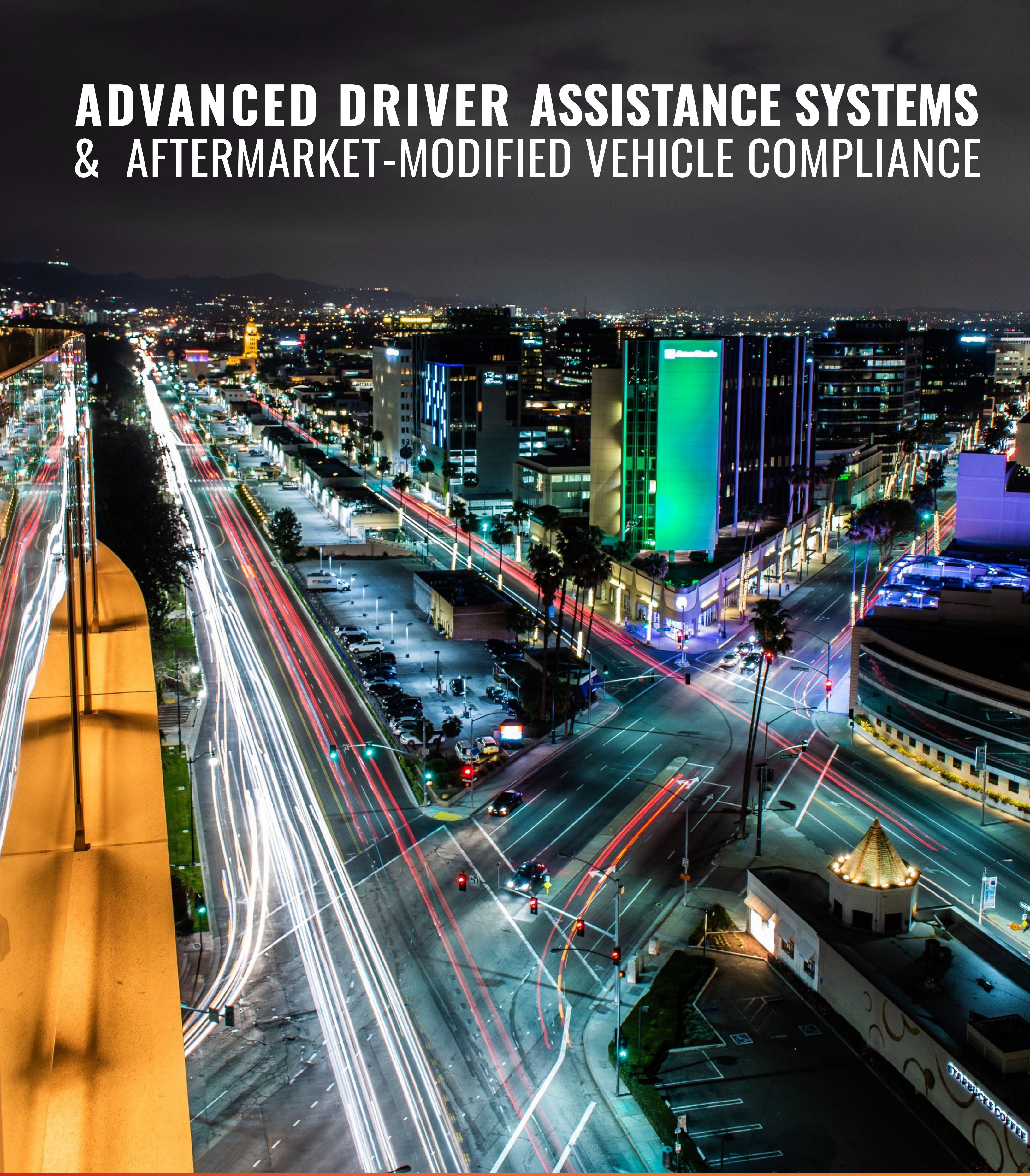
ADVANCED DRIVER ASSISTANCE SYSTEMS
& AFTERMARKET-MODIFIED VEHICLE COMPLIANCE



AUGUST 15 2020 | CUSTOMIZING WITH CONFIDENCE

SEMA — Specialty Equipment Market Association — Serving the Motor Vehicle Aftermarket

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About

This White Paper is a product of SCA Performance, Transportation Research Center and asTech in collaboration with the Equipment & Tool Institute and the Specialty Equipment Market Association. It is the first in a series of white papers to help automotive performance aftermarket manufacturers Customize with Confidence, by providing information, tools, practices, procedures and resources to help ensure that their products can be successfully integrated with the latest factory-installed Advanced Driver Assistance Systems (ADAS) technologies.

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Source: Nissan

OVERVIEW

SCA Performance Group, a division of Fox Factory, Inc., is a leading OEM-authorized specialty vehicle manufacturer for light-duty trucks. The company usually receives new vehicles directly from OEMs, takes dealers' orders and adds specialty equipment products then delivers the up-fitted vehicles to new truck dealers with a warranty fully matching the factory warranty. SCA's vehicles are differentiated by their proprietary premium design packages, high-quality installations and OEM warranties. SCA, Transportation Research Center Inc. (TRC), asTech, the Equipment and Tool Institute (ETI) and the Specialty Equipment Market Association (SEMA) worked together in 2019 to conduct the aftermarket industry's first active safety performance test for Pedestrian Automatic Emergency Braking (P-AEB), an Advanced Driver Assistance System (ADAS) designed to help mitigate or prevent certain collisions with vehicles and pedestrians.

The 2020 Nissan Titan SV Crew Cab 4x4 test vehicle, equipped with several ADAS technologies as standard equipment, including Automatic Emergency Braking with Pedestrian Detection, Blind Spot Warning, Rear Cross Traffic Alert, Lane Departure Warning, High Beam Assist and class-exclusive standard Rear Automatic Braking, was modified by SCA with a 6-inch suspension lift kit and 35-inch all-terrain tires at their headquarters in Trussville, AL. The front camera ADAS sensor of the aftermarket-modified vehicle (hereinafter "Test Vehicle") were recalibrated by asTech at their Dallas, TX facility. Federal Motor Vehicle Safety Standard (FMVSS) 126 (Electronic Stability Control) and IIHS P-AEB were tested by TRC at their proving ground in East Liberty, OH.

Michael McSweeney, President and General Manager of SCA Performance Group, said "it's imperative for SCA to be on the leading edge of calibrating lifted truck ADAS sensors and demonstrating functional safety and regulatory compliance so we can ensure the safety and reliability to the end users driving our vehicles, to the manufacturers and to the insurance companies who insure these vehicles and drivers. We have committed a tremendous amount of focus and resources to developing ADAS solutions that we can share with the industry to help ensure the sustainability of the performance aftermarket industry."

It is important to maintain ADAS functionality for customers who choose to modify their vehicles. This project demonstrated how several aftermarket parties can work together to help resolve technical challenges related to ADAS functionality on a modified vehicle. Moving forward, Nissan will continue to provide product information to support lifestyle applications of our customers.

ADVANCED DRIVER ASSISTANCE SYSTEMS (ADAS)

Advanced Driver Assistance Systems are active safety performance and convenience technologies developed to help assist drivers in a variety of driving situations, see ***Figure 1***. Electronic Stability Control (ESC) was one of the first ADAS technologies deployed and regulated with FMVSS126 in the US vehicle market starting in 2008. Leading aftermarket companies need the ability to customize with confidence and ensure compliance by understanding how ADAS sensors and the latest safety performance technologies are impacting their products, installations and businesses.

ADAS technologies are among the most rapidly evolving technologies impacting the performance aftermarket, as well as the collision-repair industry. Many OEM-installed ADAS technologies and sensors are already onboard the most popular vehicles being modified by SEMA members. Today, more than 60 million vehicles in the US are equipped with ADAS technologies and 80% of all vehicles in operation in the US will have some level of ADAS technology on board in the next 5-10 years.

ADAS technologies pose new challenges to performance aftermarket companies because of the numerous cameras, ultrasonic, RADAR and LIDAR sensors, vehicle electronics, software and cybersecurity architectures currently onboard many of today's vehicles. To help ensure proper continued operation and functional performance of these systems on vehicles equipped with ADAS features, the sensors onboard may need to be recalibrated and must be validated at the completion of every aftermarket modification or collision repair.

SEMA manufacturers, distributors, retailers and installers of suspension systems, brakes, steering, wheels, tires, lighting, body panels, bumpers, grilles, paint, wraps, mirrors, hitch racks, running boards, external accessories, cargo carriers and trailering accessories are all potentially impacted by today's ADAS technologies. SEMA's Vehicle Technology department is working with leading specialty vehicle manufacturers like SCA to address their immediate and near-term ADAS-related needs by leveraging the ADAS sensor recalibration knowledge, tools, procedures and best practices learned from the collision repair industry. The collision-repair industry is ahead of the performance aftermarket industry in terms of adopting and applying ADAS diagnostic tools, sensor calibration procedures and practices developed and approved by automakers and suppliers.

SEMA is also working with OEMs and ADAS technology suppliers, as well as leading industry associations, organizations, facilities and technology service providers, to continue developing cost-effective ADAS program tools, practices, resources, guidelines and solutions for members. These partners include: Society of Collision Repair Specialists (SCRS), Automotive Aftermarket Supplier Association (AASA), Motor Equipment & Manufacturers Association (MEMA), Inter-Industry Conference on Auto Collision Repair (I-CAR), Society of Automotive Engineers (SAE) and ETI, as well as technology and testing relationships with Link Engineering, Hunter Engineering, asTech, OPUS IVS, TRC and the American Center for Mobility.

ADAS technologies are the gateway and foundation to many of the advanced vehicle technologies being deployed by automakers today, according to John Waraniak, vice president of vehicle technology at SEMA. Waraniak firmly believes that, "Understanding how ADAS technologies and sensors function is an integral component for Customizing with Confidence and the future of successful, complete and safe vehicle repairs and aftermarket modifications." Having access to these cross-industry resources and increasing our collective knowledge of how to apply sensor recalibration procedures for collision-repaired vehicles to aftermarket-modified vehicles is speeding the development and adoption of ADAS compliance tools, practices and solutions in the SEMA community.

FIGURE 1. ADAS TECHNOLOGY CATEGORIES & APPLICATIONS

FORWARD COLLISION AVOIDANCE

- Forward Collision Warning
- Automated Emergency Braking
- Integrated Emergency Intevention

AUTOMATED PERFORMANCE ENHANCEMENT

- Antilock Braking Systems
- Traction Control
- Electronic Stability Control
- Specialty Applications

ADVANCED CRUISE CONTROL

- Adaptive Cruise Control
- Cooperative Adaptive Cruise Control
- Partial Automation

LATERAL COLLISION AVOIDANCE

- Lane Departure Warning
- Blind Spot Warning
- Lane Keeping Assistance
- Lane Centering

PARKING ASSISTANCE

- Passive Parking Assistance
- Automated Parking Assistance
- Automated Valet

DRIVER VISION AUGMENTATION

- Advanced Headlights
- Infrared Night-vision Display
- Head-up Display

CONNECTED VEHICLE TECHNOLOGY

- Dedicated Short-range communication
- Commerical Cellular
- Other communication Tech

Greg Potter, CTO of the Equipment and Tool Institute (ETI) said, "The current situation we are in is creating safety performance challenges across the industry and concerns for vehicle owners. Owners of vehicles that have ADAS technologies onboard their cars and trucks quickly become reliant on them for safety and convenience. For instance, lane departure warnings, blind spot notifications, forward collision warnings, and back-up sensors become the driver's technologies and features that they are counting on to aid them in their travels – not to mention the even more critical active safety functions like automatic braking and adaptive cruise control. When a vehicle has parts replaced, is repaired after a collision, or modified and accessorized, owners expect these ADAS features to operate as designed to help keep them safe. If the systems are not functioning as they were previously, the driver may have no idea that these systems are not operating properly until they need them, which can lead to a collision. It's imperative for repairers to have tools, procedures and methods to accurately calibrate and validate these systems prior to returning these vehicles to service."

AUTOMATIC EMERGENCY BRAKING (AEB)

Automatic emergency braking systems use vehicle sensors to detect impending crashes with a vehicle traveling ahead and can automatically intervene to help avoid or mitigate collisions. AEB systems are usually paired with or integrate a Forward Collision Warning (FCW) system to first provide a warning to the driver, and then actively intervene to help control the vehicle, if the driver does not take action to avoid the collision. AEB system components typically include external-facing cameras and/or RADARs, driver interface for warning feedback, software and electronic control unit integration with the vehicle braking system and powertrain.

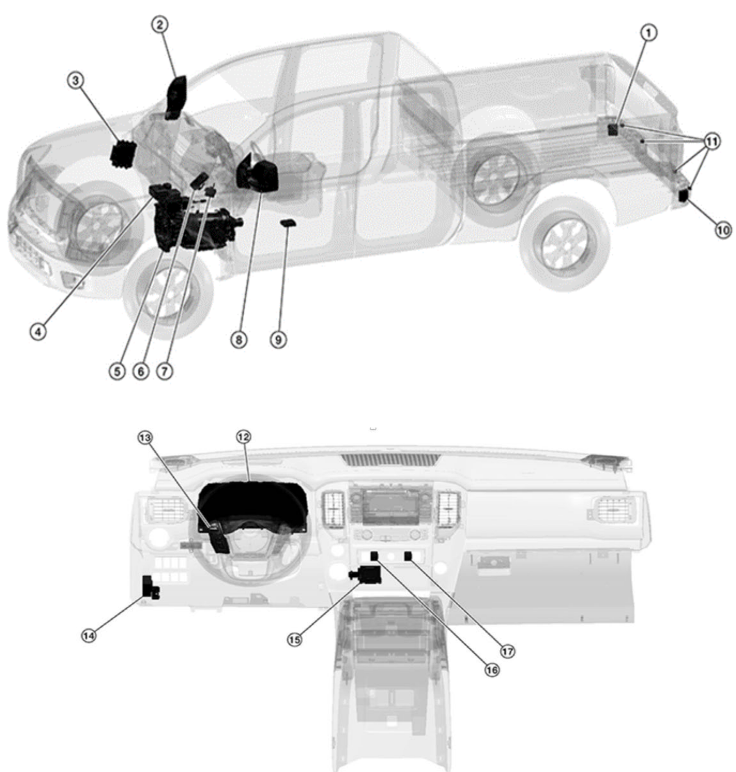
The National Highway Traffic Safety Administration (NHTSA) has adopted a definition of AEB that includes two functions: Dynamic Brake Support (DBS) and Crash Imminent Braking (CIB). The CIB function is what most people think of as AEB – it can automatically apply the vehicle's brakes even if the driver takes no action. DBS activates only if the driver applies the brakes (but not hard enough) and increases the brake force to help avoid or mitigate a collision.

AEB has been found to be very effective at avoiding many common rear-end collisions. The Insurance Institute for Highway Safety (IIHS) estimates that vehicles with collision avoidance systems that include FCW and AEB, are 50% less likely to cause a rear-end crash. This is a substantial improvement over the estimated 27% rear-end crash reduction rate for vehicles with FCW alone. Due to the high importance consumers and specialty vehicle manufacturers place on AEB systems, it is imperative that ADAS technologies maintain full operation if possible after any aftermarket modification. NHTSA recognizes the safety performance importance and value of AEB and promotes customer awareness by including AEB as a recommended technology in the New Car Assessment Program (NCAP). Twenty OEMs comprising nearly the entire US market have agreed to make AEB standard equipment on most vehicles by 2022.

SCA SENSOR RECALIBRATION OF THE TEST VEHICLE

The MY 2020 Titan SV Crew Cab 4x4 Advanced Driver Assistance Systems network consists of at least 17 different components as outlined in the diagrams below. These components monitor vehicle speed, distance from objects and engine speed. They also have several driver alert mechanisms and off/on switches to enable or disable the ADAS features. Depending on the system, the driver may be alerted of a potential event by visual indicator, auditory buzzer, and/or vibration feedback through an electric motor in the steering wheel. Many of the features operate only within specific pre-determined vehicle speed ranges. The vehicle has very specific preparations prior to calibration of front radar and side/front camera systems. The fluid levels including fuel must be full prior to static calibration. The vehicle's Intelligent Cruise Control (ICC) system calibration requires that a 4-Wheel alignment and radar alignment is performed on the alignment machine. Only a portion of the ADAS calibration procedure is described here. The 2020 Nissan Titan Service Manual includes the complete ADAS calibration procedure. It is important to understand these systems use a variety of inputs from other systems and sensors to make decisions on how the vehicle stops and reacts to the environment. Aftermarket modifiers must understand that Nissan's calibration procedures apply when the vehicle body structure is within factory specifications and has not been altered in any way. The aftermarket modifier must evaluate whether the calibration procedures should be applied or adapted for a particular modified vehicle.

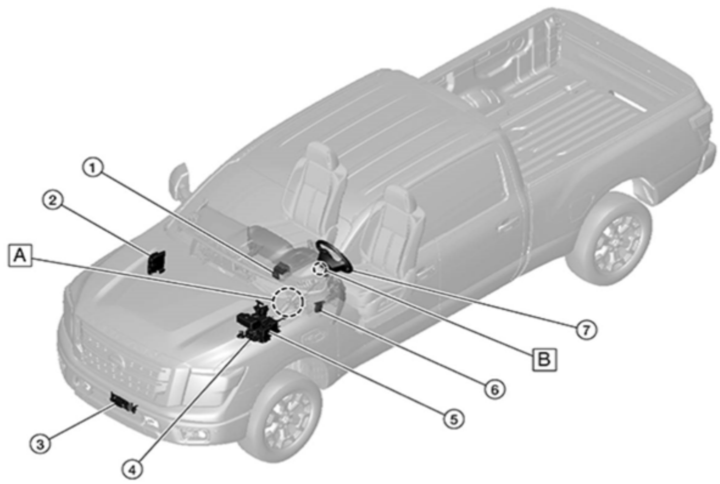
FIGURE 2. 2020 NISSAN TITAN ADAS COMPONENTS



1. Side radar RH
2. Door Mirror RH (blind spot warning indicator)
3. ECM
4. ABS actuator and electric unit (control unit)
5. TCM
6. BCM
7. Sonar control unit
8. Door Mirror LH (blind spot warning indicator)
9. Around view monitor control unit
10. Side radar LH
11. Rear sonar sensors
12. Combination meter
13. Steering switches
14. Warning buzzer
15. ADAS control unit
16. Sonar system off switch
17. BSW Switch (ITS Warning System Switch)

Source: 2020 Nissan Titan Service Manual

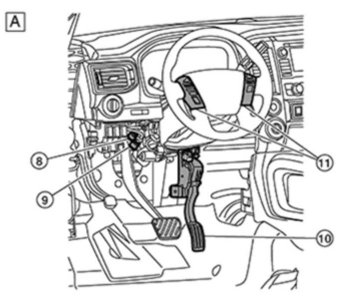
FIGURE 3. **2020 NISSAN TITAN INTELLIGENT CRUISE CONTROL (ICC) COMPONENTS**

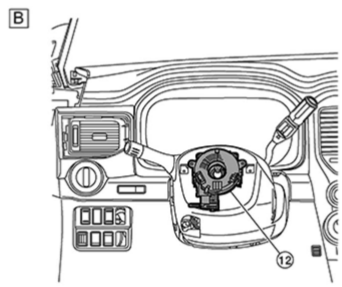


1. ADAS control unit
2. ECM
3. Distance sensor
4. TCM
5. ABS Actuator and electric unit (control unit)
6. Driver assistance buzzer
7. Steering vibration motor
8. Stop lamp switch
9. Brake pedal position switch
10. Accelerator pedal position (APP) sensor
11. ICC steering switch
12. Combination switch (spiral cable)

A Brake pedal area

B Steering solumn area (view with steering wheel removed





8. Stop lamp switch
9. Brake pedal position switch
10. Accelerator pedal position (APP) sensor
11. ICC Steering switch
12. Combination switch (spiral cable)

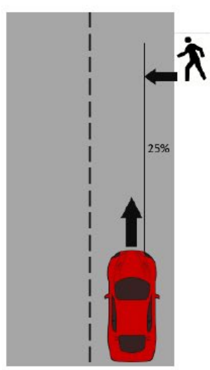
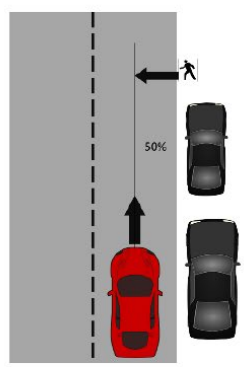
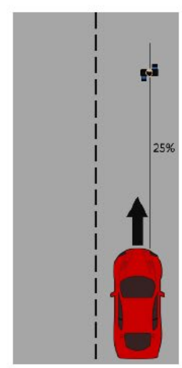
RESULTS FOR THE TEST VEHICLE

The objective of this SCA ADAS testing and validation program conducted by TRC was to appropriately provide an assessment of the P-AEB system and the Electronic Stability Control system of the Test Vehicle. Performing dynamic evaluation, exactly as the unmodified vehicle would do, allows SCA to determine the ADAS system performance level and understand the impact of the modification.

PEDESTRIAN AUTONOMOUS EMERGENCY BRAKING (P-AEB)

This assessment was completed using IIHS' Pedestrian Autonomous Emergency Braking Test Protocol-Version II, dated February 2019. The P-AEB test procedure simulates vehicle collisions with: 1. an adult pedestrian crossing a street on a path perpendicular to the travel line of a vehicle; 2. a child pedestrian crossing a street from behind an obstruction on a path perpendicular to the travel line of a vehicle; and, 3. an adult pedestrian near the edge of a road on a path parallel to the travel path of a vehicle. These three test scenarios are shown below in *Figure 4*.

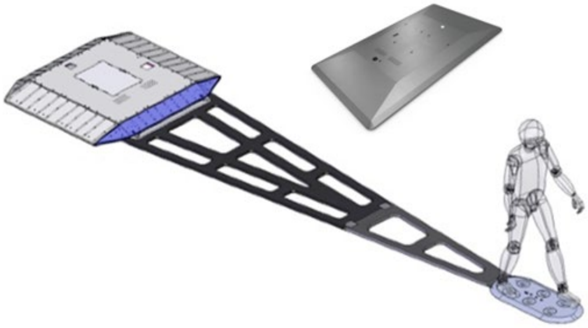
FIGURE 4. P-AEB TEST SCENARIOS

Parameter	*Scenario*		
	Perpendicular adult (CPNA-25)	**Perpendicular child (CPNC-50)**	**Parallel adult (CPLA-25)**
Test vehicle speed	20, 40 km/h	20, 40 km/h	40, 60 km/h
Pedestrian target speed	5 km/h	5 km/h	0 km/h
Target direction	Crossing (R-to-L)	Crossing (R-to-L)	Facing away
Target path (relative to test vehicle)	Perpendicular	Perpendicular	Parallel
Pedestrian dummy size	Adult	Child	Adult
Dummy articulation (fixed rate)	Yes	Yes	No
Overlap	25%	50%	25%
Obstructed	No	Yes	No
Number of valid runs	5	5	5
Test diagram			

Both static and articulating (with moving legs) pedestrian test targets were used to test the Test Vehicle's P-AEB system. Figure 5 shows the test targets and Figure 6 shows the robotic platform used to move the pedestrian targets in each test scenario. Additional test equipment used to perform the test and capture data can be seen in Figure 7.

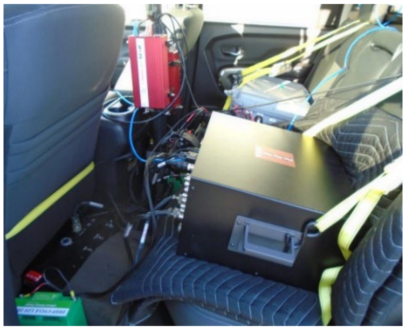
FIGURE 5. P-AEB TEST TARGETS

FIGURE 6. ROBOTIC PLATFORM



The Test Vehicle was equipped with a high-precision GPS navigation system to measure and record multi-axial position, velocity, acceleration, yaw rate, and impact time. The speed was accurately maintained using a throttle robot. A camera and microphone were positioned facing the dash to capture the visual and audible alerts coming from the Test Vehicle.

FIGURE 7. THROTTLE ROBOT, INTERIOR CAMERA AND GPS NAVIGATION



The visual alert given to the driver by the Test Vehicle as it approached the pedestrian target came in a series of stages, shown below in *Figure 8*. Additionally, the audible alert was a series of pulsing beeps that became more rapid as the Test Vehicle approached the pedestrian target.

FIGURE 8A. MY 20 TITAN P-AEB VISUAL DRIVER ALERTS

FIGURE 8B . P-AEB TEST PHOTO (ADULT TEST CPNA)

The unofficial scoring of the Test Vehicle below is based on the IIHS P-AEB Test Protocol dated February 2019. Points are awarded based on each average speed reduction and the final rating scale according to the IIHS protocol can be seen below in *Figure 9*.

FIGURE 9. IIHS P-AEB SCORING SYSTEM

Points Awarded for Average Speed Reduction

Speed reduction range (km/h)			Points
0	to	8	0.0
9	to	18	0.5
19	to	28	1.0
29	to	38	1.5
39	to	48	2.0
49	to	58	2.5
59	to	61	3.0

Final Rating Scale

Total score range	Rating	Rating icon
Total score < 1	No credit	
1 ≤ total score < 3	Basic	
3 ≤ total score < 5	Advanced	
Total score ≥ 5	Superior	

FIGURE 10. SCA- SCORING MATRIX FOR THE TEST VEHICLE

Perpendicular Scenario

	Adult Test CPNA		Child Test CPNC		Points Subtotal	Weighted Subtotal (70%)
	20 km/h	40 km/h	20 km/h	40 km/h		
Average Speed Reduction	19.71	30.55	12.45	29.43		
Truncated Speed Reduction	19	30	12	29		
Points Total	1	1.5	0.5	1.5	4.5	3.15

Parallel Scenario

	Adult Test CPLA				Points Subtotal	Weighted Subtotal (30%)
	40 km/h	60 km/h	60km/h FCW ≥ 2.1s			
Average Speed Reduction	39.93	35.43	Average TTC Time	1.1		
Truncated Speed Reduction	39	35				
Points Total	2	1.5		0	3.5	1.1

Overall Score

Perpendicular Weighted Subtotal	Parallel Weighted Subtotal	**Total Score**
3.15	1.1	**4.2**

ELECTRONIC STABILITY CONTROL (ESC)

Electronic Stability Control was one of the first ADAS technologies deployed and became regulated with NHTSA's FMVSS 126 in the US vehicle market starting in September 2008. ESC is an active safety performance vehicle technology that helps a driver maintain control of their vehicle during extreme steering maneuvers by stabilizing and helping to keep the vehicle headed in the driver's intended direction, even when the vehicle nears the limits of traction. ESC works by applying selective braking to individual wheels and modulates engine power and torque during sudden turns to help the driver maintain control in understeer or oversteer conditions. FMVSS126 requires that all new vehicles sold in the US since Sept. 1, 2011 with a gross vehicle weight rating of 10,000 lbs. or less include ESC as standard equipment, with multi-stage manufacturers and modifiers to comply by Sept. 1, 2012. Aftermarket modifications must maintain ESC functionality and cannot take a vehicle out of compliance with FMVSS 126.

Electronic stability control activates when you start your car and engages automatically to help prevent oversteering and understeering through a series of sensors and an ESC microcontroller that continuously monitors vehicle direction, steering angle, and wheel and brake speed. For SEMA Members, it is important to know that it is illegal to sell or install a product that takes a vehicle out-of-compliance with a Federal Motor Vehicle Safety Standard. The manufacturer or installer must have a reasonable basis for making a determination that the vehicle remains in compliance. The FMVSS 126 vehicle dynamics test program that SEMA has put together helps manufacturers form that reasonable basis.

NHTSA compliance involves self-certification. Manufacturers and installers must self-certify their products before sale based on their own testing and evaluation. The data and information collected from conducting an FMVSS 126 test provides manufacturers with the assurance that if a question arises about ESC performance or compliance, the manufacturer will have the test documentation to demonstrate it has formed a reasonable basis with respect to compliance and done its due diligence.

Leading SEMA companies customize with confidence and in compliance with the law by knowing how advanced vehicle technologies like ESC impact their products and businesses. Through SEMA's Vehicle Dynamics Program, aftermarket suspension manufacturers have conducted over 120 full-scale vehicle tests to demonstrate the ESC performance of aftermarket-modified vehicles.

The FMVSS 126 test is intended to replicate a driver performing an emergency obstacle avoidance maneuver, a situation which can lead to a rollover incident, particularly so for trucks and SUVs. The test involves two performance requirements, stability and responsiveness, in addition to functional requirements. In order to meet the performance requirements, a vehicle's ESC system must be capable of individually controlling the brake torque at each wheel, monitoring through the use of sensors the vehicle yaw rate, steering angle, brake and accelerator pedal position, estimating the side slip derivative of the vehicle with respect to time, and reducing the delivered engine torque.

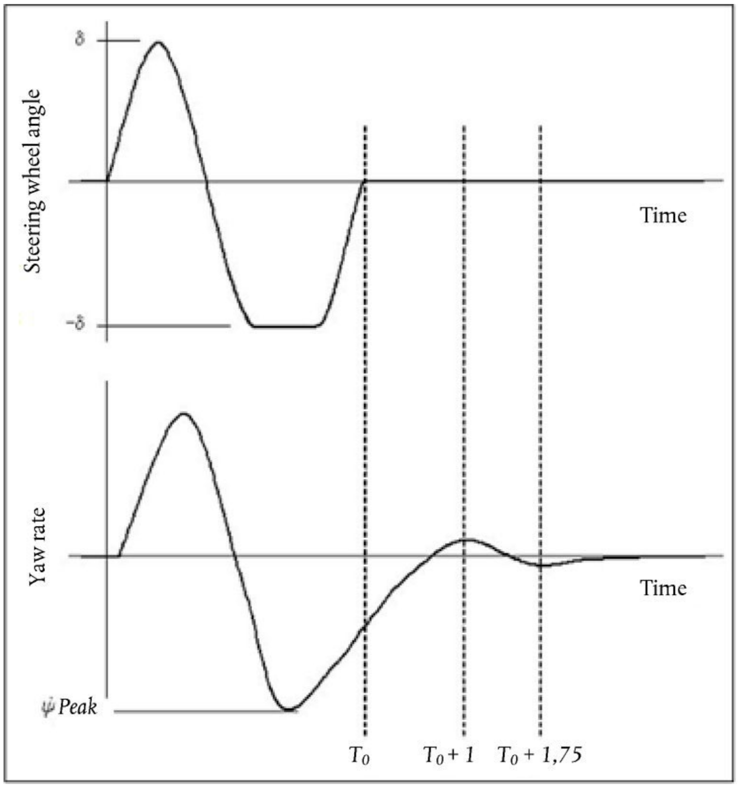
Given that FMVSS 126 is a performance test of a complete vehicle, rather than a test of an isolated component, it is important to understand how modifications made to a vehicle may affect the operation of the ESC system. Lift kits and larger, heavier wheels and tires can reduce the effectiveness of the ESC system. Testing for compliance with FMVSS 126 after modifying a vehicle can provide peace of mind that the vehicle remains in compliance with the law.

FMVSS 126 TEST RESULTS

NHTSA uses a "sine with dwell" steering maneuver for the FMVSS 126 test because it provides a consistent and easily repeatable maneuver that replicates an obstacle avoidance situation. As mentioned previously, there are both stability and responsiveness requirements to the performance test. The stability requirement focuses largely on the yaw rate of the vehicle; the rate of change of the vehicle's heading about the vertical axis through the center of gravity of the vehicle.

The sine with dwell steering maneuver will create two yaw peaks, one for the initial direction of steer and one for the reversal of the steer. The ESC system is required to reduce the yaw rate of the vehicle to 35% or less of the second yaw peak value by 1 second after the completion of the steering maneuver, and reduce the yaw rate of the vehicle to 20% or less of the second yaw peak value by 1.75 seconds after the completion of the steering maneuver. A graphical representation of the steering wheel angle and the vehicle yaw rate during a sine with dwell maneuver can be seen below in *Figure 11*.

FIGURE 11. "SINE WITH DWELL" STEERING MANEUVER EXAMPLE FOR FMVSS 126 TEST



The other performance requirement, responsiveness, pertains to the lateral displacement of the vehicle with respect to its initial straight path at the beginning of the maneuver. The vehicle must have a lateral displacement of at least 1.83 m (6 feet) for vehicles with a gross vehicle weight rating (GVWR) of 3500 kg (7716 lbs.) or less, and at least 1.52 m (5 feet) for vehicles with a GVWR greater than 3500 kg (7716 lbs.) at 1.07 seconds after the beginning of the steer. The FMVSS 126 Test of the Test Vehicle was conducted at TRC in accordance with NHTSA TP-126-03, dated September 9, 2011. The test results can be found in the following data tables in *Figures 12, 13*, and *14*.

FIGURE 12. TEST VEHICLE LATERAL STABILITY TEST SERIES NO.1 – COUNTERCLOCKWISE STEER

Maneuver #	Clock Time (1.5 – 5 min between each test run)	Commanded Steering Wheel Angle¹ (degrees)		Yaw Rates (degrees/sec)			YRR at 1.0 sec after COS [≤ 35%]		YRR at 1.75 sec after COS [≤ 20%]	
		Scalar	Angle	Ψ_{Peak}	$\Psi_{1.0sec}$	$\Psi_{1.75sec}$	%	Pass/ Fail	%	Pass/ Fail
0013	12:17 pm	1.5* δ0.3 g	52	13.078	-1.175	-0.461	-8.986	Pass	-3.522	Pass
0014	12:19 pm	2.0* δ0.3 g	70	16.717	-0.503	-0.503	-3.007	Pass	-3.006	Pass
0015	12:22 pm	2.5* δ0.3 g	87	21.283	-0.853	-0.772	-4.009	Pass	-3.628	Pass
0016	12:24 pm	3.0* δ0.3 g	105	25.186	-0.349	-0.660	-1.384	Pass	-2.621	Pass
0017	12:27 pm	3.5* δ0.3 g	122	29.136	0.012	-0.233	0.040	Pass	-0.799	Pass
0018	12:29 pm	4.0* δ0.3 g	140	27.079	-0.237	-0.268	-0.874	Pass	-0.991	Pass
0019	12:32 pm	4.5* δ0.3 g	157	28.282	-0.353	-0.367	-1.247	Pass	-1.297	Pass
0020	12:34 pm	5.0* δ0.3 g	175	28.946	0.102	0.054	0.352	Pass	0.187	Pass
0021	12:36 pm	5.5* δ0.3 g	192	29.268	-0.370	-0.311	-1.263	Pass	-1.064	Pass
0022	12:39 pm	6.0* δ0.3 g	209	28.344	-0.426	-0.217	-1.504	Pass	-0.765	Pass
0023	12:42 pm	6.5* δ0.3 g	227	29.031	-0.652	-0.548	-2.245	Pass	-1.887	Pass
0024	12:44 pm	7.0* δ0.3 g	244	30.203	-1.358	-0.652	-4.498	Pass	-2.159	Pass
0025	12:46 pm	7.5* δ0.3 g	262	30.817	-0.777	-0.355	-2.521	Pass	-1.150	Pass
0026	12:48 pm	7.7* δ0.3 g	270	31.954	-0.496	-0.280	-1.552	Pass	-0.876	Pass

FIGURE 13. TEST VEHICLE LATERAL STABILITY TEST SERIES NO. 2 – CLOCKWISE STEER

Maneuver #	Clock Time (1.5 – 5 min between each test run)	Commanded Steering Wheel Angle¹ (degrees)		Yaw Rates (degrees/sec)			YRR at 1.0 sec after COS [≤ 35%]		YRR at 1.75 sec after COS [≤ 20%]	
		Scalar	Angle	Ψ_{Peak}	$\Psi_{1.0sec}$	$\Psi_{1.75sec}$	%	Pass/ Fail	%	Pass/ Fail
0027	12:51 pm	1.5* δ0.3 g	52	-12.703	0.236	-0.489	-1.861	Pass	3.852	Pass
0028	12:53 pm	2.0* δ0.3 g	70	-16.512	-0.032	-0.451	0.191	Pass	2.734	Pass
0029	12:55 pm	2.5* δ0.3 g	87	-20.367	0.526	-0.352	-2.582	Pass	1.729	Pass
0030	12:58 pm	3.0* δ0.3 g	105	-24.619	0.581	-0.395	-2.362	Pass	1.603	Pass
0031	1:00 pm	3.5* δ0.3 g	122	-28.368	0.858	0.135	-3.025	Pass	-0.475	Pass
0032	1:02 pm	4.0* δ0.3 g	140	-31.997	0.972	0.389	-3.039	Pass	-1.217	Pass
0033	1:05 pm	4.5* δ0.3 g	157	-28.125	0.742	0.529	-2.640	Pass	-1.880	Pass
0034	1:07 pm	5.0* δ0.3 g	175	-28.494	0.787	0.626	-2.761	Pass	-2.197	Pass
0035	1:10 pm	5.5* δ0.3 g	192	-29.100	0.539	0.451	-1.852	Pass	-1.550	Pass
0036	1:12 pm	6.0* δ0.3 g	209	-29.626	0.709	0.233	-2.394	Pass	-0.786	Pass
0037	1:14 pm	6.5* δ0.3 g	227	-29.051	0.703	0.611	-2.421	Pass	-2.104	Pass
0038	1:17 pm	7.0* δ0.3 g	244	-31.791	0.712	0.327	-2.238	Pass	-1.027	Pass
0039	1:19 pm	7.5* δ0.3 g	262	-31.711	1.055	0.881	-3.327	Pass	-2.777	Pass
0040	1:21 pm	7.7* δ0.3 g	270	-30.177	1.050	0.861	-3.479	Pass	-2.854	Pass

The data from this test shows that the Test Vehicle meets the dynamic performance requirements of FMVSS 126. Many of the functional requirements of FMVSS 126 were also verified during the test as if a full NHTSA contracted compliance test were being performed; however, those requirements are unlikely to be compromised by commonly made vehicle modifications.

In order to conduct the assessment of the performance requirements, the vehicle must be fitted with a variety of sensors and data acquisition equipment. Internally, the vehicle is equipped with a steering robot, a motion pack (for roll, pitch & yaw rates and X, Y & Z accelerations), a brake pedal switch, and a data acquisition system. Externally, the vehicle is equipped with a speed sensing

FIGURE 14. TEST VEHICLE RESPONSIVENESS – LATERAL DISPLACEMENT

Maneuver #	Initial Steer Direction	Commanded Steering Wheel Angle ($5.0*\delta_{0.3\ g,\ overall}$ or greater)		Calculated Lateral Displacement[1]	
		Scalar	Angle (degrees)	Distance (m)	Pass/Fail
0020	Counter Clockwise	5.0* δ0.3 g	175	-2.38	Pass
0021	Counter Clockwise	5.5* δ0.3 g	192	-2.45	Pass
0022	Counter Clockwise	6.0* δ0.3 g	209	-2.39	Pass
0023	Counter Clockwise	6.5* δ0.3 g	227	-2.40	Pass
0024	Counter Clockwise	7.0* δ0.3 g	244	-2.40	Pass
0025	Counter Clockwise	7.5* δ0.3 g	262	-2.37	Pass
0026	Counter Clockwise	7.7* δ0.3 g	270	-2.38	Pass
0034	Clockwise	5.0* δ0.3 g	175	2.48	Pass
0035	Clockwise	5.5* δ0.3 g	192	2.47	Pass
0036	Clockwise	6.0* δ0.3 g	209	2.48	Pass
0037	Clockwise	6.5* δ0.3 g	227	2.48	Pass
0038	Clockwise	7.0* δ0.3 g	244	2.43	Pass
0039	Clockwise	7.5* δ0.3 g	262	2.49	Pass
0040	Clockwise	7.7* δ0.3 g	270	2.51	Pass

device, body roll sensors, and for vehicles other than passenger cars, a set of outriggers to prevent rollover should the vehicle tip up during the test. The Test Vehicle, as it was instrumented for testing, can be seen in *Figure 15* below.

Understanding ADAS technologies, sensors and how they function is an integral component of the future of successful, complete and safe repairs and modifications. The SEMA ADAS Forum Program will address the aftermarket challenges ADAS technologies and sensors pose for specialty equipment manufacturers and installers, as well as connect members to the resources, partnerships, tools and procedures to help members customize with confidence and help ensure ADAS technologies are operating correctly. To learn more about how vehicle modifications, including suspension, brakes, wheels, tires and steering may interact with vehicle systems visit: www.semagarage.com/services/vehicletechnology

FIGURE 15. FMVSS 126 INSTRUMENTATION – OUTRIGGERS AND STEERING ROBOT

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