstruction	Test No.	Test speeds (kph (mph))	
							SV	Pedestrian
S1d	Child	Run	Right	50	Yes	31	10 (6.2)	5 (3.1).
						32	20 (12.4)	5 (3.1).
						33	30 (18.6)	5 (3.1).
						34	40 (24.9)	5 (3.1).

*All darkness testing is to occur without the use of overhead artificial lighting.

VI. Adding Blind Spot Technologies

NHTSA is adding assessments for two blind spot technologies, blind spot warning (BSW) and blind spot intervention (BSI), to NCAP's crash avoidance program. As discussed in NHTSA's March 2022 RFC notice, these technologies have the potential to prevent or mitigate five pre-crash lane change or merge scenarios, representing approximately 503,070 crashes annually, on average—8.7 percent of all crashes that occur on U.S. roadways. These crashes result in 542 fatalities on average, and 188,304 MAIS 1–5 injuries annually, representing 1.6 percent of all fatalities and 6.7 percent of all injuries, respectively.[297] While the target population for blind spot technologies may not be as large as the populations for AEB technologies, their high consumer acceptance rate and potential safety improvements, both discussed later in this section, support their inclusion in the Agency's signature consumer information program.

A. Blind Spot Technologies

1. Blind Spot Warning (BSW)

A BSW system is a warning-based driver assistance system that automatically alerts a driver that another vehicle is approaching, or being operated within, the blind spot of the driver's vehicle in an adjacent lane. Depending on the system design, additional BSW features may be activated if the system presents an alert and the driver operates their turn signal indicator. In either case, the BSW system provides information intended to assist a driver contemplating or initiating a lane change.

Current BSW systems use camera-, radar-, or ultrasonic-based sensors, or some combination thereof, to detect other vehicles. These sensors are typically located on the sides and/or rear of a vehicle. BSWs may be auditory, visual (most common), or haptic. Visual alerts are usually presented in the outboard side mirror glass, inside edge of the mirror housing, or at the base of the front A-pillars inside the vehicle. When the BSW system detects that another vehicle traveling in an adjacent lane has entered or is approaching the driver's blind spot, the BSW visual alert is typically continuously illuminated. However, if the driver engages the turn signal in the direction of the adjacent vehicle while the visual alert is present, the visual alert may transition to a flashing state and/or be supplemented with an additional auditory or haptic alert (*e.g.,* beeping or vibration of the steering wheel or seat, respectively).

Adding BSW systems to NCAP's ADAS evaluations is appropriate not only because the technology addresses a safety need but also because of consumer interest and known differences in detection capabilities and operating conditions, the latter of which can impact system effectiveness. The general appeal of BSW systems is reflected by the systems' penetration rates. In the six years between model years 2018 and 2024, the percentage of the fleet fitted with standard BSW systems rose from 5.8 to 57 percent. Further, in market research conducted by Consumer Reports, the organization found an overwhelming majority of vehicle owners were satisfied with BSW technology, and 60 percent of those surveyed believed BSW technology had helped them avoid a crash.[298] Additionally, in a study evaluating the real-world effectiveness of ADAS technologies in model year 2013 to 2017 GM vehicles, UMTRI found BSW system effectiveness increased substantially (*i.e.,* translating to a larger reduction in lane-change crashes) for systems offering longer vehicle detection ranges.[299 300] Whereas one vehicle's BSW system may simply augment a driver's visual awareness, another may more effectively prevent crashes by warning of potential higher speed differential lane change conflicts. As such, there are reasons to provide consumers with BSW system performance information, regardless of the technology's high equipment rates and consumers' positive appreciation for such systems.

Proposed BSW Test Procedure

The Agency proposed to utilize its draft blind spot detection (BSD) test procedure[301] (referred to in this notice as BSW) to assess systems' performance and capabilities in blind spot related pre-crash scenarios. This test procedure evaluates a vehicle's BSW system using two tests performed on the test track: the Straight Lane Converge and Diverge Test and the Straight Lane Pass-by Test. These tests assess whether a test vehicle's (SV's) BSW system presents a warning when other vehicles (POVs) are within or approaching the driver's blind spot, or blind zone.[302] In each test, the POV represents a high-production mid-sized passenger car.[303] In the proposed procedure, neither the SV nor POV turn signals may be activated at any point during any test trial. A short description of each proposed test scenario and the

[297] Wang, J.S. (2019, March), *Target crash population for crash avoidance technologies in passenger vehicles* (Report No. DOT HS 812 653). Washington, DC: National Highway Traffic Safety Administration.

[298] Monticello, M. (2017, June 29), *The positive impact of advanced safety systems for cars: The latest car-safety technologies have the potential to significantly reduce crashes,* Consumer Reports, *https://www.consumerreports.org/car-safety/positive-impact-of-advanced-safety-systems-for-cars/.*

[299] Leslie, A.J., Kiefer, R.J., Meitzner, M.R., & Flannagan, C.A. (2019), *Analysis of the field effectiveness of General Motors production active safety and advanced headlighting systems,* The University of Michigan Transportation Research Institute and General Motors LLC, UMTRI–2019–6.

[300] UMTRI found systems having longer vehicle detection ranges provided an estimated 26 percent reduction in lane change crashes, compared to a corresponding non-significant 3 percent reduction for those systems having shorter detection ranges.

[301] Docket No. NHTSA–2019–0102–0010.

[302] A vehicle's blind zone is defined by two 2.5 m- (8.2 ft.-) wide rectangular regions that extend to the side and rear of the SV and begin at the rearmost part of the SV's side mirror housing, in the housing's fully extended operating position, and runs perpendicular to the SV's longitudinal centerline. The length of the blind zone is dependent upon the speed differential between the SV and the POV. See *Blind Spot Detection System Confirmation Test* for a complete definition.

[303] The POV selected must be 445 to 500 cm (175 to 197 in.) in length and 178 to 193 cm (70 to 76 in.) wide, measured at the widest part of the vehicle exclusive of signal lamps, marker lamps, outside rearview mirrors, flexible fender extensions, and mud flaps. Width is determined with doors and windows closed and the wheels in the straight-ahead position. The color of the vehicle is unrestricted.

related requirement for a passing result is provided below.

• Straight Lane Converge and Diverge Test—The POV and SV are driven parallel to one another in the outbound lanes of a three-lane straight road. Both vehicles are driven at a constant speed of 72.4 kph (45 mph) and are positioned such that the frontmost part of the POV is 1.0 m (3.3 ft.) ahead of the rearmost part of the SV. After 3.0 s of steady-state driving, the POV enters (*i.e.,* converges into) the SV's blind zone by making a single lane change into the lane immediately adjacent to the SV using a lateral velocity of 0.25 to 0.75 m/s (0.8 to 2.5 ft./s). The period of steady-state driving resumes for at least another 3.0 s and then the POV exits (*i.e.,* diverges from) the SV's blind zone by returning to its original travel lane using a lateral velocity of 0.25 to 0.75 m/s (0.8 to 2.5 ft./s). This test is repeated for a POV approach from both the left and the right side of the SV.

—To pass a test trial, during the converge lane change, the BSW must be presented by a time no later than 300 ms after any part of the POV enters the SV blind zone and must remain on while any part of the POV resides within the SV blind zone. Additionally, during the diverge lane change, the BSW may remain active when the lateral distance between the SV and POV is greater than 3 m (9.8 ft.) but less than or equal to 6 m (19.7 ft.). The BSW shall not be active once the lateral distance between the SV and POV exceeds 6 m (19.7 ft.).

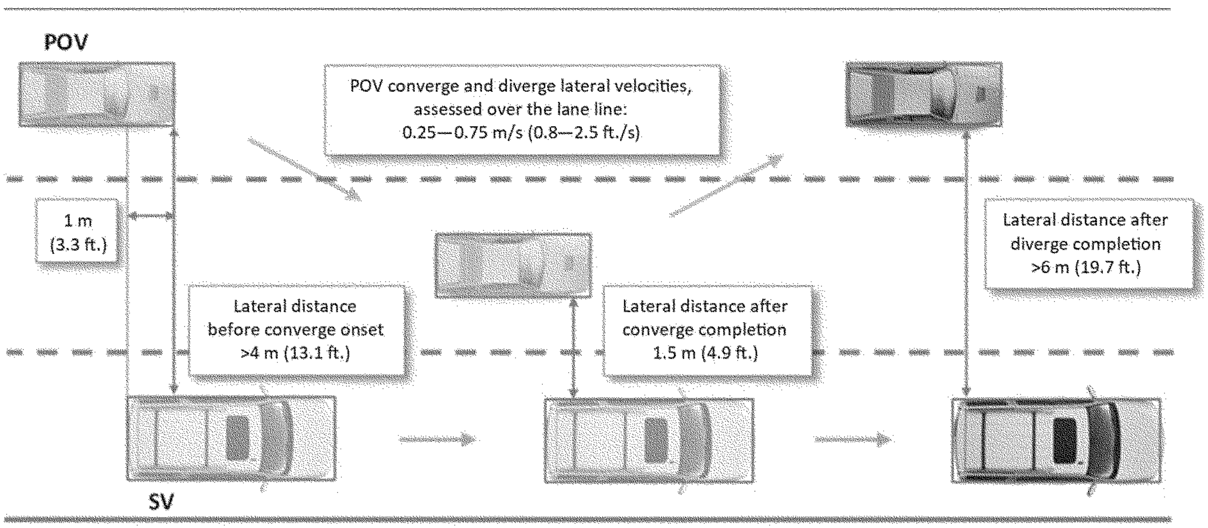


Figure 13: Straight Lane Converge and Diverge Test, Showing Converge and Diverge from the Left

• Straight Lane Pass-by Test—The POV approaches and then passes the SV while being driven in an adjacent lane. For each trial, the SV is traveling at a constant speed of 72.4 kph (45 mph) whereas the POV is traveling at one of four constant speeds: 80.5, 88.5, 96.6, or 104.6 kph (50, 55, 60, or 65 mph). The lateral distance between the two vehicles, defined as the closest lateral distance between adjacent sides of the two-dimensional polygons used to represent each vehicle's dimensions, shall nominally be 1.5 m (4.9 ft.) for the duration of the trial. This test is repeated for a POV approach towards the SV from an adjacent lane to the left and to the right of the SV.

—To pass a test trial, the BSW must be presented by a time no later than 300 ms after the frontmost part of the POV enters the SV blind zone and remain on while the frontmost part of the POV resides behind the frontmost part of the SV blind zone. The BSW shall not be active once the longitudinal distance between the frontmost part of the SV and the rearmost part of the POV exceeds the BSW termination distance specified for each POV speed.

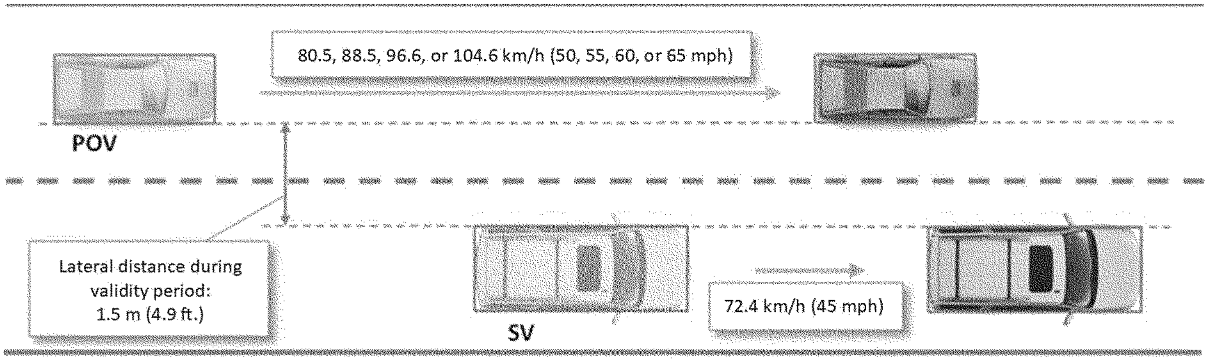


Figure 14: Straight Lane Pass-by Test, Showing Left-side POV Pass-by

NHTSA's proposed test procedure stipulates that each scenario be tested using seven repeated trials for each combination of approach direction (left and right side of the SV) and test speed. This translates to a total of 14 tests overall for the Straight Lane Converge and Diverge Test and 56 tests overall for the Straight Lane Pass-by Test. In its RFC notice, the Agency proposed that the SV must pass at least five out of seven trials conducted for each approach direction and test speed to pass the NCAP system performance requirements. Tests that NHTSA proposed for NCAP BSW testing are shown below in Table 21.

TABLE 21—BLIND SPOT WARNING (BSW) PROPOSED TEST CONDITIONS

Test scenario	SV speed (kph (mph))	POV speed (kph (mph))	POV direction of approach	Turn signal	Number of trials
Straight Lane Converge and Diverge	72.4 (45)	72.4 (45)	Right	Disabled	7
			Left	Disabled	7
Straight Lane Pass-by	72.4 (45)	80.5 (50)	Right	Disabled	7
			Left	Disabled	7
	72.4 (45)	88.5 (55)	Right	Disabled	7
			Left	Disabled	7
	72.4 (45)	96.6 (60)	Right	Disabled	7
			Left	Disabled	7
	72.4 (45)	104.6 (65)	Right	Disabled	7
			Left	Disabled	7

Model Year 2019 and 2020 Research Testing

In 2020, NHTSA utilized its proposed BSW test procedure to conduct a series of tests on 10 model year 2019 and 2020 vehicles to evaluate then-current BSW systems.[304] The Agency selected test vehicles equipped with BSI technology, and the same vehicles were also subjected to BSI testing, as detailed in the next section.

The Agency's testing showed that most of the model year 2019 and 2020 vehicles failed at least one trial throughout the course of testing. Half of the vehicles (five out of ten) only failed trials for one of the two test scenarios (*i.e.,* either the Straight Lane Pass-by test or the Straight Lane Converge and Diverge Test). Additional data findings will be discussed in the sections to follow.

2. Blind Spot Intervention (BSI)

Blind spot intervention (BSI) systems are similar to AEB systems in that they provide active intervention to help the driver avoid a collision with another vehicle. While BSW systems alert a driver that another vehicle is in their vehicle's blind spot, BSI systems automatically provide a steering input to guide the driver's vehicle back into the unobstructed lane when the BSW is ignored and/or apply the vehicle's brakes. Thus, BSI systems actively intervene to help a driver avoid collisions with other vehicles that are approaching or operating within the vehicle's blind spot.

Like BSW systems, BSI systems utilize rear-facing sensors to detect other vehicles next to or behind the vehicle in adjacent lanes. Depending on the design of these systems, BSI activation may or may not require the driver to operate their turn signal indicator during a lane change. In addition, some BSI systems may only operate if the vehicle's BSW system is also enabled.

[304] Test reports detailing the results for this research can be found in docket NHTSA–2021–0002.

Unlike BSW systems, BSI systems are not widely available in the current fleet, with only 29 percent of model year 2024 vehicles equipped with BSI systems as standard equipment. NHTSA is unaware of any effectiveness studies for this technology, which is only beginning to penetrate the fleet. Nonetheless, as mentioned previously, the Agency expects that active safety technologies are more effective than warning technologies. For example, UMTRI's study of 2013–2017 GM vehicles concluded that AEB is more effective than FCW alone, and that LKA is more effective than LDW.[305] The same relationship will likely hold true for blind spot systems, and that BSI will be more effective than BSW alone. Also, adopting ADAS technologies such as BSI into NCAP should encourage the development and robustness of enhanced BSW system capabilities (*e.g.,* motorcycle and bicycle detection).

By including BSI as a recommended technology in NCAP, NHTSA anticipates manufacturers will equip a larger portion of the fleet with BSI systems. Furthermore, by adopting objective test procedures to gauge system performance for NCAP's assessments, the Agency will best ensure that future BSI systems most effectively address the safety need stemming from lane change and merge crashes.

Proposed BSI Test Procedure

NHTSA proposed to use its published draft test procedure titled, ''Blind Spot Intervention System Confirmation Test,'' to evaluate the performance of vehicles equipped with BSI technology in NCAP. The Agency's test procedure consists of three scenarios: SV Lane Change with Constant Headway, SV Lane Change with Closing Headway, and SV Lane Change with Constant Headway, False Positive Assessment. In the first two scenarios, a test vehicle (SV) initiates a lane change into an adjacent lane while a single other vehicle (POV) resides within the SV's blind zone (Scenario 1) or approaches it from the rear (Scenario 2). The third scenario is used to evaluate the propensity of a BSI system to activate inappropriately in a non-critical driving scenario that does not present a safety risk to the occupants in the SV. In each of the tests, the POV is a strikeable vehicle test device with the characteristics of a compact passenger car. The SV's turn signal is activated in each test trial. A short description of each test scenario and the proposed evaluation criteria are detailed below.

—SV Lane Change with Constant Headway Test—The POV is driven at 72.4 kph (45 mph) in a lane adjacent and to the left of the SV also traveling at 72.4 kph (45 mph) with a constant longitudinal offset such that the frontmost part of the POV is 1 m (3.3 ft.) ahead of the rearmost part of the SV, which is laterally offset from the center of its travel lane. After a short period of steady-state driving, the SV driver engages the left turn signal indicator at least 3 s after all pre-SV lane change test validity criteria have been satisfied. Within 1.0 ± 0.5 s after the turn signal has been activated, the SV driver initiates a manual[306] lane change, and follows an 800 m (2,625 ft.) radius curved path towards the POV's travel lane. The SV driver then releases the steering wheel within 250 ms of the SV exiting the curve so as to achieve a steady state lateral velocity of 0.7 ± 0.1 m/s (2.3 ± 0.3 ft./s) relative to the line separating the SV and POV travel lanes. To pass a test trial, the BSI system must intervene to prevent any contact between the SV and the POV. Additionally, the SV BSI intervention shall not cause a secondary departure (*i.e.,* the SV BSI intervention shall not cause the SV to travel 0.3 m (1.0 ft.) or more beyond the inboard edge of the lane line separating the SV travel lane from the lane adjacent and to the right of it within the validity period).

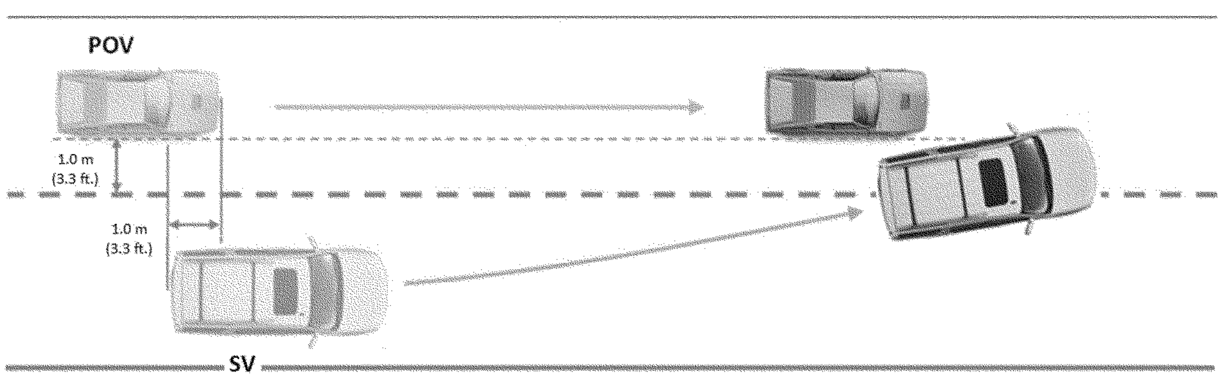


Figure 15: SV Lane Change with Constant Headway Test

• SV Lane Change with Closing Headway Test—The POV is driven at a constant speed of 80.5 kph (50 mph) towards the rear of the SV in an adjacent lane to the left of the SV, which is laterally offset from the center of its travel lane and traveling at a constant speed of 72.4 kph (45 mph). During the test, the SV driver engages the left turn signal indicator when the POV is 4.9 ± 0.5 s from a vertical plane defined by the rear of the SV and perpendicular to the SV travel lane. Within 1.0 ± 0.5 s after the turn signal has been activated, the SV driver initiates a manual lane change and follows an 800 m (2,625 ft.) radius curved path towards the POV's travel lane. The SV driver then releases the steering wheel within 250 ms of the SV exiting the curve so as to achieve a steady state lateral velocity of 0.7 ± 0.1 m/s (2.3 ± 0.3 ft./s) relative to the line separating the SV and POV travel lanes.

—To pass a test trial, the BSI system

[305] Leslie, A.J., Kiefer, R.J., Meitzner, M.R., & Flannagan, C.A. (2019), *Analysis of the field effectiveness of General Motors production active safety and advanced headlighting systems,* The University of Michigan Transportation Research Institute and General Motors LLC, UMTRI–2019–6.

[306] ''Manual'' refers to an externally commanded steering input. NHTSA will use a steering robot for such inputs to maximize accuracy, repeatability, and test efficiency.

must intervene to prevent any contact between the SV and the POV. Additionally, the SV BSI intervention shall not cause a secondary departure (*i.e.,* the SV BSI intervention shall not cause the SV to travel 0.3 m (1.0 ft.) or more beyond the inboard edge of the lane line separating the SV travel lane from the lane adjacent and to the right of it within the validity period).

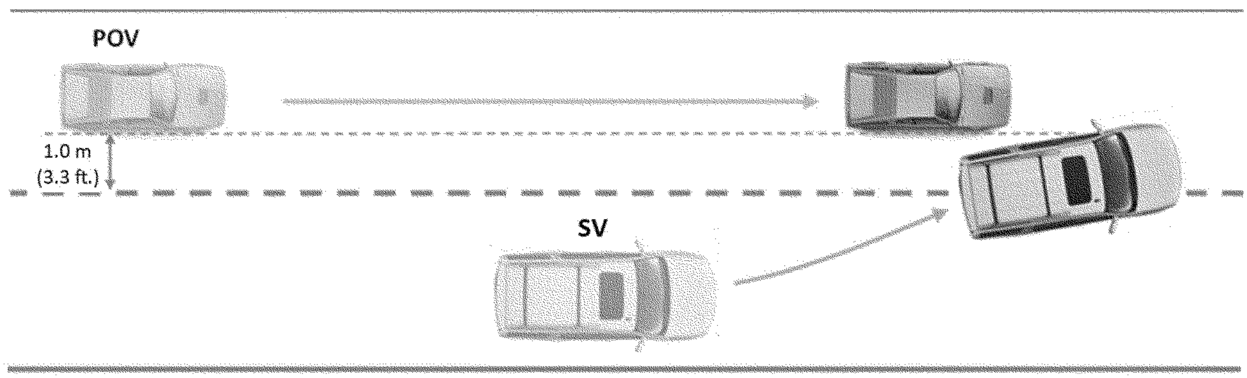


Figure 16: SV Lane Change with Closing Headway Test

• SV Lane Change with Constant Headway, False Positive Assessment Test—The POV is driven at 72.4 kph (45 mph) in a lane that is two lanes to the left of the SV's initial travel lane with a constant longitudinal offset such that the frontmost part of the POV is 1 m (3.3 ft.) ahead of the rearmost part of the SV. The SV is laterally offset from the center of its travel lane and also travelling at 72.4 kph (45 mph). The SV driver engages the left turn signal indicator at least 3 seconds after all pre-SV lane change test validity criteria have been satisfied. Within 1.0 ± 0.5 seconds after the turn signal has been activated, the SV driver initiates a manual lane change, and follows a defined path into the left adjacent lane (the one between the SV and POV), approaching the center lane line at a constant lateral velocity of 0.7 ± 0.1 m/s (2.3 ± 0.3 ft./s). For this test, the driver does not release the steering wheel.

—To pass a test trial, the SV's BSI system must not intervene during any valid trials; the lane change will not result in an SV-to-POV impact. To determine whether a BSI intervention occurred, the yaw rate data collected for the SV during the individual trials performed in this scenario are compared to a baseline composite. After being aligned in time to the baseline, the difference between the data must not exceed 1 degree/second within the test validity period.

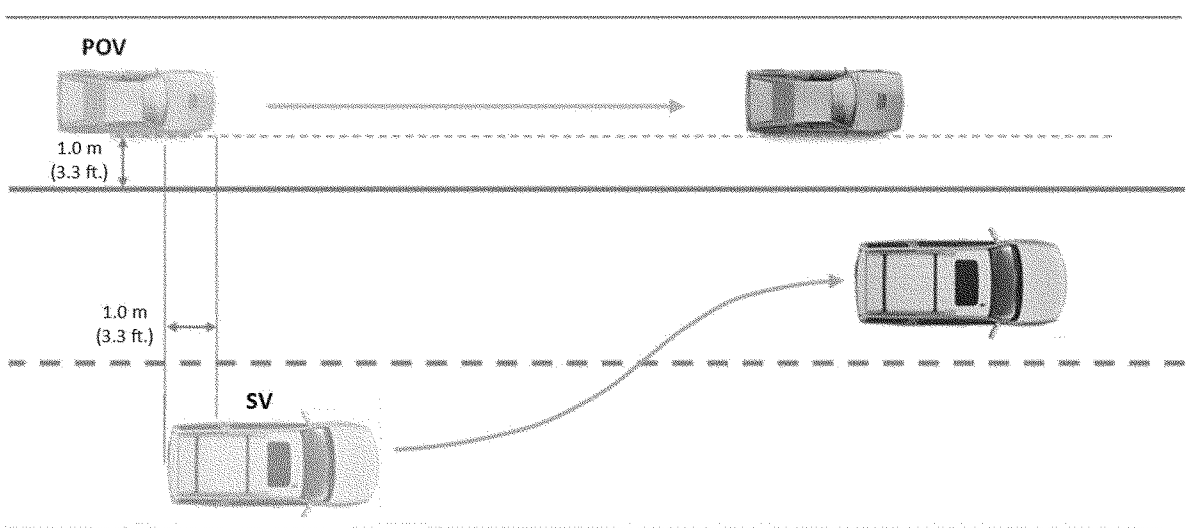


Figure 17: SV Lane Change with Constant Headway, False Positive Assessment Test

Currently, for the three BSI test scenarios, specific test procedures and specifications are dependent upon the SAE Driving Automation Level being assessed.[307] The four driving automation conditions included in the test procedure are: (1) with manual speed control and Lane Centering Assistance (LCA) off (SAE Driving Automation Level 0), (2) with cruise control enabled and LCA off (also considered SAE Level 0), (3) with ACC

[307] Society of Automotive Engineers (SAE) Standard J3016_202104, Taxonomy and Definitions for Terms Related to Driving Automation Systems for On-Road Motor Vehicles.

enabled and LCA off (SAE Level 1), and (4) with ACC on and LCA on (initially) and an automatic SV lane change occurs (SAE Levels 2 or 3). For condition 4, SV lateral lane position and lane change/path tolerance specifications are controlled by the vehicle, not the driver.

In its March 2022 RFC notice, NHTSA stated that it plans to use the [ABD] GVT Revision G as a strikeable vehicle test device when BSI is added to NCAP as a recommended ADAS technology to be consistent with Euro NCAP's ADAS test procedures that specify a strikeable vehicle test device.

Tests that NHTSA proposed to complete for NCAP BSI testing are shown below in Table 22.

TABLE 22—BLIND SPOT INTERVENTION (BSI) PROPOSED TEST CONDITIONS

Test scenario	SV speed (kph (mph))	POV speed (kph (mph))	Lane change direction	Turn signal	Number of trials
SV Lane Change with Constant Headway	72.4 (45)	72.4 (45)	Left	Enabled	7
SV Lane Change with Closing Headway	72.4 (45)	80.5 (50)	Left	Enabled	7
SV Lane Change with Constant Headway, False Positive Assessment.	72.4 (45)	72.4 (45)	Left	Enabled	7

Model Year 2019 and 2020 Research Testing

NHTSA utilized its proposed BSI test procedure to conduct a series of research tests on model year 2019 and 2020 vehicles to assess the performance of then-current BSI systems.[308] When selecting vehicles for testing, an attempt was made to choose one test vehicle from as many manufacturers as possible that had implemented BSI technology at the time. As mentioned previously, selected vehicles were also subjected to BSW testing. An ABD GVT Revision G represented the POV during testing. Results from this test series suggested there is an opportunity for performance improvement, as most vehicles failed both the SV Lane Change with Constant Headway Tests and the SV Lane Change with Closing Headway Tests.

B. Linking Proposed BSW and BSI Test Scenarios to Real-World Crashes

As mentioned in the March 2022 RFC notice, the BSW and BSI tests proposed by the Agency represent pre-crash scenarios that correspond to a substantial portion of fatalities and injuries observed in real-world lane change crashes. A review of Volpe's 2011–2015 data set showed that, for crashes where posted speed limit was known, approximately 29 percent of fatalities and 70 percent of injuries in lane change crashes occurred on roads with posted speeds of 72.4 kph (45 mph) or lower.[309 310] For crashes where the travel speed was reported in FARS and GES, approximately 44 percent of fatalities and 81 percent of injuries occurred at speeds of 72.4 kph (45 mph) or lower.[311] Volpe found that speeding was a known factor in 18 percent of the fatal lane change crashes and 3 percent of lane change crashes that resulted in injuries. This suggests that posted speed may correspond well to travel speed in most lane change crashes.[312 313]

Roadway alignment and grade for real-world lane change crashes also align with those used in NHTSA's procedures. For those crashes where roadway alignment was known in Volpe's 2011–2015 FARS and GES data set, 88 percent of fatal and 93 percent of injurious lane change crashes occurred on straight roads.[314] Furthermore, 77 percent and 86 percent of fatal and injurious lane change crashes, respectively, occurred on level roadways.[315]

C. Summary of Comments, Response to Comments, and Agency Decisions

1. Blind Spot Technology Inclusion in General

The Agency noted that commenters overwhelmingly supported the addition of BSW in response to its December 2015 notice regarding NCAP updates, and these sentiments were reiterated in the comments received in response to the March 2022 RFC notice. Many groups and individuals submitted comments supporting inclusion of both BSW and BSI in NCAP. MEMA expressed that BSW and BSI offer ''significant'' safety benefits. ITS America agreed that NHTSA provided sufficient evidence for benefits. Advocates and CFA noted that the test criteria seemed reasonable and that automatic intervention with BSI will provide greater benefits than BSW alone.

Honda supported the eventual inclusion of BSW and BSI technologies based on potential benefits but requested that NHTSA use a phased approach when adding these technologies to NCAP. The automaker further noted that the Agency included the warning technologies LDW and FCW first before proposing to add the respective active technologies, LKA and AEB, in NCAP. Thus, the Agency should consider following the same process for blind spot technologies. Although Honda acknowledged that ''active safety technologies are more effective than warning technologies,'' the manufacturer stated that it was not aware of specific effectiveness data for BSI, as it is relatively new compared to the other three new technologies proposed (*i.e.,* BSW, LKA, and PAEB). As such, Honda stated that BSI does not fulfill the Agency's four prerequisites for NCAP inclusion at the current time and requested that NHTSA wait until effectiveness data becomes available for BSI before including it in an NCAP rating.

GM and Auto Innovators agreed with Honda's sentiments regarding the absence of effectiveness data for BSI. However, Auto Innovators acknowledged there is some effectiveness data available for BSW, ''depending on system design.'' The

[308] Test reports detailing the results for this research can be found in docket NHTSA–2021–0002.

[309] The posted speed limit was either not reported or was unknown in 2 percent of fatal lane change crashes and 18 percent of lane change crashes that resulted in injuries.

[310] The lane change pre-crash scenarios referenced included (1) turning/same direction, (2) parking/same direction, (3) changing lanes/same direction, and (4) drifting/same direction crashes.

[311] The travel speed was either not reported or was unknown in 60 percent of fatal lane change crashes and 68 percent of lane change crashes that resulted in injuries.

[312] Swanson, E., Foderaro, F., Yanagisawa, M., Najm, W.G., & Azeredo, P. (2019, August), *Statistics of light-vehicle pre-crash scenarios based on 2011–2015 national crash data* (Report No. DOT HS 812 745), Washington, DC: National Highway Traffic Safety Administration.

[313] It was unknown or not reported whether speeding was a factor in 3 percent of fatal lane change crashes and 7 percent of lane change crashes that resulted in injuries.

[314] Roadway alignment was unknown or not reported in 1 percent of fatal lane change crashes and 4 percent of lane change crashes that resulted in injuries.

[315] Roadway grade was unknown or not reported in 5 percent of fatal lane change crashes and 18 percent of lane change crashes that resulted in injuries.

groups also stated that while BSW and BSI technologies may be helpful, the target populations for BSW and BSI are relatively small. Given these concerns, Auto Innovators did not support adding BSI into an ADAS rating and requested that NHTSA include BSI research in the NCAP roadmap. However, the group had no objection to adding BSI as an ''NCAP Recommended Technology'' and was not opposed to including BSW in the program. Meanwhile, GM did not recommend including either BSW or BSI. The manufacturer stated that ''any future BSI field effectiveness studies need to account for redundancies with other related ADAS features with proven safety benefits, such as LKS, LDW, and [GM's] Lane Change Alert (''LCA'').'' Regarding BSW inclusion, GM shared data from a 2022 effectiveness study of over 10.9 million GM model year 2013 to 2020 vehicles, which found that NHTSA's proposed BSW technology did not yield statistically significant field safety benefits. The automaker asserted that ''the non-statistically significant level observed for [GM's] BSW (which is a short-range detection system) was less than half that observed for [the manufacturer's] LCA (which can be thought of as ''Long Range'' BSW), which yielded statistically significant benefits.''

2. Test Conditions for BSW Testing, Including the Straight Lane Pass-by Test Scenario With Varying Speed Differentials

As previously described, NHTSA's March 2022 proposal for NCAP BSW test scenarios included a Straight Lane Converge and Diverge test scenario and a Straight Lane Pass-by test scenario. Within each scenario, NHTSA proposed to perform testing in multiple test conditions by varying POV approach directions. Within the Straight Lane Pass-by scenario, a variety of POV speeds were also introduced.

The Agency also expressed its interest in minimizing the testing burden whenever possible. As such, NHTSA requested comments on whether all test conditions should be performed to address real-world concerns, and if not, which ones should be prioritized. Specifically, the Agency mentioned possibly incorporating only the most challenging test conditions, selecting the highest and lowest speed conditions, and/or assuming symmetry to test only one side of the SV and apply results to the other side.

NHTSA also recognized that lane-change crashes associated with high speed differentials between involved vehicles may be more severe than those in which vehicle speeds are more similar. Since the ability to mitigate these higher-severity crashes is desirable, NHTSA requested comment on use of the Straight Lane Pass-by test procedure with varying POV-to-SV speed differentials to distinguish between basic and advanced BSW system capabilities. The Agency suggested that an SV that can only satisfy the BSW activation criteria when the POV approaches with a low relative velocity may be considered as having basic BSW capability, whereas a vehicle that can look further rearward to sense a passing vehicle travelling at a much higher speed may be considered to have superior detection abilities. The Agency added that the ability of a BSW system to provide long-range vehicle detection could increase the effectiveness of BSI systems and SAE Driving Automation Level 2 partial driving automation systems that incorporate automatic lane change features as well.

Summary of Comments

TRC suggested the scenarios proposed were sufficient and offered ''good coverage'' of real-world cases. Bosch also agreed that both proposed scenarios should be included, with the Straight Lane Pass-by Test differentiating between basic and advanced system capabilities and the Straight Lane Converge and Diverge Test assessing whether the SV can sense POVs travelling at the same speed. CAS stated it would be premature to only consider testing the most stringent scenarios, citing concern that manufacturers would begin designing to the test rather than to a range of conditions. The group further stated that the Agency should perform all test scenarios and conditions to ensure it addresses the variety of real-world conditions. Toyota noted that it has concerns regarding the timely release of information to consumers. Toyota also opined that if testing at a certain speed or in a specific scenario will adequately ensure acceptable performance in the entire speed range or in all similar cases, the Agency should consider running that test speed/scenario.

Tesla recommended NHTSA focus its attention on high-risk cases where BSW performance tends to be most problematic, specifically noting situations with a high speed differential. Similarly, FCA and Bosch expressed favor with testing first at the most stringent test case and, should the vehicle fail, slowly decreasing the stringency until the vehicle passes. The manufacturers conveyed that this strategy would allow NHTSA to more quickly determine the highest speed at which the BSW system can reliably function. FCA noted that manufacturers are most likely already testing their vehicles at mid-range speeds to ensure system robustness.

Conversely, ZF Group, ASC, BMW, Rivian, Auto Innovators, and Toyota recommended that NHTSA test at both low and high speeds. ZF Group and ASC mentioned that, in cases where there is a large performance differential between low and high speeds, a mid-range test speed may also be appropriate. Rivian noted that even with a mid-range test added, this strategy would result in a reduction of test speeds from four to three. Though FCA suggested starting at the most stringent test case, the automaker also noted that the Agency could test at low and high speeds as defined by each manufacturer.

ASC also supported NHTSA performing a low-speed SV scenario with high relative POV speed to approximate cases where the SV is in a slower-moving lane but intends to change into a faster-moving lane, as is the case in traffic congestion. Similarly, Vayyar requested that low-speed, or even stationary, POV tests be conducted to address real-world cases where target vehicles are stopped or moving slowly.

Auto Innovators asserted that the test speeds selected should be based on several factors: test laboratory specifications such as available test lane length, real-world crash data, capabilities of the POV vehicle test device, and the minimum operational speed of BSW systems. GM agreed with this justification for test speed selection. Advocates stated that the chosen scenarios and conditions should be able to help consumers identify vehicles which meet a minimum performance and discern between systems of minimal and higher performance.

Regarding symmetry, Toyota mentioned left-to-right symmetry specifically and suggested that the Agency could randomize the test side selected to encourage symmetrical designs. ZF Group, Tesla, BMW, ASC, Auto Innovators, and GM also noted that assuming symmetry would reduce the number of tests needed, stating data could be provided to prove symmetrical responses. However, DRI, Rivian, and Bosch asserted that NHTSA should still consider testing both sides of the vehicle. DRI explained that, in its experience, BSW performance differs from one side of the SV to the other. Rivian stated that performance can differ between sides due to differences in radar hardware location and that testing only one side of the vehicle might lead to BSW systems that do not offer strong real-world safety performance. Rivian also noted that manufacturers may ignore any discrepancies in left-to-right side design. Finally, Bosch stated both sides of the vehicle should be tested to ensure system robustness.

Straight Lane Pass-by Test With Speed Differentials To Discern Differences in Performance

Bosch, ZF Group, Toyota, CAS, BMW, Tesla, FCA, Auto Innovators, GM, and ASC agreed that NHTSA could vary test speeds in the Straight Lane Pass-by test scenario to differentiate performance between vehicles. BMW's support was bolstered by its assertion that the Straight Lane Pass-by Test evaluates the capability of both hardware (sensor) and software (functional logic). ZF Group stated that systems which mitigate crashes with higher speed differentials are more likely to improve safety in a broad range of lane-change events and therefore should warrant a higher score or rating. ASC echoed these sentiments, noting that high relative speed differentials between lanes can occur during real-world driving even though speed limits exist because of road work, traffic, and other commonly encountered scenarios. Further, GM suggested 24.1, 32.2, 48.3, and 64.4 kph (15.0, 20.0, 30.0, and 40.0 mph) speed differentials, and mentioned that, in its experience, varying test speeds is not as effective at distinguishing BSW performance as varying the speed differentials between the POV and the SV.

Toyota noted that drivers need as much time to react to threats as possible and speed-based warning timing is preferable since a POV approaching at a high speed will require relatively early warning. Auto Innovators reiterated this by stating that testing at varying speeds could differentiate products that offer detection within the blind zone only (basic performance capability) versus products that have an expanded rearward field of view to detect a vehicle advancing at a higher rate of travel (advanced performance capability). ASC also discussed this expanded rearward field of view, detailing the difference between Blind Spot Assist (BSA) systems, which are meant to mitigate short-range POV–SV scenarios, and Lane Change Assist (LCA) systems, which address longer-range POV–SV scenarios. The group voiced support for both scenarios proposed, stating that the Straight Lane Converge and Diverge test is a suitable evaluation for BSA systems while the Straight Lane Pass-by test is best for LCA systems. ASC also stated that LCA systems are more commonly found in countries without posted speed limits, whereas BSA is typically offered in countries where the posted speed limit is 80 mph or less. ASC suggested that, in these latter countries, the speed differential between lanes and vehicles is generally low. Finally, GM stated that only long-range LCA systems have been shown to reduce feature-relevant lane-change crashes, and therefore, only recommended that the Straight Lane Pass-by test be performed.

Response to Comments and Agency Decisions

This notice finalizes NHTSA's proposal including both the Straight Lane Converge and Diverge and Straight Lane Pass-by scenarios for its BSW tests.

For the Straight Lane Converge and Diverge test (shown in Figure 13), the test will begin with the POV two lanes away from the SV on a straight road. The vehicles will be positioned such that the frontmost part of the POV is 1.0 m (3.3 ft.) ahead of the rearmost part of the SV. Both vehicles will be driven in this formation at a constant speed of 72.4 kph (45 mph) for 3.0 seconds. The POV will then perform a single lane change into the lane adjacent to the SV (*i.e.,* the center lane) using a lateral velocity of 0.25 to 0.75 m/s (0.8 to 2.5 ft./s). Once the lane change is completed, the POV will continue to be driven in the lane adjacent to the SV for at least 3.0 seconds, and then will perform a lane change back into its original outboard lane using a lateral velocity of 0.25 to 0.75 m/s (0.8 to 2.5 ft./s). This test will be repeated for a POV approach from both the left and the right side of the SV (with and without the SV's turn signal engaged).

For the Straight Lane Pass-by Test (shown in Figure 14), the POV will approach and then pass the SV while being driven in an adjacent lane on a straight road. For each trial, the SV will travel at a constant speed of 72.4 kph (45 mph) whereas the POV will travel at one of four constant speeds: 80.5, 88.5, 96.6, or 104.6 kph (50, 55, 60, or 65 mph). The lateral distance between the two vehicles will nominally be 1.5 m (4.9 ft.) for the duration of each trial. This test will be repeated for a POV approach towards the SV from an adjacent lane to the left and to the right of the SV (with and without the turn signal engaged).

The Agency maintains that both of these BSW scenarios align with real-world data and are therefore appropriate for inclusion in NCAP. As mentioned previously, the 72.4 kph (45 mph) SV test speed adopted for both BSW scenarios proposed was found to cover a significant portion of fatalities and injuries, and an overwhelming majority of lane-change crashes occurred on straight roads. The adopted scenarios also encompass both ways a vehicle may approach another vehicle's blind zone when the driver does not first directly see the vehicle: laterally from two lanes away and longitudinally from behind, on both sides of the vehicle.

For both test scenarios, the POV is defined in NHTSA's updated BSW test procedure as either the ABD GVT Revision G or a high-production, compact passenger car.[316] NHTSA added the option to use a surrogate vehicle as the POV for BSW testing to align with the option provided in its BSI testing procedure. However, the Agency will use an actual vehicle as the POV during BSW testing conducted for NCAP assessments. This decision should not preclude vehicle manufacturers from using the ABD GVT Revision G in their internal testing or preclude NHTSA from revisiting its decision in the future.

At this time, both BSW test scenarios will be conducted during daylight conditions only. Real-world crash data gathered from 2011 to 2015 suggests that most lane-change crashes (62 percent of fatal lane-change crashes and 76 percent of injurious lane-change crashes) occurred annually, on average, during daylight hours. For future iterations of this consumer information program, NHTSA plans to reevaluate the real-world crash data and may adjust the test conditions accordingly.

Straight Lane Converge and Diverge Test

NHTSA received few comments directly related to the Straight Lane Converge and Diverge test. Of those commenters specifically addressing this test scenario, all but GM were in favor of its inclusion. Although NHTSA has taken into consideration GM's statements that this scenario may be less effective at reducing lane change crashes compared to the Straight Lane Pass-by scenario, the Agency agrees with Bosch that the Straight Lane Converge and Diverge test will best ensure that a vehicle's BSW system can detect a vehicle entering the blind spot while both vehicles are travelling at the same speed. Since NHTSA found that only half of the tested vehicles (five out of ten models) passed every trial run

[316] The POV selected must be 445 to 500 cm (175 to 197 in.) in length and 178 to 193 cm (70 to 76 in.) wide, measured at the widest part of the vehicle exclusive of signal lamps, marker lamps, outside rearview mirrors, flexible fender extensions, and mud flaps. Width is determined with doors and windows closed and the wheels in the straight-ahead position. The color of the vehicle is unrestricted.

conducted for the Straight Lane Converge and Diverge scenario during its model year 2019 and 2020 research testing series,[317] the Agency reasons that it is appropriate to move forward with including the Straight Lane Converge and Diverge test scenario in its BSW test series for NCAP to ensure adequate BSW system performance for this real-world situation. The test will be performed four times—twice with the POV approaching the SV from the left side (once with and once without turn signal engagement), and twice with the POV approaching from the right, as proposed (once with and once without turn signal engagement). This should ensure that the SV can detect a POV entering its blind spot from either lateral direction. If the SV does not provide a passing warning for a run conducted on one side of the vehicle, NHTSA will discontinue BSW testing for that vehicle model and the test will not be repeated for the vehicle's other side.

The prescribed test speed for both the SV and POV will be 72.4 kph (45.0 mph), as proposed. In cases where both the POV and the SV are traveling at the same speed, there is no longitudinal speed differential; thus, the speed at which the test is conducted is less relevant. However, as mentioned, for injurious lane-change crashes from 2011 to 2015 where posted speed limit was known, nearly three-quarters (70 percent) occur on roadways with posted speed limits of 72.4 kph (45.0 mph) or less on average annually, suggesting that the proposed speed is representative of real-world crashes. Furthermore, a 72.4 kph (45.0 mph) test speed is high enough that it should exceed most, if not all, vehicle models' BSW minimum speeds for activation. Specifically, data from the Agency's annual information collection from vehicle manufacturers showed a minimum operational speed range of 0 to 32 kph (0 to 19.9 mph) for model year 2024 vehicles, with the average minimum operational speed being 10 kph (6.2 mph). The Agency also recognizes that a higher test speed may require a larger test area, as both the POV and the SV must accelerate to and maintain the test speed until testing is completed. As Auto Innovators and GM noted, the Agency is aware that it must remain mindful of available test laboratory lane length when developing test specifications. Given these considerations, a test speed of 72.4 kph (45.0 mph) for both the POV and the SV is reasonable for the Straight Lane Converge and Diverge test at this time. However, the Agency may consider increasing test speeds in the future if doing so would better address the large percentage of fatalities (*i.e.,* approximately 70 percent) in lane-change crashes that occur at higher posted speeds, though in relatively low numbers.[318]

Straight Lane Pass-by Test Speeds

The second BSW test scenario that this notice finalizes for inclusion into NCAP is the Straight Lane Pass-by test. NHTSA notes that Euro NCAP currently conducts a Blind-Spot Monitoring scenario similar to NHTSA's Straight Lane Pass-by scenario. In the Euro NCAP test, a POV passes the SV in an adjacent lane; the vehicles travel at 80 kph (49.7 mph) and 72 kph (44.7 mph), respectively. Vehicles receive points toward Euro NCAP's Human Machine Interface (HMI) score if the vehicle provides continuous visual blind spot status information while the POV resides in the SV's designated blind spot area.[319] NHTSA's procedure expands upon the Euro NCAP procedure through the inclusion of three additional higher POV speeds, which increase the speed differential between the POV and SV. Four separate conditions are conducted in total, with SV/POV speeds of 72.4/80.5, 72.4/88.5, 72.4/96.6, and 72.4/104.6 kph (45.0/50.0, 45.0/55.0, 45.0/60.0, and 45.0/65.0 mph, respectively). These SV/POV speed pairs result in speed differentials equaling 8.1, 16.1, 24.2, and 32.2 kph (5.0, 10.0, 15.0, and 20.0 mph), respectively.

The Agency acknowledges several commenters suggested a reduction in the number of test conditions for the Straight Lane Pass-by test to reduce test burden. However, NHTSA's BSW research test data from model year 2019 and 2020 vehicles demonstrates the need for testing across all proposed speed combinations. Specifically, two of the ten vehicle models tested passed the lowest 8.1 kph (5 mph) speed differential test but failed[320] all remaining higher speed differential tests.[321] Further, two of the remaining eight vehicle models failed when tested at the lowest speed differential (8.1 kph, or 5 mph), while successfully passing all higher speed differential tests. Further, of the remaining six vehicles, one passed the highest speed differential test (32.2 kph, or 20 mph) but failed tests in at least one low-to-mid-range speed differential.[322] This demonstrates that not all current BSW systems struggle more with greater speed differential pass-by tests. The most stringent test case, albeit a lower or higher speed differential, is unclear. It may be true, as FCA suggested, that vehicle manufacturers test their own vehicles at mid-range speeds. However, NHTSA will evaluate all four proposed test speed pairings to better evaluate BSW performance in straight lane pass-by conditions where the SV is traveling at a moderate speed.

Despite the recommendation of several commenters, the Agency is not adopting additional test conditions that include higher speed differentials for its Straight Lane Pass-by tests. This is because to increase the speed differential between the SV and the POV, either the SV speed must be reduced or the POV speed must be increased. A reduction of the SV speed is inappropriate at this time because many BSW systems have minimum speed thresholds which would not be met at a lower speed. Increasing the POV speed also does not currently seem feasible because test facilities may not have adequate lane length available to conduct valid tests. Furthermore, the Agency did not initially propose higher speed test conditions, and it has not conducted research tests to evaluate cases where the speed delta is greater than 32.2 kph (20.0 mph). The Agency may adjust the Straight Lane Pass-by test conditions in the future when laboratory testing proves feasible.

Further, the Agency is not adopting a test condition where the SV is traveling at very low speed and contemplating a lane change into a much faster-flowing lane, despite the request of several commenters. These cases occur when traffic flow in a travel lane is slowed (*e.g.,* increased traffic, construction, or there is a disabled vehicle ahead). As mentioned, there are a range of minimum operating speeds for BSW systems, some of which are likely higher than the speed at which a vehicle in this presented stop-and-go scenario would be traveling. For instance, in data supplied by vehicle manufacturers for the model year 2024 fleet, the Agency found that, for those vehicles equipped with a BSW system, approximately 12 percent have a minimum BSW operating speed exceeding 20 kph (12.4 mph). Further, additional research would need

[317] One additional vehicle passed the left POV approach direction tests but did not pass one trial (of seven) when the POV approached from the right.

[318] In its 2011–2015 data set, Volpe found that for the 644,099 lane change crashes occurring annually, on average, 752 resulted in a fatality. This translates to approximately 526 fatalities that occurred for posted speeds exceeding 72.4 kph (45 mph).

[319] European New Car Assessment Programme (Euro NCAP) (December 2023), *Assessment Protocol—Safety Assist—Collision Avoidance, Version 10.4.*

[320] A failing result was indicative of the SV's inability to meet performance criteria on the first run and/or subsequent runs.

[321] NHTSA–2021–0002–0002.

[322] NHTSA–2021–0002–0002.

to be conducted to better understand the conditions, frequency, and severity of this crash problem. This is because unlike other scenarios, posted speed limits for the roads on which this type of scenario occurs likely do not correlate with the travel speed of the SV prior to attempting a lane change due to the unexpected nature of the situation. Thus, travel speed must be used to understand the scope of the problem but is unknown for many crash cases. Crash data from 2011–2015 does show that in 16 percent of fatal lane change/merge crashes and in 23 percent of injurious crashes, travel speed was 64.4 kph (40.0 mph) or lower. However, in 60 percent of fatal crash cases and 68 percent of injurious crashes, the travel speed prior to the crash was unknown.

For NCAP's Straight Lane Pass-by testing, NHTSA will conduct the lowest speed differential condition (SV/POV speeds of 72.4/80.5 kph (45.0/50.0 mph)) first. If the SV provides a passing warning during the run, the POV speed will incrementally increase by 8.0 kph (5.0 mph) and testing will continue, with one run conducted per speed differential condition (each with and without the turn signal engaged), until a POV speed of 104.6 kph (65.0 mph) is reached. Testing will then be repeated following a similar methodology for POV movement on the opposite side of the SV. If, for any speed differential condition, the SV does not provide a passing warning, NHTSA will discontinue BSW testing for that vehicle model. Test runs for a given speed differential will not be repeated upon a vehicle's failure to appropriately warn—a methodology consistent with that used for NCAP's AEB and PAEB performance evaluations. This test methodology aligns with those adopted for the other NCAP AEB and PAEB tests, in which the Agency chose an incremental approach to increasing test speeds.

Differentiating BSW System Performance

NHTSA will not differentiate BSW system performance with this upgrade. A vehicle passing three of the four test speed conditions in the Agency's Straight Lane Pass-by test will not receive more credit than a vehicle that passes two. Instead, a vehicle will need to pass all four Straight Lane Pass-by tests for both sides of the vehicle (with and without the turn signal engaged) and the Straight Lane Converge and Diverge test for both sides of the vehicle (with and without the turn signal engaged) to receive credit for its BSW system. Based on this, NHTSA concludes that FCA and Bosch's suggestion to determine the highest speed at which BSW can function is unnecessary. This decision still encourages manufacturers to include technology addressing a range of lane-change events, as ZF Group requested, because it ensures that the vehicle must pass all BSW test conditions for each of the two test scenarios. Further, as ASC asserted, by including the Straight Lane Converge and Diverge test in addition to the Straight Lane Pass-by test, as well as both low and high speed differential conditions for the latter, NHTSA will be able to effectively assess performance for a variety of BSW system types (*e.g.,* BSA and LCA). Specifically, for the Straight Lane Converge and Diverge test, the SV must detect a POV travelling at the same speed at a close distance, and BSA systems can best address such situations. For the Straight Lane Pass-by test, the SV must detect a faster-moving POV farther away to issue the BSW at the appropriate time, and LCA systems are best able to address these conditions. Thus, the Agency's BSW testing will ensure vehicles' BSW systems provide acceptable functionality to cover this range of real-world situations.

NHTSA will not tailor testing to each manufacturer or model but will instead apply the same test conditions to each vehicle model assessed. A methodology allowing each manufacturer to supply its own minimum and maximum POV speeds for the Agency's assessments, as suggested by FCA, would not evaluate models with the same degree of stringency, confounding attempts for consumers to compare vehicles side-by-side and leading to consumer confusion and misrepresentation.

Testing for Symmetrical System Responses

The Agency will not assume a symmetrical BSW response by testing only one side of the SV. In NHTSA's model year 2019 and 2020 BSW research test series, four out of ten vehicle models failed to provide a passing warning during at least one trial when the POV approached one side of the vehicle but not the other for a particular test condition. These findings bolster DRI's comment that BSW performance differs depending on which side is tested. Overall, for a given vehicle model, the right POV approach condition seemed more challenging than the left POV approach condition, but this was not universally true.[323]

[323] Of the 10 vehicle models, six failed more trials in right POV approach conditions than ones where the POV approached from the left. Conversely, one failed more trials for left approach conditions, and the remaining three performed approximately the same left-to-right.

Thus, without a comprehensive assessment of left-to-right performance, NHTSA cannot confirm equivalent, robust system performance. Other approaches suggested, such as random selection of sides and/or using manufacturer-supplied data to determine symmetry, introduce a level of subjectivity. Due to the high percentage of vehicle models tested by NHTSA which did not offer symmetrical performance across all five test scenarios for BSW, the Agency is hesitant to allow testing of only side of the vehicle at this time. This is subject to change in the future as vehicle hardware and software evolves.

3. Use of the Turn Signal for BSW

BSWs are automatically presented to the driver when another vehicle is operated in, or approaching, the driver's blind spot. These alerts may be visual (most common), haptic, or auditory. When the driver engages the turn signal to initiate a lane change in the direction of a vehicle in the adjacent lane, additional, escalated alerts may also activate to warn the driver more urgently that there is already a vehicle present.

NHTSA's current BSW test procedure does not stipulate turn signal activation during BSW testing. However, in its RFC notice, the Agency sought comments on whether the turn signal indicator should be engaged, with the intent to evaluate the additional alerts presented to a driver intending to make a lane change rather than only the automatic alert presented whenever another vehicle is occupying the blind spot area. If commenters were interested in testing with the turn signal enabled, the Agency requested further comments regarding the type of alerts that should be required (*e.g.,* visual, haptic, and/or auditory) and the distinction between alerts issued with and without turn signal usage.

Summary of Comments

Turn Signal Activation

Several commenters stated that the BSW system should be evaluated both with and without the use of the turn signal indicator during testing. ZF Group reasoned that both conditions should be tested because crashes can occur regardless of whether the turn signal is activated. ASC suggested that testing in both configurations can determine whether ''the BSW warning is being suppressed for planned lane changes where the turn signal indicator is activated.'' Rivian commented that NHTSA should run a limited number of tests involving the use of the turn signal only to ''verify functional logic.'' HATCI requested that finalized test procedures be made available before making a decision regarding turn signal usage but commented that the procedures should be flexible to accommodate.

While some commenters requested use of the turn signal during testing, many stated that testing without the turn signal is critical. CAS and others commented that the presence of a vehicle may inform the driver's decision to initiate a lane change. Commenters further stated that omitting the turn signal more closely represents actual driver behavior, as the turn signal is not always engaged before making a maneuver. Along these lines, one individual commented that safety assessments should be based on likely real-world driver behavior instead of idealized behavior. Honda noted that its vehicles' alert timing is independent of the driver's intentions and is based on a time-to-collision assessment. Bosch stated that, unless NHTSA plans to evaluate the warning system itself and not whether it triggers, it is not necessary to engage the turn signal.

Alert Type Requirement

Commenters expressed mixed opinions regarding what types of alerts should be required if the BSW test procedure is modified to require activation of the turn signal.

Any Alert Type

Some commenters (Honda, Bosch, HATCI, and one anonymous individual) stated that any alert type should be allowed for BSW credit if use of the turn signal is stipulated. HATCI expressed that allowing any alert modality should give manufacturers flexibility to optimize alerts based on the ''multitude of ADAS technology installed, the interactions between the technologies, and research and development findings.'' Bosch agreed that flexibility was advantageous but added that the same alert modalities used for other ADAS should not be used for BSW, since this may confuse the consumer and decrease consumer acceptance. Honda commented that there is ''no reasonable method to objectively evaluate the performance of different alert modalities'' and that doing so could complicate the test procedures. HATCI suggested that NHTSA ''consider researching performance requirements to measure effectiveness of alerts rather than prescribing specific modes'' where appropriate. Auto Innovators acknowledged that, while there is potential benefit for an escalating alert modality when the turn signal is engaged, the Agency should not prescribe a specific alert type.

Visual Warnings

Many responders commented that visual warnings were sufficient (or preferred) for BSW systems. Some commenters mentioned visual warnings can be very effective when placed in a natural location for visual checking, such as a side mirror. Toyota noted that, ''in the case that BSW is not activated, the driver should be still looking at the mirror'' to scan for other vehicles prior to a lane change. Thus, a change in desired driver behavior would not be required. GM and FCA also alluded to the importance of checking mirrors for maneuver planning and agreed that drivers should be encouraged to check mirrors rather than rely solely on other cues, such as haptic or auditory warnings. GM specified that a steady amber warning icon should be visible in the side mirror adjacent to the potential threat and should flash upon turn signal engagement. GM added that mirror-checking is especially important because short-range BSW systems ''have limited capability for alerting drivers with enough time to react to fast approaching traffic.'' Auto Innovators stated that ''visual alerts only are sufficient enough for inclusion in NCAP for evaluations and effective alert methods if they are displayed within the driver's field of view as they check their mirror before changing lanes.'' Tesla and FCA agreed that visual BSWs are sufficient.

Haptic Warnings and/or Auditory Warnings

NHTSA received varied support for haptic and/or auditory alerts for BSW. Some commenters, such as FCA and BMW, asserted that auditory warnings can become a nuisance. FCA stated its research has shown that an auditory warning can drive customer dissatisfaction when it occurs while merging in front of another vehicle and can cause the driver to disable the feature altogether. FCA stated it allows the driver to disable the auditory BSWs for this reason. BMW offered that drivers often engage their turn signals to signal their eventual intent, even when they know there is a vehicle in their blind spot. BMW reasoned that haptic and/or auditory warnings would annoy the driver in such instances. GM submitted similar sentiments regarding non-visual BSWs, stating that such alerts would be an annoyance to drivers who have no intention of switching lanes, or who signal an intent to change lanes in advance of an intended lane change.

Other commenters stated they would like to see additional alert types used for BSW. ZF Group suggested visual warnings may be ''more or less effective depending on sunlight'' and that an additional alert method might increase robustness of the system. ZF Group stated that its research suggests that haptic seat belt warnings are very effective; they added that the use of haptic or auditory warnings such as those used for LDW could be effective because they are meant to convey the same underlying information—the SV is about to experience a ''potentially hazardous'' lane departure. ASC and GM also agreed with these sentiments, with GM commenting that a single alert type (visual) could be used when the alert is ''cautionary,'' and multiple alert modalities can be used when the situation is more urgent. CAS also stated there should be an auditory or haptic warning because the cost of adding these alert types to the vehicle would be minimal.

NHTSA received some feedback suggesting the type of warning should depend on the driver's intent. IDIADA shared that its experience has been that visual alerts work best for conveying information, not for urgently alerting the driver, further noting that an auditory warning would be preferable for alerting the driver when attempting to perform an unsafe lane change. Vayyar agreed with this sentiment but suggested that either an auditory or haptic alert would be acceptable for the warning associated with the turn signal. Rivian requested allowing users to customize their alert type based on driver preference. Rivian stated that visual alerts should not be allowed to be disabled, but that an option for auditory alerts should be required and an option for haptic alerts should be encouraged.

Alert Distinctions Between Use and Non-Use of Turn Signal

Regarding distinction between alert modalities associated with and without the use of the turn signal, as mentioned previously, most commenters agreed that use of the turn signal should increase the ''urgency'' of the alert issued to the driver. Toyota, CAS, ASC, ZF Group, Tesla, BMW, FCA, Rivian, Bosch, and GM all expressed favor with the use of a flashing alert specifically to send a more intense signal to the driver when the turn signal is used since it conveys intent to maneuver. Toyota's reasoning was that a flashing or blinking visual warning is normally ''interpreted as conveying 'priority'.'' Tesla, Auto Innovators, and BMW suggested providing an escalated alert to the driver when another vehicle is detected in the

SV's blind spot and the turn signal is engaged.

Some commenters stated that the warning indicator should flash regardless of driver intent. CAS suggested that LDW/LKA and BSW/BSI be integrated so that an ''aggressive warning and correction'' should occur if the blind spot is occupied and the driver begins to make a hazardous maneuver, regardless of turn signal status, because the cost of including a combined warning is minimal. ASC also specified that the warning light should flash whether the lane change is intentional or not.

Auto Innovators did not oppose the use of a flashing symbol upon activation of the turn signal. However, the organization relayed that this is not the only acceptable alert modality and that NHTSA should not restrict performance criteria to this type of alert only. Advocates also commented that a general escalation should be required and noted that a flashing visual warning would be logical; however, it further stated that the Agency should provide data to support the alert modality ultimately selected to receive credit.

Response to Comments and Agency Decisions

The Agency has decided to modify its BSW test procedure to require additional testing with the turn signal indicator engaged. NHTSA appreciates Bosch's position that engaging the turn signal is seemingly unnecessary since the Agency plans to only assess whether the warning triggers at the appropriate time (*i.e., detects* the POV when it is in the driver's blind spot) and will not evaluate the warning system itself. However, the Agency also maintains that there is merit to Rivian's suggestion to conduct tests to verify the functionality of the BSW system when the turn signal is engaged. This additional testing should ensure that a vehicle still issues a BSW when the driver engages the turn signal with the intent to switch lanes before fully assessing their surroundings, as ASC suggested. Further, as BMW and GM noted, utilizing the turn signal to notify intent is a common practice used by drivers. Performing testing both with and without the turn signal engaged should address the greatest number of real-world driving conditions. Although several commenters correctly stated that many drivers do not use their turn signal to indicate intent to change lanes, many others do. Receiving an alert when another vehicle is present may deter this latter group of drivers from completing the lane change. Therefore, ensuring that a BSW is issued in either case seems appropriate.

For this NCAP upgrade, the Agency is requiring that FCWs be comprised of an auditory and visual signal but is not imposing specific attributes (*e.g.,* size, location, decibel level, tactile type, etc.) for either signal modality. However, for its BSW tests, NHTSA is not only implementing a visual alert requirement, but it is also imposing additional alert specifications. Specifically, a visual alert that is compliant with SAE Standard J2802, ''Blind Spot Monitoring System (BSMS): Operating Characteristics and User Interface'' must be present in the side mirror or the A-pillars. The alert must meet the timing requirements specified in the Agency's BSW test procedure. Although this visual alert requirement will apply to tests conducted both with and without use of the turn signal, the type of visual alert displayed may change for tests conducted with turn signal engagement. For BSW tests conducted without the turn signal engaged, the visual warning must be continuously illuminated. When the turn signal is engaged in the Agency's BSW tests, the visual warning may become escalatory in nature (*e.g.,* switches from steady-burning to flashing, changes color, etc.), or may remain continuously illuminated for vehicles where a second warning modality is also provided.

While acknowledging the comments manufacturers provided promoting flexibility to optimize alerts for various ADAS technologies, requiring a visual alert to appear in the side mirror or A-pillar adjacent to the potential crash threat is a reasonable minimum NCAP requirement for BSW technology, particularly since the driver's gaze when considering a lane change should be in the direction of the intended lane departure. As Toyota, GM, FCA, and Auto Innovators mentioned, drivers are expected to check their side mirrors or, at a minimum, look left or right, as appropriate, to check for the presence of other vehicles prior to initiating a lane change. Warnings should serve to assist the driver in detecting the presence of vehicles in their blind spots; they should not encourage complacency during normal driving. With short-range detection capabilities, BSW systems may not always warn drivers with enough time for them to react to fast-moving vehicles, as GM stated. As such, NHTSA agrees with commenters that the onus remains on the driver to be diligent and check their side mirrors before changing lanes, even for vehicles equipped with BSW systems.

In addition to the continuously illuminated visual cue required for all BSW tests performed without the SV turn signal engaged, the Agency is requiring issuance of an additional alert modality (*i.e.,* a dual-modality alert) or an escalating visual alert (*e.g.,* switches from steady-burning to flashing) upon turn signal engagement, as Auto Innovators suggested. With the turn signal engaged, the driver is signaling an intent to change lanes, thus altering the significance of the alert from a cautionary state to a state of urgency. The Agency agrees with GM, IDIADA, and Vayyar that a single alert type (*i.e.,* visual) may be sufficient when it serves to caution the driver; however, multiple alert modalities or alerts with escalating visual attributes are a more effective way to discourage a driver from proceeding with an intended action that may cause harm.

NHTSA recognizes that many commenters preferred use of a flashing visual alert when the turn signal is engaged and another vehicle is in or approaching the driver's blind spot. Conversely, many others expressed that non-visual alert types (*e.g.,* haptic and auditory) can be very effective if executed properly. In consideration of this, the Agency will allow vehicle manufacturers to dictate the supplemental alert type and/or escalation attributes that will be required for BSW testing when the turn signal is engaged. A vehicle may present a BSW that is comprised of a visual and auditory or visual and haptic signal, or it may simply present an alert that exhibits escalating visual attributes. Such an approach should allow manufacturers to optimize alert strategies not only for BSW systems but also for other ADAS technologies in the future, as many commenters requested.

Although the Agency recognizes that effectiveness may change with flash rate, color, etc. for visual warnings; frequency, decibel level, etc. for auditory warnings; and tactile type (*e.g.,* vibration, jerk, etc.) for haptic warnings, it will not prescribe such requirements at this time. NHTSA has not conducted research to guide such prescriptions, and, as Honda asserted, it currently has no method to objectively evaluate the performance of different BSW modalities. As such, it does not want to impose requirements for additional alert types that may be of nuisance and create customer dissatisfaction such that drivers choose to disable BSW functionality.

Further, the Agency will not require the BSW visual cue to flash when the driver departs the lane absent turn signal engagement, as CAS and ASC suggested, since NHTSA does not want to be overly prescriptive for a condition that is more representative of its lane keeping test scenarios (where lane departure is unintentional and thus turn signal engagement is not expected) than its BSW test scenarios (where lane departure is deliberate and thus turn signal engagement is likely, though not always assured). Although both turn signal use and non-use will be represented in the Agency's BSW tests, the Agency's lane keeping tests will be conducted without turn signal engagement.

4. Test Conditions for BSI Testing

In addition to a warning-based blind spot assessment, NHTSA also proposed an active safety evaluation (*i.e.,* BSI) for inclusion in NCAP. Test scenarios proposed for BSI include two lane change scenarios (SV Lane Change with Constant Headway and SV Lane Change with Closing Headway) and one false positive scenario (SV Lane Change with Constant Headway, False Positive Assessment), to be discussed later.[324]

Summary of Comments

Most respondents to the March 2022 notice did not solely address BSI, with comments generally referring to both blind spot technologies (*i.e.,* BSW and BSI). However, many commenters did express support for inclusion of BSI along with BSW. Aptiv, Consumer Reports, MEMA, ITS, Advocates, Bosch, HMNA, NADA, and two individuals, among others, stated approval of NHTSA's plan to evaluate BSI as a part of NCAP. Aptiv suggested that the proposed parameters would allow NHTSA to quantify BSI's benefits. MEMA agreed with NHTSA that all four ADAS technologies included as part of this final notice, including BSI, are mature, and would not only address a range of crash scenarios, but also offer significant safety benefits. In addition, Bosch stated that BSW and BSI may both help to reduce the risk of lane-change crashes.

However, several commenters stated that BSI technology is not mature and opposed including it in this NCAP update. GM, Auto Innovators, and Honda suggested that BSI could be included in the future, particularly once benefits numbers are better established.

Auto Innovators further clarified that NHTSA should not include the BSI evaluation in an ADAS rating but that the group would find it acceptable to include it as a recommended technology to encourage BSI adoption.

On the issue of test speeds, Advocates expressed concern that a single SV test speed of 72.4 kph (45 mph) would not ensure BSI systems operate across an appropriate range of speeds.

Response to Comments and Agency Decisions

Although some commenters opposed the immediate inclusion of BSI into NCAP, many others were in favor of including evaluations for this active technology with this program update. NHTSA expects that BSI, in tandem with BSW systems, will reduce the frequency of lane-change crashes. This is because active safety technologies are thought to be more effective than warning technologies alone, so benefit estimates for BSI systems should be greater than for BSW systems. As such, it is prudent to add BSI technology to NCAP at this time and NHTSA is proceeding with adopting all three scenarios proposed for the technology in its March 2022 RFC notice—the SV Lane Change with Constant Headway scenario, the SV Lane Change with Closing Headway scenario, and the SV Lane Change with Constant Headway False Positive scenario.

For the SV Lane Change with Constant Headway Test (shown in Figure 15), the POV, driven at the same speed of the SV (*i.e.,* 72.4 kph (45 mph)), is positioned in a lane adjacent to that of the SV with a constant longitudinal offset from the rearmost part of the SV, which is laterally offset from the center of its travel lane.[325] After a short period of steady-state driving, the SV driver (*i.e.,* robot) will initiate a manual[326] lane change, following an 800 m (2,625 ft.) radius curved path towards the POV's travel lane. The SV driver (*i.e.,* steering robot) then releases the steering wheel within 250 ms of the SV exiting the curve so as to achieve a steady state lateral velocity of 0.7 ± 0.1 m/s (2.3 ± 0.3 ft./s) relative to the line separating the SV and POV travel lanes. In response to the lane change maneuver, the BSI system is expected to intervene and prevent the rear of the SV from contacting the front of the POV. Additionally, the SV BSI intervention must not cause a secondary departure.[327]

For the SV Lane Change with Closing Headway Test (shown in Figure 16), the POV, approaching the SV from the rear, is driven at a constant speed of 80.5 kph (50 mph). The POV's speed is 8 kph (5 mph) greater than that of the SV, which is travelling in an adjacent lane at 72.4 kph (45 mph), with a lateral offset from center. During the test, the SV driver (*i.e.,* steering robot) will initiate a manual lane change, following an 800 m (2,625 ft.) radius curved path towards the POV's travel lane. The SV driver (*i.e.,* robot) then releases the steering wheel within 250 ms of the SV exiting the curve so as to achieve a steady state lateral velocity of 0.7 ± 0.1 m/s (2.3 ± 0.3 ft./s) relative to the line separating the SV and POV travel lanes. In response to the lane change maneuver, the BSI system is expected to intervene and prevent the rear of the SV from contacting the front of the POV. Additionally, the SV BSI intervention must not cause a secondary departure.

For the SV Lane Change with Constant Headway, False Positive Assessment Test (shown in Figure 17), the POV, driven at 72.4 kph (45 mph), is positioned in a lane that is two lanes to the left or right of the SV's initial travel lane with a constant longitudinal offset from the rearmost part of the SV. The SV is laterally offset from the center of its travel lane and also travelling at 72.4 kph (45 mph). After a short period of steady-state driving, the SV driver (*i.e.,* steering robot) will initiate a manual lane change into the adjacent lane (the one between the SV and POV) to either the left or to the right. The SV follows a defined path toward the adjacent lane, approaching the center lane line at a constant lateral velocity of 0.7 ± 0.1 m/s (2.3 ± 0.3 ft./s). For this test, the driver (*i.e.,* robot) does not release the steering wheel. Since no POV is present in this lane and therefore the lane change will not result in an SV-to-POV impact, the BSI system must not intervene. To determine whether a BSI intervention occurred, the yaw rate data collected for the SV during the individual trials are compared to a baseline composite. The difference between the data must not exceed 1

[324] While the Agency did not explicitly discuss SAE Driving Automation Level 2 and 3 test scenario descriptions for BSI testing in its RFC, the proposed test procedures allow for testing of these systems. However, the Agency does not anticipate testing Level 2 or 3 systems as part of NCAP at this time given the limited number of applicable vehicles currently available, along with uncertainty about the driver and vehicle interaction imposed by such implementations.

[325] The initial lateral offset of the vehicle from the centerline (based on the vehicle width and the desired lateral velocity) is to ensure the SV is being operated at the desired lateral velocity before BSI operates.

[326] "Manual" refers to an externally commanded steering input. NHTSA will use a steering robot for such inputs to maximize accuracy, repeatability, and test efficiency.

[327] For the BSI tests, a secondary departure occurs when the SV BSI intervention causes the SV to travel 0.3 m (1.0 ft.) or more beyond the inboard edge of the lane line separating the SV travel lane from the lane adjacent and to the right of it (for lane changes to the left) or adjacent and to the left of it (for lane changes to the right) within the validity period.

degree/second within the test validity period.

Assessments for each scenario will be performed during daylight conditions only for a POV approach on both the left and right sides of the SV (*i.e.,* the SV will make left and right lane changes during testing) and with and without the turn signal engaged. Tests will be conducted without LCA or cruise control (*i.e.,* conventional or adaptive cruise control, or ACC) engaged.

The Agency notes that of the three BSI test scenarios proposed by NHTSA, two closely mirror Euro NCAP's Overtaking Vehicle tests,[328] (SV Lane Change with Constant Headway scenario and SV Lane Change with Closing Headway scenario), bolstering support for their adoption into U.S. NCAP. Further, NHTSA has found feasible BSI testing according to the Agency's draft test procedures. Specifically, in its model year 2019 and 2020 BSI test series, the Agency found that, while no vehicles were able to fully and reliably meet requirements to pass [329] the SV Lane Change with Constant Headway scenario, four of the ten were able to pass the SV Lane Change with Closing Headway test. NHTSA expects that vehicle performance will improve over time as manufacturers apply strategies already in use internationally.

The Agency will conduct the adopted BSI test scenarios using the 72.4 kph (45 mph) SV proposed speed. The SV Lane Change with Closing Headway scenario will also retain the 80.5 kph (50 mph) POV speed. The rationale for this decision is similar to that provided for BSW—notably, the speeds' correlation with real-world crash data for injurious lane-change crashes and sufficiency for minimum activation of blind spot systems. Additionally, these test speeds were developed to balance the need to address a real-world safety problem with equipment capabilities dictated by the state of technology for the GVT, available testing real estate at test laboratories, and the Agency's validation efforts (*e.g.,* of the speeds accurately and repeatably attainable with the robotic platforms used to move the GVT during BSI test conduct). NHTSA concludes that the 72.4/80.5 kph (45/50 mph) test speeds best achieve this balance. Additionally, Euro NCAP's Lane Support Systems (LSS) protocol for the Emergency Lane Keeping (ELK) Overtaking Vehicle test scenarios includes the same SV and POV speeds as those NHTSA has specified in its BSI test procedure. Having said this, the Agency acknowledges Advocates' concern that a single speed may not address a range of real-world driving speeds, and NHTSA may consider testing at higher SV/POV speeds in the future. In addition, the Agency may reevaluate this decision in the future and adjust the test conditions accordingly if real-world crash data shows a need for doing so.

Although the Agency's draft BSI procedure only specified assessments for SV lane changes occurring to the left, the Agency has decided to perform BSI testing for a POV approach on both the left and right sides of the SV. This is because NHTSA asserts there is reason for it to also verify functionality of BSI systems when making a right-lane change. For example, in real-world cases, the SV may be on a multi-lane road or be in the left lane of a two-lane road and attempting to move right. As previously mentioned, during the Agency's model year 2019 to 2020 BSW research testing, BSW systems appeared to perform either the same or worse when the POV approached on the right-hand side. Thus, symmetrical responses cannot be assumed, and in the interest of providing thorough information to the consumer, NHTSA will similarly assess both left-hand and right-hand BSI performance. Though this addition deviates from Euro NCAP's test protocol, the Agency concludes that it is appropriate given the considerations mentioned.

NHTSA is also adopting ABD GVT Revision G for the POV used in its BSI tests, as detailed later in this section. This test device is the most suitable vehicle surrogate for BSI testing given its use in NCAP's BSI tests would harmonize with the vehicle test device prescribed in Euro NCAP's LSS testing protocol for the organization's Overtaking Vehicle tests and because it satisfies the specifications defined in ISO 19206–3 (2021).[330]

At this time, similar to the decision for the Agency's BSW tests, the BSI test scenarios will be conducted during daylight conditions only. NHTSA made this decision because, as mentioned previously for BSW, 2011–2015 crash data suggests that the majority of lane-change crashes (62 percent of fatal lane-change crashes and 76 percent of injurious lane-change crashes) occurred annually, on average, during daylight hours. The Agency may reevaluate this decision in the future and adjust the test conditions accordingly if real-world crash data shows a need.

The same tests must be completed for each vehicle model assessed for NCAP to provide equivalent information regarding vehicle performance across the fleet. The longitudinal speed of the SV will be maintained through manual or robotic control during conduct of NCAP's BSI tests. At this time, the Agency will not utilize conventional or ACC during NCAP's BSI testing, even though the Agency's draft test procedure allows for this flexibility during testing. Since there is no vehicle present in the SV forward path, NHTSA does not expect there would to be any difference in how the SV's speed is maintained during a given BSI test trial if manual/robotic or cruise control is used. Cruise control is designed to regulate a vehicle's longitudinal movement and therefore should not impact the lateral control functionality intrinsic to BSI. However, to ensure fairness across testing, it is most appropriate for NCAP to conduct testing utilizing only one method of speed control to ensure that the performance of one vehicle system (BSI) is not affected in any way by the performance of another system (cruise control). NHTSA is choosing to test with manual or robotic control in lieu of cruise control since consumers may sometimes opt not to use a cruise control feature, particularly on non-highway roads. NHTSA notes that 55 percent of fatal and 82 percent of injurious lane-change crashes, on average, occurred annually between 2011 and 2015 on roadways that were not considered highways.[331] [332] The Agency will also not use LCA during NCAP's BSI tests since not all vehicles are equipped with such features.

As detailed later in the section, the Agency will nominally perform four unique tests for each of the three BSI test scenarios (*i.e.,* with the POV on the

[328] These tests are specified in Euro NCAP's Lane Support Systems (LSS) test protocol as part of its Emergency Lane Keeping (ELK) test series.

[329] For SAE Driving Automation Level 0- or 1-equipped vehicles, a result is considered passing when (1) the SV intervenes to avoid contact with the POV during the test and (2) the intervention does not cause the SV to travel more than 0.3 m (1.0 ft.) beyond the inboard edge of the lane line which separates the SV travel lane from the one adjacent and to the right of it within the validity period. This must be true for any number of trials conducted.

[330] European New Car Assessment Programme (Euro NCAP) (December 2023), *Test Protocol—Lane Support Systems, Version 4.3.* See section 5.

[331] Swanson, E., Foderaro, F., Yanagisawa, M., Najm, W. G., & Azeredo, P. (2019, August), *Statistics of light-vehicle pre-crash scenarios based on 2011–2015 national crash data* (Report No. DOT HS 812 745), Washington, DC: National Highway Traffic Safety Administration.

[332] A highway was defined as such if all three precrash trafficway attributes were true: (1) a posted speed limit was ≥ 45 mph; (2) the relation to junction was a non-junction, through roadway, or other location within an interchange area; and (3) the trafficway description was a two-way, divided, unprotected (painted > 4 feet) median; two-way, divided, positive median barrier; or entrance/exit ramp.

left and right sides of the vehicle and with the SV turn signal engaged and disabled). If the SV intervenes and meets the test procedure requirements during a trial run, testing will continue until all test conditions are assessed. If the SV does not provide an acceptable intervention during any trial run conducted for a given test condition, BSI testing will cease for the vehicle model. This test methodology is appropriate for BSI because it aligns well with that adopted for BSW and the other ADAS technologies to be included in NCAP.

However, in a departure from other ADAS technologies included in this notice, NHTSA will assess BSW separately from its active technology counterpart (BSI) for NCAP. NCAP has not previously evaluated technologies associated with blind spot warning or intervention, but assessments for forward collision and lane departure warning technologies have been included in NCAP's crash avoidance testing since model year 2011. Based on this, it is appropriate to allow manufacturers to receive NCAP credit for BSW systems while working toward improved BSI performance.

Finally, in response to Auto Innovators' concern regarding inclusion of BSI results in a rating, for this NCAP update, vehicles achieving no-contact results (and, in the case of false-positive testing, no intervention) and exhibiting no secondary departure, will receive a check mark on NHTSA's website. Results will not be combined into a rating in the immediate future, but NHTSA may do so at a later date.

5. Use of the Turn Signal for BSI

NHTSA's draft BSI procedure requires utilization of the left turn signal during BSI tests, with no instances where the turn signal is not enabled in the proposed procedure. NHTSA requested comments on whether this is appropriate, and if not, how the Agency could differentiate the operation of BSI from the heading adjustments resulting from an LKA intervention. NHTSA also asked whether the SV's LKA system should be switched off during conduct of the Agency's BSI evaluations.

Summary of Comments

Turn Signal Activation

Several commenters stated that it is reasonable to perform BSI tests with the turn signal enabled. FCA, GM, Honda, Tesla, and Auto Innovators responded that BSI tests should be conducted *only* with the turn signal. FCA, Honda, Tesla, and Auto Innovators commented that drivers conduct lane changes with intent, so activation of the turn signal is appropriate. GM also noted that BSI is reliant on LKA functionality and that the use of the turn signal would distinguish BSI performance from LKA.

Toyota, IDIADA, ASC, and ZF Group commented that testing both with and without turn signal use would be appropriate. Many of these commenters noted that real-world drivers may not signal intent to make a maneuver and that the technology should operate regardless of whether the turn signal is used. ASC stated that testing in this manner could ''identify whether there is any difference in operation due to the turn signal status.''

Some commenters, including Rivian, CAS, Aptiv, and one anonymous individual, suggested that turn signals should not be used during BSI testing. Rivian likened BSI to CIB, stating that ''BSI can be equated to collision imminent braking (CIB) in the manner that CIB is the elevated interventional stage following forward collision warning (FCW).'' Rivian reasoned that turn signal activation should only affect warning behavior, not intervention behavior. CAS and an anonymous individual noted that, as previously mentioned, drivers may fail to signal intent, with CAS stating that ''NHTSA tests should not be based on idealized good driving practices but should instead include plausible driving errors''. Aptiv further stated that not engaging the turn signal is more representative of a real-world driving scenario.

LKA Status if Turn Signal is Off

The Agency also requested comments on whether LKA should be deactivated during BSI evaluations if the turn signal is not used in order to differentiate performance between LKA and BSI systems. DRI indicated that if the LKA system cannot be turned off the use of the turn signal should be required, stating otherwise it would be difficult to discern any performance difference. DRI stated it did not have an opinion on the matter if the LKA system could be turned off. Honda opined that LKA status would not ultimately be relevant as, even if LKA were allowed to remain on, BSI would ''take over authority for intervention,'' but noted that if LKA was disabled, ''the BSI performance will operate more consistently as a BSI system.''

Toyota, IDIADA, FCA, GM, BMW, and Tesla commented that they preferred the LKA system remain enabled while performing BSI tests. Toyota, IDIADA, and others also suggested NHTSA should focus on technology neutrality, meaning that the test requirements should not dictate the technologies needed to meet them. Toyota further stated that ''in the real-world condition, both systems may be active and function in combination as part of the overall vehicle ADAS features.'' Those in favor of keeping the LKA system enabled noted that BSI and LKA may be integrated systems that cannot be separated from one another. Toyota, BMW, and GM suggested that LKA is likely suppressed in the ''turn signal on'' condition for some current vehicles.

Three respondents, Aptiv, Rivian, and one anonymous individual, supported the deactivation of LKA during BSI testing. Rivian asserted that consumers may turn off LKA due to personal preference and, therefore, BSI should be assessed independently. Rivian also stated that there will be some interaction between LKA and BSI but that ''the OEM should be responsible for determining the detailed interactions and communicating their function and interaction to the customer.'' Aptiv supported disabling LKA and/or ''auto lane change features'' for vehicles equipped with SAE Driving Automation Levels 2 and 3.

ASC and ZF Group found value in evaluating BSI separately from LKA but supported a different approach to differentiate performance. Both groups mentioned that LKA may not always be active due to various circumstances. Because BSI is proximity-based and not dependent on lane markings, both groups suggested that the Agency could avoid activating LKA instead of disabling it by testing vehicles on ''a roadway without lane markings to differentiate a BSI intervention from an LKS intervention.'' Advocates also reasoned that BSI should operate independent of lane lines and recommended that the Agency determine protocols to test BSI without triggering LKA interventions and vice versa.

Other commenters stated that more research and test development is necessary. CAS commented that the ''underlying logic'' for LKA and BSI systems is different, so different tests are required. However, CAS noted logic differs between vehicle models, so the means to discriminate performance of each system may also be different. Advocates requested that NHTSA provide its ''research and evaluation of vehicles with BSI and LKS systems to justify any decision regarding testing protocols.''

Response to Comments and Agency Decisions

NHTSA will conduct all three BSI test scenarios (*i.e.,* the SV Lane Change with

Constant Headway scenario, the SV Lane Change with Closing Headway scenario, and the SV Lane Change with Constant Headway False Positive scenario) two times for each POV approach direction (left and right)—once with the turn signal engaged and once without use of the turn signal. Assessments will be performed with the vehicle's LKA system 'off' if the LKA system can be disengaged and its LCA system 'off' if the vehicle is so equipped.

The Agency agrees with commenters who stated that turn signal use during NCAP's BSI test is appropriate; the related test scenarios represent situations where drivers intend to conduct a lane change. NHTSA also agrees with GM that use of the turn signal in the Agency's BSI tests serves to distinguish BSI performance from that of LKA. NHTSA's LKA tests are designed to represent unintentional lane departures, and as such, the turn signal is not engaged. However, as mentioned for BSW, there is merit to the assertion from other commenters that drivers often fail to outwardly signal intent to make a lane change by engaging their turn signal. Both use and non-use of the turn signal can represent intentional lane departure situations during real-world driving. By omitting the latter, the Agency would fail to capture a significant portion of use cases in the real world. Rivian's point that turn signal activation may affect whether the vehicle warns the driver but not whether it intervenes once the driver begins to perform a lane change is also valid. Once the lane change maneuver has begun, the driver's intent is known, regardless of whether the driver activated the turn signal indicator, and the vehicle's BSI system should respond accordingly. Given this, the Agency would be remiss to only evaluate a BSI system's ability to intervene in situations where the driver has utilized their turn signal. As several respondents suggested, NHTSA must also assess system functionality when the turn signal is not used prior to a lane change maneuver.

NHTSA will perform all BSI assessments for a vehicle (*i.e.,* both those conducted with the turn signal activated and those conducted without) with the LKA system 'off' if the LKA system can be disengaged. LKA systems provide brief heading corrections needed to bring a vehicle away from a lane line after it has been crossed or if a crossing has been deemed imminent. Although the Agency recognizes that several respondents recommended that the LKA system remain enabled while performing BSI tests to promote technology neutrality, NHTSA asserts that setting the LKA system to 'off' is more appropriate. A vehicle's LKA system is not guaranteed to be 'on' during real-world driving. While it is true that BSI and LKA systems may both be active and function in combination during real-world driving as Toyota asserted, it is also possible that consumers may turn off LKA due to personal preference, as Rivian contended. Further, as noted in the March 2022 RFC, NHTSA is aware of studies which suggest that drivers frequently disable lane departure technologies.[333] Accordingly, assessing BSI functionality independent of LKA functionality during NCAP's BSI tests seems appropriate.

Although DRI recommended that turn signal use should be required for any tests conducted for vehicles in which the LKA system cannot be turned off to discern performance differences between a vehicle's BSI and LKA systems, it is still appropriate to perform assessments both with and without turn signal engagement in such instances. As mentioned, not all drivers utilize the turn signal indicator when changing lanes. As Honda opined, BSI should resume intervention authority even if the LKA system remains 'on' for testing. If a vehicle's LKA system were to affect BSI performance for fully-integrated LKA and BSI systems, any influence should be representative of real-world driving circumstances. As such, it is appropriate to still include an evaluation requiring that the turn signal not be activated for those vehicles where the LKA system cannot be turned 'off.'

NHTSA will not test vehicles on a roadway without lane markings to differentiate BSI and LKA interventions without deactivating LKA, as suggested by several commenters. Since most multiple lane roads conducive to lane changes on which vehicles will be travelling at the speeds to be assessed will have lane lines, conducting BSI tests on roadways devoid of lane markings would not be representative of real-world driving conditions. Further, while lane markings may not influence BSI performance for vehicles with LKA systems that can be switched off, the Agency reasons a lack of lane markings may affect both LKA and BSI system functionality (and thus BSI performance) for those vehicles with fully integrated BSI and LKA systems where LKA cannot be deactivated for BSI testing. This assumption is bolstered by GM's assertion that BSI is reliant on LKA functionality.

[333] 87 FR 13461.

Finally, as previously mentioned, the Agency will set a vehicle's LCA system, which serves to continuously provide steering inputs needed to keep a vehicle centered in its lane of travel, to 'off' (if equipped) for all BSI tests.

6. User-Configurable Settings for BSW and BSI Tests

For NHTSA's BSW and BSI testing, the Agency will set the timing for the warning in BSW systems and intervention in BSI systems to the middle (or next latest) setting (if adjustable) during its BSW/BSI evaluations, similar to that previously shown in Figure 2 for FCW evaluations. For BSW and BSI systems having only two settings, the Agency will select the later of the two settings and this test setting will meet NHTSA's middle (or next latest) BSW/BSI setting requirement. These system setting configurations align with Euro NCAP's LSS test protocol.

All BSW and BSI tests will also be conducted with LKA and cruise control (*i.e.,* conventional or adaptive cruise control, or ACC) 'off' if such systems can be disengaged. Lane centering functions will also be set to 'Off' for all BSW and BSI tests in alignment with Euro NCAP's LSS test protocol.

7. BSI False Positive Testing

NHTSA proposed including a false positive test (SV Lane Change with Constant Headway, False Positive Assessment Test) in its BSI test procedure to evaluate the propensity of the system to inappropriately activate in a situation that does not pose a crash risk to those in the SV.

Summary of Comments

Commenters expressed mixed opinions for this proposed test scenario. Some, including TRC, CAS, Advocates, ZF Group, Vayyar, Intel, Rivian, and one anonymous individual, commented that a false positive test scenario is a valuable testing inclusion. Many commenters, including CAS, Advocates, ZF Group, Vayyar, Rivian, and CR, conveyed that false positive activations could cause customer dissatisfaction, leading to customers ignoring or deactivating the technology. TRC commented that to maximize the benefit of a technology, NHTSA must encourage maximum consumer confidence and use. Advocates mentioned this is particularly important for active technologies in which the driver cannot ignore a false positive activation. CAS and Vayyar noted that inappropriate activation may cause undesirable driver reactions, leading to potentially dangerous driving behavior.

Other commenters stated that the false positive testing scenario is not appropriate or necessary for NCAP. Auto Innovators and Toyota stated that false positive activations are difficult to reproduce because of situational complexity and suggested that a limited number of test runs cannot determine the overall robustness of the system. FCA did not oppose the inclusion of a false positive test scenario but reasoned that it may be difficult to determine a concise test methodology. Toyota and others stated that manufacturers may begin designing their systems to pass tests instead of performing acceptably in real-world conditions.

As discussed in the AEB and PAEB sections, manufacturers commented that they are strongly motivated to design robust systems that do not falsely activate because they have a vested interest in maximizing consumer satisfaction. FCA responded that manufacturers will discover excessive false-positive activations through customer complaints and quality metrics. Likewise, GM noted that, due to the myriad of situations that may trigger a nuisance activation, the automaker would find these customer quality metrics and field data reports to be more useful. Rivian and BMW shared that manufacturers often already conduct in-house false positive testing to ensure customer acceptance, and Toyota stated that manufacturers must take the consumer's satisfaction into account when balancing true positive cases with true negative and false positive cases. Honda and Auto Innovators noted that BSW systems have high consumer satisfaction without the need for a false positive test, and both groups stated they expect that BSI systems will also be accepted similarly.

BMW indicated that because of the work already completed on eliminating false positives by manufacturers, there would be little benefit to adding a false positive scenario to NCAP's testing regimen. The automaker further stated that performing a small number of tests to mitigate false activations would not adequately address the variety of driving conditions that a driver may experience and would not be commensurate with the amount of test effort needed. Bosch noted that specialized infrastructure and equipment may be needed to conduct false positive test scenario runs, adding unnecessary test burden and complexity.

Tesla and Auto Innovators mentioned that the reduction of false positives may also come at the cost of increased false negatives, and HATCI suggested that false positive testing could lead to unintended consequences that may impact future technologies. HATCI recommended that NHTSA focus on test scenarios that represent safety needs from the field, particularly ones that address fatal and injurious crashes. Tesla commented that the greatest safety benefits will be realized when false negatives are minimized, adding that vehicle manufacturers may add other countermeasures to further mitigate false positives.

In relation to the false positive test procedure itself, DRI proposed that false positive scenarios do not require the full set of test runs specified for baseline tests and stated that no more than three would be necessary. Additionally, Vayyar noted the importance of including typical surroundings and static objects like fences, parked cars, trees, etc. ASC echoed this sentiment, commenting that NHTSA should consider what objects or scenarios may trigger false activations when developing and selecting test procedures for NCAP. As an example, ASC stated that BSI systems may falsely activate in response to oncoming traffic in the adjacent lane or stationary objects.

Response to Comments and Agency Decisions

The Agency is retaining the SV Lane Change with Constant Headway, False Positive Assessment test scenario currently included in its BSI test procedure. As mentioned, the objective of this test scenario is to assess whether the BSI system detects and responds to a non-threatening POV during a single lane change. The Agency's decision is consistent with the decision made by the Agency for AEB and aligns with the comments received by many, though not all, respondents.

In response to the Agency's March 2022 RFC notice, vehicle manufacturers reiterated similar comments to those submitted in response to the Agency's false positive AEB tests. Most notably, they maintained that false positive tests in NCAP should be unnecessary because automakers have an inherent interest in designing robust systems and limiting false activations to maintain high customer satisfaction. Several manufacturers asserted that excessive false activations would be realized through quality metrics and/or customer complaints or through internal testing. However, if a manufacturer's efforts were sufficient to eliminate false positive activations, such incidents would not be observed by manufacturers in field data reports. Further, while BMW contended there would be little benefit to adding a false positive scenario to the matrix because of manufacturer efforts to date to eliminate false positive activations for blind spot technologies, NHTSA questions this rationale. Only 38 percent of model year 2024 vehicles are currently equipped with BSI technology. As such, acceptable false positive rates for yet-to-be-designed BSI systems for the majority of the vehicle fleet cannot be intrinsically assumed. NHTSA also rejects Toyota's assertion that incorporating a false positive test for BSI would encourage manufacturers to design systems solely to pass the Agency's tests, rather than to perform well during real-world driving, as acting in such a manner would seemingly conflict with automakers' assertions of performing due diligence and assuring customer satisfaction. Further, the test conditions for the SV Lane Change with Constant Headway, False Positive Assessment test are not obscure. As such, NHTSA does not foresee that a vehicle will achieve good BSI false positive assessment performance as a direct result of compromised operation in other real-world driving situations. Based on these considerations, adopting a false positive test for NCAP's BSI test matrix is appropriate and can be incorporated without an associated increase in false negatives or other unintended consequences, as expressed by some commenters.

The Agency also agrees with those commenters who supported the inclusion of a false positive BSI test and suggested that NHTSA should discourage false positive activations, encourage system use, and ensure consumer confidence in blind spot technology. Any false positive activation may cause drivers to respond with irresponsible driving behavior, as CAS and Vayyar suggested, or cause general customer dissatisfaction, potentially leading to deactivation of the technology. Advocates' assertion that maintaining a high level of customer satisfaction is especially important for active technologies since a system's intervention cannot simply be ignored by the driver is valid. Though Honda and Auto Innovators suggested that, since BSW systems currently have a high rate of customer satisfaction without an associated false positive test, so too should BSI systems, the Agency does not agree with this deduction. Rather, adopting a false positive test for NCAP's BSI test matrix will help ensure sensor robustness and thereby maintain or improve overall consumer sentiment pertaining to blind spot technology.

The Agency maintains this position while also acknowledging that the proposed false positive test is neither comprehensive enough nor adequate to eliminate susceptibility to all false activations, as BMW and GM asserted. NHTSA acknowledges that a myriad of situations may trigger a false positive system response during real-world driving. It is also true, as Toyota and Auto Innovators contended, that one test may not sufficiently gauge overall system robustness. However, NHTSA reasons that its SV Lane Change with Constant Headway, False Positive Assessment test serves to provide a baseline for BSI system functionality and establish a minimum expected performance level. If the test provides even limited coverage of real-world lane change/merge conditions, it will afford additional safety, and is thus advantageous to include for NCAP's BSI evaluations.

Several commenters suggested that false positive tests are inherently difficult to conduct (Auto Innovators and Toyota) or require specialized infrastructure and equipment (Bosch). However, this is not the case for the Agency's SV Lane Change with Constant Headway, False Positive Assessment test. This test, which requires that the SV perform a single lane change into an adjacent lane while the POV is driven straight, is relatively easy to conduct and has been performed successfully as part of NHTSA's research test program. It imposes no additional complexity or test burden compared to the other BSI tests included in the Agency's test protocol, other than the additional three baseline runs necessary for each test condition that must be conducted to assess BSI system performance. NHTSA recognizes that DRI suggested it was necessary to perform only three baseline runs for the false positive test scenario (*i.e.,* three baseline runs for each test condition), and the Agency agrees, since the Agency's research testing has shown three baseline runs to be sufficient and this should keep test burden to a minimum.

At this time, NHTSA will not require placement of additional static objects within the test environment for its BSI assessments, as Vayyar and ASC requested. As previously mentioned, the Agency's false positive BSI test is intended to serve to judge a level of minimum acceptable performance. It is not expected to address the numerous potential lane change/merge driving situations that may invoke a false positive intervention. Additionally, as BSI will be a newly adopted technology for NCAP, it is currently more important to encourage technology adoption across a larger segment of the vehicle fleet rather than the adoption of overly burdensome requirements. The Agency has also not conducted research to assess the impact of such objects on system performance, and it would therefore be premature to incorporate these items in test scenarios adopted for this NCAP upgrade.

Although static objects and oncoming vehicles will not be part of the Agency's initial BSI assessments, NHTSA expects that vehicle manufacturers should design BSI systems to address the potential for false activations in all possible real-world situations so that vehicles do not pose an unreasonable risk to safety. Given the comments received, this expectation aligns with steps already being taken by automakers to ensure customer satisfaction. Similar to the plan discussed for AEB, NHTSA will continue to monitor customer complaints to look for reports of frequent false activations for BSI systems as part of its defects identification and investigation process. The Agency also has the authority to investigate whether vehicles experiencing excessive false positive activations have a safety-related defect since they may pose an unreasonable risk to safety. NHTSA will continue to handle such cases appropriately as they arise. The Agency may also consider adding other false positive tests to NCAP in the future to capture additional driving situations if real-world data suggests a safety need exists.

8. Use of the ABD GVT Revision G for BSI Testing

A real vehicle is currently utilized in the Agency's BSW test procedure. However, in the March 2022 RFC, NHTSA detailed its intent to use the [ABD] GVT Revision G in its BSI test procedure as the vehicle test device. As previously discussed in the AEB section, the ABD GVT Revision G vehicle test device includes minor changes to its shape and radar characteristics to more closely approximate an actual vehicle. Its use in NCAP's BSI test would further promote global harmonization since the GVT is used in Euro NCAP's *Lane Support Systems* testing protocol.[334] NHTSA used the ABD GVT Revision G in its pilot testing series.

Summary of Comments

Most commenters remarking on this topic agreed the [ABD] GVT Revision G is the most appropriate strikeable vehicle test device for use in BSI testing. MEMA, FCA, Bosch, Honda, Auto Innovators, Toyota, ASC, ZF Group, Rivian, BMW, HATCI, Tesla, Intel, and GM were all in favor. The use of a standardized vehicle test device was a motivating factor for nearly all commenters who indicated approval (Auto Innovators, Toyota, ASC, ZF Group, BMW, HATCI, Tesla, and Intel). Auto Innovators also commented that the use of the [ABD] GVT Revision G for BSI testing would reduce test burden for manufacturers and laboratories since the same vehicle test device could be used for CIB and DBS. Bosch noted the [ABD] GVT Revision G's improved side strength and radar characteristics.

However, GM preferred the ''most representative test target that can safely be used in all intended test scenarios,'' meaning that if there is low risk of POV-to-SV contact, a real vehicle would be more desirable. For more aggressive BSI scenarios, GM agreed that the use of the [ABD] GVT Revision G is appropriate. Advocates remarked that NHTSA should justify any aspect of the test procedures, including the strikeable vehicle test device used, through presentation of testing and data analyses. Bosch also requested that NHTSA refer to a standard[335] rather than a specific product in its test procedures to give more flexibility to those implementing tests. Should there be any changes to the ABD GVT Revision G, HATCI requested that the Agency provide a chance to review the changes with sufficient lead time to understand the impact that such changes may have on its product design.

With respect to logistical concerns, TRC questioned whether NHTSA would find it acceptable to retrofit an [ABD] GVT Revision F soft car (or other) with a kit to bring it in line with Revision G specifications. It also noted that minor impacts with the vehicle test device may interfere with vehicle kinematics at the higher test speeds specified in the proposed procedure. For this reason, the laboratory asked whether the Agency would require contact to determine performance or if a tight tolerance for no contact may be used instead, citing a desire to reduce test burden.

Response to Comments and Agency Decisions

Based on the comments received, NHTSA has decided to use the ABD Revision G GVT for NCAP's BSI tests at this time. Adopting this test device for NCAP's BSI tests should minimize burden for manufacturers since the same test device will be prescribed in the Agency's AEB test protocol and is approved for use in Euro NCAP's LSS

[334] European New Car Assessment Programme (Euro NCAP) (December 2023), *Test Protocol—Lane Support Systems, Version 4.3.* See section 5.

[335] ISO 19206–3:2021.

and AEB test protocol evaluations.[336] In addition, the ABD GVT Revision G was found to be robust and durable in the Agency's most recent BSI research tests. Further, ABD has indicated this test device complies with ISO 19206–3:2021, ''Road vehicles—Test devices for target vehicles, vulnerable road users and other objects, for assessment of active safety functions—Part 3: Requirements for passenger vehicle 3D targets'' [337] with respect to the specifications outlined for radar cross section, reflectivity, color, and physical dimensions. Therefore, the Agency considers it an acceptable surrogate of a real vehicle and appropriate for use in NCAP's BSI assessments.

Specifying a standardized vehicle test device is appropriate, as doing so should promote fairness and ensure repeatability and reproducibility of test results. That being said, the Agency also recognizes, as Bosch mentioned, that stipulating a standard the BSI vehicle test device must comply with instead of designating a specific device for use will afford more flexibility to those conducting BSI tests. While there are benefits to such an approach, NHTSA has not conducted thorough evaluations of alternative test devices that also meet the ISO specifications, such as the 4a GVT, to ensure they invoke equivalent vehicle/system performance as the ABD GVT Revision G in the Agency's BSI tests. Therefore, at this time, the Agency is specifying use of the ABD GVT Revision G in NCAP's BSI tests to mitigate variability between the Agency's official test results and those submitted by the vehicle manufacturer.

The Agency notes that while it allows use of a real vehicle during its BSW testing, this is not an appropriate approach for its BSI testing. This is because for NHTSA's BSI tests (with the exception of the false positive test scenario), the SV initiates a manual lane change into the POV's travel lane. Because of this lane change maneuver, contact between the SV and POV is possible. On the other hand, SV movement in NHTSA's BSW tests is confined to a pass-by maneuver, where both the SV and POV maintain their position within their respective lanes, or a converge/diverge maneuver, where the POV performs a lane change into a lane that is adjacent to the SV but not in the same lane as the SV. Consequently, the ABD GVT Revision G, not a real vehicle, is appropriate for NCAP's BSI testing so tests can be conducted safely. While the Agency will permit use of a real vehicle in NCAP's BSW tests, it is also amending the test procedure to allow use of the ABD GVT Revision G in those test scenarios. Further, since the BSI false positive test should not result in contact, the Agency's test procedure will permit use of a real vehicle for that test scenario.

Along these lines, NHTSA will not alter the no contact evaluation criterion currently included in the Agency's BSI test procedure to permit a tolerance, as TRC requested. Contact was observed during numerous trials conducted as part of the Agency's BSI research testing and vehicle kinematics post-contact did not generate concern for the safety of laboratory personnel or create additional test burden.

Although NHTSA will use the ABD Revision G GVT in its official BSI testing and will not accept manufacturer test data for BSI assessments performed utilizing alternative test devices at this time, manufacturers may choose to utilize ABD GVT Revision F, as TRC requested, when performing tests for NCAP data submission, if it is retrofitted with a kit to ensure it meets the specifications for Revision G. Such adaptations are necessary because ABD GVT Revision G includes changes to the front and sides when compared with Revision F, specifically to permit improved side strength and radar characteristics. Any revision of the ABD GVT utilized for BSI testing, whether Revision G or Revision F that has been retrofitted to be equivalent to Revision G, must also meet all specifications and requirements outlined herein as well as those prescribed in NHTSA's BSI test procedure.

With regards to HATCI's concerns pertaining to version control of the vehicle test device, the Agency will be as transparent as possible about any potential changes to test equipment used for its BSI performance evaluations in the future.

Vehicle Test Device Specifications

Even though it is not necessary to prescribe all specifications for the ABD GVT Revision G for NCAP testing, since compliance with the ISO standard should be inherent, the Agency is nonetheless referencing ISO 19206–3:2021 in NCAP's BSI test procedures, as it did for NCAP's AEB tests. This should ensure any device utilized for Agency testing complies with the standard's specifications.

9. Number of Trials and Pass Rate

As with the other ADAS technologies proposed, the Agency's proposed BSW and BSI test procedures included multiple trial runs for each given test scenario. The proposed BSW test procedure required seven repeated trials for each test condition (*i.e.,* left and right POV approach direction) assessed for a scenario (14 tests overall for Straight Lane Converge and Diverge and 56 tests overall for Straight Lane Pass-by). The number of proposed trials for the BSI procedure depended upon the test scenario to be performed. Seven repeated trials were specified for the SV Lane Change with Constant Headway test and the SV Lane Change with Closing Headway test, while three repeated trials were prescribed for the SV Lane Change with Constant Headway, False Positive Assessment Evaluation test. NHTSA requested comments on the appropriate number of trials required for each adopted test condition and the appropriate pass rate for BSW and BSI tests. The Agency proposed that a vehicle would have to pass five out of seven trials for a given BSW test condition to receive credit for the technology; however, no pass rate was proposed for BSI systems.

Summary of Comments

Number of Trials

Several commenters provided input suggesting the number of trials for BSW could be reduced from what NHTSA proposed. TRC, GM, IDIADA, Rivian, Auto Innovators, Tesla, and Bosch opined that fewer than seven trials are needed. Those in favor of trial run reduction mentioned there is consistency in vehicle alert times (TRC) and limited variance in test results. TRC, GM, and Rivian were in favor of reducing the number of trial runs to five, while Bosch and Tesla recommended reducing the number to three trials. Tesla stated that three trials are needed for BSW because it is a warning system only and does not intervene, with the driver maintaining control of the vehicle. IDIADA recommended reducing to just one trial run, citing relevant experience in LKA and AEB testing. However, it also stated that the BSW pass-by test is simple and subsequent trials can be performed easily if desired. Toyota and Auto Innovators suggested a reduction to either three or five trials to alleviate test burden. Like others, Intel suggested that NHTSA seek to reduce unnecessary test burden, but the company did not offer a specific number of trial runs that should be included.

TRC made the recommendation to perform five trial runs for both BSW and BSI. The laboratory asserted that the battery life of the GVT robotic platform

[336] *https://www.euroncap.com/en/for-engineers/supporting-information/technical-bulletins/.* See Appendices I & II.

[337] *https://www.iso.org/standard/70133.html.* May 2021.

can become problematic, and thus, a decrease in the number of test runs could preserve the platform's battery and eliminate some invalid runs. Rivian also recommended that NHTSA reduce the procedural requirement for BSI to five trial runs. On the other hand, Tesla recommended running seven BSI trials per test condition. While the automaker expressed support for reducing the number of BSW trial runs, it did not support a reduction for BSI tests because the system controls the vehicle on the driver's behalf. Tesla reasoned that NHTSA should more rigorously evaluate any vehicle interventions not initiated by the driver.

Other commenters stated that seven trial runs are appropriate for BSW. Honda, FCA, ASC, BMW, and ZF Group supported NHTSA's proposal for seven trials. The main reason cited for keeping the trial run count the same was maintaining consistency with existing test procedures. It should be noted that, while GM and Auto Innovators were in favor of reducing the number of trial runs per condition, both groups were also not opposed to maintaining seven trial runs. GM mentioned maintaining consistency amongst different test types and asked the Agency to consider that additional trial runs in the same test scenario are not as labor-intensive as changing the test setup to a different test scenario. GM therefore requested NHTSA optimize the number of test scenarios rather than focus on the number of test runs.

Advocates and CAS opined there must be additional evidence provided to determine the appropriate number of test runs. Advocates stated that NHTSA should provide evidence that the number of trials selected will ensure that vehicles identified with the technology will operate as intended for the life of the vehicle. Similar to its requests for the other technologies NHTSA proposed for adoption in NCAP, CAS requested that the Agency use a statistical analysis to determine an appropriate number of trials to ensure system robustness.

Pass Rate

Many commenters suggesting that seven BSW trials should be conducted held the view that five of seven tests should be required to pass to gain BSW system credit. Honda, GM, FCA, ASC, BMW, and ZF Group expressed that requiring five of seven tests to pass is reasonable, offers credit to systems which will effectively mitigate real-world crashes, and maintains consistency with existing ADAS test procedures. Although Auto Innovators expressed a preference for fewer trial runs per condition, should NHTSA continue with seven runs, the group recommended the Agency require five of seven runs to pass. Auto Innovators opined that if the first five runs pass, then the vehicle should be considered as passing and testing should be discontinued to reduce unnecessary test runs.

Commenters recommending five trials often suggested that three of five should pass (Toyota, GM, and Auto Innovators). For those recommending three trials, most often commenters requested that two of the three trial runs pass. Toyota noted that one failed trial should be permitted to prevent a vehicle from being misclassified because of a one-off occurrence. The automaker stated that this follows other crash avoidance NCAP test methodology. Some commenters stated NHTSA should not permit any failed runs. However, IDIADA stated one test per condition should be sufficient, and vehicles should be expected to pass since test data does not show wide variation.

Rivian and Tesla commented that pass rate should depend on the nature of the system evaluated, with both automakers stating that systems that deliver information (*i.e.,* BSW) should be expected to pass 100 percent of the tests conducted. Both also asserted that systems which intervene to control the vehicle movement (*i.e.,* BSI) should have a pass rate based on the nature of technology. Rivian stated that NHTSA should ''take into account external and internal variables'' and determine an appropriate pass rate based on this fact. Rivian stated it did not approve of binary pass/fail criteria for BSI but did not provide a suggested pass rate. Tesla recommended that five out of seven BSI trials per condition pass.

Like the feedback received on the number of trials mentioned in the previous section, Advocates and CAS suggested that pass rates should be based on additional information and evidence.

Response to Comments and Agency Decisions

Number of Trials for BSW

The Agency has determined that it will conduct one trial per test condition to ensure BSW system performance affords the consistency that consumers expect and safety demands. This finalized testing methodology is akin to that of AEB and PAEB testing.

NHTSA does not agree with Tesla's assertion that warning systems do not require the same level of rigor when they are assessed for NCAP. To maintain the credibility of the consumer information provided to the public, all ADAS technologies, whether warning-based or active safety features, should be proven reliable in the test conditions assessed before they are given credit for passing NCAP's testing. NHTSA maintains, as it has done elsewhere in this notice, that the best way to ensure system reliability is not to perform repeated test trials. Repeated trials inherently permit a certain threshold of failures, and failures of any number are unacceptable under the limited, ideal test conditions to be assessed. As such, the Agency will perform a single trial for each test condition to assess BSW system performance. This decision aligns with assertions from those commenters who suggested that fewer BSW trials could be conducted than were proposed initially and maintains congruity amongst NCAP's ADAS testing protocols, as multiple commenters requested.

For the Straight Lane Converge and Diverge test scenario, NHTSA will perform one trial for each test condition (*i.e.,* POV approach directions of right and left, each with turn signals enabled and disabled), resulting in four Straight Lane Converge and Diverge test trials total. For its BSW Straight Lane Pass-by testing, NHTSA will conduct one trial per each speed differential, POV approach side, and turn signal status combination for a total of 16 Straight Lane Pass-by trials per vehicle model assessed. Despite GM's concern that changing the test setup is more difficult than simply running multiple trials for one scenario, this testing methodology should balance test burden with the Agency's need to thoroughly evaluate BSW system performance. It should also limit damage to the test vehicle, vehicle test device, and equipment, and best ensure the safety of laboratory personnel.

Considering all BSW testing adopted in this notice, each vehicle model assessed for BSW system performance will undergo 20 trials total, a significant reduction from the 70 initially proposed by NHTSA. This reduction in the number of trials should address Toyota's concern regarding timely release of information to consumers.

Number of Trials for BSI

In the interest of test consistency, reduced testing burden, and ensuring system reliability, NHTSA will also apply the same one-trial test methodology to all three BSI assessment scenarios for NCAP: (1) SV Lane Change with Constant Headway, (2) SV Lane Change with Closing Headway, and (3) SV Lane Change with Constant Headway, False Positive Assessment.

Although Tesla suggested that NHTSA conduct seven trials for each BSI scenario because the vehicle intervenes on the driver's behalf, test burden and logistical considerations are also factors that must be considered. With one trial required for each assessment condition (*i.e.,* POV approach directions of right and left, each with turn signals enabled and disabled), a vehicle model will undergo 12 trials for BSI testing overall. Given TRC's concern that the GVT's robotic platform has a limited battery life, which may serve to reduce testing efficiency and delay the release of information to the public, NHTSA does not wish to impart additional burden and delay for what it concludes to be limited benefit. In addition, since other ADAS technologies will no longer undergo seven trials, NHTSA reasons that a reduction in trials for BSI testing will best maintain consistency with other test procedures, a request expressed by several commenters. Proceeding with one trial per test condition will also best ensure performance consistency and safety benefits.

Pass Rate

The pass rate for all adopted BSW and BSI testing (*i.e.,* 20 required tests to obtain credit for BSW and 12 required tests to obtain credit for BSI) will be 100 percent. No test failures will be permitted during any of the BSW or BSI trials conducted for NCAP.

NHTSA acknowledges that some commenters suggested BSW and BSI test pass rates should be treated differently because one is a warning technology only and the other is active. However, NHTSA disagrees with this assessment. As mentioned previously, the Agency reasons its assessment of performance should be handled with the same stringency whether a technology is an active technology or simply meant to provide information to the consumer.

Tests that NHTSA is adopting for BSW and BSI testing are shown in Tables 23 and 24.

TABLE 23—BLIND SPOT WARNING (BSW) ADOPTED TEST CONDITIONS

Test scenario	SV speed (kph (mph))	POV speed (kph (mph))	POV direction of approach	Turn signal
Straight Lane Converge and Diverge	72.4 (45)	72.4 (45)	Right	Enabled.
				Disabled.
			Left	Enabled.
				Disabled.
Straight Lane Pass-by	72.4 (45)	80.5 (50)	Right	Enabled.
				Disabled.
			Left	Enabled.
				Disabled.
		88.5 (55)	Right	Enabled.
				Disabled.
			Left	Enabled.
				Disabled.
		96.6 (60)	Right	Enabled.
				Disabled.
			Left	Enabled.
				Disabled.
		104.6 (65)	Right	Enabled.
				Disabled.
			Left	Enabled.
				Disabled.

TABLE 24—BLIND SPOT INTERVENTION (BSI) ADOPTED TEST CONDITIONS

Test scenario	SV speed (kph (mph))	POV speed (kph (mph))	Lane change direction	Turn signal
SV Lane Change with Constant Headway	72.4 (45)	72.4 (45)	Left	Enabled.
				Disabled.
			Right	Enabled.
				Disabled.
SV Lane Change with Closing Headway	72.4 (45)	80.5 (50)	Left	Enabled.
				Disabled.
			Right	Enabled.
				Disabled.
SV Lane Change with Constant Headway, False Positive Assessment	72.4 (45)	72.4 (45)	Left	Enabled.
				Disabled.
			Right	Enabled.
				Disabled.

10. Test Procedure Refinements

Several commenters provided suggestions for specific test procedure refinements in response to the March 2022 RFC notice. The Agency provides responses to these comments in the following section.

NHTSA also published and requested comment on draft BSW and BSI test procedures in November 2019. The Agency received feedback from the public at that time, some of which was referenced again in comments to the March 2022 RFC notice. Updated BSW and BSI test procedures reflecting the Agency's response to the comments received will be published separately in conjunction with this notice in the related docket.

Summary of Comments

Harmonization was a common underlying theme in the comments received to the Agency's March 2022 RFC notice. Aptiv encouraged NHTSA to align its blind spot test procedures with the BSW and BSI content within Euro NCAP's Lane Support System protocol to the greatest extent possible, whereas Bosch and Intel supported harmonization of NHTSA's BSW procedure with ISO 17387:2008, Intelligent transport systems—Lane change decision aid systems (LCDAS)—Performance requirements and test procedures. Bosch asserted that adopting the ISO standard would lessen testing complexity and burden on manufacturers, while still offering a system to evaluate system performance and robustness. For BSI assessments, Auto Innovators and Bosch urged the Agency to harmonize its test procedures with ISO 19638:2018. Both Auto Innovators and GM, in addition to Aptiv, noted that the lane widths specified (3.7 to 4.3 m, or 12 to 14 ft.) do not align with U.S. lane width standards and suggested that the Agency consider aligning the lane width specifications to Euro NCAP's: 3.5 to 3.7 m (11.5 to 12 ft.).

Other comments focused on specific procedural changes, with Aptiv raising concerns regarding the onset and termination headways specified in the BSW test procedure. The company recommended that the alert engagement requirement be defined as a minimum defined distance and be extinguished when the POV exits the forward boundary of the defined blind zone. Aptiv explained that this should reduce consumer confusion since the driver should be able to visually see the vehicle outside of the blind zone by this point, but the BSW could still be illuminated.

NHTSA also received comments on test applicability. Specifically, several commenters suggested that the Agency should only test blind spot systems that cannot be disabled by the driver.

Response to Comments and Agency Decisions

The original lane width specifications for BSW and BSI testing of 3.7 to 4.3 m (12.0 to 14.0 ft.) were selected to overlap with American Association of State Highway and Transportation Officials (AASHTO) recommendations,[338] to promote consistency with other NHTSA ADAS test procedures, and to allow flexibility to contract laboratories which could perform blind spot system testing. However, NHTSA's intent is to consider harmonization with other global testing programs wherever possible. Because of this strong interest, lane width specifications for BSW and BSI testing have been revised to be 3.5 to 3.7 m (11.5 to 12 ft.), consistent with Euro NCAP's lane width requirements.

NHTSA agrees with Bosch that alignment with elements of ISO standards (in addition to elements of other testing programs such as those in Euro NCAP) should lessen complexity and burden on vehicle manufacturers. Regarding harmonization with ISO 17387:2008 for BSW testing, several revisions have been made to better align the Agency's testing protocol and this ISO standard. Changes to the definition of the two-dimensional polygon representing the SV and POV, the range of POV lateral velocities used during the Straight Lane Converge and Diverge test, and the maximum SV blind zone width specification were made in response to the November 2019 publication of the draft BSW procedures. As noted earlier in this section, specific changes made in response to that earlier publication are reflected in updated BSW test procedures published in the docket for this notice.

NHTSA also concurs with commenters suggesting edits to the onset and termination headways in BSW testing. As such, the test procedure has been revised to clarify that the onset of the BSW is unrestricted and to state that the warning must be presented by a time no later than 300 ms after any part of the POV enters the SV blind zone, defined earlier. The intent of the onset requirement was to ensure that the BSW is presented by a certain time, not to restrict it from appearing earlier. Additionally, NHTSA has amended the duration of the required alert; the alert must remain on while any part of the POV resides within the SV blind zone during converge lane changes. For the Converge and Diverge test scenario, the alert must not be active once the lateral distance between the SV and the POV is greater than 6 m (19.7 ft.). For the Pass-by scenario, the alert must not be active once the longitudinal distance between the frontmost part of the SV and the rearmost part of the POV exceeds the BSW termination distances provided in the test procedure. These range in length from 2.2 m (7.3 ft.) for the 80.5 kph (50 mph) condition to 8.9 m (29.3 ft.) for the 104.6 kph (65 mph) condition.

Finally, to provide as much information as possible to consumers regarding BSW and BSI systems in new vehicles, at this time, NHTSA will not consider whether the system may be disabled when it provides assessment results to the public. Thus, all BSW and BSI systems will be eligible for NCAP credit. However, to receive credit for BSW and BSI systems during program testing, NHTSA will require the BSW or BSI systems to appear 'Default ON' during each ignition/key cycle. The Agency does not expect blind spot technology's already high consumer satisfaction to decrease because of this requirement. NHTSA also expects drivers will adjust their system's settings to meet their personal preferences instead of disengaging the system altogether.

11. Future Considerations

Use of Additional Test Devices

As mentioned in the March 2022 RFC, in response to prior RFC notices, many commenters previously recommended that the Agency expand blind spot system testing requirements to include motorcycle and bicycle detection. In response to the Agency's latest RFC, Somerville Bicycle Safety also voiced support for NHTSA using bicycle test devices in its BSW testing, stating that Euro NCAP is already performing this testing. Others also agreed that bicyclists should be accounted for in BSW and BSI testing. MIC/MSF, Lidar Coalition, and AMA requested that a motorcyclist test device be added so that manufacturers design their vehicles to recognize motorcyclist signatures. Many commenters also noted that motorcyclists and bicyclists are inherently more vulnerable to serious and fatal injuries as compared with occupants of motor vehicles.

Incorporate Other Scenarios or Technology

Many commenters suggested that NHTSA ensure all ADAS technologies assessed, including BSW and BSI, perform to a high standard in order to receive credit or the highest rating possible. This included good performance in darkness, in inclement weather, and while turning. The Agency has also received similar comments in response to prior RFC notices.

Many commenters also recommended that NHTSA address other potential blind zones drivers may experience. In addition to the lateral blind zones assessed for motor vehicle presence in the Agency's BSW/BSI test procedures, commenters asserted that NHTSA should address blind zones to the front and rear of the vehicle, which may also exist, particularly in large vehicles, as they may create a potentially hazardous situation for VRUs. Many commenters

[338] *See https://safety.fhwa.dot.gov/geometric/pubs/mitigationstrategies/chapter3/3_lanewidth.cfm.*

noted that assessments for these blind spots were not proposed and requested that the Agency take them into consideration when developing BSW and/or BSI procedures.

Response to Comments and Agency Decisions

Use of Additional Test Devices

As mentioned in its 2022 RFC notice, NHTSA agrees that BSW and BSI systems capable of detecting motorcycles and bicyclists would improve safety. A review of the 2011–2015 FARS and GES data sets [339] showed there were 106 fatal crashes and nearly 5,100 police-reported crashes annually, on average, for same-direction lane change crashes involving a vehicle and motorcycle. In comparison, there were 542 fatalities and 503,070 police-reported crashes annually, on average, for lane change crashes involving motor vehicles. These data show that although more motor vehicle occupants than motorcyclists die in lane changing crashes, the fatality rate for motorcyclists is greater than that for vehicle occupants, as several commenters asserted. While the Agency is not aware of specific crash data for pedalcyclist lane change crashes involving light vehicles, NHTSA recognizes that cyclist fatalities are on the rise, as there were 938 pedalcyclist fatalities in 2020, representing a 9 percent increase over 2019. Pedalcyclist fatalities accounted for 2.4 percent of all traffic fatalities and 38,886 pedalcyclist injuries that year.[340]

At this time, the Agency has decided to prioritize testing of BSW and BSI systems on motor vehicles (excluding motorcycles) for NCAP. NHTSA maintains that a focus on vehicle detection is a reasonable initial step forward and that performing blind spot system testing on light vehicles, particularly at higher POV closing speeds, should encourage development of robust sensing systems, which may improve the detection of VRUs such as motorcyclists and bicyclists. The Agency has conducted preliminary research designed to evaluate vehicle response to VRUs.

As part of this research effort, conducted under contract with the Transportation Research Center Inc. (TRC Inc.), the Agency utilized its current BSI test procedures but varied the POV test device (*e.g.,* GVT and motorcycle) and the SV/POV speed (as applicable, depending on test scenario).[341] NHTSA found that, overall, the vehicles tested displayed performance differences between the surrogate passenger vehicle (*i.e.,* GVT) and the surrogate motorcycle test device in the lane change scenarios assessed. For instance, one vehicle was able to detect the GVT in a blind spot for all test speeds for the SV Lane Change, Constant Headway tests but did not issue a detection alert when the motorcycle test device was within the blind spot. A similar observation was made for a vehicle in the SV Lane Change, Closing Headway BSI scenario. The vehicle failed to issue a blind spot warning at 40 kph (24.9 mph) when the motorcycle test device was within its blind spot, but it appropriately issued an alert for the GVT at this test speed. From this, it can be concluded that incorporating a motorcycle test device into the Agency's current blind spot test procedures would help to address these specific collision types.

NHTSA also plans additional research focused on characterizing the capabilities and limitations of available BSI systems, both on-road and closed track. As part of this work, the Agency plans to review crash datasets and develop additional test scenarios for motorcycles and/or bicyclists to align with the safety need. Further, as noted in the NCAP Roadmap section in this final decision notice, NHTSA plans to implement in NCAP BSW and BSI evaluation to mitigate crashes with motorcyclist and bicyclist crashes starting with model year 2031 vehicles.

Incorporate Other Scenarios or Technology

While NHTSA recognizes the need to assure crash avoidance systems perform well under all situations that a driver may encounter, it is not currently practical to evaluate each within the scope of NCAP. Therefore, the most frequent fatal and injurious conditions will be prioritized for evaluation. When BSW and BSI systems perform acceptably in these conditions (*i.e.,* clear, daylight, straight and flat road) and are present in the fleet in sufficient numbers, NHTSA will evaluate real-world conditions at that time to determine whether additional condition(s) should be subsequently addressed.

The Agency also acknowledges commenter concerns regarding driver visibility. Commenters noted that certain vehicles, including large vehicles such as pickup trucks and SUVs, may have additional blind zones to the front and rear of the vehicle. As mentioned in the NCAP Roadmap section of this notice, NHTSA is currently conducting research on driver visibility to mitigate VRU injuries and fatalities. The results of this research will inform the Agency on the most appropriate approach to reduce harm to these difficult-to-see VRUs.

VII. Updating Lane Keeping Technologies

NHTSA has decided to (1) retain its assessment for lane departure warning (LDW) and to (2) add an assessment for lane keeping assist (LKA) for this NCAP update. As mentioned in the Agency's March 2022 RFC, lane keeping technologies, including LDW, LKA, and LCA,[342] can address ten pre-crash scenarios, including roadway departure scenarios and those in which the SV passively crosses the centerline or center median and strikes a vehicle travelling in the opposite direction. These scenarios resulted in 1.13 million crashes (19 percent of all U.S. crashes), 14,844 fatalities (44 percent of all fatalities), and 479,939 MAIS 1–5 injuries (17 percent of all injuries recorded), annually on average between 2011 and 2015, showing there is a significant safety need.[343] [344]

A. Lane Keeping Technologies

1. Lane Departure Warning (LDW)

LDW is a NHTSA-recommended technology [345] currently included in NCAP to mitigate the aforementioned lane departure crashes in which a driver unintentionally allows a vehicle to drift out of its lane of travel. LDW systems often use camera-based sensors to detect

[339] Swanson, E., Azeredo, P., Yanagisawa, M., & Najm, W. (2018, September), Pre-Crash Scenario Characteristics of Motorcycle Crashes for Crash Avoidance Research (Report No. DOT HS 812 902), Washington, DC: National Highway Traffic Safety Administration. In Press.

[340] NHTSA Traffic Safety Facts, June 2022, *Bicyclists and Other Cyclists,* DOT HS 813 322.

[341] The report, *Assessment of Light Vehicle ADAS Crash Avoidance Technologies in Response to Two-Wheeled Vehicles as Principal Other Vehicles,* can be found in the docket for this notice.

[342] LDW alerts the driver when the car approaches or crosses lane markings, LKA gives steering support to assist the driver in preventing the vehicle from departing the lane, and LCA provides automatic steering to continually center the vehicle in its lane.

[343] Wang, J.-S. (2019, March), *Target crash population for crash avoidance technologies in passenger vehicles* (Report No. DOT HS 812 653), Washington, DC: National Highway Traffic Safety Administration.

[344] When only serious injuries (*i.e.,* MAIS 3–5 injuries) were considered, lane keeping crashes represented the highest number of non-fatal injuries (21,282 or 0.76 percent of all non-fatal injuries), followed by rear-end crashes (17,918 or 0.64 percent), forward pedestrian crashes (5,973 or 0.21 percent), blind spot crashes (3,476 or 0.12 percent), and backing crashes (454 or 0.02 percent).

[345] NHTSA-recommended technologies are driver assistance technologies for which the Agency has developed performance tests and metrics, and which meet the four prerequisites for inclusion.

lane markers, such as solid lines (including those marked for bike lanes), dashed lines, or raised pavement markers such as Botts' Dots [346] used to delineate the vehicle's travel lane.[347] When a LDW system detects that a vehicle is laterally approaching or crossing a lane marking, the system presents an alert to warn the driver of the unintentional shift so the driver can steer the vehicle back into its lane. LDW alerts may be visual, auditory, and/or haptic in nature. Visual alerts may show which side of the vehicle is departing the lane, and examples of haptic alerts include steering wheel or seat vibrations to alert the driver. If the driver's turn signal is activated, the LDW system interprets the lane change as an intentional act and thus does not alert the driver.

NHTSA proposed adoption of LDW systems (along with FCW systems) in its NCAP ADAS evaluations starting with 2011 model year vehicles because these systems were deemed to meet the Agency's four prerequisites for inclusion at the time.[348] While the Agency estimated that then-current LDW systems were only 6 to 11 percent effective in preventing lane departure crashes, NHTSA cited the large number of road departure and opposite direction crashes occurring on the nation's roadways as well as the resulting AIS 3+ injuries as reasons to include LDW in NCAP.

Since LDW's adoption in NCAP, more recent studies have provided varying statistics with respect to LDW effectiveness. In a 2017 study,[349] IIHS concluded that LDW systems were effective at reducing three types of passenger car crashes (single-vehicle, sideswipes, and head-on) by 11 percent, which is the same rate NHTSA originally estimated. Further, IIHS also concluded that LDW systems reduce injuries in those same types of crashes by 21 percent. UMTRI, however, found in its study of real-world effectiveness of crash avoidance technologies in GM vehicles that LDW systems showed only a 3 percent reduction (determined to be not statistically significant) for applicable crashes.[350] A second, more recent study [351] conducted by the Partnership for Analytics Research in Traffic Safety (PARTS) also showed more limited effectiveness for LDW systems. In the PARTS study, police-reported crash data (2016 to 2021) from 13 states was combined with vehicle equipment data from 47 million vehicles from eight [352] vehicle manufacturers, representing 93 vehicle models spanning from model years 2015 to 2020. The resulting study dataset of 2.4 million crash-involved vehicles did not find a significant reduction in single-vehicle road departure crashes for vehicles equipped with LDW alone.

Other studies have suggested reasons for lower LDW effectiveness rates, one of which is higher driver deactivation rates caused by dissatisfaction with system functionality. In a survey of Honda vehicles brought into Honda dealerships for service,[353] IIHS researchers found that out of 184 vehicles equipped with an LDW system, only a third of the vehicles had the system activated.

In a similar study,[354] 150 crash-involved Honda vehicles equipped with Event Data Recorders (EDRs) that captured data elements related to the function and alert status of several crash avoidance systems in the time leading up to the crash event were analyzed from NHTSA's 2017–2021 Crash Investigation Sampling System (CISS). Starting with the 2016 model year, Honda began to phase-in vehicles equipped with an EDR that captures the status and activation of crash avoidance technologies such as FCW/AEB and LDW/LKA. The EDR data were assessed to identify the use and activation statuses of these crash avoidance technologies at the time of the associated crash events. The results indicated that drivers of Honda vehicles equipped with crash avoidance systems were much more likely to have FCW/AEB systems ''On'' and LDW/LKA systems ''Off.'' Specifically, 99 percent of drivers for this study had FCW/AEB systems ''On'' in the time leading up to the crash and thus could be afforded the benefits of these systems. With respect to LDW/LKA systems, 49 percent of the drivers had these systems ''Off'' at the time of the crash, and therefore were not afforded the benefits of these systems. Differences were not identified for drivers that had the LDW/LKA system ''On'' compared to those that had it ''Off'' with respect to the driver's sex, age, and race/ethnicity.

Further, in its telematics-based study on LDW usage,[355] UMTRI found that, overall, drivers turned off LDW systems 50 percent of the time. However, in Consumer Reports' August 2019 survey of more than 57,000 CR subscribers, the organization found that 73 percent of vehicle owners reported they were satisfied with LDW technology.[356]

In its March 2022 RFC notice, the Agency proposed to continue to include LDW assessments in NCAP, as the system's adoption rate has not increased as significantly as that for FCW since the inclusion of both technologies in the program. When LDW was introduced in NCAP, its fitment rate was less than 0.2 percent.[357] For the 2018 model year, the fitment rate for LDW was 30 percent. In contrast, the fitment rate for FCW saw an approximate 40 percent increase over the same period. Since LDW technology is currently not being offered as standard equipment on all passenger vehicles, the Agency reasons that it remains important for NCAP to continue to recommend the technology to new vehicle purchasers and inform shoppers which vehicles have systems that meet NHTSA's performance criteria. Furthermore, in recent years, many vehicle manufacturers have made improvements to sensors utilized by LDW systems for the purposes of implementing SAE Driving Automation

[346] Botts' Dots are round, raised, non-reflective, pavement markers that mark travel lanes.

[347] Note that performance of LDW systems may be adversely affected by precipitation or poor roadway conditions due to construction, unmarked intersections, faded/worn/missing lane markings, markings covered with water, etc.

[348] 73 FR 40033 (July 11, 2008).

[349] Insurance Institute for Highway Safety (2017, August 23), *Lane departure warning, blind spot detection help drivers avoid trouble, https://www.iihs.org/news/detail/stay-within-the-lines-lane-departure-warning-blind-spot-detection-help-drivers-avoid-trouble.*

[350] Flannagan, C. and Leslie, A. (2020). *Crash Avoidance Technology Evaluation Using Real-World Crash Data* (No. DOT HS812 841). United States. Department of Transportation. National Highway Traffic Safety Administration.

[351] Aukema, A., Berman, K., Gaydos, T., Sienknecht, T., Chen, C.-L., Wiacek, C., Czapp, T., & St. Lawrence, S. (2023) Real-World Effectiveness of Model Year 2015–2020 Advanced Driver Assistance Systems. 27th International Technical Conference on the Enhanced Safety of Vehicles, Paper Number 23–0170.

[352] The eight participating industry partners that provided vehicle data for this study are American Honda Motor Co., Inc., General Motors LLC, Mazda North American Operations, Mitsubishi Motors R&D of America, Inc., Nissan North America, Inc., Stellantis (FCA US LLC), Subaru Corporation, and Toyota Motor North America, Inc.

[353] Insurance Institute for Highway Safety (2016, January 28), Most Honda owners turn off lane departure warning, *Status Report, Vol. 51, No. 1,* page 6.

[354] Wiacek, C., Firey, L., and Mynatt, M. (2023). EDR Reported Driver Usage of Crash Avoidance Systems for Honda Vehicles. Paper Number 23–0040. 27th International Technical Conference on the Enhanced Safety of Vehicles.

[355] Flannagan, C., LeBlanc, D., Bogard, S., Nobukawa, K., Narayanaswamy, P., Leslie, A., Kiefer, R., Marchione, M., Beck, C., and Lobes, K. (2016, February), *Large-scale field test of forward collision alert and lane departure warning systems* (Report No. DOT HS 812 247), Washington, DC: National Highway Traffic Safety Administration.

[356] Consumer Reports (2019, November), *Consumer Perceptions of ADAS, https://data.consumerreports.org/reports/consumer-perceptions-of-adas/.*

[357] Wang, J.-S. (2019, March), *Target crash population for crash avoidance technologies in passenger vehicles* (Report No. DOT HS 812 653), Washington, DC: National Highway Traffic Safety Administration.

Level 2 systems such that LDW system effectiveness may improve, and consumer dissatisfaction may wane. Some of today's systems can assess if the driver is actively steering by measuring steering rate or torque on the steering wheel, or by utilizing direct or indirect driver monitoring systems. Furthermore, the sensing capability exists to suppress unnecessary LDW alerts and LKA activations in situations that require driving over a lane marker without the use of the turn signal, such as when trying to pass a bicyclist or drive around a pothole. Finally, since the Agency is also adopting LKA as part of this upgrade to NCAP, continuing to assess LDW functionality in addition to LKA, similar to assessing FCW in addition to AEB, and BSW in addition to BSI, should provide the greatest safety gains and most effectively address the number of fatalities and injuries related to lane departure crashes.

NCAP's Current Lane Departure Warning Test Procedure

In its March 2022 RFC notice, NHTSA proposed to continue its assessment of LDW systems under NCAP using the current NCAP test procedure titled, ''Lane Departure Warning System Confirmation Test and Lane Keeping Support Performance Documentation,'' dated February 2013.[358] This protocol assesses the system's ability to issue an alert in response to a driving situation intended to represent an unintended lane departure and to quantify the test vehicle's position relative to the lane line at the time of the LDW alert.

In NCAP's LDW tests, a test vehicle is accelerated from rest to a test speed of 72.4 kph (45 mph) while travelling in a straight line, parallel to a single lane line, comprised of one of three marking types: continuous white lines, discontinuous (*i.e.,* dashed) yellow lines, or discontinuous raised pavement markers (*i.e.,* a combination of Botts' Dots and other retro reflective pavement markers). The test vehicle is driven such that the centerline of the vehicle is approximately 1.8 m (6 ft.) from the lane edge. This path must be maintained, and the test speed must be achieved, at least 61.0 m (200 ft.) prior to the start gate. Once the driver reaches the start gate, they manually input sufficient steering to achieve a lane departure with a target lateral velocity of 0.5 m/s (1.6 ft./s) with respect to the lane line. The driver of the vehicle does not activate the turn signal at any point during the test and does not apply any sudden inputs to the accelerator pedal, steering wheel, or brake pedal. The test vehicle is driven at a constant speed throughout the maneuver. The test ends when the vehicle crosses at least 0.5 m (1.7 ft.) over the edge of the lane line marking. The scenario is performed for two different departure directions, left and right, and for all three lane marking types, resulting in a total of six test conditions. Five repeated trials runs are performed per test condition.

LDW performance for each test trial is evaluated by examining the proximity of the vehicle with respect to the edge of a lane line at the time of the LDW alert. The LDW alert must not be issued when the lateral position of the vehicle, represented by a two-dimensional polygon,[359] is greater than 0.75 m (2.5 ft.) from the inboard edge of the lane line (*i.e.,* the line edge closest to the vehicle when the lane departure maneuver is initiated), and must be issued before the lane departure exceeds 0.3 m (1 ft.). To pass the test, the LDW system must satisfy the pass criteria for three of the first five valid individual trials for each combination of departure direction and lane line type (60 percent) and for 20 of the 30 trials overall (66 percent).

2. Lane Keeping Assist (LKA)

Much like FCW and BSW, LDW's limitation is that it is merely a warning-based system. These systems do not actively mitigate crashes on the driver's behalf. Rather, they require driver input for any benefit to be realized. LKA, like AEB and BSI, is an active safety system. As such, its corrective actions are designed to be initiated without driver action.[360]

LKA systems can help prevent an unintended lane departure where the driver is not using the turn signal, and not actively steering (*i.e.,* providing little to no steering wheel torque), to help prevent: ''sideswiping,'' where a vehicle strikes another vehicle in an adjacent lane that is travelling in the same direction; opposite direction crashes, where a vehicle crosses the centerline and strikes another vehicle travelling in the opposite direction in an adjacent lane; and road departure crashes, where a vehicle runs off the road, resulting in a rollover crash or an impact with a tree or other object. In addition, LKA systems may also help to prevent unintended lane departures into designated bicycle lanes.

LKA systems typically utilize the same sensor(s) used by LDW systems to monitor the vehicle's position within the lane and determine whether the vehicle is about to drift out of its lane of travel unintentionally. Because LKA systems help to guide a vehicle back into its lane without driver action, they further enhance safety beyond that achieved by LDW alone.

In its study of real-world effectiveness of ADAS technologies, UMTRI found that LKA (when combined with lane departure warning functionality) showed an estimated 30 percent reduction in applicable crashes, whereas, as mentioned previously, LDW systems alone showed a reduction of only 3 percent, which was determined to be non-significant.[361]

While the PARTS study[362] showed more limited effectiveness for LKA systems, it also highlighted the enhanced safety benefits offered by LKA compared to LDW systems. This study showed that single-vehicle road departure crashes were reduced by an estimated 8 percent (5 to 12 percent) for vehicles equipped with both LDW and LKA systems, while, as mentioned earlier, the study did not find significant results for vehicles equipped with LDW alone. Similar effectiveness was observed for LKA systems in another recent study.[363] For this study, production data for 11 model year 2015 through 2018 Toyota models were merged with police-reported crash files from eight U.S. states for crash years 2015 through 2019. The results showed LKA-equipped vehicles were 9 percent less likely to run off the road. However, vehicles equipped with LDW and LKA did not have a significant effect on risk of same-direction sideswipe or head-on crashes. As with LDW, the lower effectiveness rates for LKA systems stem

[358] National Highway Traffic Safety Administration. (2013, February). *Lane departure warning system confirmation test and lane keeping support performance documentation.* See *http://www.regulations.gov,* Docket No. NHTSA–2006–26555–0135.

[359] The two-dimensional polygon is defined by the vehicle's axles in the X-direction (fore-aft), the outer edge of the vehicle's tire in the Y-direction (lateral), and the ground in the Z-direction (vertical).

[360] LKA differs from another active lane keeping technology, lane centering assist (LCA). LKA assists the driver by providing short-duration steering and/or braking inputs when a lane departure is imminent or underway; LCA provides continuous assistance to the driver to keep their vehicle centered within the lane.

[361] Flannagan, C. and Leslie, A. (2020). *Crash Avoidance Technology Evaluation Using Real-World Crash Data* (No. DOT HS812 841). United States. Department of Transportation. National Highway Traffic Safety Administration.

[362] Aukema, A., Berman, K., Gaydos, T., Sienknecht, T., Chen, C.-L., Wiacek, C., Czapp, T., & St. Lawrence, S. (2023) Real-World Effectiveness of Model Year 2015–2020 Advanced Driver Assistance Systems. 27th International Technical Conference on the Enhanced Safety of Vehicles, Paper Number 23–0170.

[363] Spicer, R., Vahabaghaie, A., Murakhovsky, D., Bahouth, G. et al., (2021). ''Effectiveness of Advanced Driver Assistance Systems in Preventing System-Relevant Crashes,'' SAE Technical Paper 2021–01–0869. doi:10.4271/2021-01-0869.

from overall driver dissatisfaction with combined LDW/LKA system functionality. This was evidenced by the referenced studies for Honda vehicles, discussed previously, which found high rates of deactivation with LDW/LKA systems.[364] [365]

However, there is also evidence that consumers appreciate the inherent benefits LKA can provide. In an August 2019 survey, Consumer Reports found that 74 percent of vehicle owners reported they were satisfied with LKA technology.[366] Further, 84 percent of model year 2024 vehicles are equipped with LKA systems as standard equipment.

Based on these findings on system effectiveness and consumer acceptance, there is value in adopting LKA in NCAP to complement LDW systems and prevent or mitigate a greater number of lane departure crashes involving injuries and fatalities. By adopting objective test procedures to gauge LKA system performance for NCAP's assessments, the Agency will best ensure system robustness for future lane keeping systems having enhanced capabilities (*e.g.,* lane centering).

Proposed LKA Test Procedure

In its March 2022 RFC notice, the Agency proposed the adoption of certain test methods (*e.g.,* those for LKA) contained within the Euro NCAP Test Protocol—Lane Support Systems (LSS) [367] to assess technology design differences for LKA. Since the test speeds and road configurations specified in Euro NCAP's protocol are similar to those stipulated currently in the Agency's LDW test procedure, adopting Euro NCAP's test protocol would allow the Agency to sufficiently address the lane keeping crash typology currently covered for LDW while also harmonizing with the European organization.

Euro NCAP's current [368] LSS test procedure includes a series of LKA trials performed with iteratively increasing lateral velocities towards the desired lane line. Each LKA trial begins with the subject vehicle (SV) being driven at 72 kph (44.7 mph) down a straight lane delineated by a single solid white or dashed white line. Initially, the SV path is parallel to the lane line, with an offset from the lane line that depends on what lateral velocity is desired later in the maneuver. Then, after a short period of steady-state driving, the SV transitions to a path defined by a 1,200 m (3,937.0 ft.) radius curve. The lateral velocity of the SV's approach toward the lane line (from both the left and right directions) is increased from 0.2 to 0.6 m/s (0.7 to 2.0 ft./s) in 0.1 m/s (0.3 ft./s) increments or until acceptable LKA performance is no longer realized. Acceptable LKA performance occurs when the SV does not cross the inboard leading edge of the lane line by more than 0.3 m (1.0 ft.).

B. Linking Current and Proposed Lane Keeping Technology Test Scenarios to Real-World Crashes

NCAP's current LDW test conditions, as well as the future LDW/LKA test conditions described in this notice, represent pre-crash scenarios that correspond to a substantial portion of fatalities and injuries observed in real-world lane departure crashes. A review of Volpe's 2011 to 2015 data set showed that, when the posted speed limit was known, approximately 42 and 31 percent of fatalities in fatal road departure and opposite direction crashes, respectively, occurred when the posted speed was 72.4 kph (45 mph) or less.[369] Similarly, the data indicated 74 and 73 percent of injuries resulted from road departure and opposite direction crashes, respectively, that occurred when the posted speed was 72.4 kph (45 mph) or less.[370] For crashes where the travel speed was reported in FARS and GES, approximately 17 and 26 percent of fatal road departure and opposite direction crashes, respectively, occurred at travel speeds of 72.4 kph (45 mph) or less. These data also showed that, where the travel speed was reported, 71 and 78 percent of the police-reported non-fatal road departure and opposite direction crashes, respectively, occurred at 72.4 kph (45 mph) or less.[371] While this data suggests that speeding is prevalent in lane departure relevant pre-crash scenarios, particularly ones that result in fatalities, a test speed of 72.4 kph (45 mph) should address a measurable portion of the travel speeds where lane departure crashes are occurring.

Volpe's data analysis also showed the predominant roadway configuration for real-world lane departure crashes (*i.e.,* straight) also corresponds well with NCAP's test procedure. Of those road departure crashes in which roadway alignment was known, 63 percent and 78 percent of fatal and injurious crashes, respectively, occurred on straight roads.[372] For opposite direction-related crashes where roadway alignment was known, 70 percent of crashes with fatalities and 68 percent of crashes with police-reported injuries occurred on straight roads.[373] Additionally, for those road departure crashes where roadway grade was known, 71 percent of fatal crashes and 79 percent of crashes with injuries occurred on level roads.[374] For opposite direction crashes, these values were 68 percent and 69 percent, respectively.[375]

C. NHTSA's Proposals, Summary of Comments, Response to Comments, and Agency Decisions

1. Lane Keeping Technology Inclusion in General

Most commenters supported the inclusion of active lane keeping technology in NCAP. Respondents in favor of keeping LDW and additionally incorporating LKA included advocacy groups, vehicle manufacturers, and individuals alike. Families for Safe Streets called LKA a ''critical safety feature,'' MEMA suggested that it is ''ripe'' for inclusion, and, like blind spot technologies, ITS America stated that NHTSA provided sufficient data to support adding it to NCAP's suite of testing. HMNA requested that LKA, along with the other four ADAS

[364] Insurance Institute for Highway Safety (2016, January 28), Most Honda owners turn off lane departure warning, *Status Report, Vol. 51, No. 1,* page 6.

[365] Wiacek, C., Firey, L., and Mynatt, M. (2023). EDR Reported Driver Usage of Crash Avoidance Systems for Honda Vehicles. Paper Number 23–0040. 27th International Technical Conference on the Enhanced Safety of Vehicles.

[366] Consumer Reports. (2019, November), *Consumer Perceptions of ADAS, https://data.consumerreports.org/reports/consumer-perceptions-of-adas/.*

[367] European New Car Assessment Programme (Euro NCAP) (2019, July), *Test Protocol—Lane Support Systems, Version 3.0.2.* See section 7.2.5, Lane Keep Assist (LKA) tests.

[368] European New Car Assessment Programme (Euro NCAP) (November 2022), *Test Protocol—Lane Support Systems, Implementation 2023. Version 4.2.* Note that the Euro NCAP LSS test protocol has been updated from Version 3.0.2 since the March 2022 RFC's publication.

[369] Swanson, E., Foderaro, F., Yanagisawa, M., Najm, W.G., & Azeredo, P. (2019, August), *Statistics of light-vehicle pre-crash scenarios based on 2011–2015 national crash data* (Report No. DOT HS 812 745), Washington, DC: National Highway Traffic Safety Administration.

[370] Posted speed limit was unknown or not reported in 3 percent of fatal road departure crashes and in 14 percent of road departure crashes with injuries. For opposite direction crashes, these figures were 1 percent and 13 percent, respectively.

[371] Travel speed was unknown or not reported in 63 percent of fatal road departure crashes and in 68 percent of road departure crashes with injuries. For opposite direction crashes, these figures were 65 percent and 67 percent, respectively.

[372] Roadway alignment was unknown or not reported in 1 percent and 4 percent of fatal and injurious road departure crashes, respectively.

[373] Roadway alignment was unknown or not reported in 1 percent and 2 percent of fatal and injurious opposite direction crashes, respectively.

[374] Roadway grade was unknown or not reported in 4 percent and 19 percent of fatal and injurious road departure crashes, respectively.

[375] Roadway grade was unknown or not reported in 3 percent and 16 percent of fatal and injurious opposite direction crashes, respectively.

features, should be added to NCAP ''as soon as possible.'' Having said this, a number of commenters cautioned the Agency to ensure that active lane keeping technologies do not interfere with a driver's attempt to pass a bicyclist or pedestrian at a safe distance.

2. Removal or Integration of LDW

In its March 2022 RFC notice, the Agency noted that it agreed with commenters to the 2015 RFC notice who recommended that NHTSA adopt LKA technology in NCAP. However, instead of replacing LDW with LKA, as many commenters suggested, the Agency expressed that integrating its assessments for LDW into those for LKA may be a better approach to consider. Such a method (inclusive of passive and active safety capabilities for lane support systems) would be similar to that which the Agency has adopted for forward collision avoidance systems, FCW and AEB, as detailed earlier.

As mentioned, the Agency proposed to adopt Euro NCAP's LKA test scenarios to assess technology design differences for LKA, and since the test speeds and road configurations specified in Euro NCAP's LSS protocol are similar to those stipulated in the Agency's current LDW test procedure, NHTSA stated that the Euro NCAP tests should sufficiently address the lane keeping crash typology for LDW as well. As such, NHTSA solicited comment on whether it should retain its separate LDW test protocol or integrate an LDW requirement into the LKA test procedure it ultimately adopts. The Agency suggested that for systems having both LDW and LKA capabilities, it would simply turn off LKA to conduct the LDW test if both systems are to be assessed separately.

Summary of Comments

Many commenters, including ASC, Advocates, Aptiv, BMW, Bosch, GM, HATCI, IDIADA, Intel, Toyota, and TRC supported integrating the LDW assessment into the LKA test procedure.

Integrate Because of Testing Benefits

Test laboratories IDIADA and TRC supported consolidating the LDW and LKA test procedures because doing so offered ''an advantage for those conducting the test'' (TRC) and was ''more convenient'' (IDIADA). GM also added that integrating the two test procedures would enhance efficiency.[376]

Turn Off LKA Functionality To Assess LDW

ASC, Honda, TRC, and Aptiv supported turning the LKA system off to evaluate LDW, with ASC and Aptiv also expressing support for evaluating LDW alone if LKA is not available. Having said this, Aptiv stated that integrating the LDW and LKA assessments may help drive offerings of LKA. TRC mentioned that many of the scenarios and line types are already similar and that separate assessments would be easy to perform by turning off the LKA feature to conduct LDW tests.

Integrate, But Assess as a System, Not Separately

Auto Innovators recommended that since LDW and LKA interact together in the real world, and the combined system offers greater safety benefits than individual systems, assessments should be integrated to reduce test burden. The group suggested that LDW should not be assessed separately if LKA is provided, especially since not all systems allow disabling of LDW and/or LKA. The group generally supported harmonization with Euro NCAP's LSS protocol.

GM also supported an assessment of overall system performance. Like Auto Innovators, the automaker did not agree with assessing LDW functionality separately for those vehicles equipped with active lane keeping features. The commenter mentioned that not only is the ability to turn off LKA independently from LDW not an option for most vehicles, but the Agency's proposal would both limit potential safety benefits [for LKS] and also continue to allow nuisance behavior from LDW systems. The manufacturer further asserted that adopting protocols that assess LDW functionality separately (within an LKA system) would limit optimization of feature behavior since modern lane keeping systems integrate LDW into LKA, such that the passive warning serves as a secondary alert to the active system (*e.g.,* LKA, lane centering). In consideration of these comments, GM advocated that NHTSA only assess LDW functionality in cases where LKA fails to keep the vehicle in the lane per the test procedure requirements (regardless of whether the Agency maintains LDW as a separate assessment or integrates LDW assessments into an LKS test procedure).

Similarly, Auto Innovators and Toyota commented that NHTSA should evaluate LKA performance first, and if the Agency's performance criteria is not met, only then should LDW performance be evaluated. Auto Innovators and BMW, in addition to GM, as mentioned above, agreed that passing LKA systems should automatically receive credit for LDW (no separate LDW assessment should be necessary). GM stated that this would be consistent with the current Work in Progress (WIP) of SAE J3240, whereas Auto Innovators and BMW cited EU emergency lane-keeping systems (ELKS) regulations, which consider steering and/or braking intervention to be a haptic LDW warning.[377] Intel recommended that the Agency award additional points to LKA compared to LDW, since LKA can automatically prevent lane departures. HATCI also recommended that the Agency combine LDW and LKA requirements for vehicles having LKA functionality and retain a separate LDW assessment for those vehicles that do not. The manufacturer went on to say that it supports most of the test methods in Euro NCAP's LSS protocol because the safety need in the U.S. is similar.

Integrate LDW and LKA, But Continue To Test LDW Separately in Certain Instances

Some commenters agreed with combining LDW and LKA assessments but stated that LDW functionality should still be assessed separately for stand-alone LDW systems, or in instances where LKA can be disabled such that the system offers independent LDW functionality. In such cases, Bosch recommended performing Euro NCAP's single line LKA tests to assess performance for the LDW system. Advocates also supported aligning with Euro NCAP's LSS procedure and combining LDW and LKA testing if the Agency could justify doing so, but also mentioned that Euro NCAP's protocol specifies certain scenarios for LDW-only systems and systems that offer independent LDW functionality. The group also mentioned that the Agency should ''[rate] both LDW and LKS'' and weight the technology offering the greater safety benefits higher. Finally, IDIADA suggested LKA should have a performance-based assessment whereas LDW could be assessed based on fitment alone since LDW offers a much smaller safety benefit than LKA.

[376] See NHTSA–2021–0002–3856, Attachment A for more information.

[377] Commission Implementing Regulation (EU) 2021/646 of 19 April 2021 laying down rules for the application of Regulation (EU) 2019/2144 of the European Parliament and of the Council as regards uniform procedures and technical specifications for the type-approval of motor vehicles with regard to their emergency lane-keeping systems (ELKS) [2021] OJ L133/31, § 3.5.3.1.2.

Do Not Integrate LDW and LKA

Contrary to commenters who stated that the LDW and LKA assessments could be integrated, ZF Group and CAS recommended that LDW and LKA assessments be kept separate, particularly if either system can be disabled. DRI agreed. The test laboratory mentioned that it has seen varying performance for LDW depending on whether LKA was enabled or disabled, noting that when LKA was enabled, some vehicles would suppress the LDW alert as the LKA system attempted to intervene and keep the vehicle inside the lane, and then, when the intervention was not successful, the vehicle issued the LDW alert after the vehicle had departed from the lane. DRI further noted when LKA was disabled in those same vehicles, the LDW alerts were issued much earlier. As such, DRI concluded that, for vehicles where LDW and LKA are user selectable, vehicle manufacturers may vary the time of the LDW alert based on whether LKA is enabled. The test laboratory also noted that some LKA systems may intervene to the extent that one would have to impart additional steering toward the lane line (which may also suppress LDW if the vehicle senses the steering is intentional) to position the vehicle close enough to the lane line to issue an LDW alert.

Rivian recommended the Agency perform separate assessments of LDW-only, LKA-only, and LDW and LKA in combination. The manufacturer commented that this was most appropriate, particularly for user-configurable systems, to allow consumers to understand the safety benefits of each system individually and in combination.

Other Related Comments

Although Honda did not express a preference for removal of LDW or integration of the system into LKA, the automaker did support adoption of the LSS protocol used by Euro NCAP. Intel also expressly supported adopting the Euro NCAP protocol.

FCA opined that the current LDW test procedure should be maintained for a transitional period of time before a new requirement is implemented. Similarly, ASC and Aptiv mentioned the need to continue to perform LDW-only assessments, at least initially, noting that not all vehicles are currently equipped with LKA because they do not have electric power steering.[378]

Tesla stated that LDW points in Euro NCAP can be obtained either through the performance evaluation of an LDW system or presence of a BSI system; however, the automaker stated that NHTSA should evaluate the performance of LDW (rather than just presence) and BSI systems separately to ensure safety benefits for both systems are realized. Auto Innovators also noted that Euro NCAP's LSS test procedure contains the ELK—Overtaking scenario analogous to a scenario in NHTSA's BSI test procedure. However, the group suggested that the Agency keep LKA and BSI separate from one another since the U.S. market has accepted them as separate systems.

Response to Comments and Agency Decisions

The Agency has chosen to integrate LDW and LKA testing, and as such, will evaluate LDW functionality during its LKA tests.

Many commenters noted that LDW and LKA are two components of a larger lane departure mitigation system. Not only is it possible for the two systems to be enmeshed such that one may not be operational if the other is turned off, but the Agency's goal is for drivers to find lane keeping technologies supportive of the driving task and therefore leave them enabled. As Auto Innovators reiterated, the safety benefits of both systems together are greater than the benefits of a single system on its own. This improved safety cannot be realized if consumers choose to disable one or both of these systems. This holds true even if manufacturers choose to tune their LDW and/or LKA systems to compensate for the other system being turned off, for those vehicles which offer the option to do so. Although drivers may disable one or both systems according to their preference, the Agency finds it most advantageous to the consumer to integrate both components in its lane keeping technology assessment.

Commenters suggested that NHTSA's NCAP should harmonize its lane keeping tests with Euro NCAP's LSS test procedure. At the time of publication of the March 2022 RFC, Euro NCAP evaluated LDW systems using its LKA single-line test, which used a lateral velocity of 0.2 m/s to 0.5 m/s (0.7 ft./s to 1.6 ft./s), as previously noted.[379] However, after the comment period for the March 2022 RFC closed, Euro NCAP introduced an updated protocol in which LKA single-line tests are conducted using lateral velocities of 0.2 m/s to 0.6 m/s (0.7 ft./s to 2.0 ft./s), and the same procedure is used to evaluate LDW alerts from 0.6 m/s to 1.0 m/s (2.0 ft./s to 3.3 ft./s) lateral velocity.[380] It is unclear to the Agency whether these commenters desired harmonization based upon principle alone or whether commenters also believed that the specifications set at the time were appropriate.

At this time, performing LDW assessments using higher lateral velocities (*i.e.,* 0.7 m/s to 1.0 m/s (2.3 ft./s to 3.3 ft./s)) would be more representative of intentional lane changes rather than unintentional drifting, which NHTSA's LDW tests are designed to address. For intentional lane changes, LDW warnings do not serve to address a crash problem and may be viewed as a nuisance by drivers who then look to disable the LDW system. Given this possibility, the Agency will assess LDW alert functionality from 0.2 m/s to 0.6 m/s (0.7 ft./s to 2.0 ft./s) in NCAP. These same lateral velocities 0.2 m/s to 0.6 m/s (0.7 ft./s to 2.0 ft./s) will also be used for NCAP's LKA assessments. Note that NHTSA's current LDW protocol specifies an allowable lateral velocity range of 0.1 m/s to 0.6 m/s; thus, the chosen lateral velocity range has already been in use to assess LDW performance.

Since NHTSA's chosen LKA and LDW test specifications (*i.e.,* test scenarios, SV speeds, lateral velocities, etc.) are identical and LDW and LKA are meant to work together as a system, the Agency has chosen to evaluate LDW functionality during LKA testing. Assessing both technologies during the same test will promote efficiency, as IDIADA, TRC, and GM suggested, and reduce test burden on both NHTSA and manufacturers. It should additionally prompt expanded fleet coverage for LKA technology, as Aptiv asserted, and allow dual system optimization, as GM contended. In that vein, NHTSA expects that integrating LDW and LKA protocols will lead to a reduction in nuisance alerts.

HATCI's comment regarding the applicability of Euro NCAP's protocol to the U.S market due to similar safety need is sound overall. That said, NHTSA also agrees with Tesla and Auto Innovators that BSW/BSI and LDW/LKA should be evaluated separately since the Agency's desire is to address intended and unintended lane changes separately. Euro NCAP evaluates BSW (called "Blind Spot Monitoring", or

[378] ASC estimated that 85 percent of U.S. vehicles have electric power steering in 2022 and this number will increase to 92 percent in 2027.

[379] European New Car Assessment Programme (Euro NCAP) (July 2019), *Test Protocol—Lane Support Systems, Version 3.0.2.*

[380] European New Car Assessment Programme (Euro NCAP) (December 2023), *Test Protocol—Lane Support Systems, Version 4.3.*

BSM) and BSI using its Emergency Lane Keeping (ELK) Overtaking Vehicle scenario within its LSS protocol. For the Overtaking Vehicle test, lane keeping performance is evaluated using lateral velocities from 0.5 m/s to 0.7 m/s (1.6 ft./s to 2.0 ft./s), a path containing a smaller radius of curvature (800 m, or 2,625.0 ft.), and engagement of the turn signal. These requirements are designed to simulate conditions for an intentional lane change.

Because the Agency will assess LKA and LDW as a system, if a vehicle fails to adequately intervene using LKA during a lane departure, the Agency will not conduct further evaluation with the intent to provide the vehicle LDW credit only, as some commenters requested. NHTSA also will not separately evaluate LDW systems on vehicles that do not offer LKA as part of this NCAP update. These vehicles will not receive lane keeping technology credit for meeting NHTSA-approved performance metrics and the Agency will not report the presence of LDW on its website. These decisions are similar to those which the Agency has made for FCW and AEB. The Agency reasons this NCAP update is an opportunity to increase performance requirements for new vehicles to gain lane keeping technology credit to inform consumer decisions, and it is now most appropriate to highlight the performance of LKA systems, not LDW, given the greater safety gains that active technology may offer. Maintaining the current LDW protocol, even for a transitional period of time, as FCA requested, would not accomplish this goal. Having said this, the Agency does not want to discount the importance of the LDW alert to passing lane keeping scores. LKA can provide the necessary steering correction to prevent a roadway departure; however, for a distracted or inattentive driver, the LDW alert may still be necessary to ensure driver re-engagement. As will be detailed in a later section, a vehicle that fails to issue an LDW alert that conforms to NHTSA's requirements will not receive credit for lane keeping technology, regardless of whether the vehicle's LKA system provided acceptable intervention. Furthermore, as will be discussed later, while an LKA intervention will suffice as an LDW alert component, it will not be sufficient to satisfy all LDW alert requirements. As such, vehicles will not automatically receive LDW credit for a passing LKA intervention, as several commenters requested.

3. Lane Marking Configurations

Euro NCAP's LSS protocol specifies a single lane line to evaluate LKA system performance.[381] Citing the possibility that certain LKA systems may require the presence of lane lines on either side of the vehicle's travel lane before they can be enabled, the Agency sought comment on whether it should require the use of a single lane line or two lane lines on the test surface in its final LKA test procedure.

Summary of Comments

Many commenters favored adopting a test procedure featuring one lane line, while several others supported adoption of two lane lines.

Adopt a Single Lane Line

Those in favor of a single lane line included Aptiv, Intel, AASHTO, ASC, ZF Group, HATCI, Honda, Auto Innovators, Bosch, and Tesla. AASHTO stated that testing with a single lane line would best mimic real-world conditions, as oftentimes only one line is visible, even on two lane roads, due to wear and tear, snow, etc. Bosch provided similar comments, stating that center road lines are often not detectable, particularly on rural roads, and recommended using one lane line to assess LKA performance to ''maximize LKS system availability'' under such conditions. In its comments, ASC additionally mentioned that testing with a single lane line will encourage systems to operate in situations where only one line is present. Similarly, Honda opined that testing with a single lane line would incentivize systems to perform better on a greater number of roadway conditions and prevent lane departures when only one lane line is detected. HATCI, ASC, and Auto Innovators recommended adopting a single lane for U.S. NCAP testing to harmonize with Euro NCAP's LSS protocol. Similarly, ZF Group recommended adopting a single lane line to ''promote uniformity.''

Adopt Two Lane Lines

AAA and GM recommended that NHTSA adopt two lane lines rather than one in its LKA test procedure to best replicate real-world roadways. BMW, FCA, and TRC similarly recommended utilizing two lane lines to evaluate system performance because two-line lanes are more common on public roads in the U.S. In fact, FCA remarked (contrary to Auto Innovators) that roads having single lane lines are ''rare'' in this country compared to others. TRC also added that selecting a two-line lane marking configuration would permit more testing locations.

Incorporate Both One Lane Line and Two Lane Lines

Two commenters, CAS and Rivian, stated that the Agency should incorporate assessments for both one and two lane lines into NHTSA's LKA test procedure, since both line formats are present on U.S. roads. Rivian suggested that NHTSA should reward systems that perform well for both lane line types with higher scores.

Other Comments

Honda acknowledged that two lane lines may be required to initialize an LKA system but assumed the Agency was referring to the ''operation design domain for LKS systems'' in its reference to ''before they can be enabled,'' and not an initialization process. The automaker asked that the Agency clarify the meaning of the referenced statement. Auto Innovators also referenced the need to drive a vehicle between two lane lines in some instances to assure system initialization prior to testing with one lane line. The commenter, along with Tesla, generally supported harmonization with Euro NCAP LSS protocols. However, Tesla also mentioned that if NHTSA were to adopt two lane lines to address evaluations of LKA systems that require two lines to be enabled, the Agency should evaluate how a system reacts to crossing only the near side lane line as well as both lane lines and modify passing criteria and points appropriately. Tesla further asserted that the far side lane line should trigger the LKA system, which in turn should reduce false-positive and true-negative LKA system interventions in the real world.

The Advocates stated that NHTSA should conduct an analysis of road edge lines across states and correlate this information with crash data before deciding to incorporate one lane line type or another into its LKA test procedure. Citing NHTSA data that showed 7,424 fatalities occurred on rural local/collector roads in 2021 (*i.e.,* 17 percent of all fatalities),[382] the group surmised that a large number of crashes may be occurring on roads having only a dashed or solid center line. The Advocates suggested that NHTSA provide data to show whether testing with one or two lane lines is more demanding on LKA systems and

[381] European New Car Assessment Programme (Euro NCAP) (December 2023), *Test Protocol—Lane Support Systems, Version 4.3.*

[382] *https://crashstats.nhtsa.dot.gov/Api/Public/ViewPublication/813298.*

whether one lane marking format better exposes system deficiencies.

Finally, regarding lane marking specifications themselves, Toyota and Auto Innovators commented that lane marking length should be specified since it serves as a ''recognition process for the system.'' The entities recommended a minimum lane marking length of 300 m (984 ft.). Aptiv and ASC recommended that the Agency align lane widths used during LDW and LKA testing (currently 3.6 to 4.3 m (12 to 14 ft.)) with U.S. lane width standards, which specify a lane width of 2.7 to 3.6 m (9 to 12 ft.). Accordingly, the companies requested that NHTSA specify a maximum lane width of 3.7 m (12 ft.), which they stated would also better harmonize with Euro NCAP, which specifies a lane width of 3.5 to 3.7 m (11.5 to 12 ft.). ASC also added that NHTSA should always reference the latest Manual on Uniform Traffic Control Devices (MUTCD) published by the Federal Highway Administration (FHWA) for lane marking and road configurations.[383]

Response to Comments and Agency Decisions

For the purposes of evaluating a vehicle's LDW alert sensitivity and primary LKA intervention capabilities, NHTSA's testing will include the use of (1) a single solid white lane line, (2) a single dashed yellow lane line, or (3) Botts' Dots on either the right or left side of the vehicle's travel lane, depending on testing direction. These lane line colors and types are currently specified in NCAP's LDW test procedure. These lane line colors/types remain acceptable for NHTSA's testing because, per the FHWA's MUTCD, yellow lane markings for longitudinal lines are permitted to delineate, among other things: (1) the separation of traffic traveling in opposite directions and (2) the left-hand edge of the roadways of divided highways and one-way streets or ramps. White markings for longitudinal lines are permitted to delineate: (1) the separation of traffic flow in the same direction or (2) the right-hand edge of the roadway.[384] The MUTCD also states that a solid line shall be used to discourage or prohibit crossing (depending on the specific application) and a broken line shall be used to indicate a permissive condition.[385] Further, raised pavement markers, such as Botts' Dots, may serve as a substitute for pavement markings, as long as they simulate that pattern of the markings for which they substitute.[386] Euro NCAP's LSS test protocol specifies the use of either a solid or dashed line present in the direction of departure for LKA and LDW tests.

Adopting the single-line approach for these evaluations should ensure that LDW and LKA systems can operate in a greater number of real-world situations. Though roadways are typically designed to contain two lane markings denoting left and right sides of the lane, road conditions may vary greatly. The Agency sees merit in several commenters' suggestions that sometimes only a single line may be visible due to road wear or precipitation. By isolating the test conditions to a single lane line on either the right- or left-hand side of the SV, the test will assess whether the vehicle can detect the lane line independent of its other surroundings, which may vary in an infinite number of ways. Since a real-world vehicle may not have a second lane line to confirm that a lane departure is occurring, a single-line test should improve sensing such that vehicles no longer require the second lane line for LDW or LKA to reliably function. Furthermore, the use of a single lane line for the Agency's tests should not restrict manufacturers from using a second lane line, when available, to inform a vehicle's LKA system and further improve performance in the myriad of scenarios a driver will encounter in the real world.

Given the reasons above, systems which only require the presence of one lane line to function are preferable to those which require two (*i.e.,* one on each side of the vehicle); however, certain complications arise when evaluating LKA system performance using only one lane line. NHTSA acknowledges concern exists regarding secondary lane departures that may occur after an LKA intervention. In these cases, the vehicle steers back into the lane but then overcorrects and departs the lane on the opposite side of the original intervention. These cases cannot be accounted for during tests in which there is only one lane line. Therefore, the Agency will also perform additional testing with two lane lines to evaluate a vehicle's ability to properly correct the vehicle's heading after the initial intervention. As detailed in a subsequent section, the lane markings for this test series will consist of (1) a right solid white line and a left dashed white line, meant to simulate an SV traveling on a multi-lane road in the rightmost lane, and (2) a right dashed white line and a left solid yellow line, meant to simulate an SV travelling on a multi-lane road in the leftmost lane. These lane marking configurations are similar to those used[387] in Euro NCAP's Emergency Lane Keeping (ELK) Solid Line test scenarios.[388] However, unlike in Euro NCAP's testing, for each dual line configuration, assessments will be made for both left and right departures (*i.e.,* across both dashed and solid lane lines).

Thus, LKA testing will occur with both styles of lane markings: single lane lines on either the right or left side of the travel lane and two lane lines with one on each side of the vehicle. Vehicles traveling in real-world situations will likely encounter both scenarios, as CAS and Rivian remarked. By performing both single line and dual line assessments, NHTSA expects to ensure robust everyday performance. Systems will not be able to rely on the use of the second lane line for normal operation, but performance that is confounded by a second lane line should be evident.

To address concerns regarding initialization of LDW and LKA systems, NHTSA plans to accept information from vehicle manufacturers detailing the procedures necessary to properly initialize systems for use. This information is already being collected prior to NCAP's current ADAS testing of new vehicle models. Further, the Agency is aware of cases where the vehicle must be driven a minimum number of miles in normal use conditions prior to assessment of ADAS technologies.

Regarding other characteristics of lane markings, as with the BSW and BSI testing included in this final notice, NHTSA has decided to adopt a 3.5 m to 3.7 m (11.5 ft. to 12 ft.) lane width specification for its LDW and LKA tests for this NCAP update. In doing so, the Agency will align with Euro NCAP's LSS procedure and will more closely reflect AASHTO standards. The Agency will also impose a requirement that lane line markings extend for a minimum of 300 m (984 ft.), as Toyota and Auto Innovators requested. This lane line

[383] 23 CFR 655, Subpart F.

[384] *Manual on Uniform Traffic Control Devices for Streets and Highways, 11th Edition.* U.S. Department of Transportation, Federal Highway Administration. December 2023. See Section 3A.05.

[385] *Manual on Uniform Traffic Control Devices for Streets and Highways, 11th Edition.* U.S. Department of Transportation, Federal Highway Administration. December 2023. See Section 3A.06.

[386] *Manual on Uniform Traffic Control Devices for Streets and Highways, 11th Edition.* U.S. Department of Transportation, Federal Highway Administration. December 2023. See Section 3B.14.

[387] Euro NCAP's ELK Solid Line tests utilize only dashed white and solid white lane lines.

[388] European New Car Assessment Programme (Euro NCAP) (December 2023), *Test Protocol—Lane Support Systems, Version 4.3.* See Section 7.2.4.2.

length should be sufficient for LDW and LKA systems to interpret lane departures appropriately during the test validity period and accommodate secondary departure assessments. Finally, the Agency notes that it included the MUTCD as a reference for lane markings in both the LDW and draft LKA test procedures and has included it in the test procedures prepared for this NCAP update.

4. Botts' Dots/Raised Pavement Markers Test Condition

In its March 2022 RFC notice, the Agency proposed to remove the Botts' Dots (*i.e.,* raised pavement marker) test scenario from the current LDW test. This decision stemmed from the fact that information available to NHTSA suggested that the lane markers were being removed from use in California [389] and a preliminary assumption that the traditional dashed and solid lane marking tests may be sufficient to evaluate vehicle performance.

Summary of Comments

In Favor of Removal

Those in favor of removing the Botts' Dots test scenario from the Agency's LDW test procedure included BMW, GM, HATCI, Honda, Auto Innovators, Bosch, TRC, MEMA, ASC, FCA, IDIADA, Intel, Tesla, and two individuals. Both HATCI and TRC cited reduced test burden as reasons to remove the Botts' Dots test condition. ASC, FCA, Intel, Tesla, and a public commenter all cited discontinued use in California as a reason for removal. Similarly, IDIADA mentioned that the Botts' Dots condition is becoming a ''niche scenario with low relevancy'' and Honda stated that there is no longer a safety need. TRC suggested replacing the Botts' Dots test condition with a road edge detection test because it is a more common real-world condition and possible at most testing laboratories.

Oppose Removal

Although the overwhelming majority of commenters were in favor of removing the Botts' Dots test condition from the Agency's LKA test procedure, Rivian asserted that this test scenario was still a necessary assessment for LDW systems. The manufacturer contended that most vehicles would likely encounter Botts' Dots at some point since lane markings across the U.S. are not uniform. Rivian also stated that manufacturers may not design for this test condition if it was not part of NHTSA's test protocol which, in turn, would lead to reduced system effectiveness and overall safety. Along these lines, Advocates recommended that NHTSA provide information on the prevalence of Botts' Dots in states other than California and the length of time before Botts' Dots would be replaced before the Agency can be assured that removing them would not be a detriment to safety.

Response to Comments and Agency Decisions

NHTSA has decided not to remove the raised pavement markers test scenario, which utilizes Botts' Dots, from its LDW/LKA test procedure for this NCAP upgrade. The Agency agrees with Rivian that it is possible vehicles may encounter Botts' Dots or other raised pavement markers in lieu of painted lane lines at some point during their useful life. In fact, more recent information from Caltrans, which manages over 50,000 miles of California's highway and freeway lanes, suggests the organization has no intention at this time of removing Botts' Dots from California's roadways.[390] The Agency also recognizes that Botts' Dots or similar raised pavement markers are utilized in other states as well. The MUTCD provides guidelines for raised pavement markers as a substitute for broken line, solid line, and dotted lane line markings.[391] Given this, and the fact that such pavement markers are unique compared to painted lane markings, NHTSA agrees with Rivian that retaining Botts' Dots assessments for NCAP's LDW/LKA assessments will best assure overall LDW/LKA system effectiveness and safety. The Agency reasons the slight increase in test burden such testing will generate is worth the assurance that vehicles will react appropriately if they encounter similar lane markings.

Having said this, NHTSA also acknowledges FHWA's most recent guidance to agencies in its December 2023 MUTCD that discourages the use of raised pavement markers as a substitute for lane markings when designing roadways for automated vehicles.[392] As such, the Agency will monitor changes made to roadway lane demarcations to better accommodate forthcoming vehicle designs and may revisit the necessity of conducting test scenarios using Botts' Dots or other raised pavement markers in the future.

5. Addressing Secondary Departures

The Agency explained in its March 2022 RFC notice that it would like to be assured that, when a vehicle is redirected after an initial LKA system intervention, if the vehicle then approaches the lane marker on the side not tested, the LKA will again engage to prevent a secondary lane departure by not exceeding the same maximum excursion limit established for the first side.

To prevent secondary lane departures, NHTSA sought comments on whether it should consider modifying Euro NCAP's LKA evaluation criteria to be consistent with language developed for NHTSA's BSI test procedure to prevent this issue. NHTSA's BSI test procedure states that the SV's BSI intervention shall not cause the vehicle to travel more than 0.3 m (1 ft.) beyond the inboard edge of the lane line separating the SV's travel lane from the lane adjacent and to the right of it within the validity period. To assess whether this occurs, a second lane line is required; however, only one lane line is specified in the Euro NCAP LSS protocol for LKA testing. The Agency questioned whether the introduction of a second lane line would have the potential to confound LKA testing.

Summary of Comments

Agree With Adding Assessment for Secondary Lane Departures

The majority of commenters (Advocates, ASC, BMW, CAS, Honda, Intel, Rivian, Tesla, TRC, and ZF Group) expressed support for NHTSA modifying the LKA test procedure to ensure tested LKA systems intervene a second time to prevent secondary lane departures.

BMW did not comment that there was risk to adding a secondary lane line, since LKA systems are designed to align with the lane marking(s) after an intervention, but the commenter also recommended that the Agency adopt a two-line marked lane since it is most common. Along these lines, Intel recommended that, in adding a second lane line, NHTSA should ensure that the created lane represents real-world roadways and lane markings. Like BMW, ASC, Rivian, Tesla, and ZF Group reasoned that the addition of a second lane line should not adversely affect LKA performance. That said, ASC

[389] Winslow, J. (2017, May 19), Botts' Dots, after a half-century, will disappear from freeways, highways, *The Orange County Register, https://www.ocregister.com/2017/05/19/botts-dots-after-a-half-century-will-disappear-from-freeways-highways/.*

[390] *https://dot.ca.gov/programs/public-affairs/faqs.*

[391] *Manual on Uniform Traffic Control Devices for Streets and Highways, 11th Edition.* U.S. Department of Transportation, Federal Highway Administration. December 2023. See Section 3B.17.

[392] *Manual on Uniform Traffic Control Devices for Streets and Highways, 11th Edition.* U.S. Department of Transportation, Federal Highway Administration. December 2023. See Section 5B.02.

asserted that it was reasonable to expect that LKA systems would prevent secondary departures regardless, and ZF Group similarly mentioned that the second lane line should simply trigger an LKA intervention. Rivian was supportive of adopting a test scenario that allowed the SV to 'ping-pong' between lane lines two or more times to assess system functionality. CAS asserted that whether there is a lane line or not, the LKA system should keep the vehicle in the lane after an initial LKA intervention, and ensuring this functionality is important to consumers.

While CAS maintained that, for safety reasons, no amount of excursion over the other lane line was acceptable for a secondary lane departure, Honda and ASC agreed that the Agency should adopt the same maximum excursion limits for primary and secondary lane departures. Honda saw no point in deviating since the current maximum limit is based on real-world data. The automaker also requested that the Agency adopt the appropriate roadway widths (based on real-world roadways) for the tested speeds if NHTSA adopts a second lane line. The commenter asserted that adopting a lane width that is too narrow for the speeds tested may cause inadvertent LKA system activation for the opposite lane line. Similarly, Intel remarked that a dually marked lane must be greater than a certain width so that the LKA system will have sufficient margin to not exceed the maximum excursion limit.

Advocates also supported evaluating secondary lane departures but requested that if adding the second lane line reduces the stringency of lane or road departure tests, NHTSA should conduct the tests to assess prevention of secondary lane departures separately. Rivian suggested that the Agency reduce ratings for systems that struggle to prevent secondary lane departures. TRC preferred that LKA and BSI protocols have consistent language but also commented that secondary lane departure evaluations require increased space for testing.

Do Not Agree With Adding Assessment for Secondary Lane Departures

Some commenters did not agree with modifying the LKA test procedure to ensure systems intervene to prevent secondary lane/road departures. Several of these commenters relayed that such an assessment was not necessary (Bosch and Toyota) or not warranted (Auto Innovators and GM). Bosch indicated that if the system avoids a departure on one side of the lane, and separately when tested for the other side of the lane, then it should prevent a secondary departure. FCA maintained that each lane departure intervention is a single event that ends after the intervention is complete. As such, the automaker considered a secondary lane departure to be a new lane departure event.

Toyota and Auto Innovators stated that since LKA is designed to prevent or mitigate lane or roadway departures due to driver inattentiveness, drowsiness, etc., secondary departures should not serve as a basis to assess system performance. Likewise, GM commented that the first intervention serves to grab the driver's attention so that the driver intervenes to prevent a secondary departure. Auto Innovators and GM added that a driver-monitoring system may be necessary for those drivers who are not attentive after an initial LKA intervention, especially for those who may be misusing the system (*e.g.,* driving with no hands on the wheel) and who purposely allow their vehicle to 'ping-pong' between lane lines. Both groups further asserted that current systems are designed to re-center the vehicle in the lane after an intervention, not to direct the vehicle toward the opposite lane marker such that a secondary lane departure would occur.

Along the lines of those comments from Auto Innovators and GM, IIHS expressed that it shares NHTSA's concern about ramifications of LKA interventions because the group's research [393] has shown that many of those drivers involved in lane departure crashes were sleeping or otherwise incapacitated (34 percent); had a non-incapacitating medical-issue, blood alcohol concentration (BAC) of 0.08 percent or more, or physical factor that could impair their ability to safely control a vehicle (13 percent), such that they would be unlikely to regain control of the vehicle after an initial LKA intervention. Accordingly, the group encouraged NHTSA to add to NCAP technologies that could detect such a driver and intervene to safely stop their vehicle, or preferably pull their vehicle over on the side of the road.

Response to Comments and Agency Decisions

Given the comments received, the Agency has decided to incorporate additional LKA test scenarios that are comparable (though not identical) to Euro NCAP's Emergency Lane Keeping (ELK) Solid Line test to address secondary lane departures. NHTSA agrees with ASC that it is a reasonable expectation that LKA systems should prevent secondary departures, and, as CAS suggested, ensuring that LKA systems keep a vehicle in the lane after an initial intervention is important to consumers. It is also imperative for safety.

Unlike the Agency's other LKA test scenarios, these secondary departure scenarios will utilize two lane lines to permit assessment of a secondary departure. Assessments will be made for two configurations—one simulating a vehicle travelling in the rightmost lane of a multi-lane road, with a solid white line to its right and dashed white line to its left, and the second simulating a vehicle travelling in the leftmost lane of a multi-lane road, with a solid yellow line to its left and a dashed white line to its right. Since these lane line combinations are common during real-world driving on multi-lane roads, they are appropriate for inclusion in NHTSA's testing. Also, utilizing a dashed white line and solid yellow line for the secondary departure tests effectively complements the Agency's dashed yellow and solid white single lane line tests, respectively.

The Agency had expressed some concern in its March 2022 RFC notice that the addition of a second lane line in NCAP's lane keeping tests may confound LKA performance and thus test results. At the time, however, the Agency did not take into consideration that Euro NCAP's ELK Road Edge tests, which were/are performed similarly to their LKA tests, (and which the Agency is adopting for its LKA assessments), required a second lane line. Furthermore, Euro NCAP's LSS protocol has since been updated to include a second lane line for the program's ELK Solid Line tests, which will closely mirror the secondary departure tests adopted by NHTSA. As such, NHTSA now agrees with commenters that its initial concern was unwarranted. The Agency has not only adopted test parameters for the secondary departure test that align with Euro NCAP's current ELK Solid Line test (with the exception of the addition of a solid yellow lane line), but it has also adopted lane width requirements for its LKA testing that match those utilized by Euro NCAP. Euro NCAP's ability to successfully conduct the ELK Solid Line test demonstrates inherent practicality and should temper Honda's (and NHTSA's) previous concerns surrounding inadvertent LKA system activation caused by the opposite lane line. Furthermore, NHTSA has adopted lane marking length specifications to address commenter concerns regarding system lane recognition. The Agency has

[393] Cicchino & Zuby, 2017. Prevalence of driver physical factors leading to unintentional lane departure crashes. *Traffic Injury Prevention, 18(5),* 481–487.

conducted limited testing to observe secondary departures and concludes that such assessments are feasible, even considering TRC's concerns about the space required for test conduct. The Agency will specify that vehicles achieve at minimum of 3 seconds of steady state speed before the lane departure is initiated to establish a baseline path from which the vehicle will deviate. However, to restrict the required space needed for testing, NHTSA will limit the test validity period to the first of the following events: (1) the point in time when the SV travels more than 0.3 m (1 ft.) beyond the inboard edge of the primary lane line separating the SV's travel lane from the lane adjacent to it; (2) 5 seconds after the SV has established a heading away from the primary lane line and is completely within its original travel lane; or (3) 1 second after the SV travels more than 0.3 m (1 ft.) beyond the inboard edge of the secondary lane line, where the primary line is the line the SV heading's was initially directed towards and the secondary line is the line on the opposite side of the SV's travel lane with respect to the primary line. The Agency's testing has shown the track length required to fulfill these requirements is reasonable.

Like the other LKA tests adopted for this NCAP update, the SV will be driven at 72 kph (44.7 mph) for the secondary departure tests, and the lateral velocity of the SV's approach to the lane line will be increased from 0.2 to 0.6 m/s (0.7 to 2.0 ft./s) in 0.1 m/s (0.3 ft./s) increments. Acceptable LKA performance will be defined by the system's ability to prevent the SV from crossing the inboard leading edge of the lane line by more than 0.3 m (1.0 ft.). This maximum lane line excursion limit will apply for both primary and secondary departures, as several commenters requested. NHTSA agrees with Honda that there is no need to deviate from the limit adopted for the initial departure, since as mentioned earlier, it has real-world practicality. If the system's initial intervention satisfies the performance requirement, the test will continue to discern whether the vehicle's subsequent movement will cause a second LKA intervention. If the LKA system once again satisfies the performance requirements for the second intervention or does not trigger vehicle movement that necessitates a second intervention (*i.e.,* aligns the vehicle with the lane marking(s) after the initial intervention) within the validity period, the vehicle will receive passing results. Assessments will be performed for departures on both sides of the vehicle (*i.e.,* left and right) and the same LDW warning requirements adopted for the Agency's other LKA tests (which will be defined later) will apply.[394]

While NHTSA agrees in theory with Bosch that an LKA system that prevents a lane departure on one side should similarly prevent a lane departure on the opposite side such that evaluations for secondary departures should be unnecessary, the Agency has an obligation to the consumer to confirm Bosch's assumption, particularly since, as will be discussed later, the Agency's testing has shown that a vehicle's response can vary based on departure direction and lane line type. It is NHTSA's hope, however, that most systems are designed to re-center the vehicle in the lane after an intervention, as Auto Innovators and GM stated, and that systems exhibiting alternative performance will undergo design improvements conducive to lane centering. As such, the Agency will not end the test after the first lane departure event, as FCA suggested, but will instead continue to assess performance after the first intervention.

NHTSA also sees merit in conducting testing to assess secondary departures despite commenters' objections that the intent of LKA is for the initial intervention to grab the driver's attention so that the driver intervenes to prevent a secondary departure. While the commenters' perspective regarding the main purpose of LKA systems may be accurate, the Agency maintains that an inattentive or drowsy driver also would likely benefit from a secondary intervention, as the primary intervention may cause the driver to suddenly attempt to retake control, potentially overcorrecting for steering and/or braking and thus imparting additional safety risk. Further, although the Agency acknowledges commenters' assertions that a driver monitoring system may aid an incapacitated driver, NHTSA is not considering evaluations for such technology as part of this effort. As will be discussed later in this notice, such systems may be considered for adoption in NCAP in the future at such time when the research has been completed and objective test procedures are available.

[394] Specifically, LDW warning requirements specify a visual LDW alert and an auditory or haptic alert (which may be an LKA intervention) that must be issued within a tolerance that spans 0.75 m to –0.30 m (2.5 ft. to –1.0 ft.), and the visual alert must be issued prior to, or concurrent with, the LKA intervention.

6. Appropriate Lateral Velocities for LKA

In its 2022 RFC notice, NHTSA cited research it had conducted on five model year 2017 vehicles to study the effect of increasing lateral velocity on LKA system performance.[395] For this study, the Agency used a slightly modified and older version of Euro NCAP's LSS test procedure than that discussed previously. Specifically, the Agency deviated from the Euro NCAP procedure and increased the lateral velocity of the SV's approach towards the lane line from 0.1 m/s to 1.0 m/s in 0.1 m/s increments (0.3 ft./s to 3.3 ft./s in 0.3 ft./s increments).[396] LKA performance was considered acceptable in instances where the SV did not cross the inboard leading edge of the lane line by more than 0.4 m (1.3 ft.).[397] [398]

An analysis of the five tested vehicles identified performance differences between the vehicles depending on the lateral velocity used during the test. Some vehicles only provided a steering response at lower lateral velocities while others continued to produce a steering input as the lateral velocity increased. As will be discussed further in a subsequent section, the maximum excursion over the lane marking after an LKA activation was also found to be inconsistent, particularly as lateral velocity increased.

Additional LKA tests were run on six model year 2019 vehicles.[399] For each model, vehicle response to solid white and dashed white lines was assessed for both left and right departure directions. The same lateral velocities as those used in the model year 2017 vehicle tests mentioned previously were used in the model year 2019 testing. Findings from this testing were similar.

At the time of publication of the March 2022 RFC, to represent

[395] Wiacek, C., Forkenbrock, G., Mynatt, M., & Shain, K. (2019), Applying lane keeping support test track performance to real-world crash data. *26th International Technical Conference for the Enhanced Safety of Vehicles,* Eindhoven, Netherlands. Paper Number 19–0208.

[396] A robotic steering controller was used to maximize the repeatability and minimize variability associated with manual steering inputs.

[397] At the time of testing, an older version of Euro NCAP's LSS test procedure stipulated a lane keep assist assessment criterion of 0.4 m (1.3 ft.) for the maximum excursion over the inside edge of the lane marking. European New Car Assessment Programme (Euro NCAP). See *Assessment Protocol—Safety Assist, Version 7.0* (2015, November).

[398] Wiacek, C., Forkenbrock, G., Mynatt, M., & Shain, K. (2019), Applying lane keeping support test track performance to real-world crash data. *26th International Technical Conference for the Enhanced Safety of Vehicles,* Eindhoven, Netherlands. Paper Number 19–0208.

[399] Reports for these tests can be found in the docket for this notice.

unintended lane departures (*i.e.,* not an intended lane change), Euro NCAP's LSS protocol specified use of a range of lateral velocities from 0.2 to 0.5 m/s (0.7 to 1.6 ft./s) for its LKA and Road Edge recovery tests and a range of lateral velocities from 0.3 to 0.6 m/s (1.0 to 2.0 ft./s) for its Emergency Lane Keeping—Oncoming vehicle and Emergency Lane Keeping—Overtaking vehicle tests.[400] Given the Agency's findings from its research testing, NHTSA requested comment on whether it should consider adopting a combination of the two lateral velocity ranges specified by Euro NCAP for unintended lane departures, specifically 0.2 to 0.6 m/s (0.7 to 2.0 ft./s), for inclusion in NHTSA's LKA evaluation to encourage the most robust LKA system performance.

Summary of Comments

In support of combining and/or aligning tested lateral velocities to 0.2 to 0.6 m/s (0.7 to 2.0 ft./s) were Auto Innovators, Honda, ASC, BMW, FCA, HATCI, Intel, and Bosch. Several of these commenters focused on harmonization, while others mentioned system robustness.

Combine for Harmonization

Honda asserted that the lateral velocities should be consistent when test procedures are designed to represent the same pre-crash scenario. As such, the manufacturer supported combining the two ranges of lateral velocities. Similarly, FCA commented that aligning with the Euro NCAP procedures and combining the lateral velocity range would minimize test burden and adequately gauge performance. GM also supported the proposal to adopt a lateral velocity range of 0.2 to 0.6 m/s (0.7 to 2.0 ft./s) to ''simplify testing, provide more consistency in testing, and better align with Euro NCAP and limits proposed in SAE J3240 Work In Progress (WIP). HATCI supported combining the lateral velocities to harmonize with Euro NCAP test procedures, which they considered ''widely accepted'' and ''largely representative of the field.''

However, Advocates stated that NHTSA had not provided enough data or justification to support adoption of the range of lateral velocities specified in the Euro NCAP test procedures. They asked that the Agency conduct an analysis using data from event data recorders, NHTSA's crash reconstruction databases, naturalistic driving studies, etc. to justify that the proposed range is representative of U.S. crashes.

Combine To Ensure System Robustness

Intel recommended combining the lateral velocity ranges to encourage robust LKA performance, since they asserted that NCAP serves to ''raise the bar'' and incentivize adoption of the most advanced systems. At a minimum, however, the company recommended that NHTSA harmonize with Euro NCAP's LKA and Road Edge tests. ASC, which also favored combining the lateral velocity ranges, commented that testing at higher lateral velocities should improve system robustness and, in turn, safety and consumer acceptance. Auto Innovators similarly commented that higher lateral velocities will differentiate more robust system designs since respective testing will be more difficult to meet. However, the group cautioned that 0.6 m/s should be the upper limit used for testing, as unintended lane departures may be more difficult to distinguish at higher lateral velocities. Finally, CAS suggested that the Agency look into combining the two unintended departure ranges prescribed by Euro NCAP, as this should ''provide an additional safety margin.'' However, like Advocates, CAS also recommended that NHTSA conduct additional research to determine whether Euro NCAP's protocol best aligns with the crash problem in the U.S.

Other Recommendations

ZF Group didn't agree that NHTSA should simply combine the lateral velocity ranges. They stated that ''both Euro NCAP tests referenced were carefully developed and address different scenarios.'' Therefore, the group opined that the Agency should align with Euro NCAP's protocol (to the greatest extent possible) for both tests. In a similar vein, Rivian commented that the 0.6 m/s (2.0 ft./s) lateral velocity is appropriate for oncoming vehicle and overtaking vehicle tests because they are designed to assess systems that offer increased warning and assist thresholds; however, using a 0.6 m/s (2.0 ft./s) lateral velocity to assess vehicles in a traditional LKA test where this extended capability is not necessary may increase false positives and reduce usage of LKA systems. The manufacturer added that systems capable of performing well in oncoming vehicle and overtaking vehicle tests should receive higher scores.

Response to Comments and Agency Decisions

As noted at the beginning of this section, when the Agency sought comment on this specification, there were two ranges of lateral velocities being used in the Euro NCAP suite of ELK, LKA, and Road Edge tests: 0.2 m/s to 0.5 m/s (0.7 ft./s to 1.6 ft./s) and 0.3 m/s to 0.6 m/s (1.0 ft./s to 2.0 ft./s). The Agency proposed to adopt a singular range which combined the two Euro NCAP ranges for its LKA testing protocol. Newer versions of Euro NCAP's LSS procedure, dated November 2022 and December 2023, incorporate this combined range for the program's LKA and ELK tests. In tandem with the many comments received regarding harmonization, Euro NCAP's acceptance of this new range further bolsters support for the combined lateral velocity range proposed. Thus, NHTSA will adopt the combined range of 0.2 m/s to 0.6 m/s (0.7 ft./s to 2.0 ft./s) for SV lateral velocities assessed in its LDW/LKA tests, with lateral velocities tested in increasing increments of 0.1 m/s (0.3 ft./s) to ensure robustness throughout the test range.

NHTSA notes that harmonization with Euro NCAP for this test specification is desired not only by the Agency but by many commenters as well. Reasons cited included minimized test burden, simplified testing, and use of widely accepted parameters. Manufacturers and test laboratories should be familiar with performing LKA-style testing using this range of lateral velocities. Further, a move to align test procedures to the most reasonable extent possible satisfies a part of the BIL, as mentioned throughout this notice.

Beyond harmonization, as Intel, ASC, and Auto Innovators noted, a wider range of lateral velocities will be more difficult to meet and should encourage manufacturers to design more robust systems for their vehicle models. NHTSA concludes ZF Group's concern regarding the differences between test types in Euro NCAP is no longer applicable since Euro NCAP has moved toward the 0.2 m/s to 0.6 m/s (0.7 ft./s to 2.0 ft./s) lateral velocity range for all scenarios that will be implemented in NCAP. Also, the Agency notes that both lateral velocity ranges used previously in Euro NCAP were initially intended to approximate lateral velocities experienced during unintended lane departures, lending credence to Honda's comment regarding alignment of test specifications under similar scenarios. NHTSA does not anticipate a greater

[400] European New Car Assessment Programme (Euro NCAP) (July 2019), *Test Protocol—Lane Support Systems, Version 3.0.2.*

number of false positive or nuisance activation events from the use of a 0.6 m/s (2.0 ft./s) lateral velocity, as Rivian asserted, given that it is currently the upper tolerance for LDW testing and has been implemented in Euro NCAP's test protocol and the test procedure does not simulate a driver actively steering but specifies a trajectory.

Data gathered by NHTSA for both model year 2017 and 2019 vehicles shows that most vehicles failed to adequately intervene during the 0.5 m/s (1.6 ft./s) and higher lateral velocity tests; this held true for both solid and dashed line assessments.[401] Three vehicles failed to offer any LKA intervention at least once (*i.e.,* for either left- or right-side departures) at 0.5 or 0.6 m/s (1.6 ft./s or 2.0 ft./s). Overall, four of the 11 vehicles did not offer any intervention at least once in testing from 0.2 m/s to 0.6 m/s (0.7 ft./s to 2.0 ft./s). Notwithstanding, the majority of the 11 vehicles did offer some level of lane correction. Notably, one vehicle of the 11 tested successfully prevented excessive excursion (greater than 0.3 m, or 1.0 ft.) in each of the proposed lateral velocity, departure side, and lane line type combinations tested. This result demonstrates that adequate LKA performance is achievable between the proposed lateral velocities of 0.2 m/s to 0.6 m/s (0.7 ft./s to 2.0 ft./s).

7. Inboard Lane Line Tolerances and Maximum Excursion Limit

The Agency sought comment on what lane line tolerances and/or alert or intervention timing would be appropriate for LDW and LKA, respectively. As mentioned, NHTSA held concerns that the safety benefits afforded by LDW technology were diminished because consumers were disabling LDW systems to address nuisance alerts stemming from excessive activations. To improve consumer acceptance and increase safety benefits, NHTSA requested comment in its 2015 RFC notice on whether to revise certain aspects of NCAP's LDW test procedure. In particular, the Agency proposed to tighten the inboard lane line tolerance for its LDW test procedure from 0.75 to 0.3 m (2.5 to 1.0 ft.). The outboard lane line tolerance would remain −0.3 m (−1.0 ft.) from the inside edge of the lane line. Through this, an LDW alert could only be issued within a window of +0.3 to −0.3 m (+1.0 to −1.0 ft.) with respect to the inside edge of the lane line to pass an NCAP LDW trial. This proposal effectively increased the space in which a vehicle could operate within a lane before the triggering of an LDW alert.

The Agency's proposal to revise the lane line tolerances received mixed support in 2015. One commenter stated the proposed change was ''unduly prescriptive,'' and given the typical driver reaction time (*i.e.,* 1.2 s)[402] and target lateral velocity of 0.5 to 0.6 m/s (1.6 to 2.0 ft./s) prescribed in NCAP's LDW test procedure, an LDW alert would have to be issued at a distance of 0.6 to 0.72 m (1.9 to 2.4 ft.) to ensure that the majority of drivers could react in time to prevent a lane departure. Other commenters stated that some of the more robust systems available at the time could comply with the narrower specification and that the tolerance reduction should increase the required accuracy and quality of lane keeping systems, thus producing higher driver satisfaction, and, in turn, system use, compared to those systems that meet the current LDW requirements. Another commenter agreed that the narrowed lateral tolerance should reduce the issuance of false alerts on main roadways but cautioned the Agency that this change may not effectively address false alerts on secondary or curved roads. On these roads, the commenter stated vehicles not only tend to approach within one foot of lane lines, but also may cross them.

Given NHTSA's goal of reducing nuisance notifications to increase consumer acceptance of LDW systems, combined with several commenters' statements that current LDW systems can meet the reduced test specification previously proposed, the Agency believed it reasonable to propose the reduced inboard lane tolerance of 0.3 m (1.0 ft.).

Additionally, the Agency also contemplated reduced maximum excursion limits of the vehicle beyond the lane line. As previously noted, during the Agency's study of LKA system behavior for increasing lateral velocity[403] for a small sample of model year 2017 vehicles, LKA performance was considered acceptable for instances where the SV did not cross the inboard leading edge of the lane line by more than 0.4 m (1.3 ft.).[404] [405] However, the maximum excursions over the lane marking recorded during the tests were also compared to the measured shoulder width of roads where fatal road departure crashes occurred. While the Agency found that most of the roadway departure crashes were on roads where the shoulder width exceeded 0.4 m (1.3 ft.), such that a lane departure could have been prevented if a robust LKA system was engaged and functioned properly, the analysis also identified roadways where the shoulder width of the roadway was less than the 0.4 m (1.3 ft.) maximum excursion limit (*e.g.,* certain rural roadways) used in the Agency's testing. The Agency concluded that only vehicles displaying robust LKA performance, including at higher lateral velocities, would likely prevent the vehicle from departing the travel lane on these roadways. Yet, as mentioned previously, NHTSA found that many of the assessed LKA systems exhibited inconsistent performance, particularly as the lateral velocity was increased. Several vehicles exhibited no system intervention, and others exceeded the maximum excursion limit as the lateral velocity was increased. Subsequent testing for six model year 2019 vehicles revealed similar findings, with half of the vehicle models tested showing instances of no LKA response even at 0.2 m/s (0.7 ft./s).

Since the Agency's analysis showed that most fatal crashes identified in its study were on roadways having shoulder widths that exceeded the current Euro NCAP test excursion limit of 0.3 m (1.0 ft.), NHTSA expressed in its March 2022 RFC notice that adopting the Euro NCAP criterion may provide sufficient safety benefits. However, the Agency also requested comment on whether an even smaller excursion limit may be more appropriate to account for crashes occurring on roads with limited shoulder width.

Summary of Comments

Inboard Lane Line Tolerance

Many commenters were in favor of harmonizing with Euro NCAP's current LSS test protocol but did not specify

[401] For this testing, one trial was conducted per test condition (*i.e.,* combination of lane line type, lateral velocity, and departure direction).

[402] Tanaka, S., Mochida, T., Aga, M., & Tajima, J. (2012, April 16). Benefit Estimation of a Lane Departure Warning System using ASSTREET. *SAE Int. J. Passeng. Cars—Electron. Electr. Syst.* 5(1):133–145, 2012, *https://doi.org/10.4271/2012-01-0289.*

[403] For the Agency's research, the lateral velocity of the SV's approach towards the lane line was increased from 0.1 m/s to 1.0 m/s in 0.1 m/s increments (0.3 ft./s to 3.3 ft./s in 0.3 ft./s increments).

[404] At the time of testing, an older version of Euro NCAP's LSS test procedure stipulated a lane keep assist assessment criterion of 0.4 m (1.3 ft.) for the maximum excursion over the inside edge of the lane marking. European New Car Assessment Programme (Euro NCAP). See *Assessment Protocol—Safety Assist, Version 7.0* (2015, November).

[405] Wiacek, C., Forkenbrock, G., Mynatt, M., & Shain, K. (2019), Applying lane keeping support test track performance to real-world crash data. *26th International Technical Conference for the Enhanced Safety of Vehicles,* Eindhoven, Netherlands. Paper Number 19–0208.

whether they also found the lack of inboard lane line tolerances specified in these procedures for both passive and active safety technologies to be appropriate.[406]

When comparing inboard lane line tolerances for LDW and LKA system activation, Advocates suggested the tolerance for LKA should be tighter than that for LDW, since LKA involves automatic intervention whereas LDW relies on human reaction, which inherently introduces delays. In contrast, FCA suggested that the activation tolerance prior to lane markings for LKA should be wider than for LDW, since LKA ''is more accepted by drivers due to fewer activations'' and ''LKS systems need to deal with actuation latencies of steering and/or braking systems.'' Rivian agreed with FCA that the LKA tolerance should be slightly higher for LKA than for LDW, since LKA systems can have a ''dynamic activation range based on lateral velocity toward the line and may activate later than this range depending on the speed of the vehicle.''

Auto Innovators suggested a defined inboard lane line tolerance, requesting that the current protocol value, 0.75 m (2.5 ft.), be used. The group explained that this will allow the driver ample time to intervene prior to the LKA intervention. They also noted that if the warning was forced to be issued closer to the lane line, it would become redundant with the active safety technology and would no longer provide the driver time to respond.

Maximum Excursion Limits

The Agency also received comments addressing the maximum excursion limits permissible for LKA interventions and/or LDW alerts. ASC, Aptiv, Auto Innovators, BMW, Intel, Tesla, and Toyota supported an excursion limit of 0.3 m (1.0 ft.) over the inboard lane line for both LDW and LKA assessments instead of the 0.4 m (1.3 ft.) limit initially proposed by NHTSA for LKA. Auto Innovators and Toyota added that this limit was justified based on NHTSA's 2018–2019 CISS data, which showed that most road departure crashes occurred when the departure distance from the lane marking was more than 0.3 m (1.0 ft.), providing reason not to reduce the excursion limit. Auto Innovators added that this excursion tolerance should be adequate to avoid crashes on road shoulders and limit interventions. Tesla stated that adopting a 0.3 m (1.0 ft.) excursion limit was sufficient to ensure that LKA systems would ''maintain tight control over vehicle lateral motion in lane,'' and suggested that the Agency maintain this limit for LDW as well.

IDIADA stated that the Euro NCAP test protocol stipulates that the excursion limit (*i.e.,* 0.3 m (1.0 ft.)) is referenced from the outer face of the tire to the inner edge of the lane marking. Since the lane markings are typically 0.2 m (0.7 ft.) wide, this allows a vehicle to have 0.1 m (0.3 ft.) of actual excursion after the lane marking. The laboratory stated that the tolerance is provided to improve consumer acceptance, essentially preventing system designs that are overly intrusive such that they constantly correct vehicle trajectory, but is also limited enough to not cause safety concerns. BMW's comments closely aligned with those of IDIADA. The automaker explained that, with a 0.3 m (1.0 ft.) excursion limit, intrusion onto the shoulder (or into another lane) would be 0.15 to 0.2 m (0.49 to 0.66 ft.) given lane markings are typically 0.1 to 0.15 m (0.33 to 0.49 ft.) wide, which should be adequate to avoid collisions with other obstacles. Furthermore, BMW asserted that reducing the excursion limit would require earlier system interventions at higher lateral speeds, which could increase the number of interventions overall and lead to reduced acceptance.

Intel specifically remarked that the 0.3 m limit was appropriate for LDW (in addition to LKA) ''since it covers the flat and elevated road edges as a lane border.'' Other commenters supported a 0.3 m (1.0 ft.) excursion limit specifically for LKA testing. Honda commented that a 0.3 m (1.0 ft.) excursion limit was appropriate for LKA, acknowledging that the ability of a system to mitigate lane departures in the real world is associated with the amount of allowable excursion. HATCI and DENSO also recommended a 0.3 m (1.0 ft.) excursion limit for LKA, with DENSO remarking that LKA may become ''cumbersome'' when a driver must intentionally move into another lane to avoid an obstacle because of lane and tire widths if a lower limit is allowed. GM expressed support for the 0.3 m (1.0 ft.) limit for LKA, stating that such a tolerance was sufficient to prevent roadway departures even when shoulder width is limited. However, for LDW, the automaker commented that such alerts should not be required until after the referenced excursion limit is reached to minimize nuisance alerts and subsequent system deactivation.

Bosch supported an outboard excursion limit of 0.3 m (1.0 ft.) for LDW alert issuance and 0.4 m (1.3 ft.) for maximum vehicle excursion during LKA intervention but also supported aligning with Euro NCAP's tolerances. ZF Group commented that the proposed 0.4 m (1.3 ft.) excursion limit for LKA should be sufficient in most situations, but for construction areas or those with limited shoulder width, the company proposed that LKA should be disabled, and the driver should subsequently be notified.

For LDW, Rivian suggested a maximum range of 0.3 m (1.0 ft.) over the lane line and 0.15 m after crossing the outer edge of the lane line as an ''acceptable activation range,'' as this would allow for different LDW warning settings (*e.g.,* early, normal, late). The automaker further commented that 0.3 m (1.0 ft.) is an appropriate excursion tolerance for LKA and LDW testing involving lane markings, but not a road edge. Also specific to road edge testing, Rivian suggested a reduced excursion limit of 0.1 m (0.33 ft.) for systems offering road edge detection. For systems not designed for road edge detection, the company suggested that if such systems are able to meet the 0.1 m (0.33 ft.) excursion limit, they should score higher than those that can only meet the 0.3 m (1.0 ft.) limit. Similarly, Advocates suggested that different excursion limits are warranted for different conditions, stating that Euro NCAP proposes a tighter limit for their road edge detection test compared to their single line lane tests. Advocates also noted that the maximum excursion limit should be based on analysis of real-world data, including crashes and road dimensions, in the U.S. Like other commenters, MEMA suggested that the Agency should focus on road edge detection if it desires a ''more targeted approach'' for the excursion limit.

CAS stated that a 0.3 m (1.0 ft.) excursion limit over the lane marking, as specified by Euro NCAP, was ''unacceptable,'' and recommended that the limit ''be reduced to zero to account for roads with limited or no shoulder width.'' The group noted that lane markings serve to promote safety and often denote the edge of the road, such that an excursion of any extent over a lane line may induce a crash with other vehicles, pedestrians, or cyclists, or cause the vehicle to exit the roadway.

In response to NHTSA's notation that the 0.3 m (1.0 ft.) excursion limit is a Euro NCAP requirement, FCA stated that it supported harmonization efforts with other rating programs in general

[406] Euro NCAP specifies that vehicles must issue an LDW alert prior to −0.2 m (0.7 ft.) from the inner lane edge for all lateral velocities up to at least 1.0 m/s (3.3 ft./s) to receive credit for an LDW system under the Human Machine Interface (HMI) category. It does not dictate an inboard lane line tolerance prior to which an LDW system may *not* issue an alert. Similarly, Euro NCAP does not prohibit LKA interventions from occurring too early.

but cautioned NHTSA to consider the effect on U.S. driver acceptance when considering a reduced excursion limit. The manufacturer suggested that any further reduced excursion limit may translate to a more intrusive system, resulting in a reduction in acceptance. Finally, TRC did not recommend a specific tolerance, but suggested that the tolerance adopted for LKA should also be adopted for LDW.

Response to Comments and Agency Decisions

Inboard Lane Line Tolerance

Based on the lack of definitive data regarding the most appropriate LDW alert warning time, and no clear consensus among commenters, the Agency has decided to retain its current 0.75 m (2.5 ft.) inboard lane line tolerance for LDW activation during LKA testing at this time. This tolerance will also apply to LKA engagement. Neither an LDW nor LKA intervention shall occur when a vehicle is farther than 0.75 m (2.5 ft.) from the inboard edge of the lane line. NHTSA reasons this approach will allow manufacturers the flexibility to design LDW and LKA systems to better identify when a driver is actively steering and engaged in the driving task to suppress the alert and intervene when the turn signal is not in use.

NHTSA acknowledges that many commenters responding to the March 2022 RFC supported the whole or partial adoption of Euro NCAP's LSS test protocol. In accordance with the BIL mandate, NHTSA seeks to align with other global rating programs whenever it is appropriate to do so. However, as previously noted, there is no inboard lane line tolerance provided for either Euro NCAP testing or for EU regulations regarding lane keeping systems. Consequently, if enabled, these systems may activate at any time prior to an excursion limit beyond the lane line. There is a need to better define when LDW or LKA should be suppressed, and an open-ended tolerance will not solve the issue of nuisance alerts or inappropriate intervention.

NHTSA also has concerns with the initially proposed inboard tolerance of 0.3 m (1.0 ft.). The Agency is still of the opinion that a tightened inboard lane line tolerance would likely deter the excessive alerting currently driving consumer dissatisfaction. However, based on the comments received, the Agency could also limit a manufacturer from issuing a legitimate alert regarding an impending/ongoing lane departure, or initiating an intervention, at an appropriate time. Based on these concerns, the Agency has decided to retain its current 0.75 m (2.5 ft.) inboard lane line tolerance for LDW activation during LKA testing at this time. NHTSA may again consider tightening this tolerance in the future once system confidence and accuracy improves or as additional lane keeping systems (*i.e.,* LCA) are introduced.

Maximum Excursion Limit for Vehicles During LKA Intervention

The Agency received many comments in support of a −0.3 m (−1.0 ft.) excursion limit from the inboard lane line edge for both LDW issuance and LKA intervention. In addition to commenter support, the Agency notes that adoption of this maximum LKA excursion limit will harmonize NHTSA's NCAP test requirement with Euro NCAP's, meeting one of the Agency's primary objectives.[407] As such, NHTSA will move forward with the adoption of a maximum vehicle excursion of −0.3 m (−1.0 ft.) for its LKA test in NCAP.

The Agency agrees that the ideal amount of allowed vehicle excursion beyond a lane marking would be zero, as CAS suggested. However, NHTSA is concerned that requiring the vehicle to remain solely between the lane lines, particularly at higher lateral velocities, may result in a potential increase in nuisance alerts and/or excessive activations, which could result in greater system deactivation. IDIADA and BMW noted that an excursion limit of −0.3 m (1.0 ft.) from the inboard lane line edge translates to anywhere from 0.1 m (0.3 ft.) to 0.2 m (0.6 ft.) of vehicle encroachment into the adjacent lane or shoulder. Given this, combined with the data supplied by Auto Innovators and Toyota showing that the departure distance from the lane marking for most road departure crashes was greater than 0.3 m (1.0 ft.), NHTSA agrees with GM that this excursion allowance should be sufficient to prevent roadway departures, even on roads where shoulder width is limited. NHTSA also reasons that the adopted approach should balance consumer acceptance difficulties with real-world benefit.

Further, NHTSA's model year 2017 and 2019 LKA testing demonstrated that compliance with this excursion limit is achievable, even up to lateral speeds of 0.6 m/s (2.0 ft./s). Specifically, two of the total 11 vehicles tested were able to comply with an LKA excursion limit of −0.3 m (−1.0 ft.) at least once in a 0.6 m/s (2.0 ft./s) test. Three additional vehicles fell between the −0.3 m (−1.0 ft.) and −0.4 m (−1.3 ft.) limit at least once at this upper lateral velocity, demonstrating that some vehicles came within inches of achieving satisfactory performance during a trial.

Finally, NHTSA will adopt the same maximum excursion limit of −0.3 m (−1.0 ft.) over the inboard lane line for LDW alert issuance. As previously discussed, for vehicles with LKA, LDW will become part of an expected LKA activation. Thus, maximum excursion tolerance of these lane keeping technologies will match, as TRC requested. NHTSA notes that the current LDW test procedure allows activation of LDW within the same tolerance range adopted (0.75 m to −0.3 m, or 2.5 ft. to −1.0 ft.).

8. LDW Alert Modalities and Requiring an LDW Alert During LKA Intervention

As part of NHTSA's March 2022 RFC notice, the Agency sought comment on whether it should award LDW credit to vehicles equipped with LDW systems that provide a passing alert, regardless of the alert type issued, or whether there are certain LDW alert modalities (such as visual-only warnings) that it should consider unacceptable when determining whether a vehicle meets NCAP's performance test criteria. NHTSA also asked whether it should consider only certain alert modalities (such as haptic warnings) acceptable because they may be more effective at re-engaging the driver and/or have higher consumer acceptance. Finally, NHTSA questioned whether it was necessary to require that an LDW alert, designed to re-engage the driver, be issued when an LKA system is activated, since these systems are designed to intervene and provide steering and/or braking to prevent unintentional lane departures (*e.g.,* when a driver is distracted).

The Agency's questions stemmed in part from concerns (similar to those raised for FCW) that LDW systems providing only a visual alert may be less effective than systems utilizing other alert modalities (*i.e.,* auditory or haptic) in medium or high urgency situations.[408] NHTSA notes that results from a large-scale telematics-based study conducted by UMTRI on LDW usage[409] raised questions as well. As

[407] It should be noted that the LDW excursion limit in Euro NCAP is −0.2 m (−0.7 ft.).

[408] Lerner, N., Robinson, E., Singer, J., Jenness, J., Huey, R., Baldwin, C., & Fitch, G. (2014, September), *Human factors for connected vehicles: Effective warning interface research findings* (Report No. DOT HS 812 068), Washington, DC: National Highway Traffic Safety Administration.

[409] Flannagan, C., LeBlanc, D., Bogard, S., Nobukawa, K., Narayanaswamy, P., Leslie, A., Kiefer, R., Marchione, M., Beck, C., and Lobes, K. (2016, February), *Large-scale field test of forward collision alert and lane departure warning systems*

part of this effort, researchers investigated driver acceptance of LDW alerts in vehicles providing auditory-only alerts and in vehicles where the driver had the option to select between either an auditory or haptic alert. When the latter was available, the study found the driver selected the haptic warning 90 percent of the time; when this setting was chosen as the preferred alert setting, the driver turned the LDW system 'off' 38 percent of the time. Thus, the LDW system was not providing alerts. For the system that only issued an auditory warning with no option for haptic alerts, LDW functionality was turned 'off' 71 percent of the time. Based on the findings from UMTRI's research, NHTSA tentatively concluded that haptic alerts improve driver acceptance of LDW systems.

The Agency's December 2015 notice also addressed the issue of drivers choosing to disable their vehicle's LDW system.[410] In that notice, the Agency referenced several studies finding that LDW system disablement arose from frequent false activations. In response to these findings and concern over diminished safety benefits due to consumer dissatisfaction with LDW systems, the Agency solicited comment at that time as well on whether it should award NCAP credit only to LDW systems that issue haptic alerts. NHTSA opined that haptic alerts may be viewed as less of a nuisance by consumers, offering greater consumer acceptance compared to auditory alerts and potentially improving the effectiveness of LDW alerts because of less frequent system disengagement. However, commenters responding to the December 2015 notice generally did not support a requirement for a specific warning type, with most suggesting the Agency should not require a specific LDW alert modality to promote system availability across a larger number of vehicles and afford flexibility to manufacturers so they may optimize human-machine interface (HMI) designs for a growing suite of ADAS.

Summary of Comments

Similar to FCW and BSW, comments received on the allowable alert types for LDW systems were varied. Some respondents recommended the Agency impose no restrictions on alert types, a few recommended certain alerts should be unacceptable, several requested additional requirements for certain alert modalities or multi-modal modalities, and others promoted a specific alert type. Commenters also provided mixed recommendations on which type of alert, if any, should be issued in the event a vehicle's LKA system intervenes to prevent a lane departure.

Allow All Alert Types

Those in favor of allowing any type of LDW alert during Agency testing included Auto Innovators, Honda, IDIADA, HATCI, Intel, Rivian, Bosch, and an anonymous public commenter.

Auto Innovators, citing a lack of evidence that one alert type is more effective than another, stated that NHTSA should pursue a technology-agnostic approach to allow manufacturers to pursue designs preferred by their customers. A public commenter agreed. Rivian stressed that the alert type is often a subjective preference and although many drivers prefer haptic warnings, not all do, and those that don't should be able to purchase vehicles that have alerts suiting their preference.[411] Further, the automaker opined that NHTSA should award credit for any form of alert since all modalities should increase the possibility that the driver will become reengaged.

Like Auto Innovators, IDIADA stressed the importance that NHTSA be flexible with respect to alert type(s) so that manufacturers have greater opportunity to provide real-world benefits, particularly for a technology like LDW, which generally has lower consumer acceptance. HATCI expressed similar sentiments, stating that ''[current] flexibilities allow industry to optimize and adjust the alerts based on the multitude of ADAS technology installed, the interaction between the technologies, and research and development findings.'' The manufacturer warned that restricting system alerts to specific modalities may limit future alert strategies and have unintended consequences as ADAS technology evolves and other systems are introduced. Auto Innovators suggested that the Agency should encourage manufacturers to develop the most effective systems, which may involve a suite of multimodal alerts and not simply a single modality type. Similarly, Honda noted that differences in effectiveness and consumer acceptance stemming from the use of various alert approaches cannot be captured based solely on alert modality and therefore restricting the alert types would not be justifiable. Intel stated that modality should not be restricted because credit should be based on alert effectiveness (*i.e.,* an alert resulting in passing performance is effective, regardless of the alert modality type). Finally, noting that system reliability is a factor in consumer acceptance of LDW systems, not just warning type, Bosch also remarked that any alert modality type should be accepted for credit.

Restrict Alert Types

A few commenters recommended that the Agency award credit to certain alert types and not others. Aptiv and ASC encouraged the Agency to restrict auditory alerts to improve consumer acceptance and usage. Both entities cited UMTRI's findings (referenced in the March 2022 RFC notice and again above) that 90 percent of test participants opted for haptic alerts over auditory alerts, and when an auditory alert was the only option, the LDW system was turned off 71 percent of the time.

Add Requirements to Visual Alerts or Require Multiple Modalities

Other commenters suggested that certain alert types may be acceptable, but only if they meet certain requirements or are paired with a second alert modality.

DRI suggested that the Agency discontinue the acceptance of visual alerts, or alternatively, prescribe minimum characteristics for such alerts (*i.e.,* size, color, brightness, location) to help gain the driver's attention. The test laboratory contended that in many LDW systems, the visual alert, which is typically a telltale in the instrument panel that changes color, is ''too small,'' appears in ''non-attention-capturing colors (*e.g.,* white)'', or is otherwise inconspicuous. The company also stated that a distracted driver's gaze would likely not be forward-looking, such that a visual alert located in the instrument panel would not be helpful like an auditory or haptic alert would be to capture the driver's attention. DRI further stated that a visual LDW alert is often intended to be an indicator to a driver regarding the ''real'' alert, which may be auditory or haptic, such that it serves to convey visually to the driver why they are hearing or feeling, rather than the visual alert being a warning in and of itself. As such, the laboratory opined that visual LDW alerts are not effective at alerting the driver unless they are combined with an auditory or haptic alert. Toyota and AAA expressed similar comments.

Toyota noted that a visual-only LDW alert may not be effective for a distracted or drowsy driver. Accordingly, the manufacturer recommended that an LDW system

(Report No. DOT HS 812 247), Washington, DC: National Highway Traffic Safety Administration.

[410] 80 FR 78522 (Dec. 16, 2015).

[411] *https://www.regulations.gov/comment/NHTSA-2021-0002-4050.* See citation 4.

should be required to have two different warning modalities—visual plus either haptic or auditory, as research has shown that these warning types elicit essentially equivalent drivers' response times.[412] AAA recommended that any visual alert also be accompanied by a haptic alert. GM contended that multimodal (*e.g.,* visual plus directional auditory or directional haptic) alerts are necessary for 'imminent crash alerts', but visual-only alerts are acceptable for 'cautionary crash alerts' to limit instances of drivers turning off LDW systems due to alert annoyance. That said, the manufacturer opined that credit for LDW alerts in NCAP testing should only be provided for multimodal alerts that include both a visual and haptic or auditory alert. Like DRI, GM also suggested that the Agency impose additional requirements for visual alerts, recommending that visual alerts should not only ''help explain the alert to the driver (including alert criticality)'' but should also ''be positioned such that they draw the driver's attention to the general direction of the crash threat.'' This directional requirement, referenced previously, was also suggested for haptic and auditory components of multimodal alerts.

Other commenters also favored additional requirements for visual alerts. One anonymous commenter recommended that such alerts be directly visible (in the driver's line of sight) without requiring the driver to look down to notice the indicator (*e.g.,* in a heads-up display, instrument cluster that is fairly high on the dashboard, etc.). Similar to Toyota and AAA, however, the commenter stated that visual alerts presented outside of drivers' line of sight could receive credit if a separate warning type (*e.g.,* auditory or haptic) is also provided. FCA held the same view. The manufacturer, which, like others, also mentioned higher effectiveness and improved customer satisfaction for audio-visual and haptic-visual alerts, suggested that the visual warning should appear in the driver's direct line of sight for dual-modality alerts to receive credit.

Haptic-Only Alerts

With respect to haptic warnings specifically, FCA commented that the Agency should not limit credit solely to haptic warnings, as consumer acceptance of LDW systems in general has improved in recent years because of improved line detection capability and overall system performance.

Tesla recommended that NHTSA award credit to systems that issue haptic alerts, regardless of whether other alert modalities are provided. The manufacturer referenced research from the University of Michigan Transportation Research Institute (UMTRI) that cited drivers' preference for haptic alerts.[413] Similarly, IDIADA suggested that since haptic warnings have higher consumer acceptance rates, they may also offer higher real-world benefits if such systems are less prone to deactivation. Advocates favored requiring haptic alerts (to promote their adoption) if they improve driver acceptance, as NHTSA stated in the RFC Notice.[414] The group suggested that automakers would still be able to implement additional human-machine interface (HMI) designs if they chose to. ZF Group suggested that the Agency award credit to haptic seatbelt warnings, as their research has shown them to be more effective than other alternatives.

GM stated that the Agency should award additional credit to their Safety Alert Seat (SAS) vibration alerts, and to other haptic alerts that can support equivalent rationale.[415] While TRC noted testing concerns with haptic alerts, explaining that alert flags for haptic alerts are sometimes difficult to collect due to sensor noise, especially for alerts issued from the seat or steering wheel, GM stated that SAS vibration alerts are triggered simultaneously with an auditory alert by the same ADAS signal and can be detected by various means during testing (*e.g.,* voltage readings, vibration sensors, auditory microphone, etc.). GM stated SAS alerts allow non-visual crash alerts to be detected by hearing-impaired drivers, thus improving accessibility. Further, the manufacturer noted that in a large-scale telematics-based study funded by NHTSA, SAS alerts, relative to auditory alerts, were preferred by drivers and also increased usage of the LDW system.[416] More specifically, for vehicles with SAS vibration alerts, drivers left LDW on 62 percent of the time, compared to 29 percent of the time for vehicles offering only auditory alerts.

Weight Alert Credit Depending on Type

A few commenters suggested that different scores or ratings should be assigned to the various alert modalities. Rivian suggested that higher scores be assigned to systems proven to be more effective. Specifically, it recommended that the Agency should increase ratings for vehicles having alerts comprised of additional modalities beyond a visual cue but stated that vehicles offering visual-only alerts should not be penalized with a test failure. Likewise, ZF Group also recommended that NHTSA provide higher scores for alert types that reduce driver reaction time compared to other types. Along similar lines, citing both increased effectiveness and consumer acceptance for haptic alerts, one public commenter suggested that NHTSA reserve full credit for systems that offer haptic alerts, or which combine haptic alerts with visual or auditory warnings, and award partial credit to those systems that issue only a visual or auditory alert.

Other General Topics on LDW Alerts

The Agency received a few other general comments surrounding LDW alerts. One public commenter suggested that an LDW alert issued simultaneously with an LKA intervention should also receive credit. GM stated that NHTSA should only assess LDW functionality in cases where LKA fails to keep the vehicle in the lane per the test procedure requirements (regardless of whether the Agency maintains LDW as a separate assessment or integrates LDW assessments into an LKA test procedure). In such cases, the automaker recommended requiring a visual and non-visual alert, as mentioned previously.

Advocates recommended that the Agency expedite additional research on HMI to identify alert modalities and designs that are most effective at reengaging the driver and ''eliciting a safe, timely, and accurate response.'' The organization suggested there may be further benefit realized from standardizing alerts, especially for drivers that use multiple vehicles. Contrary to this, HATCI favored flexibility with respect to alert types. The automaker mentioned that it supports adopting processes and/or performance-based methods developed by organizations such as SAE's Human Factors committee to evaluate alert effectiveness to not limit future alert strategies for new ADAS technologies.

Requiring an LDW Alert During LKA Intervention

Several commenters, including AAA, AASHTO, Advocates, CAS, GM, Honda, Intel, ZF Group, and a public commenter, agreed that the Agency should specify that an LDW alert must be issued even when LKA is activated,

[412] Okuma et al. ''A Study of Tactile Driver Interface using Seat Vibrations.'' Transactions of Society of Automotive Engineers of Japan. Vol. 39, No. 6, November 2008, p.59–54.

[413] 87 FR 13460.

[414] 87 FR 13460.

[415] *https://www.regulations.gov/comment/NHTSA-2021-0002-3856.* See Appendix 2 for rationale and supporting data.

[416] DOT HS 812 247.

mainly because they reasoned that re-engaging the driver was important. CAS suggested that an LDW alert could inform the driver that either the LKA system has failed to respond, or the intervention required exceeded the system's capabilities such that the driver's response is required. AASHTO commented that the alert would serve to let the driver know the LKA system was intervening and that the vehicle was not altering its trajectory due to weather or road conditions. Similarly, AAA opined that the alert could serve to ensure the system intervention was not misinterpreted as a system malfunction. Intel requested some type of warning, explaining that it is preferable for a driver to become aware and respond during a lane departure event. IDIADA expressed that it was appropriate to issue an LDW alert in ''safety critical scenarios,'' [417] but not for other LKA interventions.

Honda specifically mentioned that the system should issue a visual alert to best balance consumer acceptance and system effectiveness (*i.e.,* safety benefits). That said, the automaker, along with many others noted below, asserted that LKA systems inherently provide a haptic alert when they move the steering wheel to actively prevent lane departures. GM also recommended issuance of a visual alert to limit driver nuisance and subsequent system deactivation. The manufacturer, like others, asserted that it may be beneficial to let the driver know that the LKA system has been activated, but this should be communicated via a visual alert, and additional non-visual alerts should not be required unless the LKA intervention is insufficient to prevent the driver from crossing the lane line. In such instances, GM recommended that a flashing visual alert should be used, along with an auditory or haptic alert. ZF Group suggested that an alert should be issued to the driver when LKA is activated, but that this alert should be different than an LDW warning to limit driver confusion.

Many other commenters, including Auto Innovators, BMW, Bosch, FCA, HATCI, Rivian, Subaru, Tesla, and Toyota, objected to NHTSA requiring an LDW alert in the event of LKA activation. Bosch asserted, similar to Honda, that an additional LDW alert would be redundant as a warning to the LKA intervention. Similarly, Rivian explained that the steering and/or braking from the LKA intervention effectively alerts the driver to the fact they are drifting from their lane. The company further stated, and Toyota agreed, that LDW alerts should only be issued to warn the driver if the LKA system fails to prevent the vehicle's departure from the lane. Toyota, Tesla, and Auto Innovators maintained that frequent LDW alerts can be annoying to drivers, with Tesla adding this is especially true for those that may actually be alert and intentionally drifting to prevent a hazard or for an upcoming turn. As such, the three commenters asserted NHTSA must find the right balance between LDW and LKA to realize the highest benefits.

Other commenters, including BMW, FCA, and Subaru, also stated that an LDW alert is not needed if LKA operates. Subaru and BMW, along with Auto Innovators, indicated, like Rivian, that steering assistance (Subaru) and/or braking (BMW) from an LKA system should serve as an effective alternative to a haptic LDW alert. Subaru pointed to Euro NCAP's 2016–2018 LSS protocol, which recognized LKA steering as a replacement for an LDW haptic alert, and BMW directed the Agency to EU regulations, which also aligned.[418]

Response to Comments and Agency Decisions

Many of the comments submitted to the Agency's most recent RFC notice on acceptable LDW alert types echoed those received previously in response to the Agency's 2015 RFC notice. Namely, most respondents were concerned about consumer dissatisfaction with LDW alerts. Thus, they favored an alert requirement that is not prescriptive with respect to the type of alert modality so that alerts may be optimized for consumer preferences. Many also cautioned the Agency that requiring an LDW alert during an LKA intervention may exacerbate existing consumer acceptance issues for LDW and LKA systems.

Considering the comments received, the Agency has decided to require a visual LDW alert for the Agency's LDW/LKA tests; the LKA intervention itself will serve as a secondary haptic alert component. In addition, at the manufacturer's option, other auditory or haptic alert signals may be provided to the driver to warn of an impending lane departure. To pass the LDW requirements for the LKA tests, no alert component may be issued before the lateral position of the vehicle, represented by a two-dimensional polygon,[419] is within 0.75 m (2.5 ft.) of the inboard edge of the lane line (*i.e.,* the line edge closest to the vehicle when the lane departure maneuver is initiated), and the visual LDW alert component and haptic LKA intervention must be issued before the lane departure exceeds 0.3 m (1 ft.). In addition, the visual alert must be issued prior to, or concurrent with, the start of the LKA intervention.

NHTSA generally agrees with commenters who stated visual alerts, which tend to be more inconspicuous, may best balance consumer acceptance and, thus, system effectiveness (*i.e.,* they limit driver annoyance and subsequent system deactivation) at low lateral velocities when the LKA system should be capable of providing the correcting action. In these situations, visual alerts are informational as they can convey to the driver that the LKA system is intervening. As some respondents stated, without this confirmation, the driver may not know whether the system is malfunctioning or whether some other condition, such as poor weather or road conditions, is altering the vehicle's path. This rationale serves as the basis for a visual alert component requirement. However, the Agency also agrees NHTSA should not dictate additional specifications for the required visual alert beyond the timing requirements mentioned previously. The Agency does not find it necessary to impose additional visual alert requirements, such as those relating to color, brightness, or location as requested by DRI and GM, because it does not wish to limit design flexibility. Additionally, manufacturers may choose to issue a visual alert that becomes escalatory (*e.g.,* flashing) in nature after some point, as GM suggested, but this is not required.

Additionally, NHTSA will consider the LKA intervention itself to be a haptic alert, as several commenters requested. An LKA intervention that is clearly related to the lateral control of the vehicle and is noticeable by the driver (*e.g.,* notable heading correction that prevents the vehicle from exceeding the allowable lateral deviation over the inboard edge of the lane line (*i.e.,* 0.3 m (1 ft.)), such as that ensuing from steering and/or braking, sufficiently provides feedback to a driver such that

[417] IDIADA defined ''safety critical scenarios'' as lane departure scenarios with a risk of road departure or a collision with other vehicles.

[418] Commission Implementing Regulation (EU) 2021/646 of 19 April 2021 laying down rules for the application of Regulation (EU) 2019/2144 of the European Parliament and of the Council as regards uniform procedures and technical specifications for the type-approval of motor vehicles with regard to their emergency lane-keeping systems (ELKS) [2021] OJ L133/31, § 3.5.3.1.2.

[419] The two-dimensional polygon is defined by the vehicle's axles in the X-direction (fore-aft), the outer edge of the vehicle's tire in the Y-direction (lateral), and the ground in the Z-direction (vertical).

it meets the requirements for a haptic LDW alert. The decision to consider an LKA steering intervention to satisfy the requirements for an LDW haptic alert aligns with the LDW alert requirements outlined in Euro NCAP's LSS test protocol for its LDW tests. This decision also reflects the Agency's agreement with respondents who expressed that visual LDW alerts are not effective at eliciting a timely response from an inattentive driver, when necessary, unless they are combined with an auditory or haptic alert. The Agency maintains this position regardless of whether a visual alert is positioned in such a way that it is directly in the driver's [typical] line of sight.

While the Agency has prescribed a visual alert component to provide information to the driver and a haptic alert component in the form of a notable heading correction, it will not stipulate the modality (*i.e.,* auditory versus haptic) for any additional LDW alert components the manufacturer may wish to include. A separate haptic or auditory LDW alert can serve to re-engage the driver in situations where either (1) the LKA system has failed to respond or (2) the system may be responding, but the intervention that is necessary may exceed the LKA system's capabilities such that the driver's response may also be required. Toyota's research showed that both warning types elicit essentially equivalent response times from drivers, suggesting it is not necessary for NHTSA to be overly prescriptive at this time. NHTSA also agrees with Honda's assertion that differences in effectiveness and consumer acceptance stemming from the use of various alert approaches cannot be captured solely based on alert modality and therefore restricting acceptable alert types would not be justifiable. The Agency also reasons there is merit to Bosch's comment that system reliability also factors into consumer acceptance of LDW systems, not just warning type, and agrees with Toyota, Tesla, and Auto Innovators that it is necessary to find the right balance between LDW alerts and LKA interventions to realize the highest safety benefits. Thus, based on the lack of consensus on best practices that optimize consumer acceptance and system effectiveness, it is the Agency's belief that vehicle manufacturers are best suited to optimize LDW alerts for this purpose. By allowing manufacturers to choose whether to issue a separate auditory or haptic LDW alert during an LKA intervention (instead of simply relying on the LKA intervention itself), it will help to abate current consumer acceptance issues for LDW and LKA systems, a concern cited by many commenters.

NHTSA will also refrain from prescribing specifications (*e.g.,* type, location, decibel level, etc.) for any additional LDW alert components at this time, as GM requested. Additional research is needed to gauge how certain haptic alert types/locations (*e.g.,* seat belt tug, seat/steering wheel vibration) and auditory alert specifications (*e.g.,* decibel level) alter system effectiveness before requiring further standardization. Should research data become available that better describes desirable (or, alternatively, undesirable) characteristics of auditory or haptic alert components, the Agency will consider adopting specifications for these additional modalities. Similar considerations will be made for the required visual alerts. NHTSA will consider being more prescriptive for visual alerts if new data suggests there is a safety need.

For haptic alerts specifically (including the LKA intervention and any additional haptic alerts), NHTSA will require that manufacturers provide additional information to NCAP's test laboratories to detail how to accurately record haptic signals without incurring damage to the test vehicle. Manufacturers who choose not to provide laboratories with such information or opt to provide information that is deemed insufficient for data collection, may risk not passing the LKA tests if the laboratories are unable to capture the alert flag for a haptic signal to ensure it meets the lane line requirements. This additional requirement is necessary because alert flags for haptic alerts may be difficult to collect due to sensor noise, particularly for alerts issued from the vehicle seat or steering wheel. Additionally, this additional requirement will not hinder a vehicle manufacturer's ability to continue to optimize alerts for current and future technologies as they see fit.

Finally, the Agency is concerned about the limited effectiveness and low consumer acceptance of LDW and its potential impact on the acceptance of LKA, which has demonstrated higher system effectiveness. However, LDW has merit and the updates the Agency is making for its lane keeping tests will provide sufficient restrictions to ensure nuisance LDW alerts are reduced during real-world driving. NHTSA's strategy will ensure higher real-world benefits for lane keeping systems overall while also providing manufacturers with the flexibility to optimize alerts for consumer preferences and future alert strategies for new ADAS technologies, which many commenters requested.

9. User-Configurable Settings for LDW and LKA Tests

Currently, the Agency requires at least one warning time setting to meet the test procedure criteria for LDW testing. NHTSA did not specifically request comment on the appropriate settings to use for LDW and/or LKA during its NCAP testing, but the Agency received several comments on this topic.

Summary of Comments

For LKA systems with adjustable settings, Honda recommended that the Agency evaluate LKA using the middle setting, as it is ''the best compromise'' to properly assessing system capabilities. HATCI proposed that NHTSA utilize the default system settings during testing. The commenter explained that their research has shown that most Hyundai and Kia customers do not change ADAS settings after purchasing a new vehicle and that changing the settings for testing purposes would likely not be most representative of most real-world driving situations. The automaker recommended that the Agency conduct a similar, fleet-wide study, and use those findings for system settings to guide future test procedural changes.

One public commenter suggested that LDW and LKA systems should be required to be default 'ON' at the start of every trip. However, Auto Innovators suggested that the 'Default ON' requirement should be changed to 'Last saved setting' because 'Default ON' has low customer acceptance in Europe.

Response to Comments and Agency Decisions

Aligning with its decisions for FCW and BSW, the Agency has decided to set the timing for the LDW alert and LKA intervention to the middle (or next latest) setting (if adjustable) during its LDW/LKA evaluations, as previously shown in Figure 2. The Agency will not adopt the default setting for the LDW alert or LKA intervention, as HATCI requested. NHTSA concludes, similar to its earlier decision for FCW, that it is reasonable to expect that the setting most preferred by drivers would (or rather, should) be the default setting, and this setting should generally fall in the middle of the range of driver setting preferences that span either earlier or later alert settings. Further, NHTSA notes that these system setting configurations align with Euro NCAP's LSS test protocol. For LDW and LKA systems having only two settings, the Agency will select the later of the two settings to align with Euro NCAP's requirements. This test setting will meet

NHTSA's middle (or next latest) LDW/LKA setting requirement. Lane centering functions will also be set to 'Off' for all LDW and LKA tests in alignment with Euro NCAP's LSS test protocol.

Tests will also be conducted without cruise control (*i.e.,* conventional or adaptive cruise control) engaged. The longitudinal speed of the SV will be maintained through manual or robotic control. Since cruise control is designed to regulate a vehicle's longitudinal movement and there is no vehicle present in the forward path of the SV during NCAP's LDW/LKA tests, NHTSA does not expect the use of manual/robotic control or cruise control to affect how the SV's speed is maintained during a test trial. The Agency also does not expect that cruise control should impact the SV's lateral movement. That being said, NHTSA will conduct testing utilizing only one method of speed control to ensure that the performance of one vehicle system (LKA) is not affected in any way by the performance of another system (cruise control). As mentioned in the BSI discussion, testing with manual or robotic control in lieu of cruise control is appropriate since consumers may sometimes opt not to use a cruise control feature, particularly on non-highway roads.

Regarding the system settings upon ''key on,'' NHTSA will require that the lane keeping technologies (*i.e.,* LDW and LKA systems) appear 'Default ON' during each ignition/key cycle. While the Agency is not prohibiting a disabling function for lane keeping technologies in its NCAP evaluation, it is taking steps to reduce the false positive alerts and activations that prompt a driver to turn off the systems in the first place. Drivers should be able to adjust their system's settings to meet their personal preference instead of needing to disengage the system altogether.

10. Radius of Curvature

In its LSS Protocol, Euro NCAP specifies use of a 1,200 m (3,937.0 ft.) curve and a series of increasing lateral offsets to establish the desired lateral velocity of the SV towards the lane line it must respond to. In the proposed LKA tests in the March 2022 RFC notice, the SV, laterally offset from the center of its travel lane,[420] is driven at a steady velocity of 72 kph (44.7 mph). After a short period of steady-state driving, the SV driver (*e.g.,* robot or human input) initiates steering to follow a 1,200 m (3,937 ft.) radius curved path until the desired lateral velocity towards the lane line is achieved. The SV driver then releases the steering wheel. Preliminary NHTSA tests have indicated that use of a 200 m (656.2 ft.) curve radius provides a clearer indication of when an LKA intervention occurs when compared to the baseline tests performed without LKA, a process specified by the Euro NCAP LSS protocol. This is because the small curve radius allows the SV to establish the desired lateral velocity more quickly, requires less initial lateral offset within the travel lane, and allows for a longer period of steady state lateral velocity to be realized before an LKA intervention occurs. Given the findings from the Agency's testing, it sought comment on whether a 200 m (656.2 ft.) curve radius was more appropriate for inclusion in NHTSA's LKA test procedure than the 1,200 m (3,937.0 ft.) radius currently specified in Euro NCAP's protocol.

Summary of Comments

Agree With Adopting a 1,200 m (3,937.0 ft.) Radius of Curvature

Many commenters did not support a reduction in curve radius to 200 m (656.2 ft.) and preferred that the Agency adopt the 1,200 m (3,937.0 ft.) radius specified by Euro NCAP instead. Commenters voiced concerns over potential lack of system intervention, unwanted consequences (including a reduction in customer satisfaction and system acceptance), and real-world relevance.

Several commenters, including GM, Toyota, Honda, and Auto Innovators, stated that the steering input (*e.g.,* constant larger steering angle/torque, higher steering velocities/speeds) and lack of steady state lateral velocity (Auto Innovators) required to navigate a tight, 200 m (656.2 ft.) curve would appear as an intentional steering input, akin to a deliberate lane change or maneuver to avoid roadway hazards, not an unintentional drift from the lane, like LKA is designed to prevent. In such instances, GM and Auto Innovators asserted that LKA systems may not intervene if a small radius of curvature is used during NCAP testing. Likewise, Rivian mentioned that although a smaller curve radius may make it easier during testing to determine when LKA activates, ''a sharper attack angle'' toward the lane line may override the LKA system in some vehicles such that the Agency would not observe the LKA systems' true capabilities at higher lateral velocities. Conversely, Honda stated that adopting a small curve radius for NCAP assessments may encourage future LKA system designs to provide undesired steering intervention even in situations where drivers intentionally input higher steering velocities, such as when the driver is intentionally changing lanes without using the turn signal or during emergency avoidance maneuvers. The automaker further stated that adopting a smaller curve radius for testing purposes may have a negative effect on an LKA system's ability to perform its intended design function and on consumer acceptance, and in turn, safety benefits. Bosch and Subaru asserted that evaluating LKA operation in a smaller, 200 m (656.2 ft.) radius curve may prompt a more aggressive system intervention if the vehicle deviates from the lane than would typically be expected for normal LKA operation, resulting in reduced driver comfort, satisfaction, and overall acceptance of LKA. Further, Auto Innovators stated that a 200 m (656.2 ft.) curve radius may encourage system designs that issue an excessive number of alerts, particularly for intentional maneuvers. Auto Innovators indicated this would be in conflict with EU regulation 2021/646 on ELKS, which ''includes a requirement to 'minimize warnings and interventions for driver intended maneuvers.'' [421]

Several commenters, including FCA, suggested that the Agency align with Euro NCAP's radius of curvature because it better represents real-world situations. Specifically, Toyota referenced AASHTO's ''A Policy on Geometric Design of Highways and Streets'' manual and stated that the potential test condition (*i.e.,* navigating a 200 m curve at 72 kph) is at the limit of road design and therefore not appropriate.[422] Toyota provided a table showing that a design speed of 70 kph (45 mph) corresponds to a minimum radius of 203 m (666.0 ft.). HATCI stated that a 200 m (656.2 ft.) radius may be ''a startling input for a vehicle driving in a straight lane'' and seemed unrepresentative of a real-world situation. The group further asserted, like Honda, that such a change made to improve testing may have unintended

[420] The initial lateral offset (based on the vehicle width and the desired lateral velocity) of the vehicle from the centerline is to ensure the SV is being operated at the desired steady state lateral velocity before LKA and LDW operate.

[421] Commission Implementing Regulation (EU) 2021/646 of 19 April 2021 laying down rules for the application of Regulation (EU) 2019/2144 of the European Parliament and of the Council as regards uniform procedures and technical specifications for the type-approval of motor vehicles with regard to their emergency lane-keeping systems (ELKS) [2021] OJ L133/31, § 2.2.

[422] American Association of State Highway and Transportation Officials (AASHTO). (2018). Policy on Geometric Design of Highways and Streets (7th Edition), including 2019 Errata. American Association of State Highway and Transportation Officials (AASHTO). Table 3–7. Minimum Radius Using Limiting Values of *e* and *f*.

consequences in how future derivations of the technology operate. Finally, GM pointed to NHTSA's proposed BSI test procedure, which uses an 800 m (2,625 ft.) curve for an intentional lane change, in support of its opinion that a 1,200 m (3,937.0 ft.) curve more accurately represents an unintentional drift out of the lane.

Several commenters remarked on a variety of other potential consequences of adopting a reduced curve radius. For example, Bosch remarked that a reduction in radius to 200 m (656.2 ft.) could create challenges for test execution. ZF Group cautioned that NHTSA should not change the curve radius too drastically, especially without further research and consideration for the consequences of doing so, since Euro NCAP's LSS protocol resulted from coordinated efforts of both vehicle manufacturers and suppliers.

Agree to a Radius of Curvature Between 200 m and 1,200 m (656.2 ft. and 3,937.0 ft.)

If a smaller curve radius is preferred, Subaru suggested that the Agency adopt an 800 m (2,624.7 ft.) curve radius. Intel commented that it would support a reduced curve radius up to 700 m (2,296.6 ft.). However, the company cautioned that even this radius may be unacceptable since drivers tend to cross lane markings while in a turn, which may elicit false positive warnings.

IDIADA recommended that the Agency use variable radii (between 200 m and 1,200 m, or 656.2 ft. and 3,937.0 ft.) and the same arc length to generate multiple lateral speeds towards the lane line instead of one fixed radius and variable arc lengths to generate the lateral speeds, as used by Euro NCAP. The laboratory stated that the appropriate lateral speed range of 0.1 m/s to 0.6 m/s could likely be generated within radii ranging between 200 m (656.2 ft.) and 1,200 m (3,937.0 ft.).

Agree With Adopting a 200 m (656.2 ft.) Radius of Curvature

Other commenters, like the ASC, BMW, and CAS, remarked that they would support reducing the curve radius to 200 m (656.2 ft.). However, BMW stated that the company's support was contingent on there being a long period of steady state lateral velocity (also referenced by Auto Innovators) to be classified as an unintended lane departure. CAS commented that it was ''essential'' to add both curve radii to the LKA test procedure to ensure that LKA systems are not designed to a test, but instead designed to perform well in multiple real-world conditions, especially since such additions would ''impose no additional cost on manufacturers.''

General Comments

Advocates recommended that NHTSA provide comparative performance data to show there are benefits of adopting a smaller curve radius rather than a 1,200 m (3,937.0 ft.) curve. Advocates also stated that ''convenience or expediency in testing should not be a substitute for robust and accurate protocols.''

Response to Comments and Agency Decisions

NHTSA is adopting a 1,200 m (3,937.0 ft.) curve radius for SV travel paths in its LKA test procedure.

Based on the comments received, NHTSA concludes a larger (*i.e.,* 1,200 m (3,937.0 ft.)) curve radius rather than a smaller (*i.e.,* 200 m (656.2 ft.)) radius is most appropriate for its LKA testing. In an unintentional lane departure, the vehicle would be expected to drift out of its lane rather than abruptly turn, as some commenters noted. As such, curve radii for unintentional lane departures would be expected to be larger than those of intentional lane changes. Along these lines, NHTSA finds merit in GM's comment noting the Agency's BSI test procedure for assessing intentional lane changes includes a (now-adopted) curve radius of 800 m (2,625 ft.), a radius significantly larger than the 200 m (656.2 ft.) curve radius considered for NHTSA's LKA testing, which simulates unintentional lane departures. The Agency also sees validity in comments that a smaller curve radius may signal an intentional departure due to the necessary steering input, such that LKA system designs which take driver intent into account may not engage the LKA system as expected. NHTSA also acknowledges the opinion that evaluation of LKA capabilities at small curve radii may encourage intervention in cases where it is not desired. Besides being potentially hazardous, excessive warnings and false activations, in addition to aggressive interventions, may deter consumers from enabling lane keeping technologies, thus reducing potential benefits, as several respondents suggested.

The Agency will not proceed as IDIADA requested and adopt variable (smaller) radii for LKA testing for this upgrade. Although the Agency recognizes CAS's concern regarding the use of a single curve radius to evaluate LKA system performance, NHTSA also agrees with FCA, Toyota, and HATCI that the use of a curve radius of 200 m (656.2 ft.) would be aggressive and not necessarily representative when considering real-world events involving straight roads, even if considering intentional lane departures. Adopting smaller curve radii would also deviate from Euro NCAP's LSS test protocol for the test conditions adopted by NHTSA. As NHTSA aims to harmonize its NCAP with other testing programs globally unless there are compelling reasons to do otherwise, it is best to mirror Euro NCAP and adopt a 1,200 m (3,937.0 ft.) curve radius for SV travel paths in its LKA test procedure at this time.

Although NHTSA acknowledges the use of a smaller curve radius could produce a positive effect on test conduct, NHTSA agrees with Advocates' comment that the Agency should first quantify any benefits of adopting any curve radius smaller than 1,200 m (3,937.0 ft.). While the Agency does not currently have plans to conduct research to compare track tests of LDW and LKA to real-world data for different combinations of curve radius, vehicle speed, and departure timing, should it choose to pursue such testing in the future, NHTSA would consider the need to amend the prescribed curve radius or to add additional assessments at that time based on the data.

11. Adding a Road Edge Detection Test

In its March 2022 RFC notice, NHTSA recognized that Euro NCAP has adopted a road edge detection test that is conducted similarly to the group's LKA tests, but which does not require the use of lane markings. The Agency also acknowledged that, while the number of vehicles equipped with an ability to recognize and respond to road edges not defined with a lane line may presently be low, there are U.S. roadways on which this capability could prevent crashes. In a study of fatal crashes using 2005 to 2007 National Motor Vehicle Crash Causation Survey (NMVCCS) and 2017 Crash Investigation Sampling System (CISS) lane/roadway departure cases that was undertaken (1) to classify the shoulder type present on the side of the roadway when a vehicle first departed its travel lane and (2) to estimate the shoulder width just after departure, NHTSA identified fatal crashes where lane markers were not present on the side of the roadway where a departure occurred.[423] In these cases, LKA would not provide any benefit unless it had the capability to identify the edge of the roadway.

[423] Wiacek, C., Forkenbrock, G., Mynatt, M., & Shain, K. (2019), Applying lane keeping support test track performance to real-world crash data. *26th International Technical Conference for the Enhanced Safety of Vehicles,* Eindhoven, Netherlands. Paper Number 19–0208.

In its March 2022 RFC notice, the Agency also recognized that it had received public comments pertaining to the addition of a road edge detection test in response to its 2015 RFC notice. Specifically, Mobileye recommended that the Agency add not only road edge detection scenarios but also scenarios that include curbs and non-structural delimiters such as gravel or dirt to reflect real-world conditions and crash scenarios more accurately. Similarly, Bosch suggested that NHTSA consider introducing road edge detection requirements in addition to lane markings since not all roads have lane markings.

Given the safety need and commenter suggestions, NHTSA sought comment in its March 2022 RFC notice on whether it should add Euro NCAP's road edge detection test to NCAP for either its LDW and/or LKA assessments to address crashes that occur where lane markings may not be present.

Summary of Comments

In Favor of Adding a Road Edge Detection Test

AASHTO, Aptiv, ASC, CAS, GM, Intel, Rivian, Bosch, ZF Group, and a public commenter recommended that a road edge detection test be added to address roads where lane markings are not present, or the markings have faded or are worn. AAA, Advocates, IDIADA, CAS, IIHS, and Toyota were also in favor, citing crash frequency and/or severity as a reason for inclusion. Advocates expressed support for the test scenario's inclusion because the Agency identified road edge departures as the third most common lane keeping scenario. Likewise, Toyota pointed to NHTSA's 2018 to 2019 CISS data which showed that there were no lane markings on the side of departure in approximately 30 percent of road departure cases. AAA commented that the possibility of injury and/or death increases for roadway departures. IDIADA similarly commented that rollovers may stem from roadway departures, therefore making road edge detection an important technology, and IIHS remarked that crashes with fixed objects are a common occurrence when vehicles leave the road, accounting for 32 percent of passenger vehicle occupant fatalities (7,253 people) in 2019. IIHS further asserted that ''44 percent of these deaths occurred on minor roads, which are more likely than other road types to have unmarked road edges.'' The group also stated that systems capable of detecting unmarked road edges should also be better able to detect obstructed or worn lane lines. GM stated that it supported a road centerline plus road edge configuration if NHTSA elected to add a road edge detection test to its LKA protocol, since such an arrangement would accurately represent a common U.S. roadway condition.

Vayyar did not comment specifically on including a road edge detection scenario in NCAP but did state that it is ''highly advisable to monitor unmarked road edges'' and noted that this can often be achieved using radar.

A Road Edge Detection Test Is Unnecessary

Two commenters, FCA and Subaru, were not in favor of adding a road edge detection test to NCAP's LDW and/or LKA test procedures. FCA cited low frequency of single lane lines [424] in the U.S. relative to other countries as a reason not to add a road edge detection scenario. Subaru opined that adding a road edge detection test to U.S. NCAP is unnecessary, but also stated that NHTSA should conduct further analysis of crash data to ascertain the relative frequency of road departures on roads with unmarked edges to better gauge representative conditions for road edge testing in the U.S.

Include for LDW, LKA, or both systems?

AAA, TRC, CAS, Rivian, and ZF Group suggested adding a road edge detection test to assess both LDW and LKA systems. Honda expressed support for adding a road edge detection test for both LDW and LKA if real-world data supports its inclusion, and Advocates indicated support for adding the assessment for both technologies if any LKA system capable of identifying a road edge also issues an LDW alert prior to automatic intervention. ASC suggested that adding a road edge detection test for both LDW and LKA would be appropriate, stating that inclusion of this test scenario would improve the safety benefits for both systems. GM additionally voiced support for adding the test scenario assessment for both systems, though they referenced only improved safety benefits for LKA. Both Intel and IIHS suggested that it would be reasonable to adopt the test for LDW, but stated priority should be given to LKA, with IIHS adding that their research has shown that drivers are more likely to use LKA compared to LDW,[425] and LKA systems that provide earlier and more frequent steering input to avoid lane departures were used more by drivers than LKA systems with later and less frequent interventions.[426] IDIADA stated that since a road edge detection test represented a ''safety critical scenario,'' it was most relevant for the active technology, LKA.

Adopt Euro NCAP's Test

AAA, ASC, CAS, GM, HATCI, IIHS, MEMA, Bosch, and Tesla specifically mentioned adding Euro NCAP's road edge detection test to the U.S. test protocol. IIHS stated that since this test has been part of Euro NCAP's protocol since 2018, vehicle manufacturers should be ''reasonably familiar'' with it and should already be developing or even implementing systems having road edge detection capability. For those vehicles lacking this capability, however, Bosch asserted that adding this test would drive the availability of these more robust LKA systems through the fleet. GM and MEMA stated that road edge excursion limits for LDW and LKA should be aligned and standardized with Euro NCAP protocols, with GM adding that more stringent limits, adopted by other regions, have spurred customer complaints and system disablement due to the need for more aggressive systems. However, GM did not support all aspects of the Euro NCAP protocol. Specifically, the manufacturer, along with Auto Innovators, stated they do not support ''the Euro NCAP double road edge lane detection'' because it can cause activation on gravel roads, which are common in rural areas in the U.S. Auto Innovators also noted that dashed road edges are not common in the U.S.

Additional Specifications Are Necessary

To improve test-to-test and lab-to-lab repeatability/reproducibility, Tesla recommended that NHTSA define what constitutes a ''road edge condition'' and specify how to detect it to minimize varying interpretations. Auto Innovators and Toyota also sought clarification regarding the road edge test conditions, further stating that selection of a road edge should be supported by validation testing using vehicles that are already equipped with LDW/LKA technology that permits road edge detection. The commenters asserted that, unlike lane

[424] The Agency believes FCA's comment was referring to two-lane, two-direction roadways having only a centerline.

[425] Reagan, I.J., Cicchino, J.B., Kerfoot, L.B., & Weast, R.A. (2018). Crash avoidance and driver assistance technologies—Are they used? Transportation Research Part F: Traffic Psychology and Behaviour, 52, 176–190. *https://doi.org/10.1016/j.trf.2017.11.015.*

[426] Reagan, I.J., Cicchino, J.B., & Montalbano, C.J. (2019). Exploring relationships between observed activation rates and functional attributes of lane departure prevention. Traffic Injury Prevention, 20(4), 424–430. *https://doi.org/10.1080/15389588.2019.1569759.*

markings, which can be clearly defined (*e.g.,* length, width, color, etc.), road edges have no quantitative definition. Auto Innovators added that systems must therefore use artificial intelligence to compare and classify how similar a captured camera image is to ''pre-learned'' road edges. Like Tesla, Auto Innovators expressed concern regarding repeatability and reproducibility issues during testing if the road edge is not clearly defined.

Toyota requested that NHTSA base selected road edge test conditions on real-world U.S. roadways, which through a review of 2009 NASS–CDS cases, showed brush, curbs, and dirt as the three primary surfaces involved in road departure crashes.[427] HATCI also stated that NHTSA should select a ''field-representative'' road edge that shows the highest safety need and suggested that road owners and vehicle manufacturers could work together to develop road edge specifications (*e.g.,* materials, shoulders, straightness, etc.) so that vehicles may more easily identify them. TRC also stressed the importance of specifying the material for the road edge (*e.g.,* gravel, dirt, etc.) and recommended a gravel road edge for safe test conduct, especially when a steering robot is used during LKA tests and for departures exceeding one foot over the road edge. Both BMW and Auto Innovators specifically mentioned that they would not approve of scenarios that use artificial turf to denote the road edge, with BMW adding that the test conditions should closely mirror real-world conditions. Finally, Auto Innovators and HATCI requested that NHTSA submit for public review and comment road edge specifications prior to inclusion in the applicable test procedure(s).

Response to Comments and Agency Decisions

Road edge departure crashes are common and may result in rollovers or collisions with fixed objects, both of which may have critical consequences. However, despite the noted frequency and severity of road departures on roads with faded or absent lane markings at the road's edge, at this time, NHTSA will not include a road edge detection test in its NCAP LDW/LKA test procedure.

NHTSA recognizes that Euro NCAP currently assesses a vehicle's ability to detect a passenger-side road's edge when no lane marking is present. This test is performed both with and without a driver-side lane marking. However, the test procedure's road edge specifications are not well-defined; the road edge may consist of grass and/or gravel, or any other approved surrogate. As noted in Annex A of the Euro NCAP LSS procedure, there is no artificial road edge with consensus at this time. Thus, a variety of real road edges are used, each of which is different.

It is the Agency's belief that every NCAP vehicle should be assessed using the same test conditions to promote fairness and maintain the program's credibility. To do so, NHTSA would have to select a road edge type and more clearly define specifications. However, it is currently unclear which single road edge type would be most appropriate. As noted by Toyota, a variety of real-world road edge types that drivers regularly encounter exist (gravel, curbs, brush, dirt, etc.). While the selection of a gravel road edge may be most desirable for safe test conduct, as TRC suggested, there is not currently data to suggest that this road edge type is the most representative.

While the Agency is not adopting a road edge detection test for this NCAP update, given the safety need identified previously to address road departure crashes in which a line at the road's edge may not be visible or present, as outlined in the NCAP roadmap long-term plans, NHTSA will consider enhanced evaluations of LKA systems in NCAP, including a road edge detection test at a future time. Prior to inclusion of a road edge detection test scenario, NHTSA must determine which road edge test condition(s) best represents road edges that drivers may encounter in real-world driving conditions, or alternatively, that which represents the largest number of crashes and thus may offer the largest safety benefit. NHTSA agrees with Bosch's comment that adding a road edge detection test would encourage the availability of more robust LKA systems throughout the fleet, but the Agency does not want to cause unintended consequences by doing so before adequate test specifications can be developed, reviewed, and adopted. Prior to implementing any future road edge detection assessments, NHTSA would consider reducing excursing limits, as mentioned in an earlier section, or aligning excursion limits with those included in Euro NCAP's test protocol, as GM and MEMA requested. It would also conduct testing with then-current vehicle models to validate any new test procedure, as Toyota and Auto Innovators suggested.

12. Correlating Straight and Curved Road Performance

NHTSA has only performed test track LKA evaluations using the straight road test configuration specified in Euro NCAP's LSS test protocol. However, the Agency recognized in its March 2022 RFC notice that a significant portion of road departure and opposite direction crashes resulting in fatalities and injuries occur on curved roads. A review of Volpe's 2011 to 2015 data set showed that for road departure crashes where roadway alignment was known, 37 percent of fatalities and 21 percent of injuries occurred on curved roads.[428] For opposite direction crashes where roadway alignment was known, 30 percent of fatalities and 32 percent of injuries occurred on curved roads.[429]

In NHTSA's study of the 2005 through 2007 fatal crashes from NMVCCS,[430] an analysis of lane departure crashes occurring on curved roads[431] showed that LKA systems would have to provide sustained lateral correction (*i.e.,* corrective steering) to prevent the vehicle from departing the travel lane. This differs from the smaller corrective steering inputs required of LKA systems to prevent lane departures on straight roads.

In its 2022 notice, NHTSA stated that it is unsure how LKA performance observed during straight road trials performed on a test track would correlate to real-world system performance on curved roads. However, the Agency hypothesized, based on on-road performance testing experience of newer model year vehicles, that some current LKA system designs include provisions to address lane departures on curved roads. The Agency found that some LKA systems engage by providing limited operation throughout a curve and thus provide little (if any) safety benefit. Conversely, more sophisticated LKA systems maintain engagement longer and offer added directional authority throughout a curve. These latter systems may provide additional

[427] *https://www.regulations.gov/comment/NHTSA-2021-0002-3898.* See submitted graphics.

[428] Roadway alignment was unknown or not reported for 1 percent of fatal roadway departure crashes and 4 percent of roadway crashes where police-reported injuries occurred.

[429] Roadway alignment was unknown or not reported for 1 percent of fatal opposite direction crashes and 2 percent of roadway crashes where police-reported injuries occurred.

[430] Wiacek, C., Fikenscher, J., Forkenbrock, G., Mynatt, M., & Smith, P. (2017), Real-world analysis of fatal run-out-of-lane crashes using the National Motor Vehicle Crash Causation Survey to assess lane keeping technologies, *25th International Technical Conference on the Enhanced Safety of Vehicles,* Detroit, Michigan. June 2017, Paper Number 17–0220.

[431] It should be noted that the paper identified crashes where lane markings were not present on the side of the departure.

safety gains because the driver has more time to re-engage (*i.e.,* restore effective manual control of the vehicle).

Given the real-world need to address lane departure crashes occurring on curved roads and the Agency's observations of vehicle system performance during on-road driving, NHTSA expressed a desire to correlate LKA performance on straight roads to that on curved roads, if possible. Specifically, NHTSA sought comment on whether it could correlate better LKA system performance at higher lateral velocities on straight roads with better curved road performance. The Agency also solicited comment on whether it could assume that a vehicle that does not exceed the maximum excursion limits at higher lateral velocities on straight roads will have superior curved road performance compared to a vehicle that only meets the excursion limits at lower lateral velocities on straight roads. Finally, the Agency asked whether it could assume that the steering intervention while the vehicle is negotiating a curve is sustained long enough for a driver to re-engage.

Summary of Comments

Straight and Curved Road Correlation

There were many commenters who suggested that the Agency could correlate better performance on straight roads at higher lateral velocities to that on curved roads. Tesla, for one, stated that vehicles that afford better straight road performance are often better at lane line detection, which typically translates to better lateral control in a curve and maintaining tighter and steadier control over the vehicle's position within the lane. Another commenter, Rivian, suggested that lane line detection, not the ability to handle high lateral velocities, was often a problem for LKA systems that offer poor performance on curved roads. The commenter recommended that assessment of LKA performance should be based on relative lateral velocity to the lane line, not absolute lateral velocity. Toyota and Auto Innovators opined that there is a correlation, and as such, there would be no need to adopt a separate curved road test, but since the entities did not have data to support their opinion, they recommended, like others below, that the Agency should conduct additional research to definitively conclude that a correlation exists. Toyota further requested that, if NHTSA was to perform such research, it should ''clarify whether the target (for LKS performance) is on a constant curve, during curve entry, or both.''

There were also several commenters that agreed the performance may be able to be correlated across the two roadway configurations; however, a few of these respondents suggested that the Agency conduct additional research to confirm the strength of the correlation. Aptiv and CAS mentioned that banking and sight line restrictions due to changing elevations may affect LKA performance on curved roads, but only research to provide comparative test results would indicate how much influence these variables have. Bosch stated that an LKA system that supports high lateral velocities on straight roads could also afford better performance on curved roads because the system should likely react faster and earlier, but like Aptiv and CAS, they suggested NHTSA conduct additional research to be sure. Although BMW didn't suggest additional research, the automaker, like Aptiv and CAS, referenced additional factors affecting curved road intervention (*i.e.,* accurate detection of road curvature and orientation angle toward the lane marking) that could lead to performance variations compared to straight roads, thus making a relative comparison difficult. ZF Group additionally cited lane detection capability, steering controller and torque overlay limits, and vehicle weight as other variables that would influence results.

GM commented that a correlation may be possible under limited conditions, such as at certain lateral velocities, but generally, curved road performance is influenced by factors like banking (*i.e.,* superelevation) (as also mentioned by Aptiv and CAS) and surface crowning which can't easily be simulated in a test environment and will vary based on design speed, curve radius, etc.

There were also commenters, including Intel and FCA, who stated that a straight road/curved road correlation was not possible. FCA, like others, voiced that many factors, including speed, lateral position in the lane, and road curvature, affect LKA system performance on curved roads, and there is currently no reliable or repeatable test method to capture these characteristics.

Equating Excursion at Higher Lateral Velocities on Straight Roads to Superior Performance on Curved Roads

With respect to whether the Agency could assume that those vehicles that don't exceed maximum excursion limits at higher lateral velocities on straight roads would have superior performance on curved roads compared to a vehicle that only meets the excursion limits at lower lateral velocities on straight roads, CAS reasoned that was not a valid assumption. The group cited influencing factors like sight line restrictions, road construction differences (*e.g.,* elevation changes), and ''underlying additive lateral acceleration'' that may affect relative performance. Bosch agreed that superior performance cannot be assumed because reaction time is often different in a curve (*i.e.,* often later) and therefore system behavior may vary compared to that observed on a straight road.

Driver Re-Engagement

A few commenters opined on whether NHTSA could assume that LKA-induced steering intervention while a vehicle is negotiating a curve is sustained long enough for the driver to re-engage. Almost all respondents said no, that is not a safe assumption. CAS expressed that there are too many variables to be considered (*i.e.,* speed, curve geometry, the ADAS warnings provided, and the driver response) for such an assumption to be made. Intel remarked that the steering intervention doesn't end until the vehicle is parallel to the road lane marking (with sufficient margin) for a few seconds. However, in sharp curves, the commenter noted that the system torque is ''limited and [it] will not be comfortable for the driver to re-engage.''

Unlike the other commenters, BMW stated that the driver would have enough time to re-engage, stating that the system intervention will last for several seconds as the system attempts to align with the lane marking. Likewise, ZF Group stated that corrective steering is provided when the system detects it is entering the 'intervention zone,' and it should be maintained throughout the curve (if the vehicle remains in the 'intervention zone') until it disengages once the vehicle is brought back into the appropriate position. Rivian stated LKA intervention *should be* sustained in a curve until a driver re-engages because the consequence of system deactivation in the middle of the curve (before driver re-engagement) could be dangerous. The commenter further stated that vehicles that disengage prior to reengagement by the driver should receive lower scores.

Unlike the other respondents who said re-engagement either was or wasn't possible, Bosch remarked that it is dependent on the system design, with some systems providing only a slight correction to the heading angle, whereas others guide the vehicle back to the center of the lane.

Adoption of a Separate Curved Road Test

BMW asserted it was more appropriate to incorporate a curved road test than to assess systems at high lateral velocities on straight roads since some systems may interpret a fast approach towards the lane marking to be an intentional lane change (without use of the turn signal) and would suppress an intervention accordingly. Auto Innovators also shared BMW's concern (though they did not favor adopting a separate curved road assessment) and added that a fast or strong system intervention in such instances may affect customer satisfaction, which must also be considered in system design. ASC agreed with BMW that NHTSA should develop a curved road test rather than attempt to correlate performance. Advocates supported incorporation of a curved road test in general, since a large proportion of crashes, especially road edge departure crashes, occur on curved roads.

Unlike Advocates, Rivian suggested that NHTSA should not adopt a curved road test because most lane departure crashes occur on straight roads [432] and therefore the safety need is not as great for curved roads. The manufacturer further asserted, along with IDIADA, that drivers tend to be more attentive on curved roads since they know they are required to steer. Because of the influential testing variables mentioned previously, GM was also not supportive of adopting a curved road test, relaying that adding test scenarios that do not accurately depict real-world driving conditions may drive LKA system changes to meet test requirements that degrade performance for real-world drivers, thus compelling drivers to turn systems off. GM further stated that Korean NCAP performs a curved road test and there is high variability in test results.

Toyota and Auto Innovators also recommended adopting only a straight road test condition at this time. The commenters expressed concerns related to repeatability and reproducibility for curved road testing, stating that (1) lane departure speed, which is the key input to initiate and evaluate LKA system performance, is strongly affected by initial lateral offset and yaw angle, and (2) it would be difficult to configure the exact same curved lane (*i.e.,* same curve radius, clothoid length, banking angle, lane width, etc.) at all testing locations, including those used by vehicle manufacturers for NCAP performance verification assessments. Similar to GM's assertion regarding Korean NCAP, the groups also relayed that Euro NCAP has not adopted a curved road assessment because of repeatability concerns.

Test labs also expressed concerns regarding the feasibility of curved road testing, with TRC cautioning that curved road testing requires much more space than straight road testing, and as such, testing locations are limited. Further, IDIADA stated that curved road scenarios are ''extremely difficult to implement.''

Response to Comments and Agency Decisions

At this time, NHTSA cannot assume that LKA performance on straight roads correlates with that expected for curved roads.

Commenters unanimously agreed that superior performance on curved roads could not be assumed for those vehicles that do not exceed maximum excursion limits at higher lateral velocities on straight roads. NHTSA acknowledges, as several commenters stated, that there are vehicle-specific factors like vehicle weight and speed, in addition to the vehicle's capability for lane line detection, which may affect LKA system performance on curved roads more so than on straight roads. The Agency also recognizes commenter concerns surrounding system suppression and unintended consequences of abrupt or strong system interventions stemming from the high lateral velocities needed to simulate curved road conditions on straight roads, both of which suggest a correlation is impracticable. Further, the Agency acknowledges that most commenters expressed that it is unreasonable to assume that an LKA steering intervention is sustained long enough in a curve for a driver to re-engage in the driving task. While Rivian acknowledged that LKA intervention *should* be sustained in a curve until a driver re-engages because of the consequences inherent to system deactivation in the middle of the curve (before driver re-engagement), most commenters contended that there are too many variables at play to have such assurance, with Bosch stating that it depends on the system design, as some systems may only offer a slight heading correction whereas others direct the vehicle back into the center of the lane. Without such assurance, it would be misguided for the Agency to consider a correlation to be a sufficient surrogate for an actual curved road assessment.

Further, commenters provided mixed support for adopting a designated curved road test in NCAP. Commenters expressing support noted that such a test would be more appropriate to reflect true system performance. Those opposed cited testing feasibility concerns, specifically limitations posed by space constraints and repeatability and reproducibility concerns arising from the need to replicate the exact test conditions/curved lane configuration across all testing locations. NHTSA acknowledges, as many commenters stated, that there are numerous roadway characteristics that can affect curved road intervention, including curve radius, elevation changes (*i.e.,* superelevation), and sight line restrictions, which are difficult to simulate in a test environment, especially in a reliable and repeatable manner. It further acknowledges GM's concern that test scenarios that don't accurately reflect real-world driving conditions may spur degradation in real-world LKA performance, leading to system deactivation and a loss of safety benefits.

In consideration of commenter concerns, the Agency plans to initiate a multifaceted curved road research effort. As part of this research, NHTSA intends to: (1) review lane and road departure crash data to identify curve radii and other roadway variables (*e.g.,* superelevation, lane width, etc.), vehicle speed, and departure timing (*e.g.,* at curve entry, mid curve, or near curve exit); (2) identify other lane departure protocols, or parts of protocols, that may be most relevant to real-world road departures, particularly those related to curved lanes; (3) identify vehicle models that have LKA systems that are designed to prevent lane departures on curved roads; (4) identify next generation LKA systems and document expected functionality; and (5) perform pilot testing to evaluate potentially suitable curved road test protocols. By taking these steps, NHTSA hopes that it will be able to develop a test protocol that accurately simulates real-world lane departures on curved roads to best address the safety problem. After the research is completed, NHTSA will consider these enhanced evaluations of LKA systems in NCAP, as noted in the NCAP roadmap long-term plans.

13. Increasing LKA Test Speed

In its recent RFC notice, NHTSA noted that a sizeable portion of fatal road departure and opposite direction crashes occur at higher posted and known travel speeds. As part of its independent analysis of the 2011 to 2015 FARS data set, Volpe found that, of those crashes where posted speed limits were known, 58 percent of fatal road departure crashes and 69 percent of fatal opposite direction crashes

[432] 87 FR 13452 at 13494.

occurred on roads with posted speeds exceeding 72.4 kph (45 mph).[433 434] Further, the study revealed that speeding was a known factor in 33 percent and 13 percent of fatal road departure and opposite direction crashes, respectively.[435 436] Volpe also found that when travel speed was known, 83 percent of fatal road departure crashes and 74 percent of fatal opposite direction crashes occurred at known travel speeds exceeding 72.4 kph (45 mph).

Since NHTSA did not have data to show that LKA system performance at Euro NCAP's current test speed of 72 kph (44.7 mph) would be indicative of system performance when tested at higher speeds, the Agency requested comment on whether it would be beneficial to incorporate additional, higher test speeds to assess the performance of lane keeping systems in NCAP, or whether the current test speed is sufficient to indicate performance at higher speeds, especially on straight roads. Given the findings from NHTSA's LKA testing of model year 2017 and 2019 vehicles, which showed differences in LKA performance at greater lateral velocities, the Agency also expressed concern about LKA performance at higher travel speeds when the vehicle first transitions from a straight to a curved road, since lateral velocity may be high in those situations.

Summary of Comments

Maintain Current Test Speed

Many commenters suggested the LKA test speed should remain at 72.4 kph (45 mph). ASC, BMW, and Bosch commented that the current NCAP test speed accurately evaluates LKA performance at higher speeds and that increasing the test speed was unnecessary. Auto Innovators agreed that performance at the current test speed is indicative of performance at higher test speeds, and additionally mentioned that performance at lower speeds could also be assured. Similarly, GM stated that the proposed 72.4 kph (45 mph) test speed accurately evaluates performance at other speeds. HATCI recommended that NHTSA harmonize with Euro NCAP's test speed of 72 kph (44.7 mph), as it is representative of LKA performance at higher speeds and sufficient to address fatal road departure and opposite direction crashes. Similarly, ZF Group agreed that the Agency should harmonize with existing protocols to the extent possible. FCA expressed that high-speed unintentional lane departures occur at lower lateral velocities, and such events would be encompassed by the 0.2 m/s lateral velocity in the current 72.4 kph (45 mph) LKA test such that no additional speed increase is necessary. On the other hand, Advocates expressed that NHTSA must have data to ''indicate whether longitudinal velocity is correlated with lateral velocity and which of these or their interaction are determining factors in assessing performance of LKS systems.'' The organization questioned whether testing at a lower longitudinal speed and higher lateral velocity is the best way to differentiate between systems having different performance.

TRC, Auto Innovators, and GM referenced logistical concerns for higher speed test assessments. TRC stated that if speeds were increased, additional lane markings and distance would have to be maintained. Likewise, Auto Innovators and GM expressed that longer and wider test tracks having additional runoff space would be necessary for safe testing at higher speeds, and yet, such testing would yield similar results to those obtained at 72 kph (44.7 mph).

Consider Additional Test Speeds

A few commenters, including Intel and CAS, favored higher test speeds to assess LKA system performance. Specifically, CAS asserted that higher speed testing would be a better indicator of LKA performance. The organization suggested that test speeds should be increased until safe performance limits are established, and these speed limits should then be communicated to consumers. That said, CAS also acknowledged that ''some LKS testing is better than no LKS testing.'' Like CAS, one public commenter recommended that the LKA test speed be increased to ''ensure accuracy.'' The commenter mentioned that most fatal road and lane departure crashes occur at higher speeds, and at such speeds, the driver's ability to react and maintain control of the vehicle is reduced. IDIADA stated that since LKA system activation occurs at speeds of 65 kph (40.4 mph) or greater, the current 72.4 kph (45 mph) test speed covers only the lower limit of system intervention. As such, the company suggested that the Agency could consider conducting testing at speeds up to 120 kph (74.6 mph). MEMA did not expressly recommend increasing the LKA test speeds. However, MEMA did mention that there is ''no technical barrier to detecting lanes at a range that would reliably support higher LKS test speeds.'' Similarly, ZF Group mentioned that ''there is no technology concern associated with testing at higher speeds.'' Finally, Rivian suggested that NHTSA evaluate LKA performance at both higher and lower speeds to better assure expected performance.

Response to Comments and Agency Decisions

As mentioned earlier, NHTSA is adopting a test speed of 72 kph (44.7 mph) for its LDW/LKA tests. This test speed aligns with many real-world road departure and opposite direction crashes and serves as an appropriate starting point for the Agency's newly adopted lane keeping tests. The Agency reasons this test speed is also appropriate because it further promotes harmonization. It is the same speed used in Euro NCAP's LDW, LKA, and ELK tests, which are comparable to those NHTSA is incorporating in NCAP.

Many commenters asserted that LKA performance at a test speed of 72 kph (44.7 mph) would be sufficient to assure similar LKA performance at higher (and lower) test speeds, and therefore, adding additional test speeds for NCAP's tests is unnecessary. However, the Agency hesitates to agree without additional research testing. It may be true, as Advocates suggested, that testing at a lower longitudinal speed and higher lateral velocity may not sufficiently differentiate between systems that have different performance at higher speeds. In this case, higher-speed tests would also be necessary to effectively address the safety problem. Conversely, it may be true, as FCA asserted, that a 72.4 kph (45 mph) LKA test is sufficient to address unintentional lane departure crashes occurring at high speeds because these real-world crashes occur at lower lateral velocities, such as those already included in the Agency's test matrix. Unfortunately, NHTSA does not currently have data to indicate whether longitudinal velocity is correlated with lateral velocity, as Advocates requested, nor does it know the extent to which each of these factors influence LKA

[433] Swanson, E., Foderaro, F., Yanagisawa, M., Najm, W.G., & Azeredo, P. (2019, August), *Statistics of light-vehicle pre-crash scenarios based on 2011–2015 national crash data* (Report No. DOT HS 812 745), Washington, DC: National Highway Traffic Safety Administration.

[434] For data where the travel speed was known, 63 and 65 percent of the data is unknown or not reported in FARS for road departure and opposite direction crashes, respectively. For road departure and opposite direction crashes, respectively, 3 and 1 percent of the posted speed data is unknown or not reported in FARS.

[435] Swanson, E., Foderaro, F., Yanagisawa, M., Najm, W.G., & Azeredo, P. (2019, August), *Statistics of light-vehicle pre-crash scenarios based on 2011–2015 national crash data* (Report No. DOT HS 812 745), Washington, DC: National Highway Traffic Safety Administration.

[436] It was unknown or not reported whether speeding was a contributing factor in 7 percent of fatal road departure crashes and 4 percent of fatal opposite direction crashes.

system performance. It also does not fully understand how driver reaction time or the driver's ability to maintain control of the vehicle as speed increases may influence overall LKA system performance or crash outcomes. As such, more research is needed before NHTSA can conclude with certainty whether the adopted LKA test conditions will be sufficient to ensure safety benefits at alternative test speeds, or whether additional test conditions are necessary. Regardless, because of the significant crash problem currently at hand, it is prudent to move forward with the adopted 72.4 kph (45 mph) SV speed at this time rather than wait for the completion of further research.

As discussed previously, the Agency plans to review real-world road departure crash data as part of a future research effort. NHTSA will document the roadway conditions associated with these crashes (*e.g.,* posted speed limits, roadway curvature, etc.) as well as other influencing factors, such as vehicle speed and lateral velocity. The Agency will consider higher speeds in future evaluations as well as other logistical concerns posed by commenters (*e.g.,* longer and wider tracks).

14. Reducing the Number of Required Test Conditions

Given the Agency's LKA test procedure currently contains many test conditions (*i.e.,* line type and departure direction), NHTSA requested comment on whether it is necessary to perform all test conditions to adequately address the lane departure safety problem or whether it could instead only test only certain conditions to minimize test burden. Specifically, NHTSA sought comment on whether it should consider incorporating the test conditions for only one departure direction if the vehicle manufacturer provides test data to assure comparable system performance for the other direction or consider adopting only the most challenging test condition(s). If commenters preferred the latter, the Agency questioned which test condition(s) would be most appropriate.

Summary of Comments

Departure Directions

NHTSA received several responses on whether it would be sufficient to assess LKA performance for only one departure direction (*i.e.,* left or right), with both BMW and Auto Innovators suggesting that this could be possible. BMW mentioned that their internal assessments evaluate performance for both departure directions, so they could provide data for the direction the Agency chooses not to assess. However, Auto Innovators, GM, and Bosch cautioned NHTSA that identical performance cannot be guaranteed for both departure directions since not all LKA systems are symmetrical. Auto Innovators recommended that manufacturers attest to their vehicles' symmetry if NHTSA was to eliminate testing on one side to reduce test burden.

Bosch maintained that the Agency should still evaluate all conditions (*e.g.,* departure directions and lane marking types) to ensure system robustness and effectiveness and consistency of test results. GM, ASC, and Aptiv agreed with the need to test both directions. In a similar vein to that expressed by Auto Innovators and Bosch, DRI and TRC also commented that they have observed different performance depending on departure direction. As such, TRC encouraged NHTSA to assess both directions for all test conditions, but at a minimum, both directions for both solid and dashed lines.

Lane Line Types

Responses received on limiting LKA testing to a specific lane line type(s) were varied. FCA and ZF Group asserted that LKA systems should afford equal performance regardless of lane line type, while DRI claimed that it has observed differing performance for various lane lines. GM and Toyota claimed the dashed lane line condition was more challenging for LKA systems since cameras detect the contrast between the road surface and the lane line paint; however, GM stated that it has not seen meaningful performance differences for the various lane line types. GM further stated that Euro NCAP reduced the number of lane lines assessed starting in 2023 for this reason. Intel suggested that the Agency assess LKA performance for only the dashed lane line to reduce test burden, whereas, for the reasons stated earlier, Bosch recommended assessing all lane line types.

Minimizing Test Burden in General

In general, Auto Innovators stated that NHTSA should minimize test burden by prioritizing those test conditions representing the highest real-world risk and harmonizing with other organizations where possible. Advocates suggested that NHTSA should determine the number of scenarios that are necessary for testing based on whether performance in the selected scenarios would be sufficient to address the [targeted] safety need. Likewise, Rivian cautioned the Agency not to sacrifice coverage of real-world conditions in an attempt to reduce test burden. Therefore, the company did not support selecting only the most challenging conditions in general, especially since, depending on the technology, system types may vary (*i.e.,* some may be camera-only, while others may use radar, lidar, or be fused) and may thus have different challenges.

On the other hand, Toyota stated that adopting the most challenging conditions, as NHTSA had also suggested, may be a viable solution to reduce test burden. As an example, Toyota suggested that if sensing for LKA systems becomes more difficult for higher lateral speeds and dashed lane lines, then that test condition would be the one adopted. CAS agreed with Toyota in sentiment but cautioned, like Advocates earlier, that if the most challenging test conditions do not actually encompass test conditions that are removed, the Agency risks the possibility that manufacturers will design to the test and thus safety benefits will be lost.

It is for this reason (*i.e.,* loss of safety benefits) that IDIADA opposed adopting only the most challenging test conditions. The test laboratory asserted that LKA systems may be designed to intervene only at high lateral speeds, which may be considered "worst-case," but won't intervene at lower speeds, which will only further reduce consumer acceptance, and thus benefits. IDIADA suggested adopting a reduced test matrix (*e.g.,* 0.2, 0.4, 0.6 m/s lateral velocity) or introducing a "GRID approach," whereby the manufacturer would provide all results for all tests required in the test matrix, but NHTSA would only verify testing for a subset of the required test conditions.

Intel and FCA suggested a similar concept to IDIADA's first suggestion, a reduced test matrix. The two entities suggested that, to reduce test burden, the Agency should limit the number of lateral velocities assessed, with FCA specifying that NHTSA should test the minimum and maximum lateral velocities considered. Along these lines, Toyota also favored "efficient" testing, whereby only those test conditions and trials should be performed that are necessary to communicate performance to consumers. Like FCA, the automaker mentioned if testing one speed can assure performance across a speed range, then only that speed should be tested.

To reduce test burden, GM also favored reducing the number of test scenarios, where possible, instead of the number of test runs (as proposed separately by NHTSA). The manufacturer stressed that setup for a different test scenario requires significantly more time than conducting additional runs. ASC suggested that NHTSA should not reduce the number of test conditions and pointed out that the removal of the Botts' Dots test condition inherently presents a reduction. ZF Group was supportive, in general, of using manufacturer test data to augment NHTSA's results for those test conditions not assessed by the Agency. The group commented that this should not affect NHTSA's ability to provide an accurate performance assessment for LKA systems.

Response to Comments and Agency Decisions

Given the comments received, NHTSA has decided to continue testing both departure directions (*i.e.,* left and right) and several lane line types for its lane keeping performance tests. As mentioned previously, the Agency will also incorporate an additional test scenario that is similar to Euro NCAP's ELK Solid Line test. With the addition of this test, the Agency will conduct LDW/LKA assessments with dashed yellow, solid yellow, dashed white, and solid white lines, in addition to Botts' Dots. This approach, which adopts two departure directions and several common lane line types, should allow the Agency to continue to ensure system effectiveness and robustness, as Bosch asserted, as well as coherence with test protocols to maintain safety benefits.

The Agency shares concerns expressed by those commenters who contended that system performance may vary for each departure direction depending on vehicle symmetry and system robustness. NHTSA has observed performance failures in one departure direction but not the other during NCAP testing of LDW systems and research testing of LKA systems.[437] While the Agency could use manufacturer data or symmetry attestations to limit testing to one departure direction to reduce test burden, NHTSA agrees with Bosch that only the Agency's own tests will ensure consistency of results for consumers.

The Agency's testing has also shown LDW system failures for a particular lane line type but passing results for the others assessed, proving, contrary to assertions from several commenters, that equivalent performance is not guaranteed. Furthermore, while several commenters suggested that NHTSA could conduct assessments for only the dashed lane line condition because it is the most challenging for lane departure systems, the Agency's LDW data has shown run failures for other lane line types as well. Notably, NHTSA has observed LDW run failures during Botts' Dots assessments but passing results for all runs conducted for the dashed line condition. Additionally, the Agency has seen LDW run failures for the solid line conditions and passing results for the dashed line configuration for a given vehicle. Similar observations were also made during NHTSA's LKA research for each of the model year 2019 vehicles tested. For a given lateral velocity, it was typically the case that failures were observed for the solid line condition but not the dashed line condition or vice versa. The Agency's data seems to show, as Rivian asserted, that different lane departure system types may have different challenges. As such, there is merit to continuing to assess multiple lane line types during the Agency's testing.

Even with the addition of Euro NCAP's ELK Solid Line test, NHTSA is taking sufficient steps to reduce test burden by integrating LDW and LKA testing and eliminating repeat trials (as discussed next) such that it is not necessary to further limit testing to assessments for one lane line type, departure direction, or, as Toyota suggested, lateral velocity. Only by retaining test conditions representing greater coverage of real-world situations will the Agency ensure that it continues to address the safety need, as several commenters requested. NHTSA also reasons, as mentioned for the other ADAS technologies included herein, that pursuing an incremental approach to increasing test stringency (*i.e.,* that realized by increasing lateral velocity) best ensures that only those lane departure systems affording robust performance achieve passing results during the Agency's testing. It is for this reason that the Agency does not plan to adopt a reduced test matrix with fewer lateral velocities, as several commenters suggested. NHTSA agrees with GM that conducting additional runs with slightly different parameters (*i.e.,* incremented lateral velocity) for a given test scenario can be accomplished rather quickly. Furthermore, NHTSA expects that its attempt to harmonize to a large extent with Euro NCAP's LSS test protocol for its future lane keeping tests should, as Auto Innovators suggested, further reduce burden such that this concession is not necessary.

15. Number of Required Trials To Pass, Repeat Trials, and Pass Rate for LKA

Similar to its request for other ADAS technologies proposed for adoption as part of this update to NCAP, the Agency sought feedback from commenters on an appropriate number of test trials to adopt for each LKA test condition, and an acceptable pass rate.

Summary of Comments

Comments on these topics were varied, with some commenters suggesting that only one test trial for each test condition was appropriate, and others recommending up to seven trials per test condition.

Those favoring one test trial per LKA test condition and lateral velocity included TRC, IDIADA, and HATCI. IDIADA suggested that current systems are very robust such that performance is repeatable. They also noted that system robustness can be evaluated two ways—performing the same test many times (as NHTSA currently does) or performing many tests one time. TRC and HATCI mentioned that if a system did not pass requirements at a given test speed (*i.e.,* lateral velocity), performance could be verified with an additional test run (TRC) or runs (HATCI) at that speed. HATCI mentioned performing seven runs in such instances and proposed a pass rate of five out of seven. TRC also recommended that testing cease and not progress through higher lateral velocities if poor performance is observed for two of three test runs.

Some commenters (GM, Rivian, FCA, Toyota, and ASC), preferred maintaining the number of trials and pass rate from NCAP's current LDW test. Currently, NCAP performs five trials for each of the LDW test conditions (defined by a combination of lane type and departure direction), and vehicles must pass three out of the five trials (60 percent) for each test condition, and 20 of the 30 trials (66 percent) overall. Both Rivian and GM stated five trials would be sufficient to assure reliability of system performance, and a pass rate of three out of five would suffice to address any variances in testing conditions. In general, GM favored optimizing the number of test conditions rather than reducing the number of test runs since the former does more to reduce overall test burden and the latter leads to a diminished understanding of system performance variation. However, GM also noted that WIP SAE J3240 is proposing four tests per condition and a pass rate of 75 percent (*i.e.,* three out of four).

Other commenters, including Bosch, BMW, Tesla, and Auto Innovators, supported a pass rate of two out of three, with BMW specifying that the pass rate apply for each lateral velocity. The automaker stated that the Agency should accept one failed run since perfect system performance in the real world cannot be guaranteed. Tesla

[437] See model year 2019 LKA test data.

suggested that the Agency harmonize test protocols with Euro NCAP, but in instances of failed runs, NHTSA should repeat the test at least two more times (*i.e.,* three runs in total) to assess ''performance consistency.'' Auto Innovators said that although it supports the current pass rate (*i.e.,* five out of seven), it would also support a reduced pass rate of two out of three to lessen test burden.

Intel expressed no preference on either the number of runs conducted for each test condition or the pass rate adopted for LKA testing, but suggested that NHTSA try to minimize test burden when deciding what is appropriate. CAS stated that NHTSA use a binomial distribution to determine an appropriate reliability and confidence so that consumers may know how reliable a technology is. Advocates opined that the Agency should select the number of trials and pass/fail criteria to ensure a higher level of confidence in testing to assure consumers that the system will work as intended across a wide range of road and line conditions, not just those limited conditions assessed by NHTSA during testing.

Response to Comments and Agency Decisions

For each LKA test condition, NHTSA will follow a testing approach similar to those it has adopted for the other ADAS technologies included in this notice. The Agency will increment the SV's lateral velocity towards the lane line in 0.1 m/s (0.3 ft./s) increments from the minimum lateral velocity to the maximum for each of the required tests (*i.e.,* 0.2 m/s to 0.6 m/s (0.7 ft./s to 2.0 ft./s)), conducting one trial for each required lateral velocity. In the event the SV fails to provide an acceptable LKA system intervention or fails to issue an LDW warning that meets the requirements outlined for the Agency's tests, testing will cease for the test condition, the test scenario, and LKA testing overall. Vehicles must pass all required trial runs (*i.e.,* one run per lateral velocity) for all test conditions to receive credit for the lane keeping tests. A vehicle that provides an acceptable LDW alert in all trials, but fails to produce an acceptable LKA intervention for a given run, will not separately receive credit for LDW and vice versa.

Number of Test Trials/Repeat Trials

Like AEB and PAEB, several respondents recommended that the Agency perform multiple trials (*e.g.,* two, three, four, five, seven, etc.) for each LKA test variant (*i.e.,* for each lateral velocity assessed for each test condition), often with the number of recommended trials varying based on prior results. However, NHTSA has made the decision to run only one valid trial per LKA test variant. The Agency concludes this decision, which aligns with what it has adopted for AEB and PAEB testing, as well as for BSW and BSI, is appropriate for the LKA tests as well.

The adopted testing approach will limit test burden while ensuring a greater number of real-world crashes are represented. As mentioned, the Agency will assess LDW alerts for multiple lateral velocities instead of one, as is required currently. NHTSA has also added a modified version of Euro NCAP's ELK Solid Line tests, which will include two additional lane marking types (*i.e.,* dashed white and solid yellow) and double lane lines, to its LDW/LKA test matrix to assess secondary departures. While this results in (at most) 50 test trials overall for the Agency's LKA testing, this is less than the number of trials that will be required for the Agency's PAEB tests and far fewer than the number of trials that would be required if NHTSA were to adopt an approach that required five trials per test variant (as is currently specified for its LDW tests) for each of the 10 test conditions adopted for LKA. Adopting five trials per test variant, as some commenters suggested, would result in 250 total test trials for the Agency's LKA testing. This would be a significant burden to both vehicle manufacturers and NHTSA and would prohibit the Agency from communicating safety information quickly to consumers.

NHTSA's decision to conduct one trial per test variant and discontinue testing upon the first instance of the system's inability to satisfy the associated performance requirements limits consumer confusion and better instills confidence and reliability in a vehicle's LDW and LKA systems. As the Agency has mentioned previously for other ADAS technologies, conducting repeat trials in the event the system fails to meet test procedural requirements—essentially, giving a system multiple opportunities to pass—may provide consumers with a false assurance of system robustness and repeatability. So, while BMW suggested that the Agency should accept a limited number of failures in system performance during testing because system performance cannot be guaranteed under all real-world conditions, NHTSA disagrees. An assessment approach that affords no tolerance for system error during controlled laboratory testing best assures that passing systems offer robust performance during real-world operation.

Furthermore, while other respondents expressed that the Agency should perform multiple trials for each test variant to ensure system reliability, the Agency maintains, as it conveyed for other ADAS technologies prior, that it is appropriate to require one trial run per test variant instead of multiple runs to achieve this goal. This point was echoed by IDIADA in its comments. The test laboratory asserted that system robustness can be evaluated two ways—either the same test can be performed many times, or, as NHTSA intends, many tests can be performed one time. Since, as discussed earlier, NHTSA will increment the SV's lateral velocity by 0.1 m/s (0.3 ft./s) from the minimum lateral velocity established for each test condition to the maximum, the slight increase in lateral velocity from one trial to the next should effectively provide the same benefit of assuring reliability as multiple runs conducted at the same speed. Inconsistent systems may pass at one lateral velocity but will likely fail at another (higher) lateral velocity as the test stringency increases. Since a failure of any one run at any given lateral velocity for any one test condition will result in an overall test failure for the tested vehicle, NHTSA concludes its approach is sufficient to serve as an acceptable gauge of system robustness.

The Agency's planned test method affords the most balanced approach to ensure system reliability across a wide range of real-world conditions with an acceptable degree of confidence without exponentially increasing test burden, sacrificing program integrity, or introducing delays in providing information to consumers.

Pass Rate

As mentioned, NHTSA has decided to adopt a pass rate of 100 percent for NCAP's LKA testing. This decision aligns with the Agency's choice for the other ADAS technologies discussed herein. Both LDW and LKA systems must achieve passing results (*i.e.,* issue a warning or intervention, respectively, to meet the associated performance requirements) for all adopted test conditions (*i.e.,* 50 tests) to receive credit for lane keeping technology. By dictating a 100 percent pass rate, consumers will be able to quickly recognize which vehicles offer robust, repeatable system performance.

The Agency has decided not to assign credit separately for LDW and LKA since the LDW and LKA requirements will be fundamentally linked such that an LDW alert will be a requirement for the LKA tests. Furthermore, like FCW, which the Agency will similarly not provide separate credit, LDW is an existing warning technology in NCAP. NHTSA reasons that it is not appropriate to continue to assign separate credit to an existing warning system (*i.e.,* LDW) once the complementary active safety system (*i.e.,* LKA) is introduced. This decision does not pertain to BSW and BSI since both blind spot technologies are simultaneously being added to NCAP as part of this program update. Furthermore, unlike the test procedure requirements for FCW and AEB as well as LDW and LKA, which will share the same test scenarios, different test scenarios are being adopted for BSW and BSI technology.

Test scenarios and conditions adopted for LDW/LKA testing are shown in Table 25.

TABLE 25—LANE DEPARTURE WARNING (LDW)/LANE KEEPING ASSIST (LKA) ADOPTED TEST CONDITIONS

Test scenario	Line type	Departure direction	Lateral velocity (m/s (ft./s))	Passing criteria	
				Maximum SV excursion (m (ft.))	LDW alert issued (m (ft.))
Primary Departure (Single Straight Lane Line)	Solid White	Left	0.2 (0.7) 0.3 (1.0) 0.4 (1.3) 0.5 (1.6) 0.6 (2.0)	-0.3 (−1.0)	0.75 to −0.3 (2.5 to −1.0)
	Solid White	Right	0.2 (0.7) 0.3 (1.0) 0.4 (1.3) 0.5 (1.6) 0.6 (2.0)		
	Dashed Yellow	Left	0.2 (0.7) 0.3 (1.0) 0.4 (1.3) 0.5 (1.6) 0.6 (2.0)		
	Dashed Yellow	Right	0.2 (0.7) 0.3 (1.0) 0.4 (1.3) 0.5 (1.6) 0.6 (2.0)		
	Raised Pavement Markers	Left	0.2 (0.7) 0.3 (1.0) 0.4 (1.3) 0.5 (1.6) 0.6 (2.0)		
	Raised Pavement Markers	Right	0.2 (0.7) 0.3 (1.0) 0.4 (1.3) 0.5 (1.6) 0.6 (2.0)		
Secondary Departure (Dual Straight Lane Line)	Solid Yellow (L)/Dashed White (R)	Left	0.2 (0.7) 0.3 (1.0) 0.4 (1.3) 0.5 (1.6) 0.6 (2.0)	−0.3 (−1.0)	0.75 to −0.3 (2.5 to −1.0)
	Solid Yellow (L)/Dashed White (R)	Right	0.2 (0.7) 0.3 (1.0) 0.4 (1.3) 0.5 (1.6) 0.6 (2.0)		
	Dashed White (L)/Solid White (R)	Left	0.2 (0.7) 0.3 (1.0) 0.4 (1.3) 0.5 (1.6) 0.6 (2.0)		
	Dashed White (L)/Solid White (R)	Right	0.2 (0.7) 0.3 (1.0) 0.4 (1.3) 0.5 (1.6) 0.6 (2.0)		

16. Test Procedure Changes and Refinements

The Agency also asked commenters if there are any aspects of NCAP's current LDW or proposed LKA test procedure that need further refinement or clarification.

Summary of Comments

Comments on this topic were varied and ranged from test procedure clarifications to future considerations.

Comments are grouped into general topics below.

Lane Line, Environmental, and Traffic Conditions

TRC, GM, Toyota, and Auto Innovators requested that the Agency clarify the lane line condition that is acceptable for testing to improve repeatability and reproducibility. The latter three commenters asserted that lane lines must be ''of high quality and free from irregularities'' to not affect detection and thus, system performance. Accordingly, they recommended that there be no coal tar, tire marks, shadows/reflections, or faded markings, while TRC additionally requested clarification regarding brightness specifications. In contrast, AASHTO suggested NHTSA should perform LDW and LKA testing using roadway conditions prevalent in the real world, including faded and undetectable lane markings, since lane markings undergo wear and tear and vary with weather conditions. CAS mentioned the U.S. typically uses double lines to separate vehicle travel lanes from bicycle lanes, whereas Europe often uses physical barriers to create lane separation. Given the rise in fatalities for cyclists, CAS asserted that it was necessary to assess U.S. roadway conditions. CAS also proposed that the Agency adopt tests to assess general system functionality under certain environmental conditions (*e.g.,* rain, ice, fog, low sun angles, roadway conditions, line of sight, etc.), traffic conditions (*e.g.,* congestion, density), or operating conditions (*e.g.,* speed) and ensure that vehicles inform drivers via a warning when the system is not working.

Test Procedure Changes

Regarding test procedure changes, GM and Auto Innovators proposed that NHTSA harmonize conceptually with Euro NCAP by specifying use of a particular robot, *e.g.,* the ABD SR15 steering robot, to initiate drift during LKA testing. Both organizations also asked that NHTSA devise a procedure to ensure that robot friction and inertia do not affect system performance, as well as consider procedural clarifications for steering friction and electric power steering tuning.

Rivian asked that the Agency add ''improved illustrations'' and ''diagrams detailing what passing each test looks like'' to the LKA test procedure so that manufacturers may better understand each test scenario.

Finally, Auto Innovators recommended that NHTSA adopt the nomenclature in SAE J3063 and the Clearing the Confusion: Recommended Common Naming for Advanced Driver Assistance Technologies document.

Additional Scenarios

Some commenters suggested test procedure additions. Massachusetts Vision Zero Coalition and Vision Zero Network, among others, suggested that the Agency should perform an assessment of LKA systems to ensure they respond appropriately to passing cyclists (*i.e.,* allow a safe distance—minimum of three feet—between the vehicle and cyclist when passing). Similarly, the League and NACTO requested that the Agency conduct research on LDW and LKA systems to document their interactions with cyclists and pedestrians (NACTO), because anecdotal reports suggest that systems are providing unwanted corrections when drivers attempt to cross a double-yellow center line into an opposing traffic lane to pass a cyclist safely. Like other commenters, NACTO stated that vehicles' LKA systems should provide cyclists with at least three feet of space while passing, as this is required by law in 36 states and the District of Columbia.

ASC, Aptiv, and an anonymous commenter recommended that the Agency consider how to change the current LDW/LKA test protocol to evaluate lane centering systems, a system the groups asserted NHTSA should encourage. These respondents stated that NHTSA could likely use the current LDW/LKA test protocol for testing of lane centering systems, but requirements for such systems should be more stringent. The commenters also suggested that it would be ''highly appropriate'' to include enhanced curved road testing as part of a lane centering test procedure. ITS reasoned that NHTSA should include lane centering assist alongside the other two lane keeping technologies in NCAP because the Agency noted it, too, can address the same pre-crash scenarios. The company requested details on why this technology was excluded.

Advocates recommended that the Agency develop tests to limit false positives for LDW based on the most frequent causes of dissatisfaction and non-use., based on the reported driver satisfaction issues with LDW and the frequency with which such systems are turned off as a result. In contrast, Aptiv and ASC did not support the addition of a false positive test for LKA systems. One anonymous public commenter stated that NHTSA should consider evaluating systems for how they react after a period of driver inactivity, suggesting that the Agency should have requirements for how long the system should operate without driver action and specify what the system should do in such instances (*e.g.,* bring the vehicle safely to stop).

While Auto Innovators generally supported harmonization with Euro NCAP, the group did not support adoption of several of the consumer information program's LSS scenarios for U.S. NCAP's LDW/LKA tests. In addition to the ELK Overtaking vehicle scenario already discussed previously in the Removal or Integration of LDW section, the organization recommended that NHTSA not include the ELK Oncoming vehicle scenario as well. The group remarked that it is similar in intent to NHTSA's Oncoming Traffic Safety Assist (OTSA) test procedure, which was included in NCAP's roadmap.

Response to Comments and Agency Decisions

Lane Line, Environmental, and Traffic Conditions

A wide variety of road conditions exist across the U.S. Nonetheless, one of the Agency's main objectives is to evaluate each vehicle model against the same protocol. To maintain a reasonable test burden, testing with multiple lane line and all pavement surface conditions that a vehicle may encounter is not possible. This is also a reason that NHTSA is unable to test general system functionality under multiple atmospheric conditions and traffic conditions.

That being said, it is necessary to clearly specify pavement condition and marking qualities to ensure vehicle models are undergoing the same procedure. The Agency will maintain the road test surface and lane line markings specifications currently included in NCAP's LKA draft test procedures. Specifically, the road test surface shall be a dry, uniform, solid-paved high-mu surface having no debris, irregularities, or undulations, such as loose pavement, large cracks, or dips. The road test surface shall produce a peak friction coefficient (PFC) of 1.02 ± 0.05 when measured using ASTM F2493 standard reference test tire when tested in accordance with ASTM Method E 1337–19 at a speed of 64.4 kph (40 mph), without water delivery.[438] Surface friction is a critical factor in testing LKA systems as vehicles are dynamically assessed for various conditions, including multiple lateral velocities and turns. Vehicles

[438] ASTM E1337–19, *Standard Test Method for Determining Longitudinal Peak Braking Coefficient (PBC) of Paved Surfaces Using Standard Reference Test Tire.*

also use steering and/or braking maneuvers for the LKA intervention during testing. Thus, the presence of moisture will significantly change the measured performance of a vehicle's ability to turn. A dry surface is more consistent and provides for greater test repeatability. Lane line markings shall have high contrast, meet U.S. DOT specifications, as required by the MUTCD, and be considered in very good condition. Lane marker color and reflectivity shall meet all applicable standards from the International Commission of Illumination (CIE) for color and the American Society for Testing and Materials (ASTM) on lane marker reflectance.

With respect to environmental conditions, the Agency's lane keeping technology tests will be performed when the ambient temperature is any temperature between 0° C (32° F) and 40° C (104° F) and the maximum wind speed is no greater than 10 m/s (22 mph). While the Agency reasons that lane keeping systems can operate acceptably at lower temperatures, the limiting factor is braking performance during LKA interventions. NHTSA has selected an ambient temperature range that matches the range specified in NHTSA's safety standard for brake system performance.[439] Excessive wind during testing could affect the ability of the SV to maintain consistent speed and/or lateral position.

Tests will be conducted during daylight hours with an ambient illumination on the test surface that is not less than 2,000 lux, as this approximates the minimum light level on a typical roadway on an overcast day. In addition, to better ensure test repeatability, testing may not be performed while driving toward or away from the sun such that the horizontal angle between the sun and a vertical plane containing the centerline of the subject vehicle is less than 25 degrees and the solar elevation angle is less than 15 degrees. The intensity of low-angle sunlight can create sensor anomalies that may lead to unrepeatable test results. Visibility (*i.e.,* a clear field of view) must be 5 km (3.0 mi) or greater. Testing will not be run during periods of precipitation (*i.e.,* rain, snow, or hail) or when visibility is affected by fog, smoke, ash, or other particulate. NHTSA reasons that the presence of precipitation could influence the outcome of lane keeping tests because wet, icy, or snow-covered pavement has lower friction. Conducting a test under those conditions also poses risks to lab personnel. This choice is also supported by crash data from 2011 to 2015 which shows that 91 percent of fatal and 87 percent of injurious road departure crashes occurred in clear weather and 87 percent of fatal and 81 percent of injurious road departure crashes occurred on dry roadway surfaces, on average, annually.[440] Additionally, when considering opposite-direction crashes, 88 percent of fatal and 85 percent of injurious crashes occurred during clear conditions, and 83 percent of fatal and 76 percent of injurious crashes occurred on dry roadway surfaces on average, annually.[441]

As stated in the March 2022 notice, LDW telltales are often present when the activation threshold speed, lane markings, and environmental conditions meet system requirements. These telltales disappear when the system is inoperable due to inadequate conditions or those which introduce too much uncertainty for the vehicle's systems to function. Given the lack of a telltale indicates to the driver a change in system status, NHTSA chose not to propose a requirement that the vehicle issue an alert if the lane keeping system is not functioning. This decision will be upheld for this NCAP update.

Test Procedure Changes

The Agency will use the AB Dynamics SR15 steering robot for its LKA tests, as GM and Auto Innovators requested. Due to its inherent low inertia, low drag (*i.e.,* friction) design, NHTSA concludes it is unnecessary to devise a procedure to ensure that steering robot friction and inertia do not affect system performance. It can also be installed on the steering wheel without removing the airbag.

NHTSA has reviewed its LDW and LKA test procedures for the release of this final notice and has added descriptive language and illustrations to improve clarity of the procedures, as Rivian has requested.

The Agency has also adopted the nomenclature for lane keeping systems in SAE J3063 and the Clearing the Confusion: Recommended Common Naming for Advanced Driver Assistance Technologies document, as Auto Innovators requested. As reflected throughout this notice and in the accompanying test procedure, the Agency will refer to lane keeping systems as Lane Keeping Assistance (LKA) systems.

Additional Scenarios

While NHTSA is not actively conducting research or developing test procedures to assess the performance of LDW and/or LKA systems around cyclists and pedestrians, in light of the comments received, it will consider doing so in the future.

NHTSA recognizes that SAE has recently finalized a performance-based test procedure to assess LCA systems; however, at this time, the Agency has not had a chance to evaluate this protocol to determine its acceptability for adoption in NCAP.[442] Even minor changes to its current LDW/LKA test protocol to make requirements more stringent, as ASC and Aptiv suggested, would require evaluation. Accordingly, LCA performance will not be assessed as part of this NCAP update. That being said, as noted earlier when discussing secondary departures after an initial LKA intervention, NHTSA expects that vehicles will continue to undergo lane centering design improvements even without a prescribed test. The Agency will reconsider assessing the performance of LCA systems in NCAP once it has thoroughly evaluated the SAE test procedure.

Regarding false positive testing for lane keeping technologies, NHTSA maintains its previous stance that a lane keeping technology false positive test is not appropriate at this time. Concerns with repeatability and reproducibility exist currently with respect to defining the appropriate delineation between a driver who is actively steering and not utilizing the turn signal, such that the system should be suppressed, and one who is not, such that the intervention would be necessary. This delineation must be assured to adequately address consumer acceptance issues. NHTSA plans to conduct research to assess such situations, as well as others where LKA interventions should be suppressed, such as when ESC, FCW, and/or AEB is in operation, or when a VRU is residing at a 25 percent offset in the SV travel lane. The Agency also notes it is further investigating human factors involved during intended and unintended driver maneuvers for future applications. Nuisance alerts often occur because the driver's intent to maneuver in a

[439] FMVSS No. 135, ''Light vehicle brake systems,'' *https://www.ecfr.gov/current/title-49/subtitle-B/chapter-V/part-571/subpart-B/section-571.135.*

[440] For road departure crashes, weather conditions were unknown or not reported in 1 percent of fatal crashes. Roadway surface conditions were unknown or not reported in 1 percent of fatal road departure crashes and 2 percent of road departure crashes with injuries.

[441] For opposite direction crashes, weather conditions were unknown or not reported in 1 percent of fatal crashes.

[442] SAE J3240, Passenger Vehicle Lane Departure Warning, Lane Keeping Assistance, and Lane Centering Assistance Systems Test Procedure, published December 20, 2023, includes provisions for an LCA assessment.

particular direction does not align with the vehicle's movement due to poor environmental/road conditions and/or vehicle hardware or software shortfalls for a particular situation. Currently, the Agency defines driver intent by the vehicle's lateral velocity; low lateral velocity is meant to simulate unintended drift without the use of a turn signal. It is possible that other information gathered by the vehicle (*i.e.,* torque on the steering wheel, steering rate, driver gaze, etc.) can play a role in determining a driver's intent to maneuver, thus allowing the vehicle to suppress unnecessary warnings and activations. Data gathered may also help inform next steps to address concerns regarding driver inactivity or distraction, which may result in unintended drifting. NHTSA notes this human factors research is ongoing, and the Agency continues to monitor consumer complaint data related to false positive activations of LDW and LKA systems. NHTSA will consider adopting additional LDW/LKA tests in the future to address relevant safety needs if such tests are found to be repeatable and reproducible during the Agency's research.

At this time, as Auto Innovators requested, NHTSA is not adopting Euro NCAP's ELK Overtaking vehicle or ELK Oncoming vehicle scenarios for NCAP's LDW/LKA assessments. However, as indicated previously, the Overtaking vehicle scenarios is similar to two of the test scenarios adopted for the NCAP's BSI assessments—the SV Lane Change with Constant Headway scenario and SV Lane Change with Closing Headway scenario.

VIII. Self-Reported Data

Currently, through the Agency's approved information collection,[443] vehicle manufacturers report internal physical test data that demonstrates whether the recommended ADAS technologies installed on their vehicle models pass NHTSA's system performance test requirements. NHTSA uses this data, in conjunction with random verification testing, to determine whether each vehicle model's performance meets NCAP's requirements. This process, in place since model year 2011, has been critical to the successful administration of the program. However, as the Agency noted in its March 2022 RFC, there are challenges associated with this process. NHTSA has identified inconsistencies in vehicle manufacturers' self-reported data submissions, many of which may stem from unfamiliarity with NCAP's test procedures. To address this issue, NHTSA stated one approach would be to require all vehicle manufacturers to provide data from independent test facilities that meet criteria demonstrating competence in NCAP testing protocols. NHTSA concludes that this step would help the Agency maintain credibility and retain public trust in its program.

A. NHTSA's Proposals, Summary of Comments, Response to Comments, and Agency Decisions

1. Self-Reported Data From Non-NHTSA Contracted Laboratories

In its March 2022 RFC notice, NHTSA proposed to only accept self-reported ADAS performance data from designated NHTSA-contracted laboratories.

Summary of Comments

Commenters were divided on whether the Agency should only accept self-reported test data from NHTSA's contracted test laboratories. TRC, Auto Innovators, Honda, GM, Mitsubishi, Toyota, FCA, Tesla, and Hyundai stated that the Agency should continue to accept self-reported test data from non-NHTSA contracted test laboratories, as restricting acceptance of data to NHTSA-contracted laboratories may increase burden and contribute to delays in the dispensing of information to the public. Honda, among others, cautioned that if the Agency limits testing to only NHTSA's contracted test laboratories, there may not be sufficient capacity available to complete all required testing, especially considering the proposed additions to the ADAS testing program. Vehicle models would then not receive credit for having a NHTSA-approved ADAS technology despite being otherwise eligible. FCA noted that self-reported data is accepted for FMVSS compliance and should therefore be acceptable for NCAP as well. Honda further requested clarification regarding NHTSA's statement in its March 2022 RFC that NHTSA will refuse data when it is not provided from a test facility that is designated as a NHTSA-contracted test lab *or* when tests are not conducted in accordance with NCAP's protocols, noting that the Agency's use of ''or'' was unclear.

TRC, a test laboratory, offered that the criteria most relevant to the successful conducting of ADAS testing are quality process and management accreditation, facility and lane marking conditions, equipment condition, calibration and traceability, independence, and a positive history of performing testing. Mitsubishi requested that test laboratories be made available in other world regions, including Japan.

Auto Innovators acknowledged NHTSA's desire to maintain program credibility and proposed that this could still be done while allowing manufacturers to conduct testing at an in-house or third-party facility. The group supported the Agency's ability to request test documentation and to review any relevant data related to the vehicle or test facility on a case-by-case basis. Tesla also suggested that NHTSA could request a dossier containing evidence of a valid ADAS test prior to granting credit, similar to Euro NCAP's process.

On the other hand, CAS, Bosch, Advocates, and a public commenter supported accepting self-reported test data only from NHTSA-contracted test laboratories. CAS suggested that NHTSA publish standards with which laboratories could comply and become a NHTSA-certified lab as well as standards for third-party organizations to audit and certify other laboratories. The public commenter opined that the Agency might consider accepting data from laboratories contracted for UN ECE testing. Bosch strongly opposed self-reported data altogether and proposed that tests should be conducted and/or contracted by an authority to ensure the repeatability and reproducibility of results. The company referred to Euro NCAP's testing process, in which vehicle manufacturers, test laboratories, or a third party pays for a vehicle test, and one of Euro NCAP's eight test laboratories must perform the testing.

Response to Comments and Agency Decisions

Regarding Honda's request for clarification on its proposal, NHTSA's intent was to not accept manufacturers' self-reported data that is either (1) derived from tests that were not conducted in accordance with NCAP's testing protocols, or (2) generated by test laboratories that are not contracted by the Agency to perform the tests in question, regardless of whether test protocols were followed. The Agency's proposal differed from the current submission process, which allows

[443] NHTSA has a current information collection under the Paperwork Reduction Act (OMB Control Number: 2127–0629) to obtain vehicle information for the general public in support of NCAP. The information collection requests responses from major motor vehicle manufacturers about the crashworthiness, crash avoidance, and other capabilities of their vehicle models. The collection is voluntary and conducted annually. The information is primarily used to provide information to consumers. It is used to disseminate safety information on *http://www.nhtsa.gov/ratings* and to address consumer inquiries as well as for internal agency analyses.

manufacturers to provide test data from any test laboratory if the test is deemed valid by the manufacturer.

Maintaining public trust is critical and has been NHTSA's long-standing goal for NCAP. However, NHTSA acknowledges that the concerns expressed by Honda and others regarding test laboratory capacity is credible. Delays in test scheduling will ultimately translate to delays in providing updated information to the American public. Due to the limited number of NHTSA-contracted test laboratories currently available, it is not currently practicable to require manufacturers to perform ADAS testing at NHTSA-contracted laboratories in order to gain NCAP ADAS credit.

As such, the Agency has determined that for data gathered in response to this NCAP update, vehicle manufacturers may utilize an in-house or third-party facility, either in the U.S. or globally, provided that the test is conducted (1) in accordance with NCAP's test procedures and (2) using U.S. production-level vehicles identical to those that could be purchased by a consumer at dealers' lots in the U.S. at any particular time during a given model year. However, it should be noted that this decision is subject to change in the future. For example, when NHTSA completes a rulemaking to update the Monroney label, the Agency may require the use of specific laboratories to generate ratings data, a testing method already used for NCAP's optional testing program. Under this provision, vehicle manufacturers fund desired testing through specified laboratories; however, test setup, test conduct, and data quality control must adhere to NHTSA's protocols.[444] In addition, NHTSA wants to be clear that vehicles failing to provide passing performance during the Agency's assessments will not receive credit for the related technology, regardless of whether passing results were provided by the vehicle manufacturer in response to the NCAP's annual data information request.

2. Other Means To Address Programmatic Challenges With Self-Reported Data

The Agency requested feedback from the public regarding new ways to alleviate some of the programmatic challenges it has encountered with NCAP ADAS testing.

Summary of Comments

GM and ASC suggested NHTSA should accept virtual forms of testing data, including computer simulations, software-in-the-loop, and hardware-in-the-loop methods. GM noted that producing data in this way would be more resource efficient. ASC recommended allowing a combined submission including real and virtual tests, particularly upon implementation.

Auto Innovators and HATCI suggested the Agency engage with vehicle manufacturers to provide clarity regarding test procedures. In particular, HATCI proposed that NHTSA conduct test procedure ''workshops'' to ensure that vehicle manufacturers and test laboratories have a common understanding of test conduct practices. Auto Innovators noted that updates to test procedures could be made to ensure more repeatable and reproducible results. Along those lines, GM supported a thorough test procedure development process involving the development of confidence intervals and adjustment to procedures after enough NHTSA-sponsored and internal tests are conducted.

Consumer Reports supported efforts to continuously review the NHTSA complaints database for ADAS systems as well as defect investigations to identify situations where systems may be creating ''a perceived or real risk'' of increasing crashes rather than mitigating them. The group also proposed reviewing data for consumer acceptance issues, such as ADAS false activations in the real world.

Response to Comments and Agency Decisions

The Agency will accept only self-reported data from physical testing at this time. NHTSA acknowledges that manufacturers must gather a significant amount of data to receive credit for any of the ADAS technologies recommended in NCAP. However, at this time, there is not sufficient evidence that virtual or computer-generated data would sufficiently demonstrate that vehicle models meet NCAP's ADAS performance requirements.

As mentioned throughout this notice, NHTSA plans to closely monitor real-world data for problematic activations, unintended consequences, and consumer acceptance concerns. As ADAS technologies become more prevalent in the fleet and more complex, it is critical that the Agency keeps abreast of the changing crash landscape. The Agency also plans to continue its research efforts to make ongoing improvements to the program, as discussed in the following NCAP Roadmap section.

IX. NCAP Roadmap

In accordance with section 24213(c) of the BIL, the March 2022 RFC notice proposed a 10-year roadmap setting forth NHTSA's plans to upgrade NCAP with mid-term plans spanning 2024 through 2028 and long-term plans spanning 2024 through 2033. NHTSA has long-established criteria for evaluating safety technologies for inclusion in NCAP. Potential program updates must meet the following four prerequisites: (1) the update to the program addresses a safety need; (2) there are system designs that can mitigate the safety problem, (3) existing or new system designs have the potential to improve safety, and (4) a performance-based objective test procedure exists that can assess system performance.

NHTSA uses the notice and comment process to seek public input on updates to NCAP and ensure the reasonableness of the time periods for NCAP changes, and the Agency expects this practice to continue. As part of the Agency's development of next steps for NCAP, NHTSA regularly evaluates other rating systems from vehicle safety consumer information programs within the United States and abroad, including whether there are safety benefits from consistency with those other rating systems.

In the mid-term portion of the roadmap, NHTSA has included only those technologies that are practicable and for which objective tests, evaluation criteria, and other consumer data exist. The mid-term potential program updates proposed in the 2022 NCAP RFC included the following:

- Adding four ADAS technologies (LKA, BSW, BSI, and PAEB).
- Updating the performance evaluation of current recommended ADAS technologies (FCW, LDW, DBS, and CIB).
- Including evaluation of advanced lighting technologies and other ADAS technologies.
- Creating a new crash avoidance rating system.
- Updating the Monroney label to include crash avoidance rating information.
- Adding a crashworthiness pedestrian protection testing program.
- Adding the THOR–50M in NCAP's full frontal impact crash tests and the WorldSID–50M in NCAP's side impact barrier and side impact pole test.
- Considering a new frontal oblique crash test with the advanced THOR–50M.

The long-term initiatives discussed in the March 2022 NCAP RFC notice

[444] 52 FR 31691.

include a variety of new technologies with safety potential that are not sufficiently mature, and thus require additional agency research and review. These include: intersection safety assist (intersection AEB); opposing traffic safety assist; and more advanced automatic emergency braking that accounts for vehicles turning right or left at intersections across the path of pedestrians, as well as bicyclists, motorcyclists, and other VRUs in applicable crash scenarios. NHTSA also stated its intent to explore opportunities to encourage the development and deployment of emerging technologies for safe driving choices such as driver monitoring systems for reducing distraction and drowsy driving, intelligent speed assist, alcohol detection systems, seat belt interlocks, and rear seat child reminder assist.

The March 2022 NCAP RFC notice explained that while the Agency can reasonably anticipate when the start of actions may occur in the mid-term portion of the roadmap, many technologies in the long-term portion of the roadmap require additional research, test procedure development, and product development and maturity, among other factors. These factors prevent the Agency from providing more details on the anticipated start of action at this time. For the mid-term initiatives, the Agency stated that the completion of action and subsequent implementation dates are highly dependent upon the notice and comment process, among other factors. Specifically, the Agency stated that completion dates depend on the number and depth of the comments received in response to an RFC notice, along with any technical research necessary to resolve any challenging issues or potential policy considerations raised in the comments. Therefore, the March 2022 NCAP RFC notice explained that the Agency cannot reasonably anticipate those timelines in advance.

NHTSA requested comment on (1) safety opportunities or technologies in development that could be included in future roadmaps, (2) opportunities to benefit from collaboration or harmonization with other consumer vehicle safety information programs, and (3) other issues to assist with long-term planning.

Summary of Comments

NHTSA received numerous comments on the proposed roadmap. Many commenters expressed general support for the proposed NCAP roadmap, with industry stakeholders noting that a roadmap with near, mid, and long-term strategies for updating NCAP incentivizes manufacturers to prioritize and accelerate the most relevant and effective safety technologies. However, many commenters, including Advocates for Highway and Auto Safety, the Consumer Federation of America, and Auto Innovators, stated that the proposed NCAP roadmap lacks sufficient specificity on future timelines, dates, and required actions. Industry stakeholders commented that the roadmap did not provide stakeholders with enough information to plan for the future. Stakeholders requested the roadmap include proposed and ongoing research and contain target dates for key milestones, decision points, and implementation of new program items to allow automakers to proactively plan and develop long-term design strategies and technology integration. Commenters also requested that the NCAP roadmap timetables align with the three-to-five-year duration associated with vehicle development.

Several industry stakeholders (Honda, Toyota, BMW, Mercedes-Benz, GM and others) requested NHTSA harmonize the NCAP roadmap with other global programs, such as Euro NCAP, with appropriate objective test procedures and evaluations tailored to the U.S. market. Industry stakeholders stated that test procedures to evaluate new technologies should be objective, measurable, repeatable, and harmonized with other global NCAP test procedures where possible. Commenters noted that harmonizing the NCAP roadmap with global NCAPs will introduce safety technologies to U.S. consumers more quickly at reduced cost to consumers and manufacturers.

Commenters encouraged NHTSA to establish regularly scheduled opportunities for stakeholder engagement and collaboration to develop the NCAP roadmap. Auto Innovators suggested establishing a representative advisory panel with annual discussions between NHTSA and stakeholders to help prioritize initiatives in the NCAP roadmap and establish timelines for the roadmap. Commenters also suggested updating the NCAP roadmap every three to five years depending on the current field data, available countermeasures, and effectiveness and safety implications of the available countermeasures.

Auto Innovators and its members requested that NHTSA align NCAP initiatives with relevant ongoing regulatory actions. Industry stakeholders recommended ensuring consistency between NCAP and planned FMVSS where possible. Specifically, they requested that, similar to how the existing NCAP is structured for crashworthiness, FMVSS should set the baseline standard for vehicle performance, with NCAP requirements evaluating safety at a level either equal to, or above, the baseline. Safety advocates stated that vehicle safety standards that save lives outside the vehicle should not be left to consumer choice. For example, commenters stated that new NCAP items, such as better headlamps, redesigned hoods and bumpers, and direct visibility should be included in FMVSS.

Commenters supported NHTSA's four prerequisites for inclusion of items into NCAP. However, industry stakeholders also requested that the roadmap include items for removal from NCAP for various reasons such as a parallel regulation already addressing the same target population.

Industry stakeholders expressed concern that certain technologies such as alcohol ignition and seat belt interlocks may not be appropriate to include in or show effectiveness through NCAP. The stakeholders further explained that certain consumers may not voluntarily seek this type of technology in a vehicle purchase, and it may be difficult to convince the average consumer who refrains from driving under the influence or driving unrestrained that these technologies directly benefit them. In contrast, several safety advocates and organizations encouraged NHTSA to include testing in NCAP to mitigate the risk of alcohol-impaired driving, and limit distracted driving caused by infotainment systems and other sources.

Commenters requested that NCAP updates include the latest safety technologies, including: rear cross-traffic warning and rear automatic braking, intersection safety assist, intelligent speed assist, driver monitoring systems (DMS), alcohol detection systems, and human-machine interaction. Several commenters suggested including rear seat child passenger detection and alert systems, along with bicyclist and motorcyclist crash avoidance and crash protection systems, similar to that in Euro NCAP. Several commenters also expressed concerns about vehicles with higher hoods and reduced direct visibility of pedestrians in the vicinity of these vehicles for the driver, requesting an evaluation of driver direct visibility in NCAP.

Safety advocates and industry stakeholders requested including advanced lighting technologies, such as automatic high beam and high beam assist systems, in NCAP. Several commenters also requested enhanced testing scenarios in future NCAP updates for all types of crash avoidance technologies to reflect less-than-ideal conditions like low light, glare, and fog.

Several commenters requested expanding the range of test dummies in crash tests to include dummies representing female occupants and older adults in driver and passenger seating positions. Additionally, commenters suggested that vehicle safety technology testing consider such factors as: micro-mobility, wheelchair users, bicyclists, and diverse human variations including size, shape, and skin color. Commenters also requested the use of advanced crash test dummies, (*e.g.,* THOR–50M and WorldSID–50M), and the use of additional crash test conditions such as frontal oblique impacts and rear seat occupant protection.

Several commenters requested the inclusion of vehicle communication systems (vehicle-to-vehicle and vehicle-to-everything technologies), while other commenters expressed cybersecurity and privacy concerns with such systems. Some commenters focused on post-crash safety and requested hazard lighting for disabled vehicles and automatic crash notification.

Response to Comments and Agency Decisions

NHTSA has developed a final roadmap for updating NCAP in multiple phases for the period 2024 through 2033. The mid-term initiatives in the roadmap span the period 2024–2028 and the long-term items span the period 2024–2033. The NCAP roadmap in this decision notice includes four phases for each NCAP initiative, along with a completion milestone for each phase. The four phases are: (1) Research phase if applicable, (2) Request for comment (RFC) phase, (3) Final decision phase, and (4) Implementation phase.

The Research phase may include field data analysis, test procedure and performance criteria development, and evaluation of vehicle technologies and designs. The Research phase may also include rulemaking to federalize tools used in the test procedures, such as new crash test dummies. The RFC phase includes the development of the proposal and publication of the RFC notice. The Final decision phase includes review of comments received, responding to the comments, and the publication of the final decision notice. The final test procedures and evaluation criteria will be provided in the final decision notice.

Depending on the comments received, there could be additional research necessary between the RFC phase and Final decision phase. There could also be overlap between the Research phase with the RFC and Final decision phases to conduct supplementary research and draft and publish research reports supporting the NCAP notice. The Implementation phase generally begins one to two calendar years after the publication of the Final decision notice.

While timing details are provided in the roadmap, NHTSA notes that some of the milestone dates may need to be changed in the future, as the completion of action and subsequent implementation dates are highly dependent upon the notice and comment process. NHTSA plans to update the NCAP roadmap approximately every four years, with timelines updated accordingly.

NHTSA asserts that the notice and comment process, which seeks input from the public on updates to NCAP, works well and effectively. Thus, the Agency intends to continue to use this method to solicit input from the public on updates to NCAP. The Agency may also consider a stakeholder meeting on updating NCAP before an update to the roadmap is released.

NHTSA will continue to monitor vehicle technologies and field data to select appropriate technologies and vehicle features to address safety needs. As requested by commenters, NHTSA will consider appropriate areas for harmonizing with other global programs such as Euro NCAP. In evaluating whether harmonization is appropriate, the Agency will assess existing procedures for updates to improve objectivity and ensure test procedures are representative of real-world crash conditions in the U.S. The Agency will also ensure any proposed tests can be used on U.S. vehicles to assess safety performance, and that the tests will evaluate technologies and vehicle designs addressing a U.S. safety need.

This roadmap outlines NHTSA's plans to update NCAP in the following three safety programs: crashworthiness, crash avoidance, and VRU safety. The NCAP rating system will consider systems that could include any of the following combinations: (1) distinct ratings for each of the safety programs; (2) a safety rating that combines the three distinct ratings; (3) other options suggested by commenters and consumers. Future updates to the roadmap could include additional safety programs, evaluation of new technologies and vehicle design features, and enhanced evaluation of vehicle technologies and designs currently in NCAP. As described in its March 2024 response to GAO recommendations,[445] NHTSA is focused on reducing fatality and injury risk for all motor vehicle occupants and addressing identified disparities expeditiously. NHTSA is taking several steps to address sex-based disparities in motor vehicle crash outcomes. Regarding requests for the use of expanded range of advanced crash test dummies and test surrogates, NHTSA developed and published a detailed plan on the development and implementation of advanced crash test dummies. This plan discusses the Agency's efforts to address the limitations of NHTSA's current test dummies to provide information relative to certain demographic groups, such as female and elderly vehicle occupants, and certain body regions, such as the lower extremities. NHTSA plans to incorporate advanced dummies into NCAP crash tests when the research is completed, necessary tools are available for implementation, and they meet the criteria for inclusion in NCAP. For example, since NHTSA has efforts underway to include the advanced 50th percentile male dummy, THOR–50M, into Federal regulation, the mid-term roadmap initiatives include using the THOR–50M in NCAP frontal impact crash tests. Since research is still underway regarding the advanced 5th percentile female dummy, THOR–05F, the NCAP long-term roadmap initiatives include adding the THOR–05F in frontal impact crash tests.

Consistent with standard practice, NHTSA conducts ongoing evaluation of technological advances in anthropomorphic test devices available in global and domestic markets to determine whether the Agency should include those devices in NCAP and will continue to do so with respect to anthropomorphic test devices that would help address the identified sex-based disparities.

While NHTSA primarily plans to update NCAP with new technologies and vehicle countermeasures, it will also consider removing existing evaluation programs found redundant due to regulations or that no longer effectively incentivize safety improvements.

The roadmap outlined in this decision notice takes into consideration the aforementioned efforts, the input received from all stakeholders on the potential updates to NCAP, the readiness of the technologies, safety

[445] NHTSA Advanced Anthropomorphic Test Devices Development and Implementation Plan, March 2024, *https://www.nhtsa.gov/sites/nhtsa.gov/files/2024-04/NHTSA-Advanced-Anthropomorphic-Test-Devices-Development-Implementation-041624-v1-tag.pdf.*

potential, and the availability of objective and representative test procedures that can be applied to the U.S. vehicle fleet. NHTSA's NCAP roadmap for mid-term and long-term updates to the program are shown in Figures 18 and 19, respectively. This roadmap represents the current state of knowledge, and any safety opportunity or technology not included in this roadmap was omitted because it did not meet the four prerequisites for inclusion in NCAP at this time. In the next update to the roadmap, the addition of other technologies or safety programs would be subject to NHTSA's four prerequisites for inclusion in NCAP and the appropriateness of the technology or opportunity for a consumer information program.[446]

In general, the implementation timing of an update in NCAP ranges from 2 to 4 years from the time of publication of an RFC notice announcing the proposed update.

A. Mid-Term Updates to NCAP (2024–2028)

1. Updates to the Crash Avoidance Program

In the near-term, NHTSA plans to finalize and implement the four additional ADAS technologies proposed in the 2022 NCAP RFC (LKA, BSW, BSI, and PAEB). NHTSA will identify vehicles with these recommended technologies by way of check marks on the NHTSA website starting in the fourth quarter of 2025 with model year 2026 vehicles. Until a crash avoidance rating system is developed and implemented, the check mark on the NHTSA website will remain the primary way of notifying consumers of available crash avoidance technologies meeting NHTSA's system performance criteria.

NHTSA plans to complete research on rear automatic braking (RAB) [447] in 2024 and plans to evaluate RAB systems in NCAP starting in the fourth quarter of 2027 with model year 2028 vehicles.

2. Updates to the Crashworthiness Program

As noted in the March 2022 NCAP RFC notice, NHTSA plans to use advanced crash test dummies with enhanced biofidelity (human-like response to impact loads) and injury assessment capabilities in current crash testing and any additional crash tests considered for the program. Mid-term updates to NCAP's crashworthiness program include:

- Using the THOR–50M instead of the HIII–50M in the NCAP frontal impact crash tests.
- Conducting a full-frontal rigid barrier crash test with the HIII–05F dummy in the driver seat.
  - Equity in crash outcomes, including female occupant safety, is a priority for NHTSA. Since the advanced 5th percentile female frontal impact test dummy, THOR–05F, is currently under evaluation and refinement, it is not yet ready for implementation in NCAP crash tests. The THOR–05F is in the long-term update to NCAP in this roadmap. Until the THOR–05F dummy is implemented in NCAP, NHTSA will use the current HIII–05F dummy for assessing small female occupant risk in the driver seating position.
- Including a frontal oblique crash test using the THOR–50M.
  - Given the enhanced biofidelity and instrumentation of the THOR–50M, especially for lower extremity injury prediction, testing with the THOR–50M in the frontal oblique crash test would help reduce the high rates of leg, foot, and ankle injuries seen in both females and males.[448]
- Replacing the ES–2re dummy with the WorldSID–50M dummy in the driver seat in the side impact Moving Deformable Barrier (MDB) crash test.
- Including the SID–IIs chest and abdomen deflections to assess overall injury potential in both the MDB crash test and the side pole impact test.[449]

NHTSA plans to implement the updated crashworthiness evaluation described above starting in the fourth quarter of 2027 with model year 2028 vehicles. Implementation of the changes discussed will address comments received pertaining to the use of advanced crash test dummies, including those representing female occupants, as well as the incorporation of additional crash test conditions capturing frontal oblique impacts.

3. Updates to the VRU Safety Program

As noted earlier, NHTSA plans to finalize the implementation of PAEB in the near term. NHTSA also plans to finalize in the near term the crashworthiness pedestrian protection proposed on May 26, 2023. The Agency will consider expanding the head impact test areas to include bicyclists' impact areas. NHTSA will include a check mark on the NHTSA website for PAEB and vehicle designs that meet the performance requirements in the NCAP crashworthiness pedestrian protection tests starting in the fourth quarter of 2025 with model year 2026 vehicles.

In response to commenters requesting protection for additional VRUs, NHTSA has expedited its research for bicyclists and motorcyclists, and is currently developing and evaluating test procedures specific to the vehicle fleet and the crash scenarios and injury profiles of bicyclists and motorcyclists in the U.S. NHTSA plans to include evaluation of AEB for mitigating crashes with bicyclists and motorcyclists (along path crash scenarios) starting in the fourth quarter of 2027 with model year 2028 vehicles.

Starting in the fourth quarter of 2024 with model year 2025 vehicles, NHTSA plans to provide consumers with information obtained from vehicle manufacturers related to whether a vehicle is equipped with direct sensing technology and an alert system to mitigate heatstroke to unattended children in vehicles. By providing this information, which will be made available in the ''Safety Features'' section of the ratings page on the NHTSA website, NHTSA is taking initial steps to address comments received pertaining to rear seat occupant protection.

4. Rating Systems

NHTSA intends to develop and propose crash avoidance and VRU safety rating systems, an updated crashworthiness rating system, and an overall safety rating system for each vehicle and seek public comment. NHTSA plans to develop the crash avoidance, crashworthiness, VRU safety, and overall safety rating system with the flexibility to allow for the addition of ratings of new technologies and vehicle

[446] Though various commenters requested V2X technology be included in NCAP, NHTSA has not included it in the roadmap because of uncertainties in the deployment of cellular V2X technologies, the research needed to determine the safety potential of these technologies in light of other emerging technologies, including AEB for intersection crashes, and the need to develop test procedures for evaluating V2X technologies, including cybersecurity.

[447] Though a number of commenters requested rear cross traffic warning (RCTW) be included in NCAP, NHTSA is not including evaluation of RCTW in NCAP at this time because the Agency's analysis of field data indicates that current RCTW systems have low safety benefits and are mainly associated with reduction in property damage crashes.

[448] Detailed analysis of field data suggests that when controlling for various factors, including crash speed and restraint use, female drivers have a higher risk of moderate lower extremity (leg and foot/ankle) injuries than male drivers in frontal crashes. Though the THOR–50M dummy is used for injury assessment, the countermeasures would also mitigate lower extremity injuries for 50th percentile and larger female occupants.

[449] This update would encourage countermeasures to reduce thoracic and abdominal injuries to small female occupants in side impact crashes. This is an interim upgrade to side impact protection for female occupants until the advanced 5th percentile female side impact test dummy, WorldSID–05F, is included in NCAP. The inclusion of WorldSID–05F in NCAP is a long-term update in this roadmap.

safety countermeasures, or for the removal of existing ones in a way that would not result in significant change to the rating systems. The final decisions on the crash avoidance, crashworthiness, and VRU safety rating system including overall vehicle rating are planned for completion in the third quarter of 2025 (crash avoidance), in the first quarter of 2026 (crashworthiness, VRU, overall vehicle safety) and implementation in NCAP in the fourth quarter of 2027 beginning with model year 2028 vehicles.

NHTSA is currently conducting consumer research on approaches to display the crashworthiness, crash avoidance, VRU safety, and overall vehicle rating on the Monroney label. NHTSA plans to complete a rulemaking update to the Monroney label by the first quarter of 2026. NHTSA also plans to implement the new rating system, to include crashworthiness, crash avoidance, and VRU safety on the Monroney label and the NHTSA website, beginning in the fourth quarter of 2027 with model year 2028 vehicles.

B. Long-Term Updates to NCAP (2024–2033)

1. Updates to the Crash Avoidance Program

NHTSA plans to include in NCAP the assessment of advanced lighting systems such as automatic driving beam (ADB), semi-automatic beam switching (SABS), and lower beam headlighting. NHTSA plans to implement the evaluation of advanced headlighting systems starting in the fourth quarter of 2030 with model year 2031 vehicles.

NHTSA will conduct research to assess AEB performance in intersection crash scenarios such as left turn across path and straight crossing path conditions. After needed research is completed, the Agency plans to consider AEB evaluation in these intersection crash scenarios for inclusion in NCAP, with possible implementation starting in the fourth quarter of 2031 with model year 2032 vehicles. NHTSA will also consider further enhancement to the current finalized AEB evaluations by including additional scenarios and conditions, with implementation starting in the fourth quarter of 2032 with model year 2033 vehicles.

The Agency is conducting research on enhanced assessment of LKA systems to include evaluation at higher speeds, curved path, and/or road edge detection scenarios. After the research is completed, NHTSA will consider these enhanced evaluations of LKA systems in NCAP, with possible implementation starting in the fourth quarter of 2030 with model year 2031 vehicles. NHTSA is postponing its research on opposing traffic safety assist technology due to low fitment of this technology in vehicles and will consider its inclusion in the next update of the roadmap.

NHTSA is researching various safe driving technologies, including driver monitoring systems to mitigate driver distraction and drowsy driving, and intelligent speed assist to mitigate crashes due to speeding. NHTSA will consider including intelligent speed assist in NCAP for occupant safety when the research on this technology is completed in 2028.[450] NHTSA is considering implementation of certain other safe driving technologies starting in the fourth quarter of 2031 with model year 2032 vehicles.

2. Updates to the Crashworthiness Program

NHTSA is conducting research on the THOR–05F crash test dummy and is considering replacing the HIII–5F dummy in crash tests with the THOR–05F starting the fourth quarter of 2031 with model year 2032 vehicles. At that time, NHTSA also plans to evaluate rear seat occupant protection using the THOR–05F, which will seek to address comments received regarding this topic.[451]

NHTSA is still developing and evaluating the WorldSID–05F dummy and will consider its adoption into NCAP when research and rulemaking actions [452] are complete. The Agency is considering replacing the SID–IIs dummy with the WorldSID–05F dummy in NCAP tests starting in the fourth quarter of 2033 with model year 2034 vehicles.

As part of these efforts, NHTSA will also consider applying different injury criteria to data collected from the crash tests utilizing these new dummies to target performance thresholds that are more appropriate for older adults to address broader equity concerns.

3. Updates to the VRU Safety Program

NHTSA plans to enhance AEB evaluation by including intersection crash scenarios (*e.g.,* crossing path, left turn across path) for bicyclists and motorcyclists, with implementation starting in the fourth quarter of 2030 with model year 2031 vehicles. NHTSA will also consider further enhancement to the current finalized PAEB evaluations to incorporate additional test speeds, test scenarios, and VRUs (such as those representing wheelchairs, scooters, and diverse human attributes), with implementation starting in the fourth quarter of 2032 with model year 2033 vehicles.

NHTSA also plans to evaluate BSW and BSI to mitigate crashes with motorcyclists and bicyclists in multiple scenarios, with implementation starting in the fourth quarter of 2030 with model year 2031 vehicles.

NHTSA plans to evaluate and include the advanced pedestrian legform impactor (aPLI, a newer pedestrian legform impactor with upper body mass and enhanced injury assessment capabilities), to assess crashworthiness pedestrian protection instead of the current FlexPLI (a flexible pedestrian legform impactor which lacks upper body mass). This VRU safety program update will be implemented starting in the fourth quarter of 2029 with model year 2030 vehicles.

NHTSA is researching driver visibility to better understand the safety problem and scenarios associated with forward blind zones and front-over crashes to develop accurate and rigorous methods of evaluating driver's visibility. After the research is completed, NHTSA will consider inclusion of driver visibility in NCAP.

By pursuing these efforts, the Agency will continue to work towards protecting those inside and outside the vehicle, as encouraged by public comments.

NHTSA's NCAP roadmaps for mid-term and long-term updates to the program are shown in Figures 18 and 19, respectively. In these two figures, the timeframe of the research, RFC, and final decision phases are in calendar years. The start of the implementation phase, represented by a star, is with vehicle models of the proceeding calendar year.

BILLING CODE 4910–59–P

[450] Since NCAP is a consumer information program with voluntary participation by vehicle manufacturers, NHTSA needs to evaluate consumer acceptance of intelligent speed assist technology for improving occupant safety.

[451] While NHTSA has accelerated research on the THOR–05F dummy, uncertainties remain on federalizing the dummy and its implementation in crash testing. Therefore, NHTSA is considering its inclusion in NCAP in the long-term phase of the roadmap.

[452] The corresponding rulemaking action is the inclusion of WorldSID–05F in Part 572.

Figure 18: Roadmap for Mid-Term Upgrades to NCAP

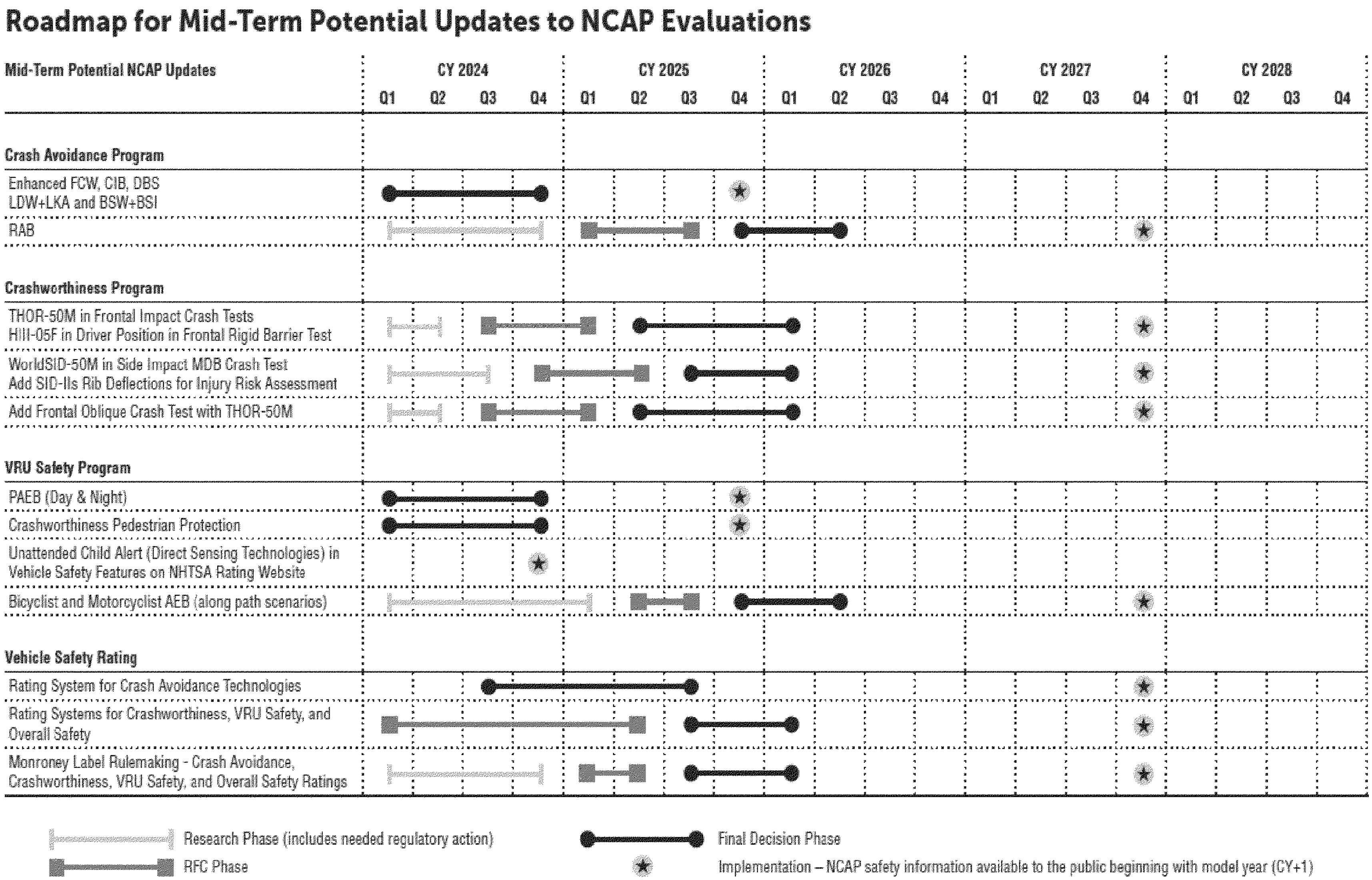
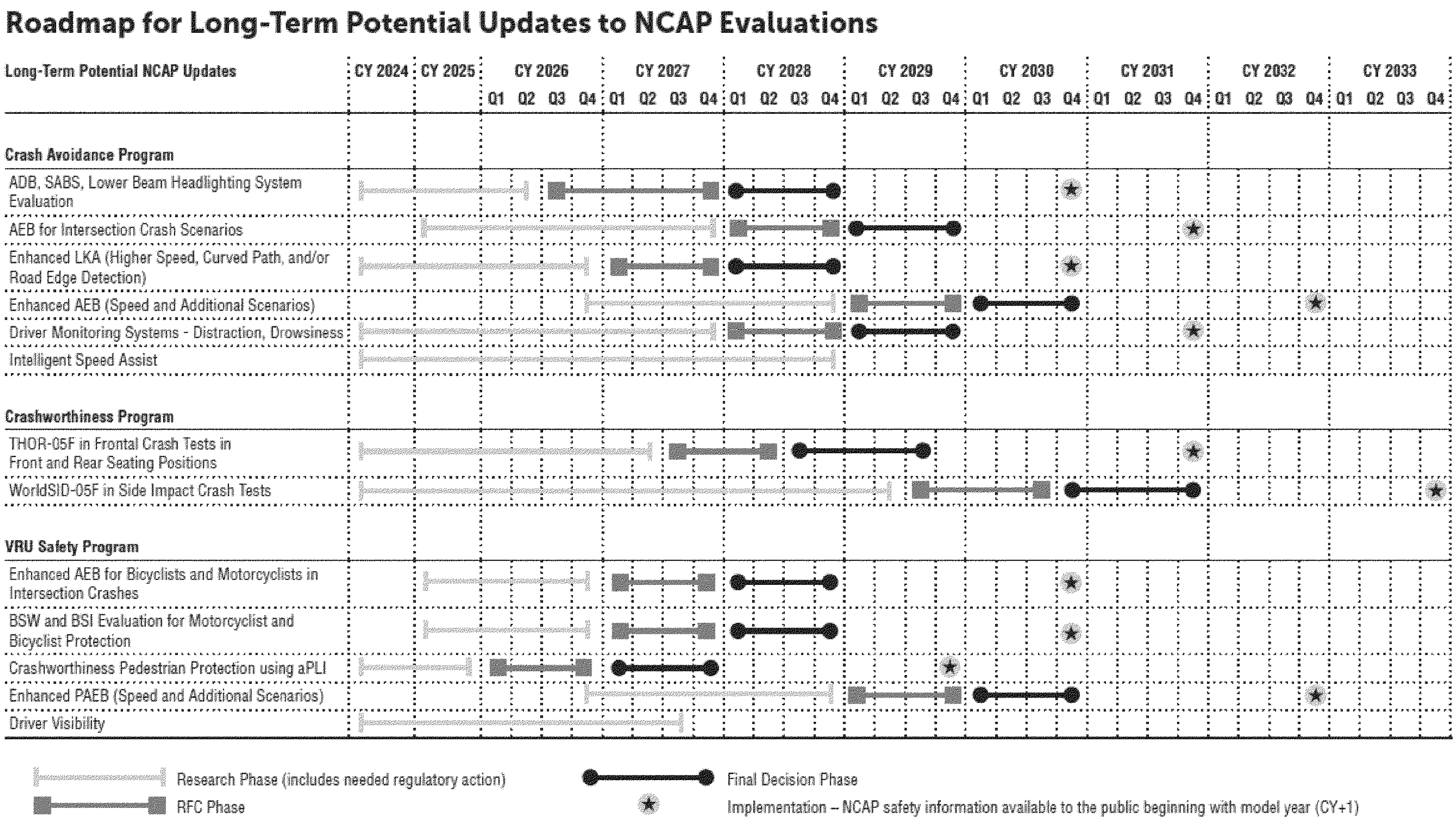


Figure 19: Roadmap for Long-Term Upgrades to NCAP



BILLING CODE 4910–59–C

X. Economic Analysis

The various changes in NCAP adopted in this final decision notice would enable the development of a new set of rating systems, which will expand the current rating system to include not only crashworthiness but also crash avoidance information and improve consumer awareness of ADAS safety features as well as encourage manufacturers to accelerate their adoption. This increased information to consumers and potential for accelerated adoption of ADAS would drive any economic and societal impacts that result from these changes and are thus the focus of this discussion of economic analysis. Hence, the Agency has considered the potential economic effects for ADAS technologies proposed for inclusion in NCAP and the potential benefit of introducing a rating system for ADAS technologies.

Unlike crashworthiness safety features, where safety improvements are attributable to improved occupant protection when a crash occurs, the impact that ADAS technologies have on fatality and injury rates is a direct function of their effectiveness in preventing crashes or reducing the severity of the crashes they are designed to mitigate. This effectiveness is typically measured by using real-world statistical data, laboratory testing, or Agency expertise.

With respect to vehicle safety, the Agency concludes, as discussed in detail in this notice, the adopted ADAS technologies have the potential to reduce vehicle crashes and crash severity. As cited in the RFC notice, researchers have conducted preliminary studies to estimate the effectiveness of ADAS technologies. Although these studies have been limited to certain models or manufacturers, which may not represent the entire fleet, they illustrate how these systems can provide safety benefits. Thus, although the Agency does not have sufficient data to determine the monetized safety impacts resulting from these technologies in a way similar to that frequently done for mandated technologies, when compared to the future without the proposed update to NCAP, NHTSA expects that these changes would likely have substantial positive safety effects by promoting earlier and more widespread deployment of these technologies.

NCAP also helps address the issue of asymmetric information (*i.e.,* when one party in a transaction is in possession of more information than the other), which can be considered a market failure. Regarding consumer information, the introduction of an upcoming new ADAS rating system is anticipated to provide consumers additional vehicle safety information (*e.g.,* rating based on ADAS performance and capability as well as the types of ADAS in vehicles) as opposed to the information provided in the current program (*e.g.,* check mark based on ADAS performance as pass/fail) to help them make more informed purchasing decisions by better presenting the performance of different ADAS technologies. The future ADAS rating would increase consumer awareness and understanding of the safety benefits in these technologies, and, in turn, incentivize vehicle manufacturers to offer the ADAS technologies that lead to higher ratings across a broader selection of their vehicles. Furthermore, as these ADAS technologies mature and become more reliable and efficient, a large portion of vehicles equipped with such systems would achieve higher ADAS ratings, and in turn consumers would have an increasing number of safer vehicles to choose from. There is an unquantifiable value to consumers in receiving accurate and comparable information about the safety performance of those technologies among manufacturers, makes, and models.

IIHS/HLDI predicted that the number of vehicles equipped with ADAS technologies, including blind spot warning and lane departure warning, will increase substantially from 2020 to 2030 and reach near full market penetration in 2050.[453] Although the Agency has limited data on costs of ADAS technologies to consumers, assuming consumer demand for safety remains high, the future ADAS rating system would likely accelerate the full adaptation of the ADAS technologies included in this notice. Nevertheless, the Agency does not have sufficient data, such as unit cost and information on how quickly full adaptation might be reached once an ADAS rating system is implemented, to predict the net increase in cost to consumers with a high degree of certainty.

XI. Appendix

The Agency's final decision for AEB and PAEB testing in NCAP is generally similar to the standards for those technologies contained in the May 9, 2024, final rule establishing FMVSS No. 127. The two standards are based on the Agency's separate authorities and are intended to serve the distinct purposes of NCAP and the FMVSS. The Agency provides the below summary to assist readers in understanding the key areas of similarity and difference.

With regard to vehicle AEB, the minimum and maximum subject vehicle (SV) test speeds and principal other vehicle (POV) test speeds for lead vehicle stopped (LVS), lead vehicle moving (LVM), and lead vehicle decelerating (LVD) crash imminent braking (CIB) and dynamic brake support (DBS) tests (as applicable) are the same in both NCAP and FMVSS No. 127, except for the minimum SV test speed for the LVS CIB test. For this LVS CIB test, the Agency has prescribed a minimum SV test speed of 40 kph (24.9 mph) for NCAP, whereas a 10 kph (6.2 mph) minimum speed is specified in FMVSS No. 127. Further, both FMVSS No. 127 and NCAP impose a test passing criterion of ''no contact'' and stipulate conducting only one trial per test condition. Other specifications pertaining to test conduct such as SV accelerator pedal release timing and manual brake application timing are also identical for NCAP and FMVSS No. 127.

There are various differences that exist with respect to the testing methods. For a given NCAP test scenario, the Agency will begin testing at the minimum prescribed test speed and will increase the test speed in 10 kph (6.2 mph) increments until the maximum test speed is reached. In comparison, FMVSS No. 127 permits testing at any speed within the speed range defined by the minimum and maximum test speeds. Similarly, for the LVD tests, NCAP and FMVSS No. 127 both establish minimum and maximum headways between 12 and 40 m (39.4 and 131.2 ft.) and POV deceleration between 0.3 and 0.5g, but NCAP will only conduct tests at those minimum and maximum values, while the FMVSS No. 127 permits testing at any headway within the range.

In addition, while both FMVSS No. 127 and NCAP will evaluate FCW functionality during AEB testing, and the requirements for the timing of the FCW alert as well as the necessary alert modalities (*i.e.,* visual and auditory signals) are identical, FMVSS No. 127 imposes additional FCW alert specifications, including auditory signal intensity and visual symbol color and location requirements. Further, FMVSS No. 127 allows for a wider variety of vehicle test devices, as any device that complies with certain specifications defined in ISO 19206–3:2021[454] is

[453] Highway Loss Data Institute. (2023). Predicted availability of safety features on registered vehicles—a 2023 update. *Loss Bulletin,* 40(2).

[454] ''Road vehicles—Test devices for target vehicles, vulnerable road users and other objects, for assessment of active safety functions—Part 3:

permitted, whereas the Agency has adopted a particular device (Revision G of the ABD GVT) that meets the requirements of the ISO standard for NCAP's AEB testing. Finally, the pass-through false positive test is included in FMVSS No. 127 but has not been adopted for NCAP.

Many of the PAEB testing requirements adopted for FMVSS No. 127 are also identical to those adopted for NCAP. In particular, the same test scenarios and pedestrian test mannequins are specified for the two initiatives, and the mannequin travel speeds align for all test conditions. Minimum and maximum SV speeds are also the same for test conditions S1a, S1b, S1e, and S4c during daylight testing and for S1b and S4c during darkness testing.

For other test conditions, though, the minimum and maximum SV travel speeds for the FMVSS and NCAP do not align. In particular, for daylight testing, NCAP imposes an upper test speed of 60 kph (37.3 mph) for the S1d test condition, whereas FMVSS No. 127 has established an upper test speed of 50 kph (31.1 mph). Similarly, for S4a, NCAP has adopted a maximum test speed of 60 kph (37.3 mph), whereas 55 kph (34.2 mph) has been adopted in FMVSS No. 127. For darkness testing, NCAP has established a maximum test speed of 60 kph (37.3 mph) for the S4a test condition, whereas FMVSS No. 127 specifies an upper test speed of 55 kph (34.2 mph) for this test condition. FMVSS No. 127 has also imposed 65 kph (40.3 mph) as the upper test speed for S4c, while NCAP has adopted a maximum test speed of 60 kph (37.3 mph) for this test condition.

Other differences between FMVSS No. 127 and NCAP's PAEB testing requirements exist for darkness testing. While NCAP, like FMVSS No. 127, will require testing in darkness, NCAP will not conduct separate performance assessments for both the SV's lower and upper beam headlamps and, instead, will only engage the vehicle's lower beams. Furthermore, FMVSS No. 127 does not require darkness testing for PAEB test conditions S1a, S1d, and S1e, whereas such testing is specified for NCAP.

The overall test requirements and test conduct for PAEB are also in general alignment, as both FMVSS No. 127 and NCAP include a passing criterion of ''no contact'' and stipulate conducting only one trial per test condition. As with vehicle AEB, though, for a given NCAP test scenario, the Agency will begin testing at the minimum prescribed test speed and will then increase the test speed in 10 kph (6.2 mph) increments until the maximum test speed is reached, while FMVSS No. 127 permits testing at any speed within the speed range.

Issued in Washington, DC, under authority delegated in 49 CFR 1.95 and 501.

Adam Raviv,

Chief Counsel.

[FR Doc. 2024–27447 Filed 12–2–24; 8:45 am]

BILLING CODE 4910–59–P

Requirements for passenger vehicle 3D targets, Edition 1, 2021–05.''