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Volume 2

Disclaimer

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16. Abstract The portion of the research project included in this volume focuses on 18 Federal Motor Vehicle Safety Standards (FMVSS). It provides research findings, including the performance requirements and test procedures, in terms of options regarding technical translations, based on potential regulatory barriers identified for compliance verification of innovative new vehicle designs that may appear in vehicles equipped with Automated Driving Systems (ADSs). This report builds on work reported on in the Volume 1 report (Blanco et al., 2020); that report documented the framework used to evaluate the regulatory text and Office of Vehicle Safety Compliance test procedures with the goal of identifying possible options to address unnecessary/unintended regulatory barriers for the compliance verification of ADS-dedicated vehicles (ADS-DVs) that lack manually operated driving controls. The current report describes activities focused on 9 crash avoidance standards (FMVSS Nos. 101, 103, 104, 110, 111, 113, 124, 125, and 126) and 9 crashworthiness standards (FMVSS Nos. 207, 208, 210, 214, 216a, 219, 222, 225, and 226).		
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Executive Summary

This project provides research findings in terms of options regarding technical translations of select Federal Motor Vehicle Safety Standards (FMVSS), including the performance requirements and the test procedures. The newly created technical translation options take into account potential unnecessary/unintended regulatory barriers[1] to innovative new vehicle designs appearing in vehicles equipped with Automated Driving Systems (ADSs).

This report builds on the FMVSS Considerations for Automated Driving Systems: Volume 1 report (Blanco et al., 2020), which documented the framework used to evaluate the regulatory text and test procedures with the goal of identifying possible options to remove regulatory barriers for the compliance verification of ADS-dedicated vehicles (ADS-DVs) that lack manually operated driving controls. This research includes feedback obtained from the research team, stakeholders, and subject matter experts (SMEs). A technical translation is a modification that would allow regulatory text and/or test procedures identified as potential regulatory barriers to result in the same basic engineering performance without manual control-specific restrictions or references. This report (Volume 2) documents the process carried out to develop technical translations and testing procedure options for the 18 FMVSS that it covers, such that the identified potential regulatory barriers could be removed for vehicles operated exclusively by an ADS that may not have the traditional controls used by human drivers.

While the Volume 1 report discussed the 12 FMVSS covered in Volume 1 research, the current Volume 2 report describes activities related to 9 crash avoidance standards and 9 crashworthiness standards. The 30 FMVSS that are part of Volume 1 and Volume 2 are shown in Figure ES-1 on the following page. The 18 FMVSS covered in this report are emphasized in this figure.

[1] The use of the term “regulatory barrier” in this report always refers to “an unintended and unnecessary regulatory barrier” because the technical translation process does not remove, reduce, or otherwise alter performance standards of the FMVSS under consideration.

Crash Avoidance			Crashworthiness & Occupant Protection		
101 Controls and displays	**110** Tire selection and rims and motor home /recreation vehicle trailer load carrying capacity information	**124** Accelerator control systems	**201** Occupant protection in interior impact	**206** Door locks and door retention components	**216a** Roof crush resistance
102 Transmission shift position sequence, starter interlock, and transmission braking effect	**111** Rear visibility	**125** Warning devices	**202a** Head restraints	**207** Seating systems	**219** Windshield zone intrusion
103 Windshield defrosting and defogging systems	**113** Hood latch system	**126** Electronic stability control systems for light vehicles	**203** Impact protection for the driver from the steering control system	**208** Occupant crash protection	**222** School bus passenger seating and crash protection
104 Windshield wiping and washing systems	**114** Theft protection and rollaway prevention	**138** Tire pressure monitoring systems	**204** Steering control rearward displacement	**210** Seat belt assembly anchorages	**225** Child restraint anchorage systems
108 Lamps, reflective devices, and associated equipment	**118** Power-operated window, partition, and roof panel systems	**141** Minimum Sound Requirements for Hybrid and Electric Vehicles	**205** Glazing materials	**214** Side impact protection	**226** Ejection Mitigation

Figure ES-1. FMVSS Covered in This Report

Despite the approach used in developing the technical translation options, limitations that should be disclosed in the interest of transparency are noted here. First, the legality of the potential options discussed in this report has not yet been fully verified. Second, the potential options in this report do not include all translation possibilities for the FMVSS or test procedures. The options included are limited to those that the authors of the report and the stakeholders involved suggested and discussed as potentially feasible at the time the research was performed. Thus, there may be other, better options not included in this report. Third, it is important to disclose that the majority of stakeholders involved in this project were representatives of industry, not public interest groups or others that the National Highway Traffic Safety Administration would consider "stakeholders" in NHTSA's processes. Please see Appendix F for a complete listing of the stakeholder organizations involved in the development of this report and in the technical translations of each of the FMVSS included in this report.

Scope

The FMVSS technical translations effort is focused on a particular type of new vehicle design, the ADS-DV, which this report defines as a vehicle designed to be operated exclusively by an SAE level 4 or level 5 ADS (as defined in SAE International Standard J3016_201806, Taxonomy and Definitions for Terms Related to Driving Automation Systems for On-Road Motor Vehicles, 2018) for all trips, and which is not equipped with manually operated driving controls. Thus, technical translation options were not developed for regulatory text or test procedures that might pose a barrier to the compliance verification of an ADS that operates with functionalities less than SAE level 4. Nor were technical translations developed for provisions within the FMVSS targeted toward vehicles equipped with an SAE level 4 or level 5 ADS that are also equipped with manually operated driving controls (sometimes referred to as "dual-mode" vehicles). Vehicles equipped with an ADS and manually operated driving controls would have the physical characteristics necessary to perform the test procedures as specified.

Technical translations for this effort present possible options for the regulatory text and test procedures when a regulatory barrier is present. Many of the FMVSS include both performance requirements and test procedures in the regulatory text. The OVSC test procedures are derived from the FMVSS regulatory text test procedures, if any. The technical translation options focus mainly on the regulatory text. Examples of potential regulatory barriers could include a feature mentioned in the regulatory text that is not available in the ADS-DV (e.g., steering column, steering wheel), instances where the feature is required as a reference point (e.g., driver's seat), or if its presence is required (e.g., rearview mirror). A portion of a test procedure that cannot be implemented as prescribed (e.g., measuring a steering wheel angle) might also present challenges for NHTSA compliance verification.

The knowledge gained and considerations made while evaluating the 30 FMVSS (18 of which are covered in this report) will be leveraged for any other FMVSS that might be evaluated in future work done by this research team. This additional work will be addressed longer term and documented in a separate report.

During the translation process, the research team reviewed the FMVSS regulatory language and test procedures. Several parts of the regulatory language include standards that are incorporated by reference (e.g., American National Standards Institute, ASTM International, International Organization for Standardization, SAE International). These standards incorporated by reference from external organizations, as part of the FMVSS, were analyzed in the same way as the regulatory text.

Crash Avoidance Standards

Work on the 100-series crash avoidance standards revealed many of the same themes that were repeatedly seen during Volume 1 research—for example: driver (operator); service brake application; shift position; and controls, telltales, indicators and auditory alerts. These themes represent some of the inherent assumptions throughout 49 C.F.R. Part 571—that a human is driving the vehicle using manually operated driving controls. In most cases, the research team determined that language in the 100-series standards could be addressed with straightforward clarification of the regulatory text. The technical translations provided options for how to treat the "driver" references in a way that may work across the standards. Since the project is focused on ADS-DVs and may not take into account all the potential considerations for dual-mode vehicles (considered outside of the current project scope), when the Volume 2 research requirements were suitable, the terms "ADS-DV" and "manually operated driving controls" were used in the technical translation options. This approach differed slightly from the Volume 1 translations, which used "vehicle operated by an ADS" and "vehicle that can be operated by a human driver," which the research team believes may include dual-mode vehicles. The methods used in the Volume 1 and Volume 2 research are compatible.

The visibility theme found in some of the standards covered in this volume (FMVSS Nos. 103, 104, 111 and 113) was distinct from the visibility theme addressed with FMVSS No. 108 (Volume 1 report). The visibility-related standards discussed herein focus on the human driver having a clear and reasonably unobstructed view and the provided technical translation options include retaining the performance requirements for ADS-DVs or, in some cases, specifying the requirement(s) for vehicles with manually operated driving controls. Additionally, FMVSS No. 101, a standard also considered as part of the Volume 2 visibility theme, specifies provisions for location, identification, color, and illumination of motor vehicle controls, telltales, and indicators. The analysis of regulatory information communicated in vehicles completed for the Volume 1 standards was also conducted for the Volume 2 standards to develop options for specifying where or to whom a telltale, indicator, or auditory alert is directed in ADS-DVs. The Volume 2 analysis was also expanded to include labels, written notices, and markings.

FMVSS No. 110 presents a unique aspect to the vehicle loading theme that was not part of the considerations for the Volume 1 translations. The vehicle normal load on the tire provisions contained in FMVSS No. 110 includes the vehicle's curb weight, accessory weight, and normal occupant weight based on typical seating patterns. Unconventional seating designs could benefit from additional research to understand the potential impacts to the vehicle normal load on the tire provisions.

Test Procedures

While much of the language in the 100-series standards could be addressed with straightforward clarifications, many of the test-procedure-related specifications may have potential compliance verification barriers. The primary goal was to identify a technically feasible path forward for execution of the test procedures through the test methods being evaluated. The intent was not to provide the final resolution or recommended implementation, but rather to demonstrate potential solutions and identify considerations for execution of the test procedures with an ADS-DV. Additional factors that may influence how the current test procedures are translated and/or executed for ADS-DVs are presented and discussed in this report.

There are some general considerations that apply to all standards. One is that, given the variety of vehicle functionalities and that the level of specificity for some functionalities is different depending on the FMVSS, there may not be a single solution for compliance verification testing of ADS-DVs that works equally well for all standards. Second, as existing test procedures are dependent upon human control of vehicle functionalities, testing of ADS-DVs may need to change as ADS-equipped vehicles themselves evolve. Because control of an ADS-DV will not be natively available to an external entity (a human), control of the vehicle will likely be manufacturer-specific, if not model-specific. With market maturation, control by authorized entities other than the manufacturer may become more accessible, potentially through standardization. This natural design evolution could influence the way test procedures are implemented and executed in the near future and later on. Therefore, the approach taken in this effort attempted to keep a broad view of the potential options and considerations that could be applicable now and in the future as the team investigated the test procedures and potential methods that could be used in their execution.

Crashworthiness Standards

In translating the 9 FMVSS 200-series standards covered in the Volume 2 research, many of the same themes repeatedly encountered in the Volume 1 research were also present—for example:

(1) references to driver (operator); (2) references to driver/passenger position; (3) references to front/rear of vehicle; (4) controls, telltales, indicators, and auditory alerts; and (5) dummy positioning. Many of these themes are also present in the 100-series Volume 1 and Volume 2 standards, so a consistent translation strategy was used in both series.

The aim of the 200-series standards is to reduce the risk of injury in the event of a crash. The occupant protection provisions of the 200-series are associated with the potential hazards to occupants at various seating positions rather than the role of the occupants seated at those locations. Bi-directional vehicles and unconventional seating configurations (e.g., rear-facing front seats) were not considered for the 200-series standards. Therefore, much of the language in the 200-series standards could be addressed with straightforward clarification of the regulatory text. The same 100-series standards approach used for the analysis of regulatory information communicated in vehicles was applied to the 200-series standards.

Test Procedures

The same approach used to provide translation options for the regulatory text of the 200-series standards was used for the associated test procedures. The technical translations provided options for how to treat the "driver" references in a way that worked across the standards. Many translations of the FMVSS 200-series test procedures involve mirroring the passenger/front right outboard seat to the left front outboard seat for ADS-DVs and, therefore, any additional test procedure development for translation may not be warranted. In many instances, the translation options use the phrase "if present" when the test procedures refer to the "steering column" or "steering wheel" to maintain the current requirements for conventional vehicles with manually operated controls. Based on the translations, additional test procedures for telltales in the FMVSS 200-series may be considered. Options for the air bag readiness indicator, passenger air bag suppression indicator, and seat belt warning system could expand the current requirements depending on who or what should receive which information.

Stakeholders and Subject Matter Experts

Stakeholders and SME reviewers were involved in the technical translation process. Several entities were engaged by the research team as collaborators on this project to obtain input and feedback, and to produce prototype technology for testing and evaluation. Stakeholders include companies, organizations, and advocacy groups that were invited to be involved in this project in the proposal stage based on their experience with FMVSS and ADS-equipped vehicles. Additional stakeholder entities have since been added; in some cases, organizations asked to be added and in other cases a need was identified for additional expert feedback, resulting in additional stakeholders being invited to participate.

SME reviewers are a subset of the larger stakeholder group; these are individuals with demonstrated expertise in and knowledge of a particular FMVSS and/or test procedure and a comprehension of how potential barriers to unconventional vehicle designs may be addressed. SMEs were divided into working groups based on their expertise. Working group members assisted with the review process once technical translation options were developed. SMEs also provided feedback on alternative methods evaluated for test procedures of interest. In addition, stakeholders participated in open project meetings and provided project input.

Report Contents

This report includes the following information:

Chapter 1 – Introduction. This chapter provides an overview of the research project as well as relevant background information.

Chapter 2 – Technical Translation Process. This chapter introduces the process followed for the development of technical translation options provided in this report. An overview describes the steps followed to analyze potential regulatory barriers for vehicles operated exclusively by an ADS in the references cited in 18 FMVSS, the methods used to develop technical translations, and the approach used for identifying and evaluating methods that NHTSA could potentially use to verify compliance. The steps followed for stakeholder and SME review and participation are also described in this chapter.

Chapter 3 – Crash Avoidance Standards. This chapter explains the results from the analysis performed for each of the nine 100-series FMVSS covered in Volume 2 research: FMVSS Nos. 101, 103, 104, 110, 111, 113, 124, 125 and 126. An overview of the technical translations as well as the stakeholder and SME feedback on each technical translation is presented.

Chapter 4 – Crashworthiness and Occupant Protection Standards. This chapter explains the results from the analysis performed for each of the nine 200-series FMVSS covered in Volume 2 research: FMVSS Nos. 207, 208, 210, 214, 216a, 219, 222, 225, and 226. The translation overview as well as the stakeholder and SME feedback on each translation are presented.

Chapter 5 – Test Method Evaluation Findings. This chapter provides a recap of the approach presented in the Volume 1 report and the specific application of the approach for the Volume 2 standards covered in the current report. While the focus for the Volume 2 research was the execution of FMVSS No. 126 test procedures that required operation of the ADS beyond what was demonstrated in the Volume 1 research, the evaluation includes the results from testing associated with the Volume 1 research. Results of the evaluation also incorporate SME insight and options captured during face-to-face panel discussions.

Chapter 6 – Summary of Research Findings. This chapter reviews the key findings from the translation analyses for the 100- and 200-series FMVSS for this portion of the research effort and summarizes the development of methods that may allow NHTSA to perform the test procedures and test procedure options.

Appendices – Appendices are included to provide information regarding definitions, technical translation worksheets, telltale tables from FMVSS No. 101, the information communicated to occupants, lists of standards incorporated by reference for the FMVSS covered in Volume 2 research, stakeholder listings, independent ADS-equipped research vehicle testing, simulation, and hardware-in-the-loop simulation.

Summary Conclusion

This study continued the work reported on in the Volume 1 report and carried forward the process for developing FMVSS translation options. As with the Volume 1 research, crosscutting analyses were developed to drive consistency in the technical translation options and clarify when individual standards required unique options or approaches. This allowed for the development of a potential range of options, and recognition of where an option in one standard could have broader implications.

In most cases options were provided for the 100-series standards that might be addressed through clarification by NHTSA and may not require additional supporting research. The 100-series standards covered in the Volume 2 research had many of the same themes that became apparent during the Volume 1 research. Many of the crash avoidance standards inherently assume that a human is driving the vehicle using manually operated driving controls. The technical translations provided options for how to treat the "driver" references in a similar manner across the Volume 1 and Volume 2 research. The visibility theme found in some of the Volume 2 research (FMVSS Nos. 103, 104 and 113) was different from the FMVSS No. 108 visibility theme covered under the Volume 1 research.

For the 200-series FMVSS, the effort focused on occupant protection in ADS-DVs with conventional seating configurations. Similar to the 100-series, in most cases, options were provided for the 200-series standards that might require clarification by NHTSA, as the focus for the Volume 2 research was limited to conventional seating configurations, and passenger side requirements could be used in most cases where a driver's designated seating position is no longer present. Many of the same themes were present across the Volume 1 and Volume 2 research. Crashworthiness requirements could be stated in terms of seating positions rather than occupant roles (e.g., driver, passenger). The test procedures developed for passenger seating positions could be used for ADS-DVs given that the main design difference between the two front outboard seating positions in conventional vehicles is the presence or absence of manually operated driving controls. ADS-DV developments may be changing the role of the rear seat to be more like that of the front seat, affecting FMVSS No. 208 in particular.

The Volume 1 report provided foundational work in developing FMVSS technical translation options and associated test procedure functionality that could be used by NHTSA to verify the compliance of ADS-DVs without manually operated driving controls, and Volume 2 used the same approach with 18 additional FMVSS. The exchange of ideas and feedback by the research team, stakeholders, and SME reviewers provided input to the options and the associated findings. Test procedures to verify FMVSS compliance for ADS-DVs without manually operated driving controls may continue to be refined during the next phase of this project. Furthermore, considerations for unconventional seating may be investigated.

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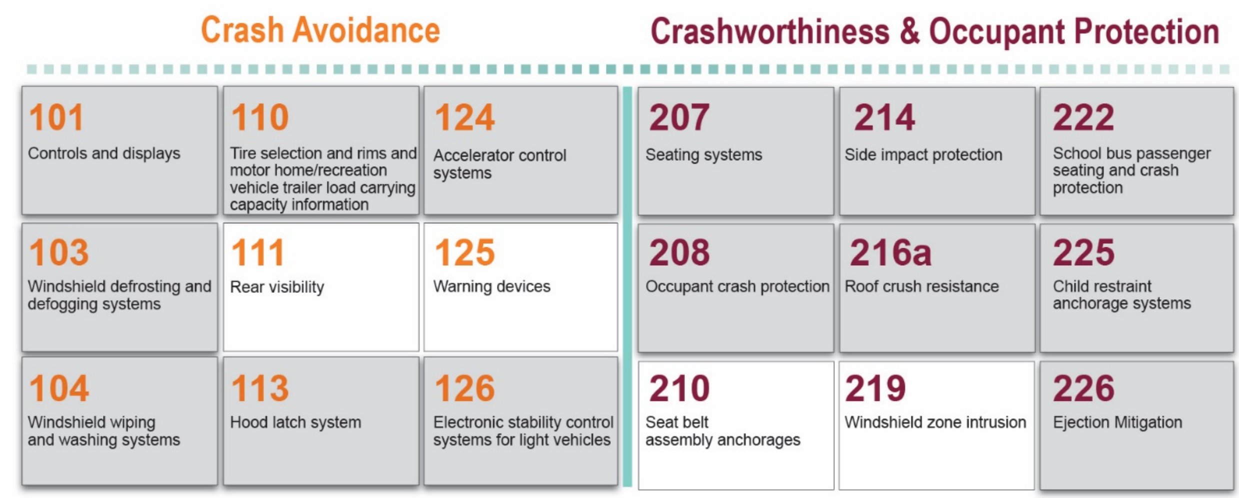
Chapter 1. Introduction

This project provides research findings in terms of options regarding technical translations of select Federal Motor Vehicle Safety Standards and test procedures. The newly created technical translation options take into account potential unnecessary/unintended regulatory barriers[1] to innovative new vehicle designs appearing in vehicles equipped with automated driving systems (ADSs) that lack manually operated driving controls. This report builds on the FMVSS Considerations for Automated Driving Systems Phase 1, Volume 1 (Blanco et al., 2020), which documented the framework used to evaluate the standards in that report. While the Volume 1 report discussed 12 FMVSS, the current report (Volume 2) describes activities related to 9 crash avoidance standards and 9 crashworthiness standards, as shown in Figure 1. (The four standards distinguished by white cells in the table are explained in footnotes under the figure.) This research includes feedback obtained from the research team, stakeholders, and subject matter experts.



FMVSS No. 111: May benefit from further research to complete technical translation options

FMVSS Nos. 125, 210, and 219: No barriers identified that required technical translation development

Figure 1. FMVSS Covered in Volume 2

For the purposes of this report, a technical translation is a modification that would allow regulatory text and/or test procedures that are identified as potential barriers to result in the same basic engineering performance without manual control-specific restrictions. Technical translations for this effort present options for the regulatory text and associated test procedures when a regulatory barrier is present. This report provides information regarding the technical translations and the test procedures for the 18 FMVSS covered in Volume 2 research in this project, such that the identified potential regulatory barriers could be removed for vehicles operated exclusively by an ADS that does not have the traditional manually operated controls used by human drivers.

[1] The use of the term "regulatory barrier" in this report always refers to "an unintended and unnecessary regulatory barrier" because the technical translation process does not remove, reduce, or otherwise alter performance standards of the FMVSSs under consideration.

Background

As part of the Volume 1 research, an analysis was performed to group features for current concept vehicles into four types of ADS-DVs: (1) First Generation, (2) Transitional, (3) Revolutionary, and (4) Low Speed. Studying the characteristics of the features for these innovative new vehicle designs allowed the research team to evaluate potential barriers. The Volume 1 research included 6 crash avoidance standards and 6 crashworthiness standards, as shown in Figure 2.

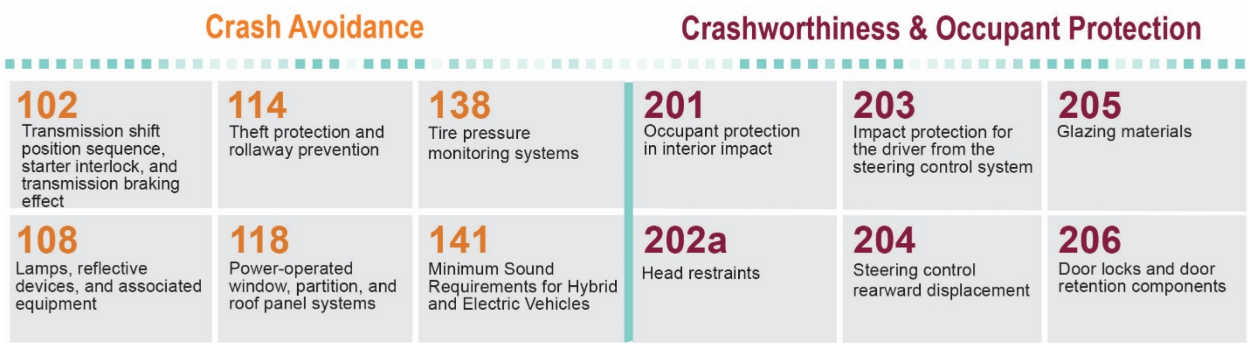


Figure 2. FMVSS Covered in Volume 1 Research

Scope

The FMVSS technical translations effort is focused on a particular type of new vehicle design, the ADS-DV, which this report defines as a vehicle designed to be operated exclusively by an SAE level 4 or level 5 ADS (as defined in SAE International Standard J3016, Taxonomy and Definitions for Terms Related to Driving Automation Systems for On-Road Motor Vehicles, June 2018) for all trips, and that is not equipped with manually operated driving controls. Thus, technical translation options were not developed for regulatory text or test procedures that might pose a barrier to the compliance verification of an ADS that operates with functionalities less than SAE level 4. Nor were technical translations developed for provisions within the FMVSS targeted toward vehicles equipped with an SAE level 4 or level 5 ADS that are also equipped with manually operated driving controls (sometimes referred to as “dual-mode” vehicles). Finally, only existent FMVSS are covered as part of the scope of this effort. The development of future standards is considered outside of the project’s scope.

Multiple factors were considered during the research scoping effort, including definitions, concept vehicles, and technical translation principles (See Appendix A for the definitions and the Volume 1 report for the technical translation principles). The scoping process allowed the development of technical translation options that the research team believes are appropriate to the vehicles of interest: ADS-DVs without manually operated driving controls. The approaches used for evaluating the translation options and test procedure implications for those standards covered in Volume 2 research are presented in their respective chapters.

Conventional Seating Configuration

During Volume 1 and Volume 2 research, the 200-series technical translation options considered conventional seating configurations only. Certain unconventional seating configurations may be explored in future research.

Bidirectional Vehicles

The current standards do not define the front and rear of the vehicle. These have been well understood to date (hood, trunk, front doors, rear axles, headlamps, etc.); however, with a bidirectional vehicle, it is possible that, depending on the vehicle's direction of travel, the hood becomes the trunk, the front doors become the rear doors, the front axles become the rear axles, the headlamps become the backup lamps, and so on. While front and rear are referenced throughout the standards, they are not defined, which can make things unclear when discussing vehicles with bidirectional functionality. Bidirectional ADS-DVs were analyzed in the context of the crash avoidance standards (100-series) and potential bidirectional vehicle definition options and application approaches were discussed. For the crashworthiness standards (200-series), bidirectional vehicles were not considered under Volume 1 or Volume 2 research. The implications of bidirectional vehicles for crashworthiness may be explored in future research.

Approach

During the translation process, potential regulatory barriers were analyzed. The first set of regulatory barrier analysis, technical translations, and test method evaluations that were reported on in the Volume 1 report were used as a framework for the evaluation of the standards covered in Volume 2. Chapter 2 of the current report provides additional detail on the process used to analyze regulatory barriers.

Definitions used in this study are provided in Appendix A. Detailed information on these definitions was included in the Volume 1 report. Research conducted under this project regarding concept vehicles as they relate to current FMVSS was also covered in that report.

Chapter 2. Technical Translation Process

Performing Technical Translations

Following, we describe the process used to analyze the potential need for technical translations. Potential barriers were analyzed at two levels: (1) regulatory language, including performance requirements and test procedures, and (2) exercise of test procedures. There are many external standards that are incorporated by reference (e.g., American National Standards Institute, ASTM International, International Organization for Standardization, SAE International). The external standards, as part of the FMVSS, were analyzed in the same way as the rest of the text.

Technical Translation Types and Reasons for Inability to Translate

The following taxonomy was used to categorize the analysis performed for each FMVSS. This initial framework allowed for the accommodation of options as they evolved and as information developed throughout the technical translation process. The standard translation assessment code is a categorical variable ranging from 0 to 2. The code assigned to each standard's technical translation conveys what the research team believes is the appropriate category (Table 1). Codes were used to categorize the considered translations throughout the technical translation development process. The technical translation type and assessment reason can be found in the individual standard translation worksheets. See Appendix B for the technical translation worksheets for each of the FMVSS covered in Volume 2 research.

Table 1. Technical Translation Taxonomy

Reason	Technical Translation Type Description
0 – Not performed	Translation evaluated but not performed.
1 – Translation is straightforward	The translation performed is straightforward.
2 – Limited research may be beneficial	Can translate standards or provisions of standards, maintaining current performance levels, with some limited amount of research for NHTSA to conduct compliance verification for both conventional vehicle designs and new vehicle designs associated with ADS-DVs.

Key Considerations

Crash Avoidance

Similar themes emerged among Volumes 1 and 2 research (e.g., driver [operator]; service brake application; shift position; and controls, telltales, indicators, and auditory alerts). Table 2 captures the crosscutting themes from both the Volume 1 and Volume 2 standards.

Table 2. Crash Avoidance Crosscutting Themes

Themes	Volume 1						Volume 2								
	102	108	114	118	138	141	101	103	104	110	111	113	124	125	126
Congressional Mandate			●	●	●	●				●	●				
Controls, Telltales, Indicators, and Auditory Alerts	●	●	●		●		●								●
Driver (Operator)	●	●	●		●		●	●	●		●		●	●	●
Driver/Passenger Position/Presence	●	●	●	●			●	●	●	●		●			●
Equipment May Not Be Applicable		●	●					●	●		●				
Front/Rear of Vehicle		●				●		●		●	●	●			
Service Brake Application	●	●	●		●	●				●					●
Shift Position (Gear, Selects, Reverse)	●	●	●			●		●	●		●				
Vehicle Loading Including Test Driver and Instrumentation			●		●	●				●					●
Visibility		●						●	●		●	●			

These themes represent some of the inherent assumptions throughout 49 C.F.R. Part 571—that a human is driving the vehicle using manually operated driving controls; this presents one of the biggest challenges to the technical translation of the 100-series standards. Among other things, an ADS is not expected to manipulate the lateral control of a vehicle through a steering wheel, is not expected to apply pressure to a brake pedal to stop a vehicle, and likely would not require illuminated telltales to make it aware of vehicle conditions. A key aspect to addressing the inherent assumptions in the standards was how to treat the “driver” references in a way that worked across the standards. This was one of the key undertakings for the Volume 1 research. As detailed in the Volume 1 report and shown in the definitions in Appendix A, the research team discussed two potential definitions for the term “driver.” Under Option 1, “driver” is used both for an ADS performing the dynamic driving task (DDT) for an ADS-DV and also for a human driver. In Option 2, the term always refers to a human as the driver—the ADS would be treated and, if necessary, defined separately. Because the latter option does not specify the entity that is operating/controlling the vehicle, the technical translation options use language such as “for a vehicle operated by an ADS” or “for a vehicle operated by a driver.”

In some cases, the Volume 2 standard requirements were not anchored on the “driver” actively performing the DDT but were more guided towards describing the vehicle in terms of its features. Therefore, when referring to vehicle features—not the driver—the technical translation options provided for the Volume 2 standards refer to the "ADS-DV" directly and, when specifying a requirement for a vehicle driven by a human driver, the phrase "vehicle with manually operated driving controls" is used. This is different than the method generally used for the Volume 1 technical translation options, which mainly specified requirements by who or what was operating the vehicle. For the Volume 1 standards, "for a vehicle operated by an ADS" was used to specify requirements for an ADS-DV and "for a vehicle that can be operated by a human driver [driver]" was used to specify requirements for a vehicle operated by a human driver. In most cases, the language used in the Volume 1 report would also work for the Volume 2 technical translation options. Since the project is focused on ADS-DVs and may not take into account all potential considerations for dual-mode vehicles (considered outside of the current project scope), when requirements were suitable, the terms "ADS-DV" and "manually operated driving controls" were used in the technical translation options.

To explain further, the current language from FMVSS No. 103 S4.2 is provided in the first paragraph below, while the subsequent paragraphs denote additions and changes to the language in red font. This translation has extracted language directly from SAE Recommended Practice J902_1964. While the extracted language from this external reference did not change, language has been added to the standard, as indicated by the use of the red, bolded, underlined font in the two paragraphs further below:

> Each passenger car windshield defrosting and defogging system shall meet the requirements of section 3 of SAE Recommended Practice J902 (1964) (incorporated by reference, see §571.5) when tested in accordance with S4.3, except that "the critical area" specified in paragraph 3.1 of SAE Recommended Practice J902 (1964) shall be that established as Area C in accordance with Motor Vehicle Safety Standard No. 104, "Windshield Wiping and Washing Systems," and "the entire windshield" specified in paragraph 3.3 of SAE Recommended Practice J902 (1964) shall be that established as Area A in accordance with §571.104.

One of the four technical translation options uses "vehicles that can be operated with manually operated driving controls" to delineate the requirements for a human driver and uses "ADS-DV" when referring to vehicles without manually operated driving controls, as follows:

> For vehicles that can be operated with manually operated driving controls, each passenger car windshield...in accordance with §571.104. For **<u>ADS-DVs</u>**, if equipped with windshield defrosting and defogging systems, Area A defrost pattern of the windshield shall be 80 percent defrosted after 25 minutes of operation. After 40 minutes of operation the entire windshield area shall be 95 percent defrosted.

While not supplied as a technical translation option, the approach used with the Volume 1 standards might also work, as shown here using the driver definition Option 2:

> For vehicles that can be operated by a driver, each passenger car windshield...in accordance with §571.104. For **<u>vehicles operated by an ADS,</u>** and if equipped with windshield defrosting and defogging systems, Area A defrost pattern of the windshield

shall be 80 percent defrosted after 25 minutes of operation. After 40 minutes of operation the entire windshield area shall be 95 percent defrosted.

As shown in Table 2, defining the front and rear of the vehicle was also a theme explored in Volume 1 research, predominantly in the context of FMVSS Nos. 108 and 141. The research team considered whether there may be a need to define front and rear to support the technical translation options for bidirectional vehicles. After review and analysis, the team presented options for defining bidirectional vehicles in section 571.3 and added a new subsection (g) of section 571.7, or a new section 571.11, which clarified that each applicable standard set forth in Subpart B shall apply to bidirectional vehicles in both directions of travel. For the most part, this same approach was applied to the development of options for the Volume 2 standards—compliant in both directions of travel. However, one of the three technical translations options for FMVSS No. 110 considers an approach that may facilitate only one placard placement for vehicles with bidirectional functionality.

The visibility theme was present in the Volume 1 standards (FMVSS No. 108); however, it was more prevalent in the Volume 2 standards. FMVSS No. 108 specifies requirements for all original and replacement lamps, reflective devices, and associated equipment; much of this standard is focused on helping the driver see and making the vehicle visible to others. In contrast, the Volume 2 standards associated with visibility (FMVSS Nos. 103, 104, 111 and 113) specify requirements for the driver having a clear and reasonably unobstructed view, and FMVSS No. 101 specifies requirements for location, identification, color, and illumination of motor vehicle controls, telltales, and indicators. While some aspects overlap the Volume 1 and Volume 2 standards (such as the use of similar SAE standards to establish an "eyellipse," a statistical representation of driver eye locations, and the options for telltale and indicators), the Volume 2 standards address different aspects of visibility.

Additionally, some of the Volume 2 standards include requirements with provisions for vehicle loading focused on testing personnel and equipment. This aspect of the vehicle loading theme that was addressed in the Volume 1 standards and the technical translation options used was also used in the pertinent Volume 2 standards' technical translations. However, FMVSS No. 110 presents a unique aspect to the vehicle loading theme that was not part of the considerations for the Volume 1 translations and, thus, required additional considerations. The vehicle normal load on the tire provisions contained in FMVSS No. 110 includes the vehicle's curb weight, accessory weight, and normal occupant weight based on typical seating patterns. ADS-DVs' unconventional seating designs and the potential impact on vehicle loading specific to FMVSS No. 110 are discussed further in Chapter 3: Crash Avoidance Standards.

<u>Test Procedures</u>

For the crash avoidance standards, the primary goal was to demonstrate potential ways to execute test procedures using an ADS-DV. Some of the key considerations that were identified during the current research are summarized here.

There are multiple factors that may influence how the current test procedures could be translated and/or executed for ADS-DVs. For example, the Office of Vehicle Safety Compliance (OVSC) test procedure for FMVSS No. 111 records the live image shown on the rearview image display for compliance verification. If an ADS-DV manufacturer chooses to use vision-based perception sensors at the rear of the vehicle and their architecture supports live viewing of the video stream, this could allow a test procedure execution similar to that currently conducted. However, if a radar-based system is used at the rear of the vehicle instead, the streaming of the raw radar data may not provide adequate information for the test operator to directly verify compliance. Similarly, ADS-DVs with an ODD that is strictly limited to an urban environment may not be designed to travel at the minimum speed required to execute the sine-with-dwell (SWD) test defined in FMVSS No. 126 for electronic stability control (ESC). This potential scenario may influence how compliance verification for ESC is defined and executed for ADS-DVs.

There may not be a single solution or test method for compliance verification testing of ADS-DVs that works equally well for all standards. The FMVSS include a wide spectrum of behavior and performance criteria, such as the ability of the transmission to hold on a hill (FMVSS No. 114) and the ability to limit vehicle yaw (FMVSS No. 126). Current execution of the associated test procedures for these two standards are carried out using different methods: human control and programmed control. Similarly, different standards may be easier to execute with one of the proposed methods investigated during this research. The different opinions offered by SMEs also reflected this ambiguity in identifying a single preferred test execution method. This difference in opinion could also be a function of the way in which a given manufacturer may architect and build an ADS, which may influence how an ADS-DV might be manually controlled.

Another consideration that was reflected in the feedback from stakeholders and SMEs is that the technology may be too new to establish a final testing solution. Market maturation may provide more tangible data on how manufactures will implement control of their vehicles outside the normal ODD. This data may provide additional insight on how to perform compliance verification testing with ADS-DVs. Therefore, the approach taken in this effort attempted to keep a broad view of the potential options and considerations that could be applicable now and in the future while investigating the test procedures and potential methods that could be used in the execution of these procedures.

Crashworthiness and Occupant Protection

In translating the FMVSS 200-series standards covered in Volume 2 research, many of the same recurring themes in the Volume 1 research were also present (e.g., driver [operator]; driver/passenger position; front/rear of vehicle; controls, telltales, indicators, and auditory alerts). Table 3 captures the crosscutting themes from both the Volume 1 and Volume 2 standards.

Table 3. Crashworthiness and Occupant Protection Crosscutting Themes

Themes	Volume 1						Volume 2								
	201	202a	203	204	205	206	207	208	210	214	216a	219	222	225	226
Assumes Front Row is Preferred Seating Position	●	●	●	●		●		●		●					
Congressional Mandate								●							
Controls, Telltales, Indicators, and Auditory Alerts						●		●							●
Driver (Operator)	●	●	●		●	●	●	●		●	●		●	●	●
Driver/Passenger Position/Presence	●	●				●	●	●		●	●		●	●	●
Dummy Positioning	●	●						●		●					
Equipment May Not Be Applicable			●	●											
Front/Rear of Vehicle	●	●				●	●	●		●	●	●	●	●	●

The aim of the 200-series standards is to reduce the risk of injury in the event of a crash. Many of the FMVSS in the 200-series use the terms "driver," "driver's seat," "driver's designated seating position," and similar terms, which might appear at first inspection to warrant technical translation. However, the occupant protection provisions of the 200-series are associated with the potential hazards to occupants at various seating positions rather than the role of the occupants seated at those locations.

In some FMVSS, the terms "driver side" or "passenger side" are used to define vehicle landmarks. Technical translation options were provided to modify these terms to "left side" or "right side," respectively.

<u>Test Procedures</u>

The same approach used to provide translation options for the regulatory text of the 200-series standards was used for the associated test procedures. Many translations of the FMVSS 200-series test procedures involved mirroring the passenger/front right outboard seat to the left front outboard seat for ADS-DVs, and therefore any additional test procedure development for translation may not be warranted. The dummy positioning procedures for the front outboard passenger designated seating position (DSP) were mirrored for dummy positioning in the left front DSP in vehicles without manually operated driving controls. In many instances, the translation options use the term "if present" when the test procedures refer to the "steering column" or "steering wheel" to maintain the current requirements for conventional vehicles.

Based on the translations, additional test procedures for telltales may be warranted in the FMVSS 200-series. Options for the air bag readiness indicator, passenger air bag suppression indicator, and seat belt warning system could expand the current requirements, depending on who should receive what information.

Controls, Telltales, Indicators, Auditory Alerts, Symbols, Labels, and Markers

In general, the performance specifications for required controls, telltales, indicators, auditory alerts, symbols, labels, and markers are contained within the individual standards and are designed to be used by, or convey information to, the driver of a vehicle and, in a few cases, to other occupants. As indicated in the crosscutting themes tables (Table 2 and Table 3 above), FMVSS Nos. 126, 208, and 226, which are covered in the Volume 2 standards, require telltales and specify performance conditions for those features.

In addition to these standards, FMVSS No. 101, Controls and Displays, contains requirements for location, identification, color, and illumination of motor vehicle controls, telltales, and indicators. For example, FMVSS No. 101, S5.1.2 specifies, "The telltales and indicators listed in Table 1 and Table 2 [in the standard] must be located so that, when activated, they are visible to a driver…." (See the tables in Appendix C of this report.) This is an "if equipped" standard—the standard applies if the vehicle is fitted with the controls, telltales, or indicators in the tables provided in FMVSS No. 101. Not all FMVSS No. 101 controls, telltales, and indicators presented in Tables 1 and 2 are referred to in other standards that specify the equipment performance. For example, the fuel level telltale and indicator equipment performance are not referred to in other standards. Conversely, FMVSS No. 208, S7.3 specifies that there should be "…a continuous or flashing warning light visible to the driver displaying the identifying symbol for the seat belt telltale shown in Table 2 of FMVSS No. 101 or, at the option of the manufacturer if permitted by FMVSS No. 101, displaying the words "Fasten Seat Belts" or "Fasten Belts," for not less than 60 seconds…." Additionally, FMVSS No. 208, S4.5.2 includes a "readiness indicator" requirement to monitor the readiness of the driver and passenger air bags. The term "readiness indicator" in FMVSS No. 208 and S4.2.2 of FMVSS No. 226 refers to the telltale in this case.

In addition to the controls, telltales, indicators, and auditory alerts, some of the standards specify information to be communicated using labels, written notices, and markings (e.g., the placard label that contains the tire pressures and the vehicle's load limits, markings identifying the child restraint anchorages, and written notices covering spare tire use information). Issues related to what an ADS should do in response are beyond the scope of this project. Nevertheless, the premise of providing a driver with a warning indicates the expectation that a response will be initiated based on that warning. To develop the different technical translation options, an analysis of the driver's expected response to telltales and other communication was conducted. The research team reviewed publicly available documents and owner's manuals and combined information from those with the team's collective knowledge in order to: (1) identify standards that require controls, telltales, indicators, symbols, labels, markers, written notices, and auditory alerts, (2) attempt to identify the "expected response" of a driver and/or occupant(s) to these items in a manually operated vehicle; (3) present options for technical translations; and (4) identify potential considerations associated with the options.

The same approach used in the Volume 1 research was applied to the Volume 2 standards. Table 4 below outlines the four areas that were used in the analysis: (1) information communicated, (2) delivery method, (3) intended for, and (4) expected response.

Table 4. Analysis of Regulatory Information Communicated in Vehicles

Categories	Analysis Questions	Examples
Information Communicated	What is communicated? What type of communication?	Engaged, warning, malfunction, identification
Delivery Method	How is information delivered?	Illumination of a telltale, auditory alert, indicator
Intended For	Who is the information for?	Driver, non-driving occupants, maintenance entity
Expected Response	What action is expected in response to information?	After a low tire pressure warning is activated, someone is expected to check the tires and take appropriate action

The analysis of the Volume 2 standards retained the 10 potential options developed during Volume 1 research for technical translation of provisions that specify where or to whom a telltale, indicator, or auditory alert is directed in ADS-DVs. The 10 options are detailed in the Volume 1 report. They range from communicating the information to the ADS only, to communicating to the ADS and all DSPs, to not communicating the information to either the ADS or DSPs, and include many options in-between.

Appendix D captures the complete results of the Volume 2 analysis of information communicated in an ADS-DV. Similar to the initial analysis completed for the Volume 1 standards, some of the FMVSS explicitly state to whom the information in question should be communicated and the expected response, such as S7.3 of FMVSS No. 208, Seat belt warning system, outlined above and further described in S4.5.1(f), which details the information to appear in the owner's manual: "The information shall emphasize that all occupants, including the driver, should always wear their seat belts whether or not an air bag is also provided at their seating position to minimize the risk of severe injury or death in the event of a crash." Based on the analysis of the expected response described in the regulatory language, only 4 of the 10 technical translation options were used in the seat belt warning system requirement translation (Volume 1 report). These options and the associated rationales are discussed in Chapter 4: Crashworthiness and Occupant Protection, FMVSS No. 208.

Other provisions had little to no indication of the expected response (e.g., the fuel level telltale and indicator in FMVSS No. 101). However, this was not unexpected since the fuel level telltale and indicator are not required. By way of example, the 2018 Ford Fusion owner's manual states, "It will illuminate when the fuel level is low or the fuel tank is nearly empty. Refuel as soon as possible" (Ford Motor Company, 2018a, p. 97). Similarly, the owner's manual for the 2018 Toyota Camry states: "Indicates that remaining fuel is approximately 2.2 gallons. Refuel the vehicle" (Toyota Motor Corporation, 2018, p. 500). Therefore, the expected response was determined to be: Verify fuel level status and refill fuel tank as soon as possible. If a vehicle is equipped with a fuel level indicator and corresponding telltale, a range of options from the

Volume 1 report could be applied as part of a new Table 3 for FMVSS No. 101 for ADS-DVs. This notion is discussed further in the upcoming Chapter 3: Crash Avoidance Standards, FMVSS No. 101 section.

The entity responsible for the vehicle's "Operational Readiness" played a role in the development of the translation options. SAE International's J3016 defines a "Dispatching Entity" as an entity that dispatches an ADS-equipped vehicle(s) in driverless operation (2018). It further outlines that while the ADS is not engaged, the dispatcher verifies operational readiness of the ADS-equipped vehicle. The responsibility for operational readiness (e.g., vehicle condition, maintenance) of an ADS-DV may no longer belong to a human driver. Rather, it could be a dispatcher or dispatching entity (e.g., vehicle owner and/or a fleet management company) that completes the operational readiness function. Items such as the fuel level indicator and telltale, along with others contained in the FMVSS No. 101 tables (e.g., engine oil pressure and air bag readiness), were reviewed for this analysis and considerations for the concept of operational readiness was explored. NHTSA's Automated Vehicle Research for Enhanced Safety report (Tellis et al., 2016) identifies some safety principles for ADS-equipped vehicles. One of these principles for SAE level 4 and 5 ADS-equipped vehicles is that the vehicle operator shall ensure vehicle operational readiness before engaging the ADS. While the term "vehicle operator" is not used in SAE's J3016 (2018)—"dispatching entity" is used instead—the principles provide insight regarding how and to whom operational readiness information may need to be delivered.

As discussed in the Volume 1 report, for an ADS-DV, the method of communicating the required regulatory written instructions, which is typically via a vehicle owner's manual, may benefit from further research to consider potential delivery methods for occupants. However, many of the labels and markings reviewed as part of the Volume 2 standards are already intended for non-driving occupants, such as those in FMVSS No. 207 S4.4, "Seats not designated for occupancy while the vehicle is in motion shall be conspicuously labeled to that effect." Other markings and labels were specific to supporting a human driver. One such example is FMVSS No. 111 S5.4.2, which states, "Each convex mirror shall have permanently and indelibly marked at the lower edge of the mirror's reflective surface, in letters not less than 4.8 mm nor more than 6.4 mm high the words 'Objects in Mirror Are Closer Than They Appear,'" which may not be relevant for ADS-DV occupants. These examples were not provided within the technical translation options since they either already addressed occupants or were specific only to human drivers, and thus did not represent a regulatory barrier.

Analysis of Standards Incorporated by Reference

Many of the FMVSS make reference to external standards; these documents are incorporated by reference in the FMVSS and they appear in 49 CFR §571.5. As stated in the Volume 1 report, the goal of this analysis is to identify potential regulatory barriers to NHTSA's compliance verification as well as to provide options for technical translations in the sections where the standard is incorporated by reference. Each incorporated reference within the FMVSS regulatory text and associated test procedures was evaluated and coded based on its potential to create a barrier for compliance verification. If it was a potential barrier, then a technical translation option(s) was provided. This was performed with criteria similar to those used for FMVSS, given that standards incorporated by reference become part of the FMVSS regulatory language (Table 5).

Table 5. Taxonomy for Translation of Standards Incorporated by Reference

Reference Classification Scale	Description
0 – No barrier	The reference could be used as originally cited and intended. It does not present any regulatory barrier.
1 – Translation is straightforward	Translations were incorporated to ensure the reference does not present a regulatory barrier.
2 – Limited research may be beneficial	Research may be beneficial in order to implement a translation in the reference or the regulatory text.

Sixty-five standards by external organizations were incorporated by reference in the regulatory text and the associated test procedures for the 18 FMVSS that were evaluated as part of this report (Figure 3). These standards represent multiple organizations external to NHTSA (e.g., ASTM, International Commission on Illumination [CIE], SAE). The total number of incorporated references within each FMVSS, as shown in Appendix E, was calculated per referenced document, not by the number of citations to said references. For example, FMVSS No. 103 contained six citations to different sections of one incorporated-by-reference document (e.g., section 3, paragraph 3.1, paragraph 3.3, paragraphs 4.1-4.7 of SAE J902) but was only counted once in the tables in Appendix E.

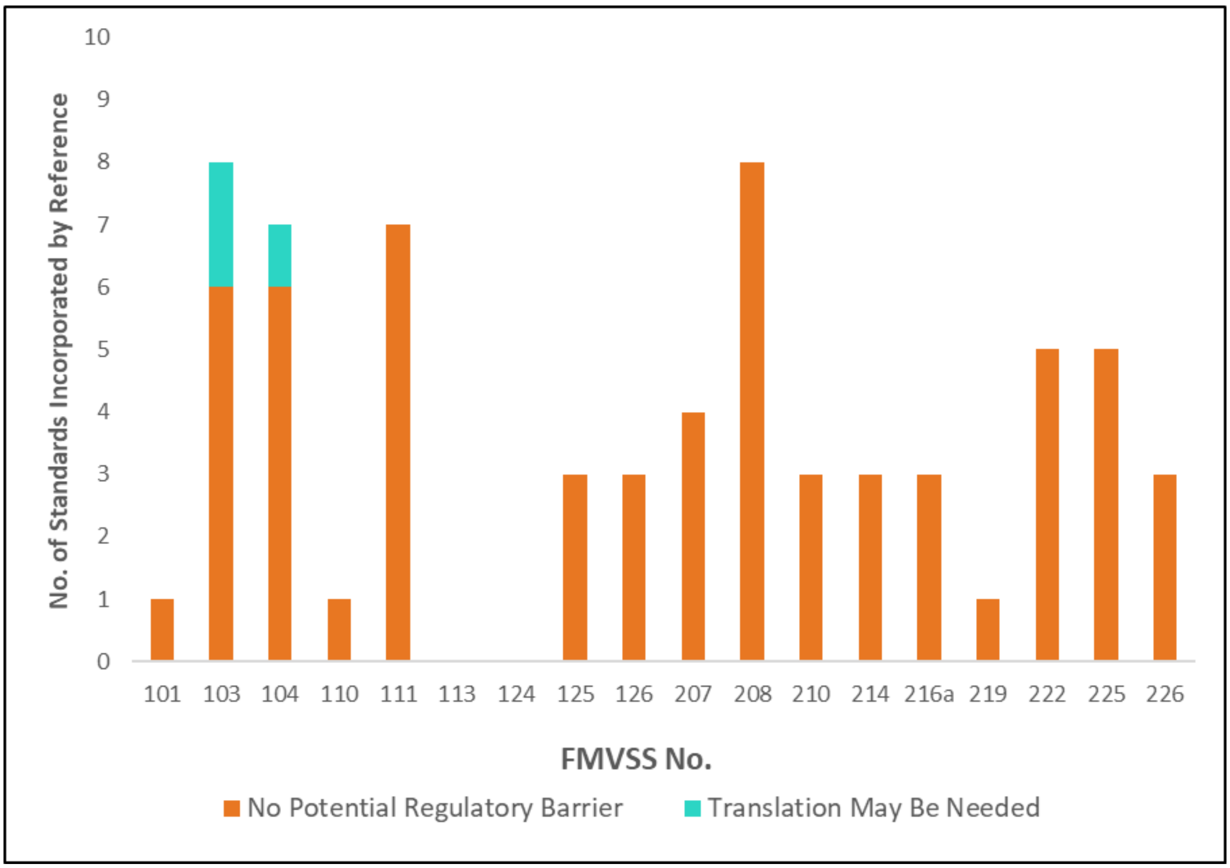


Figure 3. No. of Standards Incorporated by Reference Cited in the 18 FMVSS, Divided by Standard

References cited ranged in publication date from 1931 to 2010. Many newer references issued by external organizations have not been updated in the FMVSS. Thus, only incorporated references presently cited within the standard were assessed. The final results for this volume of the project are presented by FMVSS as well as by external organizations in case there were some organization-based trends (Figure 4). Details about the analysis of standards incorporated by reference are provided for each FMVSS in its respective section (Chapters 3 and 4).

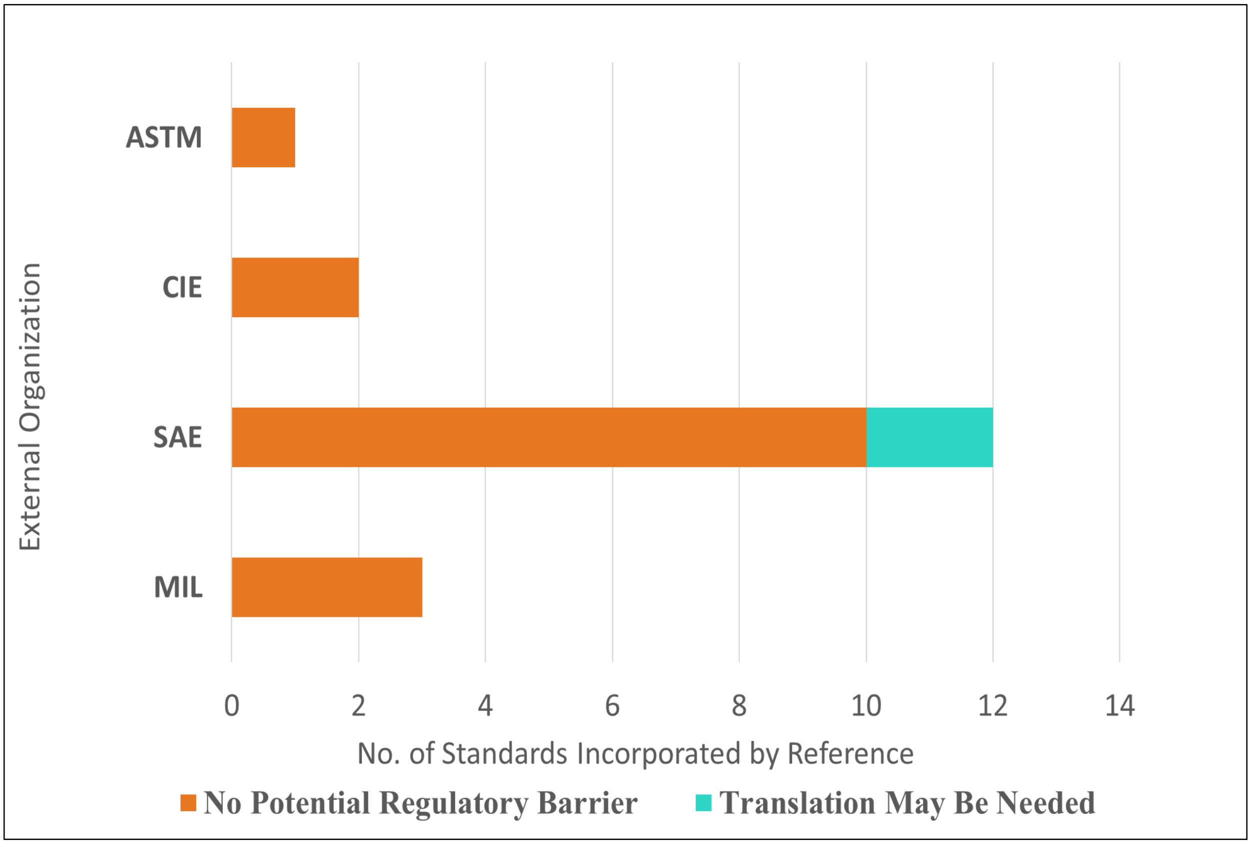


Figure 4. Standards Incorporated by Reference Cited in the 18 FMVSS, Divided by Publishing Organization

Overall, the potential barriers presented by these standards incorporated by reference are believed by the research team to be minimal. The few exceptions found involve SAE Standards and Recommended Practices over varying years that are relevant to vehicle interior layout (i.e., packaging tools). Reed (2018) presents a review of some of these standards. The November 2018 FMVSS stakeholder meeting for this study discussed several of these standards incorporated by reference that could present a barrier. Test procedure elements involving use of the H-Point (SAE J826), eyellipse (SAE J941), and metrics such as W3 and W7 dimensions (SAE J1100) may not be applicable to ADS-DV aspects such as ADS visibility. Vehicle packaging for the human driver use points of reference defined relative to the driver's DSPs and areas of driving visibility relative to the windshield and manual driving controls. Some of the technical translation options were developed using language that already exists in the current standards. For example, FMVSS No. 104 S4.2.2 current language for multipurpose vehicle suggests:

> Each multipurpose passenger vehicle, truck, and bus shall have a windshield washing system that meets the requirements of SAE Recommended Practice J942 (1965) (incorporated by reference, see §571.5), except that the reference to "the effective wipe pattern defined in SAE J903, paragraph 3.1.2" in paragraph 3.1 of SAE Recommended Practice J942 (1965) shall be deleted and "**the pattern designed by the manufacturer for the windshield wiping system on the exterior surface of the windshield glazing**" shall be inserted in lieu thereof.

This language (including adaptations for the defogging and defrosting systems) was presented in lieu of performing human driver centric calculations required by standards such as SAE J826 and SAE 941. For example, a technical translation option for FMVSS No. 104 S4.2.1 could be as follows (red font indicates changed/added text):

> Each passenger car equipped with manually operated driving controls shall have… in lieu thereof. For ADS-DVs, if equipped with a windshield washing system, the system shall meet the requirements of this standard for the pattern designed by the manufacturer for the windshield wiping system on the exterior surface of the windshield glazing.

Therefore, most of the references analyzed were determined as potentially not presenting a barrier given that translations such as the one above would allow for alternate methods to obtain the information (e.g., manufacturer-developed pattern). This alternative method would not involve standards that apply solely to aspects of human drivers. Alternatively, it would allow for the same information to be obtained for aspects related to non-driving occupants.

In the evaluation process, the research team encountered an exception to the FMVSS approach taken in the Volume 1 report with regard to the external reference citation analysis. For Volume 2, the approach was modified to consider key terms of non-incorporated references. The modified approach was used as an inclusive measure to address all potential external documents affected by a technical translation option. There were several examples of references to key terms found in non-incorporated references, such as "Manikin H-Point" (FMVSS No. 101, S5.3.4), that are not defined explicitly within the standard. Instead, these references depend on a definition derived from an external non-incorporated reference—in this case, SAE Standard J826_201511—from which the term originated. These references that rely on external definitions or specified measurements may potentially pose a barrier to NHTSA for verifying compliance testing of ADS-DVs. A table summarizing these reference exceptions can be found in Appendix E.

Stakeholder and SME Review Process

Overall Approach

Research tasks for this report benefited from input from stakeholders and associated SMEs. Stakeholders for this project were assembled from companies, organizations, and advocacy groups that were invited to be involved during the proposal stage based on their experience with FMVSS and ADS-equipped vehicles. Additional stakeholder entities have since been added; in some cases, organizations asked to be added and, in other cases, a need was identified for additional SME feedback, resulting in additional stakeholders being invited to participate. SME reviewers are a subset of the larger stakeholder group; these are individuals with expertise in and knowledge of a particular FMVSS and/or test procedure and a comprehension of how potential barriers to NHTSA's compliance verification of vehicle designs may be addressed. The SME reviewers for each FMVSS covered in Volume 2 research (Appendix F) were given opportunities to review the technical translation options and, if provided, their input was taken into consideration. It should be noted that no new information was requested or provided for the FMVSS technical translation options reviews.

As detailed in the Volume 1 report, worksheets were developed for each FMVSS to provide background information for developing the technical translation options. The FMVSS project leads completed the initial technical translation exercise after reviewing and studying the background information. They then gathered input from multiple core team members and further refined the technical translation options. The updated worksheets were provided to SME reviewers and their feedback was compiled and incorporated into the worksheets as long as the input was within the project's scope. All SME reviewer feedback was anonymized and maintained within the worksheets.

The results of this task were presented during the second FMVSS stakeholder meeting, which was held on November 28 and 29, 2018, at U.S. Department of Transportation headquarters in Washington, DC. As was the case with the first, earlier FMVSS stakeholder meeting in April 2018), this meeting enabled a larger and broader group of stakeholders to provide input (Appendix F). Details regarding this meeting are provided in the section below.

Stakeholder Meeting

The November 2018 FMVSS stakeholder meeting, FMVSS Considerations for Automated Driving Systems, was held to provide feedback on the technical translation options and to identify any additional regulatory barriers for compliance verification of innovative new vehicle designs precipitated by ADSs.

The meeting opened with a plenary session that included an overview of the project objectives, scope, FMVSS candidate standards, approach to the development of technical translation options, review of incorporated reference analysis, and the concept vehicle framework used for the project. An overview of the 100-series test method development and evaluation was presented, followed by an introduction to the potential translation of FMVSS No. 208. As this may extend to occupants seated behind the front seat, issues that may be encountered as a result of occupants being seated in locations other than the front row of an ADS-DV were introduced to provide a framework for the 200-series breakout session.

The morning meeting was rounded out by two sessions. The first was titled Analysis of Regulatory Information Communicated in an ADS-DV. The presentation outlined the intended design of telltales, indicators, and audible alerts to convey information to the driver—and, in some instances, to occupants of the vehicles—and explored considerations for communicating regulatory information in an ADS-DV. The analysis investigated what is communicated, how information is delivered, for whom the information is intended, and the action expected in response to the information. A research team member from Nissan Technical Center North

America presented the current SAE and ISO tools and procedures for understanding passenger seating and vision. The presentation concluded that the existing SAE and ISO vision standards could provide a solid basis to measure readability for occupant control icons and information displays in an ADS-DV. However, the passenger seat eyellipse for seats with greater than “minimum” fore/aft adjustment may require new definitions and measurement methods. The second session included a panel discussion on ADS-DV testing procedures.

The afternoon consisted of breakout sessions for the 100-series and 200-series FMVSS, with presentations and panelist discussions for the Volume 2 FMVSS. The following breakout sessions took place for the 100-series: FMVSS Nos. 108, 110, 111, 126 – (1) Translation Updates, (2) Test Procedure Overview, and (3) Test Method Evaluation Assessment. Breakout sessions for the 200-series were FMVSS No. 208 – (1) Rear Seat Testing, (2) Seating Location Selection, and (3) Novel Seating Configurations. The rear seat testing update included an overview of the selection of late-model vehicles spanning a range of potential rear-seat performance based on vehicle package characteristics, restraint geometry, and seat belt routing. The current and future rear-seat experiences were discussed and previous studies on rear-seat safety were summarized. Previous stakeholder remarks on novel seating configurations were presented and led to a discussion on how novel seating may impact technical translations and future research. Panel discussions were chaired by the researcher responsible for leading the technical translation for the standard. The panelists were project stakeholders who had provided feedback to the technical translation options and who represented a range of perspectives and backgrounds.

The symposium reconvened on the second day, and summaries of the previous day’s sessions were presented along with next steps and closing remarks.

SME Test Methods Feedback Meetings

A series of SME meetings was held to obtain additional feedback on the proposed 100-series test methods and associated procedures (see the Test Methods section in Chapter 5 for more details) and the means used to evaluate and assess the different options.

Seven SME focus-group meetings were facilitated in the Farmington Hills area of Michigan and the Silicon Valley region of California. This approach was selected as part of the data collection methods because it provided opportunities for exploratory research while still ensuring that a consistent set of questions was presented. Responses were aggregated for each of the focus-group meetings allowing multiple attendees to participate at one time in an open discussion format to generate new ideas and insights. As a result, researchers could better understand the rationale behind the SMEs’ thought processes.

When considering the results of this effort, it is important to recognize that while SMEs were asked a consistent set of open-ended questions, they focused their answers on aspects of testing and evaluation most significant to them at the time. For example, a test procedure-related opportunity expressed in one feedback meeting may also have been considered in a second meeting; however, due to the conversational focus of the second meeting, that opportunity was not expressly discussed.

SMEs with direct involvement in FMVSS compliance testing and/or the development of apparatuses associated with FMVSS and/or ADS were involved in these meetings. Specific experience was sought from individuals in the following positions:

- **Safety Engineers:** People who work with relevant agencies on rulemaking activities.
- **Regulatory Compliance Engineers:** People engaged in ongoing and/or future product compliance.
- **System Engineers:** People who are experts on a specific area or component associated with an FMVSS.
- **ADS Development Engineers:** People who are involved with the development of ADS-equipped vehicle software and electrical systems.
- **Test Engineers:** People who perform the physical tests associated with FMVSS.
- **Simulation Engineers:** People who perform simulation for development or compliance including those involved with hardware-in-the-loop (HIL) development.

Seven focus groups were held with representatives from 20 organizations, including advocacy and trade associations (3), equipment and service providers (6), traditional manufacturers (7), and tech and startup companies (4). Appendix F provides a summary of the 45 participating SMEs' experience by the type of organization each represents. To target diversity of ideas, each meeting was planned so that it included a variety of SME expertise.

SME feedback during the series of meetings consisted of qualitative discussion and quantitative evaluation. Qualitative feedback was focused on an exploration of the criteria pertinent to compliance verification. For the quantitative evaluation, SMEs were asked to prioritize the test procedure evaluation criteria and indicate if any criteria or definitions should be modified. Meeting findings are discussed in detail in Chapter 5: Test Method Evaluation Findings.

Chapter 3. Crash Avoidance Standards

Overview

This chapter summarizes the technical translation options of the crash avoidance standards covered in Volume 2 research: FMVSS Nos. 101, 103, 104, 110, 111, 113, 124, 125, and 126. These standards cover a range of performance requirements that help prevent motor vehicle crashes or injuries. The goal of this effort was to provide options for translating the language of each standard to accommodate ADS-DVs. In addition to the FMVSS, the associated test procedures used by NHTSA to verify compliance were reviewed; these are discussed further in the Test Procedures section below. Technical translation assessments were completed to identify potential regulatory barriers.

Technical Translations

As discussed in the Key Considerations, Crash Avoidance section in Chapter 2, themes such as driver (operator), service brake application, shift position, front and rear of the vehicle and controls, telltales, indicators, and auditory alerts were crosscutting themes addressed in the Volume 1 research, and the approaches used for the Volume 1 standards were also used in the development of translations for the Volume 2 standards. Perhaps one of the main differences was the use of the term "ADS-DV" in the Volume 2 technical translation options to specify requirements specific to an ADS-DV, whereas the term "driver" was used extensively in the Volume 1 technical translation options, as previously discussed.

The technical translation options for FMVSS Nos. 124 and 126 addressed some of the inherent assumptions that a human driver is operating the vehicle, such as assuming that a mechanical pedal is present for controlling the speed of the vehicle and that precise steering inputs are controlled through a physical steering wheel. In general, the technical translation options used included the following: utilization of the "driver" definitions options, generalized inputs, and—for FMVSS No. 126—translation to refer to equivalent inputs. These approaches are consistent with the approaches used to develop the technical translation options for the Volume 1 standards.

Other Volume 2 standards contained inherent assumptions specific to a human completing the driving task. The visibility-related requirements, for example, are intended to provide the driver with a clear and reasonably unobstructed view. A human driver uses the view through the windshield and windows as well as other equipment, such as mirrors and a rearview image, to understand the driving environment around the vehicle. Similarly, the ADS uses information from sensors to take in the environment around the ADS-DV. In many cases, when performing the technical translations, researchers considered how the measures for a human driver could be translated to measures for the ADS sensors. In general, the aim was to provide options to translate the requirements for an ADS-DV, where possible. In some cases, an option that specifies the standard for vehicles with manually operated driving controls (i.e., operated by a human) was developed. For FMVSS No. 111, it was determined that more research was needed to perform the technical translations. However, possible approaches to translating the requirements were developed and are discussed in this section.

The technical translation options for FMVSS No. 110 included the initial discovery of how unconventional seating could potentially be a barrier to compliance for the 100-series. The possible impact associated with ADS-DV unconventional seating designs and bidirectional functionality is outlined in the FMVSS No. 110 section to follow.

In most cases, it was determined that language in the 100-series standards could be addressed with textual clarification, and without the need for additional supporting research. Therefore, the regulatory language was assessed as a 0 (assigned in cases when the technical translation was evaluated but not performed) or a 1 (assigned when the technical translation was straightforward). However, many of the test procedures in the regulatory text were assessed as a 2 (assigned when limited research may be beneficial). Several of the items assessed as a 2 were related to potential compliance verification aspects. The development of methods that may allow NHTSA to perform the test procedures to verify the compliance of ADS-DVs is a critical aspect of removing regulatory barriers. While many of these same aspects were present in the Volume 1 standards, FMVSS Nos. 110 and 126 specify vehicle control requirements that may be representative of an emergency situation—for example, rapid loss of inflation pressure and an evasive steering maneuver—and are discussed further in the test procedures sections of this report.

Potential Considerations

Visibility depends on the driver's (human or ADS) unobstructed view of the driving environment. Regardless of whether the driver is a human or an ADS, weather, lighting, dirt, buildings, and other vehicles, etc., may impact visibility (Schoettle, 2017). However, the effect of these sources of obstruction may vary by driver type (human or ADS) and, for an ADS-DV, will mostly likely vary by the type of sensor technologies that provide the ADS with the information to "see" the driving environment. This project included a literature review on the sensors related to ADS and a survey of the Voluntary Safety Self-Assessment (VSSA) disclosures (Apple, Inc., 2019; Aurora Innovations, Inc., 2019; AutoX, Inc., 2018; Mercedes-Benz Research & Development North America, Inc., & Robert Bosch LLC, 2018; Ford, 2018b; General Motors, 2018; Navya, 2019; Nuro, 2018; Nvidia Corporation, 2018; Robomart, Inc., 2019; Starsky Robotics, 2018; TuSimple, Inc., 2019; Uber Technologies Inc., 2018; Waymo LLC, 2018; Zoox, 2018) to develop a representation of the anticipated sensor types and possible mounting locations. Figure 5 depicts which sensors are reported as being in use and their locations for ADS on-road testing. As demonstrated in the figure, multiple sensors are needed to provide a complete view around the vehicle. For example, using a single lidar[2] on the top of the vehicle would not provide coverage of the roof-occluded areas around the vehicle (Friedmann, 2019). For example, to ensure complete coverage of the surrounding environment with sufficient resolution, GM's 2018 Self-Driving Safety Report states that its Cruise vehicle has 5 lidars, 16

[2] [Editor's note: There is as yet no clear consensus on the capitalization of "lidar," which variously appears as LIDAR, LiDAR, LIDaR, and Lidar as well as lidar. That said, it is clearly a device similar to radar and sonar, which over decades have settled into their present, generic forms, from their early days as RADAR, R.A.D.A.R., SONAR, SoNAR, etc. Radar and sonar are no longer considered to be abbreviations or acronyms. It is clear the trend is heading toward lidar by many users (the New York *Times* and Wikipedia already have it as lidar), although it is not fully there yet. In this report, the term has been changed to "lidar," even though the source documents, specifications, and regulations use the term in several different forms. References and citations retain their original usage.]

cameras, and 21 radars (General Motors, 2018). It is expected that the sensors will continue to evolve, which may impact the type of sensor technology used, sensor positioning, and the number of sensors. Figure 5 below represents the current typical locations of sensors and type of sensors, but not their number or configurations. The locations are approximations from the information gathered in the VSSA reports. Once a sensor was noted as being placed in a certain location, when another VSSA report included the same sensor type in essentially the same area, no additional denotation was made.

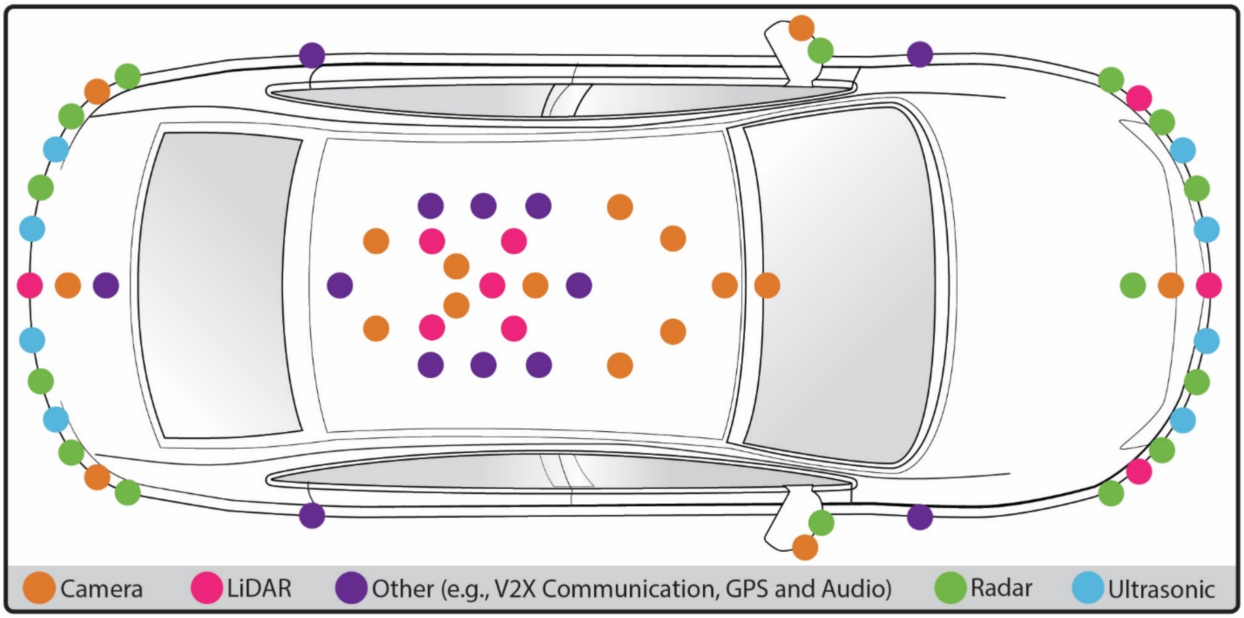


Figure 5. Generic Sensor Types and Positioning

The sensor positioning is influenced by the method that particular sensor uses to perceive the environment. Radar systems use wavelengths, which can travel through some objects and therefore can be placed behind body panels and bumper systems. However, radar can still be affected by electromagnetic characteristics of multi-layer structures (e.g., paint and material) and misalignment could substantially impact the accuracy of the radar's output (e.g., object tracking, distance calculation; Dickmann et al., 2015). One of the key aspects of radar is that it is more robust in adverse environmental conditions than other sensors (Friedmann, 2019; Waymo LLC, 2018). For camera systems, color vision capability and resolution may vary by camera type and could be impacted by weather, illumination levels, and physical obstructions. Lidar uses lasers to provide a 3D view of the surroundings. Some of the same conditions that could impact cameras may also adversely affect lidar. Sensor suppliers have developed cleaning systems for camera and lidar systems to reduce some of the adverse environmental effects (Continental Automotive GmbH, 2019). Additionally, a degraded lidar sensor may still provide information to an ADS, which could be adequate under some circumstances. For example, since lidar reflects off rain drops, precipitation increases the noise floor in the returned signal. However, it may still be possible for the processor to identify the heavy rain and filter the data, allowing the lidar data to be used in conditions in which it otherwise would not function properly (Wang et al., 2013; Filgueira et al., 2017; Goodin et al., 2019).

The differences in electromagnetic spectrum ranges, shown below in Figure 6, help to demonstrate the sensor technology complexity and the differences between how a sensor "sees" as compared to how a human driver sees the driving environment. Some of the standards have requirements based on measures of human visual performance; however, the measures for sensor capability are not the same. According to basic physics, the electromagnetic spectrum is the range of frequencies of electromagnetic radiation and their respective wavelengths (www1.phys.vt.edu). The human driver can only see in the visible range of the electromagnetic spectrum (i.e., from 430 to 750 THz or wavelengths of 400 nm to 700 nm). Current technologies, such as cameras, radars, lidars, and ultrasonics can cover a wider spectrum range. Specifically, short-range radar sensors have typically used 24 GHz, classified as super high frequency in the millimeter wave range. Sensors operating in narrow and wide bands available around the 77 GHz and 79 GHz frequencies, classified as extremely high frequency, are being used for short-range radar and long-range radar applications. This range provides advantages in performance and sensor size. Automotive lidar typically uses 905 nm and 1550 nm, classified as "infrared" (IR) from 300 GHz to 300 THz (1 mm to 1 micrometer wavelengths). Most cameras used in automotive applications have sensor arrays that are sensitive to wavelengths from 400 to 1,000 nm, which encompasses the visible spectrum classified as "visible" from 430 to 750 THz (400 nm to 700 nm wavelengths). Therefore, the measures used to perform the technical translations may not be the same as measures used for a human driver. Understanding the electromagnetic spectrum for the anticipated ADS-DV sensor technologies provided important background for approaching the technical translations.

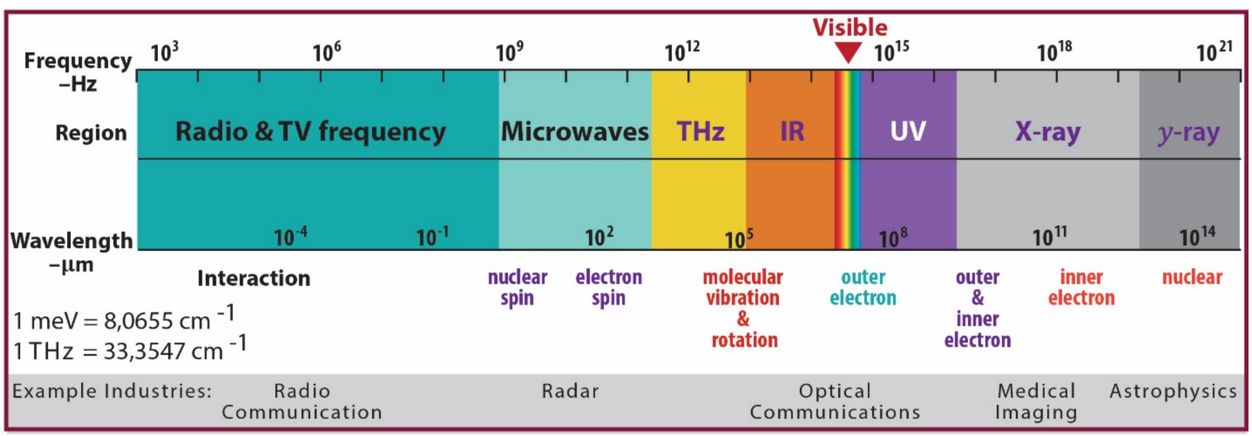


Figure 6. Electromagnetic Spectrum

The visibility-related measures (e.g., distance and resolution) for an ADS to respond appropriately to a scenario, such as an unexpected obstruction, may differ from the measures (e.g., distance and resolution) needed by a human driver to respond. For the purposes of this research, providing technical translation options for visibility-related requirements in the FMVSS standards may provide some initial measures for sensors perceiving the environment. Future research that considers ADS responsiveness instead of treating visibility separately from performance requirements may be of benefit.

While the crosscutting themes depicted in Table 2 earlier in this report helped to provide consistent technical translation approaches for both the Volume 1 and Volume 2 standards, each standard addresses a unique crash avoidance safety area and may result in some differences in the technical translations. The technical translation summary and considerations for each of the Volume 2 crash avoidance standards are provided in this chapter.

Test Procedures

The approach used in the Volume 1 standards was applied to the Volume 2 standards. Thus, many of the same considerations identified for the six 100-series FMVSS covered during Volume 1 research apply to the Volume 2 standards with similar functionalities. For example, the speed control demonstrated during Volume 1 research applies to standards such as FMVSS No. 103, which specifies engine speed constraints for vehicles that use an engine-coolant-based heat exchanger. Similarly, the engine speed control for FMVSS No. 124 also applies. However, engine speed control is unique in that it provides requirements for the return of the vehicle's throttle to idle position when the actuating force is removed or in the event of a failure. NHTSA has previously investigated how this applies to modern electronic and electrically controlled vehicles, but its application is particularly relevant for ADS-DVs where there is likely no mechanical system component nor any throttle-specific components in which to introduce a fault. Consequently, though the functionalities required by the standard and associated test procedures have been demonstrated, broader applicability to modern vehicles' accelerator control systems are not addressed in this project. In the case of FMVSS No. 110, the braking requirements will be considered more directly during the evaluation of FMVSS No. 135 and will also leverage current and previous research for additional functionalities.

FMVSS No. 111 was established based on a human driver's need for information regarding the surrounding environmental through "indirect vision." It is likely that the need for indirect vision of the surrounding environment is different for an ADS, and they way that compliance is verified may depend upon the type of perception sensor used. As discussed briefly in Chapter 2, the test procedures and methods may be influenced by factors that are based on the vehicle design. For example, if the current test target configuration remains, then testing for radar-based sensors may require some minimum processing of the data to verify compliance, whereas a vision-based system may not require any processing. A research team member with an ADS-equipped research vehicle implemented a test to demonstrate a potential means for perception sensor verification. This is discussed further in Appendix G.

FMVSS No. 126 provided the opportunity to investigate an additional subset of the steering control functionality associated with specific steering system input requirements. The standard itself contains most of the test procedures and presents a unique scenario where the inputs are based on a precise manipulation of a control—the steering wheel—which does not exist in ADS-DVs. Therefore, the primary focus for the Volume 2 research was applying the test procedures associated with FMVSS No. 126 to demonstrate how compliance verification might be accomplished via the different proposed test methods. This is discussed in more detail in Chapter 5: Test Method Evaluation Findings.

Summary of SME Open-ended Input

Additional SME input resulting from discussion questions can be generalized into the following three areas: (1) Many of the SME reviewers mentioned that NHTSA could consider adding a new category/class of vehicles (i.e., vehicles certified as being capable of being operated by an

ADS without manually operated controls) instead of making changes to the current standards applicable to conventional vehicles; (2) Several emphasized the importance of using, in this project and, when appropriate, the terms and definitions (e.g., ADS, DDT, ODD) from Surface Vehicle Recommended Practice J3016 (SAE International, 2018) as part of the technical translation options; and (3) Input outside of the project's scope was also provided. For example, several SMEs mentioned deleting or updating outdated requirements in the FMVSS, and presenting new requirements associated with an ADS in response to the regulatory information.

Standards Incorporated by Reference

As noted in Chapter 2 of this report, documents incorporated by reference were reviewed as part of the technical translation effort. Between the regulatory text and the test procedure, all Volume 2 research 100-series standards refer to documents created by an external organization, with the exceptions of FMVSS Nos. 113 and 124. Two documents, SAE J902_1964 and SAE J941_2010 (and 1965), were assessed as a 2 (i.e., limited research may be beneficial). These assessments are discussed further in the sections relating to FMVSS Nos. 103 and 104.

FMVSS No. 101: Controls and Displays

"This standard specifies performance requirements for location, identification, color, and illumination of motor vehicle controls, telltales and indicators" (S1).

"The purpose of this standard is to ensure the accessibility, visibility, and recognition of motor vehicle controls, telltales and indicators, and to facilitate the proper selection of controls under daylight and nighttime conditions, in order to reduce the safety hazards caused by the diversion of the driver's attention from the driving task, and by mistakes in selecting controls" (S2).

Technical Translations

This FMVSS ensures that information is provided to human drivers in a visible manner. While an ADS certainly needs information about the vehicle's status (e.g., the ADS may need to "know" if the ESC has malfunctioned and if the oil pressure is low), methods to satisfy all possible ADS informational needs are different than the visual means (e.g., color, contrast, symbols) of conveying information required in FMVSS No. 101. Therefore, the overall technical translation approach is to clarify that this standard is for the human driver. Some of the information that is currently communicated to the human driver might be safety-relevant or maintenance-related—rather than comfort/convenience features—for occupants in the absence of a human driver inside the occupant compartment. However, it is not clear whether all of the requirements of FMVSS No. 101 should apply to non-driving occupants. (See Appendix C for the tables from FMVSS No. 101.)

Therefore, a technical translation option is included for which manufacturers may have to present information to occupants if some of the information is safety-relevant (i.e., not related to convenience or comfort). Information communicated to the ADS could potentially be a part of the FMVSS No. 101 technical translation covering its presentation/delivery to the ADS. The information presented/delivered to the ADS was considered in the test methods to confirm that the information is accessible to the ADS. This is comparable to the visual confirmation performed as part of the compliance verification process for the information presented to the human driver in conventional vehicles. This will be discussed further in Chapter 5.

<u>Potential Considerations</u>

FMVSS No. 101 is an "if equipped" standard (i.e., the standard applies if the vehicle is fitted with the identified controls, telltales, or indicators). As mentioned in the purpose section of the standard, a goal is to provide appropriate accessibility, visibility, and recognition to minimize safety problems caused by a human driver's inattention and mistakes. Therefore, if an ADS-DV does not have a control, telltale, or indicator identified in Tables 1 or 2 from the FMVSS No. 101 standard (see Appendix C)—many of which are not mandated by another standard—the requirements would not apply.

The information presented to the driver pursuant to FMVSS No. 101 assumes certain minimal requirements for a person to hold a driver's license, such as minimum age and vision requirements. Presenting information to ADS-DV occupants might require assumption of a different minimal level of understanding and might also account for visual and auditory limitations and other impairments (i.e., defining who is a competent ADS-DV user or occupant). Other aspects, such as the required location of controls, telltales, and displays, might need to be reexamined.

The discussion and analysis presented in the Controls, Telltales, and Indicators section of Chapter 2 in the Volume 1 report, and expanded on in the current report as part of the Controls, Telltales, Indicators, Labels, Markers, and Auditory Alerts section in Chapter 2 represents an effort to address these issues, which include information communicated to ADS-DV occupants, how the information may be presented, and where it might be presented. Some examples are: at the left front DSP (as is the case in conventional vehicles), at one or more DSPs to be specified by the vehicle manufacturer, at all DSPs, or at an occupant compartment maintenance panel. That analysis describes 10 potential options for presenting such information in an ADS-DV. Additional research could be conducted to determine which of those options would be most appropriate, as well as to determine the appropriate location(s) for those displays.

Test Procedures

There are no specific test procedures identified in FMVSS No. 101, and compliance is assessed through visual inspection. However, the functionality of several of the telltales specified in the standard's Table 1 (see Appendix C) is addressed in other standards, such as FMVSS Nos. 114 and 138 (Volume 1 report).

<u>Potential Considerations</u>

The ADS might need most, if not all, of the information in order to operate the vehicle safely. As discussed in the Volume 1 report in the context of FMVSS No. 138, in order to confirm that all relevant information is communicated to the ADS (e.g., by electronic means) in a timely manner, a test procedure would need to be developed. As part of the project's scope, such a test procedure would only confirm that the information is *communicated* to the ADS; it would not evaluate what the ADS would do with the information. This is consistent with the approach taken in

FMVSS No. 101, which requires that information be presented to the human driver but does not regulate how the driver reacts to that information.

Stakeholder and SME Review Input

Stakeholders and SMEs mentioned the need for a broader definition of "driver" that incorporates remote human drivers, who may potentially use some of the identified controls or need to be aware of the information conveyed by select telltales or indicators. However, remote human drivers are not within the current scope of this project. SMEs also noted the potential need for ADS information prioritization, which is also considered outside of the scope of the current project. Some comments were related to the information presented to occupants, noting that there is a potential for gestures as well as other novel ways to implement controls that might not necessarily involve manual or physical activation, such as using voice activation instead of a button. In terms of occupant needs, a possible need was identified for presenting a standardized telltale to identify an ADS-DV (i.e., no retractable manually operated driving controls available for dual-mode use).

Standards Incorporated by Reference

One reference, SAE J826_2015, was implied by the mention of manikin H-point in S5.3.4. No technical translation was deemed as potentially needed if this FMVSS text was to implement Potential Set 1 or 2 of the driver's DSP definitions. The implementation of the driver's DSP Potential Set 1 or 2 would clarify that the manikin H-point reference applies to a vehicle seating position that is unique to the human driver and, thus, SAE J826_2015 may not be a regulatory barrier.

FMVSS No. 103: Windshield Defrosting and Defogging Systems

This standard "specifies performance requirements for windshield defrosting and defogging systems" (S1).

Technical Translations

While 49 CFR §571.103 does not contain a stated purpose for the standard, the research team believes the primary safety concern that this FMVSS is meant to address is the increased risk of crashes due to the presence of frost or fog on the windshield, which can impair a human driver's forward visibility. Because the ADS is not expected to perceive the environment in the same way, it may not need the area of interest in the windshield to be clear analogous to a human driver. Typically, the sensors that an ADS uses to perceive the driving environment are positioned in multiple locations around the vehicle, with few sensors located behind the windshield (see sensor discussion under Potential Considerations section under this chapter's Overview). Therefore, the emphasis for the technical translation is to clarify that this standard applies only to vehicles operated by a human driver (Options 1–3, Appendix B).

Option 4 presents an "if equipped" option for ADS-DVs. To explain further, if a manufacturer chooses to provide a defrost/defogging system, it will need to comply with the existing standard. The research team did not pursue options that might account for potential sensor systems placed behind the windshield based on findings from the literature review and the results of the VSSA survey.

<u>Potential Considerations</u>

Although the term "windshield" is used frequently throughout the FMVSS, the term is not defined anywhere in NHTSA's standards. For its analysis, the research team understood the term to refer to the glazing material directly in front of the driver in the forward direction of travel Under the current standard, certain specified areas of the windshield (identified as Area "A" and Area "C" [driver's side] in Figure 7) are required to be cleared of frost and fog under specific conditions within a specified time period after the vehicle is started, so that the human driver can see through the windshield while performing the DDT. As revealed by the literature review and VSSA survey conducted by the research team, the cameras and sensors that an ADS uses to perform the DDT are often mounted in locations that do not require visibility through Areas A and C. Thus, being able to clear those areas of frost or fog may not improve the ADS's ability to perceive the environment. Therefore, the technical translation options do not account for the potential placement of sensors such as cameras in Areas A and C. Moreover, the research team believes that there are types of obscuration other than frost or fog that may have a greater impact on ADS cameras' and sensors' perception (e.g., the accumulation of snow in a sensor opening). Further considerations to help ensure that sensors have a clear view beyond Areas A and C may be of benefit.

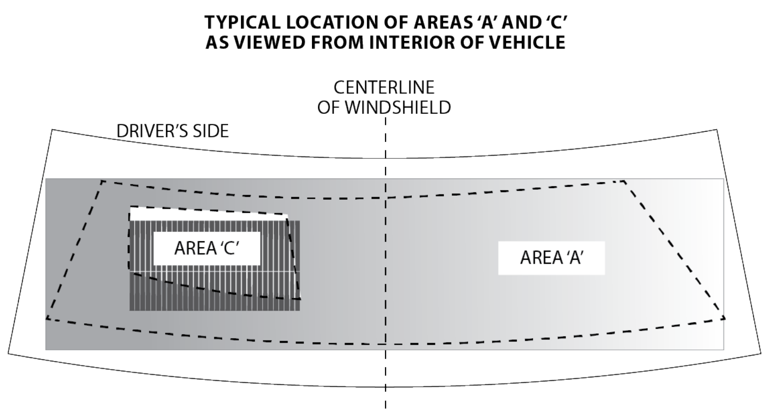


Figure 7. Areas of Interest for FMVSS No. 103 (NHTSA, 1996)

Note that ADS-DVs could include vehicles used for delivering goods that might not be used for occupants at any point. If these vehicles are close to what was designated as a First Generation ADS-DV Concept in the Volume 1 report (Blanco et al., 2020), they could potentially have a window resembling a windshield, but would not transport occupants.

Test Procedures

The current test procedure for this standard is focused on the areas of the windshield where visibility for human drivers is needed. Based on the findings from the literature review and VSSA survey results, the research team believes that the sensors needed for an ADS-DV may not need to perceive the environment through those areas of the windshield (Options 1–3). The research team has developed an "if equipped" option for an ADS-DV (Option 4), which provides an alternative for testing procedures by introducing the pattern designed by the manufacturer. This language was extracted from SAE Recommended Practice J902 (1964), which is incorporated by reference in other portions of this and other FMVSS.

Potential Considerations

The current test procedures use related industry practices (i.e., vehicle packaging metrics) such as eyellipse (SAE J941_2010) and H-point (SAE J826_2015) that assume the vehicle is operated by a human driver and that the DSP of interest will be facing the windshield. Therefore, instances in which defrost/defog systems are available for an ADS-DV might require updates in the test procedure and metrics in order to use other ADS-DV-relevant metrics. FMVSS No. 104 uses a pattern designated by the manufacturer for multipurpose passenger vehicles, trucks, and buses (FMVSS No. 104 S4.2.2). A similar approach could be considered for passenger cars in FMVSS No. 103 (Option 4 in Appendix B).

Another option could investigate a test procedure for FMVSS No. 103 that uses alternate non-driver-based metrics. To explain further, the current FMVSS No. 103 Area C is established in accordance with FMVSS No. 104. This last standard suggests using Figures 1 and 2 of SAE J903a (1966), which are driver-based. The referenced figures in the SAE recommended practice are based on a 95th percentile eye range contour. Additional technical translation options could be developed that consider the potential for sensor systems that are placed behind the windshield.

Stakeholder and SME Review Input

Similar to other FMVSS where visibility is the main focus, SME and stakeholder input suggested a new and separate FMVSS to address ADS visibility issues.

Standards Incorporated by Reference

Three standards are incorporated by reference: SAE J902_1964, SAE J902a_1967, and one mention of W3 and W7. If, as discussed above, the standard is considered applicable to a human driver's visibility needs, then none of the references present any regulatory barriers. However, if compliance testing were required for ADS-DVs (e.g., visibility for Area A), a set of measurements that depend on the manually operated driving controls could be seen as a barrier. Aspects such as H-Point and eyellipse pattern were developed by SAE, taking into account the presence of a human driver and manually operated driving controls. Therefore, translation options that allow "the pattern designated by the manufacturer" (similar to language present in current FMVSS No. 104 S4.2.2) instead of fixed areas (e.g., Area A, Area C) determined by human driver metrics might be more appropriate.

FMVSS No. 104: Windshield Wiping and Washing Systems

This standard "specifies performance requirements for windshield wiping and washing systems" (S1).

Technical Translations

Similar to the windshield defrosting and defogging systems (FMVSS No. 103) technical translations discussed above, the focus of this FMVSS (based on the research team's technical translation development process outlined in the Volume 1 report) is the need to provide the human driver adequate forward roadway visibility under conditions that would otherwise obscure vision through the windshield. The presented options treat this as an "if equipped" standard for an ADS-DV, meaning that if the manufacturer chooses to provide these systems, they will need to comply with the existing standard. Aligned with the approach taken for FMVSS No. 103, the research team did not pursue an option that considered sensor systems placed behind the windshield. Based on the literature review findings and VSSA survey results, it is not anticipated that sensors used by the ADS will be located in the windshield wiping and washing areas.

Potential Considerations

Although the term "windshield" is used frequently throughout the FMVSS, the term is not defined anywhere in NHTSA's standards. For its analysis, the research team understood the term to refer to the glazing material directly in front of the driver in the forward direction of travel. Further research may be beneficial to quantify obscuration and the potential impact on sensors.

Test Procedures

The current test procedure for this standard is focused on the areas of the windshield where visibility for human drivers is needed. Therefore, there are no technical translations for Options 1–3 for the test procedures. This is based on the expectation that the sensors will not be located in the regulated areas of the windshield (per the literature review findings and VSSA survey results. Option 4 considers an approach that is currently used for multipurpose passenger vehicles, trucks, and buses (using a pattern designated by the manufacturer; FMVSS No. 104 S4.2.2), which could be applied to ADS-DV passenger car test procedures.

Potential Considerations

The current test procedures use related industry practices (i.e., vehicle packaging metrics) such as eyellipse (SAE J941_1965) and H-point (SAE J826_2015) that assume the vehicle is operated by a human driver and that the DSP of interest will be facing the windshield. Therefore, instances where windshield washing and wiping systems are available for an ADS-DV may require updates in the test procedure and metrics in order to use other ADS-DV-relevant metrics. Further research could explore options for a test procedure for FMVSS No. 104 that considers alternate metrics (non-human-driver-based). If desired, technical translation options that consider the potential for sensor systems that are placed behind the windshield could be developed.

Stakeholder and SME Review Input

Similar to other FMVSS where visibility is the main focus, SME and stakeholder input suggested that a new and separate FMVSS might be needed for an all-encompassing ADS visibility.

Standards Incorporated by Reference

Seven standards are incorporated by reference. If, as discussed above, the standard is considered to apply to a human driver's visibility needs then none of the references may be seen as a barrier However, if other options are considered as the key reference points instead of those in Figures 1 and 2 from SAE J903a_1966, alternate metrics (non-driver-based) might be needed to accomplish the calculations. These alternate metrics might be more appropriate for non-human-driver-based standards given that current standards cite SAE J941_1965 for 95 percent eye range contour and SAE J826_2015 for the H point in order to calculate the area of interest. These SAE standards are focused on human driver needs and reference points.

FMVSS No. 110: Tire Selection and Rims and Motor Home/Recreation Vehicle Trailer Load Carrying Capacity Information for Motor Vehicles With a GVWR of 4,536 Kilograms (10,000 Pounds) or Less

The standard establishes requirements "for tire selection to prevent tire overloading and for motor home/recreation vehicle trailer load carrying capacity information" (S1). This standard was upgraded to address portions of the Transportation Recall Enhancement, Accountability, and Documentation (TREAD) Act of 2000, which required the agency, among other things, to improve public awareness regarding the importance of adhering to a vehicle's tire load limits and maintaining proper tire inflation levels for safe vehicle operation.

Technical Translations

The technical translations for FMVSS No. 110 focused on two aspects of the standard: (1) placard location and content and (2) vehicle normal load on the tire.

Placard Location and Content

Among other things, FMVSS No. 110 specifies requirements for a placard that is permanently affixed to each motor vehicle. The placard contains information about vehicle capacity weight, designated seating capacity, and information regarding the tires and loading. Under the current standard, the placard generally must be affixed to the driver's side B-pillar as shown in Figure 8. If the vehicle does not have a B-pillar, and under certain other circumstances, other locations are allowed, such as the rear edge of the driver's side door.

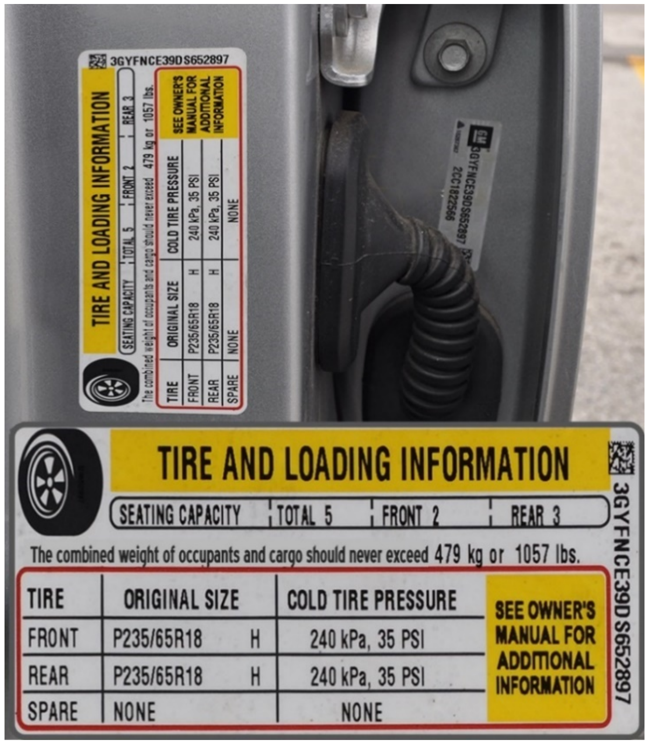


Figure 8. Placard Tire and Loading Information

FMVSS No. 110 references the driver's side areas (e.g., B-pillar) to establish a standard location. The "driver's side" reference could be addressed by using "left, front door," "left side," or by creating a new reference framework from a standard point in the vehicle such as the location of the Vehicle Identification Number (VIN) to provide a consistent placard placement. The option to develop a new frame of reference associated with the VIN is shown in Figure 9 below.

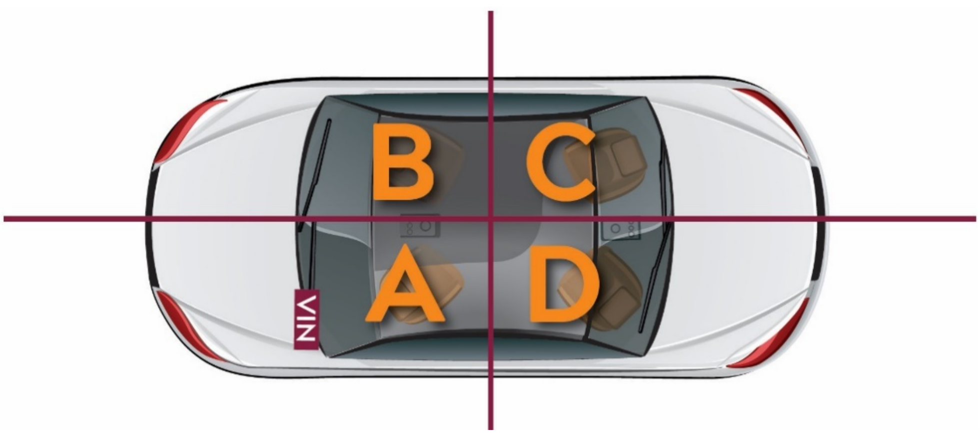


Figure 9. Placard VIN Frame of Reference Location Option

The VIN frame of reference would locate the placard on the second pillar aft of the VIN plate (or label) and on the same side. One of the considerations for this option is bidirectional vehicles. With the assumption that bidirectional vehicles are addressed as discussed in the Volume 1 report—to clarify: standards shall apply to bidirectional vehicles in both directions of travel—

retaining the reference to the left side B-pillar may require the placard to be affixed in two locations. There is a potential for the tire pressure information to differ from front to rear, and with two labels, the front and rear would differ depending on side. The VIN frame of reference would allow manufacturers to use the VIN location to determine placement of the placard in the vehicle, which may help provide one consistent location to obtain the information. The VIN location was used as one possible reference point example but other reference points could be used.

The technical translation also considered the placard content, as shown in Figure 8 above. The placard contains information regarding the front and rear seating capacity as well as the size and pressure of the front and rear tires. In general, the reference to front and rear is not a regulatory barrier for ADS-DVs. However, in a bidirectional ADS-DV, the front and rear seating capacities, tire sizes, and tire pressures may not be equivalent. One option could be to translate "front" and "rear" to "Front A-B" and "Rear C-D" specifically for vehicles with bidirectional operation or for all vehicles, as shown in the placard reference location option in Figure 10.

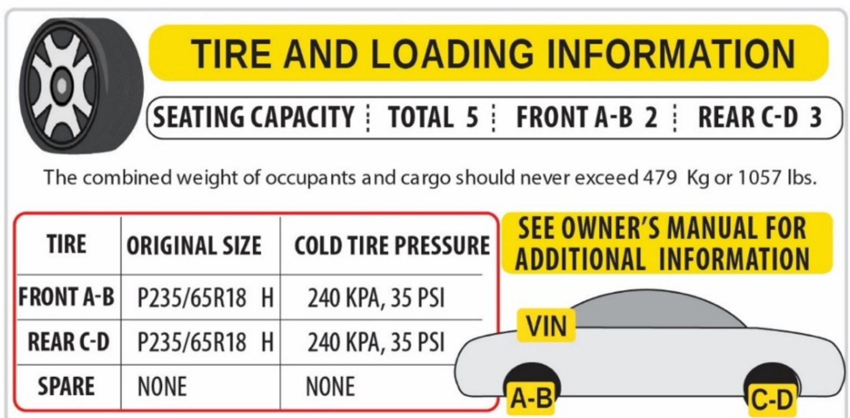


Figure 10. Placard Reference Location Option

If combined with the option for the VIN frame of reference concept, the placard or owner's manual could include a picture that describes Front A-B and Rear C-D. Figure 10 shows an example of how the placard could be modified to incorporate the reference location concept. This approach could also be applied to the manufacturer's tire inflation pressure label option that is shown in Figure 8 of the FMVSS No. 110 standard.

Vehicle Normal Load on the Tire

FMVSS No. 110, S4.2.2.3 specifies the maximum "vehicle normal load" on each tire. The vehicle normal load on a tire is determined by distributing to each axle its share of the curb weight, accessory weight, and normal occupant weight and dividing by two. FMVSS No. 110 includes a table, provided in this report as Table 6, which assumes a typical seating pattern in a unidirectional vehicle with manually operated driving controls. As shown in the table, the assumption is that if there are two occupants, they would sit in the front seats, with one additional occupant in the second row of seats, and so on, based on the vehicle's designated seating capacity. The table doesn't explicitly state, but does refer to, "row" in the context of the second seat because at the time the table was developed, most, if not all, vehicles had bench seats. Today, “second seat” is understood to mean second row when no bench seats are available.

Table 6. Occupant Loading and Distribution for Vehicle Normal Load for Various Designated Seating Capacities (FMVSS No. 110 Table 1)

Designated Seating Capacity, Number of Occupants	Vehicle Normal Load, Number of Occupants	Occupant Distribution in a Normally Loaded Vehicle
2 through 4	2	2 in front
5 through 10	3	2 in front, 1 in second seat
11 through 15	5	2 in front, 1 in second seat, 1 in third seat, 1 in fourth seat
16 through 22	7	2 in front, 2 in second seat, 2 in third seat, 1 in fourth seat

There is limited data on occupant seating patterns in ADS-DVs; thus, these may not be the typical seating patterns for such vehicles. As a practical matter, it may be necessary to retain the FMVSS No. 110 table until more is known about occupant seating patterns in ADS-DVs. However, there may be methods for determining vehicle normal loads on any given tire considering seating capacities which are not based on seating position. Research on this topic is discussed further in the Potential Considerations section below.

<u>Potential Considerations</u>

As noted, there remain unanswered questions about typical ADS-DV seating patterns. Will the front, left DSP still be occupied for every trip? How will occupant distribution normal loading be determined for unconventional seating (e.g., “campfire” seating)? For an ADS-DV ride-share application, would a single occupant sit in the rear, right side of the vehicle? In the U.S., vehicles drive on the right side of the road, making the right side of the vehicle the side that may be closest to a building or sidewalk. Research may be needed to better understand the potential ADS-DV occupant seating patterns. Furthermore, there may be benefit to research into developing new methods for maximizing the normal load on a given tire that do not assume a typical seating pattern. The result of this research could be an updated table for unconventional seating patterns or may be the development of an additional vehicle test that experimentally determines the maximum tire loading for the associated seating capacity.

Test Procedures

Most of the test procedures for FMVSS No. 110 could be addressed based on the technical translations completed for the standard that were discussed in the FMVSS No. 110 Technical Translation sections. However, there is one provision that requires general driving, speed control, service brake application, and ignition start/stop functionalities—S4.4.1(b) specifies that in the event of rapid loss of inflation pressure with the vehicle traveling in a straight line at a speed of 97 km/h (60 mph), the rim must retain the deflated tire until the vehicle can be stopped with a controlled braking application. The test methods being developed and evaluated for FMVSS

No. 126 are applicable to this test. Additional research might also help to further develop the specific test procedure for S4.4.1(b) in the ADS-DV context.

<u>Potential Considerations</u>

With regard to FMVSS No. 110 provision S4.4.1(b), it is understood how an experienced human test driver would perform this test to verify that the vehicle achieved the stop condition under controlled braking. The OVSC test procedure provides an additional test protocol: "upon initial release of air, bring the vehicle to a stop using the most rapid constant deceleration rate attainable not exceeding 2.5 m/sec² (8 ft/sec²) with no wheel skid." In evaluating an ADS-DV, it may be difficult to isolate the ADS's behavior without further defining controlled braking for this type of vehicle (e.g., lateral deviation from a straight path). Further research aimed at defining controlled braking performance metrics specific to an ADS-DV may be of benefit to translating the test procedure.

Stakeholder and SME Review Input

Opinions were mixed on the potential need to consider bidirectional operation. Some SMEs and stakeholders commented that the standard's specified normal occupant weight of 68 kilograms needs to be updated to represent the weight of the current average American. This aspect was beyond the project scope and was not considered. With regard to the standard's Table 1, most agreed that it would need to be modified to accommodate unconventional seating designs or configurations in ADS-DVs.

Standards Incorporated by Reference

The single reference, ASTM E29-06b, "Standard Practice for Using Significant Digits in Test Data to Determine Conformance with Specifications" (2006) is incorporated by reference in the OVSC test procedures for rounding measurement and was not found to have any barriers.

FMVSS No. 111: Rear Visibility

This standard specifies requirements for rear visibility devices and systems. Sections of the standard were promulgated to implement a Congressional mandate, the Cameron Gulbransen Kids Transportation Safety Act of 2007. The purpose of the standard "is to reduce the number of deaths and injuries that occur when the driver of a motor vehicle does not have a clear and reasonably unobstructed view to the rear" (S2).

Technical Translations

A human driver's capability to see what is behind the vehicle is limited by the vehicle's daylight openings (e.g., windows) and the driver's ability to turn their head. FMVSS No. 111 specifies performance requirements for mirrors and rearview image systems to help the human driver have a clear and reasonably unobstructed view to the rear. The rear visibility requirements specified for passenger cars include the following:

- *Inside rearview mirror:* A mirror of unit magnification (as defined in S4 of the standard) with specified FOV [field of view] requirements measured from a projected eye point based on the reference points specified in FMVSS No. 104 or a nominal location appropriate for any 95th percentile male driver. The mounting requirements for the inside rearview mirror include a stable support, adjustability, and head impact specifications.

- *Driver's side outside rearview mirror:* Must be of unit magnification. The mirror needs to meet specified FOV requirements measured from a projected eye point, again with a reference to FMVSS No. 104 or a 95th percentile male driver. This mirror also needs to have a stable mounting, adjustability, and no sharp points or edges that could contribute to pedestrian injury.
- *Passenger's side outside rearview mirror:* If the inside mirror does not meet FOV requirements, an outside mirror of unit magnification or convex mirror is required on the passenger's side. The passenger's side outside mirror needs to have a stable mounting, adjustability, and no sharp points or edges that could contribute to pedestrian injury.
- *Mirror construction:* These requirements cover the reflectance of the mirror.
- *Rearview image:* Required pursuant to S5.5. The rearview image needs to meet a specified FOV. There are requirements related to size, response and linger time, deactivation, default view, and durability.

Multipurpose passenger vehicles, low-speed vehicles, trucks, buses, and school buses with a gross vehicle weight rating (GVWR) of 4,536 kg or less can either meet the passenger car mirror requirements or provide outside mirrors that meet certain specifications. They also need to meet the same rearview image requirements. Additionally, FMVSS No. 111 specifies mirror requirements for heavier vehicles, school buses, and motorcycles. The school bus requirements include specifications for forward visibility.

As discussed in the Overview section of Chapter 3, it is expected that ADS-DVs would rely on a variety of sensors to perceive the surrounding environment and perform the DDT. Most likely, ADSs will use multiple sensors such as lidars, cameras, radars, and ultrasonics to provide a clear and unobstructed view to the rear of the ADS-DV. The sensor data could be fused to provide the most reliable and robust estimation of the state of the environment (Castanedo, 2013). Translating FMVSS No. 111 for ADS-DVs may ensure that the ADS is provided "a clear and reasonably unobstructed view to the rear."

Completing the technical translations for FMVSS No. 111 may require additional research. As explained further in the FOV section, some of these requirements refer to the driver's "projected eye point" and, without additional research, technical translation options cannot be provided. Additionally, due to the potential sensor complexity, the test methods for verifying compliance may not be straightforward. However, some alternative test method concepts were developed and reviewed with stakeholders.

FOV

Current FMVSS No. 111 FOV requirements for mirrors are specified on the basis of the eyellipse and assume the adjustability of the mirrors and little or no obstruction. In some cases, research could assist in determining how to identify the FOV requirements applicable to ADS-DVs. For example, current requirements for the inside rearview and driver's side outside rearview mirror specify visibility based on a driver's eye point location (see Figure 11, left and center). In other cases, such as for vehicles with a GVWR of 11,340 kg or more, current mirror-based requirements refer to providing a driver with a "view to the rear along both sides of the vehicle," using a mirror with no less than 323 cm^2 of reflective surface. School buses require visibility to the rear along both sides, as well as in front of the vehicle (see Figure 11, right). The rear visibility FOV requirements define a 10' wide by 20' long test area within which objects must be "detectable" according to the test procedures specified in S14.1 (see Figure 12).

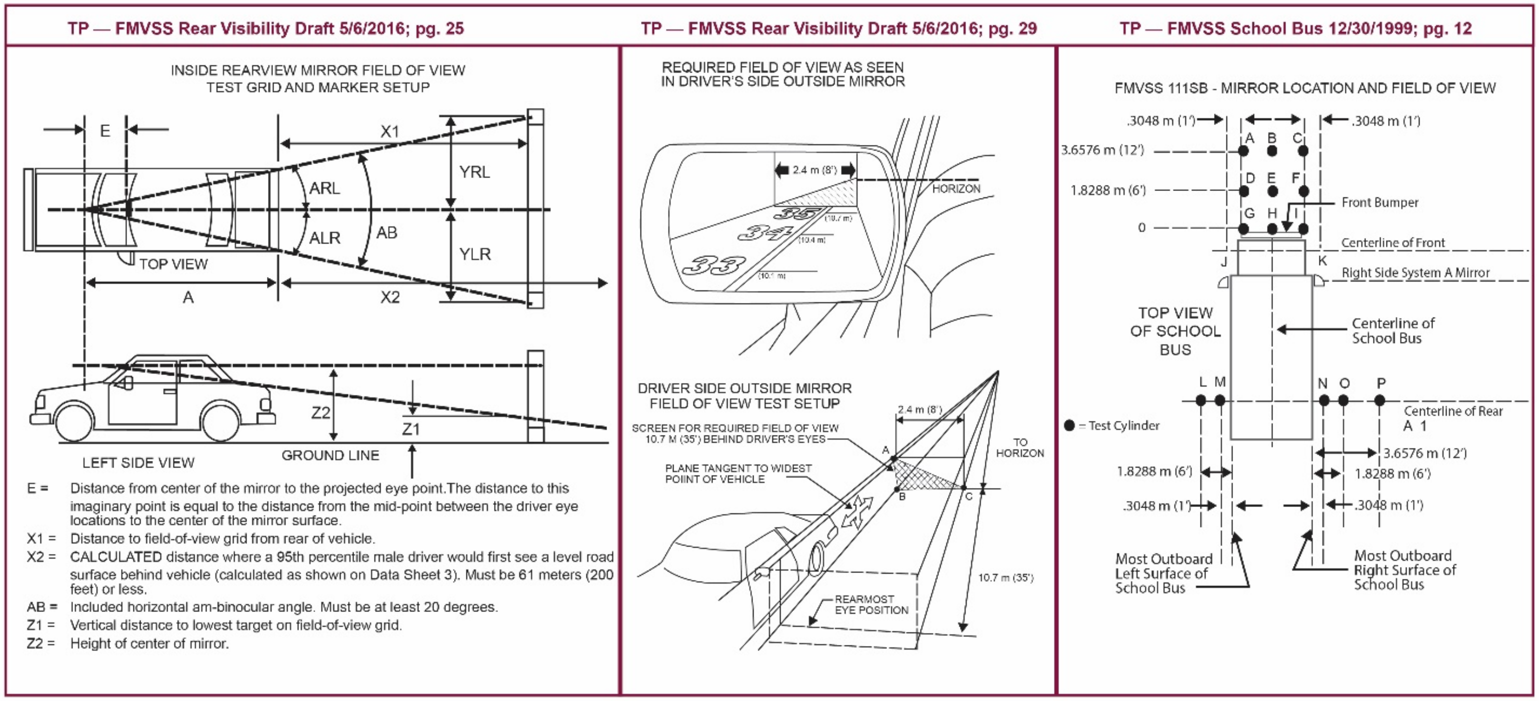


Figure 11. OVSC Laboratory Test Procedures Figures for Vehicles With Manually Operated Driving Controls; Inside (Left) and Outside Rearview Mirrors (Center) for Light Vehicles, and School Buses (right)

(Laboratory Test Procedure for FMVSS No. 111. www.nhtsa.gov/sites/nhtsa.dot.gov/files/documents/tp-111-v-01-final.pdf)

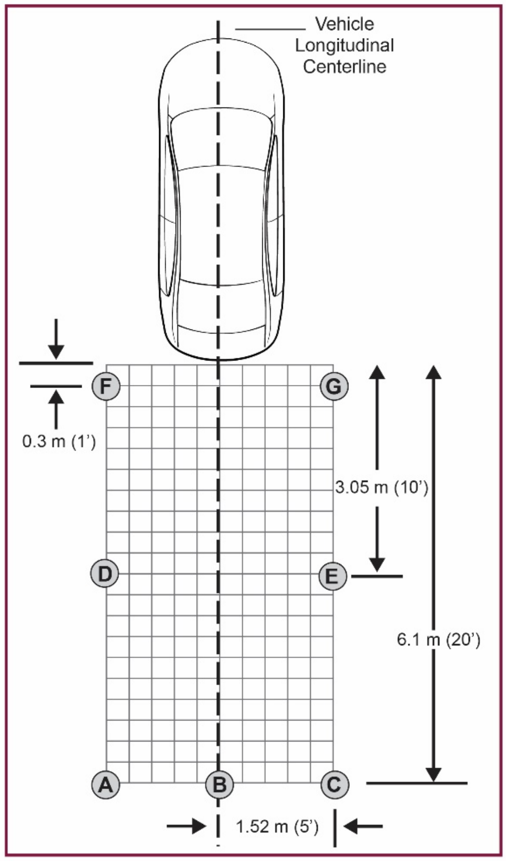


Figure 12. OVSC Laboratory Test Procedures for Rear Visibility FOV Requirements
(Laboratory Test Procedures for FMVSS No. 111 Rear visibility: https://one.nhtsa.gov/staticfiles/nvs/pdf/test-procedures/TP-111-V-01-final.pdf)

Research could be conducted to develop an FOV technical translation based on vehicle references (e.g., center of the rear wheel) instead of driver's eye reference points, similar to the current rearview image requirements. The current FOV requirements for mirrors use horizontal and vertical angles that reflect the extent to which a human driver needs to see the environment. The dimensions provided in the mirrors could be translated to sensor-based requirements. These measures could also be considered in terms of sensor specifications such as FOV, range, resolution, and accuracy.

Response Time

While FMVSS No. 111 does not specifically state this, the mirrors installed in the vehicle are always "on" and display images with no delays. With respect to rear visibility, S5.5.3 provides that the rearview image meeting the requirements of S5.5.1 and S5.5.2 of FMVSS No. 111, when tested in accordance with S14.2, shall be displayed within 2.0 seconds of the start of a backing event. The response time addresses the system response latency (i.e., the lag—in seconds—in responding once the system is activated). The response times could vary depending on the scenario (dynamic and static events). Backing event crashes typically happen at relatively low speeds with moving targets also moving at relatively low speeds. As mentioned in Perez et al.

(2011, page 7), “Not surprisingly, the overwhelming majority of backing crashes occurred at speeds of 5 mph or slower.” Therefore, backing events could have a different response time requirement as compared to vehicles traveling at higher speeds on highways. While the response time of an ADS is likely to be instantaneous, expanding response time requirements in S5.5.3 (and S6.2.3) to the sensor used by the ADS to perceive the outside and inside rearview mirrors’ FOV areas—depicted in Figure 11 above—could be considered.

Magnification

The current standard contains specifications for the mirror’s magnification, the reflective surface, and the rearview image size. These requirements account for the dimensions, size of object, and distortions. FMVSS No. 111 specifies in S5.1 that each passenger car shall have an inside rearview mirror of unit magnification. Unit magnification mirror is defined in S4 to mean “a plane or flat mirror with a reflective surface through which the angular height and width of the image of an object is equal to the angular height and width of the object when viewed directly at the same distance (except for flaws that do not exceed normal manufacturing tolerances). For the purposes of this regulation, a prismatic day-night adjustment rearview mirror, of which one position provides unit magnification, is considered a unit magnification mirror.” The unit of magnification could be translated into dimensions and units from the objects perceived by the sensors. As an example, a basketball or a construction barrel laying on its side could be used as an object located within the rearview FOV to assess whether the unit magnification requirement is satisfied. Sensor specification metrics could be developed to specify the accuracy of the dimensions. A similar approach could be considered for object size and distortions.

Mounting

FMVSS No. 111 specifies that the mounting of required mirrors shall provide a stable support for the mirror. Currently, the mirror mounting locations are directly related to the driver’s eye point. For ADS-DVs, the sensors may not need to be mounted in the same locations; rather, the ADS could receive the same information that the required mirrors can provide to a human driver, so that the ADS will be able to drive the vehicle safely. Therefore, having a stable sensor mounting is important for many of the same reasons as for a mirror mounting.

The current mounting requirements also specify that the mirrors and mountings shall be free of sharp edges. Translation of these requirements to make them applicable to the sensors that provide the required information about the view to the rear should be straightforward.

The requirements for the inside rearview mirror consider occupant protection. Specifically, S5.1.2 states, “If the mirror is in the head impact area, the mounting shall deflect, collapse, or break away without leaving sharp edges when the reflective surface of the mirror is subjected to a force of 400 N in any forward direction that is not more than 45° from the forward longitudinal direction.” It is possible that sensors perceiving the rear view could be mounted in the inside of the vehicle similar to the inside rearview mirror. Translation of this provision to apply to such sensors may be straightforward.

The standard specifies that the outside mirrors and mounting should be free of sharp points or edges that could contribute to pedestrian injury. Translation of these provisions to apply to sensors that provide information about the view to the rear may also be straightforward.

Adjustability of the required mirrors is desirable to allow for the fact that human drivers' eye positions vary. While some sensors may have adjustability (e.g., GM's Cruise has articulating radars), the current adjustment requirements are specific to human driver needs and may not be a suitable performance requirement for sensors (General Motors, 2018). However, the FOV performance requirements could indirectly create a need for self-adjustable sensors.

Durability

S14.3 of FMVSS 111 specifies durability tests for external components of the rear visibility system, which include corrosion (S14.3.1), humidity exposure (S14.3.2), and temperature exposure (S14.3.3). The external components are mounted on an environmental test fixture. It is believed that producing the technical translation options for the durability sections of FMVSS No. 111 would be straightforward. For example, a technical translation option could be something such as the following: "All externally mounted sensors in an ADS-DV that are used to meet the requirements of S5.5.1 and S.5.5.2 must meet the durability requirements specified in S14.3."

Potential Considerations

The visibility-related measures (e.g., distance and resolution) for an ADS to respond appropriately to a scenario, such as an unexpected obstruction, may differ from the measures (e.g., distance and resolution) needed by a human driver to respond.

Performing the technical translation may provide some initial requirements for sensors perceiving the environment. However, the ADS-DV performance based on these requirements may be different. For vehicles with manually operated driving controls, information is provided to the driver for decision-making with the expectation that they will use the mirrors and/or the rear image to safely maneuver the vehicle. There may be a benefit to researching specific visibility coverage needed for ADS decision-making to safely maneuver an ADS-DV and possible methods to evaluate its performance. For example, subsequent research could address the ADS's response to the detection of an object within the specified scenario instead of simply confirming detection. However, regulating ADS response is not within the scope of this project.

Test Procedures

Possible test procedure technical translation alternatives were developed and SME feedback was captured within the same review period. The regulatory text includes several test procedures used by NHTSA to verify compliance. There are several provisions that may not be applicable to ADS-DVs, such as driver's seat positioning, driver's eye position, video camera recordings, manikin testing, head/neck joints, display adjustments, steering wheel adjustments, and image response time.

The three test method alternatives for ADS-DVs identified by the research team are as follows:

- Alternative A: Vehicle provides raw data output; human test operator interprets the data to assess whether the required FOV is achieved.
- Alternative B: Vehicle provides x/y coordinates of "detected" objects within the FOV (requires ADS processing)
- Alternative C: Manufacturer provides external screen to verify FOV coverage

At this time, it is not known what sensors, or combinations thereof, ADS-DV manufacturers may use to monitor and detect objects within the FOV covered by this regulation. As such, the specific approach to determine compliance verification is complex, and multiple sensor possibilities and sensor advancements may need to be considered. More research may be needed to further develop test procedures that are applicable to ADS-DVs.

Potential Considerations

Ultimately, the ADS may need to communicate some level of "detection" to enable compliance verification, as the difficulty in interpreting sensor output by a human operator will vary depending on sensor type. Research and additional testing with multiple sensor combinations may provide a better understanding of how best to verify compliance. It is possible that, due to the sensor combinations that could be used in an ADS-DV, non-vehicle test methods such as simulation and technical documentation could be explored further (specific to FMVSS No. 111) to address the potential verification barriers.

Stakeholder and SME Review Input

Most SME reviewers provided feedback that the standard should be applicable only to vehicles with manually operated driving controls. However, some SME reviewers believed that the standard could be updated to account for ADS-DVs while maintaining the basic safety intent. Comments offered during the April 2018 stakeholder meeting were similarly mixed. Some of the comments were on aspects outside the scope of the project, such as how an ADS should respond to objects detected within the specified FOV. Currently, the standard regulates information provided to a human driver, but it is ultimately up to the driver to respond appropriately.

Standards Incorporated by Reference

There were seven incorporated references in both the regulation text and OVSC test procedures. Neither of the two SAE referenced documents pose regulatory barriers for ADS-DVs since they pertain to sections that are only relevant for vehicles equipped with manually operated driving controls. SAE J964_1984 is a "Test Procedure for Determining Reflectivity of Rear View Mirrors" while SAE J826_1995 specifies manikin requirements pertaining to driver seat positioning and related measurements. Many of the incorporated references within the OVSC test procedures would not pose a barrier should an ADS-DV-specific test procedure be developed. For example, the Standard CIE observer, for human eye perceived colors, would no longer be necessary for an ADS-DV-specific test procedure. Others, such as ASTM B117-73 may still be included in an ADS-DV-specific test procedure if technical translations are implemented to address external sensors and not just rearview cameras. At this time, no barriers were determined for the current test procedure in place for human drivers.

FMVSS No. 113: Hood Latch System

This standard "establishes the requirement for providing a hood latch system or hood latch systems (S1)." The hood latch system(s) prevents the hood from opening while the vehicle is moving and obstructing the human driver's view.

Technical Translations

FMVSS No. 113 was promulgated to assure that a human driver's forward view through the windshield would not be obstructed by an opened hood. An ADS's forward view is obtained through one or more perception sensors, which will most likely be located in multiple areas and may have the potential for a hood opening to obstruct the sensors' view. Therefore, the options include a secondary latch whenever an opened hood could obstruct any sensor used by an ADS to perform the DDT in a forward motion.

Potential Considerations

The technical translation references sensors used by an ADS, though these are not currently defined in 49 CFR Part 571. Another possibility for consideration is to use the term "perception systems used by an ADS," also not currently defined in 49 CFR Part 571. However, there may be a benefit to identifying the applicable sensors with more specificity and in a way that is agnostic, but comprehensive.

Test Procedures

The current standard does not specify a test procedure. NHTSA's website states that "Visual Inspection" is used to assess compliance. While a visual inspection presumably could be used to determine if the sensors used to provide a "forward view" to an ADS would be "partially or completely obstructed" by an opened hood, there would have to be some way to ensure that the person performing the inspection could identify which sensors are relevant to the ADS's forward view and where those sensors are located on the vehicle.

Potential Considerations

There may be complexity in identifying and locating the applicable sensors, as there is much variation expected among manufacturers and there could be critical differences in the way those sensors are implemented into the greater sensor system.

Stakeholder and SME Review Input

Many of the stakeholder and SME reviewers agreed with the technical translation approach and expressed the view that all front opening hoods that may obstruct a sensor's view should have a secondary latch. Some suggested that one possible approach would be to simply require a secondary latch on all front-opening hoods. Other reviewers noted that ADS-DVs are expected to have redundancies, so an obstruction of one sensor by an opened hood might not necessarily imply full obstruction of the forward view.

Standards Incorporated by Reference

No incorporated references.

FMVSS No. 124: Accelerator Control Systems

This standard "establishes requirements for the return of a vehicle's throttle to the idle position when the driver removes the actuating force from the accelerator control, or in the event of a severance or disconnection in the accelerator control system" (S1).

The stated purpose of FMVSS No. 124 "is to reduce deaths and injuries resulting from engine overspeed caused by malfunctions in the accelerator control system" (S2).

Technical Translations

FMVSS No. 124 refers to controls that are driver-operated and actions performed by the driver. Options were provided that used the equivalency between a human and an ADS for the driver, differentiated between the human driver and the ADS, or generalized inputs to the accelerator control system by using the passive voice to remove explicit actions or references to the driver.

Potential Considerations

FMVSS No. 124 assumes a mechanical pedal is present for controlling vehicle speed. The technical translation options provide a means to accommodate both human- and ADS-controlled vehicles with mechanical components as part of the accelerator control system. S4.2 provides a definition for electric vehicles, which addresses vehicles that use a motor speed controller in place of a fuel metering device. However, for an ADS-DV that is an electric vehicle, mechanical components would not be necessary as a control interface, since the control command would be sent from the ADS as an electrical signal to the motor speed controller. With this type of system, no force is applied to the accelerator control system.

Test Procedures

The test procedures provide steps to detect and measure throttle response as well as means to introduce failures into the system. Functionalities that are required to execute the test procedures include being able to operate the throttle or motor speed independent of the gear selection (tests are performed with the vehicle in Park) while the emergency brake is engaged.

The vehicle-based test methods, both human control and programmed, have demonstrated the ability to execute these functionalities. Executing the test procedures with normal ADS operation may not be possible given the requirement to increase the commanded acceleration (accelerator control pedal for human controls) to 25 percent, 50 percent, 75 percent, and 100 percent of wide open throttle and then suddenly release the input, all with the vehicle remaining stationary.

Potential Considerations

While the OVSC test procedure acknowledges potential unique conditions for electronically controlled systems in the Performance Test and Example Instrumentation Setup sections, it is still assumed that there will be a physical part to access, particularly for the introduction of system severance. If the vehicle is fully electronic, additional methods to introduce equivalent faults may need to be evaluated based on the individual vehicle design.

Stakeholder and SME Review Input

Stakeholder feedback focused on the applicability of the standard to a vehicle that has no accelerator pedal or mechanical linkage, particularly for vehicles that control the speed of an electric motor through an electric signal. This carried into some comments regarding the pervasive use of the accelerator pedal in the execution of the OVSC test procedures as well.

Standards Incorporated by Reference

No incorporated references.

FMVSS No. 125: Warning Devices

This standard “establishes requirements for devices, without self-contained energy sources, that are designed to be carried in motor vehicles and used to warn approaching traffic of the presence of a stopped vehicle, except for devices designed to be permanently affixed to the vehicle” (S1).

The stated purpose of FMVSS No. 125 is “to reduce deaths and injuries due to rear end collisions between moving traffic and disabled vehicles” (S2).

Technical Translations

This FMVSS is an equipment standard referenced in other standards (i.e., Federal Motor Carrier Safety Regulations). This FMVSS contains no barriers to the compliance verification of an ADS-DV. As such, translation was not performed. However, there is one instance where the word “driver” is used. Potentially, passive voice could remove the reference to “driver,” if necessary.

Potential Considerations

None.

Test Procedures

The OVSC test procedure for this standard provides the steps for the device to be tested in a laboratory setting. No barriers are presented in this test procedure.

Potential Considerations

None.

Stakeholder and SME Review Input

None.

Standards Incorporated by Reference

Three standards were incorporated by reference (ASTM B117-64; ASTM E-259; CIE 1931). All are related to laboratory testing and none present a regulatory barrier.

FMVSS No. 126: Electronic Stability Control Systems for Light Vehicles

This standard "establishes performance and equipment requirements for ESC systems" (S1). The stated purpose of FMVSS No. 126 is "to reduce the number of deaths and injuries that result from crashes in which the driver loses directional control of the vehicle, including those resulting in vehicle rollover" (S2). This standard applies to vehicles other than motorcycles with a GVWR of 10,000 pounds or less.

Technical Translations

Since much of the standard assumes the existence of a steering wheel, the technical translation approach for FMVSS No. 126 focused on vehicles without manually operated driving controls. Three primary technical translations options were developed that focused on addressing the reference to a human-controlled steering wheel. Each option is based on an underlying theme for referencing steering inputs. For Option 1, inputs into the system via the steering wheel have been translated to refer to equivalent inputs into the steering system. In addition, this option uses an equivalency between a human driver and an ADS (driver definition 1). For Option 2, new definitions have been added for "steering wheel" and "steering wheel angle" based on a generic interface with the steering system, which allows the references to these items to remain as they currently exist in the regulatory text. This option removes the references to the "driver" or distinguishes between a human driver and an ADS (driver definition 2). For Option 3, rather than specifying the independent variable as the input at the front of the steering system, the input is defined at the road wheel angle (angle of the tires relative to the longitudinal centerline of vehicle).

Potential Considerations

The current standard uses the steering wheel both to define the input signal and to apply the input. This standard's application to vehicles that have no steering wheel is the primary consideration for this translation. FMVSS No. 126 defines performance criteria for a system's output (the vehicle's yaw and lateral position) in response to given inputs (changes in the road wheel angle). The primary effect of removing the references to a steering wheel is to alter how the system inputs are controlled and defined.

The steering wheel provides a control interface to the steering system for a human driver. In the absence of a steering wheel, a means to control the lateral direction of a vehicle is still required. Changing the road wheel angle will likely continue to be the primary method employed by an ADS-DV to steer a vehicle; this will be coordinated by the steering system. This provides two likely means of defining the steering inputs: either as a steering system input or as steering system output. Currently, steering inputs are based on the position of the steering wheel, but conceptually they could be defined at any point in the steering system. By way of example, for a rack-and-pinion steering system, the vehicle input could be defined as the angular displacement of the pinion gear, the lateral displacement of the rack, or the road wheel angle. This general approach can apply to any vehicle that uses mechanical displacement to control the steering of the vehicle.

The magnitude and units of the input are a function of the steering system and how the ADS controls the input into that system. While the current technical translation option provides possible displacement ranges for road wheel angle, the displacements for other control points in the steering system may need additional information to allow for efficient testing. The current test procedures are designed to characterize the vehicle response to a given steering input. This could be applied over a broader range with smaller step sizes to determine the applicable test range; however, implementing this could be time-consuming.

A secondary consideration is the control and communication of the ESC system state. Currently, the standard allows for a means by which the driver can disengage the ESC. It is reasonable to assume that the ADS may have this ability in an ADS-DV. Communication of the ESC's state, particularly during a malfunction condition, falls within the larger discussion of what and to whom vehicle state information should be provided, as discussed in more detail in the Controls, Telltales, Indicators, Symbols, Labels, Markers, and Auditory Alerts section presented earlier in this report as well as in the Controls, Telltales, and Indicators section of the Volume 1 report.

With respect to an ESC malfunction, the technical translation options include communicating the malfunction state to the ADS. Communication of a vehicle's malfunction state is beneficial to an entity responsible for the maintenance of a vehicle regardless of whether the vehicle is an ADS-DV or not. For the occupant of an ADS-DV, having knowledge of a malfunction state for the ESC will likely be determined within the broader context of the telltales currently required by the FMVSS.

Test Procedures

The test procedures are largely specified within the regulatory text itself. The use of driver as a descriptor or to assign an action was rewritten to be more generic. For example, in the description of the ESC system, the phrase "…to assist the driver in maintaining control…" was revised to read "…to assist in maintaining control."

Since knowledge of the steering system is likely to be beneficial in the execution of the tests, in section 13.1 of the OVSC test procedures, "ESC System Technical Documentation," information regarding "steering inputs" was added.

Testing the functionality of the telltales and the ESC control will be dependent on what information is required to be provided and to whom. For example, if information about the status of the ESC must be provided to the ADS, a new test procedure may be required.

<u>Potential Considerations</u>

Since much of the test procedure is defined in the regulatory text, those potential considerations carry over to the test procedures as well.

Other potential considerations relate to the operation of the vehicle in a manner that it was not designed to operate. The following provides a list of potential considerations related to this.

- Though not unique to FMVSS No. 126, localization of an ADS-DV is a consideration, since the test is conducted on a closed test course which may be outside the ODD of the vehicle being tested.
- As written, the final test in the sequence requires the SWD maneuver to be initiated at 50 mph to ensure ESC activation on a paved surface. Some ADS-DVs may not be designed to operate at this speed. A means to confirm proper ESC operation for vehicles which do not operate at the specified test speed may need to be considered for these vehicles.
- Stakeholders commented that an ESC system is intended to account for inappropriate inputs into the vehicle's steering system, which may result in loss of directional control, and that an ADS will operate the controls of the vehicle to avoid loss of directional control within the ODD. Consequently, if the ESC is operated outside the context for which it was designed, there was a question as to whether the test could accurately capture the safety intent.
- Related to the previous two considerations, if a vehicle is designed in a manner that it will not provide a steering input that would induce an instability, the actuator(s) used for steering the vehicle may not be able to execute the SWD test through the sweep of steering inputs. The current standard is designed to test the system at the limits of the population of drivers, even though all drivers may not be capable of providing a steering input great enough to activate the ESC under test conditions. If an ADS-DV is designed in an analogous manner, how can the ESC be activated and therefore tested? Note that this does not address the ESC function when the vehicle is on low friction surfaces.

Stakeholder and SME Review Input

FMVSS No. 126 was selected as part of the SME evaluation; this process is described in detail in Chapter 5: Test Method Evaluation Findings.

Standards Incorporated by Reference

ASTM E29-06b, "Standard Practice for Using Significant Digits in Test Data to Determine Conformance With Specifications" is referenced and is independent of the manner in which data is collected. The other two ASTM references (ASTM E1337-90 and ASTM E1136-93) are independent of ADS-DVs and do not present a barrier.

Chapter 4. Crashworthiness and Occupant Protection Standards

Overview

This chapter summarizes the technical translation options of the crashworthiness and occupant protection standards covered in Volume 2 research: FMVSS Nos. 207, 208, 210, 214, 216a, 219, 222, 225, and 226. The aim of the 200-series standards is to reduce the risk of vehicle occupant injury in the event of a crash. The goal of this effort was to provide options for translating the language of each standard to accommodate ADS-DVs while maintaining the current requirements for conventional (i.e., non-ADS-equipped) vehicles. In addition to the FMVSS, the associated OVSC test procedures used by NHTSA to verify compliance were reviewed.

The current effort is focused on occupant protection for ADS-DVs with conventional seating. This includes ADS-DVs with forward-facing seating, but without a steering wheel and pedals. Unconventional seating configurations, such as rear-facing or side-facing seats, were not considered. Technical translation assessments were completed to identify potential regulatory barriers.

Technical Translations

As discussed in the Crashworthiness Key Considerations section in Chapter 2, themes such as the driver (operator); driver and passenger DSPs; dummy positioning; assumption that the front row is the preferred seating position; and controls, telltales, indicators, and auditory alerts were crosscutting themes addressed in the Volume 1 research. The approaches used for the Volume 1 standards were also used in the development of translations for the Volume 2 standards.

Several of the FMVSS 200-series reflect the difference in injury risk between a person seated in the driver's DSP and other front-seated occupants due to the presence of steering controls. The occupant protection provisions of the FMVSS 200-series are associated with the potential hazards of individual occupant seating positions rather than the role of the occupants seated at those locations. Part of estimating the potential hazards is the degree of occupant exposure to harm at each seating position; i.e., some provisions apply to front seats and not rear seats because fewer people occupy rear seats than front seats, or apply only to the driver's DSP because in conventional vehicles the driver's DSP would always be occupied. FMVSS Nos. 208 and 214 establish requirements for active and passive restraint systems, as well as performance requirements for anthropomorphic test devices (ATDs) in the front outboard seating positions in frontal impact crashes and in front and rear outboard seating positions in side impact crashes.

In general, the technical translation options provided included the following: utilization of the "driver" definition options, use of the terms "left front outboard DSP" or "right front outboard DSP," mirroring the right front DSP to the left front DSP for dummy positioning procedures in ADS-DVs, and use of the term "manually operated driving controls" to ensure the current requirements apply to ADS-DVs and conventional vehicles in standards related to the presence of a steering wheel and pedals. These approaches aligned with the options developed to address the Volume 2 standards.

In most cases, it was determined that language in the 200-series standards could be addressed with straightforward clarification, and therefore the regulatory language was assessed as a 0 (assigned in cases when the technical translation was evaluated but not performed) or a 1 (assigned when the technical translation was straightforward).

Potential Considerations

There may be cases where an FMVSS requirement or provision applies to or references the driver's seat and is silent with respect to the passenger seat (e.g., a readiness indicator for the air bag must be visible from the driver's DSP; see FMVSS No. 208, S4.5.2 and FMVSS No. 226, S4.2.2). The statement that "all DSPs would be passenger DSPs" does not mean the FMVSS requirement is unnecessary or nullified. Some technical translation options in the 200-series standards expand the current requirements of telltales or auditory alerts to ensure occupants receive safety information, since an occupant may not be seated in the left front DSP in an ADS-DV.

The current emphasis of certain FMVSS on front-seat occupants (e.g., air bags are required for front outboard DSPs but not for the rear seats in FMVSS No. 208) was considered during Volume 2 research. If front and rear seat occupancy rates remain similar between conventional vehicles and ADS-DVs, the translation of front/rear references is straightforward for conventional, forward-facing seating, but may need to be revisited for translations involving rear- or side-facing seating configurations.

While the crosscutting themes depicted in Table 3 earlier in this report helped to provide consistent technical translation approaches for both the Volume 1 and Volume 2 standards, each standard addresses a unique crashworthiness area and may result in some differences in the technical translations. The technical translation summary and considerations for each of the Volume 2 crashworthiness standards are provided in this chapter.

Test Procedures

Since the crosscutting themes of the test procedures and regulatory language of the 200-series FMVSS are very similar, the approach used in the Volume 1 standards was applied to the Volume 2 standards. This included translating vehicle landmarks, such as "driver door" or "driver side," mirroring dummy positioning from the right front DSP to the left front DSP for ADS-DVs, and using "steering controls, if present" to maintain the current requirements for vehicles while not creating a barrier for ADS-DVs. A 3D measurement device (e.g., FARO) could be added as an option for ATD positioning in the test procedures rather than requiring the physical measurement of vehicle landmarks, possibly minimizing the need for some landmarks. Based on the options provided for translating the regulatory language, additional test procedures for the telltales and auditory alerts in the 200-series FMVSS may be warranted to ensure they are visible/audible from the required seating positions and the underlying condition of an air bag, seat belt warning, or unlatched door is communicated to the ADS.

Rear Seat Testing

Although unconventional seating configurations, such as rear-facing front seats or reclining seats, are being considered by industry for ADS-DVs, occupant compartment configurations are not expected to change much in the near future. Consequently, the focus of Volume 2 research for the 200-series FMVSS was on vehicles with forward-facing seats. Since, historically, conventional vehicle front seat occupancy rates are higher than rear seat rates (e.g., there is always a driver in a front seat), some FMVSS requirements apply only to front seats, and not to rear seats. The options provided for translating the regulatory language do not extend the current requirements for the front seats to the rear seats.

Stakeholder and SME Review Input

The comments from stakeholders and SMEs were in general agreement with the options provided for translating the language of each standard. The consensus was that translations for conventional seating configurations should be considered first for the crashworthiness standards. The manufacturers in the stakeholders group felt that the first priority should be removing regulatory barriers to ADS-DVs in the short-term. Several reviewers mentioned updates that were outside of the scope of the project, such as deleting or updating outdated FMVSS requirements, and presented new ADS-associated regulatory requirements.

Standards Incorporated by Reference

As noted in Chapter 2 of this report, documents incorporated by reference were reviewed as part of the technical translation effort. Between the regulatory text and the OVSC test procedures, all Volume 2 research 200-series standards refer to documents created by an external organization. Two documents, SAE J826 and SAE J1100 (years vary), which appear in many of the 200-series standards, use the term "driver" when referring to sides or seating positions. No technical translation was deemed potentially necessary if this regulatory text was to implement Potential Set 1 or 2 of the driver's DSP definition. This would clarify that this DSP applies to a vehicle seating position that is unique to the driver and, thus, SAE J826 and SAE J1100 may not be regulatory barriers.

FMVSS No. 207: Seating Systems

This standard "establishes requirements for seats, their attachment assemblies, and their installation to minimize the possibility of their failure by forces acting on them as a result of vehicle impact" (S1). S4.1 of FMVSS No. 207 requires that "each vehicle shall have an occupant seat for the driver."

Technical Translations

Translation options were provided for the "Driver's seat" requirement in S4.1. One option is to delete the requirement, as there would always be a seat for a human driver in a vehicle with manually operated driving controls, whereas an ADS-DV would not include a seat for a human driver. Another option states, "If manual steering controls are provided, each vehicle shall have an occupant seat for a human driver." This option does not use the definitions outlined in Appendix A. There is also an option to translate "Driver's seat" to "Driver's designated seating position" and to state, "If equipped with manually operated driving controls, each vehicle shall have a driver's designated seating position." This option uses either definition of driver's DSP—

either a position providing immediate access to, or one immediately behind, the manually operated driving controls.

Potential Considerations

None

Test Procedures

Options were provided to translate vehicle landmark terms such as “driver” or “passenger” to “left (front)” or “right (front),” respectively. There are multiple sections titled, “Front Seat – Driver Position.” These sections could be translated to either “Front Seat – Driver Position for a Vehicle with Manually Operated Driving Controls” or “Front Seat – Driver’s Designated Seating Position.”

Potential Considerations

The dummy positioning procedures include the accelerator pedal as a point of contact. If the section titles exclude vehicles without manually operated driving controls, no further translation of the dummy positioning procedure would be necessary. If the option using “Left Side Occupant Position” is used, further options for dummy positioning procedures may warrant technical translations for ADS-DVs.

Stakeholder and SME Review Input

None

Standards Incorporated by Reference

There are four incorporated references in the OVSC test procedure for FMVSS No. 207. SAE J182_2015 and SAE Recommended Practice J383_1986 were analyzed and were not found to pose a regulatory barrier. SAE Recommended Practice J826_1992 and SAE J1100_2009 may not be regulatory barriers if Potential Set 1 or 2 of the DSPs and driving controls definitions are implemented.

FMVSS No. 208: Occupant Crash Protection

This standard “specifies requirements for the protection of vehicle occupants in crashes” (S1). The stated purpose of FMVSS No. 208 is to reduce the number of deaths and the severity of injuries in frontal crashes (S2). FMVSS No. 208 includes a test procedure to ensure vehicles have frontal/angular protection in the front outboard DSPs that includes both air bags and lap/shoulder belts.

Technical Translations

Similar to other 200-series standards, the definitions for “driver’s DSP,” “manually operated driving controls” and “driver” simplify the technical translation process for FMVSS No. 208. Translation options included translating many references to “driver” or “passenger” to left or right side or to left or right front outboard seating position when referring to the occupant location. Similarly, some options translated "passenger" to "front outboard" to clarify that the requirements only apply to front row passengers. Some sections referring to the passenger air bag or passenger seat were translated to apply to any front outboard passenger air bag or seat. These options consider vehicles that may have two front outboard passenger seating positions (i.e., vehicles without a driver's seat).

A "readiness indicator" is required for occupant protection systems that deploy during a crash. S4.5.2 states that this indicator, "shall monitor its own readiness and shall be clearly visible from the driver's designated seating position." The 10 potential options developed during Volume 1 research for technical translation of provisions that specify where or to whom a telltale, indicator, or auditory alert is directed in ADS-DVs, which are detailed in the Volume 1 report, were all considered for this requirement. Based on the standard's requirements and owner's manual information regarding the occupant protection readiness indicator, the expected response is to verify the air bag readiness status and check the label and owner's manual for steps to address the telltale warning.

From the 10 Volume 1 research options, the options used for the Volume 2 translations include displaying the telltale (1) to an occupant in the location currently specified by the standard (i.e., the left front DSP) and to the ADS, (2) to all front row occupants and the ADS, (3) to the ADS and all occupants, and (4) only to the ADS for vehicles without manually operated driving controls and per the current location for conventional vehicles. Options including all front row (or all) occupants were selected since the left front DSP may not be occupied or present. The options that include the ADS were selected so that if a malfunction with the readiness status occurs, that information could be communicated to the ADS, a maintenance entity, or both. The warning system required to display "Fasten Seat Belts" or "Fasten Belts" for seat belt assemblies in S7.3 of FMVSS No. 208 has similar options to communicate the warning to all front row occupants or all occupants if the left front DSP is not occupied. Since the intent of the warning system could be to encourage occupants to fasten their seat belts, there are also potential options to communicate the information only to occupants and not to the ADS. As with other telltales and alerts, the translations do not specify what actions the ADS should take in response to the information communicated.

Some provisions of FMVSS No. 208 (e.g., S19.2.2) require a telltale for vehicles equipped with automatic suppression of the passenger air bag that "emits light when the passenger air bag system is deactivated and does not emit light when the passenger air bag system is activated, except that the telltale(s) need not illuminate when the passenger seat is unoccupied." The purpose of this telltale is to allow front row occupants to confirm whether the passenger air bag is deactivated if a child restraint system is placed in the front passenger seat or if a child below a certain weight threshold is seated in the front passenger seat. The translation options include communicating the information (1) to all front outboard seating positions, (2) to all seating positions, and (3) for ADS-DVs, in addition to the current requirements, requiring the telltales to monitor their own readiness and to communicate the underlying conditions to the ADS.

FMVSS No. 208 has many sections related to dummy positioning for the associated test procedure. In many instances, references to the passenger dummy could be translated to "any front outboard passenger dummy" to account for ADS-DVs, and "the driver and passenger test dummy" could be translated to "any front outboard dummy."

Potential Considerations

Some translations would apply the current crash protection requirements (e.g., seat belt assemblies in S4.4.4.2) for the driver's DSP to all front DSPs for ADS-DVs. An alternative could be to allow the manufacturer to select a seat to be equipped with the occupant protection requirements. For the telltales required by S7.3 and S4.5.2, options were given to display the information to all front row occupants or all occupants, since there might not be an occupant in the left front outboard seating position in an ADS-DV. Also, considering rideshare ADS-DVs, the ignition may be switched to "on" only a few times in a 24-hour period. While initial riders would receive the warning light, subsequent riders may not receive the light until the ignition is cycled. Sections referring to the "driver dummy" could either maintain the current language using the definition that the driver is seated in the left front outboard seating position or refer to a seating position with direct access to manually operated driving controls.

S19 of FMVSS No. 208 includes requirements to provide protection for infants in rear-facing and convertible child restraints and car beds. While ADS-equipped vehicles with steering controls (i.e., dual-mode vehicles) are considered out of scope of this project, they could warrant additional requirements for suppressing the driver air bag for a 12-month-old Child Restraint/Air Bag Interaction (CRABI) dummy in the driver's DSP. This would be a special case, as the passenger air bag currently has requirements for an automatic suppression feature that must result in deactivation for static tests specified in S20.2 and activation for static tests specified in S20.3. Tests with a 3-year-old dummy and a 6-year-old dummy could also be included.

The requirement could state that: (1) "Each vehicle that is certified as complying with S14 shall suppress the driver air bag when a 12-month-old CRABI dummy is placed at the driver's seating position." The driver air bag would be suppressed by the same method used for suppressing the passenger side air bag. Vehicles could alternatively/additionally include a label on the controls stating, "Never allow a child smaller than X to ride in this seat, with or without a child restraint device." Additional research would be needed to assess injury risk with a child or child restraint seat behind the driving controls, regardless of air bag suppression.

Test Procedures

The test procedure for FMVSS No. 208 is used to determine whether a vehicle meets the conditions, requirements, and injury criteria as specified in S4, "General requirements," S14, "Advanced air bag requirements," and S7, "Adjustments," for seat belt assembly systems. The translations options provided for "Driver" or "Driver Only" were "Left Front Passenger" or "Driver's Designated Seating Position" when referring to dummy positioning. Many other references to driver or passenger could be translated to left or right front (e.g., driver's seat back angle, driver door, passenger side, etc.). Sections referring to both a driver and passenger dummy were translated to either include the left front outboard and right front outboard dummy or driver and passenger dummy (dummies). The term "passenger dummies" could apply to vehicles without a driver's DSP that would have multiple passenger seating positions in the front row. References to a steering column/wheel assembly were translated to steering controls (if present).

The translations for the “readiness indicator” in the test procedure are consistent with the translations provided in the regulatory text. For example, a data sheet in the test procedure of FMVSS No. 208 states, “Is the readiness indicator (S4.5.2) clearly visible to the driver?” and includes a pass/fail option. The translation options include the following:

1) Is the readiness indicator clearly visible at the driver’s designated seating position or any front designated seating position if no driver’s designated seating position is present?
2) Is the readiness indicator clearly visible at the driver’s designated seating position or any designated seating position if no driver’s designated seating position is present?
3) Is the readiness indicator clearly visible to the front left outboard seating position?
4) Is the readiness indicator clearly visible to the driver? If there is no driver, is the information specified in the readiness indicator communicated to the ADS?

Similar to the regulatory text translations, “driver and passenger dummy” could be translated to “left and right front outboard dummy” or “driver and passenger dummy, or two passenger dummies, if no driver’s designated seating position is present.” Driver’s side and passenger side were translated to left (front) side and right (front) side.

Potential Considerations

The center of the steering wheel is used as a reference point in some test sections. If there is no driver’s DSP, alternative landmarks could be the center of the left front air bag or the left front outboard head restraint.

One translation option could be to make the test procedure specified in S26 of the regulatory text applicable only to vehicles with manually operated driving controls. This test involves measuring steering wheel angles and placing the test dummy in contact with the steering wheel.

Stakeholder and SME Review Input

Commenters agreed that the seat belt warning telltale should be visible to all occupants. Another topic of discussion was that seat belt interlocks may be appropriate for ADS-DVs when there is not a driver responsible for seat belt usage (e.g., children riding in an ADS-DV without adults). Some commenters stated that with a reliable and defeat-free interlock, the requirement for the unbelted tests need to be given further consideration. Stakeholders suggested that ADS-DVs might provide more choices for seating positions and that ATDs may be unable to adequately test and predict injuries in unconventional seating configurations.

Standards Incorporated by Reference

FMVSS No. 208 has eight standards incorporated by reference: SAE Recommended Practice J211/1_1995, SAE Recommended Practice J383_2014, ASTM E274-65T, ASTM E29-06b, MIL-S-21711E, and MIL-S-13192P do not pose a regulatory barrier; SAE Standard J826_1980 and SAE J1100_2009 may not be regulatory barriers if Potential Set 1 or 2 of the DSPs and driving controls definitions are implemented.

FMVSS No. 210: Seat Belt Assembly Anchorages

This standard "establishes requirements for seat belt assembly anchorages to ensure their proper location for effective occupant restraint and to reduce the likelihood of their failure" (S1).

Technical Translations

FMVSS No. 210 was evaluated, but no translations were performed. For ADS-DVs with conventional seating configurations, the seat belt assemblies will remain present and translations for the current standard are not necessary. Unconventional seating arrangements may require further consideration.

Potential Considerations

None

Test Procedures

The test procedure for FMVSS No. 210 was evaluated and translations were not necessary.

Potential Considerations

None

Stakeholder and SME Review Input

S6 of FMVSS No. 210 states, "the owner's manual in each light vehicle shall include sections explaining that all child restraint systems are designed to be secured in seats with lap belts or the lap belt portion of a lap-shoulder belt and that children are safer when properly restrained in rear seating positions than in front seating positions." Stakeholders noted that—as with other information that the FMVSS currently require to be included in the owner's manual—information regarding child safety (such as that noted in S6, above) may warrant an alternative delivery method as ownership models change.

Standards Incorporated by Reference

FMVSS No. 210 has three standards incorporated by reference: SAE Recommended Practice J383_2014 does not pose a regulatory barrier; SAE Standard J826_1987 and SAE Recommended Practice J1100_1984 may not be regulatory barriers if Potential Set 1 or 2 of the DSPs and driving controls definitions are implemented.

FMVSS No. 214: Side Impact Protection

This standard "specifies performance requirements for protection of occupants in side impacts" (S1(a)). The stated purpose of this standard is to "reduce the risk of serious and fatal injury to occupants…in side impacts" (S1(b)). FMVSS No. 214 includes three tests: (1) a quasi-static door crush resistance test, which dictates the application of a specified force by a rigid steel cylinder or semi-cylinder to "any side doors that can be used for occupant egress;" (2) a moving deformable barrier side crash test; and (3) a dynamic rigid pole side crash test.

Technical Translations

FMVSS No. 214 has several references to driver and passenger that were translated. For example, in S10.2, Vehicle Test Attitude, the driver's and front passenger's door sills are used to measure the front-to-rear angle of the vehicle. One option provided is to translate "driver's door sill" to "left front door sill." Since measurements are taken on both sides of the vehicle, another option is to use "both front door sills." S8.3.1.3, Seat Position Adjustment, states, "If the driver and passenger seats do not adjust independently of each other…." This statement can be translated to "If the driver and any front outboard seats do not adjust..." or "If the front outboard seats do not adjust...." For ADS-DVs, language referring to the right front passenger was translated to "any front outboard passenger."

Potential Considerations

Using the definitions in 49 CFR §571.3 for driver's DSP and the associated terms, the translation process is simplified. For positioning a dummy in a rear outboard seating position, the midsagittal plane of a dummy in the driver's DSP is used as a reference. This reference was maintained for some translation options; however, in a vehicle without a driver's DSP, the seating reference point of the rear outboard seating position could be a possible reference point for the midsagittal plane, or perhaps the center of the head restraint for that DSP, if there is one, or the centerline of the seat cushion.

Test Procedures

FMVSS No. 214 has three distinct test procedures. In each case, the translation approach was to reframe the regulatory language in terms of DSPs rather than occupant roles, such as a "driver" or "passenger." Specifically, the test procedure language was translated to use the definitions for driver's DSP and associated terms. In addition, the research team provided translation options for vehicle landmarks from terms such as "driver" or "passenger" side to "left" or "right" side. The quasi-static rigid steel cylinder or semi-cylinder test requires both sides of two-door vehicle models to be tested and the driver's side forward door and opposite side rear door of four-door models to be tested (OVSC Laboratory Test Procedure No, 214S [Static], 12. Compliance Test Execution – Execution of the Static Load Test of Vehicle). For four-door vehicles without manually operated driving controls, one option is to state either "the left side forward door and opposite side rear door shall be tested" or "the right-side forward door and opposite side rear door shall be tested."

The moving deformable barrier side crash test has a section titled, "Steering Column Adjustment," which may be translated to "Steering Column Adjustment, if Present" to exclude ADS-DVs. Measurements related to the dummy positioning also use the steering wheel as a reference point (e.g., tip of the dummy's nose to the closest point on the top of the steering wheel, center of the steering wheel to the dummy's chest). The translation options could state that these measurements are used if manually operated controls are present but additional measurements could be added for ADS-DVs without a steering wheel/column present.

The same translation approach was applied to S9's vehicle-to-pole test. Many references to driver or passenger could be replaced with left (front) or right (front). Sections referring to the steering column or steering column adjustment could be translated to state "if present" to apply to ADS-DVs.

Potential Considerations

Although reference points were provided to replace the steering wheel landmarks for ADS-DVs, other landmarks may be appropriate.

Stakeholder and SME Review Input

Stakeholders stated they believed that research should be conducted to determine if applying the pole requirements to the rear row(s) of seats is appropriate.

Standards Incorporated by Reference

FMVSS No. 214 has three standards incorporated by reference: MIL-S-21711E and ASTM E29-06b do not pose a regulatory barrier; SAE Standard J826_1980 may not be a regulatory barrier if Potential Set 1 or 2 of the DSPs and driving controls definitions are implemented.

FMVSS No. 216a: Roof Crush Resistance; Upgraded Standard

This standard "establishes strength requirements for the passenger compartment roof" (S1). The stated purpose of the standard is "to reduce deaths and injuries due to the crushing of the roof into the occupant compartment in rollover crashes" (S2).

Technical Translations

In S7.1, the "driver and passenger sills" were translated to the "left and right sills." The purpose of the left and right designations in this case was to ensure that both sides of the vehicle are supported off the suspension with appropriate vehicle orientation.

Potential Considerations

S7.1 also states, "Remove roof racks or other non-structural components." For ADS-equipped vehicles, it might be appropriate to specify that sensors and housings mounted on the roof should also be removed. However, the reference to "other non-structural components" in the current regulatory text may be sufficient.

Test Procedures

Vehicle landmarks were translated from terms such as "driver" or "passenger" side to "left (front outboard)" or "right (front outboard)," respectively (e.g., driver door, driver and passenger test dummies). For the dummy positioning procedure in vehicles with bench seats, the "center of the steering wheel rim" was maintained in the language as a vehicle landmark for vehicles with manually operated driving controls. The "center of the left front head restraint" or "center of the left front SgRP [seating reference point]" could be used as alternative reference points for ADS-DVs.

Potential Considerations

The check sheet for locating the center of the head positioning fixture includes a Driver DSP section and a Passenger DSP section. For vehicles without manually operated driving controls and identical left and right front passenger seating, the Driver DSP (left front outboard) section could point to the Passenger DSP section in the test procedure.

Stakeholder and SME Review Input

A determination as to whether roof-mounted sensors (e.g., lidar) are to be designated as "roof racks or other non-structural components" should be considered.

Standards Incorporated by Reference

FMVSS No. 216a has three standards incorporated by reference: SAE J1100_2009 and ASTM E29-06b do not pose a regulatory barrier; SAE Standard J826_1995 may not be a regulatory barrier if Potential Set 1 or 2 of the DSPs and driving controls definitions are implemented.

FMVSS No. 219: Windshield Zone Intrusion

This standard "specifies limits for the displacement into the windshield area of motor vehicle components during a crash" (S1). The stated purpose of this standard is "to reduce crash injuries and fatalities that result from occupants contacting vehicle components displaced near or through the windshield" (S2).

Technical Translations

FMVSS No. 219 includes a test in which "no part of the vehicle outside the occupant compartment, except windshield molding and other components designed to be normally in contact with the windshield" should penetrate a specified protected zone template by more than 6 mm after impacting a fixed collision barrier at up to and including 48 km/h.

S6.1 of FMVSS No. 219 states that any accessories or equipment, such as the steering control system, should be removed if they obstruct the positioning of a rigid sphere with a diameter of 165 mm. Although an ADS-DV may not have a steering control system as an obstruction, the steering controls are listed as an example of items that should be removed, so a translation may not be necessary and the current language has been maintained.

Potential Considerations

None

Test Procedures

Vehicle landmarks were translated from terms such as "driver" or "passenger" side to "left (front outboard)" or "right (front outboard)," respectively (e.g., driver door, driver and passenger test dummies). For dummy positioning procedures in vehicles with bench seats, the "center of the steering wheel rim" was maintained in the text as a vehicle landmark for vehicles with manually operated driving controls. The "center of the left front head restraint" or "center of the left front SgRP" could be used as alternative reference points for ADS-DVs.

<u>Potential Considerations</u>

The left front head restraint and SgRP were presented as options for ADS-DVs with bench seats, but the longitudinal centerline of the left front seat cushion or the left front air bag could also be considered.

Stakeholder and SME Review Input

ADS-DVs without traditional vision (e.g., view via media screens, absence of a windshield) may require additional language to define the windshield zone and maintain the safety intent of FMVSS No. 219.

Standards Incorporated by Reference

FMVSS No. 219 has one standard incorporated by reference—SAE J1100a_2009—which may not be a regulatory barrier if Potential Set 1 or 2 of the DSP and driving controls definitions are implemented.

FMVSS No. 222: School Bus Passenger Seating and Crash Protection

This standard "establishes occupant protection requirements for school bus passenger seating and restraining barriers" (S1). The stated purpose of FMVSS No. 222 is "to reduce the number of deaths and the severity of injuries" sustained by school bus occupants in the event of a crash (S2).

Technical Translations

The only section of FMVSS No. 222 for which a technical translation was performed was the definition of "school bus passenger seat," which currently is defined as "a seat in a school bus, other than the driver's seat." If the definition for driver's seat is used, a translation is not required.

<u>Potential Considerations</u>

The second translation option does not use the definition for "driver's seat" and states the school bus passenger seat is a seat "other than a seat intended for use by a human driver."

Test Procedures

The terms "driver side" and "passenger side" were translated to "left side" and "right side," respectively. Under Section I. of "13. RECEIVING INSPECTION OF THE SCHOOL BUS," each bus seat must be numbered starting at the "passenger seat or wheelchair immediately behind the driver's seat…." The translation option for this statement was stated as "behind the driver's seat, if present. If there is no driver's seat, number each bus seat starting at the left front-most passenger or wheelchair seat." This expands applicability to ADS-DVs, which do not have a driver's seat.

Potential Considerations

Using the definitions outlined in Appendix A, some sections were evaluated but the current language referencing the driver's seat was retained.

Stakeholder and SME Review Input

None

Standards Incorporated by Reference

FMVSS No. 222 has five standards incorporated by reference: ASTM E29-06b, SAE Recommended Practice J211a_1971, and SAE Recommended Practice SAE J4004-2008 do not pose a regulatory barrier; SAE Standard J826_1987, and SAE Recommended Practice J1100_1984 may not be regulatory barriers if Potential Set 1 or 2 of the DSPs and driving controls definitions are implemented.

FMVSS No. 225: Child Restraint Anchorage Systems

This standard "establishes requirements for child restraint anchorage systems to ensure their proper location and strength for the effective securing of child restraints, to reduce the likelihood of the anchorage systems' failure, and to increase the likelihood that child restraints are properly secured and thus more fully achieve their potential effectiveness in motor vehicles" (S1).

Technical Translations

The word "driver" only appears twice in FMVSS No. 225. Shuttle bus is defined as "a bus with only one row of forward-facing seating positions rearward of the driver's seat." Here, the "driver's seat" reference appears to simply identify the left front seat. Using the definition for "driver's seat," this could be translated to "…rearward of the driver's seat or the left front outboard seat in a vehicle without manually operated driving controls" to provide a translation option for ADS-DVs.

Potential Considerations

A second translation option for the definition of shuttle bus does not use either definition for "driver's seat." This option has two separate specifications: one for vehicles with a driver's seat and one for vehicles without a driver's seat; i.e., "…rearward of the driver's seat in a vehicle designed to be operated by a human driver, or rearward of the left front outboard seat in a vehicle designed not to be operated by a human driver."

Test Procedures

"Driver and passenger sill" were translated to "left and right front passenger sill." The test procedure includes a measurement specified in S4.5.4.1(b) of FMVSS No. 208. This procedure includes reference points, such as “the centerline of the driver’s seat cushion” and “the center of the steering wheel rim.” The translations options use “the centerline of left front outboard seat cushion” to replace both reference points.

Potential Considerations

Alternate vehicle landmarks to the “center of the steering wheel rim” may be required for vehicles with front bench seating.

Stakeholder and SME Review Input

If changes to seating usage occur in the future, there may be a need for further research into the use of child restraint systems in the front row of ADS-DVs. The requirement of Lower Anchors and Tethers for Children (LATCH) systems at front seating positions (accompanied by automatic air bag deactivation) may be appropriate.

Standards Incorporated by Reference

FMVSS No. 225 has five standards incorporated by reference: SAE Recommended Practice J1100_1993 does not pose a regulatory barrier; SAE Standard J826_1992, SAE Standard J826_1962, SAE Standard J826_1987, and SAE Recommended Practice J1100_1984 may not be regulatory barriers if Potential Set 1 or 2 of the DSPs and driving controls definitions are implemented.

FMVSS No. 226: Ejection Mitigation

This standard “establishes requirements for ejection mitigation systems to reduce the likelihood of complete and partial ejections of vehicle occupants through side windows during rollovers or side impact events” (S1).

Technical Translations

The translation approach included reframing the regulatory language in terms of DSPs rather than occupant roles. For example, S6.1 uses the term “driver door sill” in the instructions for measuring the roll and pitch angle of the vehicle. To remove the driver reference, the translation option was to use “left front door sill.”

S4.2.2 of FMVSS No. 226 requires vehicles with an ejection countermeasure that deploys in the event of a rollover to have a monitoring system with a “readiness indicator” that must be “clearly visible from the driver’s designated seating position.” The 10 potential options developed during Volume 1 research for technical translation of provisions that specify where or to whom a telltale, indicator, or auditory alert is directed in ADS-DVs were considered for this requirement. From the 10 potential options detailed in the Volume 1 report, the proposed translations for the “readiness indicator” include communicating information (1) to the ADS and all DSPs, (2) to the ADS and all front DSPs, (3) to the occupant per the current standard location (driver’s DSP) and to the ADS, or (4) only to the ADS for vehicles without manually operating driving controls and per the current location for conventional vehicles. The options including the ADS were selected so if a readiness status malfunction occurs, that information could be communicated to the ADS, a maintenance entity, or both. As with other standards, the translations do not address how the ADS should respond to the information being communicated.

Potential Considerations

Some translation options for the location of the "readiness indicator" expand the applicability of the requirement. Novel approaches may be necessary to ensure the telltale is visible at multiple seating positions (e.g., clearly visible from all DSPs). However, if the telltale is only visible to the left front outboard seating position, the information might not be received by ADS-DV occupants at other DSPs.

Test Procedures

The approach to translating the test procedures was to reframe the test procedure language in terms of DSPs rather than occupant roles, such as a "driver" or "passenger." This included translating terms such as "driver door," "driver side," and "driver and passenger door sill" to "left door," "left side," and "left and right door sill." The test procedure requires a pass/fail check for the visibility of the readiness indicator from the driver's DSP. The translation options provided for the readiness indicator in the test procedure should be consistent with the options provided in the regulatory text.

Potential Considerations

Using the test methods further developed for the FMVSS 100-series telltales, the project may develop options that address verifying the communication of ejection mitigation countermeasures information to the ADS.

Stakeholder and SME Review Input

The ejection mitigation countermeasure should have the capability of conveying information about the readiness of the system to the ADS. Reviewers had differing opinions on whether the information should only be conveyed to the ADS in an ADS-DV, or whether it should be conveyed to multiple or all DSPs to ensure a vehicle occupant receives the information. Therefore, multiple technical translation options for the countermeasure "readiness indicator" were presented.

Standards Incorporated by Reference

FMVSS No. 226 has three standards incorporated by reference: ASTM E29-06b, SAE Recommended Practice J1100_2009, which suggests SAE Dimension W7, and Ejection Mitigation Headform Drawing Package," December 2010, none of which pose a regulatory barrier.

Chapter 5. Test Method Evaluation Findings

Approach

The following section provides a recap of the approach presented in the Volume 1 report and the specific application of the approach for the Volume 2 standards covered in the current report.

Vehicle Functionalities

As described in the Volume 1 report, the team focused on the vehicle functionalities regulated in the FMVSS or required in the execution of the associated OVSC test procedures. Table 7 provides a recap of the identified functionalities.

Table 7. Functionalities Identified in Volume 1 and Volume 2 Standards and Test Procedures

Category	Functionality	Volume 1						Volume 2								
		102	108	114	118	138	141	101	103	104	110	111	113	124	125	126
Driving Tasks	Steering control			●		●	●				●	●				●
	Speed control (vehicle/engine)			●		●	●		●	●	●	●		●		●
	Service brake application			●		●	●				●	●				●
	Parking brake			●			●					●				
	Gear selection	●		●		●	●		●	●	●	●				●
Vehicle Communications	Telltales/ warnings/ indicators	●	●	●		●		●						●		●
Key/Ignition Function	Key insertion/ removal			●												
	Ignition start/stop	●		●	●	●			●	●	●	●		●		●
	Accessory mode			●	●											
Non-driving Tasks	Door open/close			●	●											
	Non-driving controls		●		●				●	●		●				
Environment Awareness	Visibility								●	●		●	●			

The first three functionalities—steering control, speed control, and service brake application—were further divided into subcategories of general and specific requirements. General functionalities are those that do not have prescribed values or patterns associated with the requirements. Examples of these can be found in the test procedure for FMVSS No. 138, which requires the vehicle to be driven in a particular location within a given speed range. However, no precise requirements are provided as to the steering, braking, or speed. In contrast, FMVSS No. 126 requires a very precise steering input both in terms of amplitude and timing. Demonstration of the general driving functionalities in FMVSS No. 138 are necessary to operate the vehicle, but they are not sufficient to be able to confirm that the requirements in FMVSS No. 126 can be executed. This finer division was included in the evaluation of the methods.

Test Procedure Description

The focus for the Volume 2 standards was the execution of FMVSS No. 126 test procedures, which required ADS operation beyond that demonstrated in the Volume 1 research execution (discussed in the Volume 1 report). FMVSS No. 126 is made up of two conditioning procedures for brakes and tires, followed by the slowly increasing steer (SIS) test defined in S7.6 and the SWD test defined in S7.9. The SIS provides a means to characterize a relationship between the steered input and vehicle's lateral response. Based on this relationship, the starting steering angle for the SWD is defined as the steering angle associated with 0.3 g lateral acceleration response during the SIS. The SWD test specifies a steering input that consists of a 0.7 Hz sine wave with a 500 ms delay during the second peak amplitude. The amplitude of the input is defined as follows:

$d_0 = 1.5*d_{0.3g}$ where $d_{0.3g}$ is the starting angle calculated from the SIS test

$d_i = d_{i-1} + 0.5*d_0$ for $d_i \leq 6.5*d_0$ or 270 degrees, whichever is less

To perform this maneuver in a consistent and repeatable manner, the automatic steering controller is mounted to the steering wheel and programmed to provide the steering input. The steering input is initiated at a coasting speed of 50 mph. The steering angle, yaw rate, and lateral acceleration are recorded. The basic operational flow is shown in Figure 13, with steering input and lateral acceleration response shown for conditions where the ESC does and does not engage. For the test vehicle used in this study, the final steering condition corresponded to $6.5*d_0$; however, the test was extended to include the conditions up to 270 degrees to investigate potential limitations.

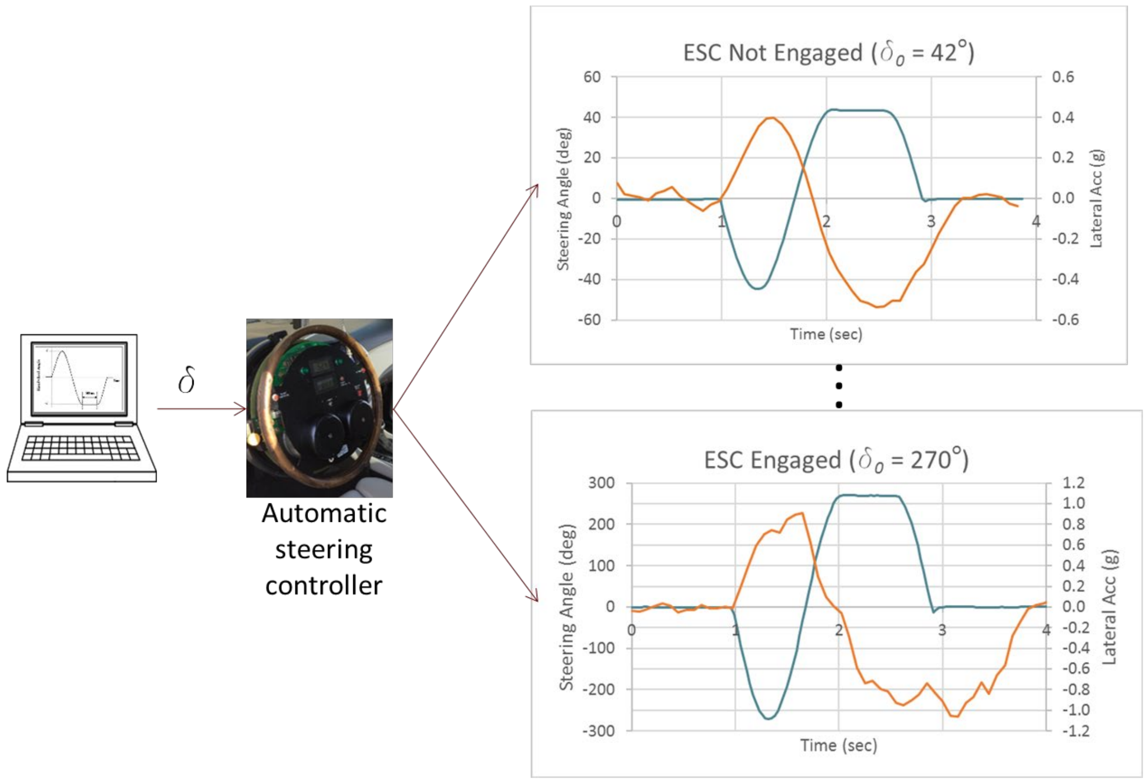


Figure 13. Operational Flow for SWD Test Using Automatic Steering Controller

For this study, the primary areas of interest were the execution of the SWD test (S7.9) to demonstrate the specific steering functionality required in the FMVSS and the tire condition procedure defined in S7.5, which requires the vehicle to be driven around a 30 m circle while the speed is adjusted to reach and maintain a lateral acceleration of 0.5 to 0.6 g. This requires a unique control loop that may not be typical for ADS-DVs.

Test Methods

Figure 14 shows the six test methods identified for evaluation categorized based on their ability to test the project's ADS-equipped vehicle. The vehicle-based methods follow the current testing model, in which the test procedures are executed using the vehicle make and model being evaluated. The non-vehicle-based methods are based on test results that evaluate the vehicle's expected performance via secondary means. While the information generated for evaluation may involve physical testing, final assessment is not based on the execution of the test procedures using the vehicle itself.

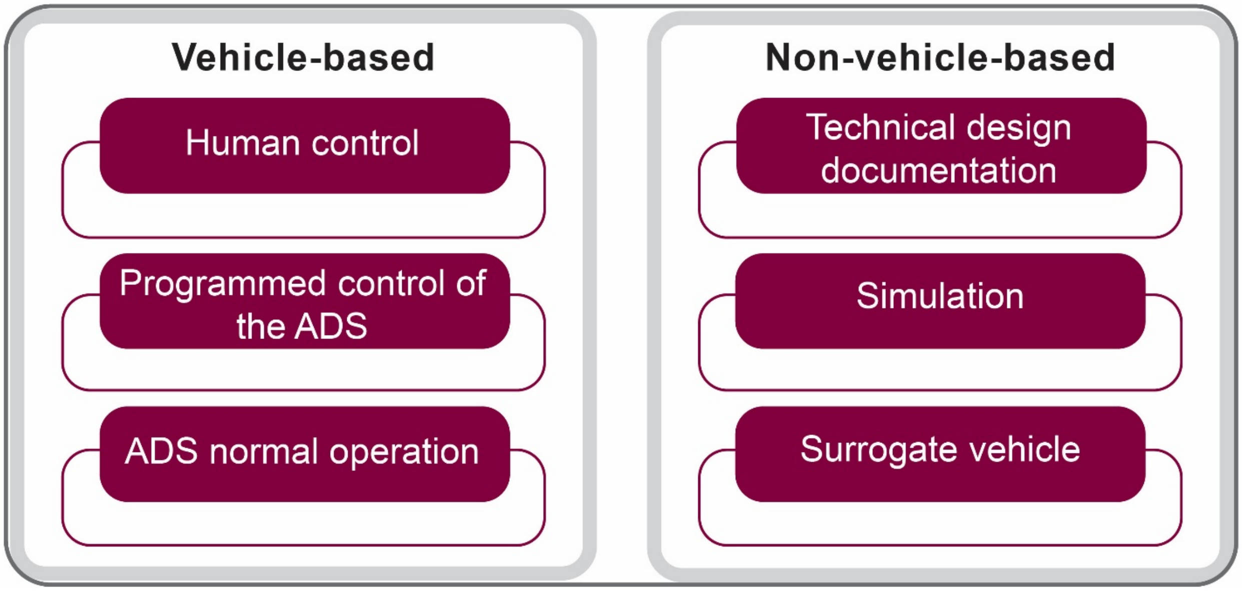


Figure 14. Potential Test Methods Investigated

The following sections provide a brief overview of the test methods, how they were implemented for the Volume 2 standards, and the associated results, followed by a brief discussion on the considerations for the different methods that build on those presented in the Volume 1 report.

Vehicle-Based Methods

While the primary test platform has direct access to the controls and signals, which allows for full control over the vehicle systems, the ADS-equipped test platform accesses the vehicle systems through the ADS computer. The ADS software architecture leverages the open-source Robot Operating System (ROS) framework and includes subsystems for perception, localization, world modeling/situational awareness, high-level routing, low-level motion planning, and vehicle control through an interface to the vehicle controller area network (CAN) bus.

Human Control

Concept
The concept behind the human control method is to provide the equipment that would allow a human to control the ADS-DV like a conventional vehicle, thus enabling execution of the current test procedures. For this method, the controls could be placed in, and hardwired to, the vehicle or they could be external to the vehicle and connected with a wireless link. For the latter method, in addition to the standard remote control of the vehicle, the vehicle perception sensor information could be fed back to the operator to allow for first person viewer, or telepresence, control of the vehicle.

Implementation
As discussed in the Volume 1 report, to evaluate human control operation, surrogate controls were added into the primary test vehicle to allow for operation from the passenger seat. These controls were tied directly to the subsystems that controlled the vehicle functionalities needed for the test procedures.

For the secondary test vehicle, a USB joystick controller was incorporated to allow the experimenter to directly inject steering, throttle, and brake inputs to the by-wire interface. This mode of operation bypassed much of the ADS architecture, specifically the route planning and lateral and longitudinal control subsystems used by the nominal driverless operation mode. A software driver opened a connection to the joystick controller and parsed its inputs. These inputs were encoded into ROS messages and transmitted directly to the vehicle interface and onto the vehicle CAN bus. The considerations to be made with this architecture-based dependency will be explored further in the Discussion section.

The focus of the Volume 2 standards for evaluating test methods was FMVSS No. 126. Due to the demands for torque and speed during the SWD maneuver in FMVSS No. 126, the steering motor had to be resized, as the steering controller used for executing the basic driving functions was insufficient. This limitation will also be explored further in the Discussion section.

The SWD test for human control created a unique configuration possibility. Adding a surrogate steering wheel allows input of an electronic signal into the ADS-DV's steering controller, which is normally operated by automated control. Running the test as it is administered today with surrogate human controls creates a scenario where a programmed input, the SWD, is used to drive the automated steering controller attached to the surrogate steering wheel, which then creates a programmed signal to feed into the ADS-DV's computer controller steering system. This amounts to turning a digital signal into an analog signal and then turning it back into a digital signal for the vehicle's steering system. While this is a viable solution, in discussions with NHTSA and stakeholders, it was decided that a more likely scenario would involve using the human control module as an interface to translate the programmed signal into a format that can be understood by the steering controller. Figure 15 provides a graphic representation of these two possible implementations.

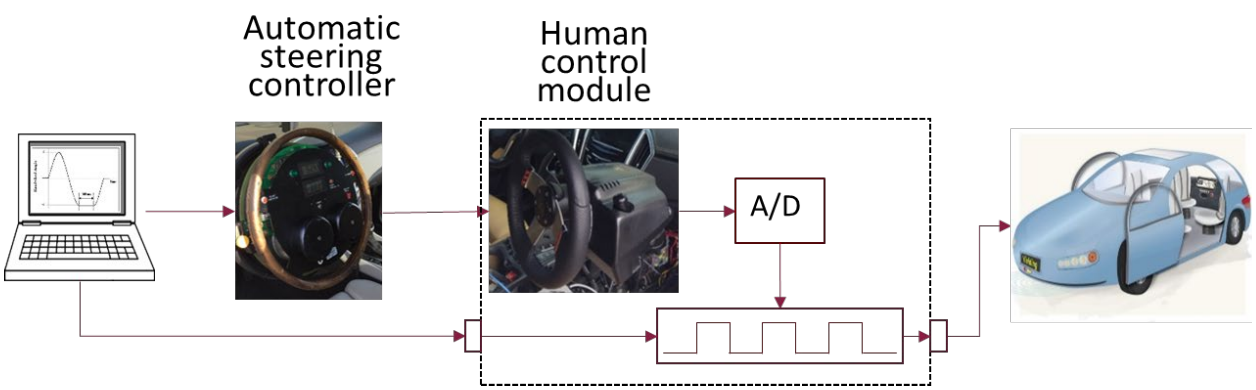


Figure 15. Options for Implementing Human Control for FMVSS No. 126

With this configuration, the SIS and SWD tests would be run as a programmed mode and the human control module would act as an interface box to the ADS. This would provide the means to reposition the vehicle via manual control while operating the specific steering commands under programmed control.

Execution
The research team implemented the configuration described above—an interface box received the command signal from the test computer and transmitted this to the ADS steering system to demonstrate the viability of the architecture. However, the final testing was executed using programmed control, as will be discussed in the Programmed Control section.

In addition, programmed execution of the functionalities associated with the Volume 1 standards research were based on FMVSS Nos. 114 and 138 OVSC test procedures.

Results
Results from the SWD test will be provided in the next section for the programmed test method.

Discussion
A more detailed discussion of the human control module was provided in the Volume 1 report. Some of the considerations are presented here as well.

The use of a human control module may provide a means to execute the test procedures similarly to the way they are executed today. Some items for consideration include the placement of the surrogate controls into a vehicle that is not designed for controls. This could be make- and model-dependent, which could add to the complexity of a single-solution design. Similarly, the interface to the vehicle will also likely be make- and model-dependent. Some of this complexity may be alleviated through standardization, but this raises additional considerations. A common interface may improve testability for new vehicles, but may also provide a standard input that might serve as a common attack vector.

Since the surrogate controls are taking a mechanical input and converting it into an electrical signal, opportunities to modify or condition the signal may exist during testing that do not exist under normal ADS operation.

While it is possible for the operator to influence test execution today, the fidelity of the surrogate controls could amplify this potential influence. For example, if the controls do not have feedback, the lack of normal cues that exist in manual controls could influence the operator's ability to execute the test in a similar manner. As discussed in the Volume 1 report, if wireless operation is employed, the operator's abilities could have an even greater influence.

The implementation of the human control method on the second test vehicle using a joystick controller revealed additional considerations. This embodiment may be similar to that implemented by manufacturers for the positioning of ADS-DVs in controlled environments, such as the manufacturing environment or shop floor.

Consistency, sensitivity to external factors, and cybersecurity are among the important considerations related to this method of operation. A human experimenter's actions when controlling the ADS can inject an element of uncertainty or non-determinism. Even a trained, experienced experimenter could manipulate the controls differently from one iteration of a test to the next. Different vehicles under test may also respond or behave differently to the commands, leading to different results even with identical or nearly identical manipulation of the controls. The interfaces for the human control equipment add a level of effort to implement if they are not already available, and also introduce another potential cybersecurity attack vector.

A wide variety of equipment and hardware could also be used to implement this method. Standardizing this hardware for testing, or at least the input signals generated, could aid in implementation and ease of use. Furthermore, constraining or moderating the input signals may be appropriate to improve the test team's safety (e.g., limiting accelerations, decelerations, or steering rates achievable). These constraints may be test-dependent, as some tests require aggressive maneuvers that would need to be implemented via the human control interface.

Programmed Control

Concept

Programmed operation is designed to leverage the automated functionality inherent to an ADS. The sequence of operations defined in the OVSC test procedures would be programmed in such a way that the vehicle would execute the test procedures independent of human control. Test procedures could be preprogrammed by the manufacturer or created with a scripting language that would allow a third party to configure the commands to control the functionalities required for a given test. The programs or scripting language could reside on the vehicle or could be contained on a device that is connected to the vehicle to execute the program or scripted routine.

Implementation

Programmed executions of general driving functionalities were performed using the vehicle and implementation described as part of the Volume 1 standards research. For the Volume 2 standards, preprogrammed scripts will be developed to execute the closed loop control for the tire conditioning test and the test sequence for the increasing steering angles associated with the SWD test.

Implementation of programmed operation on the independent research test vehicle will require additional development to bypass much of the ADS architecture, including route planning and lateral and longitudinal control subsystems used by the nominal driverless operation mode. Programmed operation is envisioned to be a modular software component that would allow for different control sequences to be programmed according to the FMVSS of interest. While this modularity may make the approach extensible, it also means the divergence of modules is possible, which may make some manner of standardization appealing.

Execution

Programmed execution of general driving and the functionalities associated with Volume 1 standards research were based on FMVSS Nos. 114 and 138 OVSC test procedures.

FMVSS No. 126 testing was performed at NHTSA's Vehicle Research and Testing Center (VRTC). The brake conditioning was performed with the manual vehicle controls while the tire conditioning, SIS, and SWD were performed under programmed control. Data was collected to compare with the baseline data gathered during a previous test session at VRTC, in which VRTC staff executed the test procedures according to the current standard for a manually operated vehicle. The baseline data was also used in designing the automated steering system to ensure the system could replicate the steering inputs. Figure 16 shows the initial turn of one of the SWD test runs with the steering wheel at approximately 135 degrees. The roll of the vehicle can be seen relative to the horizon.

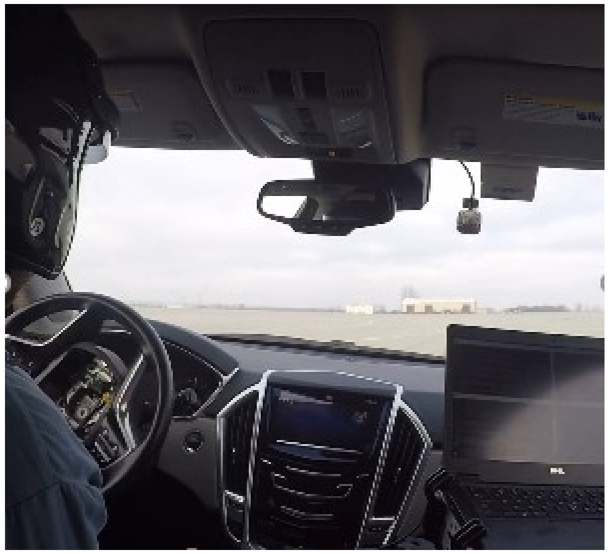


Figure 16. Initial Turn of FMVSS No. 126 SWD Test

Results
The following graph (Figure 17) provides output from the execution of the test procedures based on FMVSS No. 138 under programmed control. This particular sequence is for a low tire pressure state. The expectation is that the system will capture the change in low tire pressure state as reported by the vehicle. Since the test requires the vehicle to be driven within a given speed range for a minimum amount of time, it is also necessary to monitor speed and time above a given speed threshold (15 m/s). For this particular sequence, the tire pressure was reduced in one of the tires in accordance with the test procedures and then the vehicle was driven under programmed control around a predetermined route.

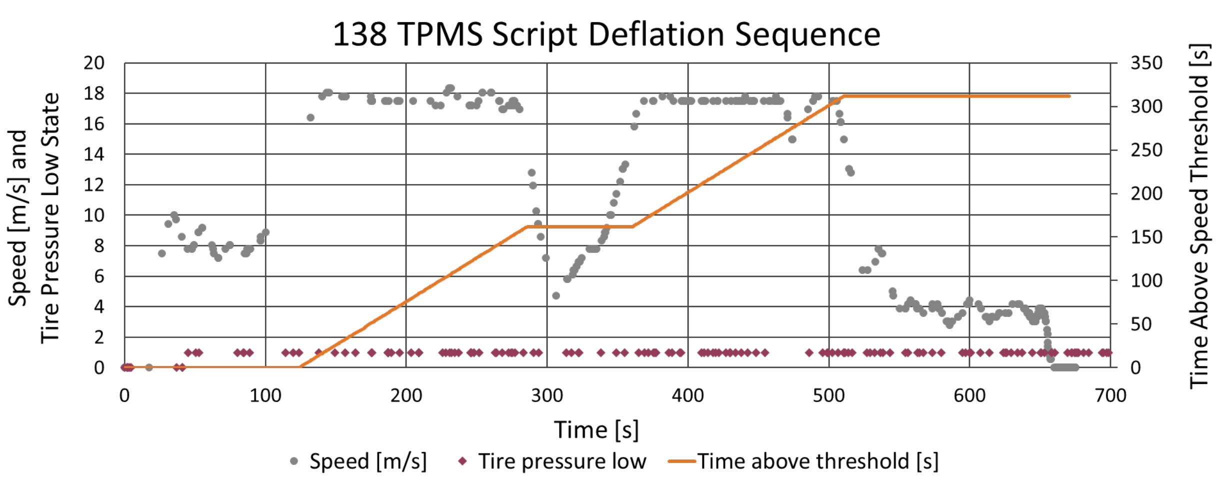


Figure 17. Example Results From the General Driving Procedures Based on FMVSS No. 138

The grey dots show the speed and indicate the ability to control speed relative to a given target. The maroon diamonds show the low tire pressure state. As the data shows, within 1 minute of driving after the tire pressure was reduced, the low tire pressure state went high, indicating the tire pressure monitoring system (TPMS) responded to the low tire pressure. The orange line is a timer programmed to keep track of the time the vehicle is operated within the speed range.

As Figure 17 indicates, the vehicle executed the test and captured the data associated with test procedures for driving functionalities. These included steering, speed, brake, gear selection, and ignition control. It was also possible to monitor and record vehicle state variables, specifically TPMS.

Subsequent results focused on the testing associated with FMVSS No. 126. Figure 18 shows the results from an intermediate test condition. While the steering inputs coincide, the yaw rate response lags in the baseline case compared with the ADS case. The pass/fail criteria are based on the peak yaw rate after the first steering reversal in relationship to the yaw rate at 1 sec and 1.75 sec after the completion of steering (COS). This is referred to as the yaw rate ratio (YRR) and is expressed as a percent. In order to pass the test, the YRR must not exceed 35 percent and 20 percent at t = 1 sec and t = 1.75 sec, respectively. While this impacts the final YRR values (5.1% and 3.7% for manual and ADS execution), they still fall well within the 35 percent limit at t = 1 sec after COS.

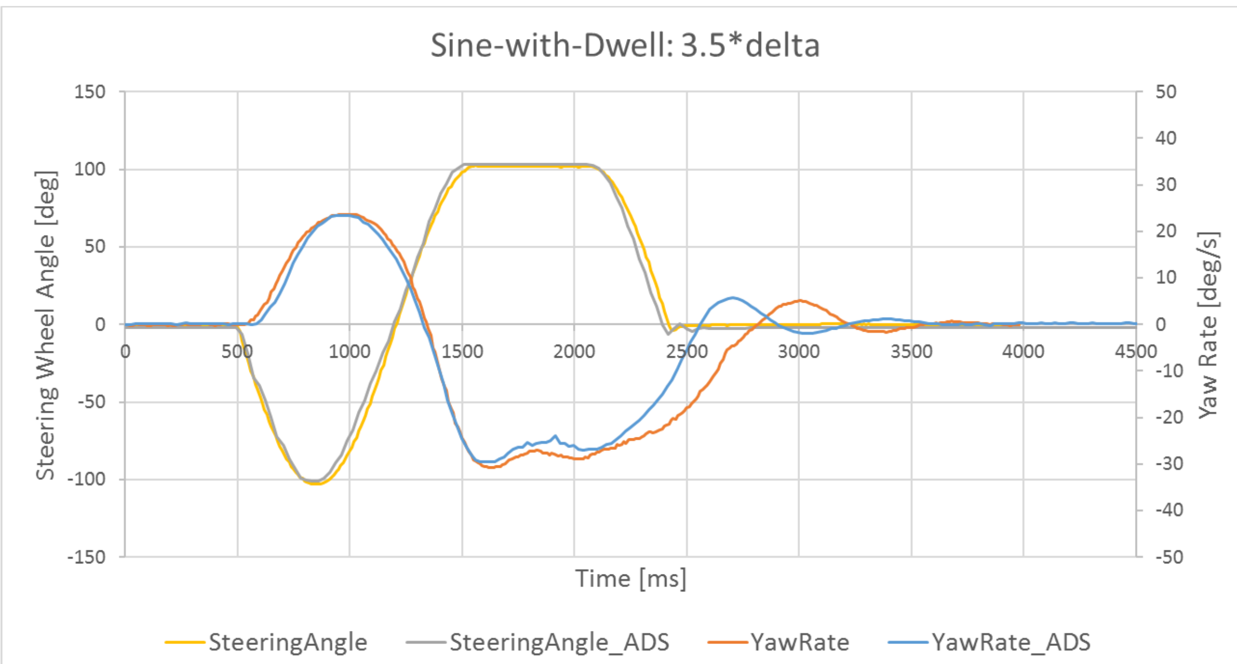


Figure 18. ADS Execution of SWD Compared to Baseline: Early ESC Engagement

The following plot (Figure 19) shows the results from the final test condition, which is 6.5 times delta (the initial starting steering angle input). For the steering condition shown, the YRR at t = 1 sec is 1.1 percent for the manual control (baseline) and 1.2 percent for the ADS control.

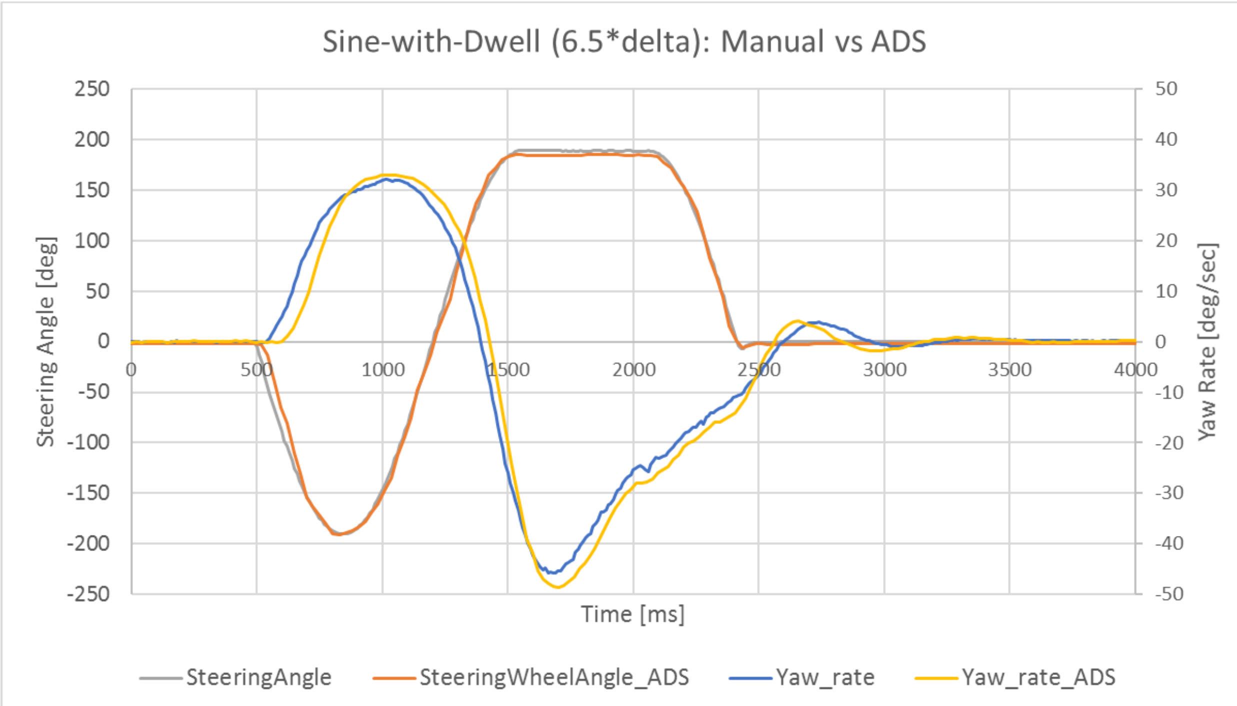


Figure 19. ADS Execution of SWD Compared to Baseline: Final Test Condition

It is important that the vehicle-based methods have the ability to replicate the input into the system that is currently generated by the automated steering machine. Looking at the completion of the steering input (Figure 20) allows an evaluation of the controller's ability to drive the steering input throughout the maneuver and, in this case, through all required test cases.

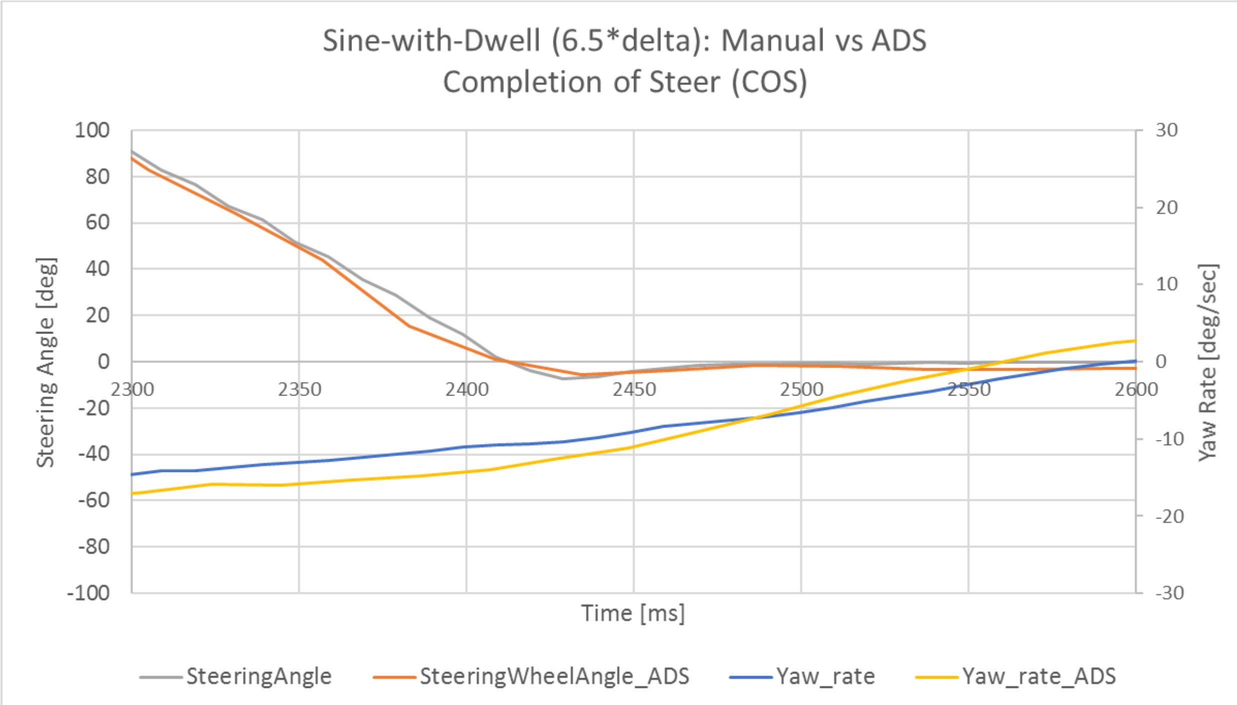


Figure 20. Completion of Steering Comparison: Final Test Condition

These results demonstrate the ability of the vehicle to replicate the results of the baseline test while in ADS operation. The offset in the yaw could be influenced by the difference in the temperature and surface conditions between when the baseline test was performed (mid-June) and when the final ADS test was performed (early December). While the baseline and the ADS testing would ideally be performed multiple times on the same or similar days, the results still confirm that it is possible to replicate the input into the steering system with the same pass/fail results.

Discussion

Programmed operation provides the opportunity to have repeatable and consistent test inputs. This is particularly relevant for the SWD test runs. However, the final position of the vehicle at the conclusion of each run is not consistent. Consequently, some flexibility in the routine that repositions the vehicle at the starting point of each run may be required. Depending on the test facility, this could be trivial or complex based on such things as facility features and shared usage.

The different potential embodiments of programmed operation—preprogrammed versus scripted and on-board versus plug-in module—provide different possibilities that should be considered. The preprogrammed routine provides a set of commands that can be tested and confirmed prior to release, allowing consistency in the execution of the test independent of the operator. However, depending on the test, independent input verification could be challenging. For the SIS and SWD tests, input could be verified by measuring a linkage in the steering system, such as the rack displacement.

A scripting language allowing an entity independent of the manufacturer to program the test procedures would provide an increased level of independence, but trust in the execution of the commands or verification of the output would still be required.

Having the program or scripting language reside on the vehicle introduces a potential risk in that the routine would be present on the vehicle at all times. Activating the routine during normal driving, either erroneously or malevolently, could create a safety risk to the occupant(s) and to those around the vehicle. Keeping these programs on a removable device eliminates the potential for activation while driving. However, the need for a device interface to the vehicle provides an additional potential attack vector for vehicle control. One SME suggested that a potential solution to both of these risks would be to have the manufacturer send an electronic control unit (ECU) with the programmed routines and the conflicting ADS constraints disabled. Depending on the level of modification to the ECU, however, this could create a situation where the vehicle being tested could be considered a different vehicle, as significant changes to the ECU might cause the vehicle to perform differently than under normal operation.

Initial testing revealed a potential consideration in that performance or test specifications could have a secondary effect of being minimum design criteria for systems not regulated by an FMVSS when the ADS is responsible for driving. While the FMVSS are focused on vehicle performance, the control inputs for testing associated with some FMVSS are based on inputs that a human could potentially provide rather than on human capabilities to safely operate a vehicle. FMVSS No. 126 reflects steering amplitudes and rates that have been demonstrated to be feasibly achievable for some drivers to ensure that the ESC system operates properly over the range of human-provided inputs. However, the higher amplitudes and rates do not necessarily correspond to all drivers' capabilities in all vehicles at all times. Results from Forkenbrock and Elsasser (2005) show that the peak SWR for four different drivers ranged from 608 deg/sec to 1,819 deg/sec depending on vehicle and filtering applied during processing. These results were used to help inform the test procedure's upper limit for the SWD steering input. Thus, the procedure is descriptive of the possible driver input rather than prescriptive of what a driver needs to be capable of for safe operation. Since not all drivers are capable of these steering inputs, it is conceivable that a manufacturer could design its ADS-DV to operate safely with much lower speed and torque requirements for their steering actuators than required for the automated steering machine currently used for testing. In this case, the test conditions would become minimum performance requirements not of the ESC system but of the steering automation subsystem. In other words, the conditions would be analogous to requiring a human driver to demonstrate the strength and agility to provide similar steering system inputs to those supplied by the automated steering machine.

Another consideration raised by FMVSS No. 126 S7.5 Tire Conditioning is the potential need to override the ADS constraints placed on the commanded inputs for occupant safety and comfort. Maintaining a path at a given speed is fundamental for vehicle operation on a roadway. This could allow for the tire conditioning procedure to be run under normal ADS operation if the threshold for lateral acceleration put in place by the manufacturer is not exceeded. However, it is likely that the threshold for sustained lateral acceleration would be less than the 0.5 to 0.6 g target. The American Association of State Highway and Transportation Officials (AASHTO) provides the simplified curve formula for calculating the minimum radius for the design of horizontal roadway curvature as follows:

$$R = \frac{V^2}{127(0.01e + f)}$$

Where

R = minimum radius (m)
V = design speed (kph)
e = superelevation
f = maximum side friction, which is provided by AASHTO

The above can be rearranged to give centripetal acceleration in m/s^2

$$a_c = \frac{V^2}{12.9R} = 9.8(0.01e + f)$$

Using the AASHTO values for friction (0.17) and the recommended range for superelevation (0 to 8 degrees) results in a range of lateral accelerations of 1.7 to 2.5 m/s^2 (0.17 to 0.26 g). If this is considered the safe speed for road design, it is likely that ADS-DVs will limit their lateral acceleration to something in a similar range for sustained cornering. If so, this is an example where the ADS may need to be modified to operate outside of its normal ODD.

ADS Normal Operation

Concept

The concept for ADS normal operation as a test method is to use the ADS-DV's normal operation design to exercise a given vehicle functionality associated with an FMVSS or to conduct applicable test procedures. For example, part of the test procedures for FMVSS No. 138 require driving for a given period of time within a speed bound at a given location. If this location is within an ADS-DV's ODD, then it may be possible to request a route that includes the test area to execute the driving portion of the test procedure.

Implementation

As discussed in the Volume 1 report, the primary test vehicle used in this study had ADS functionality but lacked the level of integration to perform as a production ADS would. To evaluate ADS normal operation, a research team member's ADS-equipped research vehicle was used for execution of a selection of general functionalities. For this vehicle, the nominal mode of operation was driverless with occupant waypoint/destination selection. The destination is selected through a tablet user interface, as shown in Figure 21.

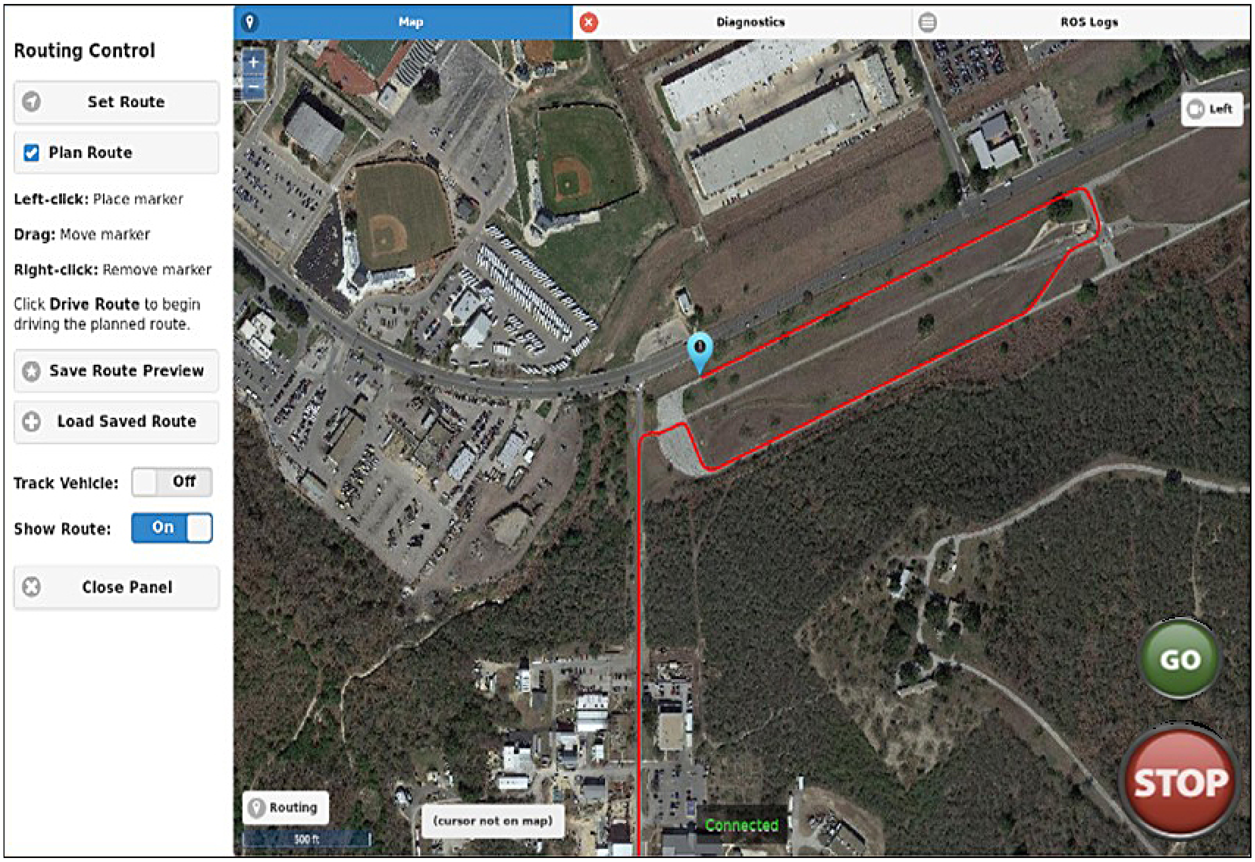


Figure 21. ADS-Equipped Research Vehicle User Interface

The user selects the desired destination from the waypoints provided and the ADS automatically generates an optimal route. The objective function used to generate the optimal route can support a variety of inputs; minimal travel distance was used as the objective for this testing. Once the generated route was approved and the ADS enabled, a pure pursuit steering algorithm managed lateral control and a proportional-integral-derivative controller managed longitudinal control based on a target speed. The target speed was provided by a software multiplexer that aggregated a number of speed recommendations and selected the optimal target speed, typically the lowest recommended speed. Desired steering, throttle, and brake inputs were then converted to appropriate CAN messages by a vehicle software interface. The research vehicle executed by-wire control of steering, throttle, and brake using the provided CAN messages.

The research vehicle that was used afforded complete visibility and open access to all of the ADS-related software subsystems and interfaces. As such, relevant data streams were identified, and sample test data was easily recorded during testing. On a production ADS-DV, some of this data may be considered proprietary and thus may not be similarly exposable. This is an important consideration, as alternative approaches for collecting the required test data may be necessary.

Execution

Several of the functionalities consistent with en-route-based operation were executed. In particular, basic driving functionalities were demonstrated along with those that require precise speed and lateral positioning. These latter functionalities confirm the ability to execute the

OVSC test procedures associated with FMVSS No. 141 but are insufficient to execute the precise steering requirements associated with FMVSS No. 126. The ability of the system to hold a precise lateral position and speed confirms the control algorithms' ability to follow a prescribed route. However, FMVSS No. 126 requires open loop control of the steering, which the ADS is unable to execute.

A more detailed description of the testing and results for ADS normal operation is provided in Appendix G.

Results
Figure 22 shows results from a portion of the test procedures designed to assess the ability of the ADS to execute specific lateral and speed control, as is required in standards such as FMVSS No. 141.

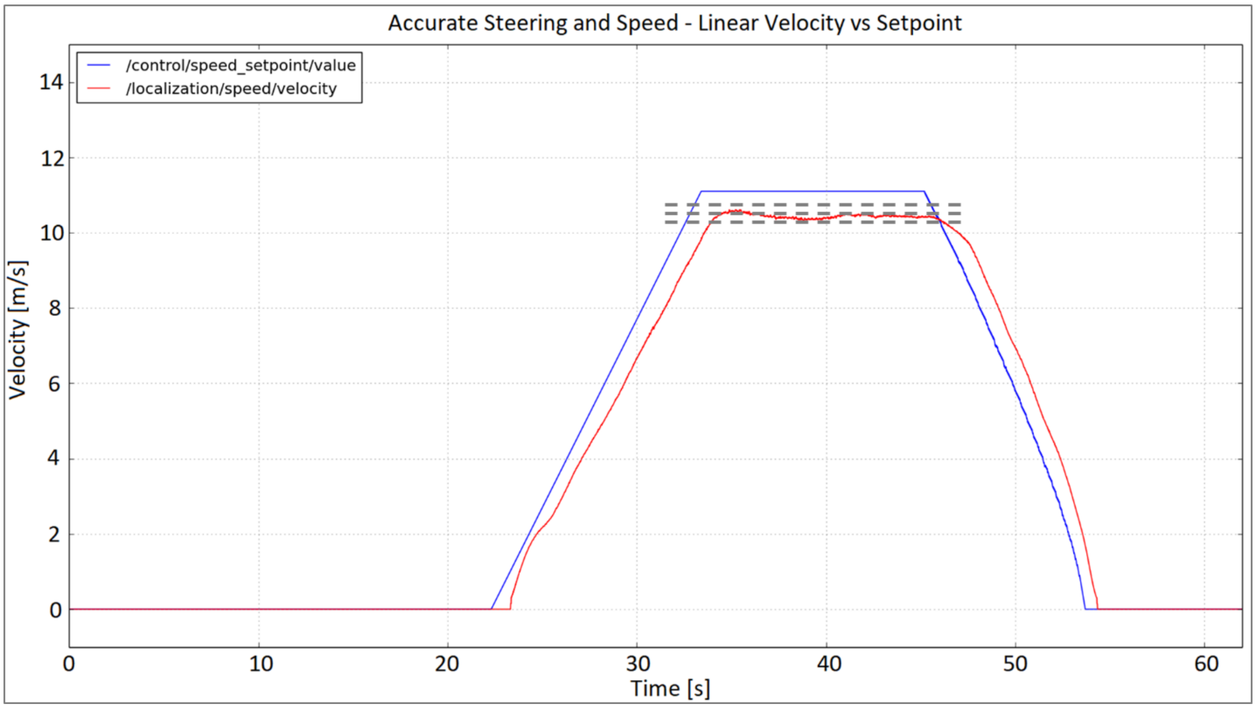


Figure 22. Example of ADS Operation – Target Speed Versus Actual Speed

A lag can be seen in the actual speed of the vehicle, and the final speed fails to reach the commanded speed. The algorithm is weighted to ensure the speed does not exceed the set point. FMVSS No. 141 has a speed tolerance of ±1 km/h (± 0.28 m/s). While the deviation is within this range, as shown by the dashed lines, the nominal value is outside the specified tolerance. Consequently, this particular vehicle would have to artificially increase the set speed, or the control algorithm would have to be modified for testing.

For the vehicle state monitoring test procedures, the TPMS state was not accessible on the network but the tire pressure was (Figure 23).

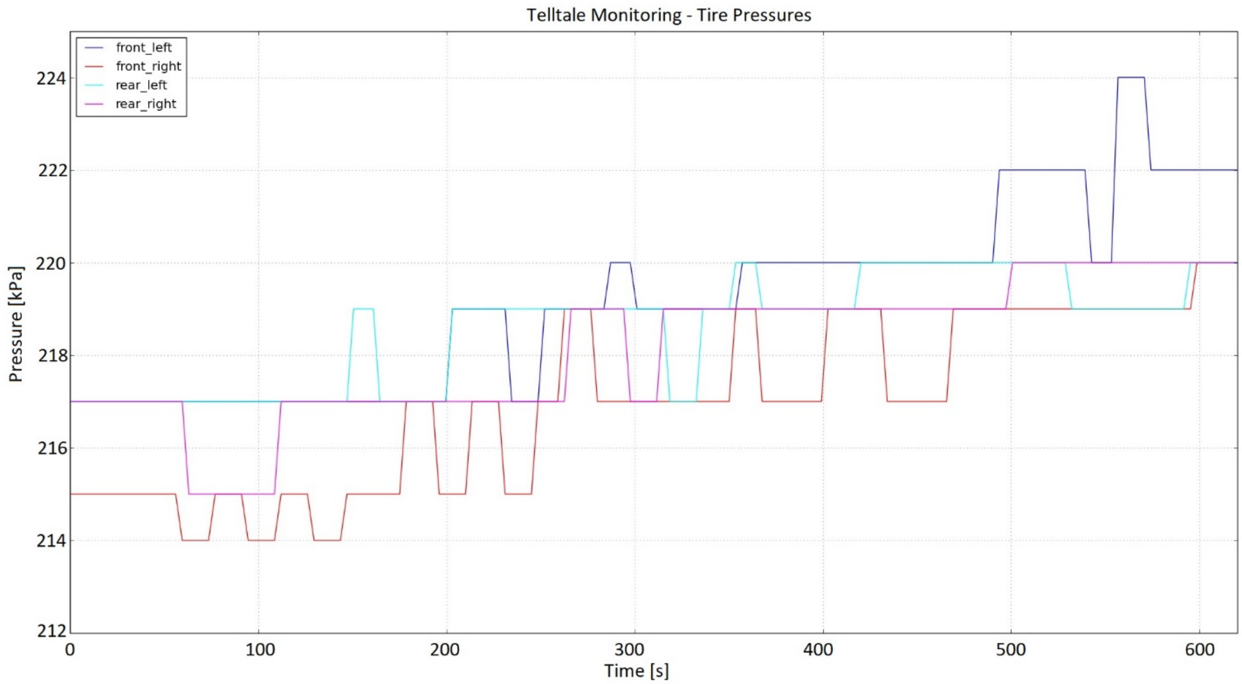


Figure 23. Sample Data From Vehicle State Monitoring Test – Tire Pressures

This data confirms that information can be accessed from the network, but it also demonstrates that the manufacturer would have to make channels available that may not otherwise be present. In this instance, low tire pressure state could be inferred from the individual tire pressures, but the TPMS state cannot be directly confirmed.

Discussion

While these test results provide insight into some of the considerations that may be pertinent for testing with normal ADS operation, they do not necessarily provide a direct assessment of testing feasibility. Because a research vehicle was used, access was available to parts of the system that may not be available for a commercial product, which could impact the ability to define certain test conditions, such as speeds.

Similarly, the rules that define normal operation or constrain the control inputs may not allow the vehicle to execute a test procedure as defined. A number of the test procedures that were implemented on the primary test vehicle had to be modified to accommodate some of the secondary vehicle's constraints. For example, the vehicle state monitoring test specified a speed range above the speed limit set in the ADS's digital map for the test facility. Consequently, the tests were run at 25 mph rather than modifying the speed limit.

As discussed in the Volume 1 report, there is also the potential that a given test facility may be outside the ADS-DV's ODD and therefore the map may not have the necessary localization information to operate. This is a potential consideration for programmed operation as well.

Non-Vehicle-Based Methods

As the name implies, non-vehicle-based methods rely on means that are not necessarily based on physical testing conducted to provide evidence of compliance. Methods that were identified include technical design documentation, simulation, and the use of a surrogate vehicle.

NHTSA has not generally used non-vehicle-based test methods to verify compliance. Instead, NHTSA's OVSC selects vehicles from dealerships to conduct physical testing to verify that the vehicle meets the standards. Non-vehicle-based methods may not be able to provide the level of compliance certainty achieved through execution of a physical test with a vehicle. However, the method does provide an option for verifying compliance when extensive barriers to physical testing may exist.

Technical Design Documentation

Concept

The approach taken for the technical design documentation is to expand upon the Test Specification Forms currently used by OVSC. The results of this effort were reported in detail in the Volume 1 report. A short recap is provided here for context.

Implementation

During the Volume 1 standards research, the project evaluated the potential use of technical design documentation to provide sufficient information and detail to show the system was designed to be in compliance with FMVSS No. 138.

Test Specification Forms are completed by manufacturers and submitted to NHTSA's OVSC after OVSC has selected one of their vehicles for potential testing. The forms vary, but OVSC generally requests some, but not all, of the information needed to verify that a vehicle complies with an FMVSS. It should be noted that not all FMVSS have an associated form. The following example is a subset of the type of information that could be required using this method and does not include the entire standard.

FMVSS No. 138 ADS-DV Technical Design Documentation Method Example (Item number 4 D) provided in the Volume 1 report asks the manufacturer to provide a systems diagram and identify vehicle information as shown below:

4. TPMS Information

   NOTE: If more than one level of TPMS is offered for the same vehicle (base versus luxury), provide information for all TPMSs. If different inflation pressure sensors (direct systems) are used depending on the rim type, provide information for Items 4.B. and 4.C. for each rim offered.

   A. Type: ____

   B. Tier-one TPMS supplier: ____

   C. Inflation pressure sensor part#/model: ___________________________________

D. Provide a systems diagram of all TPMS components including, where applicable, anti-lock braking system, speed sensors, inflation pressure sensors, antennas, electronic control unit, display interface (module), labeled with the applicable part numbers. The diagram must include the release date and revision date (if any), and it must identify the vehicle make, model, model year, and body style to which it applies.

Figure 24 shows a sample of what the systems diagram for the TPMS components could include for technical design documentation. The vehicle's overall TPMS design is explained, including that the vehicle's design connects the body control module to the ADS.

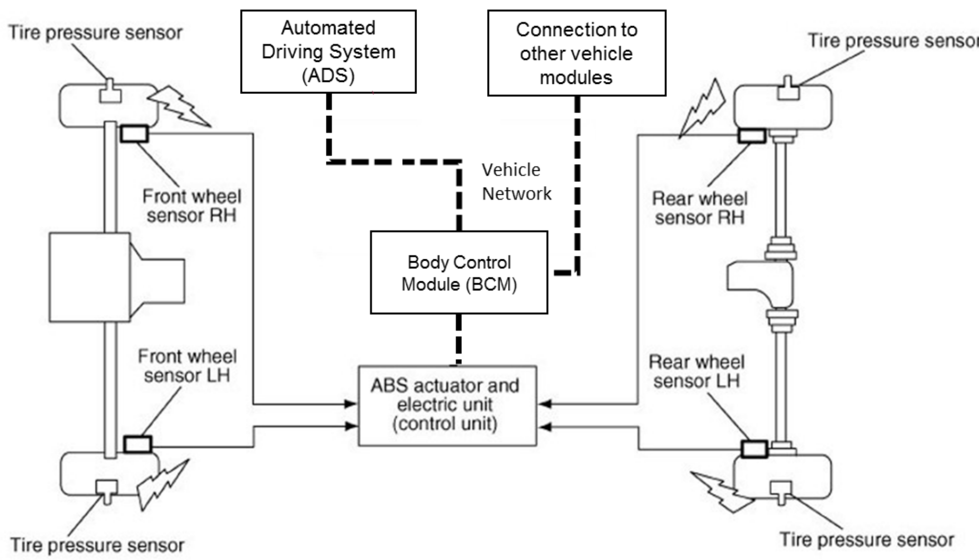


Figure 24. TPMS System Diagram

Figure 25 provides a high-level system architecture for the TPMS showing the connection between the TPMS sensors, the body control module, vehicle display, and vehicle network.

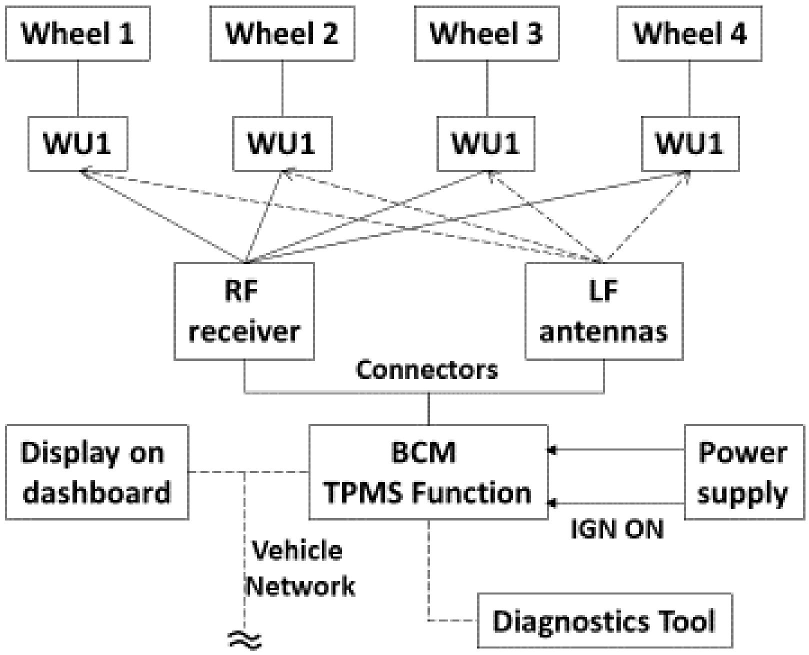


Figure 25. High Level System Architecture for TPMS

Item 6 B in the ADS-DV Technical Design Documentation Example, presented below, requests that the manufacturer describe how a low tire pressure state is communicated to the ADS. It asks for a schematic diagram showing the electrical connection transmitting the low tire state to the ADS. Similar to the system diagram, the release date and revision level(s) (if any) are also requested and the manufacturer is asked to identify the vehicle information on the diagram.

6. Low Tire Pressure Indicator

   A. Explain system calibration requirements. State whether or not the system must execute a calibration procedure before it will properly identify an under-inflated tire.

   B. Describe how the low tire pressure state is provided to the ADS. Provide a schematic diagram showing the electrical connection from the low tire state to the ADS. The diagram must include the release date and revision level (if any), and it must identify the vehicle make, model, model year, and body style(s) to which it applies.

   C. Provide the TPMS activation pressure set point (the pressure at which the low tire pressure warning state is communicated to the ADS and, if applicable, whether the telltale is set to illuminate). If different inflation pressures are specified for front and rear tires, indicate if the TPMS has two activation pressure set points. Provide one of the following items, either (i) or (ii).

      i. Provide the software architecture used to define what constitutes “low tire pressure” within the meaning of S4.2(a). The software architecture must include the software release date and revision level (if any).

Or

ii. Provide the ADS-DV network data log recorded during an FMVSS No. 138 physical test for the vehicle selected. The physical test results need to include documentation demonstrating that the S6 test procedures were followed. Provide test date, test reference number and test location.

Figure 26 is a schematic diagram that may be provided for item 6 B to help in compliance verification. This type of diagram could potentially demonstrate that the parameter IDs from the tire pressure monitoring module—in this example, 14, 13, 15, and 16—are connected to the ADS's Parameter IDs 5, 23, 31, and 47.

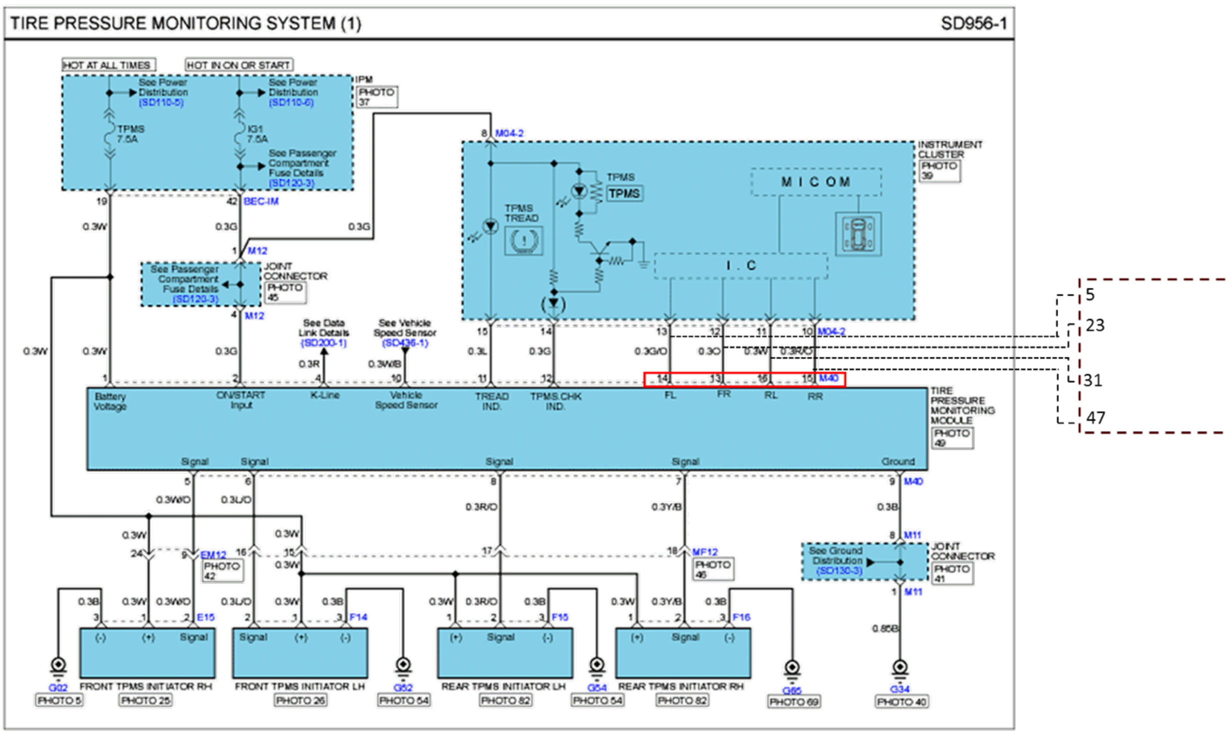


Figure 26. Schematic Showing Theoretical Example of TPMS to ADS Connection (Adapted From Autozone, 2008)

The previous diagram and schematic may not be sufficient for NHTSA to verify compliance to FMVSS No. 138. Additional information, such as a demonstration that the low tire pressure state is communicated to the ADS and, if applicable, whether a telltale illuminates, could also be documentation requirements. Other information could also be useful; for example, the software code used to define what a "low tire pressure" is within the meaning of S4.2(a) or provision of the network data log recorded during an FMVSS No. 138 physical test using the procedures set out in S5 and S6. These are requested in item 6 C, as outlined above.

Discussion
Per the current compliance verification process, NHTSA independently purchases production vehicles for physical testing to ensure that the vehicle, as manufactured and as being sold to the public, meets FMVSS requirements. This process helps NHTSA verify the adequacy of the manufacturer's quality control systems, manufacturing processes, and materials.

One of the primary considerations of using technical design documentation as well as other non-vehicle-based test methods is whether they will allow verification of the compliance of actual production vehicles, and not just illustrate the theoretical or ideal design of a vehicle or system. Deeming a design to be appropriate may not be sufficient to ensure that the end-product delivered to the consumer complies with the FMVSS. Additionally, even if there are situations where the research team believes that technical documentation might be viable for one standard, that does not necessarily mean it will be suitable for any other standards.

Simulation

Concept
Simulation was evaluated as a non-vehicle-based test method to determine its viability as a test method to verify ADS-DV compliance. As previously noted, for FMVSS testing, NHTSA currently purchases a vehicle from a dealership, outfits it with instrumentation, executes a physical test (e.g., OVSC test procedure, depending on the standard), and assesses the computed response metrics. Although the compliance verification process does (depending on the standard) include information submitted by manufacturers (e.g., NHTSA's Test Specification Forms), NHTSA verifies a vehicle's compliance independently of the manufacturer. This study will assume a similar structure and consider options for an independent process for simulation as a possible test method. The results of the virtual simulation are compared to real world data to draw conclusions about the effectiveness of the process, significant parameters defining the system behavior, and individual parameter sensitivity to the process. It is important to highlight that this study does not consider replacing vehicle-based compliance testing, but rather evaluates some aspects of using virtual simulation to augment physical testing for specific tests that are expected to have associated barriers on most production level ADS-DVs.

A more thorough presentation of this task is summarized in the following sections and is further described in Appendix H.

Implementation
For simulation to be a viable compliance test method, there must be trust in the model and its simulation output. The first step of this process is to identify the important model parameters directly related to the systems being tested. This can be established through theoretical examination of the system's underlying equations of motion or through experimental means. Experimental means can be performed with virtual simulation, given a valid model of the system has been created. This study will focus on simulation model iteration and statistical analysis to help identify the significant and sensitive model parameters. Model iteration refers to the repeated simulation of vehicle maneuvers while systematically varying the mathematical model parameters. After model iteration is completed, parameter statistical significance will be examined, and then those parameters will be investigated for their required accuracy to provide valid model outputs. The steps used for this study are outlined in the workflow diagram below (Figure 27).

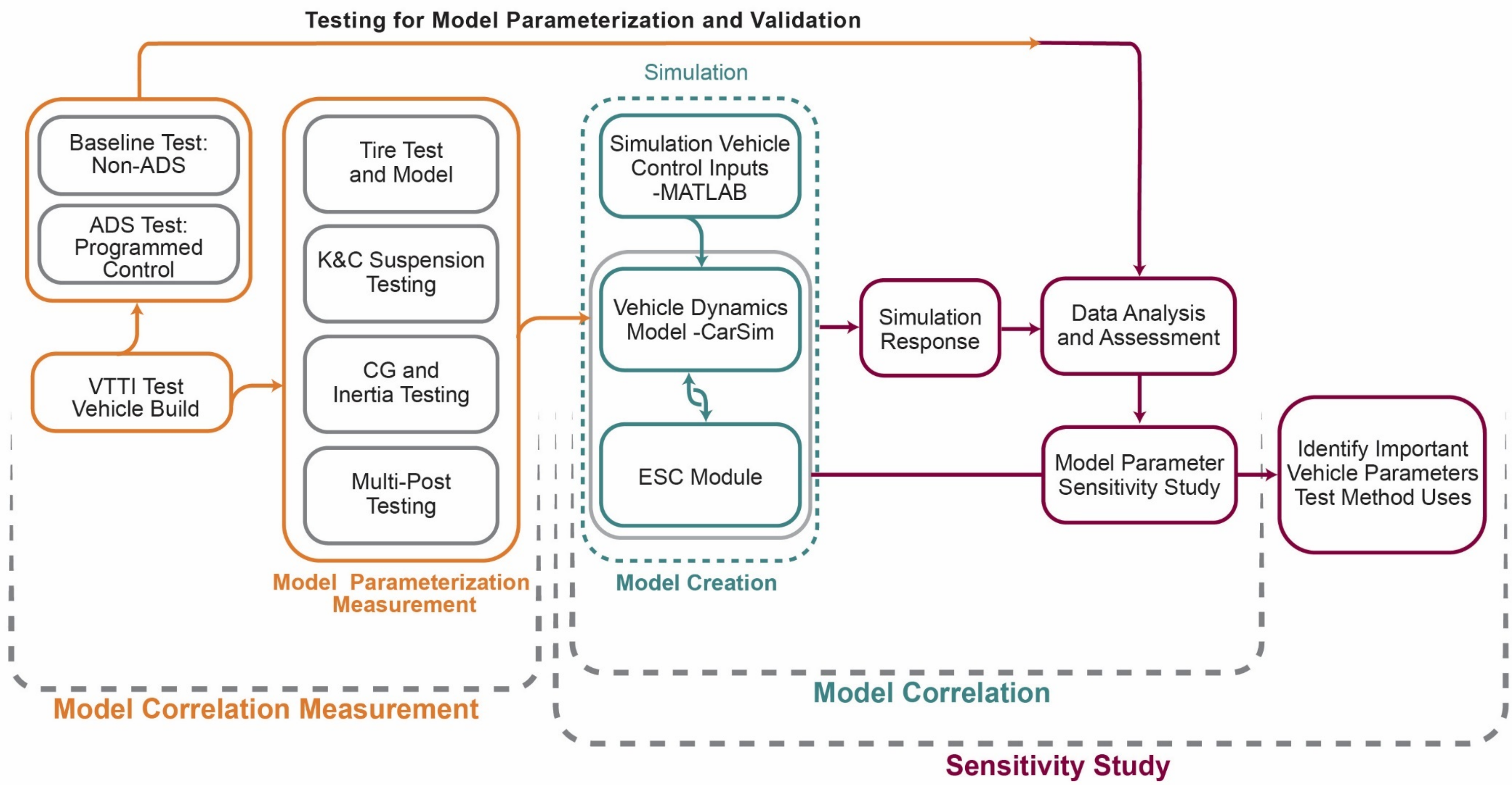


Figure 27. Simulation Workflow

Execution

The VTTI test vehicle build was the physical vehicle selected for this study. The results of the baseline test and the ADS-DV test with this vehicle are discussed in the Model Correlation section below. The other key aspects of the workflow are discussed in the following sections.

Model Measurements

To properly parameterize the relevant mathematical models, the physical vehicle components and overall vehicle system performance had to be tested and evaluated. Parameter and component measurements were performed to quantify center of gravity, mass moments of inertia, suspension characteristics, steering characteristics, and tire response. Vehicle-level measurements were performed during the FMVSS No. 126 test procedure and on a four-post shaker rig. Parameter and component level measurements were completed first, then the vehicle was instrumented and tested as a system in the laboratory.

Model Creation

The vehicle model was created by parameterizing the appropriate math models within the CarSim simulation environment. The model was primarily developed from the parameter measurements while estimated unsprung mass values were determined from the four-post shaker rig testing response.

Results

Model Correlation

Correlation was assessed between the field and model data by simulating FMVSS No. 126 and four-post shaker rig tests, and then calculating the correlation coefficient, coefficient of determination, and root mean square error between the model response and field test data. Results showed that there was sufficient correlation between the vehicle suspension and inertial models and the full vehicle system performance. Model correlation investigation also offered justification for implementing a mathematical ESC model and provided the reference for properly parameterizing that model. In validating model correlation, two inferences could be made about the measurements taken. The first is that by defining vehicle-specific mathematical models for inertial, geometry, suspension, steering, and tire response while using a more general powertrain mathematical model, the model parameter measurements and associated parameterized mathematical models produced an adequate representation of the full-vehicle system to simulate FMVSS No. 126. The second is that the model correlation measurements, as performed, offered adequate reference to determine correlation between real-world and simulated test data.

Model correlation investigation also offered ISO 19365 as a potential approach to model validation specific to FMVSS No. 126. ISO 19365 specifies comparison requirements between virtual simulation and field data to establish a valid simulation for FMVSS No. 126. ISO 19365 was applied as a method for evaluating model quality due to parameterization changes, which is not the identical application of the standard. It was also noted that ISO 19365 provides metric tolerances for the first two peaks, yaw rate crossover, and the lateral displacement, which may not adequately address the end of maneuver behavior.

Parameter Reduction Study
The simulation was iterated to provide insight into the parameters that drive system behavior. The iterated model outputs were compared to the baseline model response or field data through a variety of metrics. Time history correlation metrics, FMVSS No. 126 metrics, and ISO 19365 metrics are all possible sources of reference and were used throughout this work. N-way analysis of variance (ANOVA), D-optimal design, and parameter reduction were used to examine the effects of varying model parameters. N-way ANOVA analysis provided the means by which to establish statistical significance while D-optimal design and parameter reduction established proper design space coverage. The N-way ANOVA results were examined with reference to FMVSS No. 126 and ISO 19365 compliance metrics to assess model response for the purpose of identifying parameter sensitivity.

Parameter reduction successfully identified and eliminated parameters whose variation did not produce statistical significance or did not result in simulated non-compliance based on the established metric from FMVSS No. 126 and ISO 19365. This enabled the study to focus on the five parameters that had a significant impact on simulation response (i.e., XCG, ZCG, IZZ, IXX and tire model)

Sensitivity Study:
Once the non-compliant cases were correlated with the statistical results, the acceptable amounts of variation in the relevant parameters were examined by targeted simulation. These acceptable variation ranges were then related to measurement accuracy of the vehicle system and components. This enabled identification of the potential measurement accuracy required for establishing model trust and simulation output for the specific test vehicle.

The sensitivity study provided the maximum amount of acceptable model parameter variation for the five identified parameters in the parameter reduction study. Analysis of the response data to the ISO 19365 specification revealed that more than 10 percent parameter variation caused calculated non-compliance. Analysis of the response data to FMVSS No. 126 specifications showed that more than 20 percent parameter variation caused calculated non-compliance. Since the realistic parameter set had less than 5 percent variation, it may be possible to parameterize a vehicle dynamics model that represents the physical system with proper consideration of the ESC.

Discussion
The work performed in this study helped identify considerations for developing trust in a mathematical vehicle model and simulation. The constraints of the study only allowed for evaluation of one vehicle with an ESC model that was approximated based on the ESC performance of the physical vehicle. Future work could include evaluation of other vehicle classes and inclusion of the actual ESC either through a manufacturer-supplied model or co-simulation with the ESC hardware through HIL.

While the simulation effort implemented a full software-based solution, the use of HIL was scoped to identify potential HIL concepts to use as part of simulation. This task focused on developing potential test cases, system architectures, testable characteristics, component definitions, and guidelines for implementation. This provides a knowledge base to inform potential considerations regarding HIL simulation and aids in the integration of an HIL solution. Results from this effort are presented in Appendix I.

Figure 28 below outlines some of the process options for simulation as a potential method for compliance verification.

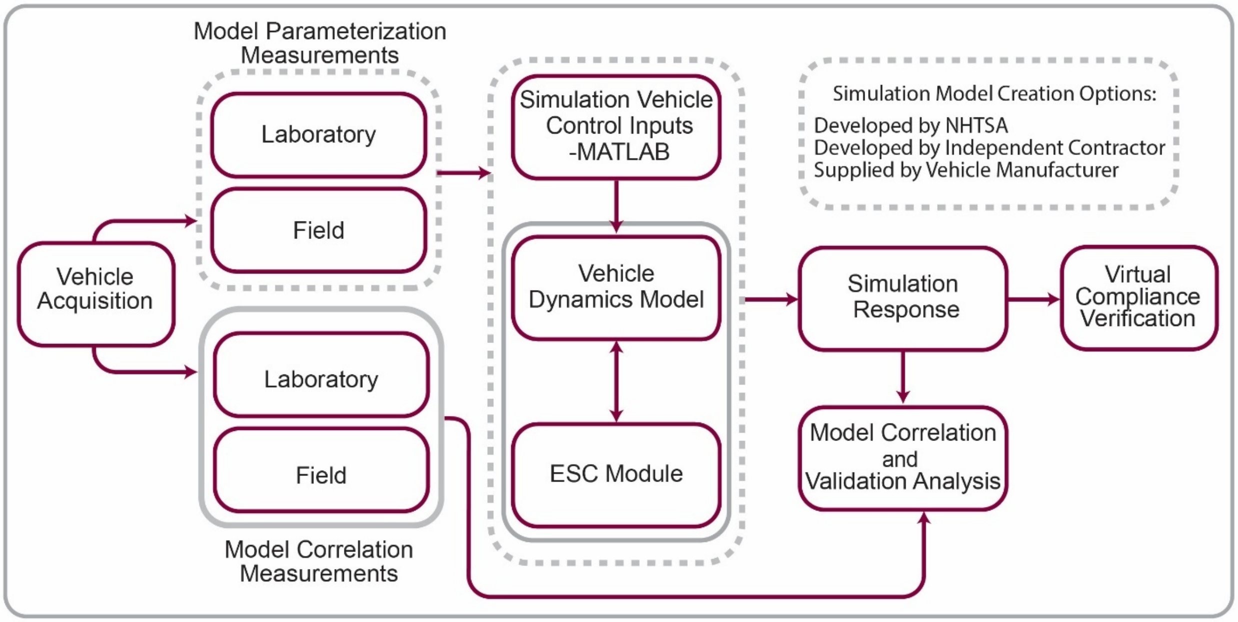


Figure 28. Potential Simulation Compliance Verification Process

The potential process for performing simulation compliance starts with vehicle acquisition and includes physical testing performed by NHTSA or an independent test laboratory (e.g., OVSC Contract Compliance Test Laboratories) to help provide compliance certainty. The physical testing may include both laboratory-based vehicle and component testing, as well as vehicle-based field testing. Field testing would not be the FMVSS No. 126 required SWD test, but might consist of normal driving, transient maneuvers, or other inputs that would exercise the vehicle and generate vehicle responses that could be used to validate the mathematical vehicle model. Vehicle-based methods (human control, programmed control of the ADS or ADS normal operation) could be used to exercise the vehicle during field testing. The physical vehicle compliance testing associated with the process flow defined above is contained within the model creation and correlation steps. If the model was supplied by the manufacturer, the focus of the physical testing would be collecting correlation data to verify that the model is a suitable representation of the vehicle for compliance evaluation. This testing would be a small subset of the test data required for this study (Model Correlation Measurements shown in Figure 28 above, described in detail in Appendix H). The model correlation and validation analysis could be considered part of the required compliance steps to verify the virtual compliance result. If the vehicle dynamic model and simulation were built and parameterized by NHTSA or an independent test laboratory, it is likely that all of the physical testing performed in this work may need to be considered (e.g., Model Parameterization Measurements and Model Correlation Measurements from Figure 28, described in detail in Appendix H). Once the model creation and correlation steps were completed, the virtual compliance verification could be completed by

NHTSA or the independent contractor, who would run the simulation and verify that the response is compliant with FMVSS No. 126.

Surrogate Vehicle

Concept

Another proposed method is the use of surrogate vehicles, in which a production vehicle with manual controls would be used to demonstrate compliance for a vehicle built on the same platform without manual controls. While this method would employ physical vehicle testing, it does not test the actual vehicle being evaluated for compliance. As such, this method is classified as a non-vehicle-based method.

Implementation

In order to physically evaluate this method, a pair of production vehicles—the conventional production vehicle and associated ADS-DV—would need to be available. This vehicle pairing is not currently available on the market, so no testing was performed in this study. Accordingly, the method is described and some of the potential considerations are discussed, but no evaluation of the method was carried out.

Discussion

The use of a surrogate vehicle for compliance verification would be limited to ADS-DVs that are based on an existing manual control platform, thus limiting this method's applicability. The surrogate vehicle method assumes that modifications do not change the performance of the equipment or system being evaluated. There would likely need to be some form of documentation capturing any differences. In addition, SMEs who commented on this potential method thought it would be available only for a small number of platforms and for a relatively short time frame, as this approach to ADS-DV development was seen as an interim solution for select manufacturers.

Evaluation

The evaluation of the methods focused on two aspects: (1) where applicable, confirming the method's ability to execute the functionalities associated with research test procedures and (2) qualitative evaluation based on criteria pertinent to compliance verification. In addition, the time horizon was considered for the different methods to examine which may be more suitable for the Volume 1, Volume 2, and long-term research timeframe.

The previous section discussed the results of the different methods relative to execution of the functionalities. For the non-vehicle methods, the research looked at specific standards as test cases to provide insight into their potential role in the process. In this section, the criteria-based evaluation is presented, including an overview of the evaluation process, a review of the criteria, and a summary of the considerations identified based on the evaluation process.

SME Feedback Meeting Data Analysis

This section details the methods used to identify the themes and opportunities associated with the qualitative portions of the SME feedback. Qualitative data analysis followed a four-step process that draws upon Marshall and Rossman (1999) and a modified version of framework methodology developed by researchers from the National Centre for Social Research (Ritchie, Spencer, & O'Connor, 2003). This approach has been used successfully in several past VTTI research efforts (e.g., Blanco et al., 2015) and allows researchers to manage and analyze the data in a logical and complete manner. Using this iterative approach allows the data to be transformed from recorded audio, to written transcripts, to charts and data in a manner that is comprehensive, transparent, and traceable.

To organize the data, researchers reviewed and became familiar with the dataset. This included cleaning the data (e.g., minor editing necessary to make materials retrievable) and preparing the data for analysis. To prepare the data for analysis, key sections were identified by the focus group moderators and transcribed using established protocols designed to ensure consistency across all transcripts. Notes taken by the moderators were also compiled to supplement the targeted transcription. Finally, participant responses to each assessment sheet, both individual scoring and written comments, were combined for analysis.

Next, researchers reviewed the transcripts, moderator notes, and combined assessment responses to become familiar with key themes and subthemes. The initial themes and subthemes closely followed the test methods, evaluation criterion key questions, and follow-on question areas within each SME feedback meeting. Themes and subthemes were then arranged in a logical order with individual spreadsheets, with the spreadsheet tabs serving as an index.

Responses were coded by theme and subtheme and grouped according to emerging patterns or categories. The indexed comments were arranged into assessment criterion-specific workbooks, and individual spreadsheets (or thematic charts). These spreadsheets/thematic charts were then further sorted by subtheme (e.g., vehicle- and non-vehicle-based test methods) and secondary subthemes (e.g., question or follow-up question). Finally, categories of similar ideas were created based on the subthemes. The secondary subthemes and categorical responses are reported in the subsequent sections (Figure 29).

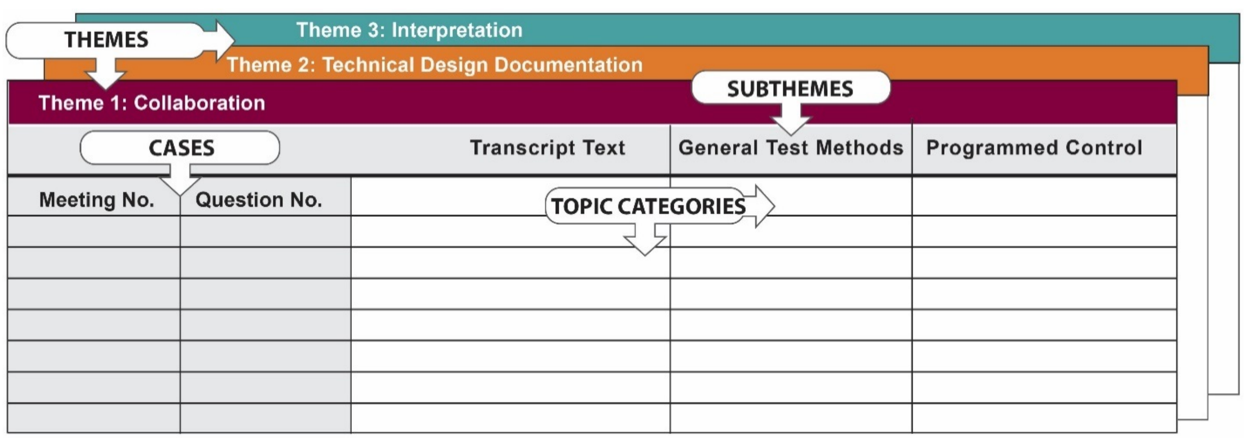


Figure 29. Illustration of the Data Analysis Process (Adapted From Ritchie et al., 2003)

To better understand the information provided, the findings from the thematic analysis were then considered concomitantly with the previous stakeholder and SME input (e.g., feedback obtained during the stakeholder meetings) and the results of the initial vehicle- and non-vehicle-based test activities.

Evaluation Review

This section first looks at SME feedback on the criteria to provide context for SME comments and subsequent scoring of the methods. Following are common themes that were expressed during the discussion and in the written comments. Finally, a review of the SME scoring is provided along with the general comments for each criterion based again on verbal and written comments that were captured during the sessions.

Criteria Ranking

The following tables (Table 8 and Table 9) provide a list of the criteria used for the evaluation, the concept behind each, and the operational definition. The final criteria list was based on feedback from NHTSA, stakeholders, and SMEs prior to the final SME review. Criteria are divided into two categories. The first category includes criteria primarily related to the test methods rather than the execution of test procedures. These are categorized under general considerations. The second category, test and functionality execution, focuses on the methods as they relate to the execution of the procedures or specific functionalities.

Table 8. Criteria: General Considerations

Criterion	Concept	Operational Definition
Safety	Can the test be performed safely?	Number and complexity of special conditions, compared to baseline, required to execute the test safely.
Cost estimate for manufacturer	What are the initial (including development and equipment) and recurring costs?	Relative cost for manufacturer to develop/implement method for new vehicle model/platform.
Cost estimate for NHTSA	What are the initial (including development and equipment) and recurring costs?	Relative cost for NHTSA to execute test on new vehicle model/platform.
Sensitivity	Are the results insensitive to changes not associated with the test?	Observed differences, variance in intermediate steps, or differences in results due to factors not controlled in test procedures (e.g., test operator, location, GPS signal quality, etc.) that may impact final result.
Standardization	Does the method (e.g., associated test tools and evaluation criteria) lend itself to standardization?	For methods that lend themselves to standardization, the level of effort required for standardization.
Cybersecurity	What, if any, is the relative level of cybersecurity considerations that could be introduced by a given method?	The possibility of introducing additional cybersecurity vulnerabilities and attack vectors.
Gaming possibility	Is a particular method susceptible to "gaming" a given test?	Ease with which a test method would allow the vehicle under test to be tuned to perform differently during testing as compared with normal operation.

Table 9. Criteria: Test and Functionality Execution

Criterion	Concept	Operational Definition
Preparation effort	Are there additional challenges in setting up an ADS-DV compared to a conventional vehicle?	Number of steps or amount of time required to set up vehicle prior to test.
Execution effort	In general, is it more or less difficult to execute the test on an ADS-DV compared to current effort?	Number of steps or amount of time required to execute the test procedures.
Additional positioning requirements	Is additional functionality required to position the vehicle at the start of or during the test?	The test method will support positioning the vehicle at the starting position of the test.
Cycle time	For procedures that require more than one trial, how quickly can a test condition be repeated?	Number of steps or amount of time required after the completion of each trial to be ready to execute the next trial.
Data access	How easily and quickly can the necessary test data be accessed?	Time and effort to get the data in a format ready to process (or to get pass/fail results).
Applicability	How well does the method apply to or demonstrate a given test condition or functionality?	The functions required to execute a given test procedure can be executed by a given method to demonstrate compliance.
Consistency	Are the results consistent with those for conventional vehicles? For non-ADS operation?	The test method yields the same test results as for a conventional non-ADS-equipped vehicle.
Variability	How much do the results change over multiple test runs?	Results do not change when test is repeated.

Each criterion was assigned a scoring system that ranged from binary to a five-point scale and was defined based on the criterion and its definition. The research team performed an initial evaluation of the methods based on the criteria to provide a reference score for the subsequent SME evaluation. While having the initial ranking had the potential to bias the SME rankings, it also provided a point of reference to evaluate whether the participant agreed or disagreed, which was more time efficient.

The following figures (Figure 30 and Figure 31) provide the results of the SME criteria ranking for the two categories.

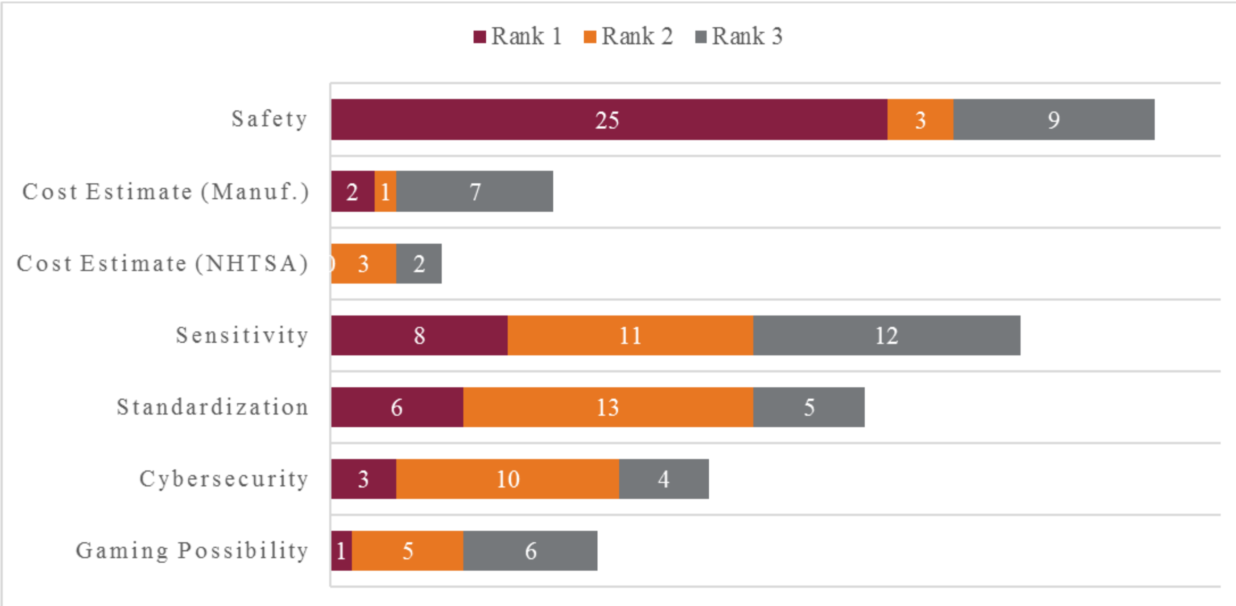


Figure 30. SME Ranking of Test and Functionality Criteria

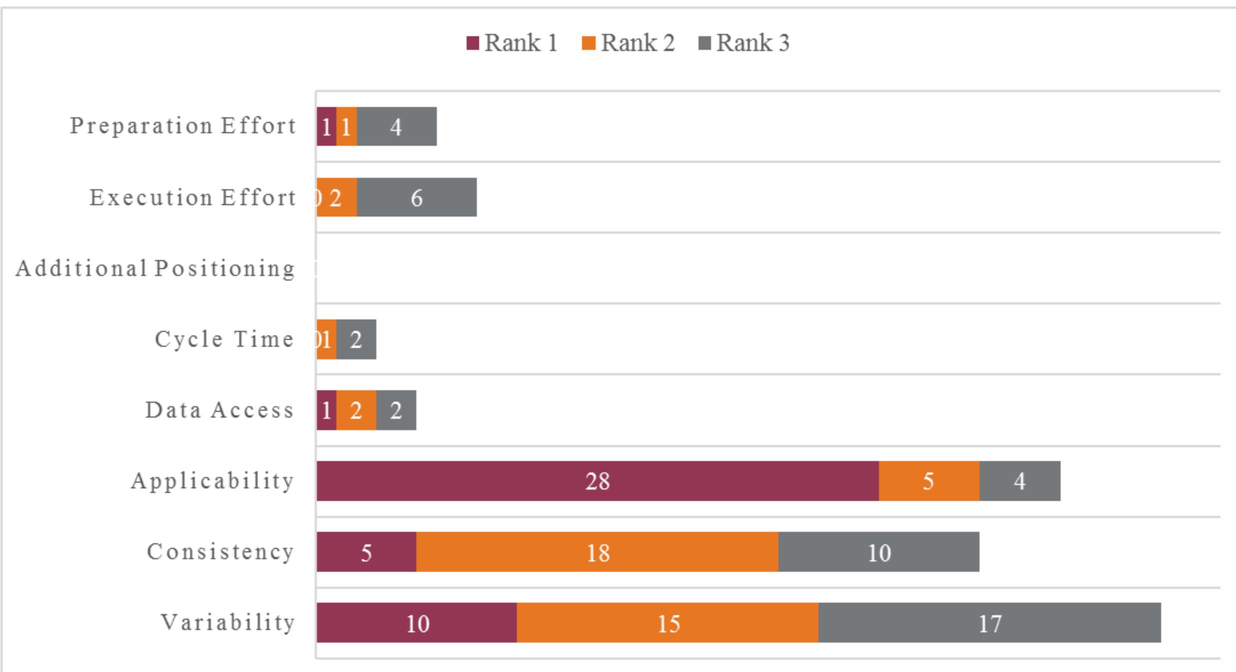


Figure 31. SME Ranking of General Considerations Criteria

As the figures show, there was good consensus on the top ranked criteria, with safety widely seen as the most important criterion. SMEs saw safety as a gating item for the rest of the criteria; if the test could not be performed in a safe manner, then the method should not be used. Sensitivity was ranked high based on the premise that if a method was not sensitive to the systems being evaluated, then it should not be used for testing. When asked to explain the reason that standardization was chosen, SMEs indicated that a method needed to be standardized across test conditions to be applicable. This may reflect a slight misunderstanding of the operational definition for standardization, which was meant to focus more on the benefit of the method being standardized to the implementation rather than the test being standardized. It is interesting to note that cybersecurity was the fourth highest ranked criterion and received a similar number of second place rankings to sensitivity and standardization. This was reflected in the comments made during the discussion as well.

It is also interesting to note which criteria were ranked low. Cost, both to the manufacturer as well as to NHTSA, were at the bottom of the scale. Gaming possibility was also ranked low based on the top three rankings. Most SMEs who commented on this expressed the opinion that there was not a significant incentive for manufacturers to game safety-related standards, where gaming is defined as having the system perform differently during testing than during normal operation. A distinction was made between this and designing a system to perform in such a way to ensure that it would pass conformance verification testing.

For the second category, the final three criteria, applicability, consistency and variability, dominated the SMEs rankings, with applicability receiving the largest number of first place rankings. The rationale provided for each of these followed the same theme—if a method is not applicable, consistent, or if there is a large amount of variability, it is not a useful method for testing. It should be noted here that those criteria all are evaluated based on a method's ability to exercise a given functionality, so the final scoring looks at a given method in relationship to steering or service brake application, for example.

Relative to the top three criteria, the other five received very few top-three votes. This is consistent with the low ranking that cost received in the first set of criteria.

At the conclusion of this activity and then again at the end of the session following the rankings of the methods, SMEs were asked if there were criteria that should be added, removed or modified. Most thought that the list was sufficient, though some expressed the opinion that a hierarchical structure might better show the relative importance such that if a method failed for a given criterion such as safety, it would not be considered any further for the other criteria.

Common Themes

The following section reflects the common themes that were most often expressed or that were particularly interesting based on expectations or previous feedback received. This reflects the thoughts and opinions of the SMEs and should not be assumed to be the opinion or position of the research team or NHTSA.

Collaboration

An opinion expressed in both the discussion and in the written comments was that the ability to test ADS-DVs effectively, regardless of the method, will need to be a collaborative effort between manufacturers and NHTSA. There were several thoughts as to what this collaboration may look like. One idea put forth for human control testing was that a manufacturer could provide a dedicated vehicle operator who would bring the necessary testing equipment and could then perform the test at the facility of NHTSA's choosing. This was consistent with another comment made regarding standardization, where an SME expressed concern that, due to the individual and proprietary nature of the vehicles and the fact that each vehicle will have different subsystems, that it could be difficult for NHTSA to conduct testing without manufacturer collaboration. An SME from Manufacturer 1's focus group noted that "[NHTSA would need to] work with OEMs and be flexible to potentially share equipment or information as well as to understand the results."

Several opinions were put forth as to how the programmed test method might be accomplished, with most comments focused on the manufacturer doing the programming. A common concern with testing in general was that the vehicle will have to operate in a manner it was not designed to operate. A solution presented by one of the manufacturers was to have the manufacturer provide a new ECU, or ECUs that could be swapped out, which would disable ADS constraints, allowing the ADS-DV to execute the test procedures. This would also allow the manufacturer to limit the ODD of the ADS-DV in space and time and allow them to limit the exposure to a single vehicle rather than their entire product line. Regarding safety, one SME expressed concern that safety may be a bigger consideration if NHTSA were to run the tests independently of the manufacturer. A Tech or Startup SME noted, regarding safety, that "[programmed control] may require additional safety measures at the test track."

Technical Design Documentation

SMEs noted that while a manufacturer would have the information to populate a technical design document package, it might require substantial effort to put that information together in a releasable format. As a Manufacturer 1 SME remarked, "Prepping and submitting a design documentation package will incur some cost." Similarly, the level of effort and expertise that may be required on NHTSA's part to review the information would likely take more effort than is currently required due to the complexity of the systems. An Advocacy or Trade Association SME commented that "[design documentation will require] staffing and expertise."

Simulation

Whereas previous feedback indicated that simulation was a likely path forward, several SMEs, including experts in simulation, expressed concerns about using simulation for compliance verification of FMVSS No. 126. The question of who supplied the model or how the model was developed was one concern. The issue of getting accurate models of subsystems, such as ESC, was also raised. Relative to this, it was expressed that the subsystems are tuned for a given model and are proprietary and unique to a manufacturer. While HIL eliminates the problem of getting a mathematical model of a subsystem or part of a subsystem, both manufacturers and suppliers noted that the effort to set up a HIL simulation can be significant and still requires specific knowledge for a given system to interface the hardware with the software. As a Manufacturer 3 SME noted in regard to HIL simulation, "[It is] very hard to emulate the interface to make brake hardware happy. If [there is a] generic brake model, then simulation could be standardized." Another consideration is the need to calibrate and validate a model for a given vehicle. It was proposed that it might be possible to define a standard test sequence that an ADS-DV could execute under normal control for use in the validation process. While this may be sufficient for linear operation of the vehicle, the question was raised as to whether a test in the linear range would be sufficient to validate the model in the non-linear range, such as for FMVSS No. 126. Even given these considerations, it was reasoned that a manufacturer-supplied model may be an adequate method.

Cybersecurity
A general consideration raised throughout the discussion (independent of the specific criteria) was the impact the testing methods may have on cybersecurity. This was pertinent for human control where a vehicle interface would be necessary, especially if there was a standard module, or even a manufacturer-supplied module, that was outside of a manufacturer's control. SMEs also commented that programmed methods could increase the cybersecurity risk if a preprogrammed routine resided on the vehicle, there was a scripting language that allowed for vehicle control, or if there was an additional vehicle interface from which to run a program. As an Advocacy or Trade Association SME commented, "Programmed control is another gateway for [cybersecurity] attacks." The general theme expressed by SMEs was balancing the potential cyber exposure on all vehicles so a single random vehicle would have the potential to be tested if deemed necessary. Again, SMEs expressed the importance of collaboration in helping address some of these considerations.

Evaluation Challenge
Another theme that was expressed several times throughout the SME evaluation workshops was the challenge associated with the exercise given the number of unknowns at this point. "It depends" was used to preface comments by several SMEs, whereas others were more explicit in stating that the evaluation was "too vague" to be able to be able to provide an accurate score. A Manufacturer 1 SME noted that "[For both programmed control on-board and dongle, the test assessment] depends on how [the test] is set up. Might be better; might be worse."

Solution Path
The predominant view expressed by the SMEs was that programmed control of the ADS is the most viable path forward. This was particularly true when looking at the long-term solution. As a SME from Manufacturer 3 noted, "[A programmed on-board scripted routine] may be the preferred method. [Our company] chooses to perform these tests so little additional costs will be incurred." However, there were still a few SMEs who expressed their opinion that human control is the best option and others who were proponents of non-vehicle-based methods (technical design documentation and simulation). For a short-term solution, there was little consensus on a single option. The use of a surrogate vehicle was expressed as a likely option. However, it was also acknowledged that this is likely only viable as a short-term option, as ADS-DVs will probably not share a platform with manually controlled vehicles for very long. Many SMEs believed that manufacturers will likely have some form of human control for ADS-DVs and therefore human control may be a short-term solution, though there may be limits as to what the vehicle can do based on the usage model for the manufacturer compared to the requirements for testing. Technical design documentation was also offered as a short-term solution, particularly if it was accompanied by some form of testing. Because no single solution currently exists, there was some consensus that a hybrid solution that includes some form of physical testing may be a reasonable short-term solution.

Evaluation Criteria Scores

The section is organized by evaluation criteria and provides the score assigned by the research team (shown in italics in the tables) and then the average and standard deviation of the scores provided by the 45 participating SMEs (Table 10). The summary statistics provide an indication of the group's general consensus, how closely they were in agreement with each other, and how this compared to the research team's assessment. A discussion follows, capturing key comments expressed by SMEs during the evaluation process, both verbally and written.

Table 10. Example Evaluation Summary Presentation

Evaluations	**Vehicle-based**					**Non-vehicle-based**		
	Human Control		**Programmed**			**Design Documentation**	**Simulation**	
	Wired	Wireless	Scripted	On-board	Dongle		SIL	HIL
Initial Assessment								
Average SME Score								
SD of SME Score								

Safety

Concept: Can the test be performed safely? (Table 11)

Definition: The number and complexity of special conditions, compared to baseline, required to execute the test safely.

Scale
1 – Needs extensive additional safety equipment
2 – Safety considerations may not be fully addressed with minor additional test equipment.
3 – Safety can be addressed with minor additional test equipment (e.g., e-stop for testing)
4 – Minor additional safety considerations (e.g., test space requirements)
5 – Same or fewer safety considerations as conventional vehicle

Table 11. Evaluation of Safety Criteria

Evaluations	**Vehicle-based**					**Non-vehicle-based**		
	Human Control		**Programmed**			**Design Documentation**	**Simulation**	
	Wired	Wireless	Scripted	On-board	Dongle		SIL	HIL
Initial Assessment	*4.0*	*3.0*	*2.0*	*3.0*	*3.0*	*n/a*	*n/a*	*n/a*
Average SME Score	3.7	2.8	2.4	2.9	2.9			
SD of SME Score	0.8	0.7	0.8	0.5	0.6			

Safety was highest rated among SMEs, as shown in Table 11. The group generally agreed with the rankings, though they did, on average, score human control slightly lower and scripted control slightly higher. A summary of SMEs considerations regarding safety is given here. The order in which the comments are presented tend to follow the order that the methods are listed in the table and do not imply an assessment of importance.

For human control, the dependence of safety on who was operating the control module and what level of control it would allow were noted considerations. One SME commented that if the adaptation was done independently of the manufacturer's help, safety would decrease.

Specific to wireless control, several SMEs commented on the possibility of connection loss and the associated safety considerations. One proposed solution was independent wireless connections for steering and brake to minimize the potential of simultaneous lateral and longitudinal control loss. For example, one Equipment or Service Provider SME noted: "What happens when connection is lost? How does [the] driver intervene? Might need separate interfaces for steering versus braking so one [connection] being lost does not stop all function or implement failsafe to stop when signal is lost." Another consideration for wireless operation is danger when the remote control vehicle is traveling toward the operator, since the controls are backwards compared to when oriented in the direction of travel. Wireless control caused two SMEs to bring up cybersecurity, one noting concern over denial of service.

In general, participants saw the programmed routine as analogous to the way that FMVSS No. 126 is run today. Consequently, the safety would be similar, though the inclusion of an e-stop or a geofence to prevent potential runaway were both suggested. One Equipment or Service Provider SME noted the latter: "Some sort of geofence may be necessary to prevent runaway."

Cost Estimate: Manufacturer

Concept: What are the initial (including development and equipment costs) and recurring costs? (Table 12)

Definition: Relative cost for manufacturer to develop/implement method for new vehicle model/platform.

Scale
1 – Could be cost prohibitive
2 – Significant additional cost
3 – Moderate additional cost
4 – Minimal additional cost
5 – No additional cost

Table 12. Evaluation of Cost Estimate to Manufacturer

Evaluations	Vehicle-based					Non-vehicle-based		
	Human Control		Programmed			Design Documentation	Simulation	
	Wired	Wireless	Scripted	On-board	Dongle		SIL	HIL
Initial Assessment	*2.0*	*3.0*	*3.0*	*3.0*	*2.0*	*5.0*	*4.0*	*3.0*
Average SME Score	2.2	2.6	2.7	2.8	2.4	4.4	3.5	2.8
SD of SME Score	0.7	0.6	0.7	0.7	0.7	0.7	0.8	0.5

Though cost was ranked low (Table 12), there was good discussion regarding the costs to the manufacturer.

Wired human control covered the spectrum, with one SME stating that it could be an extension of existing equipment, which would keep cost down, whereas another stated that it would be all new equipment, which would be costly. Cybersecurity was a consideration relative to the cost of securing the system.

Similar to human control, different SMEs had different perspectives about programmed control. One SME commented that it would all be from scratch, whereas others implied that they currently had the capability to run in programmed mode. For the scripted capability, comments from one SME indicated that there would be an additional cost to create the scripting language and interface. A Tech or Startup SME noted that, "[The scripted routine] may involve significant additional costs to give NHTSA the ability to run scripts while maintaining cybersecurity."

Regarding design documentation, several SMEs said that while they would have the necessary information, the associated costs of compiling, translating, creating a formal report, and going through the layer of approvals is not negligible, though it is significantly less than the vehicle-based methods.

Similar to design documentation, SMEs indicated that the cost considerations for simulation included the dependence on the level of fidelity required, the need to prove the correlation, the potential need to model additional components, and the question of who is responsible for creating the vehicle models. One SME commented that simulation is likely already being performed in-house so there may be little additional cost.

One SME noted that cybersecurity is a consideration for risk mitigation for the vehicle-based methods.

Cost Estimate: NHTSA

Concept: What are the initial (including development and equipment) and recurring costs? (Table 13)

Definition: Relative cost for NHTSA to execute test on new vehicle model/platform.

Scale
1 – Could be cost prohibitive
2 – Significant additional cost
3 – Moderate additional cost
4 – Minimal additional cost
5 – No additional cost

Table 13. Evaluation of Cost Estimate to NHTSA

Evaluations	Vehicle-based					Non-vehicle-based		
	Human Control		Programmed			Design Documentation	Simulation	
	Wired	Wireless	Scripted	On-board	Dongle		SIL	HIL
Initial Assessment	*3.0*	*3.0*	*5.0*	*5.0*	*5.0*	*5.0*	*2.0*	*1.0*
Average SME Score	2.9	2.9	4.4	4.6	4.5	4.7	1.9	1.2
SD of SME Score	0.8	0.7	0.9	0.7	0.9	0.6	0.5	0.5

Some of the comments for the cost to NHTSA were similar to those for cost to manufacturers (see Table 13 for scores). Human control would be a function of who provided the hardware. For programmed control, SMEs noted that there may be additional personnel costs for an operator with additional expertise to program the testing. However, they also noted this should not be a recurring cost. SMEs were of the general opinion that NHTSA would incur significant costs for simulation implementation. For design documentation, additional staffing and time to review the detailed documentation could have additional associated costs.

Three SMEs commented that the cost could be prohibitive if NHTSA and manufacturers did not work together, especially early on when everything is new.

Sensitivity

Concept: Are the results insensitive to changes not associated with the test? (Table 14)

Definition: Observed differences, variance in intermediate steps, or differences in results due to factors not controlled in test procedures (e.g., test operator, location, GPS signal quality, etc.) that may impact final result.

Scale
1 – Results likely to be impacted
2 – Results may be impacted
3 – Final results are unlikely to be impacted
4 – Intermediate results could be affected
5 – Insensitive to outside factors

Table 14. Evaluation of Sensitivity Criteria

Evaluations	Vehicle-based					Non-vehicle-based		
	Human Control		Programmed			Design Documentation	Simulation	
	Wired	Wireless	Scripted	On-board	Dongle		SIL	HIL
Initial Assessment	*5.0*	*5.0*	*4.0*	*4.0*	*4.0*	*n/a*	*n/a*	*n/a*
Average SME Score	4.3	4.2	4.0	4.0	4.0	3.0	1.7	1.3
SD of SME Score	1.1	1.1	0.5	0.6	0.5	0.0	0.5	0.5

Sensitivity was the second highest ranked criterion, as shown in Table 14. The reason for this was captured by one SME, who stated that if a method is applicable, it should be sensitive to the relevant factors and therefore yield the same results as a vehicle with manually operated driving controls. There were differences of opinion in how human control should be scored. Some SMEs considered this as applied to FMVSS No. 126 with a human executing the test inputs, which they noted would yield unrepeatable results. For the programmed criterion, some SMEs noted that this is done currently and therefore should be similar for ADS-DVs. One SME observed that it could be standard-dependent. Though non-vehicle-based methods were not ranked by the research team, some SMEs thought that it should be scored and left relatively low scores for both design documentation and simulation. For simulation, sensitivity to measured parameters had the consideration of assuming that the simulation was correct to start with.

For sensitivity, more than one SME commented on the importance of collaboration between NHTSA and manufacturers.

Standardization

Concept: Does the method (i.e., associated test tools and evaluation criteria) lend itself to standardization? (Table 15)

Definition: For methods that lend themselves to standardization, the level of effort required for standardization.

Scale
1 – Significant effort
2 – Moderate effort
3 – Minimal effort

Table 15. Evaluation of Standardization for Methods

Evaluations	Vehicle-based					Non-vehicle-based		
	Human Control		Programmed			Design Documentation	Simulation	
	Wired	Wireless	Scripted	On-board	Dongle		SIL	HIL
Initial Assessment	*1.0*	*1.0*	*2.0*	*3.0*	*2.0*	*3.0*	*1.0*	*1.0*
Average SME Score	1.1	1.1	2.0	2.5	2.0	2.8	1.1	1.1
SD of SME Score	0.4	0.3	0.4	0.7	0.5	0.5	0.6	0.6

One SME commented that standardization, once established, would greatly ease level of effort, but would also be challenging. Another commented that standardization among suppliers and manufacturers will always take at least a moderate level of effort. Based on the scoring, this appeared to be the general consensus among SMEs (Table 15).

For the methods themselves, there were few comments regarding human control, though one SME thought that wireless would be easier to standardize since there would be fewer "wires" to standardize. For programmed methods, several SMEs expressed the opinion that there would be no difference in the level of effort for the different methods. One SME commented that using a laptop for the interface would be better than using specialized hardware since the standardization could create a vulnerability that would otherwise not exist. Regarding simulation, the possibility of standardizing the testing was suggested. Things like interfaces to modules for HIL would be very challenging, as this is proprietary and unique information. For example, one Manufacturer 3 SME noted, "Standardization of the simulation SW and simulation HIL would be very difficult across OEMs and suppliers."

Cybersecurity

Concept: What, if any, is the relative level of cybersecurity considerations that could be introduced by a given method? (Table 16)

Definition: The possibility of introducing additional cybersecurity vulnerabilities and attack vectors.

Scale
1 – Introduction of cybersecurity threats
2 – Likely introduction of cybersecurity threats
3 – Moderate possibility of additional cybersecurity threats
4 – Possible cybersecurity threats
5 – No additional issues

Table 16. Evaluation of Cybersecurity

Evaluations	Vehicle-based					Non-vehicle-based		
	Human Control		Programmed			Design Documentation	Simulation	
	Wired	Wireless	Scripted	On-board	Dongle		SIL	HIL
Initial Assessment	*2.0*	*1.0*	*2.0*	*3.0*	*3.0*	*5.0*	*5.0*	*5.0*
Average SME Score	2.0	1.2	1.9	2.6	2.6	4.8	4.9	4.9
SD of SME Score	0.6	0.6	0.5	0.6	0.8	0.7	0.4	0.6

As the scores show (Table 16), in general, SMEs were more pessimistic about the introduction of threats from implementing the vehicle-based methods. The primary consideration was that an interface to the vehicle opens up a gateway for a potential attack. One SME did pose the consideration that a chip in the dongle could potentially be used as a means for security. In addition, a couple of SMEs commented that the availability of detailed information in the technical design documentation or in the simulation could potentially introduce a vulnerability as well. However, compared to the vehicle-based methods, this was seen as a relatively low probability.

Gaming Possibility

Concept: Is a particular method susceptible to "gaming" a given test? (Table 17)

Definition: Ease with which a test method would allow the vehicle under test to be tuned to perform differently during testing as with normal operation.

Scale
1 – Gaming easy to implement and difficult to detect
2 – Gaming requires effort and not easy to check for
3 – Gaming easy and easy to check for
4 – Gaming requires effort but easy to check for
5 – Insensitive to gaming efforts

Table 17. Evaluation of Gaming Possibility

Evaluations	Vehicle-based					Non-vehicle-based		
	Human Control		Programmed			Design Documentation	Simulation	
	Wired	Wireless	Scripted	On-board	Dongle		SIL	HIL
Initial Assessment	*4.0*	*4.0*	*2.0*	*1.0*	*1.0*	*1.0*	*2.0*	*1.0*
Average SME Score	3.7	3.7	2.0	1.4	1.4	1.1	1.8	1.3
SD of SME Score	0.7	0.7	0.8	0.9	0.9	0.5	0.4	0.7

The general thoughts on gaming can likely be summarized with comments from two different SMEs. One observed that since vehicle-based methods would require the vehicle to operate in a non-normal mode, they have the potential to change the system performance compared to an ADS-DV operating normally. However, several SMEs questioned the motivation for altering system response during testing. With regards to FMVSS No 126, one SME commented that the hardware is present and, while the ESC will be tuned to be "sporty" for different classes of human-driven vehicles, there is no incentive to do this for an ADS-DV. For simulation, one SME commented that since many of the subsystems are black boxes, it is nearly impossible to confirm that the code is the same as in the vehicle. So, while gaming is possible and likely difficult to catch, the general consensus was that there is little incentive to attempt it, making it an insignificant threat (Table 17).

Preparation Effort

Concept: Are there additional challenges in setting up an ADS-DV compared to a conventional vehicle? (Table 18)

Definition: Number of steps or amount of time required to set up vehicle prior to test.

Scale
1 – Significant additional prep time
2 – Slight additional prep time
3 – No additional time

4 – Slight time savings
5 – Significant time savings

Table 18. Evaluation of Preparation Effort

Evaluations	Vehicle-based					Non-vehicle-based		
	Human Control		Programmed			Design Documentation	Simulation	
	Wired	Wireless	Scripted	On-board	Dongle		SIL	HIL
Initial Assessment	*1.0*	*2.0*	*1.0*	*5.0*	*5.0*	*n/a*	*n/a*	*n/a*
Average SME Score	1.2	1.7	1.5	4.5	4.6	2.3	2.3	1.7
SD of SME Score	0.5	0.5	0.8	0.8	0.8	0.4	0.4	0.5

There were few comments regarding human control, but several SMEs had comments regarding programmed operation (Table 18). One commented that the level of effort is test dependent; while there would likely be time savings for programmed FMVSS No. 126 testing compared to current testing involving setting up the steering robot, there may not be any savings for test procedures associated with FMVSS Nos. 114 and 138. Another SME reiterated the need for interaction with the vehicle manufacturer during the preparation.

Consistent with earlier comments for non-vehicle-based methods, participants noted a time cost associated with preparing both documentation and setting up a simulation. One SME commented that for HIL, preparation time is an important consideration, as setting up a system, such as the braking system, that would benefit from HIL, requires a significant amount of work. Though execution time is fast once the simulation is set up, set-up time can be significant compared to the current test set up.

<u>Execution Effort</u>

Concept: In general, is it more or less difficult to execute the test on an ADS-DV compared to current effort? (Table 19)

Definition: Number of steps or amount of time required to execute the test procedures.

Scale
1 – Significant additional time
2 – Slight additional time
3 – No additional time
4 – Slight time savings
5 – Significant time savings

Table 19. Evaluation of Execution Effort

Evaluations	Vehicle-based					Non-vehicle-based		
	Human Control		Programmed			Design Documentation	Simulation	
	Wired	Wireless	Scripted	On-board	Dongle		SIL	HIL
Initial Assessment	*3.0*	*3.0*	*4.0*	*4.0*	*4.0*	*n/a*	*n/a*	*n/a*
Average SME Score	2.8	2.8	3.9	3.8	3.9	1.8	2.5	2.6
SD of SME Score	0.4	0.4	0.7	0.7	0.7	0.8	1.5	1.4

In general, SMEs agreed that the execution time would be similar, but several expressed that it would also be test dependent, as would the preparation effort (Table 19). For the design documentation, those who commented indicated that this method would take longer than it takes to execute a test today.

Additional Positioning Requirements

Concept: Is additional functionality required to position the vehicle at the start of or during the test? (Table 20)

Definition: The test method will support positioning the vehicle at the start of a test and/or repositioning during the test, if necessary.

Scale
1 – Test may require additional positioning equipment
5 – No special equipment required to position or reposition the vehicle

Table 20. Evaluation of Additional Positioning Requirements

Evaluations	Vehicle-based					Non-vehicle-based		
	Human Control		Programmed			Design Documentation	Simulation	
	Wired	Wireless	Scripted	On-board	Dongle		SIL	HIL
Initial Assessment	*5.0*	*5.0*	*1.0*	*1.0*	*1.0*	*n/a*	*n/a*	*n/a*
Average SME Score	4.9	4.9	1.2	1.3	1.2			
SD of SME Score	0.6	0.6	0.8	1.0	0.8			

There were few comments regarding the need for additional positioning (Table 20). However, two SMEs brought up the consideration that this could be test track dependent; if within the vehicle's ODD, additional positioning may not be needed. If the test surface is fixed, it was suggested that the starting point could be programmed, thus eliminating the need for additional positioning. Counter to this latter observation, another SME commented that a key consideration is test facility use by other groups—tests should not take more track area than they currently do in order to avoid excluding other users.

Cycle Time

Concept: For procedures that require more than one trial, how quickly can a test condition be repeated? (Table 21)

Definition: Number of steps or amount of time required after the completion of each trial to be ready to execute the next trial.

Scale
1 – Significant additional time
2 – Slight additional time
3 – No additional time
4 – Slight time savings
5 – Significant time savings

Table 21. Evaluation of Cycle Time

Evaluations	Vehicle-based					Non-vehicle-based		
	Human Control		Programmed			Design Documentation	Simulation	
	Wired	Wireless	Scripted	On-board	Dongle		SIL	HIL
Initial Assessment	*3.0*	*3.0*	*2.0*	*4.0*	*4.0*	*n/a*	*n/a*	*n/a*
Average SME Score	3.0	3.0	2.5	3.8	3.8			
SD of SME Score	0.3	0.3	0.7	0.6	0.6			

The programmed method elicited the majority of the comments and yielded a variety of opinions (Table 21). One SME stated that programmed operation should greatly reduce cycle time, whereas another thought that the location of the test could affect cycle time in terms of repositioning. In general, the opinion was that programmed testing would likely be similar to current testing.

Data Access

Concept: How easily and quickly can the necessary test data be accessed? (Table 22)

Definition: Time and effort to get the data in a format ready to process (or to get pass/fail results).

Scale
1 – Significant additional time
2 – Slight additional time
3 – No additional time
4 – Slight time savings
5 – Significant time savings

Table 22. Evaluation of Data Access

Evaluations	Vehicle-based					Non-vehicle-based		
	Human Control		Programmed			Design Documentation	Simulation	
	Wired	Wireless	Scripted	On-board	Dongle		SIL	HIL
Initial Assessment	*3.0*	*3.0*	*4.0*	*4.0*	*3.0*	*n/a*	*n/a*	*n/a*
Average SME Score	3.0	3.0	3.6	3.6	3.3			
SD of SME Score	0.1	0.1	0.6	0.6	0.5			

An interesting consideration expressed for data access is that NHTSA should use their own sensors and data acquisition system to eliminate the possibility of manufacturer influencing the results. During the discussion, a similar consideration was put forth specifically for FMVSS No. 126: it was suggested that the steering system output could be instrumented to confirm steering input independent of a particular steering system configuration.

While most SMEs responded that there would be little difference relative to current vehicles, one commented that it may not be trivial to get vehicle data given the sheer amount of ADS-DV data that exists, and that data may be on different networks and, therefore, in different locations (Table 22). Related to this, one SME drew the analogy to the standardization effort for electronic data recorders to make a common set of data accessible. Contrasting these perspectives, another SME thought that, given the ADS's computing requirements, data access would be the easy part of the process.

Functionality-Based Criteria

The next three criteria are evaluated based on how well a given method is suited for one of the vehicle functionalities associated with FMVSS or test procedures. The evaluation matrix was split into driving functionalities and non-driving functionalities for each criterion (Table 23 to Table 28). At the SME workshops, participants were instructed that they only needed to score items with which they did not agree and were asked to provide their rationale as well as any other general comments. The SME scores were averaged, and, if at least five people changed their score, then a + or – was added to indicate if the average was above or below the original. As before, a summary of the SME comments is provided following the matrix.

Applicability

Concept: How well does the method apply to a given test condition or functionality? (Table 23 and Table 24)

Definition: The functions required to execute a given test procedure can be executed by a given method to demonstrate compliance.

Scale
1 – Method is not applicable for functionality
3 – Method may be applicable
5 – Method is applicable for functionality

Table 23. Evaluation for Applicability of Driving Functionalities

	Steering Control		Speed Control (veh./eng.)		Service Brake		Parking Brake	Gear Selection
	Basic	Precise	Basic	Precise	Basic	Precise		
Human Control								
Wired	5	5-	5	5	5	5	5	5
Wireless	5	3+	5	5	5	3+	5	5
Programmed								
Scripted	5	5	5	5	5	5	5	5
Program	5	5	5	5	5	5	5	5
Design Documentation	3+	3+	3+	3+	3+	3+	5-	5
Simulation								
SW	5	3+	5	3+	5	3+	5	5
HIL	5	5-	5	3+	5	5-	5	5

Table 24. Evaluation for Applicability of Non-Driving Functionalities

	Telltales/ Warning/ Indicators	Key Insertion/ Removal	Ignition Start/ Stop	Accessory Mode	Door Open/ Close	Non-Driving Controls	Visibility
Human Control							
Wired	5	5	3+	3+	3+	5	1
Wireless	5	5	3+	3	3	5	1
Programmed							
Scripted	3+	3	5	5	3	3+	3
Program	3+	3	5	5	3	3	3
Design Documentation	3	3	3	3	3	3	3
Simulation							
SW	3+	3	3	3	1	1+	3-
HIL	5	3	3	3	1	1+	3

Several SMEs' assessments were dependent on manufacturers working with NHTSA. Similarly, more than one SME commented that the scoring was dependent on how the method was implemented. Regarding simulation, one SME indicated that they did not see how simulation would be of practical use external to a manufacturer. For technical design documentation, one SME noted that it is more applicable for some standards than others, but all should include results from some form of physical testing.

There were fewer comments for the non-driving functionalities; however, several SMEs did express the opinion that door state, non-driving controls, and visibility could be used as inputs into HIL simulation (Table 24).

Consistency

Concept: Are the results consistent with those for non-ADS operation? (Table 25 and Table 26)

Definition: The test method yields the same test results as for a non-ADS-equipped vehicle.

Scale
1 – Method may not yield consistent results
3 – Method may be consistent
5 – Method should yield consistent results

Table 25. Evaluation for Consistency of Driving Functionalities

	Steering Control		Speed Control (veh./eng.)		Service Brake		Parking Brake	Gear Selection
	Basic	Precise	Basic	Precise	Basic	Precise		
Human Control								
Wired	5	5-	5	5	5	5	5	5
Wireless	5	1+	5	1+	5	1+	5	5
Programmed								
Scripted	5	5-	5	5	5	5	5	5
Program	5	5-	5	5	5	5	5	5
Design Documentation	3+	3+	3+	3+	3+	3+	5	5
Simulation								
SW	3+	3	5	3+	5-	3+	5	5
HIL	3+	3	5	3+	5-	3+	5	5

Table 26. Evaluation for Consistency of Non-Driving Functionalities

	Telltales/ Warnings/ Indicators	Key Insertion/ Removal	Ignition Start/ Stop	Accessory Mode	Door Open/ Close	Non-Driving Controls	Visibility
Human Control							
Wired	5	5	3	3	3	5	1
Wireless	5	5	3	3	3	5	1
Programmed							
Scripted	3+	3	5	5	3	3	3
Program	3	3	5	5	3	3	3
Design Documentation	5	3	5	3	3	3	3
Simulation							
SW	3	3	3	3	1	1+	3
HIL	5	3	3	3	1	1+	3

Drawing an analogy to conventional vehicles, one SME pointed out that today's vehicles have detailed electrical and mechanical design documentation, but this does not guarantee that the signals are sent or received properly. There was a general comment regarding FMVSS No. 126 that the test procedure may be more effective for ADS-DVs if it were redefined based on path and speed profiles.

Variability: Driving Functionalities

Concept: How much do the results change over multiple test runs? (Table 27 and Table 28)

Definition: Results do not change when test is repeated.

Scale
1 – Likely to introduce variability
3 – May cause variability
5 – Method should not introduce variability

Table 27. Evaluation for Variability of Driving Functionalities

	Steering Control		Speed Control (veh./eng.)		Service Brake		Parking Brake	Gear Selection
	Basic	Precise	Basic	Precise	Basic	Precise		
Human Control								
Wired	5	5	5	5	5	5	5	5
Wireless	5	3+	5	5	5	3+	5	5
Programmed								
Scripted	5	5	5	5	5	5	5	5
Program	5	5	5	5	5	5	5	5
Design Documentation	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
Simulation								
SW	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
HIL	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a

Table 28. Evaluation for Variability of Non-Driving Functionalities

	Telltales/ Warning/ Indicators	Key Insertion/ Removal	Ignition Start/ Stop	Accessory Mode	Door Open/ Close	Non-Driving Controls	Visibility
Human Control							
Wired	5	5	3	3	3	5	1
Wireless	5	5	3	3	3	5	1
Programmed							
Scripted	3+	3	5	5	3	3	3
Program	3+	3	5	5	3	3	3
Design Documentation	n/a	n/a	n/a	n/a	n/a	n/a	n/a
Simulation							
SW	n/a	n/a	n/a	n/a	n/a	n/a	n/a
HIL	n/a	n/a	n/a	n/a	n/a	n/a	n/a

One SME put forth the consideration that the system has inherent variability that must be accounted for in the test results. For programmed operation, one SME indicated that there is a dependency on the standard being tested for telltales and key functionality.

Findings

The evaluation of the test methods provided an opportunity to investigate possible applicable methods for compliance verification of the FMVSS functionalities covered in Volume 1 and Volume 2 research. The effort demonstrated technical feasibility for vehicle-based methods, and the potential for non-vehicle-based methods, to provide an indication of compliance. The input received from the SME evaluation helps provide additional insight from industry as to a potential path forward for ADS-DVs.

Chapter 6. Summary of Research Findings

This project provides research findings in the form of technical translation options to potential regulatory barriers in the FMVSS and associated test procedures identified for compliance verification of innovative new vehicle designs that may appear in ADS-equipped vehicles. Test procedures are used by NHTSA to assess compliance with the FMVSS performance requirements. The FMVSS technical translations effort is focused on a particular type of ADS-equipped vehicle—the ADS-DV—which, for the purposes of this project, is defined as a vehicle designed to be operated exclusively by an SAE level 4 or level 5 ADS for all trips without manually operated driving controls in the vehicle.

Approach and Process

Similar to the Volume 1 research, crosscutting analyses were developed to drive consistency in the technical translation options and clarify when individual standards might benefit from unique options or approaches. This allowed for the development of a potential range of options, and recognition of where an option in one standard could have broader implications. During the translation process, the research team reviewed the FMVSS regulatory language and test procedures. Several parts of the regulatory language include standards that are incorporated by reference. This set of technical translations and test procedures work provides a framework for the evaluation of the standards covered in Volume 2 research and beyond.

Crash Avoidance Standards

In most cases, it was determined that language in the 100-series standards could be addressed with straightforward clarification of the regulatory text. The FMVSS 100-series standards covered in the Volume 2 research had many of the same themes encountered during the Volume 1 research. Many of these represent some of the inherent assumptions that a human is driving the vehicle using manually operated driving controls (e.g., FMVSS No. 124 and 126). The technical translations provided options for how to treat the "driver" references in a consistent way across the Volume 1 and Volume 2 standards. Since the project is focused on ADS-DVs and may not be taking into account all potential considerations for dual-mode vehicles (as those are outside of the current project scope), when requirements were suitable, the terms "ADS-DV" and "manually operated driving controls" are used in the technical translation options.

The visibility theme found in some of the Volume 2 standards (FMVSS No. 103, 104 and 113) was distinct from the FMVSS No. 108 visibility theme addressed with the Volume 1 technical translation options. These Volume 2 standards focused on the human driver having a clear and reasonably unobstructed view (e.g., through the windshield and windows and to the rear of the vehicle using equipment such as mirrors and a rear image). The technical translations included option(s) retaining the performance requirements for ADS-DVs or, in some cases, specifying the requirement(s) for vehicles with manually operated driving controls. For FMVSS No. 111, it was determined that more research was needed in order to perform the technical translations. However, possible approaches to translating the standard were considered. FMVSS No. 101 also includes aspects of visibility, specifying provisions for location, identification, color, and illumination of motor vehicle controls, telltales, and indicators. The research team considered that some of the information that is currently communicated to the human driver might be safety-relevant for occupants in the absence of a human driver inside the occupant compartment. ADS information delivery and presentation requirements could potentially be a part of the FMVSS No. 101 technical translation options. Mandating the communication of this information and the method of verification could also be contained within the FMVSS in which they are specified, if not already present in the FMVSS.

Many of the test procedures in the regulatory text may have potential compliance verification barriers. The development of methods that may allow NHTSA to perform the test procedures to verify the compliance of ADS-DVs is a critical aspect of removing these barriers. While many of these same verification barriers were present in the Volume 1 standards, FMVSS Nos. 110 and 126 specify vehicle control requirements that correspond to emergency driving conditions. These helped identify additional considerations for testing and influenced the design requirements for the actuators used in the automated test platform.

Crashworthiness and Occupant Protection Standards

This effort focused on occupant protection for ADS-DVs with conventional seating. This included ADS-DVs with forward-facing seating, but without manually operated driving controls. Unconventional seating configurations, such as rear-facing or side-facing seats have not yet been considered but may be part of future NHTSA research. Translations were provided for the 200-series test procedures, but no test procedure development was needed. The test procedures developed for the passenger seating positions could be used for ADS-DVs, given that the main difference between the two front outboard seating positions in conventional vehicles is the presence or absence of manually operated driving controls. ADS developments may be changing the role of the rear seat to be more like that of the front seat, affecting FMVSS No. 208 in particular.

Beyond Volume 2 Research

In general, Volume 2 research focused primarily on the 100-series (crash avoidance) and the 200-series (crashworthiness/occupant protection) FMVSS. The knowledge gained and considerations made during evaluation of the 12 FMVSS that were covered in Volume 1 research and the 18 FMVSS covered in this report will be leveraged for the remaining portions of the FMVSS. Future research conducted by NHTSA may address design aspects, such as unconventional seating configurations, and other FMVSS as NHTSA sees fit. Any additional work will be addressed longer term and documented in a separate report or reports.

One of the outcomes from this portion of the research is the need to develop vehicle interior packaging tools for designs that are not dependent on a driver's DSP (e.g., relative to H-point for driver's DSP) or a human driver facing the windshield (e.g., eyellipse) to eliminate potential barriers they may present for ADS-DVs. This would benefit multiple safety standards. The following sections also present potential future research considerations.

Crash Avoidance Standards

The potential for unknown seating patterns and unconventional seating configurations in an ADS-DV influenced some of the technical translation option development for the 100-series. As part of the technical translation presented herein, multiple seating positions were provided as options for delivering information currently communicated to the human driver that may be safety-relevant for occupants in the absence of a human driver. Research to ensure that the information presented is accessible (e.g., visible, location[s], reach) to occupants may need to be explored further with the goal of developing an occupant procedure that builds on the technical translation options.

Today, a human driver is responsible for the operational readiness of a vehicle (i.e., for putting the vehicle in a suitable condition for the trip). For an ADS-DV, a dispatcher or dispatching entity (e.g., vehicle owner and/or fleet management company) may be responsible for verifying the ADS-equipped vehicle's operational readiness. Comprehension of the information provided to the occupant assumes that the occupant is a competent user. Moving forward, research could be conducted to define what it means to be a "competent user" with considerations for the associated occupant action to be elicited. Policies associated with airline, rail, and transit travel may be a starting point for developing guidance. Other aspects of importance (e.g., cognitive and/or physical disabilities) to operationally define a competent user may be considered. This may help provide further understanding of the relevance and delivery method of regulatory information and the potential impact of the many possible ADS-DV market implementations.

A few of the Volume 2 standards may benefit from additional research focused on targeted performance criteria and associated test procedures unique to the standard. Further research may assist in identifying the FOV requirements applicable to ADS-DVs and a means of assuring that the appropriate information is provided to the ADS.

Another example would be FMVSS No. 110, which may be beneficial to research in order to develop new methods for maximizing the normal load on a given tire without assuming a typical seating pattern. The result of this research could be an updated table for unconventional seating patterns or perhaps the development of an additional vehicle test that experimentally determines the maximum tire loading for the associated seating capacity. FMVSS No. 126 is unique in the specificity of the defined control inputs and the means to execute them. Research that further evaluates the different steering input alternatives to create a potential set of test procedures may help advance the work done for this project. Further study could identify and define alternatives for specific FMVSS No. 126 test procedures, such as using low-speed human control for repositioning of the vehicle and programming for SWD test runs.

Three different vehicle-based test methods were investigated during Volume 2 research to demonstrate their applicability for different functionalities either specifically regulated in the different FMVSS or required implicitly or explicitly to verify compliance. The control of many of these functionalities is dependent on the test method employed. Some of the methods may be more applicable for different test procedures or parts of test procedures. The long-term research will include evaluation of the remaining standards—particularly the brake systems standard— to address some of the functionalities that may not have yet been assessed (e.g., brake sequence). Additionally, heavy-truck-specific standards will be assessed to ensure the test methods could apply across vehicle platforms. One of the possible next steps would be to address some of the potential implementation considerations relative to specific standards and test methods (e.g., FMVSS No. 126 steering input associated with a particular test method).

Crashworthiness Standards

Future research may review the crashworthiness standards again but with a focus on rear-facing seating configurations. As the assessment of different concept vehicles in the Volume 1 report indicates, many different seating configurations are possible (e.g., rear-facing and/or inboard-facing), even some likely not contemplated in the concept vehicles in the Volume 1 report. Therefore, results presented herein will need to be reevaluated for those potential configurations. As part of the technical translation approach, multiple seating positions were provided as options for communicating information currently conveyed to the human driver that could be deemed safety-relevant for occupants in the absence of a human driver (e.g., seat belt warnings for rear-seated occupants). Research to ensure the visibility of the presented warnings may need to be explored.

Appendix A. Definitions

<table>
<tr><th colspan="2">ADS-Related Definitions
Incorporated from SAE International's Recommended Practice J3016, Taxonomy and Definitions for Terms Related to Driving Automation Systems for On-Road Motor Vehicles</th></tr>
<tr><td>Automated Driving System (ADS)</td><td>The hardware and software that are collectively capable of performing the entire dynamic driving task (DDT) on a sustained basis, regardless of whether it is limited to a specific operational design domain (ODD); this term is used specifically to describe a level 3, 4, or 5 driving automation system (SAE International, 2018, p.3).</td></tr>
<tr><td>Operational Design Domain (ODD)</td><td>Operating conditions under which a given driving automation system or feature thereof is specifically designed to function, including, but not limited to, environmental, geographical, and time-of-day restrictions, and/or the requisite presence or absence of certain traffic or roadway characteristics (SAE International, 2018, p.14).</td></tr>
<tr><td>Dynamic Driving Task (DDT)</td><td>All of the real-time operational and tactical functions require to operate a vehicle in on-road traffic, excluding the strategic functions such as trip scheduling and selection of destinations and waypoints, and including without limitation:
• Lateral vehicle motion control via steering (operational);
• Longitudinal vehicle motion control via acceleration and deceleration (operational);
• Monitoring the driving environment via object and event detection, recognition, classification, and response preparation (operational and tactical);
• Object and event response execution (operational and tactical);
• Maneuver planning (tactical); and
• Enhancing conspicuity via lighting, signaling and gesturing, etc. (tactical) (SAE International, 2018, p.6).</td></tr>
<tr><td>Automated Driving System - Dedicated Vehicle (ADS-DV)</td><td>Based on Section 3.3 of SAE International (2018) "a vehicle designed to be operated exclusively by a level 4 or level 5 ADS during all trips within its given ODD (Operational Design Domain) limitation (if any)" and which may lack manual vehicle control systems such as braking, accelerating, steering, and transmission gear selection input devices. Additional considerations identified by SAE International in its definition of ADS-DV include the following (SAE International, 2018, p.4):
ADS-DVs might be operated temporarily by a conventional or remote driver:
(1) to manage transient deviations from the ODD,
(2) to address a system failure, or
(3) while in a marshalling yard before being dispatched.</td></tr>
<tr><td>Translation Note</td><td>ADS-related definitions are interchangeable with the driver, seating, and driving control definitions options. SAE International's definition of ADS-DV indicates that some ADS-DVs could contain driving controls and be used to describe a level 3 driving automation system as well as level 4 and level 5 systems. For the purposes of this project, the FMVSS technical translation options focused on a particular type of ADS-DV, a vehicle designed to be operated exclusively by an SAE level 4 or level 5 ADS for all trips, and which is not equipped with manually operated driving controls.</td></tr>
</table>

Driver Definitions		
Currently specified in 49 CFR § 571.3	*Driver* means the occupant of a motor vehicle seated immediately behind the steering control system.	
	Potential Option 1	**Potential Option 2**
Driver	*Driver* means: (1) the occupant (human driver) of a motor vehicle seated immediately behind the manually operated driving controls, and (2) the ADS (ADS driver), for ADS-equipped vehicles when the ADS is engaged. When the ADS is not engaged, the definition in paragraph (1) applies.	*Driver* means the occupant of a motor vehicle seated immediately behind the manually operated driving controls.
Translation Note	Driver definition Options 1 or 2 are interchangeable with the ADS-related, seating, and driving control definitions.	
	Option 1 incorporates the ADS into the definition of "driver." Therefore "driver" would refer to either a human driver or an ADS. "Human driver" is used when only (1) applies, and "ADS driver" is used when only (2) applies.	Under Option 2, the "driver" always refers to a human driver. The ADS would perform the driving of an ADS-DV and be incorporated into the standards independently from "driver."

<table>
<tr><th colspan="3">Designated Seating Positions and Driving Controls Definitions</th></tr>
<tr><td>Currently specified in 49 CFR § 571.3</td><td colspan="2">DSP means a seat location that has a seating surface width, as described in section 571.10(c), of at least 330 mm (13 inches), and section 571.10 provides a method for calculating the number of DSPs based on the width of the seat.</td></tr>
<tr><th></th><th>Potential Set 1</th><th>Potential Set 2</th></tr>
<tr><td>Driver’s Designated Seating Position (driver’s seat or driver’s seating position)</td><td>Means a DSP immediately behind the manually operated driving controls positioned such that an occupant can operate the manual driving controls, regardless of whether the occupant is in active control of the vehicle.</td><td>Means a DSP providing immediate access to the manually operated driving controls.</td></tr>
<tr><td>Manually Operated Driving Controls</td><td>Means the system used by an occupant to manipulate the vehicle’s lateral (steering) and/or longitudinal (acceleration and deceleration) motion in real time.</td><td>Means (a) the system used by an occupant for real-time sustained manipulation of the motor vehicle’s heading (steering) and/or speed (accelerator and brake); (b) positioned such that they can be used by an occupant; (c) regardless of whether the occupant is actively manipulating the vehicle’s motion.</td></tr>
<tr><th></th><th>Potential Set (1 or 2) A</th><th>Potential Set (1 or 2) B</th></tr>
<tr><td>Passenger Designated Seating Position (Passenger Seat or Passenger Seating Position)</td><td>Means any DSP other than the driver’s DSP.</td><td>Means any DSP other than the driver’s DSP. Specifically, a seating position with stowed manually operated driving controls is a passenger DSP.</td></tr>
<tr><td>Steering Control (Wheel)</td><td colspan="2">Means the manually operated driving control used to manipulate the vehicle’s heading.</td></tr>
<tr><td rowspan="2">Translation Note</td><td colspan="2">Driver’s DSP and manually operated driving controls are grouped into sets. The definitions of “passenger DSP” and “steering control” are the same for both Set 1 and Set 2. There are two options (A and B) for the definition of passenger DSP.</td></tr>
<tr><td>Driver’s DSP definition from Set 1 should be used in conjunction with the manually operated driving controls definition from Set 1.</td><td>Driver’s DSP definition from Set 2 should be used in conjunction with the manually operated driving controls definition from Set 2.</td></tr>
</table>

Bidirectional Vehicle Definitions		
	Potential Option 1	**Potential Option 2**
Bidirectional Vehicle	Means an ADS-equipped vehicle without manually operated driving controls that can perform the DDT across an equivalent range of speed and heading control in two opposite directions.	Means a motor vehicle that operates across an equivalent range of speed and heading control in two opposite directions.
Translation Note	Instead of translating within each standard, bidirectional vehicles could be addressed generically in Subpart A of 49 CDR Part 571. In addition to the Section 571.3 definition, a new section could be added to clarify the application.	

Applicability of the FMVSS to Bidirectional Vehicles	
Bidirectional Vehicle	Each applicable standard set forth in Subpart B of this Part shall apply to bidirectional vehicles in both directions of travel.
Translation Note	A new subsection (g) of section 571.7, or a new section 571.11 could be added to clarify the translations for the applicability of the FMVSS to bidirectional vehicles.

Appendix B. FMVSS Technical Translation Worksheets

This appendix provides technical translation option summaries for select FMVSS covered in Volume 2 research, followed by tables of technical translation options and their potential considerations. Only technical translations that were assessed as either a "1-Translation is straightforward" or "2-Limited research may be beneficial" are shown in this appendix; thus, FMVSS No. 125 (Warning Devices), FMVSS No. 210 (Seat belt assembly anchorages) and FMVSS No. 219 (Windshield zone intrusion) are not included in these summaries. FMVSS No. 111 (Rear Visibility) is also not presented because the research team concluded that additional research may be required to complete the technical translation option development.

Any additional considerations for discussion with regard to the sections of the FMVSS that were assessed as a "0-Not performed" are captured within the main body of this report. If the creation of a potential additional section to the FMVSS was considered, the top header row will contain the original section number in the far left-hand column, and a unique section number followed by "Added for ADS-DV Translation" in the center column. Text colored in red font corresponds to the word or phrase that was either changed or omitted from the regulatory text into one of the technical translation options. Occasionally, there is text colored in red font within the Regulatory Text column that cites an incorporated reference. The reference analysis was not captured within the tables below, please see Appendix E for more information.

FMVSS No. 101: Controls and Displays

Technical Translation Options Summary: *The purpose of this FMVSS is "to ensure the accessibility, visibility and recognition of motor vehicle controls, telltales and indicators, and to facilitate the proper selection of controls under daylight and nighttime conditions, in order to reduce the safety hazards caused by the diversion of the driver's attention from the driving task, and by mistakes in selecting controls." (S2)*

Therefore, Options 1 and 2 clarify that this standard applies only to vehicles operated by a human driver. The automated driving system (ADS) may not need aspects such as color, contrast, etc., to ensure the information is presented in a salient manner. Methods to satisfy all possible ADS informational needs are outside of the current project scope. However, some of the information that is currently communicated to the human driver might be deemed safety-relevant for occupants in the absence of a human driver inside the vehicle's cabin that could provide assistance in order to promote occupant safety. Option 3 presents option for ADS-dedicated vehicles (ADS-DVs) and if the vehicle is equipped with controls, telltales, or indicators than the requirements need to be met.

FMVSS No. 101, S2. Purpose.			
Regulatory Text	**Translation Options**		**Potential Considerations**
The purpose of this standard is to ensure the accessibility, visibility and recognition of motor vehicle controls, telltales and indicators, and to facilitate the proper selection of controls under daylight and nighttime conditions, in order to reduce the safety hazards caused by the diversion of the driver's attention from the driving task, and by mistakes in selecting controls.	**Option 1**	... hazards caused by the diversion of the human driver's attention from the driving task, and by mistakes in selecting controls.	Uses driver definition 1. Specifies that the purpose applies to vehicles designed for operation by a human driver. An ADS- dedicated vehicle (ADS-DV would not require such conventional identifiers; therefore, ADS driver is not mentioned). This is focused on human driver visibility. ADS-DVs do not require visible telltales with a particular location, identification, color, and illumination. This may not be the preferred approach to translation given that the type of information/command needs for the ADS is not specified.
	Option 2	Retain current language.	Uses driver definition 2. This option depends on an updated definition of "driver" provided as part of the working definitions. Minimizes the number of translations needed. Potential ambiguity given that the type of driver is not mentioned.

FMVSS No. 101, S4. Definitions.			
Regulatory Text	**Translation Options**		**Potential Considerations**
Control means the hand-operated part of a device that enables the driver to change the state or functioning of the vehicle or a vehicle subsystem.	**Option 1**	*Control* means the hand-operated part of a device that enables the human driver to change the state or functioning of the vehicle or a vehicle subsystem.	Uses driver definition 1. Clarifies that the word "control" is focused on what the human driver needs or interacts with. Other interface aspects that are part of typical controls and displays might not be under this denomination. There might be controls for occupants, but if they are not safety-relevant they will not be considered under this definition.
	Option 2	Retain current language.	Uses driver definition 2. This option depends on an updated definition of "driver" provided as part of the working definitions. Minimizes the number of translations needed. Potential ambiguity given that the type of driver is not mentioned.

FMVSS No. 101, S4. Definitions. (continued)			
Regulatory Text	**Translation Options**		**Potential Considerations**
Multi-function control means a control through which the driver may select, and affect the operation of, more than one vehicle function.	**Option 1**	*Multi-function control* means a control through which the human driver may select, and affect the operation of, more than one vehicle function.	Uses driver definition 1. Clarifies that the word "control" is focused on what the human driver needs or interacts with. Other interface aspects that are part of typical controls and displays might not be under this denomination. There might be controls for occupants, but if they are not safety-relevant they will not be considered under this definition.
	Option 2	Retain current language.	Uses driver definition 2. This option depends on an updated definition of "driver" provided as part of the working definitions. Minimizes the number of translations needed. Potential ambiguity given that the type of driver is not mentioned.

FMVSS No. 101, S5. Requirements.			
Regulatory Text	**Translation Options**		**Potential Considerations**
Each passenger car, multipurpose passenger vehicle, truck and bus that is fitted with a control, a telltale or an indicator listed in Table 1 or Table 2 must meet the requirements of this standard for the location, identification, color, and illumination of that control, telltale or indicator. However, the requirements for telltales and indicators do not apply to vehicles with GVWRs of 4,536 kg or greater if these specified vehicles are manufactured before September 1, 2013.	**Option 1**	Each passenger car, multipurpose passenger vehicle, truck and bus that can be operated by a human driver and is fitted with…	Uses driver definition 1. Specifies that the requirement applies to vehicles designed for operation by a human driver. This is focused on human driver visibility. The ADS-DV does not require visible telltales with a particular location, identification, color, and illumination. This may not be the preferred approach to translation given that the information/command needs for the ADS are not specified.
	Option 2	Each passenger car, multipurpose passenger vehicle, truck and bus that can be operated by a driver and is fitted with…	Uses driver definition 2. Specifies that the requirement applies to vehicles designed for operation by a human driver. This is focused on human driver visibility. The ADS-DV does not require visible telltales with a particular location, identification, color, and illumination. This may not be the preferred approach to translation given that the information/command needs for the ADS are not specified.

FMVSS No. 101, S5. Requirements. (continued)			
Regulatory Text	**Translation Options**		**Potential Considerations**
Each passenger car, multipurpose passenger vehicle, truck and bus that is fitted with a control, a telltale or an indicator listed in Table 1 or Table 2 must meet the requirements of this standard for the location, identification, color, and illumination of that control, telltale or indicator. However, the requirements for telltales and indicators do not apply to vehicles with GVWRs of 4,536 kg or greater if these specified vehicles are manufactured before September 1, 2013.	**Option 3**	Each passenger car, multipurpose passenger vehicle, truck and bus that can be operated by a human driver and is fitted with… September 1, 2013. For an ADS-DV, if the vehicle is equipped with controls, telltales or indicators listed in Table 1 or Table 2, such controls, telltales, or indicators must be operable by and/or visible to relevant DSPs.	Uses driver definition 1. Specifies that the requirement applies to vehicles designed for operation by a human driver. An ADS-DV that has controls, telltales, or indicators assumes they are for the occupants. An option is not to limit FMVSS No. 101 to vehicles intended for a human driver but to make inapplicable to ADS-DVs the location requirements that have been developed for driver visibility and operation. Therefore, such indicators, etc., that a manufacturer wants to include or another FMVSS requires could potentially be placed and oriented as the manufacturer finds most useful to occupants. The focus is on human driver visibility. ADS-DVs do not require visible telltales with a particular location, identification, color, or illumination. However, a subset of the controls, telltales or indicators might be added by manufacturers. If so, the focus of these would be for occupants. This may not be the preferred approach to translation given that the information/command needs for the ADS are not specified. The suggested requirements for ADS-DV occupants have not been tested. This alternative might benefit from research to better understand occupant needs (e.g., location, illumination). For example, Potential Option 3 found on p. 30 of the FMVSS Considerations for Vehicles with Automated Driving Systems: Volume 1 (Blanco et al., 2020) provides the location option of "to the ADS and all front DSPs," which would require telltales and indicators to be provided in the front row seating positions. Alternatively, location Option 5 provides an alternative of "to the ADS and the occupant compartment maintenance panel."

FMVSS No. 101, S5.1.1 Location			
Regulatory Text	**Translation Options**		**Potential Considerations**
The controls listed in Table 1 and in Table 2 must be located so they are operable by the driver under the conditions of S5.6.2.	**Option 1**	The controls listed in Table 1 and in Table 2 must be located so they are operable by the human driver under the conditions of S5.6.2.	Uses driver definition 1. Clarifies which driver type needs to be able to reach controls in Tables 1 and 2 while belted. For this translation, it is important to identify which driver type needs the information located in the referenced tables (i.e., human versus ADS). S2 suggests the purpose "is to ensure the accessibility, visibility and recognition of motor vehicle controls, telltales and indicators, and to facilitate the proper selection of controls under daylight and nighttime conditions, in order to reduce the safety hazards caused by the diversion of the driver's attention from the driving task, and by mistakes in selecting controls." For an ADS-DV, the ADS is considered the driver and ensuring that proper information is "accessible" to the ADS is independent of the information presented in these tables. However, the human driver has the potential for diversion of their attention and could benefit from a standardized visual cue to avoid delays and misinterpretation.
	Option 2	Retain current language.	Uses driver definition 2. This option depends on an updated definition of "driver" provided as part of the working definitions. Minimizes the number of translations needed. Potential ambiguity given that the type of driver is not mentioned.

FMVSS No. 101, S5.1.2 Location			
Regulatory Text	**Translation Options**		**Potential Considerations**
The telltales and indicators listed in Table 1 and Table 2 and their identification must be located so that, when activated, they are visible to a driver under the conditions of S5.6.1 and S5.6.2.	**Option 1**	...visible to the human driver under the conditions of S5.6.1 and S5.6.2.	Uses driver definition 1. Using "the human" instead of "a human" for consistency with S5.1.1 and S5.1.4. Similar explanation to the one above for S5.1.1 applied to S5.1.2. Clarifies which driver type needs to receive the visual information presented in Tables 1 and 2 while belted and considering lighting conditions. Attention under S2 implies communicating the appropriate level of urgency via color, flashing rate, etc. The focus for this is human attention. No procedures or standards currently exist on how similar information will be presented to the ADS.
	Option 2	Retain current language.	Uses driver definition 2. This option depends on an updated definition of "driver" provided as part of the working definitions. Minimizes the number of translations needed. Potential ambiguity given that the type of driver is not mentioned. Attention under S2 implies communicating the appropriate level of urgency via color, flashing rate, etc. The focus for this is human attention. No procedures or standards currently exist on how similar information will be presented to the ADS.

FMVSS No. 101, S5.1.2 Location (continued)			
Regulatory Text	**Translation Options**		**Potential Considerations**
The telltales and indicators listed in Table 1 and Table 2 and their identification must be located so that, when activated, they are visible to a driver under the conditions of S5.6.1 and S5.6.2.	**Option 3**	...visible to the human driver under the conditions of S5.6.1 and S5.6.2. For an ADS-DV, if equipped with controls, telltales, or indicators listed in Table 1 or Table 2 in the occupant compartment, they must be located so that, when activated, they are visible to relevant DSPs.	Uses driver definition 1. Using "the human" instead of "a human" for consistency with S5.1.1 and S5.1.4. Similar explanation to the one above for S5.1.1 applied to S5.1.2. Clarifies which driver type needs to receive the visual information presented in Tables 1 and 2 while belted and considering lighting conditions. Attention under S2 implies communicating the appropriate level of urgency via color, flashing rate, etc. The focus for this is human attention. No procedures or standards currently exist on how similar information will be presented to the ADS. The suggested requirements for occupants have not been tested.

FMVSS No. 101, S5.1.4 Location			
Regulatory Text	**Translation Options**		**Potential Considerations**
The requirement of S5.1.3 does not apply to a multi-function control, provided the multi-function control is associated with a multi-task display that: (a) Is visible to the driver under the conditions of S5.6.1 and S5.6.2, (b) Identifies the multi-function control with which it is associated graphically or using words, (c) For multi-task displays with layers, identifies on the top-most layer each system for which control is possible from the associated multifunction control, including systems not otherwise regulated by this standard. Subfunctions of the available systems need not be shown on the top-most layer of the multi-task display, and (d) Identifies the controls of Table 1 and Table 2 with the identification specified in those tables or otherwise required by this standard, whenever those are the active functions of the multi-function control. For lower levels of multi-task displays with layers, identification is permitted but not required for systems not otherwise regulated by this standard.	**Option 1**	...visible to the human driver under the conditions of S5.6.1 and S5.6.2...	Uses driver definition 1. Using "the human driver" instead of "a human" for consistency with above. Similar explanation to the one above for S5.1.1 and S5.1.2 applied to S5.1.4. Clarifies which driver type needs to receive the visual information presented in Tables 1 and 2 while belted and considering lighting conditions. Attention under S2 implies communicating the appropriate level of urgency via color, flashing rate, etc. The focus for this is human attention. No procedures or standards currently exist on how similar information will be presented to the ADS.
	Option 2	Retain current language.	Uses driver definition 2. This option depends on an updated definition of "driver" provided as part of the working definitions. Minimizes the number of translations needed. Potential ambiguity given that the type of driver is not mentioned.

FMVSS No. 101, S5.1.4 Location			
Regulatory Text	**Translation Options**		**Potential Considerations**
(e) Does not display telltales listed in Table 1 or Table 2.			

FMVSS No. 101, S5.2.1 Identification			
Regulatory Text	**Translation Options**		**Potential Considerations**
Except for the Low Tire Pressure Telltale, each control, telltale and indicator that is listed in column 1 of Table 1 or Table 2 must be identified by the symbol specified for it in column 2 or the word or abbreviation specified for it in column 3 of Table 1 or Table 2. If a symbol is used, each symbol provided pursuant to this paragraph must be substantially similar in form to the symbol as it appears in Table 1 or Table 2. If a symbol is used, each symbol provided pursuant to this paragraph must have the proportional dimensional characteristics of the symbol as it appears in Table 1 or Table 2. The Low Tire Pressure Telltale (either the	**Option 1**	…by the human driver pressing…	Uses driver definition 1. Clarifies which driver type needs to receive the visual information presented in Tables 1 and 2. Attention under S2 implies communicating the appropriate level of urgency via color, flashing rate, etc. The focus for this is human attention. No procedures or standards currently exist on how similar information will be presented to the ADS.
		Retain current language.	Uses driver definition 2.

FMVSS No. 101, S5.2.1 Identification			
Regulatory Text	**Translation Options**		**Potential Considerations**
display identifying which tire has low pressure or the display which does not identify which tire has low pressure) shall be identified by the appropriate symbol designated in column 4, or both the symbol in column 4 and the words in column 3. No identification is required for any horn (i.e., audible warning signal) that is activated by a lanyard or by the driver pressing on the center of the face plane of the steering wheel hub; or for a turn signal control that is operated in a plane essentially parallel to the face plane of the steering wheel in its normal driving position and which is located on the left side of the steering column so that it is the control on that side of the column nearest to the steering wheel face plane. However, if identification is provided for a horn control in the center of the face plane of the steering wheel hub, the identifier must meet Table 2 requirements for the horn.	**Option 2**		This option depends on an updated definition of "driver" provided as part of the working definitions. Minimizes the number of translations needed. Potential ambiguity given that the type of driver is not mentioned.

<table>
<tr><th colspan="4">FMVSS No. 101, S5.2.6 Identification</th></tr>
<tr><th>Regulatory Text</th><th colspan="2">Translation Options</th><th>Potential Considerations</th></tr>
<tr><td rowspan="2">Except as provided in S5.2.7, all identifications of telltales, indicators and controls listed in Table 1 or Table 2 must appear to the driver to be perceptually upright. A rotating control that has an ''off'' position shall appear to the driver perceptually upright when the rotating control is in the ''off'' position.</td><td>Option 1</td><td>...the human driver…</td><td>Uses driver definition 1.

The strategy for this translation is to identify which driver type needs the information located in the referenced tables.

Clarifies which driver type needs to receive the visual information presented in Tables 1 and 2.

Attention under S2 implies communicating the appropriate level of urgency via color, flashing rate, etc. The focus for this is human attention. No procedures or standards currently exist on how similar information will be presented to the ADS.</td></tr>
<tr><td>Option 2</td><td>Retain current language.</td><td>Uses driver definition 2.

This option depends on an updated definition of "driver" provided as part of the working definitions.

Minimizes the number of translations needed.

Potential ambiguity given that the type of driver is not mentioned.</td></tr>
</table>

<table>
<tr><th colspan="4">FMVSS No. 101, S5.2.7 Identification</th></tr>
<tr><th>Regulatory Text</th><th colspan="2">Translation Options</th><th>Potential Considerations</th></tr>
<tr><td rowspan="2">The identification of the following items need not appear to the driver to be perceptually upright:

(a) A horn control;

(b) Any control, telltale or indicator located on the steering wheel, when the steering wheel is positioned for the motor vehicle to travel in a direction other than straight forward; and

(c) Any rotating control that does not have an “off” position.</td><td>Option 1</td><td>...the human driver...</td><td>Uses driver definition 1.

The strategy for this translation is to identify which driver type needs the information.

Clarifies which driver type needs the information.

This section depends on mental models of a human driver and object perception/recognition. It also applies to the ADS with regard to term consistency, but not with the physical characteristics presented in this section. If the driver type is not specified, it might not be possible to translate this section.</td></tr>
<tr><td>Option 2</td><td>Retain current language.</td><td>Uses driver definition 2.

This option depends on an updated definition of "driver" provided as part of the working definitions.

Minimizes the number of translations needed.

Potential ambiguity given that the type of driver is not mentioned.</td></tr>
</table>

FMVSS No. 101, S5.2.8 Identification			
Regulatory Text	**Translation Options**		**Potential Considerations**
Each control for an automatic vehicle speed system (cruise control) and each control for heating and air conditioning systems must have identification provided for each function of each such system.	**Option 1**	For vehicles operated by a human driver, each control…	Specifies that the requirement applies to vehicles designed for operation by a human driver. ADS-DVs would not require such identifiers. Allows ADS-DVs to not display such indicators. Splitting into separate categories may not be the preferred treatment.
	Option 2	For vehicles operated by a driver, each control…	Uses driver definition 2. This option depends on an updated definition of "driver" provided as part of the working definitions. Minimizes the number of translations needed. Potential ambiguity given that the type of driver is not mentioned.

FMVSS No. 101, S5.3.2.1 Brightness of illumination of controls and indicators			
Regulatory Text	**Translation Options**		**Potential Considerations**
Means must be provided for illuminating the indicators, identifications of indicators and identifications of controls listed in Table 1 to make them visible to the driver under daylight and nighttime driving conditions.	**Option 1**	...the human driver...	Uses driver definition 1. Using "the human" for consistency with above. Similar explanation to the ones above for S5.1.1 and S5.1.2 applied to S5.3.2.1. Clarifies which driver type needs to receive the visual information. Attention under S2 implies communicating the appropriate level of urgency via color, flashing rate, etc. The focus for this is human attention. No procedures or standards currently exist on how similar information will be presented to the ADS.
	Option 2	Retain current language.	Uses driver definition 2. This option depends on an updated definition of "driver" provided as part of the working definitions. Minimizes the number of translations needed. Potential ambiguity given that the type of driver is not mentioned.

FMVSS No. 101, S5.3.2.2 Brightness of illumination of controls and indicators			
Regulatory Text	**Translation Options**		**Potential Considerations**
The means of providing the visibility required by S5.3.2.1: (a) Must be adjustable to provide at least two levels of brightness; (b) At a level of brightness other than the highest level, the identification of controls and indicators must be barely discernible to the driver who has adapted to dark ambient roadway condition; (c) May be operable manually or automatically; and (d) May have levels of brightness, other than the two required visible levels of brightness, at which those items and identification are not visible. (1) If the level of brightness is adjusted by automatic means to a point where those items or their identification are not visible to the driver, means shall be provided to enable the driver to restore visibility.	**Option 1**	(b)...the human driver... (1) ...the human driver...	Uses driver definition 1. Using "the human" for consistency with above. Similar explanation to the ones above for S5.1.1 and S5.1.2 applied to S5.3.2.1. Clarifies which driver type needs to receive the visual information. Attention under S2 implies communicating the appropriate level of urgency via color, flashing rate, etc. The focus for this is human attention. No procedures or standards currently exist on how similar information will be presented to the ADS.
	Option 2	Retain current language.	Uses driver definition 2. This option depends on an updated definition of "driver" provided as part of the working definitions. Minimizes the number of translations needed. Potential ambiguity given that the type of driver is not mentioned.

FMVSS No. 101, S5.3.3 Brightness of telltale illumination			
Regulatory Text	**Translation Options**		**Potential Considerations**
(a) Means must be provided for illuminating telltales and their identification sufficiently to make them visible to the driver under daylight and nighttime driving conditions. (b) The means for providing the required visibility may be adjustable manually or automatically, except that the telltales and identification for brakes, high beams, turn signals, and safety belts may not be adjustable under any driving condition to a level that is invisible.	**Option 1**	(a)...the human driver...	Uses driver definition 1. Using "the human" for consistency with above. Clarifies which driver is receiving the visual information. Attention under S2 implies communicating the appropriate level of urgency via color, flashing rate, etc. The focus for this is human attention. No procedures or standards currently exist on how similar information will be presented to the ADS.
	Option 2	Retain current language.	Uses driver definition 2. This option depends on an updated definition of "driver" provided as part of the working definitions. Minimizes the number of translations needed. Potential ambiguity given that the type of driver is not mentioned.

FMVSS No. 101, S5.4.1 Color			
Regulatory Text	**Translation Options**		**Potential Considerations**
The light of each telltale listed in Table 1 must be of the color specified for that telltale in column 6 of that table.	**Option 1**	For vehicles operated by a human driver, the light of…	Distinguishes that visible telltales are necessary on vehicles operated by a human driver, but not ADS-DVs. Clarifies that the requirement applies to vehicles operated by a human driver and not ADS-DVs. May not be the preferred translation approach.
	Option 2	For vehicles operated by a driver, the light of…	Uses driver definition 2. This option depends on an updated definition of "driver" provided as part of the working definitions. Distinguishes that visible telltales are necessary on vehicles operated by a human driver, but not on ADS-DVs. Minimizes the number of translations needed. Potential ambiguity given that the type of driver is not mentioned.

FMVSS No. 101, S5.4.2 Color			
Regulatory Text	**Translation Options**		**Potential Considerations**
Any indicator or telltale not listed in Table 1 and any identification of that indicator or telltale must not be a color that masks the driver's ability to recognize any telltale, control, or indicator listed in Table 1.	**Option 1**	...masks the human driver's ability....	Uses driver definition 1. Using "the human" instead of "the driver" for consistency with above. Clarifies which driver is receiving the visual information. Attention under S2 implies communicating the appropriate level of urgency via color, flashing rate, etc. The focus for this is human attention. No procedures or standards currently exist on how similar information will be presented to the ADS.
	Option 2	Retain current language.	Uses driver definition 2. This option depends on an updated definition of "driver" provided as part of the working definitions. Minimizes the number of translations needed. Potential ambiguity given that the type of driver is not mentioned.

<table>
<tr><th colspan="4">FMVSS No. 101, S5.5.4 Common space for displaying multiple messages</th></tr>
<tr><th>Regulatory Text</th><th colspan="2">Translation Options</th><th>Potential Considerations</th></tr>
<tr><td rowspan="2">Except as provided in S5.5.5, when the underlying conditions exist for actuation of two or more telltales, the messages must be either:
(a) Repeated automatically in sequence, or
(b) Indicated by visible means and capable of being selected for viewing by the driver under the conditions of S5.6.2.</td><td>Option 1</td><td>...the human driver...</td><td>Uses driver definition 1.

Using "the human" instead of "the driver" for consistency with above.

Clarifies which driver is receiving the visual information.

Attention under S2 implies communicating the appropriate level of urgency via color, flashing rate, etc. The focus for this is human attention. No procedures or standards currently exist on how similar information will be presented to the ADS.</td></tr>
<tr><td>Option 2</td><td>Retain current language.</td><td>Uses driver definition 2.

This option depends on an updated definition of "driver".

Minimizes the number of translations needed.

Potential ambiguity given that the type of driver is not mentioned.</td></tr>
</table>

FMVSS No. 101, S5.5.6 Common space for displaying multiple messages			
Regulatory Text	**Translation Options**		**Potential Considerations**
(a) Except as provided in S5.5.6 (b), messages displayed in a common space may be cancelable automatically or by the driver. (b) Telltales for high beams, turn signal, low tire pressure, and passenger air bag off, and telltales for which the color red is required in Table 1 must not be cancelable while the underlying condition for their activation exists.	**Option 1**	...the human driver...	Uses driver definition 1. Using "the human" instead of "the driver" for consistency with above. Clarifies which driver should be able to cancel the message. Attention under S2 implies communicating the appropriate level of urgency via color, flashing rate, etc. The focus for this is human attention. No procedures or standards currently exist on how similar information will be presented to the ADS.
	Option 2	Retain current language.	Uses driver definition 2. This option depends on an updated definition of "driver." Minimizes the number of translations needed. Potential ambiguity given that the type of driver is not mentioned.

FMVSS No. 101, S5.6.1 Conditions			
Regulatory Text	**Translation Options**		**Potential Considerations**
The driver has adapted to the ambient light roadway conditions.	**Option 1**	...the human driver...	Uses driver definition 1. Using "the human" instead of "the driver" for consistency with above. Clarifies that the human driver is relevant in this case. The focus for this is human visibility. No procedures or standards currently exist on how similar information (visibility) will be presented to the ADS.
	Option 2	Retain current language.	Uses driver definition 2. This option depends on an updated definition of "driver." Minimizes the number of translations needed. Potential ambiguity given that the type of driver is not mentioned.
	Option 3	The human driver and occupants in relevant DSPs for an ADS-DV have...	Uses driver definition 1. Specifies that the requirement applies to vehicles designed for operation by a human driver. An ADS-DV that has displays and controls assumes they are for the occupants. An option is not to limit FMVSS No. 101 to vehicles intended for a human driver, but to make inapplicable to ADS-DVs the location requirements that have been developed for driver visibility and operation. Therefore, such indicators, etc., that a manufacturer wants to potentially include or another FMVSS requires could be placed and oriented as the manufacturer finds most useful to occupants. This particular option

			clarifies that lighting conditions of interest, when the focus is occupants, are similar to those required for the human driver.

FMVSS No. 101, S5.6.2 Conditions			
Regulatory Text	**Translation Options**		**Potential Considerations**
The driver is restrained by the seat belts installed in accordance with 49 CFR 571.208 and adjusted in accordance with the vehicle manufacturer's instructions.	**Option 1**	...the human driver.	Uses driver definition 1. Using "the human" instead of "the driver" for consistency with above. Clarifies that the human driver is being restrained by the seat belts.
	Option 2	Retain current language.	Uses driver definition 2. This option depends on an updated definition of "driver." Minimizes the number of translations needed. Potential ambiguity given that the type of driver is not mentioned.
	Option 3	The human driver and occupants in relevant DSPs for an ADS-DV are...	Uses driver definition 1. Specifies that the requirement applies to vehicles designed for operation by a human driver. An ADS-DV that has displays and controls assumes the requirement is for the occupants. An option is not to limit FMVSS No. 101 to vehicles intended for a human driver, but to make inapplicable to ADS-DVs the location requirements developed for driver visibility and operation. Therefore, such indicators, etc., that a manufacturer wants to include or another FMVSS requires could be placed and oriented

FMVSS No. 101, S5.6.2 Conditions			
Regulatory Text	**Translation Options**		**Potential Considerations**
			as the manufacturer finds most useful to occupants. This particular option clarifies the occupant of interest should be restrained by the seat belt when testing is performed, under similar conditions to those required for the human driver.

FMVSS No. 103: Windshield Defrosting and Defogging Systems

Technical Translation Options Summary: *The purpose of this FMVSS "specifies requirements for windshield defrosting and defogging systems." (S1)*

The majority of options clarify that this standard applies only to vehicles operated by a human driver (Options 1-3). Option 1 uses driver definition 1, option 2 uses driver definition 2, and option 3 refers to the manually operated driving controls. Option 4 presents an "if equipped" option, using a manufacturer pattern designed for automated driving system-dedicated vehicles (ADS-DVs) and clarifies the human driver requirements by referencing the manually operated driving controls.

FMVSS No. 103, S4.1 Requirements.			
Regulatory Text	**Translation Options**		**Potential Considerations**
Each vehicle shall have a windshield defrosting and defogging system.	**Option 1**	Each vehicle that can be operated by a human driver shall have a windshield defrosting and defogging system.	Uses driver definition 1. This translation assumes the sensors needed for the ADS will not be positioned behind this FMVSS's windshield area of focus that needs to be kept unobstructed. This FMVSS provides for a minimum area of the windshield where visibility clearance for human drivers is needed. The sensors needed for ADS driving visibility do not require visibility in that particular area.
	Option 2	Each vehicle that can be operated by a driver shall have a windshield defrosting and defogging system.	Uses driver definition 2. This translation assumes that the sensors needed for the ADS driver will not be positioned behind this FMVSS's windshield area of focus that needs to be kept unobstructed. This FMVSS provides for a minimum area of the windshield where visibility clearance for human drivers is needed. The sensors needed for ADS driving visibility do not require visibility in that particular area.

FMVSS No. 103, S4.1 Requirements. (continued)			
Regulatory Text	**Translation Options**		**Potential Considerations**
Each vehicle shall have a windshield defrosting and defogging system.	**Option 3**	Each vehicle equipped with manually operated driving controls shall have a windshield defrosting and defogging system.	This option eliminates the need for the driver definition translation in this particular case. This translation assumes the sensors needed for the ADS will not be positioned behind this FMVSS's windshield area of focus that needs to be kept unobstructed. This FMVSS provides for a minimum area of the windshield where visibility clearance for human drivers is needed. The sensors needed for ADS driving visibility do not require visibility in that particular area. If, in future scenarios, other driving controls that are not hand/manual exist, this could potentially require further research.
	Option 4	Each vehicle equipped with manually operated driving controls shall have a windshield defrosting and defogging system. For an ADS-DV, if equipped with windshield defrosting and defogging systems, the system shall meet the requirements of	This option eliminates the need for the driver definition translation in this particular case. This translation assumes the sensors needed for the ADS driver will not be positioned behind this FMVSS's windshield area of focus that needs to be kept unobstructed. This option potentially allows for the system to be tested if installed in an ADS-DV. However, these systems might be considered convenience features for the occupants of an ADS-DV rather than safety requirements. If considered as convenience features, they could be in other windows or areas outside of Areas A and C, outside of the purview of this FMVSS. This option eliminates the need for the driver definition translation in this particular case. This FMVSS provides for a minimum area of the windshield where visibility clearance for human drivers is needed. The sensors needed for ADS driving visibility do not require visibility

FMVSS No. 103, S4.1 Requirements. (continued)			
Regulatory Text	**Translation Options**		**Potential Considerations**
		this standard for the pattern designed by the manufacturer for the windshield defrosting and defogging system on the interior surface of the windshield glazing.	in that particular area. However, this translation includes a potential option that allows manufacturers to optionally decide to provide a defrosting and defogging system in the traditional Area A and C, or as presented herein. If, in future scenarios, other driving controls that are not hand/manual exist, this could potentially require further research. This language potentially allows, but does not require, an ADS-DV to have a defrost/defog system. If the manufacturer chooses to provide one, it needs to comply with the existing standard. Note that several of the standards use controls as a reference point (e.g., H point; SAE J826) or are not available for seating positions (e.g., eyellipse; SAE J941) other than the driver's. An occupant eyellipse for adjustable seating is needed (Reed, 2018).

FMVSS No. 103, S4.2 Requirements.			
Regulatory Text	**Translation Options**		**Potential Considerations**
Each passenger car windshield defrosting and defogging system shall meet the requirements of section 3 of SAE Recommended Practice J902 (1964) (incorporated by reference, see §571.5) when tested in accordance with S4.3, except that "the critical area" specified in paragraph 3.1 of SAE Recommended Practice J902 (1964) shall be that established as Area C in accordance with Motor Vehicle Safety Standard No. 104, "Windshield Wiping and Washing Systems," and "the entire windshield" specified in paragraph 3.3 of SAE Recommended Practice J902 (1964) shall be that established as Area A in accordance with §571.104.	**Option 1**	For a vehicle that can be operated by a human driver, each passenger car windshield…	Uses driver definition 1.
	Option 2	For a vehicle that can be operated by a driver, each passenger car windshield…	Uses driver definition 2.
	Option 3	For a vehicle that can be operated with manually operated driving controls, each passenger car windshield…	This option eliminates the need for the driver definition translation in this particular case.
	Option 4	For a vehicle that can be operated with manually operated driving controls, each passenger car windshield...in accordance with §571.104. For an ADS-DV, if equipped with windshield defrosting and defogging systems, the pattern designed by the manufacturer for the windshield defrosting and defogging system on the interior surface of the windshield glazing defrost pattern of the windshield shall be 80 percent defrosted after 25 minutes of operation. After 40 minutes of operation the entire windshield area shall be 95 percent defrosted.	If there is a need to designate the defrost/defog system area as a windshield due to occupant visibility needs, a suggested area is presented based on the SAE Recommended Practice J902 (1964). This is a recommended approach that has not been evaluated for feasibility. Research may be needed in order to understand potential limitations of this approach. The test procedures would need validation to ensure they replicate the intended area.

FMVSS No. 103, S4.3 (i). Demonstration procedure.			
Regulatory Text	**Translation Options**		**Potential Considerations**
The engine speed shall not exceed 1,500 r.p.m. in neutral gear; or	**Option 1**	The engine speed shall not exceed 1,500 r.p.m. in a neutral transmission state; or	See S3.1.1 of FMVSS No. 103 for other neutral gear related translations. Does not limit the scope to ADS-DVs only.

FMVSS No. 104: Windshield Wiping and Washing Systems

Technical Translation Options Summary: *The purpose of this FMVSS "specifies requirements for windshield wiping and washing systems." (S1)*

Options 1 through 3 clarify that this standard applies only to vehicles operated by a human driver. The driver definitions used in the options are as follows: Option 1 uses driver definition 1, option 2 uses driver definition 2, and option 3 uses manually operated driving controls. Option 4 presents an "if equipped" option, using a manufacturer pattern designed for automated driving system-dedicated vehicles (ADS-DVs) and clarifies the human driver requirements by referencing the manually operated driving controls.

FMVSS No. 104, S4.1 Windshield wiping system.			
Regulatory Text	**Translation Options**		**Potential Considerations**
Each vehicle shall have a power-driven windshield wiping system that meets the requirements of S4.1.1.	**Option 1**	Each vehicle that can be operated by a human driver shall…	Uses driver definition 1. This translation assumes the sensors needed for the ADS will not be positioned in an area behind the windshield that needs to be kept unobstructed. This FMVSS provides for a minimum area of the windshield where visibility clearance for human drivers is needed. The sensors needed for ADS driving visibility may not require visibility in that particular area. This language allows, but does not require, an ADS-DV to have a wiping/washing system. Note that ADS-DVs might include vehicles that could be used for delivering goods but not for transporting occupants. For those and similar cases, a windshield might not be part of the vehicle design.
	Option 2	Each vehicle that can be operated by a driver shall…	Uses driver definition 2. This translation assumes the sensors needed for the ADS will not be positioned in an area behind the windshield that needs to be kept unobstructed. This FMVSS provides for a minimum area of the windshield where visibility clearance for human drivers is needed. The sensors needed for ADS driving visibility may not require visibility in that particular area. This language allows, but does not require, an ADS-DV to have a wiping/washing system. Note that ADS-DVs might include vehicles that could be used for delivering goods but not for transporting occupants. For those and similar cases, a windshield might not be part of the vehicle design.

FMVSS No. 104, S4.1 Windshield wiping system. (continued)			
Regulatory Text	**Translation Options**		**Potential Considerations**
Each vehicle shall have a power-driven windshield wiping system that meets the requirements of S4.1.1.	**Option 3**	Each vehicle equipped with manually operated driving controls shall...	This option eliminates the need for the driver definition translation in this particular case. This translation assumes that the sensors needed for the ADS driver will not be positioned behind this FMVSS's windshield area of focus that needs to be kept unobstructed. This FMVSS provides for a minimum area of the windshield where visibility clearance for human drivers is needed. The sensors needed for ADS driving visibility may not require visibility in that particular area. If, in future scenarios, other driving controls that are not hand/manual exist, this could potentially require further research.
	Option 4	Each vehicle equipped with manually operated driving controls shall have...of S4.1.1. For an ADS-DV, if equipped with a windshield wiping system, the system shall meet the requirements of S4.1.1.	This translation assumes that the sensors needed for the ADS driver will not be positioned behind this FMVSS's windshield area of focus that needs to be kept unobstructed. This option provides for the system to be tested if installed in an ADS-DV. However, these systems might be considered convenience features for the occupants of an ADS-DV rather than safety requirements.

FMVSS No. 104, S4.2.1 Windshield washing system.			
Regulatory Text	**Translation Options**		**Potential Considerations**
Each passenger car shall have a windshield washing system that meets the requirements of SAE Recommended Practice J942 (1965) (incorporated by reference, see §571.5), except that the reference to "the effective wipe pattern defined in SAE J903, paragraph 3.1.2" in paragraph 3.1 of SAE Recommended Practice J942 (1965) shall be deleted and "the areas established in accordance with subparagraph S4.1.2.1 of Motor Vehicle Safety Standard No. 104" shall be inserted in lieu thereof.	**Option 1**	Each passenger car that can be operated by a human driver shall…	Uses driver definition 1. This translation assumes that the sensors needed for the ADS will not be positioned behind this FMVSS's windshield area of focus that needs to be kept unobstructed. This FMVSS provides for a minimum area of the windshield where visibility clearance for human drivers is needed. The sensors needed for ADS driving visibility may not require visibility that particular area. This language allows, but does not require, an ADS-DV to have a wiping/washing system. Note that ADS-DVs might include vehicles that could be used for delivering goods but not for transporting occupants. For those and other similar cases, a windshield might not be part of the vehicle design.
	Option 2	Each passenger car that can be operated by a driver shall…	Uses driver definition 2. This translation assumes that the sensors needed for the ADS will not be positioned behind this FMVSS's windshield area of focus that needs to be kept unobstructed. This FMVSS provides for a minimum area of the windshield where visibility clearance for human drivers is needed. The sensors needed for ADS driving visibility may not require visibility in that particular area. This language allows, but does not require, an ADS-DV to have a wiping/washing system. Note that ADS-DVs might include vehicles that could be used for delivering goods and not for transporting occupants use. For those and other similar cases, a windshield might not be part of the vehicle design.

FMVSS No. 104, S4.2.1 Windshield washing system.			
Regulatory Text	**Translation Options**		**Potential Considerations**
Each passenger car shall have a windshield washing system that meets the requirements of SAE Recommended Practice J942 (1965) (incorporated by reference, see §571.5), except that the reference to "the effective wipe pattern defined in SAE J903, paragraph 3.1.2" in paragraph 3.1 of SAE Recommended Practice J942 (1965) shall be deleted and "the areas established in accordance with subparagraph S4.1.2.1 of Motor Vehicle Safety Standard No. 104" shall be inserted in lieu thereof.	**Option 3**	Each passenger car equipped with manually operated driving controls shall…	This option eliminates the need for the driver definition translation in this particular case. This translation assumes that the sensors needed for the ADS will not be positioned behind this FMVSS's windshield area of focus that needs to be kept unobstructed. This FMVSS provides for a minimum area of the windshield where visibility clearance for human drivers is needed. The sensors needed for ADS driving visibility may not require visibility in that particular area. If, in future scenarios, other driving controls that are not hand/manual exist, this could potentially require further research.

FMVSS No. 104, S4.2.2 Windshield washing system.			
Regulatory Text	**Translation Options**		**Potential Considerations**
Each multipurpose passenger vehicle, truck, and bus shall have a windshield washing system that meets the requirements of SAE Recommended Practice J942, November (1965) (incorporated by reference, see §571.5), except that the reference to ''the effective wipe pattern defined in SAE J903, paragraph 3.1.2'' in paragraph 3.1 of SAE Recommended Practice J942 (1965) shall be deleted and ''the pattern designed by the manufacturer for the windshield wiping system on the exterior surface of the windshield glazing'' shall be inserted in lieu thereof.	**Option 1**	Each multipurpose passenger vehicle, truck, and bus that can be operated by a human driver shall…	Uses driver definition 1. This translation assumes that the sensors needed for the ADS will not be positioned behind this FMVSS's windshield area of focus that needs to be kept unobstructed. This FMVSS provides for a minimum area of the windshield where visibility clearance for human drivers is needed. The sensors needed for ADS driving visibility do not require visibility in that particular area. This language allows, but does not require, an ADS-DV to have a wiping/washing system. Note that ADS-DVs might include vehicles that could be used for delivering goods and not for transporting occupants. For those and other similar cases, a windshield might not be part of the vehicle design.
	Option 2	Each multipurpose passenger vehicle, truck, and bus that can be operated by a driver shall…	Uses driver definition 2. This translation assumes that the sensors needed for the ADS will not be positioned behind this FMVSS's windshield area of focus that needs to be kept unobstructed. This FMVSS provides for a minimum area of the windshield where visibility clearance for human drivers is needed. The sensors needed for ADS driving visibility may not require visibility in that particular area. This language allows, but does not require, an ADS-DV to have a wiping/washing system. Note that ADS-DVs might include vehicles that could be used for delivering goods and not for transporting occupants use. For those and other similar cases, a windshield might not be part of the vehicle design.

FMVSS No. 104, S4.2.2 Windshield washing system. (continued)			
Regulatory Text	**Translation Options**		**Potential Considerations**
Each multipurpose passenger vehicle, truck, and bus shall have a windshield washing system that meets the requirements of SAE Recommended Practice J942, November (1965) (incorporated by reference, see §571.5), except that the reference to ''the effective wipe pattern defined in SAE J903, paragraph 3.1.2'' in paragraph 3.1 of SAE Recommended Practice J942 (1965) shall be deleted and ''the pattern designed by the manufacturer for the windshield wiping system on the exterior surface of the windshield glazing'' shall be inserted in lieu thereof.	**Option 3**	Each multipurpose passenger vehicle, truck, and bus equipped with manually operated driving controls shall…	This option eliminates the need for the driver definition translation in this particular case. This translation assumes that the sensors needed for the ADS will not be positioned behind this FMVSS's windshield area of focus that needs to be kept unobstructed. This FMVSS provides for a minimum area of the windshield where visibility clearance for human drivers is needed. The sensors needed for ADS driving visibility may not require visibility in that particular area. If, in future scenarios, other driving controls that are not hand/manual exist, this could potentially require further research.

FMVSS No. 104, S4.2.2 Windshield washing system. (continued)			
Regulatory Text	**Translation Options**		**Potential Considerations**
Each multipurpose passenger vehicle, truck, and bus shall have a windshield washing system that meets the requirements of SAE Recommended Practice J942, November (1965) (incorporated by reference, see §571.5), except that the reference to ''the effective wipe pattern defined in SAE J903, paragraph 3.1.2'' in paragraph 3.1 of SAE Recommended Practice J942 (1965) shall be deleted and ''the pattern designed by the manufacturer for the windshield wiping system on the exterior surface of the windshield glazing'' shall be inserted in lieu thereof.	**Option 4**	Each multipurpose passenger vehicle, truck, and bus equipped with manually operated driving controls shall… thereof. For an ADS-DV, if equipped with windshield washing system, the system shall meet the requirements of this standard for the pattern designed by the manufacturer for the windshield wiping system on the exterior surface of the windshield glazing.	This translation assumes that the sensors needed for the ADS will not be positioned behind this FMVSS's windshield area of focus that needs to be kept unobstructed. This option provides for the system to be tested if installed in an ADS-DV; however, these systems might be considered convenience features for the occupants of an ADS-DV and not safety requirements. If considered convenience features, then this is outside of the purview of this FMVSS. This option eliminates the need for the driver definition translation in this particular case. This FMVSS provides for a minimum area of the windshield where visibility clearance for human drivers is needed. The sensors needed for ADS driving visibility may not require visibility in that particular area. However, it includes an option for those manufacturers that decide to provide a wiping/washing system. If, in future scenarios, other driving controls that are not hand/manual exist, this could potentially require further research. This language allows, but does not require, an ADS-DV to have a wiping/washing system. If the manufacturer chooses to provide one, it needs to comply with the existing standard. Note that several of the standards use controls as a reference point (e.g., H point; SAE J826) or are not available for seating positions (e.g., eyellipse; SAE J941) other than the driver's. An occupant eyellipse for adjustable seating is needed (Reed, 2018).

FMVSS No. 110: Tire Selection and Rims and Motor Home/Recreation Vehicle Trailer Load Carrying Capacity Information for Motor Vehicles With a GVWR of 4,536 Kilograms (10,000 Pounds) or Less

Technical Translation Options Summary. *The purpose of this FMVSS "specifies requirements for tire selection to prevent tire overloading and for motor home/recreation vehicle trailer load carrying capacity information." (S1)*

Two key aspects were addressed in the technical translation: (1) the placard location and content, and (2) the vehicle normal load on the tire. There are three translations options which are summarized as follows. Option 1: Applies driver definition 1 to the driver references, uses left, front B-Pillar to locate the placard and retains Table.1. Option 2: Applies driver definition 2 to the driver references, uses an alternative frame of reference (e.g., VIN) to locate the placard, and Table 1 would need to be updated to align to new reference. Option 3: Provides an alternative to option 1 using left B-Pillar to locate the placard and considers obtaining the tire loading through additional testing not based on typical seating patterns.

FMVSS No. 110, S4.3 Placard			
Regulatory Text	**Translation Options**		**Potential Considerations**
Each vehicle, except for a trailer or incomplete vehicle, shall show the information specified in S4.3 (a) through (g), and may show, at the manufacturer's option, the information specified in S4.3 (h) and (i), on a placard permanently affixed to the driver's side B-pillar. In each vehicle without a driver's side B-pillar and with two doors on the driver's side of the vehicle opening in opposite directions, the placard shall be affixed on the forward edge of the rear side door. If the above locations do not permit the affixing of a placard that is legible, visible and prominent, the placard shall be permanently affixed to the rear edge of the driver's side door. If this location does not permit the affixing of a placard that is legible, visible and prominent, the placard shall be affixed to the inward facing surface of the vehicle next to the driver's seating position. This information shall be in the English language and conform in color and format, not including the border surrounding the entire placard, as shown in the example set forth in Figure 1 in	**Option 1**	Each vehicle that can be operated by a human driver, except for a trailer or incomplete vehicle, shall... Each vehicle that can be operated by an ADS, except for a trailer or incomplete vehicle, shall show the information specified in S4.3 (a) through (g), and may show, at the manufacturer's option, the information specified in S4.3 (h) and (i), on a placard permanently affixed to the left front B-pillar. In each vehicle without a left front B-pillar and with two doors on the left front side of the vehicle opening in opposite directions, the placard shall be affixed on the forward edge of the rear side door. If the above locations do not permit the affixing of a placard that is legible, visible and prominent, the placard shall be permanently affixed to the rear edge of the left front side door. If this location does not permit the affixing of a placard that is legible, visible and prominent, the placard shall be affixed to the inward facing surface of the vehicle next to the left front seating position. This information shall be in the English language...	Uses driver definition 1. Retains current text for human drivers. Requires unique ADS-DV requirement. Adds new text for ADSs. Does not require referencing VIN and significant VIN regulation translations. Option introduces complex regulatory language.

this standard. At the manufacturer's option, the information specified in S4.3 (c), (d), and, as appropriate, (h) and (i) may be shown, alternatively to being shown on the placard, on a tire inflation pressure label which must conform in color and format, not including the border surrounding the entire label, as shown in the example set forth in Figure 2 in this standard. The label shall be permanently affixed and proximate to the placard required by this paragraph. The information specified in S4.3 (e) shall be shown on both the vehicle placard and on the tire inflation pressure label (if such a label is affixed to provide the information specified in S4.3 (c), (d), and, as appropriate, (h) and (i)) may be shown in the format and color scheme set forth in Figures 1 and 2. If the vehicle is a motor home and is equipped with a propane supply, the weight of full propane tanks must be included in the vehicle's unloaded vehicle weight. If the vehicle is a motor home and is equipped with an on-board potable water supply, the weight of such on-board water must be treated as cargo.	**Option 2**	Each vehicle that can be operated by a driver, except for a trailer or incomplete vehicle, shall… Each vehicle that can be operated by an ADS except for a trailer or incomplete vehicle, shall show the information specified in S4.3 (a) through (g), and may show, at the manufacturer's option, the information specified in S4.3 (h) and (i), on a placard permanently affixed to the second pillar aft of the 49 CFR Section 565 Vehicle Identification Number (VIN) placement and on the same side as the VIN. For vehicles that can be operated by an ADS without a second pillar aft of the VIN placement, the placard shall be affixed on the edge facing the VIN of the rear side door. If the above locations do not permit the affixing of a placard that is legible, visible and prominent, the placard shall be permanently affixed to the rear edge of the side door closest to the VIN location. If this location does not permit the affixing of a placard that is legible, visible and prominent, the placard shall be affixed to the inward facing surface of the vehicle next to the manufacturer seating position closest to the VIN location. This information shall be in the English language...	Uses driver definition 2. Retains current text for vehicles with manually operated driving controls. Requires unique ADS-DV requirement. Adds new text for ADSs. The ADS-DV requirement uses the VIN standard to potentially establish the vehicle's reference framework to provide a consistent placard placement. This could be accomplished with another reference point but more research may be needed. Vehicles operated by a human driver could also be modified to align with the new reference point for ADS-DVs to make them consistent. The VIN standard may require translation and may need to consider options to further clarify the placard placement.

FMVSS No. 110, S4.3 Placard (continued)			
Regulatory Text	**Translation Options**		**Potential Considerations**
See regulatory text above.	**Option 3**	Each vehicle, except for a trailer or incomplete vehicle, shall show the information specified in S4.3 (a) through (g), and may show, at the manufacturer's option, the information specified in S4.3 (h) and (i), on a placard permanently affixed to the left side B-pillar. In each vehicle without a left side B-pillar and with two doors on the left side of the vehicle opening in opposite directions, the placard shall be affixed on the forward edge of the rear side door. If the above locations do not permit the affixing of a placard that is legible, visible and prominent, the placard shall be permanently affixed to the rear edge of the left side door. If this location does not permit the affixing of a placard that is legible, visible and prominent, the placard shall be affixed to the inward facing surface of the vehicle next to the front left seating position... This information shall be in the English language...	Replaces the reference to the driver's side B-pillar with the left side B-pillar, which removes the driver language from the text. Utilizes the vehicle "left side" definition to reference the placard placement and removes the dependency on the term "driver." Removes the potential need for unique ADS-DV requirement. Bidirectional vehicles may require two placard labels.

FMVSS No. 110, S4.3 Placard (b)			
Regulatory Text	**Translation Options**		**Potential Considerations**
(b) Designated seated capacity (expressed in terms of total number of occupants and number of occupants for each front and rear seat location);	**Option 1**	(b) Designated seated capacity (expressed in terms of total number of occupants and number of seating positions);	Unconventional ADS-DVs may not have front and rear seat locations. This option allows for unconventional seating.
	Option 2	(b) Designated seated capacity (expressed in terms of total number of occupants and number of occupants for each seating position located in the vehicle areas defined in 49 Section 565 Diagram XX);	49 Section 565 translation to include placing the vehicle on a grid space to designate the VIN location and define specific vehicle areas (e.g., area A would be left, front half of the vehicle). This option provides a potential generic method to establish a frame of reference that could be used across vehicles and that is inclusive of bidirectional vehicles. Using the VIN standard or another frame of reference may work for designing the vehicle. However, more research may be needed to understand a suitable method to communicate information to the end user. There may be a potential need to develop the suitable and generic frame of reference for consistency across vehicles.
	Option 3	Same as Option 1.	

FMVSS No. 110, S4.3.3 Additional labeling information for vehicles other than passenger cars.			
Regulatory Text	**Translation Options**		**Potential Considerations**
Each vehicle shall show the size designation and, if applicable, the type designation of rims (not necessarily those on the vehicle) appropriate for the tire appropriate for use on that vehicle, including the tire installed as original equipment on the vehicle by the vehicle manufacturer, after each GAWR listed on the certification label required by §567.4 or §567.5 of this chapter. This information shall be in the English language, lettered in block capitals and numerals not less than 2.4 millimeters high and in the following format: Truck Example—Suitable Tire-Rim Choice GVWR: 2,441 kilograms (5381 pounds). GAWR: Front—1,299 kilograms (2,864 pounds) with P265/70R16 tires, 16 × 8.0 rims at 248 kPa (36 psi) cold single. GAWR: Rear—1,299 kilograms (2,864 pounds) with P265/70R16 tires, 16 × 8.00 rims, at 248 kPa (36 psi) cold single.	**Option 1**	Retain current language.	The example represents a conventional truck which has a front axle or rear axle. Future research may want to consider a second example for unconventional ADS-DV.

FMVSS No. 110, S4.3.3 Additional labeling information for vehicles other than passenger cars.			
Regulatory Text	**Translation Options**		**Potential Considerations**
	Option 2	Each vehicle shall show the size designation... and in the following format: Truck that can be operated by a driver Example—Suitable Tire-Rim Choice GVWR: 2,441 kilograms (5381 pounds). GAWR: Front—1,299 kilograms (2,864 pounds) with P265/70R16 tires, 16 × 8.0 rims at 248 kPa (36 psi) cold single. GAWR: Rear—1,299 kilograms (2,864 pounds) with P265/70R16 tires, 16 × 8.00 rims, at 248 kPa (36 psi) cold single. Truck that can be operated by an ADS Example—Suitable Tire-Rim Choice GVWR: 2,441 kilograms (5381 pounds). GAWR: Axle AB—1,299 kilograms (2,864 pounds) with P265/70R16 tires, 16 × 8.0 rims at 248 kPa (36 psi) cold single. GAWR: Axle CD—1,299 kilograms (2,864 pounds) with P265/70R16 tires, 16 × 8.00 rims, at 248 kPa (36 psi) cold single.	Uses driver definition 2. Retains current text for vehicles with manually operated driving controls. Requires unique ADS-DV requirement. Adds new example for ADS-equipped vehicles.

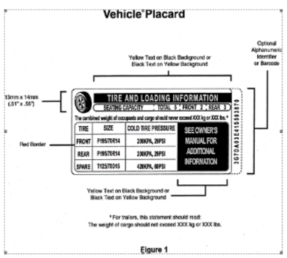
<table>
<tr><th colspan="4">FMVSS No. 110, S4.4.1 Requirements</th></tr>
<tr>
<td rowspan="2">
TABLE I—OCCUPANT LOADING AND DISTRIBUTION FOR VEHICLE NORMAL LOAD FOR VARIOUS DESIGNATED SEATING CAPACITIES
<table>
<tr><th>Designated seating capacity, number of occupants</th><th>Vehicle normal load, number of occupants</th><th>Occupant distribution in a normally loaded vehicle</th></tr>
<tr><td>2 through 4</td><td>2</td><td>2 in front.</td></tr>
<tr><td>5 through 10</td><td>3</td><td>2 in front, 1 in second seat.</td></tr>
<tr><td>11 through 15</td><td>5</td><td>2 in front, 1 in second seat, 1 in third seat, 1 in fourth seat.</td></tr>
<tr><td>16 through 22</td><td>7</td><td>2 in front, 2 in second seat, 2 in third seat, 1 in fourth seat.</td></tr>
</table>
</td>
<td>Option 1</td>
<td>Retain current language.</td>
<td>Bidirectional operation definition may need to be incorporated into Section 571.3 and the application added to Section 571.7 or a new application section, such as 571.11, may need to be added.

Current loading may not be representative of ADS-DV seating patterns or allow for unconventional seating.</td>
</tr>
<tr>
<td>Option 2</td>
<td>Update table and align with VIN translation designating vehicle areas.</td>
<td>Consider translating the VIN regulation to include vehicle placement in space with designated areas that could be used to reference seating locations or use another generic reference point.

Current normal loading condition implies that there will always be a human driver in the front/left and the next occupant will be in the front right (based on today's seating usage behaviors). Even if this were to be updated to a new reference for seating location, the occupant distribution may not be understood to represent the maximum tire loading.</td>
</tr>
</table>

FMVSS No. 110, S4.4.1 Requirements			
	Option 3	Replace Table 1 with an occupant loading and distribution test that would determine occupant placement for maximum tire loading. Completing the table based on vehicle's seating capacity shown in column 1 and 2 of Table 1.	This option looks at using a new approach to obtain the tire loading through additional testing. Table 1 Research Need, Occupant Loading and Distribution for Vehicle Normal Load for Various Designated Seating Capacities is based on a vehicle equipped with manual operating driving controls (e.g., assumes human driver in front, left seating position). The weight loading assumes human driver and passenger seating in the front seat before seating in the rear seat. This seating pattern is typical for vehicles operated by a human driver, but may not be the most likely seating pattern for an ADS-DV. Research could be conducted to develop a new method for maximizing the normal load on any given tire considering the seating capacities, which may require additional test procedures and testing.

FMVSS No. 110, S7.2 Supplementary information			
Regulatory Text	**Translation Options**		**Potential Considerations**
The owner's manual of the passenger car shall contain, in writing in the English language and in not less than 10 point type, the following information under the heading ''IMPORTANT—USE OF SPARE TIRE'': (a) A statement indicating the information related to appropriate use for the non-pneumatic spare tire including at a minimum the information set forth in S6 (a) and (b) and either the information set forth in S4.3(g) or a statement that the information set forth in S4.3(g) is located on the vehicle placard and on the non-pneumatic tire; (b) An instruction to drive carefully when the non-pneumatic spare tire is in use, and to install the proper pneumatic tire and rim at the first reasonable opportunity; and (c) A statement that operation of the passenger car is not recommended with more than one non-pneumatic spare tire in use at the same time.	**Option 1**	Retain current language.	"Drive" does not indicate who is driving the vehicle. It is inclusive of a human driver and an ADS.
	Option 2	The owner's manual of the passenger car shall contain, in writing in the English language and in not less than 10 point type, the following information under the heading ''IMPORTANT—USE OF SPARE TIRE'': (a) A statement indicating the information related to appropriate use for the non-pneumatic spare tire including at a minimum the information set forth in S6 (a) and (b) and either the information set forth in S4.3(g) or a statement that the information set forth in S4.3(g) is located on the vehicle placard and on the non-pneumatic tire; (b) An instruction to operate a vehicle carefully when the non-pneumatic spare tire is in use, and to install the proper pneumatic tire and rim at the first reasonable opportunity; and (c) A statement that operation of the passenger car is not recommended with more than one non-pneumatic spare tire in use at the same time.	May provide additional clarity when considering an ADS-DV.

<table>
<tr><th colspan="4">FMVSS No. 110, S8.2 Wheel Cover Requirements</th></tr>
<tr><th>Regulatory Text</th><th colspan="2">Translation Options</th><th>Potential Considerations</th></tr>
<tr><td rowspan="2">
</td><td>Option 1</td><td>Retain current language.</td><td>Bidirectional vehicles may require two placard labels which would need to correspond to the tires. Further research may be needed to ensure the user (e.g., person responsible for maintenance, fleet operator or occupant) understands how to interpret the bidirectional placard labels.

Perhaps for vehicles with bidirectional operation, the text for “Front” and “Rear” could be translated to “Axle A-B” and “Axle C-D” specifically for vehicle with bidirectional operation.</td></tr>
<tr><td>Option 2</td><td>Retain current language and consider translating VIN regulation to include axle placement in space.</td><td>Consider translating the VIN regulation to include vehicle placement in space with designated areas that could be used to reference seating locations or use another generic reference point.

VIN regulation would require translation and consider options to further clarify the axle placement.</td></tr>
</table>

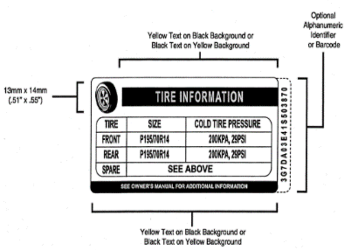
<table>
<tr><th colspan="4">FMVSS No. 110, S8.2 Wheel Cover Requirements</th></tr>
<tr><th>Regulatory Text</th><th colspan="2">Translation Options</th><th>Potential Considerations</th></tr>
<tr>
<td>Tire Inflation Pressure Label


Figure 2</td>
<td>Option 1</td>
<td>Retain current language.</td>
<td>Bidirectional vehicles may require two placard labels which would need to correspond to the tires. Further research may be needed to ensure the user understands how to interpret the bidirectional placard labels.

Perhaps for vehicles with bidirectional operation, the text for “Front” and “Rear” could be translated to “Axle A-B” and “Axle C-D” specifically for vehicle with bidirectional operation.</td>
</tr>
</table>

FMVSS No. 110, S8.2 Wheel Cover Requirements			
Regulatory Text	**Translation Options**		**Potential Considerations**
	Option 2	Retain current language and consider translating VIN regulation to include axle placement in space.	Consider translating the VIN regulation to include vehicle placement in space with designated areas that could be used to reference seating locations or use another generic reference point. The VIN standard may require translation and consider options to further clarify the axle placement.

FMVSS No. 110, S9.3.3			
Regulatory Text	**Translation Options**		**Potential Considerations**
An RV load carrying capacity label (Figures 3 or 4) must be: (a) Permanently affixed and must be visibly located on the interior of the forward-most exterior passenger door on the right side of the vehicle or; at the option of the manufacturer, (b) A temporary version of the RV load carrying capacity label (Figures 3 or 4) must be visibly located on the interior of the forward-most exterior passenger door on the right side of the vehicle. A permanent motor home or RV trailer supplemental label (Figures 5 or 6) must be permanently affixed within 25 millimeters of the placard specified in S4.3 for motor homes and S4.3.5 for RV trailers.	**Option 1**	... (b) A temporary version of the RV load carrying capacity label (Figures 3 or 4) must be visibly located on the interior of the forward-most exterior passenger door on the right side of the vehicle or; if the interior of the forward-most exterior passenger door on the right side of the vehicle does not have a visible location then the manufacturer can designate a visible location. A permanent motor home or RV trailer supplemental label (Figures 5 or 6) must be permanently affixed within 25 millimeters of the placard specified in S4.3 for motor homes and S4.3.5 for RV trailers.	Adds the option for the manufacturer to specify the label location if the exterior passenger door location is not defined.
	Option 2	... (b) A temporary version of the RV load carrying capacity label (Figures 3 or 4) must be visibly located on the interior of the forward-most exterior passenger door on the right side of the vehicle as defined in Figure XX of 49 Part 565. A permanent motor home or RV trailer supplemental label (Figures 5 or 6) must be permanently affixed within 25 millimeters of the placard specified in S4.3 for motor homes and S4.3.5 for RV trailers.	Consider translating the VIN standard to include vehicle placement in space with designated areas that could be used to reference seating locations or use another generic reference point.

FMVSS No. 110, S10.1 Weight added to vehicles between final vehicle certification and first retail sale of the vehicle (a)-(d)
Regulatory Text
(a) Permanently affix load carrying capacity modification labels (Figure 7), which display the amount the load carrying capacity is reduced to the nearest kilogram with conversion to the nearest pound, within 25 millimeters of the original, permanent RV load carrying capacity label (Figure 3 or 4) and the original placard (Figure 1). The load carrying capacity modification labels must be legible, visible, permanent, moisture resistant, presented in the English language, have a minimum print size of 2.4 millimeters (3/32 inches) high and be printed in black print on a yellow background, or (b) If the manufacturer selects S9.3.3(b), apply a temporary version of the load carrying capacity modification label (Figure 7) within 25 millimeters of the original, temporary RV load carrying capacity label (Figure 3 or 4) on the interior of the forward-most exterior passenger door on the right side of the vehicle, in addition to applying a permanent version of the same label within 25 mm of the placard required by S4.3 or S4.3.5. Both temporary and permanent versions of the load carrying capacity modification label (Figure 7) may be printed without values and values may be legibly applied to the label with a black, fine point, indelible marker. The label must contain the statements ''CAUTION—LOAD CARRYING CAPACITY REDUCED'' in block letters and ''Modifications to this vehicle have reduced the original load carrying capacity by XXX kg or XXX lbs.'' in accordance with Figure 7. If two load carrying capacity modification labels are required (one permanent and one temporary), the weight values on each must agree, or (c) Modify the original, permanent RV load carrying capacity labels (Figures 3 and 4) and the placard (Figure 1) with correct vehicle capacity weight values. If the manufacturer selects S9.3.3 (b), the temporary RV load carrying capacity labels (Figures 3 and 4) must also be modified with correct vehicle capacity weight values. Modification of labels requires a machine printed overlay with printed corrected values or blanks for corrected values that may be entered with a black, fine-point, indelible marker. Crossing out old values and entering corrected values on the original label is not permissible, or (d) Replace the original, permanent RV load carrying capacity labels (Figures 3 and 4) and the placard (Figure 1) with the same labels/placard containing correct vehicle capacity weight values. If the manufacturer selects S9.3.3 (b), the temporary RV load carrying capacity labels (Figures 3 and 4) must also be replaced with the same labels containing correct vehicle capacity weight values.

FMVSS No. 110, S10.1 Weight added to vehicles between final vehicle certification and first retail sale of the vehicle (a)-(d)			
Regulatory Text	**Translation Options**		**Potential Considerations**
See regulatory text above.	**Option 1**	…carrying capacity label (Figure 3 or 4) on the interior of the forward-most exterior passenger door on the right side of the vehicle or; if the interior of the forward-most exterior passenger door on the right side of the vehicle does not have a visible location then the manufacturer can designate a new visible location, in addition to applying a permanent version of the same label...	Adds the option for the manufacturer to specify the label location if the exterior passenger door location isn't defined. Considers bidirectional vehicles. Considers unconventional ADS-DV seating positions.
	Option 2	…carrying capacity label (Figure 3 or 4) on the interior of the forward-most exterior passenger door on the right side of the vehicle as defined in 49 Section 565 Diagram XX, in addition to applying a permanent version of the same label…	49 Section 565 translation to include placing the vehicle on a grid space to designate the VIN location and define specific vehicle areas (e.g., area A would be left, front half of the vehicle). Considers bidirectional vehicles. Approach provides a generic location for the label that is similar to the location in vehicles operated by a human driver.

FMVSS No. 113: Hood Latch System

Technical Translation Options Summary: *The purpose of this FMVSS "establishes the requirement for providing a hood latch system or hood latch systems." (S1)*

The FMVSS No. 113 technical translation approach considers the hood obstructing the human driver's ability to see through the windshield as equivalent to the hood obstructing the sensors of an automated driving system (ADS) that is used to complete the dynamic driving task (DDT) in the forward motion for an ADS-dedicated vehicle (ADS-DV). Option 1 maintains the current hood definition for human drivers and adds a new translated definition for ADS-DVs. Option 2 maintains the current definition of hood and addresses the ADS sensor obstruction in the S4.2 requirement. Option 3 provides an additional S4.2 requirement translation option and has the fewest language modifications.

FMVSS No. 113, S3. Definitions.			
Regulatory Text	**Translation Options**		**Potential Considerations**
Hood means any exterior movable body panel forward of the windshield that is used to cover an engine, luggage, storage, or battery compartment.	**Option 1**	For vehicles that can operated by a human driver, a *hood* means any exterior movable body panel forward of the windshield that is used to cover an engine, luggage, storage, or battery compartment. For vehicles that can be operated by an ADS, a *hood* means any exterior movable body panel forward of the sensors used by the ADS to complete the dynamic driving task (DDT) in the forward motion, that is used to cover an engine,	Uses driver definition 1. Retains current regulatory text for vehicles equipped with manually operated driving controls. Interchangeable with Option 3. There may be complexity in providing two unique definitions for hood (e.g., one for vehicles equipped with manually operated driving controls and one for ADS-DVs). Determining which sensors are being used to complete the DDT in the forward motion, their location and if physical blockage impacts the sensor's capability to sense the forward view may also be complex. However, an Office of Vehicle Safety Compliance (OVSC) form could be developed to request this information from the manufacturer. The use of ADS sensors in the definition may need to be defined further. For example, referencing the DDT may be too broad and include sensors beyond "seeing" the forward view. Perhaps using

FMVSS No. 113, S3. Definitions.			
Regulatory Text	**Translation Options**		**Potential Considerations**
		luggage, storage, or battery compartment.	"extrospective" ADS sensors to further describe the sensors could help provide additional clarity. ADS sensors could also be replaced with perception systems.
	Option 2	Retain current language.	Retains regulatory text for vehicles equipped with manually operated driving controls and ADS-DVs. Translations to hood definition may not be needed based on the assumption that bidirectional vehicles are addressed in the definition and application section. There may be compartments that are not forward of the windshield that could block the ADS sensors completing the forward DDT (e.g., sensors located on the side of the vehicle looking forward).
	Option 3	Interchangeable with Option 1 or 2.	

<table>
<tr><th colspan="4">FMVSS No. 113, S4.2 Requirements.</th></tr>
<tr><th>Regulatory Text</th><th colspan="2">Translation Options</th><th>Potential Considerations</th></tr>
<tr><td rowspan="2">A front opening hood which, in any open position, partially or completely obstructs a driver's forward view through the windshield must be provided with a second latch position on the hood latch system or with a second hood latch system.</td><td>Option 1</td><td>For vehicles that can operated by a human driver, a front opening hood which, in any open position, partially or completely obstructs a driver's forward view through the windshield must be provided with a second latch position on the hood latch system or with a second hood latch system.

For vehicles that can be operated by an ADS driver, a hood opening which, in any open position, partially or completely obstructs the sensors used by the ADS to complete DDT in the forward motion must be provided with a second latch position on the hood latch system or with a second hood latch system.</td><td>Uses driver definition 1.

Retains current regulatory text for vehicles equipped with manually operated driving control and adds specific ADS-DV requirement.</td></tr>
<tr><td>Option 2</td><td>For a vehicle that can be operated by a driver, a front opening hood which, in any open position, partially or completely obstructs a human driver's forward view through the windshield must be provided with a second latch position on the hood latch system or with a second hood latch system.

For vehicles that can be operated by an ADS, a hood opening which, in any open position, partially or completely obstructs the sensors used by the ADS to complete DDT in the forward motion must be provided with a</td><td>Uses driver definition 2.

Retains current regulatory text for vehicles equipped with manually operated driving control and adds specific ADS-DV requirement.</td></tr>
</table>

		second latch position on the hood latch system or with a second hood latch system.	
	Option 3	A front opening hood which, in any open position, partially or completely obstructs either a driver's forward view through the windshield or the sensors used by the ADS to complete DDT in the forward motion must be provided with a second latch position on the hood latch system or with a second hood latch system.	Uses driver definition 1. Uses same language for vehicles equipped with manually operated driving controls and ADS-DVs.

FMVSS No. 113, S4.4 Requirements	Added for ADS-DV Translation- S4.3		
Regulatory Text	**Translation Options**		**Potential Considerations**
Regulatory Text provided as an option.	**Option 1**	For vehicles that can be operated by an ADS driver, a hood opening which, in any open position, partially or completely obstructs the sensors used by the ADS to complete DDT in the forward motion must be provided with a second latch position on the hood latch system or with a second hood latch system.	ADS sensors could be replaced with perception systems. Added new requirement translating the hood obstructing the human driver's view through the windshield to the hood obstructing the forward detection (view) of the ADS sensors, radar, LiDAR. ADS sensors may need to be defined further. Referencing the DDT may be too broad and include sensors beyond "seeing" the forward view.
	Option 2	For vehicles that can be operated by an ADS, a hood opening which, in any open position, partially or completely obstructs the sensors used by the ADS to complete DDT in the forward motion must be provided with a second latch position on the hood latch system or with a second hood latch system.	Uses driver definition 2.

FMVSS No. 124: Accelerator Control Systems

Technical Translation Options Summary: *The purpose of this FMVSS "is to reduce deaths and injuries resulting from engine overspeed caused by malfunctions in the accelerator control system." (S2)*

Technical translation option 1 used the equivalency between human and automated driving system (ADS) for the driver. Option 2 explicitly called out human driver or ADS, or generalized inputs to the accelerator control system by using the passive voice to remove explicit actions or references to the driver.

FMVSS No. 124, S1. Scope.			
Regulatory Text	**Translation Options**		**Potential Considerations**
This standard establishes requirements for the return of a vehicle's throttle to the idle position when the driver removes the actuating force from the accelerator control, or in the event of a severance or disconnection in the accelerator control system.	**Option 1**	Retain current language.	No translation needed with "driver" equivalent to ADS. This carries through all references to "driver" in the subsequent test procedures unless otherwise noted.
	Option 2	This standard establishes requirements for the return of a vehicle's throttle to the idle position when the actuating force is removed from the accelerator control, or in the event of a severance or disconnection in the accelerator control system.	Option 2 removes the dependency on "driver" by using passive voice by eliminating a particular action to a given entity. Eliminates the reference to the driver.

FMVSS No. 124, S4.1 Definitions.			
Regulatory Text	**Translation Options**		**Potential Considerations**
Driver-operated accelerator control system means all vehicle components, except the fuel metering device, that regulate engine speed in direct response to movement of the driver-operated control and that return the throttle to the idle position upon release of the actuating force.	**Option 1**	Retain current language.	No translation performed—use equivalency between driver and ADS.
	Option 2	*Accelerator control system* means all vehicle components, except the fuel metering device, that regulate engine speed in direct response to movement of the control, if any, and that return the throttle to the idle position upon release of the actuating force or command.	The "if any" phrase was added to address systems that may not employ the movement of a control such as might exist in an electric ADS-DV.

FMVSS No. 124, S4.1 Definitions.			
Regulatory Text	**Translation Options**		**Potential Considerations**
Throttle means the component of the fuel metering device that connects to the driver-operated accelerator control system and that by input from the driver-operated accelerator control system controls the engine speed.	**Option 1**	Retain current language.	No translation performed—use equivalency between driver and ADS.
	Option 2	*Throttle* means the component of the fuel metering device that connects to the accelerator control system and that by input from the accelerator control system controls the engine speed.	Eliminates the reference to the driver.

FMVSS No. 124, S5.1 Requirements.			
Regulatory Text	**Translation Options**		**Potential Considerations**
There shall be at least two sources of energy capable of returning the throttle to the idle position within the time limit specified by S5.3 from any accelerator position or speed whenever the driver removes the opposing actuating force. In the event of failure of one source of energy by a single severance or disconnection, the throttle shall return to the idle position within the time limits specified by S5.3, from any accelerator position or speed whenever the driver removes the opposing actuating force.	**Option 1**	Retain current language.	No translation performed—use equivalency between driver and ADS.
	Option 2	…whenever the opposing actuating force is removed.	This translation eliminates the reference to the driver. Does not allow a direct means to determine when the opposing actuating force is removed.

FMVSS No. 124, S5.2 Requirements.			
Regulatory Text	**Translation Options**		**Potential Considerations**
The throttle shall return to the idle position from any accelerator position or any speed of which the engine is capable whenever any one component of the accelerator control system is disconnected or severed at a single point. The return to idle shall occur within the time limit specified by S5.3, measured either from the time of severance or disconnection or from the first removal of the opposing actuating force by the driver.	**Option 1**	Retain current language.	
	Option 2	... measured either from the time of severance or disconnection or from the first removal of the opposing actuating force.	This translation eliminates the reference to the driver. Does not allow a direct means to determine when the "first removal" occurs.

FMVSS No. 126: Electronic Stability Control Systems for Light Vehicles

Technical Translation Options Summary: *The purpose of this FMVSS "is to reduce the number of deaths and injuries that result from crashes in which the driver loses directional control of the vehicle, including those resulting in vehicle rollover." (S2)*

Each technical translation option has an underlying theme that works as a set. Option 1 is based on an equivalency between the human driver and ADS, using driver definition 1. Option 2 has removed a reference to the driver or specifies human driver and automated driving system (ADS), using driver definition 2. In addition, two new definitions have been added for "steering wheel" and "steering wheel angle" that create the abstraction to a generic interface to the steering system, which allows the references to these items to remain as currently used. For Option 3, rather than specifying the input at the front of the system, the steering angle (angle of the tires relative to centerline of vehicle), is used as the independent variable.

FMVSS No. 126, S2. Purpose.			
Regulatory Text	**Translation Options**		**Potential Considerations**
The purpose of this standard is to reduce the number of deaths and injuries that result from crashes in which the driver loses directional control of the vehicle, including those resulting in vehicle rollover.	**Option 1**	Retain current language.	No translation needed with "driver" equivalent to ADS. This carries through all references to "driver" in the subsequent test procedures unless otherwise noted.
	Option 2	…and injuries that result from crashes in which directional control of the vehicle is lost…	This option eliminates the reference to the driver.
	Option 3	...and injuries by keeping the vehicle from losing directional control…	This option eliminates the reference to the driver.

<table>
<tr><th colspan="4">FMVSS No. 126, S4. Definitions.</th></tr>
<tr><th>Regulatory Text</th><th colspan="2">Translation Options</th><th>Potential Considerations</th></tr>
<tr><td rowspan="2">Drive configuration means the driver-selected, or default, condition for distributing power from the engine to the drive wheels (examples include, but are not limited to, 2-wheel drive, front-wheel drive, rear-wheel drive, all-wheel drive, 4-wheel drive high gear with locked differential, and 4-wheel drive low gear).</td><td>Option 1</td><td>Retain current language.</td><td>No translation performed—use equivalency between driver and ADS.</td></tr>
<tr><td>Option 2</td><td>Drive configuration means the selected, or default, condition for distributing power…</td><td>This option eliminates the reference to the driver.</td></tr>
</table>

<table>
<tr><th colspan="4">FMVSS No. 126, S4. Definitions.</th></tr>
<tr><th>Regulatory Text</th><th colspan="2">Translation Options</th><th>Potential Considerations</th></tr>
<tr><td rowspan="2">Electronic stability control system or ESC system means a system that has all of the following attributes:

(1) That augments vehicle directional stability by applying and adjusting the vehicle brake torques individually to induce a correcting yaw moment to a vehicle;

(2) That is computer-controlled with the computer using a closed-loop algorithm to limit vehicle oversteer and to limit vehicle understeer;

(3) That has a means to determine the vehicle's yaw rate and to estimate its side slip or side slip derivative with respect to time;

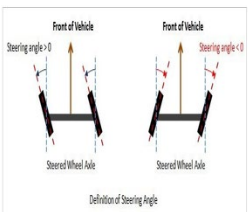
(4) That has a means to monitor driver steering inputs;

(5) That has an algorithm to determine the need, and a means to modify engine torque, as necessary, to assist the driver in maintaining control of the vehicle; and

(6) That is operational over the full speed range of the vehicle (except at vehicle speeds less than 20 km/h (12.4 mph), when being driven in reverse, or during system initialization).</td><td>Option 1</td><td>Retain current language.</td><td>No translation performed—use equivalency between driver and ADS.</td></tr>
<tr><td>Option 2</td><td>(4) That has a means to monitor steering system inputs;
(5)…to assist in maintaining control…</td><td>This option eliminates the reference to the driver.</td></tr>
</table>

S4. Definitions.	FMVSS No. 126, Added for ADS-DV Translation-New S4. Definitions.		
Regulatory Text	**Translation Options**		**Potential Considerations**
Regulatory Text Provided as an Option.	**Option 1**	Definition not used for Option 1.	Do not add translation for Option 1.
	Option 2	*Steering wheel* means the interface to the steering system that provides a means of controlling the direction of the vehicle.	For Option 2, added definition for steering wheel provides a generic translation of steering wheel to indicate the point in the steering system where control inputs are applied. May eliminate the need to translate individual clauses within the regulation. Provides an additional definition within the regulation.

S4. Definitions.	**FMVSS No. 126, Added for ADS-DV Translation-New S4. Definitions.**		
Regulatory Text	**Translation Options**		**Potential Considerations**
Regulatory Text Provided as an Option.	**Option 1**	Definition not used for Option 1.	Do not add translation for Option 1.
	Option 2	*Steering wheel angle* means the displacement of the steering wheel.	For Option 2, added definition for steering wheel angle that provides a generic translation to indicate the displacement of the steering wheel (as defined above). May eliminate the need to translate individual clauses within the regulation. Provides an additional definition within the regulation.

<table>
<tr><th>S4. Definitions.</th><th colspan="3">FMVSS No. 126, Added for ADS-DV Translation-New S4. Definitions.</th></tr>
<tr><th>Regulatory Text</th><th colspan="2">Translation Options</th><th>Potential Considerations</th></tr>
<tr><td rowspan="3">Regulatory Text Provided as an Option
.</td><td>Option 1</td><td>Definition not used for Option 1.</td><td>Do not add translation for Option 1.</td></tr>
<tr><td>Option 2</td><td>Definition not used for Option 2.</td><td>Do not add new translation for Option 2.</td></tr>
<tr><td>Option 3</td><td>The steering angle is defined as the angle between the front of the vehicle and the steered wheel direction.</td><td>For Option 3, added definition for steering angle that is at the roadwheel.
Ackerman steer angle may be appropriate here.

Provides universal reference assuming no torque steering is employed.

Does not provide means to measure angle.</td></tr>
</table>

FMVSS No. 126, S5.1.2 Required Equipment.			
Regulatory Text	**Translation Options**		**Potential Considerations**
Is operational during all phases of driving including acceleration, coasting, and deceleration (including braking), except when the driver has disabled ESC, the vehicle speed is below 20 km/h (12.4 mph), the vehicle is being driven in reverse, or during system initialization	**Option 1**	Retain current language.	No translation performed— use equivalency between driver and ADS. Does not provide context for when the ADS may disable the ESC.
	Option 2	…except when the human driver has disabled ESC…the vehicle is being driven in reverse by a human driver, ...	Requires the ESC to be active at all times for ADS-DVs, which is a higher standard of operation than for human drivers and may not be necessary or always beneficial. Uses passive voice (when the ESC has been disabled…being driven in reverse.) The addition of "human" is not consistent throughout the FMVSS.
	Option 3	Retain current language.	It is unlikely that the ADS-DV would disable the ESC, in which case the regulation would be acceptable as written.

FMVSS No. 126, S5.2 Performance Requirements.			
Regulatory Text	**Translation Options**		**Potential Considerations**
During each test performed under the test conditions of S6 and the test procedure of S7.9, the vehicle with the ESC system engaged must satisfy the stability criteria of S5.2.1 and S5.2.2, and it must satisfy the responsiveness criterion of S5.2.3 during each of those tests conducted with a commanded steering wheel angle of 5A or greater, where A is the steering wheel angle computed in S7.6.1.	**Option 1**	...with a commanded steering wheel angle or equivalent steering system input of 5A or greater, where A is the steering wheel angle or equivalent steering system input computed in S7.6.1.	Allows for input to be applied where appropriate for any given design. May need to define steering system. May require more generic test procedures for activation of the prescribed inputs defined in S7.
	Option 2	Retain current language.	No translation needed if the additional definitions for steering wheel and steering wheel angle are included.

FMVSS No. 126, S5.2.1 Performance Requirements.			
Regulatory Text	**Translation Options**		**Potential Considerations**
The yaw rate measured one second after completion of the sine with dwell steering input (time T0 + 1 in Figure 1) must not exceed 35 percent of the first peak value of yaw rate recorded after the steering wheel angle changes sign (between first and second peaks) (åPeak in Figure 1) during the same test run, and	**Option 1**	...after the steering wheel angle or equivalent steering system input changes sign (between first and second peaks)...	Allows for input to be applied where appropriate for any given design. May need to define steering system. May require more generic test procedures for activation of the prescribed inputs defined in S7.
	Option 2	Retain current language.	No translation needed if the additional definitions for steering wheel and steering wheel angle are included.

FMVSS No. 126, S5.3 ESC Malfunction.

Regulatory Text	Translation Options		Potential Considerations
ESC Malfunction. The vehicle must be equipped with a telltale that provides a warning to the driver of the occurrence of one or more malfunctions that affect the generation or transmission of control or response signals in the vehicle's electronic stability control system. When tested according to S7.10, the ESC malfunction telltale:	**Option 1**	a). The vehicle must be equipped...When tested according to S7.10, S5.3.1 - S.5.3.10 apply and the ESC malfunction telltale: b.) An ADS-DV must communicate the ESC state to the ADS as long as any malfunction condition specified in S5.3 exists that would require illumination of a telltale.	General means to address telltale for ADS-DVs. Provides requirement for awareness of the ESC state by an ADS for all of S5.3. Does not provide means to monitor state of ESC. Does not explicitly address the telltales specifications in subsequent S5.3 subclauses.
	Option 2	...When tested according to S7.10, the ESC malfunction telltale: For ADS operation, the operational state, including any malfunctions, of the ESC must be communicated to the ADS.	Provides means to monitor ESC malfunction for all of S5.3. The option could also require the information to be communicated within the vehicle compartment if NHTSA determines that this information improves the safety of an occupant. A telltale for the occupant could be applicable for a malfunction state since it provides information on which the occupant could act (e.g., not commence a ride). With an ADS-DV, for the other ESC telltale conditions (off and active), the information indicates an internal operational state.

FMVSS No. 126, S5.4.1 ESC Off and Other System Controls.			
Regulatory Text	**Translation Options**		**Potential Considerations**
The vehicle's ESC system must always return to the manufacturer's original default ESC mode that satisfies the requirements of S5.1 and S5.2 at the initiation of each new ignition cycle, regardless of what ESC mode the driver had previously selected, unless (a) the vehicle is in a low-range four-wheel drive configuration selected by the driver on the previous ignition cycle that is designed for low-speed, off-road driving, or (b) the vehicle is in a four-wheel drive configuration selected by the driver on the previous ignition cycle that is designed for operation at higher speeds on snow-, sand-, or dirt-packed roads and that has the effect of locking the drive gears at the front and rear axles together, provided that the vehicle meets the stability performance requirements of S5.2.1 and S5.2.2 in this mode.	**Option 1**	Retain current language.	
	Option 2	...regardless of what ESC mode had been previously selected, unless (a) the vehicle is in a low-range four-wheel drive configuration selected on the previous ignition cycle that is designed for low-speed, off-road driving, or (b) the vehicle is in a four-wheel drive configuration selected on the previous ignition cycle...	Translated to remove dependency of driver. May need to clarify ignition cycle for electric vehicles.
	Option 3	See Option 2.	

FMVSS No. 126, S5.4.3 ESC Off and Other System Controls.			
Regulatory Text	**Translation Options**		**Potential Considerations**
As of September 1, 2011, a control whose only purpose is to place the ESC system in a mode or modes in which it will no longer satisfy the performance requirements of S5.2.1, S5.2.2, and S5.2.3 must be identified by the symbol shown for "ESC Off" in Table 1 of Standard No. 101 (49 CFR 571.101), or the text, "ESC Off" as listed under "Word(s) or Abbreviations" in Table 1 of Standard No. 101 (49 CFR 571.101).	**Option 1**	Retain current language.	
	Option 2	a.) …or Abbreviations" in Table 1 of Standard No. 101 (49 CFR 571.101). b.) An ADS-DV must communicate the ESC state to the ADS that would require illumination of a telltale.	This option removes the requirement of telltales for ADS-DVs. This latter condition could be removed.

<table>
<tr><th colspan="4">FMVSS No. 126, S5.4.4 ESC Off and Other System Controls.</th></tr>
<tr><th>Regulatory Text</th><th colspan="2">Translation Options</th><th>Potential Considerations</th></tr>
<tr><td rowspan="2">A control for another system that has the ancillary effect of placing the ESC system in a mode in which it no longer satisfies the performance requirements of S5.2.1, S5.2.2, and S5.2.3 need not be identified by the “ESC Off” identifiers in Table 1 of Standard No. 101 (49 CFR 571.101), but the ESC status must be identified by the “ESC Off” telltale in accordance with S5.5, as of September 1, 2011, except if the vehicle is in a 4-wheel drive high gear configuration that has the effect of locking the drive gears at the front and rear axles together provided the vehicle meets the stability performance criteria of S5.2.1 and S5.2.2.</td><td>Option 1</td><td>Retain current language.</td><td></td></tr>
<tr><td>Option 2</td><td>a.) ...provided the vehicle meets the stability performance criteria of S5.2.1 and S5.2.2.

b.) An ADS-DV must communicate the ESC state to the ADS that would require illumination of a telltale.</td><td>This option removes the requirement of telltales for ADS-DVs. This latter condition could be removed.</td></tr>
</table>

FMVSS No. 126, S5.5 ESC Off Telltale- ADDED FOR ADS-DV TRANSLATION			
Regulatory Text	**Translation Options**		**Potential Considerations**
Regulatory Text Provided as an Option.	**Option 1**	Retain current language.	
	Option 2	An ADS-DV must communicate the ESC state to the ADS that would require illumination of a telltale as specified in S5.5.	This option removes the requirement of telltales for ADS-DVs. This latter condition could be removed.

FMVSS No. 126, S6.3.1 Vehicle conditions.			
Regulatory Text	**Translation Options**		**Potential Considerations**
The ESC system is enabled for all testing, except when it is turned off directly or by simulating a malfunction in accordance with S7.3 and S7.10, respectively. The ESC system shall be initialized as follows: Place the vehicle in a forward gear and obtain a vehicle speed of 48 ±8 km/h (30 ±5 mph). Drive the vehicle for at least two minutes including at least one left and one right turning maneuver and at least one application of the service brake.	**Option 1**	Retain current language.	
	Option 2	Retain current language.	
	Option 3	...The ESC system shall be initialized as follows: The vehicle is propelled forward to a vehicle speed of 48 ±8 km/h (30 ±5 mph) and maintained at that speed…	This option removes dependency on transmission state.

FMVSS No. 126, S6.3.2 Test Weight.			
Regulatory Text	**Translation Options**		**Potential Considerations**
The vehicle is loaded with the fuel tank filled to at least 75 percent of capacity, and total interior load of 168 kg (370 lbs) comprised of the test driver, approximately 59 kg (130 lbs) of test equipment (automated steering machine, data acquisition system and the power supply for the steering machine), and ballast as required by differences in the weight of test drivers and test equipment. Where required, ballast shall be placed on the floor behind the passenger front seat or if necessary in the front passenger foot well area. All ballast shall be secured in a way that prevents it from becoming dislodged during test conduct.	**Option 1**	...total interior load of 168 kg (370 lbs) comprised of the test driver (if present), approximately 59 kg (130 lbs) of test equipment (automated steering machine, data acquisition system and the power supply for the steering machine) as required. ...behind the passenger front seat or if necessary, in the front passenger foot well area or equivalent area relative to the manufacturer's designated seating position (DSP).	Does not specify the loading placement but rather defers to the manufacturer to specify the expected primary seating location. Acknowledges option of executing test without human present in the vehicle. May lead to confusion, as the ADS could be considered the test driver based on equivalency.
	Option 2	...total interior load of 168 kg (370 lbs) comprised of the test personnel (if present)... and ballast as required by differences in the weight of test personnel and test equipment...behind the passenger front seat or if necessary in the front passenger foot well area or equivalent area to provide weighting of vehicle consistent with normal operating conditions...	This option removes from the regulation dependency on the manufacturer to provide loading locations. Allows the distribution of the ballast in the vehicle to accommodate variable seating positions. Does not provide criteria for evaluating a balanced weighting.
	Option 3	Retain current language.	Leave text as written with the understanding that the ADS-DV "test driver" does not add additional weight and therefore will be accounted for with ballast.

FMVSS No. 126, S6.3.4 Outriggers.			
Regulatory Text	**Translation Options**		**Potential Considerations**
Outriggers are used for testing trucks, multipurpose passenger vehicles, and buses. Vehicles with a baseline weight less than 1,588 kg (3,500 lbs) are equipped with "light" outriggers. Vehicles with a baseline weight equal to or greater than 1,588 kg (3,500 lbs) and less than 2,722 kg (6,000 lbs) are equipped with "standard" outriggers. Vehicles with a baseline weight equal to or greater than 2,722 kg (6,000 lbs) are equipped with "heavy" outriggers. A vehicle's baseline weight is the weight of the vehicle delivered from the dealer, fully fueled, with a 73 kg (160 lb) driver. Light outriggers are designed with a maximum weight of 27 kg (59.5 lb) and a maximum roll moment of inertia of 27 kg-m2 (19.9 ft-lb-sec2). Standard outriggers are designed with a maximum weight of 32 kg (70 lb) and a maximum roll moment of inertia of 35.9 kg-m2 (26.5 ft-lb-sec2). Heavy outriggers are designed with a maximum weight of 39 kg (86 lb) and a maximum roll moment of inertia of 40.7 kg-m2 (30.0 ft-lb-sec2).	**Option 1**	Retain current language.	
	Option 2	...fully fueled, with a 73 kg (160 lb) occupant.	As this section is the determination of which outrigger to use during testing, the operational weight is what is important rather than specifying an equivalent loading as during testing. This option removes the dependency of the occupant being in control of the vehicle.

FMVSS No. 126, S6.3.5 Automated steering machine.			
Regulatory Text	**Translation Options**		**Potential Considerations**
A steering machine programmed to execute the required steering pattern must be used in S7.5.2, S7.5.3, S7.6 and S7.9. The steering machine shall be capable of supplying steering torques between 40 to 60 Nm (29.5 to 44.3 lb-ft). The steering machine must be able to apply these torques when operating with steering wheel velocities up to 1200 degrees per second.	**Option 1**	...capable of supplying steering torques between 40 to 60 Nm (29.5 to 44.3 lb-ft) or equivalent input into the steering system. The steering machine must be able to apply these torques when operating with steering wheel velocities up to 1200 degrees per second or equivalent input into the steering system.	Allows for input to be applied where appropriate for any given design. May require additional analysis or documentation from the manufacturer to confirm the system is capable of equivalent inputs.
	Option 2	...1200 degrees per second. In a vehicle designed not to be operated by a human driver and lacking a steering wheel, the steering machine may consist of whatever computer hardware and software may be necessary to execute the required steering patterns.	Explicitly calls out an alternative to steering machine. Allows flexibility in the input device. Does not specify force/torque and velocity requirements for the steering machine.

FMVSS No. 126, S7.2 Telltale bulb check.			
Regulatory Text	**Translation Options**		**Potential Considerations**
With the vehicle stationary and the ignition locking system in the “Lock” or “Off” position, activate the ignition locking system to the “On” (“Run”) position or, where applicable, the appropriate position for the lamp check. The ESC malfunction telltale must be activated as a check of lamp function, as specified in S5.3.4, and if equipped, the “ESC Off” telltale must also be activated as a check of lamp function, as specified in S5.5.6. The telltale bulb check is not required for a telltale shown in a common space as specified in S5.3.6 and S5.5.8.	**Option 1**	Retain current language.	
	Option 2	…The telltale bulb check is not required for a telltale shown in a common space as specified in S5.3.6 and S5.5.8 or for an ADS-DV.	Provides means for NHTSA to verify compliance via diagnostic message in case of telltale being broadcast to the ADS and not the occupant. Does not confirm that the ADS is monitoring telltale message on network.

FMVSS No. 126, S7.3 "ESC Off" control check.			
Regulatory Text	**Translation Options**		**Potential Considerations**
For vehicles equipped with an "ESC Off" control, with the vehicle stationary and the ignition locking system in the "Lock" or "Off" position, activate the ignition locking system to the "On" ("Run") position. Activate the "ESC Off" control and verify that the "ESC Off" telltale is illuminated, as specified in S5.5.4. Turn the ignition locking system to the "Lock" or "Off" position. Again, activate the ignition locking system to the "On" ("Run") position and verify that the "ESC Off" telltale has extinguished indicating that the ESC system has been reactivated as specified in S5.4.1.	**Option 1**	Retain current language.	
	Option 2	…with a manual "ESC Off" control…	Adding "manual" provides a condition that makes it applicable for manually operated vehicles. It does not provide a means to test proper operation of the ADS to turn the ESC off/on if so designed.

FMVSS No. 126, S7.4.3 Brake Conditioning.			
Regulatory Text	**Translation Options**		**Potential Considerations**
When executing the stops in S7.4.2, sufficient force is applied to the brake pedal to activate the vehicle's antilock brake system (ABS) for a majority of each braking event.	**Option 1**	Retain current language.	
	Option 2	…sufficient input is applied to the service brake…	

FMVSS No. 126, S7.5.2 Tire Conditioning.			
Regulatory Text	**Translation Options**		**Potential Considerations**
Using a sinusoidal steering pattern at a frequency of 1 Hz, a peak steering wheel angle amplitude corresponding to a peak lateral acceleration of 0.5-0.6 g, and a vehicle speed of 56 km/h (35 mph), the vehicle is driven through four passes performing 10 cycles of sinusoidal steering during each pass.	**Option 1**	...a peak steering wheel angle amplitude or equivalent steering system input...	Allows for input to be applied where appropriate for any given design. May need to define steering system.
	Option 2	No translation needed if the additional definitions for steering wheel and steering wheel angle are included.	May be necessary to record specific amplitude used as part of test procedure documentation.
	Option 3	...sinusoidal steering input at a frequency of 1 Hz, at a steering amplitude...	This option removes dependency on steering wheel.

FMVSS No. 126, S7.5.3 Tire Conditioning.			
Regulatory Text	**Translation Options**		**Potential Considerations**
The steering wheel angle amplitude of the final cycle of the final pass is twice that of the other cycles. The maximum time permitted between all laps and passes is five minutes.	**Option 1**	The steering wheel angle amplitude or equivalent steering system input…	Allows for input to be applied where appropriate for any given design. May need to define steering system.
	Option 2	No translation needed if the additional definitions for steering wheel and steering wheel angle are included.	May be necessary to record specific amplitude used as part of test procedure documentation.
	Option 3	The steering amplitude of the final cycle…	This option removes dependency on steering wheel.

<table>
<tr><th colspan="4">FMVSS No. 126, S7.6 Slowly Increasing Steer Test.</th></tr>
<tr><th>Regulatory Text</th><th colspan="2">Translation Options</th><th>Potential Considerations</th></tr>
<tr><td rowspan="3">The vehicle is subjected to two series of runs of the Slowly Increasing Steer Test using a constant vehicle speed of 80 ±2 km/h (50 ±1 mph) and a steering pattern that increases by 13.5 degrees per second until a lateral acceleration of approximately 0.5 g is obtained. Three repetitions are performed for each test series. One series uses counterclockwise steering, and the other series uses clockwise steering. The maximum time permitted between each test run is five minutes.</td><td>Option 1</td><td>...and a steering pattern that increases by 13.5 degrees per second or equivalent steering system input...

...One series uses counterclockwise steering or equivalent, and the other series uses clockwise steering or equivalent.</td><td>May be necessary to define left and right turn rather than counterclockwise and clockwise; e.g., one series uses a steering input that initiates a left turn and the other series uses a steering input that initiates a right turn.

Make the reference of clockwise and counterclockwise to vehicle reference frame.

Allows for input to be applied where appropriate for any given design.

May need to define steering system.</td></tr>
<tr><td>Option 2</td><td>Retain current language.</td><td></td></tr>
<tr><td>Option 3</td><td>...and a steering input that increases the front wheel steer angle (relative to the longitudinal axis of the vehicle) at a rate for 1 degree per second in order to achieve a lateral acceleration of approximately 0.5 g...</td><td>Provides reference at road wheel.

Need to confirm that this provides an equivalent result.</td></tr>
</table>

FMVSS No. 126, S7.6.1 Slowly Increasing Steer Test.			
Regulatory Text	**Translation Options**		**Potential Considerations**
From the Slowly Increasing Steer tests, the quantity “A” is determined. “A” is the steering wheel angle in degrees that produces a steady state lateral acceleration (corrected using the methods specified in S7.11.3) of 0.3 g for the test vehicle. Utilizing linear regression, A is calculated, to the nearest 0.1 degrees, from each of the six Slowly Increasing Steer tests. The absolute value of the six A's calculated is averaged and rounded to the nearest 0.1 degrees to produce the final quantity, A, used below.	**Option 1**	…the quantity "A" is determined. "A" is the steering wheel angle in degrees or equivalent steering system input…	Allows for input to be applied where appropriate for any given design. May need to define steering system.
	Option 2	Retain current language.	No translation needed if the additional definitions for steering wheel and steering wheel angle are included.
	Option 3	...“A” is the average of the two front wheel steer angles (relative to the longitudinal axis of the vehicle) that produces a steady…	Definition of “A” in terms of road wheels.

FMVSS No. 126, S7.8 Slowly Increasing Steer Test.			
Regulatory Text	**Translation Options**		**Potential Considerations**
Check that the ESC system is enabled by ensuring that the ESC malfunction and "ESC Off" (if provided) telltales are not illuminated.	**Option 1**	Retain current language.	
	Option 2	...the ESC malfunction and "ESC Off" (if provided) telltales are not illuminated or, for ADS-DVs the ESC state is communicated to the ADS.	Allow for both standard telltales and ADS-DV operational conditions. Does not confirm that the ADS-DV is monitoring telltale message on network.

FMVSS No. 126, S7.9 Sine with Dwell Test of Oversteer Intervention and Responsiveness.			
Regulatory Text	**Translation Options**		**Potential Considerations**
The vehicle is subjected to two series of test runs using a steering pattern of a sine wave at 0.7 Hz frequency with a 500 ms delay beginning at the second peak amplitude as shown in Figure 2 (the Sine with Dwell tests). One series uses counterclockwise steering for the first half cycle, and the other series uses clockwise steering for the first half cycle. The vehicle is provided a cool-down period between each test run of 90 seconds to five minutes, with the vehicle stationary.	**Option 1**	Retain current language.	
	Option 2	...One series uses a steering input that initiates a left turn for the first half cycle, and the other series uses a steering input that initiates a right turn for the first half cycle...	May be necessary to define left and right turn rather than counterclockwise and clockwise.

FMVSS No. 126, S7.9.2 Sine with Dwell Test of Oversteer Intervention and Responsiveness.			
Regulatory Text	**Translation Options**		**Potential Considerations**
In each series of test runs, the steering amplitude is increased from run to run, by 0.5A, provided that no such run will result in a steering amplitude greater than that of the final run specified in S7.9.4.	**Option 1**	Retain current language.	
	Option 2	Retain current language.	May not need translation based on determination of "A" in S7.6 for an equivalent steering system input.
	Option 3	...the steering amplitude is increased from run to run as necessary to achieve an average front wheel angle that increases, by 0.5A, provided that no such run will result in an average front wheel angle greater…	Reverted back to "amplitude" from "input." (7/11) May need to confirm the magnitudes for front wheel input.

FMVSS No. 126, S7.9.3 Sine with Dwell Test of Oversteer Intervention and Responsiveness.			
Regulatory Text	**Translation Options**		**Potential Considerations**
The steering amplitude for the initial run of each series is 1.5A where A is the steering wheel angle determined in S7.6.1.	**Option 1**	Retain current language.	
	Option 2	The steering amplitude for the initial run of each series is 1.5A where A is the steering wheel angle or equivalent steering system input determined in S7.6.1.	
	Option 3	The steering amplitude for the initial run of each series that which results in an average front wheel steer angle of 1.5A, where A is the average of the front wheel steer angles determined in S7.6.1.	May need to confirm the magnitudes for front wheel input.

FMVSS No. 126, S7.9.4 Sine with Dwell Test of Oversteer Intervention and Responsiveness.			
Regulatory Text	**Translation Options**		**Potential Considerations**
The steering amplitude of the final run in each series is the greater of 6.5A or 270 degrees, provided the calculated magnitude of 6.5A is less than or equal to 300 degrees. If any 0.5A increment, up to 6.5A, is greater than 300 degrees, the steering amplitude of the final run shall be 300 degrees.	**Option 1**	...the steering amplitude of the final run shall be 300 degrees. An equivalent maximum steering system input may be required if an equivalent steering system input is used for ADS-equipped vehicles.	Allows the manufacturer to specify an equivalent input based on their steering system design and input location. There is not a general published value for the maximum input.
	Option 2	Retain current language.	
	Option 3	The steering amplitude of the final run in each series is the greater of that which produces 6.5A or 30 degrees average front wheel steer angle, provided the calculated magnitude of 6.5A is less than or equal to 30 degrees average front wheel steer angle. If any 0.5A increment, up to 6.5A, is greater than 30 degrees, the steering input of the final run shall be that which produces an average front wheel steer angle of 30 degrees.	May need to confirm the magnitudes for front wheel input.

FMVSS No. 126, S7.10.2 ESC Malfunction Detection.			
Regulatory Text	**Translation Options**		**Potential Considerations**
With the vehicle initially stationary and the ignition locking system in the "Lock" or "Off" position, activate the ignition locking system to the "Start" position and start the engine. Place the vehicle in a forward gear and obtain a vehicle speed of 48 ±8 km/h (30 ±5 mph). Drive the vehicle for at least two minutes including at least one left and one right turning maneuver and at least one application of the service brake. Verify that within two minutes after obtaining this vehicle speed the ESC malfunction indicator illuminates in accordance with S5.3.	**Option 1**	Retain current language.	No translation needed if telltale addressed in S5.3. Allows the standard to remain as written. Does not provide direct means to monitor operation during test.
	Option 2	...the ESC malfunction indicator illuminates in accordance with S5.3. For ADS-DVs, the ESC malfunction state will be communicated to the ADS.	Changed last sentence so malfunction is communicated to ADS until corrected. Same for 10.3-4. May provide path to test for conformance.
	Option 3	...at least one activation of the service brakes...	Removes a possible implied association with a pedal.

FMVSS No. 126, S7.10.3 ESC Malfunction Detection.			
Regulatory Text	**Translation Options**		**Potential Considerations**
As of September 1, 2011, stop the vehicle, deactivate the ignition locking system to the "Off" or "Lock" position. After a five-minute period, activate the vehicle's ignition locking system to the "Start" position and start the engine. Verify that the ESC malfunction indicator again illuminates to signal a malfunction and remains illuminated as long as the engine is running or until the fault is corrected.	**Option 1**	Retain current language.	No translation needed if telltale addressed in S5.3. Allows the standard to remain as written. Does not provide direct means to monitor operation during test.
	Option 2	…or until the fault is corrected. For ADS-DVs, the ESC malfunction state will be communicated to the ADS.	May provide path to test for conformance.

FMVSS No. 126, S7.10.4 ESC Malfunction Detection.			
Regulatory Text	**Translation Options**		**Potential Considerations**
Deactivate the ignition locking system to the "Off" or "Lock" position. Restore the ESC system to normal operation, activate the ignition system to the "Start" position and start the engine. Place the vehicle in a forward gear and obtain a vehicle speed of 48 ±8 km/h (30 ±5 mph). Drive the vehicle for at least two minutes including at least one left and one right turning maneuver and at least one application of the service brake. Verify that within two minutes after obtaining this vehicle speed that the ESC malfunction indicator has extinguished.	**Option 1**	Retain current language.	No translation needed if telltale addressed in S5.3 Allows the standard to remain as written. Does not provide direct means to monitor operation during test.
	Option 2	…or until the fault is corrected. For ADS-DVs, the ESC malfunction state will be communicated to the ADS. …that the ESC malfunction indicator has extinguished. For ADS-DVs, the ESC malfunction state will be communicated to the ADS.	May provide path to test for conformance.

FMVSS No. 126, S7.11.1 Post Data Processing—Calculations for Performance Metrics.			
Regulatory Text	**Translation Options**		**Potential Considerations**
Raw steering wheel angle data is filtered with a 12-pole phaseless Butterworth filter and a cutoff frequency of 10Hz. The filtered data is then zeroed to remove sensor offset utilizing static pretest data.	**Option 1**	Raw steering wheel angle or equivalent steering system input…	Allows for input to be applied where appropriate for any given design. May need to define steering system. No translation needed if the additional definitions for steering wheel and steering wheel angle are included.
	Option 2	Retain current language.	
	Option 3	Raw front wheel steer angle data…	Use same road wheel reference as above for Option 3.

FMVSS No. 126, S7.11.4 Post Data Processing—Calculations for Performance Metrics.			
Regulatory Text	**Translation Options**		**Potential Considerations**
Steering wheel velocity is determined by differentiating the filtered steering wheel angle data. The steering wheel velocity data is then filtered with a moving 0.1 second running average filter.	**Option 1**	Steering wheel velocity is determined by differentiating the filtered steering wheel angle data or equivalent steering system input. The steering wheel velocity data is then filtered with a moving 0.1 second running average filter.	Allows for varied input locations and steering system designs. May need to define steering system.
	Option 2	No translation needed if the additional definitions for steering wheel and steering wheel angle are included.	
	Option 3	Road wheel steer angle velocity is determined by differentiating the filtered road wheel steer angle data. The road wheel steer angle velocity data is then filtered with a moving 0.1 second running average filter.	Use same road wheel reference as above for Option 3.

FMVSS No. 126, S7.11.5 Post Data Processing—Calculations for Performance Metrics.			
Regulatory Text	**Translation Options**		**Potential Considerations**
Lateral acceleration, yaw rate and steering wheel angle data channels are zeroed utilizing a defined "zeroing range." The methods used to establish the zeroing range are defined in S7.11.5.1 and S7.11.5.2.	**Option 1**	Lateral acceleration, yaw rate and steering wheel angle or equivalent steering system input data channels are zeroed…	
	Option 2	Retain current language.	
	Option 3	Lateral acceleration, yaw rate and road wheel steering wheel angle data channels are zeroed utilizing a defined "zeroing range." The methods used to establish the zeroing range are defined in S7.11.5.1 and S7.11.5.2.	

FMVSS No. 126, S7.11.5.1 Post Data Processing—Calculations for Performance Metrics.			
Regulatory Text	**Translation Options**		**Potential Considerations**
Using the steering wheel rate data calculated using the methods described in S7.11.4, the first instant steering wheel rate exceeds 75 deg/sec is identified. From this point, steering wheel rate must remain greater than 75 deg/sec for at least 200 ms. If the second condition is not met, the next instant steering wheel rate exceeds 75 deg/sec is identified and the 200 ms validity check applied. This iterative process continues until both conditions are ultimately satisfied.	**Option 1**	...This iterative process continues until both conditions are ultimately satisfied. For vehicles with an equivalent steering system input, equivalent values for the rates will be used.	Allows for varied input locations and steering system designs. Requires additional information about the steering system There are no generalized values applicable for all systems.
	Option 2	Retain current language.	
	Option 3	Using the road wheel steering rate data calculated using the methods described in S7.11.4, the first instant road wheel steering rate exceeds 5 deg/sec is identified. From this point, road wheel steering rate must remain greater than 5 deg/sec for at least 200 ms. If the second condition is not met, the next instant road wheel steering rate exceeds 5 deg/sec is identified and the 200 ms validity check applied. This iterative process continues until both conditions are ultimately satisfied.	Need to confirm the magnitudes for new values.

FMVSS No. 126, S7.11.5.2 Post Data Processing—Calculations for Performance Metrics.			
Regulatory Text	**Translation Options**		**Potential Considerations**
The "zeroing range" is defined as the 1.0 second time period prior to the instant the steering wheel rate exceeds 75 deg/sec (i.e., the instant the steering wheel velocity exceeds 75 deg/sec defines the end of the "zeroing range").	**Option 1**	...the steering wheel rate exceeds 75 deg/sec (i.e., the instant the steering wheel velocity exceeds 75 deg/sec defines the end of the "zeroing range"). For vehicles with an equivalent steering system input, equivalent values for the rates will be used.	Allows for varied input locations and steering system designs. Requires additional documentation from the manufacturer. There are no generalized values applicable for all systems.
	Option 2	Retain current language.	Allows for varied input locations and steering system designs. Requires additional documentation from the manufacturer. There are no generalized values applicable for all systems.
	Option 3	The "zeroing range" is defined as the 1.0 second time period prior to the instant road wheel steering rate exceeds 5 deg/sec (i.e., the instant the road wheel steering velocity exceeds 5 deg/sec defines the end of the "zeroing range").	Need to confirm the magnitudes for new values.

FMVSS No. 126, S7.11.6 Post Data Processing—Calculations for Performance Metrics.			
Regulatory Text	**Translation Options**		**Potential Considerations**
The Beginning of Steer (BOS) is defined as the first instance filtered and zeroed steering wheel angle data reaches –5 degrees (when the initial steering input is counterclockwise) or + 5 degrees (when the initial steering input is clockwise) after time defining the end of the "zeroing range." The value for time at the BOS is interpolated.	**Option 1**	…The value for time at the BOS is interpolated. For vehicles with an equivalent steering system input, equivalent values for the rates will be used.	May be necessary to define left and right turn rather than counterclockwise and clockwise. Allows for varied input locations and steering system designs. May need to define steering system.
	Option 2	No translation needed if the additional definitions for steering wheel and steering wheel angle are included.	
	Option 3	The Beginning of Steer (BOS) is defined as the first instance filtered and zeroed road wheel steering angle data reaches 0.3 degrees (when the initial steering input is counterclockwise) or 0.3 degrees (when the initial steering input is clockwise) after time defining the end of the "zeroing range." The value for time at the BOS is interpolated.	Need to confirm the magnitudes for new values.

FMVSS No. 126, S7.11.7 Post Data Processing—Calculations for Performance Metrics.			
Regulatory Text	**Translation Options**		**Potential Considerations**
The Completion of Steer (COS) is defined as the time the steering wheel angle returns to zero at the completion of the Sine with Dwell steering maneuver. The value for time at the zero degree steering wheel angle is interpolated.	**Option 1**	...the steering wheel angle or equivalent steering system input returns to zero at the completion of the Sine with Dwell steering maneuver. The value for time at the zero degree steering wheel angle or equivalent steering system input is interpolated.	Allows for varied input locations and steering system designs. May need to define steering system.
	Option 2	No translation needed if the additional definitions for steering wheel and steering wheel angle are included.	
	Option 3	The Completion of Steer (COS) is defined as the time the road wheel steering angle returns to zero at the completion of the Sine with Dwell steering maneuver. The value for time at the zero degree road wheel steering angle is interpolated.	Use same road wheel reference as above for Option 3.

<table>
<tr><th colspan="4">FMVSS No. 126, S7.11.8 Post Data Processing—Calculations for Performance Metrics.</th></tr>
<tr><th>Regulatory Text</th><th colspan="2">Translation Options</th><th>Potential Considerations</th></tr>
<tr><td rowspan="3">The second peak yaw rate is defined as the first local yaw rate peak produced by the reversal of the steering wheel. The yaw rates at 1.000 and 1.750 seconds after COS are determined by interpolation.</td><td>Option 1</td><td>... the reversal of the steering wheel or steering system.</td><td>Allows for varied input locations and steering system designs.

May need to define steering system.</td></tr>
<tr><td>Option 2</td><td>No translation needed if the additional definitions for steering wheel and steering wheel angle are included.</td><td>Allows for varied input locations and steering system designs.

May need to define steering system.</td></tr>
<tr><td>Option 3</td><td>The second peak yaw rate is defined as the first local yaw rate peak produced by the reversal of the road wheel steering. The yaw rates at 1.000 and 1.750 seconds after COS are determined by interpolation.</td><td>Use same road wheel reference as above for Option 3.</td></tr>
</table>

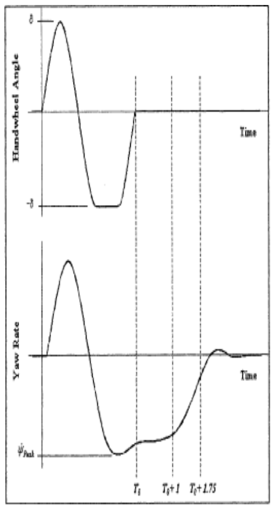
<table>
<tr><th colspan="4">FMVSS No. 126, S8.8 Final-stage manufacturers and alterers.</th></tr>
<tr><th>Regulatory Text</th><th colspan="2">Translation Options</th><th>Potential Considerations</th></tr>
<tr><td rowspan="2">

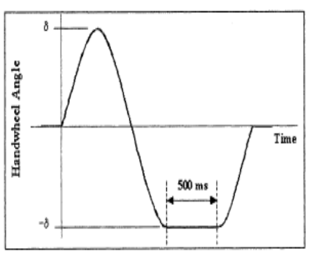
Figure 1. Steering wheel position and yaw velocity information used to assess lateral stability.


Figure 2. Sine with Dwell steering profile.</td><td>Option 1</td><td>Translate the following items in the graphics:
- Figure 1 y-axis label: "Handwheel Angle" to "Steering System Displacement"
- Figure 1 title: "Steering wheel position" to "Steering system input (e.g., steering wheel)..."</td><td>Labels should be consistent with the terminology used in the regulation text.</td></tr>
<tr><td>Option 2</td><td>Retain current language.</td><td>Translation may not be needed if the additional definitions for steering wheel and steering wheel angle are included and it is assumed that "Handwheel" is equivalent to "Steering wheel."</td></tr>
</table>

FMVSS No. 207: Seating Systems

Technical Translation Options Summary: *The purpose of this FMVSS "establishes requirements for seats, their attachment assemblies, and their installation to minimize the possibility of their failure by forces acting on them as a result of vehicle impact." (S1)*

Technical translation options are for conventional seating and non-bidirectional vehicles only. While translation is not needed to clarify this for automated driving system-dedicated vehicles (ADS-DVs), this FMVSS does require an occupant seat for the driver. Therefore, the focus for the translation is to clarify that an occupant seat for the driver is only necessary for vehicles designed to be operated by a human driver.

FMVSS No. 207, S4.1 Driver's seat.			
Regulatory Text	**Translation Options**		**Potential Considerations**
S4.1 Driver's seat.	**Option 1**	S4.1 Driver's designated seating position.	
	Option 2	S4.1 Occupant seat.	
	Option 3	Remove current language.	

FMVSS No. 207, S4.1 Driver's seat. (continued)			
Regulatory Text	**Translation Options**		**Potential Considerations**
Each vehicle shall have an occupant seat for the driver.	**Option 1**	If equipped with manually operated driving controls, each vehicle shall have a driver's designated seating position.	Uses driver definition 1. May be too circular in that the crux of the driver's DSP definition already lies in the presence of driving controls.
	Option 2	If equipped with manually operated driving controls, each vehicle shall have an occupant seat for a human driver.	Specifies a human driver and excludes ADS-DVs since by definition, there is not a driver's DSP.
	Option 3	Remove current language.	This would avoid confusion with the driver's DSP definition. If a vehicle is equipped with manually operated driving controls, a driver's DSP is necessary.

FMVSS No. 208: Occupant Crash Protection

Technical Translation Options Summary: *The purpose of this FMVSS is "to reduce the number of deaths of vehicle occupants, and the severity of injuries, by specifying vehicle crashworthiness requirements in terms of forces and accelerations measured on anthropomorphic dummies in test crashes, and by specifying equipment requirements for active and passive restraint systems." (S2)*

Technical translation options are for conventional seating and non-bidirectional vehicles only. The focus for translation is to ensure that the current crashworthiness requirements set forth are maintained for automated driving system-dedicated vehicles (ADS-DVs) while simultaneously not being compromised for conventional vehicles. ADS-DVs may not have traditional driver/front passenger DSPs, so the placement and requirements for dummies in test crashes of ADS-DVs are clarified in addition to the required active and passive restraint systems.

FMVSS No. 208, S3. Application.			
Regulatory Text	**Translation Options**		**Potential Considerations**
S3. Application.	**Option 1**	S3. Application and definitions.	

S3. Application.	FMVSS No. 208, Added for ADS-DV translation-S3.1 Application		
Regulatory Text	**Translation Options**		**Potential Considerations**
(a) This standard applies to passenger cars, multipurpose passenger vehicles, trucks, and buses. In addition, S9, Pressure vessels and explosive devices, applies to vessels designed to contain a pressurized fluid or gas, and to explosive devices, for use in the above types of motor vehicles as part of a system designed to provide protection to occupants in the event of a crash. (b) Notwithstanding any language to the contrary, any vehicle manufactured after March 19, 1997, and before September 1, 2006, that is subject to a dynamic crash test requirement conducted with unbelted dummies may meet the requirements specified in S5.1.2(a)(1), S5.1.2(a)(2), or S13 instead of the applicable unbelted requirement, unless the vehicle is certified to meet the requirements specified in S14.5, S15, S17, S19, S21, S23, and S25. (c) For vehicles which are certified to meet the requirements specified in S13 instead of the otherwise applicable dynamic crash test requirement conducted with unbelted dummies, compliance with S13 shall, for purposes of Standards No. 201, 203 and 209, be deemed as compliance with the unbelted frontal barrier requirements of S5.1.2.	**Option 1**	ADD: S3.1 Application. Maintain current sections (a)-(c)	Splits S3 into two sections with the additional definitions section.
	Option 2	ADD: S3.1 Application. Maintain current sections (a)-(c) ADD: (d) This standard applies to vehicles with or without a driver's DSP or manually operated driving controls.	With this additional statement, further clarification of definitions may not be necessary when references to the steering control (wheel), other driving controls, or driver DSP appear.
	Option 3	ADD: S3.1 Application. Maintain current sections (a)-(c) ADD: (d) This standard applies to vehicles with or without manually operated driving controls as defined in S3.2.	With this additional statement, further clarification of definitions may not be necessary when references to the steering control (wheel), other driving controls, or driver DSP appear.

S3. Application.	FMVSS No. 208, Added for ADS-DV translation-S3.2 Definitions		
Regulatory Text	**Translation Options**		**Potential Considerations**
Standard Text provided as an option.	**Option 1**	ADD: S3.2 Definitions *Driver dummy* means the test dummy in a driver's designated seating position. *Driver air bag* means the air bag installed for the protection of the occupant of the driver's designated seating position.	These definitions clarify that objects denoted "Driver" are associated with either definition of driver's DSP. The addition of these definitions, in use with the working definitions, may simplify the translation of this standard. This specific translation option would have to be used in conjunction with the working definitions. The translation would need to be updated in the case that the working definitions are not used.

FMVSS No. 208, S4.1.5.3 Passenger cars manufactured on or after September 1, 1997.			
Regulatory Text	**Translation Options**		**Potential Considerations**
Each passenger car manufactured on or after September 1, 1997 shall comply with the requirement of S4.1.5.1(a)(1) by means of an inflatable restraint system at the driver's and right front passenger's position. A vehicle shall not be deemed to be in noncompliance with this standard if its manufacturer establishes that it did not have reason to know in the exercise of due care that such vehicle is not in conformity with the requirement of this standard.	**Option 1**	Each passenger car manufactured on or after September 1, 1997 shall comply with the requirement of S4.1.5.1(a)(1) by means of an inflatable restraint system at all front outboard designated seating positions…	The standard states, "Each passenger car manufactured on or after September 1, 1997…" so translation for this section may not be necessary since it became largely obsolete for advanced air bag vehicles complying with S14. Removes driver/passenger references, but does not change the current requirements for non-ADS-DVs.

FMVSS No. 208, S4.2 Trucks and multipurpose passenger vehicles with a GVWR of 10,000 pounds or less.			
Regulatory Text	**Translation Options**		**Potential Considerations**
As used in this section, vehicles manufactured for operation by persons with disabilities means vehicles that incorporate a level change device (e.g., a wheelchair lift or a ramp) for onloading or offloading an occupant in a wheelchair, an interior element of design intended to provide the vertical clearance necessary to permit a person in a wheelchair to move between the lift or ramp and the driver's position or to occupy that position, and either an adaptive control or special driver seating accommodation to enable persons who have limited use of their arms or legs to operate a vehicle. For purposes of this definition, special driver seating accommodations include a driver's seat easily removable with means installed for that purpose or with simple tools, or a driver's seat with extended adjustment capability to allow a person to easily transfer from a wheelchair to the driver's seat.	**Option 1**	Retain current language.	Current language could be retained if the driver's DSP definition is used.
	Option 2	... between the lift or ramp and the driver's designated seating position or to occupy that position, and either an adaptive control or special driver's designated seating position accommodation to enable persons who have limited use of their arms or legs to operate a vehicle. For purposes of this definition, special driver's designated seating position accommodations include a driver's seat easily removable with means installed for that purpose or with simple tools, or a driver's seat with extended adjustment capability to allow a person to easily transfer from a wheelchair to the driver's seat.	This option uses the driver's DSP definition to replace driver's position and driver seating.

FMVSS No. 208, S4.2.6.2 Trucks, buses, and multipurpose passenger vehicles with a GVWR of 8,500 pounds or less and an unloaded vehicle weight of 5,500 pounds or less manufactured on or after September 1, 1998			
Regulatory Text	**Translation Options**		**Potential Considerations**
Each truck, bus, or multipurpose vehicle with a GVWR of 8,500 pounds or less and an unloaded vehicle weight of 5,500 pounds or less manufactured on or after September 1, 1998 shall comply with the requirement of S4.1.5.1(a)(1) by means of an inflatable restraint system at the driver's and right front passenger's position. A vehicle shall not be deemed to be in noncompliance with this standard if its manufacturer establishes that it did not have reason to know in the exercise of due care that such vehicle is not in conformity with the requirement of this standard.	**Option 1**	... comply with the requirement of S4.1.5.1(a)(1) by means of an inflatable restraint system at any front outboard designated seating position...	The standard states, "...manufactured on or after September 1, 1998...", so this section became largely obsolete for advanced air bag vehicles complying with S14. Removes driver/passenger references, but does not change the current requirement for conventional vehicles.

FMVSS No. 208, S4.4.1 Buses manufactured on or after November 28, 2016 Definitions			
Regulatory Text	**Translation Options**		**Potential Considerations**
Perimeter-seating bus means a bus with 7 or fewer designated seating positions rearward of the driver's seating position that are forward-facing or can convert to forward-facing without the use of tools and is not an over-the-road bus.	**Option 1**	*Perimeter-seating bus* means a bus with 7 or fewer designated seating positions rearward of the left front outboard seating position that are forward-facing or can convert to forward-facing without the use of tools and is not an over-the-road bus.	Translation is preferential for left front seat, but applies to ADS-DVs as well. Maintaining preference to the left front outboard seat may be unreasonable.
	Option 2	Retain current language.	Uses working definition for driver DSP. This term is used for heavy buses. Even with the new definitions, this translation does not address ADS-DVs.
	Option 3	*Perimeter-seating bus* means a bus, which is not an over-the-road bus, that has 7 or fewer designated seating positions that are forward-facing or can convert to forward-facing without the use of tools, and are rearward of the driver's designated seating position or rearward of the outboard designated seating positions in the most forward row of seats as defined in Standard No. 226 (49 CFR 571.226) if there is no driver's designated seating position.	This option does not give preference to the left front seat in an ADS-DV but preserves the current definition for conventional vehicles.

<table>
<tr><th colspan="4">FMVSS No. 208, S4.4.3.2.1 Definitions</th></tr>
<tr><td rowspan="2">The driver's designated seating position and any outboard designated seating position not rearward of the driver's seating position shall be equipped with a Type 2 seat belt assembly. The seat belt assembly shall comply with Standard No. 209 (49 CFR 571.209) and with S7.1 and S7.2 of this standard. The lap belt portion of the seat belt assembly shall include either an emergency locking retractor or an automatic locking retractor. An automatic locking retractor shall not retract webbing to the next locking position until at least 3⁄4 ; inch of webbing has moved into the retractor. In determining whether an automatic locking retractor complies with this requirement, the webbing is extended to 75 percent of its length and the retractor is locked after the initial adjustment. If the seat belt assembly installed in compliance with this requirement incorporates any webbing tension-relieving device, the vehicle owner's manual shall include the information specified in S7.4.2(b) of this standard for the tension-relieving device, and the vehicle shall comply with S7.4.2(c) of this standard.</td>
<td>Option 1</td>
<td>The driver's designated seating position and any outboard designated seating position not rearward of the driver's seating position shall be equipped with a Type 2 seat belt assembly. For a school bus without a driver’s designated seating position, the outboard designated seating positions in the most forward row of seats as defined in Standard No. 226 (49 CFR 571.226) shall be equipped with Type 2 seat belt assemblies. The seat belt assembly shall comply...</td>
<td>Uses working definition of driver’s DSP.

Maintaining the safety intent of this section using the new definitions may require further consideration/research. In an ADS-DV without a driver DSP, all seats/belts (even front outboard) would need to comply with the next section (4.4.3.2.2) rather than 4.4.3.2.1.</td></tr>
<tr><td>Option 2</td>
<td>The front left outboard designated seating position and any outboard designated seating position not rearward of the front left outboard seating position shall be equipped with a Type 2 seat belt assembly. The seat belt assembly shall comply...</td>
<td>This translation is similar to Option 1, but references the front left seat as opposed to the front row.

Maintains preference to the left side.</td></tr>
</table>

FMVSS No. 208, S4.4.3.2.2 Definitions			
Regulatory Text	**Translation Options**		**Potential Considerations**
Passenger seating positions, other than any outboard designated seating position not rearward of the driver's seating position, shall be equipped with Type 2 seat belt assemblies that comply with the requirements of S7.1.1.5, S7.1.5 and S7.2 of this standard.	**Option 1**	Passenger seating positions, other than those specified in S4.4.3.2.1, shall be equipped with Type 2 seat belt assemblies that comply with the requirements of S7.1.1.5, S7.1.5 and S7.2 of this standard.	Uses working definition of occupant DSP.
	Option 2	Occupant seating positions, other than any outboard designated seating position not rearward of the front left outboard seating position, shall be equipped with Type 2 seat belt assemblies that comply with the requirements of S7.1.1.5, S7.1.5 and S7.2 of this standard.	This translation is similar to Option 1, but references the front left seat as opposed to the front row. Maintains preference to the left side.

FMVSS No. 208, S4.4.4.1.1 First option—complete passenger protection system—driver only			
Regulatory Text	**Translation Options**		**Potential Considerations**
The vehicle shall meet the crash protection requirements of S5, with respect to an anthropomorphic test dummy in the driver's designated seating position, by means that require no action by vehicle occupants.	**Option 1**	Title: S4.4.4.1.1 First option—complete passenger protection system—driver's designated seating position only Retain current language.	Under this option, no ADS occupant would receive the occupant protection that would be afforded an occupant seated in the driver's DSP. This option does not change the current scope for conventional vehicles.
	Option 2	Title: S4.4.4.1.1 First option—complete passenger protection system—driver's or front left outboard designated seating position only The vehicle shall meet the crash protection requirements of S5, with respect to an anthropomorphic test dummy in the driver's designated seating position or the front left outboard designated seating position if there is no driver's designated seating position, by means that require no action by vehicle occupants.	The current crash protection requirements for the driver's seat would be maintained for the left front outboard seat in an ADS-DV. This option does not change the current scope for conventional vehicles.
	Option 3	Title: S4.4.4.1.1 First option—complete passenger protection system—driver's or all outboard designated seating positions in the most forward row only The vehicle shall meet the crash protection requirements of S5, with respect to an anthropomorphic test dummy in the driver's	This makes use of the row definition (FMVSS No. 226) and protects all outboard front row seat occupants if no driver's seat is present. However,

FMVSS No. 208, S4.4.4.1.1 First option—complete passenger protection system—driver only			
Regulatory Text	**Translation Options**		**Potential Considerations**
		designated seating position and all outboard designated seating positions in the most forward row of seats as defined in Standard No. 226 (49 CFR 571.226) if there is no driver's designated seating position, by means that require no action by vehicle occupants.	this does not change the scope of the current rule for conventional vehicles.
	Option 4	Title: S4.4.4.1.1 First option—complete passenger protection system—any front designated seating position The vehicle shall meet the crash protection requirements of S5, with respect to an anthropomorphic test dummy in any front designated seating positions, by means that require no action by vehicle occupants.	This translation would require crash protection for all front designated seating positions for an ADS-DV and conventional vehicles.

FMVSS No. 208, S4.4.4.1.2 Second option—belt system—driver only			
Regulatory Text	**Translation Options**		**Potential Considerations**
The vehicle shall, at the driver's designated seating position, be equipped with either a Type 1 or a Type 2 seat belt assembly that conforms to §571.209 of this part and S7.2 of this Standard. A Type 1 belt assembly or the pelvic portion of a dual retractor Type 2 belt assembly installed at the driver's seating position shall include either an emergency locking retractor or an automatic locking retractor. If a seat belt assembly installed at the driver's seating position includes an automatic locking retractor for the lap belt or the lap belt portion, that seat belt assembly shall comply with the following: (a) An automatic locking retractor used at a driver's seating position that has some type of suspension system for the seat shall be attached to the seat structure that moves as the suspension system functions. (b) The lap belt or lap belt portion of a seat belt assembly equipped with an automatic locking retractor that is installed at the driver's seating position must allow at least 3⁄4 ; inch, but less than 3 inches, of webbing movement before retracting webbing to the next locking position. (c) Compliance with S4.4.4.2.1(b) of this standard is determined as follows: (1) The seat belt assembly is buckled and the retractor end of the seat belt assembly is anchored to a horizontal surface. The webbing for the lap belt	**Option 1**	Title: S4.4.4.1.2 Second option—belt system—driver's designated seating position only Retain current language.	Under this option, no ADS occupant would receive the occupant protection that would be afforded an occupant seated in the driver's DSP. This option does not change the current scope for conventional vehicles.
	Option 2	Title: S4.4.4.1.2 Second option—belt system—driver's or front left outboard designated seating position only The vehicle shall, at the driver's designated seating position and the front left outboard designated seating position, if there is no driver's designated seating position, be equipped with either a Type 1 or a Type 2 seat belt assembly that conforms to §571.209 of this part and S7.2 of this Standard. A Type 1 belt assembly or the pelvic portion of a dual retractor Type 2 belt assembly installed at these seating positions shall include either an emergency locking retractor or an automatic locking retractor. If a seat belt assembly installed at these	The current crash protection requirements for the driver's seat would be maintained for the left front outboard seat in an ADS-DV. This option does not change the current scope for conventional vehicles.

FMVSS No. 208, S4.4.4.1.2 Second option—belt system—driver only			
Regulatory Text	**Translation Options**		**Potential Considerations**
or lap belt portion of the seat belt assembly is extended to 75 percent of its length and the retractor is locked after the initial adjustment. (2) A load of 20 pounds is applied to the free end of the lap belt or the lap belt portion of the belt assembly (i.e., the end that is not anchored to the horizontal surface) in the direction away from the retractor. The position of the free end of the belt assembly is recorded. (3) Within a 30 second period, the 20 pound load is slowly decreased, until the retractor moves to the next locking position. The position of the free end of the belt assembly is recorded again. (4) The difference between the two positions recorded for the free end of the belt assembly shall be at least 3⁄4 ; inch but less than 3 inches.		seating positions includes an automatic locking retractor for the lap belt or the lap belt portion, that seat belt assembly shall comply with the following: (a) An automatic locking retractor used at a seating position that has some type of suspension system for the seat shall be attached to the seat structure that moves as the suspension system functions. (b) The lap belt or lap belt portion of a seat belt assembly equipped with an automatic locking retractor that is installed at the seating position must allow at least 3⁄4...	
	Option 3	Title: S4.4.4.1.2 Second option—belt system—driver or all outboard designated seating positions in the most forward row only The vehicle shall, at the driver's designated seating position and all outboard designated seating positions in the most forward row of seats as defined in Standard No. 226 (49 CFR 571.226), if there is no driver's designated seating position, be equipped with either a Type 1 or a Type 2 seat belt assembly that conforms to §571.209 of this part and S7.2 of this Standard. A Type 1 belt assembly or the pelvic portion of a dual retractor Type 2 belt	This makes use of the row definition (FMVSS No. 226) and protects all outboard front row seat occupants if there is not a driver's DSP. However, this does not change the scope of the current rule for conventional vehicles.

FMVSS No. 208, S4.4.4.1.2 Second option—belt system—driver only			
Regulatory Text	**Translation Options**		**Potential Considerations**
		assembly installed at these seating positions shall include either an emergency locking retractor or an automatic locking retractor. If a seat belt assembly includes an automatic locking retractor for the lap belt or the lap belt portion, that seat belt assembly shall comply with the following: (a) An automatic locking retractor used at a seating position that has some type of suspension system for the seat shall be attached to the seat structure that moves as the suspension system functions. (b) The lap belt or lap belt portion of a seat belt assembly equipped with an automatic locking retractor that is installed must allow at least 3⁄4...	
	Option 4	Title: S4.4.4.1.2 Second option—belt system— any front designated seating position The vehicle shall, at any front designated seating position, be equipped with either a Type 1 or a Type 2 seat belt assembly that conforms to §571.209 of this part and S7.2 of this Standard. A Type 1 belt assembly or the pelvic portion of a dual retractor Type 2	This translation would add crash protection to all front occupant seats for an ADS-DV. Makes no assumption about where front row

FMVSS No. 208, S4.4.4.1.2 Second option—belt system—driver only			
Regulatory Text	**Translation Options**		**Potential Considerations**
		belt assembly installed at any front seating position shall include either an emergency locking retractor or an automatic locking retractor. If a seat belt assembly installed at any front seating position includes an automatic locking retractor for the lap belt or the lap belt portion, that seat belt assembly shall comply with the following: (a) An automatic locking retractor used at any front seating position that has some type of suspension system for the seat shall be attached to the seat structure that moves as the suspension system functions. (b) The lap belt or lap belt portion of a seat belt assembly equipped with an automatic locking retractor that is installed at any front seating position must allow at least 3⁄4...	passenger seats are located.

FMVSS No. 208, S4.4.5.1.1 Buses with a GVWR of more than 11,793 kg (26,000 lb.)			
Regulatory Text	**Translation Options**		**Potential Considerations**
The driver's designated seating position and any outboard designated seating position not rearward of the driver's seating position shall be equipped with a Type 2 seat belt assembly. The seat belt assembly shall comply with Standard No. 209 (49 CFR 571.209) and with S7.1 and S7.2 of this standard. If a seat belt assembly installed in compliance with this requirement includes an automatic locking retractor for the lap belt portion, that seat belt assembly shall comply with paragraphs (a) through (c) of S4.4.4.1.2 of this standard. If a seat belt assembly installed in compliance with this requirement incorporates any webbing tension-relieving device, the vehicle owner's manual shall include the information specified in S7.4.2(b) of this standard for the tension-relieving device, and the vehicle shall comply with S7.4.2(c) of this standard.	**Option 1**	The driver's designated seating position and any outboard designated seating position not rearward of the driver's seating position shall be equipped with a Type 2 seat belt assembly. The seat belt assembly shall comply with Standard No. 209 (49 CFR 571.209) and with S7.1 and S7.2 of this standard. For a bus without a driver's designated seating position, the outboard designated seating positions in the most forward row of seats as defined in Standard No. 226 (49 CFR 571.226) shall be equipped with Type 2 seat belt assemblies. If a seat belt...	Uses the definition for driver's DSP. Addresses ADS-DVs and conventional vehicles separately.
	Option 2	The front left outboard designated seating position and any outboard designated seating position not rearward of the front left outboard seating position shall be equipped with a Type 2 seat belt assembly. If a seat belt...	This translation option is similar to Option 1, but references the front left seat as opposed to the front row and used the same text for both ADS-DV and conventional vehicles.

FMVSS No. 208, S4.4.5.1.1 Buses with a GVWR of more than 11,793 kg (26,000 lb.)			
Regulatory Text	**Translation Options**		**Potential Considerations**
	Option 3	Any outboard designated seating position not rearward of the front left outboard seating position shall be equipped with a Type 2 seat belt assembly. If a seat belt…	Similar to Option 2, but uses fewer words to achieve the same result.

FMVSS No. 208, S4.4.5.1.2 Buses with a GVWR of more than 11,793 kg (26,000 lb.)			
Regulatory Text	**Translation Options**		**Potential Considerations**
Passenger seating positions, other than any outboard designated seating position not rearward of the driver's seating position and seating positions on prison buses rearward of the driver's seating position, shall: (a) Other than for over-the-road buses: (i) Be equipped with a Type 2 seat belt assembly at any seating position that is not a side-facing position; (ii) Be equipped with a Type 1 or Type 2 seat belt assembly at any seating position that is a side-facing position; (c) For over-the-road buses, be equipped with a Type 2 seat belt assembly; (d) Have the seat belt assembly attached to the seat structure at any seating position that has another seating position, wheelchair position, or side emergency door behind it; and (e) Comply with the requirements of S7.1.1.5, S7.1.3, S7.1.6 and S7.2 of this standard.	**Option 1**	Passenger seating positions, other than those specified in S4.4.5.1.1 and seating positions on prison buses rearward of the driver's seating position, shall: …	Uses the DSPs referenced in S4.4.5.1.1 to provide the exclusion for the DSPs S4.4.5.1.2 apply.
	Option 2	Passenger seating positions, other than any outboard designated seating position not rearward of the front left outboard seating position and seating positions on prison buses rearward of the front left outboard seating position, shall: …	References the front left seat and uses the same text for both ADS-DV and conventional vehicles.

FMVSS No. 208, S4.4.5.3 Buses with a GVWR of more than 11,793 kg (26,000 lb)			
Regulatory Text	**Translation Options**		**Potential Considerations**
Each school bus with a GVWR of more than 11,793 kg (26,000 lb.) shall be equipped with a Type 2 seat belt assembly at the driver's designated seating position. The seat belt assembly shall comply with Standard No. 209 (49 CFR 571.209) and with S7.1 and S7.2 of this standard. If a seat belt assembly installed in compliance with this requirement includes an automatic locking retractor for the lap belt portion, that seat belt assembly shall comply with paragraphs (a) through (c) of S4.4.4.1.2 of this standard. If a seat belt assembly installed in compliance with this requirement incorporates any webbing tension-relieving device, the vehicle owner's manual shall include the information specified in S7.4.2(b) of this standard for the tension-relieving device, and the vehicle shall comply with S7.4.2(c) of this standard.	**Option 1**	Each school bus with a GVWR of more than 11,793 kg (26,000 lb.) shall be equipped with a Type 2 seat belt assembly at any front designated seating position. The seat belt…	May choose to add the term "outboard" after "front." This translation would apply crash protection requirements for all front (outboard) passenger seats for an ADS-DV and conventional vehicles. Another alternative could be to allow the manufacturer to select a seat to be equipped with this occupant protection. Makes no assumption about where front row passenger seats are located.
	Option 2	Each school bus with a GVWR of more than 11,793 kg (26,000 lb.) shall be equipped with a Type 2 seat belt assembly at the front left outboard designated seating position. The seat belt…	This option uses the same text for conventional vehicles and ADS-DVs. Designates preference of safety to the left front outboard seat, which may not be reasonable in ADS-DVs.
	Option 3	Retain current language.	This would remove crash protection for occupants in the front left outboard seating position in an ADS-DV.

FMVSS No. 208, S4.5.1(c) Air bag alert label			
Regulatory Text	**Translation Options**		**Potential Considerations**
If the label required by S4.5.1(b) is not visible when the sun visor is in the stowed position, an air bag alert label shall be permanently affixed to that visor so that the label is visible when the visor is in that position. The label shall conform in content to the sun visor label shown in Figure 6(c) of this standard, and shall comply with the requirements of S4.5.1(c)(1) through S4.5.1(c)(3). (1) The message area shall be black with yellow text. The message area shall be no less than 20 square cm. (2) The pictogram shall be black with a red circle and slash on a white background. The pictogram shall be no less than 20 mm in diameter. (3) If a vehicle does not have an inflatable restraint at any front seating position other than that for the driver, the pictogram may be omitted from the label shown in Figure 6c.	**Option 1**	... (3) If a vehicle does not have an inflatable restraint at any front seating position other than that for the driver's designated seating position, the pictogram may be omitted from the label shown in Figure 6c. ...	The section may be necessary for vehicles that are not required to meet advanced air bag requirements with a voluntarily installed driver air bag. Uses the working definition for driver's DSP.

FMVSS No. 208, S4.5.1(e) Label on the dashboard			
Regulatory Text	**Translation Options**		**Potential Considerations**
(1) Except as provided in S4.5.1(e)(2) or S4.5.1(e)(3), each vehicle that is equipped with an inflatable restraint for the passenger position shall have a label attached to a location on the dashboard or the steering wheel hub that is clearly visible from all front seating positions. The label need not be permanently affixed to the vehicle. This label shall conform in content to the label shown in Figure 7 of this standard, and shall comply with the requirements of S4.5.1(e)(1)(i) through S4.5.1(e)(1)(iii). (i) The heading area shall be yellow with the word "WARNING" and the alert symbol in black. (ii) The message area shall be white with black text. The message area shall be no less than 30 cm2 (4.7 in2). (iii) If the vehicle does not have a back seat, the label shown in Figure 7 may be modified by omitting the statement: "The back seat is the safest place for children 12 and under." (2) Vehicles certified to meet the requirements specified in S19, S21, and S23 before December 1, 2003, that are equipped with an inflatable restraint for the passenger position shall have a label attached to a location on the dashboard or the steering wheel hub that is clearly visible from all front seating positions. The label need not be permanently affixed to the vehicle. This label shall conform in content to the label shown in either Figure 9 or Figure 12 of this standard, at manufacturer's option, and shall comply with the requirements of S4.5.1(e)(2)(i) through S4.5.1(e)(2)(iv). (i) The heading area shall be yellow with black text. (ii) The message area shall be white with black text. The message area shall be no less than 30	**Option 1**	(1)…steering control (wheel) hub… (2)…steering control (wheel) hub… (3)…steering control (wheel) hub…	Applies to ADS-DVs and conventional vehicles.
	Option 2	(1)…steering control hub… (2)…steering control hub… (3)…steering control hub…	May choose to use the more encompassing term "steering control." This standard may not apply to all potential types of steering controls, so the general term may not be applicable.

cm2 (4.7 in2). (iii) If the vehicle does not have a back seat, the labels shown in Figures 9 and 12 may be modified by omitting the statement: "The back seat is the safest place for children." (iv) If the vehicle does not have a back seat or the back seat is too small to accommodate a rear-facing child restraint consistent with S4.5.4.1, the label shown in Figure 12 may be modified by omitting the statement: "Never put a rear-facing child seat in the front." (3) Vehicles certified to meet the requirements specified in S19, S21, and S23 on or after December 1, 2003, that are equipped with an inflatable restraint for the passenger position shall have a label attached to a location on the dashboard or the steering wheel hub that is clearly visible from all front seating positions. The label need not be permanently affixed to the vehicle. This label shall conform in content to the label shown in Figure 12 of this standard and shall comply with the requirements of S4.5.1(e)(3)(i) through S4.5.1(e)(3)(iv). (i) The heading area shall be yellow with black text. (ii) The message area shall be white with black text. The message area shall be no less than 30 cm2 (4.7 in2). (iii) If the vehicle does not have a back seat, the label shown in Figure 12 may be modified by omitting the statement: "The back seat is the safest place for children." (iv) If the vehicle does not have a back seat or the back seat is too small to accommodate a rear-facing child restraint consistent with S4.5.4.1, the label shown in Figure 12 may be modified by omitting the statement: "Never put a rear-facing child seat in the front."			

FMVSS No. 208, S4.5.1(f) Information to appear in owner's manual			
Regulatory Text	**Translation Options**		**Potential Considerations**
(1) The owner's manual for any vehicle equipped with an inflatable restraint system shall include an accurate description of the vehicle's air bag system in an easily understandable format. The owner's manual shall include a statement to the effect that the vehicle is equipped with an air bag and lap/shoulder belt at both front outboard seating positions, and that the air bag is a supplemental restraint at those seating positions. The information shall emphasize that all occupants, including the driver, should always wear their seat belts whether or not an air bag is also provided at their seating position to minimize the risk of severe injury or death in the event of a crash. The owner's manual shall also provide any necessary precautions regarding the proper positioning of occupants, including children, at seating positions equipped with air bags to ensure maximum safety protection for those occupants. The owner's manual shall also explain that no objects should be placed over or near the air bag on the instrument panel, because any such objects could cause harm if the vehicle is in a crash severe enough to cause the air bag to inflate. (2) For any vehicle certified to meet the requirements specified in S14.5, S15, S17, S19, S21, S23, and S25, the manufacturer shall also include in the vehicle owner's manual	**Option 1**	…and that the air bag is a supplemental restraint at those seating positions. The information shall emphasize that all occupants should always wear their seat belts, …	Omits reference to the driver and simplifies the text.

a discussion of the advanced passenger air bag system installed in the vehicle. The discussion shall explain the proper functioning of the advanced air bag system and shall provide a summary of the actions that may affect the proper functioning of the system. The discussion shall include, at a minimum, accurate information on the following topics: (i) A presentation and explanation of the main components of the advanced passenger air bag system. (ii) An explanation of how the components function together as part of the advanced passenger air bag system. (iii) The basic requirements for proper operation, including an explanation of the actions that may affect the proper functioning of the system. (iv) For vehicles certified to meet the requirements of S19.2, S21.2 or S23.2, a complete description of the passenger air bag suppression system installed in the vehicle, including a discussion of any suppression zone. (v) An explanation of the interaction of the advanced passenger air bag system with other vehicle components, such as seat belts, seats or other components. (vi) A summary of the expected outcomes when child restraint systems, children and small teenagers or adults are both properly and improperly positioned in the passenger seat, including cautionary advice against improper placement of child restraint systems. (vii) For vehicles certified to meet the requirements of S19.2, S21.2 or S23.2, a discussion of the telltale light, specifying its location in the vehicle and explaining when the light is illuminated. (viii) Information on how to contact the vehicle manufacturer concerning modifications for persons with disabilities that may affect the advanced air bag system.			

FMVSS No. 208, S4.5.2 Readiness indicator			
Regulatory Text	**Translation Options**		**Potential Considerations**
An occupant protection system that deploys in the event of a crash shall have a monitoring system with a readiness indicator. The indicator shall monitor its own readiness and shall be clearly visible from the driver's designated seating position. If the vehicle is equipped with a single readiness indicator for both a driver and passenger air bag, and if the vehicle is equipped with an on-off switch permitted by S4.5.4 of this standard, the readiness indicator shall monitor the readiness of the driver air bag when the passenger air bag has been deactivated by means of the on-off switch, and shall not illuminate solely because the passenger air bag has been deactivated by the manual on-off switch. A list of the elements of the system being monitored by the indicator shall be included with the information furnished in accordance with S4.5.1 but need not be included on the label.	**Option 1**	…have a monitoring system with a readiness indicator. The indicator shall monitor its own readiness and shall be clearly visible from the driver's designated seating position, or any designated seating position if no driver's designated seating position is occupied or present. If the vehicle is equipped with a single readiness indicator for both front outboard air bags, and if the vehicle is equipped with an on-off switch permitted by S4.5.4 of this standard, the readiness indicator shall monitor the readiness of the active air bag when the other passenger air bag has been deactivated by means of the on-off switch, and shall not illuminate solely because the passenger air bag has been deactivated by the manual on-off switch. A list of the elements of the system being monitored by the indicator shall be included with the information furnished in accordance with S4.5.1 but need not be included on the label. For vehicles without manually operated driving controls, the readiness indicator for any passenger airbag shall monitor its own readiness and shall provide an input to the ADS indicating the underlying condition.	If there is a driver's DSP and it is occupied, i.e., if there is a human driver, the original purpose of the text is preserved. If not, to ensure that any person protected by the air bag receives the warning, all occupants would need to receive the warning. The readiness is also communicated to the ADS. Requires ADS to be defined. Does not assume that the active air bag will be the air bag in the driver's DSP.

FMVSS No. 208, S4.5.2 Readiness indicator			
Regulatory Text	**Translation Options**		**Potential Considerations**
	Option 2	…have a monitoring system with a readiness indicator. The indicator shall monitor its own readiness and shall be clearly visible from the driver's designated seating position, or any front outboard designated seating position if no driver's designated seating position is occupied or present. If the vehicle is equipped with a single readiness indicator for both front outboard air bags, and if the vehicle is equipped with an on-off switch permitted by S4.5.4 of this standard, the readiness indicator shall monitor the readiness of the active air bag when the other passenger air bag has been deactivated by means of the on-off switch, and shall not illuminate solely because the passenger air bag has been deactivated by the manual on-off switch. A list of the elements of the system being monitored by the indicator shall be included with the information furnished in accordance with S4.5.1 but need not be included on the label. For vehicles without manually operated driving controls, the readiness indicator for any front outboard passenger airbag shall monitor its own readiness and shall provide an input to the ADS indicating the underlying condition.	If there is a driver's DSP and it is occupied, i.e., if there is a human driver, the original purpose of the text is preserved. If not, to ensure that any person protected by the air bag receives the warning, all front outboard occupants would need to receive the warning. The readiness is also communicated to the ADS. Requires ADS to be defined. Does not assume that the active air bag will be the air bag in the driver's DSP.

FMVSS No. 208, S4.5.2 Readiness indicator			
Regulatory Text	**Translation Options**		**Potential Considerations**
	Option 3	An occupant protection system that deploys in the event of a crash shall have a monitoring system with a readiness indicator. The indicator shall monitor its own readiness and shall be clearly visible from the driver's designated seating position in a vehicle with manually operated driving controls, and shall be clearly visible to the left front outboard seating position in an ADS-DV. If the vehicle is equipped with a single readiness indicator for both the left front outboard and right front outboard air bag, and if the vehicle is equipped with an on-off switch permitted by S4.5.4 of this standard, the readiness indicator shall monitor the readiness of the air bag that has not been deactivated when the other air bag has been deactivated by means of the on-off switch, and shall not illuminate solely because that other air bag has been deactivated by the manual on-off switch. A list of the elements of the system being monitored by the indicator shall be included with the information furnished in accordance with S4.5.1 but need not be included on the label. For vehicles without manually operated driving controls, the readiness indicator for the left front outboard seating position airbag shall monitor its own readiness and shall provide an input to the ADS indicating the underlying condition.	This option maintains the current language for conventional vehicles and ensures the indicator is visible per the current standard location for ADS-DVs. Requires ADS to be defined.

FMVSS No. 208, S4.5.2 Readiness indicator			
Regulatory Text	**Translation Options**		**Potential Considerations**
	Option 4	…The indicator shall monitor its own readiness and shall be clearly visible from the driver's designated seating position in vehicles with manually operated driving controls. If the vehicle is equipped with a single readiness indicator for both front outboard air bags, and if the vehicle is equipped with an on-off switch permitted by S4.5.4 of this standard, the readiness indicator shall monitor the readiness of the active air bag when the other passenger air bag has been deactivated by means of the on-off switch, and shall not illuminate solely because the passenger air bag has been deactivated by the manual on-off switch... For vehicles without manually operated driving controls, the readiness indicator for the left front outboard seating position airbag shall monitor its own readiness and shall provide an input to the ADS indicating the underlying condition.	The telltale is visible to the driver's DSP in conventional vehicles and the information is communicated to the ADS in ADS-DVs. Requires ADS to be defined.

FMVSS No. 208, S4.11 Test duration for purpose of measuring injury criteria (d)			
Regulatory Text	**Translation Options**		**Potential Considerations**
(a) For all barrier crashes, the injury criteria specified in this standard shall be met when calculated based on data recorded for 300 milliseconds after the vehicle strikes the barrier. (b) For the 3-year-old and 6-year-old child dummy low risk deployment tests, the injury criteria specified in this standard shall be met when calculated on data recorded for 100 milliseconds after the initial deployment of the air bag. (c) For 12-month-old infant dummy low risk deployment tests, the injury criteria specified in the standard shall be met when calculated on data recorded for 125 milliseconds after the initiation of the final stage of air bag deployment designed to deploy in any full frontal rigid barrier crash up to 64 km/h (40 mph). (d) For driver-side low risk deployment tests, the injury criteria shall be met when calculated based on data recorded for 125 milliseconds after the initiation of the final stage of air bag deployment designed to deploy in any full frontal rigid barrier crash up to 26 km/h (16 mph). (e) The requirements for dummy containment shall continue until both the vehicle and the dummies have ceased moving.	**Option 1**	Retain current language.	Driver-side is an adequate specification as the low risk deployment tests are only run in a driver's DSP. Uses working definition option 2 for driver.

FMVSS No. 208, S7.1.1 Seat belt assembly requirements			
Regulatory Text	**Translation Options**		**Potential Considerations**
Except as specified in S7.1.1.1 and S7.1.1.2, the lap belt of any seat belt assembly furnished in accordance with S4.1.2 shall adjust by means of any emergency-locking or automatic-locking retractor that conforms to §571.209 to fit persons whose dimensions range from those of a 50th percentile 6-year-old child to those of a 95th percentile adult male and the upper torso restraint shall adjust by means of an emergency-locking retractor or a manual adjusting device that conforms to §571.209 to fit persons whose dimensions range from those of a 5th percentile adult female to those of a 95th percentile adult male, with the seat in any position, the seat back in the manufacturer's nominal design riding position, and any adjustable anchorages adjusted to the manufacturer's nominal design position for a 50th percentile adult male occupant. However, an upper torso restraint furnished in accordance with S4.1.2.3.1(a) shall adjust by means of an emergency-locking retractor that conforms to §571.209.	**Option 1**	Retain current language.	
	Option 2	Except as specified in S7.1.1.2, the lap belt of any seat belt assembly furnished in accordance with S4.1.2 shall adjust by means of any emergency-locking or automatic-locking retractor that conforms to §571.209 to fit persons whose dimensions range from those of a 50th percentile 6-year-old child to those of a 95th percentile adult male and the upper torso restraint shall adjust by means of an emergency-locking retractor or a manual adjusting device that conforms to §571.209 to fit persons whose dimensions range from those of a 5th percentile adult female to those of a 95th percentile adult male, with the seat in any position...	Contingent on removing S7.1.1.1. This translation would make S7.1.1 applicable to all lap belts regardless of seating position for ADS-DVs and conventional vehicles.

FMVSS No. 208, S7.1.1.1 Seat belt assembly requirements			
Regulatory Text	**Translation Options**		**Potential Considerations**
A seat belt assembly installed at the driver's seating position shall adjust to fit persons whose dimensions range from those of a 5th-percentile adult female to those of a 95th-percentile adult male.	**Option 1**	A seat belt assembly installed at the driver's designated seating position shall adjust to fit persons whose dimensions range from those of a 5th-percentile adult female to those of a 95th-percentile adult male.	Uses working definition for driver's DSP.
	Option 2	Remove entire section (S7.1.1.1).	"Driver" specific size requirements may not be mandatory. This option expands to 7.1 belt fit requirements for drivers to include all size occupants, from children to adults. Changes language for conventional vehicles.
	Option 3	A seat belt assembly installed at a seating position with manually operated driving controls shall adjust to fit persons whose dimensions range from those of a 5th-percentile adult female to those of a 95th-percentile adult male.	Translation alternative that maintains section but does not use working definitions. Achieves same effect as Option 1.

FMVSS No. 208, S7.1.1.5 Seat belt assembly requirements			
Regulatory Text	**Translation Options**		**Potential Considerations**
Passenger cars, and trucks, buses, and multipurpose passenger vehicles with a GVWR of 4,536 kg (10,000 lb.) or less manufactured on or after September 1, 1995 and buses with a GVWR of more than 11,793 kg (26,000 pounds) manufactured on or after November 28, 2016, except a perimeter-seating bus, prison bus, school bus, or transit bus, shall meet the requirements of S7.1.1.5(a), S7.1.1.5(b) and S7.1.1.5(c). (a) Each designated seating position, except the driver's position, and except any right front seating position that is equipped with an automatic belt, that is in any motor vehicle, except walk-in van-type vehicles and vehicles manufactured to be sold exclusively to the U.S. Postal Service, and that is forward-facing or can be adjusted to be forward-facing, shall have a seat belt assembly whose lap belt portion is lockable so that the seat belt assembly can be used to tightly secure a child restraint system. The means provided to lock the lap belt or lap belt portion of the seat belt assembly shall not consist of any device that must be attached by the vehicle user to the seat belt	**Option 1**	...(a) Each designated seating position, except the driver's designated seating position, and except any right front seating position ...	Uses either working definition for driver's DSP.
	Option 2	...(a) Each designated seating position, except a seating position with manually operated driving controls, and except any right front seating position that is...	Uses working definition for vehicles equipped with manually operated driving controls.

FMVSS No. 208, S7.1.1.5 Seat belt assembly requirements			
Regulatory Text	**Translation Options**		**Potential Considerations**
webbing, retractor, or any other part of the vehicle. Additionally, the means provided to lock the lap belt or lap belt portion of the seat belt assembly shall not require any inverting, twisting or otherwise deforming of the belt webbing. ….			

FMVSS No. 208, S7.1.1.6 Passenger seats, other than any outboard designated seating position not rearward of the driver's seating position, in buses with a GVWR of more than 11,793 kg (26,000 lb.) manufactured on or after November 28, 2016			
Regulatory Text	**Translation Options**		**Potential Considerations**
S7.1.1.6 Passenger seats, other than any outboard designated seating position not rearward of the driver's seating position, in buses with a GVWR of more than 11,793 kg (26,000 lb.) manufactured on or after November 28, 2016.	**Option 1**	Retain current language.	No translation necessary using either working definition for driver's DSP.

FMVSS No. 208, S7.3 Latch Mechanism			
Regulatory Text	**Translation Options**		**Potential Considerations**
(a) A seat belt assembly provided at the driver's seating position shall be equipped with a warning system that, at the option of the manufacturer, either— (1) Activates a continuous or intermittent audible signal for a period of not less than 4 seconds and not more than 8 seconds and that activates a continuous or flashing warning light visible to the driver displaying the identifying symbol for the seat belt telltale shown in Table 2 of FMVSS 101 or, at the option of the manufacturer if permitted by FMVSS 101, displaying the words "Fasten Seat Belts" or "Fasten Belts", for not less than 60 seconds (beginning when the vehicle ignition switch is moved to the "on" or the "start" position) when condition (b) exists simultaneously with condition (c), or that (2) Activates, for a period of not less than 4 seconds and not more than 8 seconds (beginning when the vehicle ignition switch is moved to the "on" or the "start" position), a continuous or flashing warning light visible to the driver, displaying the identifying symbol of the seat belt telltale shown in Table 2 of FMVSS 101 or, at the	**Option 1**	(a) A seat belt assembly provided at the driver's seating position or any designated seating position, if no driver's designated seating position is occupied or present, shall be equipped with a warning system that, at the option of the manufacturer, either— (1) Activates a continuous or intermittent audible signal for a period of not less than 4 seconds and not more than 8 seconds and that activates a continuous or flashing warning light visible to the occupant of the driver's designated seating position or any occupant of a designated seating position, if no driver's designated seating position is occupied or present, displaying ... (2) Activates, for a period of not less than 4 seconds and not more than 8 seconds (beginning when the vehicle ignition switch is moved to the "on" or the "start" position), a continuous or flashing warning light visible to the occupant of the driver's designated seating position or any occupant of a designated seating position, if no driver's designated seating position is occupied or present, displaying... (b) ... (c) The driver's designated seating position lap belt or the lap belt at any designated seating position, if no driver's designated seating position is occupied or present, is not in use, as determined, at the...	All occupants of the vehicle will receive the warning, which may be considered important if there is not an occupant at the driver's DSP or the left front outboard seating position.

FMVSS No. 208, S7.3 Latch Mechanism			
Regulatory Text	**Translation Options**		**Potential Considerations**
option of the manufacturer if permitted by FMVSS 101, displaying the words “Fasten Seat Belts” or “Fasten Belts”, when condition (b) exists, and a continuous or intermittent audible signal when condition (b) exists simultaneously with condition (c). (b) The vehicle's ignition switch is moved to the “on” position or to the “start” position. (c) The driver's lap belt is not in use, as determined, at the option of the manufacturer, either by the belt latch mechanism not being fastened, or by the belt not being extended at least 4 inches from its stowed position.			
	Option 2	(a) A seat belt assembly provided at the driver's seating position or any front outboard designated seating position shall be equipped with a warning system that, at the option of the manufacturer, either— (1) Activates a continuous or intermittent audible signal for a period of not less than 4 seconds and not more than 8 seconds and that activates a continuous or flashing warning light visible to the occupant of the driver’s designated seating position or any occupant of a front outboard designated seating position displaying ... (2) Activates, for a period of not less than 4 seconds and not more than 8 seconds (beginning when the vehicle ignition switch is moved to the “on” or the “start” position), a continuous or flashing warning light visible to the occupant of the driver’s designated seating position or any occupant of a front outboard designated seating position displaying... (b) ... (c) The driver's seating position lap belt or the lap belt at any front outboard designated seating position is not in use, as determined, at the...	This option would provide a seat belt reminder to each front outboard DSP. Expands current requirement for seat belt reminders.

FMVSS No. 208, S7.3 Latch Mechanism			
Regulatory Text	**Translation Options**		**Potential Considerations**
	Option 3	(a) A seat belt assembly provided at the driver's seating position or any front outboard designated seating position, if no driver's designated seating position is occupied or present, shall be equipped with a warning system that, at the option of the manufacturer, either— (1) Activates a continuous or intermittent audible signal for a period of not less than 4 seconds and not more than 8 seconds and that activates a continuous or flashing warning light visible to the occupant of the driver's designated seating position or any occupant of a front outboard designated seating position, if no driver's designated seating position is occupied or present, displaying ... (2) Activates, for a period of not less than 4 seconds and not more than 8 seconds (beginning when the vehicle ignition switch is moved to the "on" or the "start" position), a continuous or flashing warning light visible to the occupant of the driver's designated seating position or any front outboard occupant of a designated seating position, if no driver's designated seating position is occupied or present, displaying... (3) For vehicles without manually operated driving controls, the status of the seat belt warning indicator for any front outboard designated seating position shall monitor its own status and shall provide an input to the ADS indicating the underlying unbelted condition.	Provides a reminder to all front outboard occupants if a driver's DSP is not present. Adds condition to communicate information to the ADS. Requires ADS to be defined.

FMVSS No. 208, S7.3 Latch Mechanism			
Regulatory Text	**Translation Options**		**Potential Considerations**
		(b) ... (c) The driver's designated seating position lap belt or the lap belt at any front outboard designated seating position, if no driver's designated seating position is occupied or present, is not in use, as determined, at the...	
	Option 4	(a) A seat belt assembly provided at the driver's seating position or any designated seating position, if no driver's designated seating position is occupied or present, shall be equipped with a warning system that, at the option of the manufacturer, either— (1) Activates a continuous or intermittent audible signal for a period of not less than 4 seconds and not more than 8 seconds and that activates a continuous or flashing warning light visible to the occupant of the driver's designated seating position or any occupant of a designated seating position, if no driver's designated seating position is occupied or present, displaying ... (2) Activates, for a period of not less than 4 seconds and not more than 8 seconds (beginning when the vehicle ignition switch is moved to the "on" or the "start" position), a continuous or flashing warning light visible to the occupant of the driver's designated seating position or any occupant of a designated seating position, if no driver's designated seating position is occupied or present, displaying...	Provides a reminder to all occupants if a driver's DSP is not present. Adds condition to communicate information to the ADS.

FMVSS No. 208, S7.3 Latch Mechanism			
Regulatory Text	**Translation Options**		**Potential Considerations**
		(3) For vehicles without manually operated driving controls, the status of the seat belt warning indicator for any designated seating position shall monitor its own status and shall provide an input to the ADS indicating the underlying unbelted condition. (b) ... (c) The driver's designated seating position lap belt or the lap belt at any designated seating position, if no driver's designated seating position is occupied or present, is not in use, as determined, at the...	

FMVSS No. 208, S8.1.4 General Conditions			
Regulatory Text	**Translation Options**		**Potential Considerations**
Adjustable steering controls are adjusted so that the steering wheel hub is at the geometric center of the locus it describes when it is moved through its full range of driving positions.	**Option 1**	Retain current language.	May not apply to ADS-DVs with forms of steering controls that differ from a steering wheel.
	Option 2	Adjustable steering controls are adjusted so that the steering control (wheel) hub is at the geometric center of the locus it describes when it is moved through its full range of driving positions.	May choose to use the more encompassing term "control" rather than "wheel." However, for clarity, the relationship between wheel and control could be discussed in the preamble. A "control" of non-wheel form may not have a clearly defined "hub."

FMVSS No. 208, S10.2.1 Upper Arms			
Regulatory Text	**Translation Options**		**Potential Considerations**
The driver's upper arms shall be adjacent to the torso with the centerlines as close to a vertical plane as possible.	**Option 1**	The driver dummy's upper arms…	Uses the translation option which defines "driver dummy" in the added translation section, S3.2 Definitions.
	Option 2	The front left test dummy's upper arms…	Does not cover case where the driver becomes a passenger in an ADS-DV.

FMVSS No. 208, S10.2.2 Upper Arms			
Regulatory Text	**Translation Options**		**Potential Considerations**
The passenger's upper arms shall be in contact with the seat back and the sides of the torso.	**Option 1**	Any front outboard passenger dummy's upper arms…	Uses the translation option which defines "passenger dummy," in the added translation section, S3.2 Definitions. This translation considers the potential for more than one passenger dummy (i.e., no driver DSP/steering controls).
	Option 2	The front right test dummy's upper arms…	Does not cover case where the driver becomes a passenger in an ADS-DV.

FMVSS No. 208, S10.3.1 Hands			
Regulatory Text	**Translation Options**		**Potential Considerations**
The palms of the driver's test dummy shall be in contact with the outer part of the steering wheel rim at the rim's horizontal centerline. The thumbs shall be over the steering wheel rim and shall be lightly taped to the steering wheel rim so that if the hand of the test dummy is pushed upward by a force of not less than 2 pounds and not more than 5 pounds, the tape shall release the hand from the steering wheel rim.	**Option 1**	The palms of the driver dummy shall be in contact with the outer part of the steering wheel rim at the rim's horizontal centerline. The thumbs shall be over the steering wheel rim and shall be lightly taped to the steering wheel rim so that if the hand of the test dummy is pushed upward by a force of not less than 2 pounds and not more than 5 pounds, the tape shall release the hand from the steering wheel rim.	Uses the translation option which defines "driver dummy" in the added translation section, S3.2 Definitions.
	Option 2	The palms of the driver dummy shall be in contact with the outer part of the steering control rim at the rim's horizontal centerline. The thumbs shall be over the steering control rim and shall be lightly taped to the steering control rim so that if the hand of the test dummy is pushed upward by a force of not less than 2 pounds and not more than 5 pounds, the tape shall release the hand from the steering control rim.	Uses the translation option which defines "driver dummy" in the added translation section, S3.2 Definitions. May consider replacing the word "rim" with another term (e.g., perimeter) if "wheel" is replaced with "control." Standard may not be applicable to general steering controls via this translation option.

FMVSS No. 208, S10.3.2 Hands			
Regulatory Text	**Translation Options**		**Potential Considerations**
The palms of the passenger test dummy shall be in contact with the outside of the thigh. The little finger shall be in contact with the seat cushion.	**Option 1**	The palms of any outboard passenger test dummy shall…	Uses the translation option which defines "passenger dummy" in the added translation section, S3.2 Definitions. This translation considers the potential for more than one passenger dummy (i.e., no driver DSP/steering controls).
	Option 2	The palms of the front right test dummy…	Does not address ADS-DVs where all front test dummies are passengers.
	Option 3	The palms of the left front test dummy for a vehicle without steering controls and the right front test dummy shall be…	Uses existing language to apply to left front occupants in ADS-DVs.

FMVSS No. 208, S10.4.1.1 Torso			
Regulatory Text	**Translation Options**		**Potential Considerations**
In vehicles equipped with bench seats, the upper torso of the driver and passenger test dummies shall rest against the seat back. The midsagittal plane of the driver dummy shall be vertical and parallel to the vertical and parallel to the vehicle's longitudinal centerline, and pass through the center of the steering wheel rim. The midsagittal plane of the passenger dummy shall be vertical and parallel to the vehicle's longitudinal centerline and the same distance from the vehicle's longitudinal centerline as the midsagittal plane of the driver dummy.	**Option 1**	In vehicles equipped with bench seats, the upper torso of the front outboard test dummies shall rest against the seat back. The midsagittal plane of the driver dummy shall be vertical and parallel to the vehicle's longitudinal centerline, and pass through the center of the steering wheel rim. The midsagittal plane of any passenger dummy shall be vertical and parallel to the vehicle's longitudinal centerline and the same distance from the vehicle's longitudinal centerline as the midsagittal plane of the driver dummy, if there is a driver's designated seating position. Otherwise, the midsagittal plane of any front outboard passenger dummy shall pass through the center of the frontal air bag.	Uses working definitions for driver's DSP. Translation addresses vehicles without a driver's DSP by centering the dummy with the frontal air bag, as defined by the manufacturer.
	Option 2	In vehicles equipped with bench seats, the upper torso of the front outboard test dummies shall rest against the seat back. The midsagittal plane of the driver dummy shall be vertical and parallel to the vehicle's longitudinal centerline, and pass through the center of the steering wheel rim. The midsagittal plane of any passenger dummy shall be vertical and parallel to the vehicle's longitudinal centerline and the same distance from the vehicle's longitudinal centerline as the midsagittal plane of the driver dummy, if there is a driver's seating position. Otherwise, the midsagittal plane of any front outboard passenger dummy shall pass through the seating reference point of the seat that it occupies.	Uses working definitions. Translation addresses vehicles without a driver's DSP by centering the dummy on the seating reference point as defined by the manufacturer.

FMVSS No. 208, S10.4.1.1 Torso			
Regulatory Text	**Translation Options**		**Potential Considerations**
	Option 3	In vehicles equipped with bench seats, the upper torso of the front left and right test dummies shall rest against the seat back. The midsagittal plane of the front left dummy shall be vertical and parallel to the vehicle's longitudinal centerline, and, if manual steering controls are present, pass through the center of the steering wheel rim. For a vehicle without manual steering controls, the midsagittal plane of the front left dummy shall be parallel to the vehicle's longitudinal centerline and pass through the center of the left front head restraint. The midsagittal plane of the front right dummy shall...as the midsagittal plane of the front left dummy.	This translation addresses vehicles without a driver's DSP by centering the left front dummy on the center of the head restraint and mirrors this position laterally for the right front dummy. An alternative could be to use the head restraint of each seat as the reference. There could be an issue if the head restraints are not symmetric.
	Option 4	In vehicles equipped with bench seats, the upper torso of the front left and right test dummies shall rest against the seat back. The midsagittal plane of the front left dummy shall be vertical and parallel to the vehicle's longitudinal centerline, and, if manual steering controls are present, pass through the center of the steering wheel rim. For a vehicle without manual steering controls, the midsagittal plane of the front left dummy shall pass through the center of the left front SgRP. The midsagittal plane of the front right dummy shall...as the midsagittal plane of the front left dummy.	Addresses vehicles without a driver's seat by centering the left front dummy on the SgRP of the seat and mirroring this position laterally for the right front dummy.

FMVSS No. 208, S10.4.1.2 Torso			
Regulatory Text	**Translation Options**		**Potential Considerations**
In vehicles equipped with bucket seats, the upper torso of the driver and passenger test dummies shall rest against the seat back. The midsagittal plane of the driver and the passenger dummy shall be vertical and shall coincide with the longitudinal centerline of the bucket seat.	**Option 1**	In vehicles equipped with bucket seats, the upper torso of the driver and passenger dummies shall rest against the seat back. The midsagittal plane of the driver and any front outboard passenger dummy shall be vertical and shall coincide with the longitudinal centerline of the bucket seat.	Uses working definitions for driver and passenger. An alternative translation would state that the midsagittal planes of the dummies must coincide with the SgRP.
	Option 2	...the upper torso of the front left and right test dummies...midsagittal plane of the front left and right dummy...	Similar to Option 1, but without use of the working definitions.

FMVSS No. 208, S10.4.2.1 H-Point			
Regulatory Text	**Translation Options**		**Potential Considerations**
The H-points of the driver and passenger test dummies shall coincide within 1⁄2 inch in the vertical dimension and 1⁄2 inch in the horizontal dimension of a point 1⁄4 inch below the position of the H-point determined by using the equipment and procedures specified in SAE Standard J826-1980 (incorporated by reference, see §571.5), except that the length of the lower leg and thigh segments of the H-point machine shall be adjusted to 16.3 and 15.8 inches, respectively, instead of the 50th percentile values specified in Table 1 of SAE Standard J826-1980.	**Option 1**	The H-points of the front outboard test dummies shall…	Removes driver/passenger references.
	Option 2	The H-points of the driver and any front outboard passenger test dummies…	Retains driver terminology for conventional vehicles while addressing ADS-DVs with two or more front passenger seats.

FMVSS No. 208, S10.5 Legs			
Regulatory Text	**Translation Options**		**Potential Considerations**
The upper legs of the driver and passenger test dummies shall rest against the seat cushion to the extent permitted by placement of the feet. The initial distance between the outboard knee clevis flange surfaces shall be 10.6 inches. To the extent practicable, the left leg of the driver dummy and both legs of the passenger dummy shall be in vertical longitudinal planes. To the extent practicable, the right leg of the driver dummy shall be in a vertical plane. Final adjustment to accommodate the placement of feet in accordance with S10.6 for various passenger compartment configurations is permitted.	**Option 1**	The upper legs of the front outboard test dummies shall rest against the seat cushion to the extent permitted by placement of the feet. The initial distance between the outboard knee clevis flange surfaces shall be 10.6 inches. To the extent practicable, both legs of the front outboard passenger dummy shall be in vertical longitudinal planes...	Removes driver/passenger references. Further specification of whether or not a dummy is seated directly behind the driving controls could be included, as the current language specifies the driver's left leg and both legs of the passenger.
	Option 2	The upper legs of the driver and any front outboard passenger test dummies shall rest against the seat cushion to the extent permitted by placement of the feet. The initial distance between the outboard knee clevis flange surfaces shall be 10.6 inches. To the extent practicable, the left leg of the driver dummy and both legs of any front outboard passenger dummy shall be in vertical longitudinal planes...	Retains driver terminology for conventional vehicles while addressing ADS-DVs with two or more front passenger seats.

FMVSS No. 208, S10.6.1 Feet			
Regulatory Text	**Translation Options**		**Potential Considerations**
Driver's position	**Option 1**	Driver dummy position	Uses the translation option which defines "driver dummy" in the added translation section, S3.2 Definitions.
	Option 2	Left Front Outboard position	Does not address the presence of manual steering controls, so further translation of this section may be necessary.

FMVSS No. 208, S10.6.1.1 Feet			
Regulatory Text	**Translation Options**		**Potential Considerations**
If the vehicle has an adjustable accelerator pedal, adjust it to the full forward position. Rest the right foot of the test dummy on the undepressed accelerator pedal with the rearmost point of the heel on the floor pan in the plane of the pedal. If the foot cannot be placed on the accelerator pedal, set it initially perpendicular to the lower leg and then place it as far forward as possible in the direction of the pedal centerline with the rearmost point of the heel resting on the floor pan. If the vehicle has an adjustable accelerator pedal and the right foot is not touching the accelerator pedal when positioned as above, move the pedal rearward until it touches the right foot. If the accelerator pedal still does not touch the foot in the full rearward position, leave the pedal in that position.	**Option 1**	Retain current language.	A translation for ADS-DVs without foot pedals may be unnecessary. Paired with Option 1 in S10.6.1, above.
	Option 2	...leave the pedal in that position. If the vehicle does not have an accelerator pedal, place the right foot on the vehicle's toeboard with the heels resting on the floor pan as close as possible to the intersection point with the toeboard. If the feet cannot be placed flat on the toeboard, set them perpendicular to the lower leg centerlines and place them as far forward as possible with the heels resting on the floor pan.	Translation only necessary if Option 2 above is used. Attempts to achieve Option 1 actions without using the definitions. Paired with Option 2 in S10.6.1, above.

FMVSS No. 208, S10.6.2 Feet			
Regulatory Text	**Translation Options**		**Potential Considerations**
Passenger's position	**Option 1**	Front outboard passenger dummy position	Uses the translation option which defines "passenger dummy", in the added translation section, S3.2 Definitions.
	Option 2	Front Outboard Passenger Designated Seating Positions	Uses working definition of passenger DSP.
	Option 3	Right Front Outboard position	This is a direct translation but does not apply to ADS-DVs where the left front outboard seat is a passenger seat. Does not include the left front outboard seat if it is no longer a driver's DSP.

FMVSS No. 208, S10.7 Test dummy positioning for latchplate access			
Regulatory Text	**Translation Options**		**Potential Considerations**
The reach envelopes specified in S7.4.4 of this standard are obtained by positioning a test dummy in the driver's or passenger's seating position and adjusting that seating position to its forwardmost adjustment position. Attach the lines for the inboard and outboard arms to the test dummy as described in Figure 3 of this standard. Extend each line backward and outboard to generate the compliance arcs of the outboard reach envelope of the test dummy's arms.	**Option 1**	…positioning a test dummy in any front outboard seating position…	Applies to ADS-DVs where the driver's seating position would become a passenger seating position.
	Option 2	…positioning a test dummy in the driver's or any front outboard passenger's seating position…	Uses working definition Option 2 for driver and working definition for passenger. Addresses vehicles in which the driver's DSP becomes a passenger's DSP. Achieves the same result as Option 1, but explicitly retains the driver designation for conventional vehicles.

FMVSS No. 208, S13.3 Vehicle test attitude			
Regulatory Text	**Translation Options**		**Potential Considerations**
When the vehicle is in its “as delivered” condition, measure the angle between the driver's door sill and the horizontal. Mark where the angle is taken on the door sill. The “as delivered” condition is the vehicle as received at the test site, with 100 percent of all fluid capacities and all tires inflated to the manufacturer's specifications as listed on the vehicle's tire placard. When the vehicle is in its “fully loaded” condition, measure the angle between the driver's door sill and the horizontal, at the same place the “as delivered” angle was measured. The “fully loaded” condition is the test vehicle loaded in accordance with S8.1.1(a) or (b) of Standard No. 208, as applicable. The load placed in the cargo area shall be centered over the longitudinal centerline of the vehicle. The pretest door sill angle, when the vehicle is on the sled, (measured at the same location as the as delivered and fully loaded condition) shall be equal to or between the as delivered and fully loaded door sill angle measurements.	**Option 1**	Retain current language.	This section is no longer active (only applicable until September 1, 2006).
	Option 2	When the vehicle is in its “as delivered” condition, measure the angle between the front left door sill and the horizontal. Mark where the angle is taken on the door sill. The “as delivered” condition is the vehicle as received at the test site, with 100 percent of all fluid capacities and all tires inflated to the manufacturer's specifications as listed on the vehicle's tire placard. When the vehicle is in its “fully loaded” condition, measure the angle between the front left door sill and the horizontal, at the same place the “as delivered” angle was measured...	Driver is replaced with left front to describe the door used to take measurements.

FMVSS No. 208, S16.2.9 Test Conditions			
Regulatory Text	**Translation Options**		**Potential Considerations**
Steering wheel adjustment	**Option 1**	Steering control (wheel) adjustment	Wheel/control would apply to traditional steering wheels and vehicles without a traditional steering wheel.
	Option 2	Steering control adjustment	May choose to use the more encompassing term “control” rather than “wheel.”

FMVSS No. 208, S16.2.9.1 Test Conditions			
Regulatory Text	**Translation Options**		**Potential Considerations**
Adjust a tiltable steering wheel, if possible, so that the steering wheel hub is at the geometric center of its full range of driving positions.	**Option 1**	Adjust a tiltable steering control (wheel), if possible, so that the steering wheel/control hub is at the geometric center of its full range of driving positions.	Wheel/control would apply to traditional steering wheels and vehicles without a traditional steering wheel.
	Option 2	Adjust a tiltable steering control, if possible, so that the steering control hub is at the geometric center of its full range of driving positions.	May choose to use the more encompassing term "control" rather than "wheel."

FMVSS No. 208, S16.2.9.2 Test Conditions			
Regulatory Text	**Translation Options**		**Potential Considerations**
If there is no setting detent at the mid-position, lower the steering wheel to the detent just below the mid-position.	**Option 1**	If there is no setting detent at the mid-position, lower the steering control (wheel) to the detent just below the mid-position.	Wheel/control would apply to traditional steering wheels and vehicles without a traditional steering wheel.
	Option 2	If there is no setting detent at the mid-position, lower the steering control to the detent just below the mid-position.	May choose to use the more encompassing term “control” rather than “wheel.”

FMVSS No. 208, S16.2.9.3 Test Conditions			
Regulatory Text	**Translation Options**		**Potential Considerations**
If the steering column is telescoping, place the steering column in the mid-position. If there is no mid-position, move the steering wheel rearward one position from the mid-position.	**Option 1**	If the steering column is telescoping, place the steering column in the mid-position. If there is no mid-position, move the steering control (wheel) rearward one position from the mid-position.	Wheel/control would apply to traditional steering wheels and vehicles without a traditional steering wheel.
	Option 2	If the steering column is telescoping, place the steering column in the mid-position. If there is no mid-position, move the steering control rearward one position from the mid-position.	May choose to use the more encompassing term “control” rather than “wheel.”

FMVSS No. 208, S16.2.10.3 Seat position adjustment			
Regulatory Text	**Translation Options**		**Potential Considerations**
If the passenger seat does not adjust independently of the driver seat, the driver seat shall control the final position of the passenger seat.	**Option 1**	If the front right outboard passenger seat does not adjust independently of the front left outboard seat, the front left outboard seat shall control the final position of the front right outboard passenger seat.	If there is no driver's seat, priority is given to the front left seat to control the placement of the entire seat row. Preference to the left front outboard seat may not have to be maintained for ADS-DVs.
	Option 2	If the front right outboard passenger seat does not adjust independently of the driver's seat or front left outboard passenger seat when no driver's seat is present, shall control the final position of the front right outboard passenger seat.	Achieves same result as Option 1, but explicitly retains driver references for conventional vehicles.

FMVSS No. 208, S16.3.2 Dummy seating positioning procedures			
Regulatory Text	**Translation Options**		**Potential Considerations**
Driver dummy positioning	**Option 1**	Retain current language.	Uses the translation option which defines "driver dummy" in the added translation section, S3.2 Definitions.
	Option 2	Dummy Positioning for the Driver's Designated Seating Position	Uses working definition to specify the dummy positioning by seat functionality rather than location. Further translation for dummy positioning procedures when no driver's DSP is present could be necessary.
	Option 3	Left Front Outboard dummy positioning	This may assume that none of the driver reference marks referring to manual controls are landmarks. The presence of manually operated driving controls is not addressed so further translation of this section could be necessary.

FMVSS No. 208, S16.3.2.1 Dummy seating positioning procedures			
Regulatory Text	**Translation Options**		**Potential Considerations**
Driver torso/head/seat back angle positioning	**Option 1**	Retain current language.	Uses working definition option 1 for driver.

<table>
<tr><th colspan="4">FMVSS No. 208, S16.3.2.1.4 Bench seats</th></tr>
<tr><th>Regulatory Text</th><th colspan="2">Translation Options</th><th>Potential Considerations</th></tr>
<tr><td rowspan="2">Position the midsagittal plane of the dummy vertical and parallel to the vehicle's longitudinal centerline and aligned within ±10 mm (±0.4 in) of the center of the steering wheel rim.</td><td>Option 1</td><td>…of the center of the steering wheel/control rim.</td><td>Wheel/control would apply to traditional steering wheels and vehicles without a traditional steering wheel.</td></tr>
<tr><td>Option 2</td><td>Position the midsagittal plane of the dummy vertical and parallel to the vehicle's longitudinal centerline and aligned within ±10 mm (±0.4 in) of the center of the steering control.</td><td>May choose to use the more encompassing term “control” rather than “wheel.”
More general term “steering control” may not be applicable to all positioning specifications.</td></tr>
</table>

FMVSS No. 208, S16.3.2.1.8 Bench Seats			
Regulatory Text	**Translation Options**		**Potential Considerations**
If needed, extend the legs slightly so that the feet are not in contact with the floor pan. Let the thighs rest on the seat cushion to the extent permitted by the foot movement. Keeping the leg and the thigh in a vertical plane, place the foot in the vertical longitudinal plane that passes through the centerline of the accelerator pedal. Rotate the left thigh outboard about the hip until the center of the knee is the same distance from the midsagittal plane of the dummy as the right knee ±5 mm (±0.2 in). Using only the control that primarily moves the seat fore and aft, attempt to return the seat to the full forward position. If either of the dummy's legs first contacts the steering wheel, then adjust the steering wheel, if adjustable, upward until contact with the steering wheel is avoided. If the steering wheel is not adjustable, separate the knees enough to avoid steering wheel contact. Proceed with moving the seat forward until either the leg contacts the vehicle interior or the seat reaches the full forward position. (The right foot may contact and depress the accelerator and/or change the angle of the foot with respect to the leg during seat movement.) If necessary to avoid contact with the vehicles brake or clutch pedal, rotate the test dummy's left foot about the leg. If there is still interference, rotate the left thigh outboard about the hip the minimum distance necessary to avoid pedal interference. If a dummy leg contacts the vehicle interior before the full forward	**Option 1**	Retain current language.	
	Option 2	...the dummy's legs first contacts the steering control (wheel), then adjust the steering control (wheel), if adjustable, upward until contact with the steering control (wheel) is avoided. If the steering control (wheel) is not adjustable, separate the knees enough to avoid steering control (wheel) contact... ...If the steering control (wheel) was moved, return it to the position described in S16.2.9. If the steering control (wheel) contacts the dummy's leg(s) prior to attaining this position, adjust it to the next higher detent, or if infinitely adjustable, until there is 5 mm (0.2 in) clearance between the control (wheel) and the dummy's leg(s).	May choose to use the more encompassing term "control" rather than "wheel."

FMVSS No. 208, S16.3.2.1.8 Bench Seats			
Regulatory Text	**Translation Options**		**Potential Considerations**
position is attained, position the seat at the next detent where there is no contact. If the seat is a power seat, move the seat fore and aft to avoid contact while assuring that there is a maximum of 5 mm (0.2 in) distance between the vehicle interior and the point on the dummy that would first contact the vehicle interior. If the steering wheel was moved, return it to the position described in S16.2.9. If the steering wheel contacts the dummy's leg(s) prior to attaining this position, adjust it to the next higher detent, or if infinitely adjustable, until there is 5 mm (0.2 in) clearance between the wheel and the dummy's leg(s).			

FMVSS No. 208, S16.3.2.1.9 Bench Seats			
Regulatory Text	**Translation Options**		**Potential Considerations**
For vehicles without adjustable seat backs, adjust the lower neck bracket to level the head as much as possible. For vehicles with adjustable seat backs, while holding the thighs in place, rotate the seat back forward until the transverse instrumentation platform of the head is level to within ±0.5 degree, making sure that the pelvis does not interfere with the seat bight. Inspect the abdomen to ensure that it is properly installed. If the torso contacts the steering wheel, adjust the steering wheel in the following order until there is no contact: telescoping adjustment, lowering adjustment, raising adjustment. If the vehicle has no adjustments, or contact with the steering wheel cannot be eliminated by adjustment, position the seat at the next detent where there is no contact with the steering wheel as adjusted in S16.2.9. If the seat is a power seat, position the seat to avoid contact while assuring that there is a maximum of 5 mm (0.2 in) distance between the steering wheel as adjusted in S16.2.9 and the point of contact on the dummy.	**Option 1**	Retain current language.	
	Option 2	...If the torso contacts the steering control (wheel), adjust the steering control (wheel) in the following order until there is no contact: telescoping adjustment, lowering adjustment, raising adjustment. If the vehicle has no adjustments, or contact with the steering control (wheel) cannot be eliminated by adjustment, position the seat at the next detent where there is no contact with the steering control (wheel) as adjusted in S16.2.9. If the seat is a power seat, position the seat to avoid contact while assuring that there is a maximum of 5 mm (0.2 in) distance between the steering control (wheel) as adjusted in S16.2.9 and the point of contact on the dummy.	May choose to use the more encompassing term “control” rather than “wheel.”

FMVSS No. 208, S16.3.2.2 Driver foot positioning.			
Regulatory Text	**Translation Options**		**Potential Considerations**
S16.3.2.2 Driver foot positioning.	**Option 1**	Retain current language.	Driver-side is an adequate specification as the low risk deployment tests are only run in a driver's DSP. Uses working definition option 2 for driver.

FMVSS No. 208, S16.3.2.3 Driver arm/hand positioning.			
Regulatory Text	**Translation Options**		**Potential Considerations**
S16.3.2.3 Driver arm/hand positioning.	**Option 1**	Retain current language.	Uses working definition option 2 for driver.

FMVSS No. 208, S16.3.2.3.2 Bench seats			
Regulatory Text	**Translation Options**		**Potential Considerations**
Place the palms of the dummy in contact with the outer part of the steering wheel rim at its horizontal centerline with the thumbs over the steering wheel rim.	**Option 1**	Retain current language.	Would only apply if a steering wheel/control is present.
	Option 2	Place the palms of the dummy in contact with the outer part of the steering control (wheel) rim at its horizontal centerline with the thumbs over the steering control (wheel) rim.	May choose to use the more encompassing term "control" rather than "wheel." Positioning terminology may not be applicable to general steering controls based on potential design variations.

FMVSS No. 208, S16.3.2.3.3 Bench seats			
Regulatory Text	**Translation Options**		**Potential Considerations**
If it is not possible to position the thumbs inside the steering wheel rim at its horizontal centerline, then position them above and as close to the horizontal centerline of the steering wheel rim as possible.	**Option 1**	Retain current language.	Would only apply if a steering wheel/control is present.
	Option 2	If it is not possible to position the thumbs inside the steering control (wheel) rim at its horizontal centerline, then position them above and as close to the horizontal centerline of the steering control (wheel) rim as possible.	May choose to use the more encompassing term "control" rather than "wheel." Positioning terminology may not be applicable to general steering controls based on potential design variations.

FMVSS No. 208, S16.3.2.3.4 Bench seats			
Regulatory Text	**Translation Options**		**Potential Considerations**
Lightly tape the hands to the steering wheel rim so that if the hand of the test dummy is pushed upward by a force of not less than 9 N (2 lb.) and not more than 22 N (5 lb.), the tape releases the hand from the steering wheel rim.	**Option 1**	Retain current language.	Would only apply if a steering wheel/control is present.
	Option 2	Lightly tape the hands to the steering control (wheel) rim so that if the hand of the test dummy is pushed upward by a force of not less than 9 N (2 lb.) and not more than 22 N (5 lb.), the tape releases the hand from the steering control (wheel) rim.	May choose to use the more encompassing term "control" rather than "wheel." Positioning terminology may not be applicable to general steering controls based on potential design variations.

FMVSS No. 208, S16.3.3 Bench seats			
Regulatory Text	**Translation Options**		**Potential Considerations**
Passenger dummy positioning	**Option 1**	Retain current language.	Clarification may not be necessary since it is implicit that this section is for front row passengers only. Will accommodate passenger positioning for ADS-DVs and conventional vehicles. In an ADS-DV, the former driver position becomes a passenger position.
	Option 2	Front outboard passenger dummy positioning	Would apply to either outboard position for vehicles without a driver's DSP. May be redundant since this section only applies to front row occupants.

FMVSS No. 208, S16.3.3.1 Bench seats			
Regulatory Text	**Translation Options**		**Potential Considerations**
Passenger torso/head/seat back angle positioning	**Option 1**	Retain current language.	Clarification may not be necessary since it is implicit that this section is for front row passengers only. Will accommodate passenger positioning for ADS-DVs and conventional vehicles. In an ADS-DV, the former driver position becomes a passenger position.
	Option 2	Front outboard passenger torso/head/seat back angle positioning	Would apply to either outboard position for vehicles without a driver's DSP. May be redundant since this section only applies to front row occupants.

FMVSS No. 208, S16.3.3.1.2 Bench seats			
Regulatory Text	**Translation Options**		**Potential Considerations**
Fully recline the seat back, if adjustable. Install the dummy into the passenger seat, such that when the legs are 120 degrees to the thighs, the calves of the legs are not touching the seat cushion.	**Option 1**	Fully recline the seat back, if adjustable. Install the dummy into any passenger seat,…	Allows for the potential of multiple front outboard passenger seats rather than one passenger seat and one driver seat.
	Option 2	Fully recline the seat back, if adjustable. Install the dummy into the front outboard passenger seat,…	Would apply to either outboard position for vehicles without a driver's DSP. May be redundant since this section only applies to front row occupants.

FMVSS No. 208, S16.3.3.1.4 Bench seats			
Regulatory Text	**Translation Options**		**Potential Considerations**
Position the midsagittal plane of the dummy vertical and parallel to the vehicle's longitudinal centerline and the same distance from the vehicle's longitudinal centerline, within ±10 mm (±0.4 in), as the midsagittal plane of the driver dummy.	**Option 1**	Position the midsagittal plane of the dummy vertical and parallel to the vehicle's longitudinal centerline and the same distance from the vehicle's longitudinal centerline, within ±10 mm (±0.4 in), as the midsagittal plane of the driver dummy, if there is a driver's designated seating position. Otherwise, the midsagittal plane of the dummy shall pass through the center of the frontal air bag.	Uses working definition for driver's DSP. Considers vehicles with and without manually operated driving controls (i.e., vehicles with a driver's DSP).
	Option 2	Position the midsagittal plane of the dummy vertical and parallel to the vehicle's longitudinal centerline and the same distance from the vehicle's longitudinal centerline, within ±10 mm (±0.4 in), as the midsagittal plane of the driver dummy, if there is a driver's designated seating position. Otherwise, the midsagittal plane of the dummy shall pass through the seating reference point of the seat that it occupies.	Uses working definition for driver's DSP. Translation addresses vehicles without a driver's seat by centering the dummy on the seating reference point as defined by the manufacturer.
	Option 3	Position the midsagittal plane of the dummy vertical and parallel to the vehicle's longitudinal centerline and the same distance from the vehicle's longitudinal centerline, within ±10 mm (±0.4 in), as the midsagittal plane of the driver dummy, if there is a driver's designated seating position. Otherwise, the midsagittal plane of the dummy shall pass through the center of the head restraint of the seat that it occupies.	Uses working definition for driver's DSP. Translation addresses vehicles without a driver's seat by centering the dummy with the head restraint as defined by the manufacturer.

FMVSS No. 208, S16.3.3.2 Bench seats			
Regulatory Text	**Translation Options**		**Potential Considerations**
Passenger foot positioning	**Option 1**	Front outboard passenger foot positioning	Specifies that this section applies to front row passengers. Allows the potential for the left front outboard seat to be a passenger seat.

FMVSS No. 208, S16.3.3.3 Bench seats			
Regulatory Text	**Translation Options**		**Potential Considerations**
Passenger arm/hand positioning	**Option 1**	Front outboard passenger arm/hand positioning	Specifies that this section applies to front row passengers. Allows the potential for the left front outboard seat to be a passenger seat.

FMVSS No. 208, S16.3.4 Bench seats			
Regulatory Text	**Translation Options**		**Potential Considerations**
Driver and passenger adjustable head restraints	**Option 1**	Retain current language.	Uses working definition option 2 for driver.
	Option 2	Driver and front outboard passenger adjustable head restraints	Clarifies that this applies to front row passengers only.
	Option 3	Front occupant adjustable head restraints	Eliminates driver/passenger language from this section.

FMVSS No. 208, S16.3.5 Bench seats			
Regulatory Text	**Translation Options**		**Potential Considerations**
Driver and passenger manual belt adjustment (for tests conducted with a belted dummy)	**Option 1**	Retain current language.	Uses working definition option 2 for driver.
	Option 2	Driver and front outboard passenger manual belt adjustment…	Clarifies that this applies to front row passengers only.
	Option 3	Front occupant manual belt adjustment (for tests conducted with a belted dummy)	Eliminates driver/passenger language from this section.

FMVSS No. 208, S19.2.1 Option 1—Automatic suppression feature			
Regulatory Text	**Translation Options**		**Potential Considerations**
The vehicle shall be equipped with an automatic suppression feature for the passenger air bag which results in deactivation of the air bag during each of the static tests specified in S20.2 (using the 49 CFR part 572 Subpart R 12-month-old CRABI child dummy in any of the child restraints identified in sections B and C of appendix A or A-1 of this standard, as appropriate and the 49 CFR part 572 subpart K Newborn Infant dummy in any of the car beds identified in section A of appendix A or A-1, as appropriate), and activation of the air bag system during each of the static tests specified in S20.3 (using the 49 CFR part 572 Subpart O 5th percentile adult female dummy).	**Option 1**	The vehicle shall be equipped with an automatic suppression feature for any front outboard passenger air bag which results in deactivation of the air bag during each of the static tests specified in S20.2…	If the vehicle is not equipped with manually operated driving controls, the requirements for the occupant detection system passenger air bag out of position tests were translated to both left and right outboard seating positions ("any front outboard "). An additional section (S19.5) for ADS-equipped vehicles with steering controls could be necessary for suppressing the driver air bag or suspending the automatic driving function for a 12-month-old CRABI dummy in the driver DSP. The driver air bag could be suppressed by the same method the passenger side air bag is suppressed. Vehicles could alternatively/additionally have a label on the controls stating "Never allow a child smaller than X to ride in this seat, with or without a child restraint device." This could possibly be paired with ADS suppression.

FMVSS No. 208, S19.2.2 Option 1—Automatic suppression feature			
Regulatory Text	**Translation Options**		**Potential Considerations**
The vehicle shall be equipped with at least one telltale which emits light whenever the passenger air bag system is deactivated and does not emit light whenever the passenger air bag system is activated, except that the telltale(s) need not illuminate when the passenger seat is unoccupied. Each telltale: (a) Shall emit yellow light; (b) Shall have the identifying words "PASSENGER AIR BAG OFF" or "PASS AIR BAG OFF" on the telltale or within 25 mm (1.0 in) of the telltale; and (c) Shall not be combined with the readiness indicator required by S4.5.2 of this standard. (d) Shall be located within the interior of the vehicle and forward of and above the design H-point of both the driver's and the right front passenger's seat in their forwardmost seating positions and shall not be located on or adjacent to a surface that can be used	**Option 1**	The vehicle shall be equipped with telltales for each front outboard passenger seating position which emits light whenever the associated front outboard passenger air bag system is deactivated and does not emit light whenever the associated front outboard passenger air bag system is activated, except that the telltale(s) need not illuminate when the associated front outboard passenger seat is unoccupied. Each telltale: ... ... (d) Shall be located within the interior of the vehicle and forward of and above the design H-point of both the driver's and the front outboard passenger's seat in their forwardmost seating positions and shall not be located on or adjacent to a surface that can be used for temporary or permanent storage of objects that could obscure the telltale from either the driver's or any front outboard passenger's view, or located where the telltale would be obscured from the driver's view if a rear-facing child restraint listed in appendix A or A-1, as appropriate, is installed in any front outboard passenger's seat. (e) Shall be visible and recognizable to all front outboard occupants during night and day when the occupants have adapted to the ambient light roadway conditions. ... ... (g) Means shall be provided for making telltales visible and recognizable to the driver and any front outboard passenger under all driving conditions. The means for providing the	Under this option, the ADS must provide the information in a telltale to the front row occupants of the vehicle. Option 1 would make the suppression telltale visible to front-seat occupants. However, in an ADS-DV, a parent could place a child in the front seat and sit in a rear seat. The suppression telltale would not necessarily be visible to

FMVSS No. 208, S19.2.2 Option 1—Automatic suppression feature			
Regulatory Text	**Translation Options**		**Potential Considerations**
for temporary or permanent storage of objects that could obscure the telltale from either the driver's or right front passenger's view, or located where the telltale would be obscured from the driver's view if a rear-facing child restraint listed in appendix A or A-1, as appropriate, is installed in the right front passenger's seat. (e) Shall be visible and recognizable to a driver and right front passenger during night and day when the occupants have adapted to the ambient light roadway conditions. (f) Telltales need not be visible or recognizable when not activated. (g) Means shall be provided for making telltales visible and recognizable to the driver and right front passenger under all driving conditions. The means for providing the required visibility may be adjustable manually or automatically, except that the telltales may not be adjustable under any driving conditions to a level that they become invisible or		required visibility may be adjustable manually or automatically, except that the telltales may not be adjustable under any driving conditions to a level that they become invisible or not recognizable to the driver and any front outboard passenger. (h) The telltale must not emit light except when any passenger air bag is turned off or during a bulb check upon vehicle starting.	them. Another translation option would be to make the telltale visible to all vehicle occupants (See Option 2). This would be the only way to guarantee that if an adult is present in the vehicle, they would see the air bag suppression status.
	Option 2	The vehicle shall be equipped with at least one telltale for each front outboard passenger seat which emits light whenever the associated front outboard passenger air bag system is deactivated and does not emit light whenever the associated front outboard passenger air bag system is activated, except that the telltale(s) need not illuminate when the associated front outboard passenger seat is unoccupied. Each telltale: ...	All passengers will be made aware if a frontal air bag is deactivated.

FMVSS No. 208, S19.2.2 Option 1—Automatic suppression feature			
Regulatory Text	**Translation Options**		**Potential Considerations**
not recognizable to the driver and right front passenger. (h) The telltale must not emit light except when the passenger air bag is turned off or during a bulb check upon vehicle starting.		... (d) (1) When manually operated driving controls are present and active, the telltale shall be located within the interior of the vehicle...as appropriate, is installed in the right front passenger's seat. (2) When manually operated driving controls are not present or active, the telltale shall be located within the interior of the vehicle and forward of and above the design H-point of any passenger's seat in their forwardmost seating positions and shall not be located on or adjacent to a surface that can be used for temporary or permanent storage of objects that could obscure the telltale from any passenger's view, or located where the telltale would be obscured from any passenger’s view, except for the rear-facing occupant, if a rear-facing child restraint listed in appendix A or A-1, as appropriate, is installed in any front outboard passenger's seat. (e) (1) When manually operated driving controls are present and active, the telltale shall be visible and recognizable to a driver and right front passenger during night and day when the occupants have adapted to the ambient light roadway conditions. (2) When manually operated driving controls are not present or active, the telltale shall be visible and recognizable to any passenger, during night and day when	

FMVSS No. 208, S19.2.2 Option 1—Automatic suppression feature			
Regulatory Text	**Translation Options**		**Potential Considerations**
		the occupants have adapted to the ambient light roadway conditions. (f) Telltales need not be visible or recognizable when not activated. (g) Means shall be provided for making telltales visible and recognizable to the vehicle occupants specified in S19.2.2(e) under all driving conditions. The means for providing the required visibility may be adjustable manually or automatically, except that the telltales may not be adjustable under any driving conditions to a level that they become invisible or not recognizable to the vehicle occupants specified in S19.2.2(e). (h) The telltale must not emit light except when any passenger air bag is turned off or during a bulb check upon vehicle starting.	
	Option 3	The vehicle shall be equipped with telltales for each front outboard passenger seat which emits light whenever the associated front outboard passenger air bag system is deactivated and does not emit light whenever the associated front outboard passenger air bag system is activated, except that the telltale(s) need not illuminate when the associated front outboard passenger seat is unoccupied. Each telltale: ... ... (d) Shall be located within the interior of the vehicle and	Occupants may want to be notified of a disabled air bag. The ADS is notified of a disabled air bag but the

FMVSS No. 208, S19.2.2 Option 1—Automatic suppression feature			
Regulatory Text	**Translation Options**		**Potential Considerations**
		forward of and above the design H-point of both the driver's and front outboard passenger's seat in their forwardmost seating positions and shall not be located on or adjacent to a surface that can be used for temporary or permanent storage of objects that could obscure the telltale from either the driver's or any front outboard passenger's view, or located where the telltale would be obscured from the driver's view if a rear-facing child restraint listed in appendix A or A-1, as appropriate, is installed in any front outboard passenger's seat. (e) Shall be visible and recognizable to a driver and any front outboard passenger during night and day when the occupants have adapted to the ambient light roadway conditions. ... ... (g) Means shall be provided for making telltales visible and recognizable to the driver and any front outboard passenger under all driving conditions. The means for providing the required visibility may be adjustable manually or automatically, except that the telltales may not be adjustable under any driving conditions to a level that they become invisible or not recognizable to the driver and any front outboard passenger. (h) The telltale must not emit light except when any passenger air bag is turned off or during a bulb check upon vehicle starting.	action taken by the ADS is not provided.

FMVSS No. 208, S19.2.2 Option 1—Automatic suppression feature			
Regulatory Text	**Translation Options**		**Potential Considerations**
		(i) For ADS-equipped vehicles without manually operated driving controls, the telltales shall monitor their own readiness and shall communicate the underlying condition to the ADS.	

FMVSS No. 208, S19.2.3 Option 1—Automatic suppression feature			
Regulatory Text	**Translation Options**		**Potential Considerations**
The vehicle shall be equipped with a mechanism that indicates whether the air bag system is suppressed, regardless of whether the passenger seat is occupied. The mechanism need not be located in the occupant compartment unless it is the telltale described in S19.2.2.	**Option 1**	The vehicle shall be equipped with a mechanism that indicates whether the air bag system is suppressed, regardless of whether any front outboard passenger seat is occupied. The mechanism need not be located in the occupant compartment unless it is the telltale described in S19.2.2.	Removes reference to a passenger seat (the right front outboard seat in this section).
	Option 2	For vehicles equipped with manually operated driving controls, the vehicle shall be equipped with a mechanism that indicates whether the air bag system is suppressed, regardless of whether the passenger seat is occupied. The mechanism need not be located in the occupant compartment unless it is the telltale described in S19.2.2. For ADS-DVs, indicators shall monitor their own readiness and shall provide an input to the ADS indicating the underlying condition.	Applies to ADS-DVs in addition to conventional vehicles but does not specify what action is taken when the indicator is activated. Occupants may want to be made aware of the activation status of air bags.

FMVSS No. 208, S19.3 Option 2—Low risk deployment			
Regulatory Text	**Translation Options**		**Potential Considerations**
Each vehicle shall meet the injury criteria specified in S19.4 of this standard when the passenger air bag is deployed in accordance with the procedures specified in S20.4.	**Option 1**	Each vehicle shall meet the injury criteria specified in S19.4 of this standard when any front outboard passenger air bag is deployed in accordance with the procedures specified in S20.4.	Removes reference to a passenger seat (the right front outboard seat in this section).

FMVSS No. 208, S20.1.2 Test procedure for S19			
Regulatory Text	**Translation Options**		**Potential Considerations**
Unless otherwise specified, each vehicle certified to this option shall comply in tests conducted with the front outboard passenger seating position, if adjustable fore and aft, at full rearward, middle, and full forward positions. If the child restraint or dummy contacts the vehicle interior, move the seat rearward to the next detent that provides clearance, or if the seat is a power seat, using only the control that primarily moves the seat fore and aft, move the seat rearward while assuring that there is a maximum of 5 mm (0.2 in) clearance between the dummy or child restraint and the vehicle interior.	**Option 1**	Unless otherwise specified, each vehicle certified to this option shall comply in tests conducted with any front outboard passenger seating position, if adjustable…	Accounts for multiple front outboard passenger DSPs (for vehicles without a driver's DSP).
	Option 2	Unless otherwise specified, each vehicle certified to this option shall comply in tests conducted with a front outboard passenger seating position, if adjustable fore and aft, at full rearward, middle, and full forward positions…	Different language than Option 1 to avoid potential confusion with the word "any."

FMVSS No. 208, S20.2 Static tests of automatic suppression feature which shall result in deactivation of the passenger air bag			
Regulatory Text	**Translation Options**		**Potential Considerations**
S20.2 Static tests of automatic suppression feature which shall result in deactivation of the passenger air bag	**Option 1**	S20.2 Static tests of automatic suppression feature which shall result in deactivation of any front outboard passenger air bag	Accounts for multiple front outboard passenger DSPs (for vehicles without a driver's DSP).

FMVSS No. 208, S20.2.1.1 Static tests of automatic suppression feature which shall result in deactivation of the passenger air bag			
Regulatory Text	**Translation Options**		**Potential Considerations**
The vehicle shall comply in tests using any child restraint specified in section B and section C of appendix A or A-1 of this standard, as appropriate, installed in the front outboard passenger vehicle seat in the following orientations: (a) With the section B and section C child restraints facing rearward as appropriate; and (b) With the section C child restraints facing forward.	**Option 1**	The vehicle shall comply in tests using any child restraint specified in section B and section C of appendix A or A-1 of this standard, as appropriate, installed in any front outboard passenger vehicle seat in the following orientations:...	Accounts for multiple front outboard passenger DSPs (for vehicles without a driver's DSP).

FMVSS No. 208, S20.2.1.4 Static tests of automatic suppression feature which shall result in deactivation of the passenger air bag			
Regulatory Text	**Translation Options**		**Potential Considerations**
For bucket seats, “Plane B” refers to a vertical plane parallel to the vehicle longitudinal centerline through the longitudinal centerline of the front outboard passenger vehicle seat cushion. For bench seats, “Plane B” refers to a vertical plane through the front outboard passenger vehicle seat parallel to the vehicle longitudinal centerline the same distance from the longitudinal centerline of the vehicle as the center of the steering wheel.	**Option 1**	For bucket seats, “Plane B” refers to a vertical plane parallel to the vehicle longitudinal centerline through the longitudinal centerline of any front outboard passenger vehicle seat cushion. For bench seats in vehicles equipped with manually operated driving controls, “Plane B” refers to a vertical plane through any front outboard passenger seat parallel to the vehicle longitudinal centerline the same distance from the longitudinal centerline of the vehicle as the center of the steering wheel. For bench seats in vehicles not equipped with manually operated driving controls, “Plane B” refers to a vertical plane parallel to the vehicle longitudinal centerline, through any front outboard passenger seat’s SgRP.	Maintains current language for vehicles equipped with manually operated driving controls and adds language for vehicles with bench seats not equipped with manually operated driving controls.
	Option 2	...For bench seats, “Plane B” refers to a vertical plane through the front outboard passenger seat’s SgRP and parallel to the vehicle longitudinal centerline the same distance from the longitudinal centerline of the vehicle as the center of the steering wheel.	Removes references to driving controls, potentially simplifying the translation. This option changes the current language for conventional vehicles.
	Option 3	(a) For vehicles equipped with manually operated driving controls. For bucket seats, “Plane B” refers to a vertical plane parallel to	Uses SgRP for bench seats and bucket seats for

FMVSS No. 208, S20.2.1.4 Static tests of automatic suppression feature which shall result in deactivation of the passenger air bag			
Regulatory Text	**Translation Options**		**Potential Considerations**
		the vehicle longitudinal centerline through the longitudinal centerline of the front outboard passenger vehicle seat cushion. For bench seats, "Plane B" refers to a vertical plane through the front outboard passenger seat parallel to the vehicle longitudinal centerline the same distance from the longitudinal centerline of the vehicle as the center of the steering wheel. (b) For vehicles not equipped with manually operated driving controls. "Plane B" refers to a vertical plane parallel to the vehicle longitudinal centerline, through any front outboard passenger seat's SgRP.	vehicles without manually operated driving controls.
	Option 4	..."Plane B" refers to a vertical plane parallel to the vehicle longitudinal centerline, through any front outboard passenger vehicle seat's SgRP...	Removes references to driving controls, potentially simplifying the translation. This option would change the current language for conventional vehicles.

FMVSS No. 208, S20.2.2.3 Installation with vehicle safety belts			
Regulatory Text	**Translation Options**		**Potential Considerations**
For bucket seats, "Plane B" refers to a vertical plane parallel to the vehicle longitudinal centerline through the longitudinal centerline of the front outboard passenger vehicle seat cushion. For bench seats, "Plane B" refers to a vertical plane through the front outboard passenger seat parallel to the vehicle longitudinal centerline the same distance from the longitudinal centerline of the vehicle as the center of the steering wheel.	**Option 1**	For bucket seats, "Plane B" refers to a vertical plane parallel to the vehicle longitudinal centerline through the longitudinal centerline of any front outboard passenger vehicle seat cushion. For bench seats in vehicles equipped with manually operated driving controls, "Plane B" refers to a vertical plane through any front outboard passenger seat parallel to the vehicle longitudinal centerline the same distance from the longitudinal centerline of the vehicle as the center of the steering wheel. For bench seats in vehicles not equipped with manually operated driving controls, "Plane B" refers to the vertical plane parallel to the vehicle longitudinal centerline, through any front outboard passenger seat's SgRP.	Maintains current language for vehicles equipped with manually operated driving controls and adds language for vehicles with bench seats without manually operated driving controls.
	Option 2	...For bench seats, "Plane B" refers to a vertical plane through the front outboard passenger seat's SgRP and parallel to the vehicle longitudinal centerline.	Removes references to driving controls, simplifying the translation. This option changes the current language for conventional vehicles.
	Option 3	(a) For vehicles equipped with manually operated driving controls. For bucket seats, "Plane B" refers to a vertical plane parallel to the vehicle longitudinal centerline through the longitudinal centerline of the front outboard passenger vehicle seat cushion. For bench seats, "Plane B" refers to a vertical plane through the front outboard passenger seat parallel to the vehicle longitudinal centerline the same distance from the longitudinal centerline of the vehicle as the center of the steering wheel.	Uses SgRP for bench seats and bucket seats for vehicles not equipped with manually operated driving controls.

FMVSS No. 208, S20.2.2.3 Installation with vehicle safety belts			
Regulatory Text	**Translation Options**		**Potential Considerations**
		(b) For vehicles not equipped with manually operated driving controls. "Plane B" refers to a vertical plane parallel to the vehicle longitudinal centerline, through any front outboard passenger seat's SgRP.	
	Option 4	…For bench seats, "Plane B" refers to a vertical plane parallel to the vehicle longitudinal centerline, through any front outboard passenger vehicle seat's SgRP.	Removes references to driving controls, simplifying the translation. This option would change the current language for conventional vehicles.

FMVSS No. 208, S20.3 Installation with vehicle safety belts			
Regulatory Text	**Translation Options**		**Potential Considerations**
Static tests of automatic suppression feature which shall result in activation of the passenger air bag system	**Option 1**	Static tests of automatic suppression feature which shall result in activation of any front outboard passenger air bag system.	Accounts for the possibility of multiple front outboard passenger seats (i.e., no driver's seat present).

FMVSS No. 208, S20.3.1 Installation with vehicle safety belts			
Regulatory Text	**Translation Options**		**Potential Considerations**
Each vehicle certified to this option shall comply in tests conducted with the front outboard passenger seating position, if adjustable fore and aft, at the mid-height, in the full rearward and middle positions determined in S20.1.9.4, and the forward position determined in S16.3.3.1.8.	**Option 1**	Each vehicle certified to this option shall comply in tests conducted with any front outboard passenger seating position, if adjustable fore and aft, at the mid-height, in the full rearward and middle positions determined in S20.1.9.4, and the forward position determined in S16.3.3.1.8.	Accounts for the possibility of multiple front outboard passenger seats (i.e., no driver's seat present).

FMVSS No. 208, S20.3.2 Installation with vehicle safety belts			
Regulatory Text	**Translation Options**		**Potential Considerations**
Place a 49 CFR part 572 subpart O 5th percentile adult female test dummy at the front outboard passenger seating position of the vehicle, in accordance with procedures specified in S16.3.3 of this standard, except as specified in S20.3.1, subject to the fore-aft seat positions in S20.3.1. Do not fasten the seat belt.	**Option 1**	Place a 49 CFR part 572 subpart O 5th percentile adult female test dummy at any front outboard passenger seating position of the vehicle, in accordance with procedures specified in S16.3.3 of this standard, except as specified in S20.3.1, subject to the fore-aft seat positions in S20.3.1. Do not fasten the seat belt.	Accounts for the possibility of multiple front outboard passenger seats (i.e., no driver's seat present).

FMVSS No. 208, S20.4.1 Low risk deployment test			
Regulatory Text	**Translation Options**		**Potential Considerations**
Position the front outboard passenger vehicle seat at the mid-height in the full forward position determined in S20.1.9.4, and adjust the seat back (if adjustable independent of the seat) to the nominal design position for a 50th percentile adult male as specified in S8.1.3. Position adjustable lumbar supports so that the lumbar support is in its lowest, retracted or deflated adjustment position. Position any adjustable parts of the seat that provide additional support so that they are in the lowest or most open adjustment position. If adjustable, set the head restraint at the full down and most forward position. If the child restraint or dummy contacts the vehicle interior, do the following: using only the control that primarily moves the seat in the fore and aft direction, move the seat rearward to the next detent that provides clearance; or if the seat is a power seat, move the seat rearward while assuring that there is a maximum of 5 mm (0.2 in) clearance.	**Option 1**	Position any front outboard passenger vehicle seat at the mid-height in the full forward position determined in S20.1.9.4, and adjust the seat back (if adjustable independent of the seat) to the nominal design position for a 50th percentile adult male as specified in S8.1.3...	Accounts for the possibility of multiple front outboard passenger seats (i.e., no driver's seat present).

FMVSS No. 208, S20.4.4 Low risk deployment test			
Regulatory Text	**Translation Options**		**Potential Considerations**
For bucket seats, “Plane B” refers to a vertical plane parallel to the vehicle longitudinal centerline through the longitudinal centerline of the front outboard passenger seat cushion. For bench seats, “Plane B” refers to a vertical plane through the front outboard passenger seat parallel to the vehicle longitudinal centerline that is the same distance from the longitudinal centerline of the vehicle as the center of the steering wheel.	**Option 1**	For bucket seats, “Plane B” refers to a vertical plane parallel to the vehicle longitudinal centerline through the longitudinal centerline of any front outboard passenger vehicle seat cushion. For bench seats in vehicles equipped with manually operated driving controls, “Plane B” refers to a vertical plane through any front outboard passenger seat parallel to the vehicle longitudinal centerline the same distance from the longitudinal centerline of the vehicle as the center of the steering wheel. For bench seats in vehicles not equipped with manually operated driving controls, “Plane B” refers to the vertical plane parallel to the vehicle longitudinal centerline, through any front outboard passenger seat’s SgRP.	Maintains current language for current vehicles equipped with manually operated driving controls and adds language for vehicles with bench seats not equipped with manually operated driving controls.
	Option 2	...For bench seats, “Plane B” refers to a vertical plane through the front outboard passenger seat’s SgRP and parallel to the vehicle longitudinal centerline...	Removes references to driving controls, simplifying the translation. This option changes the current language for conventional vehicles.
	Option 3	(a) For vehicles equipped with manually operated driving controls. For bucket seats, “Plane B” refers to a vertical plane parallel to	Uses SgRP for bench seats and bucket seats for

FMVSS No. 208, S20.4.4 Low risk deployment test			
Regulatory Text	**Translation Options**		**Potential Considerations**
		the vehicle longitudinal centerline through the longitudinal centerline of the front outboard passenger vehicle seat cushion. For bench seats, “Plane B” refers to a vertical plane through the front outboard passenger seat parallel to the vehicle longitudinal centerline the same distance from the longitudinal centerline of the vehicle as the center of the steering wheel. (b) For vehicles not equipped with manually operated driving controls. "Plane B” refers to a vertical plane parallel to the vehicle longitudinal centerline, through any front outboard passenger seat’s SgRP.	vehicles without manually operated driving controls.
	Option 4	…“Plane B” refers to a vertical plane parallel to the vehicle longitudinal centerline, through any front outboard passenger vehicle seat’s SgRP.	Removes references to driving controls, simplifying the translation. This option would change the current language for conventional vehicles.

FMVSS No. 208, S20.4.9 Low risk deployment test			
Regulatory Text	**Translation Options**		**Potential Considerations**
Deploy the front outboard passenger frontal air bag system. If the air bag system contains a multistage inflator, the vehicle shall be able to comply at any stage or combination of stages or time delay between successive stages that could occur in the presence of an infant in a rear facing child restraint and a 49 CFR part 572, subpart R 12-month-old CRABI dummy positioned according to S20.4, and also with the seat at the mid-height, in the middle and full rearward positions determined in S20.1.9.4, in a rigid barrier crash test at speeds up to 64 km/h (40 mph).	**Option 1**	Deploy any front outboard passenger frontal air bag system...	Accounts for the possibility of multiple front outboard passenger seats (i.e., no driver's seat present). An additional section (S21.6) for ADS-equipped vehicles with steering controls could be necessary for suppressing the driver air bag or suspending the automatic driving function for a 3-year-old dummy in the driver DSP. The driver air bag could be suppressed by the same method the passenger side air bag is suppressed. Vehicles could alternatively/additionally have a label on the controls stating "Never allow a child smaller than X to ride in this seat, with or without a child restraint device." This could possibly be paired with ADS suppression.

FMVSS No. 208, S21.2.1 Option 1—Automatic suppression feature			
Regulatory Text	**Translation Options**		**Potential Considerations**
The vehicle shall be equipped with an automatic suppression feature for the passenger air bag which results in deactivation of the air bag during each of the static tests specified in S22.2 (using the 49 CFR part 572 subpart P 3-year-old child dummy and, as applicable, any child restraint specified in section C and section D of appendix A or A-1 of this standard, as appropriate), and activation of the air bag system during each of the static tests specified in S22.3 (using the 49 CFR part 572 subpart O 5th percentile adult female dummy).	**Option 1**	The vehicle shall be equipped with an automatic suppression feature for any front outboard passenger air bag which results in deactivation of the air bag during each of the static tests specified in S22.2…	Accounts for the possibility of multiple front outboard passenger seats (i.e., no driver's seat present). ADS-equipped vehicles with steering controls may require an additional section (S21.6) for suppressing the driver air bag or suspending the automatic driving function for a 3-year-old dummy in the driver DSP. The driver airbag could be suppressed by the same method the passenger side air bag is suppressed. Vehicles could alternatively/additionally have a label on the controls stating "Never allow a child smaller than X to ride in this seat, with or without a child restraint device." This could possibly be paired with ADS suppression. In ADS-equipped vehicles that have a driver's DSP, there may be an instance where a human driver may not be required. In this instance, a child restraint system or child could be in the driver's DSP, presenting additional potential for injury.

FMVSS No. 208, S21.2.3 Option 1—Automatic suppression feature			
Regulatory Text	**Translation Options**		**Potential Considerations**
The vehicle shall be equipped with a mechanism that indicates whether the air bag is suppressed, regardless of whether the passenger seat is occupied. The mechanism need not be located in the occupant compartment unless it is the telltale described in S21.2.2.	**Option 1**	The vehicle shall be equipped with a mechanism that indicates whether any front outboard air bag is suppressed, regardless of whether the passenger seat is occupied…	Accounts for the possibility of multiple front outboard passenger seats (i.e., no driver's seat present).

FMVSS No. 208, S21.3 Option 2—Dynamic automatic suppression system that suppresses the air bag when an occupant is out of position			
Regulatory Text	**Translation Options**		**Potential Considerations**
(This option is available under the conditions set forth in S27.1.) The vehicle shall be equipped with a dynamic automatic suppression system for the passenger air bag system which meets the requirements specified in S27.	**Option 1**	The vehicle shall be equipped with a dynamic automatic suppression system for any front outboard passenger air bag system which meets the requirements specified in S27.	Accounts for the possibility of multiple front outboard passenger seats (i.e., no driver's seat present).

FMVSS No. 208, S21.4 Option 3—Low risk deployment			
Regulatory Text	**Translation Options**		**Potential Considerations**
Each vehicle shall meet the injury criteria specified in S21.5 of this standard when the passenger air bag is deployed in accordance with both of the low risk deployment test procedures specified in S22.4.	**Option 1**	Each vehicle shall meet the injury criteria specified in S21.5 of this standard when any front outboard passenger air bag is deployed in accordance with both of the low risk deployment test procedures specified in S22.4.	Accounts for the possibility of multiple front outboard passenger seats (i.e., no driver's seat present).

FMVSS No. 208, S22.1.2 Test procedure for S21			
Regulatory Text	**Translation Options**		**Potential Considerations**
Unless otherwise specified, each vehicle certified to this option shall comply in tests conducted with the front outboard passenger seating position at the mid-height, in the full rearward, middle, and the full forward positions determined in S22.1.7.4. If the dummy contacts the vehicle interior, using only the control that primarily moves the seat fore and aft, move the seat rearward to the next detent that provides clearance. If the seat is a power seat, move the seat rearward while assuring that there is a maximum of 5 mm (0.2 in) clearance.	**Option 1**	Unless otherwise specified, each vehicle certified to this option shall comply in tests conducted with any front outboard passenger seating position at the mid-height, in the full rearward, middle, and the full forward positions determined in S22.1.7.4…	Accounts for the possibility of multiple front outboard passenger seats (i.e., no driver's seat present).
	Option 2	Retain current language.	

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<tr><th colspan="4">FMVSS No. 208, S22.1.3</th></tr>
<tr><th>Regulatory Text</th><th colspan="2">Translation Options</th><th>Potential Considerations</th></tr>
<tr><td rowspan="2">Except as otherwise specified, if the child restraint has an anchorage system as specified in S5.9 of FMVSS No. 213 and is tested in a vehicle with a front outboard passenger vehicle seat that has an anchorage system as specified in FMVSS No. 225, the vehicle shall comply with the belted test conditions with the restraint anchorage system attached to the vehicle seat anchorage system and the vehicle seat belt unattached. It shall also comply with the belted test conditions with the restraint anchorage system unattached to the vehicle seat anchorage system and the vehicle seat belt attached.</td><td>Option 1</td><td>Except as otherwise specified, if the child restraint has an anchorage system as specified in S5.9 of FMVSS No. 213 and is tested in a vehicle with any front outboard passenger vehicle seat that has an anchorage system as specified in FMVSS No. 225, the vehicle shall comply with the belted test conditions with the restraint anchorage system attached to the vehicle seat anchorage system and the vehicle seat belt unattached...</td><td>Accounts for the possibility of multiple front outboard passenger seats (i.e., no driver's seat present).</td></tr>
<tr><td>Option 2</td><td>Retain current language.</td><td></td></tr>
</table>

FMVSS No. 208, S22.2 Static tests of automatic suppression feature which shall result in deactivation of the passenger air bag			
Regulatory Text	**Translation Options**		**Potential Considerations**
S22.2 Static tests of automatic suppression feature which shall result in deactivation of the passenger air bag	**Option 1**	S22.2 Static tests of automatic suppression feature which shall result in deactivation of any front outboard passenger air bag	Accounts for the possibility of multiple front outboard passenger seats (i.e., no driver's seat present).

FMVSS No. 208, S22.2.1.1 Static tests of automatic suppression feature which shall result in deactivation of the passenger air bag			
Regulatory Text	**Translation Options**		**Potential Considerations**
Install the restraint in the front outboard passenger vehicle seat in accordance, to the extent possible, with the child restraint manufacturer's instructions provided with the seat for use by children with the same height and weight as the 3-year-old child dummy.	**Option 1**	Install the restraint in any front outboard passenger vehicle seat in accordance, to the extent possible, with the child restraint manufacturer's instructions provided with the seat for use by children with the same height and weight as the 3-year-old child dummy.	Accounts for the possibility of multiple front outboard passenger seats (i.e., no driver's seat present).
	Option 2	Retain current language.	

FMVSS No. 208, S22.2.1.3 Static tests of automatic suppression feature which shall result in deactivation of the passenger air bag			
Regulatory Text	**Translation Options**		**Potential Considerations**
For bucket seats, "Plane B" refers to a vertical longitudinal plane through the longitudinal centerline of the seat cushion of the front outboard passenger vehicle seat. For bench seats, "Plane B" refers to a vertical plane through the front outboard passenger vehicle seat parallel to the vehicle longitudinal centerline the same distance from the longitudinal centerline of the vehicle as the center of the steering wheel.	**Option 1**	For bucket seats, "Plane B" refers to a vertical plane parallel to the vehicle longitudinal centerline through the longitudinal centerline of any front outboard passenger vehicle seat cushion. For bench seats in vehicles equipped with manually operated driving controls, "Plane B" refers to a vertical plane through any front outboard passenger seat parallel to the vehicle longitudinal centerline the same distance from the longitudinal centerline of the vehicle as the center of the steering wheel/control. For bench seats in vehicles not equipped with manually operated driving controls, "Plane B" refers to the vertical plane parallel to the vehicle longitudinal centerline, through any front outboard passenger seat's SgRP.	Maintains current language for current vehicles equipped with manually operated driving controls and adds language for vehicles with bench seats not equipped with manually operated driving controls.
	Option 2	...For bench seats, "Plane B" refers to a vertical plane through the front outboard passenger seat's SgRP and parallel to the vehicle longitudinal centerline.	Removes references to driving controls, simplifying the translation. This option would change the current language for conventional vehicles.
	Option 3	(a) For vehicles equipped with manually operated driving controls. For bucket seats, "Plane B" refers to a vertical longitudinal plane parallel to the vehicle longitudinal centerline through the longitudinal centerline of the front outboard passenger vehicle seat cushion. For bench seats, "Plane B" refers to a vertical plane through the front outboard passenger seat parallel to the vehicle longitudinal centerline the same	Uses SgRP for bench seats and bucket seats for vehicles without manually operated driving controls.

		distance from the longitudinal centerline of the vehicle as the center of the steering wheel. (b) For vehicles not equipped with manually operated driving controls. "Plane B" refers to a vertical longitudinal plane parallel to the vehicle longitudinal centerline, through any front outboard passenger seat's SgRP.	
	Option 4	"Plane B" refers to a vertical plane parallel to the vehicle longitudinal centerline, through any front outboard passenger vehicle seat's SgRP.	Removes references to driving controls, simplifying the translation. This option would change the current language for conventional vehicles.

FMVSS No. 208, S22.2.2 Unbelted tests with dummies			
Regulatory Text	**Translation Options**		**Potential Considerations**
Place the 49 CFR part 572 subpart P 3-year-old child dummy on the front outboard passenger vehicle seat in any of the following positions (without using a child restraint or booster seat or the vehicle's seat belts):	**Option 1**	Place the 49 CFR part 572 subpart P 3-year-old child dummy on any front outboard passenger vehicle seat in any of the following positions (without using a child restraint or booster seat or the vehicle's seat belts):	

<table>
<tr><th colspan="4">FMVSS No. 208, S22.2.2.1 Sitting on seat with back against seat back</th></tr>
<tr><th>Regulatory Text</th><th colspan="2">Translation Options</th><th>Potential Considerations</th></tr>
<tr><td rowspan="2">(a) Place the dummy on the front outboard passenger seat.

(b) In the case of vehicles equipped with bench seats, position the midsagittal plane of the dummy vertically and parallel to the vehicle's longitudinal centerline and the same distance from the vehicle's longitudinal centerline, within ±10 mm (±0.4 in), as the center of the steering wheel. In the case of vehicles equipped with bucket seats, position the midsagittal plane of the dummy vertically such that it coincides with the longitudinal centerline of the seat cushion, within ±10 mm (±0.4 in). Position the torso of the dummy against the seat back. Position the dummy's thighs against the seat cushion.

(c) Allow the legs of the dummy to extend off the surface of the seat.

(d) Rotate the dummy's upper arms down until they contact the seat back.

(e) Rotate the dummy's lower arms until the dummy's hands contact the seat cushion.

(f) Start the vehicle engine or place the ignition in the “on” position, whichever will turn on the</td><td>Option 1</td><td>(a) Place the dummy on any front outboard passenger seat.

(b) In the case of vehicles equipped with bench seats and equipped with manually operated driving controls, position the midsagittal plane of the dummy vertically and parallel to the vehicle's longitudinal centerline and the same distance from the vehicle's longitudinal centerline, within ±10 mm (±0.4 in), as the center of the steering control. For bench seats in vehicles without manually operated driving controls, position the midsagittal plane of any front outboard dummy vertically and parallel to the vehicle’s longitudinal centerline, within ±10 mm (±0.4 in) of the seating reference point of the seat that it occupies. In the case of vehicles equipped with bucket seats, position the midsagittal plane of any front outboard dummy vertically such that it coincides with the longitudinal centerline of the seat cushion, within ±10 mm (±0.4 in). Position the torso of the dummy against the seat back. Position the dummy's thighs against the seat cushion...</td><td>Bench seats in vehicles equipped with and without manually operated driving controls are considered.</td></tr>
<tr><td>Option 2</td><td>(a) Place the dummy on any front outboard passenger seat.</td><td>May choose to use the more encompassing</td></tr>
</table>

suppression system, and then close all vehicle doors. (g) Wait 10 seconds, then check whether the air bag is deactivated.		(b) In the case of vehicles equipped with bench seats, position the midsagittal plane of the dummy vertically and parallel to the vehicle's longitudinal centerline and the same distance from the vehicle's longitudinal centerline, within ±10 mm (±0.4 in), as the center of the steering control. For bench seats in vehicles without manually operated driving controls, position the midsagittal plane of any front outboard dummy vertically and parallel to the vehicle's longitudinal centerline, within ±10 mm (±0.4 in) of the head restraint of the seat that it occupies. In the case of vehicles equipped with bucket seats, position the midsagittal plane of the dummy vertically such that it coincides with the longitudinal centerline of the seat cushion, within ±10 mm (±0.4 in). Position the torso of the dummy against the seat back. Position the dummy's thighs against the seat cushion...	term "control" rather than "wheel." Bench seats in vehicles equipped with and without manually operated driving controls are considered.

FMVSS No. 208, S22.2.2.3 Sitting on seat with back not against seat back			
Regulatory Text	**Translation Options**		**Potential Considerations**
(a) Place the dummy on the front outboard passenger seat. (b) In the case of vehicles equipped with bench seats, position the midsagittal plane of the dummy vertically and parallel to the vehicle's longitudinal centerline and the same distance from the vehicle's longitudinal centerline, within ±10 mm (±0.4 in), as the center of the steering wheel. In the case of vehicles equipped with bucket seats, position the midsagittal plane of the dummy vertically such that it coincides with the longitudinal centerline of the seat cushion, within ±10 mm (±0.4 in). Position the dummy with the spine vertical so that the horizontal distance from the dummy's back to the seat back is no less than 25 mm (1.0 in) and no more than 150 mm (6.0 in), as measured along the dummy's midsagittal plane at the mid-sternum level. To keep the dummy in position, a material with a maximum breaking strength of 311 N (70 lb.) may be used to hold	**Option 1**	(a) Place the dummy on any front outboard passenger seat... (b) In the case of vehicles equipped with bench seats and manually operated driving controls, position the midsagittal plane of the dummy vertically and parallel to the vehicle's longitudinal centerline and the same distance from the vehicle's longitudinal centerline, within ±10 mm (±0.4 in), as the center of the steering control. For bench seats in vehicles without manually operated driving controls, position the midsagittal plane of any front outboard dummy vertically and parallel to the vehicle's longitudinal centerline, within ±10 mm (±0.4 in) of the seating reference point of the seat that it occupies. In the case of vehicles equipped with bucket seats, position the midsagittal plane of any front outboard dummy vertically such that it coincides with the longitudinal centerline of the seat cushion, within ±10 mm (±0.4 in). Position the dummy with the spine vertical...	Accounts for the possibility of multiple front outboard passenger seats (i.e., no driver's seat present). Bench seats in vehicles equipped with and without manually operated driving controls are considered.

FMVSS No. 208, S22.2.2.3 Sitting on seat with back not against seat back			
Regulatory Text	**Translation Options**		**Potential Considerations**
the dummy. (c) Position the dummy's thighs against the seat cushion. (d) Allow the legs of the dummy to extend off the surface of the seat. (e) Position the upper arms parallel to the spine and rotate the dummy's lower arms until the dummy's hands contact the seat cushion. (f) Start the vehicle engine or place the ignition in the "on" position, whichever will turn on the suppression system, and then close all vehicle doors. (g) Wait 10 seconds, then check whether the air bag is deactivated.	**Option 2**	(a) Place the dummy on any front outboard passenger seat. (b) In the case of vehicles equipped with bench seats and manually operated driving controls, position the midsagittal plane of the dummy vertically and parallel to the vehicle's longitudinal centerline and the same distance from the vehicle's longitudinal centerline, within ±10 mm (±0.4 in), as the center of the steering control. For bench seats in vehicles without manually operated driving controls, position the midsagittal plane of any front outboard dummy vertically and parallel to the vehicle's longitudinal centerline, within ±10 mm (±0.4 in) of the head restraint of the seat that it occupies. In the case of vehicles equipped with bucket seats, position the midsagittal plane of any front outboard dummy vertically such that it coincides with the longitudinal centerline of the seat cushion, within ±10 mm (±0.4 in). Position the dummy with the spine vertical…	May choose to use the more encompassing term "control" rather than "wheel." Bench seats in vehicles equipped with and without manually operated driving controls are considered.

FMVSS No. 208, S22.2.2.4 Sitting on seat edge, spine vertical, hands by the dummy's sides			
Regulatory Text	**Translation Options**		**Potential Considerations**
(a) In the case of vehicles equipped with bench seats, position the midsagittal plane of the dummy vertically and parallel to the vehicle's longitudinal centerline and the same distance from the vehicle's longitudinal centerline, within ±10 mm (±0.4 in), as the center of the steering wheel. In the case of vehicles equipped with bucket seats, position the midsagittal plane of the dummy vertically such that it coincides with the longitudinal centerline of the seat cushion, within ±10 mm (±0.4 in). (b) Position the dummy in the seated position forward in the seat such that the legs are vertical and the back of the legs rest against the front of the seat with the spine vertical. If the dummy's feet contact the floor pan, rotate the legs forward until the dummy is resting on the seat with the feet positioned flat on the floor pan and the dummy spine vertical. To keep the dummy in position, a material with a maximum breaking strength of 311 N (70 lb.) may be used to hold the dummy. (c) Place the upper arms parallel to the spine.	**Option 1**	(a) In the case of vehicles equipped with bench seats and manually operated driving controls, position the midsagittal plane of the dummy vertically and parallel to the vehicle's longitudinal centerline and the same distance from the vehicle's longitudinal centerline, within ±10 mm (±0.4 in), as the center of the steering wheel. For bench seats in vehicles without manually operated driving controls, position the midsagittal plane of any front outboard dummy vertically and parallel to the vehicle's longitudinal centerline, within ±10 mm (±0.4 in) of the seating reference point of the seat that it occupies. In the case of vehicles equipped with bucket seats, position the midsagittal plane of the dummy vertically such that it coincides with the longitudinal centerline of the seat cushion, within ±10 mm (±0.4 in).	Bench seats in vehicles equipped with and without manually operated driving controls are considered.

FMVSS No. 208, S22.2.2.4 Sitting on seat edge, spine vertical, hands by the dummy's sides			
Regulatory Text	**Translation Options**		**Potential Considerations**
(d) Lower the dummy's lower arms such that they contact the seat cushion. (e) Start the vehicle engine or place the ignition in the "on" position, whichever will turn on the suppression system, and then close all vehicle doors. (f) Wait 10 seconds, then check whether the air bag is deactivated.			
	Option 2	(a) In the case of vehicles equipped with bench seats, position the midsagittal plane of the dummy vertically and parallel to the vehicle's longitudinal centerline and the same distance from the vehicle's longitudinal centerline, within ±10 mm (±0.4 in), as the center of the steering control. For bench seats in vehicles without manually operated driving controls, position the midsagittal plane of any front outboard dummy vertically and parallel to the vehicle's longitudinal centerline, within ±10 mm (±0.4 in) of the head restraint of the seat that it occupies. In the case of vehicles equipped with bucket seats, position the midsagittal plane of the dummy vertically such that it coincides with the longitudinal centerline of the seat cushion, within ±10 mm (±0.4 in)...	May choose to use the more encompassing term "control" rather than "wheel." Bench seats in vehicles equipped with and without manually operated driving controls are considered.

FMVSS No. 208, S22.2.2.5 Standing on seat, facing forward			
Regulatory Text	**Translation Options**		**Potential Considerations**
(a) In the case of vehicles equipped with bench seats, position the midsagittal plane of the dummy vertically and parallel to the vehicle's longitudinal centerline and the same distance from the vehicle's longitudinal centerline, within ±10 mm (±0.4 in), as the center of the steering wheel rim. In the case of vehicles equipped with bucket seats, position the midsagittal plane of the dummy vertically such that it coincides with the longitudinal centerline of the seat cushion, within ±10 mm (±0.4 in). Position the dummy in a standing position on the front outboard passenger seat cushion facing the front of the vehicle while placing the heels of the dummy's feet in contact with the seat back. (b) Rest the dummy against the seat back, with the arms parallel to the spine. (c) If the head contacts the vehicle roof, recline the seat so that the head is no longer in contact with the vehicle roof, but allow no more than 5 mm (0.2 in) distance between the head and the roof. If the seat does not sufficiently recline to allow clearance, omit the test.	**Option 1**	(a) In the case of vehicles equipped with bench seats and manually operated driving controls, position the midsagittal plane of the dummy vertically and parallel to the vehicle's longitudinal centerline and the same distance from the vehicle's longitudinal centerline, within ±10 mm (±0.4 in), as the center of the steering wheel rim. For bench seats in vehicles without manually operated driving controls, position the midsagittal plane of any front outboard dummy vertically and parallel to the vehicle's longitudinal centerline, within ±10 mm (±0.4 in) of the seating reference point of the seat that it occupies. In the case of vehicles equipped with bucket seats, position the midsagittal plane of the dummy vertically such that it coincides with the longitudinal centerline of the seat cushion, within ±10 mm (±0.4 in). Position the dummy in a standing position on any front outboard passenger seat cushion facing the front of the vehicle while placing the heels of the dummy's feet in contact with the seat back...	Accounts for the possibility of multiple front outboard passenger seats (i.e., no driver's seat present). Bench seats in vehicles equipped with and without manually operated driving controls are considered.
	Option 2	(a) In the case of vehicles equipped with bench seats and manually operated driving controls, position the midsagittal plane of	May choose to use the more encompassing term

(d) If necessary use a material with a maximum breaking strength of 311 N (70 lb.) or spacer blocks to keep the dummy in position. (e) Start the vehicle engine or place the ignition in the "on" position, whichever will turn on the suppression system, and then close all vehicle doors. (f) Wait 10 seconds, then check whether the air bag is deactivated.		the dummy vertically and parallel to the vehicle's longitudinal centerline and the same distance from the vehicle's longitudinal centerline, within ±10 mm (±0.4 in), as the center of the steering control rim. For bench seats in vehicles without manually operated driving controls, position the midsagittal plane of any front outboard dummy vertically and parallel to the vehicle's longitudinal centerline, within ±10 mm (±0.4 in) of the head restraint of the seat that it occupies. In the case of vehicles equipped with bucket seats, position the midsagittal plane of the dummy vertically such that it coincides with the longitudinal centerline of the seat cushion, within ±10 mm (±0.4 in). Position the dummy in a standing position on any front outboard passenger seat cushion facing the front of the vehicle while placing the heels of the dummy's feet in contact with the seat back...	"control" rather than "wheel." Bench seats in vehicles equipped with and without manually operated driving controls are considered.

FMVSS No. 208, S22.2.2.6 Kneeling on seat, facing forward			
Regulatory Text	**Translation Options**		**Potential Considerations**
(a) In the case of vehicles equipped with bench seats, position the midsagittal plane of the dummy vertically and parallel to the vehicle's longitudinal centerline and the same distance from the vehicle's longitudinal centerline, within ±10 mm (±0.4 in), as the center of the steering wheel. In the case of vehicles equipped with bucket seats, position the midsagittal plane of the dummy vertically such that it coincides with the longitudinal centerline of the seat cushion, within ±10 mm (±0.4 in). (b) Position the dummy in a kneeling position in the front outboard passenger vehicle seat with the dummy facing the front of the vehicle with its toes at the intersection of the seat back and seat cushion. Position the dummy so that the spine is vertical. Push	**Option 1**	(a) In the case of vehicles equipped with bench seats and manually operated driving controls, position the midsagittal plane of the dummy vertically and parallel to the vehicle's longitudinal centerline and the same distance from the vehicle's longitudinal centerline, within ±10 mm (±0.4 in), as the center of the steering wheel. For bench seats in vehicles without manually operated driving controls, position the midsagittal plane of any front outboard dummy vertically and parallel to the vehicle's longitudinal centerline, within ±10 mm (±0.4 in) of the seating reference point of the seat that it occupies. In the case of vehicles equipped with bucket seats, position the midsagittal plane of the dummy vertically such that it coincides with the longitudinal centerline of the seat cushion, within ±10 mm (±0.4 in). (b) Position the dummy in a kneeling position in any front outboard passenger vehicle seat with the dummy facing the front of the vehicle with its toes at the intersection of the seat back and seat cushion. Position the dummy so that the spine is vertical. Push down on the legs so that they contact the seat as much as possible and then release. Place the arms parallel to the spine...	Accounts for the possibility of multiple front outboard passenger seats (i.e., no driver's seat present). Bench seats in vehicles equipped with and without manually operated driving controls are considered.
	Option 2	(a) In the case of vehicles equipped with bench seats and manually operated driving controls, position the midsagittal plane of the dummy vertically and parallel to the vehicle's	May choose to use the more encompassing

FMVSS No. 208, S22.2.2.6 Kneeling on seat, facing forward			
Regulatory Text	**Translation Options**		**Potential Considerations**
down on the legs so that they contact the seat as much as possible and then release. Place the arms parallel to the spine. (c) If necessary use a material with a maximum breaking strength of 311 N (70 lb.) or spacer blocks to keep the dummy in position. (d) Start the vehicle engine or place the ignition in the "on" position, whichever will turn on the suppression system, and then close all vehicle doors. (e) Wait 10 seconds, then check whether the air bag is deactivated.		longitudinal centerline and the same distance from the vehicle's longitudinal centerline, within ±10 mm (±0.4 in), as the center of the steering control. For bench seats in vehicles without manually operated driving controls, position the midsagittal plane of any front outboard dummy vertically and parallel to the vehicle's longitudinal centerline, within ±10 mm (±0.4 in) of the head restraint of the seat that it occupies. In the case of vehicles equipped with bucket seats, position the midsagittal plane of the dummy vertically such that it coincides with the longitudinal centerline of the seat cushion, within ±10 mm (±0.4 in). (b) Position the dummy in a kneeling position in any front outboard passenger vehicle seat with the dummy facing the front of the vehicle with its toes at the intersection of the seat back and seat cushion. Position the dummy so that the spine is vertical. Push down on the legs so that they contact the seat as much as possible and then release. Place the arms parallel to the spine...	term "control" rather than "wheel." Bench seats in vehicles equipped with and without manually operated driving controls are considered.

FMVSS No. 208, S22.2.2.7 Kneeling on seat, facing rearward			
Regulatory Text	**Translation Options**		**Potential Considerations**
(a) In the case of vehicles equipped with bench seats, position the midsagittal plane of the dummy vertically and parallel to the vehicle's longitudinal centerline and the same distance from the vehicle's longitudinal centerline, within ±10 mm (±0.4 in), as the center of the steering wheel. In the case of vehicles equipped with bucket seats, position the midsagittal plane of the dummy vertically such that it coincides with the longitudinal centerline of the seat cushion, within ±10 mm (±0.4 in). (b) Position the dummy in a kneeling position in the front outboard passenger vehicle seat with the dummy facing the rear of the vehicle. Position the dummy such that the dummy's head and torso are in contact with the seat back. Push down on the legs so that they contact the seat as much as possible and then release. Place the arms parallel to the spine. (c) Start the vehicle engine or place the ignition in the "on" position, whichever will turn on the suppression system, and then close all vehicle doors. (d) Wait 10 seconds, then check whether the air bag is deactivated.	**Option 1**	(a) In the case of vehicles equipped with bench seats and manually operated driving controls, position the midsagittal plane of the dummy vertically and parallel to the vehicle's longitudinal centerline and the same distance from the vehicle's longitudinal centerline, within ±10 mm (±0.4 in), as the center of the steering wheel. For bench seats in vehicles without manually operated driving controls, position the midsagittal plane of any front outboard dummy vertically and parallel to the vehicle's longitudinal centerline, within ±10 mm (±0.4 in) of the seating reference point of the seat that it occupies. In the case of vehicles equipped with bucket seats, position the midsagittal plane of the dummy vertically such that it coincides with the longitudinal centerline of the seat cushion, within ±10 mm (±0.4 in). (b) Position the dummy in a kneeling position in any front outboard passenger vehicle seat with the dummy facing the rear of the vehicle. Position the dummy such that the dummy's head and torso are in contact with the seat back. Push down on the legs so that they contact the seat as much as	Accounts for the possibility of multiple front outboard passenger seats (i.e., no driver's seat present). Bench seats in vehicles equipped with and without manually operated driving controls are considered.

FMVSS No. 208, S22.2.2.7 Kneeling on seat, facing rearward			
Regulatory Text	**Translation Options**		**Potential Considerations**
		possible and then release. Place the arms parallel to the spine...	
	Option 2	(a) In the case of vehicles equipped with bench seats and manually operated driving controls, position the midsagittal plane of the dummy vertically and parallel to the vehicle's longitudinal centerline and the same distance from the vehicle's longitudinal centerline, within ±10 mm (±0.4 in), as the center of the steering control. For bench seats in vehicles without manually operated driving controls, position the midsagittal plane of any front outboard dummy vertically and parallel to the vehicle's longitudinal centerline, within ±10 mm (±0.4 in) of the head restraint of the seat that it occupies. In the case of vehicles equipped with bucket seats, position the midsagittal plane of the dummy vertically such that it coincides with the longitudinal centerline of the seat cushion, within ±10 mm (±0.4 in). (b) Position the dummy in a kneeling position in any front outboard passenger vehicle seat with the dummy facing the rear of the vehicle. Position the dummy such that the dummy's head and torso are in contact	May choose to use the more encompassing term "control" rather than "wheel." Bench seats in vehicles equipped with and without manually operated driving controls are considered.

FMVSS No. 208, S22.2.2.7 Kneeling on seat, facing rearward			
Regulatory Text	**Translation Options**		**Potential Considerations**
		with the seat back. Push down on the legs so that they contact the seat as much as possible and then release. Place the arms parallel to the spine...	

FMVSS No. 208, S22.2.2.8 Lying on seat			
Regulatory Text	**Translation Options**		**Potential Considerations**
This test is performed only in vehicles with 3 designated front seating positions. (a) Lay the dummy on the front outboard passenger vehicle seat such that the following criteria are met: (1) The midsagittal plane of the dummy is horizontal, (2) The dummy's spine is perpendicular to the vehicle's longitudinal axis, (3) The dummy's arms are parallel to its spine, (4) A plane passing through the two shoulder joints of the dummy is vertical, (5) The anterior of the dummy is facing the vehicle front, (6) The head of the dummy is positioned towards the passenger door, and (7) The horizontal distance from the topmost point of the dummy's head to the vehicle door is 50 to 100 mm (2-4 in). (8) The dummy is as far back in the seat as possible. (b) Rotate the thighs as much as possible toward the chest of the dummy and rotate the legs as much as possible against the thighs. (c) Move the dummy's upper left arm parallel to the vehicle's transverse plane and the lower left arm 90 degrees to the upper arm. Rotate the lower left arm about the elbow joint and toward the dummy's head until movement is obstructed. (d) Start the vehicle engine or place the ignition in the "on" position, whichever will turn on the suppression system, and then close all vehicle doors. (e) Wait 10 seconds, then check whether the air bag is deactivated.	**Option 1**	(a) Lay the dummy on any front outboard passenger vehicle seat such that the following criteria are met: (1) The midsagittal plane of the dummy is horizontal, (2) The dummy's spine is perpendicular to the vehicle's longitudinal axis, (3) The dummy's arms are parallel to its spine, (4) A plane passing through the two shoulder joints of the dummy is vertical, (5) The anterior of the dummy is facing the vehicle front, (6) The head of the dummy is positioned towards the nearest passenger door, and (7) The horizontal distance from the topmost point of the dummy's head to the vehicle door is 50 to 100 mm (2-4 in). (8) The dummy is as far back in the seat as possible...	Accounts for the possibility of multiple front outboard passenger seats (i.e., no driver's seat present).

FMVSS No. 208, S22.3			
Regulatory Text	**Translation Options**		**Potential Considerations**
Static tests of automatic suppression feature which shall result in activation of the passenger air bag system	**Option 1**	Static tests of automatic suppression feature which shall result in activation of any front outboard passenger air bag system	Accounts for the possibility of multiple front outboard passenger seats (i.e., no driver's seat present).

FMVSS No. 208, S22.3.1			
Regulatory Text	**Translation Options**		**Potential Considerations**
Each vehicle certified to this option shall comply in tests conducted with the front outboard passenger seating position at the mid-height, in the full rearward, and middle positions determined in S22.1.7.4, and the forward position determined in S16.3.3.1.8.	**Option 1**	Each vehicle certified to this option shall comply in tests conducted with any front outboard passenger seating position at the mid-height, in the full rearward, and middle positions determined in S22.1.7.4, and the forward position determined in S16.3.3.1.8.	Accounts for the possibility of multiple front outboard passenger seats (i.e., no driver's seat present).

FMVSS No. 208, S22.3.2			
Regulatory Text	**Translation Options**		**Potential Considerations**
Place a 49 CFR part 572 subpart O 5th percentile adult female test dummy at the front outboard passenger seating position of the vehicle, in accordance with procedures specified in S16.3.3 of this standard, except as specified in S22.3.1. Do not fasten the seat belt.	**Option 1**	Place a 49 CFR part 572 subpart O 5th percentile adult female test dummy at any front outboard passenger seating position of the vehicle, in accordance with procedures specified in S16.3.3 of this standard, except as specified in S22.3.1. Do not fasten the seat belt.	Accounts for the possibility of multiple front outboard passenger seats (i.e., no driver's seat present).

FMVSS No. 208, S22.4.2.2 Low risk deployment tests			
Regulatory Text	**Translation Options**		**Potential Considerations**
Place the dummy in the front outboard passenger seat such that:	**Option 1**	Place the dummy in any front outboard passenger seat such that:	Accounts for the possibility of multiple front outboard passenger seats (no driver's seat).
	Option 2	Retain current language.	

FMVSS No. 208, S22.4.3.1 Position 2 (head on instrument panel)			
Regulatory Text	**Translation Options**		**Potential Considerations**
Place the front outboard passenger seat at the mid-height, in full rearward seating position determined in S22.1.7.4. Place the seat back, if adjustable independent of the seat, at the manufacturer's nominal design seat back angle for a 50th percentile adult male as specified in S8.1.3. Position any adjustable parts of the seat that provide additional support so that they are in the lowest or most open adjustment position. If adjustable, set the head restraint in the lowest and most forward position.	**Option 1**	Place any front outboard passenger seat at the mid-height, in full rearward seating position determined in S22.1.7.4…	Accounts for the possibility of multiple front outboard passenger seats (i.e., no driver's seat present).
	Option 2	Retain current language.	

FMVSS No. 208, S22.4.3.2 Position 2 (head on instrument panel)			
Regulatory Text	**Translation Options**		**Potential Considerations**
Place the dummy in the front outboard passenger seat such that:	**Option 1**	Place the dummy in any front outboard passenger seat such that:	Accounts for the possibility of multiple front outboard passenger seats (i.e., no driver's seat present).
	Option 2	Retain current language.	

FMVSS No. 208, S22.4.4 Position 2 (head on instrument panel)			
Regulatory Text	**Translation Options**		**Potential Considerations**
Deploy the front outboard passenger frontal air bag system. If the frontal air bag system contains a multistage inflator, the vehicle shall be able to comply with the injury criteria at any stage or combination of stages or time delay between successive stages that could occur in a rigid barrier crash test at or below 26 km/h (16 mph), under the test procedure specified in S22.5.	**Option 1**	Deploy any front outboard passenger frontal air bag system...	Accounts for the possibility of multiple front outboard passenger seats (i.e., no driver's seat present).
	Option 2	Retain current language.	

FMVSS No. 208, S22.5.1 Test procedure for determining stages of air bag systems subject to low risk deployment (low speed crashes) test requirement.			
Regulatory Text	**Translation Options**		**Potential Considerations**
The test described in S22.5.2 shall be conducted with an unbelted 50th percentile adult male test dummy in the driver seating position according to S8 as it applies to that seating position and an unbelted 5th percentile adult female test dummy either in the front outboard passenger vehicle seating position according to S16 as it applies to that seating position or at any fore-aft seat position on the passenger side.	**Option 1**	The test described in S22.5.2 shall be conducted with an unbelted 50th percentile adult male test dummy in the driver's designated seating position according to S8 as it applies to that seating position and an unbelted 5th percentile adult female test dummy either in any front outboard passenger vehicle seating position according to S16 as it applies to that seating position or at any fore-aft seat position on either passenger side.	Uses working definition for driver's DSP. Instructions for vehicles without a driver's DSP are not provided although it is suggested that either side of the vehicle could have a passenger DSP.
	Option 2	The test described in S22.5.2 shall be conducted with an unbelted 50th percentile adult male test dummy in the front left outboard seating position according to S8 as it applies to that seating position and an unbelted 5th percentile adult female test dummy either in the front right outboard passenger vehicle seating position according to S16 as it applies to that seating position or at any fore-aft seat position on the right passenger side.	Removes driver reference and specifies sides of the vehicle rather than functions of the seat. Differentiation between a driver's seat and a left front outboard passenger's seat may be necessary for positioning.

FMVSS No. 208, S23.2.1 Option 1—Automatic suppression feature			
Regulatory Text	**Translation Options**		**Potential Considerations**
The vehicle shall be equipped with an automatic suppression feature for the passenger frontal air bag system which results in deactivation of the air bag during each of the static tests specified in S24.2 (using the 49 CFR part 572 subpart N 6-year-old child dummy in any of the child restraints specified in section D of appendix A or A-1 of this standard, as appropriate), and activation of the air bag system during each of the static tests specified in S24.3 (using the 49 CFR part 572 subpart O 5th percentile adult female dummy).	**Option 1**	The vehicle shall be equipped with an automatic suppression feature for any front outboard passenger frontal air bag system which results in deactivation of the air bag during each of the static tests specified in S24.2…	Accounts for the possibility of multiple front outboard passenger seats (i.e., no driver's seat present). An additional section (S23.6) for ADS-equipped vehicles with steering controls could be necessary for suppressing the driver air bag or suspending the automatic driving function for a 6-year-old CRABI dummy in the driver's DSP. The driver air bag could be suppressed by the same method the passenger side air bag is suppressed. Vehicles could alternatively/additionally have a label on the controls stating "Never allow a child smaller than X to ride in this seat, with or without a child restraint device." This could possibly be paired with ADS suppression. In ADS-equipped vehicles that have a driver's DSP, there may be an instance where a human driver may not be required. In this instance, a child restraint system or child could be in the driver's DSP, presenting additional potential for injury.

FMVSS No. 208, S23.2.3 Option 1—Automatic suppression feature			
Regulatory Text	**Translation Options**		**Potential Considerations**
The vehicle shall be equipped with a mechanism that indicates whether the air bag is suppressed, regardless of whether the passenger seat is occupied. The mechanism need not be located in the occupant compartment unless it is the telltale described in S23.2.2.	**Option 1**	The vehicle shall be equipped with a mechanism that indicates whether the air bag is suppressed, regardless of whether any front outboard passenger seat is occupied…	Accounts for the possibility of multiple front outboard passenger seats (i.e., no driver's seat present).
	Option 2	Retain current language.	

FMVSS No. 208, S23.3 Option 2—Dynamic automatic suppression system that suppresses the air bag when an occupant is out of position			
Regulatory Text	**Translation Options**		**Potential Considerations**
(This option is available under the conditions set forth in S27.1.) The vehicle shall be equipped with a dynamic automatic suppression system for the passenger frontal air bag system which meets the requirements specified in S27.	**Option 1**	(This option is available under the conditions set forth in S27.1.) The vehicle shall be equipped with a dynamic automatic suppression system for any front outboard passenger frontal air bag system which meets the requirements specified in S27.	Accounts for the possibility of multiple front outboard passenger seats (i.e., no driver's seat present).

FMVSS No. 208, S23.4 Option 3—Low risk deployment			
Regulatory Text	**Translation Options**		**Potential Considerations**
Each vehicle shall meet the injury criteria specified in S23.5 of this standard when the passenger air bag is statically deployed in accordance with both of the low risk deployment test procedures specified in S24.4.	**Option 1**	Each vehicle shall meet the injury criteria specified in S23.5 of this standard when any front outboard passenger air bag is statically deployed in accordance with both of the low risk deployment test procedures specified in S24.4.	Accounts for the possibility of multiple front outboard passenger seats (i.e., no driver's seat present).

FMVSS No. 208, S24.1.2 Test procedure for S23			
Regulatory Text	**Translation Options**		**Potential Considerations**
Unless otherwise specified, each vehicle certified to this option shall comply in tests conducted with the front outboard passenger seating position at the mid-height, in the full rearward seat track position, the middle seat track position, and the full forward seat track position as determined in this section. Using only the control that primarily moves the seat in the fore and aft direction, determine the full rearward, middle, and full forward positions of the SCRP. Using any seat or seat cushion adjustments other than that which primarily moves the seat fore-aft, determine the SCRP mid-point height for each of the three fore-aft test positions, while maintaining as closely as possible, the seat cushion angle determined in S16.2.10.3.1. Set the seat back angle, if adjustable independent of the seat, at the manufacturer's nominal design seat back angle for a 50th percentile adult male as specified in S8.1.3. If the dummy contacts the vehicle interior, move the seat rearward to the next detent that provides clearance. If the seat is a power seat, move the seat rearward while assuring that there is a maximum of 5 mm (0.2 in) distance between the vehicle interior and the point on the dummy that would first contact the vehicle interior.	**Option 1**	Unless otherwise specified, each vehicle certified to this option shall comply in tests conducted with any front outboard passenger seating position at the mid-height, in the full rearward seat track position, the middle seat track position, and the full forward seat track position as determined in this section...	Accounts for the possibility of multiple front outboard passenger seats (i.e., no driver's seat present).
	Option 2	Retain current language.	

FMVSS No. 208, S24.1.3 Test procedure for S23			
Regulatory Text	**Translation Options**		**Potential Considerations**
Except as otherwise specified, if the booster seat has an anchorage system as specified in S5.9 of FMVSS No. 213 and is used under this standard in testing a vehicle with a front outboard passenger vehicle seat that has an anchorage system as specified in FMVSS No. 225, the vehicle shall comply with the belted test conditions with the restraint anchorage system attached to the FMVSS No. 225 vehicle seat anchorage system and the vehicle seat belt unattached. It shall also comply with the belted test conditions with the restraint anchorage system unattached to the FMVSS No. 225 vehicle seat anchorage system and the vehicle seat belt attached. The vehicle shall comply with the unbelted test conditions with the restraint anchorage system unattached to the FMVSS No. 225 vehicle seat anchorage system.	**Option 1**	Each vehicle that is certified as complying with S23.2 of FMVSS No. 208 shall meet the following test requirements with the child restraint in any front outboard passenger vehicle seat under the following conditions:…	Accounts for the possibility of multiple front outboard passenger seats (i.e., no driver's seat present).
	Option 2	Retain current language.	

FMVSS No. 208, S24.2 Static tests of automatic suppression feature which shall result in deactivation of the passenger air bag			
Regulatory Text	**Translation Options**		**Potential Considerations**
Each vehicle that is certified as complying with S23.2 of FMVSS No. 208 shall meet the following test requirements with the child restraint in the front outboard passenger vehicle seat under the following conditions: (a) Using the vehicle safety belts as specified in S22.2.1.5 with section D child restraints designed to be secured to the vehicle seat even when empty; (b) If the child restraint is certified to S5.9 of §571.213, and the vehicle seat has an anchorage system as specified in §571.225, using only the mechanism provided by the child restraint manufacturer for attachment to the lower anchorage as specified in S22.2.1.6; and (c) Without securing the child restraint with either the vehicle safety belts or any mechanism provided with a child restraint certified to S5.9 of §571.213.	**Option 1**	Each vehicle that is certified as complying with S23.2 of FMVSS No. 208 shall meet the following test requirements with the child restraint in any front outboard passenger vehicle seat under the following conditions:…	Accounts for the possibility of multiple front outboard passenger seats (no driver's seat present).
	Option 2	Retain current language.	

FMVSS No. 208, S24.2.3 Static tests of automatic suppression feature which shall result in deactivation of the passenger air bag			
Regulatory Text	**Translation Options**		**Potential Considerations**
(a) Place the dummy in the seated position in the front outboard passenger vehicle seat. For bucket seats, position the midsagittal plane of the dummy vertically such that it coincides with the longitudinal centerline of the seat cushion, within ±10 mm (±0.4 in). For bench seats, position the midsagittal plane of the dummy vertically and parallel to the vehicle's longitudinal centerline and the same distance from the longitudinal centerline of the vehicle, within ±10 mm (±0.4 in), as the center of the steering wheel. (b) Place the dummy's back against the seat back and rest the dummy's thighs on the seat cushion. (c) Allow the legs and feet of the dummy to extend off the surface of the seat. If this positioning of the dummy's legs is prevented by contact with the instrument panel, using only the control that primarily moves the seat fore and aft, move the seat rearward to the next detent that provides clearance. If the seat is a power seat, move the seat rearward, while assuring that there is a maximum of 5 mm	**Option 1**	(a) Place the dummy in the seated position in any front outboard passenger vehicle seat. For bucket seats, position the midsagittal plane of the dummy vertically such that it coincides with the longitudinal centerline of the seat cushion, within ±10 mm (±0.4 in). In the case of vehicles equipped with bench seats and manually operated driving controls, position the midsagittal plane of the dummy vertically and parallel to the vehicle's longitudinal centerline and the same distance from the vehicle's longitudinal centerline, within ±10 mm (±0.4 in), as the center of the steering control. For bench seats in vehicles without manually operated driving controls, position the midsagittal plane of any front outboard dummy vertically such that it coincides with the longitudinal centerline of the SgRP of the seat it occupies, within ±10 mm (±0.4 in)...	Accounts for the possibility of multiple front outboard passenger seats (i.e., no driver's seat present). The SgRP is used as an alternative landmark for bench seats in ADS-DVs.
	Option 2	(a) Place the dummy in the seated position in any front outboard passenger vehicle seat. For bucket seats, position the midsagittal plane of the dummy vertically such that it coincides with the longitudinal centerline of the seat cushion, within ±10 mm (±0.4 in). In the case of vehicles equipped with bench seats and manually operated driving controls, position the midsagittal plane of the dummy vertically and parallel to the vehicle's longitudinal centerline and the same distance from the vehicle's longitudinal centerline, within ±10 mm (±0.4 in), as the center of the steering control. For bench seats in vehicles without manually operated driving controls,	Accounts for the possibility of multiple front outboard passenger seats (i.e., no driver's seat present). The head restraint is used as an

FMVSS No. 208, S24.2.3 Static tests of automatic suppression feature which shall result in deactivation of the passenger air bag			
Regulatory Text	**Translation Options**		**Potential Considerations**
(0.2 in) distance between the vehicle interior and the part of the dummy that was in contact with the vehicle interior. (d) Rotate the dummy's upper arms toward the seat back until they make contact. (e) Rotate the dummy's lower arms down until they contact the seat. (f) Close the vehicle's passenger-side door and then start the vehicle engine or place the ignition in the “on” position, whichever will turn on the suppression system. (g) Push against the dummy's left shoulder to lean the dummy against the door; close all remaining doors. (h) Wait ten seconds, then check whether the air bag is deactivated.		position the midsagittal plane of any front outboard dummy vertically such that it coincides with the longitudinal centerline of the head restraint of the seat it occupies, within ±10 mm (±0.4 in)…	alternative landmark for bench seats in ADS-DVs.

FMVSS No. 208, S24.3 Static tests of automatic suppression feature which shall result in activation of the passenger air bag system			
Regulatory Text	**Translation Options**		**Potential Considerations**
Static tests of automatic suppression feature which shall result in activation of the passenger air bag system	**Option 1**	Static tests of automatic suppression feature which shall result in activation of any front outboard passenger air bag system	Accounts for the possibility of multiple front outboard passenger seats (i.e., no driver's seat present).

FMVSS No. 208, S24.3.1 Static tests of automatic suppression feature which shall result in activation of the passenger air bag system			
Regulatory Text	**Translation Options**		**Potential Considerations**
Each vehicle certified to this option shall comply in tests conducted with the front outboard passenger seating position at the mid-height, in the full rearward and middle positions determined in S24.1.2, and the forward position determined in S16.3.3.1.8.	**Option 1**	Each vehicle certified to this option shall comply in tests conducted with any front outboard passenger seating position at the mid-height, in the full rearward and middle positions determined in S24.1.2, and the forward position determined in S16.3.3.1.8.	Accounts for the possibility of multiple front outboard passenger seats (i.e., no driver's seat present).
	Option 2	Retain current language.	

FMVSS No. 208, S24.3.2 Static tests of automatic suppression feature which shall result in activation of the passenger air bag system			
Regulatory Text	**Translation Options**		**Potential Considerations**
Place a 49 CFR part 572 subpart O 5th percentile adult female test dummy at the front outboard passenger seating position of the vehicle, in accordance with procedures specified in S16.3.3 of this standard, except as specified in S24.3.1. Do not fasten the seat belt.	**Option 1**	Place a 49 CFR part 572 subpart O 5th percentile adult female test dummy at any front outboard passenger seating position of the vehicle, in accordance with procedures specified in S16.3.3 of this standard, except as specified in S24.3.1. Do not fasten the seat belt.	Accounts for the possibility of multiple front outboard passenger seats (i.e., no driver's seat present).
	Option 2	Retain current language.	

FMVSS No. 208, S24.4.2.3 Position 2 (head on instrument panel)			
Regulatory Text	**Translation Options**		**Potential Considerations**
Place the dummy in the front outboard passenger seat such that: (a) The midsagittal plane is coincident with Plane D within ±10 mm (±0.4 in). (b) The upper arms are parallel to the torso and the hands are next to where the thighs would be. (c) Without changing the seat position and with the dummy's thorax instrument cavity rear face 6 degrees forward of the vertical, move the dummy forward until the dummy head/torso contacts the instrument panel. If the dummy loses contact with the seat cushion because of the forward movement, maintain the height of the dummy while moving the dummy forward. If the head contacts the windshield before head/torso contact with the instrument panel, maintain the thorax instrument cavity angle and move the dummy forward such that the head is following the angle of the windshield until there is head/torso contact with the instrument panel. Once contact is made, raise or lower the dummy vertically until Point 1 lies in Plane C within ±10 mm (±0.4 in). If the dummy's head contacts the windshield and keeps Point 1 from reaching Plane C, lower the dummy until there is no more than 5 mm (0.2 in) clearance between the head and the windshield. (The dummy shall remain in contact with the instrument panel while being raised or lowered which may change the dummy's fore-aft position.)	**Option 1**	Place the dummy in any front outboard passenger seat such that: …	Accounts for the possibility of multiple front outboard passenger seats (i.e., no driver's seat present).
	Option 2	Retain current language.	

FMVSS No. 208, S24.4.3.1 Position 2 (head on instrument panel)			
Regulatory Text	**Translation Options**		**Potential Considerations**
Place the front outboard passenger seat at the mid-height full rearward seating position determined in S24.1.2. Place the seat back, if adjustable independent of the seat, at the manufacturer's nominal design seat back angle for a 50th percentile adult male as specified in S8.1.3. Position any adjustable parts of the seat that provide additional support so that they are in the lowest or most open adjustment position. Position an adjustable head restraint in the lowest and most forward position.	**Option 1**	Place any front outboard passenger seat at the mid-height full rearward seating position determined in S24.1.2…	Accounts for the possibility of multiple front outboard passenger seats (i.e., no driver's seat present).
	Option 2	Retain current language.	

FMVSS No. 208, S24.4.3.2 Position 2 (head on instrument panel)			
Regulatory Text	**Translation Options**		**Potential Considerations**
Place the dummy in the front outboard passenger seat such that: (a) The midsagittal plane is coincident with Plane D within ±10 mm (±0.4 in). (b) The legs are perpendicular to the floor pan, the back of the legs are in contact with the seat cushion, and the dummy's thorax instrument cavity rear face is 6 degrees forward of vertical. If it is not possible to position the dummy with the legs in the prescribed position, rotate the legs forward until the dummy is resting on the seat with the feet positioned flat on the floor pan and the back of the legs are in contact with the front of the seat cushion. Set the transverse distance between the longitudinal centerlines at the front of the dummy's knees at 112 to 117 mm (4.4 to 4.6 in), with the thighs and the legs of the dummy in vertical planes. (c) The upper arms are parallel to the torso and the hands are in contact with the thighs.	**Option 1**	Place the dummy in any front outboard passenger seat such that:...	Accounts for the possibility of multiple front outboard passenger seats (i.e., no driver's seat present).
	Option 2	Retain current language.	

FMVSS No. 208, S24.4.4 Position 2 (head on instrument panel)			
Regulatory Text	**Translation Options**		**Potential Considerations**
Deploy the front outboard passenger frontal air bag system. If the frontal air bag system contains a multistage inflator, the vehicle shall be able to comply with the injury criteria at any stage or combination of stages or time delay between successive stages that could occur in a rigid barrier crash test at or below 26 km/h (16 mph), under the test procedure specified in S22.5.	**Option 1**	Deploy any front outboard passenger frontal air bag system...	Accounts for the possibility of multiple front outboard passenger seats (i.e., no driver's seat present).
	Option 2	Retain current language.	

FMVSS No. 208, S25. Requirements using an out-of-position 5th percentile adult female dummy at the driver position.			
Regulatory Text	**Translation Options**		**Potential Considerations**
S25. Requirements using an out-of-position 5th percentile adult female dummy at the driver position.	**Option 1**	Retain current language.	Uses working definition option 2 for driver.

FMVSS No. 208, S26. Procedure for low risk deployment tests of driver air bag			
Regulatory Text	**Translation Options**		**Potential Considerations**
Procedure for low risk deployment tests of driver air bag	**Option 1**	Retain current language.	Uses new definition of "driver air bag." Entire section will not apply if there is no driver's DSP.

FMVSS No. 208 S26.2 Driver position 1 (chin on module)			
Regulatory Text	**Translation Options**		**Potential Considerations**
Driver position 1 (chin on module)	**Option 1**	Retain current language.	Entire section will not apply if there is no driver's DSP.

FMVSS No. 208, S26.2.1 Driver position 1 (chin on module)			
Regulatory Text	**Translation Options**		**Potential Considerations**
Adjust the steering controls so that the steering wheel hub is at the geometric center of the locus it describes when it is moved through its full range of driving positions. If there is no setting at the geometric center, position it one setting lower than the geometric center. Set the rotation of the steering wheel so that the vehicle wheels are pointed straight ahead.	**Option 1**	Retain current language.	
	Option 2	Adjust the steering controls so that the steering control hub is at the geometric center of the locus it describes when it is moved through its full range of driving positions. If there is no setting at the geometric center, position it one setting lower than the geometric center. Set the rotation of the steering control so that the vehicle wheels are pointed straight ahead.	May choose to use the more encompassing term "control" rather than "wheel." This standard may not apply to all potential types of steering controls, so the general term may not be applicable.

FMVSS No. 208, S26.2.2 Driver position 1 (chin on module)			
Regulatory Text	**Translation Options**		**Potential Considerations**
Mark a point on the steering wheel cover that is longitudinally and transversely, as measured along the surface of the steering wheel cover, within ±6 mm (±0.2 in) of the point that is defined by the intersection of the steering wheel cover and a line between the volumetric center of the smallest volume that can encompass the folded undeployed air bag and the volumetric center of the static fully inflated air bag. Locate the vertical plane parallel to the vehicle longitudinal centerline through the point located on the steering wheel cover. This is referred to as "Plane E."	**Option 1**	Retain current language.	
	Option 2	Mark a point on the steering control cover that is longitudinally and transversely, as measured along the surface of the steering control cover, within ±6 mm (±0.2 in) of the point that is defined by the intersection of the steering control cover and a line between the volumetric center of the smallest volume that can encompass the folded undeployed air bag and the volumetric center of the static fully inflated air bag. Locate the vertical plane parallel to the vehicle longitudinal centerline through the point located on the steering control cover. This is referred to as "Plane E."	May choose to use the more encompassing term "control" rather than "wheel." This standard may not apply to all potential types of steering controls, so the general term may not be applicable.

FMVSS No. 208 S26.2.4 Driver position 1 (chin on module)			
Regulatory Text	**Translation Options**		**Potential Considerations**
Place the dummy in the driver's seat such that:	**Option 1**	Retain current language.	Entire section will not apply if there is no driver's DSP.

FMVSS No. 208, S26.2.4.3 Driver position 1 (chin on module)			
Regulatory Text	**Translation Options**		**Potential Considerations**
The dummy's thorax instrument cavity rear face is 6 degrees forward (toward the front of the vehicle) of the steering wheel angle (i.e., if the steering wheel angle is 25 degrees from vertical, the thorax instrument cavity rear face angle is 31 degrees).	**Option 1**	Retain current language.	
	Option 2	The dummy's thorax instrument cavity rear face is 6 degrees forward (toward the front of the vehicle) of the steering control angle (i.e., if the steering control angle is 25 degrees from vertical, the thorax instrument cavity rear face angle is 31 degrees).	May choose to use the more encompassing term "control" rather than "wheel." This standard may not apply to all potential types of steering controls, so the general term may not be applicable.

FMVSS No. 208, S26.2.5 Driver position 1 (chin on module)			
Regulatory Text	**Translation Options**		**Potential Considerations**
Maintaining the spine angle, slide the dummy forward until the head/torso contacts the steering wheel.	**Option 1**	Retain current language.	
	Option 2	Maintaining the spine angle, slide the dummy forward until the head/torso contacts the steering control.	May choose to use the more encompassing term "control" rather than "wheel." This standard may not apply to all potential types of steering controls, so the general term may not be applicable.

FMVSS No. 208 S26.3 Driver position 2 (chin on rim)			
Regulatory Text	**Translation Options**		**Potential Considerations**
S26.3 Driver position 2 (chin on rim)	**Option 1**	Retain current language.	Entire section will not apply if there is no driver's DSP.

FMVSS No. 208, S26.3.2 Driver position 2 (chin on rim)			
Regulatory Text	**Translation Options**		**Potential Considerations**
Adjust the steering controls so that the steering wheel hub is at the geometric center of the locus it describes when it is moved through its full range of driving positions. If there is no setting at the geometric center, position it one setting lower than the geometric center. Set the rotation of the steering wheel so that the vehicle wheels are pointed straight ahead.	**Option 1**	Retain current language.	
	Option 2	Adjust the steering controls so that the steering control hub is at the geometric center of the locus it describes when it is moved through its full range of driving positions. If there is no setting at the geometric center, position it one setting lower than the geometric center. Set the rotation of the steering control so that the vehicle wheels are pointed straight ahead.	May choose to use the more encompassing term "control" rather than "wheel." This standard may not apply to all potential types of steering controls, so the general term may not be applicable.

FMVSS No. 208, S26.3.3 Driver position 2 (chin on rim)			
Regulatory Text	**Translation Options**		**Potential Considerations**
Mark a point on the steering wheel cover that is longitudinally and transversely, as measured along the surface of the steering wheel cover, within ±6 mm (±0.2 in) of the point that is defined by the intersection of the steering wheel cover and a line between the volumetric center of the smallest volume that can encompass the folded undeployed air bag and the volumetric center of the static fully inflated air bag. Locate the vertical plane parallel to the vehicle longitudinal centerline through the point located on the steering wheel cover. This is referred to as "Plane E."	**Option 1**	Retain current language.	
	Option 2	Mark a point on the steering control cover that is longitudinally and transversely, as measured along the surface of the steering control cover, within ±6 mm (±0.2 in) of the point that is defined by the intersection of the steering control cover and a line between the volumetric center of the smallest volume that can encompass the folded undeployed air bag and the volumetric center of the static fully inflated air bag. Locate the vertical plane parallel to the vehicle longitudinal centerline through the point located on the steering control cover. This is referred to as "Plane E."	May choose to use the more encompassing term "control" rather than "wheel." This standard may not apply to all potential types of steering controls, so the general term may not be applicable.

FMVSS No. 208 S26.3.4 Driver position 2 (chin on rim)			
Regulatory Text	**Translation Options**		**Potential Considerations**
Place the dummy in the driver's seat position such that:	**Option 1**	Retain current language.	Entire section will not apply if there is no driver's DSP.

FMVSS No. 208, S26.3.4.3 Driver position 2 (chin on rim)			
Regulatory Text	**Translation Options**		**Potential Considerations**
The dummy's thorax instrument cavity rear face is 6 degrees forward (toward the front of the vehicle) of the steering wheel angle (i.e., if the steering wheel angle is 25 degrees from vertical, the thorax instrument cavity rear face angle is 31 degrees).	**Option 1**	Retain current language.	
	Option 2	The dummy's thorax instrument cavity rear face is 6 degrees forward (toward the front of the vehicle) of the steering control angle (i.e., if the steering control angle is 25 degrees from vertical, the thorax instrument cavity rear face angle is 31 degrees).	May choose to use the more encompassing term "control" rather than "wheel." This standard may not apply to all potential types of steering controls, so the general term may not be applicable.

FMVSS No. 208, S26.3.5 Driver position 2 (chin on rim)			
Regulatory Text	**Translation Options**		**Potential Considerations**
Maintaining the spine angle, slide the dummy forward until the head/torso contacts the steering wheel.	**Option 1**	Retain current language.	
	Option 2	Maintaining the spine angle, slide the dummy forward until the head/torso contacts the steering control.	May choose to use the more encompassing term "control" rather than "wheel." This standard may not apply to all potential types of steering controls, so the general term may not be applicable.

FMVSS No. 208, S26.3.6 Driver position 2 (chin on rim)			
Regulatory Text	**Translation Options**		**Potential Considerations**
While maintaining the spine angle, position the dummy so that a point on the chin 40 mm (1.6 in) ±3 mm (±0.1 in) below the center of the mouth (chin point) is, within ±10 mm (±0.4 in), in contact with a point on the steering wheel rim surface closest to the dummy that is 10 mm (0.4 in) vertically below the highest point on the rim in Plane E. If the dummy's head contacts the vehicle windshield or upper interior before the prescribed position can be obtained, lower the dummy until there is no more than 5 mm (0.2 in) clearance between the vehicle's windshield or upper interior, as applicable.	**Option 1**	Retain current language.	
	Option 2	While maintaining the spine angle, position the dummy so that a point on the chin 40 mm (1.6 in) ±3 mm (±0.1 in) below the center of the mouth (chin point) is, within ±10 mm (±0.4 in), in contact with a point on the steering control rim surface closest to the dummy that is 10 mm (0.4 in) vertically below the highest point on the rim in Plane E...	May choose to use the more encompassing term “control” rather than “wheel.” This standard may not apply to all potential types of steering controls, so the general term may not be applicable.

FMVSS No. 208, S26.3.7 Driver position 2 (chin on rim)			
Regulatory Text	**Translation Options**		**Potential Considerations**
If the steering wheel can be adjusted so that the chin point can be in contact with the rim of the uppermost portion of the steering wheel, adjust the steering wheel to that position. If the steering wheel contacts the dummy's leg(s) prior to attaining this position, adjust it to the next highest detent, or if infinitely adjustable, until there is a maximum of 5 mm (0.2 in) clearance between the wheel and the dummy's leg(s). Readjust the dummy's torso such that the	**Option 1**	Retain current language.	
	Option 2	If the steering control can be adjusted so that the chin point can be in contact with the rim of the uppermost portion of the steering control, adjust the steering control to that position. If the steering control contacts the dummy's leg(s) prior to attaining this	May choose to use the more encompassing term “control” rather than “wheel.” This standard may not

thorax instrument cavity rear face is 6 degrees forward of the steering wheel angle. Position the dummy so that the chin point is in contact, or if contact is not achieved, as close as possible to contact with the rim of the uppermost portion of the steering wheel.		position, adjust it to the next highest detent, or if infinitely adjustable, until there is a maximum of 5 mm (0.2 in) clearance between the control and the dummy's leg(s). Readjust the dummy's torso such that the thorax instrument cavity rear face is 6 degrees forward of the steering control angle. Position the dummy so that the chin point is in contact, or if contact is not achieved, as close as possible to contact with the rim of the uppermost portion of the steering control.	apply to all potential types of steering controls, so the general term may not be applicable.

FMVSS No. 208, S26.4 Deploy the driver frontal air bag system.			
Regulatory Text	**Translation Options**		**Potential Considerations**
S26.4 Deploy the driver frontal air bag system.	**Option 1**	Retain current language.	Entire section will not apply if there is no driver's DSP.
	Option 2	Deploy the left front air bag system. If the frontal…	Applies to the air bag system in the left front outboard seat whether or not it is a driver's DSP.

FMVSS No. 208, S27.5.1 Driver (49 CFR part 572 subpart O 5th percentile female dummy)			
Regulatory Text	**Translation Options**		**Potential Considerations**
Title: S27.5.1 Driver… Each vehicle shall meet the injury criteria specified in S15.3 of this standard when the driver air bag is deployed in accordance with the procedures specified in S28.1.	**Option 1**	Retain current language.	Uses working definition option 2 for driver.

FMVSS No. 208, S27.5.2 Passenger (49 CFR part 572 subpart P 3-year-old child dummy and 49 CFR part 572 subpart N 6-year-old child dummy)			
Regulatory Text	**Translation Options**		**Potential Considerations**
Title: S27.5.2 Passenger… Each vehicle shall meet the injury criteria specified in S21.5 and S23.5, as appropriate, when the passenger air bag is deployed in accordance with the procedures specified in S28.2.	**Option 1**	Retain current language.	Uses either working definition for passenger DSP (i.e., any DSP other than the driver's DSP). Further clarification may be unnecessary since it is implicit that this section is for front row passengers only.
	Option 2	S27.5.2: Front outboard passenger… Each vehicle shall meet the injury criteria specified in S21.5 and S23.5, as appropriate, when any front outboard passenger air bag is deployed in accordance with the procedures specified in S28.2.	Further clarification that this section is for any front outboard passenger DSP.

FMVSS No. 208, S27.6.1 Driver			
Regulatory Text	**Translation Options**		**Potential Considerations**
Title: S27.6.1 Driver The DASS shall suppress the driver air bag before the head, neck, or torso of the specified test device enters the ASZ when the vehicle is tested under the procedures specified in S28.3.	**Option 1**	Retain current language.	Uses working definition option 2 for driver.

FMVSS No. 208, S27.6.2 Passenger			
Regulatory Text	**Translation Options**		**Potential Considerations**
Title: S27.6.2 Passenger The DASS shall suppress the passenger air bag before head, neck, or torso of the specified test device enters the ASZ when the vehicle is tested under the procedures specified in S28.4.	**Option 1**	Retain current language.	
	Option 2	S27.6.2: Front outboard passenger The DASS shall suppress any front outboard passenger air bag before head, neck, or torso of the specified test device enters the ASZ when the vehicle is tested under the procedures specified in S28.4.	Uses working definitions for passenger. Includes a condition where there is more than a front row passenger seat (i.e., no driver's DSP is present).

FMVSS No. 208, S28.2 Passenger suppression zone verification test (49 CFR part 572 subpart P 3-year-old child dummy and 49 CFR part 572 subpart N 6-year-old child dummies)			
Regulatory Text	**Translation Options**		**Potential Considerations**
Title: S28.2 Passenger suppression zone verification test (49 CFR part 572 subpart P 3-year-old child dummy and 49 CFR part 572 subpart N 6-year-old child dummies)	**Option 1**	Retain current language.	Uses working definitions for passenger. Further clarification may be unnecessary since it is implicit that this section is for front row passengers only.
	Option 2	S28.2: Front outboard passenger suppression zone verification test (49 CFR part 572 subpart P 3-year-old child dummy and 49 CFR part 572 subpart N 6-year-old child dummies)	Further clarification that this section is for any front outboard passenger DSP.

FMVSS No. 208, S28.4 Passenger dynamic test procedure for DASS requirements			
Regulatory Text	**Translation Options**		**Potential Considerations**
Title: S28.4 Passenger dynamic test procedure for DASS requirements	**Option 1**	Retain current language.	
	Option 2	S28.4: Front outboard passenger dynamic test procedure for DASS requirements	Further clarification that this section is for any front outboard passenger DSP.

FMVSS No. 214: Side Impact Protection

Technical Translation Options Summary: *The purpose of this FMVSS is "to reduce the risk of serious and fatal injury to occupants of passenger cars, multipurpose passenger vehicles, trucks and buses in side impacts by specifying strength requirements for side doors, limiting the forces, deflections and accelerations measured on anthropomorphic dummies in test crashes, and by other means." (S1)*

Technical translation options are for conventional seating and non-bidirectional vehicles only. Therefore, the focus for translation is to ensure that the strength requirements for side doors and acceptable dummy responses in side impact testing are maintained for automated driving system-dedicated vehicles (ADS-DVs) while simultaneously being uncompromised for conventional vehicles.

FMVSS No. 214, S3. Definitions.			
Regulatory Text	**Translation Options**		**Potential Considerations**
Walk-in van means a special cargo/mail delivery vehicle that has only one designated seating position. That designated seating position must be forward facing and for use only by the driver. The vehicle usually has a thin and light sliding (or folding) side door for easy operation and a high roof clearance that a person of medium stature can enter the passenger compartment area in an up-right position.	**Option 1**	*Walk-in van* means a special cargo/mail delivery vehicle that has only a driver's designated seating position, a single passenger's designated seating position, or no designated seating positions…	This option expands the definition for ADS-equipped walk-in vans without manually operated driving controls.
	Option 2	*Walk-in van* means a special cargo/mail delivery vehicle that has only one designated seating position. That designated seating position must be forward facing and for use only by a driver.	A translation may be unnecessary if the working definition for driver's DSP (driver's seat) is used. "…a driver" would apply to a human driver or the ADS. The definition for Walk-in van in FMVSS No. 226 and FMVSS No. 214 should be consistent.

FMVSS No. 214, S5. General exclusions.			
Regulatory Text	**Translation Options**		**Potential Considerations**
(a) Exclusions from S6 (door crush resistance). A vehicle need not meet the requirements of S6 (door crush resistance) for— (1) Any side door located so that no point on a ten-inch horizontal longitudinal line passing through and bisected by the H-point of a manikin placed in any seat, with the seat adjusted to any position and the seat back adjusted as specified in S8.3, falls within the transverse, horizontal projection of the door's opening, (2) Any side door located so that no point on a ten-inch horizontal longitudinal line passing through and bisected by the H-point of a manikin placed in any seat recommended by the manufacturer for installation in a location for which seat anchorage hardware is provided, with the seat adjusted to any position and the seat back adjusted as specified in S8.3, falls within the transverse, horizontal projection of the door's opening, (3) Any side door located so that a portion of a seat, with the seat adjusted to any position and the seat back adjusted as specified in S8.3, falls within	**Option 1**	…(c)(4) Vehicles in which the seat for the driver or any front outboard passenger has been removed…	Any front outboard passenger can apply to ADS-DVs without manually operated driving controls while the driver's seat is maintained for conventional vehicles.

the transverse, horizontal projection of the door's opening, but a longitudinal vertical plane tangent to the outboard side of the seat cushion is more than 254 mm (10 inches) from the innermost point on the inside surface of the door at a height between the H-point and shoulder reference point (as shown in Figure 1 of Federal Motor Vehicle Safety Standard No. 210 (49 CFR 571.210)) and longitudinally between the front edge of the cushion with the seat adjusted to its forwardmost position and the rear edge of the cushion with the seat adjusted to its rearmost position. (4) Any side door that is designed to be easily attached to or removed (e.g., using simple hand tools such as pliers and/or a screwdriver) from a motor vehicle manufactured for operation without doors. (b) Exclusions from S7 (moving deformable barrier test). The following vehicles are excluded from S7 (moving deformable barrier test): (1) Motor homes, ambulances and other emergency rescue/medical vehicles (including vehicles with fire-fighting equipment), vehicles equipped with wheelchair lifts, and vehicles			

which have no doors or exclusively have doors that are designed to be easily attached or removed so the vehicle can be operated without doors. (2) Passenger cars with a wheelbase greater than 130 inches need not meet the requirements of S7 as applied to the rear seat. (3) Passenger cars, multipurpose passenger vehicles, trucks and buses need not meet the requirements of S7 (moving deformable barrier test) as applied to the rear seat for side-facing rear seats and for rear-seating areas that are so small that a Part 572 Subpart V dummy representing a 5th percentile adult female cannot be accommodated according to the positioning procedure specified in S12.3.4 of this standard. Vehicles that are manufactured before September 1, 2010, and vehicles that manufactured on or after September 1, 2010, that are not part of the percentage of a manufacturer's production meeting the moving deformable barrier test requirements with advanced test dummies (S7.2 of this section) or are otherwise excluded from the phase-in requirements of S7.2, need not meet the requirements of the moving			

deformable barrier test as applied to the rear seat for rear-seating areas that are so small that a Subpart F dummy (SID) cannot be accommodated according to the positioning procedure specified in S12.1 of this standard. (4) Multipurpose passenger vehicles, trucks and buses with a GVWR of more than 2,722 kg (6,000 lb) need not meet the requirements of S7 (moving deformable barrier test). (c) Exclusions from S9 (vehicle-to-pole test). The following vehicles are excluded from S9 (vehicle-to-pole test) (wholly or in limited part, as set forth below): (1) Motor homes; (2) Ambulances and other emergency rescue/medical vehicles (including vehicles with fire-fighting equipment) except police cars; (3) Vehicles with a lowered floor or raised or modified roof and vehicles that have had the original roof rails removed and not replaced; (4) Vehicles in which the seat for the driver or right front passenger has been removed and wheelchair restraints installed in place of the seat are excluded from meeting the vehicle-to-pole test at that position; and			

(5) Vehicles that have no doors, or exclusively have doors that are designed to be easily attached or removed so that the vehicle can be operated without doors.			
	Option 2	…(c)(4) Vehicles in which the seat for any front outboard occupant has been removed…	Similar to Option 1 in that any front outboard applies to ADS-DVs; however, the reference to the driver's seat is removed.

FMVSS No. 214, S8.3.1.3 Seat position adjustment.			
Regulatory Text	**Translation Options**		**Potential Considerations**
If the driver and passenger seats do not adjust independently of each other, the struck side seat shall control the final position of the non-struck side seat. If the driver and passenger seats adjust independently of each other, adjust both the struck and non-struck side seats in the manner specified in S8.3.1.	**Option 1**	If the driver and any front outboard passenger seats do not adjust independently of each other, the struck side seat shall control the final position of the non-struck side seat. If the driver and any front outboard passenger seats adjust independently of each other, adjust both the struck and non-struck side seats in the manner specified in S8.3.1.	May apply to ADS-DVs with more than one front passenger seat but maintains reference to driver for current vehicles.
	Option 2	If the front outboard seats do not adjust independently of each other, the struck side seat shall control the final position of the non-struck side seat. If the front outboard seats adjust independently of each other, adjust both the struck and non-struck side seats in the manner specified in S8.3.1.	Option 2 is similar to Option 1 but removes the driver/passenger references.

FMVSS No. 214, S8.4 Adjustable steering wheel.			
Regulatory Text	**Translation Options**		**Potential Considerations**
Adjustable steering controls are adjusted so that the steering wheel hub is at the geometric center of the locus it describes when it is moved through its full range of driving positions. If there is no setting detent in the mid-position, lower the steering wheel to the detent just below the mid-position. If the steering column is telescoping, place the steering column in the mid-position. If there is no mid-position, move the steering wheel rearward one position from the mid-position.	**Option 1**	Adjustable steering controls are adjusted so that the steering control hub is at the geometric center of the locus it describes when it is moved through its full range of driving positions. If there is no setting detent in the mid-position, lower the steering control to the detent just below the mid-position. If the steering column is telescoping, place the steering column in the mid-position. If there is no mid-position, move the steering control rearward one position from the mid-position.	More general term "control" is used to account for potential designs for manually operated driving controls. These adjustments may not apply to all types of steering control.
	Option 2	Adjustable steering controls are adjusted so that the steering control/wheel hub is at the geometric center of the locus it describes when it is moved through its full range of driving positions. If there is no setting detent in the mid-position, lower the steering control/wheel to the detent just below the mid-position. If the steering column is telescoping, place the steering column in the mid-position. If there is no mid-position, move the steering control/wheel rearward one position from the mid-position.	Maintains steering wheel reference but includes the potential of different types of steering control.

FMVSS No. 214, S10.2 Vehicle test attitude.			
Regulatory Text	**Translation Options**		**Potential Considerations**
When the vehicle is in its "as delivered," "fully loaded" and "as tested" condition, locate the vehicle on a flat, horizontal surface to determine the vehicle attitude. Use the same level surface or reference plane and the same standard points on the test vehicle when determining the "as delivered," "fully loaded" and "as tested" conditions. Measure the angles relative to a horizontal plane, front-to-rear and from left-to-right for the "as delivered," "fully loaded," and "as tested" conditions. The front-to-rear angle (pitch) is measured along a fixed reference on the driver's and front passenger's door sill. Mark where the angles are taken on the door sill. The left to right angle (roll) is measured along a fixed reference point at the front and rear of the vehicle at the vehicle longitudinal center plane. Mark where the angles are measured. The "as delivered" condition is the vehicle as received at the test site, with 100 percent of all fluid capacities and all tires inflated to the manufacturer's specifications listed on the vehicle's tire placard. When the vehicle is in its "fully loaded" condition, measure the angle between the driver's door sill and the horizontal, at the same place the "as delivered" angle was measured. The "fully loaded condition" is the test vehicle loaded in accordance with S8.1 of this standard (49 CFR 571.214). The load placed in the cargo area is centered over the longitudinal centerline of the vehicle. The vehicle "as tested" pitch and roll angles are between the "as delivered" and "fully loaded" condition, inclusive.	**Option 1**	...The front-to-rear angle (pitch) is measured along a fixed reference on the left and right front door sill... When the vehicle is in its "fully loaded" condition, measure the angle between the left front door sill and the horizontal, ...	This option removes driver/passenger references.
	Option 2	...The front-to-rear angle (pitch) is measured along a fixed reference on both front door sills... When the vehicle is in its "fully loaded" condition, measure the angle between the left front door sill and the horizontal, ...	Uses both instead of left and right front as stated in Option 1.

FMVSS No. 214, S10.3.1 Driver and front passenger seat set-up for 50th percentile male dummy			
Regulatory Text	**Translation Options**		**Potential Considerations**
S10.3.1 Driver and front passenger seat set-up for 50th percentile male dummy. The driver and front passenger seats are set up as specified in S8.3.1 of this standard, 49 CFR 571.214.	**Option 1**	Title: Driver and front outboard passenger seat set-up for 50th percentile male dummy The driver and front outboard passenger seats are set up…	Uses working definitions.
	Option 2	Title: Front outboard occupant seat set-up for... The front outboard occupant seats are set up…	Removes driver/passenger references. The working definitions for this translation are not necessary.

FMVSS No. 214, S10.3.2. Driver and front passenger seat set-up for 49 CFR Part 572 Subpart V 5th percentile female dummy.			
Regulatory Text	**Translation Options**		**Potential Considerations**
S10.3.2. Driver and front passenger seat set-up for 49 CFR Part 572 Subpart V 5th percentile female dummy	**Option 1**	Title: Driver and front outboard passenger seat set-up for 49 CFR Part 572 Subpart V 5th percentile female dummy.	Uses working definitions.
	Option 2	Title: Front outboard occupant seat set-up for...	Removes driver/passenger references. The working definitions for this translation are not necessary.

FMVSS No. 214, S10.3.2.3 Seat position adjustment.			
Regulatory Text	**Translation Options**		**Potential Considerations**
If the driver and passenger seats do not adjust independently of each other, the struck side seat shall control the final position of the non-struck side seat. If the driver and passenger seats adjust independently of each other, adjust both the struck and non-struck side seats in the manner specified in S10.3.2.	**Option 1**	If the driver and any front outboard passenger seats do not adjust independently of each other, the struck side seat shall control the final position of the non-struck side seat. If the driver and any front outboard passenger seats adjust independently of each other, adjust both the struck and non-struck side seats in the manner specified in S10.3.2.	Uses working definitions.
	Option 2	If the front outboard seats do not adjust independently of each other, the struck side seat shall control the final position of the non-struck side seat. If the driver and front outboard seats adjust independently, …	Removes driver/passenger references. The term "driver" does not have to be defined under this option.

FMVSS No. 214, S10.5 Adjustable steering wheel			
Regulatory Text	**Translation Options**		**Potential Considerations**
Adjustable steering controls are adjusted so that the steering wheel hub is at the geometric center of the locus it describes when it is moved through its full range of driving positions. If there is no setting detent in the mid-position, lower the steering wheel to the detent just below the mid-position. If the steering column is telescoping, place the steering column in the mid-position. If there is no mid-position, move the steering wheel rearward one position from the mid-position.	**Option 1**	Adjustable steering controls are adjusted so that the steering control hub is at the geometric center of the locus it describes when it is moved through its full range of driving positions. If there is no setting detent in the mid-position, lower the steering control to the detent just below the mid-position. If the steering column is telescoping, place the steering column in the mid-position. If there is no mid-position, move the steering control rearward one position from the mid-position.	More encompassing term "control" is used instead of "wheel." Generalizing to steering control may not be appropriate. Different steering controls may not fit under this standard.
	Option 2	Adjustable steering controls are adjusted so that the steering control/wheel hub is at the geometric center of the locus it describes when it is moved through its full range of driving positions. If there is no setting detent in the mid-position, lower the steering control/wheel to the detent just below the mid-position. If the steering column is telescoping, place the steering column in the mid-position. If there is no mid-position, move the steering control/wheel rearward one position from the mid-position.	Maintains specific reference of the steering wheel. Allows for other types of steering controls.

FMVSS No. 214, S12.1.1 Positioning a Part 572 Subpart F (SID) dummy in the driver position.			
Regulatory Text	**Translation Options**		**Potential Considerations**
S12.1.1 Positioning a Part 572 Subpart F (SID) dummy in the driver position. (a) Torso. Hold the dummy's head in place and push laterally on the non-impacted side of the upper torso in a single stroke with a force of 66.7-89.0 N (15-20 lb) towards the impacted side. (1) For a bench seat. The upper torso of the test dummy rests against the seat back. The midsagittal plane of the test dummy is vertical and parallel to the vehicle's longitudinal centerline, and passes through the center of the steering wheel. (2) For a bucket seat. The upper torso of the test dummy rests against the seat back. The midsagittal plane of the test dummy is vertical and parallel to the vehicle's longitudinal centerline, and coincides with the longitudinal centerline of the bucket seat. (b) Pelvis. (1) H-point. The H-points of each test dummy coincide within 12.7 mm (1⁄2 inch) in the vertical dimension and 12.7 mm (1⁄2 inch) in the horizontal dimension of a point that is located 6.4 mm (1⁄4 inch) below the position of the H-point determined by using the equipment for the 50th percentile and procedures specified in SAE Standard J826-1980 (incorporated by reference, see §571.5), except that Table 1 of SAE Standard J826-1980 is not applicable. The length of the lower leg and thigh segments of the H-point machine are adjusted to 414 and 401 mm (16.3 and 15.8 inches), respectively. (2) Pelvic angle. As determined using the pelvic angle	**Option 1**	Title: Positioning a Part 572 Subpart F (Side) dummy in the driver's designated seating position …(1) For a bench seat. For vehicles with manually operated driving controls, the upper torso of the test dummy rests against the seat back. The midsagittal plane of the test dummy is vertical and parallel to the vehicle's longitudinal centerline, and passes through the center of the steering control. For vehicles without manually operated driving controls, position using the procedures under S12.1.2(a)(1).	Driver's DSP is used to replace driver position. The term control is used instead of wheel. Since S12.1.2 covers dummy positioning in any front outboard seat, bench seating does not have to be addressed for ADS-DVs not equipped with steering controls/wheels.

gauge (GM drawing 78051-532 incorporated by reference in part 572, Subpart E of this chapter) which is inserted into the H-point gauging hole of the dummy, the angle of the plane of the surface on the lumbar-pelvic adaptor on which the lumbar spine attaches is 23 to 25 degrees from the horizontal, sloping upward toward the front of the vehicle. (3) Legs. The upper legs of each test dummy rest against the seat cushion to the extent permitted by placement of the feet. The left knee of the dummy is positioned such that the distance from the outer surface of the knee pivot bolt to the dummy's midsagittal plane is 152.4 mm (6.0 inches). To the extent practicable, the left leg of the test dummy is in a vertical longitudinal plane. (4) Feet. The right foot of the test dummy rests on the undepressed accelerator with the heel resting as far forward as possible on the floorpan. The left foot is set perpendicular to the lower leg with the heel resting on the floorpan in the same lateral line as the right heel.			

FMVSS No. 214, S12.1.2 Positioning a Part 572 Subpart F (SID) dummy in the front outboard seating position.			
Regulatory Text	**Translation Options**		**Potential Considerations**
Title: S12.1.2 Positioning a Part 572 Subpart F (SID) dummy in the front outboard seating position. (a) Torso. Hold the dummy's head in place and push laterally on the non-impacted side of the upper torso in a single stroke with a force of 66.7-89.0 N (15-20 lb) towards the impacted side.	**Option 1**	Title: Positioning a Part 572 Subpart F (SID) dummy in any front outboard passenger seating position ...(1) For a bench seat. The upper torso of the test dummy rests against the seat back. The midsagittal plane of the test dummy is vertical and parallel to the vehicle's longitudinal centerline. For vehicles with manually operated driving controls, the midsagittal plane of the test dummy is the same distance from the vehicle's longitudinal centerline as would be the midsagittal plane of a test dummy positioned in the driver designated seating position under S12.1.1(a)(1). For vehicles without manually operated driving controls, the midsagittal plane of the test dummy passes through the longitudinal centerline of the SgRP of the seat it occupies...	Considers the potential for more than one passenger DSP in the front row (e.g., vehicles without a driver's DSP). The center of the SgRP is used as an alternative landmark to the steering wheel for ADS-DVs.
(1) For a bench seat. The upper torso of the test dummy rests against the seat back. The midsagittal plane of the test dummy is vertical and parallel to the vehicle's longitudinal centerline, and the same distance from the vehicle's longitudinal centerline as would be the midsagittal plane of a test dummy	**Option 2**	Title: Positioning a Part 572 Subpart F (SID) dummy in any front outboard passenger seating position ...(1) For a bench seat. The upper torso of the test dummy rests against the seat back. The midsagittal plane of the test dummy is vertical and parallel to the vehicle's longitudinal centerline. For vehicles with manually operated driving controls, the midsagittal plane of the test dummy is the same distance from the vehicle's longitudinal centerline as would be the midsagittal plane of a test dummy positioned in the driver designated seating position under S12.1.1(a)(1). For vehicles without manually operated driving controls, the midsagittal	Considers the potential for more than one passenger DSP in the front row (e.g., vehicles without a driver’s DSP). The center of the head restraint is used as an alternative landmark to the

FMVSS No. 214, S12.1.2 Positioning a Part 572 Subpart F (SID) dummy in the front outboard seating position.			
Regulatory Text	**Translation Options**		**Potential Considerations**
positioned in the driver position under S12.1.1(a)(1). (2) For a bucket seat. The upper torso of the test dummy rests against the seat back. The midsagittal plane of the test dummy is vertical and parallel to the vehicle's longitudinal centerline, and coincides with the longitudinal centerline of the bucket seat.		plane of the test dummy passes through the longitudinal centerline of the head restraint of the seat it occupies…	steering wheel for ADS-DVs.

<table>
<tr><th colspan="4">FMVSS No. 214, S12.1.3 Positioning a Part 572 Subpart F (SID) dummy in the rear outboard seating positions</th></tr>
<tr><th>Regulatory Text</th><th colspan="2">Translation Options</th><th>Potential Considerations</th></tr>
<tr><td rowspan="2">(a) Torso. Hold the dummy’s head in place and push laterally on the non-impacted side of the upper torso in a single stroke with a force of 66.7-89.0 N (15-20 lb) towards the impacted side.
(1) For a bench seat. The upper torso of the test dummy rests against the seat back. The midsagittal plane of the test dummy is vertical and parallel to the vehicle’s longitudinal centerline, and, if possible, the same distance from the vehicle’s longitudinal centerline as the midsagittal plane of a test dummy positioned in the driver position under S12.1.1(a)(1). If it is not possible to position the test dummy so that its midsagittal plane is parallel to the vehicle longitudinal centerline and is at this distance from the vehicle’s longitudinal centerline, the test dummy is positioned so that some portion of the test dummy just touches, at or above the seat level, the side surface of the vehicle, such as the upper quarter panel, an armrest, or</td><td>Option 1</td><td>…(1) For a bench seat. The upper torso of the test dummy rests against the seat back. The midsagittal plane of the test dummy is vertical and parallel to the vehicle’s longitudinal centerline, and, if possible, the same distance from the vehicle’s longitudinal centerline as the midsagittal plane of a test dummy positioned in the driver designated seating position under S12.1.1(a)(1) or left front passenger’s designated seating position under S12.1.2(a)(1) in vehicles not equipped with manually operated driving controls…</td><td>Whether or not a driver DSP is present, the positioning of the midsagittal plane for the rear passenger dummies should be consistent with the front passenger position(s) in S12.1.2.</td></tr>
<tr><td>Option 2</td><td>…(1) For a bench seat. The upper torso of the test dummy rests against the seat back. The midsagittal plane of the test dummy is vertical and parallel to the vehicle's longitudinal centerline, and, if possible, the same distance from the vehicle's longitudinal centerline as the midsagittal plane in the driver’s designated seating position under S12.1.1(a)(1), if there is a driver designated seating position. Otherwise, the midsagittal plane of the dummy shall pass through the center of the SgRP of the seat it occupies…</td><td>The driver DSP positioning procedure is used if it exists. Otherwise, the SgRP is used as an alternative landmark for the center of the steering wheel for ADS-DVs.</td></tr>
</table>

FMVSS No. 214, S12.1.3 Positioning a Part 572 Subpart F (SID) dummy in the rear outboard seating positions			
Regulatory Text	**Translation Options**		**Potential Considerations**
any interior trim (i.e., either the broad trim panel surface or a smaller, localized trim feature).	**Option 3**	…(1) For a bench seat. The upper torso of the test dummy rests against the seat back. The midsagittal plane of the test dummy is vertical and parallel to the vehicle's longitudinal centerline, and, if possible, the same distance from the vehicle's longitudinal centerline as the midsagittal plane in the driver designated seating position under S12.1.1(a)(1), if there is a driver designated seating position. Otherwise, the midsagittal plane of the dummy shall pass through the longitudinal centerline of the head restraint of the seat it occupies…	The driver DSP positioning procedure is used if it exists. Otherwise, the head restraint is used as an alternative landmark for the center of the steering wheel for ADS-DVs.

FMVSS No. 214, S12.2.1 Positioning an ES-2re dummy in all seating positions.			
Regulatory Text	**Translation Options**		**Potential Considerations**
Position a correctly configured ES-2re test dummy, conforming to the applicable requirements of part 572 of this chapter, in the front outboard seating position on the side of the test vehicle to be struck by the moving deformable barrier or pole. Restrain the test dummy using all available belt systems in the seating positions where the belt restraints are provided. Place any adjustable anchorages at the manufacturer's nominal design position for a 50th percentile adult male occupant. Retract any folding armrest. (a) Upper torso. (1) The plane of symmetry of the dummy coincides with the vertical median plane of the specified seating position. (2) Bend the upper torso forward and then lay it back against the seat back. Set the shoulders of the dummy fully rearward. (b) Pelvis. Position the pelvis of the dummy according to the following: (1) Position the pelvis of the dummy such that a lateral line passing through the dummy H-points is perpendicular to the longitudinal center plane of the seat. The line through the dummy H-points is horizontal with a maximum inclination of ±2 degrees. The dummy may be equipped with tilt sensors in the thorax and the pelvis. These instruments can help to obtain the desired position. (2) The correct position of the dummy pelvis may be checked relative to the H-point of the H-point Manikin by using the M3 holes in the H-point back plates at each side of the ES-2re pelvis. Position the dummy such that the M3 holes are located	**Option 1**	...(c) Arms. For the driver's designated seating position and for any front outboard passenger seating position, place the dummy's upper arms...	Uses working definitions. Would apply to current vehicles and ADS-DVs.
	Option 2	...(c) Arms. For any front outboard seating position, place the dummy's...	Removes driver/passenger references.

FMVSS No. 214, S12.2.1 Positioning an ES-2re dummy in all seating positions.			
Regulatory Text	**Translation Options**		**Potential Considerations**
within a circle of radius 10 mm (0.39 in.) around the H-point of the H-point Manikin. (c) Arms. For the driver seating position and for the front outboard passenger seating position, place the dummy's upper arms such that the angle between the projection of the arm centerline on the mid-sagittal plane of the dummy and the torso reference line is 40° ±5°. The torso reference line is defined as the thoracic spine centerline. The shoulder-arm joint allows for discrete arm positions at 0, 40, and 90 degree settings forward of the spine. (d) Legs and Feet. Position the legs and feet of the dummy according to the following: (1) For the driver's seating position, without inducing pelvis or torso movement, place the right foot of the dummy on the un-pressed accelerator pedal with the heel resting as far forward as possible on the floor pan. Set the left foot perpendicular to the lower leg with the heel resting on the floor pan in the same lateral line as the right heel. Set the knees of the dummy such that their outside surfaces are 150 ±10 mm (5.9 ±0.4 inches) from the plane of symmetry of the dummy. If possible within these constraints, place the thighs of the dummy in contact with the seat cushion. (2) For other seating positions, without inducing pelvis or torso movement, place the heels of the dummy as far forward as possible on the floor pan without compressing the seat cushion more than the compression due to the weight of the leg. Set the knees of the dummy such that their outside			

FMVSS No. 214, S12.2.1 Positioning an ES-2re dummy in all seating positions.			
Regulatory Text	**Translation Options**		**Potential Considerations**
surfaces are 150 ±10 mm (5.9 ±0.4 inches) from the plane of symmetry of the dummy.			

FMVSS No. 214, S12.3.1 General provisions and definitions.			
Regulatory Text	**Translation Options**		**Potential Considerations**
(a) Measure all angles with respect to the horizontal plane unless otherwise stated. (b) Adjust the SID-IIs dummy's neck bracket to align the zero degree index marks. (c) Other seat adjustments. The longitudinal centerline of a bucket seat cushion passes through the SgRP and is parallel to the longitudinal centerline of the vehicle. (d) Driver and passenger manual belt adjustment. Use all available belt systems. Place adjustable belt anchorages at the nominal position for a 5th percentile adult female suggested by the vehicle manufacturer. (e) Definitions. (1) The term "midsagittal plane" refers to the vertical plane that separates the dummy into equal left and right halves. (2) The term "vertical longitudinal plane" refers to a vertical plane parallel to the vehicle's longitudinal centerline. (3) The term "vertical plane" refers to a vertical plane, not necessarily parallel to the vehicle's longitudinal centerline. (4) The term "transverse instrumentation platform" refers to the transverse instrumentation surface inside the dummy's skull casting to which the neck load cell mounts. This surface is perpendicular to the skull cap's machined inferior-superior mounting surface. (5) The term "thigh" refers to the femur between, but not including, the knee and the pelvis. (6) The term "leg" refers to the lower part of the entire leg including the knee.	**Option 1**	...(d) Manual belt adjustment. Use all available belt systems. Place adjustable belt anchorages at the nominal position for a 5th percentile adult female suggested by the vehicle manufacturer...	Removes driver/passenger references.
	Option 2	...(d) Driver and passenger dummy manual belt adjustment...	Clarifies that manual belt adjustments are being made for dummy positioning.

FMVSS No. 214, S12.3.1 General provisions and definitions.			
Regulatory Text	**Translation Options**		**Potential Considerations**
(7) The term “foot” refers to the foot, including the ankle. (8) For leg and thigh angles, use the following references: (i) Thigh—a straight line on the thigh skin between the center of the 1⁄2 -13 UNC-2B tapped hole in the upper leg femur clamp and the knee pivot shoulder bolt. (ii) Leg—a straight line on the leg skin between the center of the ankle shell and the knee pivot shoulder bolt. (9) The term “seat cushion reference point” (SCRP) means a point placed on the outboard side of the seat cushion at a horizontal distance between 150 mm (5.9 in) and 250 mm (9.8 in) from the front edge of the seat used as a guide in positioning the seat. (10) The term “seat cushion reference line” means a line on the side of the seat cushion, passing through the seat cushion reference point, whose projection in the vehicle vertical longitudinal plane is straight and has a known angle with respect to the horizontal.			

FMVSS No. 214, S12.3.2 5th percentile female driver dummy positioning.			
Regulatory Text	**Translation Options**		**Potential Considerations**
(a) Driver torso/head/seat back angle positioning. (1) With the seat in the position determined in S10.3.2, use only the control that moves the seat fore and aft to place the seat in the rearmost position. If the seat cushion reference line angle automatically changes as the seat is moved from the full forward position, maintain, as closely as possible, the seat cushion reference line angle determined in S10.3.2.3.3, for the final forward position when measuring the pelvic angle as specified in S12.3.2(a)(11). The seat cushion reference line angle position may be achieved through the use of any seat or seat cushion adjustments other than that which primarily moves the seat or seat cushion fore-aft. (2) Fully recline the seat back, if adjustable. Install the dummy into the driver's seat, such that when the legs are positioned 120 degrees to the thighs, the calves of the legs are not touching the seat cushion. (3) Bucket seats. Center the dummy on the seat cushion so that its midsagittal plane is	**Option 1**	..(4) Bench seats. Position the midsagittal plane of the dummy vertical and parallel to the vehicle's longitudinal centerline and aligned within ±10 mm (±0.4 in) of the center of the steering control rim... …(8)…If either of the dummy's legs first contacts the steering control, then adjust the steering control, if adjustable, upward until contact with the steering control is avoided. If the steering control is not adjustable, separate the knees enough to avoid steering control contact…If the steering control was moved, return it to the position described in S10.5. If the steering control contacts the dummy's leg(s) prior to attaining this position, … …(9) Head leveling… (ii) Vehicles with adjustable seat backs…(If the torso contacts the steering control, use S12.3.2(a)(10) before proceeding with the remaining portion of this	Uses working definitions for "driver dummy" and "passenger dummy." May consider translating “rim” to another term (e.g., “perimeter”) since “wheel” is translated to "control". All steering controls may not fit this standard based on potentially different designs.

FMVSS No. 214, S12.3.2 5th percentile female driver dummy positioning.			
Regulatory Text	**Translation Options**		**Potential Considerations**
vertical and passes through the SgRP within ±10 mm (±0.4 in). (4) Bench seats. Position the midsagittal plane of the dummy vertical and parallel to the vehicle's longitudinal centerline and aligned within ±10 mm (±0.4 in) of the center of the steering wheel rim. (5) Hold the dummy's thighs down and push rearward on the upper torso to maximize the dummy's pelvic angle. (6) Place the legs at 120 degrees to the thighs. Set the initial transverse distance between the longitudinal centerlines at the front of the dummy's knees at 160 to 170 mm (6.3 to 6.7 in), with the thighs and legs of the dummy in vertical planes. Push rearward on the dummy's knees to force the pelvis into the seat so there is no gap between the pelvis and the seat back or until contact occurs between the back of the dummy's calves and the front of the seat cushion. (7) Gently rock the upper torso relative to the lower torso laterally in a side to side motion three times through a ±5 degree arc (approximately 51 mm (2 in) side to side).		paragraph.)… …(10) If the torso contacts the steering control, adjust the steering control in the following order until there is no contact: telescoping adjustment, lowering adjustment, raising adjustment. If the vehicle has no adjustments or contact with the steering control cannot be eliminated by adjustment, position the seat at the next detent where there is no contact with the steering control as adjusted in S10.5…	

(8) If needed, extend the legs slightly so that the feet are not in contact with the floor pan. Let the thighs rest on the seat cushion to the extent permitted by the foot movement. Keeping the leg and the thigh in a vertical plane, place the foot in the vertical longitudinal plane that passes through the centerline of the accelerator pedal. Rotate the left thigh outboard about the hip until the center of the knee is the same distance from the midsagittal plane of the dummy as the right knee ±5 mm (±0.2 in). Using only the control that moves the seat fore and aft, attempt to return the seat to the full forward position. If either of the dummy's legs first contacts the steering wheel, then adjust the steering wheel, if adjustable, upward until contact with the steering wheel is avoided. If the steering wheel is not adjustable, separate the knees enough to avoid steering wheel contact. Proceed with moving the seat forward until either the leg contacts the vehicle interior or the seat reaches the full forward position. (The right foot may contact and depress the accelerator and/or change the angle of the foot with respect to the leg during seat movement.) If necessary to avoid contact with the vehicle's brake or clutch pedal, rotate the test dummy's left foot about			

the leg. If there is still interference, rotate the left thigh outboard about the hip the minimum distance necessary to avoid pedal interference. If a dummy leg contacts the vehicle interior before the full forward position is attained, position the seat at the next detent where there is no contact. If the seat is a power seat, move the seat fore and aft to avoid contact while assuring that there is a maximum of 5 mm (0.2 in) distance between the vehicle interior and the point on the dummy that would first contact the vehicle interior. If the steering wheel was moved, return it to the position described in S10.5. If the steering wheel contacts the dummy's leg(s) prior to attaining this position, adjust it to the next higher detent, or if infinitely adjustable, until there is 5 mm (0.2 in) clearance between the wheel and the dummy's leg(s). (9) Head leveling. (i) Vehicles with fixed seat backs. Adjust the lower neck bracket to level the transverse instrumentation platform angle of the head to within ±0.5 degrees. If it is not possible to level the transverse instrumentation platform to within ±0.5 degrees, select the neck bracket adjustment position that minimizes the difference between the transverse			

instrumentation platform angle and level. (ii) Vehicles with adjustable seat backs. While holding the thighs in place, rotate the seat back forward until the transverse instrumentation platform angle of the head is level to within ±0.5 degrees, making sure that the pelvis does not interfere with the seat bight. (If the torso contacts the steering wheel, use S12.3.2(a)(10) before proceeding with the remaining portion of this paragraph.) If it is not possible to level the transverse instrumentation platform to within ±0.5 degrees, select the seat back adjustment position that minimizes the difference between the transverse instrumentation platform angle and level, then adjust the neck bracket to level the transverse instrumentation platform angle to within ±0.5 degrees if possible. If it is still not possible to level the transverse instrumentation platform to within ±0.5 degrees, select the neck bracket angle position that minimizes the difference between the transverse instrumentation platform angle and level. (10) If the torso contacts the steering wheel, adjust the steering wheel in the following order until there is no contact: telescoping adjustment, lowering adjustment, raising adjustment. If the			

FMVSS No. 214, S12.3.2 5th percentile female driver dummy positioning.			
Regulatory Text	**Translation Options**		**Potential Considerations**
vehicle has no adjustments or contact with the steering wheel cannot be eliminated by adjustment, position the seat at the next detent where there is no contact with the steering wheel as adjusted in S10.5. If the seat is a power seat, position the seat to avoid contact while assuring that there is a maximum of 5 mm (0.2 in) distance between the steering wheel as adjusted in S10.5 and the point of contact on the dummy. ….			

FMVSS No. 214, S12.3.3 5th percentile female front passenger dummy positioning.			
Regulatory Text		**Translation Options**	**Potential Considerations**
(a) Passenger torso/head/seat back angle positioning. (1) With the seat at the mid-height in the full-forward position determined in S10.3.2, use only the control that primarily moves the seat fore and aft to place the seat in the rearmost position, without adjusting independent height controls. If the seat cushion reference line angle automatically changes as the seat is moved from the full forward position, maintain, as closely as possible, the seat cushion reference line angle determined in S10.3.2.3.3, for the final forward position when measuring the pelvic angle as specified in S12.3.3(a)(11). The seat cushion reference line angle position may be achieved through the use of any seat or seat cushion adjustments other than that which primarily moves the seat or seat cushion fore-aft. (2) Fully recline the seat back, if adjustable. Place the dummy into the passenger's seat, such that when the legs are positioned 120 degrees to the thighs, the calves of the legs are not touching the seat cushion. (3) Bucket seats. Place the dummy on the seat cushion so that its midsagittal plane is vertical and passes through the SgRP within ±10 mm (±0.4 in). (4) Bench seats. Position the midsagittal plane of the dummy vertical and parallel to the vehicle's longitudinal centerline and the same distance from the vehicle's longitudinal centerline, within ±10 mm (±0.4 in), as the midsagittal plane of the driver dummy. (5) Hold the dummy's thighs down and push rearward on the upper torso to maximize the dummy's pelvic angle.	**Option 1**	...(2) Fully recline the seat back, if adjustable. Place the dummy into any front passenger's seat, ... (4) Bench seats. Position the midsagittal plane of the dummy vertical and parallel to the vehicle's longitudinal centerline. For vehicles equipped with manually operated driving controls, the midsagittal plane of the test dummy is the same distance from the vehicle's longitudinal centerline, within ±10 mm (±0.4 in), as the midsagittal plane of the driver's dummy. For vehicles not equipped with manually operated driving controls, the midsagittal plane of the test dummy passes through the center any front outboard passenger seat's SgRP .	The translation of (a)(4) should be consistent with S12.1.2.

FMVSS No. 214, S12.3.3 5th percentile female front passenger dummy positioning.			
Regulatory Text		Translation Options	Potential Considerations
(6) Place the legs at 120 degrees to the thighs. Set the initial transverse distance between the longitudinal centerlines at the front of the dummy's knees at 160 to 170 mm (6.3 to 6.7 in), with the thighs and legs of the dummy in vertical planes. Push rearward on the dummy's knees to force the pelvis into the seat so there is no gap between the pelvis and the seat back or until contact occurs between the back of the dummy's calves and the front of the seat cushion. (7) Gently rock the upper torso relative to the lower torso laterally in a side to side motion three times through a ±5 degree arc (approximately 51 mm (2 in) side to side). (8) If needed, extend the legs slightly so that the feet are not in contact with the floor pan. Let the thighs rest on the seat cushion to the extent permitted by the foot movement. With the feet perpendicular to the legs, place the heels on the floor pan. If a heel will not contact the floor pan, place it as close to the floor pan as possible. Using only the control that primarily moves the seat fore and aft, attempt to return the seat to the full forward position. If a dummy leg contacts the vehicle interior before the full forward position is attained, position the seat at the next detent where there is no contact. If the seats are power seats, position the seat to avoid contact while assuring that there is a maximum of 5 mm (0.2 in) distance between the vehicle interior and the point on the dummy that would first contact the vehicle interior. (9) Head leveling. (i) Vehicles with fixed seat backs. Adjust the lower neck bracket to level the transverse instrumentation platform angle of the			

FMVSS No. 214, S12.3.3 5th percentile female front passenger dummy positioning.			
Regulatory Text		Translation Options	Potential Considerations
head to within ±0.5 degrees. If it is not possible to level the transverse instrumentation platform to within ±0.5 degrees, select the neck bracket adjustment position that minimizes the difference between the transverse instrumentation platform angle and level. (ii) Vehicles with adjustable seat backs. While holding the thighs in place, rotate the seat back forward until the transverse instrumentation platform angle of the head is level to within ±0.5 degrees, making sure that the pelvis does not interfere with the seat bight. If it is not possible to level the transverse instrumentation platform to within ±0.5 degrees, select the seat back adjustment position that minimizes the difference between the transverse instrumentation platform angle and level, then adjust the neck bracket to level the transverse instrumentation platform angle to within ±0.5 degrees if possible. If it is still not possible to level the transverse instrumentation platform to within ±0.5 degrees, select the neck bracket angle position that minimizes the difference between the transverse instrumentation platform angle and level. (10) Measure and set the dummy's pelvic angle using the pelvic angle gage. The angle is set to 20.0 degrees ±2.5 degrees. If this is not possible, adjust the pelvic angle as close to 20.0 degrees as possible while keeping the transverse instrumentation platform of the head as level as possible by adjustments specified in S12.3.2(a)(9). (11) If the dummy is contacting the vehicle interior after these adjustments, move the seat rearward until there is a maximum			

FMVSS No. 214, S12.3.3 5th percentile female front passenger dummy positioning.			
Regulatory Text		Translation Options	Potential Considerations
of 5 mm (0.2 in) between the contact point of the dummy and the interior of the vehicle or if it has a manual seat adjustment, to the next rearward detent position. If after these adjustments, the dummy contact point is more than 5 mm (0.2 in) from the vehicle interior and the seat is still not in its forwardmost position, move the seat forward until the contact point is 5 mm (0.2 in) or less from the vehicle interior, or if it has a manual seat adjustment, move the seat to the closest detent position without making contact, or until the seat reaches its forwardmost position, whichever occurs first. (b) Passenger foot positioning. (1) Place the front passenger's feet flat on the toe board. (2) If the feet cannot be placed flat on the toe board, set them perpendicular to the leg center lines and place them as far forward as possible with the heels resting on the floor pan. (3) If either foot does not contact the floor pan, place the foot parallel to the floor pan and place the lower leg as perpendicular to the thigh as possible. (c) Passenger arm/hand positioning. Place the dummy's upper arm such that the angle between the projection of the arm centerline on the midsagittal plane of the dummy and the torso reference line is 45° ±5°. The torso reference line is defined as the thoracic spine centerline. The shoulder-arm joint allows for discrete arm positions at 0, ±45, ±90, ±135, and 180 degree settings where positive is forward of the spine.			

FMVSS No. 216a: Roof Crush Resistance; Upgraded Standard

Technical Translation Options Summary: *The purpose of this FMVSS is "to reduce deaths and injuries due to the crushing of the roof into the occupant compartment in rollover crashes." (S2)*

Technical translation options are for conventional seating and non-bidirectional vehicles only. Therefore, the focus for translation is to ensure that passenger compartment roof strength requirements are maintained for automated driving system-dedicated vehicles (ADS-DVs) while simultaneously being uncompromised for conventional vehicles.

FMVSS No. 216a, S7.1 Test Procedure.			
Regulatory Text	**Translation Options**		**Potential Considerations**
Support the vehicle off its suspension and rigidly secure the sills and the chassis frame (when applicable) of the vehicle on a rigid horizontal surface(s) at a longitudinal attitude of 0 degrees ±0.5 degrees. Measure the longitudinal vehicle attitude along both the driver and passenger sill. Determine the lateral vehicle attitude by measuring the vertical distance between a level surface and a standard reference point on the bottom of the driver and passenger side sills. The difference between the vertical distance measured on the driver side and the passenger side sills is not more than ±10 mm. Close all windows, close and lock all doors, and close and secure any moveable roof panel, moveable shade, or removable roof structure in place over the occupant compartment. Remove roof racks or other non-structural components. For a vehicle built on a chassis-cab incomplete vehicle that	**Option 1**	...Measure the longitudinal vehicle attitude along both the left and right sill. Determine the lateral vehicle attitude by measuring the vertical distance between a level surface and a standard reference point on the bottom of the left and right side sills. The difference between the vertical distance measured on the left side and the right side sills is not more than ±10 mm...	This translation could also cover bidirectional vehicles. The purpose of left and right is to ensure the two sides of the vehicle are supported. For bidirectional vehicles, the left and right sides could simply switch.
	Option 2	...Measure the longitudinal vehicle attitude along both the left and right sill. Determine the lateral vehicle attitude by measuring the vertical distance between a level surface and a standard reference point on the bottom of the left and right side sills. The difference between the vertical distance measured on the left side and the right side sills is not more than ±10	Includes language to remove sensors and housings that may be mounted on the roof of an ADS-DV. Option 2 may not be necessary since the

FMVSS No. 216a, S7.1 Test Procedure.			
Regulatory Text	Translation Options		Potential Considerations
has some portion of the added body structure above the height of the incomplete vehicle, remove the entire added body structure prior to testing (the vehicle's unloaded vehicle weight as specified in S5 includes the weight of the added body structure).		mm...Remove roof racks or other non-structural components, including sensors and housings mounted on the roof that are part of the vehicle's automated driving system. For a vehicle built on...	current regulatory text already states that "non-structural components" are to be removed. The current text may be sufficient to address ADS components.

FMVSS No. 222: School Bus Passenger Seating and Crash Protection

Technical Translation Options Summary: *The purpose of this FMVSS is "to reduce the number of deaths and the severity of injuries that result from the impact of school bus occupants against structures within the vehicle during crashes and sudden driving maneuvers." (S2) Technical translation options are for conventional seating and non-bidirectional vehicles only. Therefore, the focus for the translation is to maintain current occupant protection requirements for automated driving system (ADS)-equipped school buses while simultaneously being uncompromised for school buses with manually operated driving controls.*

FMVSS No. 222, S4. Definitions.			
Regulatory Text	**Translation Options**		**Potential Considerations**
School bus passenger seat means a seat in a school bus, other than the driver's seat.	**Option 1**	Retain current language.	Uses Option 2 for driver in the working definitions.
	Option 2	...other than a seat intended for use by a human driver.	The use of working definitions for "driver" is not necessary.

FMVSS No. 225: Child Restraint Anchorage Systems

Technical Translation Options Summary: *This FMVSS "establishes requirements for child restraint anchorage systems to ensure their proper location and strength for the effective securing of child restraints, to reduce the likelihood of the anchorage systems' failure, and to increase the likelihood that child restraints are properly secured and thus more fully achieve their potential effectiveness in motor vehicles." (S1)*

Technical translation options are for conventional seating and non-bidirectional vehicles only. Therefore, the focus for the translation is to ensure the proper location and strength requirements are maintained for ADS-DVs while simultaneously being uncompromised for vehicles with manually operated driving controls.

FMVSS No. 225, S3. Definitions.			
Regulatory Text	**Translation Options**		**Potential Considerations**
Shuttle bus means a bus with only one row of forward-facing seating positions rearward of the driver's seat.	**Option 1**	...rearward of the driver's seat or the left front outboard seat in a vehicle without manually operated driving controls.	Uses driver's seat definition in working definitions. Does not change current requirement for vehicles with a human driver, but provides translation for automated driving system-dedicated vehicles (ADS-DVs).
	Option 2	...rearward of the driver's seat in a vehicle that can be operated by a human driver, or, rearward of the left front outboard seat in a vehicle without manually operated driving controls.	Similar to Option 1 but not necessary to add any definitions.

FMVSS No. 226: Ejection Mitigation

Technical Translation Options Summary: *The purpose of this FMVSS is "to reduce the likelihood of complete and partial ejections of vehicle occupants through side windows during rollovers or side impact events." (S1)*

Technical translation options are for conventional seating and non-bidirectional vehicles only. Therefore, the focus of the translation is to ensure that the requirements for ejection mitigation systems are maintained for automated driving system-dedicated vehicles (ADS-DVs) while simultaneously being uncompromised for conventional vehicles.

FMVSS No. 226, S3. Definitions.			
Regulatory Text	**Translation Options**		**Potential Considerations**
Modified roof means the replacement roof on a motor vehicle whose original roof has been removed, in part or in total, or a roof that has to be built over the driver's compartment in vehicles that did not have an original roof over the driver's compartment.	**Option 1**	…a roof that has to be built over the occupant compartment in vehicles that did not have an original roof over the occupant compartment.	The term "occupant compartment" is used since it is more encompassing than "driver's compartment."

FMVSS No. 226, S3. Definitions.			
Regulatory Text	**Translation Options**		**Potential Considerations**
Walk-in van means a special cargo/mail delivery vehicle that only has a driver designated seating position. The vehicle has a sliding (or folding) side door and a roof clearance that enables a person of medium stature to enter the passenger compartment area in an up-right position.	**Option 1**	*Walk-in* van means a special cargo/mail delivery vehicle that only has a driver designated seating position, a single passenger designated seating position, or no designated seating positions…	No further translation is necessary if the definition for driver's DSP (Driver's Seat) is added, as suggested in Option 1. This translation should be consistent with the definition for "Walk-In Van" in FMVSS No. 214.

FMVSS No. 226, S4.2.2 Performance and other requirements.			
Regulatory Text	**Translation Options**		**Potential Considerations**
Vehicles that have an ejection mitigation countermeasure that deploys in the event of a rollover must have a monitoring system with a readiness indicator. The indicator shall monitor its own readiness and must be clearly visible from the driver's designated seating position. The same readiness indicator required by S4.5.2 of FMVSS No. 208 may be used to meet the requirement. A list of the elements of the system being monitored by the indicator shall be included with the information furnished in accordance with S4.2.3.	**Option 1**	...clearly visible from the driver's designated seating position and clearly visible from any designated seating position if the driver's designated seating position is not occupied or present. For vehicles without manually operated driving controls that are operated by an ADS, the telltale shall monitor its own readiness and shall communicate the underlying condition to the ADS. The same readiness indicator...	Uses definition of driver's DSP. Expands applicability of requirement. No longer assumes front row is preferred seating position for ADS-DVs, potentially assuring an occupant that an ADS would receive the warning. For vehicles equipped with manually operated driving controls, this translation would ensure someone receives the telltale if the driver's seat is present but not occupied, i.e., steering controls are present but the occupant is seated in the passenger seat.
	Option 2	...clearly visible from the driver's designated seating position and clearly visible from any front designated seating position if the driver's designated seating position is not occupied or present. For vehicles without manually operated driving controls that are operated by an ADS, the telltale shall monitor its own readiness and shall communicate the	Uses definition of driver's DSP. Expands applicability of requirement. For dual-mode vehicles, this translation would ensure someone receives the telltale if the driver's seat is present but not occupied, i.e., steering controls are present but the occupant is seated in the passenger seat.

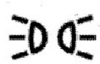
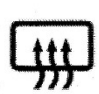
FMVSS No. 226, S4.2.2 Performance and other requirements.			
Regulatory Text	**Translation Options**		**Potential Considerations**
		underlying condition to the ADS. The same readiness indicator...	The warning may not be received by any occupant in an ADS-DV.
	Option 3	...clearly visible from the driver's designated seating position and clearly visible from the front left designated seating position if the driver's designated seating position is not occupied or present. For vehicles without manually operated driving controls that are operated by an ADS, the telltale shall monitor its own readiness and shall communicate the underlying condition to the ADS. The same readiness indicator...	Maintains preference for left front seat. The warning may not be received by any occupant in an ADS-DV.
	Option 4	...clearly visible from the driver's designated seating position. For vehicles without manually operated driving controls that are operated by an ADS, the telltale shall monitor its own readiness and shall communicate the underlying condition to the ADS.	A test procedure to verify an action is taken by the ADS may be necessary. Vehicle could operate in fault condition without occupants of the vehicle being aware/notified.

FMVSS No. 226, S6.1 Vehicle test attitude			
Regulatory Text	**Translation Options**		**Potential Considerations**
The vehicle is supported off its suspension at an attitude determined in accordance with S6.1(a) through (f). (a) The vehicle is loaded to its unloaded vehicle weight. (b) All tires are inflated to the manufacturer's specifications listed on the vehicle's tire placard. (c) Place vehicle on a level surface. (d) Pitch: Measure the sill angle of the driver door sill and mark where the angle is measured. (e) Roll: Mark a point on the vehicle body above the left and right front wheel wells. Determine the vertical height of these two points from the level surface. (f) Support the vehicle off its suspension such that the driver door sill angle is within ±1 degree of that measured at the marked area in S6.1(d) and the vertical height difference of the two points marked in S6.1(e) is within ±5 mm of the vertical height difference determined in S6.1(e).	**Option 1**	…(d) Pitch: Measure the sill angle of the left front door sill and mark where the angle is measured. (f) Support the vehicle off its suspension such that the left front door sill angle is…	Removes reference to driver.

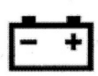
FMVSS No. 226, S6.3 Steering wheel, steering column, seats, grab handles, and exterior mirrors.			
Regulatory Text	**Translation Options**		**Potential Considerations**
During targeting and testing, the steering wheel, steering column, seats, grab handles and exterior mirrors may be removed from the vehicle or adjusted to facilitate testing and/or provide an unobstructed path for headform travel through and beyond the vehicle.	**Option 1**	Retain current language.	Although a steering wheel is referenced, it is part of a list of equipment that may be removed for the compliance test(s) in FMVSS No. 226. This equipment may not be included in an ADS-DV.
	Option 2	… the steering wheel, steering column, steering controls, seats, grab handles, and exterior mirrors.	Includes steering controls for ADS-equipped vehicles that do not have a steering wheel and/or steering column.

Appendix C. Telltale Tables From FMVSS No. 101

Table 1
Controls, Telltales, and Indicators
With Illumination or Color Requirements[1]

Column 1 ITEM	Column 2 SYMBOL	Column 3 WORDS OR ABBRE-VIATIONS	Column 4 FUNCTION	Column 5 ILLUMIN-ATION	Column 6 COLOR
Highbeam [2]	 3, 5	-------	Telltale	-------	Blue or Green [4]
Turn signals [2]	 3, 6	-------	Control	-------	-------
			Telltale	-------	Green [4]
Hazard warning signal	 3	Hazard	Control	Yes	-------
		-------	Telltale [7]	-------	-------
Position, side marker, end-outline marker, identification, or clearance lamps	 3,8	Marker Lamps or MK Lps [8]	Control	Yes	-------
Windshield wiping system		Wiper or Wipe	Control	Yes	-------
Windshield washing system		Washer or Wash	Control	Yes	-------
Windshield washing and wiping system combined		Washer-Wiper or Wash-Wipe	Control	Yes	-------
Windshield defrosting and defogging system		Defrost, Defog, or Def.	Control	Yes	-------
Rear window defrosting and defogging system		Rear Defrost, Rear Defog, Rear Def., or R-Def.	Control	Yes	-------

Column 1 ITEM	Column 2 SYMBOL	Column 3 WORDS OR ABBRE-VIATIONS	Column 4 FUNCTION	Column 5 ILLUMIN-ATION	Column 6 COLOR
Brake system malfunction	-------	Brake	Telltale	-------	Red [4]
Antilock brake system malfunction for vehicles subject to FMVSS 105 or 135	-------	Antilock, Anti-lock, or ABS [9]	Telltale	-------	Yellow
Malfunction in Variable Brake Proportioning System	-------	Brake Proportioning [9]	Telltale	-------	Yellow
Regenerative brake system malfunction	-------	RBS or ABS/RBS [9]	Telltale	-------	Yellow
Malfunction in antilock system for vehicles other than trailers subject to FMVSS 121	-------	ABS or Antilock [9]	Telltale	-------	Yellow
Antilock brake system trailer fault for vehicles subject to FMVSS 121		Trailer ABS or Trailer Antilock	Telltale	-------	Yellow
Brake pressure (for vehicles subject to FMVSS 105 or 135)	-------	Brake Pressure [9]	Telltale	-------	Red [4]
Low brake fluid condition (for vehicles subject to FMVSS 105 or 135)	-------	Brake Fluid [9]	Telltale	-------	Red [4]
Parking brake applied (for vehicles subject to FMVSS 105 or 135)	-------	Park or Parking Brake [9]	Telltale	-------	Red [4]
Brake lining wear-out condition (for vehicles subject to FMVSS 135)	-------	Brake Wear [9]	Telltale	-------	Red [4]
Electronic Stability Control System Malfunction (for vehicles subject to FMVSS 126) [10, 11]		ESC [12]	Telltale	-------	Yellow

Column 1 ITEM	Column 2 SYMBOL	Column 3 WORDS OR ABBRE-VIATIONS	Column 4 FUNCTION	Column 5 ILLUMIN-ATION	Column 6 COLOR
Electronic Stability Control System "OFF" (for vehicles subject to FMVSS 126) [10]		ESC OFF	Control	Yes	-------
			Telltale	-------	Yellow
Electronic Stability Control System Malfunction (for vehicles subject to FMVSS 136) [11]	 or  or 	ESC	Telltale	-------	Yellow
Fuel Level	 or 	Fuel	Telltale	-------	-------
			Indicator	Yes	-------
Engine oil pressure	 [13]	Oil	Telltale	-------	-------
			Indicator	Yes	-------
Engine coolant temperature	 [13]	Temp	Telltale	-------	-------
			Indicator	Yes	-------
Electrical charge		Volts or Charge or Amp	Telltale	-------	-------
			Indicator	Yes	-------
Engine stop	-------	Engine Stop [14]	Control	Yes	-------
Automatic vehicle speed (cruise control)	-------	-------	Control	Yes	-------

Column 1 ITEM	Column 2 SYMBOL	Column 3 WORDS OR ABBRE-VIATIONS	Column 4 FUNCTION	Column 5 ILLUMIN-ATION	Column 6 COLOR
Speedometer	-------	MPH, or MPH and km/h [15]	Indicator	Yes	-------
Heating and Air conditioning system	-------	-------	Control	Yes	-------
Automatic transmission control position *(park)* *(reverse)* *(neutral)* *(drive)*	-------	P R N D [16]	Indicator	Yes	-------
Heating and/or air conditioning fan	 or 	Fan	Control	Yes	-------
Low Tire Pressure (including malfunction) (See FMVSS 138)	 [17]	Low Tire [17]	Telltale	-------	Yellow
Low Tire Pressure (including malfunction that identifies involved tire) (See FMVSS 138)	 [17]	Low Tire [17]	Telltale	-------	Yellow
Tire Pressure Monitoring System Malfunction (See FMVSS 138) [18]	-------	TPMS [17, 19]	Telltale	-------	Yellow

Notes:

[1] An identifier is shown in this table if it is required for a control for which an illumination requirement exists or if it is used for a telltale for which a color requirement exists. If a line appears in column 2 and column 3, the control, telltale, or indicator is required to be identified, however the form of the identification is the manufacturer's option. Telltales are not considered to have an illumination requirement, because by definition the telltale must light when the condition for its activation exists.

[2] Additional requirements in FMVSS 108.

[3] Framed areas of the symbol may be solid; solid areas may be framed.

[4] Blue may be blue-green. Red may be red-orange.

[5] Symbols employing four lines instead of five may also be used.

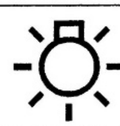
[6] The pair of arrows is a single symbol. When the controls or telltales for left and right turn operate independently, however, the two arrows may be considered separate symbols and be spaced accordingly.

[7] Not required when arrows of turn signal telltales that otherwise operate independently flash simultaneously as hazard warning telltale.

[8] Separate identification is not required if function is combined with master lighting switch.

[9] Refer to FMVSS 105 or FMVSS 135, as appropriate, for additional specific requirements for brake telltale labeling and color. If a single telltale is used to indicate more than one brake system condition, the brake system malfunction identifier must be used.
[10] Requirement effective September 1, 2011.
[11] A manufacturer may use this telltale in flashing mode to indicate ESC operation.
[12] This symbol may also be used to indicate the malfunction of related systems/functions, including traction control, trailer stability assist, corner brake control, and other similar functions that use throttle and/or individual wheel torque control to operate and share common components with ESC.
[13] Combination of the engine oil pressure symbol and the engine coolant temperature symbol in a single telltale is permitted.
[14] Use when engine control is separate from the key locking system.
[15] If the speedometer is graduated in both miles per hour and in kilometers per hour, the scales must be identified "MPH" and "km/h", respectively, in any combination of upper- and lowercase letters.
[16] The letters 'P', 'R', 'N', and 'D' are considered separate identifiers for the individual gear positions. Their locations within the vehicle, and with respect to each other, are governed by FMVSS 102. The letter 'D' may be replaced by another alphanumeric character or symbol chosen by the manufacturer.
[17] Required only for FMVSS 138 compliant vehicles.
[18] Alternatively, either low tire pressure telltale may be used to indicate a TPMS malfunction. See FMVSS 138.
[19] Required only for vehicles manufactured on or after September 1, 2007.

Table 2
Identifiers for Controls, Telltales and Indicators with No Color or Illumination Requirements

Column 1 ITEM	Column 2 SYMBOL	Column 3 WORD(S) OR ABBREVIATION
Hand Throttle Control	—	Throttle
Engine Start Control	—	Engine Start[1]
Manual Choke Control	—	Choke
Odometer	—	Kilometers or km, if kilometers are shown. Otherwise, no identifier is required. [2]
Horn		Horn
Master Lighting Switch	 [3]	Lights
Headlamps and Taillamps Control	—	— [4,5]
Low Brake Air Pressure Telltale (for vehicles subject to FMVSS 121)	—	Brake Air
Seat Belt Unfastened Telltale	 or 	Fasten Belts or Fasten Seat Belts

Notes:

1. Use when engine control is separate from the key locking system.
2. Any combination of upper- or lowercase letters may be used.
3. Framed areas may be filled.
4. If a line appears in Column 2 and Column 3, the Control, Telltale or Indicator is required to be identified, however the form of the identification is the manufacturer's option.
5. Separate identification not required if function is combined with Master Lighting Switch.

Appendix D. Analysis of Information Communicated in an ADS-DV

Notation	Meaning
X	Denotes category applicable to regulatory information being communicated in an ADS-DV
?	Technical translation includes options with and without a noted entity or system

FMVSS	Component	Information Communicated	Delivery Method				Intended For			Expected Response (after receiving the information)	Required	Expected Response Regulatory Citation	Citation Example	Relevance Considerations				Expected Response Owner Manual References
			Symbol	Telltale	Auditory Alert	Indicator	Human Driver	Passengers	Maintenance Entity					ADS	Occupant(s)	Maintenance Entity	Observations	
101	Fuel level	status/warning	X	X		X	X		X	Verify fuel level status and refill fuel tank to optimal level for trip	if equipped				?	?	If fuel level information is presented in an ADS-DV to the occupants and/or maintenance entity, it should be salient to the intended recipient. May be important for operational readiness.	**Ford, 2018a: pg. 97;** It will illuminate when the fuel level is low or the fuel tank is nearly empty. Refuel as soon as possible. ----- **Honda, 2018: pg. 26;** Refuel as soon as possible. If the indicator blinks, there is a problem with the fuel gauge. See your dealer. ----- **Toyota, 2018: pg. 500;** Indicates that remaining fuel is approximately 2.2 gallons. Refuel the vehicle.

FMVSS	Component	Information Communicated	Delivery Method				Intended For			Expected Response (after receiving the information)	Required	Expected Response Regulatory Citation	Citation Example	Relevance Considerations				Expected Response Owner Manual References
			Symbol	Telltale	Auditory Alert	Indicator	Human Driver	Passengers	Maintenance Entity					ADS	Occupant(s)	Maintenance Entity	Observations	
101	Engine oil pressure	status/warning	X	X		X	X		X	Verify the engine oil pressure status and check owner manual for steps to address low engine oil pressure telltale warning	if equipped				?	?	If engine oil pressure information is presented in an ADS-DV to the occupants and/or maintenance entity, it should be salient to the intended recipient. May be important for operational readiness.	**Ford, 2018a: pg. 113;** Stop your vehicle as soon as safely possible and turn off the engine. Check the oil level. If the warning stays on or continues to come on with your engine running, contact an authorized dealer as soon as possible. ----- **Honda, 2018: pg. 24;** Engine oil pressure is low. Stop in a safe place. Open the hood. Check the oil level and add oil if necessary (see page 134). If the indicator does not turn off, have your vehicle repaired immediately. ----- **Toyota, 2018: pg. 511;** The engine oil level may be low. Check the level of the engine oil, and add engine oil if necessary. This message may be displayed if the vehicle is stopped on a slope. Move the vehicle to a level surface and check if the message disappears.

FMVSS	Component	Information Communicated	Delivery Method				Intended For			Expected Response (after receiving the information)	Required	Expected Response Regulatory Citation	Citation Example	Relevance Considerations				Expected Response Owner Manual References
			Symbol	Telltale	Auditory Alert	Indicator	Human Driver	Passengers	Maintenance Entity					ADS	Occupant(s)	Maintenance Entity	Observations	
101	Engine coolant temperature	status/warning	X	X		X	X		X	Verify engine coolant temperature status and check owner manual for steps to address engine telltale warning	if equipped				?	?	If engine coolant temperature information is presented in an ADS-DV to the occupants and/or maintenance entity, it should be salient to the intended recipient. May be important for operational readiness.	**Ford, 2018a: pg. 90;** Shows the temperature of the engine coolant. At normal operating temperature, the needle will remain in the center section. If the needle enters the red section, the engine is overheating. Stop the engine, switch the ignition off and determine the cause once the engine has cooled down. ----- **Toyota, 2018: pg. 86;** The engine may be overheating if the engine coolant temperature gauge is in the red zone (H). In this case, immediately stop the vehicle in a safe place, and check the engine after it has cooled completely

FMVSS	Component	Information Communicated	Delivery Method				Intended For			Expected Response (after receiving the information)	Required	Expected Response Regulatory Citation	Citation Example	Relevance Considerations				Expected Response Owner Manual References
			Symbol	Telltale	Auditory Alert	Indicator	Human Driver	Passengers	Maintenance Entity					ADS	Occupant(s)	Maintenance Entity	Observations	
101	Electrical charge	status/warning	X	X		X	X		X	Verify electrical charge status and check owner manual for steps to take to address telltale warning	if equipped				?	?	If electrical charge information is presented in an ADS-DV to the occupants and/or maintenance entity, it should be salient to the intended recipient. May be important for operational readiness.	**Honda, 2018: pg. 24;** The battery is not charging. Turn off all electrical items, but do not turn off the vehicle to prevent further battery discharge. Have your vehicle repaired immediately. -----

FMVSS	Component	Information Communicated	Delivery Method				Intended For			Expected Response (after receiving the information)	Required	Expected Response Regulatory Citation	Citation Example	Relevance Considerations				Expected Response Owner Manual References
			Symbol	Telltale	Auditory Alert	Indicator	Human Driver	Passengers	Maintenance Entity					ADS	Occupant(s)	Maintenance Entity	Observations	
101	Engine Stop	n/a					X			Change engine stop state when engine control is separated from the key locking system	if equipped						Engine stop device is not mandated by FMVSS. The control enables the change in state or function.	**Ford, 2018a: pg. 147:** Turns the ignition off. Without applying the brake pedal, press and release the button once when the ignition is in the on mode, or when your vehicle is running but is not moving. ----- **Honda, 2018; pg.118:** The ENGINE START/STOP button may be used to stop the engine due to an emergency situation even while driving. If you must stop the engine, choose one of the following operations: Press and hold the ENGINE START/STOP button for two seconds, or firmly press the ENGINE START/STOP button three times. ----- **Toyota, 2018; pg. 488:** If the engine has to be turned off while driving: Power assist for the brakes and steering wheel will be lost, making the brake pedal harder to depress and the steering wheel heavier to turn, then decelerate as much as possible before turning off the engine. For vehicles without a smart key system, never attempt to remove the key, as doing so will lock the steering wheel.

FMVSS	Component	Information Communicated	Delivery Method				Intended For			Expected Response (after receiving the information)	Required	Expected Response Regulatory Citation	Citation Example	Relevance Considerations				Expected Response Owner Manual References
			Symbol	Telltale	Auditory Alert	Indicator	Human Driver	Passengers	Maintenance Entity					ADS	Occupant(s)	Maintenance Entity	Observations	
101	Automatic vehicle speed (cruise control)	n/a					X			Change cruise control state	if equipped						Cruise control device is not mandated by FMVSS. The control enables the change the state or function.	**Ford, 2018a: pg. 92;** [Telltale] will illuminate when you switch this feature on. ----- **Honda, 2018: pg. 27;** Cruise control is on -----
101	Speedometer	status				X	X			Verify current speed (control)	if equipped						Speedometer is not mandated by FMVSS. The indicator provides the vehicle's speed magnitude. Occupants may want to know the speed of the ADS-DV is traveling. However, this could be consider comfort and beyond the project scope.	**Ford, 2018a: pg. 97;** Shows the speed your vehicle is traveling. ----- **Toyota, 2018: pg. 91;** Displays the vehicle speed

FMVSS	Component	Information Communicated	Delivery Method				Intended For			Expected Response (after receiving the information)	Required	Expected Response Regulatory Citation	Citation Example	Relevance Considerations				Expected Response Owner Manual References
			Symbol	Telltale	Auditory Alert	Indicator	Human Driver	Passengers	Maintenance Entity					ADS	Occupant(s)	Maintenance Entity	Observations	
101	Heating and air conditioning system	n/a					X			Change the heating and air conditioning system state	if equipped				?		Heating and air conditioning system controls are not mandated by FMVSS. Occupants activating the control does not impact the driving task for an ADS.	**Ford, 2018a: pg. 121;** Adjusts the temperature of the air circulated in your vehicle. ----- **Honda, 2018: pg. 47;** Maintains your preferred interior temperature by selecting the proper mix of heated or cooled air and fan speed. Use the buttons on the dashboard to control the system. ----- **Toyota, 2018: pg. 350;** To adjust the temperature setting, turn clockwise [picture of dial] to increase the temperature and counterclockwise to decrease the temperature.

FMVSS	Component	Information Communicated	Delivery Method				Intended For			Expected Response (after receiving the information)	Required	Expected Response Regulatory Citation	Citation Example	Relevance Considerations				Expected Response Owner Manual References
			Symbol	Telltale	Auditory Alert	Indicator	Human Driver	Passengers	Maintenance Entity					ADS	Occupant(s)	Maintenance Entity	Observations	
101	Windshield Defrosting and Defogging System(s)	identification	X				X			Change the defrosting and defogging system(s) state	if equipped				?		Windshield defrosting and defogging system(s) controls are not mandated by FMVSS. Occupants activating the control does not impact the driving task for an ADS.	**Ford, 2018a: pg. 425;** When on, defrost provides outside air to reduce window fogging and distributes air through the windshield defroster vents and demister vents. ----- **Toyota, 2018: pg. 351;** Defoggers are used to defog the windshield and front side windows.
101	Windshield Wiping and Washing System(s)	n/a	X				X			Change the wiping and washing system(s) state	if equipped				?		Windshield wiping and washing system(s) controls are not mandated by FMVSS. Occupants activating the control does not impact the driving task for an ADS.	**Honda, 2018: pg. 38;** The windshield wipers and washers can be used when the vehicle is on. Move the wiper lever up or down to the desired position. -----

FMVSS	Component	Information Communicated	Delivery Method				Intended For			Expected Response (after receiving the information)	Required	Expected Response Regulatory Citation	Citation Example	Relevance Considerations				Expected Response Owner Manual References
			Symbol	Telltale	Auditory Alert	Indicator	Human Driver	Passengers	Maintenance Entity					ADS	Occupant(s)	Maintenance Entity	Observations	
126	Electronic Stability Control (ESC)	status	X	X			X			Reactivate ESC when appropriate	X	S5.5.1	"the vehicle manufacturer must provide a telltale indicating that the vehicle has been put into a mode that renders it unable to satisfy the requirements of S5.2.1, S5.2.2 and S5.2.3, if such a mode is provided..."	X			The ADS may encounter situations that could benefit from turning ESC off. The ESC telltale provides a reminder to the human driver that ESC is in the OFF state. The state information could be communicated to the ADS. May not be needed for occupants.	**Honda, 2018: pg. 101;** Press and hold the VSA OFF button until you hear a beep to turn VSA on or off. The VSA OFF indicator appears when the system is off. ----- **Toyota, 2018: pg. 298;** Be especially careful and drive at a speed appropriate to the road conditions. As these are the systems to help ensure vehicle stability and driving force, do not turn the TRAC/VSC systems off unless necessary

FMVSS	Component	Information Communicated	Delivery Method				Intended For			Expected Response (after receiving the information)	Required	Expected Response Regulatory Citation	Citation Example	Relevance Considerations				Expected Response Owner Manual References
			Symbol	Telltale	Auditory Alert	Indicator	Human Driver	Passengers	Maintenance Entity					ADS	Occupant(s)	Maintenance Entity	Observations	
126	Electronic Stability Control Malfunction	malfunction	X	X			X		X	Check owner manual for steps to take to address telltale malfunction	X	S5.3	"ESC Malfunction. The vehicle must be equipped with a telltale that provides a warning to the driver of the occurrence of one or more malfunctions that affect the generation or transmission of control or response signals in the vehicle's electronic stability control system."	X		?	May be important for operational readiness.	**Ford, 2018a: pg. 181;** If a fault occurs in either the stability control or the traction control system, you may experience the following conditions: The stability and traction control light illuminates steadily; The stability control and traction control systems do not enhance your vehicle's ability to maintain traction of the wheels. ----- **Honda, 2018: pg. 25;** There is a problem with the VSA system or hill start assist system. If the vehicle battery was disconnected, the system is temporarily deactivated. Drive a short distance at 12 mph (20 km/h) or more and the indicator should go off. ----- **Toyota, 2018: pg. 499;** The slip indicator indicates a malfunction in the VSC (Vehicle Stability Control) system, TRAC (Traction Control) system, or ABS. Have the vehicle inspected by your Toyota dealer immediately.

FMVSS	Component	Information Communicated	Delivery Method				Intended For			Expected Response (after receiving the information)	Required	Expected Response Regulatory Citation	Citation Example	Relevance Considerations				Expected Response Owner Manual References
			Symbol	Telltale	Auditory Alert	Indicator	Human Driver	Passengers	Maintenance Entity					ADS	Occupant(s)	Maintenance Entity	Observations	
208	[Air Bag] Readiness Indicator	status	X	X		X	X		X	Verify airbag readiness status and check label and owner manual for steps to take to address telltale warning.	X	62 FR 798 ((January 6, 1997)	"..the Standard [FMVSS No. 208] currently specifies that if a vehicle is equipped with a single indicator for both a driver and passenger air bag, and if the vehicle is equipped with a cutoff device, the readiness indicator must monitor only the readiness of the driver air bag when the passenger air bag has been deactivated by means of the cutoff device. The purpose of this requirement was to ensure that drivers would not miss a message that the driver air bag was not functional, simply because the passenger side bag was intentionally deactivated."	X	X	?	The readiness indicator is currently only required to be visible at the driver's DSP. However, if the driver's DSP is not occupied or not present, any front (or any) passenger air bag may require a readiness indicator that communicates the underlying condition to the ADS. If there is a malfunction with the readiness status, that information could be communicated to the ADS, a maintenance entity, or both. May be important for operational readiness.	**Ford, 2018a: pg. 48;** A difficulty with the system is indicated by one or more of the following: The readiness light will not illuminate immediately after the ignition is turned on. It will either flash or stay lit and a series of five beeps will be heard (if equipped). The tone pattern will repeat periodically until the problem, the light or both are repaired. If any of these things happen, even intermittently, have the supplemental restraint system serviced at an authorized dealer immediately. Unless serviced, the system may not function properly in the event of a crash. ----- **Honda, 2018: pg. 10;** If the indicator comes on at any other time besides vehicle start-up, or does not come on at all, have the system checked by a dealer as soon as possible. If you don't, your airbags and seat belt tensioners may not work properly when they are needed. ----- **Toyota, 2018: pg. 497;** SRS warning light indicates a malfunction in the SRS airbag system, the front passenger occupant classification system, or the seat belt pretensioner system. Have the vehicle inspected by your Toyota dealer immediately.

FMVSS	Component	Information Communicated	Delivery Method				Intended For			Expected Response (after receiving the information)	Required	Expected Response Regulatory Citation	Citation Example	Relevance Considerations				Expected Response Owner Manual References
			Symbol	Telltale	Auditory Alert	Indicator	Human Driver	Passengers	Maintenance Entity					ADS	Occupant(s)	Maintenance Entity	Observations	
208	Passenger Air Bag Automation Suppression Indicator	status	X	X			X	X		Verify that passenger air bag is activated or deactivated properly for front passenger	X	S19.2.2, S4.5.1(f)(2)	"The vehicle shall be equipped with at least one telltale which emits light whenever the passenger air bag system is deactivated and does not emit light whenever the passenger air bag system is activated. For any vehicle certified to meet the requirements specified in S14.5, S15, S17, S19, S21, S23, and S25, the manufacturer shall also include in the vehicle owner's manual a discussion of the advanced passenger air bag system installed in the vehicle. " -- "(vi) A summary of the expected outcomes when child restraint systems, children and small teenagers or adults are both properly and improperly positioned in the passenger seat, including cautionary advice against improper placement of child restraint systems. (vii) For vehicles certified to meet the requirements of S19.2, S21.2 or S23.2, a discussion of the telltale light, specifying its location in the vehicle and explaining when the light is illuminated."	?	X		The status of the passenger air bag is currently required to be visible at the driver and right front passenger seating positions. In a scenario where an adult places a child restraint system in the front of the vehicle and sits in the back of the vehicle, they could require knowledge of the air bag status from their seating position. May be important for operational readiness.	**Ford, 2018a: pg. 44;** The front passenger sensing system uses a passenger airbag status indicator that illuminates indicating that the front passenger frontal airbag is either ON (enabled) or OFF (disabled). ----- **Honda, 2018: pg. 11;** The indicator comes on to alert you that the front passenger's front airbag has been turned off. This occurs when the front passenger's weight sensors detect 65 lbs. (29 kg) or less, the weight of an infant or small child, on the seat. ----- **Toyota, 2018: pg. 46-47;** various tables showing the indicator when the passenger airbag is turned off

FMVSS	Component	Information Communicated	Delivery Method				Intended For			Expected Response (after receiving the information)	Required	Expected Response Regulatory Citation	Citation Example	Relevance Considerations				Expected Response Owner Manual References
			Symbol	Telltale	Auditory Alert	Indicator	Human Driver	Passengers	Maintenance Entity					ADS	Occupant(s)	Maintenance Entity	Observations	
208	Seat belt Warning System	warning	X	X	X		X			Fasten seat belts	X	S7.3, S4.5.1(f)	"...a continuous or flashing warning light visible to the driver displaying the identifying symbol for the seat belt telltale shown in Table 2 of FMVSS 101 or, at the option of the manufacturer if permitted by FMVSS 101, displaying the words “Fasten Seat Belts” or “Fasten Belts”, for not less than 60 seconds..." "The information shall emphasize that all occupants, including the driver, should always wear their seat belts whether or not an air bag is also provided at their seating position to minimize the risk of severe injury or death in the event of a crash."	?	X		The seat belt warning system is provided to the driver and they are expected to encourage unbelted occupants to fasten their seat belts.	**Ford, 2018a: pg. 93;** It will illuminate and a chime will sound to remind you to fasten your seatbelt. ----- **Honda, 2018: pg. 26;** Make sure seat belts are fastened for you and all passengers. The indicator blinks and beeps sound continuously if you or your front passenger has not fastened your seat belts when you begin driving. If the indicator remains on after seat belts are fastened, see your dealer ----- **Toyota, 2018: pg. 47;** In the event the front passenger does not wear a seat belt.

FMVSS	Component	Information Communicated	Delivery Method				Intended For			Expected Response (after receiving the information)	Required	Expected Response Regulatory Citation	Citation Example	Relevance Considerations				Expected Response Owner Manual References
			Symbol	Telltale	Auditory Alert	Indicator	Human Driver	Passengers	Maintenance Entity					ADS	Occupant(s)	Maintenance Entity	Observations	
226	Ejection Mitigation Countermeasure Readiness Indicator	stat us	X	X		X	X			Verify ejection mitigation readiness status and check label and owner manual for steps to take to address telltale warning.	X	S4.2.3(b)	Vehicles that have an ejection mitigation countermeasure that deploys in the event of a rollover must include in written information a discussion of the readiness indicator required by S4.2.2, specifying a list of the elements of the system being monitored by the indicator, a discussion of the purpose and location of the telltale, and instructions to the consumer on the steps to take if the telltale is illuminated.	X	X	?	The [air bag] readiness indicator in FMVSS No. 208 can be used to meet the indicator requirements for the ejection mitigation countermeasure. In an ADS-DV, occupants in seating positions other than the front row may also want to be made aware of the status of the side curtain air bags.	**Honda, 2018: pg. 26;** If a problem occurs in the airbag system, the SRS indicator comes on and a message appears on the Driver Information Interface. SRS (Supplemental Restraint System) indicator If the indicator comes on at any other time besides vehicle start-up, or does not come on at all, have the system checked by a dealer as soon as possible. If you don't, your airbags and seat belt tensioners may not work properly when they are needed.---**Toyota Civic, 2018:** pg. 47; Table for "There is a malfunction in the system" Indicator/ warning light, SRS warning light, On.

FMVSS	Component	Information Communicated	Delivery Method			Intended For			Expected Response (after receiving the information)	Required	Expected Response Regulatory Citation	Citation Example	Relevance Considerations				Expected Response Owner's Manual References
			Label	Written Notice	Marking	Human Driver	Passengers	Maintenance Entity					ADS	Occupant(s)	Maintenance	Observations	
110	Vehicle Placard	Identification and use	X			X		X	Obtain recommended tire pressures and adhere to the vehicle's load limits	X	[Docket No. NHTSA–02–13678 Tire Safety Information (Nov. 18, 2002)]	"A standardized location for tire information placards and labels would have contributed to consumer awareness of recommended tire inflation pressures and load limits"		X	X	Currently labeling will provide owners and users of an ADS-DV the tire and loading information for proper use. Future research may need to understand the ADS capability to detect when the ADS-DV exceeds its loading capacity and the expected response to low tire pressure warning.	**Ford, 2018a: pg. 286;** A label showing the original equipment tire sizes, recommended inflation pressure and the maximum weight the vehicle can carry. [...] Tire Label located on the B-Pillar or the edge of the driver's door. ----- **Honda, 2018: pg. 144;** The tires that came on your vehicle have a number of markings. Those you should be aware of are described below. ----- **Toyota, 2018: pg.459;** Picture of tire and loading information label

FMVSS	Component	Information Communicated	Delivery Method			Intended For			Expected Response (after receiving the information)	Required	Expected Response Regulatory Citation	Citation Example	Relevance Considerations				Expected Response Owner's Manual References
			Label	Written Notice	Marking	Human Driver	Passengers	Maintenance Entity					ADS	Occupant(s)	Maintenance	Observations	
110	Additional Tire Label	Use	X			X			Appropriate tire replacement	X	S4.3.3			X	X	Currently labeling will provide owners and users of an ADS-DV the tire and loading information for proper use. Future research may need to understand the ADS capability to detect when the ADS-DV exceeds its loading capacity and the expected response to low tire pressure warning.	**Ford, 2018a: pg. 296;** Only use replacement tires and wheels that are the same size, load index, speed rating and type (such as P-metric versus LT-metric or all-season versus all-terrain) as those originally provided by Ford. The recommended tire and wheel size may be found on either the Safety Compliance Certification Label (affixed to either the door hinge pillar, door-latch post, or the door edge that meets the door-latch post, next to the driver's seating position), or the Tire Label which is located on the B-Pillar or edge of the driver's door. ----- **Honda, 2018: pg. 142;** Replace your tires with radials of the same size, load range, speed rating, and maximum cold tire pressure rating (as shown on the tire's sidewall). Using tires of a different size or construction can cause certain vehicle systems such as ABS and Vehicle Stability Assist (VSA) to work incorrectly. It is best to replace all four tires at the same time. If that isn't possible, replace the front or rear tires in pairs. If you change or replace a wheel, make sure that the wheel's specifications match those of the original wheels. ----- **Toyota, 2018: pg. 462;** When replacing wheels, care should be taken to ensure that they are equivalent to those removed in load capacity, diameter, rim width and inset. Replacement wheels are available at your Toyota dealer

FMVSS	Component	Information Communicated	Delivery Method			Intended For			Expected Response (after receiving the information)	Required	Expected Response Regulatory Citation	Citation Example	Relevance Considerations				Expected Response Owner's Manual References
			Label	Written Notice	Marking	Human Driver	Passengers	Maintenance Entity					ADS	Occupant(s)	Maintenance	Observations	
110	Additional Trailer Cargo Weight Label	Use	X			X			Maintain a proper cargo weight	X	S4.3.4	"The weight of cargo should never exceed XXX kilograms or XXX pounds"		X		Currently labeling will provide owners and users of an ADS-DV the tire and loading information for proper use. Future research may need to understand the ADS capability to detect when the ADS-DV exceeds its loading capacity and the expected response to low tire pressure warning.	**Ford, 2018a: pg. 219;** The maximum payload for your vehicle appears on the Tire and Loading label. The label is either on the B-pillar or the edge of the driver door. Vehicles exported outside the US and Canada may not have a tire and loading label. Look for "The combined weight of occupants and cargo should never exceed XXX kg OR XXX lb." for maximum payload. The payload listed on the Tire and Loading Information label is the maximum payload for your vehicle as built by the assembly plant. If you install any additional equipment on your vehicle, you must determine the new payload. Subtract the weight of the equipment from the payload listed on the Tire and Loading label. When towing, trailer tongue weight or king pin weight is also part of payload. ----- **Honda, 2018: pg. 93;** This figure includes the total weight of all occupants, cargo, and accessories, and the tongue load if you are towing a trailer. Below are the steps for determining the correct load limit: 1. Locate the statement "The combined weight of occupants and cargo should never exceed XXX kg or XXX lbs." on your vehicle's placard. 2. Determine the combined weight of the driver and passengers that will be riding in your vehicle. 3. Subtract the combined weight of the driver and passengers from XXX kg or XXX lbs. 4. The resulting figure equals the available amount of cargo and luggage load capacity. For example, if the "XXX" amount equals 1,400 lbs. and there will be five 150 lb. passengers in your vehicle, the amount of available cargo and luggage load capacity is 650 lbs. (1,400 - 750 (5 x 150) = 650 lbs.) 5. Determine the combined weight of luggage and cargo being loaded on the vehicle. That weight may not safely exceed the available cargo and luggage load capacity calculated in step 4. 6. If your vehicle will be towing a trailer, load from your trailer will be transferred to your vehicle. Consult the Owner's Manual to determine how this reduces the available cargo and luggage load capacity of your vehicle. In addition, the total weight of the vehicle, all occupants, accessories, cargo, and trailer tongue load must not exceed the Gross Vehicle Weight Rating (GVWR) or the Gross Axle Weight Rating (GAWR). Both are on a label on the driver's doorjamb

FMVSS	Component	Information Communicated	Delivery Method			Intended For			Expected Response (after receiving the information)	Required	Expected Response Regulatory Citation	Citation Example	Relevance Considerations				Expected Response Owner's Manual References
			Label	Written Notice	Marking	Human Driver	Passengers	Maintenance Entity					ADS	Occupant(s)	Maintenance	Observations	
110	Additional Trailer Cargo Weight Label	Use	X			X			Maintain a proper cargo weight	X	S4.3.4	"The weight of cargo should never exceed XXX kilograms or XXX pounds"		X		Currently labeling will provide owners and users of an ADS-DV the tire and loading information for proper use. Future research may need to understand the ADS capability to detect when the ADS-DV exceeds its loading capacity and the expected response to low tire pressure warning.	**<u>Toyota, 2018: pg. 192;</u>** Steps for Determining Correct Load Limit — (1) Locate the statement "The combined weight of occupants and cargo should never exceed XXX kg or XXX lbs." on your vehicle's placard. (2) Determine the combined weight of the driver and passengers that will be riding in your vehicle. (3) Subtract the combined weight of the driver and passengers from XXX kg or XXX lbs. (4) The resulting figure equals the available amount of cargo and luggage load capacity. For example, if the "XXX" amount equals 1400 lbs. and there will be five 150 lb. passengers in your vehicle, the amount of available cargo and luggage load capacity is 650 lbs. (1400 − 750 (5 × 150) = 650 lbs.) (5) Determine the combined weight of luggage and cargo being loaded on the vehicle. That weight may not safely exceed the available cargo and luggage load capacity calculated in Step 4. If your vehicle will be towing a trailer, load from your trailer will be transferred to your vehicle. Consult this manual to determine how this reduces the available cargo and luggage load capacity of your vehicle. Toyota does not recommend towing a trailer with your vehicle. Your vehicle is not designed for trailer towing

FMVSS	Component	Information Communicated	Delivery Method			Intended For			Expected Response (after receiving the information)	Required	Expected Response Regulatory Citation	Citation Example	Relevance Considerations				Expected Response Owner's Manual References
			Label	Written Notice	Marking	Human Driver	Passengers	Maintenance Entity					ADS	Occupant(s)	Maintenance	Observations	
110	Rim Markings	Use			X	X		X	Obtain rim information	X	S4.4.2				X	Currently labeling will provide owners and users of an ADS-DV the tire and loading information for proper use. Future research may need to understand the ADS capability to detect when the ADS-DV exceeds its loading capacity and the expected response to low tire pressure warning.	**Ford Fusion 2018:** Pg. 287 - 290 ----- **Honda Civic, 2018**: pg. 144 ----- Toyota Camry, 2018: pg. 562 - 565

FMVSS	Component	Information Communicated	Delivery Method			Intended For			Expected Response (after receiving the information)	Required	Expected Response Regulatory Citation	Citation Example	Relevance Considerations				Expected Response Owner's Manual References
			Label	Written Notice	Marking	Human Driver	Passengers	Maintenance Entity					ADS	Occupant(s)	Maintenance	Observations	
110	Spare Tire	Use		X		X			Appropriate use of the spare tire	X	S7.2	‘‘IMPORTANT—USE OF SPARE TIRE’’		X	X		**Ford, 2018a: pg. 305;** *This spare tire begins with the letter T for tire size and may have Temporary Use Only molded in the sidewall. This spare tire has a label on the wheel that states: THIS WHEEL AND TIRE ASSEMBLY FOR TEMPORARY USE ONLY ----- **Honda, 2018: pg. 121;** If a tire goes flat while driving, grasp the steering wheel firmly and brake gradually to reduce speed. Stop in a safe place. Replace the flat tire with the compact spare tire* in the trunk or repair the flat tire using the tire repair kit*. Go to a dealer as soon as possible to have the full-size tire repaired or replaced. ----- **Toyota, 2018: pg. 555;** “TEMPORARY USE ONLY” A compact spare tire is identified by the phrase “TEMPORARY USE ONLY” molded on its sidewall. This tire is designed for temporary emergency use only.

FMVSS	Component	Information Communicated	Delivery Method			Intended For			Expected Response (after receiving the information)	Required	Expected Response Regulatory Citation	Citation Example	Relevance Considerations				Expected Response Owner's Manual References
			Label	Written Notice	Marking	Human Driver	Passengers	Maintenance Entity					ADS	Occupant(s)	Maintenance	Observations	
110	RV Carry Capacity	Use	X			X	X		Appropriate occupant, capacity and loading	X	S9.3			X			

FMVSS	Component	Information Communicated	Delivery Method			Intended For			Expected Response (after receiving the information)	Required	Expected Response Regulatory Citation	Citation Example	Relevance Considerations				Expected Response Owner's Manual References
			Label	Written Notice	Marking	Human Driver	Passengers	Maintenance Entity					ADS	Occupant(s)	Maintenance	Observations	
111	Side Mirrors (Convex Mirror)	Use			X	X			Understanding of the depth perception altering effect of the mirror	X	S5.4.2	Each convex mirror shall have permanently and indelibly marked at the lower edge of the mirror's reflective surface, in letters not less than 4.8 mm nor more than 6.4 mm high the words “Objects in Mirror Are Closer Than They Appear.”					

FMVSS	Component	Information Communicated	Delivery Method			Intended For			Expected Response (after receiving the information)	Required	Expected Response Regulatory Citation	Citation Example	Relevance Considerations				Expected Response Owner's Manual References
			Label	Written Notice	Marking	Human Driver	Passengers	Maintenance Entity					ADS	Occupant(s)	Maintenance	Observations	
111	School Bus Mirror (Rear Visibility)	Use	X			X			Use of mirror to identify pedestrians, not while vehicle is in motion	X	S9.3 (c)	Each school bus which has a mirror installed in compliance with S9.3(a) that has an average radius of curvature of less than 889 mm, as determined under S12, shall have a label visible to the seated driver. The label shall be printed in a type face and color that are clear and conspicuous. The label shall state the following: "Use cross view mirrors to view pedestrians while bus is stopped. Do not use these mirrors to view traffic while bus is moving. Images in such mirrors do not accurately show another vehicle's location."					

FMVSS	Component	Information Communicated	Delivery Method			Intended For			Expected Response (after receiving the information)	Required	Expected Response Regulatory Citation	Citation Example	Relevance Considerations				Expected Response Owner's Manual References
			Label	Written Notice	Marking	Human Driver	Passengers	Maintenance Entity					ADS	Occupant(s)	Maintenance	Observations	
125	Warning Devices Information	Manufacturer			X	X		X	Information only, no expected response	X	S5.1.4					This is an equipment standard, not vehicle level.	

FMVSS	Component	Information Communicated	Delivery Method			Intended For			Expected Response (after receiving the information)	Required	Expected Response Regulatory Citation	Citation Example	Relevance Considerations				Expected Response Owner's Manual References
			Label	Written Notice	Marking	Human Driver	Passengers	Maintenance Entity					ADS	Occupant(s)	Maintenance	Observations	
125	Warning Devices Information S5.1.5	Use			X	X			Activate the hazard warnings and proper positioning of the warning device	X	S5.1.2	Each warning device shall have instructions for its erection and display. (a) The instructions shall be either indelibly printed on the warning device or attached in such a manner that they cannot be easily removed. (b) Instructions for each warning device shall include a recommendation that the driver activate the vehicular hazard warning signal lamps before leaving the vehicle to erect the warning device. (c) Instructions shall include the illustration depicted in Figure 3 indicating recommended positioning.				This is an equipment standard, not vehicle level.	

FMVSS	Component	Information Communicated	Delivery Method			Intended For			Expected Response (after receiving the information)	Required	Expected Response Regulatory Citation	Citation Example	Relevance Considerations				Expected Response Owner's Manual References
			Label	Written Notice	Marking	Human Driver	Passengers	Maintenance Entity					ADS	Occupant(s)	Maintenance	Observations	
207	Seat	Warning	X				X		Occupants should not use the seat	X	S4.4	Seats not designated for occupancy while the vehicle is in motion shall be conspicuously labeled to that effect.		X			

FMVSS	Component	Information Communicated	Delivery Method			Intended For			Expected Response (after receiving the information)	Required	Expected Response Regulatory Citation	Citation Example	Relevance Considerations				Expected Response Owner's Manual References
			Label	Written Notice	Marking	Human Driver	Passengers	Maintenance Entity					ADS	Occupant(s)	Maintenance	Observations	
208	Sun visor air bag warning label	Warning	X				X		Occupant will not place child restraint seat in that designated seating position	X	S4.5.1(b)	The label shall conform in content to the label shown either in Figure 8 or Figure 11 of this standard. Figure 8 lists the following statements: "Children can be seriously injured by the air bag", "The back seat is the safest place for children", "Always use seat belts and child restraints", "See owner's manual for more information about air bags".		X		This warning will be relevant for any passenger designated seating position that has an air bag. One consideration is if ADS-DVs will have sun visors, and whether a new location for the label should be investigated in future research.	**Ford. 2018a: pg. 12;** NEVER use a rearward facing child restraint on a seat protected by an ACTIVE AIRBAG in front of it, DEATH or SERIOUS INJURY to the CHILD can occur. ----- **Honda, 2018: pg. 21;** Safety labels are in the locations shown. They warn you of potential hazards that can cause serious injury or death. Read these labels carefully. ----- **Toyota, 2018: pg. 36;** Improperly seated and/or restrained infants and children can be killed or seriously injured by a deploying airbag. An infant or child who is too small to use a seat belt should be properly secured using a child restraint system.

FMVSS	Component	Information Communicated	Delivery Method			Intended For			Expected Response (after receiving the information)	Required	Expected Response Regulatory Citation	Citation Example	Relevance Considerations				Expected Response Owner's Manual References
			Label	Written Notice	Marking	Human Driver	Passengers	Maintenance Entity					ADS	Occupant(s)	Maintenance	Observations	
208	Airbags Temporary Exemption	Warning	X	X		X	X	X	Proceed with caution due to lack of airbag	X	S12.7.2	The label shall set forth the following information in block capital letters and numerals not less than three thirty-seconds of an inch high: THIS VEHICLE DOES NOT CONTAIN AN AIR BAG IN CONFORMANCE WITH THE FEDERAL MOTOR VEHICLE SAFETY STANDARD FOR OCCUPANT CRASH PROTECTION. IT WAS EXEMPTED PURSUANT TO NHTSA EXEMPTION NO. (insert number assigned by NHTSA).		X	X	Considerations for accessibility of information contained in owner's manuals for ADS-DV occupants may benefit from further research.	

FMVSS	Component	Information Communicated	Delivery Method			Intended For			Expected Response (after receiving the information)	Required	Expected Response Regulatory Citation	Citation Example	Relevance Considerations				Expected Response Owner's Manual References
			Label	Written Notice	Marking	Human Driver	Passengers	Maintenance Entity					ADS	Occupant(s)	Maintenance	Observations	
210	Child Restraint Systems	Use		X		X	X		Child seat restraints will be properly restrained and use rear seating positions, when available	X	S6	A section explaining that all child restraint systems are designed to be secured in vehicle seats by lap belts or the lap belt portion of a lap-shoulder belt. The section shall also explain that children could be endangered in a crash if their child restraints are not properly secured in the vehicle. (b) In a vehicle with rear designated seating positions, a statement alerting vehicle owners that, according to accident statistics, children are safer when properly restrained in the rear seating positions than in the front seating positions.		X		Considerations for accessibility of information contained in owner's manuals for ADS-DV occupants may benefit from further research.	**Ford, 2018a: pg. 18;** Always make sure your child is secured properly in a device that is appropriate for their height, age and weight. Child safety restraints must be bought separately from your vehicle. Failure to follow these instructions and guidelines may result in an increased risk of serious injury or death to your child. ----- **Honda, 2018: pg. 14;** Each year, many children are injured or killed in vehicle crashes because they are either unrestrained or not properly restrained. In fact, vehicle collisions are the number one cause of death of children ages 12 and under. The National Highway Traffic Safety Administration and Transport Canada recommend that all children ages 12 and under be properly restrained in a rear seat. Some states or provinces/territories have laws restricting where children may ride. To reduce the number of child deaths and injuries, every state, Canadian province and territory requires that infants and children be properly restrained when they ride in a vehicle. **Toyota, 2018: pg. 53;** Toyota strongly urges the use of a proper child restraint system that con-forms to the weight and size of the child, installed on the rear seat. According to accident statistics, the child is safer when properly restrained in the rear seat than in the front seat.

FMVSS	Component	Information Communicated	Delivery Method			Intended For			Expected Response (after receiving the information)	Required	Expected Response Regulatory Citation	Citation Example	Relevance Considerations				Expected Response Owner's Manual References
			Label	Written Notice	Marking	Human Driver	Passengers	Maintenance Entity					ADS	Occupant(s)	Maintenance	Observations	
222	School Bus Passenger Seating	Warning	X			X	X		Occupants under 10 years of age will not sit in the middle seat	X	S5.5	"Do Not Sit in Middle Seat If Over Age 10"		X			

FMVSS	Component	Information Communicated	Delivery Method			Intended For			Expected Response (after receiving the information)	Required	Expected Response Regulatory Citation	Citation Example	Relevance Considerations				Expected Response Owner's Manual References
			Label	Written Notice	Marking	Human Driver	Passengers	Maintenance Entity					ADS	Occupant(s)	Maintenance	Observations	
225	Child Restraint Anchorage Systems	Identification and use			X	X	X		Locate child restraint anchorages for proper child restraint installation	X	68 Fed. Reg. 38209, 38209 - 38214 (June 27, 2003)	The purposes of marking the location of the bars were to provide a visual reminder to consumers that the LATCH (Lower Anchors and Tethers for Children) system is present and to help users locate and use the bars.		X			**Ford, 2018a: pg. 24;** Do not attach two child safety restraints to the same anchor. In a crash, one anchor may not be strong enough to hold two child safety restraint attachments and may break, causing serious injury or death. Depending on where you secure a child restraint, and depending on the child restraint design, you may block access to certain seatbelt buckle assemblies and LATCH lower anchors, rendering those features potentially unusable. To avoid risk of injury, make sure occupants only use seating positions where they are able to be properly restrained. ----- **Honda, 2018: pg. 17;** A LATCH-compatible child seat can be installed in either of the two outer rear seats. A child seat is attached to the lower anchors with either the rigid or flexible type of connectors. ----- **Toyota, 2018: pg. 65;** Child restraint LATCH anchors LATCH anchors are provided for the outboard rear seats. (Marks displaying the location of the anchors are attached to the seats.)

FMVSS	Component	Information Communicated	Delivery Method			Intended For			Expected Response (after receiving the information)	Required	Expected Response Regulatory Citation	Citation Example	Relevance Considerations				Expected Response Owner's Manual References
			Label	Written Notice	Marking	Human Driver	Passengers	Maintenance Entity					ADS	Occupant(s)	Maintenance	Observations	
225	Child Restraint Anchorage Systems	Identification and use		X		X	X		Location and directions for proper child restraint anchorages usage	X	S12	(a) Indicate which seating positions in the vehicle are equipped with tether anchorages and child restraint anchorage systems; (b) In the case of vehicles required to be marked as specified in paragraphs S4.1, S9.5(a), or S15.4, explain the meaning of markings provided to locate the lower anchorages of child restraint anchorage systems; and (c) Include instructions that provide a step-by-step procedure, including diagrams, for properly attaching a child restraint system's tether strap to the tether anchorages.		X		Considerations for accessibility of information contained in owner's manuals for ADS-DV occupants may benefit from further research.	**Ford, 2018a: pg. 25 - 31**; various photos and instructions for the location of anchorage points and proper child seat installation ----- **Honda, 2018: pg. 16-21;** various photos and instructions for the location of anchorage points and proper child seat installation ----- **Toyota, 2018: pg. 54 - 70;** various photos and instructions for the location of anchorage points and proper child seat installation

FMVSS	Component	Information Communicated	Delivery Method			Intended For			Expected Response (after receiving the information)	Required	Expected Response Regulatory Citation	Citation Example	Relevance Considerations				Expected Response Owner's Manual References
			Label	Written Notice	Marking	Human Driver	Passengers	Maintenance Entity					ADS	Occupant(s)	Maintenance	Observations	
226	Ejection Mitigation	Functionality		X		X			Information only, no expected response	X	S4.2.3	(a) Vehicles with an ejection mitigation countermeasure that deploys in the event of a rollover must be described as such in the vehicle's owner manual or in other written information provided by the vehicle manufacturer to the consumer. (b) Vehicles that have an ejection mitigation countermeasure that deploys in the event of a rollover must include in written information a discussion of the readiness indicator required by S4.2.2, specifying a list of the elements of the system being monitored by the indicator, a discussion of the purpose and location of the telltale, and instructions to the consumer on the steps		X		Considerations for accessibility of information contained in owner's manuals for ADS-DV occupants may benefit from further research.	**Ford Fusion 2018a: pg. 47:** The Safety Canopy deploys during significant side crashes or when a certain likelihood of a rollover event is detected by the rollover sensor. The Safety Canopy is mounted to the roof side rail sheet metal, behind the headliner, above each row of seats. In certain sideways crashes or rollover events, the Safety Canopy will be activated, regardless of which seats are occupied. The Safety Canopy is designed to inflate between the side window area and occupants to further enhance protection provided in side impact crashes and rollover events. ----- **Honda Civic, 2018: pg. 9** :Side curtain airbags help protect the heads of the driver and passengers in the outer seating positions during a moderate-to-severe side impact. The side curtain airbags equipped in this vehicle are also designed to help reduce the likelihood of partial and complete ejection of vehicle occupants through side windows in crashes, particularly rollover crashes. ----- **Toyota Camry, 2018: pg. 33 and 43:** SRS curtain shield airbags: Can help protect primarily the head of

FMVSS	Component	Information Communicated	Delivery Method			Intended For			Expected Response (after receiving the information)	Required	Expected Response Regulatory Citation	Citation Example	Relevance Considerations				Expected Response Owner's Manual References
			Label	Written Notice	Marking	Human Driver	Passengers	Maintenance Entity					ADS	Occupant(s)	Maintenance	Observations	
												to take if the telltale is illuminated.					occupants in the outer seats. Can help prevent the occupants from being thrown from the vehicle in the event of vehicle rollover. Types of collisions that may not deploy the SRS airbags (SRS side and curtain shield airbags) are shown and explained on page 43.

Appendix E. Lists of Standards Incorporated by Reference for the Volume 2 FMVSS

Table 29. FMVSS Reference Summary

FMVSS No.	Number of Incorporated References	No Regulatory Barrier	Potential Research Needed
101	1	1	0
103	8	6	2
104	7	6	1
110	1	1	0
111	7	7	0
113	0	0	0
124	0	0	0
125	3	3	0
126	3	3	0
207	4	4	0
208	8	8	0
210	3	3	0
214	3	3	0
216a	3	3	0
219	1	1	0
222	5	5	0
225	5	5	0
226	3	3	0
Total	65	62	3

Table 30. FMVSS Non-Incorporated Reference Key Term Summary

FMVSS No.	Total Number of Non-Incorporated References	Regulatory Text Section or Lab TP Element	Key Term	Non-Incorporated Reference Origin
101	1	RT S5.3.4	Manikin H-Point	SAE J826
103	6	RT S3	Portland cement concrete pavement	ASTM C150
		LTP Compliance Test Execution (2), (A.);	SAE Dimensions W3 (shoulder room) and W7 (steering wheel centerline to vehicle centerline);	SAE J1100
		LTP Compliance Test Execution (C.), (E)	H-Point	SAE J826
		LTP Compliance Test Execution (E.), (B), (C), (B), (C)	Eyellipse pattern	SAE J941
		Compliance Test Execution (A), (B)	Glazing Surface Reference Line	SAE J903a
		Compliance Test Execution (D.)	Seating Reference Point	SAE J4004
104	1	RT S3	Manikin H-point	SAE J826
111	3	RT S5.1.1, S5.2.1	95th percentile driver's eye reference point	SAE J941
		RT S14.1.4; LTP Definitions, Procedure	Vehicle's longitudinal centerline	SAE J1100
		LTP and LTP SB Definitions	Seating reference point	SAE J4004
216a	1	RT S7.3, S7.4; LTP Definitions	Vehicle's longitudinal centerline	SAE J1100
222	1	LTP 11.5, 11.21, 11.22	Seating reference point	SAE J4004
226	1	LTP Definitions, Data Sheet No. 4	Vehicle's longitudinal centerline	SAE J1100

Table 31. FMVSS No. 101 Reference List

Referenced Document	Regulatory Text or Lab TP	Section	Total No. of Citations	Translation Assessment	External Standard Status	Regulatory Barrier Identified
Manikin H-point suggests SAE Standard J826_201511 *Devices for Use in Defining and Measuring Vehicle Seating Accommodation*	RT	S5.3.4	1	0 – No barrier	Current	None.

Table 32. FMVSS No. 103 Reference List

Referenced Document	Regulatory Text or Lab TP	Section	Total No. of Citations	Translation Assessment	External Standard Status	Regulatory Barrier Identified
Portland cement concrete pavement suggests ASTM C150-07 *Standard Specification for Portland Cement*	RT	S3	1	0 – No barrier	Current	None.
Section 3 of SAE Recommended Practice J902_1964 *Passenger Car Windshield Demisting and Defrosting Systems*	RT	S4.2	1	2 – Limited research may be beneficial	Newer standard issued, but not incorporated by reference in FMVSS: SAE J902_201108	SAE J902_1964 has been updated multiple times since 1964; current version is Aug. 2011. §571.104 cites SAE J903a_1966 Figures 1 and 2, which in turn cites SAE J941 for 95 percent eye range contour and SAE J826 for the H point in order to calculate the area generation. The current language options suggest that the standard applies only for windshields. If the ADS-DV has an area denominated as a windshield, a set of temporary and/or virtual controls will be placed in the location where it is needed to calculate appropriate windshield areas. These calculations and areas may not be needed if it is a regular window and not a windshield. Research on how the temporary/virtual

Referenced Document	Regulatory Text or Lab TP	Section	Total No. of Citations	Translation Assessment	External Standard Status	Regulatory Barrier Identified
						controls could be placed and used is potentially needed.
Paragraph 3.1 of SAE Recommended Practice J902_1964 *Passenger Car Windshield Demisting and Defrosting Systems*	RT	S4.2	1	2 – Limited research may be beneficial	Newer standard issued, but not incorporated by reference in FMVSS: SAE J902_201108	SAE J902_1964 has been updated multiple times since 1964; current version is Aug. 2011. §571.104 cites SAE J903a_1966 Figures 1 and 2, which in turn cites SAE J941 for 95 percent eye range contour and SAE J826 for the H point in order to calculate the area generation. The current language options suggest that the standard applies only for windshields. If the ADS-DV has an area denominated as a windshield, a set of temporary and/or virtual controls will be placed in the location where it is needed to calculate appropriate windshield areas. These calculations and areas may not be needed if it is a regular window and not a windshield. Research on how the temporary/virtual controls could be placed and used is potentially needed.

Referenced Document	Regulatory Text or Lab TP	Section	Total No. of Citations	Translation Assessment	External Standard Status	Regulatory Barrier Identified
Paragraph 3.3 of SAE Recommended Practice J902_1964 *Passenger Car Windshield Demisting and Defrosting Systems*	RT	S4.2	1	2 – Limited research may be beneficial	Newer standard issued, but not incorporated by reference in FMVSS: SAE J902_201108	SAE J902_1964 has been updated multiple times since 1964; current version is Aug. 2011. §571.104 cites SAE J903a_1966 Figures 1 and 2, which in turn cites SAE J941 for 95 percent eye range contour and SAE J826 for the H point in order to calculate the area generation. The current language options suggest that the standard applies only for windshields. If the ADS-DV has an area denominated as a windshield, a set of temporary and/or virtual controls will be placed in the location where it is needed to calculate appropriate windshield areas. These calculations and areas may not be needed if it is a regular window and not a windshield. Research on how the temporary/virtual controls could be placed and used is potentially needed.

Referenced Document	Regulatory Text or Lab TP	Section	Total No. of Citations	Translation Assessment	External Standard Status	Regulatory Barrier Identified
Paragraphs 4.1 through 4.4.7 of SAE Recommended Practice J902 _1964 *Passenger Car Windshield Demisting and Defrosting Systems*	RT	S4.3	1	2 – Limited research may be beneficial	Newer standard issued, but not incorporated by reference in FMVSS: SAE J902_201108	SAE J902_1964 has been updated multiple times since 1964; current version is Aug. 2011. §571.104 cites SAE J903a_ 1966 Figures 1 and 2, which in turn cites SAE J941 for 95 percent eye range contour and SAE J826 for the H point in order to calculate the area generation. The current language options suggest that the standard applies only for windshields. If the ADS-DV has an area denominated as a windshield, a set of temporary and/or virtual controls will be placed in the location where it is needed to calculate appropriate windshield areas. These calculations and areas may not be needed if it is a regular window and not a windshield. Research on how the temporary/virtual controls could be placed and used is potentially needed.
Paragraphs 4.1 through 4.4.7 of SAE Recommended Practice J902a_1967 *Passenger Car Windshield*	RT	S4.3	1	0 – No barrier	Newer standard issued, but not incorporated by reference in FMVSS: SAE J902_201108	Similar as above. SAE J902a_1967 has been revised.

Referenced Document	Regulatory Text or Lab TP	Section	Total No. of Citations	Translation Assessment	External Standard Status	Regulatory Barrier Identified
Demisting and Defrosting Systems						
Designated windshield areas "A" and "C" of SAE Recommended Practice J902_1964 *Passenger Car Windshield Demisting and Defrosting Systems*	LTP	General Requirements; Compliance Test Execution (A.),(F.), (H.) ; Vehicle Preparation (A.), (I.)	6	2 – Limited research may be beneficial	Newer standard issued, but not incorporated by reference in FMVSS: SAE J902_201108	SAE J902_1964 has been updated multiple times since 1964; current version is Aug. 2011. §571.104 cites SAE J903a_1966 Figures 1 and 2, which in turn cites SAE J941 for 95 percent eye range contour and SAE J826 for the H point in order to calculate the area generation. The current language options suggest that the standard applies only for windshields. If the ADS-DV has an area denominated as a windshield, a set of temporary controls and/or virtual controls will be placed in the location where it is needed to calculate appropriate windshield areas. These calculations and areas will not be needed if it is a regular window and not a windshield. Research on how the temporary/virtual controls could be placed and used is potentially needed.
SAE Recommended Practice J902a_1967 *Passenger Car Windshield*	LTP	General Requirements	1	0 – No barrier	Newer standard issued, but not incorporated by reference in FMVSS: SAE J902_201108	Similar as above. SAE J902a _1967 has been revised.

Referenced Document	Regulatory Text or Lab TP	Section	Total No. of Citations	Translation Assessment	External Standard Status	Regulatory Barrier Identified
Demisting and Defrosting Systems						
SAE Dimensions W3 (shoulder room) and W7 (steering wheel centerline to vehicle centerline) suggest SAE J1100_2009 *Motor Vehicle Dimensions*	LTP	Compliance Test Execution (2), (A.)	2	0 – No barrier	Current	None.
Paragraph 3.2 of SAE Recommended Practice J902_ 1964 *Passenger Car Windshield Demisting and Defrosting Systems*	LTP	Compliance Test Execution (H.)	1	2 – Limited research may be beneficial	Newer standard issued, but not incorporated by reference in FMVSS: SAE J902_201108	SAE J902_1964 has been updated multiple times since 1964; current version is Aug. 2011. §571.104 cites SAE J903a_1966 Figures 1 and 2, which in turn cites SAE J941 for 95 percent eye range contour and SAE J826 for the H point in order to calculate the area generation. The current language options suggest that the standard applies only for windshields. If the ADS-DV has an area denominated as a windshield, a set of temporary controls and/or virtual controls will be placed in the location where it is needed to calculate appropriate windshield areas. These calculations and areas won't be needed

Referenced Document	Regulatory Text or Lab TP	Section	Total No. of Citations	Translation Assessment	External Standard Status	Regulatory Barrier Identified
						if it is a regular window and not a windshield. Research on how the temporary/virtual controls could be placed and used is potentially needed.
H-point suggests SAE J826_2015 *Devices for Use in Defining and Measuring Vehicle Seating Accommodations*	LTP	Compliance Test Execution (C.), (E.)	1	0 – No barrier	Current	None.
Eyellipse pattern suggests SAE J941_2010 *Motor Vehicle Drivers Eye Locations*	LTP	Compliance Test Execution (E.), (B), (C), (B), (C)	5	2 – Limited research may be beneficial	Current	The current language options suggest that the standard applies only for windshields. If the ADS-DV has an area denominated as a windshield, a set of temporary controls and/or virtual controls will be placed in the location where it is needed to calculate appropriate windshield areas. These calculations and areas will not be needed if it is a regular window and not a windshield. Research on how the temporary/virtual controls could be placed and used is potentially needed.
Glazing surface reference line suggests SAE J903a_1966 from	LTP	Compliance Test Execution (A), (B)	2	0 – No barrier	Newer standard issued, but not incorporated by reference in FMVSS: SAE J903a_199905	None.

Referenced Document	Regulatory Text or Lab TP	Section	Total No. of Citations	Translation Assessment	External Standard Status	Regulatory Barrier Identified
§571.104 definitions *Passenger Car Windshield Wiper Systems*						
Seating Reference Point (SRP) suggests SAE J4004_2008 *Positioning the H-Point Design Tool—Seating Reference Point and Seat Track Length*	LTP	Compliance Test Execution (D.)	1	0 – No barrier	Current	None.

Table 33. FMVSS No. 104 Reference List

Referenced Document	Regulatory Text or Lab TP	Section	Total No. of Citations	Translation Assessment	External Standard Status	Regulatory Barrier Identified
Manikin H-point suggests SAE J826_2015 *Devices for Use in Defining and Measuring Vehicle Seating Accommodations*	RT	S3	1	0 – No barrier	Current	None.
Paragraph 2.3.12 of section E, *Ground Vehicle Practice, SAE Aerospace-Automotive Drawing Standards, September 1963*	RT	S3	1	0 – No barrier	Current	None.
Figure 1 of SAE Recommended Practice J903a _1966 *Passenger Car Windshield Wiper Systems*	RT	S3	1	0 – No barrier	Newer standard issued, but not incorporated by reference in FMVSS: SAE J903a_199905	This was categorized as no barrier if it is noted as a seating reference point and not as the manikin H point presented in the SAE standard Figure 1.
‘‘W3’’ as defined in section E, *Ground Vehicle Practice", of SAE Aerospace-Automotive Drawing Standards, September (1963)*	RT	S3	1	0 – No barrier	Current	None.

Referenced Document	Regulatory Text or Lab TP	Section	Total No. of Citations	Translation Assessment	External Standard Status	Regulatory Barrier Identified
''W116'', as defined in section E, *Ground Vehicle Practice, SAE Aerospace-Automotive Drawing Standards, September (1963)*	RT	S3	1	0 – No barrier	Current	None. Taken from referenced standard (p – E1.11) : W116 Maximum Overall Body Width. Measured across body, excluding hardware and applied moldings, but including fenders when integral with body.
Figure 2 of SAE Recommended Practice J903a _1966 *Passenger Car Windshield Wiper Systems*	RT	S3	1	0 – No barrier	Newer standard issued, but not incorporated by reference in FMVSS: SAE J903a_19990 5	None.
Sections 4.1.1 and 4.1.2 of SAE Recommended Practice J903a_1966 *Passenger Car Windshield Wiper Systems*	RT	S4.1.1.4	1	0 – No barrier	Newer standard issued, but not incorporated by reference in FMVSS: SAE J903a_19990 5	None.

Referenced Document	Regulatory Text or Lab TP	Section	Total No. of Citations	Translation Assessment	External Standard Status	Regulatory Barrier Identified
Figures 1 and 2 of SAE Recommended Practice J903a_1966 *Passenger Car Windshield Wiper Systems*	RT	S4.1.2.1	1	0 – No barrier	Newer standard issued, but not incorporated by reference in FMVSS: SAE J903a_199905	None.
95 percent eye range contour as specified in SAE Recommended Practice J941_1965 *Motor Vehicle Drivers Eye Locations*	RT	S4.3	2	0 – No barrier	Newer standard issued, but not incorporated by reference in FMVSS: SAE J941_201003	None.
SAE Recommended Practice J942_1965 *Passenger Car Windshield Washer Systems*	RT	S4.2.1, S4.2.2	2	0 – No barrier	Newer standard issued, but not incorporated by reference in FMVSS: SAE J942_199906	None.
SAE Recommended Practice J942_1965 *Passenger Car Windshield Washer Systems*	LTP	General Requirements	1	0 – No barrier	Newer standard issued, but not incorporated by reference in FMVSS: SAE J942_199906	None.
SAE Recommended Practice J903a_1966	LTP	General Requirements	1	0 – No barrier	Newer standard issued, but not incorporated	None.

Referenced Document	Regulatory Text or Lab TP	Section	Total No. of Citations	Translation Assessment	External Standard Status	Regulatory Barrier Identified
Passenger Car Windshield Wiper Systems					by reference in FMVSS: SAE J903a_19990 5	
MIL-C-45662A *Calibration System Requirements*	LTP	Calibration of Test Instruments	1	0 – No barrier	Newer standard issued, but not incorporated by reference in FMVSS: ANSI/NCSL Z540-1-1994	None
Windshield pattern containing areas "A", "B", and "C" suggest SAE J902_1964 *Passenger Car Windshield Demisting and Defrosting Systems*	LTP	Compliance Test Execution (H.), (G.); Post Test Requiremen ts (C.)	3	2 – Limited research may be beneficial	Newer standard issued, but not incorporated by reference in FMVSS: SAE J902_201108	SAE J902_Aug 1964 has been updated multiple times since 1964; current version is Aug. 2011. §571.104 cites SAE J903a_1966 Figures 1 and 2, which in turn cites SAE J941 for 95 percent eye range contour and SAE J826 for the H point in order to calculate the area generation. The current language options suggest that the standard applies only for

Referenced Document	Regulatory Text or Lab TP	Section	Total No. of Citations	Translation Assessment	External Standard Status	Regulatory Barrier Identified
						windshields. If the ADS-DV has an area denominated as a windshield, a set of temporary controls and/or virtual controls will be placed in the location where it is needed to calculate appropriate windshield areas. These calculations and areas will not be needed if it is a regular window and not a windshield. Research on how the temporary/virtual controls could be placed and used is potentially needed.

Table 34. FMVSS No. 110 Reference List

Referenced Document	Regulatory Text or Lab TP	Section	Total No. of Citations	Translation Assessment	External Standard Status	Regulatory Barrier Identified
ASTM E29-06b *Standard Practice for Using Significant Digits in Test Data to Determine Conformance with Specification*	LTP PC, LTP LT	Metric System of Measurement	2	0 – No barrier	Newer standard issued, but not incorporated by reference in FMVSS: ASTM E29_13	None.

Table 35. FMVSS No. 111 Reference List

Referenced Document	Regulatory Text or Lab TP	Section	Total No. of Citations	Translation Assessment	External Standard Status	Regulatory Barrier Identified
SAE J964_1984 *Recommended Practice for Measuring Haze and Reflectance of Mirrors*	RT	S11	1	0 – No barrier	Newer standard issued, but not incorporated by reference in FMVSS: SAE J964_201611	None.
95th percentile driver's eye reference point suggests SAE Recommended Practice J941_1965 from §571.104 definitions *Motor Vehicle Drivers Eye Locations*	RT	S5.1.1, S5.2.1	2	0 – No barrier	Newer standard issued, but not incorporated by reference in FMVSS: SAE J941_201003	Manikin not required for ADS-DV compliance, so changes to SAE standard may not be necessary.
Vehicle's longitudinal centerline suggests SAE Dimension W7 from SAE J1100_2009 *Motor Vehicle Dimensions*	RT	S14.1.4	1	0 – No barrier	Current	None.
Manikin H-point suggests J826__1995 *Devices for Use in Defining and Measuring Vehicle Seating Accommodations*	RT	S14.1.2.5.3, S14.1.5	1	0 – No barrier	Newer standard issued, but not incorporated by reference in FMVSS: SAE J826_201511	Manikin not required for ADS-DV compliance, so changes to SAE standard may not be necessary.
ASTM B117-03 *Standard Method of Salt Spray (Fog) Testing*	RT	S14.3.1	1	0 – No barrier	Current	None.

Referenced Document	Regulatory Text or Lab TP	Section	Total No. of Citations	Translation Assessment	External Standard Status	Regulatory Barrier Identified
SAE J964_1984 *Recommended Practice for Measuring Haze and Reflectance of Mirrors*	LTP, LTP SB	Requirement Reflectance Test	2	0 – No barrier	Newer standard issued, but not incorporated by reference in FMVSS: SAE J964_201611	None.
ASTM E29-06b *Standard Practice for Using Significant Digits in Test Data to Determine Conformance with Specification*	LTP	General Requirements	1	0 – No barrier	Newer standard issued, but not incorporated by reference in FMVSS: ASTM E29-13	None.
Manikin H-point suggests J826__1995 Devices for Use in Defining and Measuring Vehicle Seating Accommodations	LTP, LTP SB	Suggested Test Equipment, Definitions	5	0 – No barrier	Newer standard issued, but not incorporated by reference in FMVSS: SAE J826_201511	Manikin not required for ADS-DV compliance, so changes to SAE standard may not be necessary.
95th percentile driver's eye reference point suggests SAE Recommended Practice J941_1965 from §571.104 definitions	LTP	Definitions, Procedure	3	0 – No barrier	Newer standard issued, but not incorporated by reference in FMVSS: SAE J41_2010	Manikin not required for ADS-DV compliance, so changes to SAE standard may not be necessary.
Seating reference point (SRP) suggests SAE J4004_2008	LTP, LTP SB	Definitions	2	0 – No barrier	Current	None.
Vehicle's longitudinal centerline suggests SAE Dimension W7 from SAE J1100_2009	LTP SB	Definitions, Procedure	3	0 – No barrier	Current	None.

Table 36. FMVSS No. 125 Reference List

Referenced Document	Regulatory Text or Lab TP	Section	Total No. of Citations	Translation Assessment	External Standard Status	Regulatory Barrier Identified
CIE 1931 *Standard Colorimetric Observer System*	RT	S5.3.1, S5.3.2	2	0 – No barrier	Current	None.
CIE Chromaticity Diagram Figure 4	RT	S5.3.1	1	0 – No barrier	Current	None.
ASTM B117-64 *Standard Method of Salt Spray (Fog) Testing*	RT	S5.3.2	1	0 – No barrier	Current	None.
Fluorescent material suggests CIE 1931 *Standard Colorimetric Observer System*	RT	S5.2.1	1	0 – No barrier	Current	None.
Reflex reflective and fluorescent material suggests CIE 1931 *Standard Colorimetric Observer System*	RT	S4, S5.1.1, S5.2.1	3	0 – No barrier	Current	None.
Orange fluorescent material suggests CIE 1931 *Standard Colorimetric Observer System*	RT	S5.1.1, S5.3.2, S5.5, S6.3 (2 times)	5	0 – No barrier	Current	None.
Red reflex reflective material suggests CIE 1931 *Standard Colorimetric Observer System*	RT	S5.1.1, S5.2.3, S5.3.1, S5.4, S6.2 (4 times), S6.3	9	0 – No barrier	Current	None.
ASTM E-259 *Standard Practice for Preparation of Pressed Powder White Reflectance Factor Transfer Standards for Hemispherical and Bi-Directional Geometries*	LTP	Luminance	1	0 – No barrier	Newer standard issued, but not incorporated by reference in FMVSS: ASTM E259-06	None.

Referenced Document	Regulatory Text or Lab TP	Section	Total No. of Citations	Translation Assessment	External Standard Status	Regulatory Barrier Identified
					reapproved 2015	
Reflex reflective and fluorescent material suggests CIE 1931 *Standard Colorimetric Observer System*	LTP	General Requirements, Visual Inspection and Assembly of Test Articles, Inspection, Measurements of Reflective and Fluorescent Materials	4	0 – No barrier	Current	None.
Orange fluorescent material suggests CIE 1931 *Standard Colorimetric Observer System*	LTP	General Requirements, Measurements of Reflective and Fluorescent Materials, Reflectivity, Luminance (2 times)	5	0 – No barrier	Current	None.
Red reflex reflective material suggests CIE 1931 *Standard Colorimetric Observer System*	LTP	General Requirements, Measurements of Reflective and Fluorescent Materials, Reflectivity (2 times), Luminance	5	0 – No barrier	Current	None.
Red reflex reflective chromaticity and orange fluorescent chromaticity suggests CIE 1931 *Standard Colorimetric Observer System*	LTP	Dual Purpose (Reflective and Fluorescent) Material	1	0 – No barrier	Current	None.

Table 37. FMVSS No. 126 Reference List

Referenced Document	Regulatory Text or Lab TP	Section	Total No. of Citations	Translation Assessment	External Standard Status	Regulatory Barrier Identified
ASTM E1337-90 *Standard Test Method for Determining Longitudinal Peak Braking Coefficient of Paved Surfaces Using Standard Reference Test Tire*	RT	S6.2.2	1	0 – No barrier	Newer standard issued, but not incorporated by reference in FMVSS: ASTM E1337-90 (2018)	These references are independent of ADS-DVs.
ASTM E1136-93 *Standard Specification for P195/75R14 Radial Standard Reference Test Tire*	RT	S6.2.2	1	0 – No barrier	Newer standard issued, but not incorporated by reference in FMVSS: ASTM E1136-17	These references are independent of ADS-DVs.
ASTM E1337-90 *Standard Test Method for Determining Longitudinal Peak Braking Coefficient of Paved Surfaces Using Standard Reference Test Tire*	LTP	Vehicle and Test Track Data (Data Sheet 5)	1	0 – No barrier	Newer standard issued, but not incorporated by reference in FMVSS: ASTM E1337-90 (2018)	These references are independent of ADS-DVs.
ASTM E29-06b *Standard Practice for Using Significant Digits in Test Data to Determine Conformance with Specification*	LTP	General Requirements	1	0 – No barrier	Newer standard issued, but not incorporated by reference in FMVSS: ASTM E29-13	None.

Table 38. FMVSS No. 207 Reference List

eferenced Document	Regulatory Text or Lab TP	Section	Total No. of Citations	Translation Assessment	External Standard Status	Regulatory Barrier Identified
Manikin or H-Point from SAE Recommended Practice J826_1992 *Devices for Use in Defining and Measuring Vehicle Seating Accommodations*	LTP	Definitions (5x), Appendix B Scope (2x), Description, Application, Position Procedure (2x), Installation Procedure (29x), Appendix C (6x)	46	0 – No barrier	Newer standard issued, but not incorporated by reference in FMVSS: SAE J826_201511	None.
SAE J1100_2009 *Motor Vehicle Dimensions*	LTP	Appendix B Scope, Installation Procedure	2	0 – No barrier	Current	None.
SAE J182_2015 *Motor Vehicle Fiducial Marks and Three-Dimensional Reference System*	LTP	Appendix B Installation Procedure	1	0 – No barrier	Current	None.
SAE Recommended Practice J383_1986 *Motor Vehicle Seat Belt Anchorages - Design Recommendations*	LTP	Definitions, Appendix B Installation Procedure, Appendix C	3	0 – No barrier	Newer standard issued, but not incorporated by reference in FMVSS: SAE J383_201410	None.

Table 39. FMVSS No. 208 Reference List

Referenced Document	Regulatory Text or Lab TP	Section	Total No. of Citations	Translation Assessment	External Standard Status	Regulatory Barrier Identified
Appendix C of SAE Recommended Practice J211/1_1995 *Instrumentation for Impact Test–Part 1–Electronic Instrumentation*	RT	S4.13	1	0 – No Barrier	Newer standard issued, but not incorporated by reference in FMVSS: SAE 211/1_201403	None.
SAE Recommended Practice J211/1_1995 *Instrumentation for Impact Test–Part 1–Electronic Instrumentation*	RT	S6.6, S13.1, S15.3.6, S19.4.4, S21.5.5, S23.5.5, S25.4	7	0 – No Barrier	Newer standard issued, but not incorporated by reference in FMVSS: SAE 211/1_201403	None.
SAE Standard J826_1980 *Devices for Use in Defining and Measuring Vehicle Seating Accommodations*	RT	S10.4.2.1	1	0 – No Barrier	Newer standard issued, but not incorporated by reference in FMVSS: SAE J826_201511	None.
H-point suggests SAE Standard J826_1980 *Devices for Use in Defining and Measuring Vehicle Seating Accommodations*	RT	S10.4.2.2, S22.4.3.5, S24.4.3.5	3	0 – No Barrier	Newer standard issued, but not incorporated by reference in FMVSS: SAE J826_201511	None.
Table 1 of SAE Standard J826_1980 *Devices for Use in Defining and Measuring Vehicle Seating Accommodations*	RT	S10.4.2.1	1	0 – No Barrier	Newer standard issued, but not incorporated by reference in FMVSS: SAE J826_201511	None.

Referenced Document	Regulatory Text or Lab TP	Section	Total No. of Citations	Translation Assessment	External Standard Status	Regulatory Barrier Identified
ASTM E274-65T *Tentative Method of Test for Skid Resistance of Pavements Using a Two-Wheel Trailer*	RT	S8.2.5, S8.3.2	2	0 – No Barrier	Newer standard issued, but not incorporated by reference in FMVSS: ASTM E274/E274M-15	None.
MIL-S-21711E *Military Specification: Shoes, Women's*	RT	S16.2.5	1	0 – No Barrier	Newer standard issued, but not incorporated by reference in FMVSS: MIL-S-21711E amended 1994	None
MIL-S-13192P *Military Specification: Shoes, Men's Dress, Oxford*	RT	S8.1.8.2	1	0 – No Barrier	Current	None
ASTM E29-06b *Standard Practice for Using Significant Digits in Test Data to Determine Conformance with Specifications*	LTP	General Requirements	1	0 – No Barrier	Newer standard issued, but not incorporated by reference in FMVSS: ASTM E29-13	None.
SAE Standard J826_1987 *Devices for Use in Defining and Measuring Vehicle Seating Accommodations*	LTP	10.16, 10.22	1	0 – No Barrier	Newer standard issued, but not incorporated by reference in FMVSS: SAE J826_201511	None.
SAE J1100_2009 *Motor Vehicle Dimensions*	LTP	10.10, 10.22 (2x),	2	0 – No barrier	Newer standard issued, but not incorporated by reference in	None.

Referenced Document	Regulatory Text or Lab TP	Section	Total No. of Citations	Translation Assessment	External Standard Status	Regulatory Barrier Identified
					FMVSS: SAE J1100_200911	
H-Point suggests SAE Standard J826_1987 *Devices for Use in Defining and Measuring Vehicle Seating Accommodations*	LTP	10.18, Data Sheet 15,16,	3	0 – No Barrier	Newer standard issued, but not incorporated by reference in FMVSS: SAE J826_201511	None.

Table 40. FMVSS No. 210 Reference List

Referenced Document	Regulatory Text or Lab TP	Section	Total No. of Citations	Translation Assessment	External Standard Status	Regulatory Barrier Identified
SAE Standard J826_1987 *Devices for Use in Defining and Measuring Vehicle Seating Accommodations*	RT	S4.3.2	1	0 – No Barrier	Newer standard issued, but not incorporated by reference in FMVSS: SAE J826_201511	None.
SAE Recommended Practice J1100_1984 *Motor Vehicle Dimensions*	RT	S4.3.2	1	0 – No Barrier	Newer standard issued, but not incorporated by reference in FMVSS: SAE J1100_200911	None.
H-point and manikin from SAE Standard J826_1987 *Devices for Use in Defining and Measuring Vehicle Seating Accommodations*	LTP	Definitions (4x)	4	0 – No Barrier	Newer standard issued, but not incorporated by reference in FMVSS: SAE J826_201511	None.
SAE Recommended Practice J383_2014 *Motor Vehicle Seat Belt Anchorage*	LTP	Definitions	1	0 – No Barrier	Current	None.

Table 41. FMVSS No. 214 Reference List

Referenced Document	Regulatory Text or Lab TP	Section	Total No. of Citations	Translation Assessment	External Standard Status	Regulatory Barrier Identified
SAE Standard J826-1980 *Devices for Use in Defining and Measuring Vehicle Seating Accommodations*	RT	S12.1.1, S12.1.2, S12.1.3	3	0 – No Barrier	Newer standard issued, but not incorporated by reference in FMVSS: SAE J826_201511	None.
H-point from SAE Standard J826_1980 *Devices for Use in Defining and Measuring Vehicle Seating Accommodations*	RT	S5 (3x), S12.1.1, S12.1.2. S12.1.3, S12.2.1 (4x)	8	0 – No Barrier	Newer standard issued, but not incorporated by reference in FMVSS: SAE J826_201511	None.
Table 1 of SAE Standard J826_1980 *Devices for Use in Defining and Measuring Vehicle Seating Accommodations*	RT	S12.1.1, S12.1.2, S12.1.3	3	0 – No Barrier	Newer standard issued, but not incorporated by reference in FMVSS: SAE J826_201511	None.
MIL-S-21711E *Military Specification: Shoes, Women's*	RT	S11.1	1	0 – No Barrier	Newer standard issued, but not incorporated by reference in FMVSS: MIL-S-21711E amended 1994	None.
ASTM E29-06b *Standard Practice for Using Significant Digits in Test Data to Determine Conformance with Specifications*	LTP MDB	Door Opening Requirements	1	0 – No Barrier	Newer standard issued, but not incorporated by reference in FMVSS: ASTM E29-13	None.

Referenced Document	Regulatory Text or Lab TP	Section	Total No. of Citations	Translation Assessment	External Standard Status	Regulatory Barrier Identified
SAE Standard J826_1987 *Devices for Use in Defining and Measuring Vehicle Seating Accommodations*	LTP MDB, LTP RPS	10.4	1	0 – No Barrier	Newer standard issued, but not incorporated by reference in FMVSS: SAE J826_201511	None.
H-point from SAE Standard J826_1987 *Devices for Use in Defining and Measuring Vehicle Seating Accommodations*	LTP MDB	10.4, Data Sheet No. 5 (2x), Check Sheet 13 (2x)	5	0 – No Barrier	Newer standard issued, but not incorporated by reference in FMVSS: SAE J826_201511	None.
H-point from SAE Standard J826_1987 *Devices for Use in Defining and Measuring Vehicle Seating Accommodations*	LTP RPS	Data Sheet No. 6 (2x), Check Sheet 12 (2x)	4	0 – No Barrier	Newer standard issued, but not incorporated by reference in FMVSS: SAE J826_201511	None.

Table 42. FMVSS No. 216a Reference List

Referenced Document	Regulatory Text or Lab TP	Section	Total No. of Citations	Translation Assessment	External Standard Status	Regulatory Barrier Identified
SAE Standard J826_1995 and H-point Manikin *Devices for Use in Defining and Measuring Vehicle Seating Accommodations*	RT	S5 (4x)	4	0 – No Barrier	Newer standard issued, but not incorporated by reference in FMVSS: SAE J826_201511	None.
Table 1 of SAE Standard J826_1995 *Devices for Use in Defining and Measuring Vehicle Seating Accommodations*	RT	S5	1	0 – No Barrier	Newer standard issued, but not incorporated by reference in FMVSS: SAE J826_201511	None.
Vehicle's longitudinal centerline suggests SAE Dimension W7 from SAE J1100_2009 *Motor Vehicle Dimensions*	RT	S7.3, S7.4	2	0–No Barrier	Current	None.
ASTM E29-06b *Standard Practice for Using Significant Digits in Test Data to Determine Conformance with Specifications*	LTP	General Requirements	1	0–No Barrier	Newer standard issued, but not incorporated by reference in FMVSS: ASTM E29-13	None.
SAE Standard J826_1995 and H-point Manikin *Devices for Use in Defining and Measuring Vehicle Seating Accommodations*	LTP	Definitions	1	0–No Barrier	Newer standard issued, but not incorporated by reference in FMVSS: SAE J826_201511	None.

Referenced Document	Regulatory Text or Lab TP	Section	Total No. of Citations	Translation Assessment	External Standard Status	Regulatory Barrier Identified
Vehicle's longitudinal centerline suggests SAE Dimension W7 from SAE J1100_2009 *Motor Vehicle Dimensions*	LTP	Definitions	1	0 – No Barrier	Current	None.
H-point suggests SAE Standard J826_1995 *Devices for Use in Defining and Measuring Vehicle Seating Accommodations*	LTP	Appendix A	1	0 – No Barrier	Newer standard issued, but not incorporated by reference in FMVSS: SAE J826_201511	None.

Table 43. FMVSS No. 219 Reference List

Referenced Document	Regulatory Text or Lab TP	Section	Total No. of Citations	Translation Assessment	External Standard Status	Regulatory Barrier Identified
SAE J1100a_2009 *Motor Vehicle Dimensions*	LTP	Definitions	1	0 – No Barrier	Current	None.

Table 44. FMVSS No. 222 Reference List

Referenced Document	Regulatory Text or Lab TP	Section	Total No. of Citations	Translation Assessment	External Standard Status	Regulatory Barrier Identified
SAE Recommended Practice J211a_1971 *Instrumentation for Impact Test–Part 1–Electronic Instrumentation*	RT	S6.6.2, S6.7.2	2	0 – No Barrier	Newer standard issued, but not incorporated by reference in FMVSS: SAE J211_1_201403	None.
ASTM E29-06b *Standard Practice for Using Significant Digits in Test Data to Determine Conformance with Specifications*	LTP	General Requirements	1	0 – No Barrier	Newer standard issued, but not incorporated by reference in FMVSS: ASTM E29-13	None.
SAE Recommended Practice J1100_1984 *Motor Vehicle Dimensions*	LTP	11.21 (2x)	1	0 – No Barrier	Newer standard issued, but not incorporated by reference in FMVSS: SAE J1100_2009	None.
SAE Standard J826_1987 *Devices for Use in Defining and Measuring Vehicle Seating Accommodations*	LTP	11.21	1	0 – No Barrier	Newer standard issued, but not incorporated by reference in FMVSS: SAE J826_201511	None.
Seating reference point (SRP) suggests SAE J4004_2008 *Positioning the H-Point Design Tool—Seating Reference Point and Seat Track Length*	LTP	11.5, 11.21, 11.22	3	0 – No barrier	Current	None.

Table 45. FMVSS No. 225 Reference List

Referenced Document	Regulatory Text or Lab TP	Section	Total No. of Citations	Translation Assessment	External Standard Status	Regulatory Barrier Identified
H-point defined in Section 3.1 of SAE Standard J826_1992 *Devices for Use in Defining and Measuring Vehicle Seating Accommodations*	RT	S6.2.1.1, S6.2.2, S6.2.2.1 (3x)	5	0 – No Barrier	Newer standard issued, but not incorporated by reference in FMVSS: SAE J826_201511	None.
Section 2.2.11.1 of SAE Recommended Practice J1100-1993 *Motor Vehicle Dimensions*	RT	S6.2.2.1	1	0 – No Barrier	Newer standard issued, but not incorporated by reference in FMVSS: SAE J1100_2009	None.
Section 2.2.11.3 of SAE Recommended Practice J1100-1993 *Motor Vehicle Dimensions*	RT	S6.2.1.1	1	0 – No Barrier	Newer standard issued, but not incorporated by reference in FMVSS: SAE J1100_2009	None.
SAE Standard J826_1992 *Devices for Use in Defining and Measuring Vehicle Seating Accommodations*	LTP	Definitions	1	0 – No Barrier	Newer standard issued, but not incorporated by reference in FMVSS: SAE J826_201511	None.
SAE Standard J826_1987 *Devices for Use in Defining and Measuring Vehicle Seating Accommodations*	LTP	Definitions, Compliance Test Execution, Test Equipment	3	0 – No Barrier	Newer standard issued, but not incorporated by reference in FMVSS: SAE J826_201511	None.
SAE J1100_1984 *Motor Vehicle Dimensions*	LTP	Definitions, Compliance Test Execution	1	0 – No Barrier	Newer standard issued, but not incorporated by reference in FMVSS: SAE J1100_2009	None.

Table 46. FMVSS No. 226 Reference List

Referenced Document	Regulatory Text or Lab TP	Section	Total No. of Citations	Translation Assessment	External Standard Status	Regulatory Barrier Identified
Parts List and Drawings; Ejection Mitigation Headform Drawing Package, December 2010	RT	S7.1.1	1	0 – No Barrier	Current	None.
ASTM E29-06b *Standard Practice for Using Significant Digits in Test Data to Determine Conformance with Specifications*	LTP	General Requirements	1	0 – No Barrier	Newer standard issued, but not incorporated by reference in FMVSS: ASTM E29-13	None.
Vehicle's longitudinal centerline suggests SAE Dimension W7 from SAE J1100_2009 *Motor Vehicle Dimensions*	LTP	Definitions, Data Sheet No. 4	1	0 – No Barrier	Current	None.

Appendix F. Stakeholders and SME Involvement

As a part of Volume 2, there were three types of stakeholder engagements: (1) SME Involvement for the Volume 2 FMVSS Technical Translation Options Feedback, (2) November 2018 FMVSS stakeholder meeting, and (3) SME Test Method Feedback Meeting Involvement. The stakeholders and SMEs involved in these engagements are listed below

SME Involvement for the Volume 2 FMVSS

FMVSS No. 101
Advocates for Highway and Auto Safety
Apple
Automotive Safety Council (ASC)
Auto Alliance
Truck & Engine Manufacturers Association (EMA)
Honda
National Association of Mutual Insurance Companies (NAMIC)
NIO
Tesla
Valeo
Waymo

FMVSS No. 103
Advocates for Highway and Auto Safety
Apple
Auto Alliance
Global Automakers
Honda
NIO
Waymo

FMVSS No. 104
Advocates for Highway and Auto Safety
Apple
Auto Alliance
Global Automakers
Honda
NIO
Valeo
Waymo

FMVSS No. 110
Apple
ASC
Auto Alliance
Global Automakers
Honda
NIO
Waymo

FMVSS No. 111
Advocates for Highway and Auto Safety
Apple
Auto Alliance
Bosch
EMA
Global Automakers
Honda
NIO
Tesla
Waymo

FMVSS No. 113
Apple
Auto Alliance
EMA
Global Automakers
Honda
NIO
Waymo

FMVSS No. 124
Apple
Auto Alliance
EMA
Global Automakers
Honda
NIO
Tesla
Waymo

FMVSS No. 125
Auto Alliance
EMA
Global Automakers
Honda
Waymo

FMVSS No. 126
Apple
ASC
Auto Alliance
Bosch
Global Automakers
Honda
Insurance Institute for Highway Safety (IIHS)
NIO
Tesla
Waymo

FMVSS No. 207
Apple
ASC
Auto Alliance
Global Automakers
Honda
NIO
Tesla
Waymo

FMVSS No. 208
Apple
ASC
Auto Alliance
Bosch
Global Automakers
Honda
IIHS
NIO
Tesla
Waymo

FMVSS No. 210
Apple
Auto Alliance
Global Automakers
Honda
IIHS
NIO
Waymo

FMVSS No. 214
Apple
ASC
Auto Alliance
Global Automakers
Honda
IIHS
NIO
Waymo

FMVSS No. 216a
Apple
ASC
Auto Alliance
Honda
IIHS
NIO
Waymo

FMVSS No. 219
Apple
Auto Alliance
Honda
NIO
Waymo

FMVSS No. 222
Auto Alliance
EMA
Honda
IIHS
Waymo

FMVSS No. 225
Apple
ASC
Auto Alliance
Honda
NIO
Waymo

FMVSS No. 226
Apple
ASC
Auto Alliance
Honda
IIHS
NIO
Waymo

Organizations Represented at the November 2018 FMVSS Stakeholder Meeting

Organization
Active Safety Engineering LLC
Adient
Advocates for Highway and Auto Safety
Aisin Technical Center of America
Alliance of Automobile Manufacturers (Auto Alliance)
Amazon
American Honda
Apple

Organization
Association of Global Automakers (Global Automakers)
Autoliv
Automotive Safety Council
Babst Calland
BIA North America, LLC
BMW of North America
Booz Allen Hamilton
Center for Auto Safety
Community Transportation Association of America
Consumer Reports
Continental Automotive
Daimler
Dale Kardos & Associates, Inc.
Disability Rights Education & Defense Fund
Engineering Systems Inc.
ESi
Exponent
Faurecia Automotive Seating
Federal Motor Carrier Safety Administration
Ford Motor Company
General Motors
George Mason University
HERE Technologies
Honda
Humanetics Innovative Solutions, Inc.
Hyundai-Kia America Technical Center, Inc.
Insurance Institute for Highway Safety
IPG Automotive USA
ITS America
Japan Automobile Standards Internationalization Center
Joyson Safety Systems
Lindsey Research Services, LLC
Magna International
Mazda North American Operations

Organization
Mechanical Simulation Corp
Mercedes-Benz Research & Development North America
Michael Cammisa Consulting, LLC
MSC Software
National Association of Mutual Insurance Companies
National Automobile Dealers Association
National Council on Independent Living
National Safety Council
Navistar Inc
NHTSA
National Institutes of Health
NIO
Nissan Motor Co., LTD.
Nissan Technical Center North America
National Transportation Safety Board
Robert Bosch LLC
Roger C. Fairchild Esq., PC
SAE International
SFB Consulting, LLC
Squire Patton Boggs (U.S.) LLP
Subaru
Technova
Tesla, Inc.
The Potomac Alliance
Toyoda Gosei North America
Toyota Motor North America
Toyota Research Institute
TRW Automotive Inc.
U.S. DOT, Office of the Secretary
Venable
Veritext/Capital Court Reporting
Virginia Tech
The Global Center for Automotive Performance Simulation
Volkswagen Group

Organization
Volvo Cars
VTTI
Waymo LLC
ZF Friedrichshafen AG
ZF TRW
Zoox, Inc.

SME Test Method Feedback Meeting Involvement

The SME Feedback Meetings were introduced in Ch. 2 of this report and discussed further in Chapter 5. Responses were aggregated for each of the focus-group meetings, allowing multiple attendees to participate at one time in an open discussion format to generate new ideas and insights. The seven focus groups consisted of SMEs representing 20 organizations, including advocacy and trade associations (3), equipment and service providers (6), traditional manufacturers (7), and tech and startup companies (4). To promote a guided but free-form discussion, no focus group contained more than 9 participants. Table 47 provides a summary of the 45 participating SMEs' experience by the type of organization each represents. To target diversity of ideas, each meeting was planned to include a variety of SME expertise. Because a number of SMEs noted experience in several areas, experience representation is broader than represented in the table below.

Table 47. Breakdown of SME Experience by Organization Represented

Organization Type	ADS Development Engineer	Regulatory Compliance	Safety Engineer	Simulation Engineer	Systems Engineer	Test Engineer
Advocacy or Trade Associations		2	3			
Equipment or Service Providers		1		3	4	4
Manufacturer 1		6	3	1	1	1
Manufacturer 2		2	2			
Manufacturer 3	3	4	2	2	5	
Manufacturer 4			1			
Manufacturer 5		1	1			
Manufacturer 6		2	2		2	
Manufacturer 7		1	1			
Tech or Startup Companies	1	4	2		1	1
Total SMEs	4	23	17	6	13	6

Appendix G. Independent ADS-Equipped Research Vehicle Testing

A research team member with an ADS-equipped research vehicle executed the generic tests at their facilities. This testing served to provide a set of independent processes and procedures developed by a third party that fed into considerations for testing with ADS-equipped vehicles. The test methods and procedures were documented, sample tests were executed, and sample data was collected.

Independent ADS-Equipped Research Vehicle

Platform

The ADS-equipped research vehicle used for the independent testing was a modified passenger sedan, shown in Figure 32. The research vehicle ADS software architecture leverages the open-source ROS framework and includes subsystems for perception, localization, world modeling/situational awareness, high-level routing, low-level motion planning, and vehicle control through an interface to the vehicle CAN bus.

Figure 32. Independent ADS-Equipped Research Vehicle

The vehicle was equipped with a variety of sensors for perception including a 16-plane lidar, forward-facing automotive radar, and forward-facing stereo camera pair. The vehicle was also equipped with an integrated GPS/ inertial navigation system to provide supplemental localization information. The primary localization input comes from a proprietary vision-based system performing feature-matching on the road surface.

Methods of Operation

Three test methods were considered for the independent testing. Of these three, only the driverless or normal ADS method of operation was used for actual testing. The other two methods were only preliminarily or partially implemented.

Normal ADS Operation

The nominal method of operation of the prototype ADS was that of driverless operation with occupant waypoint/destination selection. The destination selection is facilitated through a tablet user interface (UI), shown in Figure 33. The user selects the desired destination from the waypoints provided and the ADS automatically generates an optimal route. The objective function used to generate the optimal route can support a variety of inputs; however, minimal travel distance was used as the objective for this testing. Once the generated route was approved and the ADS enabled, a pure pursuit steering algorithm managed lateral control and a PID controller managed longitudinal control based on a target speed. The target speed was provided by a software multiplexer that aggregated a number of speed recommendations and selected the optimal target speed, typically the lowest recommended speed. Desired steering, throttle, and brake inputs were then converted to appropriate CAN messages by a vehicle software interface. The research vehicle executed by-wire control of steering, throttle, and brake using the provided CAN messages.

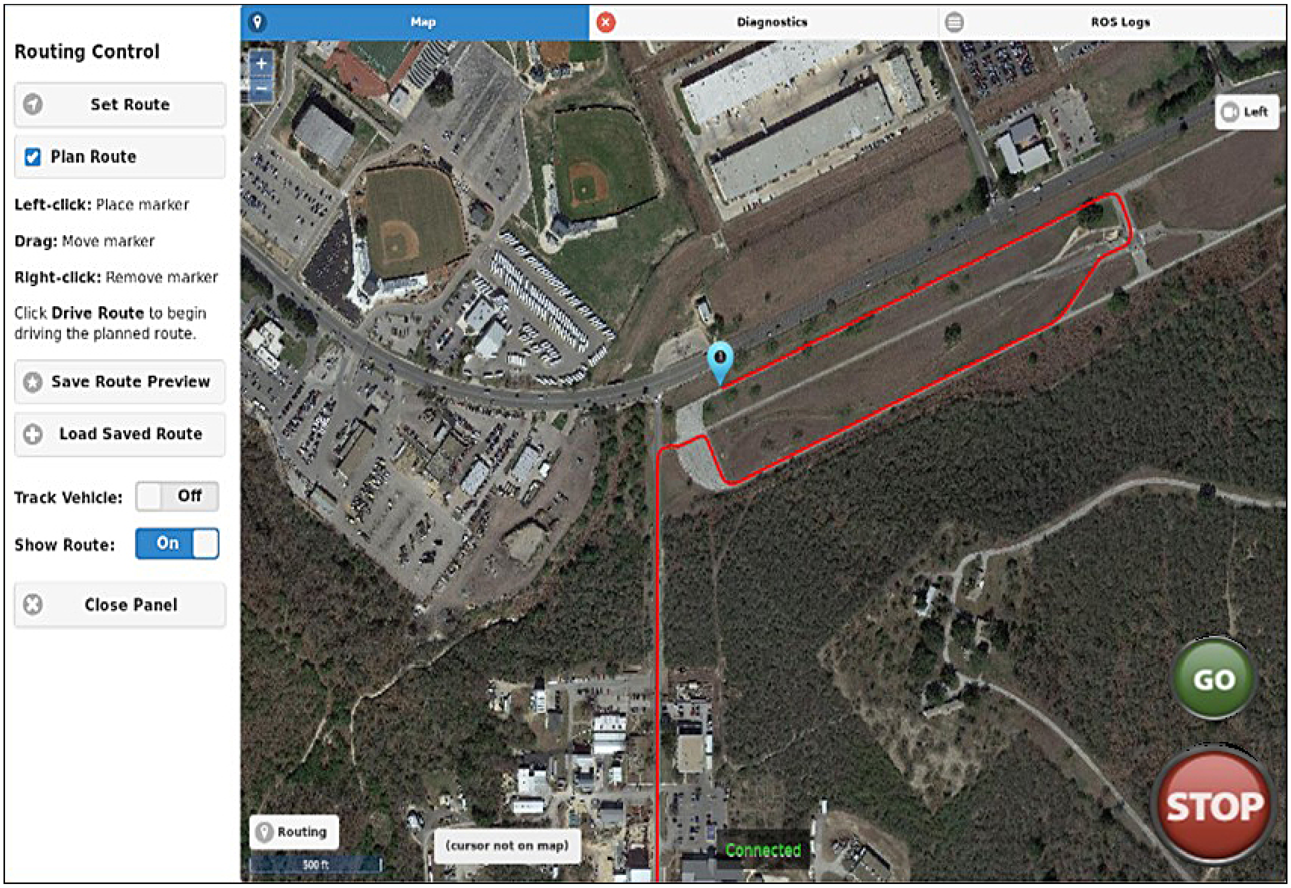


Figure 33. ADS-Equipped Research Vehicle User Interface

Human Control

A secondary method of operation of the prototype ADS was implemented to enable human control. This method incorporated a USB joystick controller, shown in Figure 34, to allow the experimenter to directly inject steering, throttle, and brake inputs to the by-wire interface. This method of operation bypassed much of the ADS architecture, specifically the route planning and lateral and longitudinal control subsystems used by the nominal driverless operation method. A software driver opened a connection to the joystick controller and parsed its inputs. These inputs were encoded into ROS messages and transmitted directly to the vehicle interface and onto the vehicle CAN bus.

Consistency, sensitivity to external factors, and cybersecurity are important considerations related to this method of operation, among others. The use of a human experimenter to control the ADS can inject an element of uncertainty or non-determinism because of the experimenter's actions. Even a trained, experienced experimenter could manipulate the controls differently from one iteration of a test to the next. Different vehicles under test may also respond or behave differently to the commands, leading to different results even with identical or nearly-identical manipulation of the controls. The interfaces for the human control equipment, such as the gaming controller shown in Figure 34, add a level of effort to implement if not already available. The additional interface also introduces another potential cybersecurity attack vector.

There is also a wide variety of equipment and hardware that could be used to implement this method. Standardization this hardware for testing, or at least standardizing the input signals generated, could aid in implementation and ease of use. Furthermore, consideration for constraining or moderating the input signals may be appropriate to improve test team safety (e.g., limiting accelerations, decelerations, or steering rates achievable). These constraints may be test-dependent, as some tests (e.g., FMVSS No. 126) require aggressive maneuvers that would need to be implemented via the human control interface.

Figure 34. Joystick Used for Human Control Testing

Programmed Control

Another secondary method of operation is being implemented to enable scripted control of the prototype ADS. When fully implemented, this method will enable input of specific and complete sequences of commands for lateral and longitudinal control (e.g., steering input sequence for SWD maneuver from FMVSS No. 126). This method will also bypass much of the ADS architecture, including route planning and lateral and longitudinal control subsystems used by the nominal driverless operation method. The new method is envisioned to be a modular software component that would allow for different control sequences to be programmed according to the FMVSS of interest. While this modularity may make the approach extensible, it also opens it up to divergence of modules, which may make some manner of standardization appealing.

As is it currently being implemented for the independent research vehicle, full access to ADS source code, interfaces, and message definitions makes this approach relatively straight-forward. This level of access would not necessarily be available in a production ADS. The level of effort required for developing this method of operation is also quite extensive. Once implemented, this method could offer improved repeatability and time savings associated with test preparation and execution.

Independent ADS Testing Facilities

The test facility was an access-controlled paved track, shown in Figure 35. The track included an approximately 1.9 km single-lane outer loop and a multi-lane signalized intersection, with simulated entrance and exit ramps further connecting the intersection to the outer loop. Most lanes, including the outer loop lane, are approximately 12 ft wide with degraded lane markings. Full map coverage required by the prototype ADS was available for the test track. The map included definitions of lanes and their directionality, as well as stop points, entry points, and exit points for the central intersection. The traffic signals were inactive and the intersection stop points were temporarily masked from the map for the independent test execution. No other vehicles or obstacles were present on the test track during test execution. The tests were conducted during nominal environmental conditions (i.e., no significant precipitation or visibility limitations). The tests were also conducted during differing, albeit nominal, lighting conditions (i.e., clear and overcast skies).

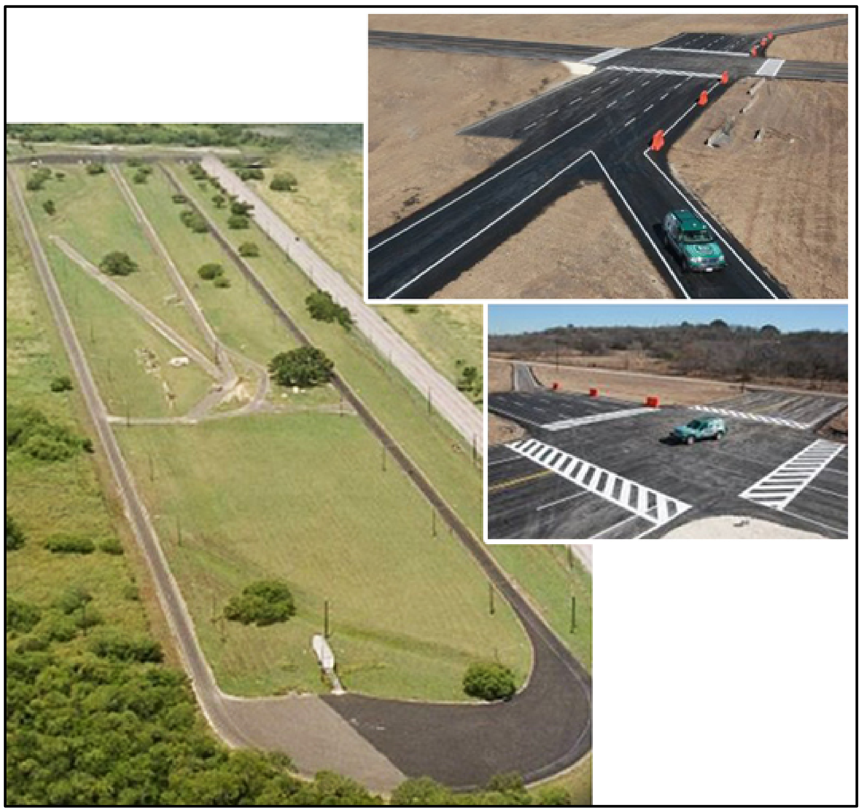


Figure 35. Test Facility for Independent Testing

Independent Testing Sample Data

The ADS-equipped research vehicle used for independent testing afforded complete visibility and open access to all of the ADS-related software subsystems and interfaces. As such, relevant data streams were identified and sample test data was easily recorded during testing. All data was recorded in ROS bag file format using ROS tools via the test laptop command line interface. These bag files were then downloaded off the vehicle for post-processing and visualization. Sample data examples included the following.

- ADS waypoint route
- Reported vehicle odometry
- ADS target speed
- Reported vehicle speed
- ADS commanded steering angle
- Reported vehicle steering angle
- ADS commanded brake effort
- Reported vehicle brake effort
- ADS commanded throttle effort
- Reported vehicle throttle effort
- ADS commanded transmission state
- Reported vehicle transmission state
- Reported vehicle tire pressures
- Reported ADS object table
- Reported vehicle door state

On a production ADS-DV, this data will likely be considered proprietary and will probably not be exposed in this manner. This is an important consideration for potential future FMVSS testing, as alternative approaches for collecting the required testing data may be necessary.

Generic Functionality Testing

Several types of generic tests were conducted as part of the independent testing, descriptions of which are provided below. The following sections also present high-level procedures used for the tests as well as sample results.

<u>Basic Driving Testing</u>

During the basic driving tests, the prototype ADS navigated to a user-defined waypoint. During the nominal driverless method of operation, the ADS had complete control over navigation, including route planning and lateral and longitudinal control.

The general test route for the basic driving tests is shown in Figure 36.

Figure 36. General Route for Basic Driving Tests

The general procedures for the basic driving test during driverless operation were as follows:

1. Safety driver manually positions ADS-equipped research vehicle at specified initial position and orientation and stops vehicle using service brake.
2. Experimenter initiates ADS (if not already enabled).
3. Experimenter begins data acquisition via data collection laptop command line.
4. Safety driver shifts vehicle to Park and releases service brake.
5. Safety driver selects destination via ADS UI to generate desired route.
6. Safety driver initiates ADS operation via ADS UI.
7. Experimenter announces to safety driver and other occupants (if any) that trial has begun.
8. ADS shifts to Drive, releases service brake, and navigates generated route at or near specified target speed.
9. For duration of trial, safety driver monitors the driving environment while the ADS is navigating the generated route.
10. ADS stops vehicle at desired destination waypoint, holds service brake, and shifts to Park.
11. Experimenter announces to the safety driver and other occupants (if any) that trial has ended.
12. Safety driver disengages ADS and retakes manual control of the vehicle.
13. Experimenter ends data acquisition.

These final procedures deviated slightly from initial proposed procedures for basic driving tests in the following ways:

The initial procedures called for the vehicle to be placed in Drive after initial positioning; however, the prototype ADS required the vehicle to be in Park.

The initial procedures called for the vehicle's parking brake to be applied; however, this disabled the prototype ADS on the research vehicle. Figure 37 shows a visualization of sample data collected during a basic driving test, in this case the generated route for the ADS to follow (purple in figure) compared to the actual vehicle path followed (green path not clearly visible in figure). Figure 38 shows an enhanced, zoomed view of a portion of the same data set. This figure more clearly shows the vehicle odometry (green) compared to the route (purple). This figure also shows that the ADS does not exactly follow the prescribed path as the vehicle kino-dynamics come into play. It tracks very closely for the most part, but there are visible and quantifiable deviations. This was especially observable through turns or curves. This is important to consider for potential future FMVSS testing that may require a very precise path.

Figure 37. Visualization of Sample Data From Basic Driving Test – High-Level Route Versus Vehicle Odometry

Figure 38. Enhanced Visualization of Sample Data From Basic Driving Test – High-Level Route Versus Vehicle Odometry

Figure 39 shows a visualization of additional sample data collected, in this case target speed versus actual speed. The sample results show constrained acceleration and deceleration, with speed capped at a maximum speed defined in the routes generated from the feature map. Deviations from this maximum speed can be attributed to recommendations of lower target speeds when considering turns or curvature of the route. These sample results also show a small temporal lag in response to a change in the target speed, as well as a general undershooting of the target speed. The control algorithm used for acceleration and deceleration was tuned such that a small undershoot of the target speed was preferable to any overshoot of the target speed. This could be considered typical of the expectation of an ADS, although a production system may track more closely. Production ADS-DVs could also make use of other types of control algorithms that have different responses or behaviors. This could be important for tests that require very accurate tracking of target speed and may be taken into consideration when setting target speeds or speed ranges, such as for FMVSS Nos. 138 or 126, among others.

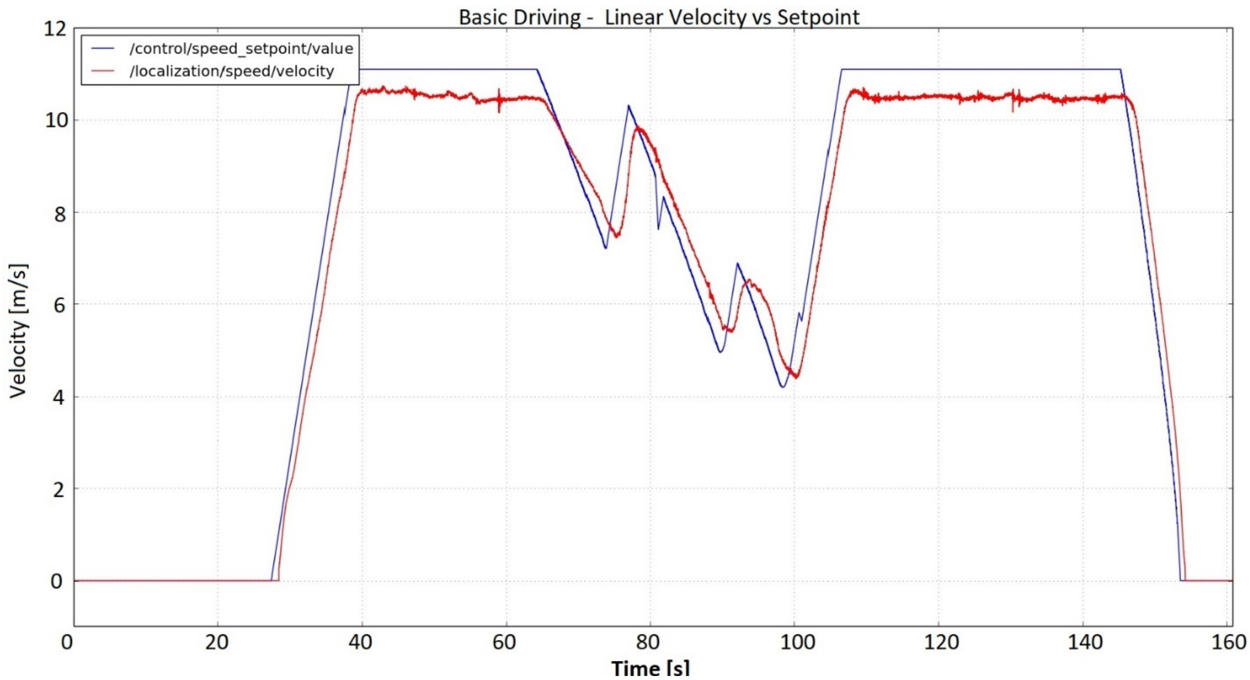


Figure 39. Sample Data From Basic Driving Test – Target Speed Versus Actual Speed

Accurate and Precise Steering and Speed Testing

A subset of the basic driving testing included testing of accurate and precise steering and speed control to evaluate the ADS-equipped vehicle's ability to follow a prescribed path and track a prescribed target speed. During the nominal driverless method of operation, the ADS had complete control over navigation, including route planning and lateral and longitudinal control.

The general test route for the basic driving tests is shown in Figure 40.

Figure 40. General Route for Accurate and Precise Steering and Speed Tests

The general procedures for the basic driving test during driverless operation were as follows:

1. Safety driver manually positions ADS-equipped research vehicle at specified initial position and orientation and stops vehicle using service brake.
2. Experimenter initiates ADS (if not already enabled).
3. Experimenter begins data acquisition via data collection laptop command line.
4. Safety driver shifts vehicle to Park and releases service brake.
5. Safety driver selects destination in front of the vehicle such that a generally straight route will be generated.
6. Safety driver initiates ADS operation via ADS UI.
7. Experimenter announces to safety driver and other occupants (if any) that trial has begun.
8. ADS shifts to Drive, releases service brake, and navigates generated route at or near specified target speed.
9. For duration of trial, safety driver monitors the driving environment while the ADS is navigating the generated route.
10. ADS stops vehicle at desired destination waypoint, holds service brake, and shifts to Park.
11. Experimenter announces to the safety driver and other occupants (if any) that trial has ended.
12. Safety driver disengages ADS and retakes manual control of the vehicle.
13. Experimenter ends data acquisition.

These final procedures did not deviate significantly from initial proposed procedures for the accurate and precise steering and speed tests.

Figure 41 and Figure 42 again show a visualization and enhanced visualization, respectively, of the generated route for the ADS-equipped research vehicle to follow (purple) compared to the actual vehicle path followed (green). It should be noted that while the prototype ADS tracks the intended route very closely, there are still observable lateral deviations from the route that should be considered for tests that may require specific routes or lateral motions.

Figure 41. Visualization of Sample Data From Accurate and Precise Steering and Speed Testing – High-Level Route Versus Vehicle Odometry

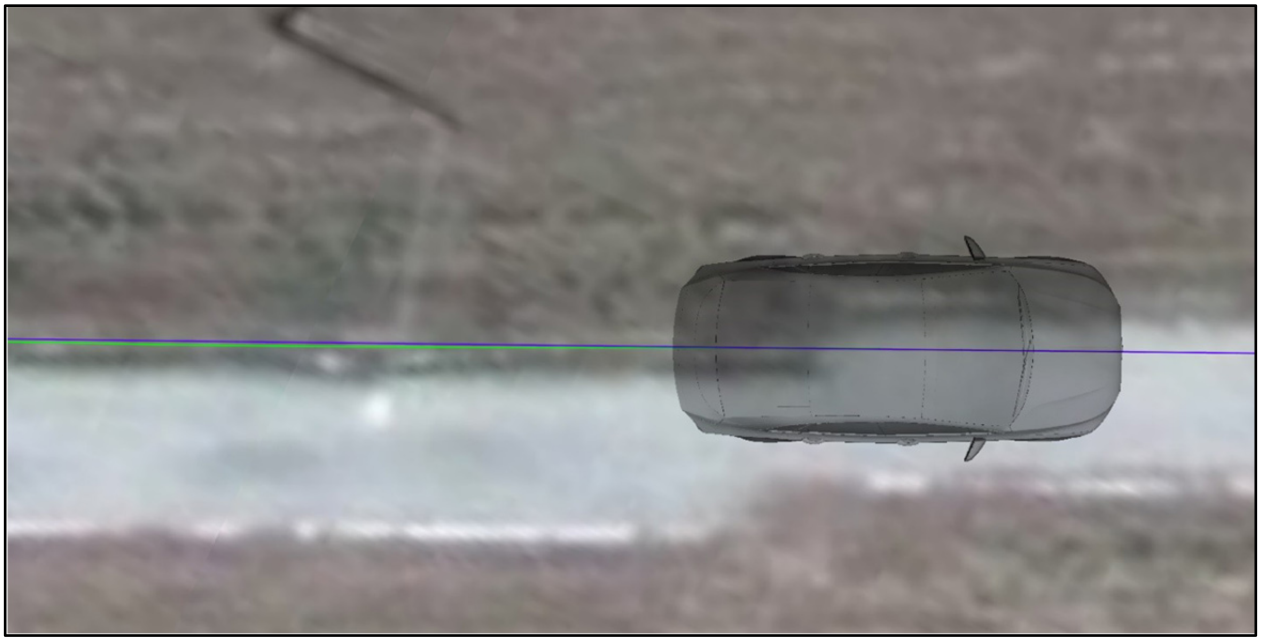


Figure 42. Enhanced Visualization of Sample Data From Accurate and Precise Steering and Speed Testing – High-Level Route Versus Vehicle Odometry

Figure 43 shows a visualization of some of the sample data collected, in this case target speed versus actual speed. Similar to the results for the basic driving test, these sample results show constrained acceleration and deceleration and a small temporal lag and slight undershoot of the target velocity. As the route was straight, no deviations from the maximum route speed were observed. As previously noted, a production system may track the target speed more closely. Production ADS-DVs could also make use of other types of control algorithms that have different responses or behaviors. This could be important for tests that require very accurate tracking of target speed and may be taken into consideration when setting target speeds or speed ranges, such as for FMVSS Nos. 138 or 126, among others.

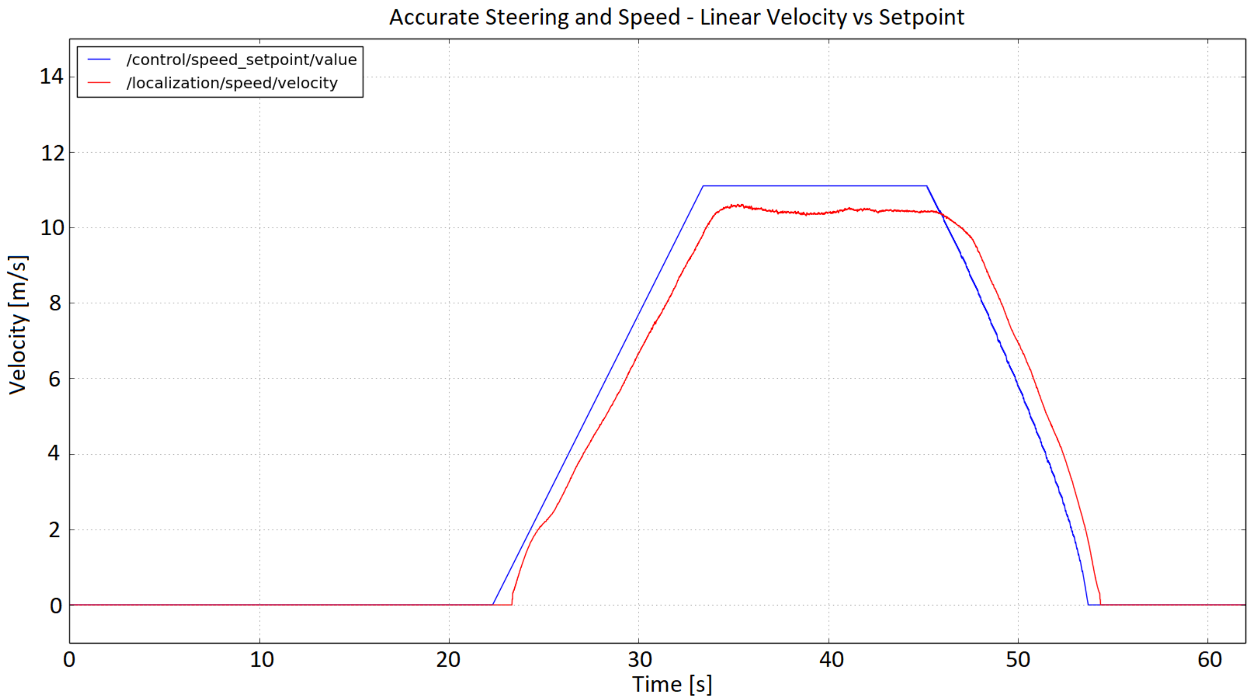


Figure 43. Sample Data From Accurate and Precise Steering and Speed Testing – Target Speed Versus Actual Speed

Vehicle State Monitoring Testing

Vehicle state monitoring tests were similar to basic driving tests in that the ADS-equipped research vehicle navigate to the closest waypoint behind the initial vehicle position. In this case the ADS was instructed to navigate a specified number of loops of the generated route to accumulate a desired amount of driving time as required by some FMVSS (e.g., FMVSS No. 138). During the nominal driverless method of operation, the ADS had complete control over navigation, including route planning and lateral and longitudinal control, and navigated the route the specified number of times before coming to a stop at the destination waypoint.

The general test route for the basic driving tests is shown in Figure 44.

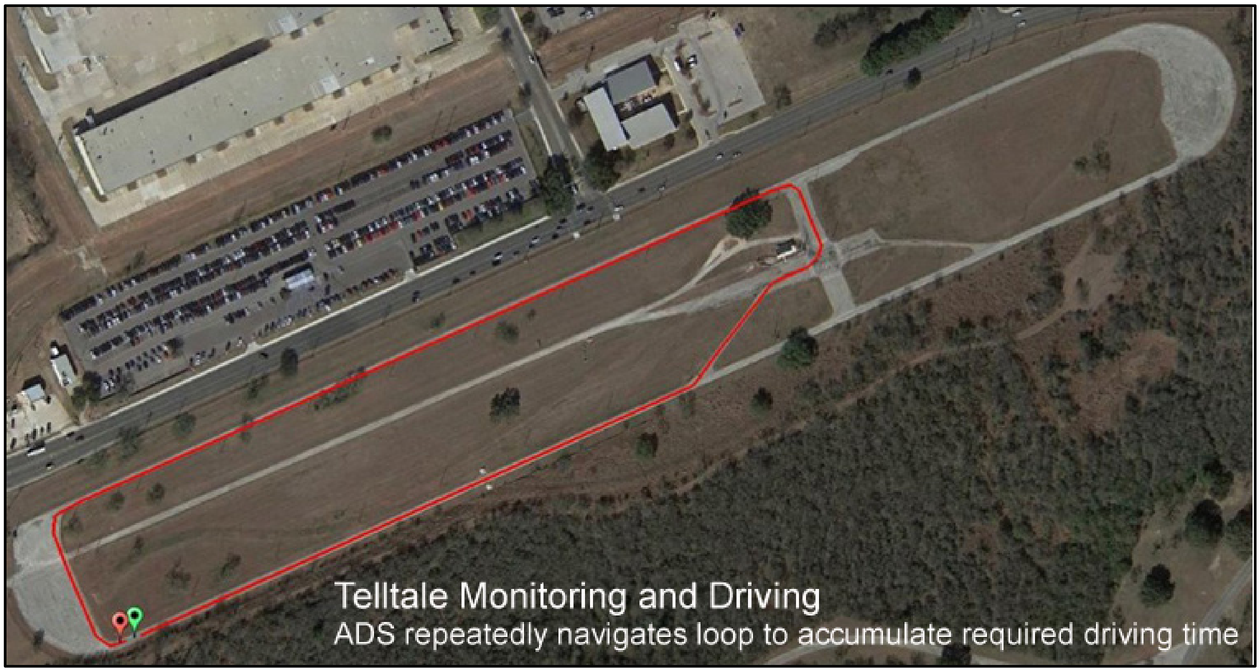


Figure 44. General Route for Vehicle State Monitoring Tests

The general procedures for the basic driving test during driverless operation were as follows:

1. Safety driver manually positions ADS-equipped research vehicle at specified initial position and orientation and stops vehicle using service brake.
2. Experimenter initiates ADS (if not already enabled).
3. Experimenter begins data acquisition via data collection laptop command line.
4. Safety driver shifts vehicle to Park and releases service brake.
5. Safety driver selects destination directly behind the initial vehicle position via the ADS UI to generate a route that will end with the vehicle situated with the same heading and in nearly the same position, and specifies a number of iterations for the ADS to navigate the closed-loop route.
6. Safety driver initiates ADS operation via ADS UI.
7. Experimenter announces to safety driver and other occupants (if any) that trial has begun.
8. ADS shifts to Drive, releases service brake, and navigates generated route at or near specified target speed.
9. For duration of trial, safety driver monitors the driving environment while the ADS is navigating the generated route.
10. ADS stops vehicle at desired destination waypoint after specified number of iterations, holds service brake, and shifts to Park.
11. Experimenter announces to the safety driver and other occupants (if any) that trial has ended.
12. Safety driver disengages ADS and retakes manual control of the vehicle.
13. Experimenter ends data acquisition.

These final procedures deviated slightly from initial proposed procedures for vehicle state monitoring tests in the following ways:

The initial procedures called for a higher speed range (31 to 62 mph). The digital map used by the prototype ADS artificially set a maximum speed limit of 25 mph. This speed limit could have been modified for the purposes of testing, but the decision was made to execute the tests with the existing speed limit.

Figure 45 and Figure 46 show examples of sample data for target speed versus actual speed and tire pressures collected during a vehicle state monitoring test.

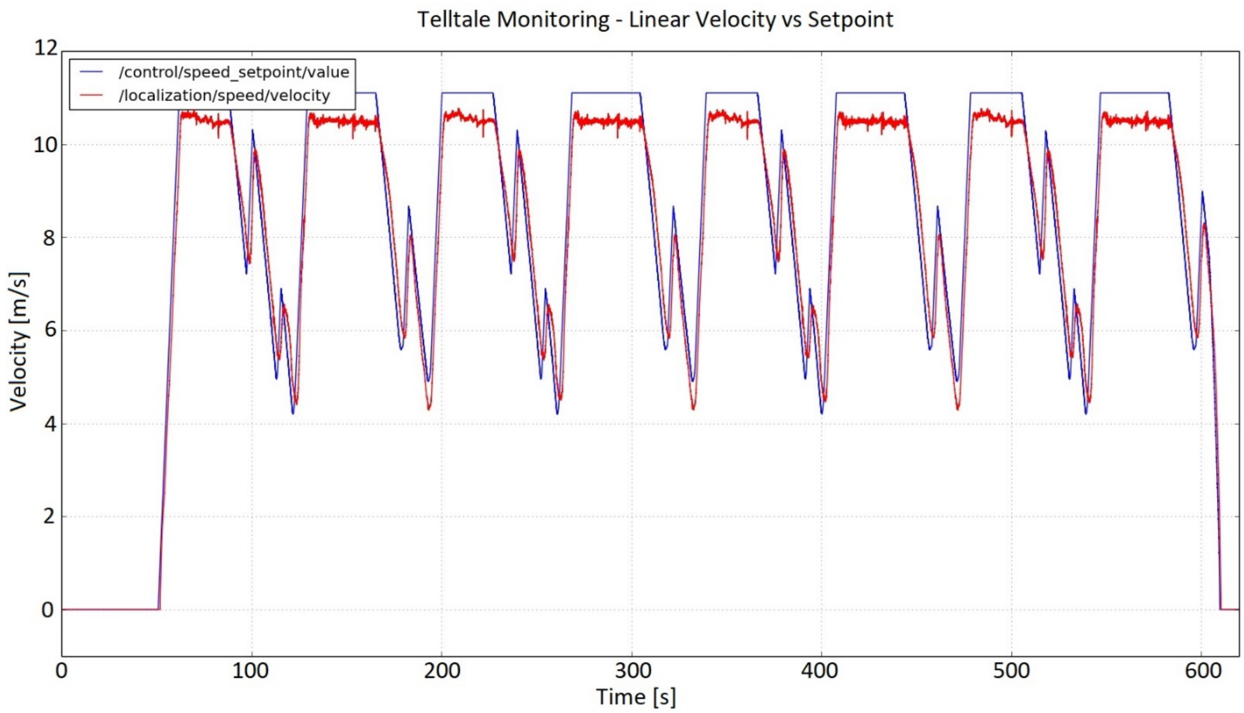


Figure 45. Sample Data From Vehicle State Monitoring Test – Target Speed Versus Actual Speed

The sample results show a repeated pattern due to the multiple loops navigated by the research vehicle. The pattern generally follows that of the results for the basic driving test, which is expected, as the vehicle followed a nearly identical route with multiple iterations. Figure 45 shows the same data but focused on the first iteration of the route. The target speed and actual speed track nearly identically over time when compared to the results from the basic driving test shown in Figure 46.

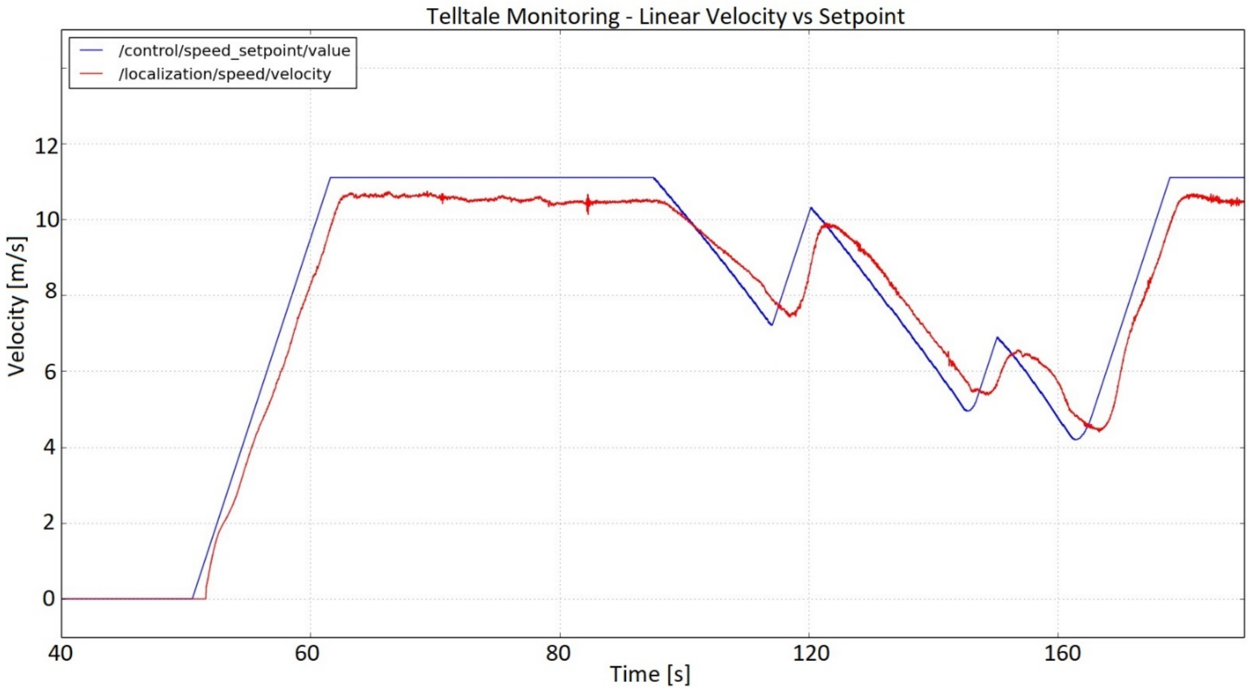


Figure 46. Vehicle State Monitoring – Target Speed Versus Set Point Zoomed

The sample data in Figure 47 shows pressure values for the four tires on the research vehicle, revealing that the pressure increased in all tires over the course of the test (approximately 10 minutes). This data was collected via the ADS data bus and shows the feasibility of collecting similar data for FMVSS testing. It should be noted that other telltale data, while likely present on the vehicle CAN bus, was not immediately available on the ADS bus for capture. This data was collected after the CAN messaging structure and ID were exposed. This is not typical, as the CAN messaging information is often considered proprietary, requiring alternative approaches to generating or collecting relevant telltale test data (or other data from the CAN bus).

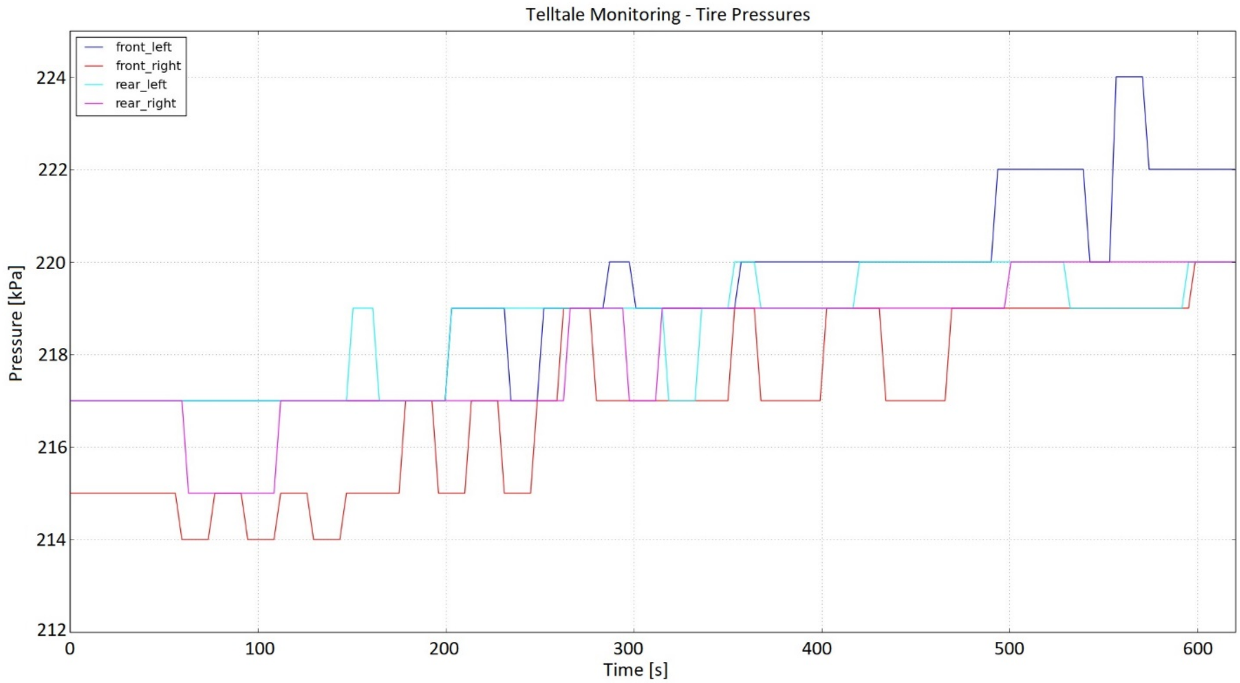


Figure 47. Sample Data From Vehicle State Monitoring Test – Tire Pressures

Visibility Testing

Visibility testing acquired data from the base vehicle platform sensors as well as from ADS sensors and perception subsystems. The tests were performed with the ADS-equipped research vehicle static and situated in a largely open area with an object of interest moving around it with a prescribed path.

The general positioning of the research vehicle and path of object(s) of interest are shown in Figure 48.

Figure 48. General Research Vehicle Position and Object Path for Visibility Tests

The general procedures for the basic driving test during driverless operation were as follows:

1. Safety driver manually positions ADS-equipped research vehicle at specified initial position and orientation and stops vehicle using service brake.
2. Experimenter initiates ADS (if not already enabled).
3. Experimenter begins data acquisition via data collection laptop command line.
4. Safety driver shifts vehicle to Park and releases service brake.
5. Safety driver selects destination directly behind the initial vehicle position via the ADS UI to generate a route that will end with the vehicle situated with the same heading and in nearly the same position, and specifies a number of iterations for the ADS to navigate the closed-loop route.
6. Safety driver initiates ADS operation via ADS UI.
7. Experimenter announces to safety driver and other occupants (if any) that trial has begun.
8. ADS shifts to Drive, releases service brake, and navigates generated route at or near specified target speed.
9. For duration of trial, safety driver monitors the driving environment while the ADS is navigating the generated route.
10. ADS stops vehicle at desired destination waypoint after specified number of iterations, holds service brake, and shifts to Park.
11. Experimenter announces to the safety driver and other occupants (if any) that trial has ended.
12. Safety driver disengages ADS and retakes manual control of the vehicle.
13. Experimenter ends data acquisition.

Note that for this test, the destination coincided with the initial position to keep the vehicle stationary during the data collection. These final procedures did not deviate significantly from initial proposed procedures for visibility tests.

Figure 49 shows sample data in the form of a tabulated version of the ADS object table for a visibility test. This data represents objects detected by the research vehicle's sensor suite comprised of radar, lidar, and vision sensors. The data shown simply represents objects segmented from point cloud data, with no associated object type or classification, which is handled later in the perception pipeline. The objects are represented by polygonal "bounding boxes" with polygon points defined in a local coordinate frame. This type of data could be valuable for future FMVSS that may include assessment of an ADS's object and event detection and response capabilities. This data and the interface to access it could likely be considered proprietary, and as such, alternative methods to capture this data may be required for FMVSS testing.

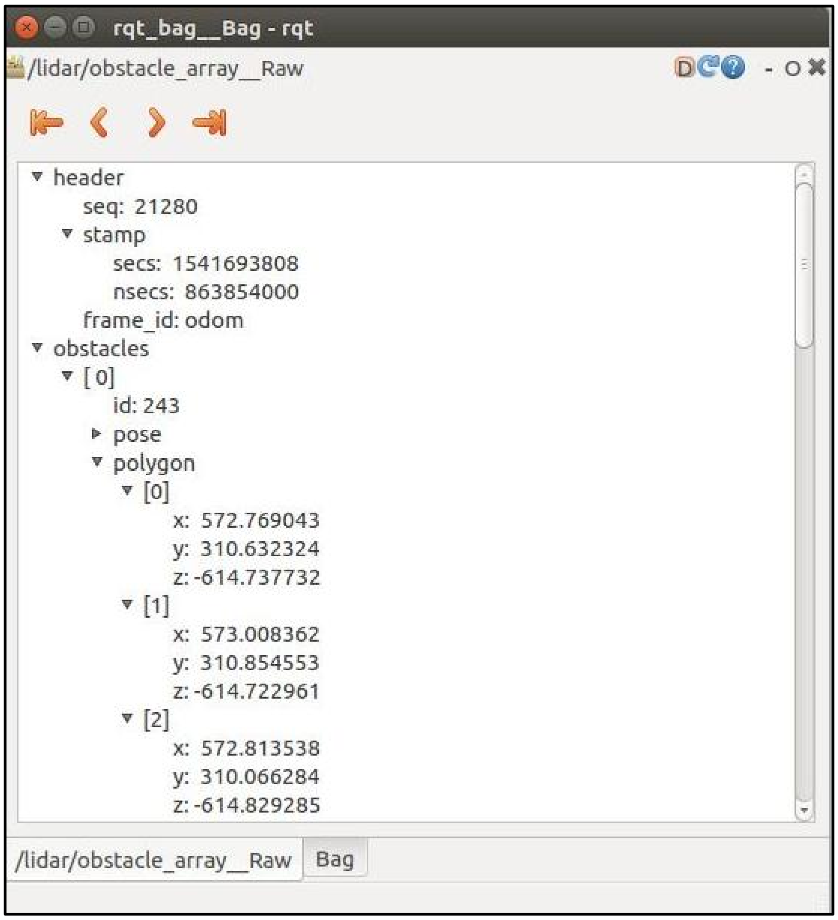


Figure 49. Sample Data From Visibility Test – ADS Object Table

Testing Considerations

The following sections describe some of the important considerations that were identified during preparation and execution of the independent testing. These are not intended to be exhaustive, but rather a sampling of the test execution-related impacts ADS may have. Many of the considerations are related to the research vehicle's nominal driverless method of operation; however, thoughts are also provided on human control and preprogrammed control modes of operation.

Research Vehicle

The ADS-equipped research vehicle used for the independent testing is a recent production vehicle that has been modified to enable ADS functionality. It is equipped with conventional features, such as a steering wheel, gas and brake pedals, audible and visual telltales, side and rearview mirrors, among others. These features may serve to allow for manual control of the vehicle or convey important platform warnings to a driver. A future ADS-DV may be missing a subset or all of these conventional features, some of which were used to either prepare for or execute the independent testing. The research vehicle has also been retrofitted with some unconventional features, including but not limited to, an emergency stop button, and tablet user interface. Some of these unconventional features may not be present or readily available on a future ADS-DV.

The research vehicle also afforded open accessibility to the primary ADS-related hardware and software components, including source code that may not be readily available on production ADS-DVs. This access was not required for testing using the nominal driverless operation method; however, it was required to enable the human control and programmed control modes of operation for the research vehicle. Modifications have been or will be made to allow a test entity to directly inject control signals through the ADS-equipped vehicle interface. For human control, a gaming joystick was added to the ADS hardware and an accompanying software module was added to the ADS architecture to effectively replace the nominal ADS speed and steering control subsystems. This setup was simple in terms of hardware changes in that the joystick could be plugged directly into an appropriate ADS computer; however, this interface may not be readily available on a future production vehicle. Furthermore, more sophisticated systems for enabling human control may require additional hardware or software changes. For programmed control, a new software module is being developed to enable onboard preprogrammed control of steering, throttle, and braking that will similarly replace the nominal ADS speed and steering control subsystems. This method of software update (source code update in this case) may not be possible on a future ADS-DV. Messaging data structures and interfaces are also exposed on the research vehicle for all modes of operation for data collection during testing. A script was created and run from the test laptop command line to record the desired data streams locally. A future ADS-DV may not expose these interfaces for similar data collection.

The base vehicle platform itself has relevant performance characteristics that were analyzed and characterized long before the execution of any tests. This characterization (e.g., steering range, steering rate, acceleration or deceleration rate or hysteresis effects) may be an important part of preparing to test a new ADS-DV. In addition to the base vehicle platform characteristics, the ADS has certain performance characteristics that need to be considered for certain FMVSS. For example, obstacle detection and avoidance subsystems may affect the navigation performance of an ADS-DV if, during a test, it detects and responds to an object or scenario that was not intended to be a part of that test.

Procedural Differences

As a result of ADS design or implementation decisions, it was not always possible to follow stated procedures for some tests with the research vehicle, whether formal FMVSS or general tests procedures. For example, some of the generic test procedures call for engaging or disengaging the vehicle parking brake. This functionality is not currently supported by the independent research vehicle ADS architecture and, as such, the parking brake was engaged or disengaged manually by the safety driver. Similarly, some of the generic test procedures call for automatically starting or stopping the vehicle engine, which is also not currently supported by the independent research vehicle ADS architecture, and therefore the vehicle engine was started or stopped manually by the safety driver.

Configuration Changes

Some testing may require changes to ADS configurations or parameterizations to achieve desired test conditions or behaviors. For example, the digital map used by the research vehicle ADS encoded maximum speed limits along route segments. While not required for the independent testing thus far, these values may need to be updated for some tests that may require higher speeds than those currently allowed for in the existing map. One example of this is FMVSS No. 138 (TPMS) which calls for the vehicle to drive and maintain a speed between 31 and 62 mph for 10 to 15 minutes of cumulative time. Another example relates to steering control algorithms, which can potentially constrain the steering value or rate based on vehicle speed. Modification to these constraints and other similar parameters may be required for some tests that involve dramatic steering maneuvers (e.g., FMVSS No. 126), which an ADS-DV may otherwise not execute by design. For human control, some inputs may be constrained for safety (throttle rate limited to avoid hard accelerations, steering rate limited based on vehicle speed, etc.). Some of these constraints may prohibit the vehicle from executing some maneuvers and may need to be relaxed or removed. Furthermore, methods to enable human control or preprogrammed control may necessitate characterization of the vehicle platform and/or ADS subsystems.

Test Environments

Some test environments may need to be specially constrained or contrived to attempt to compel the ADS to exhibit a desired behavior during a test. For example, a specific route may be necessary to get an ADS-DV to navigate in a specific lane or make a specific turn or approach a specific object and not navigate around it. This could be implemented by the physical infrastructure (number of lanes, geometry of lanes or roadway, objects, etc.) or some other means.

Some ADS-DVs may require *a priori* digital maps of their operating environments to function as intended. For example, the ADS-equipped research vehicle used for independent testing required the specialized road surface feature map described earlier in this chapter. Depending on where the testing takes place, it is possible that the test area is not included in the *a priori* map and the ADS may interpret that it is outside of its ODD and therefore will not operate as desired.

Appendix H. Simulation

Implementation

The key objective for studying simulation as a non-vehicle-based test method was to evaluate its viability as a test method in verifying ADS-DV compliance. Today, NHTSA purchases a vehicle from a dealership, outfits it with instrumentation, executes a physical test (e.g., NHTSA's OVSC test procedure, depending on the regulation), and assesses the computed response metrics. While the compliance verification process does (dependent on regulation) include information submitted by manufacturers (e.g., NHTSA's Test Specification Forms) NHTSA verifies vehicle compliance independently of the manufacturer. This assumes a similar structure and considers options for retaining an independent process for simulation as a possible test method. It is necessary to compare the results of the virtual simulation to real-world data to obtain findings about the effectiveness of the process, significant parameters defining the system behavior, and individual parameter sensitivity to the process. It is important to highlight that this study does not consider replacing vehicle-based compliance testing but uses virtual simulation to augment physical testing for specific tests which may have associated testing barriers on production-level ADS-DVs.

For simulation to be a viable test method for compliance, there must be trust in the model and its simulation output. The first step of this process is to develop trust in the model by understanding the important model parameters directly related to the systems being tested. This can be established through theoretical examination of the underlying equations of motion of the system or through experimental means. Experimental means can be performed with virtual simulation, given that a valid model of the system has been created. This study focuses on simulation model iteration and statistical analysis to help identify the significant and sensitive model parameters. Model iteration refers to the repeated simulation of vehicle maneuvers while systematically varying the mathematical model parameters. After model iteration is completed, parameter statistical significance will be examined, and then those parameters will be investigated for their required accuracy to provide valid model outputs. The steps used for this study are outlined in the workflow diagram below (Figure 50).

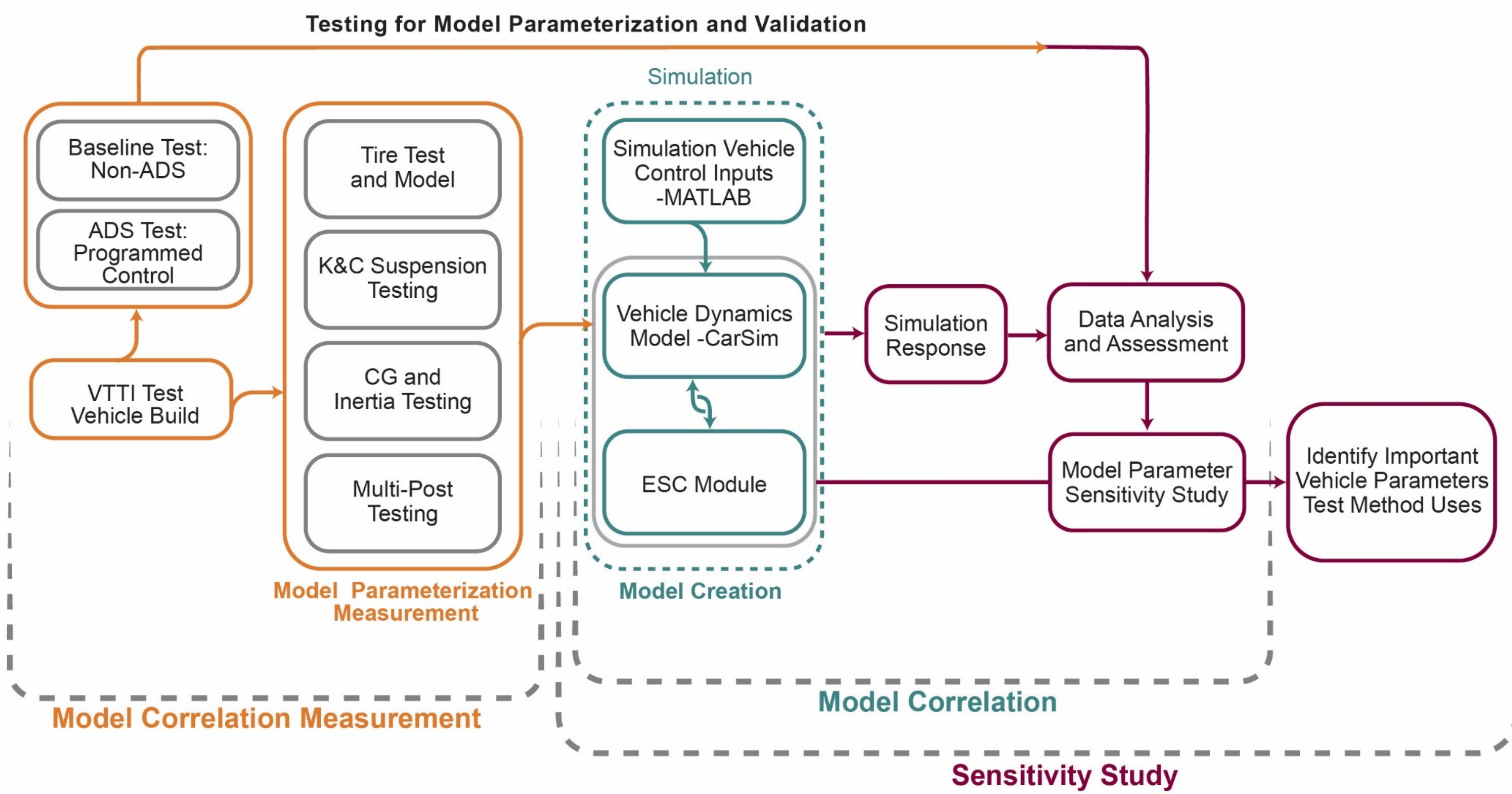


Figure 50. Simulation Workflow

Execution

The physical vehicle selected for this study was the VTTI test vehicle build. The results of the baseline test and ADS-DV test with this vehicle are discussed in the Model Correlation section further below in this appendix. The other key aspects of the workflow will be discussed in the following sections.

Model Measurements

To properly parameterize the relevant mathematical models, the physical vehicle components and overall vehicle system performance were tested and evaluated. Parameter and component measurements were performed to quantify center of gravity, mass moments of inertia, suspension characteristics, steering characteristics, and tire response. Vehicle-level measurements were performed during the FMVSS No. 126 test procedure and on a four-post shaker rig. Parameter and component-level measurements were completed first, then the vehicle was instrumented and tested as a system in the laboratory.

Model Creation

The vehicle model was created by parameterizing the appropriate math models within the CarSim simulation environment. The model was primarily developed from the parameter measurements while estimated unsprung mass values were determined from the four-post shaker rig testing response.

Results

Model Correlation

Correlation was assessed between the field and model data by simulating FMVSS No. 126 and four-post shaker rig tests, and then calculating the correlation coefficient, coefficient of determination and root mean square error between the model response and field test data. From the correlation investigation, it was concluded that there was sufficient correlation between the vehicle suspension and inertial models and the system performance of the full vehicle. Model correlation investigation also offered justification to implement a mathematical ESC model and provided the reference for properly parameterizing that model. Through validating model correlation, two inferences could be made about the measurements performed to achieve this result. The first is that by defining vehicle-specific mathematical models for inertial, geometry, suspension, steering, and tire response while using a more general powertrain mathematical model, the model parameter measurements and associated parameterized mathematical models produced an adequate representation of the full-vehicle system to simulate FMVSS No. 126. The second is that the model correlation measurements as performed offered adequate reference to determine correlation between real-world and simulated test data.

Model correlation investigation also offered ISO 19365 as a potential approach to model validation specific to FMVSS No. 126. ISO 19365 specifies comparison requirements between virtual simulation and field data to establish a valid simulation for FMVSS No. 126. ISO 19365 was applied as a method for evaluating model quality due to parameterization changes, which is not the identical application of the standard. It was also noted that ISO 19365 provides metric tolerances for the first two peaks, yaw rate crossover, and the lateral displacement, which may not adequately address the end of maneuver behavior.

Parameter Reduction Study

The simulation was iterated to provide insight into the parameters that drive system behavior. The iterated model outputs were to be compared to the baseline model response or field data through a variety of metrics. Time history correlation metrics, FMVSS No. 126 metrics, and ISO 19365 metrics are all possible sources of reference and were used throughout this work. N-way analysis of variance (ANOVA), D-optimal design, and parameter reduction were used to examine the effects of varying model parameters. N-way ANOVA analysis provided the means by which to establish statistical significance while D-optimal design and parameter reduction established proper design space coverage. The N-way ANOVA results were examined with reference to FMVSS No. 126 and ISO 19365 compliance metrics to assess model response for the purpose of identifying parameter sensitivity.

Parameter reduction successfully identified and eliminated parameters whose variation did not produce statistical significance or did not result in simulated non-compliance based on the established metric from FMVSS No. 126 and ISO 19365. This enabled the study to focus on the five parameters that had a significant impact on simulation response (i.e., XCG, ZCG, IZZ, IXX and tire model)

Sensitivity Study

Once the non-compliant cases were correlated with the statistical results, the acceptable amounts of the relevant parameters' variation were examined by targeted simulation. These acceptable variation ranges were then related to measurement accuracy of the vehicle system and components. This resulted in identifying the potential measurement accuracy required for establishing model trust and simulation output for the specific test vehicle.

The sensitivity study provided the maximum amount of acceptable model parameter variation for the five identified parameters in the parameter reduction study. Analysis of the response data to the ISO 19365 specification revealed that more than 10 percent parameter variation caused calculated non-compliance. Analysis of the response data to FMVSS No. 126 specifications showed that more than 20 percent parameter variation caused calculated non-compliance. Since the realistic parameter set had less than 5 percent variation, it may be possible to parameterize a vehicle dynamics model that represents the physical system with proper consideration of the ESC.

Findings

The work performed in this study helped identify considerations for developing trust in a mathematical vehicle model and simulation. The constraints of the study only allowed for evaluation of one vehicle with an ESC model that was approximated based on the ESC performance of the physical vehicle. Future work could include evaluation of other vehicle classes and inclusion of the actual ESC either through a manufacturer-supplied model or co-simulation with the ESC hardware through HIL.

Figure 51 below outlines some of the process options for simulation as a potential method for compliance verification.

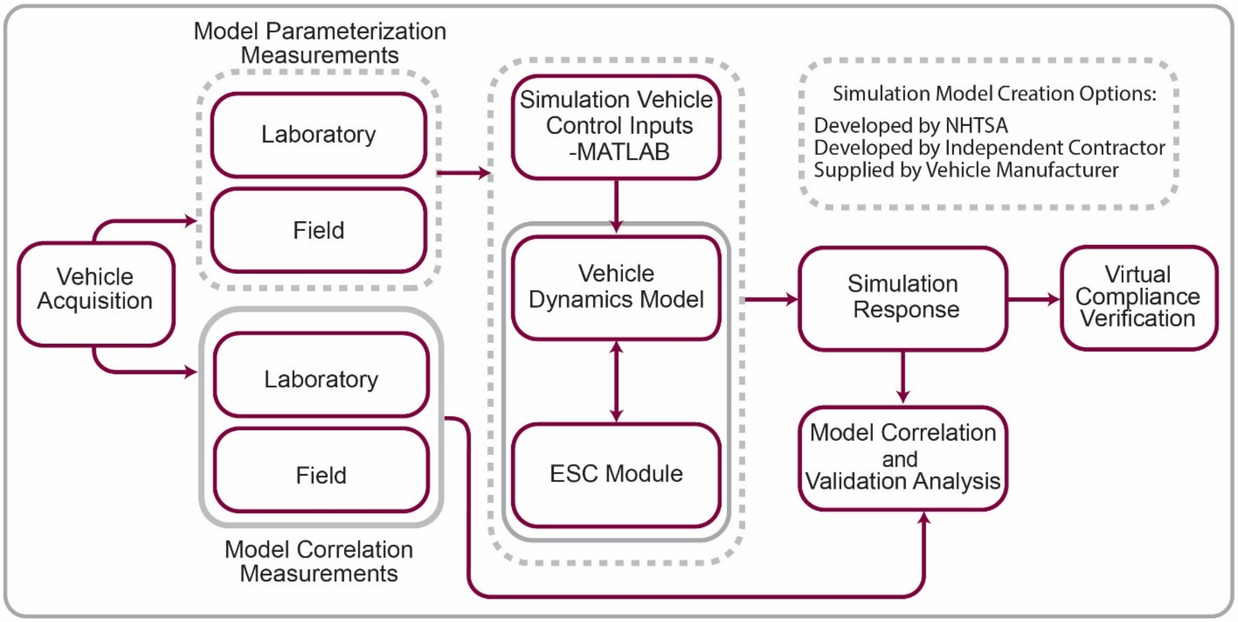


Figure 51. Model Creation

Relating this proposed process back to the current physical vehicle compliance testing, the potential burden associated with the process flow defined above is contained within the model creation and correlation steps. If the model was supplied by the manufacturer, the focus of the vehicle testing would be collecting correlation data, which is a small subset of the test data required for this study. If the vehicle dynamic model and simulation were parameterized by NHTSA or an independent contractor, all testing performed in this work may need to be considered.

Model Parameter Measurement

Model parameter measurement was required to populate the associated mathematical model values within the vehicle simulation software. Properties such as vehicle mass, suspension information, and vehicle control electronics needed to be addressed. More specifically, to develop a model for FMVSS No. 126, the physical vehicle system was exercised within its design capability while focusing on the speeds and maneuvers defined by the performance standard (e.g., by operating and/or component testing). The test results were then compared to a simulated model output.

The parameter measurements performed for this simulation study were center of gravity location, mass moments of inertia, unsprung mass, steering and suspension kinematics and compliances, tire force and moment response, and damper characterization. The powertrain subsystem did not require parameter measurement and a more general representative model was used to obtain meaningful simulation results. Powertrain inputs were not applicable to FMVSS No. 126 as the vehicle was not under power during the SWD test runs. Therefore, if engine braking and relative deceleration are similar, a high-fidelity powertrain model may not be required.

Model Parameter Measurement: Center of Gravity and Moments of Inertia

Center of gravity location and mass moments of inertia were measured on a dedicated test rig. Measurements were taken by positioning the vehicle on a balance table and methodically tilting and swinging the table in the heave, pitch, and roll directions to determine the X, Y, and Z locations of the center of gravity as well as the mass moments of inertia for roll (Ixx), pitch (Iyy), and yaw (Izz) directions. Figure 52 is a picture of a third-party test rig that could be used to measure these parameters.

Figure 52. Photograph of Center of Gravity and Moment of Inertia Test Rig

Center of Gravity Location and Mass Moments of Inertia Results

Testing took approximately four hours to complete. Center of gravity and moment of inertia measurements were taken for two vehicle setups, baseline curb weight and loaded with two passengers. The results are shown in Table 48, Table 49, and Table 50 below.

Table 48. Weight and Mass Measurement Results

Configuration	Weight (lbs)	Mass (slugs)	Weight (N)	Mass (kg)
Baseline curb	-4443.2	138.1	19764.3	2015.4
Run 1 with 2 passengers	-4828.4	150.1	21477.8	2190.5

Table 49. Center of Gravity Location Results

Configuration	Units	XCG	YCG	GCG
Baseline curb	in	8.530	-0.494	26.839
Run 1 with 2 passengers	in	8.044	-0.449	27.428
Baseline curb	mm	216.659	-12.557	681.722
Run 1 with 2 passengers	mm	204.309	-11.409	696.666

Table 50. Moment of Inertia Results

Configuration	Units	PITCH MR^2	YAW MR^2	ROLL MR^2
Baseline curb	English (lbs-ft-sec^2)	2212.1	2800.3	621.1
Run 1 with 2 passengers	English (lbs-ft-sec^2)	2635.4	2869.6	646.1
Baseline curb	Metric (kg-m^2)	2999.2	3796.7	842.1
Run 1 with 2 passengers	Metric (kg-m^2)	3573.1	5147.6	876.0

Model Parameter Measurement: Kinematics and Compliance

The vehicle kinematics and compliance parameters were also measured on a dedicated test rig. The purpose of the kinematics and compliance testing was to quantify the force-displacement relationships of the suspension and steering systems throughout their ranges of travel. Figure 53 is a picture of the test build vehicle on the kinematics and compliance test rig.

Figure 53. Photograph of Test Vehicle on the Kinematics and Compliance Test Rig

The vehicle chassis is fastened to the kinematics and compliance rig, which slowly moves the chassis in the heave, pitch, and roll directions while four individual tire platens position the tire contact patch center location for specific test conditions. Instrumentation on the vehicle and test fixtures, such as encoders and load cells, measure the displacement and force response of the vehicle suspension, such as the tire load and orientation properties during chassis motion. Measurements took approximately 2 days to complete. The third-party supplier offered an option to reduce the test data into a format that could directly import the mathematical model parametrizations within the selected vehicle dynamic simulation software. The supplied suspension and steering kinematics and compliance lookup tables and parameter relationships for the front and rear suspensions are listed below and shown in full in the VTTI simulation supplement document.

Kinematics and Compliance Results
Suspension:

- Auxiliary Roll Moment
- Camber Versus Longitudinal Wheel Force
- Dive Versus Lateral Wheel Moment
- Inclination Versus Lateral Wheel Force
- Inclination Versus Vertical Wheel Moment
- Wheel Center Lateral Displacement Versus Lateral Wheel Force
- Wheel Center Longitudinal Displacement Versus Longitudinal Wheel Force
- Spring Compression: Vertical Wheel Force Versus Vehicle Body to Wheel Vertical Displacement

Spring Extension:

- Vertical Wheel Force Versus Vehicle to Wheel Vertical Displacement
- Vertical Wheel Force Versus Tire Compression
- Toe-in Versus Wheel Longitudinal Force
- Toe-in Versus Vehicle Body to Wheel Vertical Displacement
- Camber Versus Vertical Wheel Displacement
- Wheel Spin Change Versus Vehicle Body to Wheel Vertical Displacement
- Wheel Center Longitudinal Position Versus Vehicle Body to Wheel Vertical Displacement
- Wheel Center Lateral Position Versus Vehicle Body to Wheel Vertical Displacement

Steering:

- Rack Displacement Versus Steering Angle
- Road Wheel Steer Angle Versus Rack Displacement
- Average Steer Versus Kingpin Moment
- Steer Versus Lateral Wheel Force
- Steer Versus Wheel Torque
- Steering Wheel Torque Versus Kingpin Moment

Model Parameter Measurement: Tire Force and Moment Response

Force and moment tire testing were performed on a Flat-trac tire measurement system. Once the tire measurements were completed, a Magic Formula MF-SWIFT 6.2 tire model was parameterized to represent the test data. In order to perform the tire testing, a tire is mounted on an electric motorized spindle that drives the tire-wheel assembly along a friction belt moving at a commanded speed. The machine actuates the driven and loaded tire to a specific condition of inclination, slip angle, slip ratio or steering and their combinations, and measures the dynamic force and moment response via specialized loadcells. In order to properly parametrize the tire model, the tire was actuated in the steer, camber, vertical load, drive/brake degrees of freedom individually and simultaneously. Figure 54 is a picture of the force and moment test rig used for the tire testing in this study.

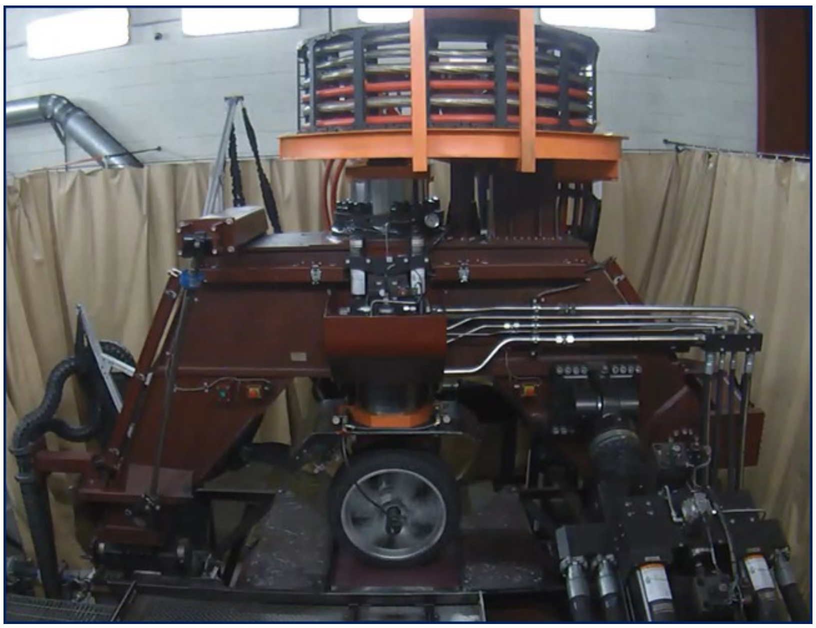


Figure 54. Photograph of Tire Force and Moment Test Rig

The resulting data was used in the fitting process to generate the tire model. Measurements and tire model parameterization took approximately 4 weeks to complete.

Model Parameter Measurement: Damper Characterization

Damper characterization was performed using a Roehrig 4K EMA dynamometer. The damper was mounted to the dynamometer and actuated in the vertical direction at a specified velocity while force response was measured with a loadcell. This was repeated across a range of velocities that represent velocities experienced during real-world vehicle operation. The average force at each speed was calculated and a force versus velocity curve was developed. Figure 55 is a picture of the damper dynamometer used to measure the damper response data.

Figure 55. Photographs of Interface Load Cell and Roehrig 4K EMA Dynamometer

Measurements took four hours to perform. Two dampers were measured from the test vehicle for this study: one damper from the front and one from the rear. The resulting front and rear damper data is shown in Table 51 below and can be found in the VTTI simulation supplement document.

Table 51. Damper Characterization Results

Front		Rear	
Rate (mm/s)	Force (N)	Rate (mm/s)	Force (N)
-1268.73	-1771.98	-1269.46	-2991.66
-1140.67	-1666.15	-1141.17	-2742.97
-1014.17	-1573.25	-1014.17	-2518.86
-887.87	-1480.77	-888	-2302.65
-761.56	-1378.55	-761.56	-2099.56
-634.57	-1270.41	-634.48	-1903.03
-507.92	-1158.72	-507.92	-1702.14
-380.74	-1031.85	-380.74	-1488.34
-253.85	-882.43	-253.88	-1195.34
-190.32	-778.43	-190.32	-807.59
-126.94	-521.1	-126.92	-382.9
-101.52	-382.57	-101.54	-260.19
-76.16	-265.77	-76.1	-166.11
-50.84	-171.46	-50.77	-94.24
-25.37	-101.76	-25.37	-42.84
0	0	0	0
25.41	188.5	25.48	58.81
50.74	359.16	50.79	121.32
76.16	416.31	76.05	205.36
101.52	447.72	101.52	307.42
126.92	476.55	126.92	424.14
190.29	536.21	190.29	681.24
253.62	590.03	253.69	793.65
380.4	695.67	380.4	953.14
507.54	793.61	507.54	1090.57
633.62	889.52	633.71	1227.97
760.59	991.57	760.47	1367.11
887.6	1095.23	887.47	1511.21
1014.77	1207.07	1014.46	1662.65
1141.64	1328.2	1141.46	1807.28
1268.55	1448.3	1268.91	1977.37

Model Correlation Measurement

Once the vehicle parameter measurements were established, vehicle full-system testing was conducted to provide the real-world reference for mathematical model correlation. Two sets of full-vehicle test sequences were examined. The first test set was four test sequences performed on a vertical shaker rig. The second set of tests was the FMVSS No. 126 test procedure sequence performed in the field for the non-ADS VTTI test vehicle build.

Model Correlation Measurement: Four-Post Vertical Shaker Rig Testing

The four-post vertical shaker rig testing consisted of positioning the vehicle on four vertically actuated posts (platen) centered at the tire contact patches and then actuating the suspension of the vehicle by moving the posts for specific test conditions.

Figure 56 below is a picture of the four-post vertical shaker rig.

Figure 56. Photograph of Four-Post Shaker Test Rig

String pots, accelerometers, and load cells were used to capture the resulting suspension and chassis behavior. The first three tests completed on the four-post vertical shaker rig were heave, pitch, and roll sine sweep sequences and the fourth was a road impulse and bump sequence. The heave, pitch, and roll sine sweep test sequences were developed to excite the sprung mass of the vehicle in the vertical, pitch, and roll directions. The sine sweeps were designed to input a range of frequencies into the appropriate degree of freedom and to excite natural frequency responses. The sine sweeps are not a traditional time-varying frequency sweep but a collection of discrete sine waves at a constant frequency. The heave sine sweep ranged from 0.5 Hz to 30 Hz to excite the sprung and unsprung natural frequencies of the suspension and vehicle system. The pitch and roll sine sweeps provided an input frequency of 0.5 Hz to 6 Hz to excite the inertial vehicle response in the pitch and roll directions. Figure 57 demonstrates the input time histories for one frequency in the heave test.

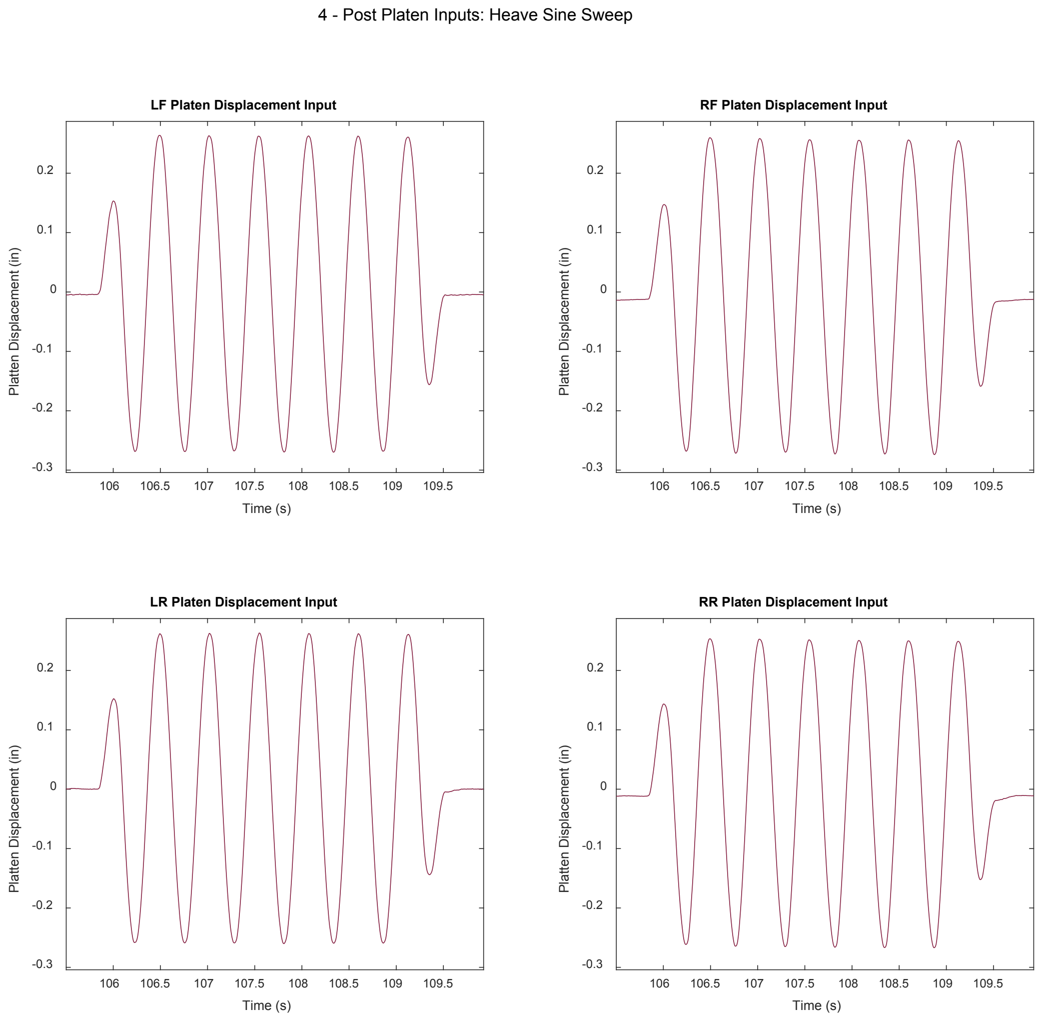


Figure 57. Four-Post Shaker Rig Heave Sine Sweep Platen Displacement

Each time history plot in Figure 57 shows the vertical displacement of the platen located under each tire for the test rig at one frequency. At each wheel location, the tire contact patch force and wheel displacement were measured for model correlation.

The second type of test performed was the impulse and bump test. Figure 58 below shows a sample of the input time histories for each platen.

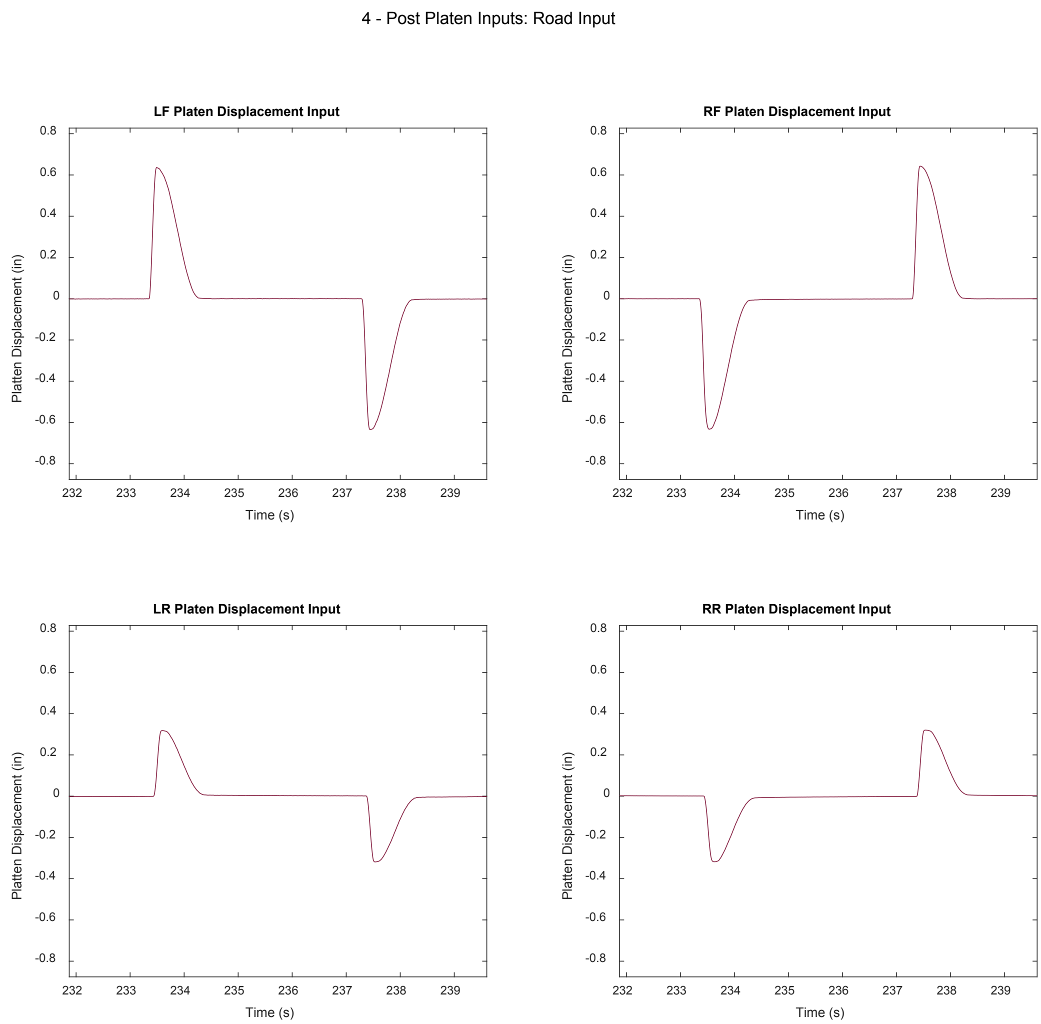


Figure 58. Four-Post Shaker Rig Road Input Platen Displacement

The purpose of this test input was to excite the vehicle suspension with a higher frequency impulsive bump input. As can be seen in Figure 58, the bump has a sharp leading edge and a softer trailing edge. The impulse and bumps are applied in the heave, pitch, and roll directions and with a front axle and rear axle bump profile timed according to simulated vehicle speed. As with the sine sweep tests, the tire contact patch force and wheel displacement were measured for model correlation.

The four-post vertical shaker rig measurements took approximately 1 day to perform.

<u>Model Correlation Measurement: FMVSS No. 126 Test Procedure</u>

The FMVSS No. 126 tests were performed on the non-ADS VTTI test vehicle build and used for vehicle dynamic model correlation. An understanding of this test procedure was fundamental for this study to replicate the FMVSS No. 126 field testing virtually. The replicated FMVSS No. 126 field testing procedure consists of a slowly increasing steer test and the FMVSS No. 126 SWD maneuver test runs. The purpose of the slowly increasing steer test was to quantify the base steering angle and increment for the SWD maneuver runs and to ensure the proper range of test inputs was covered. The SWD maneuver sequence was the dynamic exercise that was investigated for stability compliance. The vehicle was instrumented with accelerometers, a GPS receiver, and steering controller prior to testing. These instruments provide the hand wheel angle input to the vehicle and record the four vital channels for calculation of FMVSS No. 126 compliance: steering wheel angle, vehicle longitudinal speed, lateral acceleration, and yaw rate.

The SWD runs consisted of a series of test runs from low to high steering amplitude; one set beginning with steering to the left and then turning right and the other beginning with the right and then turning left. The steering handwheel angle pattern for an SWD maneuver is a 0.7 Hz frequency sine wave with a 500ms delay beginning at the second peak. This waveform is shown in Figure 59 below.

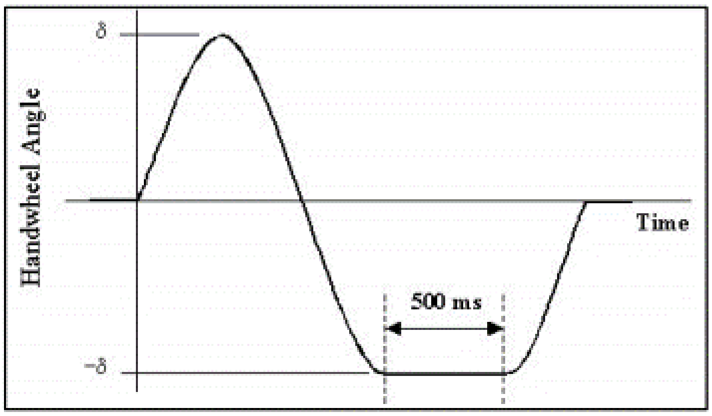


Figure 59. SWD Handwheel Angle Waveform

(Source: Figure 2 in **§571.126 Standard No. 126; Electronic stability control systems for light vehicles.**)

The initial and final amplitude maneuver magnitude is calculated as described in S7.9 of the FMVSS No. 126 standard. The SWD maneuver was performed by accelerating the vehicle to 87 +/- 2kph (54+/- 1mph), releasing the throttle, coasting to 80 +/-2kph target speed and activating the steering controller to execute the controlled SWD maneuver. The maneuver was repeated for the full range and increments defined by the calculations performed in S7.9 of the FMVSS No. 126 standard. Field-collected data channels for the test vehicle speed, steering angle, lateral acceleration, and yaw rate are shown in Figure 60 below.

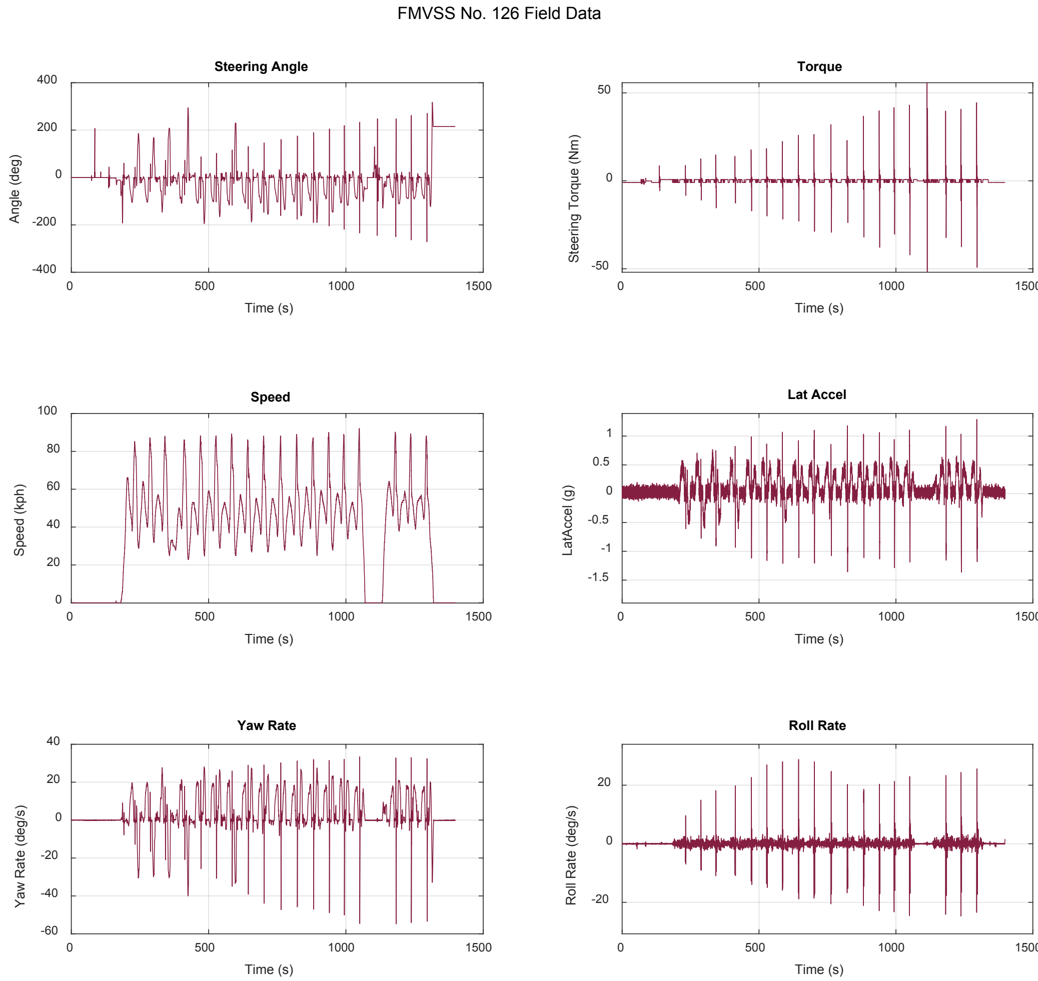


Figure 60. SWD Field Results for the Non-ADS Test Vehicle Build

The FMVSS No. 126 procedure outlines performance requirements to be calculated from this collected data. If all requirements are met, the vehicle is said to comply with FMVSS No. 126. These requirements pertain to calculated yaw rate 1s after completion of steering input (COS), yaw rate 1.75s after COS, and lateral displacement 1.07s after the beginning of the steering maneuver (BOS). Specific data processing techniques must be used to calculate these metrics. The performance requirements also define beginning of steer, completion of steer, and second peak yaw rate to use in the compliance calculations. These definitions and calculations are used in the evaluation of the simulated test runs just as they are applied to the field data to determine simulation compliance and support calculation of response correlation. Figure 61 shown below details the pertinent calculations used to evaluate the field and simulated data for the first FMVSS No. 126 run.

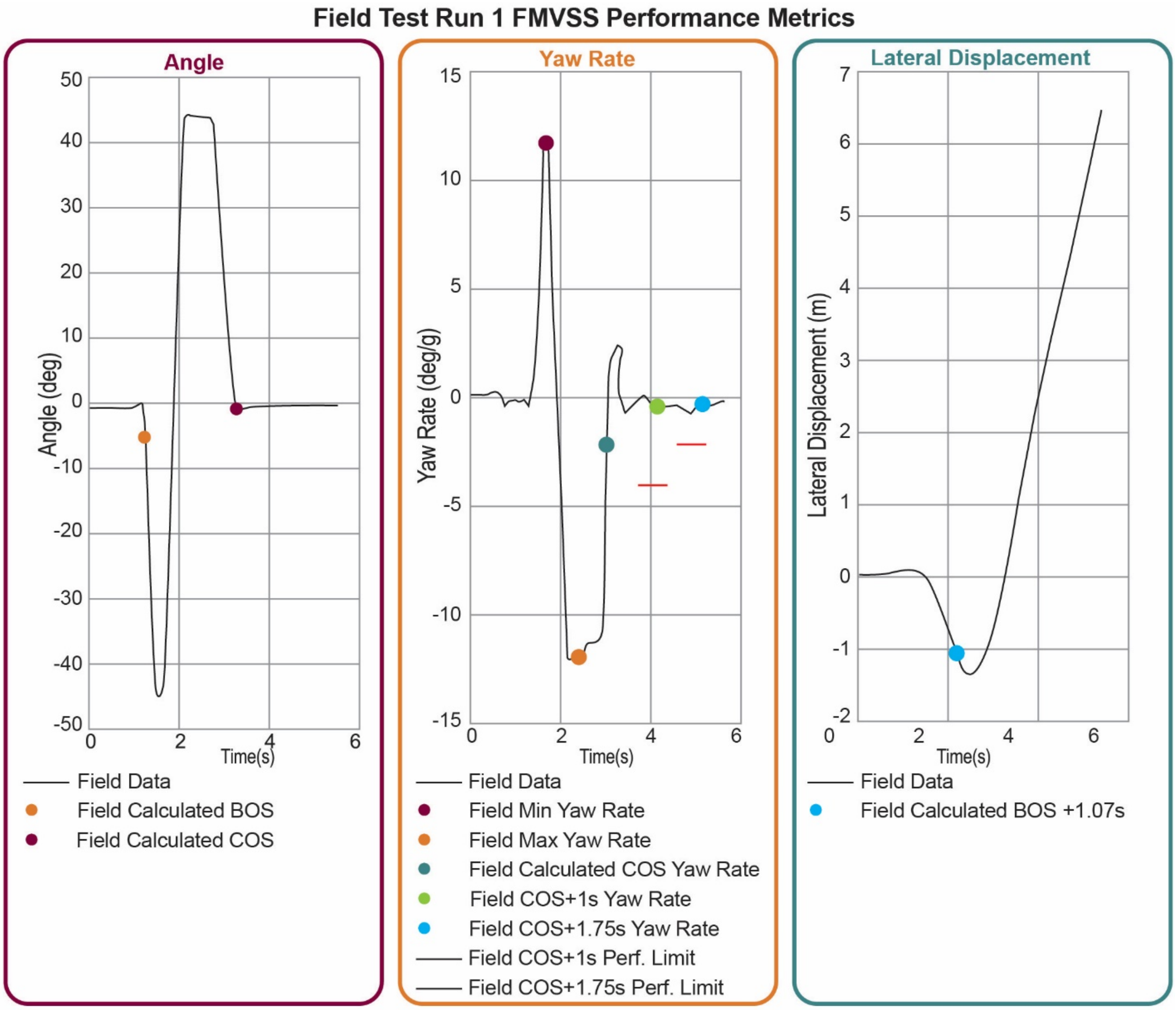


Figure 61. SWD Run #1 Calculated Values

Model Creation

Once the third-party parameterization data was collected, the vehicle model could be assembled using CARSIM as the simulation environment. Mathematical models for the various parts of the vehicle exist within the CARSIM simulation environment. The appropriate math models were parameterized with the third-party data to describe the vehicle-specific subsystems. CARSIM math models were extended using co-simulation with MATLAB-Simulink to provide the vehicle-level test inputs directly to the simulation during simulation runs. In order to provide accurate simulation results for ESC engagement, a simple ESC was also modeled within the simulation environment.

The mathematical models were parameterized by the test data using parameter set values and lookup tables for all data gathered from third parties. The third-party data included center of gravity location, mass moments of inertia, unsprung mass, steering and suspension kinematics and compliance data, MF-SWIFT 6.2 tire model, and damper characterization data. Center of gravity and mass moment of inertia values were entered under the CARSIM "Vehicle configuration" "Rigid sprung mass (whole)" parameter set. Z center of gravity height and all moments of inertia are direct value inputs from the third-party data, while X and Y center of gravity locations were defined by vehicle corner weights. The corner weight values for the baseline setup were calculated to produce desired baseline X and Y center of gravity locations. Unsprung mass was entered directly in the CARSIM "Vehicle configuration" "Rigid sprung mass" parameter set as well as within the independent front and rear suspension configuration sets. Figure 62 is a screenshot of the "Vehicle configuration" window demonstrating the direct input of the vehicle parameters into the vehicle dynamic simulation software.

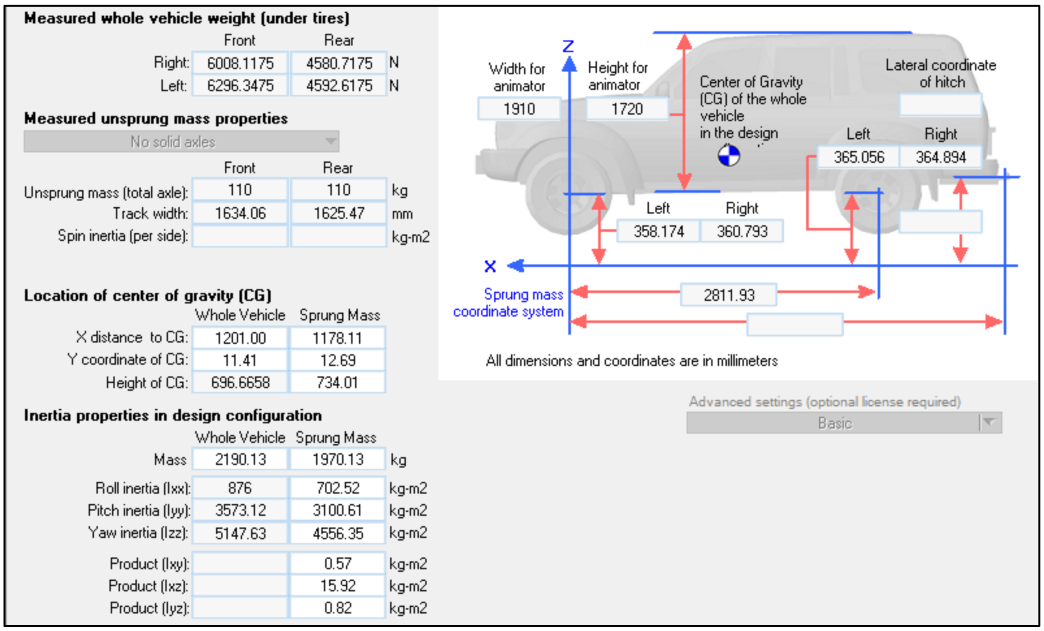


Figure 62. CARSIM Rigid Sprung Mass Definition Screen

Steering and suspension kinematics and compliance parameters were imported directly into CARSIM. This process automatically updated the CARSIM model parameters with the pertinent information in the "Vehicle configuration" "Steering system: 4-wheel steer," front and rear independent suspension parameter sets, and front and rear "Spring, Dampers and Compliance" parameter sets.

The tire model was associated to the mathematical model using the MF Swift dynamic link library file (.dll) and the .TIR tire model file. This association was defined in the "Vehicle configuration" "Tires: Specify all four tires alike" parameter set.

The damper characterization curves are input in the "Vehicle configuration" "Springs, Dampers, and Compliance" parameter set for the respective front and rear suspensions. Figure 63 demonstrates the incorporation of the damper characterization data into the vehicle dynamic model in the lookup table form.

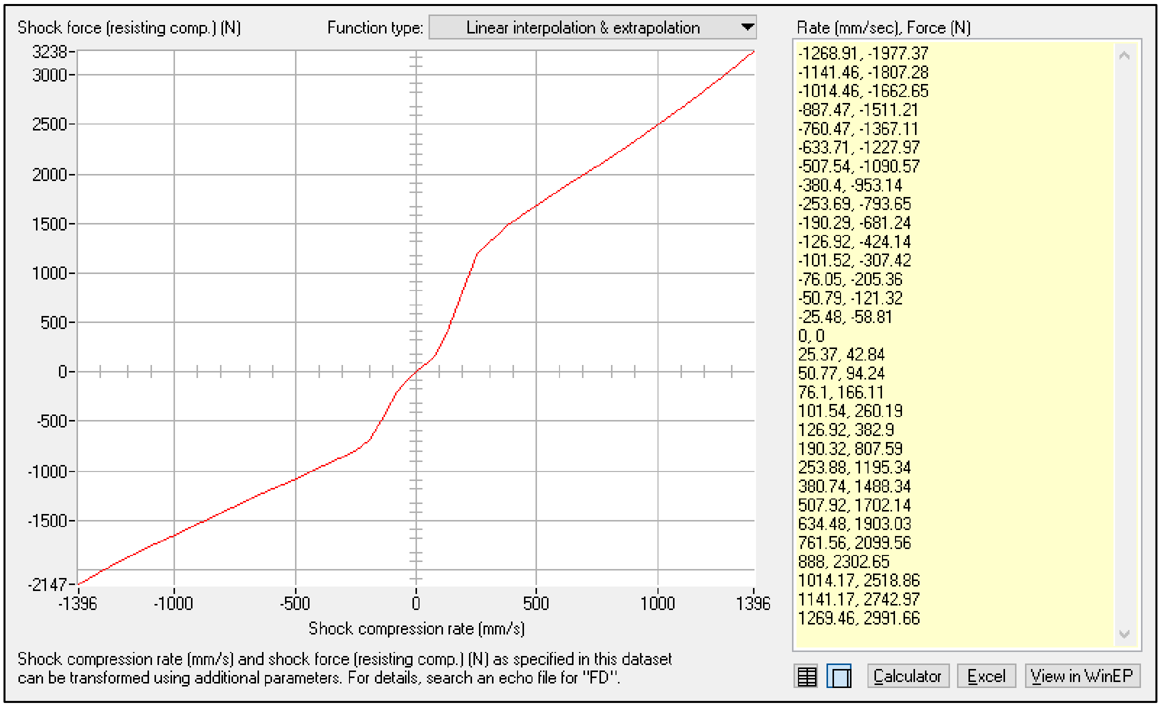


Figure 63. CARSIM Damper Model Lookup-Table Screen

With the basic vehicle model parameters defined, it was necessary to model the ESC control system. There was no ESC model available for simulation use at the start of this project; however, there were a few options available to handle ESC implementation. The first option was to ignore it entirely, which was not reasonable for this study. The second option was to implement the ESC through a HIL configuration. This would not have been practical for an initial simulation evaluation and could be included in future work dependent on simulation results. The third option was to create a simple ESC model that could be implemented within the CARSIM simulation environment. For this study, the third option was selected.

The ESC model was implemented within the CARSIM simulation environment itself using its built-in programming language. The simple ESC used the understeer gradient and approximate brake performance to estimate the desired yaw and sideslip angle rates. When the rate difference between measured and desired yaw or sideslip rate exceeded an allowable error threshold, the brakes were applied to the appropriate wheel to provide the vehicle restoring moment. The simple ESC has six parameters that parameterize its performance. The six parameters for the simple ESC are the following.

- Minimum speed to activate controller
- ESC controller gain for yaw rate
- ESC controller gain for sideslip rate
- Yaw rate error threshold
- Sideslip rate error threshold
- Maximum brake pressure

The minimum speed parameter defines the lowest speed with which the ESC is engaged. The ESC controller gains define the magnitude of the restoring moment for the yaw rate and sideslip rate. The yaw and sideslip rate error thresholds define the bounds wherein the ESC is engaged. The maximum brake pressure defines the maximum brake pressure that can be applied to the system. The yaw and sideslip rate difference tolerances and controller gains were set and tuned to produce the desired ESC performance, as addressed in the following Model Correlation section.

Model Correlation

Once the vehicle dynamic model and simulation were developed, they could be used with the correlation measurements to correlate the vehicle dynamic model. In order to correlate the model, the simulation needed to be able to replicate the correlation tests and store the identical output data that was measured during the field and laboratory testing. For the purposes of this study, MATLAB Simulink co-simulation was used to provide the test vehicle maneuver input data to the CARSIM vehicle dynamics solver and to store the model output data. Correlation coefficient, R^2, and root mean square values were calculated from the model output data in reference to the test data collected as the model correlation metrics. The modeled vehicle output was first compared to the collected field test data for the four-post vertical shaker rig tests. This established that the inertial and kinematic properties of the suspension were sufficiently parameterized in the mathematical model. After the four-post simulation data was correlated, the model was compared to the FMVSS No. 126 field test data. Specifically, the first SWD runs that do not activate the ESC were used to help assess overall vehicle model fidelity prior to tuning the ESC.

The simple ESC model was then tuned to provide representative vehicle responses for the maneuver runs with ESC activation. Their outputs were then compared to the FMVSS No. 126 field test data by using the compliance metrics and the time history metrics previously defined. Furthermore, ISO Standard 19365 compliance was also evaluated. This standard defines the requirements for an FMVSS No. 126 simulation to be considered as a valid representation of the field test data. The results of the FMVSS No. 126 and ISO 19365 compliance metric calculations were used to assess the overall correlation of the model to the field test data.

Model Correlation: Four-Post Shaker Rig Testing

It was essential to correlate the model and the shaker rig test data to determine if the parameterization of the suspension and inertial models were representative of the real vehicle. The first step for correlation was to replicate the shaker rig inputs within the CARSIM software for time history data comparison. The shaker rig feedback channels for all four platen displacements were made into MATLAB time history objects for use within Simulink. The CARSIM procedure was modified to describe a stationary vehicle by setting speed to a constant zero. The simulations were performed with the platen time histories as the tire ground height inputs, and the model output time history data for tire vertical force and wheel center displacement was collected. These time history values were then compared to the laboratory shaker rig data to assess model correlation. The shaker rig simulations were performed for the four shaker rig tests: heave sine sweep, pitch sine sweep, roll sine sweep, and road bump and impulse.

To compare the modeled vehicle output to the laboratory test data, the correlation coefficient, R^2, and root-mean-square error metrics for the wheel displacement and contact patch force channels were calculated for each shaker rig test performed. The correlation coefficient and the root-mean-square error values follow the normal definitions, but the calculation of the R^2 value will be described. The R^2 value is the coefficient of determination for a linear fit between the test rig response data and the model output data. The slope of the best fit line was fixed to one and the coefficient of determination was calculated for the resulting linear model. This means that an R^2 of one may imply perfect correlation between the test rig response data and the model output data. The results of these calculations can be found in Table 52 below.

Table 52. Four-Post Shaker Rig Test Correlation Metric Summary

Test	Correlation Coefficient	Displacement R^2	Force R^2	Displacement RMSE (mm)	Force RMSE (N)	Maximum Displacement (mm)	Maximum Force (N)
Heave Sine Sweep	0.87	0.67	0.46	1.47	289	15	2000
Pitch Sine Sweep	0.94	0.82	0.86	3.25	208	35	2000
Roll Sine Sweep	0.91	0.82	0.83	3.27	304	30	3500
Road Inputs	0.91	0.81	0.83	3.70	206	60	5000

For the pitch sine sweep, roll sine sweep, and road input tests, good correlation existed between the model and laboratory test data. For the heave sine sweep data, the correlation coefficient was reasonable, but the displacement and force R^2 value were not very good. Further inspection of the time history data identified that the heave sine sweep test was performed with inputs that ranged from 0.5 Hz to 30 Hz and significant deviation in model response occurred in the 10-30 Hz range. The other sine sweep data is only from 0.5 Hz to 6 Hz. This deviation was the root cause of the bad R^2 values, and, since the vehicle inputs were less than 1 Hz for the FMVSS No. 126 test, the higher frequency error shouldn't have a strong effect on the simulation. The correlation was thus deemed acceptable.

Model Correlation: FMVSS No. 126 Field Testing

The next step in performing model correlation was to compare the FMVSS No. 126 simulation to the non-ADS FMVSS No. 126 field data. In order to replicate the field tests in simulation, two specific parts of the raw data were collected. Raw steering inputs from each sine with dwell field test run were saved as MATLAB time history objects and the first data point of the speed time history for each run was saved to define the initial vehicle velocity. The simulation ground friction level was set to 0.9 for each test. Each simulation run was evaluated, and the following model data was collected: steering angle, longitudinal speed, lateral acceleration, and yaw rate. The same model and field response time history metrics evaluated for the shaker rig test were calculated and the model correlation was assessed. Table 53 below shows the lateral acceleration and yaw rate correlation metrics of FMVSS No.126 runs 1 through 18.

Table 53. SWD Test Sequence Correlation Metrics

Test	Correlation Coefficient	Lateral Acceleration R^2	Yaw Rate R^2	Lateral Acceleration RMSE (g)	Yaw Rate RMSE (deg/s)
Run 1	0.979	0.957	0.982	0.047	0.749
Run 2	0.978	0.957	0.983	0.064	0.955
Run 3	0.960	0.921	0.986	0.105	1.128
Run 4	0.979	0.958	0.983	0.074	1.187
Run 5	0.975	0.946	0.991	0.105	1.120
Run 6	0.964	0.924	0.966	0.141	2.544
Run 7	0.706	0.307	0.407	0.383	9.620
Run 8	0.700	0.301	0.518	0.394	10.409
Run 9	0.742	0.406	0.548	0.363	10.999
Run 10	0.703	0.345	0.630	0.390	10.551
Run 11	0.796	0.588	0.821	0.360	7.635
Run 12	0.725	0.341	0.627	0.372	10.104
Run 13	0.745	0.416	0.675	0.363	10.019
Run 14	0.682	0.307	0.712	0.410	9.830
Run 15	0.747	0.511	0.742	0.386	10.145
Run 16	0.863	0.740	0.823	0.282	8.580
Run 17	0.929	0.861	0.858	0.208	7.763
Run 18	0.926	0.854	0.853	0.202	7.781

The correlation coefficients displayed in Table 53 for runs 1 through 6 are above 0.95. Root mean square errors rise dramatically between runs 6 and 7. From these values it can be concluded that FMVSS No. 126 simulation runs 1 through 6 correlated well with the field testing, while runs 7 through 18 required the ESC model intervention for correlation, as the unmodeled response effects of the ESC were likely the cause of the poor correlation metric results.

When applying the simple ESC controller, a need arose to quantify when the ESC-tuned model data was a proper representation of the field data. ISO 19365 provided this reference. ISO 19365: Passenger cars—Validation of vehicle dynamic simulation—Sine with dwell stability control testing, offers “a repeatable and discriminatory method for comparing simulation results to data measured from a physical test vehicle” for the FMVSS No. 126 SWD maneuver. The standard required calculated metrics from the last run without ESC activation, the first run with ESC activation, and the last run performed during the test collection. These runs were selected to represent the full range of ESC activation pertaining to the FMVSS No.126 maneuver.

Four calculated metrics were obtained from each run to determine trust in the model. The four metrics were tolerances on how well the model data must fit the yaw rate first peak, yaw rate second peak, time of yaw rate zero crossing, and lateral displacement of the field data. Figure 64 and Figure 65 below outline the ISO requirements for yaw rate and lateral displacement. Figure 66 below lists the performance metric tolerances for each of the runs.

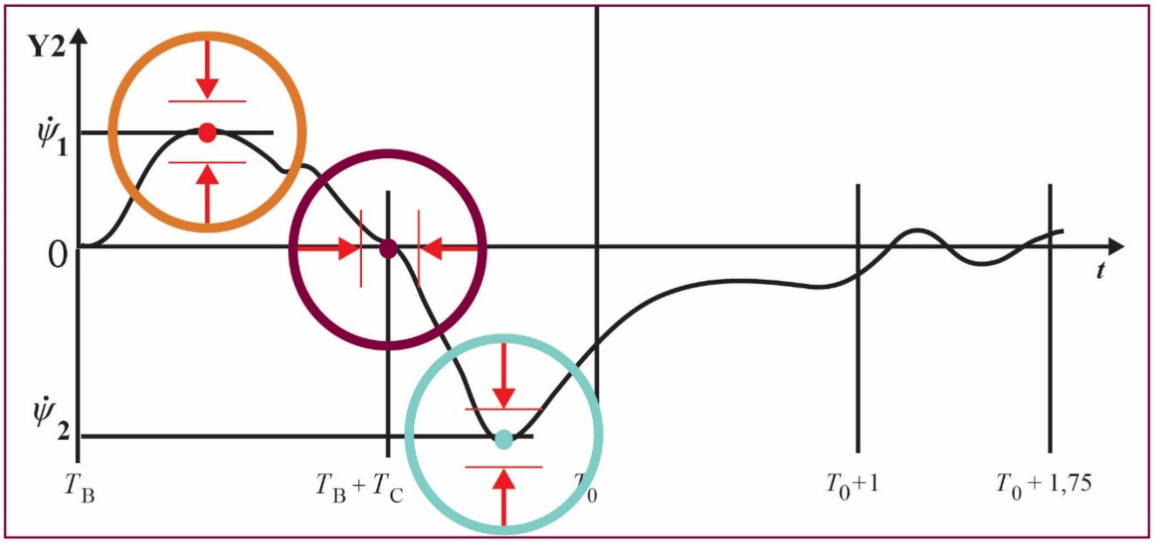


Figure 64. SWD Yaw Rate ISO 19365 Metric Definitions

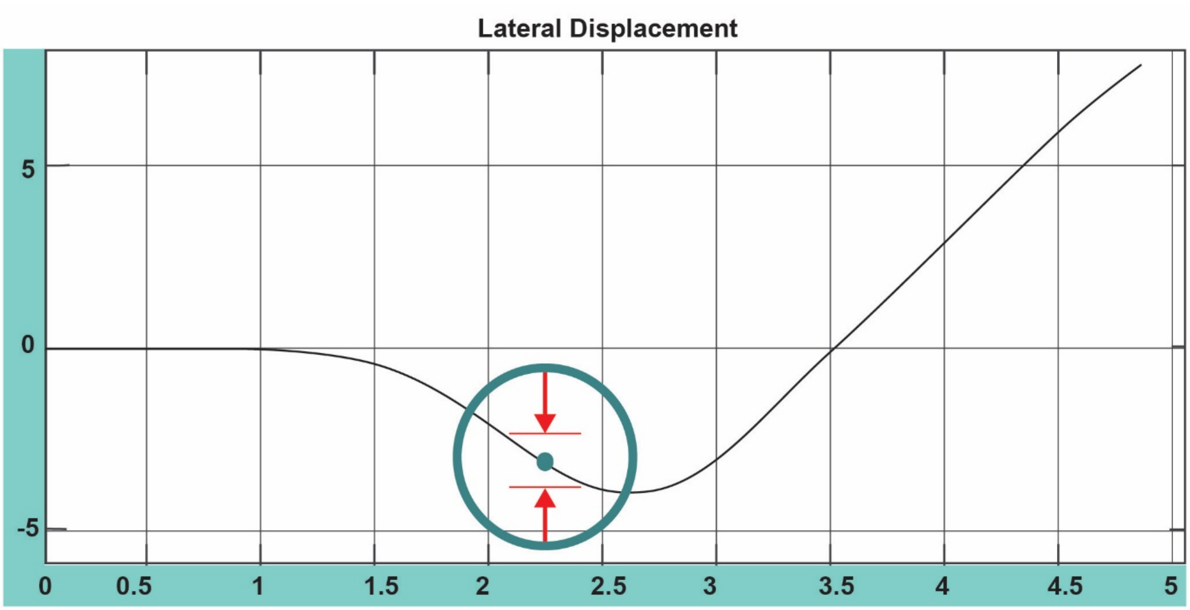


Figure 65. SWD Lateral Displacement ISO 19365 Metric Definition

Metric	Test run	Tolerance
First peak yaw rate ($\dot{\psi}_1$ in Figure 2)	Last run without ESC intervention	±15%
	First run with ESC intervention	
	Last run	
Time of yaw rate crossing zero (T_C in Figure 2)	Last run without ESC intervention	±0,1 s
	First run with ESC intervention	
	Last run	
Second peak yaw rate ($\dot{\psi}_2$ in Figure 2)	Last run without ESC intervention	±20%
	First run with ESC intervention	±25%
	Last run	±25%
Lateral displacement of the vehicle C.G.	Last run without ESC intervention	±15%
	First run with ESC intervention	±18%
	Last run	±18%

Figure 66. ISO 19365 Metric Tolerances

In the figures, the threshold on the yaw rate first peak is displayed in orange. The threshold time of the yaw rate zero crossing is displayed in purple. The threshold for the yaw rate second peak is displayed in green. The threshold on lateral displacement is displayed in blue. Figure 67 outlines the acceptable tolerances for the model response metrics compared to the field response metrics. The model data for the last run without ESC activation must have a first peak yaw rate value within 15 percent of the field data, a second peak yaw rate value within 20 percent of the field data, and lateral displacement within 15 percent of the field data. The first run with ESC activation must have a first peak yaw rate value within 15 percent of the field data, a second peak yaw rate value within 25 percent of the field data, and lateral displacement within 18 percent of the field data. The last test run performed must have a first peak yaw rate value within 15 percent of the field data, a second peak yaw rate value within 25 percent of the field data, and lateral displacement within 18 percent of the field data. The model data runs for the last run without ESC activation, the first run with ESC activation, and the last test run performed must all have zero crossing times within 0.1s of the zero crossing times of the field data.

The last run without ESC, first run with ESC, and last run of the field test sequence were runs 5, 6, and 18, respectively. Run 6 was chosen as the first run with ESC activation due to the increase in root mean square error observed from Run 5 to Run 6. ESC threshold and gain parameters were tuned to establish ISO compliance for the runs 5, 6, and 18. Figure 67 below shows the yaw rate, lateral acceleration, and lateral displacement response for before and after the simple ESC model was applied and tuned for Run 18.

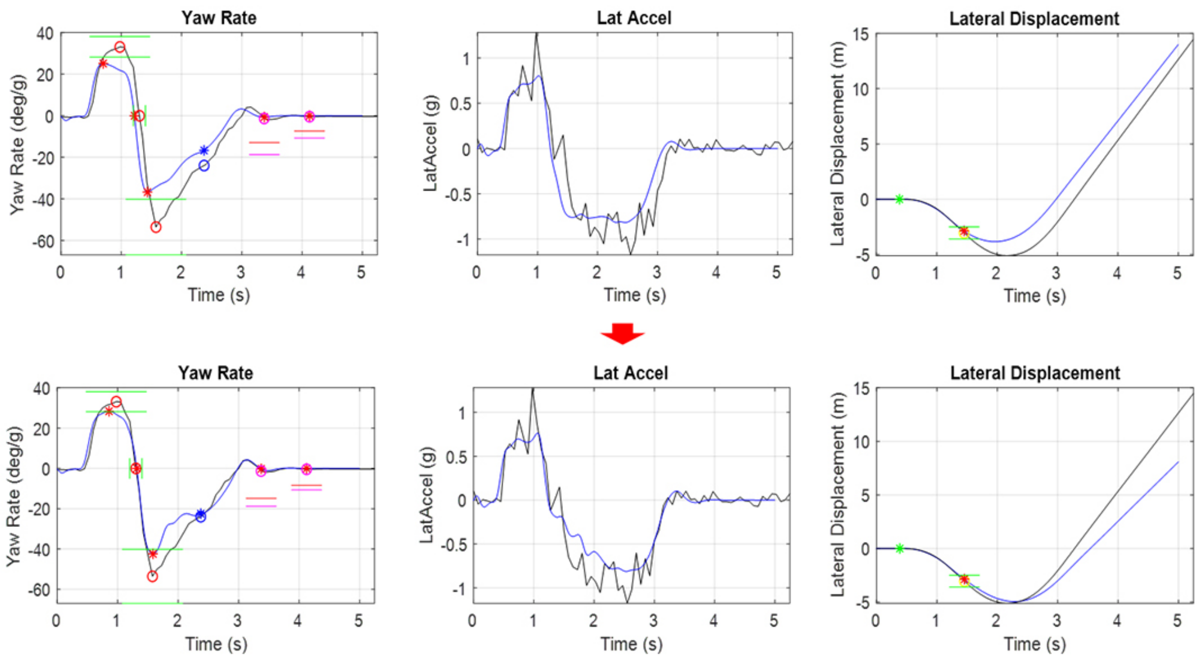


Figure 67. Vehicle Response Before and After ESC Model Tuning

The graphs in the figure above highlight vehicle yaw rate, lateral acceleration, and lateral displacement differences between the unmodeled versus modeled ESC data. The vehicle yaw rate plot includes several points of interest. The displayed red points and circles indicate the model and field maximum and minimum peak yaw rates as well as the yaw rate zero crossover time. The blue point and circle indicate the moment of COS. The green bounds establish the ISO performance requirements. The pink points, circles, and lines represent the FMVSS yaw rate check values and thresholds of the model and field data. The lateral displacement green point indicates the lateral position value at BOS, while the red is the value BOS+1.07s for FMVSS compliance. The green bars around the red lateral displacement point define the ISO performance requirement.

When comparing the plots, some notable differences were apparent. Run 18 yaw rate peaks moved into the FMVSS compliance range with the tuned ESC model. Furthermore, yaw rate zero crossing moved closer to the field data and the yaw rate and lateral acceleration decays were more representative of the field data. Lateral displacement, while not affecting the FMVSS check value, was also more accurately represented in the time after this check occurred.

The FMVSS simulation sequence was performed with the tuned ESC model for the remainder of the field runs. The correlation coefficient, R2, and root mean square error were calculated for the lateral acceleration and yaw rate channels from the tuned ESC model data. The results of these calculations are shown below in Table 54.

Table 54. Tuned ESC SWD Test Sequence Correlation Metrics

Test	Correlation Coefficient	Lateral Acceleration R^2	Yaw Rate R^2	Lateral Acceleration RMSE (g)	Yaw Rate RMSE (deg/s)
Run 1	0.979	0.957	0.982	0.047	0.749
Run 2	0.978	0.957	0.983	0.064	0.955
Run 3	0.960	0.921	0.986	0.105	1.128
Run 4	0.979	0.958	0.983	0.074	1.187
Run 5	0.975	0.946	0.991	0.105	1.120
Run 6	0.984	0.945	0.990	0.120	1.345
Run 7	0.905	0.818	0.845	0.196	4.920
Run 8	0.960	0.918	0.940	0.135	3.665
Run 9	0.941	0.885	0.913	0.160	4.830
Run 10	0.910	0.828	0.898	0.200	5.551
Run 11	0.867	0.751	0.902	0.280	5.634
Run 12	0.855	0.720	0.852	0.243	6.367
Run 13	0.848	0.707	0.840	0.257	7.042
Run 14	0.804	0.631	0.845	0.299	7.208
Run 15	0.840	0.704	0.849	0.300	7.753
Run 16	0.922	0.838	0.919	0.223	5.811
Run 17	0.935	0.853	0.944	0.213	4.889
Run 18	0.961	0.900	0.951	0.168	4.511

Correlation coefficients and R2 values for the runs all increased while root mean square error decreased. Runs 6 and 18 moved to be above the 0.95 coefficient correlation threshold limit. With simple ESC implemented and tuned to ISO 19365 compliance, the model more accurately represents field performance for runs 7 through 18.

A single set of ESC parameters was found to provide a reasonable correlation improvement for all runs. As the runs progressed, the metrics got slightly worse until Run 14 and then they began to improve again. This may indicate that different ESC tuning sets may be required to capture real-world ESC performance and improve correlation. However, since the correlation was acceptable with the single set of tuning parameters, this parameter set was used for the sensitivity study. The model parameters along with the tuned ESC model parameters created an FMVSS No. 126 simulation that was acceptable for performing the sensitivity study. These model parameters and the resulting FMVSS No. 126 simulation will be referred to as the baseline model and baseline simulation.

Sensitivity Study

Since model correlation was established across the range of steering maneuver inputs, the simulated FMVSS No. 126 test procedure could be iterated to determine the parameters that drive system behavior. The iterated simulation outputs were compared to the baseline simulation output to generate the relevant comparison metrics. N-way ANOVA and D-optimal design were used to examine the effects of varying model parameters with high-order interactions. N-way

ANOVA provided the means to establish statistical significance while D-optimal experimental design ensured proper design space coverage. The N-way ANOVA results were examined along with the FMVSS and ISO specification non-compliance cases.

Main and two-factor experimental design was then performed to determine if any of the higher order effects were due to the result of dominant parameters. After the non-compliant cases were examined with reference to the statistical results, the acceptable amount of variation of the relevant parameters was determined by targeted simulation. These acceptable variation ranges were then tied back to measurement accuracy of the vehicle system and its components. This established the measurement accuracy required for trust in a model and its associated simulation output.

Sensitivity Study: Parameter Set Identification

To perform the sensitivity study, it became necessary to determine which specific parameters to examine. The intent of this study was to establish what level of error was acceptable within the measurement data to determine trust in the model. Therefore, model parameter measurements were directly manipulated for the sensitivity study. It was prudent to target all main sources of measurement data to establish proper coverage of the model design. Therefore, a range of data from center of gravity and inertial measurement, suspension measurement, and tire force and moment model variation were all evaluated. As a result of model response data trust being inherently linked with ESC response, the parameters relating to the ESC response were manipulated as well.

The first examined parameter set was from the center of gravity and mass moment of inertia data. The supplier provided data consisting of values for the X, Y, and Z coordinates for the center of gravity and roll (Ixx), pitch (Iyy), and yaw (Izz) moments of inertia. It was decided that all of these parameters were to be manipulated in the initial sensitivity study due to their underlying influence on vehicle dynamic response.

The baseline values for X, Y, and Z center of gravity locations were directly defined from the center of gravity and inertial measurement data. Variation in the X location was a function based on percentage of the total baseline front axle weight. Variation in the Y location was a function based on percentage of the total baseline vehicle right side weight. Variation in the Z direction was a direct percentage of the center of gravity z height. Variations of all moment of inertia data were a direct percentage of their respective values.

The second examined parameter set comes from the suspension data received from the kinematics and compliance third-party data supplier. The resultant dataset included the force versus displacement measurements of the front and rear springs in both loaded and unloaded conditions. The parameterization of this data for the simulation directly affected the vehicle suspension dynamics behavior and it was practical to manipulate within the iterative simulation environment. The curves were manipulated for the study by percentage of their baseline values. Figure 68 below demonstrates how the percent variation of the data was performed for the springs.

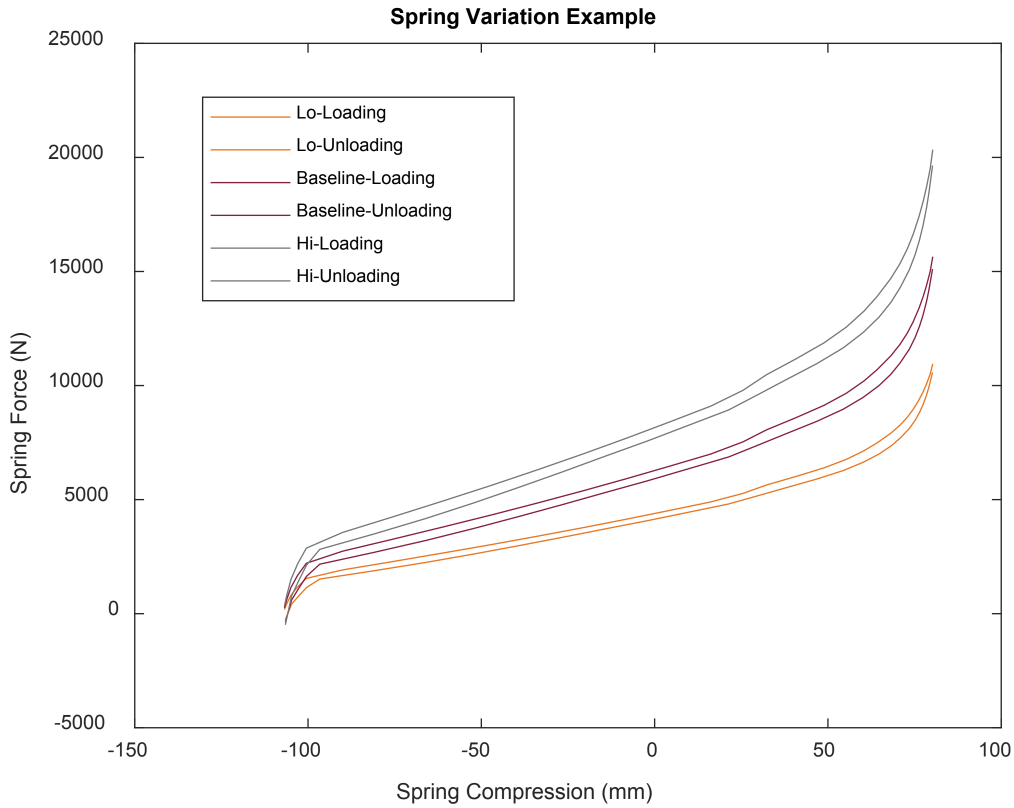


Figure 68. Lo-Baseline Hi-Spring Variation

The third examined parameter set consisted of the damper characterization curve data. The damper force versus compression velocity lookup tables also influenced the vehicle suspension dynamics. The overall front and rear damper curves were manipulated by percentage of baseline value in the rebound and compression directions. Figure 69 below demonstrates pure rebound and compression variation performed on the dampers. Figure 70 below demonstrates how the damper rebound and compression directions were individually manipulated. For example, the blue curve shows the result of the compression side defined by the LO variation and the rebound side defined by the HI variation.

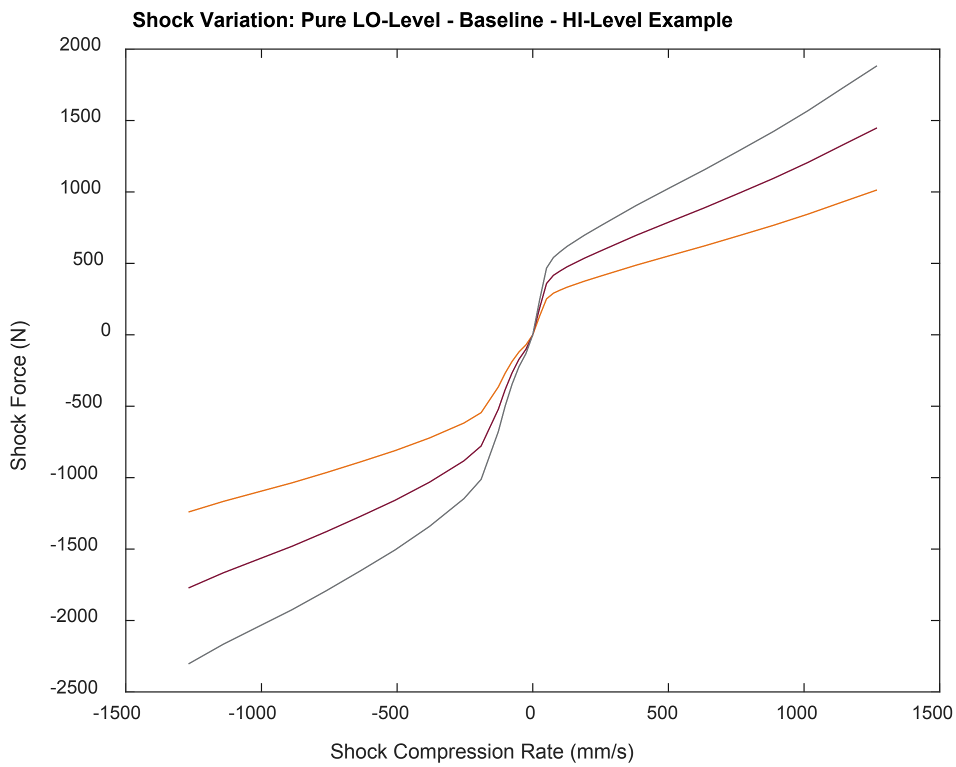


Figure 69. LO-Baseline-HI Damper Variation

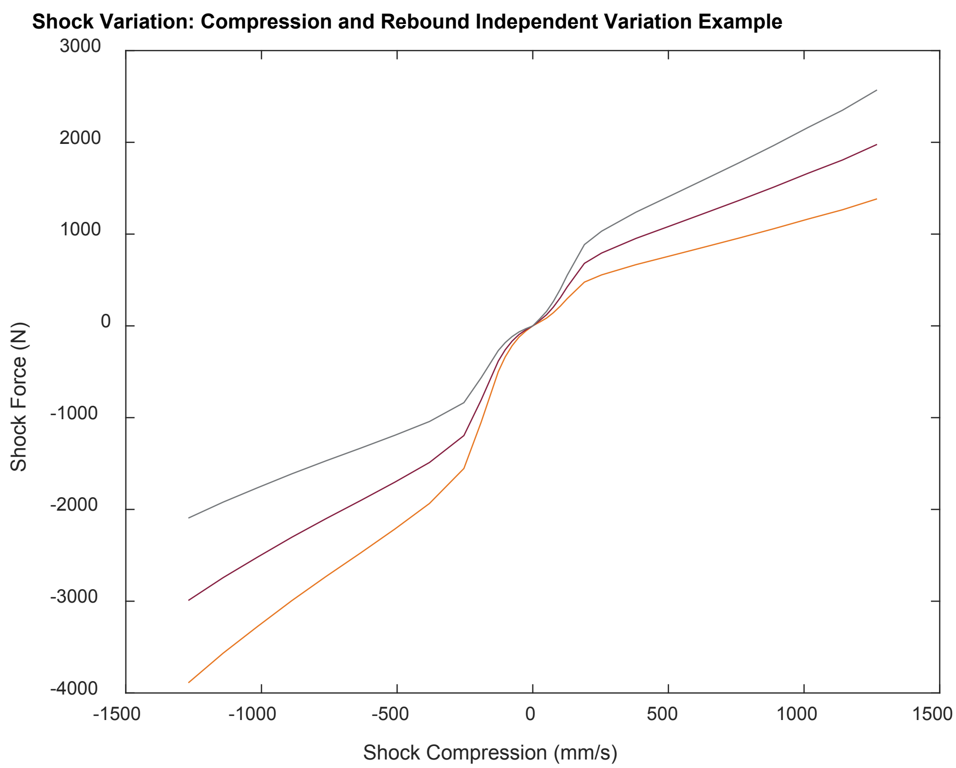


Figure 70. Independent Compression and Rebound Damper Variation

The fourth parameter set was defined by variation in the tire model. The tire force and moment response drove overall vehicle performance, so variations in tire model had to be evaluated. Four tire models were examined in this study, representing different parameterizations based on data fidelity. In order to describe the variations, it was necessary to understand some basic properties of the tire models and how they could differ. Figure 71 below is a pictorial representation of Pacejka's Magic Formula (MF) tire model. The MF tire model inputs were loaded radius, slip angle, slip ratio, camber angle and speed, and its outputs are the tire force and moment responses. The outputs of the tire model were used as the tire input forces to the vehicle for the vehicle dynamics simulation.

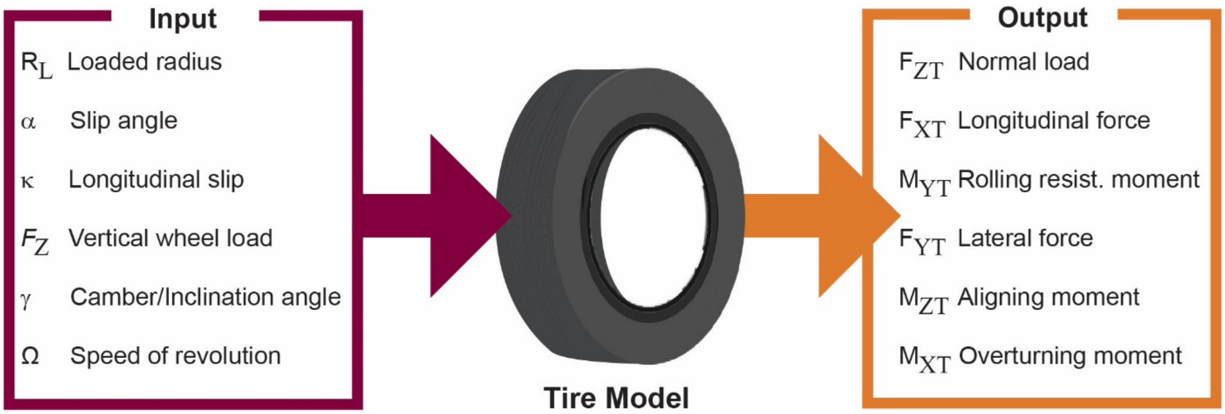


Figure 71. Tire Model Inputs and Outputs

The MF tire model is a series of empirical formulas that calculate the tire forces and moments in the longitudinal, lateral, and vertical directions. A series of coefficients within the empirical formulas are parameterized during the tire model creation process. The parameterization uses the known test inputs and the resulting test responses to provide the best fit between the tire model response and the tire test data.

The highest fidelity MF tire model was built using pure longitudinal, pure lateral, and a combination of longitudinal and lateral experimental tire response data. The resulting model was defined as the baseline tire model for the baseline simulation. The tire model variations were built using different levels of experimental data for fitting. This methodology was applicable to the sensitivity study because experimental tire test data can vary in response type based on the third-party test supplier and their associated tire test equipment. Furthermore, the simulation software allows for using different modes of the tire model within the simulation. The variation in tire data was included, as was one of the tire model variations.

The first variation in the tire model used the pure lateral and longitudinal experimental tire response data for tire model parameterization. This model was different from the baseline because it did not include the experimental lateral and longitudinal combined tire test data. The second variation in tire model was parameterized with only the lateral tire test data. The final variation in tire model consisted of coefficients parameterized by using pure longitudinal, pure lateral, and combined data, but used the MF-Tyre modes to reference longitudinal and lateral information separately in an uncombined way.

The fifth parameter set was related to the simple ESC model parameters. The four primary parameters that govern ESC behavior were the yaw and sideslip gains and their associated threshold values. These parameters were defined previously in the model correlation section. While the vehicle measurement parameters were modified by percentage of baseline value, the ESC parameter variations were varied based on experience with ESC tuning. The ESC parameters were varied to produce a change in vehicle response for the runs with ESC engaged. Table 55 below outlines the LO, baseline, and HI levels of variation for the ESC parameters.

Table 55. ESC Parameter Lo-Baseline-Hi Values

Parameter	LO-Level	Baseline	HI-Level
ESC Yaw Gain	61	80	99
ESC Roll Gain	10	18	26
ESC Yaw Threshold	10	19	23
ESC Roll Threshold	.2	2	3.4

The full list of parameters used in the sensitivity study are listed below in Table 56.

Table 56. Sensitivity Study Parameters

Parameters Used in Sensitivity Study	
1.	XCG- Center of Gravity Location
2.	YCG- Center of Gravity Location
3.	ZCG- Center of Gravity Location
4.	IXX Moment of Inertia
5.	IYY Moment of Inertia
6.	IZZ Moment of Inertia
7.	Front Spring
8.	Rear Spring
9.	Front Damper Compression
10.	Front Damper Rebound
11.	Rear Damper Compression
12.	Rear Damper Rebound
13.	ESC Yaw Rate Gain
14.	ESC Sideslip Rate Gain
15.	ESC Yaw Rate Threshold
16.	ESC Sideslip Rate Threshold
17.	Tire Model

Sensitivity Study: Initial Study

Once the list of parameters and their associated variations were defined, it was necessary to iterate through the numerous parameter variations within the simulation environment to study the effect on model results. Because the parameter variation may change the SIS test response, the simulation included the SIS test. The resulting SIS metric was used as defined in the FMVSS No. 126 test requirement to define the appropriate hand wheel angles for the SWD runs. This effect was included because the model response variation due to different maximum hand wheel angles needed to be accounted for within the sensitivity analysis. Furthermore, as a result of using ISO 19365 as a reference for trust in the model, FMVSS No. 126 runs 5, 6, and 18 had to be performed to quantify the significance of the parameter changes throughout the range of ESC activation. As such, the resulting simulation test suite included the SIS test, and SWD maneuvers for runs 5, 6, and 18. The rest of the SWD runs were omitted to save computational time.

To establish a starting point for the analysis, only the parameter main effects were evaluated for parameter variations ranging from 10 percent to 50 percent in increments of 10 percent. The main effects were evaluated by varying each parameter individually and calculating the effect on FMVSS and ISO compliance. For each parameter and associated variation, the model response data was evaluated by grouping the number of FMVSS and ISO noncompliance cases. Through this process, it was determined that 30 percent parameter variation had an appropriate ratio of compliance to noncompliance cases to be worthy of further higher-order interaction analysis. Once the initial parameter variation starting point was defined, it was necessary to develop a design of experiment test to evaluate the full range of interaction effects for all 17 parameters.

Full factorial test design is a way to systematically vary a set of experimental factors and develop a test plan that contains all possible combinations of those experimental factors. By assigning each factor a discrete set of levels, full factorial design allows for all combinations of the factor levels to be tested in a systematic way. Full factorial multi-level design for n factors with N1, …, Nn levels will produce a (N1 x … x Nn) by n matrix. Experimental test design such as full factorial design are typically used for fitting a linear surface to the response metrics to define a relationship between the input factors and metric response. The resulting linear model can be used for design space investigation. Full-factorial designs can contain a large set of test combinations to completely cover the full design space. D-optimal experimental designs can address this limitation by minimizing the covariance of the parameter estimates within a model and maximizing the determinant. This can be used to create a targeted combination matrix of N-total test combinations (less than full factorial) that covers the full design space in an optimal way.

In order to perform a full factorial experiment with the 17 identified parameters, greater than 43,046,721 simulation runs would be required to generate the outputs for analysis. The time constraints of this study would not allow for this level of examination. To perform an initial analysis of the design space, D-optimal design was used to generate a test matrix of 10,000 simulation runs. The 10,000 simulation run data was then used to analyze the design space to reduce the parameter set to a smaller size so full factorial experimentation could be performed. The full factorial experiment was then to be repeated for various ranges of parameter variation to determine parameter sensitivity.

Once the initial parameter variation and initial design space coverage was established, the simulation test matrix could be performed. The FMVSS No. 126 simulation sequence was performed for the 10,000 combinations defined by D-optimal design at 30 percent parameter variation. Parameter definitions for the 30 percent variation can be found in full within the VTTI simulation supplement document. To examine this quantity of data it was necessary to establish the statistical significance of the model effects. N-way ANOVA analysis was used to evaluate the statistical significance of the following FMVSS No. 126 metrics: yaw rate peak one value, yaw rate peak two value, yaw rate check one value, yaw rate check two value, and calculated understeer gradient from the SIS test. Further, the yaw rate R2 and lateral acceleration R2 time history metrics were included. The purpose of the N-way ANOVA analysis was to determine if the mean values within the set of data differed with respect to the levels of multiple factors. The N-way ANOVA significance of the 17 chosen parameters from the 10,000-combination study is shown in Figure 72 below.

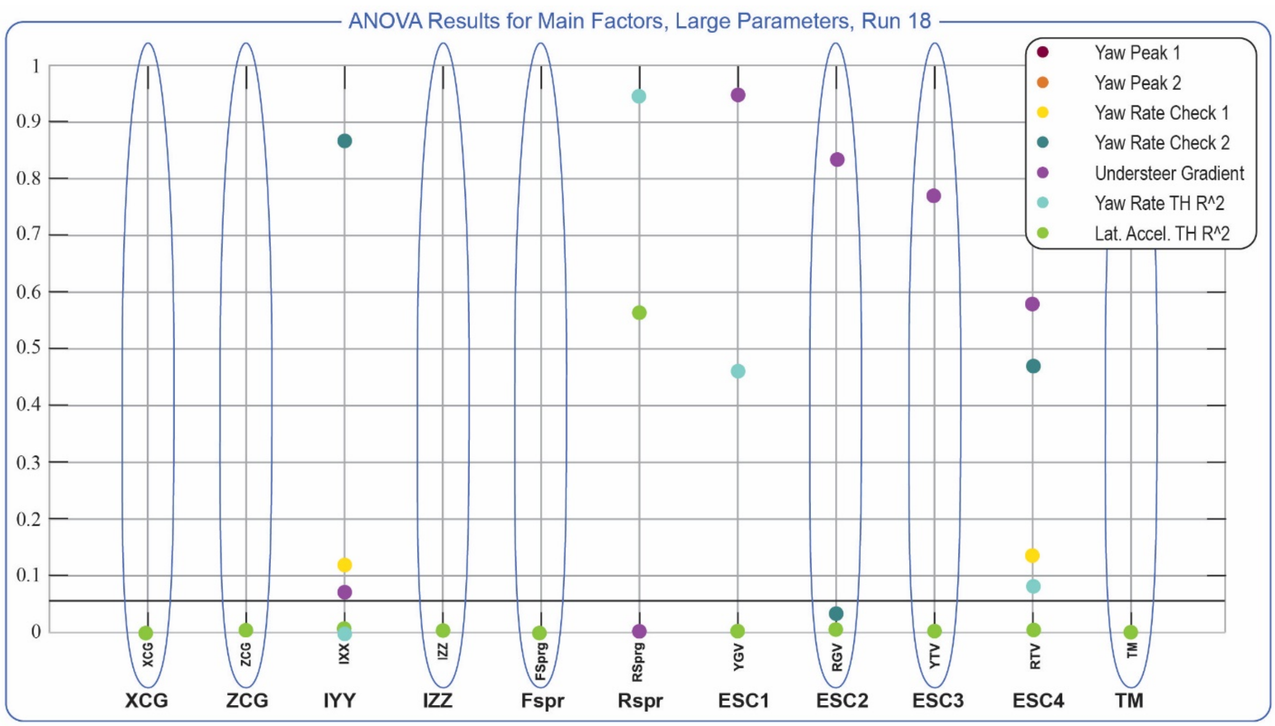


Figure 72. SWD Run 18 Large Variation ANOVA Results

Figure 72 above shows that XCG, ZCG, IZZ moment of inertia, front spring force, the ESC parameters, and the tire model variations caused statistically significant variation in the response metrics. One point on the graph exists for every metric evaluated for each parameter. If the point on the graph is below the 0.05 black line, then for that metric, the parameter variation produced statistically significant change in the response metric. For example, for the ESC2 parameter, the yaw peak 1 metric lies below the black line, indicating that the variation in the ESC2 parameter produced a statistically significant change in the yaw peak 1 metric. Conversely, for the ESC2 parameter the understeer gradient metric does not lie below the black line, indicating that the variation in the ESC2 parameter did not produce a statistically significant change in the understeer gradient. This result makes sense because the ESC should not be active during the understeer gradient test, so an ESC parameter change should not affect the result of the understeer gradient metric, producing no statistically significant different value.

ANOVA significance can only qualify the changes to the response metrics as statistically relevant and does not provide any information about the magnitude of the observed difference. As such, it was also necessary to examine the effect the parameter variations had on the metrics defined by FMVSS No.126 and ISO 19365. To achieve this, the 10,000 combination model response data set was evaluated for noncompliance per FMVSS No. 126 and ISO 19365. Figure 73 and Figure 74 below show the histogram of the variation configurations that cause FMVSS No. 126 and ISO 19365 noncompliance.

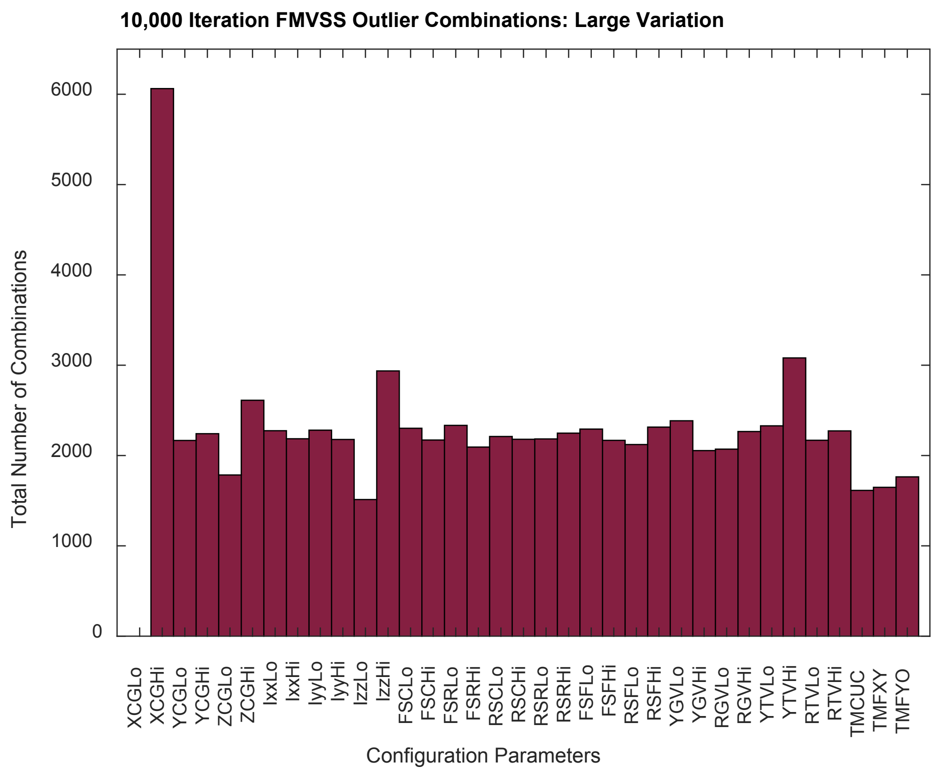


Figure 73. FMVSS Noncompliance Combinations for Large Parameter Variation

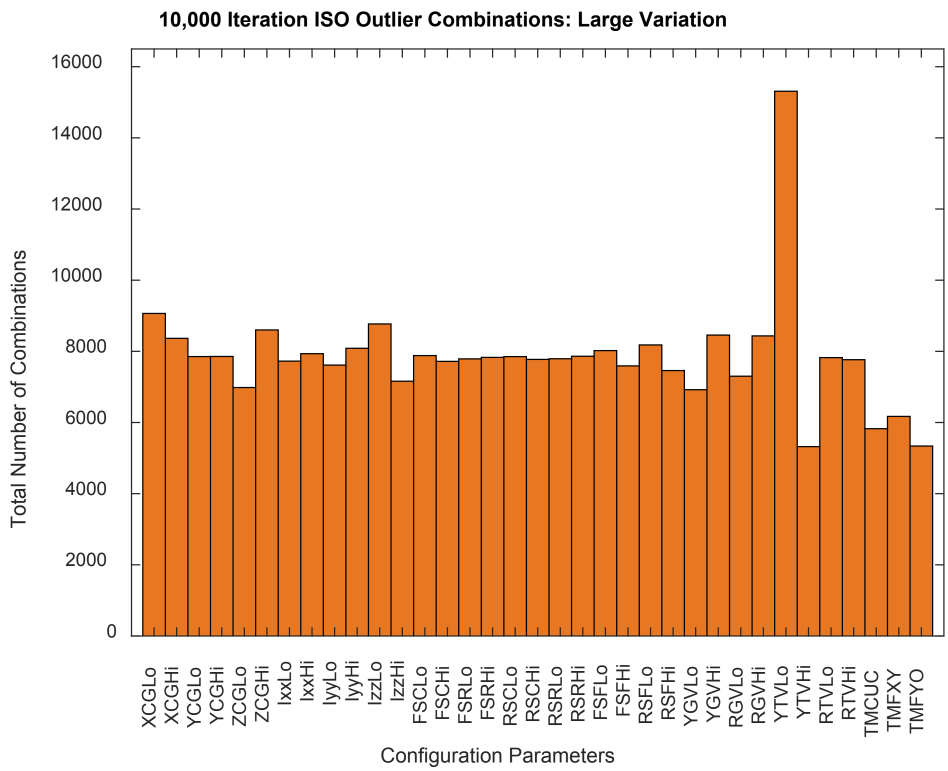


Figure 74. ISO Noncompliance Combinations for Large Parameter Variation

Upon inspection, the four parameters with the highest total number of noncompliance combinations from both FMVSS No. 126 and ISO 19365 noncompliance charts were XCG, ZCG, IZZ moment of Inertia, and YTVLo (an ESC parameter). Both the N-way ANOVA and the analysis of noncompliance identify these factors as significant. However, there was a possibility that due to the large magnitude of variation in parameters, analysis would show parameter variation significance that may not exist with a smaller magnitude parameter variation. A second, more realistic, set of parameters was chosen for analysis based on the reported third-party measurement accuracies. The more realistic parameter list is shown in full within the VTTI simulation supplement document.

The FMVSS No. 126 simulation sequence was performed for the 10,000-factor combination for the realistic variation parameter set. Figure 75 shows the ANOVA significance of the realistic parameter case.

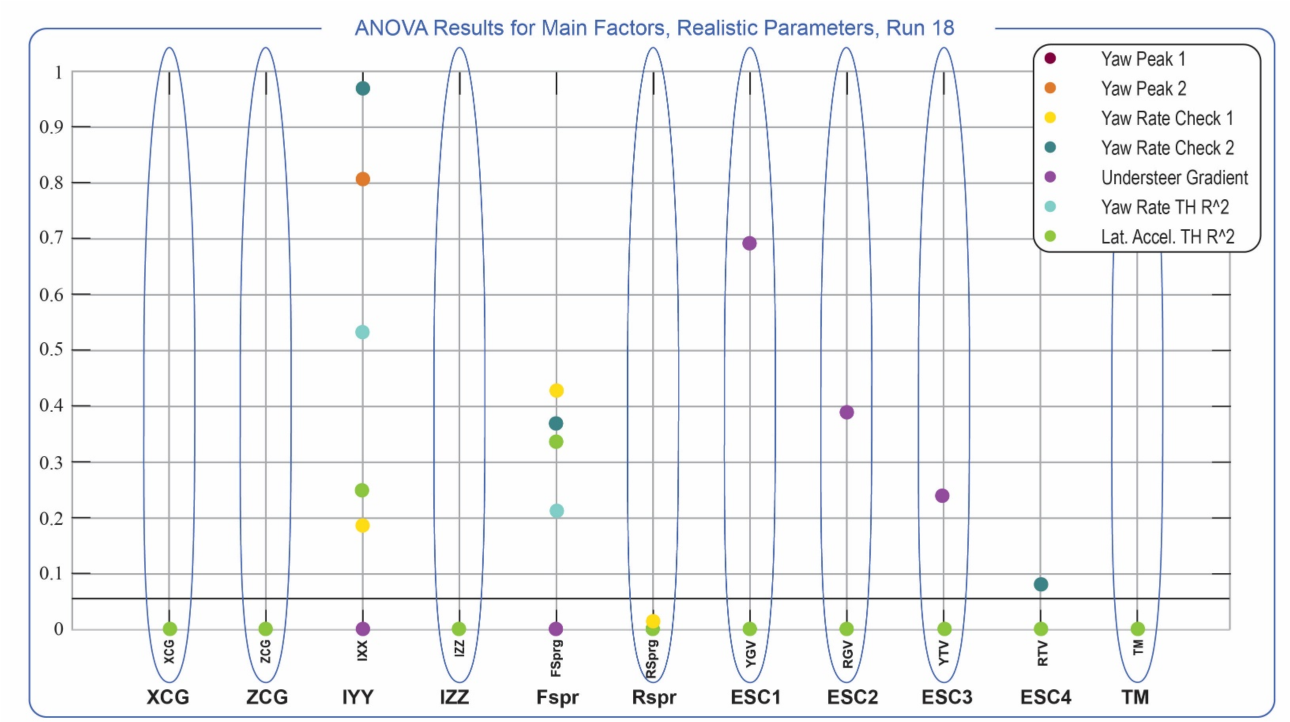


Figure 75. SWD Run 18 Reasonable Variation ANOVA Results

ANOVA results of the realistic parameter variation identified the same significant parameters that were present in the data at 30 percent variation, except significance shifted from front to rear springs. This confirmed XCG, ZCG, and IZZ moment of inertia as sources of statistically relevant variation, while the switch in spring significance questioned the overall importance of the spring force parameters. Figure 76 and Figure 77 below show the histogram of the variation configurations that cause FMVSS No. 126 and ISO noncompliance for the realistic case.

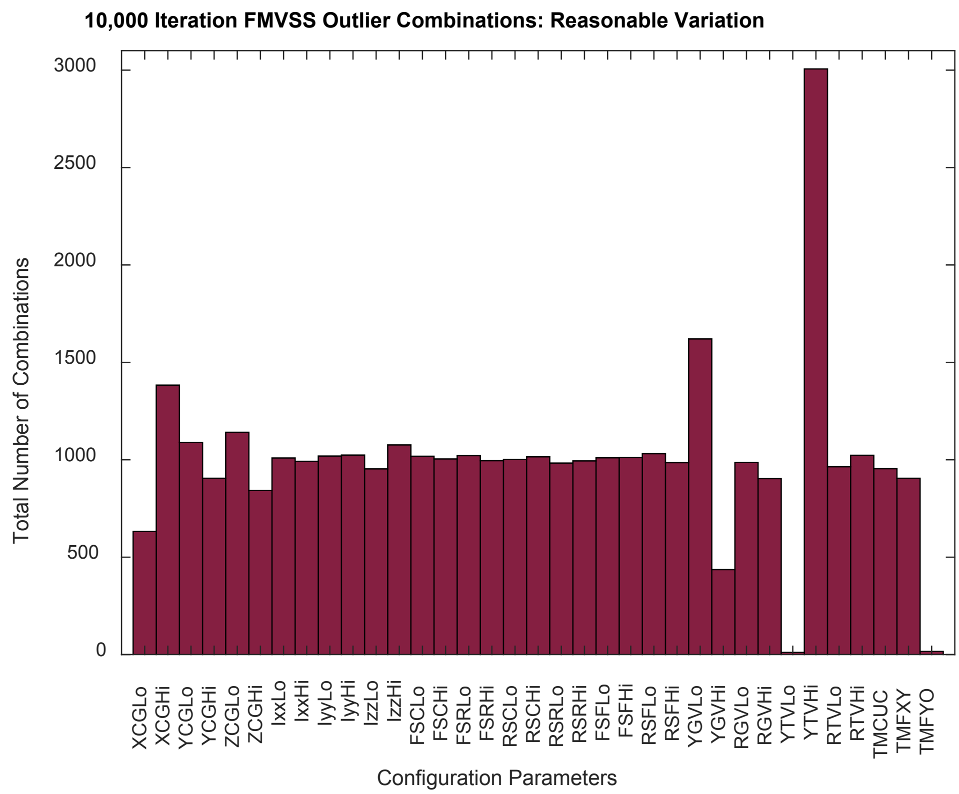


Figure 76. FMVSS Noncompliance Combinations for Reasonable Parameter Variation

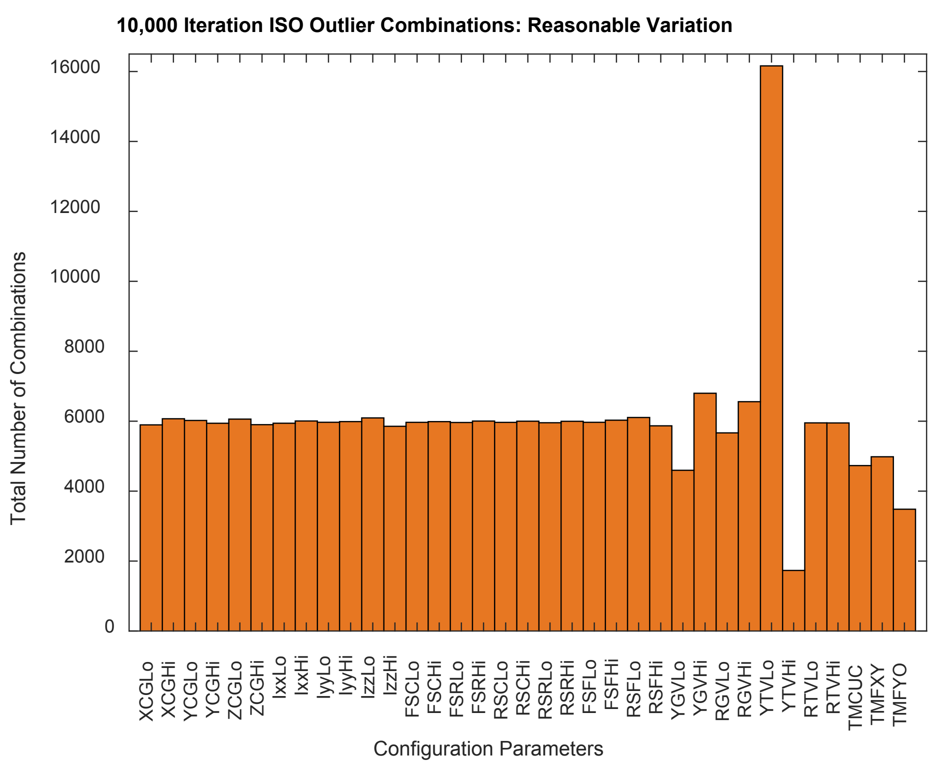


Figure 77. ISO Noncompliance Combinations for Reasonable Parameter Variation

Examination of the FMVSS noncompliance chart details the four most popular parameters as two inertial parameters: XCG and ZCG, and two ESC parameters: YGVLo and YTVHi. Statistical significance of the ISO non-compliance cases for the reasonable variation did not detail any significance except for ESC parameters. ESC parameter statistical significance was present in ISO and FMVSS noncompliance metrics for both the 30 percent variation and reasonable variation.

Sensitivity Study: Main and Two-Factor Study

The 10,000-run factor study was performed to provide an overall understanding of parameter significance across all 17 parameters. As such, the factor interaction order, or the number of parameters that were varied simultaneously, ranged from 5 to 17. Figure 78 below shows a histogram of the factor orders for the 10,000-simulation run test matrix.

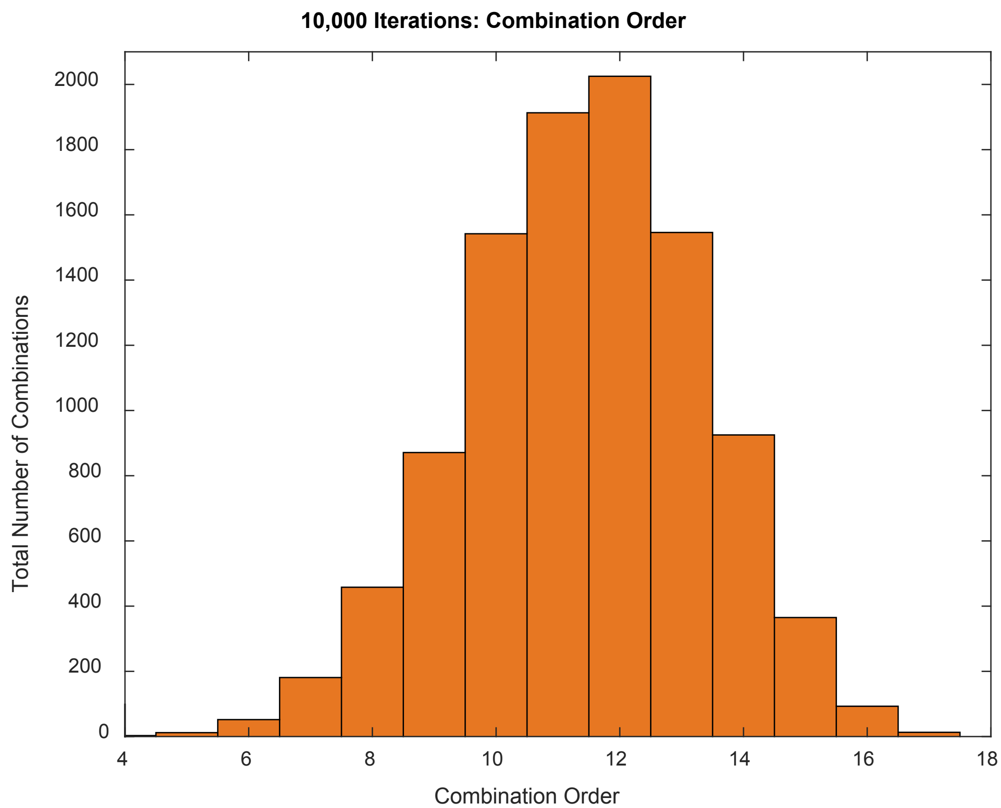


Figure 78. DOE Matrix Parameter Combination Order

Noncompliance of ISO and FMVSS standards could be the result of dominant parameter pairings within the factor combinations due to the high interaction orders. For example, if XCG was a dominant factor, any combination, including XCG, may show as significant even if the other parameters were not significant. The main effects and two-factor interaction time history data was used to help determine if, or which, parameters were dominant. The main effects were evaluated by adjusting a single parameter to a non-baseline level and holding the rest at baseline for all LO and HI parameter values. Two-factor interaction runs were evaluated by holding one factor at a constant non-baseline level and individually iterating through every other parameter non-baseline variation. For example, iteration 1 holds XCG HI and YCG HI with the rest at baseline, iteration 2 holds XCG HI and YCG LO with the rest at baseline, continue until all two-factor combinations have been evaluated. The FMVSS No. 126 simulation sequence was performed for the main interaction combinations of realistic and 30 percent parameter variation cases. The response metrics for FMVSS No. 126 and ISO 19365 were calculated with reference to model baseline response. Figure 79, Figure 80, Figure 81, and Figure 82 below show the parameter combinations that cause noncompliance with FMVSS No. 126 and ISO 19365 at reasonable and 30 percent variation parameter sets.

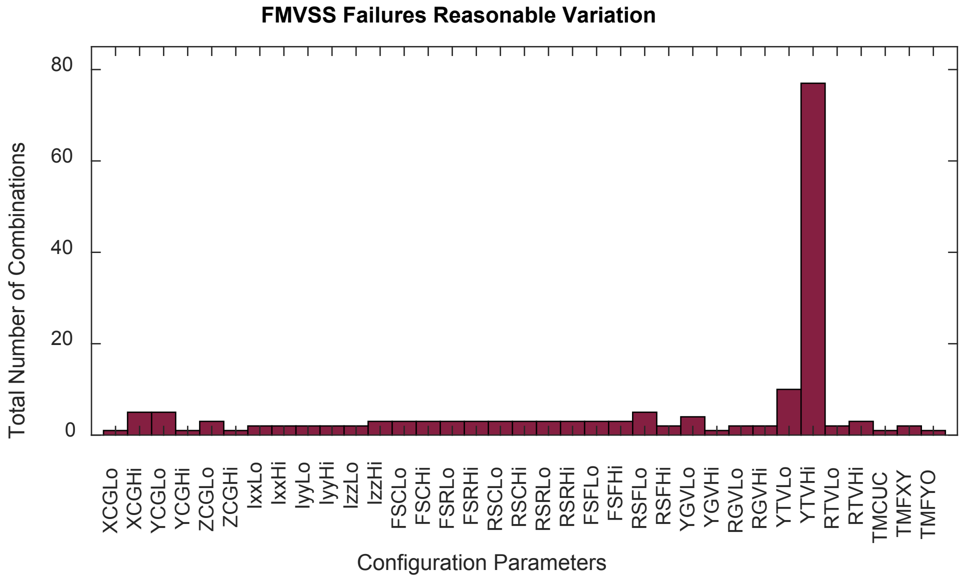


Figure 79. Main and Two-Factor Interaction Noncompliance Combinations, FMVSS Reasonable Variation

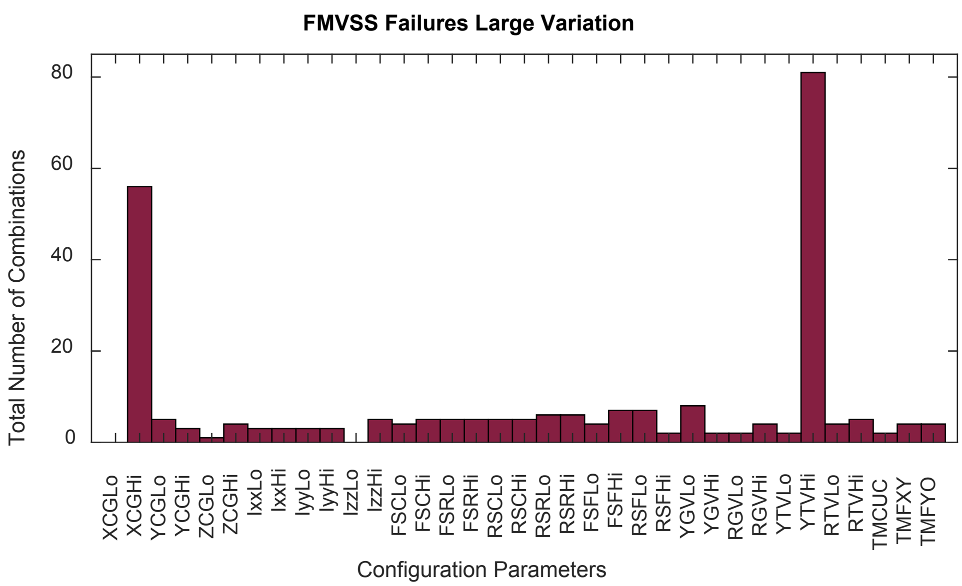


Figure 80. Main and Two-Factor Interaction Noncompliance Combinations, FMVSS Large Variation

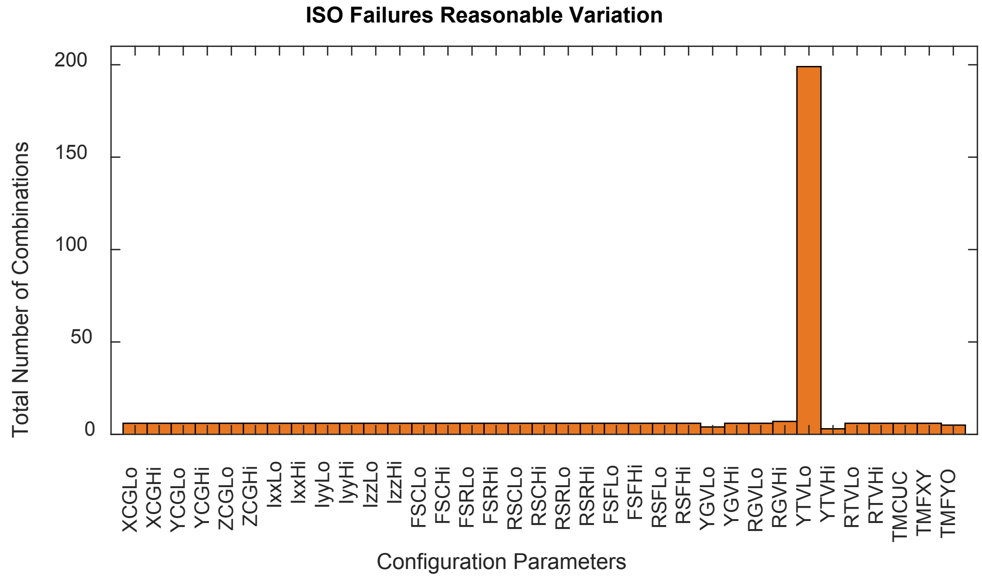


Figure 81. Main and Two-Factor Interaction Noncompliance Combinations, ISO Reasonable Variation

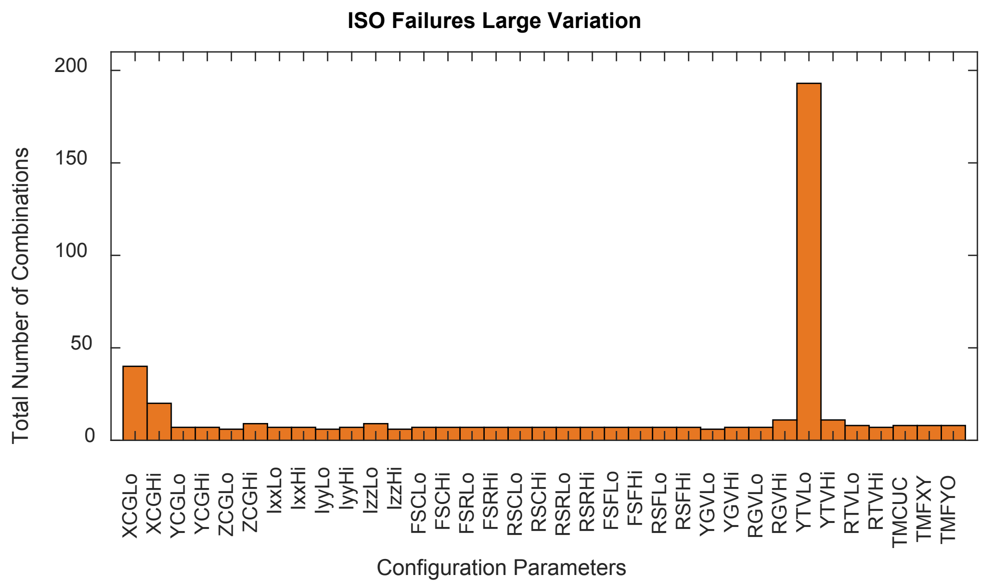


Figure 82. Main and Two-Factor Interaction Noncompliance Combinations, ISO Large Variation

Inspection of the main and two-factor combinations that caused noncompliance showed a strong dependence on XCG and the ESC parameters. This dependence on ESC parameters was also seen in the initial 10,000 combination cases. It becomes necessary to note that the implemented ESC model may not be an accurate representation of the ESC on the physical vehicle. Varying of the ESC parameters in this case may not provide useful information for vehicle analysis. As a result, the combinations of noncompliance that included the ESC parameters were removed and the remaining combinations were examined. The graphs in Figure 83, Figure 84, Figure 85, and

Figure 86 below show the main effect and two-factor noncompliance cases that remained after combinations containing ESC variations were eliminated.

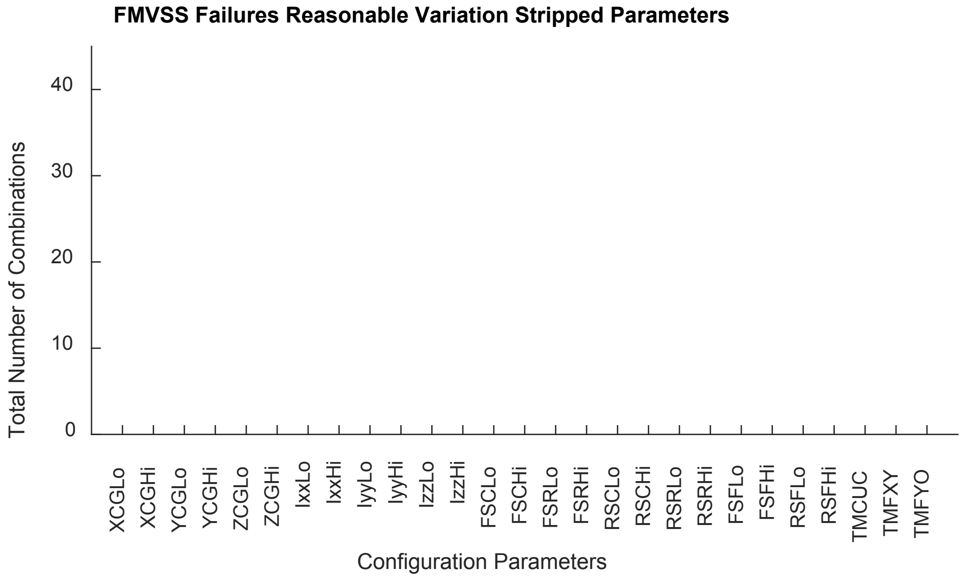


Figure 83. ESC Deleted Main and Two-Factor Interaction Noncompliance Combinations, FMVSS Reasonable Variation

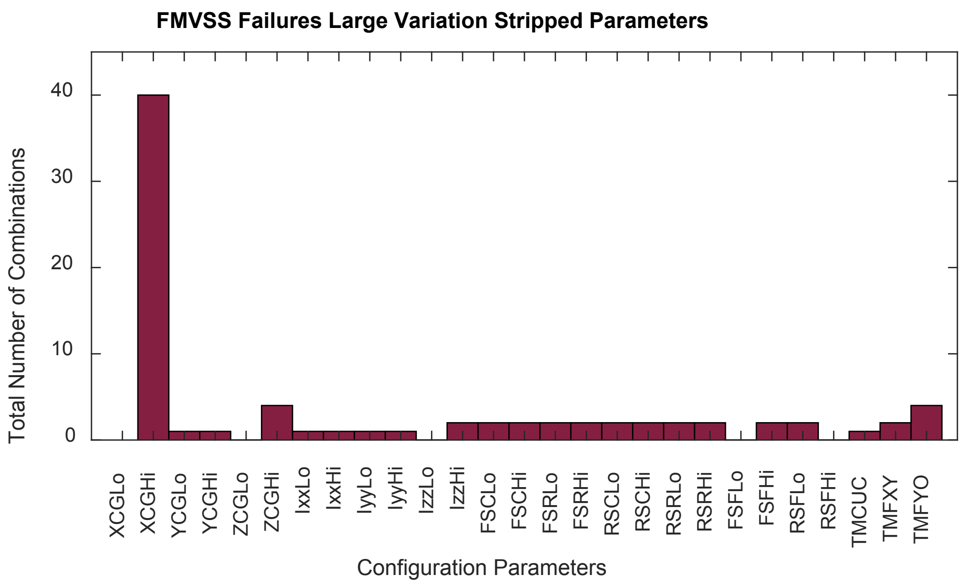


Figure 84. ESC Deleted Main and Two-Factor Interaction Noncompliance Combinations, FMVSS Large Variation

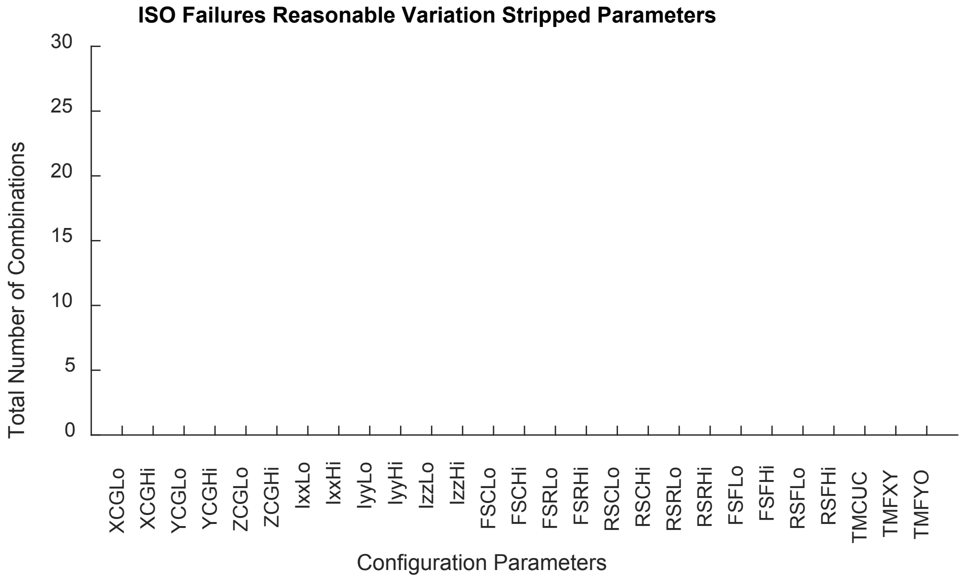


Figure 85. ESC Deleted Main and Two-Factor Interaction Noncompliance Combinations, ISO Reasonable Variation

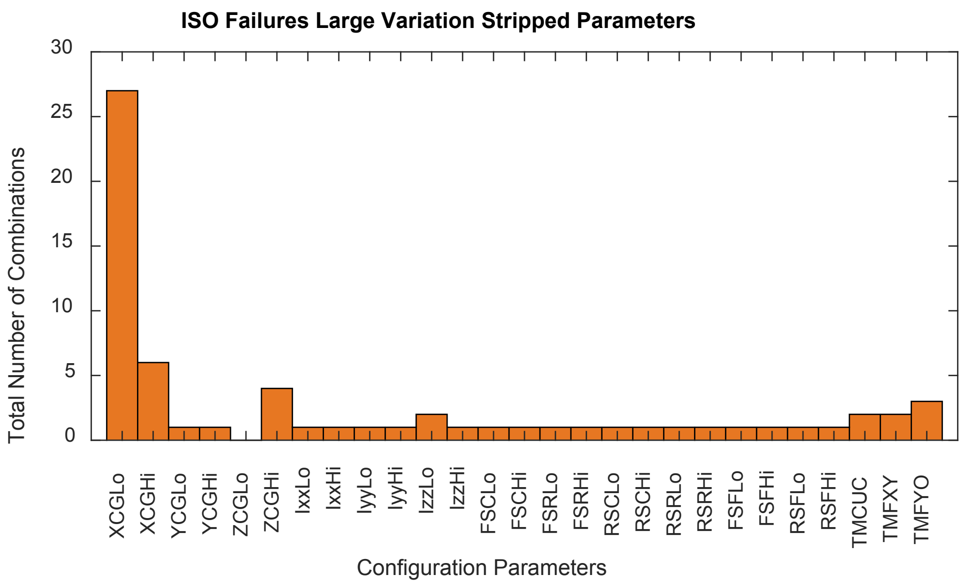


Figure 86. ESC Deleted Main and Two-Factor Interaction Noncompliance Combinations, ISO Large Variation

With ESC combinations removed, all combinations producing noncompliance were eliminated in the reasonable variation case. This indicated that the ESC parameters were dominant and reasonable variation of the remaining parameters produced an acceptable simulation response. For the 30 percent variation case, the FMVSS compliance figure identified XCG, ZCG, and tire models as popular parameters while the ISO compliance figure details XCG, ZCG, IZZ moment of inertia, and tire model relevance changed. This transition from compliance to noncompliance indicated that the amount of acceptable variation can be quantified within this 2.5 percent to 30 percent variation range for XCG, ZCG, IZZ, and tire models.

ANOVA identified XCG, ZCG, IZZ, spring forces, and tire models as statistically relevant parameters. FMVSS and ISO compliance metrics identified XCG, ZCG, IZZ, and tire models as relevant sources of variation in simulation response. The inclusion of spring forces in the first collection but not in the second will qualify it as a less significant factor. It is prudent to examine the HI and LO effects of these parameters on the time history data to identify which parameters were significant and which parameters were not. Only a subset of the main interactions are shown for brevity. Three plots are provided, one with strong parameter sensitivity, one with weak parameter sensitivity, and one that could be excluded if required. XCG is examined as the strong sensitivity factor, IYY is examined as the insensitive factor, and rear spring force is examined as the weak sensitivity factor. Figure 87 below shows the yaw rate and lateral acceleration time history plots for LO, baseline, and HI level values of XCG for both the reasonable and 30 percent variation cases.

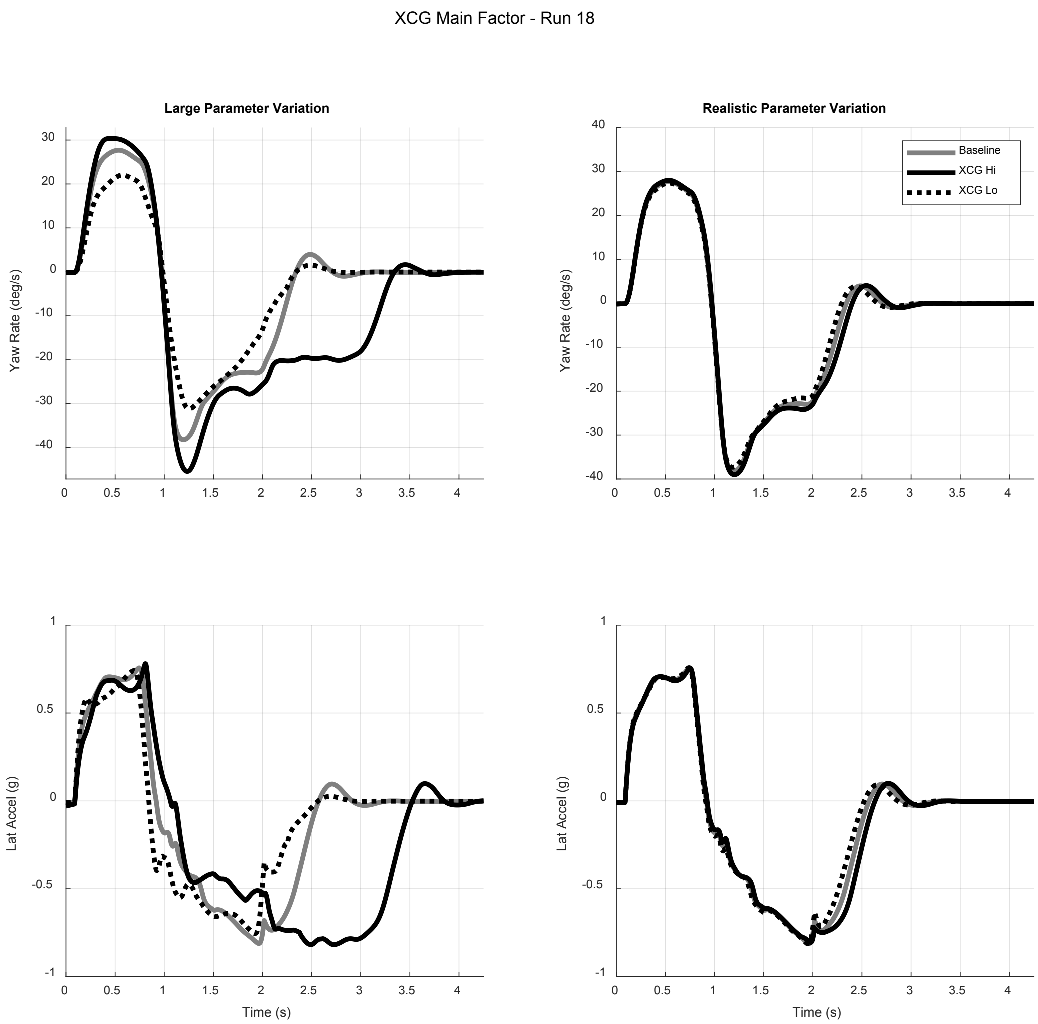


Figure 87. XCG Variation Yaw Rate and Lateral Acceleration

The plot shows the large and realistic parameter sets for the yaw rate and lateral acceleration time histories. Each plot has the baseline, HI, and LO parameter value time history responses. ANOVA analysis identified XCG as a statistically relevant factor at 30 percent variation. It is clear from the difference in the broken and solid yaw rate and lateral acceleration plots that XCG can be identified as a relevant parameter for the main interaction at 30 percent variation. For realistic variation, the parameter plots demonstrate that XCG appears to affect the settling time of the vehicle after the second peak.

Figure 88 below shows the yaw rate and lateral acceleration time history plots for LO, baseline, and HI level values of IYY for both the reasonable and 30 percent variation cases.

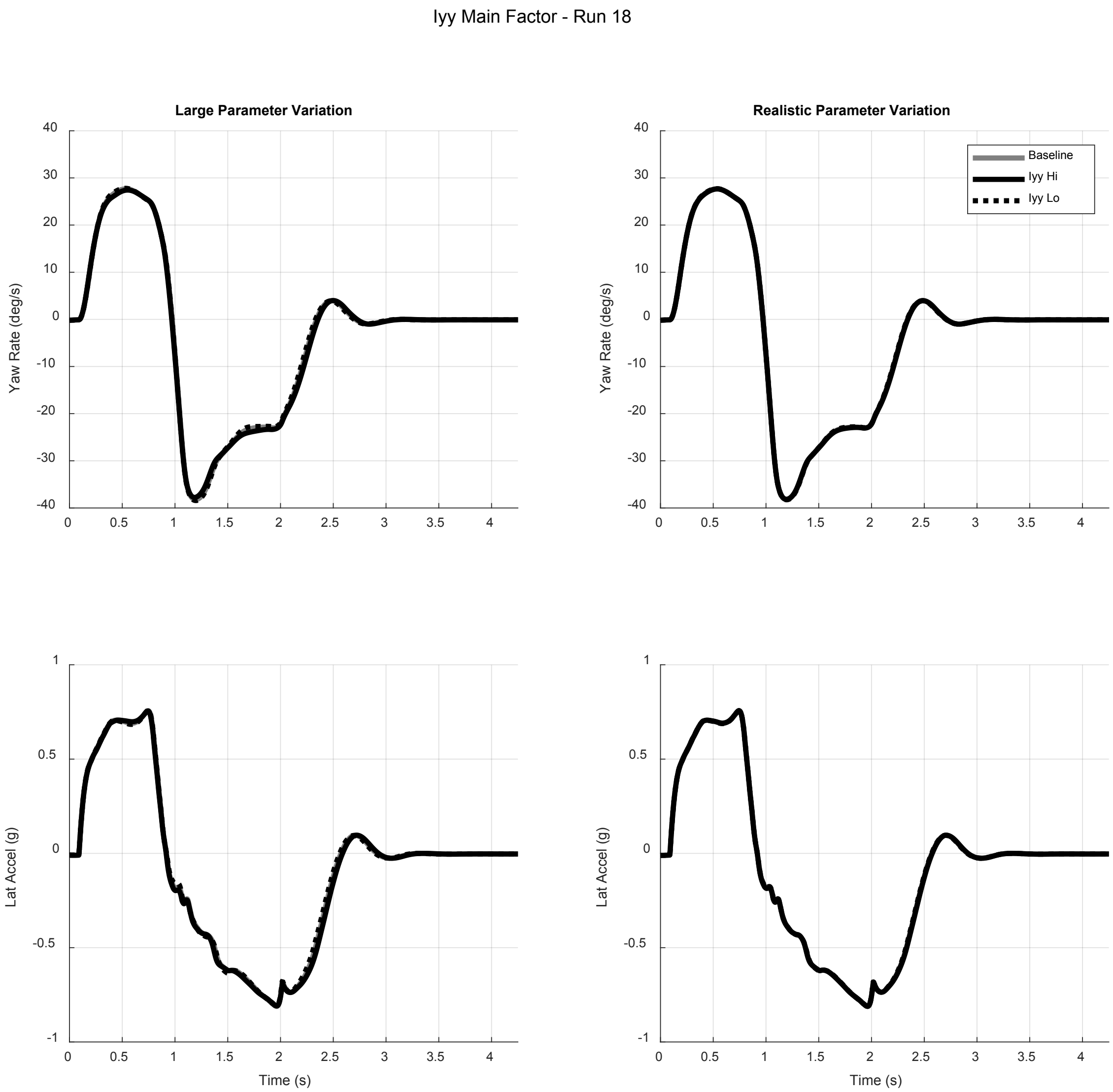


Figure 88. IYY Variation Yaw Rate and Lateral Acceleration

The plot shows the large and realistic parameter sets for the yaw rate and lateral acceleration time histories. Each plot has the baseline, HI, and LO parameter value time history responses. IYY did not show as a statistically relevant parameter for the main and first interactions in the ANOVA analysis. The first figure shows that large parameter variation has no significant effect on the response. The realistic parameter plots demonstrate that IYY appears to have no effect on the vehicle response either. This verifies that this parameter is not important to the evaluation of FMVSS No. 126 and can be omitted from further analysis.

Figure 89 below shows the yaw rate and lateral acceleration time history plots for LO, baseline, and HI level values of rear spring force for both the reasonable and 30 percent variation cases.

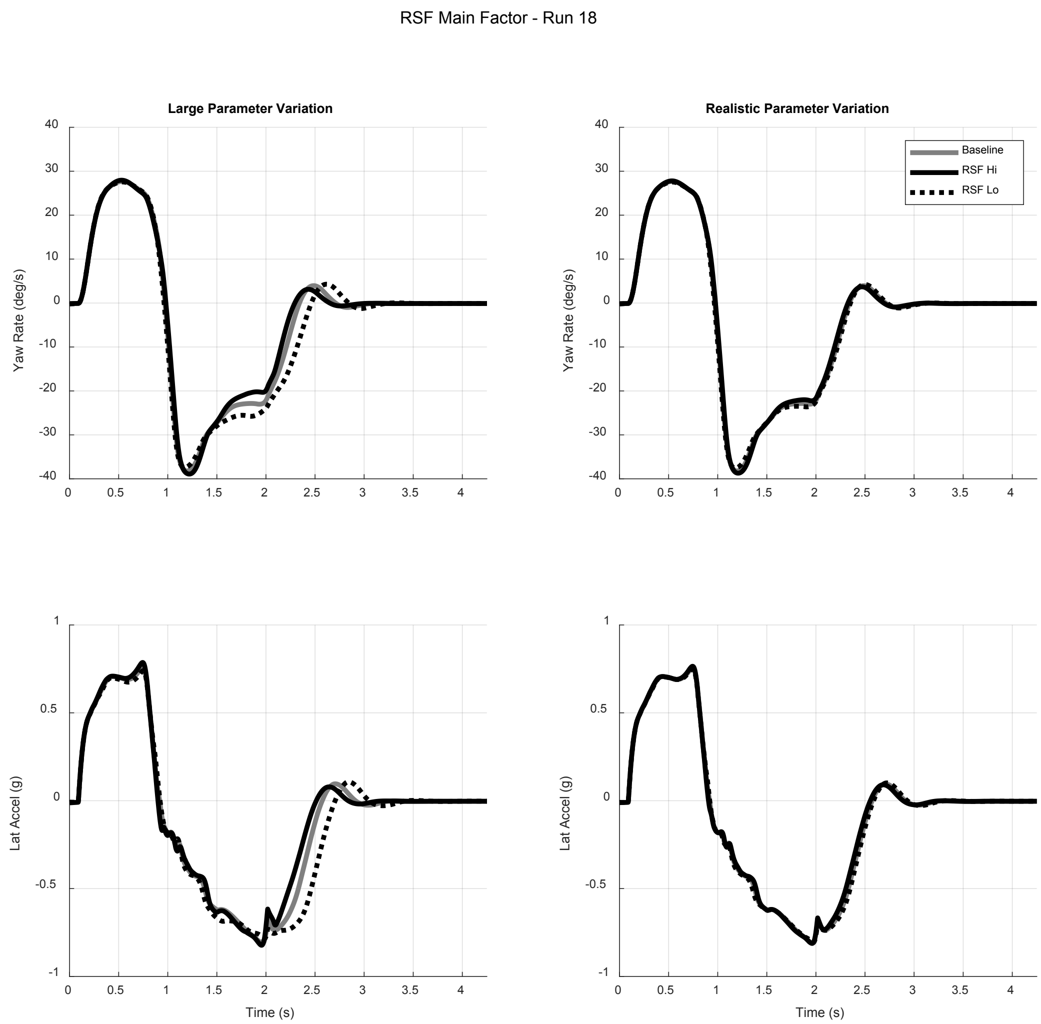


Figure 89. RSF Variation Yaw Rate and Lateral Acceleration

The plot shows the large and realistic parameter sets for the yaw rate and lateral acceleration time histories. Each plot has the baseline, HI, and LO parameter value time history responses. The rear spring showed as a statistically relevant parameter for the main and first interactions. Large parameter variation has a small effect on the response, primarily in the yaw rate settling region after the second peak. The realistic parameter plots demonstrate that the rear spring parameter appears to have a minimal effect on the vehicle response. These spring force variation time history plots do not show significant variation to the reference time history data in the same regions where the ISO 19365 metrics are evaluated but do show variations in the tails of the yaw rate decay. This verifies that this parameter may not be important to the evaluation of FMVSS No. 126 and can possibly be omitted from the analysis.

Sensitivity study: Targeted Study

ANOVA as well as FMVSS and ISO compliance of the 10,000-combination study identified four significant parameters: XCG, ZCG, IZZ moment of inertia, and tire model. The intent of the 10,000-combination study was to reduce the parameter list to a smaller set so that a full factorial design of experiment analysis could be performed. The four primary parameters were included as the first choices. A full factorial design of three factors with three levels and one factor with four levels would be 108 combinations per variation percentage. Because of the direct relationship of IXX to the sine with dwell maneuver and ESC performance, it was decided to include IXX in the study. A full factorial design of four factors with three levels and one factor with four levels would be 324 combinations. Since 324 simulation runs was reasonable per parameter variation case, a full factor analysis with these five parameters was performed for FMVSS and ISO compliance for a group of parameter variation cases that ranged between 2.5 percent to 35 percent. ISO and FMVSS compliance of these runs were calculated with reference to baseline model data.

Figure 90 below shows spy plots of the FMVSS pass/fail statements for the three performed runs from 2.5 percent variation to 30 percent variation. These calculations were done with reference to the model baseline response.

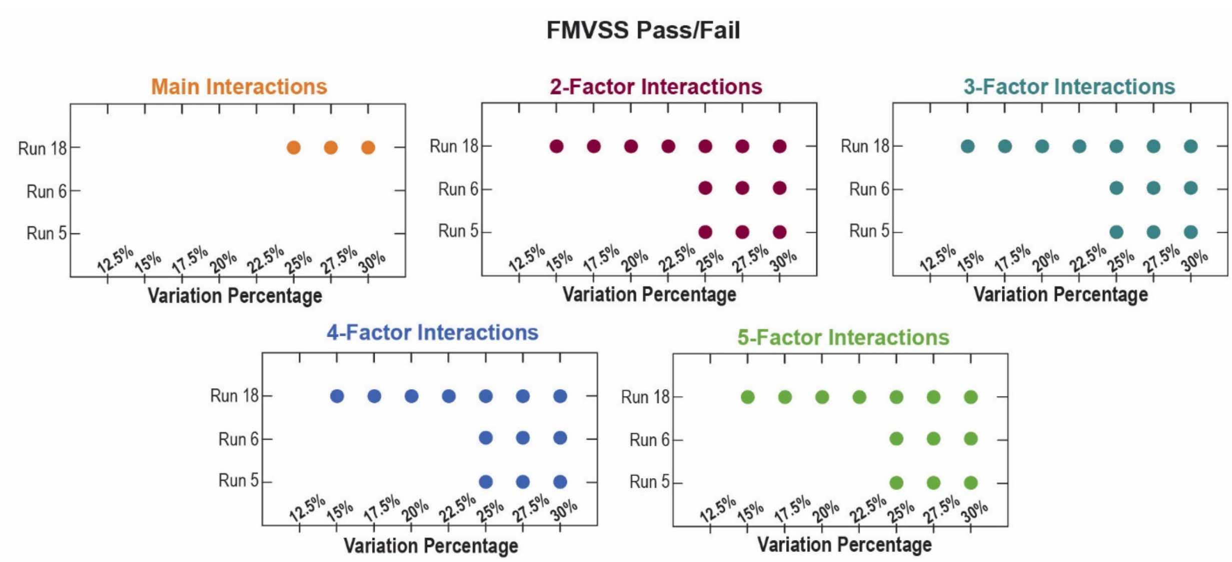


Figure 90. Parameter Variation Percentage and FMVSS Compliance

The FMVSS noncompliance is plotted by run and variation percentage for the various levels of interactions. This was done to convey the acceptable amount of parameter variation allowed before non-compliance occurred, and to examine how the parameter tolerance changed as interaction order increased. A point on the plot indicates that FMVSS compliance was not satisfied for that run at that parameter variation percentage. For example, in the main interaction plot for Run 18, FMVSS compliance was not met for a parameter variation of 25 percent or higher. As the number of interactions increased, the acceptable parameter tolerance for compliance decreased. Figure 90 shows that as factor order increases, there is a compounding effect that drives the simulation towards noncompliance.

For all Run 18 simulations to satisfy FMVSS compliance, all parameters must be within 12.5 percent of the baseline value. For all Run 5 and Run 6 simulations to satisfy FMVSS compliance, all parameters must be within 22.5 percent of the baseline value. For FMVSS compliance, Run 18 defines the maximum acceptable tolerance for the variation in parameters which is 12.5 percent.

The ISO compliance pass/fail can be visualized in a similar way. Figure 91 below shows spy plots of the ISO metric pass/fail for the three performed runs from 2.5 percent variation to 35 percent variation. These calculations were done with reference to the model baseline response as well.

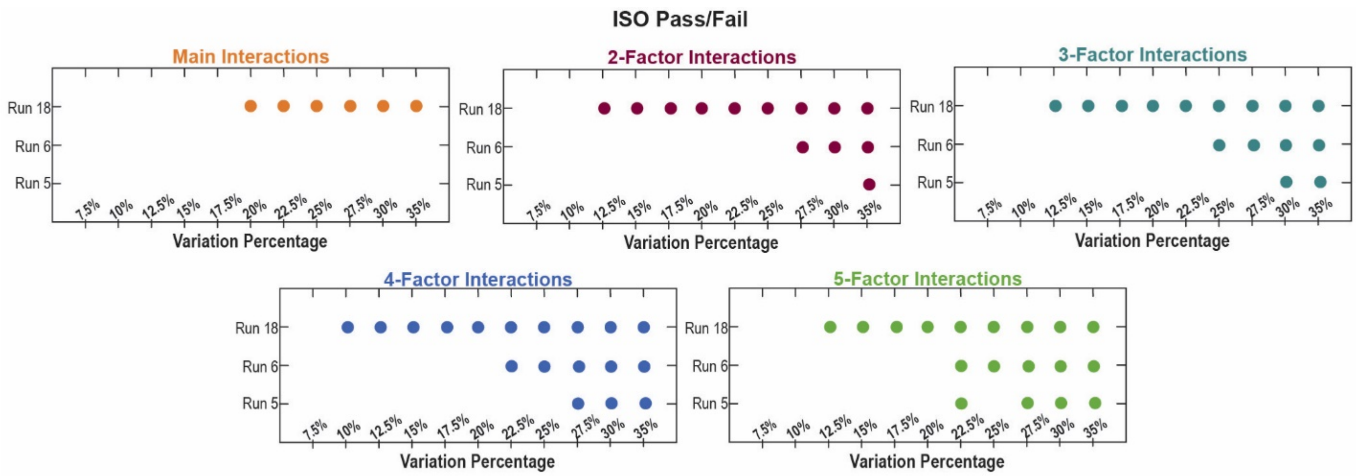


Figure 91. Parameter Variation Percentage and ISO Compliance

The figure above shows the following: for all Run 18 simulations to comply with the ISO standards, all parameters must be within 7.5 percent of the baseline value; for all Run 5 and Run 6 simulations to pass ISO standards, all parameters must be within 20 percent of the baseline value. Again, Run 18 is more sensitive to variation than runs 5 and 6. Just as with the FMVSS case, less variation is acceptable as interaction order increases.

The ISO standard compliance was shown to be more sensitive to parameter variation than FMVSS compliance. The highest amount of variation allowed before any non-compliance occurs was 7.5 percent, which comes from violation of the ISO standard. From the maximum allowable tolerance of 7.5 percent, the amount of acceptable variation in terms of the model parameters can be represented in engineering units and can be found in Table 57 below.

Table 57. Allowable Tolerance Engineering Units

Configuration		Metric Units	English Units
X	Center of Gravity Location	120.8 mm	4.7 in
Z	Center of Gravity Location	52.3 mm	2.1 in
IXX	Moment of Inertia	65.7 kg*m2	48.5 lb-ft-sec2
IZZ	Moment of Inertia	386.1 kg*m2	284.7 lb-ft-sec2

The 7.5 percent error is greater than the measurement accuracy of the model parameter measurements made at the center of gravity and moment of inertia testing. Table 58 details the quoted accuracy and repeatability of the CG and Inertial measurements, taken from the third-party supplier.

Table 58. Accuracy and Repeatability of CG and Inertia Measurements

Parameter	Accuracy	Repeatability
XCG	< 0.01 in	< 0.01 in
ZCG	< 0.01 in	< 0.01 in
IXX	0.2%	0.02%
IZZ	0.3%	0.02%

Findings Summary

The purpose of this study was to evaluate the applicability of virtual vehicle simulation for FMVSS compliance testing. One of the fundamental issues related to virtual vehicle simulation is how to ensure trust in the mathematical vehicle dynamic model, which was the focus of this study. Trust in the vehicle model and simulation was related to its associated parameterization and a parameter sensitivity study was performed. Specifically, FMVSS No. 126 was the focus of the sensitivity study.

The following work was completed as part of the study. First a mathematical vehicle dynamic model and simulation were developed. The testing required for parameterization and correlation was performed with third-party laboratories. Testing included component-level and vehicle system-level laboratory and field tests. The resulting test data was used to parameterize the mathematical vehicle models and the correlation data was used in conjunction with the resulting simulations to define and correlate a baseline vehicle model and simulation. The target vehicle ESC model was not available for this study, so as part of the model creation and correlation process a simple ESC model was implemented in the simulation and tuned using the FMVSS No. 126 non-ADS-equipped vehicle configuration test data.

During the FMVSS 126 correlation process, a literature review identified ISO Standard 19365 as a potential approach for virtual model validation for SWD testing. ISO 19365 was used as part of both the model correlation process and the sensitivity study. There were two considerations with using ISO 19365 in this study. First, ISO 19365 was applied as a method for evaluating model quality due to parameterization variation. Using ISO 19365 in this way for the study was similar to the application for the standard but not identical. ISO 19365 provides criteria to evaluate virtual simulation acceptability for re-creating FMVSS No. 126 field test data responses. This study used ISO 19365 to help assess model parameter variation and the resulting virtual simulation results relative to the baseline simulation. Second, ISO 19365 only applies criteria to the first two yaw peaks, the cross over time between the two peaks, and the lateral displacement. It does not have any criteria to address the model behavior past the second yaw peak. The lateral displacement criterion may not be sufficient to account for the model behavior in this region. To address these considerations, the FMVSS No. 126 evaluation metrics were included in the analysis. Even though there are considerations for applying ISO 19365, it does provide a basis for the evaluation of applicability of simulation for FMVSS No. 126 compliance evaluation.

Once model, procedure, and ESC baselines were established, a parameter reduction study was performed to eliminate the least important parameters so that a full factor sensitivity analysis for the important parameters could be completed. The parameter reduction study reduced the parameter set from 17 to 5.

The sensitivity study was a full factor study of the five important parameters. The full factor study evaluated every combination of the five parameters including the baseline values for parameter set variations between 5 percent and 35 percent, in steps of 2.5 percent. The results of the study were used to determine the maximum allowable tolerance for the parameters. The maximum allowable tolerances for the parameters were 7.5 percent for ISO 19365 compliance and 12.5 percent for FMVSS No. 126 compliance. What this means is that if the parameters were varied by more than 7.5 percent of baseline, ISO 19365 compliance would not be satisfied. Similarly, if the parameters were varied by more than 12.5 percent, FMVSS No. 126 compliance would not be satisfied. The parameter tolerance as defined by the third-party laboratory data was approximately 2.5 percent. Since the realistic parameter tolerance was smaller than the tolerance required to satisfy ISO 19365 and FMVSS No. 126, a vehicle dynamic model parameterized in a similar way with the proper consideration of the ESC may be a sufficient representation of the physical vehicle for virtual FMVSS No. 126 compliance evaluation. The results of the sensitivity study may help in understanding important model parameters and their measurement accuracy, which may drive test methodology for parameter measurement from the physical vehicle and correlation to virtual model.

In order to implement a process for virtual compliance evaluation of FMVSS No. 126, a workflow process may be similar to the process conveyed by Figure 51 Model Creation shown previously.

Relating this proposed process back to the current physical vehicle compliance testing, the additional burden associated with the process flow defined above is contained within the model creation and correlation steps. If the model was supplied by the vehicle manufacturer, the focus of the vehicle testing would be collecting correlation data, which is a small subset of the test data required for this study. If the vehicle dynamic model and simulation were parameterized by NHTSA or an independent contractor, all testing performed in this work may be required.

The work performed in this study helped identify considerations for developing trust in a mathematical vehicle model and simulation. The constraints of the study only allowed for evaluation of one vehicle with an ESC model that approximated the ESC performance of the physical vehicle. Future work could include evaluation of other vehicle classes and inclusion of the actual ESC either through a manufacturer supplied model or co-simulation with the ESC hardware through HIL.

Appendix I. Hardware-in-the-Loop Simulation for FMVSS Testing

Concepts for the Proposed System

Introduction

HIL simulation was identified as a potential augmentation for the simulation method described in Chapter 5. HIL provides the opportunity to integrate physical components into a simulation environment, which eliminates the requirement for modeling of components that may be unique to a given model and include potentially unavailable proprietary design, such as ESC or ABS modules. While a purely software-based model is potentially less complex and less costly, replacing the virtual models with the physical hardware used in the vehicle under test, HIL may be able to achieve higher fidelity results.

The objective of this task was to identify potential concepts and considerations for the use of HIL as a potential test method. FMVSS No. 126 was used as the test case to parallel the broader software investigation. This task focused on developing potential test cases, system architectures, testable characteristics, component definitions, and potential steps guidelines for implementation. In addition, this task identified cost, fidelity, and complexity considerations for comparing between HIL concepts and to other test modes.

Four potential HIL test cases were developed for FMVSS No. 126, each of which provides unique advantages and limitations. These four test cases identified are as follows.

- Test Case 1: Vehicle Chassis ECU
- Test Case 2: Physical Braking System
- Test Case 3: Automated Vehicle Perception ECU
- Test Case 4: Full Vehicle HIL

While this document does reference specific tools and software solutions to display the feasibility of HIL concepts, it does not endorse any of these tools. Rather, potential steps and tools for implementation in a production environment are presented for possible use as the basis for the implementation of HIL in the simulation environment described in Chapter 5.

This task was decomposed into six subtasks that were approached with a tailored systems engineering process that leverages the *International Council of Systems Engineering Handbook* (Walden et al., 2015) best practices as guidance, starting at a high level with an operational concept and increasing in definition and understanding of systems, leading to guidelines for implementation.

The appendix is organized as follows: The first subtask defines the operational concept for FMVSS No. 126 HIL; the second provides definitions for the system architecture subsystem and components as well as any associated data inputs and outputs; the third presents the HIL test cases for FMVSS No. 126 as well as the considerations (i.e., cost, fidelity, complexity) and verification and validation (V&V) techniques for each test case; the fourth presents suggested steps and procedures to implement the various test case architectures; the fifth presents possible considerations for HIL in a production environment and presents possible mitigation strategies; and the last section discusses the key conclusions of the analysis.

HIL Operational Concept

HIL simulation testing incorporates some level of physical hardware into the simulation environment, which could provide real data inputs and processing for those vehicle features being tested in FMVSS No. 126. This would allow for the necessary physical components to be directly tested without involving the entire vehicle itself. Incorporating hardware components into a simulation could result in higher accuracy and/or fidelity by providing more representative performance of specific physical subsystems to the simulation mode

Findings from literature assessments on HIL suggested that a combination of incorporating industry-driven simulation tools, coupled with the development of a physical test rig containing testable components (like the ESC and braking system), could provide a feasible solution for FMVSS testing. At a high level, the physical components that influence the performance and function of the ESC system would replace the ESC module in the process diagram presented in Chapter 5 and Appendix I and shown below for reference (Figure 92). It should be noted that the following figure provides a representation of the process for simulation. Subsequent diagrams provide a HIL system architecture and provide complementary but different information than that contained in Figure 92.

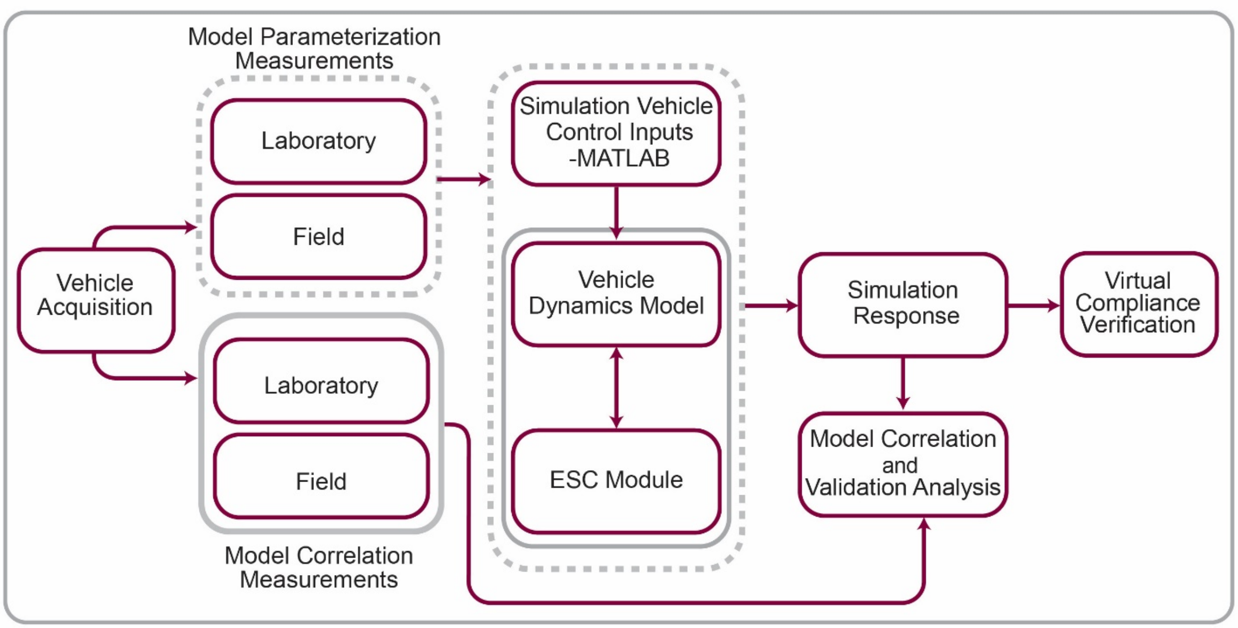


Figure 92. Potential Simulation Compliance Verification Process

The ESC controller for this operational concept performs as if it is experiencing the maneuver in an actual vehicle. This could be extended to provide data for the application of the individual brakes by using pressure transducers at each brake to report the application pressure back to the simulation software, which would then determine the individual brake forces and the subsequent dynamic vehicle response.

Understanding how the ESC and other essential HIL components interact with virtual simulation tools can help describe proposed architecture for HIL testing. Test cases with increasing complexity that incorporate additional vehicle hardware components are presented and explored to evaluate a broad range of potential HIL implementation scenarios.

HIL Subsystem Components

Defining Subsystems

In order to develop HIL test cases for FMVSS No. 126 testing that are applicable for current and future vehicles, definitions for subsystems and their components within the system architecture must first be addressed. The subsystems and components identified in this document were adopted from a previous NHTSA study, which proposed an HIL subsystem architecture for ESC in heavy trucks (Svenson et al., 2009). The HIL architecture proposed in this document includes the following subsystems and components for simulating the test procedures associated with FMVSS No. 126

Computer Cluster: Tools used to interact with the vehicle test bed and conduct simulation response data analysis. Computer Cluster subsystem component definitions and data inputs and outputs are described in Table 59.

Table 59. Computer Cluster Subsystem Component Definitions

Component	Description	Inputs and Outputs to HIL Simulation
Host PC	Computer used to process data and results from HIL.	**Inputs:** data output from ECU diagnostics **Outputs:** processed ECU diagnostics data
Real-Time Node (ABS)	Simulated or manufacturer computer used to process simulated vehicle dynamics data in real time.	**Inputs:** simulated and/or physical vehicle dynamics data, depending on the test case **Outputs:** processed vehicle dynamics data for ABS*
Real-Time Node (ESC)	Simulated or computer used to process simulated vehicle dynamics data in real time.	**Inputs:** simulated and/or physical vehicle dynamics data, depending on the test case **Outputs:** processed vehicle dynamics data for ESC*
Remote Servers	Computer that is located remotely for data storage and post processing	**Inputs:** processed ECU diagnostics data **Outputs:** stored simulation data and post-processing to determine FMVSS No. 126 pass/fail
* Indicates that the data inputs and/or outputs may contain proprietary information that could differ from vehicle to vehicle (e.g., chassis ECUs encoded with VINs)		

HIL: Hardware components used in the simulations for various test cases. These vary by test case, ranging from a singular ECU to a complex braking system including solenoids and hydraulic lines. HIL subsystem component descriptions can be found in the Test Cases section of the report, as these components vary for each test case.

Software Simulation: Virtual tools used to simulate a test approach. Pass/fail is determined by the output from the software model as described in Chapter 5. Software Simulation subsystem component definitions and data inputs and outputs are described in Table 60.

Table 60. Software Simulation Subsystem Component Definitions

Component	Description	Inputs and Outputs to HIL Simulation
CarSim	Software tool used to simulate vehicle behavior dynamics for FMVSS No. 126 test procedures.	**Inputs:** vehicle parameters and characteristics such as weight, suspension, and tires **Outputs:** simulated Vehicle Dynamics as a CarSim file
MATLAB/ Simulink	Software tool used to simulate vehicles controls such as throttle and brake signals for FMVSS No. 126 test procedures.	**Inputs:** throttle, braking, and steering commands as defined by FMVSS No. 126 test procedures **Outputs:** simulated Vehicle Dynamics as a MATLAB/Simulink file

Control Interfaces: Connection used to interact with simulated vehicle hardware, such as CAN interfaces, motion sensor, and perception sensor simulators. Similar to the HIL subsystem, the control interface subsystem components differ between test cases and as a result are presented in the Test Cases section of the report.

Testing for Model Parameterization and Validation: References for the simulated vehicle to test. This includes scenario design and configuration, CAN data communication, vehicle dynamic controls, and an end of line test. Testing for Model Parameterization and Validation subsystem component definitions and data inputs and outputs are described in Table 61.

Table 61. Testing for Model Parameterization and Validation Subsystem Components

Component	Description	Inputs and Outputs to HIL Simulation
Brake/Throttle Control	Brake and throttle inputs to Simulink and CarSim	**Inputs:** engine type, engine power, Percentage of wide-open throttle, and percentage of full brake **Outputs:** horsepower, torque, and speed at each time step of the simulation
CAN Communication Models	High-speed CAN messages that contain critical engine, transmission, brake, and steering angle data	**Inputs:** readings from motion sensor simulators (e.g., wheel speed sensors and accelerometers) **Outputs:** control messages and data sets sent from the ECU
Field of Reference, Tire, Suspension, Powertrain Model	The virtual environment and component models that are simulated for FMVSS No. 126 test procedures	**Inputs:** vehicle parameters such as weight, tire profile (i.e., tread width and tire height), height of vehicle, and center of gravity into CarSim Model **Outputs:** vehicle profile for simulation
End of Line Test	Short-duration, mechanical and electrical evaluations of automotive ECUs, mechanical parts, and systems, to catch any defects missed during the assembly process.	**Inputs:** basic function check of all components **Outputs:** pass/fail report that details all component functionality testing and their outputs
Scenario Design and Configuration	Assigning mechanical features environmental features (weather, for simulation	**Inputs:** mechanical (e.g., gear ratios and any unique features to the vehicle such as torque vectors) and environmental features (e.g., weather and temperature) of the simulation **Outputs:** field of reference (i.e., virtual environment and component model)
Real World Component Calibration	Calibrating the real-world components (i.e., sensors and brake components) to emulate the vehicle tested	**Inputs:** standard vehicle components and specifications as recommended by the manufacturer (e.g., tire size, tire pressure, caliper and rotor size, and the other components of the physical brake subsystem) **Outputs:** representative system for the vehicle tested

Defining System Architecture Entities for HIL Simulation

System architectures are relative to the model of interest. Typically, system architectures provide a reference point in which requirements can be developed to sustain the model of interest. Using SE techniques (Walden et al., 2015) as best practices, requirements in this case will be acknowledged as reference guidelines that the system parameters can adhere to. The architecture of a system, in the context of HIL, is its fundamental structure, which illustrates processes applied to the structure as well as specific substructures (or entities) and can be broadened to include principles associated with the realization of the system (e.g., implementation) or governing of its evolution over time. Entities in this context define components, functions, and guidelines, which are individual pieces that compose the entirety of a system architecture. Components are the individual pieces used to make up a system architecture.

The identification of fundamental types of structure usually depends on the nature of the system as well as its purpose. Structure that is judged not to be fundamental should be excluded from the architecture. Following an SE process, architectural entities address the functional guidelines of a system. For FMVSS No. 126 compliance, the following entities defined in this task are the input/output flows and data elements. Components and functions, as well as guidelines (e.g., electrical system and software guidelines), will be defined in later sections. Other entities, such as containers and communication resources, which address different types of guidelines (interface guidelines, environmental guidelines, etc.) can typically be found as part of a system architecture but are not pertinent to this HIL setup.

V&V

As discussed in Appendix I, V&V is an important part of generating confidence in the simulation model. This applies to HIL as well. The HIL setup must have a means for being validated as a functional test apparatus itself. Essentially, by ensuring that the HIL setup itself serves its intended purpose, a type of ground truth of the component's behavior must be provided. This can be facilitated via the component supplier's cooperation in providing a closed response curve, or performance catalog for NHTSA to anticipate HIL results. Alternatively, a reference library in the simulation software model may be used as a reference from historic simulation data taken from other vehicle types of the same class (weight, vehicle type, dynamics, etc.).

Test Cases

Potential HIL system architectures for FMVSS No. 126 are presented as test cases, which vary in terms of cost, fidelity, and complexity. The complexity of the test case is based on the level of effort needed to procure and develop a test apparatus which NHTSA can use to verify FMVSS No. 126 compliance using the proposed hardware components. Fidelity (i.e., accuracy of the results) and cost (i.e., hardware, labor, and software purchasing costs) considerations are also taken into account when evaluating the four test cases. Since HIL focuses on a specific physical component or system in a controlled environment, it has potential benefits over traditional test methods, such as full-track vehicle testing, since an HIL test can be repeatable and adjustable with a relatively inexpensive setup. Additionally, HIL may provide more benefits than other methods of testing such as software-in-the-loop (SIL) since the inclusion of a physical component can allow for real-world datasets to provide a more practical analysis of the component or system being tested.

This section presents the system architectures for four test cases and defines their respective control interface and HIL subsystem components and corresponding data inputs/outputs. Each test case can be simulated in a lab environment, but the scale varies, with Test Cases 1 and 3 being conducted on a bench-top, Test Case 2 on a rack-system, and Test Case 4 on a full vehicle. Table 62 summarizes the test cases by providing a general description of the method, as well as the relative scale of implementation when comparing to SIL or full vehicle testing.

Table 62. Test Case Summary

Test Case		Description	Test Scale	Comparison between Test Cases
1	Vehicle Chassis ECU	A setup composed of a computer cluster, software suite, and control interface, interacting with a hardware component	Bench top: HIL apparatus can be developed in a compact station, such as a table top or bench.	Allows the setup to have in-the-loop proprietary ESC algorithm for transferring data sets between simulation and computer clusters. It can be a mobilized configuration where the bench top can be set up at a manufacturers' facility upon inspection
2	Physical Braking System	A setup expanding on Test Case 1, with the inclusion of a functioning physical braking system	Rack system: incorporates similar apparatus seen in Test Case 1, but will include a physical braking system outfitted on a rack in an accessible arrangement to monitor components	A rack system can be designed to conform to a unique table or rack, allowing for functioning components to be individually accessible. While this setup may not be as portable, it can provide additional braking input when validating an FMVSS simulation
3	Automated Vehicle Perception ECU	A setup expanding on Test Case 1, with the inclusion of vehicle perception modules for lidar, radar, vision, or other sensors	Bench top: See Test Case 1	See Test Case 1

Test Case		Description	Test Scale	Comparison between Test Cases
4	Full Vehicle	A production (or prototype) vehicle connected through a vehicle interface port (VIP), such as onboard diagnostics (OBD)-II, which receives simulation inputs from the HIL computer cluster and software parameters	Full-vehicle: A vehicle that can be tested in a static environment, minimizing set up labor or apparatus tuning	This setup uses the vehicle itself. While it is the least physically complex arrangement (a vehicle, simulation computer, and a physical connection), it may introduce additional factors when acquiring a make or model vehicle

For the first two test cases, the information flow is defined for the system architecture. The final two test cases integrate additional levels of hardware into the simulation environment and may offer increased fidelity of an ADS-DV's general performance during a scenario, which could result in the activation of ESC due to the interdependencies the ESC may have with the sensor perception system. However, since the current test procedures are defined to test only the ESC performance, it is not likely that any of these interdependencies will be critical for FMVSS testing. As a result, an in-depth analysis of information flows were not undertaken for these test cases. Rather, they are presented to provide a full scope of the potential integration of vehicle hardware into the simulation environment.

For each test case architecture layout, the subsystem and its respective components are color-coded and connected by input/output connection links, which represent the logical interfaces (i.e., information and data flows) within the HIL setup. The definitions for the system architecture layout are shown below in Figure 93.

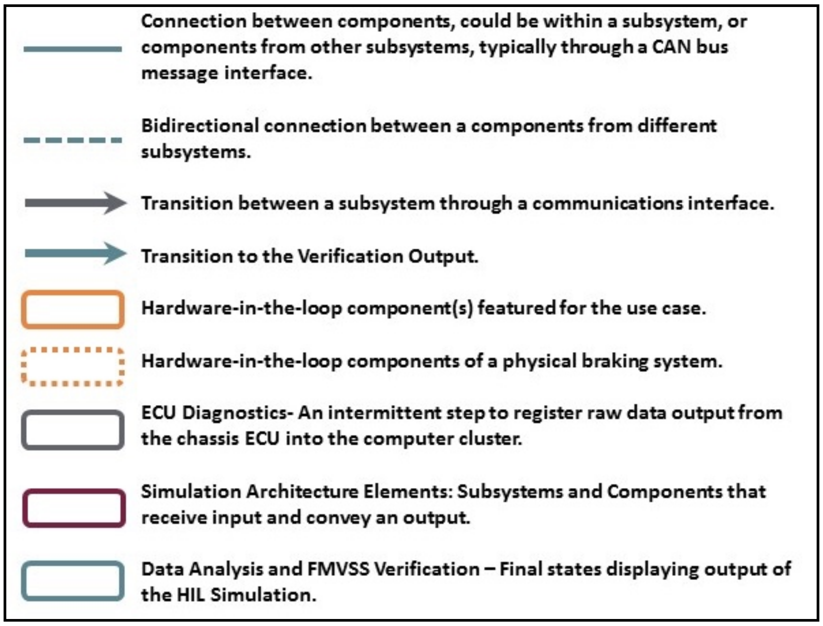


Figure 93. Definitions for HIL System Architecture Layout

Test Case 1: Vehicle Chassis ECU

Test Case 1 presents the least complex system architecture. This test case consists of only one hardware component, the chassis ECU, which would allow for the integration of the proprietary ABS and ESC algorithms used on a vehicle, rather than relying on the development of generic algorithms, such as was developed in the simulation research. As discussed in Appendix H on simulation, the ESC model is an important parameter. Therefore, having the physical component integrated into the simulation provided the opportunity for improved accuracy of commands for vehicle response commands, such as those sent to the brake, which would improve the accuracy of the vehicle maneuver, leading to more accurate vehicle response (e.g., yaw rate and position) used in the evaluation of test procedure results.

For V&V, the HIL setup itself may benefit from guidance from the manufacturer to provide initial data sets to provide a baseline for the function of the ESC. Once this data is obtained, the HIL test apparatus would run with the new component and execute commands to perform the simulation.

While an HIL setup with an ESC as the only physical hardware does provide advantages to testing in terms of complexity, it should be noted that this hardware component transmits proprietary data that is likely to differ from vehicle to vehicle (Bosch Automotive Service Solutions, Inc., 2019), which may necessitate coordination with the manufacturer. There may also be proprietary interfaces to the components that would need to be defined to be able to communicate to a given component. Manufacturers may also need a unique subsystem build to allow procurement and interfacing with HIL components that does not correspond to a standard offering.

The information flows and data elements within the Vehicle Chassis ECU Test Case adhere to the process below, demonstrated in a graphical representation of the system architecture in Figure 94 and described in further detail in Table 63.

Table 64 and Table 65 define the HIL and control interface subsystem components, respectively, for Test Case 1.

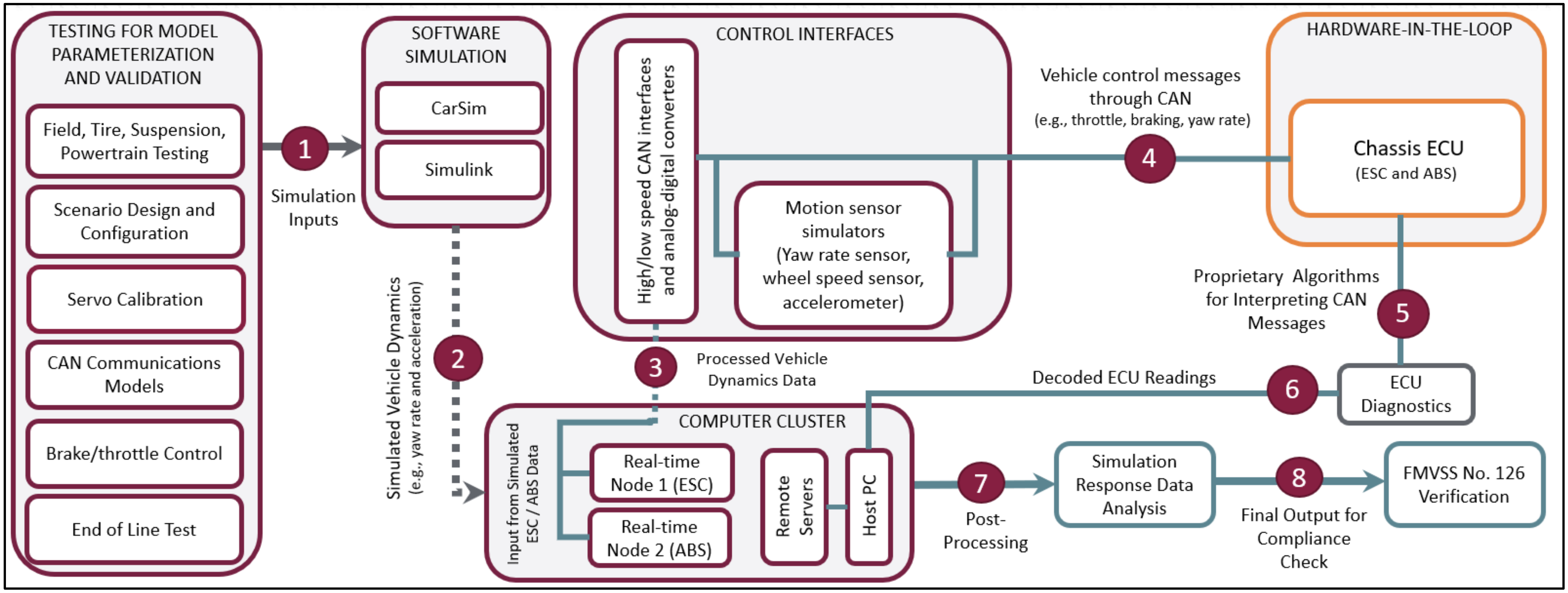


Figure 94. Test Case 1: Chassis ECU

Table 63. Test Case 1: Processes and Critical Data Sets

Step	Description	Critical Data sets and related standards
1	Simulation inputs, which include the vehicle parameters identified in the model parameterization subsystem and are fed into the software simulation subsystem.	Vehicle parameters and characteristics such as weight, suspension (e.g., mass, spring constant, damping constant), tires (e.g., friction, rolling resistance).
2	In the software, simulation subsystem tools such as CarSim and Simulink can be used to simulate the SWD Test. This simulation software will be used to capture data on those vehicle dynamics for hardware not present in the HIL system architecture. These simulation parameters results flow into the computer cluster subsystem.	Simulated dynamic properties of the car including yaw rate, braking, acceleration, steering angle. The data could be stored and transferred in CarSim or Simulink file formats, depending on the software used to conduct the simulation.
3	Within the computer cluster subsystem, there are intermittent processes between this subsystem and the control interfaces' subsystems. These include cycling ECU data in a loop between the computer cluster and control interfaces subsystems.	Processed vehicle dynamics data, which could take the form of automotive grade Linux, or other data types (e.g., CAN message or plain text) transferred through an ethernet or optic line (Institute of Electronic and Electrical Engineers, 2018), depending on the manufacturer.
4	The control interfaces feed motion data to the chassis ECU.	Wheel speed, steering angle, braking, yaw rate, and vehicle displacement, data sent as a CAN message (Robert Bosch GmbH, 1991).
5	The chassis ECU communicates with the ECU diagnostics.	Adjusted throttle, braking, steering commands from your chassis ECU sent as a CAN message. The data transferred during this step may contain proprietary information and message sets are likely to differ from vehicle to vehicle (Bosch Automotive Service Solutions, Inc., 2019).
6	The data output from the ECU diagnostics are sent back to the computer cluster for processing.	Decoded ECU readings, which could be ported to OBD-II format (CSS Electronics, 2019) or as a CAN message, depending on the manufacturer.
7	The final phase would be post-processing and analysis, where information taken from the Software Simulation (SWD) parameters and readings from the ECU are evaluated. This input would be taken after it cycles from the simulation model after the HIL inputs are identified.	Displacement, speed, and steering angle data for each time step of the simulation, which could be a Simulink file, text file, or CarSim file, depending on the software used to conduct the simulation.
8	Once the readings from the ECU and results from the simulation are processed, the final step is an output for pass/fail for FMVSS No. 126 compliance verification.	FMVSS No. 126 performance requirements identified in SWD (i.e., lateral displacement, yaw rate, steering wheel angle).

Table 64. Test Case 1: Control Interface Subsystem Component Definitions

Component	Description	Inputs and Outputs to HIL Simulation
High Speed CAN Interfaces and Analog-Digital Converters	Converts data from the ECU to electrical signals to run components	**Inputs:** data/commands from components (e.g., the physical braking system) **Outputs:** commands from the ECU
Motion Sensor Simulators	Sensors to measure yaw rate, vehicle displacement, wheel speed, and steering angle	**Inputs:** processed vehicle dynamics data as a digital signal **Outputs:** wheel speed, steering angle, braking, yaw rate, and vehicle displacement

Table 65. Test Case 1: HIL Subsystem Component Definitions

Component	Description	Inputs and Outputs to HIL Simulation
Chassis ECU (ESC and ABS)	Embedded automotive electronic system that controls the electrical systems and subsystems of the electronic stability control and ABS within a vehicle.	**Inputs*:** wheel speed, yaw rate, and acceleration measurements from motion sensors **Outputs*:** processed yaw rate, wheel speed, and acceleration information
* The data inputs and/or outputs may contain proprietary information that could differ from vehicle to vehicle (e.g., chassis ECUs encoded with VINs) (Bosch Automotive Service Solutions, Inc., 2019).		

Test Case 2: Physical Braking System

Test Case 2 introduces the physical dynamics of the hydraulic braking system into the HIL system architecture, which allows for a more accurate braking force measurement. Since braking is a key aspect of ESC performance, this could allow the vehicle dynamics model to simulate a more accurate vehicle maneuver. Hydraulic systems are challenging to virtually model due to the variability of brake system designs across manufacturers and the complexity of fluid dynamics. (Heisler, 2002; Hedrick & Uchanski, 2001; Neys, 2012). Using virtual models may result in poor representation of the braking response in a production vehicle. The increased fidelity from incorporating real-time braking response could improve accuracy for compliance testing of a SWD maneuver. This braking system could include typical brake components traditionally seen on a light-duty vehicle, as defined by FMVSS No. 126.

This setup can increase fidelity of FMVSS No. 126 testing when compared to Test Case 1 by more accurately reflecting the application of brakes. Due to the increased number of HIL components and test apparatus complexity for configuring and interfacing with the physical braking system, this option would be more expensive to implement than the first test case.

Introducing mechanical and hydraulic components to the test apparatus will increase complexity, requiring more sensors and physical and digital connections. In addition, there are increased safety risks associated with these components that must be mitigated. The physical braking system may use proprietary data and protocols, which may require coordination with manufacturers to ensure communications with the chassis ECU and correct brake system operation. Manufacturers may also need to develop a unique subsystem build to allow procurement of the system components.

The HIL setup could be validated with physical track testing or based on guidance and test results provided by the manufacturer. Either of these data sets would provide a baseline for the function of the ECU and the respective braking system.

Figure 95 illustrates a rack setup where the HIL apparatus can be compact enough to fit in a confined space, such as a laboratory or office room, allowing for the specific physical component to move in tolerable ranges for accurate measurements. In the context of Test Case 2, the rack setup would include a physical braking system in addition to a bench top setup, as introduced in Test Case 1.

Figure 95. Sample HIL Configuration With Braking System (Adapted From Svenson et al., 2009)

Similar to Test Case 1, this system architecture setup will follow the same process flow to verify compliance. The information flows and data elements within the Physical Braking System test case adhere to the process below, which is presented in a graphical representation of the system architecture in Figure 96, and is described in further detail in Table 66, Table 67, and Table 68, which define the HIL and control interface subsystem components, respectively. It should be noted that the physical braking systems components presented in this test case assume that the vehicle is equipped with a hydraulic braking system, but this may not always be the case.

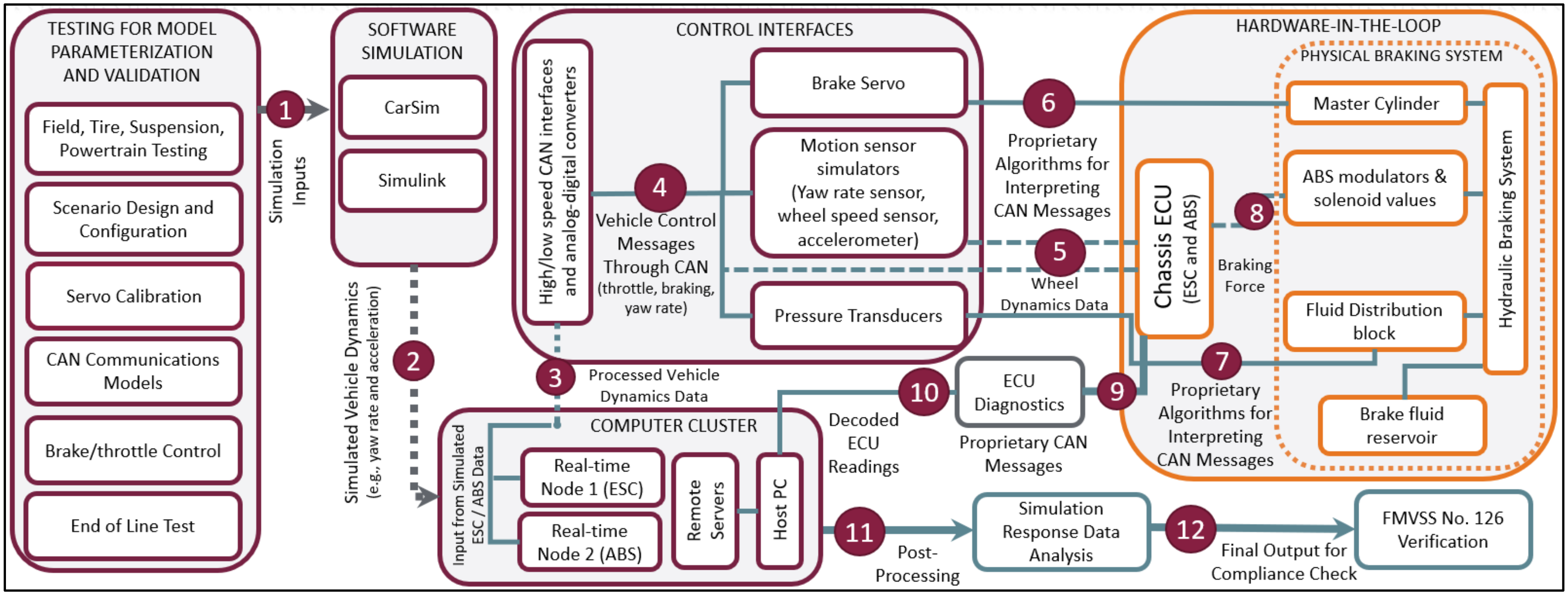


Figure 96. Test Case 2: Physical Braking System

Table 66. Test Case 2: Processes and Critical Data Sets

Step	Description	Critical Data sets and related standards
1	Simulation inputs, which include the vehicle parameters identified in the model parameterization subsystem and are fed into the software simulation subsystem.	Vehicle parameters and characteristics such as weight, suspension (e.g., mass, spring constant, damping constant), tires (e.g., friction, rolling resistance), and powertrain (e.g., engine power and engine type).
2	In the software simulation subsystem tools such as CarSim and Simulink can be used to simulate the SWD Test. This simulation software will be used to capture data on those vehicle dynamics for hardware not present in the HIL system architecture. These results of your simulation parameters flow into the computer cluster subsystem.	Simulated dynamic properties of the car including yaw rate, braking, acceleration, steering angle. Data could be stored and transferred in CarSim or Simulink file formats, depending on the software used to conduct the simulation.
3	Within the computer cluster subsystem there are intermittent processes between this subsystem and the control interfaces subsystems. These include cycling ECU data in a loop between the computer cluster and control interfaces subsystems.	Processed vehicle dynamics data, which could take the form of a C++ file, automotive grade Linux, or data transferred through an ethernet or optic line (Institute of Electronic and Electrical Engineers, 2018), depending on the manufacturer.
4	The control interfaces feed motion data to the chassis ECU.	Wheel speed, steering angle, braking, yaw rate, vehicle displacement, and engine temperature data sent as a CAN message.
5	The control interfaces feed motion data to the chassis ECU (a) and (b) before circulating back to the computer cluster for processing (c). Steps 3 and 4 are iterative and repeats itself during the duration of the test.	Wheel speed, steering angle, engine temp sensor, and braking sent as a CAN message; the data transferred during this step could be proprietary.
6	The input from the control interfaces subsystem feeds signals to the master cylinder from the braking servo.	Desired brake pressure is communicated as a CAN message; the data transferred during this step could be proprietary.
7	The input from the control interfaces subsystem feeds pressure inputs to the fluid distribution block.	Desired brake fluid pressure is communicated as a CAN message; the data transferred during this step could be proprietary.
8	The input from the braking system is fed into the ECU.	Braking force, computed through caliper pressure based on simulated input from the control interface is communicated as a CAN message.

Step	Description	Critical Data sets and related standards
9	The chassis ECU communicates with the ECU diagnostics.	Adjusted throttle, braking, steering commands from your chassis ECU as a CAN message (Robert Bosch GmbH, 1991). The data transferred during this step may contain proprietary information and message sets are likely to differ from vehicle to vehicle (Bosch Automotive Service Solutions, Inc., 2019).
10	The data output from the ECU diagnostics are sent back to the computer cluster for processing.	Decoded ECU readings, which could be ported to OBD-II format (CSS Electronics, 2019) or as a CAN message, depending on the manufacturer.
11	The final phase would be post-processing and analysis, where information taken from the Software Simulation (SWD) parameters, and readings from the ECU are evaluated.	Displacement, speed, and orientation data for each time step of the simulation, which could be a Simulink file, text file, or CarSim file, depending on the software used to conduct the simulation.
12	Once the readings from the ECU and results from the simulation are processed, the final step is an output for pass/fail for FMVSS No. 126 compliance verification.	FMVSS No. 126 performance requirements identified in SWD (i.e., lateral displacement, yaw rate, steering wheel angle).

Table 67. Test Case 2: Control Interface Subsystem Component Definitions

Component	Description	Inputs and Outputs to HIL Simulation
Brake Servo	An electromechanical servo used to simulate a haptic braking response from the software simulation to the braking system	**Inputs:** digital signal messages for brake pressure **Outputs:** physical motion of the servo to the braking system, which results in brake force to ECU
High Speed CAN Interfaces and Analog-Digital Converters	Converts data from the ECU to electrical signals to run components	**Inputs:** data/commands from components (e.g., the physical braking system) **Outputs:** commands from the ECU
Motion Sensor Simulators	Sensors to measure yaw rate, vehicle displacement, wheel speed, and steering angle	**Inputs:** processed vehicle dynamics data as a digital signal **Outputs:** wheel speed, steering angle, braking, yaw rate, and vehicle displacement
Pressure Transducers	Physical component that introduces a force to the fluid distribution block of a braking system	**Inputs:** physical component that converts pressure into an analog electrical signal **Outputs:** force to the fluid distribution block

Table 68. Test Case 2: HIL Subsystem Component Definitions

Component	Description	Inputs and Outputs to HIL Simulation
ABS Modulator unit and Solenoid Valves	Hydraulic modulator that contains the valves, solenoids, and pistons that control the holding and release of the hydraulic brake circuit if a wheel were to begin to skid.	**Inputs:** processed wheel speed measurements **Outputs:** braking force needed to optimize traction
Brake Fluid Reservoir	Container that stores a supply of brake fluid until it is needed. This component could be connected directly to the hydraulic braking system.	Inputs: N/A **Outputs:** fluid to hydraulic braking system
Chassis ECU (ESC and ABS)	Embedded automotive electronic system that controls the electrical systems and subsystems of the ESC and ABS within a vehicle.	**Inputs:** wheel speed, yaw rate, and acceleration measurements from motion sensors **Outputs*:** processed yaw rate, wheel speed, and acceleration information
Fluid Distribution Block	Distribution block connected to the master cylinder that distributes brake fluid.	**Inputs*:** desired brake fluid pressure **Outputs:** distributed fluid into hydraulic braking system
Hydraulic Braking System	Braking system in which a fluid is used to transmit the brake lever force from the brake lever to the final drum shoes or disc caliper to achieve braking.	**Inputs:** hydraulic pressure, brake fluid Outputs: braking force
Master Cylinder	Hydraulic pump of an automotive braking system that sends pressurized brake fluid through the brake lines and into the brake calipers/wheel cylinders.	**Inputs*:** physical force to engage master cylinder **Outputs:** hydraulic pressure
* Indicates that the data inputs and/or outputs may contain proprietary information that could differ from vehicle to vehicle (e.g., chassis ECUs encoded with VINs; Bosch Automotive Service Solutions, Inc., 2019).		

Test Case 3: Automated Vehicle Perception ECU

This test case builds upon Test Case 1 and introduces perception controllers, such as a perception ECUs or multi-domain controllers, into the HIL system architecture, which may influence the behavior of the vehicle chassis ECU for some manufacturers. While levels of fidelity could increase, the additional input from auxiliary ECUs may not impact simulation results for FMVSS No. 126 since these components are not part of the current test procedures. Consequently, this added fidelity may not significantly improve the accuracy of the pass/fail results. As a result, the example system architecture is developed but architectural elements, such as the information flows and data types for this test case, are not defined in this document.

The cost of the perception controllers is unknown, due to the nascent state of the technology. Due to the large research and development costs that go into the production of sensor perception ECUs, they may be more costly than other vehicle ECUs. Additional software that could support sensor inputs may need to be purchased. The costs for computing, software and virtual models (e.g., vehicle dynamics, road-tire models) are common across the other test cases.

The sensor perception ECUs are liable to contain proprietary information, which will likely require coordination with manufacturers. As with the other test cases, manufacturers may need a unique subsystem build to allow procurement and interfacing with HIL components.

Figure 97 illustrates a modular setup, where the HIL apparatus, equipped with perception sensors and other hardware of interest, is compact enough to fit in a confined space, such as a laboratory or office room. In the context of Test Case 3, this setup could be designed to fit the needs of a compact bench top configuration, or could have modular racks to introduce various sensors for the simulation.

Figure 97. Sample Rack-Mounted HIL Configuration With Perception Sensors

As with the other test cases, an initial or baseline data set would be needed to validate the HIL setup. This may require coordination with the manufacturer. Once this is obtained, the HIL test apparatus will run with the new components to execute the defined simulation.

An example HIL system architecture for Test Case 3 is shown in Figure 98. Table 69 and Table 70 define the HIL and control interface subsystem components, respectively.

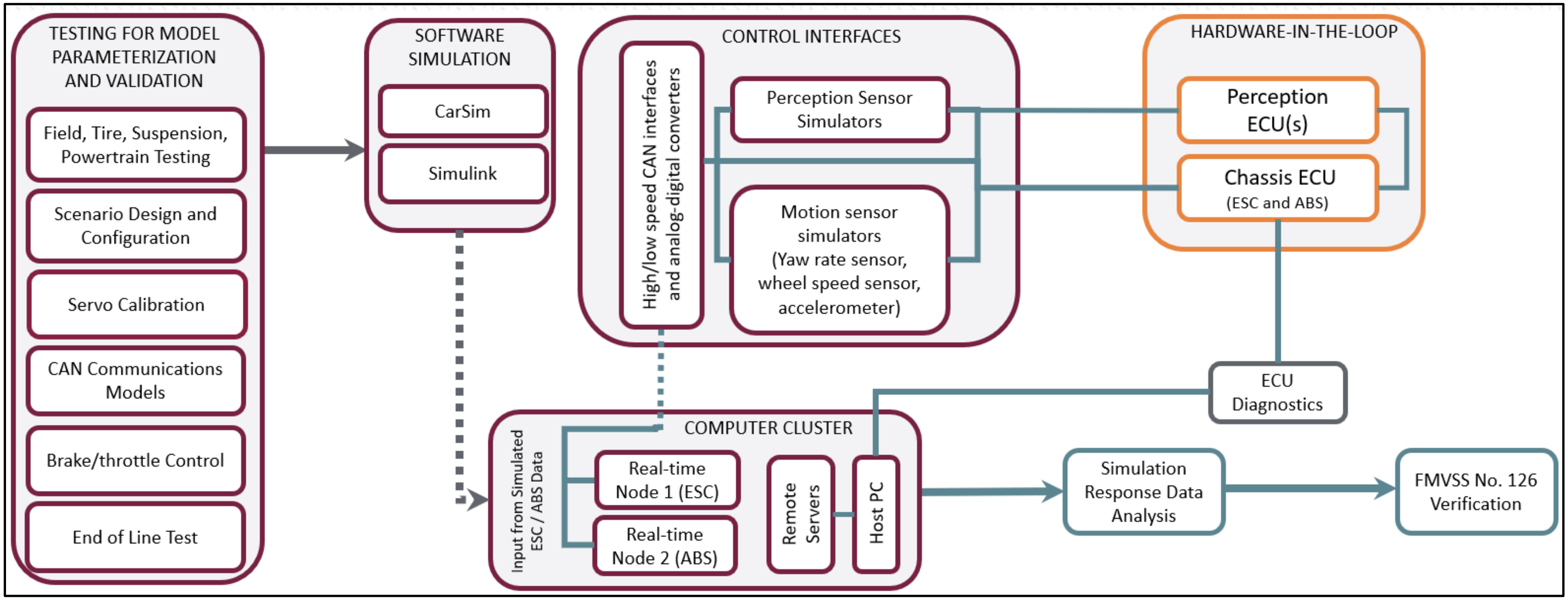


Figure 98. Test Case 3: ADS Perception ECU System Architecture

Table 69. Test Case 3: Control Interface Subsystem Component Definitions

Component	Description	Inputs and Outputs to HIL Simulation
High Speed CAN Interfaces and Analog-Digital Converters	Converts data from the ECU to electrical signals to run components	**Inputs:** data/commands from components (e.g., the physical braking system) **Outputs:** commands from the ECU
Motion Sensor Simulators	Sensors to measure yaw rate, vehicle displacement, wheel speed, and steering angle	**Inputs:** processed vehicle dynamics data as a digital signal **Outputs:** wheel speed, steering angle, braking, yaw rate, and vehicle displacement
Perception Sensor Simulators	Simulated feedback for objects interpreted by perception sensor ECUs	**Inputs:** modeled obstacle in a virtual environment detected by perception sensor **Outputs:** response from perception ECUs to central vehicle ECU

Table 70. Test Case 3: HIL Subsystem Component Definitions

Component	Description	Inputs and Outputs to HIL Simulation
Chassis ECU	Embedded automotive electronic system that controls the electrical systems and subsystems of the ESC and ABS within a vehicle.	**Inputs:** wheel speed, yaw rate, and acceleration measurements from motion sensors **Outputs*:** processed yaw rate, wheel speed, and acceleration information
Perception ECU	Embedded automotive electronic system that controls the electrical systems and subsystems of ADS features (cites testable cases)	**Inputs:** radio signals from test field (i.e., simulation environment) **Outputs:** ECU responding and changing the behavior of the vehicle
* Indicates that the data inputs and/or outputs may contain proprietary information that could differ from vehicle to vehicle (e.g., chassis ECUs encoded with VINs; Bosch Automotive Service Solutions, Inc., 2019).		

Test Case 4: Full Vehicle HIL

Test Case 4 uses the vehicle itself as the "hardware" component in the HIL setup. In this configuration, the vehicle would provide a common interface between the simulation software and the components of interest. Using a full vehicle as the hardware component of interest simplifies the logistics of component acquisition. Physical and mechanical components could still pose a risk in system failure and maintenance logistics would need to be considered when operating this setup.

Test Case 4 would likely have the vehicle solely interact with the simulation tools through a vehicle interface port (VIP). This port could provide users with specialized testing equipment to access the vehicle CAN bus, ECUs, head unit, ADS, and wireless communication systems as well as execute testing procedures in a "testing mode."

In this case, a wired connection would allow injection of commands through a test device to communicate control signals to the vehicle chassis controller via the communication bus. Initial advantages from this test case would be the modularity in conducting verification: the vehicle itself could mount on a dynamometer, simulating throttle and braking commands or experimented on inside a facility to test safety precautions identified in SWD.

While having a fully functional vehicle may reduce complexity of the testing apparatus, the costs for computing, software and virtual models (e.g., vehicle dynamics, road-tire models) will be similar to other options.

Proprietary data and protocols are needed for communicating with the vehicle and would likely require coordination with manufacturers. However, the manufacturers would not need to develop specific subsystem builds with particular component configurations as with the other test cases. There may be increased safety risks associated with full vehicle testing that would need to be mitigated.

Because the ABS and ESC may have interdependencies with other vehicle systems that vary by manufacturer, using the full vehicle allows for these interdependencies to be satisfied. The nature of these interdependencies may be proprietary, and the effect of not permitting these connections in Test Cases 1, 2, and 3 may impact behavior of the ABS and ESC systems. As discussed previously, it is not likely that any of those interdependencies will impact results from current FMVSS No. 126 test procedures. As a result, an example system architecture is developed, but the system architecture elements, such as the information flows and data types, for this test case are not defined in this document. An example HIL system architecture for Use Case 4 is shown in Figure 99. Table 71 and Table 72 define the HIL and control interface subsystem components, respectively.

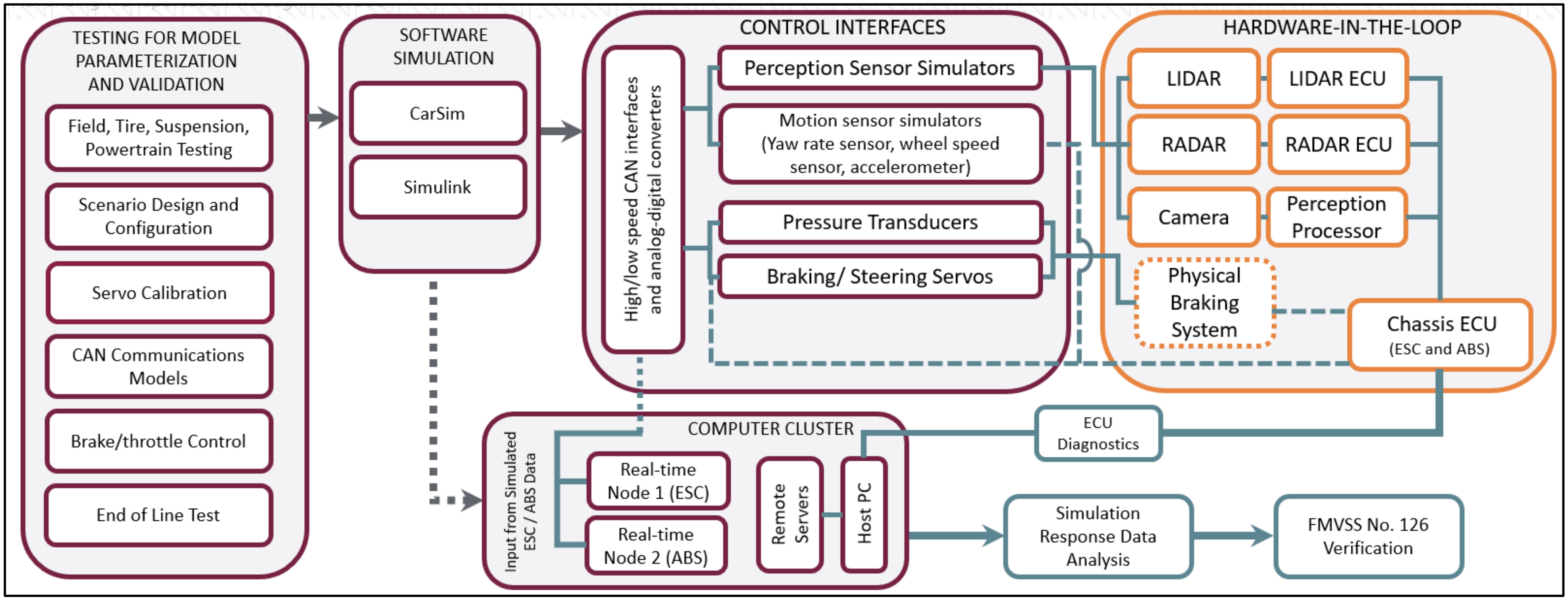


Figure 99. Test Case 4: Physical Sensor Models with Steering and Braking

Table 71. Test Case 4: Control Interface Subsystem Component Definitions

Component	Descriptions	Inputs and Outputs to HILS
Full Vehicle	A production vehicle taken from an automaker that can be accessed through a VIP	**Inputs:** simulation commands connected through a VIP **Outputs:** real-time perception sensors reaction, braking, and throttle responses from the vehicle
Brake Servo	A subset of the Full Vehicle: An electromechanical servo used to simulate a haptic braking response from the software simulation to the braking system	**Inputs:** digital signal messages for brake pressure **Outputs:** physical motion of the servo to the braking system, which results in brake force to ECU
High-speed CAN Interfaces and Analog-Digital Converters	A subset of the Full Vehicle: Converts data from the ECU to electrical signals to run components	**Inputs:** data/commands from components (e.g., the physical braking system) **Outputs:** commands from the ECU
Motion Sensor Simulators	A subset of the Full Vehicle: Sensors to measure yaw rate, vehicle displacement, wheel speed, and steering angle	**Inputs:** processed vehicle dynamics data as a digital signal **Outputs:** wheel speed, steering angle, braking, yaw rate, and vehicle displacement
Perception Sensor Simulators	A subset of the Full Vehicle: Simulated feedback for objects interpreted by perception sensor ECUs	**Inputs:** modeled obstacle in a virtual environment detected by perception sensor **Outputs:** response from perception ECUs to chassis ECU
Pressure Transducers	A subset of the Full Vehicle: Physical component that introduces a force to the fluid distribution block of a braking system	**Inputs:** physical component that converts pressure into an analog electrical signal **Outputs:** force to the fluid distribution block

Table 72. Test Case 4: HIL Subsystem Component Definitions

Component	Description	Inputs and Outputs to HILS
Camera	Embedded automotive electronic system that controls the electrical systems and subsystems of the camera within an ADS-DV.	**Inputs:** images recorded from FOV **Outputs:** data sets sent to processor; specific datasets sent to ECU dependent on vehicle manufacturer and hardware used
Chassis ECU	Embedded automotive electronic system that controls the electrical systems and subsystems of the electronic stability control and ABS within a vehicle.	**Inputs:** wheel speed, yaw rate, and acceleration measurements from motion sensor simulators **Outputs*:** processed yaw rate, wheel speed, and acceleration information
LiDAR	A detection system that measures distance to a target by illuminating the target with pulsed laser light and measuring the reflected pulses with a sensor.	**Inputs:** data from FOV **Outputs:** data sets sent to ECU; specific datasets sent to ECU dependent on vehicle manufacturer and hardware used
LiDAR ECU	Embedded automotive electronic system that controls the electrical systems and subsystems of the lidar within an ADS-DV.	**Inputs:** simulated and/or physical input from lidar sensors **Outputs:** data sets sent to ECU; specific datasets sent to ECU dependent on vehicle manufacturer and hardware used
Radar	A detection system that uses radio waves to detect moving or stationary targets, including cars, trains, trucks, and cargo.	**Inputs:** data from FOV **Outputs:** data sets sent to ECU; specific datasets sent to ECU dependent on vehicle manufacturer and hardware used
Radar ECU	Embedded automotive electronic system that controls the electrical systems and subsystems of the radar within an ADS-DV.	**Inputs:** simulated and/or physical input from radar sensors **Outputs:** data sets sent to ECU; specific datasets dependent on vehicle manufacturer and hardware used
Perception Processor	Converts perceived images from a perception sensor (e.g. camera) into data sets that can be processed into an ECU	**Inputs:** image(s) of interest during vehicle operation **Outputs:** data sets that can be processed by an ECU; specific datasets sent to ECU dependent on vehicle manufacturer and hardware used
Physical Braking System	Components used to simulate a braking system on a vehicle	**Inputs:** control interfaces that simulate a braking response **Outputs:** brake force and braking time sent to the chassis ECU

[*] Indicates that the data inputs and/or outputs may contain proprietary information that could differ from vehicle to vehicle (e.g., chassis ECUs encoded with VINs; Bosch Automotive Service Solutions, Inc., 2019).

Potential Guideline Structure for Execution of HIL Simulation

This chapter captures a potential structure for notional system guidelines for the HIL simulation, where “system” refers to a test case architecture, as previously described. Table 73 consists of an example of potential guidelines to implement the various test case architectures and their applicability to specific test case architectures. In order to develop a robust set of potential guidelines, the states of HIL for ABS and ESC were reviewed (Weiqiang et al., 2012; Enisz et al., 2011; Ashby, 2013; Svenson et al., 2009; Joshi, 2017; Salaani et al., 2016). The following provides a lens into the standardization interoperability considerations for each test case and provides further insights into cost, fidelity, and complexity considerations.

Each of the following (shown below in Table 73) includes a “Test Case Applicability” column that identifies the test cases that each potential guideline applies to. They are also sub-divided into the following types.

- **Hardware (HW):** define the system’s physical hardware components
- **Software (SW):** define the system’s software components
- **Communications (COM):** define the system’s communication interfaces
- **Data (DAT):** define the critical data stored and processed within the system
- **Operational and System Performance (OSP):** define the system’s operational conditions and systems performance characteristics

Table 73. Potential HIL System Guidelines

ID	Statement	Test Case Applicability	Notes
HW-1	The system may have a host PC to process data and output results from the HIL simulation.	1, 2, 3, 4	A computer workstation may be used to satisfy this guideline.
HW-2	The system may be equipped with an ECU component to model the various control techniques for a vehicle experiencing a SWD maneuver.	1, 2, 3, 4	ECU that includes ESC and ABS systems.
HW-3	The system may be equipped with motion sensor instrumentation for measuring yaw rate, wheel speed, and acceleration.	1, 2, 3, 4	This include a yaw rate sensor, wheel speed sensor, and accelerometer.
HW-5	The system may be equipped with proper instrumentation for monitoring data exchange between subsystems.	1, 2, 3, 4	This may include a CAN bus sniffer to process CAN data between subsystems
HW-6	The HIL components within the system may be powered through an external power supply.	1, 2, 3, 4	Voltage guidelines needed to power components dependent on the hardware used.
HW-7	The system may be equipped with physical braking components to capture input and output data from a physical braking system.	2, 4	Braking components are dependent on the type of braking system selected, which could include, but are not limited to, pneumatic, hydraulic, or electromagnetic braking systems.
HW-8	The system may be equipped with perception sensor ECU components.	3, 4	Example components could include radar and lidar ECUs, or imaging sensor processors
HW-9	The system may be equipped with physical sensor components.	4	Example components could include radar, lidar, and imaging sensors

ID	Statement	Test Case Applicability	Notes
HW-10	The system may be equipped with data acquisition instrumentation for post-processing and verifying the fidelity of the system.	1, 2, 3, 4	Data acquisition units fed into the software simulation suite may be used by the personnel exhibiting the test; needed for post-processing and needed to check fidelity of system. Information can be aggregated and collected to manufacturers
HW-11	The system could may be equipped with hardware to be capable of storing information and data collected from HIL simulation.	1, 2, 3, 4	Examples include remote servers or a drive that can store any data format.
HW-12	The system may include a prototype or production vehicle that has an accessible VIP to interact with	4	Manufacturers and NHTSA must coordinate on the development on a VIP standard.
SW-1	The system may have computational tools to simulate vehicle dynamics as defined by FMVSS No. 126	1, 2, 3, 4	Example simulation tools include CarSim
SW-2	The system may have computational tools to simulate vehicle controls as defined by FMVSS No. 126	1, 2, 3, 4	Example simulation tools include Simulink
SW-3	The system may have computational tools for receiving, storing, and processing simulated vehicle dynamics and control data	1, 2, 3, 4	Examples include a virtual real-time node
SW-4	The system may simulate perception features for the perception ECU to interpret	3	Examples include simulated information such as environmental road features or obstacles the radar and lidar ECUs may interpret

ID	Statement	Test Case Applicability	Notes
COM-1	The computer cluster subsystem may communicate to the control interfaces subsystem	1, 2, 3, 4	Specific communication mediums (e.g., optic line, ethernet) can be determined by automotive manufacturers
COM-2	The control interfaces subsystem may communicate to the HIL subsystem	1, 2, 3, 4	Specific communication mediums (e.g., CAN bus) can be determined by automotive manufacturers
COM-3	The HIL subsystem may communicate to the computer cluster subsystem	1, 2, 3, 4	Specific communications medium (e.g., CAN bus) can be determined by automotive manufacturers
DAT-1	The system may be able to output data needed for final verification for FMVSS No. 126	1, 2, 3, 4	Example data sets could include displacement, speed and orientation data for each time step of simulation and could be validated externally by personnel (i.e., Test Case 1, Step 7; Test Case 2, Step 11)
DAT-2	The system may process proprietary data from a chassis ECU and output it to an industry standard format	1, 2, 3, 4	Data set could be dependent on manufacturer of vehicle; specific data needed from the ECU includes ESC data such as wheel speed, braking and acceleration (i.e., Test Case 1, Step 6; Test Case 2, Step 9)

ID	Statement	Test Case Applicability	Notes
DAT-3	The system may return pass or fail indication based on verification output data as defined by FMVSS No. 126	1, 2, 3, 4	Pass or fail criteria is defined by FMVSS No. 126 (i.e., Test Case 1, Step 8; Test Case 2, Step 12)
DAT-4	The system may use vehicle parameter data	1, 2, 3, 4	Vehicle parameter data includes characteristics such as weight, suspension, tires, and powertrain (i.e., Test Case 1, Step 1; Test Case 2, Step 1)
DAT-5	The system may use simulated vehicle dynamics data	1, 2, 3, 4	Data could be stored and transferred in CarSim file formats, depending on the software used to conduct the simulation (i.e., Test Case 1, Step 2; Test Case 2, Step 2)
DAT-6	The system may use simulated vehicle control data	1, 2, 3, 4	Data could be stored and transferred in Simulink file formats, depending on the software used to conduct the simulation (i.e., Test Case 1, Step 2; Test Case 2, Step 2)
DAT-7	The system may use data from motion sensors (e.g., yaw rate sensor, wheel speed sensor)	1, 2, 3, 4	Example data includes vehicle wheel speed, steering angle, and acceleration (i.e., Test Case 1, Step 4; Test Case 2, Step 5)
DAT-8	The system may use data from virtual perception sensor simulators (e.g., yaw rate sensor, wheel speed sensor)	3	DAT-8 is only applicable for Test cases with simulated ADS technologies (i.e. lidar, radar ECUs)

ID	Statement	Test Case Applicability	Notes
DAT-9	The system may use data from physical perception sensor units (e.g., yaw rate sensor, wheel speed sensor)	4	DAT-9 is only applicable for Test cases with physical ADS technologies (i.e. lidar, radar, camera)
DAT-10	The system may use braking response from the simulated braking system to communicate with the ECU	1, 3	Response would be brake, independent of style of braking system (pneumatic, hydraulic, etc.) (i.e., Test Case 1, Step 2)
DAT-11	The system may use braking response from the physical braking system to communicate with the ECU	2, 4	Response would be brake, independent of style of braking system (pneumatic, hydraulic, etc.) (i.e., Test Case 1, Step 2)
DAT-12	The system may include a standardized message set and communication protocol for communicating via the VIP to conduct simulation	4	VIP must be able to support frequency, bandwidth, and security requirements of the test.
OSP-1	The system may operate in a temperature-and weather-controlled environment to ensure optimal performance of hardware components	1, 2, 3, 4	Ambient environments can be regulated in a closed facility
OSP-2	The system may have sufficient computation power to execute simulations for FMVSS No. 126 test procedures	1, 2, 3, 4	Guideline for computer equipment to run simulation
OSP-3	The system may have sufficient memory to store data generated from FMVSS No. 126 HIL simulation	1,2,3,4	Guideline for data storage

Considerations for HIL System Architecture

HIL Considerations in a Production Environment

Although HIL simulation could serve as a test method for FMVSS No. 126 compliance verification, there are considerations for implementing this test method in a production environment. As compared to a product development environment where a high degree of access to vehicle subsystems and signals may be granted, in a production environment, subject vehicles and components may not be available to the public. In a production environment, manufacturers take several steps to address security and proprietary concerns, such as hardening of components and providing discrete part numbers for all subsystems. Considerations identified in this research include procurement of HIL subsystem components, developing a common test platform or rig that is able test a wide range of components from different manufacturers, and cooperation between manufacturers and regulatory agencies to share proprietary information or techniques.

Procurement of Components

Obtaining components for HIL testing may require the manufacturer to have a distinct subsystem assembly configuration for each item. Currently, manufacturers may not have individual part numbers for all the components listed in each test case. This challenge is greater for test cases that have a greater number of HIL subsystem components. For example, Test Case 2 has ECUs and brake system components as part of its system architecture. Obtaining all of the peripheral components for a given vehicle may require coordination with manufacturers.

Testing Platform Apparatus

Developing a test rig that can serve as a platform for testing components from a wide range of manufacturers is another consideration. The physical interfaces with the system would potentially need to be customized for each manufacturer and potentially for different models. For example, the system architectures that include a physical braking system (e.g., Test Case 2) assume that the vehicle being tested is equipped with a hydraulic braking system. If the braking system were to change to another type of braking system (e.g., electromagnetic braking), different hardware components would be needed for brake functionality. Even in cases where the vehicle is equipped with a hydraulic braking system, ESCs and motion sensors (e.g., wheel speed sensor) could differ by vehicle model and manufacturer and could possess unique characteristics (e.g., communication frequency). In addition, the physical connections that connect the control interface subsystem components to the HIL subsystem components would need to be taken into account, as they could differ by manufacturer and vehicle model.

Industry Cooperation on Digital Message Sets

As discussed earlier, the components may transfer message sets containing proprietary information and may use proprietary interfaces that may differ from vehicle to vehicle. To access this information and acquire the necessary data, the HIL interface would need to be able to access and decode this proprietary information from each vehicle make and model.

Findings

The four test cases presented in this document offer different considerations for supporting simulation as a test method for compliance verification. The results present considerations for cost, complexity, and fidelity for different test cases that may apply for FMVSS No. 126 and may be extrapolated to other standards for which simulation may be applicable. For example, Test Case 1 is the least complex due to its relatively simple system architecture, but any interdependencies between other physical hardware components may not be captured by this model. Test Case 2 introduces a physical braking system into the HIL system architecture to eliminate the complexity of modeling a hydraulic brake system, but this comes with increased cost and complexity, as more hardware components need to be procured and configured. Test Case 3 resolves any interdependencies the ESC may have with a perception system, but proprietary data from perception sensor ECUs will need to be accessed and perception sensor ECUs would add cost. Test Case 4 resolves any interdependencies the ESC may have with any other physical car components and while this system may increase accuracy of simulation results, the means to interface to the vehicle and access the required subsystem information for all vehicle makes and models should be considered. Table 74 compares all four test cases and their respective considerations.

Table 74. Comparison of Considerations for FMVSS No. 126 HIL Test Cases

Test Case ID	Test Case Name	Considerations
1	Vehicle Chassis ECU	**Cost**: Least costly of all options, including only a vehicle chassis ECU or required ESC ECUs. The physical equipment required for securing and connecting to the HIL is minimal. The costs for computing, software and virtual models (e.g., vehicle dynamics, road-tire models) will be similar to other options. **Fidelity**: Compared to pure SIL, introducing proprietary ABS and ESC algorithms to the simulation improves the accuracy. As a result, the vehicle dynamics model will simulate a more accurate vehicle maneuver, leading to more accurate vehicle response measures needed for compliance verification. **Complexity**: The vehicle chassis ECU is integrated into a bench-top setup. Proprietary data and protocols are needed for communicating with the ECU. Manufacturers may need a unique subsystem build to allow procurement and interfacing with HIL components.
2	Physical Braking System	**Cost**: This option is more costly than Test Case 1 due to the increased number of HIL components and the test apparatus complexity for configuring and interfacing with the physical braking system. The costs for computing, software and virtual models (e.g., vehicle dynamics, road-tire models) will be similar to other options. **Fidelity**: Introducing physical dynamics of a hydraulic braking system will provide a more accurate braking force measurement As a result, the vehicle dynamics model will simulate a more accurate vehicle maneuver, leading to more accurate vehicle response measures needed for compliance verification. **Complexity**: Introducing mechanical and hydraulic components to the test apparatus will increase complexity, requiring more sensors and physical and digital connections. There are increased safety risks associated with these components that must be mitigated. Proprietary data and protocols are needed for communicating with the ECU. Manufacturers may need to develop a unique subsystem build to allow procurement and interfacing with HIL components.

Test Case ID	Test Case Name	Considerations
3	Automated Vehicle Perception ECU	**Cost**: This test case builds upon Test Case 1 and introduces perception controllers, such as a perception ECU or multi-domain controller, into the HIL system architecture. The cost of the perception controllers is unknown, due to the nascent state of the technology. Additional software that can support sensor inputs may be needed. The costs for computing, software and virtual models (e.g., vehicle dynamics, road-tire models) will be similar to other options. **Fidelity**: This test case introduces signals from the sensor perception ECU to the simulation, which may influence the behavior of the vehicle chassis ECU for some manufacturers. However, there are no physical obstacles or markings defined in the FMVSS No. 126 test procedures, so it is unlikely that inclusion of the sensors would influence the results of the simulation testing. **Complexity**: In addition to the vehicle chassis ECU, sensor perception sensor models are incorporated into the HIL system architecture. Proprietary data and protocols are needed for communicating with the ECU. Manufacturers may need a unique subsystem build to allow procurement and interfacing with HIL components.
4	Full Vehicle HIL	**Cost**: While this reduces the complexity of the testing apparatus, it may introduce additional equipment for interfacing with different makes and models. The costs for computing, software and virtual models (e.g., vehicle dynamics, road-tire models) will be similar to other options. **Fidelity**: The ABS and ESC systems may have interdependences with other vehicle systems that vary by manufacturer. The nature of these interdependencies may be proprietary, and the effect of not permitting these connections in Test Cases 1, 2, and 3 may significantly impact behavior of the ABS and ESC systems. This test case would satisfy these interdependencies. **Complexity**: Proprietary data and protocols are needed for communicating with the vehicle (i.e., through a VIP), which may require additional coordination with manufacturers or some type of standardized interface. However, the manufacturers will not need to develop specific subsystem builds as with the other test cases. There may be increased safety risks associated with testing full vehicle systems.

Elements of V&V explored in Appendix I apply to elements needed for the proposed test cases to help ensure the simulation produces representative results. Based on the anticipation of acquiring certain testing components, like an ECU from manufacturers, a type of ground truth of the component's behavior is needed to confirm the integration and performance of the hardware into the simulation. This can be facilitated by cooperation from the component supplier or manufacturer, who may provide datasets, such as a closed response curve, or performance catalog, for NHTSA to provide a reference for expected HIL results.

This document identifies HIL concepts as a means to augment the use of simulation as a potential test method for compliance verification. Four test cases were identified in this analysis that may be applicable. For FMVSS No. 126, some test cases may be more suitable than others based on complexity, cost, and fidelity. Test cases with fewer hardware components (i.e., Test Case 1) will not have the fidelity of Test Case 4, but could have a less complex system architecture. More detailed cost, fidelity, and complexity considerations could be explored in a proof of concept testing. This analysis serves as a building block for further HIL assessment.

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