REGULATORY BLOCKBUSTER: WHAT’S NEW AND WHAT’S ON THE HORIZON?

April 4, 2019
American Bar Association
2019 Emerging Issues in Motor Vehicle Product Liability Litigation
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GM’S PETITION FOR EXEMPTION

General Motors, LLC—Receipt of Petition for Temporary Exemption From Various Requirements of the Safety Standards for an All-Electric Vehicle With an Automated Driving System

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

ACTION: Notice of receipt of petition for temporary exemption; request for public comment.

The petition was submitted on March 13, 2019, by General Motors, LLC, 300 Renaissance Center, Detroit, MI 48201. The petition requests that the NHTSA grant a temporary exemption from the Federal Motor Vehicle Safety Standard (FMVSS) 208, “Occupant Protection in Rollover Crashes,” and the provisions of Federal Motor Vehicle Safety Standard (FMVSS) 202, “Highway Vehicle Exterior Object Wikimedia Commons,” for the purpose of implementing automated driving systems (ADS) on GM’s vehicles. The petition states that GM believes that the ADS technology will improve safety by reducing the risk of accidents and fatalities. The petition also requests that the NHTSA consider granting a temporary exemption for GM’s vehicles to operate in a modified form of passive safety systems, such as side impact airbags and head restraints, to ensure that the vehicles meet the safety standards during the period of the temporary exemption. The petition includes detailed technical specifications and data to support GM’s claims regarding the safety benefits of the ADS technology.

The NHTSA will accept comments on the petition from the public on or before May 20, 2019. Comments may be submitted electronically at www.regulations.gov or by mail to the Start Printed Page 3,025

ENDS; comments must be received before May 20, 2019.

For further information contact: Deborah Horton, Senior General Motors, LLC, 300 Renaissance Center, Detroit, MI 48201. Telephone: 313-362-3158. Facsimile: 313-362-3167.
NURO, INC.’S PETITION FOR EXEMPTION

Nuro, Inc.; Receipt of Petition for Temporary Exemption for an Electric Vehicle With an Automated Driving System

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

ACTION: Notice of receipt of petition for temporary exemption; request for public comment.

Federal Register / Vol. 84, No. 53 / Tuesday, March 19, 2019 / Notices

DEPARTMENT OF TRANSPORTATION
National Highway Traffic Safety Administration (NHTSA), Department of Transportation (DOT).

ACTION: Notice of receipt of petition for temporary exemption; request for public comment.

For information about NHTSA’s notice, see http://www.regulations.gov. You may submit comments identified by docket number in the heading of this notice by any of the following methods:

• Federal eRulemaking Portal: Go to http://www.regulations.gov. Follow the on-line instructions for submitting comments.

Instructions: All submissions must include the agency name and docket number. Note that all comments received will be posted without change to http://www.regulations.gov, including any personal information provided. Please see the Privacy Act discussion below. NHTSA will consider only comments received before the close of business on the comment closing date indicated above. To the extent possible, NHTSA will also consider comments filed after the closing date.

Do not submit Docket for access to the docket or background documents or comments received. To go to http://www.regulations.gov at any time or to 1200 New Jersey Avenue SE, West Building Ground Floor, Room W12-140, Washington, DC 20590, between 9 a.m. and 5 p.m. Monday through Friday, except Federal Holidays. Telephone: 202-366-9292.

Privacy Act: In accordance with 5 U.S.C. 552(a), DOT will consider comments submitted from the public to better inform its decisionmaking process. DOT posts these comments, without edit, by name or as described in the system of records notice, DOT-DE-14, accessible through http://www.dot.gov/privacy. In order to facilitate comment tracking and response, we encourage commenters to provide their name, or the name of their organization, however, subpoena of names is completely optional. Whether or not commenters identify themselves, all publicly posted comments will be fully considered. If you wish to provide comments containing proprietary or confidential information, please contact the agency for alternate submission instructions.
NHTSA’S REQUEST FOR COMMENT REGARDING FMVSS BARRIERS TO AUTOMATED VEHICLES

ACTION: Request for comment (RFC).

SUMMARY: NHTSA seeks public comments to identify any regulatory barriers to the testing, compliance certification and compliance verification of motor vehicles with Automated Driving Systems (ADSs) and certain unconventional interior designs.
NHTSA’S ANPRM FOR COLLABORATIVE ON AUTOMATED VEHICLES

Pilot Program for Collaborative Research on Motor Vehicles With High or Full Driving Automation

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

ACTION: Advance notice of proposed rulemaking (ANPRM).

ENVIRONMENTAL PROTECTION AGENCY

49 CFR Parts 721

EPA-HG-OPPT-2018-0548; FPL-9894-07-N

Additional instructions on commenting or visiting the dockets, along with more information about dockets generally, is available at http://www.epa.gov/dockets.

FOR FURTHER INFORMATION CONTACT:

Kathryn Moss, Chemical Control Division (OCP); Office of Pollution Prevention and Toxics, Environmental Protection Agency, 1200 Pennsylvania Ave. NW, Washington, DC 20460-0001; telephone number (512) 544-8239; email address: moss.kathryn@epa.gov.

For general information contact: The NHTSA-HQBox, APB-100 (219), 400 Independence Ave. SW, Washington, DC 20590; telephone number (202) 544-1808; email address: NHTSA-HQBox.epa.gov.

SUPPLEMENTARY INFORMATION: In addition to this Notice of Proposed Rulemaking, EPA is leaving the actions as a direct final rule elsewhere in this issue of the Federal Register. For further information about the proposed significant new source rule, please see the information provided in the direct final action, with the same title, that is located in the “Rules and Regulations” section of this issue of the Federal Register.
Automated Vehicles 3.0

PREPARING FOR THE FUTURE OF TRANSPORTATION
PANELISTS

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DEPARTMENT OF TRANSPORTATION
National Highway Traffic Safety Administration

[Docket No. NHTSA–2019–0016]

General Motors, LLC—Receipt of Petition for Temporary Exemption From Various Requirements of the Safety Standards for an All-Electric Vehicle With an Automated Driving System

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

ACTION: Notice of receipt of petition for temporary exemption; request for public comment.

SUMMARY: In accordance with the procedures in the Temporary Exemption from Motor Vehicle Safety and Bumper Standards, General Motors, LLC (GM) has applied for a temporary exemption for its driverless “Zero-Emission Autonomous Vehicle” (ZEAV), an all-electric vehicle with an Automated Driving System (ADS), from part of each of 16 Federal Motor Vehicle Safety Standards (FMVSS). The ZEAVs would not be equipped with a steering wheel, manually-operated gear selection mechanism, or foot pedals for braking and accelerating. If the requested exemption were granted, GM would use the ZEAVs to provide on-demand mobility services in GM-controlled fleets.

GM requests the exemption be granted on either or both of two statutory bases: That it would facilitate the development or field evaluation of a new motor vehicle safety feature providing a level of safety at least equal to those of FMVSS from which exemption is requested, or that it would facilitate the development or field evaluation of a low-emission vehicle without unreasonably lowering the safety performance of the vehicle.

NHTSA seeks comment on the merits of the petition after receiving and considering the public comments on this notice, the petition, public responses to the questions in this notice, and any additional information that might be forthcoming from GM.

DATES: Comments must be received on or before May 20, 2019.


Comments: NHTSA invites you to submit comments on the petition described herein and the questions posed below. You may submit comments identified by docket number in the heading of this notice by any of the following methods:

• Fax: 202–493–2251.
• Hand Delivery: 1200 New Jersey Avenue SE, West Building Ground Floor, Room W12–140, Washington, DC, between 9 a.m. and 5 p.m., Monday through Friday, except Federal Holidays.
• Federal eRulemaking Portal: Go to http://www.regulations.gov. Follow the online instructions for submitting comments.

Instructions: All submissions must include the agency name and docket number. Note that all comments received will be posted without change to http://www.regulations.gov, including any personal information provided. Please see the Privacy Act discussion below. NHTSA will consider all comments received before the close of business on the comment closing date indicated above. To the extent possible, NHTSA will also consider comments filed after the closing date.

Docket: For access to the docket to read background documents or comments received, go to http://www.regulations.gov at any time or to 1200 New Jersey Avenue SE, West Building Ground Floor, Room W12–140, Washington, DC 20590, between 9 a.m. and 5 p.m., Monday through Friday, except Federal Holidays. Telephone: 202–366–9826.

Privacy Act: In accordance with 5 U.S.C. 553(c), DOT solicits comments from the public to better inform its rulemaking process. DOT posts these comments, without edit, to www.regulations.gov, as described in the system of records notice, DOT/ALL–14 FDMS, accessible through www.dot.gov/privacy. In order to facilitate comment tracking and response, we encourage commenters to provide their name, or the name of their organization; however, submission of names is completely optional. Whether or not commenters identify themselves, all timely comments will be fully considered. If you wish to provide comments containing proprietary or confidential information, please contact the agency for alternate submission instructions.

Confidential Business Information: If you wish to submit any information under a claim of confidentiality, you should submit three copies of your complete submission, including the information you claim to be confidential business information, to the Chief Counsel, NHTSA, at the address given under FOR FURTHER INFORMATION CONTACT. In addition, you should include a cover letter setting forth the information specified in our confidential business information regulation (49 CFR part 512).

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I. Background

One of the key tasks of NHTSA, the agency responsible for issuing and enforcing the existing FMVSS, in getting ready for ADS vehicles is to ensure that those standards do not impose unnecessary obstacles to those vehicles. Most existing FMVSS were drafted years ago, based on the assumption that each vehicle would have a human driver who needs controls for manually operating the vehicle, information about the vehicle’s operating condition, and a clear view in all directions of the vehicle, information about the vehicle would have a human driver who needs controls for manually operating the vehicle, information about the vehicle’s operating condition, and a clear view in all directions of the driving environment in all weather and lighting conditions. While many of the existing FMVSS need to be updated so that they are appropriate for vehicles with modern technologies, they do not pose barriers to the manufacturing of dual mode ADS vehicles, i.e., ADS vehicles designed to be driven either by an ADS or a human driver. Some of them could, however, pose barriers to ADS vehicles designed to be driven exclusively by an ADS.

NHTSA can address the needs of exclusively ADS vehicles in different ways, depending on the time frame. In the longer term, it can conduct research on how to update the performance requirements and test procedures and then initiate rulemaking proceedings to modernize the FMVSS. In the near term, the agency can, if needed and merited, grant, in whole or in part, petitions from vehicle manufacturers to exempt limited numbers of their vehicles from select FMVSS so that the manufacturers can gain additional on-road experience. While established vehicle manufacturers can conduct on-road tests to evaluate their vehicles without first obtaining an exemption, if they wish to mix such testing with operations involving transporting the public, exemptions may, to that extent, be necessary.

In January 2018, GM submitted such a petition for the ZEAV, a vehicle designed to be driven exclusively by an ADS. GM requested the vehicle’s temporary exemption from parts of each of 16 FMVSS. This notice accomplishes two things. First, it serves as a notice of receipt of GM’s petition. Second, it requests (a) comments on the petition and the discussion in this notice and (b) responses to a series of questions related to the petition.

While the analysis of exemption petitions based on rationales other than economic hardship generally involves comparing the relative safety of exempted vehicles and nonexempted vehicles, this is the first petition whose analysis by NHTSA will involve a comparison of (1) a vehicle in which all driving decisions as to when and how it is appropriate to use crash avoidance technologies and take actions to implement those decisions would be made by an ADS to (2) a vehicle in which almost all of those decisions are made and implemented by a human driver. This difference could affect the amount of safety benefits generated by Federally-mandated safety technologies. Because this is an important case of first impression and because other petitions for the exemption of other vehicles with ADS are expected in the coming years, NHTSA believes that inclusion of the list of questions is necessary to inform the public about the novel and important issues presented by this petition and to elicit public feedback to aid the agency in determining how to address and resolve those issues. The feedback will also aid the agency, if it partially or fully grants an exemption, in determining how to promote, through the setting of terms and monitoring GM’s adherence to them, the safe operation of GM’s ZEAVs.

II. Authority and Procedures for Temporary Exemptions

Chapter 301 of title 49, United States Code, authorizes the Secretary of Transportation to exempt, on a temporary basis, under specified circumstances, and on terms the Secretary deems appropriate, motor vehicles from a FMVSS or bumper standard. This authority is set forth at 49 U.S.C. 30113. The Secretary has delegated the authority for implementing this section to NHTSA. The Safety Act authorizes the Secretary to grant, in whole or in part, a temporary exemption to a vehicle manufacturer if the Secretary makes specific findings. The Secretary must look comprehensively at the request for exemption and find that the exemption is consistent with the public interest and with the objectives of the Vehicle Safety Act. In addition, the Secretary must make one of the following more focused findings:

(i) compliance with the standard[s] [from which exemption is sought] would cause substantial economic hardship to a manufacturer that has tried to comply with the standard[s] in good faith;
(ii) the exemption would make easier the development or field evaluation of a new motor vehicle safety feature providing a safety level at least equal to the safety level of the standard;
(iii) the exemption would make easier the development or field evaluation of a low-emission motor vehicle easier and would not unreasonably lower the safety level of that vehicle; or
(iv) compliance with the standard would prevent the manufacturer from selling a motor vehicle with an overall safety level at least equal to the overall safety level of nonexempt vehicles. The second and third of these additional findings are the bases for GM’s request for exemption. First, GM requests the Secretary to grant its petition based on finding that an exemption is consistent with the public interest and with the Safety Act, and that the exemption would make easier the development or field evaluation of a new motor vehicle safety feature providing a safety level at least equal to the safety level of the standard. Second, GM requests the Secretary to grant its petition on finding that an exemption would facilitate the development or field evaluation of a low-emission motor vehicle and would not unreasonably reduce the safety of that vehicle.

NHTSA established 49 CFR part 555, Temporary Exemption from Motor Vehicle Safety and Bumper Standards, to implement the statutory provisions concerning temporary exemptions. The requirements in 49 CFR 555.5 state that the petitioner must set forth the basis of the petition by providing the information required under 49 CFR 555.6, and the reasons why the exemption would be in the public interest and consistent with the objectives of the Safety Act. A petition justified on the basis that an exemption from a FMVSS would facilitate the development or field evaluation of a new motor vehicle safety feature providing a level of safety at least equal to the level of safety required by the standard must include the following information specified in 49 CFR 555.6(b):

(1) A description of the safety features, and research, development, and testing documentation establishing the innovational nature of such features;
(2) An analysis establishing that the level of safety of the feature is equivalent to or exceeds the level of safety established in the standard from which exemption is sought;
(i) A detailed description of how a vehicle equipped with the safety or impact protection feature differs from one that complies with the standard;
(ii) If applicant is presently manufacturing a vehicle conforming to the standard, the results of tests conducted to substantiate certification to the standard; and

49 CFR 1.94.
GM states that, during the exemption period, it would work with NHTSA and industry stakeholders on rulemaking to address autonomous vehicle technology.\(^6\) GM states that if that rulemaking were not completed during the two-year exemption period, it would likely request a renewal of the exemption.\(^9\) It also states that (if its petition were granted) it would operate any ZEAVs produced during the exemption period throughout their normal service life \(^10\)—i.e., well beyond the two-year exemption period.

GM provides the following explanation of how it organized the arguments in its petition:

GM seeks an “exemption” under two separate statutory provisions, 49 U.S.C. 30113(b)(3)(B)(ii) and (iii). As this Petition makes clear, “exemption” is a term of art that is a misnomer in this context because GM does not seek to be “exempted” from any safety requirements. Rather, through this Petition, GM seeks authorization to satisfy the safety purpose and intent of certain FMVSS requirements and tests through different designs and systems. Because the ZEAV satisfies the requirements of both provisions, NHTSA may grant this Petition under either or both provisions.

First, under 49 U.S.C. 30113(b)(3), NHTSA may issue an FMVSS exemption “on finding that—(A) an exemption is consistent with the public interest and this chapter or chapter 325 of this title (as applicable); and (B) . . . the exemption would make the development or field evaluation of a low-emission motor vehicle easier and would not unreasonably lower the safety level of that vehicle.” Thus, in order to justify an exemption, a petition under this provision must support three primary showing: the public interest showing; the low-emission showing; and the FMVSS safety showing, as set forth in 49 U.S.C. 30113(b)(3)(B)(ii).

The discussion below supports findings that GM’s proposed ZEAV deployment fully satisfies the three criteria of both 30113(b)(3)(B)(ii) and (iii), and that NHTSA should therefore grant the Petition.

In furtherance of this Petition, the discussion below contains:

A description of GM’s ZEAV program and the vehicle;
A discussion of how the Petition should be evaluated under the Safety Act and NHTSA’s regulations and procedures;
A Standard-by-Standard description of how GM’s ZEAV achieves the safety purposes of the affected human-driver based FMVSS requirements;
An explanation of how granting this Petition will facilitate the development and field evaluation of a low-emission vehicle;
A discussion of how granting this Petition will benefit the public interest; and
A discussion of GM’s plans for compliance with applicable FMVSS during and after the effective dates of the proposed exemption.

(Footnotes omitted.)

A. Zero Emission Automated Vehicle

i. Parent Vehicle—Chevrolet Bolt

The ZEAV would be built from the architecture of the Chevrolet Bolt EV.\(^1\) GM describes its Bolt EV as a zero-emission vehicle, with an Environmental Protection Agency (EPA) estimated all-electric range of 238 miles on a full charge.\(^2\) The company states it created the original prototypes for the ZEAV by retrofitting Bolt EVs with autonomous controls and equipment.\(^3\)

ii. Comparison of Bolt and ZEAV

The Bolt EV and the ZEAV are both all-electric vehicles. GM did not indicate whether the motor and battery pack of the ZEAV would differ in any significant way from those of the Bolt EV. GM notes that the ZEAV would have electrification options incorporated from the Bolt EV, but does not elaborate on the nature, extent or importance of those innovations.\(^4\)

As discussed later in this notice, GM notes that the ZEAV’s high-performance computer system and array of sensors would draw power from the power supply for the zero-emission propulsion system, potentially affecting the range of the ZEAV. GM states that the all-electric

\(^{6}\)GM Petition at 3.


\(^{9}\)GM Petition at 38.

\(^{10}\)Id.

\(^{11}\)Id. at 7.

\(^{12}\)Id. at 7 and FN 11.

\(^{13}\)Id. at 8.

\(^{14}\)Id. at 7.
range of the ZEAV has not yet been determined.

There are significant differences between the Bolt EV and the ZEAV with respect to how they are designed to be driven and how safety systems would be activated. The Bolt EV is exclusively driven by a human driver. In contrast, the ZEAV would be exclusively driven by an ADS. More specifically, in relation to the SAE International Levels of Automation 3–5—Automated Driving Systems (ADSs)—Conditional, High, and Full Automation, the Bolt EV’s highest driving automation capability would be considered to be at automation Level 0 and the ZEAV’s capability at driving automation Level 4.

The ZEAV’s ADS would be a combination of various hardware and software components that function as a system to perform functions traditionally performed by human drivers, i.e., perceive and interpret the driving environment, the objects in that environment, and their likely future movement, make decisions about accelerating, braking and steering so as to select and navigate safe paths through that environment and around those objects, and implement those decisions. While the Bolt EV is equipped with a steering wheel and brake and accelerator pedals, among other manual controls, the ZEAV would have none of these components. To emphasize this point, GM notes: “By removing human input from the formula, these changes provide the safety advantages of autonomous transportation while ensuring that passengers cannot interfere, purposefully or inadvertently, with the safe operation of the vehicle.” These differences are further described in Appendix II of the petition. GM suggests that these differences might affect the range of the ZEAV.

iii. Planned Usage of the ZEAV

GM states that if it were granted an exemption, it would deploy the ZEAVs in a GM-controlled rideshare program. This approach would, GM says, allow it to “closely monitor and address safety in every ZEAV deployed.” If an incident were to occur, GM states it “could promptly analyze the situation in depth and address it.” According to GM, “common factors such as human driver behavior, consumer failure to maintain the vehicle, and consumer failure to repair the vehicle or obtain recall repairs will not be factors for the safety of GM-maintained-and-operated ZEAV fleets.” GM says that the operations of the ZEAVs would be carefully circumscribed, stating:

- GM’s ZEAV fleet will operate only within defined geographic boundaries, and limited to predefined speeds and weather conditions. GM’s limitations on the operation of its ZEAV fleet will enhance safety—limited speeds eliminate events due to driving above the speed limit, and weather restrictions reduce occurrences of safety system activations due to weather-related road conditions. GM’s program parameters will reduce the number of miles that the ZEAVs will be driven in higher-risk situations, so the ZEAV is not likely to encounter many of the risk scenarios that other vehicles encounter.

- The vehicles will drive only in pre-mapped areas for which GM fully understands the infrastructure and conditions that the vehicles will encounter.

- GM notes, however, that while the ZEAVs would have not-to-exceed speeds, GM expects to increase their “not-to-exceed speeds” during the requested two-year exemption period.

- GM further notes that while GM’s ZEAVs would be weather restricted, GM expects to expand its operational design domain (OOD) for rain, snow, and winter driving during the proposed exemption period. GM does not address what additional changes, if any, it might make after that period.

B. Safety Showing

In support of both statutory bases cited in its petition for an exemption, GM asserts that, for each of the 16 FMVSS from which it seeks temporary exemption, in part or in full, the ZEAVs would “effectively meet all FMVSS safety requirements” and would provide a safety level at least equal to the safety level of the affected standard[s] as required by statute. In order to deploy the ZEAVs, GM seeks a temporary exemption from the following FMVSS, either in whole or in part: No. 101, Controls and Displays; No. 102, Transmission Shift Position Sequence, Starter Interlock, and Transmission Braking Effect; No. 108, Lamps, Reflective Devices, and Associated Equipment; No. 111, Rearview Mirrors; No. 114, Theft Protection and Rollaway Prevention; No. 124, Accelerator Control Systems; No. 126, Electronic Stability Control Systems; No. 135, Light Vehicle Brake Systems; No. 138, Tire Pressure Monitoring Systems; No. 141, Minimum Sound Requirements for Hybrid and Electric Vehicles; No. 203, Impact Protection for the Driver from the Steering Control System; No. 204, Steering Control Rearward Displacement; No. 207, Seating Systems; No. 208, Occupant Crash Protection; No. 214, Side Impact Protection; and No. 226, Ejection Mitigation.

The following paragraphs paraphrase how the GM petition discusses each standard from which GM seeks exemption:

i. FMVSS No. 101

The purpose of FMVSS No. 101 is “to ensure the accessibility, visibility and recognition of motor vehicle controls, telltales and indicators, and to facilitate the proper selection of controls.” In order to reduce safety hazards caused by the diversion of the driver’s attention from the driving task and mistakes by the driver in selecting controls, because the ZEAV would not be equipped with human driver controls and would not have a human driver, GM states that the requirements for certain controls, telltales and indicators should not apply and requests an exemption from them. GM further states that, instead, its vehicle would be equipped with functionally equivalent ADS interfaces that provide the ADS with access to the information and controls necessary to drive the vehicle and maintain safety.

ii. FMVSS No. 102

FMVSS No. 102 specifies requirements for transmission shift position sequence, starter interlock, and transmission braking effect. The purpose of these requirements is to reduce the likelihood of shifting errors, to prevent starter engagement by the driver when the transmission is in a drive position, and to provide supplemental braking at speeds below 25 mph. Paragraph S3.1.4 and its...
subparagraphs require that identification of shift positions and shift position sequence be displayed in view of the driver. GM states that the ZEAV would not have a human driver, the information would be provided electronically to its ADS. GM further states that its vehicle would meet all other requirements of this standard.

iii. FMVSS No. 108

FMVSS No. 108 was established to provide adequate illumination of the roadway and to enhance the conspicuity of motor vehicles so that their presence is perceived by other roadway users and signals understood in daylight, darkness and reduced visibility. GM explains that the ZEAV would use radar and lidar and would not rely on visible light and, therefore, operation of headlamp switches as required by the standard would be unnecessary. GM explains that the vehicle would continue to use ordinary lower beams, but would not use upper beams. GM further explains that the ZEAV would have “interfaces that allow the ADS to receive, monitor, and analyze information otherwise provided by the telltales and indicators related to turn signals and headlamps, and to issue commands to control the headlamps and turn signals.”

iv. FMVSS No. 111

FMVSS No. 111 pertains to rearview visibility and requires rearview mirrors and images to provide a driver with a clear and reasonably unobstructed view to the rear. GM states that the ZEAV would include “rear-facing cameras, radar sensors, and lidars that continuously provide full rear-field-of-view information to the ADS.” GM further states that its vehicle would have sensors that provide overlapping coverage and environmental information to the ADS, allowing it to perceive the vehicle’s surroundings in “significantly more breadth and detail than interior and exterior rearview mirrors provide to human drivers.”

v. FMVSS No. 114

GM asserts that under the ZEAV would comply with the performance requirements of FMVSS No. 114, the test procedures in paragraph S6 should not apply and requests an exemption. GM explains that its vehicle would not have conventional controls for the parking brake, service brake or transmission gear selection. GM further explains that the ZEAV would be designed to enable the ADS to determine and control the brake system status electronically.

vi. FMVSS No. 124

FMVSS No. 124 requires the return of the throttle to the idle position when the driver removes actuating force from the accelerator control (or if the accelerator control system is disconnected). GM states that the ZEAV would be the driver in the ZEAV, and therefore, the ADS would regulate vehicle propulsion. As a result, GM suggests that FMVSS No. 124 should not apply and requests as exemption. GM explains that its ADS would include two independent software controls that establish vehicle propulsion and asserts that its system could satisfy the time and temperature requirements of this standard.

vii. FMVSS No. 126

The purpose of FMVSS No. 126 is to prevent driver loss of directional control, including loss of control resulting in vehicle rollover. GM states that the ZEAV would have an Electronic Stability Control (ESC) system functionally similar to that of the Bolt EV. However, the ZEAV would not have a steering wheel, brake or accelerator pedals, and could not be tested pursuant to paragraph S5.2 and paragraphs S7.6 through S7.9. The ADS would electronically interface with the steering, braking and accelerator control systems. Because there would be no human driver, GM also states that it would not meet the telltale requirements or related test protocols of paragraphs S5.3, S7.2, S7.3, S7.8 and S7.10. GM asserts that it would “run tests to ascertain the full functionality of the ESC system” before deployment. To do so, GM explains that it would use test versions of ZEAVs that differ from the vehicles described in this petition in that they would be equipped with standard human driving controls (including steering, accelerator and brake controls). GM states that it intends to certify compliance with the performance requirements of this standard based on those tests.

viii. FMVSS No. 135

FMVSS No. 135 was established to ensure safe braking performance under normal and emergency driving conditions. In GM’s ZEAV, the ADS would control braking through commands to the brake control module as the vehicle would not be equipped with an accelerator pedal, a service brake pedal, or manual parking brake controls. For that reason, GM states that the vehicle control requirements of paragraph S5.3.1, the telltale requirements of paragraphs S5.1.2, S5.5, S5.5.5, and the tests in paragraph S7 are not applicable and requests an exemption. GM asserts that, because of the ADS, the vehicle would meet the performance requirements of this standard and the vehicle’s braking system would satisfy the stopping distance and grade-holding performance requirements of this standard. GM further asserts that its vehicle would undergo brake testing to demonstrate it meets the performance requirements before deployment. To do so, GM would use test versions of ZEAVs that differ from the vehicles described in this petition in that they would be equipped with standard human driving controls (including steering, accelerator and brake controls). GM states that it intends to certify compliance with the performance requirements of this standard based on those tests.

ix. FMVSS No. 138

FMVSS No. 138 specifies requirements for tire pressure monitoring systems to warn drivers of underinflation of tires and the resulting safety problems. Paragraphs S4.3 and S4.4 require telltales visible to the driver. GM explains that the ZEAV would not have a driver seating position and would not include tire pressure telltales visible to vehicle occupants. Instead, the vehicle’s ADS would monitor the tire pressure electronically, detect low pressure, and recognize malfunctions in the tire pressure monitoring system. To help in controlling the maintenance and operation of vehicle fleets, the ADS...
would communicate tire pressure status to GM.\textsuperscript{60}

x. FMVSS No. 141

FMVSS No. 141 specifies minimum requirements for hybrid and electric vehicles to reduce injuries resulting from collisions with pedestrians by providing a sound with the loudness and characteristics necessary for the vehicles to be detected and recognized as vehicles by pedestrians. GM asserts that it would test and certify its vehicle to meet this standard, but the ZEAV would not have a human-controlled gear selector to demonstrate compliance with paragraph S5 of this standard (which requires sounds to be produced when the gear selector is moved to the “drive” position or other forward gear).\textsuperscript{61} GM explains that the ZEAV’s ADS would communicate with the gear selector control actuators, and in response, trigger the sound emission performance required by this standard.\textsuperscript{62}

xi. FMVSS Nos. 203, 204 and 207

FMVSS Nos. 203 and 204 relate to impact protection for the driver from a vehicle’s steering control system (steering wheel and steering column) in the event of a crash. GM states that the ZEAV would not be equipped with a steering wheel or steering column; therefore, there is no risk of chest, neck or facial injury being caused by either.\textsuperscript{63} GM asserts that computer simulation crash tests and subsequent physical crash tests would validate occupant protection for all seating positions.\textsuperscript{64} Additionally, GM asserts that these tests would verify that “the left front seating position safety protection provides occupant protection comparable to that provided to the right front seat passenger.”\textsuperscript{65} For these same reasons, and because there would not be a human driver, GM asserts that the FMVSS No. 207 requirement to have a seat for the driver also should not apply and requests an exemption.\textsuperscript{66}

xii. FMVSS No. 208

GM makes the same assertion for certain paragraphs of FMVSS No. 208, which specifies test procedures and requirements for the driver’s seating position. The purpose of this standard is to reduce the number of deaths and the severity of injuries by specifying vehicle crashworthiness and equipment requirements. Some paragraphs within this standard refer to positioning an anthropomorphic test device (“dummy”) in the driver position.\textsuperscript{67} Because GM’s ZEAV would not have a steering control system or a human driver, GM states that it is precluded from using the specified test procedures in this standard.\textsuperscript{68} Instead, GM states that it would “mirror the dummy-positioning provisions of the right front passenger seating position in the left front seating position.”\textsuperscript{69} Paragraph S7.3 specifies requirements for an audible and visual warning system for the driver seating position’s seat belt assembly. Again, GM explains that because its vehicle would not have a driver, the vehicle’s ADS would electronically receive the status of passengers’ seat belt utilization.\textsuperscript{70} GM stated that the vehicle’s ADS would also provide seat belt reminders and warnings to all vehicle occupants before initiating a ride.\textsuperscript{71} Finally, paragraph S4.5.2 requires that an air bag readiness indicator be visible from the driver’s seating position to alert the driver that the vehicle’s air bags may not function properly and may require service. GM states that this information would be provided to the ADS, instead of a human driver.\textsuperscript{72} Because GM would control the operation of its vehicles, the company explains that it would receive diagnostics from the vehicles and thus would be able to determine whether further evaluation or repair is necessary.\textsuperscript{73}

C. Low-Emission Showing

To be eligible for a temporary exemption on the grounds that the exemption would make development or field evaluation of a low-emission vehicle easier without unreasonably lowering the safety performance of the vehicle, the applicant must substantiate that the vehicle is a low-emission vehicle. To qualify as a low-emission vehicle under 49 U.S.C. 30113(a), the vehicle must meet the applicable standards for new motor vehicles under the Clean Air Act, 42 U.S.C. 7521, et seq. The EPA’s regulations issued pursuant to the Clean Air Act establish exhaust emission thresholds for light-duty low-emission vehicles and zero-emission vehicles. To qualify as a zero-emission vehicle, a vehicle must meet the applicable standards specified at 40 CFR 88.104–94.

GM asserts that its vehicle would be “an all-electric, zero-emission vehicle that does not utilize any form of combustion or emit any of the pollutants covered by Section 202 of the Clean Air Act.”\textsuperscript{74} According to GM, although this vehicle would share a platform with the Bolt EV, the vehicle’s zero-emission propulsion system would perform differently because (1) the vehicle’s computer system and sensors would draw power from the power supply for the propulsion system, and (2) the vehicle would be driven by the ADS.\textsuperscript{75} GM believes that the real world field evaluation of this vehicle would “generate valuable data about advantages and disadvantages of incorporating the sophisticated computer and sensors of an ADS in a
zero-emission platform.’’ GM believes this data would allow it to evaluate the impact of a fully autonomous on-demand service on the performance of the zero-emission propulsion system. GM states that granting this exemption would encourage the development and introduction of zero-emission autonomous vehicles by GM and other manufacturers.

D. Public Interest Argument

GM asserts that granting this exemption would be beneficial to the public. GM states that the safety advances resulting from this exemption would have the potential to save lives and reduce motor vehicle crashes and injuries. According to GM, granting the exemption would “support thousands of jobs, increase urban mobility options, foster public acceptance of both low-emission and autonomous vehicles, generate important real-world data, and inform future NHTSA action.’’

E. Appendices

In further support of its request for temporary exemption, GM’s petition includes three appendices.

Appendix I provides additional information to support the petition on the basis of facilitating the development or field evaluation of a low-emission vehicle (49 CFR 555.6(c)).

Appendix II provides supplemental technical information, including an overview of the vehicle’s ADS and external sensor system; how the vehicle processes and translates information to control vehicle movement; the vehicle’s connectivity, redundancy and fail-safe functionality; GM’s approach to testing the vehicle’s ESC and brake systems; information on how the vehicle would interact with passengers in a ride-share scheme; and some test data.

Appendix III details GM’s approach to demonstrating how its safety assurance, comprehensive risk management and deep integration processes for its vehicle and ADS meet the Safety Act requirements. Appendix III also provides additional information on cybersecurity, passenger and other road-user interactions, and fleet management.

IV. Agency’s Review of GM’s Petition

The agency has not yet made any judgment on the merits of the petition or on the adequacy of the information submitted. NHTSA will assess the merits of GM’s petition after receiving and considering the public comments on this notice and the petition and responses to the questions in this notice, and any additional information that may be forthcoming from GM.

We note that GM identifies several tests that would be performed to demonstrate safety equivalence, which GM did not include in its petition, and which we presume had not been performed as of the submission of the petition. NHTSA will assess the first passive restraints did not appear in on-road test fleets until 1971, and the first ones in vehicles available to the public did not arrive until 1973.

V. Potential Types of Terms

Once a manufacturer receives an exemption from the prohibitions of 49 U.S.C. 30112(a)(1), NHTSA can effect the use of those vehicles produced pursuant to the exemption only to the extent that NHTSA either sets terms when partially or fully granting the exemption or exercises its enforcement authority (e.g., its safety defect authority). The agency’s authority to set terms is broad. Since the terms would be the primary means of monitoring and affecting the safety operation of the exempted vehicles, the agency would consider carefully whether to establish terms and what types of terms to establish if it were to grant a petition. The manufacturer would need to agree to abide by the terms set for that exemption in order to begin and continue producing vehicles pursuant to that exemption.

Nothing in either the statute or implementing regulations limits the application of these terms to the period during which the exempted vehicles are produced. NHTSA could set terms that continue to apply to the vehicles throughout their normal service life if it deems that such application is necessary to serve the interests of safety. Thus, if NHTSA were to grant an exemption, in whole or in part, it could establish, for example, reporting terms to ensure a continuing flow of information to the agency throughout the normal service life of the exempted vehicles, not just during the two-year period of exemption. Given the uniqueness of GM’s vehicles, its petition, and public safety concerns, and especially given GM’s expectations that the capabilities of the ZEAVs would evolve over their lifetime, extended reporting may be appropriate. Since only a portion of the total mileage that the vehicles, if exempted, could be expected to travel during their normal service life would have been driven by the end of the exemption period, the data would need to be reported over a longer period of time to enable the agency to make sufficiently reliable judgments. Such judgments might include those made in a retrospective review of the agency’s determination about the anticipated safety effects of the exemption.

NHTSA could also establish terms to specify what the consequences would be if the flow of information were to cease or become inadequate during or after the exemption period. Other potential terms could include limitations on vehicle operations (based upon speed, weather, identified ODDs, road types, ownership and management, etc.). Conceivably, some conditions could be graduated, i.e., restrictions could be progressively relaxed after a period of demonstrated driving performance. Further, as with data-sharing, it may be necessary to specify
that these terms would apply to the exempted vehicles beyond the two-year exemption period.

NHTSA notes that its regulations at 49 CFR part 555 provide that the agency can revoke an exemption if a manufacturer fails to satisfy the terms of the exemption. NHTSA could also seek injunctive relief.91

VI. Request for Comments and Information

As noted above, the ADS in GM’s ZEAV seeks to replicate and replace the complex perceiving and judging capabilities of a human driver. As GM states,

With the ADS as the driver, there is no need for features designed to interface with a human driver, such as manual human driver controls (e.g., steering wheel, brake pedal, and accelerator pedal), human-driver-specific information systems (e.g., tolltapes and indicator lamps), human-driver-oriented visibility features (e.g., rearview mirrors), or human-driver-specific occupant protection (e.g., steering-wheel-mounted airbag).92

NHTSA anticipates that the complexity of the technologies involved in this petition will complicate its efforts to assess the safety performance of the ZEAVs. Further complicating those efforts will be the expected evolution of the capabilities of the ZEAVs during the course of their normal service life. This expectation is based on GM’s statements in its petition that the ZEAVs would operate initially only in highly constrained driving scenarios, e.g., at low speed, in daylight and fair weather, on streets with one lane in each direction, but later in progressively less constrained circumstances. As a result, the safety record of the ZEAVs during the potential two-year period of requested exemption might not be predictive of their safety record during balance of their normal service life.

An additional consideration raised by this petition is whether to set terms and conditions on the exemption and, if so, what terms and for what duration.93

Given the complexity of projecting the safety effects of granting an exemption in this instance, it might be desirable to require reporting to validate the agency’s projections and monitor the safety record of the ZEAVs. If the agency were to decide to require reporting, it would take into consideration the possibility that reporting terms sufficient for an early stage of the ZEAV’s normal service life may not be sufficient for a later stage. Because of the anticipated progressive relaxation of operating scenarios, early data might not be predictive of later data.

Thus, for the above reasons, and because this is an important case of first impression and petitions for other vehicles with similar ADS are expected in the coming years, NHTSA has set forth below a list of questions to elicit public feedback to aid the agency in determining how to address and resolve the variety of novel and important issues presented in the petition and how to promote, through the setting of terms, the safe operation of such vehicles if the agency ultimately decides to grant an exemption.

Please note that answers supported by data and analysis will be given greater weight. GM is also encouraged to submit any supplemental information to the agency that the petitioner may deem persuasive. Commenters are requested to provide specific references to all sources for all studies, data, assumptions, scientific reasoning, and methodology they cite or submit.

Statutory Bases for Exemption

1. Which of the two bases for exemption (field evaluation of a new motor vehicle safety feature (30113(b)(3)(B)(i)) or field evaluation of a low-emission vehicle (30113(b)(3)(B)(iii)) identified by GM in its petition is more appropriate for the agency to use in analyzing and in granting or denying the petition and why?

2. If the agency determines that its authority to grant exemptions to facilitate the development or field evaluation of a new motor vehicle safety feature is the more appropriate basis under which to evaluate GM’s petition, does the petition provide sufficient information to enable the agency to make the required statutory finding as to whether the level of safety is equivalent to or exceeds the level of safety established in the FMVSS from which exemption is sought? If not, what additional information should the agency seek prior to rendering its final determination and why?

3. If the agency determines that its authority to grant exemptions to facilitate the development or field evaluation of a low-emission motor vehicle is the more appropriate basis under which to evaluate GM’s petition, does the petition provide sufficient information to enable the agency to determine whether exempting the vehicle would unreasonably degrade the safety of the vehicle? If not, what additional information should the agency seek prior to rendering its final determination and why?

4. In lieu of either of the two bases relied upon by GM, would it be more appropriate to consider GM’s petition under 49 U.S.C. 30113(b)(3)(B)(iv) (authority to grant exemptions from FMVSS for vehicles with an overall safety level at least equal to the overall safety level of nonexempt vehicles low-emission vehicles)? If so, why?

Safety Analyses

5. What studies, data, assumptions, scientific reasoning, and methodologies are needed for the agency to evaluate and compare the ZEAV and a FMVSS-compliant non-ADS vehicle? For example, should the agency assess whether an ADS steers, brakes, and accelerates at least as effectively and safely (e.g., as quickly) as the average human driver? If so, what methodology should it use? Are there other approaches to making the safety evaluation and comparison? Please provide specific references to all sources of such tools or evaluation approaches.

6. Given that the ZEAV is expected to evolve over its full-service life, how should the effects of that evolution be taken into consideration in assessing the safety of the exempted vehicle relative to the FMVSS-compliant vehicle?

7. What studies, data, assumptions, scientific reasoning, and methodologies should a petitioner submit to the agency to substantiate its record of research, development, and testing establishing the innovative nature of the safety feature?

8. What studies, data, assumptions, validation test results, scientific reasoning, methodologies, and analyses should a petitioner submit to the agency to validate that its ADS provides safety at least equal to the level of the standards for which an exemption is sought?

9. What studies, data, assumptions, validation test results, scientific reasoning, methodologies, and analyses should a petitioner submit to the agency to validate that its ADS during its operation will have sufficient reliability to accomplish its designed intent, e.g., timely and sufficiently applying the service brakes when braking is needed for safety purposes?

10. The test procedures of some FMVSS listed in the exemption petition involve the use of human drivers and controls (e.g., light vehicle braking). GM indicated that it plans to perform tests with a human driver operating a version of the ZEAV modified to include human controls. Would performance of tests with such a modified vehicle be appropriate, or would programming the

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91 49 U.S.C. 30163(a).
92 Petition, page 12.
93 Greenkraft Inc.; Grant of Application for a Temporary Exemption from FMVSS No. 108, 80 FR 12057, 12060 (March 5, 2015).
ADS of the ZEAV to perform test maneuvers be a better means of evaluating compliance with performance requirements?
11. 49 CFR 555.6(b)(ii) requires the petitioner to submit “results of tests conducted on the safety or impact protection features that demonstrates performance which meets or exceeds the requirements of the standard” from which temporary exemption is sought. In the case of a petition submitted for a vehicle that has not yet been produced, and therefore, cannot be tested in order to compare its performance to that of existing vehicles, how should the agency evaluate the safety level of the vehicle? On what preliminary analyses, assumptions, and methodologies should the agency rely to assess whether such performance has been persuasively demonstrated? How would the answers to those questions change if a petitioner could demonstrate that the safety features and systems on the vehicle to be exempted are comparable in performance to those in a non-exempted vehicle and that the addition of the ADS to the vehicle to be exempted did not adversely affect the performance of those safety features and systems?
12. It could be argued that some FMVSS may either not be needed for safety or at least less needed for safety in the case of a vehicle that can be driven by only an ADS. Examples of potentially unnecessary features include inside and outside mirrors as well as the display of images from the rearview camera. Should test results or data be required to justify such an argument? If yes, what would be the most appropriate types of test results or data, and why?
13. GM asserts that a FMVSS that requires telltales to provide drivers with information is not applicable because the ADS would be receiving that information. The agency requests comment on whether and to what extent the telltales might serve a safety purpose for passengers in the vehicle, regardless of whether the information would be transmitted to the ZEAV’s ADS and whether the ADS would act on that information in a timely and appropriate way.\(^{14}\) What weight should the agency give to the extent of the ADS’ ability to respond in appropriate ways to the information it receives?
14. For a FMVSS whose benefits depend, in part, on the attentiveness, judgment, and responsiveness of a human driver (e.g., FMVSS No. 135, which requires that a foot control be provided to activate service brakes), how should the agency, in considering a petition for the exemption of a vehicle equipped with ADS and with no human driver controls, evaluate the safety effects of substituting an ADS for a human driver? What types of testing and data, and how much, would the agency need to evaluate those effects?
15. Would it be appropriate to use computer simulation as one of the methods to determine equivalent safety? If yes, why and how? If not, why not? Are there adequately validated simulation models that could be used for this purpose?
16. If the ADS is responsible for decision-making aspects of driving that a human driver otherwise would control, is it appropriate for the agency to evaluate the responsiveness and driving skills of the ADS in relation to the component, system, test procedure, or performance requirement from which an FMVSS exemption is sought? If so, how should the agency evaluate the safety of the ADS in different scenarios, e.g., negotiating a path through oncoming traffic when making a left turn, stopping when a pedestrian crosses the vehicle’s path, and yielding to emergency vehicles? What kind of data would be needed for the agency to evaluate the performance of the ADS in these and other scenarios? How should the performance of the ADS be compared to that of a human driver in a nonexempt vehicle?
17. To what extent and how should GM’s contemplated limited deployment (e.g., in a petitioner-controlled rideshare program, with established ODD constraints and the ability to pull vehicles off the street to remedy, including through software updates, any potential safety issues that might arise) be considered when evaluating safety equivalence? Does GM’s continuous control over the exempted vehicles and the ability to make continual improvements in vehicle safety performance through software updates argue for acceptance of a greater degree of uncertainty about safety effects than in the case of a petition for exemption of vehicles to be sold to the public?
18. If some of the constraints of the ZEAV’s initial deployment would eventually be progressively relaxed by GM, what types of data should the agency use in evaluating the safety of the ZEAV over its lifetime and deciding whether to grant or deny the petition? If an exemption is granted, should the agency monitor and periodically validate these data throughout the ZEAV’s service life?
19. NHTSA requests comment on how NHTSA should evaluate whether granting this exemption would be consistent with the “public interest” and the Vehicle Safety Act. What elements of the public interest and the Act would be most important in that evaluation?
20. In the absence of real-world demonstration of quality of the decision-making by the ZEAV’s ADS, if the petition were to be granted, what terms and conditions, if any, should the agency place on the exemption, and any similar future requests, to protect public safety, facilitate agency efforts to monitor the operations of exempted vehicles, and maximize the learning opportunities presented by the on-road experience of the exempted vehicles during the exemption period and thereafter?
21. Should NHTSA consider how the ZEAV would respond if it needed to deal with an unusual situation, e.g., cross the yellow line to pass a stopped vehicle blocking the way forward for a prolonged period of time or obey a policeman giving instructions instead of obeying a traffic light?

Terms and Conditions
22. Please comment on the potential utility of NHTSA’s placing terms and conditions on an exemption requiring the submission of the following categories of data:
a. Statistics on use (e.g., for each functional class of roads, the number of miles, speed, hours of operation, climate/weather and related road surface conditions).
b. Statistics and other information on performance (e.g., type, number, and causes, and results of collisions or near misses, disengagements, and transitions to fallback mechanisms, if appropriate). How can the term “near misses” best be defined so that there is uniform understanding of the term and consistent practices across all manufacturers in the identifying and reporting of “near misses”?
c. Metrics that the manufacturer is tracking to identify and respond to progress toward higher levels of safety (e.g., miles without a crash and software updates that increase the ODD).
d. Information related to community, driver and pedestrian awareness, behavior, concerns, and acceptance related to vehicles with an ADS.
e. Metrics or information concerning the durability of the ADS equipment and calibration, and need for maintenance of the ADS. For example, would the ADS work in all identified operating conditions or would there be additional limitations? How would any limitations be addressed and managed?

\(^{14}\) See the discussion of “response states” on pages All–11 through All–13 of Appendix II of GM’s petition.
f. Data and information on the initial and subsequent ODDs and software updates.
g. For all categories of information, how should any concerns about confidential business information and privacy be addressed?
23. If there would be other categories of data that should be considered, please identify them and the purposes for which they would be useful to the agency in carrying out its responsibilities under the Safety Act.
24. If the agency were to require the reporting of data, for what period should the agency require it to be reported—the two-year exemption period or the ZEAVs’ entire normal service life?

25. Given estimates that vehicles with high and full driving automation would generate terabytes of data per vehicle per day, how should the need for data be appropriately balanced with the burden on manufacturers of providing and maintaining it and with the ability of the agency to absorb and use it effectively?

26. If supporting information (including analysis, methodology, data, and computer simulation results involving proprietary systems or specialized computer programs) is submitted by a petitioner under a request for confidential treatment and relied upon by the agency in its determination whether to grant or deny a petition, how can the public be provided with an evaluation and a justification for the determination that are transparent, readily understandable and persuasive?

27. Are there any mechanisms that may help further mitigate the underlying safety risks, if any, presented by this petition? For example, what additional safety and engineering redundancies, if any, should NHTSA consider requiring as a condition to granting the exemption?

28. Over the history of the Agency, exemption petitions based on some form of safety analysis, as opposed to the much more common type of petition based on a claim of economic hardship, have averaged only 1–2 per year. Typically, these safety-based petitions have involved technologies that affect only a single vehicle function or at least a very narrow range of functions and that were well described and tested. Such petitions were resolved by the Agency’s either granting or denying them after soliciting and considering public comments. In some cases, the Agency sent requests to the applicant for additional test data. In most cases, this second group of petitions were either granted or denied, again after public comment. In a few instances, the petition remained as “pending.”

In our current innovative environment, such an approach presents challenges for technologies, e.g., automated driving systems for vehicles without manual driving controls, that affect a broad range of functions and that have not been developed sufficiently to incorporate them in vehicles in order to generate the real-world test data that has typically been required for granting petitions. The lack of real-world test data could result in lengthy delays and even non-approval.

To address this problem, NHTSA solicits public comment on alternative approaches to analyzing and resolving petitions for exemption from FMVSS in a timely and appropriate way, including but not limited to:

—After public comment, exercising our discretion to rely upon other forms of evidence in making the statutorily required findings quickly for petitions related to technology with significant lifesaving potential to allow for expedited approval for testing and development of a very limited number of vehicles under well-defined, risk-managed conditions;

—Deny petitions if applicants are unable to respond adequately to NHTSA requests for further information within a specified time period;

—For vehicles that would be deployed only within very limited operating areas, go beyond seeking public comment by hosting public meetings or otherwise providing for targeted and transparent public engagement in the intended geographical operating area to allow for full and transparent public discussion of novel safety issues and concerns, emergency response considerations, or other issues of interest to state and local stakeholders regarding the exemption requested and relevant to NHTSA’s review of the petition;

—Any other options to process petitions in a way that is timely, transparent and supportive of the safety goals of the FMVSS from which exemption is sought.

VII. Comment Period

Because of the novelty and complexity of the petition, the agency is providing a 60-day comment period. After considering public comments and other available information, NHTSA will publish a notice of final action on the petition in the Federal Register.

Please note that even after the comment closing date, we will continue to file relevant information in the docket as it becomes available. Further, some people may submit late comments. Accordingly, we recommend that you periodically check the Docket for new material. You can arrange with the docket to be notified when others file comments in the docket. See www.regulations.gov for more information. We will reopen or extend the comment period for this petition, as needed.


Issued in Washington, DC under authority delegated pursuant to 49 CFR 1.95 and 49 CFR 501.8.

Heidi R. King,
Deputy Administrator.
[PR Doc. 2019–05119 Filed 3–18–19; 8:45 am]

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DEPARTMENT OF TRANSPORTATION

Office of the Secretary

[Docket No. DOT–OST–2018–0190]

Aviation Consumer Protection Advisory Committee Matters;
Subcommittee on In-Flight Sexual Misconduct

AGENCY: Office of the Secretary (“OST”), Department of Transportation (“DOT”).

ACTION: Notice of rescheduled first meeting of the Aviation Consumer Protection Advisory Committee.

SUMMARY: The U.S. Department of Transportation has rescheduled the previously announced January 16, 2019, meeting of the Aviation Consumer Protection Advisory Committee (“ACPAC” or “Committee”). The new date for the first meeting of the reestablished ACPAC is April 4, 2019. The meeting will be held in the Media Center (located on the lobby level of the West Building) at the U.S. Department of Transportation Headquarters, 1200 New Jersey Ave. SE, Washington, DC 20590. Three topics will be discussed at that meeting—establishment of the National In-Flight Sexual Misconduct Task Force (“Task Force”) (including the tasks to be carried out by the Task Force); transparency of airline ancillary service fees; and involuntary changes to travel itineraries.

DATES: The first meeting of the reestablished ACPAC will be held on April 4, 2019, from 9:00 a.m. to 5:00 p.m. Eastern Time.

E.g., a number significantly less than the 2,500 vehicles per year authorized by 49 U.S.C. 30113.
DEPARTMENT OF TRANSPORTATION
National Highway Traffic Safety Administration

[Docket No. NHTSA–2019–0017]

Nuro, Inc.; Receipt of Petition for Temporary Exemption for an Electric Vehicle With an Automated Driving System

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

ACTION: Notice of receipt of petition for temporary exemption; request for public comment.

SUMMARY: Nuro, Inc. (Nuro) has petitioned NHTSA for a temporary exemption from certain requirements in Federal Motor Vehicle Safety Standard (FMVSS) No. 500, which establishes standards for “Low-speed vehicles,” on the basis that an exemption would make the development and field evaluation of a low-emission vehicle easier without unreasonably lowering the safety of that vehicle. The vehicle for which Nuro requests an exemption is a low-speed, highly automated delivery vehicle intended to be operated without any human occupants and thus designed without any seating. Specifically, Nuro requests exemptions from the requirements in FMVSS No. 500 that its vehicle be equipped with rearview mirrors, a windshield that complies with FMVSS No. 205, and a rear visibility (backup camera) system that complies with FMVSS No. 111. Nuro states that the absence of human occupants, combined with the vehicle’s various safety design features, including the vehicle’s Automated Driving System (ADS), make compliance with these provisions of FMVSS No. 500 either unnecessary for, or detrimental to, the safety of pedestrians and cyclists.

NHTSA is publishing this document in accordance with statutory and administrative provisions, and requests comments on this document and the petition submitted by Nuro. NHTSA will assess the merits of the petition and decide whether to grant or deny it after receiving and considering the public comments on this notice, the petition, public responses to the questions in this notice and such additional information as Nuro may provide.

DATES: Comments on this petition must be submitted by May 20, 2019.


Comments: NHTSA invites you to submit comments on the petition described herein and the questions posed below. You may submit comments identified by docket number in the heading of this notice by any of the following methods:

- Hand Delivery: 1200 New Jersey Avenue SE, West Building Ground Floor, Room W12–140, Washington, DC, between 9 a.m. and 5 p.m., Monday through Friday, except Federal Holidays.
- Federal eRulemaking Portal: Go to http://www.regulations.gov. Follow the online instructions for submitting comments.

Instructions: All submissions must include the agency name and docket number. Note that all comments received will be posted without change to http://www.regulations.gov, including any personal information provided.

Please see the Privacy Act discussion below. NHTSA will consider all comments received before the close of business on the comment closing date indicated above. To the extent possible, NHTSA will also consider comments filed after the closing date.

Docket: For access to the docket to read background documents or comments received, go to http://www.regulations.gov at any time or to 1200 New Jersey Avenue SE, West Building Ground Floor, Room W12–140, Washington, DC 20590, between 9 a.m. and 5 p.m., Monday through Friday, except Federal Holidays. Telephone: 202–366–9826.

Privacy Act: In accordance with 5 U.S.C. 553(c), DOT solicits comments from the public to better inform its rulemaking process. DOT posts these comments, without edit, to www.regulations.gov, as described in the system of records notice, DOT/ALL–14 FDMS, accessible through www.dot.gov/privacy. In order to facilitate comment tracking and response, we encourage commenters to provide their name, or the name of their organization; however, submission of names is completely optional. Whether or not commenters identify themselves, all timely comments will be fully considered. If you wish to provide comments containing proprietary or confidential information, please contact the agency for alternate submission instructions.
Confidential Business Information: If you wish to submit any information under a claim of confidentiality, you should submit three copies of your complete submission, including the information you claim to be confidential business information, to the Chief Counsel, NHTSA, at the address given under: FOR FURTHER INFORMATION CONTACT. In addition, you should submit two copies, from which you have deleted the claimed confidential business information, to Docket Management at the address given above. When you send a comment containing information claimed to be confidential business information, you should include a cover letter setting forth the information specified in our confidential business information regulation (49 CFR part 512).

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I. Introduction

This document notifies the public that NHTSA has received from Nuro Inc. (“Nuro”) a petition for a temporary exemption from three requirements of FMVSS No. 500, which establishes standards for “low-speed vehicles.” Nuro submits its request on the basis that an exemption would make the development or field evaluation of a low-emission vehicle easier without unreasonably lowering the safety of that vehicle.¹ The vehicle that is the subject of the petition is the “R2X,” which Nuro describes as a highly automated (SAE Level 4 or simply L4),² low-speed (25 mph maximum), electric-powered delivery robot. According to Nuro, the R2X would be designed to carry cargo exclusively, and accordingly would not have any passenger compartment or designated seating positions. The provisions of FMVSS No. 500 from which Nuro requests an exemption are the requirements that low speed vehicles (LSVs) be equipped with (1) rearview mirrors, (2) an FMVSS No. 205-compliant windshield, and (3) an FMVSS No. 111-compliant rear visibility (backup camera) system. Because this vehicle would not have any designated seating positions, Nuro states that the vehicle should not be required to have any seatbelts, and, thus, does not need an exemption from that requirement. Nuro requests a two-year exemption, during which it seeks to be allowed to introduce fewer than 2,500 exempted vehicles into interstate commerce for each 12-month period covered by the exemption.³

This notice solicits comments from the public to inform NHTSA’s analysis of the merits of Nuro’s petition under the low-emission vehicle exemption basis in 49 U.S.C. 30113. To this end, this notice includes requests for comments and poses specific questions regarding issues that NHTSA believes could be relevant in deciding whether to grant the petition. If commenters believe that there are other potentially relevant issues, NHTSA invites them to identify those issues and explain their potential relevance.

II. Background

a. Statutory Authority and Regulatory Requirements for Temporary Exemption Petitions

The National Traffic and Motor Vehicle Safety Act (Safety Act), codified at Chapter 301 et seq., of title 49, United States Code, authorizes the Secretary of Transportation to exempt, on a temporary basis, under specified circumstances, and on terms the Secretary deems appropriate, motor vehicles from a FMVSS or bumper standard. This authority is set forth at 49 U.S.C. 30113. The Secretary has delegated the authority for implementing this section to NHTSA.⁴ The Safety Act authorizes the Secretary (by delegation, NHTSA) to grant, in whole or in part, a temporary exemption to a vehicle manufacturer if certain specified findings are made. The Secretary must look comprehensively at the request for exemption and find that the exemption is consistent with the public interest and with the objectives of the Vehicle Safety Act.⁵

In addition, the Secretary must make one of the following more-focused findings:

(i) Compliance with the standard[s] [from which exemption is sought] would cause substantial economic hardship to a manufacturer that has tried to comply with the standard[s] in good faith;

(ii) the exemption would make easier the development or field evaluation of a new motor vehicle safety feature providing a safety level at least equal to the safety level of the standard;

(iii) the exemption would make the development or field evaluation of a low-emission motor vehicle easier and would not unreasonably lower the safety level of that vehicle; or

(iv) compliance with the standard would prevent the manufacturer from selling a motor vehicle with an overall safety level at least equal to the overall safety level of nonexempt vehicles.⁶

The third of these additional findings is the basis for Nuro’s request for exemption. Nuro requests the Secretary to grant its petition based on a finding that the exemption is consistent with the public interest and with the Safety Act, and that the exemption would facilitate the development or field evaluation of a low-emission motor vehicle and would not unreasonably reduce the safety level of that vehicle.⁷

The statute further states that, for exemptions under this subsection, “a record of the research, development, and testing establishing that the motor vehicle is a low-emission motor vehicle and that the safety level of the vehicle is not lowered unreasonably by exemption from the standard” must also be included in the application.

NHTSA established 49 CFR part 555, “Temporary Exemption from Motor

¹ 49 U.S.C. 30113(b)(3).
⁴ 49 CFR 1.95.
Vehicle Safety and Bumper Standards,” to implement the statutory provisions concerning temporary exemptions. The requirements in 49 CFR 555.5 state that the petitioner must set forth the basis of the petition by providing the information required under 49 CFR 555.6, and the reasons why the exemption would be in the public interest and consistent with the objectives of the Safety Act.

A petition justified on the low-emission vehicle exemption basis must include the following information specified in 49 CFR 555.6(c):

(1) Substantiation that the vehicle is a low-emission vehicle;
(2) Research, development, and testing documentation establishing that a temporary exemption would not unreasonably degrade the safety or impact protection of the vehicle;
(i) A detailed description of how the motor vehicle equipped with the low-emission engine would, if exempted, differ from one that complies with the standard;
(ii) If the petitioner is presently manufacturing a vehicle conforming to the standard, the results of tests conducted to substantiate certification to the standard;
(iii) The results of any tests conducted on the vehicle that demonstrate its failure to meet the standard, expressed as comparative performance levels; and
(iv) Reasons why the failure to meet the standard does not unreasonably degrade the safety or impact protection of the vehicle.
(3) Substantiation that a temporary exemption would facilitate the development or field evaluation of the vehicle; and
(4) A statement of whether the petitioner intends to conform to the standard at the end of the exemption period; and
(5) A statement that not more than 2,500 exempted vehicles will be sold in the U.S. in any 12-month period for which an exemption may be granted.

b. Low-Speed Vehicles and FMVSS No. 500

Nuro states that the R2X would be a LSV. NHTSA defines an LSV as a motor vehicle: (1) That is 4-wheeled; (2) Whose speed attainable in 1.6 kilometers (1 mile) is more than 32 kilometers per hour (20 miles per hour) and not more than 40 kilometers per hour (25 miles per hour) on a paved level surface; and (3) Whose gross vehicle weight rating (GVWR) is less than 1,361 kilograms (3,000 pounds). Unlike other vehicle categories that must meet a wide array of FMVSSs and other standards, LSVs are only required to meet a single standard: FMVSS No. 500.

Currently, FMVSS No. 500 requires that LSVs be equipped with headlamps, stop lamps, turn signal lamps, taillamps, reflex reflectors, parking brakes, rearview mirrors, windshields, seat belts for all designated seating positions, a vehicle identification number and a rear visibility (backup camera) system.

NHTSA created the LSV classification and FMVSS No. 500 in June 1998 in response to safety concerns over the growing use of golf carts and other similar-sized, 4-wheeled “Neighborhood Electric Vehicles” (NEVs) on public roads. In developing FMVSS No. 500, NHTSA determined that, given the speed and weight limitations of the LSV classification, and the closed or controlled environments in which LSVs typically operate (usually planned communities and golf courses), there was not a safety need to apply the full range of FMVSS to them. Thus, the safety equipment required under FMVSS No. 500 is far more limited than what is required for other vehicle categories. Examples of FMVSS that are not applicable to LSVs include but are not limited to requirements related to antitheft, structural integrity, and flammability.

Of the eleven requirements in FMVSS No. 500, Nuro states that it intends to meet seven requirements, believes that the requirement related to seat belts is inapplicable as the vehicle lacks any designated seating positions, and petitions for exemption from the remaining three requirements. First is S5(b)(6), which requires that LSVs be equipped with an exterior (rearview) mirror mounted on the driver’s side, and either an exterior mirror mounted on the passenger’s side of the vehicle or an interior mirror. Second is S5(b)(8), which requires that LSVs be equipped with a windshield that conforms to FMVSS No. 205. Third is S5(b)(11), which requires that LSVs be equipped with a rear visibility (backup camera) system that conforms to the requirements of S6.2 of FMVSS No. 111.

III. Nuro’s Petition

The following discussion provides: An overview of the R2X based on information submitted in Nuro’s petition; Nuro’s explanation of why it believes exemption is justified under the low-emission vehicle exemption basis; and the information that Nuro provided regarding the safety of its vehicle.12

a. Overview of the “R2X” Low-Speed Automated Delivery Robot

Nuro contends that the R2X would be fundamentally different from any other vehicle with motive power currently regulated by NHTSA. Intended to provide retailers with local “last-mile” delivery services, the R2X would be designed without an occupant compartment (and thus, without any designated seating positions), nor is there any clear way for a human to enter the interior of the vehicle to use it for transportation. Instead, the R2X would be equipped with storage compartments in which goods, such as groceries, home goods, and hardware, may be placed for delivery to customers in urban or suburban “neighborhood” environments. See Figure 1 below showing the R2X with its gull wing cargo hatch covers open. To enable the operation of a vehicle lacking any occupant compartment, the R2X would be driven entirely by an L4 Automated Driving System (ADS), described in more detail below.

8 49 CFR 571.3
9 FMVSS No. 141, “Minimum sound requirements for hybrid and electric vehicles,” will apply to LSVs once it is phased in on September 1, 2020.
10 63 FR 33194 (June 17, 1998).
11 These rearview mirrors are not required to conform to FMVSS No. 111.

12 NHTSA notes that the statements in the description of Nuro’s petition are attributable to Nuro. NHTSA will review and assess those statements in deciding whether to grant the petition.
Nuro states that the R2X’s propulsion system would be electric, and states it would be a low-emission vehicle as defined under Section 202 of the Clean Air Act because it would be a zero-emission vehicle that emits regulated air pollutants at levels “significantly below” what is permitted for new motor vehicles. Nuro also avers that the R2X would meet the elements of the LSV definition as follows:

1. An LSV must be 4-wheeled—Nuro states that the R2X would have 4 wheels;
2. An LSV must be capable of attaining a maximum speed of between 32 kilometers per hour and 40 kilometers per hour (20 miles per hour and 25 miles per hour) within 1.6 kilometers (1 mile) on a paved level surface—Nuro states that the R2X would be able to achieve a maximum speed of not more than 40 kilometers per hour (25 miles per hour);13 and
3. An LSV must have a GVWR less than 1,361 kilograms (3,000 pounds). 49 CFR 571.3. Nuro also states that the vehicle would have an “unladen” weight (i.e., curb weight) of 1,134 kilograms (2,500 pounds), and that the vehicle’s GVWR would be less than the 1,361-kilogram (3,000-pound) limitation in the LSV definition. (A vehicle’s “curb weight” is its unloaded weight, whereas a vehicle’s GVWR is its loaded weight rating as specified by the manufacturer.) We note that Nuro does not provide the precise GVWR of the R2X, which is needed to determine whether the R2X would properly be classified as an LSV.

Nuro also describes the aspects of the R2X that would permit automated driving, namely the L4 ADS and the suite of cameras, LIDAR 14 and radar sensors which provide the ADS information about the driving environment. As noted above, one of the key features that would make the R2X unique is that the driving task would be automated through the use of an L4 ADS. Nuro indicates throughout its petition that it has designed the R2X’s ADS to operate the vehicle on low-speed surface roads in “neighborhood” environments.15 According to Nuro, the R2X would be equipped with 12 high definition cameras, radar sensors, and a top-mounted LIDAR that together provide the ADS with a 360° view of the vehicle’s surroundings. Nuro states that these cameras would be waterproof, rated to International Electrotechnical Commission (IEC) standard IP69K,16 and able to operate in temperatures between −40 °Celsius (C) and 85 °C. However, Nuro does not provide information on the operational capabilities of the radar and LIDAR systems.

Regarding the ADS itself, Nuro states that its software would rely on “advanced machine learning” to improve its driving capabilities.17 Nuro explains this to mean that the driving performance of the ADS would improve as the system is exposed to new or unfamiliar driving situations, which Nuro has thus far done using on-road testing and simulations. Nuro states it has conducted two on-road testing programs to develop the ADS used in the R2X.18 For the first program, Nuro retrofitted FMVSS-certified passenger vehicles with its ADS, and states that it has “continuously operated” these retrofitted vehicles (with a safety driver backup) on public roads for the past year. For the second program, Nuro operated a prototype of the R2X on the company’s private testing facility, which Nuro says is intended to simulate driving conditions in urban and suburban neighborhood settings. Nuro’s petition did not include additional information concerning either of these programs, including how many miles were driven and in what conditions. In addition, Nuro says that it has supplemented these real-world testing programs with testing in a wide variety of simulated environments. Nuro states that these testing programs have led to continuous safety improvements to the ADS, although Nuro does not provide the metrics by which the company measures the safety of the ADS, nor does Nuro provide specific information about how the ADS’s decision-making process works beyond general statements that the ADS would avoid collisions with obstacles.

Nuro states that the R2X is intended to make “short neighborhood trips” to provide last-mile delivery services for retailers in urban or suburban neighborhood settings. Nuro states that the R2X would have “built-in” operational limits that are consistent with this intended use, such as a maximum speed of 25 mph, and being restricted to marked surface streets that

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13 We note that Nuro does not state whether the R2X is physically incapable of going faster, or whether its speed is limited by something that can be readily modified, such as software. As NHTSA has noted in prior interpretation letters, some modifications to vehicles are so fundamental that the agency would consider the act of modifying the vehicle to be the manufacture of a new vehicle. See letter to Susan Gabel (Feb. 16, 2005), available at https://isearch.nhtsa.gov/files/GP008529.html. Modifying a vehicle in such a way as to change its vehicle classification category arguably arises to that level of importance. In NHTSA’s view, because the safety features of an LSV are so fundamentally tied to its low speed and weight, changing its maximum speed or its weight to exceed the limits in the definition could be regarded as tantamount to the manufacture of a new vehicle of another classification.

14 A LIDAR system, or a Light Detection And Ranging system, measures distance to objects by sending out pulses of light and measuring the time it takes for pulses to be reflected off objects back to the LIDAR system.

15 Nuro petition at 2, 3, 4, 8, 10, & 18.

16 Conformity to IEC IP69K indicates resistance to dust, steam, and high-pressure water.

17 Nuro petition, at 5.

18 Nuro petition, at 18–19.
Nuro has extensively pre-mapped.\textsuperscript{19} (Nuro specifically notes that it does not intend to relax these operational restrictions to permit Level 5 automation for the R2X.) Nuro states that, to ensure the safety and reliability of exempted vehicles, it does not intend to lease or sell them.\textsuperscript{20} Instead, Nuro intends to own and centrally operate the entire fleet of R2Xs through partnerships with local businesses such as retailers. The petition, though, does not provide further information about what Nuro means by “short neighborhood trips” or the operational limits Nuro would place on the R2X vehicles.

For additional background information on Nuro’s vehicle, see Nuro’s report “Delivering Safety: Nuro’s Approach” at https://static1.squarespace.com/static/57bcb0e029944ca366c2e7e746c1/5/5ba084b092d88eaece3f6a22/1536819358607/delivering_safety_nuros_approach.pdf.


Nuro requests an exemption on the basis that an exemption is necessary to facilitate the development and field evaluation of a low-emission vehicle\textsuperscript{21} (its R2X vehicle) and would not unreasonably lower the safety of that vehicle as compared to a vehicle that complies with the standard. Nuro claims that the exemption would facilitate the development the R2X’s ADS, which is necessary for developing and evaluating its low-emission R2X.

Nuro states that because the R2X’s ADS relies on advanced machine learning to improve its level of safety, the R2X must be exposed to new driving scenarios. Nuro’s existing testing programs have consisted of operating its FMVSS-compliant vehicle on public roads autonomously, and operating the R2X in its private test track. Nuro argues that this testing has led to consistent improvements in the ADS’s driving performance, but that it has “nearly exhausted the safety gains” it can accrue from its existing research and testing programs. Accordingly, Nuro argues that an exemption is needed to enable Nuro to perform a greater volume of real-world testing on public roads, which the company says would “expose the R2X to a greater variety of real-world situations than can be achieved in simulation or through the use of other FMVSS-compliant hardware platforms.”\textsuperscript{22} In addition, Nuro states that testing with ADS-equipped traditional passenger vehicles does not provide Nuro with information on how other road users would react to the R2X’s unique design, which is a critical element of the vehicle’s safety.

For each of the three FMVSS No. 500 requirements from which Nuro requests an exemption, Nuro provides an analysis explaining why granting an exemption would not unreasonably degrade the safety of the R2X. Nuro’s safety analyses focus on the specific safety purposes that underlie the three individual requirements from which an exemption is sought, and discuss whether there is a safety need for each requirement on a vehicle that is controlled by an ADS. Using this framework, Nuro argues that an exemption from the three requirements in the petition would either not affect vehicle safety, or would improve vehicle safety. Nuro’s analyses of the safety impacts of granting its three requested exemptions are summarized below.

i. Exterior Mirror Requirement

Per FMVSS No. 500, S5(b)(6), all LSVs are required to be equipped with “an exterior mirror mounted on the driver’s side of the vehicle and either an exterior mirror mounted on the passenger’s side of the vehicle or an interior mirror.” Nuro states the R2X would differ from a compliant LSV because it would not be equipped with either exterior or interior mirrors for rear visibility. Nuro explains that the R2X would instead use a sensor-based system to detect obstacles and other objects in the surrounding environment.

Nuro argues that an exemption from the mirror requirement would not unreasonably lower the safety of the R2X because the ADS does not use mirrors to perceive its surroundings for purposes of operating the vehicle.\textsuperscript{23} Rather, the R2X’s ADS perceives its surroundings using a suite of sensors that provide a continually-updated, complete 360-degree view of the area around the vehicle. Thus, Nuro argues that mirrors would not serve any safety purpose on the R2X, and that removing them would not lower safety.

Beyond not serving any safety function on the R2X, Nuro further argues that the presence of exterior mirrors may actually present a safety risk to pedestrians, and that removing them would improve the safety of the R2X. First, Nuro explains that because the R2X is designed to operate in pedestrian-heavy environments (neighborhood streets), it would contain various features that are intended to protect pedestrians in a crash. These features would include design elements such as rounded edges that avoid direct strikes, and pedestrian “crumple zones” to reduce the severity of impacts. Nuro states that equipping the R2X with the required mirrors would interfere with these features. Nuro also states that mirrors might increase the likelihood of pedestrian impacts because they would widen the R2X’s profile, which may increase the risk of a collision in certain situations, such as when other road users pass the R2X too closely.

ii. Windshield Requirement

Per FMVSS No. 500, S5(b)(6), all LSVs are required to be equipped with “a windshield that conforms to the Federal motor vehicle safety standard on glazing materials (49 CFR 571.205).” Nuro states that the R2X would differ from a compliant LSV because it would not be equipped with a windshield of any kind. Instead, the front face of the R2X would be equipped with the various pedestrian safety features described in the previous section.

Nuro argues that exempting the R2X from the windshield requirement would not unreasonably lower the safety of the R2X principally for two reasons.\textsuperscript{24} First, Nuro argues that the absence of human occupants in the R2X would make the windshield unnecessary for occupant protection because there would not be any risk that human occupants would could be injured by an impact with glazing or ejected from the R2X. Second, Nuro argues that there is not any need for a windshield to ensure driver

\textsuperscript{19} Nuro petition, at 8.
\textsuperscript{20} Nuro petition, at 3.
\textsuperscript{21} The legislative history of the low-emission vehicle exemption basis indicates the purpose of the basis was to encourage the development of new vehicle propulsion technologies. First, according to the Congressional Record, Congress enacted the predecessor to the low-emission vehicle basis (which temporarily authorized NHTSA to grant an exemption if it “would facilitate the development of vehicles utilizing a propulsion system other than or supplementing an internal combustion engine”) as part of the 1968 Amendment to the Safety Act, Public Law 90–283 (April 10, 1968), to encourage the development of new propulsion technologies. See 114 Cong. Rec. 7285 (1968) (Statement of Rep. Murphy). In 1972, Congress replaced this temporary exemption authority with permanent authority, and revised the language to what is currently found in 49 U.S.C. §30113(b)(1)(B)(ii). Public Law 92–548 (October 25, 1972), so as “not to stifle the development and evaluation of low-emission vehicles.” 118 Cong. Rec. 34209 (1972) (Statement of Sen. Hartke).
\textsuperscript{22} Nuro petition, at 19.
\textsuperscript{23} Nuro petition, at 8–10.
\textsuperscript{24} Nuro petition, at 10–12.
visibility because the driving task would be performed by the ADS, which would not require a transparent windshield to observe the driving environment.\textsuperscript{25}

Nuro further states that meeting the windshield requirement could lower the safety of the R2X because the presence of a windshield made from FMVSS No. 205-compliant glazing could injure pedestrians in a collision due to its rigidity (if the glazing does not break) or due to the harm that could result if the glazing shatters. As noted in the previous section, Nuro argues that one of the primary pedestrian protection features of the R2X is that its design incorporates energy-absorbing pedestrian “crumple zones” that reduce collision impact severity. Nuro states that equipping the R2X with an FMVSS No. 205-compliant windshield would reduce the effectiveness of these pedestrian impact mitigation features.

Finally, Nuro notes that, while the R2X would not be equipped with a windshield, the front of the vehicle would be equipped with a “plate” that resembles the appearance of a windshield. Nuro states that this design is intended to indicate to other road users the front of the vehicle, which would provide visual cues as to the R2X’s potential driving behavior, reducing confusion.

iii. Rear Visibility (Backup Camera) Requirement

FMVSS No. 500, S5(b)(11), requires that all LSVs “comply with the rear visibility requirements specified in paragraph S6.2 of FMVSS No. 111 [Rear visibility].” This requirement states that vehicles to which it applies must be equipped with a rear visibility (i.e., backup camera) system that produces an image of the area immediately behind the vehicle under specified test conditions. The standard includes a number of provisions that are designed to minimize the risk of backover crashes, such as requirements for minimum image size and quality.\textsuperscript{26}

Nuro states that the R2X meets the “field of view” and “image size” requirements for rear visibility systems (FMVSS No. 111, S6.2.1–2),\textsuperscript{27} but requests an exemption from the “linger time” and “deactivation” requirements (FMVSS No. 111, S6.2.4–5), which require that the rear visibility image be deactivated under certain specified conditions.

Nuro argues that exemption the R2X from the “linger time” and “deactivation” requirements would not unreasonably lower the safety of the vehicle because those requirements are intended to address a safety need that would not exist for the R2X. According to Nuro, the aspect of the “linger time” and “deactivation” requirements that is relevant to its request is that they both specify that the rear visibility image not be displayed when certain conditions are met. According to Nuro, the purpose of these requirements is to protect against the possibility that a driver would be distracted by the rear visibility image when travelling in the forward direction. Nuro states that this risk would not exist for the R2X because the R2X’s ADS is not susceptible to distraction. Moreover, Nuro states that compliance with these requirements would be detrimental to the safety of the R2X, because compliance would require the R2X’s rear-facing camera and sensors to be deactivated under certain conditions, effectively partially blinding the ADS.

In addition, while Nuro states that the R2X would meet the “field of view” and “image size” requirements, Nuro requests an exemption from four of the conditions in the test procedures that are used to verify compliance with those requirements because, according to Nuro, the R2X’s various unconventional design features would make the test conditions impossible to perform. These four test conditions are “fuel tank loading” (S14.1.2.2), “driver’s seat positioning” (S14.1.2.5), “steering wheel adjustment” (S14.1.7), and a portion of the “image response time test procedure” (S14.2). Although Nuro requests exemptions from these conditions, Nuro also suggests ways in which each of these four test conditions could be modified so that compliance could be verified using the R2X’s remote operation capability. The following table summarizes Nuro’s explanations for why these four required test conditions cannot be achieved with the R2X, and describes Nuro’s suggestions for modifying the test conditions for the purpose of compliance verification:

\textsuperscript{25} We note that NHTSA stated in the final rule establishing FMVSS No. 500 that the agency had decided to require LSVs to use passenger vehicle glazing (as opposed to other materials that may be more durable) due to concerns that the visibility provided by other materials might degrade over time. 63 FR at 33211.

\textsuperscript{26} 79 FR 19177.

\textsuperscript{27} Nuro’s basis for stating that the R2X meets the Field of View and Image Size requirements is that the vehicle’s extensive array of cameras and sensors “display” a constant live image of the entire area surrounding the vehicle to the ADS, including the area behind the vehicle that must be displayed by the rear visibility system. Nuro provides an illustration of the area observed by the R2X’s rear-facing camera, which includes the area that must be displayed per FMVSS No. 111.

In order to petition successfully under the low-emission vehicle exemption basis, the vehicle for which exemption is sought must meet the definition of "low-emission motor vehicle" at 49 U.S.C. 30113(a), meaning that it must be "a motor vehicle meeting the standards for new motor vehicles applicable to the vehicle under section 202 of the Clean Air Act when the vehicle is manufactured and emitting an air pollutant in an amount significantly below one of those standards." 28

Nuro argues that its vehicle would meet that definition:

The R2X is a zero-emission vehicle. It will emit no hydrocarbons, carbon monoxide, oxides of nitrogen, or particulate matter, which are four of the air pollutants regulated under the Clean Air Act. Its emissions are therefore significantly below the Clean Air Act standards. 28

Nuro Petition, at 5.

Table 2

<table>
<thead>
<tr>
<th>Required Test Condition</th>
<th>Reason it cannot be achieved</th>
<th>Proposed Modification</th>
</tr>
</thead>
<tbody>
<tr>
<td>S14.1.2.2 “Fuel tank loading.”</td>
<td>The R2X would be an electric vehicle runs on a charge in a battery, not on fuel in a fuel tank.</td>
<td>Conduct the test with the battery at full charge capacity.</td>
</tr>
<tr>
<td>S14.1.2.5 “Driver’s seat positioning.”</td>
<td>The R2X would not have a driver’s seat or designated seating position of any kind.</td>
<td>Treat a remote operator’s seat as the driver’s seating position.</td>
</tr>
<tr>
<td>S14.7 “Steering wheel adjustment.”</td>
<td>The R2X would not have a steering wheel.</td>
<td>Conduct the test with the wheels pointed in the forward direction, as would be consistent with the test state in the standard.</td>
</tr>
<tr>
<td>S14.2 “Image response time test procedure.”</td>
<td>The R2X would not have a driver’s door to open or close.</td>
<td>Perform the test procedure using the cargo compartment doors, which are the primary method for accessing the interior of the R2X.</td>
</tr>
</tbody>
</table>

28 Motor vehicle,” for Clean Air Act purposes, means “any self-propelled vehicle designed for transporting persons or property on a street or highway,” so it appears that the R2X would qualify. 42 U.S.C. 7550.

29 Nuro Petition, at 7.

e. Why Nuro Believes That Granting Its Petition Would Be in the Public Interest

Nuro argues that an exemption would be in the public interest because it states that the R2X would incorporate several design features to enable the ADS to operate reliably, and to minimize safety risks that may occur if the ADS malfunctions or otherwise encounters a driving situation it cannot handle. Further, according to Nuro, by allowing the company to develop a safer ADS, an exemption would lead to downstream environmental improvements and economic productivity.

i. ADS Safety

Throughout its petition, Nuro describes several design features or characteristics that it says illustrate the high level of safety that the R2X’s ADS would provide. First would be the ADS’s maneuvering capability. Nuro argues that the R2X’s low GVWR, combined with the absence of human passengers, would make the R2X capable of stopping or performing emergency maneuvers that are not possible for heavier vehicles with passengers. Moreover, Nuro states that the fact that the R2X would not have any human occupants means that it “has the unique opportunity to prioritize the safety of humans, other road users, and occupied vehicles over its own contents and chassis.” 30 We note, however, that the petition does not provide information regarding the quality of the ADS’s decision-making process when performing the driving task.

Nuro also states that the R2X would continuously perform self-diagnostics of vehicle systems. Nuro further states that safety-critical vehicle systems, including computing, steering, braking, and sensing systems would include redundancies for reliability, so that if a system or critical piece of equipment failed, the vehicle (including the ADS) would be able to continue operation. In the event that the R2X experienced a malfunction, the ADS’ programming would enable it to identify and pull over to a safe location nearby. Nuro states that the ADS would continuously map the area surrounding the R2X to track pull over locations, and that, should the R2X’s sensors fail, the ADS would pull the vehicle over using a trajectory calculated with data collected before the failure.

In addition to these on-board features, Nuro states that the R2X would at all times be monitored by “experienced human operators who are extensively trained in the vehicle’s systems,” and would be able to take over driving control from the ADS if needed. 31

According to Nuro, these remote

30 Nuro petition, at 5.

31 Training program described in the VSSA.
operators would play a similar backup safety role as safety drivers utilized in other ADS vehicle testing programs. Nuro states that situations in which a human operator might take over include the detection of a sensor malfunction, a “pullover event,” or the alerting by the ADS of the remote operator that it has encountered a situation for which human operator control is recommended. Nuro states that the remote operation system would ensure connection reliability by using “several redundant, independent cellular connections with end-to-end encryption.” Moreover, Nuro states that the R2X would avoid areas known to have weak cellular service by relying on Nuro’s custom-built maps.

Nuro also identifies additional design features that it states would further support the safe operation of the ADS. For example, Nuro states that a number of vehicle components, including the braking system, would perform at the same level as full-speed passenger cars. In addition, Nuro states that the R2X would be equipped with a sound generator to alert other road users to the vehicle’s presence and intent. These sounds are designed to mimic an internal combustion engine, and modulate based on the driving actions the R2X would take to indicate when the vehicle is accelerating and/or slowing down.

ii. Environmental and Economic Benefits

Nuro provides two additional non-safety based arguments for why granting its petition would be in the public interest. First, Nuro argues that the R2X would provide environmental benefits by reducing pollution. According to Nuro, the electricity that would power the R2X can come from a wide-variety of sources, including alternative fuels, and because the deliveries it would displace are trips that would otherwise likely be made in gasoline-powered privately-owned passenger vehicles. Nuro believes that the R2X could also decrease the number of total trips by efficiently combining trips. Nuro, however, does not provide further information about the capabilities of the R2X’s propulsion system, such as its battery life, range, or efficiency. Second, Nuro argues that the R2X would increase economic productivity by, among other things, providing businesses with an additional option for delivering goods to local customers. These justifications are discussed in further detail in Nuro’s petition.

IV. Agency Review

NHTSA has not yet made any judgment on the merits of Nuro’s petition nor on the adequacy of the information submitted. NHTSA will assess the merits of the petition after receiving and considering the public comments on this notice and the petition and responses to the questions in this notice, as well as any additional information that the agency receives from Nuro. NHTSA is placing a non-confidential copy of the petition in the docket in accordance with statutory and administrative provisions. The agency will update the docket with any additional information it receives from Nuro and will extend or reopen the comment period for this petition as needed.

V. Terms

Once a manufacturer receives an exemption from the prohibitions of 49 U.S.C. 30112(a)(1), NHTSA can affect the use of those vehicles produced pursuant to the exemption only to the extent that NHTSA either has set terms in partially or fully granting the exemption or exercises its enforcement authority (e.g., its safety defect authority). The agency’s authority to set terms is broad. Since the terms would be the primary means of monitoring and affecting the safe operation of the exempted vehicles, the agency would consider carefully whether to establish terms and what types of terms to establish if it were to grant a petition. The manufacturer would need to agree to abide by the terms set for that exemption in order to begin and continue producing vehicles pursuant to that exemption.

Nothing in either the statute or implementing regulations limits the application of these terms to the period during which the exempted vehicles are produced. NHTSA could set terms that continue to apply to the vehicles throughout their normal service life if it deems that such application is necessary to serve the interests of safety. Thus, if NHTSA were to grant an exemption, in whole or in part, it could establish, for example, reporting terms to ensure a continuing flow of information to the agency throughout the normal service life of the exempted vehicles, not just during the two-year period of exemption. Given the uniqueness of Nuro’s vehicle, its petition, the myriad of public safety concerns surrounding an occupant-less vehicle operating on public roads, and the fact only a small portion of the total mileage that the vehicles (if exempted) could be expected to travel during their normal service life would have been driven by the end of the exemption period, NHTSA could require data to be reported over a longer period of time to enable the agency to make sufficiently reliable judgments. Such judgments might include those made in a retrospective review of the agency’s determination about the anticipated safety effects of the exemption.

NHTSA could also establish terms to specify what the consequences would be if the flow of information were to cease or become inadequate during or after the exemption period. Other potential terms could include limitations on vehicle operations (based upon ownership and management, identified aspects of the operational design domains (ODD) such as speed, weather, road types, etc.). Conceivably, some terms could be graduated, i.e., restrictions could be progressively relaxed after a period of demonstrated safe driving performance. Further, as with data-sharing, it may be necessary to specify that these terms would apply to the exempted vehicles beyond the two-year exemption period.

NHTSA notes that its regulations at 49 CFR part 555, “Temporary exemption from motor vehicle safety and bumper standards,” provides that the agency can revoke an exemption if a manufacturer fails to satisfy the terms of the exemption. NHTSA could also seek injunctive relief.

VI. Request for Comments and Information

NHTSA has set forth below a list of questions to elicit public feedback to aid the agency in determining how to address and resolve the variety of novel and important issues presented in the petition and how to promote, through the setting of terms, the safe operation of such vehicles if the agency ultimately decides to grant an exemption. Please note that answers supported by data and analysis will be given greater weight.

Nuro is also encouraged to submit any supplemental information to the agency that the petitioner may deem persuasive. Commenters are requested to provide specific references to all sources for all studies, data, assumptions, scientific reasoning, and methodology they cite or submit.

Statutory Basis for Exemption

The choice of the basis for an exemption petition can significantly affect the scope and depth of the safety analysis and finding that NHTSA must make in order to grant an exemption. In view of this, the agency asks the following questions:
Safety—Exempted Standards

11. Is Nuro correct in its conclusion that the safety purposes of the three requirements from which it is requesting an exemption are not relevant to the R2X because it would not have any occupants? Do these requirements serve any safety purposes beyond those discussed in the petition?

12. Regarding the rear visibility requirement, how would the agency assess whether the R2X actually would meet the “field of view” and “image size” requirements?

Safety—Performance of the ADS

13. To what degree could the R2X’s capabilities or ODD be changed through post-deployment software updates over the lifetime of the R2Xs for which Nuro is seeking an exemption? While Nuro states that it does not intend to “upgrade” the R2X’s ADS to L5, are there ODD or other changes Nuro should be able to make to the R2X over the lifetime of the vehicles? How should NHTSA address the possibility of such changes in conducting its safety analysis?

14. Did Nuro provide sufficient information about how the R2X would interact with human-controlled vehicles on the road? Should the agency be concerned about the front-end stiffness of the R2X and its impact on collision partners?

15. Did Nuro provide enough information about its design features to enable the ADS to operate reliably and to minimize safety risks that may occur if the ADS malfunctions or otherwise encounters a driving situation it cannot handle? If not, what should the agency ask to see?

16. Did Nuro provide enough information on development and testing to support the safety performance of the vehicle? Should more specificity on the types of sensors and their limitations be provided?

17. Did Nuro provide enough information about pedestrian detection and mitigation strategies? Would the R2X be able to sense and respond appropriately around school buses, emergency vehicles, neighborhood construction, etc.? Would the R2X be able to understand traffic laws?

18. What communication protocols should the R2X follow when faced with unexpected human interactions, such as being pulled over by a police officer or being directed through a construction zone by a road worker?

19. How should the R2X’s ADS “prioritize” the safety of other road users?

20. What importance should NHTSA place on Nuro’s statement that some safety-critical components in the R2X perform at the levels required under the FMVSS, even though those requirements are not applicable to LSVs?

21. Would the pedestrian safety features described in the petition (rounded edges, pedestrian “crumple zones”) be effective in the environment in which the R2X would be used? Can the effectiveness of these measures be validated? If so, should NHTSA require Nuro to provide testing data to demonstrate the effectiveness of these measures?

22. Did Nuro’s petition provide enough information regarding what types of “trigger” events would require the remote operator to take over? What sorts of events should “trigger” the remote operator to take over? Should these be specifically articulated as a term if the petition is granted? If so, did the petition provide sufficient information for the agency to establish such terms?

23. What additional situations and risk events (e.g., weather) should NHTSA consider when assessing the safe operation of the vehicle?

24. Would the various fail-safe protocols described in the petition provide a sufficient level of safety? What criteria/methodology should be used to assess their sufficiency? If the protocols are believed to be sufficient, explain why. If the protocols are not believed to be sufficient, explain why and discuss how the fail-safe protocols could be improved to deal with both expected and unexpected situations and events, so that they would provide a sufficient level of safety?

25. Did Nuro provide sufficient information concerning the training of the remote operators? What should be the level of training of remote operators? How should they be trained? How should they be evaluated?
26. How should remote operators “monitor” the R2X’s operation to detect reductions in or complete losses of its ADS’ functionality (i.e., could they observe the R2X’s sensor readings in real time, or would they simply wait for the ADS to send an alert)? How much discretion should the remote operator have in deciding whether to take control or decommission the vehicle? For the range of circumstances in which the remote operator is free to exercise discretion, what guidance should Nuro provide regarding whether it would be appropriate to take control?

27. Nuro states, if it receives the exemptions, it “would take a highly incremental and controlled approach to deployment” which would include extensive evaluation and mapping of any area where the vehicles would be deployed, and that “any early on-road tests would occur with human-manned professional safety drivers with override abilities supervising the vehicle for any anomalies in behavior.”32 Over what portion of the R2X’s life would this level of supervision be provided? What would be the circumstances under which Nuro would reduce or eliminate its supervision? Once this initial testing period is over, what is the expected ratio of remote operators to R2Xs, and would this ratio change over time? What would be the human oversight protocol for the R2X once it is past the initial testing stage?

28. How frequently should Nuro update its maps for accuracy, especially with regard to the reliability of cellular data? What other information is mapped?

29. How should Nuro address the issue of the potential effects of cyber threats on safety? In particular, is Nuro’s assurance of “end-to-end encryption” sufficient for the agency to grant an exemption? If not, what additional assurances should Nuro provide?

30. Are there any additional safety considerations that the agency should analyze in deciding whether to grant Nuro’s petition?

Other Public Interest Considerations

31. We seek comment on whether the potential environmental and economic benefits described by Nuro in its petition are sufficient (or sufficiently likely to occur) to enable NHTSA to make a finding that an exemption is in the public interest and is consistent with the Safety Act, per 49 U.S.C. 30113(b)(3)(A).

32. In particular, we seek comment on whether a petitioner under the low-emission vehicle exemption basis must cite benefits that are directly related to the original purpose of 30113(b)(3)(B)(ii), which was to encourage the development of vehicles with low-emission propulsion technologies.33

Terms

33. If NHTSA were to grant Nuro’s petition, what would be the potential utility of NHTSA’s placing terms requiring the submission of the following categories of data?

a. Statistics on use (e.g., for each functional class of roads, provide the number of miles, speed and hours of operation, climate/weather and related road surface conditions).

b. Statistics and other information on performance (e.g., type, number, and causes, and results of collisions or near misses, disengagements, and transitions to fallback mechanisms, if appropriate). How can the term “near miss” be defined so that there is uniform understanding of the term and consistent practices across manufacturers in the identifying and reporting of “near misses”?

c. Metrics that the manufacturer is tracking to identify and respond to progress toward higher levels of safety (e.g., miles without a crash and software updates that increase the ODD).

d. Information related to measures to be taken by Nuro to address community, driver and pedestrian awareness, behavior, concerns, and acceptance related to vehicles with an ADS.

e. Metrics or information concerning the durability of the ADS equipment and calibration, and need for maintenance of the ADS. For example, does the ADS work in all identified operating conditions or are there additional limitations? How are any limitations addressed and managed?

f. Data on the initial and subsequent ODDS and software updates.

g. For all categories of information, how should any concerns about confidentiality business information and privacy be addressed?

34. If there are other categories of data that should be considered, please identify them and the purposes for which they would be useful to the agency in carrying out its responsibilities under the Safety Act.

35. If the agency were to require the reporting of data, for what period should the agency require it to be reported—the two-year exemption period, the R2X’s entire normal service life, or a time period in between?

36. Given estimates that vehicles with high and full driving automation would generate terabytes of data per vehicle per day, how should the need for data be appropriately balanced with the burden on manufacturers of providing and maintaining it and the ability of the agency to absorb and use it effectively?

37. If supporting information (including analysis, methodology, data, and computer simulation results involving proprietary systems or specialized computer programs) were submitted by Nuro under a request for confidential treatment and relied upon by the agency in its determination whether to grant or deny a petition, how can the public be provided with an evaluation and a justification for the determination that are transparent, readily understandable and persuasive?

38. Are there any mechanisms that may help further mitigate the underlying safety risks, if any, that might result from granting this petition? For example, what additional safety redundancies, if any, should NHTSA consider requiring as a condition to granting the exemption?

39. In the absence of information demonstrating the safe real-world operation of the Nuro vehicle, would it be prudent for NHTSA to place terms on the exemption to protect public safety? If so, what terms would be appropriate? In addition, what terms, if any, should the agency consider placing on an exemption to facilitate agency efforts to monitor the operations of exempted vehicles, and maximize the learning opportunities presented by the on-road experience of the exempted vehicles during the exemption period and thereafter?

VII. Comment Period

The agency seeks comment from the public on the merits of Nuro’s petition for a temporary exemption from three requirements in FMVSS No. 500, “Low-speed vehicles.” We are providing a 60-day comment period. After considering public comments and other available information, we will publish a notice of final action on the petition in the Federal Register.

Please note that even after the comment closing date, we will continue to file relevant information in the docket as it becomes available. Further, some people may submit late comments. Accordingly, we recommend that you periodically check the Docket for new material. You can arrange with the docket to be notified when others file comments in the docket. See www.regulations.gov for more information. We will reopen or extend the comment period for this petition, as needed.
SUMMARY: In accordance with the procedures in the Temporary Exemption from Motor Vehicle Safety and Bumper Standards, General Motors, LLC (GM) has applied for a temporary exemption for its driverless “Zero-Emission Autonomous Vehicle” (ZEAV), an all-electric vehicle with an Automated Driving System (ADS), from part of each of 16 Federal Motor Vehicle Safety Standards (FMVSS). The ZEAVs would not be equipped with a steering wheel, manually-operated gear selection mechanism, or foot pedals for braking and accelerating. If the requested exemption were granted, GM would use the ZEAVs to provide on-demand mobility services in GM-controlled fleets.

GM requests the exemption be granted on either or both of two statutory bases: That it would facilitate the development or field evaluation of a new motor vehicle safety feature providing a level of safety at least equal to those of FMVSS from which exemption is requested, or that it would facilitate the development or field evaluation of a low-emission vehicle without unreasonably lowering the safety performance of the vehicle.

NHTSA seeks comment on the merits of and most appropriate statutory basis for GM’s exemption petition and whether the petition satisfies the substantive requirements for an exemption.
DEPARTMENT OF TRANSPORTATION

National Highway Traffic Safety Administration

49 CFR Part 571

[Docket No. NHTSA–2018–0009]

Removing Regulatory Barriers for Vehicles With Automated Driving Systems

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

ACTION: Request for comment (RFC).

SUMMARY: NHTSA seeks public comments to identify any regulatory barriers in the existing Federal Motor Vehicle Safety Standards (FMVSS) to the testing, compliance certification and compliance verification of motor vehicles with Automated Driving Systems (ADSs) and certain unconventional interior designs. NHTSA is focusing primarily, but not exclusively, on vehicles with ADSs that lack controls for a human driver; e.g., steering wheel, brake pedal or accelerator pedal. The absence of manual driving controls, and thus of a human driver, poses potential barriers to testing, compliance certification and compliance verification. For example, many of the FMVSS refer to the “driver” or “driver’s seating position” in specifying where various vehicle features and systems need to be located so that they can be seen and/or used by a person sitting in that position. Further, the compliance test procedures of some FMVSS depend on the presence of such things as a human test driver who can follow instructions on test driving maneuvers or a steering wheel that can be used by an automated steering machine. NHTSA also seeks comments on the research that would be needed to determine how to amend the FMVSS in order to remove such barriers, while retaining those existing safety requirements that will be needed and appropriate for those vehicles. In all cases, the Agency’s goal would be to ensure the maintenance of currently required levels of safety performance. These comments will aid the Agency in setting research priorities as well as informing its subsequent actions to lay a path for innovative vehicle designs and technologies that feature ADSs.

DATES: Comments are due no later than March 5, 2018.

ADDRESSES: Comments must refer to the docket number above and be submitted by one of the following methods:

• Federal eRulemaking Portal: Go to http://www.regulations.gov. Follow the online instructions for submitting comments.

• Mail: Docket Management Facility, M–30, U.S. Department of Transportation, West Building, Ground Floor, Room W12–140, 1200 New Jersey Avenue SE, Washington, DC 20590.

• Hand Delivery or Courier: U.S. Department of Transportation, West Building, Ground Floor, Room W12–140, 1200 New Jersey Avenue SE, Washington, DC, between 9 a.m. and 5 p.m. Eastern time, Monday through Friday, except Federal holidays.

• Fax: 202–493–2251.

Regardless of how you submit your comments, you must include the docket number identified in the heading of this notice.

Note that all comments received, including any personal information provided, will be posted without change to http://www.regulations.gov. Please see the “Privacy Act” heading below. You may call the Docket Management Facility at 202–366–9324.

Docket: For access to the docket to read background documents or comments received, go to http://www.regulations.gov or the street address listed above. We will continue to file relevant information in the Docket as it becomes available.

Privacy Act: In accordance with 5 U.S.C. 553(c), DOT solicits comments from the public to better inform its decision-making process. DOT posts these comments, without edit, including any personal information the commenter provides, to http://www.regulations.gov, as described in the system of records notice (DOT/ALL–14 FDMS), which can be reviewed at https://www.transportation.gov/privacy. Anyone can search the electronic form of all comments received into any of our dockets by the name of the individual submitting the comment (or signing the comment, if submitted on behalf of an association, business, labor union, etc.).

FOR FURTHER INFORMATION CONTACT:


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I. Overview

NHTSA wants to avoid impeding progress with unnecessary or unintended regulatory barriers to motor vehicles that have Automated Driving Systems (ADS) and unconventional designs, especially those with unconventional interior designs. These barriers may complicate or may even make impossible the testing and certification of motor vehicles. At this stage, the Agency is primarily, but not exclusively, concerned with vehicles with ADSs that do not have the means for human driving, e.g., a steering wheel and brake and accelerator pedals. NHTSA is also interested in the additional testing and certification problems for vehicles with ADSs and with seating or other systems that have multiple modes, such as front seats that rotate. Some FMVSS, therefore, may pose barriers to the testing and certification of those vehicles. To enable vehicles with ADSs and with unconventional interiors while maintaining those existing safety requirements that will be needed and appropriate for those vehicles, NHTSA is developing plans and proposals for removing or modifying existing regulatory barriers to testing and compliance certification in those areas for which existing data and knowledge are sufficient to support decision-making. In other areas, plans and proposals cannot be developed until the completion of near-term research to determine how to revise the test procedures for those vehicles. In all
cases, the Agency’s goals would be to ensure that the safety performance currently required by the FMVSS is as effective and needed for safety in vehicles with unconventional interiors (or exteriors) as in conventionally-designed vehicles.

The Agency is mindful that, in some cases, the most appropriate response to an existing requirement in a FMVSS that may complicate or may even make impossible to test a motor vehicle to assess compliance with that requirement may not be to ask how the requirement can be adapted to apply to motor vehicles without manual driving controls. Instead, a more appropriate response may be to ask whether the requirement should be applied in any form to those motor vehicles. These requirements may serve a safety purpose in vehicles with manual driving controls, but may not in vehicles without such means of control. For example, there may not be any need to require that the telltales and other displays in a vehicle that does not have any manual driving controls be visible either to the occupant of a particular seating position or even to any occupant at all. In addition, some requirements may serve a safety purpose in vehicles that carry human occupants, but not in vehicles that will not carry any occupants.

To these ends, NHTSA is soliciting public comments on (1) the barriers identified thus far, (2) any as of yet unidentified, barriers, (3) whether the requirements or test procedures creating those barriers should be modified to eliminate the testing difficulties or should simply be amended so that the requirements do not apply to vehicles without means of manual control, (4) the research that needs to be done to determine how to remove some of the barriers; (5) and how to prioritize this research and any follow-on rulemaking proceedings.

This input will help NHTSA to plan and undertake more comprehensive and strategic efforts to remove barriers and to develop a stronger, more collaborative research plan that will complement research by the motor vehicle industry and other stakeholders. This will enable the Agency to use its resources as efficiently as possible in moving toward eliminating potential regulatory barriers to innovation.

II. Automation Revolution

Automotive transportation is evolving faster today than it has at any time since the introduction of the first motor vehicle. Artificial intelligence, combined with rapid improvements in sensors, such as cameras, lidar, and radar, is beginning to enable motor vehicles to drive themselves.

The introduction of vehicles with ADSs into the fleet has the potential to reduce injuries, the loss of life, and property damage, reduce congestion, enhance mobility, and improve productivity. NHTSA anticipates that automation can serve a vital safety role given that human error or choice are estimated to be the critical reason in 94 percent of crashes. In the best of circumstances, people make errors in judgment or action. In the best of circumstances, humans drive or make error in judgment or action. Many people drive less favorably in circumstances as a result of the choices they make. Despite decades of efforts by NHTSA, States, local jurisdictions, safety groups, and industry, many people continue to choose to drive when they are fatigued, intoxicated, speeding, unbelted, or distracted. To the extent that ADSs are able to support and perhaps eventually replace human drivers, human error and unsafe choices would likely be reduced as causes of crashes. As the Federal agency whose primary mission is to reduce motor vehicle related deaths and injuries, NHTSA is excited about these prospects and is working with industry and other stakeholders to help make them a reality.


Part of NHTSA’s responsibility in carrying out its safety mission is not only to develop and set new safety standards for new motor vehicles and motor vehicle equipment, but also to modify existing standards as necessary to respond to changing circumstances such as the introduction of new technologies. Some old standards or portions of standards may no longer be needed or at least need to be updated to keep them relevant. Examples of previous technological transitions that triggered the need to adapt and/or replace requirements in the FMVSS include the replacing of analog dashboards by digital ones, the replacing of mechanical control systems by electronic ones and then by wireless ones, and the first production of electric vehicles in appreciable numbers.

The existing FMVSS can be found in the Code of Federal Regulations at 49 CFR part 571. NHTSA has over 60 FMVSS today. The FMVSS specify minimum performance requirements and test procedures for brake, seat belt, airbag, and other components. Manufacturers are prohibited from selling vehicles and vehicle equipment unless they comply with all applicable FMVSS and their compliance has been self-certified by their manufacturer.

Almost all of NHTSA’s FMVSS were developed and established well before vehicles with ADSs became practicable possibility. As a result, the performance requirements and test procedures in many of the FMVSS are based on the assumption that the driver

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1. As defined in FMVSS No. 101, Control and Displays, “telltales mean an optical signal that, when illuminated, indicates the actuation of a device, a correct or improper functioning or condition, or a failure to function.”

2. Lidar (light detection and ranging) is a type of sensor that continually fires beams of laser light, and then measures how long it takes for the light to return to the sensor. The measurements are used to create three-dimensional images of a vehicle’s surroundings, everything from cars to cyclists to pedestrians to fixed objects like poles and trees, in a variety of environments and under a variety of lighting conditions.


4. The National Motor Vehicle Crash Causation Survey (NMVCCS), conducted from 2005 to 2007, was aimed at collecting on-scene information about the events and associated factors leading up to crashes involving light vehicles. Several factors of crash occurrence were investigated during data collection, namely the pre-crash movement, critical pre-crash event, critical event, and the associated factors. A weighted sample of 5,470 crashes was investigated over a period of two and a half years, which represents an estimated 2,189,000 crashes nationwide. About 4,031,000 vehicles, 3,945,000 drivers, and 1,382,000 passengers were estimated to have been involved in these crashes. The critical reason, which is the last event in the crash causal chain, was assigned to the driver in 94 percent (±2.2%) of the crashes. In about 2 percent (±0.7%) of the crashes, the critical reason was assigned to a vehicle component’s failure or degradation, and in 2 percent (±1.1%) of crashes, it was attributed to the environment (slick roads, weather, etc.). Among an estimated 2,046,000 drivers who were assigned critical reasons, recognition errors accounted for about 41 percent (±1.5%), decision errors 37 percent (±3.7%), and performance errors 11 percent (±2.7%) of the crashes. A fact sheet containing more detail can be found at https://crashstats.nhtsa.dot.gov/Api/Public/ViewPublication/812115.

5. 70 FR 48295 (August 17, 2005).

6. 60 FR 62061 (December 4, 1995).

7. See, e.g., 59 FR 11004 [March 9, 1994] and 59 FR 49901 [September 30, 1994].

will be human, will sit in the vehicle’s left front seat to drive (in left-hand drive vehicles), and will need certain controls to be accessible and telltales and other displays to be viewable in order to do the driving. A further and even more basic assumption is that there will be at least one occupant in each vehicle. In the case of ADS delivery vehicles without manual driving controls, this assumption may prove incorrect. If, instead, a vehicle is designed so that only an ADS can drive it and vehicle designers modify the passenger compartment to take advantage of the flexibility afforded them if a human driver is not needed, then many of those assumptions will likely be invalid for that vehicle, and some may be actually problematic from a testing perspective.

NHTSA has set out below some illustrative examples of potential problems with the existing FMVSS. The Agency requests commenters to identify other potential problems.

- If the FMVSS can no longer specify where controls and displays are located by requiring them to be visible to or within the reach of a person sitting in the driver’s seat, then it is unclear for which person or persons in which seating position or positions must they be visible to or within the reach of or even if they are necessary at all.
- After the barriers to determining compliance are removed from the FMVSS, the Agency will turn to other closely related questions such as whether there is a continued need for certain current performance requirements in the FMVSS. For example, among the questions that the agency would need to address are: Would occupants still need warning telltales and other displays to be viewable if they did not have any means of driving their vehicles? Could there be any risk of adverse safety consequences if some or all of those warnings and messages were not provided to the occupants of those vehicles either before or during trips? If a vehicle, such as an ADS delivery vehicle without manual driving controls, were unlikely to be occupied during trips, would there be any safety need for warning telltales and other displays to be viewable?
- If future vehicles with ADSs lack any means of human control, it is unclear how the Agency and the manufacturers can conduct compliance tests (such as those for stopping distance) that are currently performed by human test drivers performing prescribed driving maneuvers on test tracks.

- FMVSS No. 126, Electronic stability control systems for light vehicles, specifies the use of an automated steering machine that depends on a vehicle’s steering wheel to steer vehicles when they are tested for compliance. If a vehicle with ADS is not equipped with a steering wheel because the ADS will do all of the driving, the agency would need to determine how to amend the standard to enable the agency to conduct stability control testing and maintain the current level of effectiveness.
- Some vehicles with ADSs may have unique seating configurations that may make it impossible for existing crash protection requirements, test procedures and test devices (e.g., anthropomorphic dummies) to evaluate adequately the level of crashworthiness protection provided.
- There may be other existing performance requirements and test procedures that would fail to accommodate unconventional designs. If there are, the Agency will need to identify them and determine how the Agency should amend them in ways to maintain the current level of effectiveness.
- There may be some safety attributes or testing procedures that will no longer have sufficient value in a vehicle whose usage is anticipated to be predominantly automated, but still retains manual driving controls.

The Agency wishes to address these issues (and many others) in the coming months and years. We anticipate doing so publicly, seeking all available research and public input to help us adapt the FMVSS and possibly adopt other measures that are well-calibrated to promote innovation, respond to changing circumstances and address emerging technologies while maintaining safety.

We want to emphasize, in an attempt to ensure that there is not any misunderstanding about the source and nature of the barriers or about the vehicles affected by those barriers, that the FMVSS (or any other kind of legally-binding standards) do not have any provisions designed to address the self-driving capability of a motor vehicle. Further, nothing in the existing FMVSS prohibit ADS. Likewise, nothing in those standards poses testing or certification challenges for vehicles with ADSs so long as the vehicles have means of manual control and conventional seating.

If, however, manufacturers design vehicles with ADSs not only lack manual driving controls, but also have unconventional, flexible seating, i.e., seats that slide and/or rotate, then under the Agency’s line of interpretations involving vehicle systems that have multiple modes, there may be testing or even compliance difficulties. Similar problems might be encountered by vehicles with ADSs equipped with retractable manual driving controls.

Thus, it is not the inclusion of an ADS in a new vehicle that complicates testing and certifying the compliance of the vehicle to the existing FMVSS. Testing and certifying compliance potentially becomes complicated only if a manufacturer wishes to go a step further and design a vehicle with ADS but without a steering wheel, brake pedal and accelerator pedal or with novel configurations or orientations for certain vehicle systems. As noted above, this problem arises because the FMVSS, as currently written, are premised on the presence of means of manual control and on conventional seating configurations and orientations.

Although the Agency may have a degree of flexibility in interpreting some of its existing FMVSS to accommodate innovative interior designs, in most instances, it will be necessary to amend the FMVSS. The FMVSS and the rulemaking process through which they are established and amended are subject to the Administrative Procedure Act, the National Traffic and Motor Vehicle Safety Act (Vehicle Safety Act), other statutes, and various Executive Orders and guidance documents from the Office of Management and Budget. Together, they ensure the FMVSS meet the requirements and goals set by Congress and are adopted only after sufficient opportunities for public participation and careful consideration and analysis of available information and public comments. Under the Vehicle Safety Act, moreover, the FMVSS need to be “objective, practicable, and meet the need for safety” when initially issued and must remain so after being amended. If NHTSA revises a test procedure in an FMVSS to accommodate an innovative new vehicle design, it must make sure that the FMVSS continues to be objective and practicable and meet the need for safety. Accomplishing this goal will, in a number of instances, require research to develop revised test procedures and performance criteria. Defining the needed research and establishing priorities in conducting it is the subject of this RFC.

See, e.g., May 6, 1986 letter to Paul Utans regarding a Sahara with two adjustment positions for suspension—a high one and a low one. In it, NHTSA stated that it reserves the right to activate either mode in conducting compliance tests.

5 U.S.C. 551 et seq.

9 49 U.S.C. 30101 et seq.
IV. Initial Agency Efforts To Identify Testing, Certification and Compliance Verification Issues

NHTSA began the process of evaluating existing FMVSS for potential barriers in August of 2015. In August of that year, NHTSA contracted with DOT’s Volpe Center to conduct a review of the FMVSS and issue a report identifying the standards that pose potential barriers to the introduction of vehicles with ADSs and with unconventional interior designs.

While that review was underway, Google submitted a letter, dated November 12, 2015, requesting an interpretation regarding the application of certain FMVSS to vehicles with ADSs. In describing its ADS vehicle, Google indicated its intent to design the vehicle so that it does not include conventional manual driving controls, including a steering wheel, accelerator, or brake pedal. NHTSA responded to that letter on February 4, 2016.12

In its letter, NHTSA took the position that a motor vehicle’s “self-driving system” (SDS) could be regarded as the driver or that the left front seating position could be regarded as the driver’s position in a variety of standards referencing the “driver” or “driver’s seating position.”

The response then addressed the question of whether and how Google could certify that the SDS meets a standard developed and designed to apply to a vehicle with a human driver. NHTSA said that in order for it to interpret a standard as allowing certification of compliance by a vehicle manufacturer, NHTSA must first have a suitable test procedure or other means of verifying such compliance. That is, NHTSA said that if a FMVSS lacks a test procedure that is capable for the Agency’s use in verifying a manufacturer’s certification of the compliance of some of its vehicles with a FMVSS, the manufacturer cannot validly certify the compliance of those vehicles with the standard. As NHTSA further explained in the letter,

...allowing certification of compliance by a vehicle manufacturer, NHTSA must first have a test procedure or other means of verifying such compliance.

Volpe completed its review of the FMVSS before NHTSA sent its February 4 letter to Google and thus did not consider that letter in conducting its review. The report on the results of the review was published one month later in March 2016.13 (To read the executive summary of the report and a list of the FMVSS identified in the report, please see the appendix at the end of this document.) In that report, Volpe described the two reviews that it conducted of the FMVSS: A driver reference scan to identify which standards include an explicit or implicit reference to a human driver and driving automation concepts scan to identify which standards could pose a challenge for a wide range of driving automation capabilities and concepts. The review revealed that there are few barriers for a vehicle with ADS to comply with the FMVSS; so long as the vehicle does not significantly diverge from a conventional vehicle design. Two standards, FMVSS 114 for theft protection and rollaway prevention and FMVSS 135 for light vehicle brake systems, were identified as having potential issues for vehicles with an ADS and with conventional designs.14

In addition, NHTSA subject matter experts have identified specific requirements and test procedure limitations. NHTSA is initiating new research on the assessment and evaluation of, and solutions to, the preliminary challenges identified in the Volpe report to the testing, compliance verification and self-certification of vehicles with ADSs. Most of these challenges are precipitated by alternative vehicle designs, such as ones lacking manual driving controls. NHTSA’s initial research focuses primarily on the FMVSS compliance test procedures, but will also explore options for telltales, visual and auditory displays and controls and other innovative new vehicle design challenges that may not have been identified in the original Volpe report.

NHTSA has contracted with the Virginia Tech Transportation Institute to perform this research. This is a multidisciplinary project to develop technical translations to existing FMVSS and related testing procedure approaches for emerging innovative and non-traditional vehicle designs. The project is being conducted by a core team comprising FMVSS experts; industry team members General Motors and Nissan; testing facilities Dynamic Research, Inc., and MGA Research Corporation; and research institutions Booz Allen Hamilton and the Southwest Research Institute in concert with stakeholders and peer review groups. The research will review and identify alternative new vehicle designs, develop candidate alternative approaches, and establish an evaluation process as well as associated tools in close collaboration with critical stakeholders. This research project started at the beginning of FY2018 and is expected to develop robust alternative approaches within the next 12 months to demonstrate compliance with many of the identified FMVSS whose existing test procedures present challenges. The results of this research will be made public after the completion of the project.

V. Requests for Comment

To help guide NHTSA’s research to address testing and self-certification issues, we seek comments on the topics below. The Agency urges that, where possible, comments be supported by data and analysis to increase their usefulness. Please clearly indicate the source of such data.

A. Barriers to Testing, Certification and Compliance Verification

1. What are the different categories of barriers that the FMVSS potentially create to the testing, certification and compliance verification of a new ADS vehicle lacking manual driving controls? Examples of barrier categories include the following:

a. Test procedures that cannot be conducted for vehicles with ADSs and with innovative interior designs; and

b. Performance requirements that at the end of a vehicle...
with ADS and thus potentially impose more cost and more restrictions on design than are warranted. As noted earlier in this document, the first of the above categories is the primary focus of this document. However, the Agency seeks comments on both categories of barriers. If you believe that there are still other barrier categories, please identify them.

2. NHTSA requests comments on the statement made in NHTSA’s February 2016 letter of interpretation to Google, that if a FMVSS lacks a test procedure that is suitable for the Agency’s use in verifying a manufacturer’s certification of compliance with a provision in that FMVSS, the manufacturer cannot validly certify the compliance of its vehicles with that provision. Do commenters agree that each of the standards identified in the letter as needing to be amended before manufacturers can certify compliance with it must be amended in order to permit certification? Why or why not? If there are other solutions, please describe them.

3. Do you agree (or disagree) that the FMVSS provisions identified in the Volpe report or Google letter as posing barriers to testing and certification are, in fact, barriers? Please explain why.

4. Do commenters think there are FMVSS provisions that pose barriers to testing and certification of innovative new vehicle designs, but were not covered in the Volpe report or Google letter? If so, what are they, how do they pose barriers, and how do you believe NHTSA should consider addressing them?

5. Are there ways to solve the problems that may be posed by any of these FMVSS provisions without conducting additional research? If so, what are they and why do you believe that no further research is necessary? For example, can some apparent problems be solved through interpretation? If so, which ones?

6. Similarly, are there ways to solve the problems that may be posed by any of these FMVSS provisions without rulemaking? For example, can some apparent problems be solved through interpretation without either additional research or through rulemaking? If so, which ones?

7. In contrast, if a commenter believes that legislation might be necessary to enable NHTSA to remove a barrier identified by the commenter, please explain why and please identify the specific existing law that the commenter thinks should be changed and describe how it should be changed. If there are associated regulations that the commenter believes should be changed, please identify the specific CFR citation and explain why they need to be changed.

8. Many FMVSS contain test procedures that are based on the assumed presence of a human driver, and will therefore likely need to be amended to accommodate vehicles that cannot be driven by humans. Other FMVSS test procedures may seem, based on a plain reading of their language, to accommodate vehicles that cannot be driven by humans, but it may nevertheless be unclear how NHTSA (or a manufacturer attempting to self-certify to the test) would instruct the vehicle to perform the test as written.

a. Do commenters believe that these procedures should apply to a vehicle that cannot be driven by a human? If so, why? If there are data to support this position, please provide it.

b. If not, can NHTSA test in some other manner? Please identify the alternative manner and explain why it would be appropriate.

c. Does the answer to the question about the continued need for a telltale or other display to be visible to the occupant of a vehicle without manual driving controls change if a manufacturer equips the vehicle with a device like an “emergency stop button”?

9. What research would be necessary to determine how to instruct a vehicle with ADS but without manual means of control to follow a driving test procedure? Is it possible to develop a single approach to inputting these “instructions” in a manner applicable to all vehicle designs and all FMVSS, or will the approach need to vary, and if so, why and how? If commenters believe there is a risk of gaming, what would that risk be and how could it be reduced or prevented?

10. In lieu of the approaches suggested in questions 8 and 9, is there an alternative means of demonstrating equivalent level of safety that is reliable, objective and practicable?

11. For FMVSS that include test procedures that assume a human driver is seated in a certain seating position (for example, procedures that assess whether a rearview mirror provides an image in the correct location), should NHTSA simply amend the FMVSS to require, for instance, that “driver’s seat” requirements apply to any front seating position? If so, please explain why. If not, what research would need to be conducted to determine how NHTSA should amend those requirements?

12. A variety of FMVSS require safety-related dashboard telltales and other displays, if provided, to be visible to a human driver and controls to be within reach of that driver. Generally speaking, is there a safety need for the telltales and other displays in Table 1 and 2 of FMVSS 101 to be visible to any of the occupants in vehicles without manual driving controls? Commenters are requested to provide their own list of the telltales and other displays they believe are most relevant to meeting any potential safety need in those vehicles. For each item on that list, please answer the following questions:

a. Should the telltale or other display be required to be visible to one or more vehicle occupants in vehicles without manual driving controls?

b. If there is a need for continued visibility, to the occupant(s) of which seating position(s) should the telltale or other display be visible?

c. Does the answer to the question about the continued need for a telltale or other display to be visible to the occupant of a vehicle without manual driving controls change if a manufacturer equips the vehicle with a device like an “emergency stop button”?

13. If NHTSA is going to conduct research to determine whether there is any safety need for the occupants of fully-self-driving vehicles to continue to
have any access to any of the nondriving controls (e.g., controls for windshield washer/wiper system, turn signals and lights) in a vehicle without manual driving controls, what should that research include and how should NHTSA conduct it?

a. If there is a safety need for the occupants of fully-self-driving vehicles to have access to any of the existing vehicle non-driving controls, please identify those controls and explain the safety need.

b. Do commenters believe that research should be conducted to determine whether any additional controls (such as an emergency stop button) might be necessary for safety or public acceptance if manual driving controls are removed from fully-self-driving vehicles? Why or why not, and what is the basis for your belief?

c. If NHTSA is going to conduct research to determine whether there is a safety need for the occupants of fully-self-driving vehicles to continue to be able to control exterior lighting like turn signals and headlamp beam switching devices, what should that research include and how should NHTSA conduct it? Separately, if NHTSA is going to conduct research on what exterior lighting continues to be needed for safety when a human is not driving, what should that research include and how should NHTSA conduct it?

14. If NHTSA is going to conduct research to determine whether there is a safety need for the occupants of vehicles with ADSs but without manual driving controls to be able to see to the side and behind those vehicles using mirrors or cameras, what should that research include and how should NHTSA conduct it? Separately, if NHTSA is going to conduct research to determine how NHTSA would test the ability of a vehicle’s ADS to “see” around and behind the vehicle as well as (or better than) a human driver would, what should that research include and how should NHTSA conduct it?

15. Do the FMVSS create testing and certification issues for vehicles with ADSs other than those discussed above? If so, which FMVSS do so and why do you believe they present such issues? For example, FMVSS No. 108, “Lamps, reflective devices, and associated equipment,” could potentially pose obstacles to certifying the compliance of a vehicle that uses exterior lighting and messaging, through words or symbols, to communicate to nearby pedestrians, cyclists, and motorists, such as at a 4-way stop intersection, the vehicle’s awareness of their presence and the vehicle’s willingness to code priority of movement to any of those people. If research is needed to eliminate the barriers in an appropriate way, please describe the research and explain why it is needed. Are there other lighting issues that should be considered? For example, what lighting will be needed to ensure the proper functioning of the different types of vehicle sensors, especially cameras whose functions include reading traffic control signs?

16. If occupants of vehicles with ADSs, especially those without manual driving controls, are less likely to sit in what is now called the driver’s seating position or are less likely to sit in seats that are facing forward, how should these factors affect existing requirements for crashworthiness safety features?

17. If vehicles with ADSs have emergency controls that can be accessed through unconventional means, such as a smart phone or multi-purpose display and have unconventional interiors, how should the Agency address those controls?

18. Are there any specific regulatory barriers related to small businesses that NHTSA should consider, specifically those that may help facilitate small business participation in this emerging technology?

B. Research Needed To Address Those Barriers and NHTSA’s Role in Conducting it

19. For issues about FMVSS barriers that NHTSA needs research to resolve, do commenters believe that there are specific items that would be better addressed through research by outside stakeholders, such as industry or research organizations, instead of by NHTSA itself?

a. Which issues is industry better equipped to undertake on its own, and why? Which issues are research organizations or other stakeholders better equipped to undertake on their own, and why?

b. What research is needed to determine which types of safety performance metrics should be used to evaluate a particular safety capability and to develop a test procedure for evaluating how well a vehicle performs in terms of those metrics?

c. Which questions is NHTSA better equipped to undertake and why? For example, would NHTSA, as the regulator, be the more appropriate party to conduct research needed to determine what performance threshold to require vehicles to meet with respect to that metric? Why or why not?

d. What research have industry, research organizations, and other stakeholders done related to barriers to testing and certification? What research are they planning to do? With respect to research planned, but not yet completed, please identify the research and state the starting and end dates for that research.

e. How can NHTSA, industry, states, research organizations, and other stakeholders work together to ensure that, if the research on these issues were eventually to lead to rulemaking, it is done with the rigor and thoroughness that NHTSA would need to meet its statutory obligations, regardless of who performs it (e.g., done in a manner that enables the Agency to ensure that the FMVSS continue to be objective and practicable and continue to meet the need for safety)?

20. For the issues identified above or by commenters, which merit the most attention? How should the agency prioritize its research and any follow-on rulemakings to remove the barriers to testing and certification?

21. Correcting barriers associated with the track testing of motor vehicles will be particularly challenging. Examples of such barriers follow:

a. As noted above, FMVSS No. 126 specifies the use of an automated steering machine that depends on a vehicle’s steering wheel to steer vehicles when they are tested for compliance. NHTSA will need to determine how to amend the standard to enable the agency to conduct stability control testing in vehicles that lack a steering wheel. Further, if NHTSA is going to conduct research to consider how to change the “sine with dwell” test procedure for FMVSS No. 126, so that steering wheel angle would not be measured at the steering wheel in determining compliance with the standard, what should that research include and how should NHTSA conduct it?

b. If NHTSA is going to conduct research to develop a performance test to verify how a vehicle is activating its service brakes, what should that research include and how should NHTSA conduct it? If NHTSA is going to conduct research to determine whether there continues to be a safety need to maintain a human-operable service brake, what should that research include and how should NHTSA conduct it?

The purpose of formulating safety performance metrics for motor vehicles is to facilitate the quantitative assessment of their capabilities. An example of a crash avoidance performance metric is the ability of a vehicle with ADS to sense and avoid colliding with a surrogate pedestrian crossing a street on a test course.
22. Are there industry standards, existing or in development, that may be suitable for incorporation by reference by NHTSA in accordance with the standards provisions of the National Technology Transfer and Advancement Act of 1995 and Office of Management and Budget Circular A–119, “Federal Participation in the Development and Use of Voluntary Consensus Standards and Conformity Assessment Activities?”

VI. Public Participation

How do I prepare and submit comments?

Your comments must be written and in English. To ensure that your comments are filed in the correct docket, please include the docket number of this document in your comments.

Your comments must not be more than 15 pages long (49 CFR 553.21). NHTSA established this limit to encourage you to write your primary comments in a concise fashion. However, you may attach necessary additional documents to your comments. There is no limit on the length of the attachments.

Please submit one copy (two copies if submitting by mail or hand delivery) of your comments, including the attachments, to the docket following the instructions given above under ADDRESSES. Please note, if you are submitting comments electronically as a PDF (Adobe) file, we ask that the documents submitted be scanned using an Optical Character Recognition (OCR) process, thus allowing NHTSA to search and copy certain portions of your submissions.

How do I submit confidential business information?

If you wish to submit any information under a claim of confidentiality, you must submit three copies of your complete submission, including the information you claim to be confidential business information, to the Office of the Chief Counsel, NHTSA, at the address given above under FOR FURTHER INFORMATION CONTACT.

In addition, you may submit a copy (two copies if submitting by mail or hand delivery) from which you have deleted the claimed confidential business information, to the docket by one of the methods given above under ADDRESSES. When you send a comment containing information claimed to be confidential business information, you should include a cover letter setting forth the information specified in NHTSA’s confidential business information regulation (49 CFR part 512).

Will NHTSA consider late comments?

NHTSA will consider all comments received before the close of business on the comment closing date indicated above under DATES. To the extent possible, NHTSA will also consider comments received after that date.

How can I read the comments submitted by other people?

You may read the comments received at the address given above under ADDRESSES. The hours of the docket are indicated above in the same location. You may also read the comments on the internet, identified by the docket number at the heading of this notice, at http://www.regulations.gov. Please note that, even after the comment closing date, NHTSA will continue to file relevant information in the docket as it becomes available. Further, some people may submit late comments. Accordingly, NHTSA recommends that you periodically check the docket for new material.


Issued in Washington, DC, on January 10, 2018, under authority delegated in 49 CFR part 1.95.

Heidi King,
Deputy Administrator.

Appendix

1. Executive Summary of the Volpe Report

Review of Federal Motor Vehicle Safety Standards (FMVSS) for Automated Vehicles

Identifying Potential Barriers and Challenges for the Certification of Automated Vehicles Using Existing FMVSS

Preliminary Report—March 2016

Anita Kim, David Perlman, Dan Bogard and Ryan Harrington Technology Innovation and Policy Division

• Current Federal Motor Vehicle Safety Standards (FMVSS) do not explicitly address automated vehicle technology and often assume the presence of a human driver. As a result, existing language may create certification challenges for manufacturers of automated vehicles that choose to pursue certain vehicle concepts.

• The purpose of this work is to identify instances where the existing FMVSS may pose challenges to the introduction of automated vehicles. It identifies standards requiring further review—both to ensure that existing regulations do not unduly stifle innovation and to help ensure that automated vehicles perform their functions safely.

• The review highlighted standards in the FMVSS that may create certification challenges for automated vehicle concepts with particular characteristics, including situations in which those characteristics could introduce ambiguity into the interpretation of existing standards. The review team’s approach was meant to be as inclusive as possible, with the intent to identify standards that would require further review or discussion.

This is a preliminary report summarizing the review of FMVSS and includes a discussion on approach, findings, and analysis. As a preliminary review, the contents of this report reflect the results of an initial analysis and may be modified based on stakeholder input and future discussion.

• The Volpe team conducted two reviews of the FMVSS: a driver reference scan to identify which standards include an explicit or implicit reference to a human driver and an automated vehicle concepts scan to identify which standards could pose a challenge for a wide range of automated vehicle capabilities and concepts.

• The driver reference scan revealed references in numerous standards to a driver (defined in § 571.3 as “... the occupant of the motor vehicle seated immediately behind the steering control system”), a driver’s seating position, or controls and displays that must be visible to or operable by a driver, or actuated by a driver’s hands or feet.

• In order to conduct the automated vehicle concepts scan, the Volpe team developed 13 different automated vehicle concepts, ranging from limited levels of automation (and near-term applications) to highly-automated, driverless concepts with innovative vehicle designs. The idea was to evaluate the FMVSS against these different automated vehicle concepts.

• In summary, the review revealed that there are few barriers for automated vehicles to comply with FMVSS, as long as the vehicle does not significantly diverge from a conventional vehicle design. Two standards: theft protection and rollaway prevention (§ 571.114) and light vehicle brake systems (§ 571.135) were identified as having potential issues for automated vehicles with conventional designs.

• Automated vehicles that begin to push the boundaries of conventional design (e.g., alternative cabin layouts, omission of manual controls) would be constrained by the current FMVSS or may conflict with policy objectives of the FMVSS. Many standards, as currently written, are based on assumptions of conventional vehicle designs and thus pose challenges for certain design concepts, particularly for ‘driverless’ concepts where occupants have no way of driving the vehicle (e.g., § 571.101, controls and displays § 571.111, rear visibility, § 571.206, occupant crash protection represent a few examples).

• Subsequent to the Volpe Center’s review of the FMVSS, but prior to the publication of this report, NHTSA released interpretations to BMW of North America and Google, Inc. in response to questions regarding how to interpret certain FMVSS requirements in the context of automated vehicles. As a result, the review does not reflect this subsequent development. The full text of these interpretations are available in NHTSA’s repository of interpretation files at the website: isearch.nhtsa.gov.”
2. List of Standards Identified in the Volpe Report

In the report, the Volpe Center reported 32 of 63 FMVSS’s that may present certification challenges for certain types of automated vehicles because they contain performance specifications, test procedures, or equipment requirements that present potential barriers to the certification of one or more AV concepts:

1. Conventional Vehicles (with driver controls) with highly-automated features (2 standards identified).
   - key must be in position before moving out of park position, and park position interlock with the service brake (571.114).
   - foot-actuated service brake control, brake system warning indicator, and warning device for lining replacements (571.135).

2. Fully-self-driving vehicles (no driver controls or novel design) (32 standards identified, some examples listed below).
   - controls and displays visible to the driver (571.101).
   - transmission shift position sequence and interlock (571.102).
   - windshield defrosting and defogging (571.103).
   - windshield wipers (571.104).
   - foot-actuated service brake control, brake system warning indicator, and warning device for lining replacements (571.105).
   - turn signal, flasher, headlamp beam switch, and upper beam indicator (571.108).
   - tire/rim retention requirement for driver (571.110).
   - requirements for rear visibility for the driver (571.111).
   - key must be in position before moving out of park position, and park position interlock with the service brake (571.114).
   - powered windows and roof panels (571.116).
   - foot-actuated service brake control, low-pressure brake system warning indicator, and brake adjustment indicators (571.121).
   - motorcycle brake systems (571.122).
   - accelerator pedal must return to neutral when released by the driver (571.124).
   - a steering wheel (a requirement for completing tests) and certain controls and displays (571.126).
   - foot-actuated service brake control, brake system warning indicator, and warning device for lining replacements (571.135).
   - TPMS telltale for low tire pressure to warn driver (571.138).
   - occupant protection in interior impact (571.201).
   - door locks and door retention components (571.206).
   - a designated seating position for the driver (571.207).
   - occupant protection and warning system for non-buckled seat belt (571.208).
   - seat belt anchorages (571.210).
   - side impact protection (571.214).
   - windshield zone intrusion (571.219).
   - child restraint anchorages (571.225).
   - readiness monitor for ejection mitigation countermeasures visible to the driver (571.226).
   - flammability of interior materials (571.302).
   - interior trunk release (571.401).
   - other equipment may pose barriers to certification.

[FR Doc. 2018–00671 Filed 1–17–18; 8:45 am]
eliminate drafting errors and ambiguity, minimize potential litigation, and provide a clear legal standard for affected conduct.

11. Executive Order 12630: Evaluation of Risk and Avoidance of Unanticipated Takings

EPA has complied with Executive Order 12630 (53 FR 8859, March 18, 1988) by examining the takings implications of this action in accordance with the Attorney General’s Supplemental Guidelines for the Evaluation of Risk and Avoidance of Unanticipated Takings issued under the executive order.

12. Executive Order 12898: Federal Actions To Address Environmental Justice in Minority Populations and Low Income Populations

Because this rulemaking proposes authorization of pre-existing state rules and imposes no additional requirements beyond those imposed by state law and there are no anticipated significant adverse human health or environmental effects, the proposed rule is not subject to Executive Order 12898 (59 FR 7629, February 16, 1994).

13. Executive Order 13771: Reducing Regulations and Controlling Regulatory Costs

This action is not an Executive Order 13771 (82 FR 9339, February 3, 2017) regulatory action because actions such as today’s final authorization of Michigan's revised hazardous waste management program under RCRA are exempted under Executive Order 12866.

List of Subjects in 40 CFR Part 271

Environmental Protection; Administrative practice and procedure, Confidential business information, Hazardous materials transportation, Hazardous waste, Indians-lands, Intergovernmental relations, Penalties, Reporting and recordkeeping requirements.

Authority: 42 U.S.C. 6905, 6912(a), 6926, and 6939g.

Dated: September 18, 2018.

Cathy Stepp,
Regional Administrator, Region 5.

ENVIRONMENTAL PROTECTION AGENCY

40 CFR Part 721

[EAH—HQ—OPPT—2018–0649; FRL—9984–67]

RIN 2070–AB27

Significant New Use Rules on Certain Chemical Substances

AGENCY: Environmental Protection Agency (EPA).

ACTION: Proposed rule.

SUMMARY: EPA is proposing significant new use rules (SNURs) under the Toxic Substances Control Act (TSCA) for 28 chemical substances which were the subject of premanufacture notices (PMNs). The chemical substances are subject to Orders issued by EPA pursuant to section 5(e) of TSCA. This action would require persons who intend to manufacture (defined by statute to include import) or process any of these 28 chemical substances for an activity that is designated as a significant new use by this rule to notify EPA at least 90 days before commencing that activity. The required notification initiates EPA’s evaluation of the intended use within the applicable review period. Persons may not commence manufacture or processing for the significant new use until EPA has conducted a review of the notice, made an appropriate determination on the notice, and has taken such actions as are required with that determination. In addition to this Notice of Proposed Rulemaking, EPA is issuing the action as a direct final rule elsewhere in this issue of the Federal Register.

DATES: Comments must be received on or before November 9, 2018.

ADDRESSES: Submit your comments, identified by docket identification (ID) number EPA—HQ—OPPT—2018–0649, by one of the following methods:

• Federal eRulemaking Portal: http://www.regulations.gov. Follow the online instructions for submitting comments. Do not submit electronically any information you consider to be Confidential Business Information (CBI) or other information whose disclosure is restricted by statute.


• Hand Delivery: To make special arrangements for hand delivery or delivery of boxed information, please follow the instructions at http://www.epa.gov/dockets/contacts.html.

Additional instructions on commenting or visiting the docket, along with more information about dockets generally, is available at http://www.epa.gov/dockets.

FOR FURTHER INFORMATION CONTACT:
For technical information contact: Kenneth Moss, Chemical Control Division (7405M), Office of Pollution Prevention and Toxics, Environmental Protection Agency, 1200 Pennsylvania Ave. NW, Washington, DC 20460–0001; telephone number: (202) 564–9232; email address: moss.kenneth@epa.gov.

For general information contact: The TSCA-Hotline, ABVI-Goodwill, 422 South Clinton Ave. Rochester, NY 14620; telephone number: (202) 554–1404; email address: TSCA-Hotline@epa.gov.

SUPPLEMENTARY INFORMATION: In addition to this Notice of Proposed Rulemaking, EPA is issuing the action as a direct final rule elsewhere in this issue of the Federal Register. For further information about the proposed significant new use rules, please see the information provided in the direct final action, with the same title, that is located in the “Rules and Regulations” section of this issue of the Federal Register.

List of Subjects in 40 CFR Part 721

Environmental protection, Chemicals, Hazardous substances, Reporting and recordkeeping requirements.

Dated: October 1, 2018.

Jeffery T. Morris,
Director, Office of Pollution Prevention and Toxics.

[FR Doc. 2018–21870 Filed 10–9–18; 8:45 am]

BILLING CODE 6560–50–P

DEPARTMENT OF TRANSPORTATION

National Highway Traffic Safety Administration

49 CFR Parts 555, 571 and 591

[Docket No. NHTSA–2018–0092]

RIN 2127–AL99

Pilot Program for Collaborative Research on Motor Vehicles With High or Full Driving Automation

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

ACTION: Advance notice of proposed rulemaking (ANPRM).

SUMMARY: NHTSA is seeking public comment on matters related to the near-term and long-term challenges of...
Automated Driving Systems (ADS) testing, development and eventual deployment. ADS testing and development are already underway in several areas of the United States. As technology evolves and in anticipation of requests to test and further develop high and full ADS, including those in vehicles without traditional controls necessary for a human driver, NHTSA is issuing this ANPRM to obtain public comments on the factors and structure that are appropriate for the Agency to consider in designing a national pilot program that will enable it to facilitate, monitor and learn from the testing and development of the emerging advanced vehicle safety technologies and to assure the safety of those activities.

The Agency seeks these comments from interested stakeholders, including State and local authorities, companies, researchers, safety advocates and other experts interested in, engaged in or planning to become engaged in the design, development, testing, and deployment of motor vehicles with high and full driving automation. The Agency also seeks comments from road users, including vehicle drivers and passengers, cyclists and pedestrians.

More specifically, NHTSA requests comments on the following topics related to ADS safety research. First, NHTSA seeks comments on potential factors that should be considered in designing a pilot program for the safe on-road testing and deployment of vehicles with high and full driving automation and associated equipment. Second, the Agency seeks comments on the use of existing statutory provisions and regulations to allow for the implementation of such a pilot program. Third, the Agency seeks comment on any additional elements of regulatory relief (e.g., exceptions, exemptions, or other potential measures) that might be needed to facilitate the efforts to participate in the pilot program and conduct on-road research and testing involving these vehicles, especially those that lack controls for human drivers and thus may not comply with all existing safety standards. Fourth, with respect to the granting of exemptions to enable companies to participate in such a program, the Agency seeks comments on the nature of the safety and any other analyses that it should perform in assessing the merits of individual exemption petitions and on the types of terms and conditions it should consider attaching to exemptions to protect public safety and facilitate the Agency’s monitoring and learning from the testing and deployment, while preserving the freedom to innovate.

By developing a robust record of the answers to these important questions, NHTSA expects to learn more about the progress of ADS and the ways in which the Agency can facilitate safe and efficient ADS testing and deployment for the benefit of individual consumers and the traveling public as a whole.

**DATES:** Comments on this document are due no later than November 26, 2018.

**ADDRESSES:** Comments must be identified by Docket Number NHTSA–2018–0092 and may be submitted using any of the following methods:
- **Federal eRulemaking Portal:** http://www.regulations.gov. Follow the online instructions for submitting comments.
- **Mail:** Docket Management Facility, U.S. Department of Transportation, Room W12–140, 1200 New Jersey Avenue SE, Washington, DC 20590–0001.
- **Hand Delivery or Courier:** West Building, Ground Floor, Room W12–140, 1200 New Jersey Avenue SE, Washington, DC, between 9 a.m. and 5 p.m. E.T., Monday through Friday, except Federal holidays.
- **Fax:** 1–202–493–2251.

Regardless of how you submit your comments, you must include the docket number identified in the heading of this document. Note that all comments received, including any personal information provided, will be posted without change to http://www.regulations.gov. Please see the “Privacy Act” heading below.

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**FOR FURTHER INFORMATION CONTACT:**


**SUPPLEMENTARY INFORMATION:**

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I. Background and Overview

As the Federal agency charged with improving motor vehicle safety through reducing crashes, and preventing deaths...
and injuries from crashes, NHTSA is encouraged by the new ADS vehicle technologies being developed and implemented by automobile manufacturers and other innovators. NHTSA anticipates that automation can serve a vital safety role on our Nation’s roads, particularly since human error and choice are currently the critical factors behind the occurrence of a large number of crashes. ADS vehicle technologies possess the potential to save thousands of lives, as well as reduce congestion, enhance mobility, and improve productivity.

To aid in determining how best to foster the safe development and implementation of ADS vehicle technologies on our Nation’s roadways, NHTSA believes it is prudent to facilitate the conducting of research and gathering of data about these new and developing technologies in their various iterations and configurations. Thus, NHTSA is seeking comment on creating a national ADS vehicle pilot program for the testing of vehicles and associated equipment and to gather data from such testing, including data generated in real-world scenarios. NHTSA anticipates that this data will provide information needed to help realize the promises and meet the challenges of ADS vehicle development and deployment.

The purpose of this ANPRM is to obtain public views and suggestions for steps that NHTSA can take to facilitate, monitor and learn from on-road research through the safe testing and eventual deployment of high and full automated vehicles, i.e., Level 4 and 5* ADS vehicles, primarily through a pilot program.

To explain these levels of automation and put them in context with the other levels defined by SAE (Society of Automotive Engineers) International in Table 1 of SAE J3016, the Agency provides the following simplified description of the full array of levels:

<table>
<thead>
<tr>
<th>Level of automation</th>
<th>What does the vehicle do, what does the human driver/occupant do, and when and where do they do it?</th>
</tr>
</thead>
<tbody>
<tr>
<td>Level 0</td>
<td>No Automation of driving task: While the vehicle may provide warnings (e.g., forward collision warning and blind-spot warning), the human driver must in all conditions and at all times perform all aspects of the driving task like monitoring the driving environment, steering, braking and accelerating.</td>
</tr>
<tr>
<td>Level 1</td>
<td>Driver Assistance: The vehicle may have some features that can automatically assist the human driver with either steering (e.g., lane keeping assist) or braking/accelerating (e.g., adaptive cruise control), but not with both simultaneously. The human driver performs all other aspects of the driving task like monitoring the driving environment, steering, braking and accelerating.</td>
</tr>
<tr>
<td>Level 2</td>
<td>Partial Driving Automation: The vehicle has combined automated functions, like speed control and steering simultaneously, but the driver must remain engaged with the driving task by controlling the other elements of driving, monitoring the driving environment at all times, and being ready to take over immediately if conditions exceed the capabilities of the vehicle’s automated functions.</td>
</tr>
<tr>
<td>Level 3</td>
<td>Conditional Driving Automation: The vehicle can perform most aspects of the driving task, including monitoring the driving environment and making decisions, under some conditions (e.g., speeds under a set threshold). The presence of a human driver is still a necessity, but is not required to monitor the driving environment when the ADS is engaged and operating in those conditions. The driver must always be ready to intervene and take control of the vehicle when the ADS gives the driver notice to do so or the vehicle experiences a driving-task-related failure.</td>
</tr>
<tr>
<td>Level 4</td>
<td>High Driving Automation: The vehicle can perform most aspects of the driving task under certain conditions without the involvement of or oversight by a human driver. Outside of those conditions, the vehicle will enter a safe fallback mode if a human occupant does not resume control. The vehicle may or may not be designed to allow a human occupant to assume control.</td>
</tr>
<tr>
<td>Level 5</td>
<td>Full Driving Automation: The vehicle can perform all aspects of the driving task at all times and under all conditions. While the human occupants need to set the trip destination and start the ADS, they need never be involved in any aspects of the driving task. The vehicle may or may not be designed to allow a human occupant to assume control.</td>
</tr>
</tbody>
</table>

This ANPRM is the latest effort by DOT and NHTSA to address issues relating to the testing and deployment of vehicles with high and full driving automation. Automated Driving Systems 2.0: A Vision for Safety (“A Vision for Safety”), issued by DOT in September 2017, included guidance to manufacturers and other entities seeking to document for themselves how they are addressing safety. It further outlined a summary document that they could use to disclose their voluntary safety self-assessments to the public in order to describe to the public, to stakeholders, and to Federal, State and local governments the manufacturers’ approach to assuring safe testing and development.

In a separate notice published in January 2018, the Agency took the next step by publishing a request for public comments to identify any regulatory barriers in the existing Federal motor vehicle safety standards (FMVSS) to the testing, compliance certification and compliance verification of automated motor vehicles. In that notice, NHTSA focused primarily, but not exclusively, on vehicles with certain unconventional interior designs, such as those that lack controls for a human driver; e.g., steering wheel, brake pedal or accelerator pedal. The absence of manual driving controls, and thus of a human driver, poses potential barriers to testing, compliance certification and compliance verification. Further, the compliance test procedures of some FMVSS depend on the presence of such things as a human test driver who can follow test instructions or a steering wheel that can be used by an automated steering mechanism. In addressing all of these issues, the Agency’s focus will be on ensuring the maintenance of currently required levels of safety performance.

This ANPRM focuses on the related question of how the Agency can best encourage and facilitate the necessary research to allow for the development and establishment, as needed, of standards for ADS vehicles, including vehicles that have unconventional designs, can operate in “dual modes” (one of which may involve unconventional designs), and can comply with the existing FMVSS.

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1 See table below for explanations of these terms.

2 SAE J3016 201806 Taxonomy and Definitions for Terms Related to Driving Automation Systems for On-Road Motor Vehicles.

* 83 FR 2607, January 18, 2018.
NHTSA believes that in order to anticipate, identify and address potential safety concerns and realize the full promise of ADS, it is vital that the developers of vehicles with high and full driving automation have broad opportunities to gain practical, real world experience, in locations of their choosing, with different approaches to, and combinations of, hardware and software in order to learn which approaches and combinations offer the greatest levels of safety and reliability. Simulated testing, or testing in laboratory or other controlled settings is very beneficial, but NHTSA also recognizes the importance of preparing for a world in which ADS vehicles operate on a broad scale on our Nation’s roads under a vast array of complex and changing road, traffic and weather conditions. ADS must be able to operate in and adapt to such conditions, just as human drivers must when driving their vehicles today. On-the-road testing and evaluation of ADS vehicles will be critical to the successful development and integration of these vehicles into the roads and highways throughout the country.

Based on the foregoing, NHTSA is considering the establishment of a national pilot research program. The Agency emphasizes that it has not made any decisions whether to establish a pilot program or how to structure one. For this reason, it cannot currently estimate the timing, cost or duration of a pilot program. After analyzing the public comments on this ANPRM and other available information, NHTSA will further assess the prospects for implementing a viable and effective program and identify the best approach to structuring one.

I. NHTSA’s Safety Mission, Authority, and Programmatic Needs With Respect to ADS

NHTSA, an operating administration within DOT, was established, as a successor to the National Highway Safety Bureau, by the Highway Safety Act of 1970 to carry out safety programs under the National Traffic and Motor Vehicle Safety Act of 1966 (“the Act”) and the Highway Safety Act of 1966. The Act directs the Department of Transportation “(1) to prescribe motor vehicle safety standards for motor vehicles and motor vehicle equipment in interstate commerce; and (2) to carry out needed safety research and development.”

Its vehicle safety mission is to save lives and prevent injuries due to road traffic crashes through a variety of means. More specifically, the Agency carries out its vehicle safety mission by:

- Collecting real world data on the safety of motor vehicles and items of motor vehicle equipment;
- Conducting safety research;
- Setting FMVSS for new motor vehicles and motor vehicle equipment (to which manufacturers must certify compliance before sale or introduction into interstate commerce);
- Enforcing compliance with the standards;
- Investigating and overseeing the recall and remedy of noncompliant products and products containing safety-related defects;
- Communicating with and educating the public about motor vehicle safety issues through comparative performance ratings and other means; and
- Issuing guidance for vehicle and equipment manufacturers to follow on important issues affecting safety.

In addition, NHTSA works with State highway safety agencies and other partners under the Highway Safety Act to encourage the safe behavior of drivers, occupants, cyclists, and pedestrians across the country.

A. NHTSA Has Authority Over All Aspects of ADS Design

NHTSA’s authority over ADS is broad and clear. The Act obligates NHTSA to regulate the safety of motor vehicles and motor vehicle equipment.5 “Motor vehicle equipment” is defined broadly enough to include both tangible components, e.g., hardware, and intangible components, e.g., software, of modern electronic motor vehicle systems.6 Both types of components, working in combination, are indispensable to the functioning of modern vehicle electronic systems and critical to the future safety of the motor vehicle occupants, cyclists and pedestrians.7 Indeed, without their software components, these electronic systems would not be systems; instead, they would be nonfunctional assemblages of hardware components. Hardware and software components are also at the heart of each building block technology for vehicle automation and are indispensable to the combining of the technologies in ADS vehicles. As technology has evolved, NHTSA has responded to Congressional mandates to use its authority to specify how and when the hardware components of electronic systems such as air bags, anti-lock braking systems and electronic stability control systems must activate and perform. This approach gives manufacturers freedom to develop the software components needed to control the performance of each system’s hardware components. NHTSA has also repeatedly exercised its authority under the Act when the software and/or hardware components of computerized electronics have been the subject of safety defect recall and remedy campaigns. Software updates have been the remedy for software found to contain a safety defect.8

NHTSA is also authorized to regulate certain other software, specifically, software that has functionality similar to that of the software in either a vehicle manufacturer’s key fob/smart key or even some of the systems integrated into some current vehicles.9 Some of this software, e.g., that for remotely starting a vehicle’s engine, affects motor vehicle systems only when the vehicles are parked, i.e., in circumstances called “nonoperational” safety. Other software, e.g., forward crash warning and remote automated parking systems, affects motor vehicles when they are moving, i.e., “operational” safety. The Act’s definition of “motor vehicle safety” encompasses both aspects of safety.10

B. NHTSA’s Flexibility To Develop and Implement Non-Traditional Standards for ADS

NHTSA’s primary exercise of its regulatory authority involves the development and establishment of the FMVSS.11 Under the Act, NHTSA’s

49 U.S.C. 30111(a).
49 U.S.C. 30102(a)(6) and (7).

49 U.S.C. 30111(a).
49 U.S.C. 30102(a)(6) and (7).

49 U.S.C. 30102(a)(8).
11 It is important to note that, even in the absence of standards, ADS-equipped vehicles must still be
FMVSS must meet a variety of requirements. They must be performance-oriented. They must be practicable, both technologically and economically. They must be objective, meaning that they must be capable of producing identical results when tests are conducted in identical conditions and compliance must be based on scientific measurements, not subjective opinion. Finally, they must meet the need for safety.

The FMVSS can address all aspects and phases of ensuring that new motor vehicles are designed and perform safely. NHTSA can establish crash avoidance standards to reduce the chance that a vehicle will become involved in a crash or cause another vehicle to become involved in crash or reduce the severity of crashes that cannot be avoided. Likewise, NHTSA can issue crashworthiness standards requiring that a vehicle be designed so that its occupants are less likely to be seriously injured in a crash and so that it is less likely to cause injury to the occupants of other vehicles or other roadway users such as pedestrians and cyclists. In addition, NHTSA can issue standards for post-crash safety, such as minimizing the risk of electrical fires.

NHTSA believes that the FMVSS structure has the necessary flexibility to regulate the design and performance of ADS appropriately. Although the existing FMVSS rely on physical tests and measurements to evaluate safety performance, there is no requirement in the Act that they rely exclusively or even at all on such tests and measurements so long as they are objective and meet the other statutory requirements. In the future, other approaches such as simulation and requirements expressed in terms of mathematical functions might be considered.

In addition, because the software environment is likely to evolve and change at a rapid rate, NHTSA recognizes that it will need a new approach to the development and drafting of FMVSS, especially any FMVSS that might be established for ADS. The accelerating pace of technological change is incompatible with lengthy rulemaking proceedings that last at least 6–8 years from initiating rulemaking to conducting research to translating the research results into regulatory text to conducting and completing a notice and comment rulemaking. Further, the FMVSS of the future will need to be reconceptualized, developed and drafted so that they are nimbler, more performance-oriented and thus more accommodating of anticipated and continued rapid technological change than has generally been the case for the FMVSS to date.

Similarly, although existing FMVSS generally address specific predictable events (e.g., stopping and turning safely on low friction surfaces, specific types of crashes), it may be desirable, even necessary, to meet the need for safety, for future FMVSS focused on ADS technologies to also address the common, yet unpredictable, events that occur in real-world driving, e.g., the one person among crowds of people standing on two or more corners of an intersection who suddenly decides to cross the street, the approaching vehicle that suddenly turns left, the parked vehicle that suddenly leaves its parking place, and the vehicle that suddenly emerges from a blind alley or other obscured location. Test procedures could replicate those events, including their unpredictability. A degree of unpredictability might be accomplished by varying the location of standardized surrogate vehicles, cyclists and pedestrians on a test course and the sequence in which they are encountered during testing. A sufficient degree of randomization should help avoid the risks that using a completely predictable test procedure might create, i.e., that a test vehicle could be programmed to anticipate the predictable encounters with surrogate objects and avoid a collision with them by being pre-programmed to do so, not by relying on its sensors and decision-making algorithms.

Further, future FMVSS could test the ability of ADS vehicles to monitor not only simple scenarios involving a single surrogate pedestrian or vehicle, but also more complex and realistic scenarios involving multiple surrogate pedestrians and vehicles and their ability to identify and respond appropriately to all surrogate pedestrians and vehicles without the ADS vehicles’ knowing in advance precisely which pedestrian or vehicle would move and when into their path.

Finally, future FMVSS could be drafted in more technology-neutral performance terms than many of the existing technology-specific FMVSS. This approach may allow for the development and deployment of cutting-edge technology, as long as FMVSS performance mandates are satisfied. This approach could allow for testing and deployment of critical safety equipment without requiring time-consuming regulatory amendments to respond to changes in technology.

C. Research Is Needed To Generate Data on ADS

In order to establish standards that ensure safety without jeopardizing innovation, NHTSA must conduct significant research, as well as leverage research conducted by outside entities, including industry and universities. When the Act was enacted, Congress recognized the importance of research, development, testing, and evaluation, and provided “broad authority to initiate and conduct” those activities. Additionally, Congress recognized that safety standards “cannot be set in a vacuum. They must be based on reliable information and research.” In the Moving Ahead for Progress in the 21st Century Act, Congress reiterated and strengthened NHTSA’s role in conducting research, particularly in areas of innovative technology, and directed that “[t]he Secretary of Transportation shall conduct research, development, and testing on any area or aspect of motor vehicle safety necessary to carry out this chapter.” In carrying out this directive, Congress instructed the Secretary to “[c]onduct motor vehicle safety research, development, and testing programs and activities, including activities related to new and emerging technologies that impact or may impact motor vehicle safety” and to “[c]ollect and analyze all types of motor vehicle and highway safety data” relating to motor vehicle performance and crashes. Further, the Secretary was given broad authority to “enter into cooperative agreements, collaborative research, or contracts with Federal agencies, interstate authorities, State and local governments, other public entities, private organizations and persons,” and other appropriate institutions.

To aid in determining how best to foster the safe introduction of vehicles with high and full driving automation onto our Nation’s roadways, NHTSA seeks to facilitate research and data gathering involving these new and developing technologies in their various iterations and configurations. The

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12 49 U.S.C. 30102(a)(10), 30111(a).
13 NHTSA notes that its Corporate Average Fuel Economy Standards are required to be stated in terms of a mathematical function. 49 U.S.C. 23902(b)(3)(A).
16 Public Law 112–141.
18 49 U.S.C. 30182(a) (emphasis added).
19 Id. at § 30182(b)(5).
Agency wants the entities involved in this research to gain practical, real-world experience to determine the best approaches to enhancing safety. This research is expected to generate the data needed to assist in developing methods of validating the safety performance of vehicles with high and full driving automation. NHTSA recognizes both the safety potential of ADS and the need to ensure that all testing and operation of vehicles with high and full driving automation are conducted in a manner that ensures the appropriate levels of safety for everyone involved—and most importantly, all roadway users.

D. Regulatory Relief May Be Needed To Facilitate Research Involving Vehicles With High and Full Driving Automation

In the separate notice on barriers mentioned above, NHTSA stated that it believes that vehicles with traditional interior designs, e.g., ones including steering wheels and foot pedals, that meet the existing FMVSS would still comply with the FMVSS even if those vehicles were designed to be operated as vehicles with high and full driving automation. However, vehicles with high and full driving automation that do not have traditional designs might not meet the existing FMVSS and would, therefore, require an exemption. NHTSA’s statutes provide two separate avenues under sections 30113 and 30114 for an exemption of vehicles that do not comply with the standards and another process designed for vehicles that would initially comply with the standard, but also may need exemptions if they operate in “dual modes,” one of which could run afoul of NHTSA’s “make inoperative” prohibition. Under both types of exemptions, NHTSA may set terms by which the exempted entity must abide.

In this document, NHTSA announces that it is contemplating creating an ADS vehicle pilot research program for the testing of vehicles and associated equipment and gathering of data from such testing, including in real-world scenarios, which the Agency would consider as setting the terms of the exemptions. NHTSA anticipates that these data will provide needed information that will better enable the public and private sectors to realize the promises and overcome the challenges of vehicles with high and full driving automation.

E. A Pilot Program Can Provide Relief and Promote Research on ADS

To summarize, NHTSA’s authority covers all relevant aspects of ADS design, including vehicles with high and full driving automation. NHTSA, therefore, has an affirmative duty to establish the measures necessary to ensure the safe design and operation of these types of vehicles. However, to do so in a way that actually achieves those safety goals and does not unnecessarily impede innovation requires significant research on these cutting-edge issues. Due to the complexity of real-world driving, this research cannot simply be done in laboratories or other highly controlled testing environments and, instead, part of it must be done on public roads with real driving conditions. To help ensure that this testing is being done safely and with an eye towards obtaining the data necessary to support such future standards as may be needed, NHTSA is considering establishing a pilot program for vehicles with high and full driving automation for entities wishing to engage in the testing or, in some cases, deployment of vehicles with high and full driving automation that would require some type of an exemption from NHTSA’s existing standards. The Agency believes that such a program could aid developers of vehicles with high and full driving automation in testing and deploying their vehicles across the country in a wide variety of scenarios, e.g., different climates, weather patterns, topographical features, road systems, population and traffic densities, etc.

III. Pilot Program for the Safe Testing and Deployment of Vehicles With High and Full Driving Automation

Technological innovations in automotive transportation are diverse and evolving quickly in the United States and abroad. The potential safety benefits that could result from deploying vehicles with high and full driving automation justify a considered approach at the Federal, State and local levels to the design and implementation of pilot programs for the safe testing, learning and eventual deployment of these vehicles, including on public roadways. Safety is a primary concern and is the primary mission of NHTSA. The issuance of this ANPRM on pilot program design is intended to stimulate public discussion of both safety aspects of new technology testing and development, as well as approaches to learning from pilot programs for technological improvement and eventual deployment. NHTSA acknowledges that there are also mobility, efficiency and accessibility opportunities associated with ADS and that infrastructure could play a key role in the broader operational availability of these technologies. Numerous companies, researchers, safety advocates, State and local governments, and other stakeholders are engaged in, planning to become engaged in or otherwise interested in the design, development, testing, and deployment of vehicles with high and full driving automation. NHTSA recognizes that it is restricted in its ability to apply requirements to certain manufacturers testing vehicles on public highways if the manufacturers agree not to offer for sale or sell those vehicles. Discussion of pilot program design and implementation does not assume that such regulatory and statutory limits are either appropriate or necessary, but rather that pilot programs might require NHTSA to address certain barriers.

Further, pilot programs should anticipate the need to coordinate Federal, State and local governments’ responsibilities and efforts and should recognize other Federal agencies, and State and local governments are effective sources of information needed for risk management as ADS technology approaches deployment. State and local governments have traditionally played important roles in motor vehicle and road safety, through enforcement, traffic management and planning, research, and much more. It is critical to NHTSA to partner effectively with State and local governments to permit them to continue these important functions while the Agency works collaboratively to facilitate the safe and efficient deployment of ADS technology.

Finally, at this stage, NHTSA is only considering a pilot program for light-duty vehicles; to the extent the Agency will consider establishing future pilot projects for other motor vehicles, such as truck tractors or buses, it will do so in coordination with the other relevant operating administrations within the Department.

Questions.

20 49 U.S.C. 30113 and 30114.

21 Certain ADS vehicles that do not comply with existing standards are currently allowed to be introduced into interstate commerce if they meet the requirements in section 30112(b)(10). The section exempts motor vehicles from the prohibition in section 30112(b)(10) against introducing a noncompliant motor vehicle into commerce, but, among other constraints, only if the vehicle is introduced by a manufacturer solely for the purpose of its being tested and evaluated on public roads, only for vehicle manufacturers that manufactured and distributed compliant vehicles in the United States before December 4, 2015, and only if those vehicles are not sold after the conclusion of testing. Importantly, then, this exception is limited in both which manufacturers can take advantage of it and what can be done while using it.

22 49 U.S.C. 30112(b)(10).
In furtherance of the goals of this ANPRM, NHTSA requests interested persons to answer a variety of questions about the structure of a national pilot program and about the types of regulatory relief that may be needed to make such a program successful. The views and information provided in response to those that will aid the Agency in deciding whether to create a national program and, if so, how to do so.

Guidance on answering questions.

In responding to each question, please provide data, analyses, research reports or other justification to support your response. In addition, please respond to the questions and requests in the same sequence in which they appear below and include the number of each question and request.

Question 1. What potential factors should be considered in designing the structure of a pilot program that would enable the Agency to facilitate, monitor and learn from on-road research through the safe testing and eventual deployment of vehicles with high and full driving automation and associated equipment?

Question 2. If NHTSA were to create a pilot program, how long would there be a need for such a program? What number of vehicles should be involved? Should NHTSA encourage the conducting of research projects in multiple locations with different weather conditions, topographical features, traffic densities, etc.?

Question 3. What specific difficulties should be addressed in designing a national vehicle pilot program for vehicles with high and full driving automation either through the exemption request process relevant for FMVSS or more broadly related to other areas of NHTSA and/or other authorities?

Question 4. How can existing statutory provisions and regulations be more effectively used in implementing such a pilot program?

Question 5. Are there any additional elements of regulatory relief (e.g., exceptions, exemptions, or other potential measures) that might be needed to facilitate the efforts to participate in the pilot program and conduct on-road research and testing involving these vehicles, especially those that lack controls for human drivers and thus may not comply with all existing FMVSS?

A. Considerations in Designing the Pilot Program

NHTSA believes that a safe and effective pilot program for vehicles with high and full driving automation would necessarily address each of the following critical areas: (1) Vehicle design for safe operation; (2) vehicle design for risk mitigation in the event of an unplanned event; (3) vehicle design for intended operating conditions; and (4) data reporting and information sharing to identify and mitigate risks identified during the pilot program.

1. Vehicle Design for Safe Operation

As described above, NHTSA has long assessed vehicle attributes for safe operation under reasonably anticipated conditions. Such an assessment has historically included detailed elements of structural integrity and design, as well as hardware, software and telecommunications elements that contribute to either operational or nonoperational vehicle safety.

NHTSA believes that vehicles with high and full driving automation participating in pilot programs for testing and evaluation and eventual deployment should continue to meet most FMVSS for the protection of vehicle occupants, pedestrians, and other vulnerable road users. However, in the case of certain elements, safety might be enhanced through approaches different than those contained in the current FMVSS, given that they were developed for vehicles designed only for human operation.

As noted above, NHTSA has issued a Request for Comment regarding those provisions in the FMVSS that may pose barriers for the design, testing and deployment of some safe vehicles with high and full driving automation.

Question 6. What vehicle design elements might replace existing required safety equipment and/or otherwise enhance vehicle safety under reasonably anticipated operating conditions?

2. Vehicle Design for Risk Mitigation

As described in section I (overview) above, the primary difference between lower level driving automation systems and high and full driving automation systems is the reliance in the latter systems on the vehicle to perform all driving functions in at least certain circumstances. It is anticipated that vehicles with high and full driving automation will accomplish this through the combination of highly sophisticated detection systems, systems for digital interpretation of detected objects, data retention and processing, communication protocols, and highly sophisticated decision-making software. Together, this combination of features is intended to replace and improve upon the ability of human drivers to detect, interpret, communicate and react to vehicle operational needs and conditions.

Some vehicles with high driving automation will require an additional design consideration to address human-machine interface when operating outside of their Operational Design Domain.23 Specifically, given the reliability of those vehicles on vehicle, and not human, systems, the design of those vehicles should account for both the vehicle and human elements of any transition from one type of driver (human or vehicle) to another type of driver (vehicle or human).

In A Vision for Safety, the Department of Transportation described a voluntary safety self-disclosure approach recommended to innovators seeking to test and deploy vehicles with high and full driving automation on public roadways.

NHTSA’s existing authorities under the Act, e.g., provisions concerning research, standard setting and consumer information, are adequate for NHTSA to evaluate and recommend protocols to ensure the safety of vehicle design for risk mitigation. In fact, NHTSA has already developed and adopted protocols for a wide variety of technologies for use in either the FMVSS or the New Car Assessment Program. Examples include anti-lock braking systems, electronic stability control, automatic emergency braking, and lane departure warning.

Furthermore, NHTSA’s authorities supporting the current FMVSS program are adequate and appropriate for developing very broadly drafted safety performance standards that might be necessary for the eventual safe widespread deployment on public roadways of vehicles with high and full driving automation. Such performance standards should allow for unencumbered innovation where such innovation provides equivalent or improved safety for future transportation designs when compared to the safety of human drivers. For example, future performance-based standards might include standards and testing for safe lane change performance on highways, hazard detection and avoidance in urban environments, or collision avoidance on rural highways.

Question 7. What types of performance measures should be considered to ensure safety while allowing for innovation of emerging

23 The Operational Design Domain describes the specific conditions under which a given ADS or feature is intended to function. More specifically, it defines where (such as what roadway types and speeds) and when (under what conditions, such as day/night, weather limits, etc.) an ADS is designed to operate.
technology in vehicles with high and full driving automation participating in a pilot program?

3. Vehicle Design Safety Elements

A Vision for Safety seeks to help designers of ADS to analyze, identify, and resolve safety considerations prior to deployment by using their own, industry, and other best practices. It outlines 12 safety elements, which the Agency believes represent the consensus across the industry, that are generally considered to be the most salient design aspects to consider and address when developing, testing, and deploying ADS on public roadways. Within each safety design element, entities are encouraged to consider and document for themselves their use of industry standards, best practices, company policies, or other methods they have employed to provide for increased system safety in real-world conditions.

For example, vehicles with high and full driving automation are currently tested and deployed in carefully risk-managed phases to allow for safe operation during development of increasingly complex systems. As described in A Vision for Safety, the circumstances in which the automated operation of a vehicle is enabled are set forth in the vehicle’s Operational Design Domain.

NHTSA believes that any pilot program for the testing of vehicles with high and full driving automation should include defined Operational Design Domains as a component of safe automated vehicle operation. Examples of an Operational Design Domain include, but are not limited to, geographic, environmental or other conditions in which the vehicle is designed to operate, detect and respond safely to a variety of normal and unexpected objects and events, and to fall back to a minimal risk condition in the event that the ADS fails or that the ADS encounters conditions outside the Operational Design Domain.

NHTSA has historically regulated the enabling conditions for safety systems, such as air bags, anti-lock brakes and electronic stability control, that are designed to intervene when certain conditions, and only those conditions, exist. NHTSA believes that the critical relationship between the safety of a vehicle’s design and the vehicle’s decision-making system similarly makes it necessary to evaluate the safety of automated vehicle performance in light of appropriate and well-defined Operational Design Domains. For example, if a vehicle is capable of safely operating automatically only at speeds below 30 mph, NHTSA might consider whether it would be appropriate to require that the vehicle be designed so that it cannot operate automatically at speeds of 30 mph or more unless and until it acquires the capability (e.g., through software updates) of safely operating automatically above that speed. Similarly, if a vehicle would become incapable of operating safely if one or more of its sensors became non-functional, NHTSA might consider whether it would be appropriate to require that the vehicle be designed so that it cannot operate automatically in those circumstances.

State and local authorities also have a role to play. Through establishing and enforcing their rules of the road, these authorities have traditionally controlled such operational matters as the speed at which vehicles may be driven and the condition of certain types of safety equipment such as head and tail lights. In the future, it is reasonable to expect that these authorities may establish new rules of the road to address ADS vehicles specifically. While NHTSA might require the manufacturers of these vehicles to design them so that their vehicles know the State and locality in which they are operating and what the rules of the road are for that location and so that they observe those rules, the States and localities would enforce those rules if broken.

Question 8. How should the Operational Design Domains of individual vehicle models be defined and reinforced and how should Federal, State and local authorities work together to ensure that they are observed?

4. Data and Reporting

The purpose of a pilot program is to allow for safe on-road testing and on-road learning in order to provide feedback for further safe development. An important element of any pilot program is the creation, sharing and appropriate use of performance data to allow constant improvement to the test technology and improved risk management.

NHTSA believes that the novel challenge of assessing the safety of the emerging technologies in vehicles with high and full driving automation requires a commitment to timely and accurate data reporting and analysis.

Question 9. What type and amount of data should participants be expected to share with NHTSA and/or with the public for the safe testing of vehicles with high and full driving automation and how frequently should the sharing occur?

Question 10. In the design of a pilot program, how should NHTSA address the following issues—

a. confidential business information?

b. privacy?

c. data storage and transmission?

d. data retention and reporting?

e. other elements necessary for testing and deployment?

5. Additional Considerations in Pilot Program Design

NHTSA seeks comments on whether there are additional critical areas to consider in the design of a safe pilot program for the testing and deployment of vehicles with high and full driving automation.

Question 11. In the design of a pilot program, what role should be played by—

a. The 12 safety elements listed in A Vision for Safety?

b. The elements listed below,

i. Failure risk analysis and reduction during design process (functional safety)?

ii. Objective performance criteria, testable scenarios and test procedures for evaluating crash avoidance performance of vehicles with high and full driving automation?

iii. Third party evaluation?

A. Failure risk reduction?

B. Crash avoidance performance of vehicles with high and full driving automation?

iv. Occupant/non-occupant protection from injury in the event of a crash (crashworthiness)?

v. Assuring safety of software updates?

vi. Consumer education?

vii. Post deployment Agency monitoring?

viii. Post-deployment ADS updating, maintenance and recalibration?

c. Are there any other elements that should be considered?

Question 12. Are there any additional critical areas to consider in the design of a safe pilot program for the testing and deployment of vehicles with high and full driving automation?

6. Issues Relating To Establishing a Pilot Program

In addition to the general issues identified above, NHTSA seeks comment on the following questions related to the development of the potential pilot program.

i. Applications for Participation and Potential Terms of Participation

Question 13. Which of the following matters should NHTSA consider requiring parties that wish to participate in the pilot program to address in their applications?
a. “Safety case” for vehicles to be used in the pilot program (e.g., system safety analysis (including functional safety analysis), demonstration of safety capability based on objective performance criteria, testable scenarios and test procedures, adherence to NHTSA’s existing voluntary guidance, including the submission of a voluntary safety self-assessment, and third party review of those materials).

i. What methodology should the Agency use in assessing whether an exempted ADS vehicle would offer a level of safety equivalent to that of a nonexempted vehicle? For example, what methodology should the Agency use in assessing whether an ADS vehicle steers and brakes at least as effectively, appropriately and timely as an average human driver?

b. Description of research goals, methods, objectives, and expected results.

c. Test design (e.g., route complexity, weather and related road surface conditions, illumination and institutional review board assessment).

d. Considerations for other road users (e.g., impacts on vulnerable road users and proximity of such persons to the vehicle).

e. Reporting of data, e.g., reporting of crashes/incidents to NHTSA within 24 hours of their occurrence.

f. Recognition that participation does not negate the Agency’s investigative or enforcement authority, e.g., independent of any exemptions that the Agency might issue to program participants and independent of any terms that the Agency might establish on those exemptions, the Agency could conduct defect investigations and order recalls of any defective vehicles involved in the pilot program. Further, the Agency could investigate the causes of crashes of vehicles involved in the program.

g. Adherence to recognized practices for standardizing the gathering and reporting of certain types of data in order to make possible the combining of data from different sources and the making of statistically stronger findings.

h. For which types of data would standardization be necessary in order to make such findings and why?

i. To what extent would standardization be necessary for those types?

j. Occupant/non-occupant protection from injury in the event of a crash (crashworthiness).

k. Assuring safety of software updates.

l. Consumer education.

m. Post-deployment monitoring

n. Post-deployment maintenance and calibration considerations.

Question 14. What types of terms and conditions should NHTSA consider attaching to exemptions to enhance public safety and facilitate the Agency’s monitoring and learning from the testing and deployment, while preserving the freedom to innovate, including terms and conditions for each of the subjects listed in question 13? What other subjects should be considered, and why?

i. What methodology should the Agency use in assessing whether an ADS vehicle steers and brakes at least as effectively, appropriately and timely as an average human driver?

ii. Potential Categories of Data To Be Provided by Program Participants

Question 15. What value would there be in NHTSA’s obtaining one or more of the following potential categories of data from the participants in the pilot program? Are there other categories of data that should be considered? How should these categories of data be defined?

a. Statistics on use (e.g., for each functional class of roads, the number of miles, speed, hours of operation, climate/weather and related road surface conditions).

b. Statistics and other information on outcome (e.g., type, number and cause of crashes or near misses, injuries, fatalities, disengagements, and transitions to fallback mechanisms, if appropriate).

c. Vehicle/scene/injury/roadway/traffic data and description for each crash or near miss (e.g., system status, pre-crash information, injury outcomes).

d. Sensor data from each crash or near miss (e.g., raw sensor data, perception system output, and control action).

e. Mobility performance impacts of vehicles with high and full driving automation, including string stability of multiple consecutive ADS vehicles and the effects of ADS on vehicle spacing, which could ultimately impact flow safety, and public acceptance.

f. Difficult scenarios (e.g., scenarios in which the system gave control back to an operator or transitioned to its safe state by, for example, disabling itself to a slow speed or stopped position).

g. Software updates (e.g., reasons for updates, extent to which updates are made to each vehicle for which the updates are intended, effects of updates).

h. Metrics that the manufacturer is tracking to identify and respond to progress (e.g., miles without a crash and software updates that increase the operating domain).

i. Information related to community, driver and pedestrian awareness, behavior, concerns and acceptance related to vehicles with high and full driving automation operation. For example, if vehicles with high and full driving automation operated only in limited defined geographic areas, might that affect the routing choices of vehicles without high and full driving automation? For another example, if vehicles with high and full driving automation are programmed to cede right of way to avoid collision with other vehicles and with pedestrians and cyclists, might some drivers of vehicles without such automation, pedestrians and cyclists take advantage of this fact and force vehicles with high and full driving automation to yield to them?

j. Metrics or information concerning the durability of the ADS equipment and calibration, and need for maintenance of the ADS.

k. Data from “control groups” that could serve as a useful baseline against which to compare the outcomes of the vehicle participating in the pilot program.

l. If there are other categories of data that should be considered, please identify them and the purposes for which they would be useful to the Agency in carrying out its responsibilities under the Act.

m. Given estimates that vehicles with high and full driving automation would generate terabytes of data per vehicle per day, how should the need for data be appropriately balanced with the burden on manufacturers of providing it and the ability of the Agency to absorb and use it effectively?

n. How would submission of a safety assurance letter help to promote public safety and build public confidence and acceptance?

For all of the above categories of information, how should the Agency handle any concerns about confidential business information and privacy?

B. Use of Exemptions To Provide Regulatory Relief for Pilot Program Participants

As discussed above, NHTSA has several means to provide regulatory relief for vehicles with high and full driving automation whose innovative designs make compliance with existing regulations impracticable or impossible. In this document, the Agency has outlined and requested comment on a potential pilot program for these vehicles, to encourage and facilitate the necessary research and data to ensure their safe deployment and allow NHTSA to determine how to appropriately evaluate and regulate these vehicles.

As part of this pilot program, NHTSA is considering what effect participation in the pilot program could have on the exemption process and vice versa.
grant such exemptions under each of the separate bases for exemptions in section 30113? Can the exemption process be used to facilitate safe and effective ADS development in an appropriate manner?

Question 17. Could a single pilot program make use of multiple statutory sources of exemptions or would different pilot programs be needed, one program for each source of exemption?

Question 18. To what extent would NHTSA need to implement the program via new regulation or changes to existing regulation? Conversely, could NHTSA implement the program through a non-regulatory process? Would the answer to that question change based upon which statutory exemption provision the agency based the program on?

1. Exemptions From Prohibitions Concerning Noncompliant Vehicles Under Section 30113

Section 30112, except as otherwise provided, e.g., under sections 30113 and 30114, prohibits any person from manufacturing, for sale, selling, offering for sale, introducing or delivering for introduction in interstate commerce, or importing into the United States, any motor vehicle or motor vehicle equipment manufactured on or after the date an applicable FMVSS takes effect unless the vehicle or equipment complies with the standard and is covered by a certification issued under section 30115 of the Act.24 Under section 30113, upon application by a vehicle manufacturer, NHTSA may exempt, on a temporary basis, motor vehicles from a FMVSS, on terms the Agency considers appropriate, if it finds that—

(a) an exemption is consistent with the public interest and this chapter or chapter 325 of this title (as applicable); and either

(b) compliance with the standard would cause substantial economic hardship to a manufacturer that has tried to comply with the standard in good faith;

(ii) the exemption would make easier the development or field evaluation of a new motor vehicle safety feature providing a safety level at least equal to the safety level of the standard;

(iii) the exemption would make the development or field evaluation of a low-emission motor vehicle easier and would not unreasonably lower the safety level of that vehicle; or

(iv) compliance with the standard would prevent the manufacturer from selling a motor vehicle with an overall safety level at least equal to the overall safety level of nonexempt vehicles.25

A manufacturer is eligible for an economic hardship exemption only if the manufacturer’s total motor vehicle production in the most recent year of production is not more than 10,000. An economic hardship exemption can be granted for not more than 3 years, although it can be renewed. Any manufacturer, regardless of its total production, is eligible for an exemption on the other three bases listed in the paragraph immediately above, but only if the exemption is for not more than 2,500 vehicles to be sold in the United States in any 12-month period. Exemptions on these three bases may be granted for not more than 2 years and can be renewed. Over the years, NHTSA has granted numerous exemptions under the “substantial economic hardship” criteria, but relatively few under the other three bases. This proportion may change in the future. The use of the other three bases for granting petitions for the exemption of vehicles with high and full driving automation may become increasingly important prior to the development of ADS-specific standards.

Since the Act does not contain any prohibitions regarding the use of a motor vehicle, whether compliant or noncompliant, once a manufacturer receives an exemption from the prohibitions of section 30112(a)(1), the use of those vehicles is controlled only to the extent that NHTSA sets terms on the exemption. Its authority to set terms is broad. Since the terms would be the primary means of ensuring the safe operation of those vehicles, the Agency would consider carefully what types of terms to establish. The manufacturer would need to agree to abide by the terms set for that exemption in order to begin and continue producing vehicles pursuant to that exemption. Thus, if NHTSA were to establish the collaborative pilot research program for such vehicles discussed in this document, it could establish, for example, reporting terms to ensure a continuing flow of information to the Agency during and after the period of exemption to meet the Agency’s, as well as the manufacturer’s, research needs. Since only a very small portion of the total mileage that the exempted vehicles could be expected to travel during their useful life would have been driven by the end of the exemption period, it might be desirable for the data to be reported over a longer period of time to enable the Agency to make sufficiently reliable judgements. Such judgments might include a retrospective review of the judgments that the Agency made, at the time of granting the petition, about the anticipated safety effects of the exemption. Regardless of the period specified for reporting, NHTSA could also establish terms to specify what the consequences would be if the flow of information were to cease or become inadequate during or after the exemption period. NHTSA’s regulations in 49 CFR part 555 provide that the Agency can revoke an exemption if a manufacturer fails to satisfy the terms of the exemption.

Question 19. How could the exemption process in section 30113 be used to facilitate a pilot program? For vehicles with high and full driving automation that lack means of manual control, how should NHTSA consider their participation, including their continued participation, in the pilot program in determining whether a vehicle would meet the statutory criteria for an exemption under section 30113?

More specifically:

a. Would participation assist a manufacturer in showing that an exemption from a FMVSS would facilitate the development or field evaluation of a new motor vehicle safety feature providing a safety level at least equal to the safety level of the FMVSS, as required to obtain an exemption under section 30113(b)(iii)? If so, please explain how.

b. Would participation assist a manufacturer in showing that compliance with the FMVSS would prevent the manufacturer from selling a motor vehicle with an overall safety level at least equal to the overall safety level of nonexempt vehicles, as required to obtain an exemption under section 30113(b)(iv)? If so, please explain how.

c. The Agency requests comment on what role a pilot program could play in determining when to grant an exemption from the “make inoperative” prohibition under section 30122 for certain “dual mode” vehicles. Relatedly, what tools does NHTSA have to incentivize vehicles with high and full driving automation that have means of manual control and thus do not need an exemption to participate in the pilot program?

2. Exemptions From Prohibitions Concerning Noncompliant Vehicles Under Section 30114

Next, under section 30114, the “Secretary of Transportation may exempt a motor vehicle or item of motor vehicle equipment from section 30112(a) of this title, on terms the Secretary decides are necessary, for


research, demonstrations, training, competitive racing events, show, or display.” 26
NHTSA has historically focused these types of exemptions on the noncompliant vehicles made outside the U.S. However, NHTSA is examining whether the language of section 30114 gives NHTSA the discretion to create a level playing field by expanding the coverage of exemption under that section to any vehicle, regardless of whether it is domestic or foreign, that meets the criteria of that section, particularly vehicles with high and full driving automation that do not meet existing standards and whose manufacturers are or seek to become engaged in research and demonstrations involving those vehicles. If so, NHTSA would be able to establish the terms with which a participant would need to comply in order to receive and continue to enjoy the benefits of an exemption. Such terms could include a wide variety of matters, including participation in a pilot program.

Question 20. What role could exemptions under section 30114 play in the pilot program? Could participation in the pilot program assist a manufacturer in qualifying for an exemption under section 30114? Could participation be considered part of the terms the Secretary determines are necessary to be granted an exemption under section 30114 for vehicles that are engaged in “research, investigations, demonstrations, training, competitive racing events, show, or display”?

3. Exemption From Rendering Inoperative Prohibition

Finally, NHTSA has related exemption authority with regard to the “make inoperative” provision in its statute. Manufacturers, distributors, dealers, and motor vehicle repair businesses are prohibited from knowingly making inoperative any part of a device or element of design installed on or in a motor vehicle or motor vehicle equipment in compliance with an applicable FMVSS unless they reasonably believe the vehicle or equipment will not be used (except for testing or a similar purpose during maintenance or repair) when the device or element is inoperative.27

However, NHTSA may prescribe regulations to exempt a person or a class of persons from this prohibition if the Agency decides the exemption is consistent with motor vehicle safety and the purposes of the Act. For example, pursuant to that authority, NHTSA has exempted from the “make inoperative” prohibition,28 as a class, all motor vehicle repair businesses that modify a motor vehicle to enable a person with a disability to operate, or ride as a passenger in, the motor vehicle to the extent that those modifications affect the motor vehicle’s compliance with the FMVSS or portions thereof specified in paragraph (c) of 49 CFR part 595. Such an exemption may be warranted for certain “dual-mode” vehicles, i.e., those that may be operated with or without a human driver and are designed to have mandated and/or regulated components, such as brake pedals, retract under specified conditions. Comments are invited on this issue.

Question 21. What role could a pilot program play in determining when to grant an exemption from the “make inoperative” prohibition under section 30122 for certain “dual mode” vehicles? Relatedly, what tools does NHTSA have to incentivize vehicles with high and full driving automation that have means of manual control and thus do not need an exemption to participate in the pilot program?

4. Other Potential Obstacles

The Agency also wishes to better understand any other potential obstacles either to the development of the pilot program or vehicles with high and full driving automation more generally.

Question 22. If there are any obstacles other than the FMVSS to the testing and development of vehicles with high and full driving automation, please explain what those are and what could be done to relieve or lessen their burdens. To the extent any tension exists between a Federal pilot program and State or local law, how can NHTSA better partner with State and local authorities to advance our common interests in the safe and effective testing and deployment of ADS technology?

IV. Confidentiality of Information Provided by Program Participants

NHTSA recognizes that companies may be reluctant to share certain data or information with the Agency in connection with an exception, an exemption, or a pilot program because the data or information is proprietary. The Agency notes that 49 CFR part 512 sets forth the procedures and standards by which it will consider claims that information submitted to the Agency is entitled to confidential treatment under 5 U.S.C. 552(b), most often because the information constitutes confidential business information as described in 5 U.S.C. 552(b)(4). Part 512 also addresses the treatment of information determined to be entitled to confidential treatment. Commercial or financial information is considered confidential if it is voluntarily submitted to the Agency and is the type of information that is customarily not released to the general public. The Agency is seeking information from interested parties on how it might further protect non-public information that the Agency might need in connection with an exemption or pilot program.

V. Next Steps

The Agency wishes to re-emphasize that it has not made any decisions whether to establish a pilot program or how to structure such a program. After analyzing the public comments on this ANPRM and other available information, NHTSA will further assess the prospects for implementing a viable and effective program and identify the best approach to structuring one. Once it has done so, it will issue a notice, either an NPRM, if regulatory changes are determined to be necessary or a request for comment, if no regulatory changes are required, describing that approach and any promising alternative approaches and again seek public comment. After considering that second round of comments, the Agency will make a final decision about such a program in a final rule, if needed, or through another notice.

VI. Regulatory Notices

This action has been determined to be significant under Executive Order 12866, as amended by Executive Order 13563, and the Department of Transportation’s Regulatory Policies and Procedures. It has been reviewed by the Office of Management and Budget under that Order. Executive Orders 12866 (Regulatory Planning and Review) and 13563 (Improving Regulation and Regulatory Review) require agencies to regulate in the “most cost-effective manner,” to make a “reasoned determination that the benefits of the intended regulation justify its costs,” and to develop regulations that “impose the least burden on society.” Additionally, Executive Orders 12866 and 13563 require agencies to provide a meaningful opportunity for public participation. Accordingly, we have asked commenters to answer a variety of questions to elicit practical information about alternative approaches and relevant technical data. These comments will help the Department evaluate whether a proposed rulemaking is needed and appropriate. This action is not subject to the requirements of E.O. 13771 (82 FR 9339,
February 3, 2017) because it is an advance notice of proposed rulemaking.

VII. Public Comment

How do I prepare and submit comments?

Your comments must be written and in English. To ensure that your comments are filed in the correct docket, please include the docket number of this document in your comments.

Your comments must not be more than 15 pages long (49 CFR 553.21). NHTSA established this limit to encourage you to write your primary arguments in a concise fashion so that the Agency and the public can more readily identify the more significant aspects of your comments. However, you may provide additional supporting arguments and relevant data by attaching necessary additional documents to your comments. There is no limit on the number or length of the attachments.

Please submit one copy (two copies if submitting by mail or hand delivery) of your comments, including the attachments, to the docket following the instructions given above under ADDRESSES. Please note, if you are submitting comments electronically as a PDF (Adobe) file, we ask that the documents submitted be scanned using an Optical Character Recognition (OCR) process, thus allowing NHTSA to search and copy certain portions of your submissions.

How do I submit confidential business information?

If you wish to submit any information under a claim of confidentiality, you must submit three copies of your complete submission, including the information you claim to be confidential business information, to the Office of the Chief Counsel, NHTSA, at the address given above under FOR FURTHER INFORMATION CONTACT.

In addition, you may submit a copy (two copies if submitting by mail or hand delivery) from which you have deleted the claimed confidential business information, to the docket by one of the methods given above under ADDRESSES. When you send a comment containing information claimed to be confidential business information, you should include a cover letter setting forth the information specified in NHTSA’s confidential business information regulation (49 CFR part 512).

Will NHTSA consider late comments?

NHTSA will consider all comments received before the close of business on the comment closing date indicated above under DATES. To the extent possible, NHTSA will also consider comments received after that date.

How can I read the comments submitted by other people?

You may read the comments received at the address given above under Comments. The hours of the docket are indicated above in the same location. You may also read the comments on the internet, identified by the docket number at the heading of this document, at http://www.regulations.gov.

Please note that, even after the comment closing date, NHTSA will continue to file relevant information in the docket as it becomes available. Further, some people may submit late comments. Accordingly, NHTSA recommends that you periodically check the docket for new material.


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Heidi Renate King,
Deputy Administrator.

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Preparing for
THE FUTURE OF TRANSPORTATION

Automated Vehicles 3.0

October 2018
https://www.transportation.gov/av

U.S. Department of Transportation

PREPARING FOR THE FUTURE OF TRANSPORTATION
With the development of automated vehicles, American creativity and innovation hold the potential to once again transform mobility.

AV 3.0 is the beginning of a national discussion about the future of our surface transportation system. Your voice is essential to shaping this future.
Preparing for the Future of Transportation

Automated Vehicles 3.0

U.S. Department of Transportation
America has always been a leader in transportation innovation. From the mass production of automobiles to global positioning system navigation, American ingenuity has transformed how we travel and connect with one another. With the development of automated vehicles, American creativity and innovation hold the potential to once again transform mobility.

Automation has the potential to improve our quality of life and enhance the mobility and independence of millions of Americans, especially older Americans and people with disabilities.

Moreover, the integration of automation across our transportation system has the potential to increase productivity and facilitate freight movement. But most importantly, automation has the potential to impact safety significantly—by reducing crashes caused by human error, including crashes involving impaired or distracted drivers, and saving lives.

Along with potential benefits, however, automation brings new challenges that need to be addressed. The public has legitimate concerns about the safety, security, and privacy of automated technology. So I have challenged Silicon Valley and other innovators to step up and help address these concerns and help inform the public about the benefits of automation. In addition, incorporating these technologies into our transportation systems may impact industries, creating new kinds of jobs. This technology evolution may also require workers in transportation fields to gain new skills and take on new roles. As a society, we must help prepare workers for this transition.

The U.S. Department of Transportation is taking active steps to prepare for the future by engaging with new technologies to ensure safety without hampering innovation. With the release of Automated Driving Systems 2.0: A Vision for Safety in September 2017, the Department provided voluntary guidance to industry, as well as technical assistance and best practices to States, offering a path forward for the safe testing and integration of automated driving systems. The Department also bolstered its engagement with the automotive industry, technology companies,
and other key transportation stakeholders and innovators to continue to develop a policy framework that facilitates the safe integration of this technology into our transportation systems.

Preparing for the Future of Transportation: Automated Vehicles 3.0 (AV 3.0) is another milestone in the Department’s development of a flexible, responsible approach to a framework for multimodal automation. It introduces guiding principles and describes the Department’s strategy to address existing barriers to safety innovation and progress. It also communicates the Department’s agenda to the public and stakeholders on important policy issues, and identifies opportunities for cross-modal collaboration.

The Department is committed to engaging stakeholders to identify and solve policy issues. Since the publication of Automated Driving Systems 2.0: A Vision for Safety, the Department has sought input on automation issues from stakeholders and the general public through a wide range of forums including formal Requests for Information and Comments. In March 2018, I hosted the Automated Vehicle Summit to present the Department’s six Automation Principles and discuss automation issues with public and private sector transportation stakeholders across every mode. The ideas and issues raised by stakeholders through these forums are reflected in this document. The goal of the Department is to keep pace with these rapidly evolving technologies so America remains a global leader in safe automation technology.

AV 3.0 is the beginning of a national discussion about the future of our surface transportation system. Your voice is essential to shaping this future.

Working together, we can help usher in a new era of transportation innovation and safety, and ensure that our country remains a global leader in automated technology.
The United States Department of Transportation (U.S. DOT) has established a clear and consistent Federal approach to shaping policy for automated vehicles, based on the following six principles.

1. We will prioritize safety.

Automation offers the potential to improve safety for vehicle operators and occupants, pedestrians, bicyclists, motorcyclists, and other travelers sharing the road. However, these technologies may also introduce new safety risks. U.S. DOT will lead efforts to address potential safety risks and advance the life-saving potential of automation, which will strengthen public confidence in these emerging technologies.

2. We will remain technology neutral.

To respond to the dynamic and rapid development of automated vehicles, the Department will adopt flexible, technology-neutral policies that promote competition and innovation as a means to achieve safety, mobility, and economic goals. This approach will allow the public—not the Federal Government—to choose the most effective transportation and mobility solutions.

3. We will modernize regulations.

U.S. DOT will modernize or eliminate outdated regulations that unnecessarily impede the development of automated vehicles or that do not address critical safety needs. Whenever possible, the Department will support the development of voluntary, consensus-based technical standards and approaches that are flexible and adaptable over time. When regulation is needed, U.S. DOT will seek rules that are as nonprescriptive and performance-based as possible. As a starting point and going forward, the Department will interpret and, consistent with all applicable notice and comment requirements, adapt the definitions of “driver” and “operator” to recognize that such terms do not refer exclusively to a human, but may in fact include an automated system.
4. We will encourage a consistent regulatory and operational environment.

Conflicting State and local laws and regulations surrounding automated vehicles create confusion, introduce barriers, and present compliance challenges. U.S. DOT will promote regulatory consistency so that automated vehicles can operate seamlessly across the Nation. The Department will build consensus among State and local transportation agencies and industry stakeholders on technical standards and advance policies to support the integration of automated vehicles throughout the transportation system.

5. We will prepare proactively for automation.

U.S. DOT will provide guidance, best practices, pilot programs, and other assistance to help our partners plan and make the investments needed for a dynamic and flexible automated future. The Department also will prepare for complementary technologies that enhance the benefits of automation, such as communications between vehicles and the surrounding environment, but will not assume universal implementation of any particular approach.

6. We will protect and enhance the freedoms enjoyed by Americans.

U.S. DOT embraces the freedom of the open road, which includes the freedom for Americans to drive their own vehicles. We envision an environment in which automated vehicles operate alongside conventional, manually-driven vehicles and other road users. We will protect the ability of consumers to make the mobility choices that best suit their needs. We will support automation technologies that enhance individual freedom by expanding access to safe and independent mobility to people with disabilities and older Americans.
SAE AUTOMATION LEVELS

0 No Automation
The full-time performance by the human driver of all aspects of the dynamic driving task, even when enhanced by warning or intervention systems.

1 Driver Assistance
The driving mode-specific execution by a driver assistance system of either steering or acceleration/deceleration using information about the driving environment and with the expectation that the human driver perform all remaining aspects of the dynamic driving task.

2 Partial Automation
The driving mode-specific execution by one or more driver assistance systems of both steering or acceleration/deceleration using information about the driving environment and with the expectation that the human driver perform all remaining aspects of the dynamic driving task.

3 Conditional Automation
The driving mode-specific performance by an automated driving system of all aspects of the dynamic driving task with the expectation that the human driver will respond appropriately to a request to intervene.

4 High Automation
The driving mode-specific performance by an automated driving system of all aspects of the dynamic driving task, even if a human driver does not respond appropriately to a request to intervene.

5 Full Automation
The full-time performance by an automated driving system of all aspects of the dynamic driving task under all roadway and environmental conditions that can be managed by a human driver.

A Note on Terminology
Clear and consistent definition and use of terminology is critical to advancing the discussion around automation. To date, a variety of terms (e.g., self-driving, autonomous, driverless, highly automated) have been used by industry, government, and observers to describe various forms of automation in surface transportation. While no terminology is correct or incorrect, this document uses “automation” and “automated vehicles” as general terms to broadly describe the topic, with more specific language, such as “Automated Driving System” or “ADS” used when appropriate. A full glossary is in the Appendix.

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EXECUTIVE SUMMARY

Preparing for the Future of Transportation: Automated Vehicles 3.0 (AV 3.0) advances U.S. DOT’s commitment to supporting the safe, reliable, efficient, and cost-effective integration of automation into the broader multimodal surface transportation system. AV 3.0 builds upon—but does not replace—voluntary guidance provided in Automated Driving Systems 2.0: A Vision for Safety.

Automation technologies are new and rapidly evolving. The right approach to achieving safety improvements begins with a focus on removing unnecessary barriers and issuing voluntary guidance, rather than regulations that could stifle innovation.

In AV 3.0, U.S. DOT’s surface transportation operating administrations come together for the first time to publish a Departmental policy statement on automation. This document incorporates feedback from manufacturers and technology developers, infrastructure owners and operators, commercial motor carriers, the bus transit industry, and State and local governments. This document considers automation broadly, addressing all levels of automation (SAE automation Levels 1 to 5), and recognizes multimodal interests in the full range of capabilities this technology can offer.

AV 3.0 includes six principles that guide U.S. DOT programs and policies on automation and five implementation strategies for how the Department translates these principles into action (see facing page).

AV 3.0 Provides New Multimodal Safety Guidance

In accordance with the Department’s first automation principle, AV 3.0 outlines how automation will be safely integrated across passenger vehicles, commercial vehicles, on-road transit, and the roadways on which they operate. Specifically, AV 3.0:

- Affirms the approach outlined in A Vision for Safety 2.0 and encourages automated driving system developers to make their Voluntary Safety Self-Assessments public to increase transparency and confidence in the technology.
- Provides considerations and best practices for State and local governments to support the safe and effective testing and operation of automation technologies.
- Supports the development of voluntary technical standards and approaches as an effective non-regulatory means to advance the integration of automation technologies into the transportation system.
- Describes an illustrative framework of safety risk management stages along the path to full commercial integration of automated vehicles. This framework promotes the benefits of safe deployment while managing risk and provides clarity to the public regarding the distinctions between various stages of testing and full deployment.
- Affirms the Department is continuing its work to preserve the ability for transportation safety applications to function in the 5.9 GHz spectrum.

See Appendix B for a summary of public input received.

AV 3.0 Clarifies Policy and Roles

AV 3.0 responds to issues raised by stakeholders and includes the following key policy and role clarifications:

- States that U.S. DOT will interpret and, consistent with all applicable notice and comment requirements, adapt the definitions of “driver” and “operator” to recognize that such terms do not refer exclusively to a human, but may include an automated system.
- Recognizes that given the rapid increase in automated vehicle testing activities in many locations, there is no need for U.S. DOT to favor particular locations or to pick winners and losers. Therefore, the Department no longer recognizes the designations of ten Automated Vehicle Proving Grounds announced on January 19, 2017.
- Urges States and localities to work to remove barriers—such as unnecessary and incompatible regulations—to automated vehicle technologies and to support interoperability.
- Affirms U.S. DOT’s authority to establish motor vehicle safety standards that allow for innovative automated vehicle designs—such as vehicles without steering wheels, pedals, or mirrors—and notes that such an approach may require a more fundamental revamping of the National Highway Traffic Safety Administration’s (NHTSA) approach to safety standards for application to automated vehicles.
- Reaffirms U.S. DOT’s reliance on a self-certification approach, rather than type approval, as the way to balance and promote safety and innovation; U.S. DOT will continue to advance this approach with the international community.
Clarifies that, rather than requiring a one-size-fits-all approach, the Federal Transit Administration will provide transit agencies with tailored technical assistance as they develop an appropriate safety management system approach to ensuring safe testing and deployment of automated transit bus systems.

**AV 3.0 Outlines How to Work with U.S. DOT as Automation Technology Evolves**

It identifies opportunities for partnership and collaboration among the private sector, State and local agencies, and U.S. DOT on issues ranging from accessibility to workforce development to cybersecurity. Specifically, AV 3.0:

- Announces a forthcoming notice of proposed rulemaking, which includes the possibility of setting exceptions to certain safety standards—that are relevant only when human drivers are present—for automated driving system (ADS)-equipped vehicles.
- Informs stakeholders that U.S. DOT will seek public comment on a proposal to streamline and modernize the procedures NHTSA will follow when processing and deciding exemption petitions.
- Defines a targeted Federal role in automation research.
- Informs stakeholders of the Federal Motor Carrier Safety Administration’s (FMCSA) intent to initiate an Advance Notice of Proposed Rulemaking to better understand areas of responsibility between the State and Federal governments in the context of ADS-equipped commercial motor vehicles and commercial carriers.
- States that FMCSA will also consider changes to its motor carrier safety regulations to accommodate the integration of ADS-equipped commercial motor vehicles.
- Informs stakeholders that U.S. DOT plans to update the 2009 Manual on Uniform Traffic Control Devices, taking new technologies into consideration.
- Identifies automation-related voluntary standards being developed through standards development organizations and associations.

**U.S. DOT’s Operating Administrations are United in Their Commitment to Safety**

We act as “One DOT” in pursuing strategies to successfully integrate automation technologies into the transportation system. The operating administrations shown on the facing page contributed to AV 3.0.

Each of these U.S. DOT operating administrations actively encourages the integration of automation in ways guided by the U.S. DOT’s automation principles and strategies noted above. AV 3.0 focuses on the automation of motor vehicles on roadways and the roles of NHTSA, FMCSA, FHWA, and FTA, with consideration of intermodal points (e.g., motor vehicles at ports and highway-rail grade crossings).

4 See https://www.transportation.gov/av for more information on automation efforts at U.S. DOT.
OPERATING ADMINISTRATIONS

For more information on how U.S. DOT agencies engage with automation, see www.transportation.gov/av

Federal Highway Administration

The Federal Highway Administration (FHWA) is responsible for providing stewardship over the construction, maintenance, and preservation of the Nation’s highways, bridges, and tunnels. Through research and technical assistance, the FHWA supports its partners in Federal, State, and local agencies to accelerate innovation and improve safety and mobility.

Federal Motor Carrier Safety Administration

The Federal Motor Carrier Safety Administration’s (FMCSA) mission is to reduce crashes, injuries, and fatalities involving large trucks and buses. FMCSA partners with industry, safety advocates, and State and local governments to keep the Nation’s roads safe and improve commercial motor vehicle (CMV) safety through regulation, education, enforcement, research, and technology.

Federal Aviation Administration

The Federal Aviation Administration (FAA) provides the safest and most efficient aviation system in the world. Annually, FAA manages over 54 million flights, approaching a billion passengers.

Federal Railroad Administration

The Federal Railroad Administration’s (FRA) mission is to enable the safe, reliable, and efficient movement of people and goods for a strong America. FRA is advancing the use of new technology in rail.

Federal Transit Administration

The Federal Transit Administration (FTA) provides financial and technical assistance to local public transit systems, including buses, subways, light rail, commuter rail, trolleys, and ferries. FTA also oversees safety measures and helps develop next-generation technology research.

Maritime Administration

The Maritime Administration (MARAD) promotes the use of waterborne transportation and its seamless integration with other segments of the transportation system, and the viability of the U.S. merchant marine.

National Highway Traffic Safety Administration

The National Highway Traffic Safety Administration’s (NHTSA) mission is to save lives, prevent injuries, and reduce the economic costs of road traffic crashes through education, research, safety standards, and enforcement activity. NHTSA carries out highway safety programs by setting and enforcing safety performance standards for motor vehicles and equipment, identifying safety defects, and through the development and delivery of effective highway safety programs for State and local jurisdictions.

Pipeline and Hazardous Materials Safety Administration

The Pipeline and Hazardous Materials Safety Administration (PHMSA) protects people and the environment by advancing the safe transportation of energy and other hazardous materials that are essential to our daily lives. To do this, PHMSA establishes national policy, sets and enforces standards, educates, and conducts research to prevent incidents.
Automated vehicles that accurately detect, recognize, anticipate, and respond to the movements of all transportation system users could lead to breakthrough gains in transportation safety.
The United States surface transportation system provides tremendous mobility benefits, including widespread access to jobs, goods, and services. It also connects many remote regions of the country to the larger economy. These benefits, however, come with significant safety challenges, as motor vehicle crashes remain a leading cause of death, with an estimated 37,133 lives lost on U.S. roads in 2017. Traditional safety programs and policies have made road travel significantly safer than in the past, but there is much room to improve traffic fatality and injury rates.

Automated vehicles that accurately detect, recognize, anticipate, and respond to the movements of all transportation system users could lead to breakthrough gains in transportation safety. Unlike human drivers, automation technologies are not prone to distraction, fatigue, or impaired driving, which contribute to a significant portion of surface transportation fatalities. Automated vehicle technologies that are carefully integrated into motor vehicles could help vehicle operators detect and avoid bicyclists, motorcyclists, pedestrians, and other vulnerable users on our roadways, and increase safety across the surface transportation system. Their potential to reduce deaths and injuries on the Nation’s roadways cannot be overstated.

Automated vehicles rely on sensors and software that allow an expansive view of the environment across a range of lighting and weather conditions. They can quickly learn and adapt to new driving situations by learning from previous experience through software updates. Fully realizing the life-saving potential of automated vehicles, however, will require careful risk management as new technologies are introduced and adopted across the surface transportation system.

To support the deployment of safe automation technologies, the Department released A Vision for Safety 2.0 in September 2017, which included 12 automated driving system (ADS) safety elements to help industry partners analyze, identify, and resolve safety considerations using best practices—all before deployment. The voluntary guidance outlined in A Vision for Safety 2.0 on the design, testing, and safe deployment of ADS remains central to U.S. DOT’s approach. ADS developers are encouraged to use these safety elements to publish safety self-assessments to describe to the public how they are identifying and addressing potential safety issues.

On-road testing and early deployments are important to improving automated vehicle performance and allowing them to reach their full performance potential. Careful real-world testing allows developers to identify and rapidly fix system shortcomings, not just on individual vehicles but across fleets. Reasonable risks must be addressed through the application of robust systems engineering processes, testing protocols, and functional safety best practices, such as those documented in A Vision for Safety 2.0.
2.0. However, delaying or unduly hampering automated vehicle testing until all specific risks have been identified and eliminated means delaying the realization of global reductions in risk.

AV 3.0 maintains U.S. DOT’s primary focus on safety, while expanding the discussion to other aspects and modes of surface transportation. AV 3.0 introduces a comprehensive, multimodal approach toward safely integrating automation.

AV 3.0 introduces a comprehensive, multimodal approach toward safely integrating automation.

5 As documented in A Vision for Safety 2.0, ADS developers should consider employing systems engineering guidance, best practices, design principles, and standards developed by established and accredited standards-developing organizations (as applicable) such as the International Standards Organization (ISO) and SAE International as well as standards and processes available from other industries, such as aviation, space, and the military and other applicable standards or internal company processes as they are relevant and applicable. They should also consider available and emerging approaches to risk mitigation, such as methodologies that focus on functional safety (e.g., ISO 26262) and safety of the intended functionality.
Safety by the Numbers

- An estimated **39,141** people lost their lives on all modes of our transportation system in 2017. The vast majority—**37,133** deaths—were from motor vehicle crashes.

- **Driver Factors:** Of all serious motor vehicle crashes, **94 percent** involve driver-related factors, such as impaired driving, distraction, and speeding or illegal maneuvers.

  In 2017:
  - Nearly **11,000** fatalities involved drinking and driving.
  - Speeding was a factor in nearly **10,000** highway fatalities.
  - Nearly **3,500** fatal crashes* involved distracted drivers.

- **Commercial Vehicles:** **13 percent** of annual roadway fatalities occur in crashes involving large trucks.

- In 2017, **82 percent** of victims in fatal large truck crashes were road users who were not an occupant of the truck(s) involved.

- **Professional Drivers:** Professional drivers are **ten times** more likely to be killed on the job, and nearly nine times more likely to be injured on the job compared to the average worker.

- **Pedestrians:** **5,977** pedestrians were killed by motor vehicles in 2017, representing 16 percent of all motor vehicle fatalities.

- **Highway-Rail Grade Crossings:** Over the past decade, highway and rail grade crossing fatalities averaged **253** per year, representing about one-third of total railroad-related fatalities.

**Sources:**

A. U.S. Department of Transportation, Bureau of Transportation Statistics, special tabulation, September 8, 2018

B. NHTSA 2017 Fatal Motor Vehicle Crashes: Overview (DOT HS 812 603)


* This number is likely underreported.
Only by working in partnership can the public and the private sector improve the safety, security, and accessibility of automation technologies and address the concerns of the general public.
The traditional roles of the Federal Government, State and local governments, and private industry are well suited for addressing automation. The Federal Government is responsible for regulating the safety performance of vehicles and vehicle equipment, as well as their commercial operation in interstate commerce, while States and local governments play the lead role in licensing drivers, establishing rules of the road, and formulating policy in tort liability and insurance. Private industry remains a primary source of transportation research investment and commercial technology development. Governments at all levels should not unnecessarily impede such innovation. The Department relies on partners to play their respective roles, while continuing to encourage open dialogue and frequent engagement.

The Department seeks to address policy uncertainty and provide clear mechanisms by which partners can participate and engage with the U.S. DOT.

**The Federal Government and Automation**

U.S. DOT’s role in transportation automation is to ensure the safety and mobility of the traveling public while fostering economic growth. As a steward of the Nation’s roadway transportation system, the Federal Government plays a significant role by ensuring that automated vehicles can be safely and effectively integrated into the existing transportation system, alongside conventional vehicles, pedestrians, bicyclists, motorcyclists, and other road users. U.S. DOT also has an interest in supporting innovations that improve safety, reduce congestion, improve mobility, and increase access to economic opportunity for all Americans. Finally, by partnering with industry in adopting market-driven, technology-neutral policies that encourage innovation in the transportation system, the Department seeks to fuel economic growth and support job creation and workforce development.

To accomplish these goals, the Department works closely with stakeholders in the private and public sectors to pursue the following activities:

- Establish performance-oriented, consensus-based, and voluntary standards and guidance for vehicle and infrastructure safety, mobility, and operations.
- Conduct targeted research to support the safe integration of automation.
- Identify and remove regulatory barriers to the safe integration of automated vehicles.
- Ensure national consistency for travel in interstate commerce.
- Educate the public on the capabilities and limitations of automated vehicles.

**Integrating Safety into Surface Transportation Automation**

Each operating administration has its respective area of authority over improving the safety of the Nation’s transportation system. Assuring the safety of automated vehicles will not only rely on the validation of the technology, such as the hardware, software, and components, but it will also depend on appropriate operating
rules, roadway conditions, and emergency response protocols. The following sections outline the primary authorities and policy issues for the National Highway Traffic Safety Administration (NHTSA), Federal Motor Carrier Safety Administration (FMCSA), Federal Highway Administration (FHWA), and Federal Transit Administration (FTA) to demonstrate how the U.S. DOT is incorporating safety throughout the surface transportation system as it relates to automated vehicles. These sections also discuss ADS-equipped vehicles (SAE automation Levels 3 to 5) and lower level technologies (SAE automation Levels 0 to 2), depending on the role of each operating administration and its current engagement with automation.

**NHTSA Authorities and Key Policy Issues**

**Safety Authority Over ADS-Equipped Vehicles and Equipment**

NHTSA has broad authority over the safety of ADS-equipped vehicles and other automated vehicle technologies equipped in motor vehicles. NHTSA has authority to establish Federal safety standards for new motor vehicles introduced into interstate commerce in the United States, and to address safety defects determined to exist in motor vehicles or motor vehicle equipment used in the United States. The latter authority focuses on the obligations that Federal law imposes on the manufacturers of motor vehicles and motor vehicle equipment to notify NHTSA of safety defects in those vehicles or vehicle equipment and to remedy the defects, subject to NHTSA’s oversight and enforcement authority.

Under Federal law, no State or local government may enforce a law on the safety performance of a motor vehicle or motor vehicle equipment that differs in any way from the Federal standard. The preemptive force of the Federal safety standard does not extend to State and local traffic laws, such as speed limits. Compliance with the Federal safety standard does not automatically exempt any person from liability at common law, including tort liability for harm caused by negligent conduct, except where preemption may apply. The Federal standard would supersede if the effect of a State law tort claim would be to impose a performance standard on a motor vehicle or equipment manufacturer that is inconsistent with the Federal standard.

NHTSA’s application of Federal safety standards to the performance of ADS-equipped vehicles and equipment is likely to raise questions about preemption and the future complementary mix of Federal, State and local powers. The Department will carefully consider these jurisdictional questions as NHTSA develops its regulatory approach to ADS and other automated vehicle technologies so as to strike the appropriate balance between the Federal Government’s use of its authorities to regulate the safe design and operational performance of an ADS-equipped vehicle and the State and local authorities’ use of their traditional powers.

**Federal Safety Standards for ADS-Equipped Vehicles**

Several NHTSA safety standards for motor vehicles assume a human occupant will be able to control the operation of the vehicle, and many standards incorporate performance requirements and test procedures geared toward ensuring safe operation by a human driver. Some standards focus on the safety of drivers and occupants in particular seating arrangements. Several standards impose specific requirements for the use of steering wheels, brakes, accelerator pedals, and other control features, as well as the visibility for a human driver of instrument displays, vehicle status indicators, mirrors, and other driving information.

NHTSA’s current safety standards do not prevent the development, testing, sale, or
use of ADS built into vehicles that maintain the traditional cabin and control features of human-operated vehicles. However, some Level 4 and 5 automated vehicles may be designed to be controlled entirely by an ADS, and the interior of the vehicle may be configured without human controls. There may be no steering wheel, accelerator pedal, brakes, mirrors, or information displays for human use. For such ADS-equipped vehicles, NHTSA's current safety standards constitute an unintended regulatory barrier to innovation.

The Department, through NHTSA, intends to reconsider the necessity and appropriateness of its current safety standards as applied to ADS-equipped vehicles. In an upcoming rulemaking, NHTSA plans to seek comment on proposed changes to particular safety standards to accommodate automated vehicle technologies and the possibility of setting exceptions to certain standards—that are relevant only when human drivers are present—for ADS-equipped vehicles.

Going forward, NHTSA may also consider a more fundamental revamping of its approach to safety standards for application to automated vehicles. However, reliance on a self-certification approach, instead of type approval, more appropriately balances and promotes safety and innovation; U.S. DOT will continue to advance this approach with the international community. NHTSA’s current statutory authority to establish motor vehicle safety standards is sufficiently flexible to accommodate the design and performance of different ADS concepts in new vehicle configurations.

NHTSA recognizes that the accelerating pace of technological change, especially in the development of software used in ADS-equipped vehicles, requires a new approach to the formulation of the Federal Motor Vehicle Safety Standards (FMVSS). The pace of innovation in automated vehicle technologies is incompatible with lengthy rulemaking proceedings and highly prescriptive and feature-specific or design-specific safety standards. Future motor vehicle safety standards will need to be more flexible and responsive, technology-neutral, and performance-oriented to accommodate rapid technological innovation. They may incorporate simpler and more general requirements designed to validate that an ADS can safely navigate the real-world roadway environment, including unpredictable hazards, obstacles, and interactions with other vehicles and pedestrians who may not always adhere to the traffic laws or follow expected patterns of behavior. Existing standards assume that a vehicle may be driven anywhere, but future standards will need to take into account that the operational design domain (ODD) for a particular ADS within a vehicle is likely to be limited in some ways that may be unique to that system. For example, not all Level 3 vehicles will have the same ODD.

Performance-based safety standards could require manufacturers to use test methods, such as sophisticated obstacle-course-based test regimes, sufficient to validate that their ADS-equipped vehicles can reliably handle the normal range of everyday driving scenarios as well as unusual and unpredictable scenarios. Standards could be designed to account for factors such as variations in weather, traffic, and roadway conditions within a given system’s ODD, as well as sudden and unpredictable actions by other road users. Test procedures could also be developed to ensure that an ADS does not operate outside of the ODD established by the manufacturer. Standards could provide for a range of potential behaviors—e.g., speed, distance, angles, and size—for surrogate vehicles, pedestrians, and other obstacles that ADS-equipped vehicles would need to detect and avoid. Other approaches, such as computer simulation and requirements expressed in terms of mathematical functions could be considered, as Federal law does not require that NHTSA’s safety standards rely on physical tests and measurements, only that they be objective, repeatable, and transparent.

Exemptions from FMVSS for ADS Purposes

NHTSA values a streamlined and modernized exemptions procedure, and removing unnecessary delays. NHTSA intends to seek
public comment on a proposal to streamline and modernize procedures the Agency will follow when processing and deciding exemption petitions. Among other things, the proposed changes will remove unnecessary delays in seeking public comment as part of the exemption process, and clarify and update the types of information needed to support such petitions. The statutory provision authorizing NHTSA to grant exemptions from FMVSS provides sufficient flexibility to accommodate a wide array of automated operations, particularly for manufacturers seeking to engage in research, testing, and demonstration projects.11

In order to develop experience with the technology, demonstrate its capabilities, and socialize the idea of automated vehicles on the road with traditional vehicles, FMCSA will continue to hold public demonstrations of the technology—such as the recent truck platooning demonstration on the I-66 Corridor co-hosted with FHWA—with key stakeholders such as law enforcement.

FMCSA consults with NHTSA on matters related to motor carrier safety.13 NHTSA and FMCSA have different but complementary authorities over the safety of commercial motor vehicles (CMVs) and commercial vehicle equipment. NHTSA has exclusive authority to prescribe Federal safety standards for new motor vehicles, including trucks and motor coaches, and oversees actions that manufacturers take to remedy known safety defects in motor vehicles and motor vehicle equipment.14 NHTSA and FMCSA collaborate and consult to develop and enforce safety requirements that apply to the operation and maintenance of vehicles by existing commercial motor carriers. They will continue to do so in the context of ADS-equipped commercial motor vehicles. FMCSA also works closely with States and private stakeholders to develop and enforce safety standards related to the inspection, maintenance, and repair of commercial motor vehicles.

11 49 U.S.C. § 30114


13 49 U.S.C. § 113(i)

14 See 49 U.S.C. §§ 30111 and 30166
Operating ADS-Equipped CMVs under Existing Regulations

In the context of ADS-equipped CMVs, FMCSA will continue to exercise its existing statutory authority over the safe operation of the vehicle.\(^{15}\) When driving decisions are made by an ADS rather than a human, FMCSA’s authority over the safe and proper operating condition of the vehicle and its safety inspection authority may be even more important, particularly between when ADS operations begin and when a revised regulatory framework is established. In addition, FMCSA retains its authority to take enforcement action if an automated system inhibits safe operation.\(^{16}\)

In exercising its oversight, FMCSA will first ask whether the ADS-equipped CMV placed into operation complies with the requirements for parts and accessories for which there are no FMVSS (e.g., fuel tanks and fuel lines, exhaust systems, and rear underride guards on single unit trucks). A motor carrier may not operate an ADS-equipped CMV—or any CMV—until it complies with the requirements and specifications of 49 CFR Part 393, Parts and Accessories Necessary for Safe Operation. If the ADS is installed aftermarket, any equipment that decreases the safety of operation could subject the motor carrier to a civil penalty.\(^{17}\) In addition, ADS-equipped vehicles that create an “imminent hazard” may be placed out of service and the motor carrier that used the vehicle similarly fined.\(^{18}\)

FMCSA will then consider whether the motor carrier has complied with the operational requirements of the current Federal Motor Carrier Safety Regulations (FMCSRs). These include, for example, compliance with rules on driving CMVs, including the laws, ordinances, and regulations of the jurisdiction in which the vehicle is operated. Notably, however, in the case of vehicles that do not require a human operator, none of the human-specific FMCSRs (i.e., drug testing, hours-of-service, commercial driver’s licenses (CDLs), and physical qualification requirements) apply.

If the motor carrier cannot fully comply with the FMCSRs through use of its ADS-equipped CMV, then the carrier may seek an exemption.\(^{19}\) The carrier would need to demonstrate that the ADS-equipped CMV likely achieves an equivalent level of safety. Ultimately, a motor carrier would not be permitted to operate an ADS-equipped CMV on public highways until it complies with the operational requirements or until the carrier obtains regulatory relief.

In general, subject to the development and deployment of safe ADS technologies, the Department’s policy is that going forward FMCSA regulations will no longer assume that the CMV driver is always a human or that a human is necessarily present onboard a commercial vehicle during its operation.

The Department and FMCSA are aware of the concerns that differing State regulations present for ADS technology development, testing, and deployment in interstate commerce. If FMCSA determines that State or local legal requirements may interfere with the application of FMCSRs, the Department has preemptive authority. The Department works with State partners to promote compatible safety oversight programs. U.S. DOT will carefully consider the appropriate lines of preemption in the context of ADS-equipped commercial motor vehicles and commercial carriers.

FMCSA also has authority, in coordination with the States, to set the Federal qualifications required for CDLs\(^{20}\). States have an essential role in training commercial drivers and issuing CDLs, but they must follow the FMCSA regulations that set minimum qualifications and limitations on CDLs in order to stay eligible for Federal grants\(^{21}\). The Department will carefully consider the appropriate division of authority between

\(^{15}\) 49 U.S.C. §§ 31136(a)(1) and 31502(b)(1).
\(^{16}\) 49 CFR 396.7(a).
\(^{17}\) 49 CFR 393.3
\(^{18}\) 49 U.S.C. § 5122(b); 49 CFR 386.72.
\(^{19}\) 49 U.S.C. §§ 31315 and 31136(e).
Considering Changes to Existing Regulations

FMCSA is in the process of broadly considering whether and how to amend its existing regulations to accommodate the introduction of ADS in commercial motor vehicles. As noted above, some FMCSA regulatory requirements for commercial drivers have no application to ADS—such as drug and alcohol testing requirements—but many regulations, such as those involving inspection, repair, and maintenance requirements, can be readily applied in the context of ADS-equipped commercial trucks and motor coaches. Current FMCSRs would continue to apply, and motor carriers can seek regulatory relief if necessary. Carriers therefore may deploy ADS-equipped CMVs in interstate commerce, using existing administrative processes.

In adapting its regulations to accommodate automated vehicle technologies, FMCSA will seek to make targeted rule changes and interpretations, and will supplement its rules as needed to account for significant differences between human operators and computer operators. FMCSA is soliciting feedback through various mechanisms to understand which parts of the current FMCSRs present barriers to advancing ADS technology. FMCSA plans to update regulations to better accommodate ADS technology with stakeholder feedback and priorities in mind. FMCSA will also consider whether there is a reasonable basis to adapt its CDL regulations for an environment in which the qualified commercial driver may be an ADS.

Workforce and Labor

Automated vehicles could have implications for the millions of Americans who perform driving-related jobs or work in related industries. There is a high level of uncertainty regarding how these impacts will evolve across job categories with differing levels of driving and non-driving responsibilities. Past experience with transportation technologies suggests that there will be new and sometimes unanticipated business and employment opportunities from automation. For example, the advent of widespread automobile ownership after World War II led not only to direct employment in vehicle manufacturing and servicing, but also to new markets for vehicle financing and insurance, and ultimately to larger shifts in American lifestyles that created a wave of demand for tourism, roadside services, and suburban homebuilding. Automation will create jobs in programming, cybersecurity, and other areas that will likely create demand for new skills and associated education and training. At the same time, the Department is also aware of the need to develop a transition strategy for manual driving-based occupations. U.S. DOT is working with other cabinet agencies on a comprehensive analysis of the employment and workforce impacts of automated vehicles. Individual operating administrations within the Department have also begun reaching out to stakeholders and sponsoring research on workforce issues affecting their respective modes of transportation.

Entities involved in developing and deploying automation technologies may want to consider how to assess potential workforce effects, future needs for new skills and capabilities, and how the workforce will transition into new roles over time. Identifying these workforce effects and training needs now will help lead to an American workforce that has the appropriate skills to support new technologies.

Finally, FMCSA recognizes emerging concerns and uncertainty around potential impacts of ADS on the existing workforce. U.S. DOT is working with the Department of Labor to assess the impact of ADS on the workforce, including the ability of ADS to mitigate the current driver
shortage in the motor carrier industry. The study will also look at longer-term needs for future workforce skills and at the demand for a transportation system that relies on ADS technology.

**FHWA’s Authorities Over Traffic Control Devices**

U.S. DOT recognizes that the quality and uniformity of road markings, signage, and other traffic control devices support safe and efficient driving by both human drivers and automated vehicles.

As part of its role to support State and local governments in the design, construction, and maintenance of the Nation’s roads, FHWA administers the Manual on Uniform Traffic Control Devices (MUTCD).\(^{22}\) The MUTCD is recognized as the national standard for all traffic control devices installed on any street, highway, bikeway, or private road open to public travel. Traffic control devices generally refer to signs, signals, markings, and other devices used to regulate or guide traffic on a street, highway, and other facilities. FHWA, in partnership with key stakeholder associations and the practitioner community, is conducting research and device experimentation for overall improvements to the manual, and to better understand the specific needs of the emerging automated vehicle technologies. Incorporating existing interim approved devices, experimentations, and other identified proposed changes into the updated MUTCD will help humans and emerging automated vehicles to interpret the roadway. FHWA will use current research to supplement knowledge regarding different sensor and machine vision system capabilities relative to interpreting traffic control devices. As part of this effort, FHWA will pursue an update to the 2009 MUTCD that will take into consideration these new technologies and other needs.

**FTA’s Safety Authority Over Public Transportation**

Safety issues are the highest priority for all providers of public transportation. In recent years, Congress has granted FTA significant new safety authorities that have expanded the Agency’s role as a safety oversight regulatory body.\(^{23}\) Consequently, FTA developed and published a National Public Transportation Safety Plan (NSP).\(^{24}\) The NSP functions as FTA’s strategic plan and primary guidance document for improving transit safety performance; a policy document and communications tool; and a repository of standards, guidance, best practices, tools, technical assistance, and other resources.

A key foundational component of FTA’s safety authority is the new Public Transportation Agency Safety Plan (PTASP) rule.\(^{25}\) The PTASP rule, which FTA issued on July 18, 2018, and which becomes effective on July 19, 2019, is applicable to transit agencies that operate rail fixed-guideway and/or bus services. Transit agencies must develop, certify, and implement an agency safety plan by July 20, 2020. The PTASP rule requires transit agencies to incorporate Safety Management System (SMS) policies and procedures as they develop their individual safety plans. The PTASP rule sets scalable and flexible requirements for public transportation agencies by requiring them to establish appropriate safety objectives; to identify safety risks and hazards and to develop plans to mitigate those risks; to develop and implement a process to monitor and measure their safety performance; and to engage in safety promotion through training and communication. An overview of the PTASP is available here: https://www.transit.dot.gov/PTASP.

This new PTASP rule provides a flexible approach to evaluating the safety impacts of automated buses. FTA recognizes that operating domains and vehicle types and capabilities differ significantly. That is why FTA is not proposing a one-size-fits-all approach.

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\(^{22}\) 23 CFR 655.603

\(^{23}\) 49 U.S.C. § 5329


\(^{25}\) 49 C.F.R. Part 673
Disability, Accessibility, and Universal Design

Automation presents enormous potential for improving the mobility of travelers with disabilities. Through the Accessible Transportation Technologies Research Initiative (ATTRI), the Department is initiating efforts to partner with the U.S. Department of Labor (DOL), U.S. Department of Health and Human Services (HHS), and the broader disability community to focus research efforts and initiatives on areas where market incentives may otherwise lead to underinvestment.

ATTRI focuses on emerging research, prototyping, and integrated demonstrations with the goal of enabling people to travel independently and conveniently, regardless of their individual abilities. ATTRI research focuses on removing barriers to transportation for people with disabilities, veterans with disabilities, and older adults, with particular attention to those with mobility, cognitive, vision, and hearing disabilities. By leveraging principles of universal design and inclusive information and communication technology, these efforts are targeting solutions that could be transformative for independent mobility.

ATTRI applications in development include wayfinding and navigation, pre-trip concierge and virtualization, safe intersection crossing, and robotics and automation. Automated vehicles and robotics are expected to improve mobility for those unable or unwilling to drive and enhance independent and spontaneous travel capabilities for travelers with disabilities. One area of particular interest among public transit agencies is exploring the use of vehicle automation to solve first mile/last mile mobility issues, possibly providing connections for all travelers to existing public transportation or other transportation hubs.

In addition, machine vision, artificial intelligence (AI), assistive robots, and facial recognition software solving a variety of travel-related issues for persons with disabilities in vehicles, devices, and terminals, are also included to create virtual caregivers/concierge services and other such applications to guide travelers and assist in decision making.
or providing a paper checklist for safety certification. Rather, FTA will provide transit agencies with tailored technical assistance as they develop an appropriate SMS approach to ensuring safe testing and deployment of its automated transit bus system.

FTA recognizes the benefits that automated transit bus operations may introduce, but also new types of risks, ranging from technology limitations, hardware failures, and cybersecurity breaches, to subtler human factors issues, such as overreliance on technology and degradation of skills. FTA’s transit bus automation research program is outlined in the five-year Strategic Transit Automation Research (STAR) Plan. FTA aims to advance transit readiness for automation by conducting enabling research to achieve safe and effective transit automation deployments, demonstrating market-ready technologies in real-world settings, and transferring knowledge to the transit stakeholder community, among other objectives.

The Federal Role in Automation Research

U.S. DOT has a limited and specific role in conducting research related to the integration of automation into the Nation’s surface transportation system. U.S. DOT’s research focuses on three key areas:

Removing barriers to innovation. U.S. DOT identifies and develops strategies to remove unnecessary barriers to innovation, particularly barriers stemming from existing regulations. In order to identify and evaluate solutions, U.S. DOT employs research to establish safety baselines; supports cost-benefit analysis for rulemaking; develops and implements processes to make the government more agile (e.g., updates to exemption and waiver processes to support the testing and deployment of novel technologies); and supports the development of voluntary standards that can enable the safe integration of automation.

Evaluating impacts of technology, particularly with regard to safety. U.S. DOT develops and verifies estimates of the impacts of automation on safety, infrastructure conditions and performance, mobility, and the economic competitiveness of the United States. The Department employs a variety of methods including simulation, modeling, and field and on-road testing. The Department also develops innovative methodologies to support the broader transportation community in estimating and evaluating impacts.

Addressing market failures and other compelling public needs. Public investments in research are often warranted to support the development of potentially beneficial technologies that are not easily commercialized because the returns are either uncertain, distant, or difficult to capture. This can include research that responds to safety, congestion, cybersecurity, or asymmetric information (e.g., public disclosures), or where a lack of private sector investment may create distributional issues that disadvantage particular groups (e.g., access for individuals with disabilities).

Across the areas outlined above, U.S. DOT collaborates with partners in the public and private sectors and academia, shares information with the public on research insights and findings, and identifies gaps in public and private sector research.

U.S. DOT Role in Key Cross-Cutting Policy Issues

Cooperative Automation and Connectivity

Connectivity enables communication among vehicles, the infrastructure, and other road users. Communication both between vehicles (V2V) and with the surrounding environment (V2X) is an important complementary technology that is expected to enhance the benefits of automation at all levels, but should not be and realistically cannot be a precondition to the deployment of automated vehicles.
Automation to Support Intermodal Port Facility Operations

Automation has the potential to transform the Nation’s freight transportation system, a vital asset that supports every sector of the economy. Intermodal port facilities could benefit from applications of automation, enabling more seamless transfers of goods and a less strenuous experience for operators. The Maritime Administration (MARAD) and FMCSA are jointly exploring how SAE Level 4 truck automation might improve operations at intermodal port facilities. Currently at many of the Nation’s busiest ports, commercial vehicle drivers must wait in slow-moving queues for hours to pick up or deliver a load. MARAD and FMCSA are evaluating how automation might relieve the burden on a driver under these circumstances, and, in particular, the regulatory and economic feasibility of using automated truck queueing as a technology solution to truck staging, access, and parking issues at ports. The study will investigate whether full or partial automation of queuing within ports could lead to increased productivity by altering the responsibilities and physical presence of drivers, potentially allowing them to be off-duty during the loading and unloading process.

Throughout the Nation there are over 70 active deployments of V2X communications utilizing the 5.9 GHz band. U.S. DOT currently estimates that by the end of 2018, over 18,000 vehicles will be deployed with aftermarket V2X communications devices and over 1,000 infrastructure V2X devices will be installed at the roadside. Furthermore, all seven channels in the 5.9 GHz band are actively utilized in these deployments.

In addition to the Dedicated Short-Range Communication (DSRC)-based deployments, private sector companies are already researching and testing Cellular-V2X technology that would also utilize the 5.9 GHz spectrum.

An effort led by State and local public-sector transportation infrastructure owner operators is the Signal Phase and Timing (SPaT) Challenge. This initiative has plans to deploy a V2X communications infrastructure with SPaT broadcasts in at least one corridor in each of the 50 States by January 2020. Over 200 infrastructure communications devices are already deployed with over 2,100 planned by 2020 under this initiative in 26 States and 45 cities with a total investment of over $38 million. The SPaT message is designed to enhance both safety and efficiency of traffic movements at intersections.

Also underway are the U.S. DOT-funded deployment programs such as the Ann Arbor

27 https://transportationops.org/spatchallenge
Planned and Operational Connected Vehicle Deployments
Where Infrastructure and In-Vehicle Units are Planned or In Use

Operational Projects
Planned Projects

Source: USDOT September 2018

<table>
<thead>
<tr>
<th>Infrastructure Units</th>
<th>In-Vehicle Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>Operational (52 Projects)*</td>
<td>2,044</td>
</tr>
<tr>
<td>Planned (23 projects)*, **</td>
<td>242</td>
</tr>
<tr>
<td>Total</td>
<td>2,286</td>
</tr>
</tbody>
</table>

* Projects shown include those sponsored by U.S. DOT and others.
** Device numbers for many of the planned projects are currently unavailable.
Cooperative Automation

FHWA is conducting research to measure the efficiency and safety benefits of augmenting automated vehicle capabilities with connected vehicle technologies to enable cooperative automation. Cooperative automation allows automated vehicles to communicate with other vehicles and the infrastructure to coordinate movements and increase efficiency and safety. It uses a range of automation capabilities, including automation technologies at SAE Level 1 and Level 2. Examples of cooperative automation applications include:

- Vehicle platooning to enable safe close following between vehicles and improve highway capacity.
- Speed harmonization using wireless speed control to reduce bottleneck conditions.
- Cooperative lane change and merge functions to mitigate traffic disruptions at interchanges.
- Coordination of signalized intersection approach and departure, using Signal Phase and Timing (SPaT) data to enable automated vehicles to enter and exit signalized intersections safely and efficiently, to mitigate delays and reduce fuel consumption.

Current activities focus on technical assessments, traffic modeling, and proof-of-concept/prototype tests to understand how to improve safety, smooth traffic flow, and reduce fuel consumption. FHWA is partnering with automotive manufacturers to further develop these concepts and is conducting modeling and analysis of corridors in several States. FHWA may pursue further proof-of-concept testing on test tracks and on public roads in the future. Additionally, studies are underway to consider how early automation applications like lane keeping and adaptive cruise control are being used and accepted by everyday drivers.

Connected Vehicle Environment, Connected Vehicle Pilots Program, and the Advanced Transportation and Congestion Management Technologies Deployment Program, which have combined over $150 million in Federal and State funding to deploy V2X communications. Finally, states such as Colorado are combining Federal-aid highway program funding with State funding ($72 million) to deploy V2X communications throughout the State highways by 2021.28

Over the past 20 years, the U.S. DOT has invested over $700 million in research and development of V2X through partnerships with industry and state/local governments. As a result of these investments and partnerships, V2X technology is on the verge of wide-scale deployment across the Nation.

The Department encourages the automotive industry, wireless technology companies, IOOs, and other stakeholders to continue developing technologies that leverage the 5.9 GHz spectrum for transportation safety benefits. Yet, the Department does not promote any particular technology over another. The Department also encourages the development of connected infrastructure because such technologies offer the potential to improve safety and efficiency. As IOOs consider enabling V2X deployment in their region, the Department encourages IOOs to engage with the U.S. DOT for guidance and assistance.

As part of this approach, U.S. DOT is continuing its work to preserve the ability for transportation safety applications to function in the 5.9 GHz spectrum while exploring methods for sharing the spectrum with other users in a manner

that maintains priority use for vehicle safety communications. A three-phase test plan was collaboratively developed with the Federal Communications Commission (FCC) and the U.S. Department of Commerce, and the FCC has completed\( ^{29} \) the first phase. Phases 2 and 3 of the spectrum sharing test plan will explore potential sharing solutions under these more real-world conditions.

**Pilot Testing and Proving Grounds**

U.S. DOT supports and encourages the testing and development of automation technologies throughout the country with as few barriers as needed for safety. ADS developers are already testing automated vehicle technologies at test tracks, on campuses, and on public roadways across the United States. Pilots on public roads provide an opportunity to assess roadway infrastructure, operational elements, user acceptance, travel patterns, and more.

The Department appreciates that there are significant automated vehicle research and testing activities occurring in many States and locations across the country, and there is considerable private investment in these efforts. The Department does not intend to pick winners and losers or to favor particular automated vehicle proving grounds over others. Therefore, the Department no longer recognizes the designations of ten “Automated Vehicle Proving Grounds” as announced on January 19, 2017. The Department has taken no actions to direct any Federal benefits or support to those ten locations on the basis of these designations, and these designations will have no effect—positive or negative—going forward on any decisions the Department may make regarding Federal support or recognition of research, pilot or demonstration projects, or other developmental activities related to automated vehicle technologies.

Instead, if and when the Department is called upon to provide support or recognition of any kind with regard to automated vehicle proving grounds, the Department intends to apply neutral, objective criteria and to consider all locations in all States where relevant research and testing activities are actually underway.

**Cybersecurity**

Transportation systems are increasingly complex, with a growing number of advanced, integrated functions. Transportation systems are also more reliant than ever on multiple paths of connectivity to communicate and exchange data, and they depend on commodity technologies to achieve functional, cost, and marketing objectives.

Surface transportation is a broad sector of the economy and requires coordination across all levels of government and the private sector in the event of a significant cyber incident to enable shared situational awareness and allow for a unified approach to sector engagement. U.S. DOT will work closely with the U.S. Department of Justice; the U.S. Department of Commerce and its National Institute of Standards and Technology (NIST); the Federal Trade Commission; the Federal Communications Commission; the U.S. Department of Homeland Security (DHS); industry subject matter experts; and other public agencies to address cyber vulnerabilities and manage cyber risks related to automation technology and data.

Transportation-related cyber vulnerabilities and exploits can be shared with Government partners anonymously through various Information Sharing and Analysis Centers (ISACs). [DHS’s National Cybersecurity and Communications Integration Center (NCCIC)](https://ics-cert.us-cert.gov/Report-Incident) is a 24x7 cyber situational awareness, incident response, and management center that is a national nexus of cyber and communications integration for the Federal Government, intelligence community, and law enforcement.

If a transportation sector entity deems Federal assistance may be warranted, they are encouraged to contact NCCIC\( ^{30} \) and the relevant

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\( ^{30} \) [https://ics-cert.us-cert.gov/Report-Incident](https://ics-cert.us-cert.gov/Report-Incident)
ISACs (e.g., Auto-ISAC, Aviation ISAC, Maritime ISAC, and Surface Transportation ISAC).

Privacy

While advanced safety technologies have the potential to provide enormous safety, convenience, and other important benefits to consumers, stakeholders frequently raise data privacy concerns as a potential impediment to deployment. U.S. DOT takes consumer privacy seriously, diligently considers the privacy implications of our safety regulations and voluntary guidance, and works closely with the Federal Trade Commission (FTC)—the primary Federal agency charged with protecting consumers’ privacy and personal information—to support the protection of consumer information and provide resources relating to consumer privacy. The Department suggests that any exchanges of data respect consumer privacy and proprietary and confidential business information. Additional information is available here: https://www.ftc.gov/news-events/media-resources/protecting-consumer-privacy.

State, Local, and Tribal Governments and Automation

State, local, and Tribal governments hold clearly defined roles in ensuring the safety and mobility of road users in their jurisdictions. They are responsible for licensing human drivers, registering motor vehicles, enacting and enforcing traffic laws, conducting safety inspections, and regulating motor vehicle insurance and liability. They are also responsible for planning, building, managing, and operating transit and the roadway infrastructure. Many of those roles may not change significantly with the deployment of automated vehicles.

There are many ways these governments can prepare for automated vehicles:

- Review laws and regulations that may create barriers to testing and deploying automated vehicles.
- Adapt policies and procedures, such as licensing and registration, to account for automated vehicles.
- Assess infrastructure elements, such as road markings and signage, so that they are conducive to the operation of automated vehicles.
- Provide guidance, information, and training to prepare the transportation workforce and the general public.

This section provides best practices and considerations for State, local and Tribal government officials as they engage with new transportation technologies.

Best Practices for State Legislatures and State Highway Safety Officials

A Vision for Safety 2.0 provided best practices for both State legislatures and State highway safety officials. In reviewing recent State legislation and executive orders, and in engaging with stakeholders, U.S. DOT identified new insights, commonalities, and elements that States should consider including when developing legislation. Additional best practices for State highway safety officials are also discussed in this section. The best practices provided here are not intended to replace recommendations made in A Vision for Safety 2.0, but rather are meant to supplement them. For more information, refer to www.transportation.gov/av.

31 https://www.automotiveisac.com/
32 https://www.a-isac.com/
33 http://www.maritimesecurity.org/
34 https://www.surfacetransportationisac.org/
Automated Vehicles at Rail Crossings

To explore the interaction between automated vehicles and highway-rail grade crossings and identify what information automated vehicles will need in order to negotiate highway-rail intersections, the Federal Railroad Administration (FRA) has conducted a literature review, engaged with stakeholders, and used scenarios to develop and demonstrate a concept of operations, including system requirements (technology and sensors).

A broad stakeholder set was identified to represent researchers, manufacturers, transit agencies, and infrastructure owner-operators, among others. Currently, FRA is expanding the research with U.S. DOT partners and the Association of American Railroads to develop a closed loop safety system to support the safe interaction of connected and automated vehicles with grade crossings.

Best Practices for State Legislatures

States are taking differing legislative approaches and have enacted varying laws related to testing and operating automated vehicles. U.S. DOT regularly monitors legislative activities in order to support the development of a consistent national framework for automated vehicle legislation.

A Vision for Safety 2.0 recommended that State legislators follow best practices, such as providing a technology-neutral environment, licensing and registration procedures, and reporting and communications methods for public safety officials. States should consider reviewing and potentially modifying traffic laws and regulations that may be barriers to automated vehicles. For example, several States have following distance laws that prohibit trucks from following too closely to each other, effectively prohibiting automated truck platooning applications.

In addition to the best practices identified in A Vision for Safety 2.0, the Department recommends that State officials consider the following safety-related best practices when crafting automated vehicle legislation:

Engage U.S. DOT on legislative technical assistance. State legislatures are encouraged to routinely engage U.S. DOT on legislative activities related to multimodal automation...
safety. State legislatures may want to first determine if there is a need for State legislation. Unnecessary or overly prescriptive State requirements could create unintended barriers for the testing, deployment, and operations of advanced vehicle safety technologies. U.S. DOT stands ready to provide technical assistance to States on request.

Adopt terminology defined through voluntary technical standards. Different use and interpretations of terminology regarding automated vehicles can be confusing for the public, State and local agencies, and industry. In the interest of supporting consistent terminology, State legislatures may want to use terminology already being developed through voluntary, consensus-based, technical standards. SAE terminology on automation represents one example and includes terms such as ADS, the Dynamic Driving Task (DDT), minimal risk conditions, and ODD.

Assess State roadway readiness. States may want to assess roadway readiness for automated vehicles, as such assessments could help infrastructure for automated vehicles, while improving safety for drivers today. Automated vehicle developers are designing their technologies with the assumption that these technologies will need to function with existing infrastructure. There is general agreement that greater uniformity and quality of road markings, signage, and pavement condition would be beneficial for both human drivers and automated vehicles.

Best Practices for State Highway Safety Officials

States are responsible for reducing traffic crashes and resulting deaths, injuries, and property damage for all road users in their jurisdictions. States use this authority to establish and maintain highway safety programs addressing driver education and testing, licensing, pedestrian safety, and vehicle registration and inspection. States also use this authority to address traffic control, highway design and maintenance, crash prevention, investigation and recordkeeping, and law enforcement and emergency service considerations.

The following best practices build on those identified in A Vision for Safety 2.0 and provide a framework for States looking for assistance in developing procedures and conditions for the operation of automated vehicles on public roadways. For additional best practices, see Section 2 of A Vision for Safety 2.0.

Consider test driver training and licensing procedures for test vehicles. States may consider minimum requirements for test drivers who operate test vehicles at different automation levels. States may want to coordinate and collaborate with a broad and diverse set of stakeholders when developing and defining jurisdictional guidelines for safe testing and deployment of automated vehicles.

Recognize issues unique to entities offering automated mobility as a service. Automated mobility providers are exploring models to move people and goods using automated vehicle technology. States may consider identifying and addressing issues that are unique to companies providing mobility as a service using automated vehicle technologies. These could include such issues as congestion or the transportation of minors, persons with disabilities, and older individuals.

Considerations for Infrastructure Owners and Operators

Infrastructure owners and operators are involved in the planning, design, construction, maintenance, and operation of the roadway infrastructure. Infrastructure owners and operators have expressed interest in more information and guidance on how to prepare for automated vehicle deployment and testing on public roadways. FHWA is conducting the National Dialogue on Highway Automation, a series of workshops with partners, stakeholders, and the public to obtain input regarding the safe
and efficient integration of automated vehicles into the roadway system. U.S. DOT provides the following considerations for infrastructure owners and operators, including State DOTs, metropolitan planning organizations (MPOs), and local agencies. FHWA, in particular, will continue to update these considerations as informed by continued research efforts, stakeholder engagement, and testing. Suggested considerations include:

Support safe testing and operations of automated vehicles on public roadways. State DOTs and local agencies want to understand under what conditions automated vehicles can safely operate in automated mode and how they will affect the highway infrastructure and surrounding communities. Where testing is taking place, State and local agencies should consider ways to establish consistent cross-jurisdictional approaches and work with first responders to develop commonly understood traffic law enforcement practices and emergency response plans for automated vehicle testing and operation.

Learn from testing and pilots to support highway system readiness. State and local agencies may consider collaborating with automated vehicle developers and testers to identify potential infrastructure requirements that support readiness for automated vehicles and to understand their expectations for automated vehicle operations under varying roadway and operational conditions. This interaction could assist with identifying what balance of capabilities (for both vehicles and the roadway) promotes safe and efficient operations of automated vehicles. Testing, research, and pilot programs can help State and local agencies understand automation and identify opportunities to inform transportation planning, infrastructure design, and traffic operations management.

Build organizational capacity to prepare for automated vehicles in communities. State and local agencies may need to assess their workforce capacity and training needs to address new issues that emerge from having automated vehicles on public roads. State and local agencies will want to work with peers, industry, associations, the research community, and FHWA to build knowledge of automated vehicle technologies and identify technical assistance resources.

Identify data needs and opportunities to exchange data. The exchange of data and information in the roadway environment can help

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35 More information can be found at https://ops.fhwa.dot.gov/automationdialogue/
automated vehicles address static and dynamic elements that otherwise may be challenging for ADS (e.g., work zones, rail crossings, managed lanes, and varying traffic laws). State and local agencies and industry may work together to identify data elements that will help automated vehicles navigate challenging, unique roadway environments and alter operational behavior in relation to changing traffic laws.

Collaborate with stakeholders to review the existing Uniform Vehicle Code (UVC). Each State creates its own laws governing traffic codes, and many municipalities enact ordinances as allowed in the State. The UVC is a model set of traffic laws developed years ago by stakeholders that States can consult when considering legislation. FHWA suggests working with automated vehicle developers, traffic engineers, and law enforcement stakeholders to revise the UVC to be consistent with automated vehicle operations.

Support scenario development and transportation planning for automation. There is uncertainty around how automation will change travel behavior, land use, and public revenues across the transportation landscape in the long term. State and local policymakers must wrestle with the effects of automation when conducting long-term transportation planning. Scenario planning tools allow States and MPOs to review multiple scenarios for how automation technologies could be adopted and used, and analyze issues including infrastructure investment, congestion, operations, and other transportation needs.\textsuperscript{36} To assist in this process, FHWA is supporting scenario development for State and local agencies to use for incorporating automation into transportation planning processes.

Considerations for State Commercial Vehicle Enforcement Agencies

U.S. DOT recommends that State agencies responsible for enforcing commercial vehicle operating rules and regulations consider the following as ADS-equipped commercial motor vehicles are tested and operated on public roads:

Compatibility between intrastate and interstate commercial motor vehicle regulations. State enforcement agencies should monitor prevailing regulatory activity, including regulatory guidance by FMCSA—including a forthcoming Advance Notice of Proposed Rulemaking (ANPRM)—and consider whether amendments of their intrastate motor carrier safety regulations are needed in order to be compatible with the Federal requirements concerning the operation of ADS-equipped commercial motor vehicles. Ensuring compatibility between intrastate and interstate commercial vehicle regulations is important for maintaining eligibility for grant funding under the Motor Carrier Safety Assistance Program (MCSAP).

Continued application of roadside inspection procedures. State enforcement agencies should continue to apply existing inspection selection procedures to identify which CMVs should be examined during a roadside inspection. State enforcement agencies should refrain from selecting ADS-equipped CMVs solely because the vehicle is equipped with advanced technology. States can partner with FMCSA as it develops appropriate roadside inspection procedures and inspection criteria for use in examining ADS-equipped CMVs, so that the movement of such vehicles is not delayed unless there are problems that are likely to adversely impact safety.

Considerations for Public Sector Transit Industry and Stakeholders

U.S. DOT offers the following for consideration by public sector transit industry stakeholders (e.g., transit agencies) when developing, demonstrating, deploying, and evaluating transit bus automation:

\textsuperscript{36} For more information on scenario planning, see https://www.fhwa.dot.gov/planning/scenario_and_visualization/scenario_planning/
Needs-based implementation. Transit agencies should consider automation as a means of addressing specific needs and solving particular problems. Implementation of new technologies and service models should not be based merely on novelty. Agencies should obtain input from stakeholders to determine unmet needs and identify potential solutions that might be addressed through automation. Ongoing dialogue with community residents, original equipment manufacturers (OEMs), technology developers, integrators, and industry associations will help identify the most appropriate transit bus automation technology solutions for their communities.

Realistic expectations. Public transportation operators should establish realistic expectations when implementing transit bus automation projects and demonstrations. As an example, transit agencies engaged in pilots to retrofit vehicles with advanced driver assistance capabilities, such as pedestrian avoidance and automatic emergency braking, might find that implementation may take longer than expected for a variety of reasons. Integration, test planning, contracting, and data management can present significant challenges that cause delay. Another example may be where transit providers are conducting pilots of low-speed automated vehicles or shared automated vehicles. Although these service approaches could potentially address first-mile/last-mile needs, agencies may find that the vehicles themselves currently have technological limitations such as lower speeds and passenger capacity constraints.

Workforce and labor. An important consideration for public transportation operators is to begin preparing for workforce changes that may accompany an automated bus fleet. The transit workforce will require new, high-tech skills for inspecting and maintaining automated transit buses at all levels of automation. The transit industry should begin thinking about retraining the current workforce to help transit operators transition into new roles and to adapt to a transforming surface transportation industry.

Transit agencies should recognize emerging workforce needs and requirements, identify new future career paths, and conduct succession planning in this new, high-technology environment. Transit agencies can work with FTA, industry associations, and private sector consultants to identify core training needs; academic institutions may be able to assist in implementing training.

Complete Streets. Transit agencies should seek out and work with local partners to review complete streets policies and practices when planning and deploying transit automation. Early consideration of complete streets will help make automation-enhanced mobility safer, more convenient, and more reliable for all travelers, while reducing the overall cost of widespread deployment. Transit agencies, MPOs, and local governments may seek assistance from industry associations, private sector consultants, and automation technology developers to create and implement complete streets concepts.37

Accessibility. It is critical that all agencies considering automated transit vehicles in revenue service ensure accessibility for persons with disabilities. Although some users will likely continue to require the human assistance that existing paratransit service provides, automation has the potential to offer improved levels of service for persons with disabilities. Transit agencies must ensure that infrastructure, such as stations and stops, is accessible and Americans with Disabilities Act (ADA)-compliant. Transit agencies should continue to partner with local governments as appropriate to create and maintain an accessible environment for all travelers. Transit agencies may work with industry associations, private sector consultants, and technology developers for new accessibility tools and solutions such as those in the U.S. DOT’s ATTRI. FTA can provide guidance and clarification regarding ADA requirements.

Engagement and education. To fully realize the benefits of automated transit vehicles, transit operators, riders, and other road users

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37 Complete Streets are streets designed and operated to enable safe use and support mobility for all users. Those include people of all ages and abilities, regardless of whether they are traveling as drivers, pedestrians, bicyclists, or public transportation riders.
must understand and be wholly comfortable with the technology. Transit agencies seeking to test and pilot automated transit vehicles may wish to develop appropriate messaging as well as public engagement and education activities to promote awareness, understanding, and acceptance of automated transit buses. Public-facing technology demonstrations can create opportunities for members of the public to experience and learn about new technologies. Other knowledge transfer and stakeholder engagement activities can help align demonstrations and pilots with local needs and increase local stakeholder confidence and buy-in.

Considerations for Local Governments

Local governments control a substantial part of the Nation’s roadway and parking infrastructure, and have considerable influence over land use, via zoning and permitting. Local governments are closest to citizens. Automation provides an opportunity to address local goals, including making more land available for housing and business, as well as improving transportation options for citizens who are not motorists. U.S. DOT suggests that local governments may wish to consider the following topics as they formulate local policies.

Facilitate safe testing and operation of automated vehicles on local streets. Local streets, with their variety of uses, offer a challenging environment for automated vehicles. As owner-operators of this infrastructure, local governments have an opportunity to partner with automated vehicle suppliers to test on their streets, learn from testing, and be prepared to enable safe deployment.

Understand the near-term opportunities that automation may provide. In the near term, automation provides increased driver assistance capabilities—such as automatic emergency braking and pedestrian detection—which may be useful for municipal fleets. Several low-speed passenger shuttle tests are also underway. Local governments should be aware of these efforts and the opportunities that they may provide, while being realistic about their limitations.

Consider how land use, including curb space, will be affected. A shared vehicle environment in which automated vehicles are used by a number of travelers over the course of a day could result in a significant reduction in private vehicle ownership, leading to less need for on- and off-street parking. At the same time, such an environment will require curb space for pick-up and drop-off activities. There may be an opportunity to reallocate curb space from long-term parking to other uses, including pick-up and drop-off. Furthermore, if vehicle ownership declines, minimum parking requirements in zoning may need to be revisited, freeing up land for other purposes. Finally, in such an environment, revenue from parking fees and fines may be reduced.

Consider the potential for increased congestion, and how it might be managed. If automation provides a convenient, low-cost option for single occupant vehicle trips, it may lead to more congestion. For example, some current transit users may shift to lower-occupancy automated vehicles. Automated vehicles may engage in zero-occupant vehicle trips, for vehicle repositioning. Automation will also provide new mobility options for people who do not travel much today. Local and State governments may need to consider appropriate policies to manage the potential for increased congestion.

Engage with citizens. Local governments are in an ideal position to engage with citizens, to address their concerns and to ensure that automation supports local needs. Such engagement may include public events associated with automated vehicle testing, educational forums, and consideration of automation in public planning and visioning meetings.

State, Local, and Tribal Roles in Transportation Sector Cybersecurity

State, local, and Tribal governments face unique cybersecurity threats that can endanger
Transportation systems that depend on digital infrastructure are at risk when they do not prioritize maintaining security, modernizing systems to reduce vulnerabilities, and implementing enhancements to increase the resiliency of digital infrastructure. Significant service degradation has occurred when technology, people, and processes failed to prevent security failures; including data encrypting ransomware, other malware, and insider-threat activities. To mitigate potential threats, appropriate investments in the digital infrastructure that supports ADS should include strong security and functional testing of the technology, people, and processes. As threats evolve, key decision makers should have an effective and flexible security program in place to assess and manage risk, including evaluating technology, key facilities, engaged personnel, and security processes. Plans to respond to cyber-attacks should be exercised, and should be aligned with emergency management and recovery protocols shared across all industry sectors.

State, local, and Tribal governments play an important role in managing cyber risks by investing in improvements to cyber defenses and infrastructure. Those governments also identify, prioritize, and allocate resources to counteract cybersecurity threats, especially where a threat may affect transportation critical infrastructure. U.S. DOT encourages States, local, Tribal, and Territorial governments to fully utilize the resources provided by United States Computer Emergency Readiness Team (US-CERT).38

Local governments are in an ideal position to engage with citizens, to address their concerns and to ensure that automation supports local needs.

The Private Sector and Automation

While the initial development of automated vehicle technologies received strong support from government-funded research projects, such as the Defense Advanced Research Projects Agency (DARPA),39 over the past decade private sector innovators have taken the lead in developing and commercializing automation technologies. Today, private sector leadership is critical to advancing the development, testing, and commercialization of automated vehicles. U.S. DOT does not expect the private sector to be singularly responsible for addressing issues introduced alongside new technologies. The public sector—as planners, owners, and

38 See: https://www.us-cert.gov/ccubedvp/sltt
operators of transportation infrastructure, regulators and enforcers of transportation safety, and representatives of public concerns—must play a critical, complementary role in engaging automation technologies to improve safety and meet the public interest without hampering innovation.

In addition to developing and commercializing automation technology, the private sector also should play a critical role in promoting consumer acceptance in two distinct ways. First, companies developing and deploying automation technology need to be transparent about vehicle safety performance. Second, companies should engage with consumers through public education campaigns.

The exchange of information between the public and private sector is also critical for helping policymakers understand the capabilities and limitations of these new technologies, while ensuring that the private sector understands the priorities of policymakers and the issues they face. Only by working in partnership can the public and the private sector improve the safety, security, and accessibility of automation technologies, address the concerns of the general public, and prepare the workforce of tomorrow.

The sections below outline several critical areas where the private sector’s role will be significant.

**Demonstrate Safety through Voluntary Safety Self-Assessments**

Demonstrating the safety of ADS is critical for facilitating public acceptance and adoption. Entities involved in the development and testing of automation technology have an important role in not only the safety assurance of ADS-equipped vehicles, but also in providing transparency about how safety is being achieved.

A Vision for Safety 2.0 provided voluntary guidance to stakeholders regarding the design, testing, and safe deployment of ADS. It identified 12 safety elements that ADS developers should consider when developing and testing their technologies. A Vision for Safety 2.0 also introduced the Voluntary Safety Self-Assessment (VSSA), which is intended to demonstrate to the public that entities are:

- considering the safety aspects of an ADS;
- communicating and collaborating with the U.S. DOT;
- encouraging the self-establishment of industry safety norms; and
- building public trust, acceptance, and confidence through transparent testing and deployment of ADS. Entities are encouraged to demonstrate how they address the safety elements contained in A Vision for Safety 2.0 by publishing a VSSA, as it is an important tool for companies to showcase their approach to safety, without needing to reveal proprietary intellectual property.

VSSAs allow the public to see that designers, developers, and innovators are taking safety seriously and that safety considerations are built into the design and manufacture of vehicles that are tested on our roadways. Therefore, U.S. DOT encourages entities to make their VSSA available publicly as a way to promote transparency and strengthen public confidence in ADS technologies. The Department currently provides a template for one of the elements in a VSSA, which entities can use to construct their own VSSA.\(^40\) NHTSA also established a website where entities who have disclosed and made the Agency aware of their VSSAs can be listed in one central location.\(^41\) Entities developing ADS technology may want to consider making available their VSSAs through this website.

**Incorporate New Safety Approaches for Automation in Commercial Vehicle Operations**

U.S. DOT recommends that motor carrier owners and operators consider the following as they explore the adoption of advanced driver assistance features and ADS in their vehicle fleets. As automation technology evolves,
Hazardous Materials Documentation

The Pipeline and Hazardous Materials Safety Administration (PHMSA) is exploring alternatives to longstanding requirements for providing paper documentation to accompany hazmat shipments, while ensuring that the information is readily available to transport workers and emergency responders. This capability may become increasingly important as transporters of hazardous materials explore the use of automation in their operations. As motor carriers and railroads explore the use of automation to move hazardous materials, the ability to create electronic documentation also raises the potential to electronically transmit information to first responders before they arrive at an incident. PHMSA is also collaborating with the Environmental Protection Agency on the development of an e-manifest system that will digitize the exchange of information on hazardous material shipments.

FMCSA and PHMSA plan to solicit stakeholder input and provide more detailed guidance regarding the use of ADS in commercial vehicle operations.

System knowledge. If a motor carrier of passengers or property plans to begin operating a commercial motor vehicle equipped with driver-assist systems and/or ADS, the motor carrier’s personnel should understand the capabilities and limitations of these systems, as well as ODD limitations (e.g., the types of roadway environments or environmental conditions under which they can operate). The motor carrier should also ask the equipment’s manufacturer about the capabilities and limitations of these systems. Motor carriers may also wish to inquire about whether the manufacturer has completed a voluntary safety self-assessment, as described in A Vision for Safety 2.0.

System functionality. Motor carriers should ensure the driver assist system and/or ADS is functioning properly before activating these systems. This functionality should be able to be validated during a roadside inspection.

System training. Motor carriers should implement a training program to familiarize fleet managers, maintenance personnel, and drivers with the equipment and how it operates, including the procedures to follow in the event of an ADS malfunction.

Equipment maintenance. Motor carriers should be aware of maintenance requirements of driver-assist systems and/or ADS to enable safe and optimal operation. This includes understanding self-diagnostic capabilities of the system and the status or error messages the system may display.

Information exchange. Motor carriers should be aware that under certain situations such as a safety inspection or roadway crash, it may be necessary to exchange critical safety-oriented vehicle performance data with Federal and State officials. The motor carrier should maintain records of the systems it is using, the training provided, and the operation of those vehicles.

Safety inspections. Motor carriers should be prepared to interact and cooperate with roadside and other safety inspections of driver assist systems and ADS. This includes responding to law enforcement instructions, resolving any identified mechanical or software malfunction, implementing the equipment’s safe shutdown procedures, and demonstrating system functionality.

Develop Safe and Accessible Transit Buses and Applications: Considerations for Private Sector Transit Industry

U.S. DOT offers the following considerations for private sector transit industry stakeholders when developing, demonstrating, deploying, and evaluating transit bus automation:

Accessibility. It is important to think about how to make automated vehicles and their technological capabilities accessible to persons with disabilities (including those with physical, sensory, and cognitive impairments) early in...
the design process. This vital element is more easily integrated at the initial stages of vehicle research and development, rather than trying to incorporate it into the design through retrofits, which may be more difficult. Bus OEMs, technology developers, and integrators should work with transit agencies, industry associations, and the disability community to obtain input on functional and performance needs as well as the consequent human factors considerations. The Federal Government (e.g., FTA) can provide guidance and clarification with respect to the requirements of ADA.

Human factors. Consider human factors in the design of buses and vehicles for all levels of automation—for all participants in the system (transit operators, passengers, and other road users). The interaction between human and machine, ease of use, and comprehensibility of human-machine interfaces (HMI) should be explored thoroughly, particularly with respect to maintaining safety under all operating conditions. Where possible, technology companies should partner with transit agencies and passenger organizations to test various user-interface technologies and designs.

Testing. Open a dialogue and seek a collaborative relationship with FTA when developing and testing new bus technologies and products. FTA can provide guidance, feedback, and clarification on policies, requirements, and recommendations as they pertain to transit automation.

Provide Information to the Public

The understanding of automation technologies varies considerably across the general public, caused in part by a lack of consistency in terminology and confusion about the technology’s limitations. The public needs accurate sources of information regarding automation to better understand the technology so that they can use it safely and make informed decisions about its integration. This can be done through direct communications with consumers and other users, demonstrations, public outreach in areas where vehicles are being tested, and a variety of other means.
With respect to currently available Level 1 and Level 2 automation technologies and Level 3 technologies under development, consumers and other users should understand what the technology is and is not capable of, when human monitoring of the system is needed, and where it should be operated (i.e., appropriate ODD). The private sector may need to consider new approaches for providing information so that consumers can use the technology safely and effectively. As part of their education and training programs and before consumer release, automated vehicle dealers and distributors may want to consider including an on-road or on-track experience demonstrating automated vehicle operations and how humans interact with vehicle controls. Other innovative approaches (e.g., virtual reality (VR) or onboard vehicle systems) may also be considered, tested, and employed.

Public education challenges are different for automated vehicle technologies at higher levels of automation or Level 4 and Level 5 systems, where the consumer becomes a passenger rather than a driver. For these systems, the members of the public may require more general information and awareness of what the technology is and how they should interact with it, either as passengers or as others sharing the road with automated vehicles.

Developers of automated vehicle technologies are encouraged to develop, document, and

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**Travel Patterns of American Adults with Disabilities**

An estimated 25.5 million Americans have disabilities that make traveling outside the home difficult, according to the Bureau of Transportation Statistics report *Travel Patterns of American Adults with Disabilities.* An estimated 3.6 million with disabilities do not leave their homes.

People with travel-limiting disabilities are less likely to own a vehicle or have vehicle access than people without disabilities.

When people with disabilities do use vehicles, they are often passengers. People with disabilities are less likely to have jobs, are more likely to live in very low-income households, and use smartphones and ride-hailing services less often than the general population. An estimated 71 percent reduce their day-to-day-travel, while an estimated 41 percent rely on others for rides.

Automated vehicles and other assistive technologies may provide substantial mobility benefits to people with disabilities who cannot drive.

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### Compensating Strategies for People with Travel-Limiting Disabilities (age 18–64)

- Reducing day-to-day travel: 70.6%
- Asking others for rides: 55.7%
- Limiting travel to daytime: 22.6%
- Giving up driving: 21.6%
- Using special transportation services: 14.4%
- Using public transit less often: 14.4%

*Source: U.S. Department of Transportation, Federal Highway Administration, 2017 National Household Travel Survey.*
considerations for the future of transportation

Maintain Employee, Dealer, Distributor, and Consumer Education and Training Programs to Address the Anticipated Differences in the Use and Operation of Automated Vehicles from Those of the Conventional Vehicles That the Public Owns and Operates Today. Successful programs will provide target users with the necessary level of understanding to utilize these technologies properly, efficiently, and in the safest manner possible.

Consider All Possible Surface Transportation Conditions and Different Roadway Landscapes

Entities that are testing and operating on public roadways will want to consider the whole roadway environment, which could include different infrastructure conditions and operating rules. It will be important to account for all possible surface transportation conditions an ADS may encounter within its ODD. Such conditions, when appropriate, include maneuvering at-grade rail crossings, roundabouts, bicycle lanes, pedestrian walkways and special designated traffic lanes or crossing areas, entrances and driveways, and other potential hazards, especially in different roadway landscapes (e.g., urban versus rural). As part of their important role in the safety assurance of ADS-equipped vehicles, entities are also encouraged to consider such conditions in the design, testing, and validation of the designated fallback method. Entities are encouraged to engage with the U.S. DOT and infrastructure owners and operators to understand the full ODD for safe and efficient operations of automated vehicles.

Work with All Potential User Groups to Incorporate Universal Design Principles

The potential for automation to improve mobility for all Americans is immense, but if products and technologies are not designed with usability by a broad spectrum of travelers in mind, it may not be achieved.

U.S. DOT encourages developers and deployers to work proactively with the disability community to support efforts that focus on the array of accommodations needed for different types of disabilities, and ways to improve mobility as a whole—not just from curb to curb, but also from door to door.

Anticipate Human Factors and Driver Engagement Issues

Consider human factors design for surface transportation—at all levels of automation—for all road users. Safety risks, such as driver distraction and confusion, should influence early stages of design and vehicle development. User-interface usability and comprehension need to be explored, particularly during emergency situations, and in maintaining safety if vehicle functions are compromised.

In addition, it will be important to recognize human factors challenges related to driver awareness and engagement. Entities could consider methods that ensure driver awareness and engagement during ADS-equipped vehicle testing, to mitigate the potential for distraction, fatigue, and other possible risks.

Testing on public roadways is necessary for vehicle automation development and deployment. Public trust can be built during testing by using an in-vehicle driver engagement monitoring system, a second test driver, or other methods. It can be helpful for entities developing ADS technologies to share information with Federal agencies and appropriate organizations about the testing of user interface technologies and designs.

Identify Opportunities for Voluntary Data Exchanges

Voluntary data exchanges can help improve the safety and operations of ADS and lead to the development of industry best practices, voluntary standards, and other useful tools.
Work Zone Data Exchanges

The Work Zone Data Exchange project responds to priorities identified by public and private sector stakeholders. The goal is to develop a harmonized specification for work zone data that infrastructure owners and operators can make available as open feeds that automated vehicles and others can use.

Accurate and up-to-date information about dynamic conditions occurring on the roads—such as work zones—can help automated vehicles navigate safely and efficiently. Many infrastructure owners and operators maintain data on work zone activity, but a common specification for this type of data does not currently exist. This makes it difficult and costly for third parties—including vehicle manufacturers and makers of navigation applications—to access and use work zone data across various jurisdictions.

Several State DOT agencies and private companies are voluntarily participating in the project, with U.S. DOT acting as a technical facilitator. U.S. DOT has been working with these partners to help define the core data elements that should be included in an initial work zone specification and to determine what types of technical assistance the data producers will need to implement it, expand it over time, and address broader work zone data management challenges.

In U.S. DOT’s Guiding Principles on Data for Automated Vehicle Safety, available at www.transportation.gov/av/data, the Department defines an approach that seeks to prioritize and enable voluntary data exchanges to address critical issues that could slow the safe integration of ADS technologies. These principles include:

- Promote proactive, data-driven safety, cybersecurity, and privacy-protection practices.
- Act as a facilitator to inspire and enable voluntary data exchanges.
- Start small to demonstrate value, and scale what works toward a larger vision.
- Coordinate across modes to reduce costs, reduce industry burden, and accelerate action.

The industry as a whole should consider working with Federal, State, and local agencies as well as relevant standards bodies (IEEE, SAE International, etc.) to identify opportunities to establish voluntary exchanges of data that can provide mutual benefit and help accelerate the safe integration of automation into the surface transportation system. This can include exchanges of data between the public and private sector regarding infrastructure conditions as well as exchanges among private sector entities to enable mutual learning and risk mitigation.

ROLES IN AUTOMATION: PRIVATE
Any exchanges of data should respect consumer privacy as well as proprietary and confidential business information.

**Contribute to the Development of Voluntary, Consensus-Based, and Performance-Oriented Technical Standards**

Voluntary standards offer flexibility and responsiveness to the rapid pace of innovation, can encourage investment and bring cost-effective innovation to the market more quickly, and may be validated by private sector conformity assessment and testing protocols. There are existing processes followed by Standards Development Organizations (SDOs), such as SAE International or IEEE, where industry participates in the development of voluntary standards. Industry and SDOs can continue to provide leadership in this area and collaborate with each other, as well as with U.S. DOT and other stakeholders, to address key issues. Areas where industry can support standards development include—but are not limited to—topics such as definitions, taxonomy, testing, interoperability, and performance characteristic definitions.

The Department supports the development and continuing evolution of stakeholder-driven voluntary standards, which in many cases can be an effective non-regulatory means to support interoperable integration of technologies into the transportation system. The Department supports these efforts through multiple mechanisms, including cooperation and funding support to SDOs; cooperation with industry and governmental partners; making Federal, State, and local technical expertise available; and through international coordination.

Appendix C provides more information on key topic areas and work underway in standards development for automation.

**Adopt Cybersecurity Best Practices**

It is the responsibility of ADS developers, vehicle manufacturers, parts suppliers, and all stakeholders who support transportation to follow best practices, and industry standards, for managing cyber risks in the design, integration, testing, and deployment of ADS. As documented in *A Vision for Safety 2.0*, these entities are encouraged to consider and incorporate voluntary guidance, best practices, and design principles published by NIST, NHTSA, SAE International, the Alliance of Automobile Manufacturers, the Association of Global Automakers, the Auto ISAC, and other stakeholders who support transportation.

The Federal Trade Commission maintains oversight over, and provides resources related to, protecting consumer privacy. Additional information is available at https://www.ftc.gov/news-events/media-resources/protecting-consumer-privacy.
other relevant organizations, as appropriate. Stakeholders are also encouraged to report to the Auto ISAC—or another mode-specific ISAC—44—all discovered incidents, exploits, threats, and vulnerabilities from internal testing, consumer reporting, or external security research as soon as possible, and provide voluntary reports of such information to the DHS NCCIC when and where Federal assistance may be warranted in response and recovery efforts.

**Engage with First Responders and Public Safety Officials**

To ensure public safety, first responders and public safety officials need to have ways to interact with automated vehicles during emergencies. During traffic incidents, emergencies, and special events automated vehicles may need to operate in unconventional ways. Police officers responsible for traffic enforcement may need new procedures to signal an ADS-equipped vehicle to pull over and determine whether the occupant is violating the law or using the ADS appropriately. Responder personnel across many disciplines (including police, fire, emergency medical services, and towing) will need training to safely interact with partially or fully disabled ADS-equipped vehicles at the scene of a crash. Also, laws covering distracted driving, operating under the influence, and open alcohol containers may not be applicable or may be modified for operators or occupants of ADS-equipped vehicles.

Public safety officials also see the potential for automated vehicles to improve emergency response by improving data about traffic incidents and providing first responders with new tools to respond to traffic incidents quickly, effectively, and safely.

To educate, raise awareness, and develop emergency response protocols, automated vehicle developers should consider engaging with the first responder community when developing and testing automation technologies. Through such engagement, technology developers could potentially identify new applications of automation technologies that can enhance emergency response. The Federal Government may also act as a convener between public safety officials, technology companies, automobile manufacturers, and other stakeholders to build consensus around uniform voluntary data-sharing standards, protocols, and practices.

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44 Including the Aviation ISAC (https://www.a-isac.com/), the Maritime Security ISAC (http://www.maritimesecurity.org/), and the Public Transit ISAC and Surface Transportation ISAC (https://www.surfacetransportationisac.org/)

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Private sector leadership is critical to advancing the development, testing, and commercialization of automated vehicles.
U.S. DOT sees a bright future for automation technology and great potential for transforming our surface transportation system for the better, toward a future with enhanced safety, mobility, and economic competitiveness across all transportation modes.
This section discusses U.S. DOT’s approach to moving forward on automation, informed by lessons from experience with the adoption of new technologies.

**Automation Implementation Strategies**

U.S. DOT is implementing five core strategies to accelerate the integration of automated vehicles and to understand their impact across all modes of the surface transportation system. The Department will put its six automation principles into action through these strategies. The strategies appear below in roughly sequential order, though some may occur in parallel. Stakeholders will be engaged throughout the process.

1. **Engage stakeholders and the public** as a convener and leader to address the issues automation raises. The Department will engage a broad range of stakeholders and provide them with opportunities to voice their concerns, expectations, and questions about the future of automation, to inform future research and policy development. U.S. DOT will also work to leverage knowledge and experience from across academia, industry, public sector agencies, and research organizations.

2. **Provide best practices and policy considerations to support stakeholders** as they work to better understand automation, how it may impact their roles and responsibilities, and how best to integrate automated vehicles into existing and future transportation networks. The Department is committed to providing best practices and updated policies as supported by research and will provide additional and more detailed information as the technology develops.

3. **Support voluntary technical standards** by working with stakeholders and SDOs to support technical standards and policies development. When in the public interest, the Department will support the integration of automation technologies throughout the Nation’s transportation system. See Appendix C for more information.

4. **Conduct targeted technical research** to inform future policy decisions and agency actions. Research is critical for producing and analyzing data to inform policy decisions, moving beneficial applications and technologies toward deployment, and evaluating the safety of new technologies.

5. **Modernize regulations** as existing Federal regulations and standards may pose challenges to the widespread integration of automated vehicles. U.S. DOT developed many of its regulations over a period of decades, generally with the assumption that a human driver would always be present. U.S. DOT is in the process of identifying and modifying regulations that unnecessarily impede the testing, sale, operation, or use of automation across the surface transportation system.
Safety Risk Management Stages along the Path to Full Commercial Integration

In addition to meeting any regulatory or statutory requirements, U.S. DOT envisions that entities testing and eventually deploying ADS technologies will employ a mixture of industry best practices, consensus standards, and voluntary guidance to manage safety risks along the different stages of technology development.

This conceptual framework provides an opportunity for discussion around one potential vision for promoting safety, managing risk, and encouraging the benefits possible from the adoption of automated vehicle technologies. The following description is in no way intended to imply that there is only one path for ADS development. Collaboration is needed among manufacturers, technology developers, infrastructure owners and operators, and relevant government agencies to establish protocols that will help to advance safe operations in these testing environments. ADS developers may decide that this path does not make sense for them or that they will combine different phases in unique ways, all of which the Department fully supports, as long as safety risks are appropriately managed and all testing is conducted in accordance with applicable laws and regulations. Likewise, to the extent an ADS developer wishes to use this framework, it is not intended to provide benchmarks for when a developer may move from one phase to another, as that is best left to the ADS developer.

### Conceptual Framework: Safety Risk Management Stages for AV

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<th>Development and Early Stage Road Testing</th>
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<tr>
<td>Further Develop the Technology—understand safety risks and implement mitigation strategies</td>
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<th>Expanded ADS Road Testing</th>
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<td>Build Confidence in the Technology Within the Intended Operational Environment—observe system failures, receive safety driver feedback, and execute fail-safe systems</td>
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<th>Limited to Full ADS Deployment</th>
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<tr>
<td>Move Towards Commercial Operation and Widely Engaging with the Public—validate underlying safety assumptions, gather user/public feedback, and identify fine-tuning opportunities</td>
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### Development and Early Stage Road Testing

ADS development does not start with public road testing. Significant engineering and safety analysis are performed prior to on-road testing with a prototype ADS to understand safety risks and implement mitigation strategies. The primary purpose of this stage is to further develop the technology (software and hardware). There are many existing industry standards that guide general technology development. Conceptually, this stage can be characterized by these general characteristics:
• The system would generally be characterized as a prototype that already passed laboratory and/or closed-course testing.\(^{45}\)

The hardware and the vehicle platform may be comprised of development or rapid prototyping-level equipment.

• ADS use cases and associated ADS functions are identified and implemented, and requisite software validation and verification are performed in controlled environments prior to this stage. The primary purpose of this stage of road testing is to validate the completeness of use cases and to verify that implemented software can perform associated functions.

• Controlled environment (track, simulation, etc.) testing and software development are continuing alongside ADS prototype road testing. Known use cases are being tested in controlled environments and new use cases identified in road testing are being evaluated and stored.

• Development of use cases could include initial assessments of a broad range of roadway characteristics (e.g., lane markings, signage) and operational scenarios (e.g., work zones, road weather) to inform ADS performance in the roadway environment.

• In conjunction, additional software development is taking place in failure handling, crash imminent scenario handling, and edge case handling (non-nominal scenarios).\(^{46}\)

• Safety drivers serve as the main risk mitigation mechanism at this stage. Safety-driver vigilance and skills are critical to ensuring safety of road testing and identifying new scenarios of interest.

• Some safety items (such as cybersecurity and human-machine interface) may be addressed in alternative ways when compared to production systems.

• Usually, in addition to a safety driver, an employee engaged in the ADS function/software development track is also present in the vehicle. Software changes could happen frequently (both for safety-critical issues and other reasons) but are tracked and periodically harmonized.

• Members of the public are not in ADS prototype vehicles during early stage road testing.

\(^{45}\) For general guidance in safety of road testing associated with these types of systems, see: SAE International, SAE J3018, Guidelines for On-Road Testing of SAE Level 3, 4, and 5 Prototype Automated Driving Systems (Warrendale: SAE International, 2015), https://www.sae.org/standards/content/j3018_201503/

\(^{46}\) These scenarios are more suitable to develop, test, and validate in controlled environments for several reasons, including testing non-nominal scenarios in naturalistic real-world environments can involve high risk, probabilities of natural encounters are too low, and repeatability of tests is very difficult to establish.

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**Progressing through Testing Stages**

The stage of testing and deployment of “an ADS in one ODD” does not adequately represent the maturity of all ADS development activities an entity may be pursuing. For example, an entity may be at a “limited-deployment stage” in one specific ODD giving limited rides to members of the public (e.g., daytime-only, less than 35 miles per hour, no precipitation, on a few streets in a metropolitan area). However, simultaneously that same entity may be developing its technologies to advance its ADS capabilities and expand the ODD elsewhere (e.g., to include nighttime, higher speeds, precipitation, or larger or different geographical areas).

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**Expanded ADS Road Testing**

Once the development progresses and specifications and software components are validated to be generally complete, software handling of non-nominal cases is integrated into an ADS. The primary purpose of this stage of testing is to build statistical confidence in matured software and hardware within the intended operational environment and observe system failures, safety driver subjective
The Role of On-Road Testing in Validation/Verification and Safety Assurance

Advancing an ADS function from prototyping stages to production release involves numerous development objectives. These include the ability for the ADS to perform nominal driving functions in known use cases, perform crash-avoidance maneuvers, revert to a safe state when there are identified system and sensor failures, and react reasonably safely in edge cases. **On-road testing cannot be expected to address all aspects of testing needs towards deployment.** For example, crash avoidance and failure response tests that put systems in imminent crash encounters cannot be safely performed in a naturalistic environment. On-road testing is an important part of the overall development process in identifying and validating the completeness of use cases, gaining statistical confidence in a system’s ability to handle use cases, and identifying edge cases and otherwise interesting/difficult cases, as well as public perceptions and expectations. However, once a new scenario of interest is identified in road-testing, it is usually added to a library and retested many times in controlled environments (simulation, track, hardware-in-the-loop, software-in-the-loop, etc.) and integrated as part of each software update release readiness assessment.

Limited to Full ADS Deployment

Limited ADS deployment is similar to what the public understands as demonstrations. Full deployment of automated vehicles represents an ADS that is able to, for example, operate commercially and widely engage with the public. The main purpose of this stage is to reach statistical confidence in the software for the intended operational environment, validate underlying safety assumptions, gather user and public feedback, and identify fine-tuning feedback, and execution of fail-safe/fail-operational system behaviors. Conceptually, this stage can be characterized by these general attributes:

- The ADS has matured both in terms of hardware and software. Information necessary to establish a safety self-assessment should be available and reasonably stable.
- Targeted operational design domain is more clearly identified and near fully specified. This could include an understanding of how the ADS-equipped vehicle interprets the standard roadway environment, such as lane markings, signage, varying traffic laws, dynamic roadway conditions, and other users.
- The functional safety approach has been carried out; safety goals are identified and risk management controls implemented.
- ADS use cases are validated to be nearly complete. Implemented ADS functions are validated and verified to meet engineering requirements in both controlled and on-road environments.
- Most elements of the ADS—such as fallback (minimal risk condition) mechanisms—are identified and implemented. Safety drivers are still in the loop, but they are expected to serve as the secondary risk mitigation strategy.

- Depending on the vehicle platform, some safety items (such as cybersecurity and human-machine interface) may still be addressed in alternative ways.
- The safety driver may be the only person in the vehicle. Time between subsequent safety driver actions may be extending. Ensuring that safety drivers can maintain their vigilance in reduced workload is important.
- Members of the public are still not in ADS prototype vehicles during expanded road testing.
opportunities in user compatibility areas. Conceptually, this stage can be characterized by these general characteristics:

- Complete engineering requirements for ADS are specified by the entity developing the technology, and internally documented. Engineering design reviews are performed, and documented.
- The operational design domain is specified clearly and ADS operation only takes place within that ODD. Relevant ODD elements are monitored to ensure full coverage. Any ODD expansions go through requisite validation and verification processes, are documented, and are appropriately communicated when applied as a software update in deployed units.
- Near-full software, hardware, system failure validation, and verification processes have been carried out with near production hardware.
- Software is stable. Software changes are centrally managed at the fleet level. Any major change goes through new release readiness testing.
- Nearly all elements of ADS—such as fallback (minimal risk condition) mechanisms—are identified and implemented. Safety drivers (including remote safety drivers) may still be used, but their roles are limited and may eventually be eliminated. Risk-based assessments are performed to assure safety of these approaches.
- Safety and key performance indicators are set and monitored.
- All safety items (including cybersecurity and human-machine interface) are addressed in a production manner.
- Members of the public are allowed in ADS-equipped vehicles on public roads, initially on a limited basis.
- Systems move toward full operation by being offered for sale, lease, or rent (to include free ridesharing) or otherwise engaged in commerce in the form of the transport of goods or passengers.
- In specified deployment areas, law enforcement, first responders, and relevant State and local agencies know of operational protocols and administrative procedures following a crash or other roadway event related to an ADS-equipped vehicle in the ODD.

Engaging with U.S. DOT along the Way

As ADS developers move along their respective paths from development to full commercial integration, it is useful to identify opportunities to further engage with U.S. DOT and the broader stakeholder community. The path discussed in the previous section illustrates example phases of testing and deployment, with sample general characteristics defining each stage. This framework can help lay out points at which the U.S. DOT, ADS developers, and stakeholders can engage with each other throughout the technology development process and align to prioritize safety and manage risks. Rather than waiting to interact at the very end of the technology development cycle, the U.S. DOT prefers a collaborative approach for working with industry to address and solve major challenges together, where possible.

In the near-term, the U.S. DOT and its modal agencies will continue to pursue its safety oversight role within its existing authorities (as discussed in Section 2). NHTSA, for example, has authority over the safety of ADS-equipped vehicles, including establishing Federal safety standards for new motor vehicles and addressing known safety defects in motor vehicles and motor vehicle equipment. FMCSA’s oversight begins once the vehicles are placed into commercial operation in interstate commerce, whether for hire or as a private motor carrier, on public roadways. At that point, certain regulations designed to ensure safe operation apply.

During the first several years of ADS integration, light vehicles, transit vehicles, and the motor carrier industry will consist of a mixed fleet. For example, motor carriers that employ Level 4
or Level 5 driverless CMVs, those carriers with Level 3 or lower ADS-equipped CMVs that still have a human driver present, and carriers using only traditional non-ADS-equipped vehicles will at times be sharing the roadways. Some carriers will be operating mixed fleets and the ADS-equipped vehicles in deployment will represent an even broader array of operational design domains. As a result, the U.S. DOT and its State and local partners will need to adapt enforcement practices and other processes to new and rapidly developing ADS technology, while also continuing to ensure safe operation of conventional human driven vehicles. This will be an important area for stakeholders to work with the U.S. DOT going forward.

Moving Forward

In the long term, the U.S. DOT will pursue strategies to address regulatory gaps or unnecessary challenges that inhibit a safe and reasonable path to full commercial integration. The operating agencies within the U.S. DOT will be working together and with stakeholders to support a flexible and transparent policy environment to accommodate the safe development and integration of ADS technology.

Looking ahead, the U.S. DOT encourages stakeholder engagement in several areas as it pursues its long-term vision of modernizing regulations and supporting the path to full ADS commercialization:

- **NHTSA** will seek comment on existing motor vehicle regulatory barriers and other unnecessary barriers to the introduction and industry self-certification of ADS. NHTSA is developing an ANPRM to determine methods to maintain existing levels of safety while enabling innovative vehicle designs. The ANPRM also explores removing or modifying requirements that would no longer be appropriate if a human driver is not operating the vehicle. NHTSA previously published a Federal Register notice requesting public comment on January 18, 2018. NHTSA is issuing an ANPRM requesting public comments on designing a national pilot program that will enable it to facilitate, monitor, and learn from the testing and development of emerging advanced driving technologies and to assure the safety of those activities.

- **FMCSA** is finalizing an ANPRM to address ADS, particularly to identify regulatory gaps, including in the areas of inspection, repair, and maintenance for ADS. FMCSA anticipates considerable public interest and participation in this rulemaking effort, which will include an opportunity for formal written public comments as well as multiple public listening sessions.

- **FTA** is investing significant research resources to support the commercialization of innovative solutions in transit automation. As part of this research, FTA will assess areas of potential regulatory and other unnecessary barriers. Examples include FTA funding eligibility and technology procurement requirements, as well as ADA compliance. Currently, FTA is preparing guidance to provide stakeholders with clarity on existing FTA rules relevant to developing, testing, and deploying automated transit buses.

- **FHWA** will continue to work with stakeholders through its National Dialogue and other efforts to address the readiness of the roadway infrastructure to support ADS-equipped vehicles. It is reviewing existing standards to address uniformity and consistency of traffic control devices, such as signage, and plans to update the existing MUTCD.

FMCSA is in the process of developing policy recommendations to address ADS technology. Through public listening sessions, the Agency hopes to solicit information on issues relating to the design, development, testing, and integration of ADS-equipped commercial motor vehicles. FMCSA is excited to share its progress to date and learn more about the perspective of the trucking and bus industries firsthand as it considers future guidance.
Stakeholders are encouraged to engage directly with the Department where and when possible to support collaboration. It will be important to gather information and feedback from the stakeholder community, including ADS developers, commercial motor vehicle carriers, transit agencies, infrastructure owners and operators, the public, and other groups to jointly address key challenges and promote safe technology development and deployment.

**Conclusion**

Over the past century, motor vehicles have provided tremendous mobility benefits, including widespread access to jobs, goods, and services. They have also helped connect many of the most remote and isolated regions of the country to the larger economy. Along with these benefits, however, have come significant safety risks and other challenges. Motor vehicle crashes remain a leading cause of death in the United States, with an estimated 37,133 lives lost on U.S. roads in 2017. Automation has the potential to improve the safety of our transportation system, improve our quality of life, and enhance mobility for Americans, including those who do not drive today.

Many Americans remain skeptical about the notion that their car could one day be driving itself, rather than being driven by humans. We certainly cannot predict the exact way consumers will choose to interact with these technologies. Therefore, the U.S. DOT will not rush to regulate a nascent and rapidly evolving technology. Instead, the Department supports an environment where innovation can thrive and the American public can be excited and confident about the future of transportation. Doing this requires a flexible policy architecture.

With AV 3.0, U.S. DOT acknowledges the need to modernize existing regulations and think about new ways to deliver on our mission. The Department will work with partners and stakeholders in government, industry, and the public to provide direction, while also remaining open to learning from their experiences and needs. Wherever possible, U.S. DOT will partner with industry to develop voluntary consensus-based standards and will reserve non-prescriptive, performance-based regulations for when they are necessary. The Department will work to assess and minimize the possible harms and spread the benefits of automation technology across the Nation.

Regarding the integration of automation into professional driving tasks, lessons learned through the aviation industry’s experience with the introduction of automated systems may be instructive and inform the development of thoughtful, balanced approaches. These are not perfect comparisons, but are still worth considering (See Learning from the History of...
The aviation industry discovered that automation required careful consideration of human factors, but led to improved safety ultimately. This transition also did not result in the elimination of pilot jobs, as some had feared.

Despite the great promise of automation technology, important questions remain. For example, as driving becomes more automated, how can safety be improved? How will people interact with these technologies? What happens when a human vehicle operator switches to or from an automated driving mode? As automated driving technologies develop, how will the Nation’s 3.8 million professional drivers be affected? Which regulatory obstacles need to be removed? What opportunities and challenges does automation present for long-range regional planning? Will automation lead to increased urban congestion?

U.S. DOT sees a bright future for automation technology and great potential for transforming our surface transportation system for the better, toward a future with enhanced safety, mobility, and economic competitiveness across all transportation modes.

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**Learning from the History of Automation in the Aviation Workforce**

The aviation industry developed technological solutions to help airline pilots manage factors such as high workload, distractions, and abnormal situations. Innovation at that time eventually led to the introduction of autopilot, autothrottle, flight director, sophisticated alerting systems, and more. In part because of these innovations, the safety record for aviation improved significantly. Early automation technology in aviation performed very simple functions; for example, maintaining a set altitude or heading—comparable to conventional cruise control systems offered on most passenger cars today. Pilots readily accepted these systems because they reduced their workload and were easy to understand.

As computer technology became more capable, automation in the flight deck became more complex. For example, it enabled sophisticated navigation using precise flight paths that contributed to more efficient operations. This increased automation came at a cost. It became harder for pilots to understand what the automated systems were doing, yet they remained responsible for taking over when the automated systems reached the limits of their operating domains or malfunctioned. Pilots were also encouraged to use automation to the exclusion of manual flight controls, potentially degrading manual flight skills.

Systems that alert pilots to hazardous conditions (e.g., proximity to the ground or to other aircraft—lane departure alerts are an analogous example offered in many passenger cars) have also contributed significantly to aviation safety despite initial challenges. Early alert systems sometimes had a high number of false alarms, so pilots did not trust them. Many improvements were made, such as better algorithms, better sensors, and improved and standardized display of alerts (and associated information) on the flight deck. These improvements have led to more reliable alerts and pilots are more willing to heed them.

Automation has undeniably made flying safer by supporting pilots. The characteristics that have improved trust in and effectiveness of these systems include:

- Reliable, robust systems that minimize false or missed alarms/reports.

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• Pilot interfaces that are easy to understand and enhance awareness.

• Training to understand how the systems work (and how to operate them).

• Avoidance of skill degradation by encouraging pilots to practice manual flight and basic skills.

In the early days of aviation automation, many pilots worried that autopilot functions would completely replace them. Yet today, pilots are still paid well, highly regarded, and very much in demand. Although aviation is still undergoing technological changes, including increased automation of many services, its first four decades of experience shows that the transition from a mode of transportation of primarily human operation to one where humans and automated systems share in the vehicle's operation can occur in ways that dramatically increase safety while minimizing social disruption.
U.S. DOT supports an environment where innovation can thrive and the American public can be excited and confident about the future of transportation.
**APPENDIX A**

**KEY TERMS AND ACRONYMS**

**Adaptive Cruise Control:** A driver assistance system that automatically adjusts a vehicle’s speed to maintain a set following distance from the vehicle in front. (NHTSA)

**ADS-Dedicated Vehicle:** A vehicle designed to be operated exclusively by a Level 4 or Level 5 ADS for all trips. (SAE J3016)

**Advanced Driver-Assistance Systems (ADAS):** Systems designed to help drivers with certain driving tasks (e.g., staying in the lane, parking, avoiding collisions, reducing blind spots, and maintaining a safe headway). ADAS are generally designed to improve safety or reduce the workload on the driver. With respect to automation, some ADAS features could be considered SAE Level 1 or Level 2, but many are Level 0 and may provide alerts to the driver with little or no automation.

**Automation:** Use of electronic or mechanical devices to operate one or more functions of a vehicle without direct human input. Generally applies to all modes.

**Automated Driving System (ADS):** The hardware and software that are collectively capable of performing the entire Dynamic Driving Task on a sustained basis, regardless of whether it is limited to a specific operational design domain. This term is used specifically to describe a Level 3, 4, or 5 driving automation system. (SAE J3016)

**Automated Vehicle:** Any vehicle equipped with driving automation technologies (as defined in SAE J3016). This term can refer to a vehicle fitted with any form of driving automation. (SAE Level 1–5)

**Commercial Motor Vehicle:** Any self-propelled or towed motor vehicle used on a highway in interstate commerce to transport passengers or property when the vehicle:

1. Has a gross vehicle weight rating or gross combination weight rating, or gross vehicle weight or gross combination weight, of 4,536 kg (10,001 pounds) or more, whichever is greater; or
2. Is designed or used to transport more than 8 passengers (including the driver) for compensation; or
3. Is designed or used to transport more than 15 passengers, including the driver, and is not used to transport passengers for compensation; or
4. Is used in transporting material found by the Secretary of Transportation to be hazardous under 49 U.S.C. 5103 and transported in a quantity requiring placarding under regulations prescribed by the Secretary under 49 CFR, subtitle B, chapter I, subchapter C. (FMCSA, defined in 49 CFR 390.5)

**Cooperative Automation:** Ability for automated vehicles to communicate with each other and with infrastructure to coordinate their movements.

**Cooperative Lane Change and Merge:** A dynamic driving task for automated vehicles that uses communications to enable negotiations between vehicles to provide safe gaps for manual or automated lane change or merge maneuver on a roadway. (FHWA)

**Driver Assistance Technologies:** Cameras and sensors in vehicles that help drivers see more than they can with the naked eye and warn of a possible collision. Driver assistance technologies can help drivers with
backing up and parking, maintaining safe distance from other vehicles, preventing forward collisions, and navigating lanes safely. (NHTSA)

**Driving Automation System or Technology:** The hardware and software that are collectively capable of performing part or all of the Dynamic Driving Task on a sustained basis; this term is used generically to describe any system capable of Level 1–5 driving automation. (SAE J3016)

**Dynamic Driving Task (DDT):** All of the real-time operational and tactical functions required to operate a vehicle in on-road traffic, excluding the strategic functions such as trip scheduling and selection of destinations and waypoints. (SAE J3016)

**DDT Fallback:** The response by the user or by an ADS to either perform the DDT or achieve a minimal risk condition after occurrence of a DDT performance-relevant system failure(s) or upon Operational Design Domain (ODD) exit. (SAE J3016)

**GlidePath:** A prototype application of signalized approach and departure that has been demonstrated to stakeholders. (FHWA)

**Hazardous Material:** The Secretary shall designate material (including explosive, radioactive material, infectious substance, flammable or combustible liquid, solid, or gas, toxic, oxidizing, or corrosive material, and compressed gas) or a group or class of material as hazardous when the Secretary determines that transporting the material in commerce in a particular amount and form may pose an unreasonable risk to health and safety or property. (PHMSA, defined 49 U.S.C. § 5103)

**Human-in-the-loop:** Intermittent remote operation or intervention by a human of an automated or autonomous vehicle for emergency or special handling reasons. (FRA)

**Minimal Risk Condition:** A condition to which a user or an ADS may bring a vehicle after performing the DDT fallback in order to reduce the risk of a crash when a given trip cannot or should not be completed. (SAE J3016)

**Object Event Detection and Response (OEDR):** The subtasks of the DDT that include monitoring the driving environment (detecting, recognizing, and classifying objects and events and preparing to respond as needed) and executing an appropriate response to such objects and events (i.e., as needed to complete the DDT and/or DDT fallback). (SAE J3016)

**Operational Design Domain (ODD):** The specific conditions under which a given driving automation system or feature thereof is designed to function, including, but not limited to, driving modes. This can incorporate a variety of limitations, such as those from geography, traffic, speed, and roadways. (SAE J3016)

**Remote Driver/Remote Operation:** A driver who is not seated in a position to manually exercise in-vehicle braking, accelerating, steering, and transmission gear selection input devices (if any) but is able to operate the vehicle. (SAE J3016)

**Signalized Intersection Approach and Departure:** An automated vehicle that communicates with infrastructure using Signal Phase and Timing (SPaT) and Map Data Message (MAP) messages to automate the movement of single or multiple automated vehicles through intersections to increase traffic flow and safety. (FHWA)

**Speed Harmonization:** A strategy to increase traffic flow enabled by communications between an automated vehicle and infrastructure to change traffic speed on roads that approach areas of traffic congestion, bottlenecks, incidents, special events, and other conditions that affect flow. (FHWA)

**Vehicle Platooning:** A group of automated vehicles that use communications to enable negotiations between vehicles to support organized behavior and safe close following. (FHWA)
<table>
<thead>
<tr>
<th>Abbreviation</th>
<th>Full Form</th>
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<tbody>
<tr>
<td>ADA</td>
<td>Americans with Disabilities Act</td>
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<td>ADS</td>
<td>Automated Driving Systems</td>
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<tr>
<td>AI</td>
<td>Artificial Intelligence</td>
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<tr>
<td>ANPRM</td>
<td>Advance Notice of Proposed Rulemaking</td>
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<td>ATTRI</td>
<td>Accessible Transportation Technologies Research Initiative</td>
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<tr>
<td>CDL</td>
<td>Commercial Driver’s License</td>
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<td>CMV</td>
<td>Commercial Motor Vehicle</td>
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<tr>
<td>DARPA</td>
<td>Defense Advanced Research Projects Agency</td>
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<tr>
<td>DDT</td>
<td>Dynamic Driving Task</td>
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<tr>
<td>DHS</td>
<td>Department of Homeland Security</td>
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<tr>
<td>DOL</td>
<td>Department of Labor</td>
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<tr>
<td>FCC</td>
<td>Federal Communications Commission</td>
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<td>FHWA</td>
<td>Federal Highway Administration</td>
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<tr>
<td>FMCSA</td>
<td>Federal Motor Carrier Safety Administration</td>
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<tr>
<td>FMCSR</td>
<td>Federal Motor Carrier Safety Regulations</td>
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<tr>
<td>FMVSS</td>
<td>Federal Motor Vehicle Safety Standards</td>
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<tr>
<td>FRA</td>
<td>Federal Railroad Administration</td>
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<tr>
<td>FTA</td>
<td>Federal Transit Administration</td>
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<tr>
<td>FTC</td>
<td>Federal Trade Commission</td>
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<tr>
<td>HHS</td>
<td>Health and Human Services</td>
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<tr>
<td>HMI</td>
<td>human-machine interface</td>
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<tr>
<td>ICT</td>
<td>Information and Communications Technology</td>
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<tr>
<td>IEEE</td>
<td>Institute of Electrical and Electronics Engineers</td>
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<tr>
<td>ISAC</td>
<td>Information Sharing and Analysis Center</td>
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<td>ISO</td>
<td>International Standards Organization</td>
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<td>MARAD</td>
<td>Maritime Administration</td>
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<tr>
<td>MCSAP</td>
<td>Motor Carrier Safety Assistance Program</td>
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<tr>
<td>MPO</td>
<td>Metropolitan Planning Organization</td>
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<tr>
<td>MRC</td>
<td>Minimal Risk Condition</td>
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<tr>
<td>MUTCD</td>
<td>Manual on Uniform Traffic Control Devices</td>
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<tr>
<td>NCCIC</td>
<td>National Cybersecurity and Communications Integration Center</td>
</tr>
<tr>
<td>NHTSA</td>
<td>National Highway Traffic Safety Administration</td>
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<tr>
<td>NIST</td>
<td>National Institute of Standards and Technology</td>
</tr>
<tr>
<td>NSP</td>
<td>National Public Transportation Safety Plan</td>
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<tr>
<td>ODD</td>
<td>operational design domain</td>
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<tr>
<td>OEDR</td>
<td>Object and Event Detection and Response</td>
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<tr>
<td>OHMS</td>
<td>Office of Hazardous Materials Safety</td>
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<tr>
<td>PHMSA</td>
<td>Pipeline and Hazardous Materials Safety Administration</td>
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<tr>
<td>PTASP</td>
<td>Public Transportation Agency Safety Plan</td>
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<tr>
<td>PTC</td>
<td>Positive Train Control</td>
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<td>SAE</td>
<td>Society of Automotive Engineers</td>
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<tr>
<td>SDO</td>
<td>Standards Development Organization</td>
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<tr>
<td>SMS</td>
<td>Safety Management System</td>
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<tr>
<td>SPaT</td>
<td>Signal Phase and Timing</td>
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<tr>
<td>STAR</td>
<td>Strategic Transit Automation Research</td>
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<tr>
<td>U.S. DOT</td>
<td>U.S. Department of Transportation</td>
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<tr>
<td>US-CERT</td>
<td>United States Computer Emergency Readiness Team</td>
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<tr>
<td>UVC</td>
<td>Uniform Vehicle Code</td>
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<tr>
<td>VRU</td>
<td>Vulnerable Road User</td>
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<tr>
<td>VSSA</td>
<td>Voluntary Safety Self-Assessment</td>
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</table>
Since the publication of A Vision for Safety 2.0, the U.S. DOT has sought input from the public through public meetings, demonstration projects, expert roundtables and workshops, Requests for Information, and Requests for Comment. In March 2018, U.S. DOT hosted an Automated Vehicle Summit to discuss the cross-modal issues most critical to the successful integration of automated vehicles and provide input to this document. For more information, see transportation.gov/AV.

The most common themes and concerns stakeholders shared with the U.S. DOT include:

- **Consumer and public education**: Stakeholders agreed on the need for improved public and consumer education regarding the capabilities of vehicles with different levels of automation. Responses emphasized the need to engage a diverse range of stakeholders.

- **Data and digital infrastructure**: Respondents identified a need for standardized frameworks and enhanced digital infrastructure for collecting, managing, and exchanging data related to automated vehicle operation.

- **Connectivity**: Many respondents suggested continued investment in research into V2V and V2I communications and their potential to complement automated vehicle technologies. Responses noted the need for standardized and interoperable communications.

- **Mobility and accessibility**: Many stakeholders see great promise in the potential for automated vehicles to support the independence of people with disabilities by improving the accessibility of mobility options. To achieve this potential, stakeholders stressed that innovators and policymakers need to engage in an open dialogue with the disability community.

- **Public safety and emergency response**: Some respondents emphasized the need for establishing protocols for emergency responders, including emergency overrides to transfer control to a human in case of an emergency or equipment malfunction.

- **Roadway readiness**: Stakeholders recognize that improved roadway maintenance, enhanced digital infrastructure, and increased uniformity have the potential to enhance automated vehicle operations. However, many are concerned about making long-term infrastructure investments given the uncertainty about automation capabilities and requirements.

- **Insurance and liability**: Respondents raised concerns regarding insurance requirements and methods for determining liability.

- **Cybersecurity**: Stakeholder responses stressed the need for setting cybersecurity standards and establishing models and partnerships to mitigate the risk of hacking or intrusions.

- **Workforce impacts**: Stakeholders expressed concerns about the potential impact of automation on employment, particularly in the motor carrier, transit, and rail industries, and encouraged additional research into opportunities for re-training and workforce development.
Standardization-related needs associated with surface vehicle automation are in various stages of identification, development, definition, and adoption. Standardization-related documents can include voluntary technical standards published by standards developing organizations (SDOs) as well as specifications, best practices descriptions and other types of documents. There are standards that apply to almost all levels of vehicle automation. These include ISO 26262 Road Vehicles Functional Safety and SAE’s J3016_201806 Taxonomy and Definitions for Terms Related to On-Road Motor Vehicle Automated Driving Systems. There are many existing standards, but they may not fully address automated vehicle needs. Some standards specific to automated vehicles and many standards in other automation-relevant domains have been developed, but gaps remain where activity is underway or anticipated.

In addition to those standards that support interoperable integration, many standards development efforts are focused on describing common terminology, required performance capabilities, and interfaces between subsystems inside automated systems. These efforts include both automation-specific standards and domain-specific standards—for example, Information and Communications Technology (ICT) standards—applicable to subsystems and technologies that are then integrated into the overall automation system or surface transportation system. There are also sets of published best practices and frameworks that complement and are used in conjunction with voluntary technical standards. For example, the NIST cybersecurity framework describes a holistic approach to mitigating cyber threats across complex systems.

The Department will continue our cooperative, coordinated approach to supporting development of stakeholder-driven voluntary technical standards and similar documents across internal modal partners. The Department will follow a similar process to the approach for modernizing regulation, including:

1. **Gather information** through research, internal analysis, and stakeholder engagement on voluntary technical standardization needs.

2. **Explore and execute new approaches** to meet technical challenges in a way acceptable to the broad, diverse stakeholder community.

3. **Work to ease implementation** of automated vehicle products by supporting development of voluntary technical standards, system architecture options and user services for the interface between vehicles and infrastructure, along with companion software toolsets and implementation support programs.

   Means include cooperation and funding support to SDOs, cooperation with industry and governmental partners, making Federal technical expertise available, and international coordination.

4. **Cooperate with stakeholders** to maximize interoperability throughout North America as well as to take advantage of common international interests and global expertise by leveraging work across multiple regions and markets.

Vehicle automation systems represent one element of a larger system-of-systems architecture within surface transportation. Vehicle manufacturers
control what goes into the vehicle, while infrastructure owners and operators control the physical environment where the vehicle operates. That infrastructure covers more than the roadway and can include communications networks, electric vehicle charging stations, and other components. Surface vehicle automation systems have technological crossovers and interdependencies. These include considerations about software reliability as the degree of software dependency increases. Interdependencies are not directly mapped from traditional standards, and those factors expand the scope of consensus agreement on systems architectures and voluntary technical standards.

To gain a general understanding of what standards might be beneficial for vehicle automation, the interests, goals, and perspectives of innovators and stakeholders can be used as a basis to categorize the different types of existing and prospective standards. Figure 1 offers one way of logically dividing the voluntary technical standards landscape into three complementary category areas to encompass multiple perspectives.

As innovators and stakeholders advance the state of the art in automation, it is useful to identify those standards that already are available. Table 1 organizes existing standards by three functional areas: technology, functional standards, and safety, and identifies the associated organization. In some cases, these standards are applicable globally or multi-regionally; in other cases, differing standards have evolved in specific regions. This is reflected in Table 1, which describes work by a wide spectrum of organizations whose standardization-related documents are applicable domestically and across global markets. There may be ongoing work that is not captured below.

<table>
<thead>
<tr>
<th>Technology Areas</th>
<th>Functional Standards Areas</th>
<th>Safety Areas</th>
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<tbody>
<tr>
<td>Software</td>
<td>Definitions and Architecture</td>
<td>System Safety</td>
</tr>
<tr>
<td>System Engineering</td>
<td>Data</td>
<td>Operational Design Domain (ODD)</td>
</tr>
<tr>
<td>Communications</td>
<td>Design</td>
<td>Object and Event Detection and Response (OEDR)</td>
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<tr>
<td>Position, Navigation and Timing (PNT)</td>
<td>Maintenance and Inspection</td>
<td>Fallback (Minimal Risk Condition - MRC)</td>
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<tr>
<td>Mapping</td>
<td>Functional / Performance</td>
<td>Validation Methods</td>
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<tr>
<td>Sensing</td>
<td>Protocol (Communications)</td>
<td>HMI</td>
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<tr>
<td>Infrastructure</td>
<td>Security</td>
<td>Vehicle Cybersecurity</td>
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<td>Human-Machine Interface (HMI)</td>
<td>Testing / Test Targets</td>
<td>Crashworthiness</td>
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<td>Training</td>
<td>Post-Crash ADS Behavior</td>
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<td>Data Recording</td>
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<td>Consumer Education and Training</td>
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<td>Federal, State, and Local Laws</td>
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<td>Commercial Vehicle Inspection</td>
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### Table 1. Relevant Standardization-Related Document by Functional Area (as of August 2018)

<table>
<thead>
<tr>
<th>Functional Area</th>
<th>Standardization-Related Documents</th>
</tr>
</thead>
</table>
| **Definitions and Architecture** | • SAE J2944_201506 — Operational Definitions of Driving Performance Measures and Statistics  
• SAE J3016_201806 — Taxonomy and Definitions for Terms Related to On-Road Motor Vehicle Automated Driving Systems  
• SAE J3018_201503 — Guidelines for Safe On-Road Testing of SAE Level 3, 4, and 5 Prototype Automated Driving Systems  
• SAE J3063_201511 — Active Safety Systems Terms and Definitions  
• SAE J3077_201512 — Definitions and Data Sources for the Driver Vehicle Interface (DVI)  
• SAE J3087_201710 — Automatic Emergency Braking (AEB) System Performance Testing  
• SAE AS-4 Joint Architecture for Unmanned Systems (JAUS)  
• SAE AIR5372A:2014 Information on Brake-By-Wire (BBW) Brake Control Systems [pertains to aircraft, but may be of use to surface transportation]  
• National Institute of Standards and Technology (NIST) Special Publication (SP) 1011 I-2.0 Autonomy Levels for Unmanned Systems (ALFUS) Framework  
• NIST NISTIR 6910 — 4D/RCS Version 2.0: A Reference Model Architecture for Unmanned Vehicle Systems  
• ASTM Committee F45 on Driverless Automatic Guided Industrial Vehicles Architecture  
• ISO/IEC/IEEE 12207:2017(E) — Systems and software engineering — Software life cycle processes  
• U.S. Army Robotic Systems Joint Project Office Interoperability Profiles  
• Automotive Open System Architecture (AUTOSAR) Testing  
• European Committee for Standardization (CEN) European Standard (EN) 1525: Safety of Industrial Trucks — Driverless Trucks and Their Systems  
Table 1. Relevant Standardization-Related Document by Functional Area (as of August 2018)

<table>
<thead>
<tr>
<th>Functional Area</th>
<th>Standardization-Related Documents</th>
</tr>
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| Data            | • Navigation Data Standard (NDS) — a standardized format for automotive-grade navigation databases, jointly developed by automobile manufacturers and suppliers.  
• North American Datum 1983 (NAD83)  
• World Geodetic System 1984 (WGS84)  
• European Terrestrial Reference System 1989 (ETRS89)  
• Chinese encrypted datum 2002 (CSJ-02)  
• ADASIS Forum vehicle to cloud messaging standards  
• Coordinated Universal Time (UTC)  
• International Atomic Time (TAI)  
• ISO 11270:2014 — Intelligent Transport Systems — Lane Keeping Assistance Systems (LKAS) — Performance requirements and test procedures  
• ISO 14296:2016 — Intelligent Transport Systems — Extension of map database specifications for applications of cooperative Intelligent Transportation Systems  
• ISO 14825:2011 — Intelligent Transport Systems — Geographic Data Files (GDF) — GDF5.0  
• ISO 19237:2017 — Intelligent Transport Systems — Pedestrian detection and collision mitigation systems (PDCMS) — Performance requirements and test procedures  
• ISO 22178:2009 — Intelligent Transport Systems — Low speed following (LSF) systems — Performance requirements and test procedures  
• ISO 22179:2009 — Intelligent Transport Systems — Full Speed Range Adaptive (FSRA) systems — Performance requirements and test procedures  
• ISO 22839:2013 — Intelligent Transport Systems — Forward vehicle collision mitigation systems — Operation, performance, and verification requirements  
• ISO/DIS 20035 — Intelligent Transport Systems — Cooperative adaptive cruise control (CACC) — Operation, performance, and verification requirements  
• SAE J1698 — Event Data Recorder (EDR) |

(Continued)
<table>
<thead>
<tr>
<th>Functional Area</th>
<th>Standardization-Related Documents</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Design</strong></td>
<td>• Federal Highway Administration Manual on Uniform Traffic Control Devices (MUTCD)</td>
</tr>
<tr>
<td></td>
<td>• American Association of State Highway and Transportation Officials (AASHTO) A Policy on Geometric Design of Highways and Streets (Green Book)</td>
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<td></td>
<td>• AASHTO Roadside Design Guide</td>
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<td></td>
<td>• Joint SAE-AASHTO Committee on Road Markings</td>
</tr>
<tr>
<td></td>
<td>• ISO 2575:2010 — Road vehicles — Symbols for controls, indicators, and tell-tales</td>
</tr>
<tr>
<td><strong>Maintenance and Inspections</strong></td>
<td>• Commercial Vehicle Safety Alliance (CVSA) North American Standard Inspection Program (roadside inspection process for inspecting commercial motor vehicles and drivers throughout North America)</td>
</tr>
<tr>
<td><strong>Functional / Performance</strong></td>
<td>• SAE J2958:2011 — Report on Unmanned Ground Vehicle Reliability</td>
</tr>
<tr>
<td></td>
<td>• SAE J2980_201804 — Considerations for ISO 26262 Automotive Safety Integrity Levels (ASIL) Hazard Classification</td>
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<tr>
<td></td>
<td>• SAE J3088 — Active Safety System Sensors</td>
</tr>
<tr>
<td></td>
<td>• SAE J3116_201706 — Active Safety Pedestrian Test Mannequin Recommendation</td>
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<tr>
<td></td>
<td>• Radio Technical Commission for Aeronautics (RTCA) DO-178C Software Considerations in Airborne Systems and Equipment Certification</td>
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<tr>
<td></td>
<td>• National Aeronautics and Space Administration (NASA) — GB-8719.13 Software Safety Guidebook</td>
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<td></td>
<td>• Automated Driving and Platooning Task Force of the American Trucking Associations Technology and Maintenance Council</td>
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<tr>
<td></td>
<td>• ISO 13482:2014 — Robots and robotic devices — Safety requirements for personal care robots</td>
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<tr>
<td></td>
<td>• ISO 15622:2010 — Intelligent Transport Systems — Adaptive Cruise Control systems — Performance requirements and test procedures</td>
</tr>
<tr>
<td></td>
<td>• ISO 17386:2010 — Transport information and control systems — Maneuvering Aids for Low Speed Operation (MALSO) — Performance requirements and test procedures</td>
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<tr>
<td></td>
<td>• ISO 22840:2010 — Intelligent Transport Systems — Devices to aid reverse maneuvers — Extended-range backing aid (ERBA) systems</td>
</tr>
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<td>• ISO 26262 — Road vehicles — Functional safety</td>
</tr>
</tbody>
</table>
**Table 1. Relevant Standardization-Related Document by Functional Area (as of August 2018)**

<table>
<thead>
<tr>
<th>Functional Area</th>
<th>Standardization-Related Documents</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Protocols (Communications)</strong></td>
<td>• IEEE 802.11X</td>
</tr>
<tr>
<td></td>
<td>• IEEE 1609.2: 2016 — WAVE - Security Services for Applications and Management Messages</td>
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<tr>
<td></td>
<td>• IEEE 1609.2a: 2017 — WAVE — Security Services and Message Sets — Amendment 1</td>
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<td></td>
<td>• IEEE 1609.3: 2016 — WAVE — Networking Services</td>
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<td></td>
<td>• IEEE 1609: 2016 — WAVE — Multi-channel Operations</td>
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<tr>
<td></td>
<td>• IEEE 1609.12: 2016 — WAVE — Identifier Allocation</td>
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<tr>
<td></td>
<td>• IEEE 8802-3-2014 — Standard for Ethernet</td>
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<tr>
<td></td>
<td>• IEEE 8802-3-2017 — Standard for Ethernet — Amendments</td>
</tr>
<tr>
<td></td>
<td>• SAE J1939 Core Standards — Serial Control and Communications Heavy Duty Vehicle Network</td>
</tr>
<tr>
<td></td>
<td>• SAE J2735_201603 — Vehicle-to-Vehicle Message Sets</td>
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<tr>
<td><strong>Security</strong></td>
<td>• SAE J3061_201601 — Cybersecurity Guidebook for Cyber-Physical Vehicle Systems</td>
</tr>
<tr>
<td></td>
<td>• NIST Cybersecurity Framework (CSF)</td>
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<td></td>
<td>• National Highway Traffic Safety Administration Cybersecurity Framework</td>
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<tr>
<td></td>
<td>• International Electrotechnical Commission (IEC) — 62443 Industrial communication networks — Network and system security</td>
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<tr>
<td></td>
<td>• ISO/IEC 15408 — Information technology — Security techniques — Evaluation criteria for information technology (IT) Security</td>
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<tr>
<td></td>
<td>• ISO/IEC 18045:2008 — Information technology — Security techniques — Methodology for IT security evaluation</td>
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<tr>
<td>Functional Area</td>
<td>Standardization-Related Documents</td>
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<tr>
<td><strong>Testing/Test Target</strong></td>
<td></td>
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<tr>
<td>• SAE J3018_201503 — Guidelines for Safe On-Road Testing of SAE Level 3, 4, and 5 Prototype Automated Driving Systems</td>
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<tr>
<td>• SAE J3048_201602 — Driver-Vehicle Interface Considerations for Lane Keeping Assistance Systems</td>
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<tr>
<td>• SAE J3077_201512 — Definitions and Data Sources for the DVI</td>
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<tr>
<td>• SAE J3114_201612 — Human Factors Definitions for Automated Driving and Related Research Topics</td>
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<tr>
<td>• IEC-61508 — Functional Safety of Electrical/Electronic/Programmable Electronic Safety-related Systems</td>
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<tr>
<td>• ISO/DIS 11270:2014 — Intelligent Transport Systems — Lane keeping assistance systems (LKAS) — Performance requirements and test procedures</td>
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<td>• ISO 19237:2017 — Intelligent Transport Systems — Pedestrian detection and collision mitigation systems (PDCMS) — Performance requirements and test procedures</td>
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Table 1. Relevant Standardization-Related Document by Functional Area (as of August 2018)

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<tr>
<th>Functional Area</th>
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</tr>
</thead>
<tbody>
<tr>
<td>Testing/Test Target</td>
<td>Architecture/Software</td>
</tr>
<tr>
<td></td>
<td>ISO/IEC/IEEE 29119 — Software and systems engineering — Software testing</td>
</tr>
</tbody>
</table>
As automation technologies advance, additional needs may become evident that are not covered by currently available standards. Those needs may be met by a combination of automation-specific standards and domain-specific standards. The table below presents an inventory of known standards development activities underway to support known and anticipated automation needs.

Table 2: Known Current Standards Development Activities Relevant to Automated Surface Vehicles *(as of August 2018)*

<table>
<thead>
<tr>
<th>Topic Area</th>
<th>Functional Needs</th>
<th>Standardization-Related Activities</th>
</tr>
</thead>
</table>
| **Cooperative Situational Awareness** | • Need to utilize perception systems from other surface vehicles and infrastructure systems to overcome sensor occlusion and range. | • SENSORIS, ADASIS Forum  
• SAE J2945/6 — Performance Requirements for Cooperative Adaptive Cruise Control and Platooning  
• SAE J3161 — On-Board System Requirements for LTE V2X V2V Safety Communications |
| **Cybersecurity Framework**        | • Describe best practices  
• Cover aspects of identify, respond, recover, protect, and detect for vehicles and infrastructure | • Auto-ISAC Best Practices  
• NHTSA — Cyber Resiliency Framework project (RFP released winter 2017)  
• National Cooperative Highway Research Program (NCHRP) 03-127 Cybersecurity of Traffic Management Systems research project  
• ITS Joint Program Office Data Program ADS Data Roundtable  
• American Trucking Association Technology and Maintenance Council  
• Association of Global Automakers — Framework for Automotive Cybersecurity Best Practices |
| **Data sharing: Scenarios**        | • Provide common set of parameters and interface definitions to enable sharing of scenarios | • Pegasus Open-Simulation Interface  
• ITS JPO Data Program ADS Data Roundtable  
• International work on standards harmonization |
<table>
<thead>
<tr>
<th>Topic Area</th>
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</tr>
</thead>
<tbody>
<tr>
<td><strong>Communications</strong></td>
<td>• Assure required reliability and availability of wireless communications links</td>
<td>• SAE J2945/2 — DSRC Requirements for V2V Safety Awareness</td>
</tr>
<tr>
<td><strong>Performance</strong></td>
<td></td>
<td>• SAE J2945/3 — Requirements for Vehicle-to-Infrastructure (V2I) Weather Applications</td>
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<td></td>
<td></td>
<td>• SAE J2945/4 — DSRC Messages for Traveler Information and Basic Information Delivery</td>
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<td></td>
<td>• SAE J2945/6 — Performance Requirements for CACC and Platooning</td>
</tr>
<tr>
<td><strong>DVI Guidelines</strong></td>
<td>• Design for all user types including those with disabilities</td>
<td>• SAE J3171 — ADS-DV User Issues for Persons with Disabilities</td>
</tr>
<tr>
<td></td>
<td>• Identify different driver states</td>
<td>• SAE DVI Task Force (TF) 5 — Automated Vehicles and DVI Challenges Committee</td>
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<tr>
<td></td>
<td>• Helps define minimal risk condition</td>
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<td></td>
<td>• Need to define approaches for testing and certification</td>
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<tr>
<td><strong>Emergency Vehicle</strong></td>
<td>• V2V/V2I or other communication/sensing techniques for ensuring safe and efficient passage of emergency vehicles</td>
<td>• SAE J2945/2 — DSRC Requirements for V2V Safety Awareness</td>
</tr>
<tr>
<td><strong>Interaction</strong></td>
<td></td>
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<tr>
<td><strong>Encrypted Communications</strong></td>
<td>• Some communications can be signed and some will need to be encrypted</td>
<td>• IEEE 1609.2 — Standard for Wireless Access in Vehicular Environments — Security Services for Applications and Management Messages</td>
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<td></td>
<td>• ISO TC204 WG16 and WG18 activity</td>
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<tr>
<td><strong>Event Data Recorder</strong></td>
<td>• Data elements for crash reconstruction and determining if ADS defect may exist</td>
<td>• SAE Event Data Recorder Committee</td>
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<tr>
<td>Topic Area</td>
<td>Functional Needs</td>
<td>Standardization-Related Activities</td>
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<tr>
<td><strong>Functional Architecture</strong></td>
<td>• Encourage interoperability and enable system-level innovation and more complex applications to emerge</td>
<td>• SAE On-Road Automated Driving (ORAD)</td>
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<tr>
<td></td>
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<td>• SAE J3131 — Automated Driving Reference Architecture</td>
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<td>• IEEE WG2040 — Standard for Connected, Automated and Intelligent Vehicles: Overview and Architecture</td>
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<td>• IEEE WG2040.1 — Standard for Connected, Automated and Intelligent Vehicles: Taxonomy and Definitions</td>
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<td></td>
<td>• IEEE WG2040.2 — Standard for Connected, Automated and Intelligent Vehicles: Testing and Verification</td>
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<td></td>
<td></td>
<td>• Other domains: Robot Operating System (ROS), JAUS, VICTORY, AUTOSAR</td>
</tr>
<tr>
<td><strong>Functional Safety</strong></td>
<td>• Using verification and validation (V&amp;V) from current standards to ensure a safe vehicle design</td>
<td>• ISO 26262 — Road Vehicles — Functional Safety</td>
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<td></td>
<td>• IEC 62508 — Dynamic Test Procedures for Verification and Validation of Automated Driving Systems</td>
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<td></td>
<td>• SAE J3092 — Dynamic Test Procedures for Verification and Validation of Automated Driving Systems</td>
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<td>ISO/WD PAS 21448 — Road vehicles — Safety of the intended functionality</td>
</tr>
<tr>
<td><strong>General Atmospheric Conditions/Road Weather</strong></td>
<td>• Classify various weather conditions and data formats</td>
<td>• Reference model architecture efforts within ISO TC204 WG 1 include provision for road weather (connected vehicle focus)</td>
</tr>
<tr>
<td></td>
<td>• Identify ODD boundaries</td>
<td>• NHTSA Testable Cases Project</td>
</tr>
<tr>
<td></td>
<td>• Identify minimal risk condition and transition of control</td>
<td>• SAE J3164 — Taxonomy and Definitions for Terms Related to Automated Driving System Behaviors and Maneuvers for On-Road Motor Vehicles</td>
</tr>
<tr>
<td></td>
<td>• Define approaches for testing and certification</td>
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</tbody>
</table>
### Table 2: Known Current Standards Development Activities Relevant to Automated Surface Vehicles (as of August 2018)

<table>
<thead>
<tr>
<th>Topic Area</th>
<th>Functional Needs</th>
<th>Standardization-Related Activities</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Global Positioning System (GPS) Spoofing</strong></td>
<td>• Describe risk mitigations&lt;br&gt;• Define test apparatus, infrastructure, procedures</td>
<td>• SAE J3061_201601 — Cybersecurity Guidebook for Cyber-Physical Vehicle Systems&lt;br&gt;• ISO 26262 — Road vehicles — Functional safety</td>
</tr>
<tr>
<td><strong>Infrastructure signage and traffic control device design</strong></td>
<td>• Describe how tests address functional requirements&lt;br&gt;• Facilitate discussion between parties&lt;br&gt;• Define test apparatus, infrastructure, and procedures&lt;br&gt;• Define ODD-specific Object and Event Detection and Response (OEDR) tests</td>
<td>• Current joint SAE/AASHTO Task Force&lt;br&gt;• SAE J2945/X — Dedicated Short Range Communication (DSRC) Systems&lt;br&gt;• NCHRP 20-102(15) — Impacts of Connected and Automated Vehicle Technologies on the Highway Infrastructure</td>
</tr>
<tr>
<td><strong>Interactions with Vulnerable Road Users (VRU)</strong></td>
<td>• Identify minimal risk condition and transition of control&lt;br&gt;• Define approaches for testing and certification</td>
<td>• Ongoing activity in SAE lighting committee&lt;br&gt;• SAE J3122 — Test Target Correlation</td>
</tr>
<tr>
<td><strong>Maintenance and inspection of sensors, software</strong></td>
<td>• Automation benefits from routine maintenance of systems for optimal performance and operations</td>
<td>• ISO 3888 — Diagnostic, maintenance and test equipment may provide a guideline for this</td>
</tr>
<tr>
<td><strong>Minimal Risk Condition</strong></td>
<td>• Minimal Risk Condition (MRC) definition provides common understanding to enable discussion; it exists, but may need to be updated&lt;br&gt;• MRC performance requirements set expectations between OEMs, regulators, and public&lt;br&gt;• MRC data elements in EDR enable crash reconstruction</td>
<td>• SAE J3131 — Automated Driving Reference Architecture&lt;br&gt;• SAE Event Data Recorder Task Force</td>
</tr>
<tr>
<td>Topic Area</td>
<td>Functional Needs</td>
<td>Standardization-Related Activities</td>
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</table>
| **ODD Definition**                             | • Specify the boundaries of the ODD including: road type, lighting, weather, traffic volume, incidents, etc.  
• Boundaries may be set by vehicle capabilities and/or jurisdictional requirement or other factors.                                                                                                                                   | • American Association of Motor Vehicle Administrators (AAMVA) Jurisdictional Guidelines for the Safe Testing and Deployment of Highly Automated Vehicles 46  
• No known work with standards organizations; however, States are believed to have initiatives underway (Caltrans, Florida DOT)  
• SAE J3016 — Definitions of ODD                                                                                                                                                                                                           |
| **Over-the-Air (OTA) Software Updates**        | • Assess security threats, risks and vulnerabilities  
• Provision common methods to update vehicle software by a secure procedure  
• Security controls and protocol definition                                                                                                                                                                                                 | • ITU-T X.1373 (03/2017) — International Telecommunication Standardization Sector (ITU-T) — Recommendation Secure Software Update Capability for Intelligent Transportation System Communication Devices |
| **Sharing of static and dynamic road segment and traffic control device data** | • Automation benefits from dynamic data on work zones, road closures, SPAT, etc., and static data like bus stop locations and crosswalk geometry, and laws that originate from roadway owner-operators and may be relayed via digital maps | • U.S. DOT is convening States that publish work zone data and want to harmonize feeds (e.g., Iowa DOT, Colorado DOT), standards activity may follow  
• NCHRP 20-102(15) — Impacts of Connected and Automated Vehicle Technologies on the Highway Infrastructure  
• SAE J2945/10 — Recommended Practices for MAP/SPaT Message Development                                                                                                                                                                     |

### Table 2: Known Current Standards Development Activities Relevant to Automated Surface Vehicles (as of August 2018)

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<th>Topic Area</th>
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</table>
| **Testing Approaches** | • Describe how tests address functional requirements  
• Facilitate discussion between parties  
• Define test apparatus, infrastructure, procedures  
• Define ODD-specific OEDR tests  
• Define role of simulation, track testing and on-road testing | • SAE ORAD Verification and Validation Committee  
• SAE J3018 — Guidelines for Safe On-Road Testing of SAE Level 3, 4, and 5 Prototype Automated Driving Systems  
• Pegasus/AdaptIVe project  
• TNO Streetwise methodology  
• U.S. Army Tank Automotive Research, Development and Engineering Center (TARDEC) guidelines  
• Department of Defense Unmanned Systems Safety Guide being updated  
• FHWA Test and Evaluation for Vehicle Platooning  
• AAMVA — Jurisdictional Guidelines for the Safe Testing and Deployment of Highly Automated Vehicles  
• FHWA and SAE Cooperative Automation Research Modeling and Analysis (CARMA) program  
• US DOT V2I research program DSRC Roadside Unit (RSU) Specifications development |
| **Transition of DDT Control** | • Research to define time to alert, alert format, time to react if no takeover and driver states  
• Helps define minimal risk condition  
• Need to define approaches for testing and certification | • SAE ORAD Levels of Automation  
• SAE DVI Committee |

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<th>Topic Area</th>
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</table>
| **ADS-DV Issues for Persons with Disabilities** | • L4 and L5 ADS-Dedicated Vehicles (ADS-DVs) will eventually enable persons to travel at will who are otherwise unable to obtain a driver’s license for a conventional vehicle  
• This work will document user issues specific to this population. | • SAE J3171 — ADS-DV User Issues for Persons with Disabilities                                                                 |
With the development of automated vehicles, American creativity and innovation hold the potential to once again transform mobility.

AV 3.0 is the beginning of a national discussion about the future of our surface transportation system. Your voice is essential to shaping this future.
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Preparing for the Future of Transportation

Automated Vehicles 3.0
LETTER FROM THE SECRETARY

America has always been a leader in transportation innovation. From the mass production of automobiles to global positioning system navigation, American ingenuity has transformed how we travel and connect with one another. With the development of automated vehicles, American creativity and innovation hold the potential to once again transform mobility.

Automation has the potential to improve our quality of life and enhance the mobility and independence of millions of Americans, especially older Americans and people with disabilities.

Moreover, the integration of automation across our transportation system has the potential to increase productivity and facilitate freight movement. But most importantly, automation has the potential to impact safety significantly—by reducing crashes caused by human error, including crashes involving impaired or distracted drivers, and saving lives.

Along with potential benefits, however, automation brings new challenges that need to be addressed. The public has legitimate concerns about the safety, security, and privacy of automated technology. So I have challenged Silicon Valley and other innovators to step up and help address these concerns and help inform the public about the benefits of automation. In addition, incorporating these technologies into our transportation systems may impact industries, creating new kinds of jobs. This technology evolution may also require workers in transportation fields to gain new skills and take on new roles. As a society, we must help prepare workers for this transition.

The U.S. Department of Transportation is taking active steps to prepare for the future by engaging with new technologies to ensure safety without hampering innovation. With the release of Automated Driving Systems 2.0: A Vision for Safety in September 2017, the Department provided voluntary guidance to industry, as well as technical assistance and best practices to States, offering a path forward for the safe testing and integration of automated driving systems. The Department also bolstered its engagement with the automotive industry, technology companies,
and other key transportation stakeholders and innovators to continue to develop a policy framework that facilitates the safe integration of this technology into our transportation systems.

Preparing for the Future of Transportation: Automated Vehicles 3.0 (AV 3.0) is another milestone in the Department’s development of a flexible, responsible approach to a framework for multimodal automation. It introduces guiding principles and describes the Department’s strategy to address existing barriers to safety innovation and progress. It also communicates the Department’s agenda to the public and stakeholders on important policy issues, and identifies opportunities for cross-modal collaboration.

The Department is committed to engaging stakeholders to identify and solve policy issues. Since the publication of Automated Driving Systems 2.0: A Vision for Safety, the Department has sought input on automation issues from stakeholders and the general public through a wide range of forums including formal Requests for Information and Comments. In March 2018, I hosted the Automated Vehicle Summit to present the Department’s six Automation Principles and discuss automation issues with public and private sector transportation stakeholders across every mode. The ideas and issues raised by stakeholders through these forums are reflected in this document. The goal of the Department is to keep pace with these rapidly evolving technologies so America remains a global leader in safe automation technology.

AV 3.0 is the beginning of a national discussion about the future of our surface transportation system. Your voice is essential to shaping this future.

Working together, we can help usher in a new era of transportation innovation and safety, and ensure that our country remains a global leader in automated technology.
U.S. DOT AUTOMATION PRINCIPLES

The United States Department of Transportation (U.S. DOT) has established a clear and consistent Federal approach to shaping policy for automated vehicles, based on the following six principles.

1. We will prioritize safety.
   Automation offers the potential to improve safety for vehicle operators and occupants, pedestrians, bicyclists, motorcyclists, and other travelers sharing the road. However, these technologies may also introduce new safety risks. U.S. DOT will lead efforts to address potential safety risks and advance the life-saving potential of automation, which will strengthen public confidence in these emerging technologies.

2. We will remain technology neutral.
   To respond to the dynamic and rapid development of automated vehicles, the Department will adopt flexible, technology-neutral policies that promote competition and innovation as a means to achieve safety, mobility, and economic goals. This approach will allow the public—not the Federal Government—to choose the most effective transportation and mobility solutions.

3. We will modernize regulations.
   U.S. DOT will modernize or eliminate outdated regulations that unnecessarily impede the development of automated vehicles or that do not address critical safety needs. Whenever possible, the Department will support the development of voluntary, consensus-based technical standards and approaches that are flexible and adaptable over time. When regulation is needed, U.S. DOT will seek rules that are as nonprescriptive and performance-based as possible. As a starting point and going forward, the Department will interpret and, consistent with all applicable notice and comment requirements, adapt the definitions of “driver” and “operator” to recognize that such terms do not refer exclusively to a human, but may in fact include an automated system.
4. **We will encourage a consistent regulatory and operational environment.**

Conflicting State and local laws and regulations surrounding automated vehicles create confusion, introduce barriers, and present compliance challenges. U.S. DOT will promote regulatory consistency so that automated vehicles can operate seamlessly across the Nation. The Department will build consensus among State and local transportation agencies and industry stakeholders on technical standards and advance policies to support the integration of automated vehicles throughout the transportation system.

5. **We will prepare proactively for automation.**

U.S. DOT will provide guidance, best practices, pilot programs, and other assistance to help our partners plan and make the investments needed for a dynamic and flexible automated future. The Department also will prepare for complementary technologies that enhance the benefits of automation, such as communications between vehicles and the surrounding environment, but will not assume universal implementation of any particular approach.

6. **We will protect and enhance the freedoms enjoyed by Americans.**

U.S. DOT embraces the freedom of the open road, which includes the freedom for Americans to drive their own vehicles. We envision an environment in which automated vehicles operate alongside conventional, manually-driven vehicles and other road users. We will protect the ability of consumers to make the mobility choices that best suit their needs. We will support automation technologies that enhance individual freedom by expanding access to safe and independent mobility to people with disabilities and older Americans.
SAE AUTOMATION LEVELS

0  No Automation
The full-time performance by the human driver of all aspects of the dynamic driving task, even when enhanced by warning or intervention systems.

1  Driver Assistance
The driving mode-specific execution by a driver assistance system of either steering or acceleration/deceleration using information about the driving environment and with the expectation that the human driver perform all remaining aspects of the dynamic driving task.

2  Partial Automation
The driving mode-specific execution by one or more driver assistance systems of both steering or acceleration/deceleration using information about the driving environment and with the expectation that the human driver perform all remaining aspects of the dynamic driving task.

3  Conditional Automation
The driving mode-specific performance by an automated driving system of all aspects of the dynamic driving task with the expectation that the human driver will respond appropriately to a request to intervene.

4  High Automation
The driving mode-specific performance by an automated driving system of all aspects of the dynamic driving task, even if a human driver does not respond appropriately to a request to intervene.

5  Full Automation
The full-time performance by an automated driving system of all aspects of the dynamic driving task under all roadway and environmental conditions that can be managed by a human driver.

A Note on Terminology
Clear and consistent definition and use of terminology is critical to advancing the discussion around automation. To date, a variety of terms (e.g., self-driving, autonomous, driverless, highly automated) have been used by industry, government, and observers to describe various forms of automation in surface transportation. While no terminology is correct or incorrect, this document uses “automation” and “automated vehicles” as general terms to broadly describe the topic, with more specific language, such as “Automated Driving System” or “ADS” used when appropriate. A full glossary is in the Appendix.
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PREPARING FOR THE FUTURE OF TRANSPORTATION  vii
EXECUTIVE SUMMARY

Preparing for the Future of Transportation: Automated Vehicles 3.0 (AV 3.0) advances U.S. DOT's commitment to supporting the safe, reliable, efficient, and cost-effective integration of automation into the broader multimodal surface transportation system. AV 3.0 builds upon—but does not replace—voluntary guidance provided in Automated Driving Systems 2.0: A Vision for Safety.

Automation technologies are new and rapidly evolving. The right approach to achieving safety improvements begins with a focus on removing unnecessary barriers and issuing voluntary guidance, rather than regulations that could stifle innovation.

In AV 3.0, U.S. DOT’s surface transportation operating administrations come together for the first time to publish a Departmental policy statement on automation. This document incorporates feedback from manufacturers and technology developers, infrastructure owners and operators, commercial motor carriers, the bus transit industry, and State and local governments. This document considers automation broadly, addressing all levels of automation (SAE automation Levels 1 to 5), and recognizes multimodal interests in the full range of capabilities this technology can offer.

AV 3.0 includes six principles that guide U.S. DOT programs and policies on automation and five implementation strategies for how the Department translates these principles into action (see facing page).

AV 3.0 Provides New Multimodal Safety Guidance

In accordance with the Department’s first automation principle, AV 3.0 outlines how automation will be safely integrated across passenger vehicles, commercial vehicles, on-road transit, and the roadways on which they operate. Specifically, AV 3.0:

- Affirms the approach outlined in A Vision for Safety 2.0 and encourages automated driving system developers to make their Voluntary Safety Self-Assessments public to increase transparency and confidence in the technology.
- Provides considerations and best practices for State and local governments to support the safe and effective testing and operation of automation technologies.
- Supports the development of voluntary technical standards and approaches as an effective non-regulatory means to advance the integration of automation technologies into the transportation system.
- Describes an illustrative framework of safety risk management stages along the path to full commercial integration of automated vehicles. This framework promotes the benefits of safe deployment while managing risk and provides clarity to the public regarding the distinctions between various stages of testing and full deployment.
- Affirms the Department is continuing its work to preserve the ability for transportation safety applications to function in the 5.9 GHz spectrum.

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2 See Appendix B for a summary of public input received.

### AV 3.0 Clarifies Policy and Roles

AV 3.0 responds to issues raised by stakeholders and includes the following key policy and role clarifications:

- States that U.S. DOT will interpret and, consistent with all applicable notice and comment requirements, adapt the definitions of “driver” and “operator” to recognize that such terms do not refer exclusively to a human, but may include an automated system.

- Recognizes that given the rapid increase in automated vehicle testing activities in many locations, there is no need for U.S. DOT to favor particular locations or to pick winners and losers. Therefore, the Department no longer recognizes the designations of ten Automated Vehicle Proving Grounds announced on January 19, 2017.

- Urges States and localities to work to remove barriers—such as unnecessary and incompatible regulations—to automated vehicle technologies and to support interoperability.

- Affirms U.S. DOT’s authority to establish motor vehicle safety standards that allow for innovative automated vehicle designs—such as vehicles without steering wheels, pedals, or mirrors—and notes that such an approach may require a more fundamental revamping of the National Highway Traffic Safety Administration’s (NHTSA) approach to safety standards for application to automated vehicles.

- Reaffirms U.S. DOT’s reliance on a self-certification approach, rather than type approval, as the way to balance and promote safety and innovation; U.S. DOT will continue to advance this approach with the international community.
• Clarifies that, rather than requiring a one-size-fits-all approach, the Federal Transit Administration will provide transit agencies with tailored technical assistance as they develop an appropriate safety management system approach to ensuring safe testing and deployment of automated transit bus systems.

AV 3.0 Outlines How to Work with U.S. DOT as Automation Technology Evolves

It identifies opportunities for partnership and collaboration among the private sector, State and local agencies, and U.S. DOT on issues ranging from accessibility to workforce development to cybersecurity. Specifically, AV 3.0:

• Announces a forthcoming notice of proposed rulemaking, which includes the possibility of setting exceptions to certain safety standards—that are relevant only when human drivers are present—for automated driving system (ADS)-equipped vehicles.

• Informs stakeholders that U.S. DOT will seek public comment on a proposal to streamline and modernize the procedures NHTSA

will follow when processing and deciding exemption petitions.

• Defines a targeted Federal role in automation research.

• Informs stakeholders of the Federal Motor Carrier Safety Administration’s (FMCSA) intent to initiate an Advance Notice of Proposed Rulemaking to better understand areas of responsibility between the State and Federal governments in the context of ADS-equipped commercial motor vehicles and commercial carriers.

• States that FMCSA will also consider changes to its motor carrier safety regulations to accommodate the integration of ADS-equipped commercial motor vehicles.

• Informs stakeholders that U.S. DOT plans to update the 2009 Manual on Uniform Traffic Control Devices, taking new technologies into consideration.

• Identifies automation-related voluntary standards being developed through standards development organizations and associations.


U.S. DOT’s Operating Administrations are United in Their Commitment to Safety

We act as “One DOT” in pursuing strategies to successfully integrate automation technologies into the transportation system. The operating administrations shown on the facing page contributed to AV 3.0.

Each of these U.S. DOT operating administrations actively encourages the integration of automation in ways guided by the U.S. DOT’s automation principles and strategies noted above. AV 3.0 focuses on the automation of motor vehicles on roadways and the roles of NHTSA, FMCSA, FHWA, and FTA, with consideration of intermodal points (e.g., motor vehicles at ports and highway-rail grade crossings).

4 See https://www.transportation.gov/av for more information on automation efforts at U.S. DOT.
OPERATING ADMINISTRATIONS

For more information on how U.S. DOT agencies engage with automation, see www.transportation.gov/av

Federal Highway Administration

The Federal Highway Administration (FHWA) is responsible for providing stewardship over the construction, maintenance, and preservation of the Nation’s highways, bridges, and tunnels. Through research and technical assistance, the FHWA supports its partners in Federal, State, and local agencies to accelerate innovation and improve safety and mobility.

Federal Motor Carrier Safety Administration

The Federal Motor Carrier Safety Administration’s (FMCSA) mission is to reduce crashes, injuries, and fatalities involving large trucks and buses. FMCSA partners with industry, safety advocates, and State and local governments to keep the Nation’s roads safe and improve commercial motor vehicle (CMV) safety through regulation, education, enforcement, research, and technology.

Federal Aviation Administration

The Federal Aviation Administration (FAA) provides the safest and most efficient aviation system in the world. Annually, FAA manages over 54 million flights, approaching a billion passengers.

Federal Railroad Administration

The Federal Railroad Administration’s (FRA) mission is to enable the safe, reliable, and efficient movement of people and goods for a strong America. FRA is advancing the use of new technology in rail.

Federal Transit Administration

The Federal Transit Administration (FTA) provides financial and technical assistance to local public transit systems, including buses, subways, light rail, commuter rail, trolleys, and ferries. FTA also oversees safety measures and helps develop next-generation technology research.

Maritime Administration

The Maritime Administration (MARAD) promotes the use of waterborne transportation and its seamless integration with other segments of the transportation system, and the viability of the U.S. merchant marine.

National Highway Traffic Safety Administration

The National Highway Traffic Safety Administration’s (NHTSA) mission is to save lives, prevent injuries, and reduce the economic costs of road traffic crashes through education, research, safety standards, and enforcement activity. NHTSA carries out highway safety programs by setting and enforcing safety performance standards for motor vehicles and equipment, identifying safety defects, and through the development and delivery of effective highway safety programs for State and local jurisdictions.

Pipeline and Hazardous Materials Safety Administration

The Pipeline and Hazardous Materials Safety Administration (PHMSA) protects people and the environment by advancing the safe transportation of energy and other hazardous materials that are essential to our daily lives. To do this, PHMSA establishes national policy, sets and enforces standards, educates, and conducts research to prevent incidents.
Automated vehicles that accurately detect, recognize, anticipate, and respond to the movements of all transportation system users could lead to breakthrough gains in transportation safety.
INTRODUCTION: AUTOMATION AND SAFETY

The United States surface transportation system provides tremendous mobility benefits, including widespread access to jobs, goods, and services. It also connects many remote regions of the country to the larger economy. These benefits, however, come with significant safety challenges, as motor vehicle crashes remain a leading cause of death, with an estimated 37,133 lives lost on U.S. roads in 2017. Traditional safety programs and policies have made road travel significantly safer than in the past, but there is much room to improve traffic fatality and injury rates.

Automated vehicles that accurately detect, recognize, anticipate, and respond to the movements of all transportation system users could lead to breakthrough gains in transportation safety. Unlike human drivers, automation technologies are not prone to distraction, fatigue, or impaired driving, which contribute to a significant portion of surface transportation fatalities. Automated vehicle technologies that are carefully integrated into motor vehicles could help vehicle operators detect and avoid bicyclists, motorcyclists, pedestrians, and other vulnerable users on our roadways, and increase safety across the surface transportation system. Their potential to reduce deaths and injuries on the Nation’s roadways cannot be overstated.

Automated vehicles rely on sensors and software that allow an expansive view of the environment across a range of lighting and weather conditions. They can quickly learn and adapt to new driving situations by learning from previous experience through software updates. Fully realizing the life-saving potential of automated vehicles, however, will require careful risk management as new technologies are introduced and adopted across the surface transportation system.

To support the deployment of safe automation technologies, the Department released A Vision for Safety 2.0 in September 2017, which included 12 automated driving system (ADS) safety elements to help industry partners analyze, identify, and resolve safety considerations using best practices—all before deployment. The voluntary guidance outlined in A Vision for Safety 2.0 on the design, testing, and safe deployment of ADS remains central to U.S. DOT’s approach. ADS developers are encouraged to use these safety elements to publish safety self-assessments to describe to the public how they are identifying and addressing potential safety issues.

On-road testing and early deployments are important to improving automated vehicle performance and allowing them to reach their full performance potential. Careful real-world testing allows developers to identify and rapidly fix system shortcomings, not just on individual vehicles but across fleets. Reasonable risks must be addressed through the application of robust systems engineering processes, testing protocols, and functional safety best practices, such as those documented in A Vision for Safety...
However, delaying or unduly hampering automated vehicle testing until all specific risks have been identified and eliminated means delaying the realization of global reductions in risk.

AV 3.0 maintains U.S. DOT’s primary focus on safety, while expanding the discussion to other aspects and modes of surface transportation. AV 3.0 introduces a comprehensive, multimodal approach toward safely integrating automation.

AV 3.0 introduces a comprehensive, multimodal approach toward safely integrating automation.

As documented in A Vision for Safety 2.0, ADS developers should consider employing systems engineering guidance, best practices, design principles, and standards developed by established and accredited standards-developing organizations (as applicable) such as the International Standards Organization (ISO) and SAE International as well as standards and processes available from other industries, such as aviation, space, and the military and other applicable standards or internal company processes as they are relevant and applicable. They should also consider available and emerging approaches to risk mitigation, such as methodologies that focus on functional safety (e.g., ISO 26262) and safety of the intended functionality.
Safety by the Numbers

- An estimated **39,141** people lost their lives on all modes of our transportation system in 2017. The vast majority—37,133 deaths—were from motor vehicle crashes.

- **Driver Factors:** Of all serious motor vehicle crashes, **94 percent** involve driver-related factors, such as impaired driving, distraction, and speeding or illegal maneuvers.

  In 2017:
  - Nearly **11,000** fatalities involved drinking and driving.
  - Speeding was a factor in nearly **10,000** highway fatalities.
  - Nearly **3,500** fatal crashes involved distracted drivers.

- **Commercial Vehicles:** **13 percent** of annual roadway fatalities occur in crashes involving large trucks.

- **In 2017,** **82 percent** of victims in fatal large truck crashes were road users who were not an occupant of the truck(s) involved.

- **Professional Drivers:** Professional drivers are **ten times** more likely to be killed on the job, and nearly nine times more likely to be injured on the job compared to the average worker.

- **Pedestrians:** **5,977** pedestrians were killed by motor vehicles in 2017, representing 16 percent of all motor vehicle fatalities.

- **Highway-Rail Grade Crossings:** Over the past decade, highway rail grade crossing fatalities averaged **253** per year, representing about one-third of total railroad-related fatalities.

Sources:

A U.S. Department of Transportation, Bureau of Transportation Statistics, special tabulation, September 8, 2018
B NHTSA 2017 Fatal Motor Vehicle Crashes: Overview (DOT HS 812 603)

* This number is likely underreported.
Only by working in partnership can the public and the private sector improve the safety, security, and accessibility of automation technologies and address the concerns of the general public.
The traditional roles of the Federal Government, State and local governments, and private industry are well suited for addressing automation. The Federal Government is responsible for regulating the safety performance of vehicles and vehicle equipment, as well as their commercial operation in interstate commerce, while States and local governments play the lead role in licensing drivers, establishing rules of the road, and formulating policy in tort liability and insurance. Private industry remains a primary source of transportation research investment and commercial technology development. Governments at all levels should not unnecessarily impede such innovation. The Department relies on partners to play their respective roles, while continuing to encourage open dialogue and frequent engagement.

The Department seeks to address policy uncertainty and provide clear mechanisms by which partners can participate and engage with the U.S. DOT.

The Federal Government and Automation

U.S. DOT’s role in transportation automation is to ensure the safety and mobility of the traveling public while fostering economic growth. As a steward of the Nation’s roadway transportation system, the Federal Government plays a significant role by ensuring that automated vehicles can be safely and effectively integrated into the existing transportation system, alongside conventional vehicles, pedestrians, bicyclists, motorcyclists, and other road users. U.S. DOT also has an interest in supporting innovations that improve safety, reduce congestion, improve mobility, and increase access to economic opportunity for all Americans. Finally, by partnering with industry in adopting market-driven, technology-neutral policies that encourage innovation in the transportation system, the Department seeks to fuel economic growth and support job creation and workforce development.

To accomplish these goals, the Department works closely with stakeholders in the private and public sectors to pursue the following activities:

- Establish performance-oriented, consensus-based, and voluntary standards and guidance for vehicle and infrastructure safety, mobility, and operations.
- Conduct targeted research to support the safe integration of automation.
- Identify and remove regulatory barriers to the safe integration of automated vehicles.
- Ensure national consistency for travel in interstate commerce.
- Educate the public on the capabilities and limitations of automated vehicles.

Integrating Safety into Surface Transportation Automation

Each operating administration has its respective area of authority over improving the safety of the Nation’s transportation system. Assuring the safety of automated vehicles will not only rely on the validation of the technology, such as the hardware, software, and components, but it will also depend on appropriate operating...
rules, roadway conditions, and emergency response protocols. The following sections outline the primary authorities and policy issues for the National Highway Traffic Safety Administration (NHTSA), Federal Motor Carrier Safety Administration (FMCSA), Federal Highway Administration (FHWA), and Federal Transit Administration (FTA) to demonstrate how the U.S. DOT is incorporating safety throughout the surface transportation system as it relates to automated vehicles. These sections also discuss ADS-equipped vehicles (SAE automation Levels 3 to 5) and lower level technologies (SAE automation Levels 0 to 2), depending on the role of each operating administration and its current engagement with automation.

NHTSA Authorities and Key Policy Issues

Safety Authority Over ADS-Equipped Vehicles and Equipment

NHTSA has broad authority over the safety of ADS-equipped vehicles and other automated vehicle technologies equipped in motor vehicles. NHTSA has authority to establish Federal safety standards for new motor vehicles introduced into interstate commerce in the United States, and to address safety defects determined to exist in motor vehicles or motor vehicle equipment used and equipment is likely to raise questions about preemption and the future complementary mix of Federal, State and local powers. The Department will carefully consider these jurisdictional questions as NHTSA develops its regulatory approach to ADS and other automated vehicle technologies so as to strike the appropriate balance between the Federal Government’s use of its authorities to regulate the safe design and operational performance of an ADS-equipped vehicle and the State and local authorities’ use of their traditional powers.

Federal Safety Standards for ADS-Equipped Vehicles

Several NHTSA safety standards for motor vehicles assume a human occupant will be able to control the operation of the vehicle, and many standards incorporate performance requirements and test procedures geared toward ensuring safe operation by a human driver. Some standards focus on the safety of drivers and occupants in particular seating arrangements. Several standards impose specific requirements for the use of steering wheels, brakes, accelerator pedals, and other control features, as well as the visibility for a human driver of instrument displays, vehicle status indicators, mirrors, and other driving information.

NHTSA’s current safety standards do not prevent the development, testing, sale, or
use of ADS built into vehicles that maintain the traditional cabin and control features of human-operated vehicles. However, some Level 4 and 5 automated vehicles may be designed to be controlled entirely by an ADS, and the interior of the vehicle may be configured without human controls. There may be no steering wheel, accelerator pedal, brakes, mirrors, or information displays for human use. For such ADS-equipped vehicles, NHTSA’s current safety standards constitute an unintended regulatory barrier to innovation.

The Department, through NHTSA, intends to reconsider the necessity and appropriateness of its current safety standards as applied to ADS-equipped vehicles. In an upcoming rulemaking, NHTSA plans to seek comment on proposed changes to particular safety standards to accommodate automated vehicle technologies and the possibility of setting exceptions to certain standards—that are relevant only when human drivers are present—for ADS-equipped vehicles.

Going forward, NHTSA may also consider a more fundamental revamping of its approach to safety standards for application to automated vehicles. However, reliance on a self-certification approach, instead of type approval, more appropriately balances and promotes safety and innovation; U.S. DOT will continue to advance this approach with the international community. NHTSA’s current statutory authority to establish motor vehicle safety standards is sufficiently flexible to accommodate the design and performance of different ADS concepts in new vehicle configurations.

NHTSA recognizes that the accelerating pace of technological change, especially in the development of software used in ADS-equipped vehicles, requires a new approach to the formulation of the Federal Motor Vehicle Safety Standards (FMVSS). The pace of innovation in automated vehicle technologies is incompatible with lengthy rulemaking proceedings and highly prescriptive and feature-specific or design-specific safety standards. Future motor vehicle safety standards will need to be more flexible and responsive, technology-neutral, and performance-oriented to accommodate rapid technological innovation. They may incorporate simpler and more general requirements designed to validate that an ADS can safely navigate the real-world roadway environment, including unpredictable hazards, obstacles, and interactions with other vehicles and pedestrians who may not always adhere to the traffic laws or follow expected patterns of behavior. Existing standards assume that a vehicle may be driven anywhere, but future standards will need to take into account that the operational design domain (ODD) for a particular ADS within a vehicle is likely to be limited in some ways that may be unique to that system. For example, not all Level 3 vehicles will have the same ODD.

Performance-based safety standards could require manufacturers to use test methods, such as sophisticated obstacle-course-based test regimes, sufficient to validate that their ADS-equipped vehicles can reliably handle the normal range of everyday driving scenarios as well as unusual and unpredictable scenarios. Standards could be designed to account for factors such as variations in weather, traffic, and roadway conditions within a given system’s ODD, as well as sudden and unpredictable actions by other road users. Test procedures could also be developed to ensure that an ADS does not operate outside of the ODD established by the manufacturer. Standards could provide for a range of potential behaviors—e.g., speed, distance, angles, and size—for surrogate vehicles, pedestrians, and other obstacles that ADS-equipped vehicles would need to detect and avoid. Other approaches, such as computer simulation and requirements expressed in terms of mathematical functions could be considered, as Federal law does not require that NHTSA’s safety standards rely on physical tests and measurements, only that they be objective, repeatable, and transparent.

Exemptions from FMVSS for ADS Purposes

NHTSA values a streamlined and modernized exemptions procedure, and removing unnecessary delays. NHTSA intends to seek
public comment on a proposal to streamline and modernize procedures the Agency will follow when processing and deciding exemption petitions. Among other things, the proposed changes will remove unnecessary delays in seeking public comment as part of the exemption process, and clarify and update the types of information needed to support such petitions. The statutory provision authorizing NHTSA to grant exemptions from FMVSS provides sufficient flexibility to accommodate a wide array of automated operations, particularly for manufacturers seeking to engage in research, testing, and demonstration projects.\(^{11}\)

**FMCSA Authorities and Key Policy Issues**

**Safety Authority Over Commercial Motor Vehicle Operations, Drivers, and Maintenance**

The Department, through FMCSA, regulates the safety of commercial motor carriers operating in interstate commerce, the qualifications and safety of commercial motor vehicle drivers, and the safe operation of commercial trucks and motor coaches.\(^{12}\) The best way to accomplish FMCSA’s core mission of reducing fatalities and crashes involving large trucks and buses is to avoid unnecessary barriers to the development of ADS in commercial vehicles.

As automation introduces new policy questions, FMCSA will work with (1) industry, State governments, and other partners to further the safe operation of ADS-equipped commercial vehicles, and (2) law enforcement, inspection officers, and first responders to create new techniques and protocols.

In order to develop experience with the technology, demonstrate its capabilities, and socialize the idea of automated vehicles on the road with traditional vehicles, FMCSA will continue to hold public demonstrations of the technology—such as the recent truck platooning demonstration on the I-66 Corridor co-hosted with FHWA—with key stakeholders such as law enforcement.

FMCSA consults with NHTSA on matters related to motor carrier safety.\(^{13}\) NHTSA and FMCSA have different but complementary authorities over the safety of commercial motor vehicles (CMVs) and commercial vehicle equipment. NHTSA has exclusive authority to prescribe Federal safety standards for new motor vehicles, including trucks and motor coaches, and oversees actions that manufacturers take to remedy known safety defects in motor vehicles and motor vehicle equipment.\(^{14}\) NHTSA and FMCSA collaborate and consult to develop and enforce safety requirements that apply to the operation and maintenance of vehicles by existing commercial motor carriers. They will continue to do so in the context of ADS-equipped commercial motor vehicles. FMCSA also works closely with States and private stakeholders to develop and enforce safety standards related to the inspection, maintenance, and repair of commercial motor vehicles.

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\(^{11}\) 49 U.S.C. § 30114


\(^{13}\) 49 U.S.C. § 113(i)

\(^{14}\) See 49 U.S.C. §§ 30111 and 30166
Operating ADS-Equipped CMVs under Existing Regulations

In the context of ADS-equipped CMVs, FMCSA will continue to exercise its existing statutory authority over the safe operation of the vehicle. When driving decisions are made by an ADS rather than a human, FMCSA’s authority over the safe and proper operating condition of the vehicle and its safety inspection authority may be even more important, particularly between when ADS operations begin and when a revised regulatory framework is established. In addition, FMCSA retains its authority to take enforcement action if an automated system inhibits safe operation.

In exercising its oversight, FMCSA will first ask whether the ADS-equipped CMV placed into operation complies with the requirements for parts and accessories for which there are no FMVSS (e.g., fuel tanks and fuel lines, exhaust systems, and rear underride guards on single unit trucks). A motor carrier may not operate an ADS-equipped CMV—or any CMV—until it complies with the requirements and specifications of 49 CFR Part 393, Parts and Accessories Necessary for Safe Operation. If the ADS is installed aftermarket, any equipment that decreases the safety of operation could subject the motor carrier to a civil penalty. In addition, ADS-equipped vehicles that create an “imminent hazard” may be placed out of service and the motor carrier that used the vehicle similarly fined.

FMCSA will then consider whether the motor carrier has complied with the operational requirements of the current Federal Motor Carrier Safety Regulations (FMCSRs). These include, for example, compliance with rules on driving CMVs, including the laws, ordinances, and regulations of the jurisdiction in which the vehicle is operated. Notably, however, in the case of vehicles that do not require a human operator, none of the human-specific FMCSRs (i.e., drug testing, hours-of-service, commercial driver’s licenses (CDLs), and physical qualification requirements) apply.

If the motor carrier cannot fully comply with the FMCSRs through use of its ADS-equipped CMV, then the carrier may seek an exemption. The carrier would need to demonstrate that the ADS-equipped CMV likely achieves an equivalent level of safety. Ultimately, a motor carrier would not be permitted to operate an ADS-equipped CMV on public highways until it complies with the operational requirements or until the carrier obtains regulatory relief.

In general, subject to the development and deployment of safe ADS technologies, the Department’s policy is that going forward FMCSA regulations will no longer assume that the CMV driver is always a human or that a human is necessarily present onboard a commercial vehicle during its operation.

The Department and FMCSA are aware of the concerns that differing State regulations present for ADS technology development, testing, and deployment in interstate commerce. If FMCSA determines that State or local legal requirements may interfere with the application of FMCSRs, the Department has preemptive authority. The Department works with State partners to promote compatible safety oversight programs. U.S. DOT will carefully consider the appropriate lines of preemption in the context of ADS-equipped commercial motor vehicles and commercial carriers.

FMCSA also has authority, in coordination with the States, to set the Federal qualifications required for CDLs. States have an essential role in training commercial drivers and issuing CDLs, but they must follow the FMCSA regulations that set minimum qualifications and limitations on CDLs in order to stay eligible for Federal grants. The Department will carefully consider the appropriate division of authority between States and FMCSA.

15 49 U.S.C. §§ 31136(a)(1) and 31502(b)(1).
16 49 CFR 396.7(a).
17 49 CFR 393.3
18 49 U.S.C. § 5122(b); 49 CFR 386.72.
19 49 U.S.C. §§ 31315 and 31136(e).
Considering Changes to Existing Regulations

FMCSA is in the process of broadly considering whether and how to amend its existing regulations to accommodate the introduction of ADS in commercial motor vehicles. As noted above, some FMCSA regulatory requirements for commercial drivers have no application to ADS—such as drug and alcohol testing requirements—but many regulations, such as those involving inspection, repair, and maintenance requirements, can be readily applied in the context of ADS-equipped commercial trucks and motor coaches. Current FMCSRs would continue to apply, and motor carriers can seek regulatory relief if necessary. Carriers therefore may deploy ADS-equipped CMVs in interstate commerce, using existing administrative processes.

In adapting its regulations to accommodate automated vehicle technologies, FMCSA will seek to make targeted rule changes and interpretations, and will supplement its rules as needed to account for significant differences between human operators and computer operators. FMCSA is soliciting feedback through various mechanisms to understand which parts of the current FMCSRs present barriers to advancing ADS technology. FMCSA plans to update regulations to better accommodate ADS technology with stakeholder feedback and priorities in mind. FMCSA will also consider whether there is a reasonable basis to adapt its CDL regulations for an environment in which the qualified commercial driver may be an ADS.

Workforce and Labor

Automated vehicles could have implications for the millions of Americans who perform driving-related jobs or work in related industries. There is a high level of uncertainty regarding how these impacts will evolve across job categories with differing levels of driving and non-driving responsibilities. Past experience with transportation technologies suggests that there will be new and sometimes unanticipated business and employment opportunities from automation. For example, the advent of widespread automobile ownership after World War II led not only to direct employment in vehicle manufacturing and servicing, but also to new markets for vehicle financing and insurance, and ultimately to larger shifts in American lifestyles that created a wave of demand for tourism, roadside services, and suburban homebuilding. Automation will create jobs in programming, cybersecurity, and other areas that will likely create demand for new skills and associated education and training. At the same time, the Department is also aware of the need to develop a transition strategy for manual driving-based occupations. U.S. DOT is working with other cabinet agencies on a comprehensive analysis of the employment and workforce impacts of automated vehicles. Individual operating administrations within the Department have also begun reaching out to stakeholders and sponsoring research on workforce issues affecting their respective modes of transportation.

Entities involved in developing and deploying automation technologies may want to consider how to assess potential workforce effects, future needs for new skills and capabilities, and how the workforce will transition into new roles over time. Identifying these workforce effects and training needs now will help lead to an American workforce that has the appropriate skills to support new technologies.

Finally, FMCSA recognizes emerging concerns and uncertainty around potential impacts of ADS on the existing workforce. U.S. DOT is working with the Department of Labor to assess the impact of ADS on the workforce, including the ability of ADS to mitigate the current driver
shortage in the motor carrier industry. The study will also look at longer-term needs for future workforce skills and at the demand for a transportation system that relies on ADS technology.

**FHWA’s Authorities Over Traffic Control Devices**

U.S. DOT recognizes that the quality and uniformity of road markings, signage, and other traffic control devices support safe and efficient driving by both human drivers and automated vehicles.

As part of its role to support State and local governments in the design, construction, and maintenance of the Nation’s roads, FHWA administers the Manual on Uniform Traffic Control Devices (MUTCD). The MUTCD is recognized as the national standard for all traffic control devices installed on any street, highway, bikeway, or private road open to public travel. Traffic control devices generally refer to signs, signals, markings, and other devices used to regulate or guide traffic on a street, highway, and other facilities. FHWA, in partnership with key stakeholder associations and the practitioner community, is conducting research and device experimentation for overall improvements to the manual, and to better understand the specific needs of the emerging automated vehicle technologies. Incorporating existing interim approved devices, experimentations, and other identified proposed changes into the updated MUTCD will help humans and emerging automated vehicles to interpret the roadway. FHWA will use current research to supplement knowledge regarding different sensor and machine vision system capabilities relative to interpreting traffic control devices.

As part of this effort, FHWA will pursue an update to the 2009 MUTCD that will take into consideration these new technologies and other needs.

**FTA’s Safety Authority Over Public Transportation**

Safety issues are the highest priority for all providers of public transportation. In recent years, Congress has granted FTA significant new safety authorities that have expanded the Agency’s role as a safety oversight regulatory body. Consequently, FTA developed and published a National Public Transportation Safety Plan (NSP). The NSP functions as FTA’s strategic plan and primary guidance document for improving transit safety performance; a policy document and communications tool; and a repository of standards, guidance, best practices, tools, technical assistance, and other resources.

A key foundational component of FTA’s safety authority is the new Public Transportation Agency Safety Plan (PTASP) rule. The PTASP rule, which FTA issued on July 18, 2018, and which becomes effective on July 19, 2019, is applicable to transit agencies that operate rail fixed-guideway and/or bus services. Transit agencies must develop, certify, and implement an agency safety plan by July 20, 2020. The PTASP rule requires transit agencies to incorporate Safety Management System (SMS) policies and procedures as they develop their individual safety plans. The PTASP rule sets scalable and flexible requirements for public transportation agencies by requiring them to establish appropriate safety objectives; to identify safety risks and hazards and to develop plans to mitigate those risks; to develop and implement a process to monitor and measure their safety performance; and to engage in safety promotion through training and communication. An overview of the PTASP is available here: https://www.transit.dot.gov/PTASP.

This new PTASP rule provides a flexible approach to evaluating the safety impacts of automated buses. FTA recognizes that operating domains and vehicle types and capabilities differ significantly. That is why FTA is not proposing a one-size-fits-all approach.
Disability, Accessibility, and Universal Design

Automation presents enormous potential for improving the mobility of travelers with disabilities. Through the Accessible Transportation Technologies Research Initiative (ATTRI), the Department is initiating efforts to partner with the U.S. Department of Labor (DOL), U.S. Department of Health and Human Services (HHS), and the broader disability community to focus research efforts and initiatives on areas where market incentives may otherwise lead to underinvestment.

ATTRI focuses on emerging research, prototyping, and integrated demonstrations with the goal of enabling people to travel independently and conveniently, regardless of their individual abilities. ATTRI research focuses on removing barriers to transportation for people with disabilities, veterans with disabilities, and older adults, with particular attention to those with mobility, cognitive, vision, and hearing disabilities. By leveraging principles of universal design and inclusive information and communication technology, these efforts are targeting solutions that could be transformative for independent mobility.

ATTRI applications in development include wayfinding and navigation, pre-trip concierge and virtualization, safe intersection crossing, and robotics and automation. Automated vehicles and robotics are expected to improve mobility for those unable or unwilling to drive and enhance independent and spontaneous travel capabilities for travelers with disabilities. One area of particular interest among public transit agencies is exploring the use of vehicle automation to solve first mile/last mile mobility issues, possibly providing connections for all travelers to existing public transportation or other transportation hubs.

In addition, machine vision, artificial intelligence (AI), assistive robots, and facial recognition software solving a variety of travel-related issues for persons with disabilities in vehicles, devices, and terminals, are also included to create virtual caregivers/concierge services and other such applications to guide travelers and assist in decision making.
or providing a paper checklist for safety certification. Rather, FTA will provide transit agencies with tailored technical assistance as they develop an appropriate SMS approach to ensuring safe testing and deployment of its automated transit bus system.

FTA recognizes the benefits that automated transit bus operations may introduce, but also new types of risks, ranging from technology limitations, hardware failures, and cybersecurity breaches, to subtler human factors issues, such as overreliance on technology and degradation of skills. FTA’s transit bus automation research program is outlined in the five-year Strategic Transit Automation Research (STAR) Plan. FTA aims to advance transit readiness for automation by conducting enabling research to achieve safe and effective transit automation deployments, demonstrating market-ready technologies in real-world settings, and transferring knowledge to the transit stakeholder community, among other objectives.

The Federal Role in Automation Research

U.S. DOT has a limited and specific role in conducting research related to the integration of automation into the Nation’s surface transportation system. U.S. DOT’s research focuses on three key areas:

- Removing barriers to innovation. U.S. DOT identifies and develops strategies to remove unnecessary barriers to innovation, particularly barriers stemming from existing regulations. In order to identify and evaluate solutions, U.S. DOT employs research to establish safety baselines; supports cost-benefit analysis for rulemaking; develops and implements processes to make the government more agile (e.g., updates to exemption and waiver processes to support the testing and deployment of novel technologies); and supports the development of voluntary standards that can enable the safe integration of automation.

- Evaluating impacts of technology, particularly with regard to safety. U.S. DOT develops and verifies estimates of the impacts of automation on safety, infrastructure conditions and performance, mobility, and the economic competitiveness of the United States. The Department employs a variety of methods including simulation, modeling, and field and on-road testing. The Department also develops innovative methodologies to support the broader transportation community in estimating and evaluating impacts.

- Addressing market failures and other compelling public needs. Public investments in research are often warranted to support the development of potentially beneficial technologies that are not easily commercialized because the returns are either uncertain, distant, or difficult to capture. This can include research that responds to safety, congestion, cybersecurity, or asymmetric information (e.g., public disclosures), or where a lack of private sector investment may create distributional issues that disadvantage particular groups (e.g., access for individuals with disabilities).

Across the areas outlined above, U.S. DOT collaborates with partners in the public and private sectors and academia, shares information with the public on research insights and findings, and identifies gaps in public and private sector research.

U.S. DOT Role in Key Cross-Cutting Policy Issues

Cooperative Automation and Connectivity

Connectivity enables communication among vehicles, the infrastructure, and other road users. Communication both between vehicles (V2V) and with the surrounding environment (V2X) is an important complementary technology that is expected to enhance the benefits of automation at all levels, but should not be and realistically cannot be a precondition to the deployment of automated vehicles.

Automation to Support Intermodal Port Facility Operations

Automation has the potential to transform the Nation’s freight transportation system, a vital asset that supports every sector of the economy. Intermodal port facilities could benefit from applications of automation, enabling more seamless transfers of goods and a less strenuous experience for operators. The Maritime Administration (MARAD) and FMCSA are jointly exploring how SAE Level 4 truck automation might improve operations at intermodal port facilities. Currently at many of the Nation’s busiest ports, commercial vehicle drivers must wait in slow-moving queues for hours to pick up or deliver a load. MARAD and FMCSA are evaluating how automation might relieve the burden on a driver under these circumstances, and, in particular, the regulatory and economic feasibility of using automated truck queueing as a technology solution to truck staging, access, and parking issues at ports. The study will investigate whether full or partial automation of queuing within ports could lead to increased productivity by altering the responsibilities and physical presence of drivers, potentially allowing them to be off-duty during the loading and unloading process.

Throughout the Nation there are over 70 active deployments of V2X communications utilizing the 5.9 GHz band. U.S. DOT currently estimates that by the end of 2018, over 18,000 vehicles will be deployed with aftermarket V2X communications devices and over 1,000 infrastructure V2X devices will be installed at the roadside. Furthermore, all seven channels in the 5.9 GHz band are actively utilized in these deployments.

In addition to the Dedicated Short-Range Communication (DSRC)-based deployments, private sector companies are already researching and testing Cellular-V2X technology that would also utilize the 5.9 GHz spectrum.

An effort led by State and local public-sector transportation infrastructure owner operators is the Signal Phase and Timing (SPaT) Challenge. This initiative has plans to deploy a V2X communications infrastructure with SPaT broadcasts in at least one corridor in each of the 50 States by January 2020. Over 200 infrastructure communications devices are already deployed with over 2,100 planned by 2020 under this initiative in 26 States and 45 cities with a total investment of over $38 million. The SPaT message is designed to enhance both safety and efficiency of traffic movements at intersections.

Also underway are the U.S. DOT-funded deployment programs such as the Ann Arbor

27 https://transportationops.org/spatchallenge
Cooperative Automation

FHWA is conducting research to measure the efficiency and safety benefits of augmenting automated vehicle capabilities with connected vehicle technologies to enable cooperative automation. Cooperative automation allows automated vehicles to communicate with other vehicles and the infrastructure to coordinate movements and increase efficiency and safety. It uses a range of automation capabilities, including automation technologies at SAE Level 1 and Level 2. Examples of cooperative automation applications include:

- **Vehicle platooning** to enable safe close following between vehicles and improve highway capacity.
- **Speed harmonization** using wireless speed control to reduce bottleneck conditions.
- **Cooperative lane change and merge functions** to mitigate traffic disruptions at interchanges.
- **Coordination of signalized intersection approach and departure**, using Signal Phase and Timing (SPaT) data to enable automated vehicles to enter and exit signalized intersections safely and efficiently, to mitigate delays and reduce fuel consumption.

Current activities focus on technical assessments, traffic modeling, and proof-of-concept/prototype tests to understand how to improve safety, smooth traffic flow, and reduce fuel consumption. FHWA is partnering with automotive manufacturers to further develop these concepts and is conducting modeling and analysis of corridors in several States. FHWA may pursue further proof-of-concept testing on test tracks and on public roads in the future. Additionally, studies are underway to consider how early automation applications like lane keeping and adaptive cruise control are being used and accepted by everyday drivers.

Over the past 20 years, the U.S. DOT has invested over $700 million in research and development of V2X through partnerships with industry and state/local governments. As a result of these investments and partnerships, V2X technology is on the verge of wide-scale deployment across the Nation. The Department encourages the automotive industry, wireless technology companies, IOOs, and other stakeholders to continue developing technologies that leverage the 5.9 GHz spectrum for transportation safety benefits. Yet, the Department does not promote any particular technology over another. The Department also encourages the development of connected infrastructure because such technologies offer the potential to improve safety and efficiency.

As IOOs consider enabling V2X deployment in their region, the Department encourages IOOs to engage with the U.S. DOT for guidance and assistance.

As part of this approach, U.S. DOT is continuing its work to preserve the ability for transportation safety applications to function in the 5.9 GHz spectrum while exploring methods for sharing the spectrum with other users in a manner that maximizes efficiency and safety. Combined over $150 million in Federal and State funding to deploy V2X communications. Finally, states such as Colorado are combining Federal-aid highway program funding with State funding ($72 million) to deploy V2X communications throughout the State highways by 2021.28

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that maintains priority use for vehicle safety communications. A three-phase test plan was collaboratively developed with the Federal Communications Commission (FCC) and the U.S. Department of Commerce, and the FCC has completed\textsuperscript{29} the first phase. Phases 2 and 3 of the spectrum sharing test plan will explore potential sharing solutions under these more real-world conditions.

**Pilot Testing and Proving Grounds**

U.S. DOT supports and encourages the testing and development of automation technologies throughout the country with as few barriers as needed for safety. ADS developers are already testing automated vehicle technologies at test tracks, on campuses, and on public roadways across the United States. Pilots on public roads provide an opportunity to assess roadway infrastructure, operational elements, user acceptance, travel patterns, and more.

The Department appreciates that there are significant automated vehicle research and testing activities occurring in many States and locations across the country, and there is considerable private investment in these efforts. The Department does not intend to pick winners and losers or to favor particular automated vehicle proving grounds over others. Therefore, the Department no longer recognizes the designations of ten “Automated Vehicle Proving Grounds” as announced on January 19, 2017. The Department has taken no actions to direct any Federal benefits or support to those ten locations on the basis of these designations, and these designations will have no effect—positive or negative—going forward on any decisions the Department may make regarding Federal support or recognition of research, pilot or demonstration projects, or other developmental activities related to automated vehicle technologies.

Instead, if and when the Department is called upon to provide support or recognition of any kind with regard to automated vehicle proving grounds, the Department intends to apply neutral, objective criteria and to consider all locations in all States where relevant research and testing activities are actually underway.

**Cybersecurity**

Transportation systems are increasingly complex, with a growing number of advanced, integrated functions. Transportation systems are also more reliant than ever on multiple paths of connectivity to communicate and exchange data, and they depend on commodity technologies to achieve functional, cost, and marketing objectives.

Surface transportation is a broad sector of the economy and requires coordination across all levels of government and the private sector in the event of a significant cyber incident to enable shared situational awareness and allow for a unified approach to sector engagement. U.S. DOT will work closely with the U.S. Department of Justice; the U.S. Department of Commerce and its National Institute of Standards and Technology (NIST); the Federal Trade Commission; the Federal Communications Commission; the U.S. Department of Homeland Security (DHS); industry subject matter experts; and other public agencies to address cyber vulnerabilities and manage cyber risks related to automation technology and data.

Transportation-related cyber vulnerabilities and exploits can be shared with Government partners anonymously through various Information Sharing and Analysis Centers (ISACs). DHS’s National Cybersecurity and Communications Integration Center (NCCIC) is a 24x7 cyber situational awareness, incident response, and management center that is a national nexus of cyber and communications integration for the Federal Government, intelligence community, and law enforcement.

If a transportation sector entity deems Federal assistance may be warranted, they are encouraged to contact NCCIC\textsuperscript{30} and the relevant agencies.


\textsuperscript{30} https://ics-cert.us-cert.gov/Report-Incident
ISACs (e.g., Auto-ISAC, 31 Aviation ISAC, 32 Maritime ISAC, 33 and Surface Transportation ISAC 34).

**Privacy**

While advanced safety technologies have the potential to provide enormous safety, convenience, and other important benefits to consumers, stakeholders frequently raise data privacy concerns as a potential impediment to deployment. U.S. DOT takes consumer privacy seriously, diligently considers the privacy implications of our safety regulations and voluntary guidance, and works closely with the Federal Trade Commission (FTC)—the primary Federal agency charged with protecting consumers’ privacy and personal information—to support the protection of consumer information and provide resources relating to consumer privacy. The Department suggests that any exchanges of data respect consumer privacy and proprietary and confidential business information. Additional information is available here: https://www.ftc.gov/news-events/media-resources/protecting-consumer-privacy.

**State, Local, and Tribal Governments and Automation**

State, local, and Tribal governments hold clearly defined roles in ensuring the safety and mobility of road users in their jurisdictions. They are responsible for licensing human drivers, registering motor vehicles, enacting and enforcing traffic laws, conducting safety inspections, and regulating motor vehicle insurance and liability. They are also responsible for planning, building, managing, and operating transit and the roadway infrastructure. Many of those roles may not change significantly with the deployment of automated vehicles.

There are many ways these governments can prepare for automated vehicles:

- Review laws and regulations that may create barriers to testing and deploying automated vehicles.
- Adapt policies and procedures, such as licensing and registration, to account for automated vehicles.
- Assess infrastructure elements, such as road markings and signage, so that they are conducive to the operation of automated vehicles.
- Provide guidance, information, and training to prepare the transportation workforce and the general public.

This section provides best practices and considerations for State, local and Tribal government officials as they engage with new transportation technologies.

**Best Practices for State Legislatures and State Highway Safety Officials**

A Vision for Safety 2.0 provided best practices for both State legislatures and State highway safety officials. In reviewing recent State legislation and executive orders, and in engaging with stakeholders, U.S. DOT identified new insights, commonalities, and elements that States should consider including when developing legislation. Additional best practices for State highway safety officials are also discussed in this section. The best practices provided here are not intended to replace recommendations made in A Vision for Safety 2.0, but rather are meant to supplement them. For more information, refer to www.transportation.gov/av.

31 https://www.automotiveisac.com/
32 https://www.a-isac.com/
33 http://www.maritimesecurity.org/
34 https://www.surfacetransportationisac.org/
Automated Vehicles at Rail Crossings

To explore the interaction between automated vehicles and highway-rail grade crossings and identify what information automated vehicles will need in order to negotiate highway-rail intersections, the Federal Railroad Administration (FRA) has conducted a literature review, engaged with stakeholders, and used scenarios to develop and demonstrate a concept of operations, including system requirements (technology and sensors).

A broad stakeholder set was identified to represent researchers, manufacturers, transit agencies, and infrastructure owner-operators, among others. Currently, FRA is expanding the research with U.S. DOT partners and the Association of American Railroads to develop a closed loop safety system to support the safe interaction of connected and automated vehicles with grade crossings.

Best Practices for State Legislatures

States are taking differing legislative approaches and have enacted varying laws related to testing and operating automated vehicles. U.S. DOT regularly monitors legislative activities in order to support the development of a consistent national framework for automated vehicle legislation.

A Vision for Safety 2.0 recommended that State legislators follow best practices, such as providing a technology-neutral environment, licensing and registration procedures, and reporting and communications methods for public safety officials. States should consider reviewing and potentially modifying traffic laws and regulations that may be barriers to automated vehicles. For example, several States have following distance laws that prohibit trucks from following too closely to each other, effectively prohibiting automated truck platooning applications.

In addition to the best practices identified in A Vision for Safety 2.0, the Department recommends that State officials consider the following safety-related best practices when crafting automated vehicle legislation:

Engage U.S. DOT on legislative technical assistance. State legislatures are encouraged to routinely engage U.S. DOT on legislative activities related to multimodal automation...
safety. State legislatures may want to first determine if there is a need for State legislation. Unnecessary or overly prescriptive State requirements could create unintended barriers for the testing, deployment, and operations of advanced vehicle safety technologies. U.S. DOT stands ready to provide technical assistance to States on request.

Adopt terminology defined through voluntary technical standards. Different use and interpretations of terminology regarding automated vehicles can be confusing for the public, State and local agencies, and industry. In the interest of supporting consistent terminology, State legislatures may want to use terminology already being developed through voluntary, consensus-based, technical standards. SAE terminology on automation represents one example and includes terms such as ADS, the Dynamic Driving Task (DDT), minimal risk conditions, and ODD.

Assess State roadway readiness. States may want to assess roadway readiness for automated vehicles, as such assessments could help infrastructure for automated vehicles, while improving safety for drivers today. Automated vehicle developers are designing their technologies with the assumption that these technologies will need to function with existing infrastructure. There is general agreement that greater uniformity and quality of road markings, signage, and pavement condition would be beneficial for both human drivers and automated vehicles.

**Best Practices for State Highway Safety Officials**

States are responsible for reducing traffic crashes and resulting deaths, injuries, and property damage for all road users in their jurisdictions. States use this authority to establish and maintain highway safety programs addressing driver education and testing, licensing, pedestrian safety, and vehicle registration and inspection. States also use this authority to address traffic control, highway design and maintenance, crash prevention, investigation and recordkeeping, and law enforcement and emergency service considerations.

The following best practices build on those identified in A Vision for Safety 2.0 and provide a framework for States looking for assistance in developing procedures and conditions for the operation of automated vehicles on public roadways. For additional best practices, see Section 2 of A Vision for Safety 2.0.

**Consider test driver training and licensing procedures for test vehicles.** States may consider minimum requirements for test drivers who operate test vehicles at different automation levels. States may want to coordinate and collaborate with a broad and diverse set of stakeholders when developing and defining jurisdictional guidelines for safe testing and deployment of automated vehicles.

**Recognize issues unique to entities offering automated mobility as a service.** Automated mobility providers are exploring models to move people and goods using automated vehicle technology. States may consider identifying and addressing issues that are unique to companies providing mobility as a service using automated vehicle technologies. These could include such issues as congestion or the transportation of minors, persons with disabilities, and older individuals.

**Considerations for Infrastructure Owners and Operators**

Infrastructure owners and operators are involved in the planning, design, construction, maintenance, and operation of the roadway infrastructure. Infrastructure owners and operators have expressed interest in more information and guidance on how to prepare for automated vehicle deployment and testing on public roadways. FHWA is conducting the National Dialogue on Highway Automation, a series of workshops with partners, stakeholders, and the public to obtain input regarding the safe
and efficient integration of automated vehicles into the roadway system. U.S. DOT provides the following considerations for infrastructure owners and operators, including State DOTs, metropolitan planning organizations (MPOs), and local agencies. FHWA, in particular, will continue to update these considerations as informed by continued research efforts, stakeholder engagement, and testing. Suggested considerations include:

**Support safe testing and operations of automated vehicles on public roadways.** State DOTs and local agencies want to understand under what conditions automated vehicles can safely operate in automated mode and how they will affect the highway infrastructure and surrounding communities. Where testing is taking place, State and local agencies should consider ways to establish consistent cross-jurisdictional approaches and work with first responders to develop commonly understood traffic law enforcement practices and emergency response plans for automated vehicle testing and operation.

**Learn from testing and pilots to support highway system readiness.** State and local agencies may consider collaborating with automated vehicle developers and testers to identify potential infrastructure requirements that support readiness for automated vehicles and to understand their expectations for automated vehicle operations under varying roadway and operational conditions. This interaction could assist with identifying what balance of capabilities (for both vehicles and the roadway) promotes safe and efficient operations of automated vehicles. Testing, research, and pilot programs can help State and local agencies understand automation and identify opportunities to inform transportation planning, infrastructure design, and traffic operations management.

**Build organizational capacity to prepare for automated vehicles in communities.** State and local agencies may need to assess their workforce capacity and training needs to address new issues that emerge from having automated vehicles on public roads. State and local agencies will want to work with peers, industry, associations, the research community, and FHWA to build knowledge of automated vehicle technologies and identify technical assistance resources.

**Identify data needs and opportunities to exchange data.** The exchange of data and information in the roadway environment can help promote safe and efficient operations of automated vehicles.
Automated vehicles address static and dynamic elements that otherwise may be challenging for ADS (e.g., work zones, rail crossings, managed lanes, and varying traffic laws). State and local agencies and industry may work together to identify data elements that will help automated vehicles navigate challenging, unique roadway environments and alter operational behavior in relation to changing traffic laws.

**Collaborate with stakeholders to review the existing Uniform Vehicle Code (UVC).** Each State creates its own laws governing traffic codes, and many municipalities enact ordinances as allowed in the State. The UVC is a model set of traffic laws developed years ago by stakeholders that States can consult when considering legislation. FHWA suggests working with automated vehicle developers, traffic engineers, and law enforcement stakeholders to revise the UVC to be consistent with automated vehicle operations.

**Support scenario development and transportation planning for automation.** There is uncertainty around how automation will change travel behavior, land use, and public revenues across the transportation landscape in the long term. State and local policymakers must wrestle with the effects of automation when conducting long-term transportation planning. Scenario planning tools allow States and MPOs to review multiple scenarios for how automation technologies could be adopted and used, and analyze issues including infrastructure investment, congestion, operations, and other transportation needs. To assist in this process, FHWA is supporting scenario development for State and local agencies to use for incorporating automation into transportation planning processes.

**Considerations for State Commercial Vehicle Enforcement Agencies**

U.S. DOT recommends that State agencies responsible for enforcing commercial vehicle operating rules and regulations consider the following as ADS-equipped commercial motor vehicles are tested and operated on public roads:

- **Compatibility between intrastate and interstate commercial motor vehicle regulations.** State enforcement agencies should monitor prevailing regulatory activity, including regulatory guidance by FMCSA—including a forthcoming Advance Notice of Proposed Rulemaking (ANPRM)—and consider whether amendments of their intrastate motor carrier safety regulations are needed in order to be compatible with the Federal requirements concerning the operation of ADS-equipped commercial motor vehicles.

**Ensuring compatibility between intrastate and interstate commercial vehicle regulations is important for maintaining eligibility for grant funding under the Motor Carrier Safety Assistance Program (MCSAP).**

**Continued application of roadside inspection procedures.** State enforcement agencies should continue to apply existing inspection selection procedures to identify which CMVs should be examined during a roadside inspection. State enforcement agencies should refrain from selecting ADS-equipped CMVs solely because the vehicle is equipped with advanced technology. States can partner with FMCSA as it develops appropriate roadside inspection procedures and inspection criteria for use in examining ADS-equipped CMVs, so that the movement of such vehicles is not delayed unless there are problems that are likely to adversely impact safety.

**Considerations for Public Sector Transit Industry and Stakeholders**

U.S. DOT offers the following for consideration by public sector transit industry stakeholders (e.g., transit agencies) when developing, demonstrating, deploying, and evaluating transit bus automation:

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36 For more information on scenario planning, see [https://www.fhwa.dot.gov/planning/scenario_and_visualization/scenario_planning/](https://www.fhwa.dot.gov/planning/scenario_and_visualization/scenario_planning/)

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Needs-based implementation. Transit agencies should consider automation as a means of addressing specific needs and solving particular problems. Implementation of new technologies and service models should not be based merely on novelty. Agencies should obtain input from stakeholders to determine unmet needs and identify potential solutions that might be addressed through automation. Ongoing dialogue with community residents, original equipment manufacturers (OEMs), technology developers, integrators, and industry associations will help identify the most appropriate transit bus automation technology solutions for their communities.

Realistic expectations. Public transportation operators should establish realistic expectations when implementing transit bus automation projects and demonstrations. As an example, transit agencies engaged in pilots to retrofit vehicles with advanced driver assistance capabilities, such as pedestrian avoidance and automatic emergency braking, might find that implementation may take longer than expected for a variety of reasons. Integration, test planning, contracting, and data management can present significant challenges that cause delay. Another example may be where transit providers are conducting pilots of low-speed automated vehicles or shared automated vehicles. Although these service approaches could potentially address first-mile/last-mile needs, agencies may find that the vehicles themselves currently have technological limitations such as lower speeds and passenger capacity constraints.

Workforce and labor. An important consideration for public transportation operators is to begin preparing for workforce changes that may accompany an automated bus fleet. The transit workforce will require new, high-tech skills for inspecting and maintaining automated transit buses at all levels of automation. The transit industry should begin thinking about retraining the current workforce to help transit operators transition into new roles and to adapt to a transforming surface transportation industry. Transit agencies should recognize emerging workforce needs and requirements, identify new future career paths, and conduct succession planning in this new, high-technology environment. Transit agencies can work with FTA, industry associations, and private sector consultants to identify core training needs; academic institutions may be able to assist in implementing training.

Complete Streets. Transit agencies should seek out and work with local partners to review complete streets policies and practices when planning and deploying transit automation. Early consideration of complete streets will help make automation-enhanced mobility safer, more convenient, and more reliable for all travelers, while reducing the overall cost of widespread deployment. Transit agencies, MPOs, and local governments may seek assistance from industry associations, private sector consultants, and automation technology developers to create and implement complete streets concepts.37

Accessibility. It is critical that all agencies considering automated transit vehicles in revenue service ensure accessibility for persons with disabilities. Although some users will likely continue to require the human assistance that existing paratransit service provides, automation has the potential to offer improved levels of service for persons with disabilities. Transit agencies must ensure that infrastructure, such as stations and stops, is accessible and Americans with Disabilities Act (ADA)-compliant. Transit agencies should continue to partner with local governments as appropriate to create and maintain an accessible environment for all travelers. Transit agencies may work with industry associations, private sector consultants, and technology developers for new accessibility tools and solutions such as those in the U.S. DOT’s ATTRI. FTA can provide guidance and clarification regarding ADA requirements.

Engagement and education. To fully realize the benefits of automated transit vehicles, transit operators, riders, and other road users

37 Complete Streets are streets designed and operated to enable safe use and support mobility for all users. Those include people of all ages and abilities, regardless of whether they are traveling as drivers, pedestrians, bicyclists, or public transportation riders.
must understand and be wholly comfortable with the technology. Transit agencies seeking to test and pilot automated transit vehicles may wish to develop appropriate messaging as well as public engagement and education activities to promote awareness, understanding, and acceptance of automated transit buses. Public-facing technology demonstrations can create opportunities for members of the public to experience and learn about new technologies. Other knowledge transfer and stakeholder engagement activities can help align demonstrations and pilots with local needs and increase local stakeholder confidence and buy-in.

Considerations for Local Governments

Local governments control a substantial part of the Nation’s roadway and parking infrastructure, and have considerable influence over land use, via zoning and permitting. Local governments are closest to citizens. Automation provides an opportunity to address local goals, including making more land available for housing and business, as well as improving transportation options for citizens who are not motorists. U.S. DOT suggests that local governments may wish to consider the following topics as they formulate local policies.

Facilitate safe testing and operation of automated vehicles on local streets. Local streets, with their variety of uses, offer a challenging environment for automated vehicles. As owner-operators of this infrastructure, local governments have an opportunity to partner with automated vehicle suppliers to test on their streets, learn from testing, and be prepared to enable safe deployment.

Understand the near-term opportunities that automation may provide. In the near term, automation provides increased driver assistance capabilities—such as automatic emergency braking and pedestrian detection—which may be useful for municipal fleets. Several low-speed passenger shuttle tests are also underway. Local governments should be aware of these efforts and the opportunities that they may provide, while being realistic about their limitations.

Consider how land use, including curb space, will be affected. A shared vehicle environment in which automated vehicles are used by a number of travelers over the course of a day could result in a significant reduction in private vehicle ownership, leading to less need for on- and off-street parking. At the same time, such an environment will require curb space for pick-up and drop-off activities. There may be an opportunity to reallocate curb space from long-term parking to other uses, including pick-up and drop-off. Furthermore, if vehicle ownership declines, minimum parking requirements in zoning may need to be revisited, freeing up land for other purposes. Finally, in such an environment, revenue from parking fees and fines may be reduced.

Consider the potential for increased congestion, and how it might be managed. If automation provides a convenient, low-cost option for single occupant vehicle trips, it may lead to more congestion. For example, some current transit users may shift to lower-occupancy automated vehicles. Automated vehicles may engage in zero-occupant vehicle trips, for vehicle repositioning. Automation will also provide new mobility options for people who do not travel much today. Local and State governments may need to consider appropriate policies to manage the potential for increased congestion.

Engage with citizens. Local governments are in an ideal position to engage with citizens, to address their concerns and to ensure that automation supports local needs. Such engagement may include public events associated with automated vehicle testing, educational forums, and consideration of automation in public planning and visioning meetings.

State, Local, and Tribal Roles in Transportation Sector Cybersecurity

State, local, and Tribal governments face unique cybersecurity threats that can endanger
Local governments are in an ideal position to engage with citizens, to address their concerns and to ensure that automation supports local needs.

The Private Sector and Automation

While the initial development of automated vehicle technologies received strong support from government-funded research projects, such as the Defense Advanced Research Projects Agency (DARPA), over the past decade private sector innovators have taken the lead in developing and commercializing automation technologies. Today, private sector leadership is critical to advancing the development, testing, and commercialization of automated vehicles. U.S. DOT does not expect the private sector to be singularly responsible for addressing issues introduced alongside new technologies. The public sector—as planners, owners, and...
operators of transportation infrastructure, regulators and enforcers of transportation safety, and representatives of public concerns—must play a critical, complementary role in engaging automation technologies to improve safety and meet the public interest without hampering innovation.

In addition to developing and commercializing automation technology, the private sector also should play a critical role in promoting consumer acceptance in two distinct ways. First, companies developing and deploying automation technology need to be transparent about vehicle safety performance. Second, companies should engage with consumers through public education campaigns.

The exchange of information between the public and private sector is also critical for helping policymakers understand the capabilities and limitations of these new technologies, while ensuring that the private sector understands the priorities of policymakers and the issues they face. Only by working in partnership can the public and the private sector improve the safety, security, and accessibility of automation technologies, address the concerns of the general public, and prepare the workforce of tomorrow.

The sections below outline several critical areas where the private sector’s role will be significant.

**Demonstrate Safety through Voluntary Safety Self-Assessments**

Demonstrating the safety of ADS is critical for facilitating public acceptance and adoption. Entities involved in the development and testing of automation technology have an important role in not only the safety assurance of ADS-equipped vehicles, but also in providing transparency about how safety is being achieved.

*A Vision for Safety 2.0* provided voluntary guidance to stakeholders regarding the design, testing, and safe deployment of ADS. It identified 12 safety elements that ADS developers should consider when developing and testing their technologies. *A Vision for Safety 2.0* also introduced the Voluntary Safety Self-Assessment (VSSA), which is intended to demonstrate to the public that entities are: considering the safety aspects of an ADS; communicating and collaborating with the U.S. DOT; encouraging the self-establishment of industry safety norms; and building public trust, acceptance, and confidence through transparent testing and deployment of ADS. Entities are encouraged to demonstrate how they address the safety elements contained in *A Vision for Safety 2.0* by publishing a VSSA, as it is an important tool for companies to showcase their approach to safety, without needing to reveal proprietary intellectual property.

VSSAs allow the public to see that designers, developers, and innovators are taking safety seriously and that safety considerations are built into the design and manufacture of vehicles that are tested on our roadways. Therefore, U.S. DOT encourages entities to make their VSSA available publicly as a way to promote transparency and strengthen public confidence in ADS technologies. The Department currently provides a template for one of the elements in a VSSA, which entities can use to construct their own VSSA. NHTSA also established a website where entities who have disclosed and made the Agency aware of their VSSAs can be listed in one central location. Entities developing ADS technology may want to consider making available their VSSAs through this website.

**Incorporate New Safety Approaches for Automation in Commercial Vehicle Operations**

U.S. DOT recommends that motor carrier owners and operators consider the following as they explore the adoption of advanced driver assistance features and ADS in their vehicle fleets. As automation technology evolves,
Hazardous Materials Documentation

The Pipeline and Hazardous Materials Safety Administration (PHMSA) is exploring alternatives to longstanding requirements for providing paper documentation to accompany hazmat shipments, while ensuring that the information is readily available to transport workers and emergency responders. This capability may become increasingly important as transporters of hazardous materials explore the use of automation in their operations. As motor carriers and railroads explore the use of automation to move hazardous materials, the ability to create electronic documentation also raises the potential to electronically transmit information to first responders before they arrive at an incident. PHMSA is also collaborating with the Environmental Protection Agency on the development of an e-manifest system that will digitize the exchange of information on hazardous material shipments.

FMCSA and PHMSA plan to solicit stakeholder input and provide more detailed guidance regarding the use of ADS in commercial vehicle operations.

System knowledge. If a motor carrier of passengers or property plans to begin operating a commercial motor vehicle equipped with driver-assist systems and/or ADS, the motor carrier's personnel should understand the capabilities and limitations of these systems, as well as ODD limitations (e.g., the types of roadway environments or environmental conditions under which they can operate). The motor carrier should also ask the equipment’s manufacturer about the capabilities and limitations of these systems. Motor carriers may also wish to inquire about whether the manufacturer has completed a voluntary safety self-assessment, as described in A Vision for Safety 2.0.

System functionality. Motor carriers should ensure the driver assist system and/or ADS is functioning properly before activating these systems. This functionality should be able to be validated during a roadside inspection.

System training. Motor carriers should implement a training program to familiarize fleet managers, maintenance personnel, and drivers with the equipment and how it operates, including the procedures to follow in the event of an ADS malfunction.

Equipment maintenance. Motor carriers should be aware of maintenance requirements of driver-assist systems and/or ADS to enable safe and optimal operation. This includes understanding self-diagnostic capabilities of the system and the status or error messages the system may display.

Information exchange. Motor carriers should be aware that under certain situations such as a safety inspection or roadway crash, it may be necessary to exchange critical safety-oriented vehicle performance data with Federal and State officials. The motor carrier should maintain records of the systems it is using, the training provided, and the operation of those vehicles.

Safety inspections. Motor carriers should be prepared to interact and cooperate with roadside and other safety inspections of driver assist systems and ADS. This includes responding to law enforcement instructions, resolving any identified mechanical or software malfunction, implementing the equipment’s safe shutdown procedures, and demonstrating system functionality.

Develop Safe and Accessible Transit Buses and Applications: Considerations for Private Sector Transit Industry

U.S. DOT offers the following considerations for private sector transit industry stakeholders when developing, demonstrating, deploying, and evaluating transit bus automation:

Accessibility. It is important to think about how to make automated vehicles and their technological capabilities accessible to persons with disabilities (including those with physical, sensory, and cognitive impairments) early in
the design process. This vital element is more easily integrated at the initial stages of vehicle research and development, rather than trying to incorporate it into the design through retrofits, which may be more difficult. Bus OEMs, technology developers, and integrators should work with transit agencies, industry associations, and the disability community to obtain input on functional and performance needs as well as the consequent human factors considerations. The Federal Government (e.g., FTA) can provide guidance and clarification with respect to the requirements of ADA.

**Human factors.** Consider human factors in the design of buses and vehicles for all levels of automation—for all participants in the system (transit operators, passengers, and other road users). The interaction between human and machine, ease of use, and comprehensibility of human-machine interfaces (HMI) should be explored thoroughly, particularly with respect to maintaining safety under all operating conditions. Where possible, technology companies should partner with transit agencies and passenger organizations to test various user-interface technologies and designs.

**Testing.** Open a dialogue and seek a collaborative relationship with FTA when developing and testing new bus technologies and products. FTA can provide guidance, feedback, and clarification on policies, requirements, and recommendations as they pertain to transit automation.

**Provide Information to the Public**

The understanding of automation technologies varies considerably across the general public, caused in part by a lack of consistency in terminology and confusion about the technology’s limitations. The public needs accurate sources of information regarding automation to better understand the technology so that they can use it safely and make informed decisions about its integration. This can be done through direct communications with consumers and other users, demonstrations, public outreach in areas where vehicles are being tested, and a variety of other means.
Travel Patterns of American Adults with Disabilities

An estimated 25.5 million Americans have disabilities that make traveling outside the home difficult, according to the Bureau of Transportation Statistics report Travel Patterns of American Adults with Disabilities. An estimated 3.6 million with disabilities do not leave their homes.

People with travel-limiting disabilities are less likely to own a vehicle or have vehicle access than people without disabilities.

When people with disabilities do use vehicles, they are often passengers. People with disabilities are less likely to have jobs, are more likely to live in very low-income households, and use smartphones and ride-hailing services less often than the general population. An estimated 71 percent reduce their day-to-day travel, while an estimated 41 percent rely on others for rides.

Automated vehicles and other assistive technologies may provide substantial mobility benefits to people with disabilities who cannot drive.

Compensating Strategies for People with Travel-Limiting Disabilities (age 18–64)

<table>
<thead>
<tr>
<th>Strategy</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reducing day-to-day travel</td>
<td>70.6%</td>
</tr>
<tr>
<td>Asking others for rides</td>
<td>55.7%</td>
</tr>
<tr>
<td>Limiting travel to daytime</td>
<td>22.6%</td>
</tr>
<tr>
<td>Giving up driving</td>
<td>21.6%</td>
</tr>
<tr>
<td>Using special transportation services</td>
<td>14.4%</td>
</tr>
<tr>
<td>Using public transit less often</td>
<td>14.4%</td>
</tr>
</tbody>
</table>

Source: U.S. Department of Transportation, Federal Highway Administration, 2017 National Household Travel Survey.

With respect to currently available Level 1 and Level 2 automation technologies and Level 3 technologies under development, consumers and other users should understand what the technology is and is not capable of, when human monitoring of the system is needed, and where it should be operated (i.e., appropriate ODD). The private sector may need to consider new approaches for providing information so that consumers can use the technology safely and effectively. As part of their education and training programs and before consumer release, automated vehicle dealers and distributors may want to consider including an on-road or on-track experience demonstrating automated vehicle operations and how humans interact with vehicle controls. Other innovative approaches (e.g., virtual reality (VR) or onboard vehicle systems) may also be considered, tested, and employed.

Public education challenges are different for automated vehicle technologies at higher levels of automation or Level 4 and Level 5 systems, where the consumer becomes a passenger rather than a driver. For these systems, the members of the public may require more general information and awareness of what the technology is and how they should interact with it, either as passengers or as others sharing the road with automated vehicles.

Developers of automated vehicle technologies are encouraged to develop, document, and
maintain employee, dealer, distributor, and consumer education and training programs to address the anticipated differences in the use and operation of automated vehicles from those of the conventional vehicles that the public owns and operates today. Successful programs will provide target users with the necessary level of understanding to utilize these technologies properly, efficiently, and in the safest manner possible.

Consider All Possible Surface Transportation Conditions and Different Roadway Landscapes

Entities that are testing and operating on public roadways will want to consider the whole roadway environment, which could include different infrastructure conditions and operating rules. It will be important to account for all possible surface transportation conditions an ADS may encounter within its ODD. Such conditions, when appropriate, include maneuvering at-grade rail crossings, roundabouts, bicycle lanes, pedestrian walkways and special designated traffic lanes or crossing areas, entrances and driveways, and other potential hazards, especially in different roadway landscapes (e.g., urban versus rural). As part of their important role in the safety assurance of ADS-equipped vehicles, entities are also encouraged to consider such conditions in the design, testing, and validation of the designated fallback method. Entities are encouraged to engage with the U.S. DOT and infrastructure owners and operators to understand the full ODD for safe and efficient operations of automated vehicles.

Work with All Potential User Groups to Incorporate Universal Design Principles

The potential for automation to improve mobility for all Americans is immense, but if products and technologies are not designed with usability by a broad spectrum of travelers in mind, it may not be achieved.

U.S. DOT encourages developers and deployers to work proactively with the disability community to support efforts that focus on the array of accommodations needed for different types of disabilities, and ways to improve mobility as a whole—not just from curb to curb, but also from door to door.

Anticipate Human Factors and Driver Engagement Issues

Consider human factors design for surface transportation—at all levels of automation—for all road users. Safety risks, such as driver distraction and confusion, should influence early stages of design and vehicle development. User-interface usability and comprehension need to be explored, particularly during emergency situations, and in maintaining safety if vehicle functions are compromised.

In addition, it will be important to recognize human factors challenges related to driver awareness and engagement. Entities could consider methods that ensure driver awareness and engagement during ADS-equipped vehicle testing, to mitigate the potential for distraction, fatigue, and other possible risks.

Testing on public roadways is necessary for vehicle automation development and deployment. Public trust can be built during testing by using an in-vehicle driver engagement monitoring system, a second test driver, or other methods. It can be helpful for entities developing ADS technologies to share information with Federal agencies and appropriate organizations about the testing of user interface technologies and designs.

Identify Opportunities for Voluntary Data Exchanges

Voluntary data exchanges can help improve the safety and operations of ADS and lead to the development of industry best practices, voluntary standards, and other useful tools.
Work Zone Data Exchanges

The Work Zone Data Exchange project responds to priorities identified by public and private sector stakeholders. The goal is to develop a harmonized specification for work zone data that infrastructure owners and operators can make available as open feeds that automated vehicles and others can use.

Accurate and up-to-date information about dynamic conditions occurring on the roads—such as work zones—can help automated vehicles navigate safely and efficiently. Many infrastructure owners and operators maintain data on work zone activity, but a common specification for this type of data does not currently exist.

This makes it difficult and costly for third parties—including vehicle manufacturers and makers of navigation applications—to access and use work zone data across various jurisdictions.

Several State DOT agencies and private companies are voluntarily participating in the project, with U.S. DOT acting as a technical facilitator. U.S. DOT has been working with these partners to help define the core data elements that should be included in an initial work zone specification and to determine what types of technical assistance the data producers will need to implement it, expand it over time, and address broader work zone data management challenges.

In U.S. DOT’s Guiding Principles on Data for Automated Vehicle Safety, available at www.transportation.gov/av/data, the Department defines an approach that seeks to prioritize and enable voluntary data exchanges to address critical issues that could slow the safe integration of ADS technologies. These principles include:

- Promote proactive, data-driven safety, cybersecurity, and privacy-protection practices.
- Act as a facilitator to inspire and enable voluntary data exchanges.
- Start small to demonstrate value, and scale what works toward a larger vision.
- Coordinate across modes to reduce costs, reduce industry burden, and accelerate action.

The industry as a whole should consider working with Federal, State, and local agencies as well as relevant standards bodies (IEEE, SAE International, etc.) to identify opportunities to establish voluntary exchanges of data that can provide mutual benefit and help accelerate the safe integration of automation into the surface transportation system. This can include exchanges of data between the public and private sector regarding infrastructure conditions as well as exchanges among private sector entities to enable mutual learning and risk mitigation.
Any exchanges of data should respect consumer privacy\textsuperscript{43} as well as proprietary and confidential business information.

**Contribute to the Development of Voluntary, Consensus-Based, and Performance-Oriented Technical Standards**

Voluntary standards offer flexibility and responsiveness to the rapid pace of innovation, can encourage investment and bring cost-effective innovation to the market more quickly, and may be validated by private sector conformity assessment and testing protocols. There are existing processes followed by Standards Development Organizations (SDOs), such as SAE International or IEEE, where industry participates in the development of voluntary standards. Industry and SDOs can continue to provide leadership in this area and collaborate with each other, as well as with U.S. DOT and other stakeholders, to address key issues. Areas where industry can support standards development include—but are not limited to—topics such as definitions, taxonomy, testing, interoperability, and performance characteristic definitions.

The Department supports the development and continuing evolution of stakeholder-driven voluntary standards, which in many cases can be an effective non-regulatory means to support interoperable integration of technologies into the transportation system. The Department supports these efforts through multiple mechanisms, including cooperation and funding support to SDOs; cooperation with industry and governmental partners; making Federal, State, and local technical expertise available; and through international coordination.

Appendix C provides more information on key topic areas and work underway in standards development for automation.

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\textsuperscript{43} The Federal Trade Commission maintains oversight over, and provides resources related to, protecting consumer privacy. Additional information is available at https://www.ftc.gov/news-events/media-resources/protecting-consumer-privacy

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**Adopt Cybersecurity Best Practices**

It is the responsibility of ADS developers, vehicle manufacturers, parts suppliers, and all stakeholders who support transportation to follow best practices, and industry standards, for managing cyber risks in the design, integration, testing, and deployment of ADS. As documented in *A Vision for Safety 2.0*, these entities are encouraged to consider and incorporate voluntary guidance, best practices, and design principles published by NIST, NHTSA, SAE International, the Alliance of Automobile Manufacturers, the Association of Global Automakers, the Auto ISAC, and...
other relevant organizations, as appropriate. Stakeholders are also encouraged to report to the Auto ISAC—or another mode-specific ISAC44—all discovered incidents, exploits, threats, and vulnerabilities from internal testing, consumer reporting, or external security research as soon as possible, and provide voluntary reports of such information to the DHS NCCIC when and where Federal assistance may be warranted in response and recovery efforts.

Engage with First Responders and Public Safety Officials

To ensure public safety, first responders and public safety officials need to have ways to interact with automated vehicles during emergencies. During traffic incidents, emergencies, and special events automated vehicles may need to operate in unconventional ways. Police officers responsible for traffic enforcement may need new procedures to signal an ADS-equipped vehicle to pull over and determine whether the occupant is violating the law or using the ADS appropriately. Responder personnel across many disciplines (including police, fire, emergency medical services, and towing) will need training to safely interact with partially or fully disabled ADS-equipped vehicles at the scene of a crash. Also, laws covering distracted driving, operating under the influence, and open alcohol containers may not be applicable or may be modified for operators or occupants of ADS-equipped vehicles.

Public safety officials also see the potential for automated vehicles to improve emergency response by improving data about traffic incidents and providing first responders with new tools to respond to traffic incidents quickly, effectively, and safely.

To educate, raise awareness, and develop emergency response protocols, automated vehicle developers should consider engaging with the first responder community when developing and testing automation technologies. Through such engagement, technology developers could potentially identify new applications of automation technologies that can enhance emergency response. The Federal Government may also act as a convener between public safety officials, technology companies, automobile manufacturers, and other stakeholders to build consensus around uniform voluntary data-sharing standards, protocols, and practices.

Private sector leadership is critical to advancing the development, testing, and commercialization of automated vehicles.

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44 Including the Aviation ISAC (https://www.a-isac.com/), the Maritime Security ISAC (http://www.maritimesecurity.org/), and the Public Transit ISAC and Surface Transportation ISAC (https://www.surfacetransportationisac.org/)
U.S. DOT sees a bright future for automation technology and great potential for transforming our surface transportation system for the better, toward a future with enhanced safety, mobility, and economic competitiveness across all transportation modes.
This section discusses U.S. DOT’s approach to moving forward on automation, informed by lessons from experience with the adoption of new technologies.

**Automation Implementation Strategies**

U.S. DOT is implementing five core strategies to accelerate the integration of automated vehicles and to understand their impact across all modes of the surface transportation system. The Department will put its six automation principles into action through these strategies. The strategies appear below in roughly sequential order, though some may occur in parallel. Stakeholders will be engaged throughout the process.

1. **Engage stakeholders and the public** as a convener and leader to address the issues automation raises. The Department will engage a broad range of stakeholders and provide them with opportunities to voice their concerns, expectations, and questions about the future of automation, to inform future research and policy development. U.S. DOT will also work to leverage knowledge and experience from across academia, industry, public sector agencies, and research organizations.

2. **Provide best practices and policy considerations to support stakeholders** as they work to better understand automation, how it may impact their roles and responsibilities, and how best to integrate automated vehicles into existing and future transportation networks. The Department is committed to providing best practices and updated policies as supported by research and will provide additional and more detailed information as the technology develops.

3. **Support voluntary technical standards** by working with stakeholders and SDOs to support technical standards and policies development. When in the public interest, the Department will support the integration of automation technologies throughout the Nation’s transportation system. See Appendix C for more information.

4. **Conduct targeted technical research** to inform future policy decisions and agency actions. Research is critical for producing and analyzing data to inform policy decisions, moving beneficial applications and technologies toward deployment, and evaluating the safety of new technologies.

5. **Modernize regulations** as existing Federal regulations and standards may pose challenges to the widespread integration of automated vehicles. U.S. DOT developed many of its regulations over a period of decades, generally with the assumption that a human driver would always be present. U.S. DOT is in the process of identifying and modifying regulations that unnecessarily impede the testing, sale, operation, or use of automation across the surface transportation system.
Safety Risk Management Stages along the Path to Full Commercial Integration

In addition to meeting any regulatory or statutory requirements, U.S. DOT envisions that entities testing and eventually deploying ADS technologies will employ a mixture of industry best practices, consensus standards, and voluntary guidance to manage safety risks along the different stages of technology development.

This conceptual framework provides an opportunity for discussion around one potential vision for promoting safety, managing risk, and encouraging the benefits possible from the adoption of automated vehicle technologies. The following description is in no way intended to imply that there is only one path for ADS development. Collaboration is needed among manufacturers, technology developers, infrastructure owners and operators, and relevant government agencies to establish protocols that will help to advance safe operations in these testing environments.

ADS developers may decide that this path does not make sense for them or that they will combine different phases in unique ways, all of which the Department fully supports, as long as safety risks are appropriately managed and all testing is conducted in accordance with applicable laws and regulations. Likewise, to the extent an ADS developer wishes to use this framework, it is not intended to provide benchmarks for when a developer may move from one phase to another, as that is best left to the ADS developer.

Development and Early Stage Road Testing
ADS development does not start with public road testing. Significant engineering and safety analysis are performed prior to on-road testing with a prototype ADS to understand safety risks and implement mitigation strategies. The primary purpose of this stage is to further develop the technology (software and hardware). There are many existing industry standards that guide general technology development. Conceptually, this stage can be characterized by these general characteristics:

- Development and Early Stage Road Testing
- Expanded ADS Road Testing
- Limited to Full ADS Deployment

U.S. DOT ENGAGEMENT
A collaborative approach to discuss key issues
The system would generally be characterized as a prototype that already passed laboratory and/or closed-course testing. The hardware and the vehicle platform may be comprised of development or rapid prototyping-level equipment.

ADS use cases and associated ADS functions are identified and implemented, and requisite software validation and verification are performed in controlled environments prior to this stage. The primary purpose of this stage of road testing is to validate the completeness of use cases and to verify that implemented software can perform associated functions.

Controlled environment (track, simulation, etc.) testing and software development are continuing alongside ADS prototype road testing. Known use cases are being tested in controlled environments and new use cases identified in road testing are being evaluated and stored.

Development of use cases could include initial assessments of a broad range of roadway characteristics (e.g., lane markings, signage) and operational scenarios (e.g., work zones, road weather) to inform ADS performance in the roadway environment.

In conjunction, additional software development is taking place in failure handling, crash imminent scenario handling, and edge case handling (non-nominal scenarios).

Safety drivers serve as the main risk mitigation mechanism at this stage. Safety-driver vigilance and skills are critical to ensuring safety of road testing and identifying new scenarios of interest.

Some safety items (such as cybersecurity and human-machine interface) may be addressed in alternative ways when compared to production systems.

Usually, in addition to a safety driver, an employee engaged in the ADS function/software development track is also present in the vehicle. Software changes could happen frequently (both for safety-critical issues and other reasons) but are tracked and periodically harmonized.

Members of the public are not in ADS prototype vehicles during early stage road testing.

Progressing through Testing Stages

The stage of testing and deployment of “an ADS in one ODD” does not adequately represent the maturity of all ADS development activities an entity may be pursuing. For example, an entity may be at a “limited-deployment stage” in one specific ODD giving limited rides to members of the public (e.g., daytime-only, less than 35 miles per hour, no precipitation, on a few streets in a metropolitan area). However, simultaneously that same entity may be developing its technologies to advance its ADS capabilities and expand the ODD elsewhere (e.g., to include nighttime, higher speeds, precipitation, or larger or different geographical areas).

Expanded ADS Road Testing

Once the development progresses and specifications and software components are validated to be generally complete, software handling of non-nominal cases is integrated into an ADS. The primary purpose of this stage of testing is to build statistical confidence in matured software and hardware within the intended operational environment and observe system failures, safety driver subjective
feedback, and execution of fail-safe/fail-operational system behaviors. Conceptually, this stage can be characterized by these general attributes:

- The ADS has matured both in terms of hardware and software. Information necessary to establish a safety self-assessment should be available and reasonably stable.
- Targeted operational design domain is more clearly identified and near fully specified. This could include an understanding of how the ADS-equipped vehicle interprets the standard roadway environment, such as lane markings, signage, varying traffic laws, dynamic roadway conditions, and other users.
- The functional safety approach has been carried out; safety goals are identified and risk management controls implemented.
- ADS use cases are validated to be nearly complete. Implemented ADS functions are validated and verified to meet engineering requirements in both controlled and on-road environments.
- Most elements of the ADS—such as fallback (minimal risk condition) mechanisms—are identified and implemented. Safety drivers are still in the loop, but they are expected to serve as the secondary risk mitigation strategy.

- The ADS has matured both in terms of hardware and software. Information necessary to establish a safety self-assessment should be available and reasonably stable.

The Role of On-Road Testing in Validation/Verification and Safety Assurance

Advancing an ADS function from prototyping stages to production release involves numerous development objectives. These include the ability for the ADS to perform nominal driving functions in known use cases, perform crash-avoidance maneuvers, revert to a safe state when there are identified system and sensor failures, and react reasonably safely in edge cases. **On-road testing cannot be expected to address all aspects of testing needs towards deployment.** For example, crash avoidance and failure response tests that put systems in imminent crash encounters cannot be safely performed in a naturalistic environment. On-road testing is an important part of the overall development process in identifying and validating the completeness of use cases, gaining statistical confidence in a system’s ability to handle use cases, and identifying edge cases and otherwise interesting/difficult cases, as well as public perceptions and expectations. However, once a new scenario of interest is identified in road-testing, it is usually added to a library and retested many times in controlled environments (simulation, track, hardware-in-the-loop, software-in-the-loop, etc.) and integrated as part of each software update release readiness assessment.

Limited to Full ADS Deployment

Limited ADS deployment is similar to what the public understands as demonstrations. Full deployment of automated vehicles represents an ADS that is able to, for example, operate commercially and widely engage with the public. The main purpose of this stage is to reach statistical confidence in the software for the intended operational environment, validate underlying safety assumptions, gather user and public feedback, and identify fine-tuning
opportunities in user compatibility areas. Conceptually, this stage can be characterized by these general characteristics:

- Complete engineering requirements for ADS are specified by the entity developing the technology, and internally documented. Engineering design reviews are performed, and documented.
- The operational design domain is specified clearly and ADS operation only takes place within that ODD. Relevant ODD elements are monitored to ensure full coverage. Any ODD expansions go through requisite validation and verification processes, are documented, and are appropriately communicated when applied as a software update in deployed units.
- Near-full software, hardware, system failure validation, and verification processes have been carried out with near production hardware.
- Software is stable. Software changes are centrally managed at the fleet level. Any major change goes through new release readiness testing.
- Nearly all elements of ADS—such as fallback (minimal risk condition) mechanisms—are identified and implemented. Safety drivers (including remote safety drivers) may still be used, but their roles are limited and may eventually be eliminated. Risk-based assessments are performed to assure safety of these approaches.
- Safety and key performance indicators are set and monitored.
- All safety items (including cybersecurity and human-machine interface) are addressed in a production manner.
- Members of the public are allowed in ADS-equipped vehicles on public roads, initially on a limited basis.
- Systems move toward full operation by being offered for sale, lease, or rent (to include free ridesharing) or otherwise engaged in commerce in the form of the transport of goods or passengers.
- In specified deployment areas, law enforcement, first responders, and relevant State and local agencies know of operational protocols and administrative procedures following a crash or other roadway event related to an ADS-equipped vehicle in the ODD.

Engaging with U.S. DOT along the Way

As ADS developers move along their respective paths from development to full commercial integration, it is useful to identify opportunities to further engage with U.S. DOT and the broader stakeholder community. The path discussed in the previous section illustrates example phases of testing and deployment, with sample general characteristics defining each stage. This framework can help lay out points at which the U.S. DOT, ADS developers, and stakeholders can engage with each other throughout the technology development process and align to prioritize safety and manage risks. Rather than waiting to interact at the very end of the technology development cycle, the U.S. DOT prefers a collaborative approach for working with industry to address and solve major challenges together, where possible.

In the near-term, the U.S. DOT and its modal agencies will continue to pursue its safety oversight role within its existing authorities (as discussed in Section 2). NHTSA, for example, has authority over the safety of ADS-equipped vehicles, including establishing Federal safety standards for new motor vehicles and addressing known safety defects in motor vehicles and motor vehicle equipment.

FMCSA’s oversight begins once the vehicles are placed into commercial operation in interstate commerce, whether for hire or as a private motor carrier, on public roadways. At that point, certain regulations designed to ensure safe operation apply.

During the first several years of ADS integration, light vehicles, transit vehicles, and the motor carrier industry will consist of a mixed fleet. For example, motor carriers that employ Level 4
or Level 5 driverless CMVs, those carriers with Level 3 or lower ADS-equipped CMVs that still have a human driver present, and carriers using only traditional non-ADS-equipped vehicles will at times be sharing the roadways. Some carriers will be operating mixed fleets and the ADS-equipped vehicles in deployment will represent an even broader array of operational design domains. As a result, the U.S. DOT and its State and local partners will need to adapt enforcement practices and other processes to new and rapidly developing ADS technology, while also continuing to ensure safe operation of conventional human driven vehicles. This will be an important area for stakeholders to work with the U.S. DOT going forward.

Moving Forward

In the long term, the U.S. DOT will pursue strategies to address regulatory gaps or unnecessary challenges that inhibit a safe and reasonable path to full commercial integration. The operating agencies within the U.S. DOT will be working together and with stakeholders to support a flexible and transparent policy environment to accommodate the safe development and integration of ADS technology.

Looking ahead, the U.S. DOT encourages stakeholder engagement in several areas as it pursues its long-term vision of modernizing regulations and supporting the path to full ADS commercialization:

- **NHTSA** will seek comment on existing motor vehicle regulatory barriers and other unnecessary barriers to the introduction and industry self-certification of ADS. NHTSA is developing an ANPRM to determine methods to maintain existing levels of safety while enabling innovative vehicle designs. The ANPRM also explores removing or modifying requirements that would no longer be appropriate if a human driver is not operating the vehicle. NHTSA previously published a Federal Register notice requesting public comment on January 18, 2018. NHTSA is issuing an ANPRM requesting public comments on designing a national pilot program that will enable it to facilitate, monitor, and learn from the testing and development of emerging advanced driving technologies and to assure the safety of those activities.

- **FMCSA** is finalizing an ANPRM to address ADS, particularly to identify regulatory gaps, including in the areas of inspection, repair, and maintenance for ADS. FMCSA anticipates considerable public interest and participation in this rulemaking effort, which will include an opportunity for formal written public comments as well as multiple public listening sessions.

- **FTA** is investing significant research resources to support the commercialization of innovative solutions in transit automation. As part of this research, FTA will assess areas of potential regulatory and other unnecessary barriers. Examples include FTA funding eligibility and technology procurement requirements, as well as ADA compliance. Currently, FTA is preparing guidance to provide stakeholders with clarity on existing FTA rules relevant to developing, testing, and deploying automated transit buses.

- **FHWA** will continue to work with stakeholders through its National Dialogue and other efforts to address the readiness of the roadway infrastructure to support ADS-equipped vehicles. It is reviewing existing standards to address uniformity and consistency of traffic control devices, such as signage, and plans to update the existing MUTCD.

FMCSA is in the process of developing policy recommendations to address ADS technology. Through public listening sessions, the Agency hopes to solicit information on issues relating to the design, development, testing, and integration of ADS-equipped commercial motor vehicles. FMCSA is excited to share its progress to date and learn more about the perspective of the trucking and bus industries firsthand as it considers future guidance.
Stakeholders are encouraged to engage directly with the Department where and when possible to support collaboration. It will be important to gather information and feedback from the stakeholder community, including ADS developers, commercial motor vehicle carriers, transit agencies, infrastructure owners and operators, the public, and other groups to jointly address key challenges and promote safe technology development and deployment.

**Conclusion**

Over the past century, motor vehicles have provided tremendous mobility benefits, including widespread access to jobs, goods, and services. They have also helped connect many of the most remote and isolated regions of the country to the larger economy. Along with these benefits, however, have come significant safety risks and other challenges. Motor vehicle crashes remain a leading cause of death in the United States, with an estimated 37,133 lives lost on U.S. roads in 2017. Automation has the potential to improve the safety of our transportation system, improve our quality of life, and enhance mobility for Americans, including those who do not drive today.

Many Americans remain skeptical about the notion that their car could one day be driving itself, rather than being driven by humans. We certainly cannot predict the exact way consumers will choose to interact with these technologies. Therefore, the U.S. DOT will not rush to regulate a nascent and rapidly evolving technology. Instead, the Department supports an environment where innovation can thrive and the American public can be excited and confident about the future of transportation. Doing this requires a flexible policy architecture.

With AV 3.0, U.S. DOT acknowledges the need to modernize existing regulations and think about new ways to deliver on our mission. The Department will work with partners and stakeholders in government, industry, and the public to provide direction, while also remaining open to learning from their experiences and needs. Wherever possible, U.S. DOT will partner with industry to develop voluntary consensus-based standards and will reserve non-prescriptive, performance-based regulations for when they are necessary. The Department will work to assess and minimize the possible harms and spread the benefits of automation technology across the Nation.

Regarding the integration of automation into professional driving tasks, lessons learned through the aviation industry’s experience with the introduction of automated systems may be instructive and inform the development of thoughtful, balanced approaches. These are not perfect comparisons, but are still worth considering (See Learning from the History of...
Automation in Aviation. The aviation industry discovered that automation required careful consideration of human factors, but led to improved safety ultimately. This transition also did not result in the elimination of pilot jobs, as some had feared.

Despite the great promise of automation technology, important questions remain. For example, as driving becomes more automated, how can safety be improved? How will people interact with these technologies? What happens when a human vehicle operator switches to or from an automated driving mode? As automated driving technologies develop, how will the Nation’s 3.8 million professional drivers be affected? Which regulatory obstacles need to be removed? What opportunities and challenges does automation present for long-range regional planning? Will automation lead to increased urban congestion?

U.S. DOT sees a bright future for automation technology and great potential for transforming our surface transportation system for the better, toward a future with enhanced safety, mobility, and economic competitiveness across all transportation modes.

Learning from the History of Automation in the Aviation Workforce

The aviation industry developed technological solutions to help airline pilots manage factors such as high workload, distractions, and abnormal situations. Innovation at that time eventually led to the introduction of autopilot, autothrottle, flight director, sophisticated alerting systems, and more. In part because of these innovations, the safety record for aviation improved significantly. Early automation technology in aviation performed very simple functions; for example, maintaining a set altitude or heading—comparable to conventional cruise control systems offered on most passenger cars today. Pilots readily accepted these systems because they reduced their workload and were easy to understand.

As computer technology became more capable, automation in the flight deck became more complex. For example, it enabled sophisticated navigation using precise flight paths that contributed to more efficient operations. This increased automation came at a cost. It became harder for pilots to understand what the automated systems were doing, yet they remained responsible for taking over when the automated systems reached the limits of their operating domains or malfunctioned. Pilots were also encouraged to use automation to the exclusion of manual flight controls, potentially degrading manual flight skills.

Systems that alert pilots to hazardous conditions (e.g., proximity to the ground or to other aircraft—lane departure alerts are an analogous example offered in many passenger cars) have also contributed significantly to aviation safety despite initial challenges. Early alert systems sometimes had a high number of false alarms, so pilots did not trust them. Many improvements were made, such as better algorithms, better sensors, and improved and standardized display of alerts (and associated information) on the flight deck. These improvements have led to more reliable alerts and pilots are more willing to heed them.

Automation has undeniably made flying safer by supporting pilots. The characteristics that have improved trust in and effectiveness of these systems include:

- Reliable, robust systems that minimize false or missed alarms/reports.

• Pilot interfaces that are easy to understand and enhance awareness.
• Training to understand how the systems work (and how to operate them).
• Avoidance of skill degradation by encouraging pilots to practice manual flight and basic skills.

In the early days of aviation automation, many pilots worried that autopilot functions would completely replace them. Yet today, pilots are still paid well, highly regarded, and very much in demand. Although aviation is still undergoing technological changes, including increased automation of many services, its first four decades of experience shows that the transition from a mode of transportation of primarily human operation to one where humans and automated systems share in the vehicle's operation can occur in ways that dramatically increase safety while minimizing social disruption.
U.S. DOT supports an environment where innovation can thrive and the American public can be excited and confident about the future of transportation.
APPENDIX A

KEY TERMS AND ACRONYMS

Adaptive Cruise Control: A driver assistance system that automatically adjusts a vehicle’s speed to maintain a set following distance from the vehicle in front. (NHTSA)

ADS-Dedicated Vehicle: A vehicle designed to be operated exclusively by a Level 4 or Level 5 ADS for all trips. (SAE J3016)

Advanced Driver-Assistance Systems (ADAS): Systems designed to help drivers with certain driving tasks (e.g., staying in the lane, parking, avoiding collisions, reducing blind spots, and maintaining a safe headway). ADAS are generally designed to improve safety or reduce the workload on the driver. With respect to automation, some ADAS features could be considered SAE Level 1 or Level 2, but many are Level 0 and may provide alerts to the driver with little or no automation.

Automation: Use of electronic or mechanical devices to operate one or more functions of a vehicle without direct human input. Generally applies to all modes.

Automated Driving System (ADS): The hardware and software that are collectively capable of performing the entire Dynamic Driving Task on a sustained basis, regardless of whether it is limited to a specific operational design domain. This term is used specifically to describe a Level 3, 4, or 5 driving automation system. (SAE J3016)

Automated Vehicle: Any vehicle equipped with driving automation technologies (as defined in SAE J3016). This term can refer to a vehicle fitted with any form of driving automation. (SAE Level 1–5)

Commercial Motor Vehicle: Any self-propelled or towed motor vehicle used on a highway in interstate commerce to transport passengers or property when the vehicle:

1. Has a gross vehicle weight rating or gross combination weight rating, or gross vehicle weight or gross combination weight, of 4,536 kg (10,001 pounds) or more, whichever is greater; or
2. Is designed or used to transport more than 8 passengers (including the driver) for compensation; or
3. Is designed or used to transport more than 15 passengers, including the driver, and is not used to transport passengers for compensation; or
4. Is used in transporting material found by the Secretary of Transportation to be hazardous under 49 U.S.C. 5103 and transported in a quantity requiring placarding under regulations prescribed by the Secretary under 49 CFR, subtitle B, chapter I, subchapter C. (FMCSA, defined in 49 CFR 390.5)

Cooperative Automation: Ability for automated vehicles to communicate with each other and with infrastructure to coordinate their movements.

Cooperative Lane Change and Merge: A dynamic driving task for automated vehicles that uses communications to enable negotiations between vehicles to provide safe gaps for manual or automated lane change or merge maneuver on a roadway. (FHWA)

Driver Assistance Technologies: Cameras and sensors in vehicles that help drivers see more than they can with the naked eye and warn of a possible collision. Driver assistance technologies can help drivers with
backing up and parking, maintaining safe distance from other vehicles, preventing forward collisions, and navigating lanes safely. (NHTSA)

**Driving Automation System or Technology:** The hardware and software that are collectively capable of performing part or all of the Dynamic Driving Task on a sustained basis; this term is used generically to describe any system capable of Level 1–5 driving automation. (SAE J3016)

**Dynamic Driving Task (DDT):** All of the real-time operational and tactical functions required to operate a vehicle in on-road traffic, excluding the strategic functions such as trip scheduling and selection of destinations and waypoints. (SAE J3016)

**DDT Fallback:** The response by the user or by an ADS to either perform the DDT or achieve a minimal risk condition after occurrence of a DDT performance-relevant system failure(s) or upon Operational Design Domain (ODD) exit. (SAE J3016)

**GlidePath:** A prototype application of signalized approach and departure that has been demonstrated to stakeholders. (FHWA)

**Hazardous Material:** The Secretary shall designate material (including explosive, radioactive material, infectious substance, flammable or combustible liquid, solid, or gas, toxic, oxidizing, or corrosive material, and compressed gas) or a group or class of material as hazardous when the Secretary determines that transporting the material in commerce in a particular amount and form may pose an unreasonable risk to health and safety or property. (PHMSA, defined 49 U.S.C. § 5103)

**Human-in-the-loop:** Intermittent remote operation or intervention by a human of an automated or autonomous vehicle for emergency or special handling reasons. (FRA)

**Minimal Risk Condition:** A condition to which a user or an ADS may bring a vehicle after performing the DDT fallback in order to reduce the risk of a crash when a given trip cannot or should not be completed. (SAE J3016)

**Object Event Detection and Response (OEDR):** The subtasks of the DDT that include monitoring the driving environment (detecting, recognizing, and classifying objects and events and preparing to respond as needed) and executing an appropriate response to such objects and events (i.e., as needed to complete the DDT and/or DDT fallback). (SAE J3016)

**Operational Design Domain (ODD):** The specific conditions under which a given driving automation system or feature thereof is designed to function, including, but not limited to, driving modes. This can incorporate a variety of limitations, such as those from geography, traffic, speed, and roadways. (SAE J3016)

**Remote Driver/Remote Operation:** A driver who is not seated in a position to manually exercise in-vehicle braking, accelerating, steering, and transmission gear selection input devices (if any) but is able to operate the vehicle. (SAE J3016)

**Signalized Intersection Approach and Departure:** An automated vehicle that communicates with infrastructure using Signal Phase and Timing (SPaT) and Map Data Message (MAP) messages to automate the movement of single or multiple automated vehicles through intersections to increase traffic flow and safety. (FHWA)

**Speed Harmonization:** A strategy to increase traffic flow enabled by communications between an automated vehicle and infrastructure to change traffic speed on roads that approach areas of traffic congestion, bottlenecks, incidents, special events, and other conditions that affect flow. (FHWA)

**Vehicle Platooning:** A group of automated vehicles that use communications to enable negotiations between vehicles to support organized behavior and safe close following. (FHWA)
<table>
<thead>
<tr>
<th>Abbreviation</th>
<th>Description</th>
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<tbody>
<tr>
<td>ADA</td>
<td>Americans with Disabilities Act</td>
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<td>ADS</td>
<td>Automated Driving Systems</td>
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<td>AI</td>
<td>Artificial Intelligence</td>
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<td>ANPRM</td>
<td>Advance Notice of Proposed Rulemaking</td>
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<td>ATTRI</td>
<td>Accessible Transportation Technologies Research Initiative</td>
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<tr>
<td>CDL</td>
<td>Commercial Driver’s License</td>
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<td>CMV</td>
<td>Commercial Motor Vehicle</td>
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<tr>
<td>DARPA</td>
<td>Defense Advanced Research Projects Agency</td>
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<tr>
<td>DDT</td>
<td>Dynamic Driving Task</td>
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<tr>
<td>DHS</td>
<td>Department of Homeland Security</td>
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<td>DOL</td>
<td>Department of Labor</td>
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<td>FCC</td>
<td>Federal Communications Commission</td>
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<td>FHWA</td>
<td>Federal Highway Administration</td>
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<td>FMCSA</td>
<td>Federal Motor Carrier Safety Administration</td>
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<td>FMCSR</td>
<td>Federal Motor Carrier Safety Regulations</td>
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<td>FMVSS</td>
<td>Federal Motor Vehicle Safety Standards</td>
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<td>FRA</td>
<td>Federal Railroad Administration</td>
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<td>FTA</td>
<td>Federal Transit Administration</td>
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<td>FTC</td>
<td>Federal Trade Commission</td>
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<td>HHS</td>
<td>Health and Human Services</td>
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<td>HMI</td>
<td>human-machine interface</td>
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<td>ICT</td>
<td>Information and Communications Technology</td>
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<td>IEEE</td>
<td>Institute of Electrical and Electronics Engineers</td>
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<td>ISAC</td>
<td>Information Sharing and Analysis Center</td>
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<td>ISO</td>
<td>International Standards Organization</td>
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<td>MARAD</td>
<td>Maritime Administration</td>
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<td>MCSAP</td>
<td>Motor Carrier Safety Assistance Program</td>
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<td>MPO</td>
<td>Metropolitan Planning Organization</td>
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<td>MRC</td>
<td>Minimal Risk Condition</td>
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<td>MUTCD</td>
<td>Manual on Uniform Traffic Control Devices</td>
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<tr>
<td>NCCIC</td>
<td>National Cybersecurity and Communications Integration Center</td>
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<td>NHTSA</td>
<td>National Highway Traffic Safety Administration</td>
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<td>NIST</td>
<td>National Institute of Standards and Technology</td>
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<td>NSP</td>
<td>National Public Transportation Safety Plan</td>
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<td>ODD</td>
<td>operational design domain</td>
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<tr>
<td>OEDR</td>
<td>Object and Event Detection and Response</td>
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<td>OHMS</td>
<td>Office of Hazardous Materials Safety</td>
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<td>PHMSA</td>
<td>Pipeline and Hazardous Materials Safety Administration</td>
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<td>PTASP</td>
<td>Public Transportation Agency Safety Plan</td>
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<td>PTC</td>
<td>Positive Train Control</td>
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<td>SAE</td>
<td>Society of Automotive Engineers</td>
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<td>SDO</td>
<td>Standards Development Organization</td>
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<td>SMS</td>
<td>Safety Management System</td>
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<td>SPaT</td>
<td>Signal Phase and Timing</td>
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<td>STAR</td>
<td>Strategic Transit Automation Research</td>
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<td>U.S. DOT</td>
<td>U.S. Department of Transportation</td>
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<tr>
<td>US-CERT</td>
<td>United States Computer Emergency Readiness Team</td>
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<td>UVC</td>
<td>Uniform Vehicle Code</td>
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<tr>
<td>VRU</td>
<td>Vulnerable Road User</td>
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<tr>
<td>VSSA</td>
<td>Voluntary Safety Self-Assessment</td>
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APPENDIX B

STAKEHOLDER ENGAGEMENT

Since the publication of *A Vision for Safety 2.0*, the U.S. DOT has sought input from the public through public meetings, demonstration projects, expert roundtables and workshops, Requests for Information, and Requests for Comment. In March 2018, U.S. DOT hosted an Automated Vehicle Summit to discuss the cross-modal issues most critical to the successful integration of automated vehicles and provide input to this document. For more information, see transportation.gov/AV.

The most common themes and concerns stakeholders shared with the U.S. DOT include:

- **Consumer and public education**: Stakeholders agreed on the need for improved public and consumer education regarding the capabilities of vehicles with different levels of automation. Responses emphasized the need to engage a diverse range of stakeholders.

- **Data and digital infrastructure**: Respondents identified a need for standardized frameworks and enhanced digital infrastructure for collecting, managing, and exchanging data related to automated vehicle operation.

- **Connectivity**: Many respondents suggested continued investment in research into V2V and V2I communications and their potential to complement automated vehicle technologies. Responses noted the need for standardized and interoperable communications.

- **Mobility and accessibility**: Many stakeholders see great promise in the potential for automated vehicles to support the independence of people with disabilities by improving the accessibility of mobility options. To achieve this potential, stakeholders stressed that innovators and policymakers need to engage in an open dialogue with the disability community.

- **Public safety and emergency response**: Some respondents emphasized the need for establishing protocols for emergency responders, including emergency overrides to transfer control to a human in case of an emergency or equipment malfunction.

- **Roadway readiness**: Stakeholders recognize that improved roadway maintenance, enhanced digital infrastructure, and increased uniformity have the potential to enhance automated vehicle operations. However, many are concerned about making long-term infrastructure investments given the uncertainty about automation capabilities and requirements.

- **Insurance and liability**: Respondents raised concerns regarding insurance requirements and methods for determining liability.

- **Cybersecurity**: Stakeholder responses stressed the need for setting cybersecurity standards and establishing models and partnerships to mitigate the risk of hacking or intrusions.

- **Workforce impacts**: Stakeholders expressed concerns about the potential impact of automation on employment, particularly in the motor carrier, transit, and rail industries, and encouraged additional research into opportunities for re-training and workforce development.
Standardization-related needs associated with surface vehicle automation are in various stages of identification, development, definition, and adoption. Standardization-related documents can include voluntary technical standards published by standards developing organizations (SDOs) as well as specifications, best practices descriptions and other types of documents. There are standards that apply to almost all levels of vehicle automation. These include ISO 26262 Road Vehicles Functional Safety and SAE’s J3016_201806 Taxonomy and Definitions for Terms Related to On-Road Motor Vehicle Automated Driving Systems. There are many existing standards, but they may not fully address automated vehicle needs. Some standards specific to automated vehicles and many standards in other automation-relevant domains have been developed, but gaps remain where activity is underway or anticipated.

In addition to those standards that support interoperable integration, many standards development efforts are focused on describing common terminology, required performance capabilities, and interfaces between subsystems inside automated systems. These efforts include both automation-specific standards and domain-specific standards—for example, Information and Communications Technology (ICT) standards—applicable to subsystems and technologies that are then integrated into the overall automation system or surface transportation system. There are also sets of published best practices and frameworks that complement and are used in conjunction with voluntary technical standards. For example, the NIST cybersecurity framework describes a holistic approach to mitigating cyber threats across complex systems.

The Department will continue our cooperative, coordinated approach to supporting development of stakeholder-driven voluntary technical standards and similar documents across internal modal partners. The Department will follow a similar process to the approach for modernizing regulation, including:

1. **Gather information** through research, internal analysis, and stakeholder engagement on voluntary technical standardization needs.
2. **Explore and execute new approaches** to meet technical challenges in a way acceptable to the broad, diverse stakeholder community.
3. **Work to ease implementation** of automated vehicle products by supporting development of voluntary technical standards, system architecture options and user services for the interface between vehicles and infrastructure, along with companion software toolsets and implementation support programs.
   
   Means include cooperation and funding support to SDOs, cooperation with industry and governmental partners, making Federal technical expertise available, and international coordination.
4. **Cooperate with stakeholders** to maximize interoperability throughout North America as well as to take advantage of common international interests and global expertise by leveraging work across multiple regions and markets.

Vehicle automation systems represent one element of a larger system-of-systems architecture within surface transportation. Vehicle manufacturers
control what goes into the vehicle, while infrastructure owners and operators control the physical environment where the vehicle operates. That infrastructure covers more than the roadway and can include communications networks, electric vehicle charging stations, and other components. Surface vehicle automation systems have technological crossovers and interdependencies. These include considerations about software reliability as the degree of software dependency increases. Interdependencies are not directly mapped from traditional standards, and those factors expand the scope of consensus agreement on systems architectures and voluntary technical standards.

To gain a general understanding of what standards might be beneficial for vehicle automation, the interests, goals, and perspectives of innovators and stakeholders can be used as a basis to categorize the different types of existing and prospective standards. Figure 1 offers one way of logically dividing the voluntary technical standards landscape into three complementary category areas to encompass multiple perspectives.

As innovators and stakeholders advance the state of the art in automation, it is useful to identify those standards that already are available. Table 1 organizes existing standards by three functional areas: technology, functional standards, and safety, and identifies the associated organization. In some cases, these standards are applicable globally or multi-regionally; in other cases, differing standards have evolved in specific regions. This is reflected in Table 1, which describes work by a wide spectrum of organizations whose standardization-related documents are applicable domestically and across global markets. There may be ongoing work that is not captured below.
<table>
<thead>
<tr>
<th>Functional Area</th>
<th>Standardization-Related Documents</th>
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<tr>
<td><strong>Definitions and Architecture</strong></td>
<td><strong>Definitions</strong></td>
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<tr>
<td></td>
<td>• SAE J2944_201506 — Operational Definitions of Driving Performance Measures and Statistics</td>
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<td>• SAE J3016_201806 — Taxonomy and Definitions for Terms Related to On-Road Motor Vehicle Automated Driving Systems</td>
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<td>• SAE J3018_201503 — Guidelines for Safe On-Road Testing of SAE Level 3, 4, and 5 Prototype Automated Driving Systems</td>
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<td>• SAE J3063_201511 — Active Safety Systems Terms and Definitions</td>
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<td>• SAE J3077_201512 — Definitions and Data Sources for the Driver Vehicle Interface (DVI)</td>
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<td>• SAE J3087_201710 — Automatic Emergency Braking (AEB) System Performance Testing</td>
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<td>• SAE AS-4 Joint Architecture for Unmanned Systems (JAUS)</td>
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<td>• SAE AIR5372A:2014 Information on Brake-By-Wire (BBW) Brake Control Systems [pertains to aircraft, but may be of use to surface transportation]</td>
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<td></td>
<td>• National Institute of Standards and Technology (NIST) Special Publication (SP) 1011 I-2.0 Autonomy Levels for Unmanned Systems (ALFUS) Framework</td>
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<td></td>
<td>• NIST NISTIR 6910 — 4D/RCS Version 2.0: A Reference Model Architecture for Unmanned Vehicle Systems</td>
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<td>• ASTM Committee F45 on Driverless Automatic Guided Industrial Vehicles Architecture</td>
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<td></td>
<td>• ISO/IEC/IEEE 12207:2017(E) — Systems and software engineering — Software life cycle processes</td>
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<td></td>
<td>• U.S. Army Robotic Systems Joint Project Office Interoperability Profiles</td>
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<td>• Automotive Open System Architecture (AUTOSAR) Testing</td>
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<td></td>
<td>• European Committee for Standardization (CEN) European Standard (EN) 1525: Safety of Industrial Trucks — Driverless Trucks and Their Systems</td>
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<td>Functional Area</td>
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| **Data**        | • Navigation Data Standard (NDS) — a standardized format for automotive-grade navigation databases, jointly developed by automobile manufacturers and suppliers.  
• North American Datum 1983 (NAD83)  
• World Geodetic System 1984 (WGS84)  
• European Terrestrial Reference System 1989 (ETRS89)  
• Chinese encrypted datum 2002 (CSJ-02)  
• ADASIS Forum vehicle to cloud messaging standards  
• Coordinated Universal Time (UTC)  
• International Atomic Time (TAI)  
• ISO 11270:2014 — Intelligent Transport Systems — Lane Keeping Assistance Systems (LKAS) — Performance requirements and test procedures  
• ISO 14296:2016 — Intelligent Transport Systems — Extension of map database specifications for applications of cooperative Intelligent Transportation Systems  
• ISO 14825:2011 — Intelligent Transport Systems — Geographic Data Files (GDF) — GDF5.0  
• ISO 19237:2017 — Intelligent Transport Systems — Pedestrian detection and collision mitigation systems (PDCMS) — Performance requirements and test procedures  
• ISO 22178:2009 — Intelligent Transport Systems — Low speed following (LSF) systems — Performance requirements and test procedures  
• ISO 22179:2009 — Intelligent Transport Systems — Full Speed Range Adaptive (FSRA) systems — Performance requirements and test procedures  
• ISO 22839:2013 — Intelligent Transport Systems — Forward vehicle collision mitigation systems — Operation, performance, and verification requirements  
• ISO/DIS 20035 — Intelligent Transport Systems — Cooperative adaptive cruise control (CACC) — Operation, performance, and verification requirements  
• SAE J1698 — Event Data Recorder (EDR) |
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<th>Functional Area</th>
<th>Standardization-Related Documents</th>
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<tr>
<td><strong>Design</strong></td>
<td>• Federal Highway Administration Manual on Uniform Traffic Control Devices (MUTCD)</td>
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<td>• American Association of State Highway and Transportation Officials (AASHTO) A Policy on Geometric Design of Highways and Streets (Green Book)</td>
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<td></td>
<td>• AASHTO Roadside Design Guide</td>
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<td>• Joint SAE-AASHTO Committee on Road Markings</td>
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<td></td>
<td>• ISO 2575:2010 — Road vehicles — Symbols for controls, indicators, and tell-tales</td>
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<tr>
<td><strong>Maintenance and Inspections</strong></td>
<td>• Commercial Vehicle Safety Alliance (CVSA) North American Standard Inspection Program (roadside inspection process for inspecting commercial motor vehicles and drivers throughout North America)</td>
</tr>
<tr>
<td><strong>Functional / Performance</strong></td>
<td>• SAE J2958:2011 — Report on Unmanned Ground Vehicle Reliability</td>
</tr>
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<td></td>
<td>• SAE J2980_201804 — Considerations for ISO 26262 Automotive Safety Integrity Levels (ASIL) Hazard Classification</td>
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<td></td>
<td>• SAE J3088 — Active Safety System Sensors</td>
</tr>
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<td></td>
<td>• SAE J3116_201706 — Active Safety Pedestrian Test Mannequin Recommendation</td>
</tr>
<tr>
<td></td>
<td>• Radio Technical Commission for Aeronautics (RTCA) DO-178C Software Considerations in Airborne Systems and Equipment Certification</td>
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<td></td>
<td>• National Aeronautics and Space Administration (NASA) — GB-8719.13 Software Safety Guidebook</td>
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<td></td>
<td>• Automated Driving and Platooning Task Force of the American Trucking Associations Technology and Maintenance Council</td>
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<td>• ISO 13482:2014 — Robots and robotic devices — Safety requirements for personal care robots</td>
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<td></td>
<td>• ISO 15622:2010 — Intelligent Transport Systems — Adaptive Cruise Control systems — Performance requirements and test procedures</td>
</tr>
<tr>
<td></td>
<td>• ISO 17386:2010 — Transport information and control systems — Maneuvering Aids for Low Speed Operation (MALSO) — Performance requirements and test procedures</td>
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<tr>
<td></td>
<td>• ISO 22840:2010 — Intelligent Transport Systems — Devices to aid reverse maneuvers — Extended-range backing aid (ERBA) systems</td>
</tr>
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<td></td>
<td>• ISO 26262 — Road vehicles — Functional safety</td>
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</tbody>
</table>
(Continued) Table 1. Relevant Standardization-Related Document by Functional Area (as of August 2018)

<table>
<thead>
<tr>
<th>Functional Area</th>
<th>Standardization-Related Documents</th>
</tr>
</thead>
<tbody>
<tr>
<td>Protocols</td>
<td>• IEEE 802.11X</td>
</tr>
<tr>
<td>(Communications)</td>
<td>• IEEE 1609.0: 2013 — IEEE Draft Guide for Wireless Access in Vehicular Environments (WAVE) — Architecture</td>
</tr>
<tr>
<td></td>
<td>• IEEE 1609.2: 2016 — WAVE - Security Services for Applications and Management Messages</td>
</tr>
<tr>
<td></td>
<td>• IEEE 1609.2a: 2017 — WAVE — Security Services and Message Sets — Amendment 1</td>
</tr>
<tr>
<td></td>
<td>• IEEE 1609.3: 2016 — WAVE — Networking Services</td>
</tr>
<tr>
<td></td>
<td>• IEEE 1609.4: 2016 — WAVE — Multi-channel Operations</td>
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<tr>
<td></td>
<td>• IEEE 1609.12: 2016 — WAVE — Identifier Allocation</td>
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<tr>
<td></td>
<td>• IEEE 8802-3-2014 — Standard for Ethernet</td>
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<tr>
<td></td>
<td>• IEEE 8802-3-2017 — Standard for Ethernet — Amendments</td>
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<tr>
<td></td>
<td>• SAE J1939 Core Standards — Serial Control and Communications Heavy Duty Vehicle Network</td>
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<tr>
<td></td>
<td>• SAE J2735_201603 — Vehicle-to-Vehicle Message Sets</td>
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<tr>
<td></td>
<td>• SAE J2945/1_201603 — On-Board System Requirements for Vehicle-to-Vehicle (V2V) Safety Communications</td>
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<td>• SAE J2945/9_201703 — Vulnerable Road User Safety Message Minimum Performance Requirements</td>
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<td></td>
<td>• SAE J3067_201408 — Candidate Improvements to Dedicated Short Range Communications Message Set Dictionary [SAE J2735] Using Systems Engineering Methods</td>
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<td>• SAE AS6802 — Time-Triggered Ethernet</td>
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<td></td>
<td>• Time-Sensitive Networking Task Group (IEEE 802.1X Ethernet)</td>
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<tr>
<td></td>
<td>• Association of Radio Industries and Businesses (ARIB) Standard (STD) — T109 700 MHz Band ITS (V2V communications)</td>
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<tr>
<td></td>
<td>• ARIB STD-T110 — Dedicated Short Range Communications (Japan) Basic Application Interface</td>
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<tr>
<td></td>
<td>• ARIB STD-T88 Dedicated Short Range Communications (Japan) Application Sublayer</td>
</tr>
<tr>
<td>Security</td>
<td>• SAE J3061_201601 — Cybersecurity Guidebook for Cyber-Physical Vehicle Systems</td>
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<td></td>
<td>• NIST Cybersecurity Framework (CSF)</td>
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<td></td>
<td>• National Highway Traffic Safety Administration Cybersecurity Framework</td>
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<tr>
<td></td>
<td>• International Electrotechnical Commission (IEC) — 62443 Industrial communication networks — Network and system security</td>
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<tr>
<td></td>
<td>• ISO/IEC 15408 — Information technology — Security techniques — Evaluation criteria for information technology (IT) Security</td>
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<tr>
<td></td>
<td>• ISO/IEC 18045:2008 — Information technology — Security techniques — Methodology for IT security evaluation</td>
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<tr>
<td>Functional Area</td>
<td>Standardization-Related Documents</td>
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<tr>
<td><strong>Testing/Test Target</strong></td>
<td></td>
</tr>
<tr>
<td>- SAE J3077_201512 — Definitions and Data Sources for the DVI</td>
<td>- ISO 22839:2013 — Intelligent Transport Systems — Forward vehicle collision mitigation systems — Operation, performance, and verification requirements</td>
</tr>
<tr>
<td>- SAE J3114_201612 — Human Factors Definitions for Automated Driving and Related Research Topics</td>
<td>- ISO/DIS 20035 — Intelligent Transport Systems — Cooperative adaptive cruise control systems (CACC) — Performance requirements and test procedures</td>
</tr>
<tr>
<td>- IEC-61508 — Functional Safety of Electrical/Electronic/Programmable Electronic Safety-related Systems</td>
<td></td>
</tr>
</tbody>
</table>
(Continued) Table 1. Relevant Standardization-Related Document by Functional Area (as of August 2018)

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<tbody>
<tr>
<td>Testing/Test Target</td>
<td>Architecture/Software</td>
</tr>
<tr>
<td>ISO/IEC/IEEE 29119 — Software and systems engineering — Software testing</td>
<td></td>
</tr>
</tbody>
</table>
As automation technologies advance, additional needs may become evident that are not covered by currently available standards. Those needs may be met by a combination of automation-specific standards and domain-specific standards. The table below presents an inventory of known standards development activities underway to support known and anticipated automation needs.

Table 2: Known Current Standards Development Activities Relevant to Automated Surface Vehicles (as of August 2018)

<table>
<thead>
<tr>
<th>Topic Area</th>
<th>Functional Needs</th>
<th>Standardization-Related Activities</th>
</tr>
</thead>
</table>
| **Cooperative Situational Awareness** | • Need to utilize perception systems from other surface vehicles and infrastructure systems to overcome sensor occlusion and range. | • SENSORIS, ADASIS Forum  
• SAE J2945/6 — Performance Requirements for Cooperative Adaptive Cruise Control and Platooning  
• SAE J3161 — On-Board System Requirements for LTE V2X V2V Safety Communications |
| **Cybersecurity Framework**   | • Describe best practices  
• Cover aspects of identify, respond, recover, protect, and detect for vehicles and infrastructure | • Auto-ISAC Best Practices  
• NHTSA — Cyber Resiliency Framework project (RFP released winter 2017)  
• National Cooperative Highway Research Program (NCHRP) 03-127 Cybersecurity of Traffic Management Systems research project  
• ITS Joint Program Office Data Program ADS Data Roundtable  
• American Trucking Association Technology and Maintenance Council  
• Association of Global Automakers — Framework for Automotive Cybersecurity Best Practices |
| **Data sharing: Scenarios**   | • Provide common set of parameters and interface definitions to enable sharing of scenarios | • Pegasus Open-Simulation Interface  
• ITS JPO Data Program ADS Data Roundtable  
• International work on standards harmonization |
Table 2: Known Current Standards Development Activities Relevant to Automated Surface Vehicles (as of August 2018)

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<th>Topic Area</th>
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</thead>
<tbody>
<tr>
<td><strong>Communications</strong></td>
<td>• Assure required reliability and availability of wireless communications links</td>
<td>• SAE J2945/2 — DSRC Requirements for V2V Safety Awareness</td>
</tr>
<tr>
<td><strong>Performance</strong></td>
<td></td>
<td>• SAE J2945/3 — Requirements for Vehicle-to-Infrastructure (V2I) Weather Applications</td>
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<td></td>
<td></td>
<td>• SAE J2945/4 — DSRC Messages for Traveler Information and Basic Information Delivery</td>
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<tr>
<td></td>
<td></td>
<td>• SAE J2945/6 — Performance Requirements for CACC and Platooning</td>
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</tbody>
</table>
| **DVI Guidelines**      | • Design for all user types including those with disabilities  
• Identify different driver states  
• Helps define minimal risk condition  
• Need to define approaches for testing and certification                                                                 | • SAE J3171 — ADS-DV User Issues for Persons with Disabilities                                                                                                                     |
<p>|                         |                                                                                                                                                                                                                  | • SAE DVI Task Force (TF) 5 — Automated Vehicles and DVI Challenges Committee                                                                                                   |
| <strong>Emergency Vehicle</strong>   | • V2V/V2I or other communication/sensing techniques for ensuring safe and efficient passage of emergency vehicles                                                                                             | • SAE J2945/2 — DSRC Requirements for V2V Safety Awareness                                                                                                                      |
| <strong>Interaction</strong>         |                                                                                                                                                                                                                  |                                                                                                                                                                                  |
| <strong>Encrypted</strong>           | • Some communications can be signed and some will need to be encrypted                                                                                                                                              | • IEEE 1609.2 — Standard for Wireless Access in Vehicular Environments — Security Services for Applications and Management Messages                                                                                       |
| <strong>Communications</strong>      |                                                                                                                                                                                                                  | • ISO TC204 WG16 and WG18 activity                                                                                                                                               |
| <strong>Event Data Recorder</strong> | • Data elements for crash reconstruction and determining if ADS defect may exist                                                                                                                                    | • SAE Event Data Recorder Committee                                                                                                                                               |</p>
<table>
<thead>
<tr>
<th>Topic Area</th>
<th>Functional Needs</th>
<th>Standardization-Related Activities</th>
</tr>
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</table>
| **Functional Architecture**    | • Encourage interoperability and enable system-level innovation and more complex applications to emerge | • SAE On-Road Automated Driving (ORAD)  
• SAE J3131 — Automated Driving Reference Architecture  
• IEEE WG2040 — Standard for Connected, Automated and Intelligent Vehicles: Overview and Architecture  
• IEEE WG2040.1 — Standard for Connected, Automated and Intelligent Vehicles: Taxonomy and Definitions  
• IEEE WG2040.2 — Standard for Connected, Automated and Intelligent Vehicles: Testing and Verification  
• Other domains: Robot Operating System (ROS), JAUS, VICTORY, AUTOSAR |
| **Functional Safety**           | • Using verification and validation (V&V) from current standards to ensure a safe vehicle design | • ISO 26262 — Road Vehicles — Functional Safety  
• IEC 62508 — Dynamic Test Procedures for Verification and Validation of Automated Driving Systems  
• SAE J3092 — Dynamic Test Procedures for Verification and Validation of Automated Driving Systems  
• ISO/WD PAS 21448 — Road vehicles — Safety of the intended functionality |
| **General Atmospheric Conditions/Road Weather** | • Classify various weather conditions and data formats  
• Identify ODD boundaries  
• Identify minimal risk condition and transition of control  
• Define approaches for testing and certification | • Reference model architecture efforts within ISO TC204 WG 1 include provision for road weather (connected vehicle focus)  
• NHTSA Testable Cases Project  
• SAE J3164 — Taxonomy and Definitions for Terms Related to Automated Driving System Behaviors and Maneuvers for On-Road Motor Vehicles |
### Table 2: Known Current Standards Development Activities Relevant to Automated Surface Vehicles (as of August 2018)

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<th>Topic Area</th>
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<tbody>
<tr>
<td><strong>Global Positioning System (GPS) Spoofing</strong></td>
<td>• Describe risk mitigations&lt;br&gt;• Define test apparatus, infrastructure, procedures</td>
<td>• SAE J3061_201601 — Cybersecurity Guidebook for Cyber-Physical Vehicle Systems&lt;br&gt;• ISO 26262 — Road vehicles — Functional safety</td>
</tr>
<tr>
<td><strong>Infrastructure signage and traffic control device design</strong></td>
<td>• Describe how tests address functional requirements&lt;br&gt;• Facilitate discussion between parties&lt;br&gt;• Define test apparatus, infrastructure, and procedures&lt;br&gt;• Define ODD-specific Object and Event Detection and Response (OEDR) tests</td>
<td>• Current joint SAE/AASHTO Task Force&lt;br&gt;• SAE J2945/X — Dedicated Short Range Communication (DSRC) Systems&lt;br&gt;• NCHRP 20-102(15) — Impacts of Connected and Automated Vehicle Technologies on the Highway Infrastructure</td>
</tr>
<tr>
<td><strong>Interactions with Vulnerable Road Users (VRU)</strong></td>
<td>• Identify minimal risk condition and transition of control&lt;br&gt;• Define approaches for testing and certification</td>
<td>• Ongoing activity in SAE lighting committee&lt;br&gt;• SAE J3122 — Test Target Correlation</td>
</tr>
<tr>
<td><strong>Maintenance and inspection of sensors, software</strong></td>
<td>• Automation benefits from routine maintenance of systems for optimal performance and operations</td>
<td>• ISO 3888 — Diagnostic, maintenance and test equipment may provide a guideline for this</td>
</tr>
<tr>
<td><strong>Minimal Risk Condition</strong></td>
<td>• Minimal Risk Condition (MRC) definition provides common understanding to enable discussion; it exists, but may need to be updated&lt;br&gt;• MRC performance requirements set expectations between OEMs, regulators, and public&lt;br&gt;• MRC data elements in EDR enable crash reconstruction</td>
<td>• SAE J3131 — Automated Driving Reference Architecture&lt;br&gt;• SAE Event Data Recorder Task Force</td>
</tr>
<tr>
<td>Topic Area</td>
<td>Functional Needs</td>
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| **ODD Definition**                             | • Specify the boundaries of the ODD including: road type, lighting, weather, traffic volume, incidents, etc.  
• Boundaries may be set by vehicle capabilities and/or jurisdictional requirement or other factors.                                                                 | • American Association of Motor Vehicle Administrators (AAMVA) Jurisdictional Guidelines for the Safe Testing and Deployment of Highly Automated Vehicles  
46  
• No known work with standards organizations; however, States are believed to have initiatives underway (Caltrans, Florida DOT)  
• SAE J3016 — Definitions of ODD                                                                                                                   |
| **Over-the-Air (OTA) Software Updates**        | • Assess security threats, risks and vulnerabilities  
• Provision common methods to update vehicle software by a secure procedure  
• Security controls and protocol definition                                                                                                         | • ITU-T X.1373 (03/2017) — International Telecommunication Standardization Sector (ITU-T) — Recommendation Secure Software Update Capability for Intelligent Transportation System Communication Devices                                                                 |
| **Sharing of static and dynamic road segment and traffic control device data**                  | • Automation benefits from dynamic data on work zones, road closures, SPAT, etc., and static data like bus stop locations and crosswalk geometry, and laws that originate from roadway owner-operators and may be relayed via digital maps | • U.S. DOT is convening States that publish work zone data and want to harmonize feeds (e.g., Iowa DOT, Colorado DOT), standards activity may follow  
• NCHRP 20-102(15) — Impacts of Connected and Automated Vehicle Technologies on the Highway Infrastructure  
• SAE J2945/10 — Recommended Practices for MAP/SPaT Message Development                                                                                                                                   |

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<th>Topic Area</th>
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</thead>
<tbody>
<tr>
<td><strong>Testing Approaches</strong></td>
<td>• Describe how tests address functional requirements</td>
<td>• SAE ORAD Verification and Validation Committee</td>
</tr>
<tr>
<td></td>
<td>• Facilitate discussion between parties</td>
<td>• SAE J3018 — Guidelines for Safe On-Road Testing of SAE Level 3, 4, and 5 Prototype Automated Driving Systems</td>
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<tr>
<td></td>
<td>• Define test apparatus, infrastructure, procedures</td>
<td>• Pegasus/AdaptIVe project</td>
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<td></td>
<td>• Define ODD-specific OEDR tests</td>
<td>• TNO Streetwise methodology</td>
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<td></td>
<td>• Define role of simulation, track testing and on-road testing</td>
<td>• U.S. Army Tank Automotive Research, Development and Engineering Center (TARDEC) guidelines</td>
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<td></td>
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<td>• Department of Defense Unmanned Systems Safety Guide being updated</td>
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<td>• FHWA Test and Evaluation for Vehicle Platooning</td>
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<td>• AAMVA — Jurisdictional Guidelines for the Safe Testing and Deployment of Highly Automated Vehicles</td>
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<td>• FHWA and SAE Cooperative Automation Research Modeling and Analysis (CARMA) program</td>
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<td>• US DOT V2I research program DSRC Roadside Unit (RSU) Specifications development</td>
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<tr>
<td><strong>Transition of DDT Control</strong></td>
<td>• Research to define time to alert, alert format, time to react if no takeover and driver states</td>
<td>• SAE ORAD Levels of Automation</td>
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<td>• Helps define minimal risk condition</td>
<td>• SAE DVI Committee</td>
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<td>• Need to define approaches for testing and certification</td>
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<th>Standardization-Related Activities</th>
</tr>
</thead>
<tbody>
<tr>
<td>ADS-DV Issues for Persons with Disabilities</td>
<td>• L4 and L5 ADS-Dedicated Vehicles (ADS-DVs) will eventually enable persons to travel at will who are otherwise unable to obtain a driver’s license for a conventional vehicle&lt;br&gt;• This work will document user issues specific to this population.</td>
<td>• SAE J3171 — ADS-DV User Issues for Persons with Disabilities</td>
</tr>
</tbody>
</table>
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U.S. Department of Transportation
A Framework for Automated Driving System Testable Cases and Scenarios
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# A Framework for Automated Driving System Testable Cases and Scenarios

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### Abstract

This report describes a framework for establishing sample preliminary tests for Automated Driving Systems. The focus is on light duty vehicles exhibiting higher levels of automation, where the system is required to perform the full dynamic driving task, including lateral and longitudinal control, as well as object and event detection and response.

### Key Words

automated driving systems, fail-safe mechanisms, object and event detection and response, tests, operational design domain
EXECUTIVE SUMMARY

Automated driving systems (ADS) are being developed to perform the primary functions of the dynamic driving task (DDT). These technologies hold great promise to improve safety and mobility for transportation. The goal of this research was to develop an example of a preliminary test framework for ADS that are in development and may come to market in the near to mid future. The following steps were conducted to support the development of the sample test framework.

1. Identify concept ADS
2. Identify attributes that define the operational design domain (ODD)
3. Identify object and event detection and response (OEDR) capabilities
4. Identify and assess failure modes and failure mitigation strategies

Technologies of interest in this work included light-duty automated driving functions that fell within Level 3 (L3) to Level 5 (L5) of the SAE\textsuperscript{1} levels of driving automation (SAE International, 2016). The functions were identified based on prototype vehicles and conceptual systems. A literature review which included popular media, press releases, technical journals, and conference proceedings was performed. This review identified potential concept ADS being developed or proposed by original equipment manufacturers (OEMs), suppliers, technology companies, and other organizations. The identified ADS were categorized into a set of generic names. The terminology was modified to ADS features (as opposed to functions) to more closely align with the standardization community’s language.

Twenty-four conceptual features were identified, and although a thorough search was conducted, the list is not exhaustive. The identified features were grouped into seven generic categories.

- L4 Highly Automated Vehicle/Transportation Network Company (TNC)
- L4 Highly Automated Highway Drive
- L4 Highly Automated Low Speed Shuttle
- L4 Highly Automated Valet Parking
- L4 Highly Automated Emergency Takeover
- L3 Conditional Automated Highway Drive
- L3 Conditional Automated Traffic Jam Drive

The generic names were developed to align with terminology from the SAE levels of driving automation (i.e., conditional driving automation [L3], high driving automation [L4], and full driving automation [L5]). Three of these generic features were selected to further support the development of an example of a testing framework for ADS (L3 Conditional Automated Traffic Jam Drive, L3 Conditional Automated Highway Drive, and L4 Highly Automated Vehicle/TNC).

\textsuperscript{1} In 2006 the Society of Automotive Engineers changed its name to SAE International. It’s standards are still called SAE standards.
The ODD describes the specific operating domains in which the ADS is designed to function. The ODD will likely vary for each ADS feature on a vehicle and specifies the condition in which that feature is intended and able to operate with respect to roadway types, speed range, lighting conditions, weather conditions, and other operational constraints. The ODD is specified by the technology developer, and the ADS should be able to identify whether it is operating within or outside of that ODD.

A literature review was performed for all the generic ADS features to identify the attributes that define the ODD. The review included popular media, press releases, technical journals, videos, and conference proceedings. An ODD taxonomy for this report was then defined. This taxonomy is hierarchical and includes the following top-level categories.

- Physical Infrastructure
- Operational Constraints
- Objects
- Connectivity
- Environmental Conditions
- Zones

Some of the challenges associated with ODD elements include their variability (e.g., rain droplet sizes can vary greatly: light rain; moderate rain; and heavy rain), as well as identifying or defining their boundaries. The work performed to identify the ODD lays a foundational framework from which the ODD can be further defined and delineated by the developer, and from which industry standards for ODD definition can be established.

OEDR refers to the subtasks of the DDT that include monitoring the driving environment (detecting, recognizing, and classifying objects and events and preparing to respond as needed) and executing an appropriate response to such objects and events (i.e., as needed to complete the DDT and/or DDT fallback; (SAE International, 2016).

A notional concept of operations (ConOps) was considered for the three selected ADS features. This served as a basis to perform an evaluation of the normal driving scenarios each ADS feature may encounter, including expected hazards (e.g., other vehicles, pedestrians) and sporadic/fluctuating events (e.g., emergency vehicles, construction zones). Baseline ODDs were identified for each of the features to frame this analysis. These baseline ODDs and scenario analyses were used to identify important OEDR functional capabilities. This analysis, along with the survey of ADS features, helped to identify two key sets of behaviors for the selected ADS features.

- Tactical Maneuver Behaviors
- OEDR Behaviors

Tactical maneuver behaviors may be viewed as more control-related tasks (e.g., lane following, turning). OEDR behaviors may be regarded as perception and decision-making related tasks.
(e.g., detecting and responding to pedestrians). This analysis generated a list of fundamental objects that may be relevant to an ADS’s driving task, as well as important events, which can be viewed as interactions with those objects. A list of potential responses the ADS could implement was identified, and these responses were mapped to the objects and events.

To develop a preliminary testing framework, existing test methods and tools were identified and evaluated to formulate an appropriate, comprehensive testing architecture. The evaluation resulted in three main components of a testing architecture for ADS, as well as advantages and disadvantages of each.

- Modeling and Simulation (M&S)
- Closed-Track Testing
- Open-Road Testing

A test scenario framework that fit flexibly within the test architecture was then identified and developed. The framework can be viewed as a multidimensional test matrix, with the following principal elements.

- Tactical Maneuver Behavior
- ODD Elements
- OEDR Behavior
- Failure Mode Behaviors

An ADS test scenario can be defined at a high level by these dimensions. Each of these dimensions can be viewed as a checklist of sorts to identify the maneuvers, ODD, OEDR, and failure mode behaviors that will outline the test setup and execution. Preliminary test procedures for a sampling of defined scenarios were then developed and these included, among other things, information on potential test personnel, test facilities, test execution, data collection, performance metrics, and success criteria that are translated from collected data and results.

Key challenges related to testing and evaluating ADS were also identified. These challenges were associated with the technology itself, as well as test setup and execution.

A high-level system failure mode and effects analysis (FMEA) was performed for a representative ADS. This representative ADS is described by a functional architecture under development by SAE International (Underwood, 2016). This notionally identified potential ADS failure modes, as well as their potential causes and effects. These failure modes were then mapped back to the selected ADS features. The FMEA focused on subsystems and processes related to the ADS, and the identified failure modes could largely be attributed to lack of information (e.g., resulting from a hardware failure) or poor/inadequate information (e.g., resulting from system latency). These potential failures could have significant impacts, ultimately resulting in collisions that could damage the vehicle or harm its occupants or other roadway users.
Potential failure mitigation strategies, including both fail-operational (FO) and fail-safe (FS) techniques, were then identified and analyzed. FS techniques are used when the ADS cannot continue to function, and may include options such as the following.

- Transitioning control to fallback-ready user
- Safely stopping in lane
- Safely moving out of travel lane/park

FO techniques can be used to allow the ADS to function at a reduced capacity, potentially for a brief period of time or with reduced capabilities, and may include options such as the following.

- Adaptive compensation – weighting data from a complementary component or subsystem more heavily (e.g., weighting camera data more heavily if lidar fails, etc.)
- Degraded modes of operation:
  o Reduced speed operation
  o Reduced level of automation operation
  o Reduced ODD operation
  o Reduced maneuver behavior operation
  o Reduced OEDR behavior operation

The appropriate failure mitigation strategy is highly dependent on the nature of the failure and the initial conditions under which the failure occurs. As such, implementing a hierarchy of techniques, which may include the list above, may be appropriate. ADS internal health-monitoring capabilities, such as measurement and indication of sensor and localization subsystem performance, were also identified as being important.
## Glossary of Terms and Acronyms

<table>
<thead>
<tr>
<th>Acronym</th>
<th>Description</th>
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<tbody>
<tr>
<td>4D/RCS</td>
<td>4-dimensional real-time control system</td>
</tr>
<tr>
<td>ACC</td>
<td>adaptive cruise control</td>
</tr>
<tr>
<td>ABS</td>
<td>antilock braking system</td>
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<tr>
<td>ADS</td>
<td>automated driving system</td>
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<tr>
<td>AEB</td>
<td>automatic emergency braking</td>
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<tr>
<td>ALC</td>
<td>automated lane centering</td>
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<tr>
<td>ASILS</td>
<td>ISO 26262 Automotive Safety Integrity Levels</td>
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<tr>
<td>BSW</td>
<td>blind spot warning</td>
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<tr>
<td>CBD</td>
<td>central business districts</td>
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<tr>
<td>ConOps</td>
<td>concept of operations</td>
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<tr>
<td>CV</td>
<td>connected vehicle</td>
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<tr>
<td>DARPA</td>
<td>Defense Advanced Research Projects Agency</td>
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<tr>
<td>DDT</td>
<td>dynamic driving task</td>
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<tr>
<td>DOD</td>
<td>Department of Defense</td>
</tr>
<tr>
<td>DSRC</td>
<td>dedicated short-range communication</td>
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<tr>
<td>ECU</td>
<td>electronic control unit</td>
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<tr>
<td>ESC</td>
<td>electronic stability control</td>
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<tr>
<td>FCW</td>
<td>forward collision warning</td>
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<tr>
<td>FHWA</td>
<td>Federal Highway Administration</td>
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<tr>
<td>FMEA</td>
<td>failure mode and effects analysis</td>
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<tr>
<td>FMECA</td>
<td>failure modes, effects, and criticality analysis</td>
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<tr>
<td>FMVSS</td>
<td>Federal Motor Vehicle Safety Standard</td>
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<tr>
<td>FO</td>
<td>fail-operational</td>
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<tr>
<td>FS</td>
<td>fail-safe</td>
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<tr>
<td>FTA</td>
<td>fault tree analysis</td>
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<tr>
<td>GPS</td>
<td>global positioning system</td>
</tr>
<tr>
<td>HAV</td>
<td>Highly Automated Vehicle</td>
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<tr>
<td>HazOP</td>
<td>Hazard and operability analysis</td>
</tr>
<tr>
<td>HIL</td>
<td>hardware-in-the-loop</td>
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<tr>
<td>HMI</td>
<td>human-machine interface</td>
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<tr>
<td>HOV</td>
<td>high-occupancy vehicle</td>
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<tr>
<td>HWD</td>
<td>highway drive</td>
</tr>
<tr>
<td>IMU</td>
<td>inertial measurement unit</td>
</tr>
<tr>
<td>INS</td>
<td>inertial navigation system</td>
</tr>
<tr>
<td>ISO</td>
<td>International Organization for Standardization</td>
</tr>
<tr>
<td>LDW</td>
<td>lane departure warning</td>
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<tr>
<td>LKA</td>
<td>lane keeping assist</td>
</tr>
<tr>
<td>LTAP/OD</td>
<td>left turn across path/opposite direction</td>
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<tr>
<td>M&amp;S</td>
<td>modeling and simulation</td>
</tr>
<tr>
<td>MRC</td>
<td>minimal risk condition</td>
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<tr>
<td>MUTCD</td>
<td>Manual on Uniform Traffic Control Devices</td>
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CHAPTER 1. INTRODUCTION AND BACKGROUND

PROJECT BACKGROUND AND PURPOSE

Since 1975, the first year that the Fatality Analysis Reporting System began collecting data, the rate of traffic fatalities per 100 million miles traveled in the United States has decreased by 66 percent, according to the National Highway Traffic Safety Administration’s Traffic Safety Facts 2015 data (NHTSA, 2017b). Advancements in motor vehicle safety have been made through continuous engineering innovation, public education, industry agreements, safety regulations, and safety rating programs. There is, however, significant room for continued focus on motor vehicle traffic safety. In October 2017 NHTSA reported that traffic fatalities increased by 5.4 percent from 2015 to 2016 (35,485 to 37,461) for the United States (NCSA, 2017), which follows an 8.4 percent increase from 2014 to 2015 (32,744 to 35,485) (NHTSA, 2017b).

Many forces are at work in the automotive industry to advance safety technology. The worldwide automotive industry has recognized driver performance (e.g., error and choice) as a key factor that impacts safety and has begun to introduce systems that complement the driver in terms of enhanced perception with 360-degree vehicle views and rear video systems. Systems that monitor the operational environment seeking to enhance driver detection and response, such as forward collision warning and even assisted automation such as lane keeping assist, are becoming ubiquitous in newer model vehicles. Additionally, 20 automakers have committed to making automatic emergency braking a standard feature in new vehicles by 2022 (IIHS, 2016).

Recently, research activities by several companies to develop automated driving systems that can perform certain driving functions automatically have captured the Nation's attention. ADS have been the subject of multiple congressional hearings and the public has provided numerous responses to NHTSA’s Federal Automated Vehicles Policy (Howe, Xu, Hoover, Elsasser, & Barickman, 2016), including over 1,100 responses from industry participants, State and municipal transportation agencies, policy groups, and citizens (Kyrouz, 2017). The United States Department of Transportation (USDOT) and NHTSA recently released an update to their Federal guidance for ADS that focused on their development and safe deployment and operation. NHTSA also continues to advance its ADS research. The research project summarized in this report sought to analyze aspects of ADS testing and develop examples of tests and evaluation methods for specific ADS features. A sample testing framework was developed that could further support the goals of improving safety for all users of the transportation network.

This project was accomplished in cooperation and consultation with NHTSA by completing the seven tasks described below.

Task 1: Revised Technical Work Plan

This work focused on reviewing, revising, and finalizing the work activities for the project. The project’s objectives, planned course of actions, milestones and deliverables, and any concerns
Task 2: Identification of Sample Concept ADS Functions

The goal of this work was to identify sample concept ADS functions based on specific automation technologies. The analysis and results of this task are presented in Chapter 2. Technologies of interest focused on light-duty vehicle functions that fell within L3 through L5 of the SAE International levels of automation (SAE International, 2016). The functions were identified based on prototype vehicles and conceptual systems. A literature review which included popular media, press releases, technical journals, and conference proceedings was performed. From this review, concept ADS being developed or proposed by original equipment manufacturers, suppliers, technology companies, and other organizations were identified. The identified functions were categorized into a set of generic names to be used throughout the subsequent tasks. The terminology was modified to ADS “features” (as opposed to “functions”) to be more in line with the standardization community’s language.

Twenty-four conceptual features were identified, and although a thorough search was conducted, the list is not exhaustive. The identified features were grouped into seven generic categories. Although all generic ADS features are considered in subsequent tasks, a deeper analysis was conducted on three select features.

Task 3: Identification of the Operational Design Domain

This work focused on identifying the ODD for all conceptual ADS. The analysis and results of this task are presented in Chapter 3. The ODD describes the specific operating domains in which the ADS is designed to function. The ODD will likely vary for each ADS feature on a vehicle, and specifies when that feature is intended and able to operate with respect to roadway types, speed range, lighting conditions, weather conditions, and other operational constraints. The ODD is specified by the technology developer, and the ADS should be able to identify whether it is operating within or outside of that ODD.

A literature review was conducted for all seven generic ADS features to determine the attributes that define the ODD. Three of the features were selected to further refine the ODD analysis. The review included popular media, press releases, technical journals, videos, and conference proceedings. The team then defined a hierarchical ODD taxonomy that could be used by government and industry to discuss ADS.

Some of the challenges associated with ODD elements include their variability (e.g., rain droplet sizes can vary greatly: light rain, moderate rain, heavy rain), as well as identifying or defining their boundaries. The work performed in this task to identify the ODD laid the foundation for subsequent tasks.
Task 4: Delineation of Object and Event Detection and Response Capabilities

This work sought to identify OEDR capabilities for the three selected ADS features that will enable them to function safely within their specified ODDs. The analysis and results of this task are presented in Chapter 4. OEDR refers to “the subtasks of the dynamic driving task (DDT) that include monitoring the driving environment (detecting, recognizing, and classifying objects and events and preparing to respond as needed) and executing an appropriate response to such objects and events (i.e., as needed to complete the DDT and/or DDT fallback (SAE International, 2016).

A notional concept of operations – called ConOps -- was developed for each of the three selected ADS features. These served as a basis for performing an evaluation of the normal driving scenarios each ADS feature may encounter, including expected hazards (e.g., other vehicles, pedestrians) and sporadic/ fluctuating events (e.g., emergency vehicles, construction zones). Baseline ODDs were defined for each of the selected features to frame this analysis. The baseline ODDs were developed by the research team by identifying relevant ODD attributes within the ConOps for each selected feature. These baselines were necessary because of the potential variability of ODDs for a given feature, as defined by their developers. These baseline ODDs and scenario analyses helped identify important OEDR functional capabilities.

Task 5: Development of Preliminary Tests and/or Evaluation Methods

This work sought to develop examples of preliminary tests and evaluation methods that could be used for ADS. The analysis and results of this task are presented in Chapter 5. Engineering judgments from previous test development experience, functional requirements, and use cases were used to identify test scenarios and preliminary procedures. These scenarios and procedures built upon the identified ADS features, ODDs, and OEDR capabilities.

Existing test methods and tools were identified and evaluated to formulate an appropriate, comprehensive testing architecture. A test scenario framework was then identified and developed that fit flexibly within the test architecture. The framework can be viewed as a multidimensional test matrix, with the dimensions encapsulating the principal elements from the other tasks (Feature, ODD, OEDR, Failure Modes). Preliminary test procedures — including information on potential test personnel, test facilities, test execution, data collection, and performance metrics, among other things — were developed for a sampling of these scenarios. No physical testing was conducted as part of this project.

Key challenges related to testing and evaluating ADS were also identified. These challenges were associated with the technology itself as well as test execution.

Task 6: Assessment of Fail-Operational/Fail-Safe Mechanisms

The goal of this work was to perform an assessment of fail-operational and fail-safe mechanisms for ADS. The analysis and results of this task are presented in Chapter 6. FO and FS mechanisms
are used when an ADS fails, resulting in unintended functionality or behavior. Designing, testing, and validating these mechanisms ensures that an ADS can achieve a minimal risk operating condition that removes the vehicle and its occupants from harm’s way in the event of a failure. For some features, the minimal risk condition may be to transition control back to a fallback-ready user; however, in other cases the ADS feature itself achieves that condition.

A high-level system failure mode and effects analysis for a representative ADS was performed. This representative ADS is described by a functional architecture under development by SAE International (Underwood, 2016). This analysis notionally identified potential ADS failure modes and their potential causes and effects. These failure modes were then mapped back to the selected ADS features. The FMEA focused on subsystems and processes related to the ADS, and the identified failure modes could largely be attributed to lack of information (e.g., resulting from a hardware failure) or poor/inadequate information (e.g., resulting from system latency). These potential failures could have significant impacts, ultimately resulting in collisions that could damage the vehicle or harm its occupants or other roadway users.

Failure mitigation strategies, including both FO and FS techniques, were identified and analyzed. FS techniques are used when the ADS cannot continue to function, while FO techniques allow the ADS to continue to function, although potentially at a reduced capacity or for an abbreviated period of time. The appropriate failure mitigation strategy is highly dependent on the nature of the failure and the initial conditions when the failure occurs. As such, a hierarchy of the techniques listed above may be appropriate. Health-monitoring capabilities were also identified as being important.

**Task 7: Final Report**

This task involved combining the results from the preceding tasks into a cohesive final report. The current report is the product of that effort.

This project contributes to the body of knowledge for ADS safety performance assessment, which could also play a role in system validation and verification. V&V includes methods and tools for determining whether design specifications and customer needs associated with the automated driving function have been met. Testing is critical in the development of an ADS, especially as it relates to safety performance and functionality. Testing occurs from the system-wide level all the way down to the individual unit level (e.g., camera sensor). This work focuses mostly on developing test cases that evaluate system-level functionality and capabilities (e.g., stay within a lane and stop at a stop sign).

**Federal Automated Vehicles Policy**

As mentioned above, NHTSA released the Federal Automated Vehicles Policy in 2016 (NHTSA, 2016a), which presents several key factors that play into the safe development and deployment of ADS, namely the following.
• Vehicle Performance Guidance
• Model State Policy
• NHTSA’s Current Regulatory Tools
• New Tools and Authorities

In 2017 NHTSA released an updated version of the 2016 FAVP policy titled *Automated Driving Systems 2.0: A Vision for Safety* (NHTSA, 2017a), which responded to the public comments received while maintaining the overall goal of safe development and deployment of ADS. NHTSA plans to regularly update its guidance as the technology and deployment landscape evolve. Most of the research described in this report was conducted before ADS 2.0 was published, and therefore relies on the information contained in the 2016 FAVP document. The document’s vehicle performance guidance section provides recommended best practices and expectations for the design, development, and testing stages for ADS. It applies to any entity performing activities related to ADS in any of those stages. It provides guidance on a number of ADS safety elements, including human-machine interfaces, vehicle cybersecurity, and crashworthiness, among others. It also provides guidance on four other areas that are specific to each individual ADS.

• ODD
• OEDR
• Fallback MRC
• Validation Methods

These four areas factor prominently in this research and in this report. The ODD, which is specified by the manufacturer or developing entity, describes the specific operating domains and conditions in which the system can function. Chapter 3 provides a thorough discussion of the importance and expansiveness of potential ODDs and presents a notional taxonomy for major ODD categories. OEDR refers to the subtasks of the DDT that include monitoring the driving environment (detecting, recognizing, and classifying objects and events and preparing to respond as needed) and executing an appropriate response to such objects and events (i.e., as needed to complete the DDT and/or DDT fallback) (SAE International, 2016). Chapter 4 presents an analysis of OEDR and identifies specific OEDR capabilities that are applicable to many ADS within their specified ODDs. It is important for ADS to have a fallback strategy and be able to execute that strategy when things go wrong. The MRC is a state that places the vehicle and its occupants out of harm’s way, to the best extent possible. Chapter 6 provides an analysis of potential failure modes for ADS and the potential mitigation strategies that ADS may be able to implement to achieve that MRC. Finally, existing testing and validation tools and methods may be insufficient to assess the safe operation of ADS, considering their added complexity and capabilities compared to traditional vehicles. The guidance suggests that developers should determine the appropriate testing methods and document their efforts and results to demonstrate that their systems are meeting performance expectations. Chapter 5 presents a discussion on potential methods for testing and validating ADS that seeks to assess safe performance and
identify performance boundaries. The chapter also identifies several key challenges associated with testing ADS.

**Stakeholder Engagement**

Relevant stakeholders expressed significant interest in this research project from an early stage. Therefore, a stakeholder working group was established to solicit their feedback on the research materials. The motivation for establishing this working group included incorporating expert perspectives to inform the project framework and provide input to conclusions. Multiple OEMs and Tier 1 suppliers participated in the working group, as well as representatives from academia conducting research in ADS.

Outreach and materials were planned for the early research tasks, which, after review by NHTSA, were disseminated to the stakeholders. Feedback provided by the stakeholders was reviewed and facilitated follow-up discussions, as deemed necessary. Many of the stakeholders had multiple personnel reviewing the project materials. This included personnel with policy and strategic planning expertise, in addition to personnel with technical expertise related to ADS. Holistically, the stakeholder group provided a breadth of knowledge to comment on the issues evaluated in this research. Information shared by the stakeholders was treated as non-attributable as it was incorporated into the project and this report. While the stakeholders did not provide any proprietary information or data as part of the engagement, information was collected individually and was not shared between stakeholders.

In addition to per-task engagement, which was conducted largely in a virtual setting, an in-person workshop open to all stakeholders was organized and held near the end of the technical portion of the research project. The workshop was held immediately after the conclusion of the Automated Vehicles Symposium² in San Francisco, California, in July 2017. The goals of the workshop included providing an interactive venue for sharing insights about the concepts addressed by the research, providing a summary review of the project tasks, and offering an opportunity to work toward consensus on some of the elements of those tasks. Ten experts from the stakeholder working group participated in the workshop, along with five members of the research team. The experts agreed on the importance of the research and the potential need to consider a common set of test scenarios. They also provided many suggestions on the content of the resulting task materials. The suggestions and feedback are incorporated into the discussions in the following chapters.

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² [www.automatedvehiclessymposium.org/home](http://www.automatedvehiclessymposium.org/home)
CHAPTER 2. AUTOMATED DRIVING SYSTEM FEATURES

OVERVIEW

This chapter describes the identification of sample concept ADS features that have been proposed for deployment. This analysis is focused on SAE Levels 3-5 ADS, such as Google’s self-driving car project (i.e., Waymo), and others like it that focus on next-generation automation. This step is critical because the sample concept ADS features are used to identify ODDs and OEDRs, develop preliminary tests and/or evaluation methods, and assess FS and FO mechanisms, which form a foundation to begin considering validation and verification approaches for ADS.

This chapter is organized into four sections: the approach to identifying concept ADS features, a framework for defining concept ADS features (including behaviors), a list and description of concept ADS features, and a set of generic ADS feature categories used throughout the report.

APPROACH

A four-stage approach was followed to identify ADS features: (1) review the literature, (2) define a framework for discussing ADS features, (3) define features and behaviors, and (4) categorize the features. To guide later analysis, priority ADS features on which to focus were identified.

To support the identification of ADS features, a framework for describing ADS throughout the project was established and implemented. As part of this effort, industry stakeholders were engaged. The stages involved in ADS feature identification were as follows.

- Review the literature, including popular media, press releases, technical journals, and conference proceedings, to identify concept ADS features proposed by major OEMs, technology companies, suppliers, and cities.
- Define a framework for describing ADS features, including a functional architecture, behaviors, level of automation, ODD, and OEDR.
- Define ADS features, including operational concepts and behaviors; further description of the ADS features can be found in subsequent chapters (e.g., ODD in Chapter 3).
- Categorize ADS features into a set of generic ADS features.

Over 50 literature sources were reviewed, including OEM websites, press releases of vehicles being tested in specific domains, NHTSA pre-crash scenario analysis (Najm, Smith, & Yanagisawa, 2007), NHTSA’s Fiscal Year 2017 budget request (NHTSA, 2016b), NHTSA L2 and L3 Human Factors Concepts (Blanco et al., 2015), Federal Highway Administration-managed lane use cases (FHWA, 2008), and technical and international publications, including proceedings of the 2015 and 2016 Automated Vehicles Symposiums and United Nations Economic Commission for Europe World Forum for Harmonization of Vehicle Regulations (WP.29) Automatically Commanded Steering Function working group. Research sponsored by
USDOT, such as the Crash Avoidance Metrics Partnership Automated Vehicle Research for Enhanced Safety (Christensen et al., 2015; NHTSA, 2016c), which details functional descriptions for on-road driving automation levels, was also used. Figure 1 depicts the stages involved in the ADS feature identification process.

![Figure 1. ADS Feature Selection Process](image)

**FRAMEWORK FOR DISCUSSING ADS FEATURES**

The development of a framework for discussing ADS features began with defining the terminology and a reference functional architecture. The term ADS “feature” was selected to be used in place of “function” or “application” since it is the same term used by OEMs to market a vehicle’s capabilities. While these terms have been used interchangeably, using “feature” is most consistent with existing descriptions of vehicle functionality in the marketplace. Using “feature” minimizes confusion when examining proprietary ADS offerings from OEMs in the literature review, as well as for future stakeholder engagement efforts with OEMs.

SAE International’s On-Road Automated Driving activities were used to develop a robust system to describe each feature. SAE J3016 defines an ADS feature as “a driving automation system’s design-specific functionality at a specific level of driving automation within a particular Operational Design Domain.” Referring to this definition, each feature can be described in terms of the following.
• Level of driving automation (using SAE International’s levels of driving automation)

• Design-specific functionality, with a focus on the DDT, is defined in SAE J3016 as: “All of the real-time operational and tactical functions required 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 the following.

1. Lateral vehicle motion control via steering (operational)

2. Longitudinal vehicle motion control via acceleration and deceleration (operational)

3. Monitoring the driving environment via object and event detection, recognition, classification, and response preparation (operational and tactical)

4. Object and event response execution (operational and tactical)

5. Maneuver planning (tactical)

6. Enhancing conspicuity via lighting, signaling and gesturing, etc. (tactical)

• ODDs in which it operates

• FS/FO capability

Per SAE J3016, DDT elements 3 and 4 can be collectively referred to as OEDR and are covered in Chapter 4 of this report. The remaining DDT elements 1, 2, 5, and 6 are discussed in this chapter, and are loosely described as “tactical and operational maneuvers.” That term would typically include aspects of OEDR, but OEDR is covered in Chapter 4. It should be noted that nomenclature for many of these terms, such as behaviors, maneuvers, ODD, OEDR, and FS/FO can vary in their use throughout the literature in the context of ADS. There are ongoing efforts at SAE to clarify and standardize these terms. For example, the SAE ORAD Committee Task Force on Behaviors and Maneuvers is in the process of developing an information report to describe several of these terms and supporting taxonomies. Without an existing common framework, this report has been kept as consistent as possible with existing SAE efforts, but does consider other literature sources. More information on strategic, tactical, and operational levels of control will be provided below.

**Levels of Driving Automation**

SAE International, the Bundesanstalt für Straßenwesen, Organisation Internationale des Constructeurs d’Automobiles, and UNECE WP.29 have agreed upon common definitions for levels of driving automation, which are described in SAE J3016. SAE J3016 provides definitions for key terms, including MRC and ODD. It should be noted that J3016 was revised in September 2016, and now a joint SAE-International Organization for Standardization task force has been
formed for future updates. Table 1 shows the SAE J3016 levels of driving automation for on-road vehicles. USDOT adopted these levels of driving automation into its policy guidance to establish standardization to aid in clarity and consistency.

<table>
<thead>
<tr>
<th>Level</th>
<th>Name</th>
<th>Narrative Definition</th>
<th>DDT - Sustained lateral and longitudinal vehicle motion control</th>
<th>DDT - OEDR</th>
<th>DDT fallback</th>
<th>ODD</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>No Driving Automation</td>
<td>The performance by the driver of the entire DDT, even when enhanced by active safety systems.</td>
<td>Driver</td>
<td>Driver</td>
<td>Driver</td>
<td>n/a</td>
</tr>
<tr>
<td>1</td>
<td>Driver Assistance</td>
<td>The sustained and ODD-specific execution by a driving automation system of either the lateral or the longitudinal vehicle motion control subtask of the DDT (but not both simultaneously) with the expectation that the driver performs the remainder of the DDT.</td>
<td>Driver and System</td>
<td>Driver</td>
<td>Driver</td>
<td>Limited</td>
</tr>
<tr>
<td>2</td>
<td>Partial Driving Automation</td>
<td>The sustained and ODD-specific execution by a driving automation system of both the lateral or the longitudinal vehicle motion control subtask of the DDT with the expectation that the driver completes the OEDR subtask and supervises the driving automation system.</td>
<td>System</td>
<td>Driver</td>
<td>Driver</td>
<td>Limited</td>
</tr>
<tr>
<td>3</td>
<td>Conditional Driving Automation</td>
<td>The sustained and ODD-specific performance by an ADS of the entire DDT with the expectation that the DDT fallback-ready user is receptive to ADS-issued requests to intervene, as well as to DDT performance-relevant system failures in other vehicle systems, and will respond appropriately.</td>
<td>System</td>
<td>System</td>
<td>Fallback-ready user (becomes the driver during fallback)</td>
<td>Limited</td>
</tr>
<tr>
<td>4</td>
<td>High Driving Automation</td>
<td>The sustained and ODD-specific performance by an ADS of the entire DDT and DDT fallback without any expectation that a user will respond to a request to intervene.</td>
<td>System</td>
<td>System</td>
<td>System</td>
<td>Limited</td>
</tr>
<tr>
<td>5</td>
<td>Full Driving Automation</td>
<td>The sustained and unconditional (i.e., not ODD-specific) performance by an ADS of the entire DDT and DDT fallback without any expectation that a user will respond to a request to intervene.</td>
<td>System</td>
<td>System</td>
<td>System</td>
<td>Unlimited</td>
</tr>
</tbody>
</table>

**Design Specific Functionality**

To best define the identified functions, a framework that references a functional system architecture was established and implemented. SAE International ORAD’s J3131 work on
The SAE International draft functional architecture (Figure 3) was adapted to describe system components (i.e., sensors, environment [ODD], perception, plan, act, etc.) and their interactions in relation to the technical analysis in this project. The functional architecture is helpful in structuring a definition of specific embodiments of ADS features. This architecture depicts the organization of vehicle software, electronics, and hardware, as well as the relationship to the external environment.
Behaviors can be used to help to define the functionality of each feature in terms of OEDR behaviors (described in Chapter 4) and other tactical and operational maneuvers (described in this chapter). Behaviors may be distributed within a hierarchy based on the duration of the behavior (as shown in Figure 4; note: the durations shown are rough order-of-magnitude estimates.) This work focuses on tactical and operational behaviors in the 1- to 10-s range, based on the logic that strategic/mission-level behaviors are not part of the DDT, and that active safety is out of the scope of this work because it is not specific to ADS.
ADS Tactical and Operational Maneuvers

Through the literature review and analysis, a working list of tactical and operational maneuvers related to ADS driving control was created.

- **Parking** – ADS comes to a complete stop within a vacant parking spot; may be further qualified by parallel or perpendicular orientations, lot type (closed/open), initiation conditions, etc.
- **Maintain Speed** – ADS maintains a safe speed set through longitudinal control with acceptable following distances.
- **Car Following** – ADS identifies and follows a target vehicle at acceptable following distance while staying within a lane through longitudinal and lateral control.
- **Lane Centering** – ADS stays within a lane through lateral control.
- **Lane Switching/Overtaking** – ADS crosses lanes or overtakes an upcoming vehicle based on a projected path or hazard.
- **Enhancing Conspicuity** – ADS controls vehicle blinkers, headlights, horn, or other methods used to communicate with other drivers.
- **Obstacle Avoidance** – ADS identifies and responds to on-road hazards, such as pedestrians, debris, animals, etc.
- **Low-Speed Merge** – ADS merges into a lane below about 45 mph, for example from an exit ramp, by identifying a vacant lane position and matching speed.
- **High-Speed Merge** – ADS merges into a lane above about 45 mph, for example from an exit ramp, by identifying a vacant lane position and matching speed.
- **Navigate On/Off-Ramps** – ADS drives on on/off-ramps, which are typically one-way, steeply curved, and banked road segments.
- **Right-of-Way Decisions** – ADS obeys directional restrictions; for example, one-way roads and actively managed lanes.
- **Follow Driving Laws** – ADS obeys motor vehicle codes and local ordinances; for example, following distances, speed limits, etc. This may include driving norms that vary by region as well.
- **Navigate Roundabouts** – ADS determines right-of-way, enters, navigates, and exits a roundabout, and communicates with other road users as necessary.
- **Navigate Intersection** – ADS determines right-of-way, enters, navigates, and exits intersections, including signalized, stop signs, 4/3/2-ways, and communicates with other road users as necessary; may include left or right turns across oncoming traffic.
- **Navigate Crosswalk** – ADS determines right-of-way, enters, navigates, and exits pedestrian crosswalks, and communicates with other road users as necessary.
- **Navigate Work Zone** – ADS determines right-of-way and traffic patterns, enters, navigates and exits work zone, and communicates with other road users as necessary.
- **N-Point Turn** – ADS makes a heading adjustment that involves alternating between forward and reverse movement and adjusting steering to reposition the vehicle within a tight space.
- **U-Turn** – ADS determines right-of-way, initiates, and completes a U-turn, and communicates with other road users as necessary.
• **Route Planning** – ADS uses various information to define (and potentially update) a route network including road segments, turns, etc.

To serve as an example, Figure 5 displays some of the behaviors for L3 Nissan Piloted Drive.

![Sample Capabilities for Nissan Piloted Drive](Inside EVs, 2015)

**Figure 5. Sample Capabilities for Nissan Piloted Drive (Inside EVs, 2015)**

**IDENTIFICATION OF CONCEPT ADS FEATURES**

Twenty-four concept ADS features were identified.

1. Audi Traffic Jam Pilot
2. Audi Highway Pilot
3. Auro Self-Driving Shuttle
4. Baidu Automated TNC
5. Bosch Valet Parking
6. CityMobil2 Automated Shuttle
7. Bosch Highway Pilot
8. EZ10 Self-Driving Shuttle
9. Ford Automated TNC
10. GM Cruise Automation TNC
11. Google Car
12. Honda Automated Drive

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3 TNC: Transportation Network Company
13. Mercedes Highway Pilot Truck
14. Navya Arma Shuttle
15. Nissan Autonomous Drive
16. Olli Local Motors Shuttle
17. Otto Trucking
18. Tesla Self-Drive
19. Toyota Chauffeur
20. Toyota Guardian
21. Uber Automated TNC
22. Varden Labs Self-Driving Shuttles
23. Volkswagen I.D. Pilot
24. Volvo IntelliSafe Auto Pilot

These 24 features were categorized into the following seven generic categories.

1. L3 Conditional Automated Traffic Jam Drive
2. L3 Conditional Automated Highway Drive
3. L4 Highly Automated Low Speed Shuttle
4. L4 Highly Automated Valet Parking
5. L4 Highly Automated Emergency Take-Over
6. L4 Highly Automated Highway Drive
7. L4 Highly Automated Vehicle/TNC

Table 2 shows which ADS features belong to the seven generic categories.

<table>
<thead>
<tr>
<th>Category</th>
<th>Generic ADS Feature</th>
<th>ADS Features</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>L3 Conditional Automated Traffic Jam Drive</td>
<td>Audi Traffic Jam Pilot</td>
</tr>
<tr>
<td>2</td>
<td>L3 Conditional Automated Highway Drive</td>
<td>Mercedes Highway Pilot Truck</td>
</tr>
<tr>
<td>3</td>
<td>L4 Highly Automated Low Speed Shuttle</td>
<td>Auro Self-Driving Shuttle, CityMobil2 Automated Shuttle, EZ10 Self-Driving Shuttle, Navya Arma Shuttle, Olli Local Motors Shuttle, Varden Labs Self-Driving Shuttles</td>
</tr>
<tr>
<td>4</td>
<td>L4 Highly Automated Valet Parking</td>
<td>Bosch Valet Parking</td>
</tr>
<tr>
<td>5</td>
<td>L4 Highly Automated Emergency-Take Over</td>
<td>Toyota Guardian</td>
</tr>
<tr>
<td>6</td>
<td>L4 Highly Automated Highway Drive</td>
<td>Audi Highway Pilot, Bosch Highway Pilot, Otto Trucking</td>
</tr>
</tbody>
</table>
Each of the concept ADS features is described below, organized by generic ADS feature categories. Each generic feature category is described in terms of ConOps and enabling technology, and each identified concept ADS feature is described in terms of tactical maneuver behaviors, commercial availability, and level of automation. The analysis was based largely on the literature review. Due to the incompleteness of the publicly available information, engineering judgment was used in some cases to predict certain data. In these cases, a “?” is provided in the accompanying table instead of an “X.”

**Category 1, L3 Conditional Automated Traffic Jam Drive Feature**

L3 Traffic Jam Drive features autonomous travel for stop-and-go traffic. It allows the vehicle to act without input from the human operator at slower speeds if a preceding car can be followed. A human operator is the fallback for the DDT. The Audi Traffic Jam Pilot (Audi, 2015) uses adaptive cruise control and LKA to allow slow driving in traffic jams. The 2017 Audi A4 and Q7, which contain an early version of this feature (SAE International L2), follow the vehicle ahead and automatically operate the accelerator and brake within the limits of the system so the vehicle is kept in lane. The car steers, accelerates, and brakes automatically, and allows the driver to take his/her hands off the steering wheel in slow-moving traffic for 15 seconds at a time (Jaynes, 2016). The future version of the feature is expected to achieve L3 driving automation, and to be commercially available on the 2019 Audi A8.

Ford has announced that the company is finalizing their own traffic jam assist; however, they have offered no timeline for its debut. The traffic jam assist will be an autopilot that combines ACC and LKA, assisting the driver with steering, braking and acceleration (Ford Motor Company, 2015).

Table 3. L3 Conditional Automated Traffic Jam Drive Features

| ADS Features and Tactical and Operational Maneuvers | Commercially Available? (Y/N) | Level of Automation (SAE 1-5) | Parking | Maintain Speed | Car Following | Lane Centering | Lane Switching/Overtaking | Enhancing Conspicuity | Merge | Navigate On/Off Ramps | Follow Driving Laws | Navigate Roundabouts | Navigate Intersection | Navigate Crosswalk | Navigate Work Zone | N-Point Turn | U-Turn | Route Planning |
|---------------------------------------------------|------------------------------|------------------------------|---------|----------------|---------------|----------------|------------------------|----------------------|-------|----------------------|-------------------|------------------|------------------|------------------|------------------|----------------|---------|
| Audi Traffic Jam Pilot (2019)                      | N                            | 3                            | X       | X              | X             |                |                        |                      |       |                      |                   |                  |                  |                  |                  |                  |            |        |

**Category 2, L3 Conditional Automated Highway Drive Feature**

L3 Highway Drive allows the vehicle to act without input from the human operator on highways (e.g., ACC and close-headway platooning). The feature enables the vehicle to travel at a desired speed and adjust the speed based on the surrounding traffic. The system is also able to overtake slower vehicles or merge at highway junctions.

Table 4. L3 Conditional Automated Highway Drive Features

| ADS Features and Tactical and Operational Maneuvers | Commercially Available? (Y/N) | Level of Automation (SAE 1-5) | Parking | Maintain Speed | Car Following | Lane Centering | Lane Switching/Overtaking | Enhancing Conspicuity | Merge | Navigate On/Off Ramps | Follow Driving Laws | Navigate Roundabouts | Navigate Intersection | Navigate Crosswalk | Navigate Work Zone | N-Point Turn | U-Turn | Route Planning |
|---------------------------------------------------|------------------------------|------------------------------|---------|----------------|---------------|----------------|------------------------|----------------------|-------|----------------------|-------------------|------------------|------------------|------------------|------------------|----------------|---------|
| Mercedes Highway Pilot Truck (2020)                | N                            | 3?                           | X       | X              | X             |                |                        |                      |       |                      |                   |                  |                  |                  |                  |                  |            |        |

**Category 3, L4 Highly Automated Low-Speed Shuttle Feature**

L4 Highly Automated Low Speed Shuttle is an automated shuttle that drives along a predetermined route. The system does not need an onboard driver control interface and is limited to speeds below 25 mph. For example, Olli (Local Motors, 2017) is a self-driving electric vehicle that has been tested in several locations in the United States and is currently deployed in Germany. Olli can be part of a fleet management system with a central operation center designed to solve the transportation needs of large campuses and municipalities. A smart phone application is available for users to find existing routes, share a ride, and input pick-up and drop-off locations for door-to-door service.
CityMobil2 (CityMobil2, 2017) piloted a platform for automated road transport systems, which was implemented in several urban environments across Europe. A large-scale demonstration in the Greek city of Trikala was completed in winter 2015. A fleet of six Robosoft vehicles drove at a speed of about 12.5 mph along a 1.5-mile itinerary that was integrated into the main city road network. During the last large-scale demonstration, automated shuttles operated in conditions close to normal traffic conditions, operating along with other road users, including cars, pedestrians, and cyclists. Almost 1,490 trips were recorded during the demonstration period. During this time, the vehicles covered more than 3,500 km and transported more than 12,000 passengers in the city center.

The French manufacturer Navya Technologies SAS’s Arma (Navya, 2017) is a 100-percent electric, intelligent, and autonomous shuttle at the service of mobility, launched in October 2015. French specialists spent 10 years of research to achieve L4 driving automation. The Navya Arma does not require any driver or specific infrastructure, can avoid static and dynamic obstacles, and can transport up to 15 passengers and safely drive up to 28 mph. In terms of functional safety, the L4 Highly Automated Shuttle Feature could address some of the safety concerns (i.e., human error and situational awareness) associated with driving 15-passenger vehicles. Other safety concerns with vehicles of this size (such as tire pressure) could still pose a safety hazard if not checked regularly. Its batteries can be recharged by induction and can last from 5 to 13 hours, depending on the configuration and the traffic conditions.

Another French manufacturer, Easymile SAS, (EasyMile, 2017) is a start-up specializing in providing both the software powering autonomous vehicles and last-mile smart mobility solutions. Its EZ10 is an electric shuttle dedicated to smart mobility designed to cover short distances and predefined routes in multi-use environments. EZ10 can operate in three modes, needs only light infrastructure to operate, meets smart transportation requirements, and has operational and top speeds of 12 mph and 25 mph, respectively. The shuttle service runs on virtual tracks that can be easily configured to accommodate sudden shifts in demand. The service operator can set up new timetables and create new virtual stops to facilitate the flow of traffic. Using redundant embedded systems inspired by aeronautics, EZ10 ensures the safety of passengers and road users from road hazards and technical failures. Their hybrid sensing approach combines shuttle localization through vision, laser, and differential GPS data. This approach ensures smooth operation irrespective of infrastructure constraints, visibility, and/or weather conditions. Detection of static or moving objects and people relies on redundant perception systems. Following the detection of an object, the EZ10 adjusts its trajectory and speed, leading to obstacle avoidance. A “safety chain” as a stand-alone collision avoidance feature adds to vehicle and user safety. Additionally, fleet management software enables the remote and real-time monitoring and control of the fleet of EZ10 shuttles.
### Table 5. L4 Highly Automated Low Speed Shuttle Features

<table>
<thead>
<tr>
<th>ADS Features and Tactical and Operational Maneuvers</th>
<th>Commericially Available? (Y/N)</th>
<th>Level of Automation (SAE 1-5)</th>
<th>Parking</th>
<th>Maintain Speed</th>
<th>Car Following</th>
<th>Lane Centering</th>
<th>Lane Switching/Overtaking</th>
<th>Enhancing Conspicuity</th>
<th>Merge</th>
<th>Navigate On/Off Ramps</th>
<th>Follow Driving Laws</th>
<th>Navigate Roundabouts</th>
<th>Navigate Crosswalk</th>
<th>Navigate Work Zone</th>
<th>Navigate Intersection</th>
<th>N-Point Turn</th>
<th>U-Turn</th>
<th>Route Planning</th>
</tr>
</thead>
<tbody>
<tr>
<td>CityMobil2 <em>(demo in multiple European cities, 2014-2016)</em></td>
<td>N</td>
<td>4</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>?</td>
<td>?</td>
<td>?</td>
</tr>
</tbody>
</table>

**Category 4. L4 Highly Automated Valet Parking Feature**

L4 Highly Automated Valet Parking involves a car, potentially unoccupied, that can find a parking spot and park itself. Bosch’s Valet Parking feature is a future concept (release date unclear) offering a new laser technology that operates without the assistance of GPS signals. Drivers drop the vehicle off at a designated area near a parking garage entrance and pick it up at a designated area *(Bosch, 2017)*. This feature combines a variety of different connected and automated parking solutions being developed by Bosch.

### Table 6. L4 Highly Automated Urban Valet Parking Features

<table>
<thead>
<tr>
<th>ADS Features and Tactical and Operational Maneuvers</th>
<th>Commericially Available? (Y/N)</th>
<th>Level of Automation (SAE 1-5)</th>
<th>Parking</th>
<th>Maintain Speed</th>
<th>Car Following</th>
<th>Lane Centering</th>
<th>Lane Switching/Overtaking</th>
<th>Enhancing Conspicuity</th>
<th>Merge</th>
<th>Navigate On/Off Ramps</th>
<th>Follow Driving Laws</th>
<th>Navigate Roundabouts</th>
<th>Navigate Crosswalk</th>
<th>Navigate Work Zone</th>
<th>Navigate Intersection</th>
<th>N-Point Turn</th>
<th>U-Turn</th>
<th>Route Planning</th>
</tr>
</thead>
</table>
Category 5, L4 Highly Automated Emergency Takeover

In the event a driver is in impending danger, Emergency Takeover assumes control of the vehicle and guides it to a safe stop. Cameras inside the car track the driver’s head movement, while software uses sensor data to estimate when a person needs help spotting or avoiding a potentially dangerous situation. Toyota’s Guardian system is distinct from other ADS features and operates in parallel with a human rather than in series (Goreham, 2017). The system is designed to reduce complications of a handoff between the car and human driver, since the driver is expected to maintain control at all times.

Table 7. L4 Highly Automated Emergency Takeover Features

| ADS Features and Tactical and Operational Maneuvers | Commericially Available? (Y/N) | Level of Automation (SAE 1-5) | Parking | Maintain Speed | Car Following | Lane Centering | Lane Switching/Overtaking | Enhancing Conspicuity | Merge | Navigate On/Off Ramps | Follow Driving Laws | Navigate Roundabouts | Navigate Intersection | Navigate Crosswalk | Navigate Work Zone | N-Point Turn | U-Turn | Route Planning |
|---------------------------------------------------|---------------------------------|-------------------------------|---------|----------------|---------------|----------------|--------------------------|----------------------|------|-----------------------|------------------|----------------------|-------------------|------------------|-------------------|-----------------|------------------|-----------------|--------|---------------|
| Toyota Guardian                                   | N                               | 4                             | X       | X              | X             | X              | X                        | X                   | X    | X                     |                  |                     |                   |                 |                   |                 |                  |

Category 6, L4 Highly Automated Highway Drive Feature

The L4 Highway Drive system handles the entire DDT on a highway route, allowing the passenger to engage in other tasks; the system is responsible for the fallback performance of DDT.

Bosch has publicly outlined its concept for its Highway Pilot system that can assume all driving duties on open highways, from entrance ramp to exit ramp. According to Bosch, emerging technology will be aided by vehicle-to-vehicle and vehicle-to-infrastructure communication. Bosch expects a fully self-driving Highway Pilot by 2020 (Stoklosa, 2016). Otto demonstrated a highly automated truck (Barber, 2016) in 2016 in coordination with the Colorado Department of Transportation that was intended as an SAE International L4 system operating on highways.
**Category 7, L4 Highly Automated Vehicle/Transportation Network Company (TNC) Feature**

L4 Highly Automated Vehicle/TNC enables the vehicle to pick up passengers or goods and drive to a destination without the need for an onboard driver. This feature may operate within a broad ODD, which is explored in further detail in Chapter 3. However, confirmation has not yet been provided that these features will operate in all ODDs, and thus they are categorized as L4 as opposed to full driving automation (L5). For example, these vehicle fleets may initially be limited to the cities in which they are tested. OEMs developing this technology have stated that they intend to pursue full autonomy. This feature could become commercially available as soon as 2020. Examples of this feature include the Google Car (Waymo, 2017a), Tesla Self-Drive (Tesla, 2017), Volkswagen I.D. Pilot Mode (Nishimoto, 2016), Volvo Intellisafe Auto Pilot (Volvo, 2017), and Nissan Autonomous Drive (Nissan, 2017).

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**Table 8. L4 Highly Automated Highway Drive Features**

<table>
<thead>
<tr>
<th>ADS Features and Tactical and Operational Maneuvers</th>
<th>Commercially Available? (Y/N)</th>
<th>Level of Automation (SAE 1-5)</th>
<th>Parking</th>
<th>Maintain Speed</th>
<th>Car Following</th>
<th>Lane Centering</th>
<th>Lane Switching/Overtaking</th>
<th>Enhancing Conspicuity</th>
<th>Merge</th>
<th>Navigate On/Off Ramps</th>
<th>Follow Driving Laws</th>
<th>Navigate Roundabouts</th>
<th>Navigate Intersection</th>
<th>Navigate Crosswalk</th>
<th>Navigate Work Zone</th>
<th>N-Point Turn</th>
<th>U-Turn</th>
<th>Route Planning</th>
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<tr>
<td>Audi Highway Pilot</td>
<td>N</td>
<td>4</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>?</td>
<td>X</td>
<td>?</td>
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</tr>
</tbody>
</table>
Table 9. L4 Highly Automated Vehicle/TNC Features

| ADS Features and Tactical and Operational Maneuvers | Commercially Available? (Y/N) | Level of Automation (SAE 1-5) | Parking | Maintain Speed | Car Following | Lane Centering | Lane Switching/Overtaking | Enhancing Conspicuity | Merge | Navigate On/Off Ramps | Follow Driving Laws | Navigate Roundabouts | Navigate Intersection | Navigate Crosswalk | Navigate Work Zone | N-Point Turn | U-Turn | Route Planning |
|---------------------------------------------------|-------------------------------|-------------------------------|--------|---------------|---------------|---------------|--------------------------|-----------------------|-------|------------------------|----------------------|---------------------|---------------------|----------------|----------------|---------------|-----------|
| Waymo Automated TNC                               | N                             | 4                             | X      | X             | X             | X             | X                        | X                      | X     | X                      | X                    | X                   | X                   | X             | X             | X            | X         | X             |
| Tesla Self-Drive                                  | N                             | 4                             | X      | X             | X             | X             | X                        | X                      | X     | X                      | X                    | X                   | X                   | X             | X             | X            | X         | X             |
| Volkswagen I.D. Pilot                             | N                             | 4?                            | X      | X             | X             | X             | X                        | X                      | X     | X                      | X                    | X                   | X                   | X             | X             | X            | X         | X             |
| Volvo IntelliSafe Auto Pilot                      | N                             | 4?                            | X      | X             | X             | X             | X                        | X                      | X     | X                      | X                    | X                   | X                   | X             | X             | X            | X         | X             |
| Nissan Autonomous Drive (2020)                     | N                             | 4?                            | X      | X             | X             | X             | X                        | X                      | X     | X                      | X                    | X                   | X                   | X             | X             | X            | X         | X             |
| GM Cruise Automation                              | N                             | 4                             | X      | X             | X             | X             | X                        | X                      | X     | X                      | X                    | X                   | X                   | X             | X             | X            | X         | X             |
| Uber Automated TNC                                 | N                             | 4                             | X      | X             | X             | X             | X                        | X                      | X     | X                      | X                    | X                   | X                   | X             | X             | X            | X         | X             |
| Honda Automated Drive (2020)                       | N                             | 4                             | X      | X             | X             | X             | X                        | X                      | X     | X                      | X                    | X                   | X                   | X             | X             | X            | X         | X             |
| Ford Automated TNC (2022)                          | N                             | 4                             | X      | X             | X             | X             | X                        | X                      | X     | X                      | X                    | X                   | X                   | X             | X             | X            | X         | X             |
| Baidu Automated TNC                               | N                             | 4                             | X      | X             | X             | X             | X                        | X                      | X     | X                      | X                    | X                   | X                   | X             | X             | X            | X         | X             |
| Toyota Chauffeur                                   | N                             | 4                             | X      | X             | X             | X             | X                        | X                      | X     | X                      | X                    | X                   | X                   | X             | X             | X            | X         | X             |

**Summary of Generic ADS Features**

Table 10 compares the generic ADS features. The tactical maneuver behaviors exhibited by each feature vary as a function of where and how they are intended to operate. Having more tactical maneuver behaviors does not necessarily indicate complexity. For example, low-speed shuttles may exhibit most of the tactical maneuver behaviors, but their ODD is limited by speed and reduces the complexity of the technical problem, thus enabling near-term deployment.
### Table 10. Summary of Generic ADS Features

| Generic ADS Features and Tactical and Operational Maneuvers (Summary) | Commercially Available? (Y/N) | Level of Automation (SAE 1-5) | Parking | Maintain Speed | Car Following | Lane Centering | Lane Switching/Overtaking | Enhancing Conspicuity | Merge | Navigate On/Off Ramps | Follow Driving Laws | Navigate Roundabouts | Navigate Intersection | Navigate Crosswalk | Navigate Work Zone | N-Point Turn | U-Turn | Route Planning |
| L3 Conditional Automated Highway Drive (2020) | N | 3 | X | X | X | X | X | X | | | | | | | | | | | | | |
| L4 Highly Automated Low Speed Shuttle (2018) | Y | 4 | X | X | X | X | X | X | X | X | X | ? | X | X | X | | | | | |
| L4 Highly Automated Highway Drive (2020) | N | 4 | X | X | X | ? | X | ? | | | | | | | | | | | | |
| L4 Highly Automated Emergency Take-Over (?) | N | 4 | X | X | X | X | X | X | X | | | | | | | | | | | |
| L4 Highly Automated Vehicle/TNC (2020) | N | 4 | X | X | X | X | X | X | X | X | X | X | X | X | X | | | | | |

**SUMMARY**

This chapter identified concept ADS features and illustrated how ADS functionality is emerging. Specifically, it described functionality and proposed timelines for commercial deployment across the different SAE International levels of driving automation. There is no clear correlation between level of driving automation and the timeline for commercial deployment. For L3 systems, conditional automated traffic jam drive is expected in 2018, while conditional automated highway drive is not expected until 2020. For L4 systems, highly automated low speed shuttles are expected in 2018, and other features are slated for 2020. A figure showing ADS deployment timelines from SAE J3016 is reproduced in Figure 6.
The ADS features described in this chapter provide the basis for identifying ODD attributes in Chapter 3, OEDR capabilities in Chapter 4, test cases in Chapter 5, and FS/FO mechanisms in Chapter 6. Operational descriptions of the features provide insights into where and when an ADS can operate. The tactical maneuver behaviors describe the functionality that test cases will need to evaluate. The generic names provide a simple and consistent naming system that is referenced throughout to describe concept ADS features.
CHAPTER 3. OPERATIONAL DESIGN DOMAIN

OVERVIEW

This chapter describes the identification of attributes that can be used to define the ODDS for ADS. An ODD describes the specific operating domains in which an ADS feature is designed to function with respect to roadway types, speed range, lighting conditions (day and/or night), weather conditions, and other operations constraints. ODD will likely vary for each ADS feature, even if there is more than one ADS feature on a vehicle. The testing framework presented in this report considers the potential range of ODDS and how ODDS factor into developing potential test cases.

APPROACH

A three-stage approach was taken to define the ODDS.

1. Review the literature, including popular media, press releases, technical journals, and conference proceedings to identify key concepts, enumerate potential ODD characteristics, and examine approaches to ODD in other industries.
2. Define and categorize ODD into a taxonomy that can be used by DOTs and industry to discuss ADS.
3. Describe ODDs in which concept ADS features may operate based on literature review and engineering judgment.

Over 50 literature sources were reviewed, including OEM websites, press releases, USDOT documents, including NHTSA pre-crash scenario analysis and FHWA managed lane use case, as well as technical and international publications, including proceedings of the 2015 and 2016 automated vehicles symposiums. Additionally, the NHTSA fiscal year 2017 Budget Request to Congressional Appropriations Committees (NHTSA, 2016b) identifies several ADS use cases that were considered when defining the ODD for this analysis. It should be noted that given the emerging and highly competitive nature of ADS technology, it is inherently difficult to obtain explicit and complete information about the intended ODD of an ADS feature. In the absence of information about an ODD, engineering judgement was used at times to define the ODD taxonomy and identify the ODD for concept ADS features.
Certain pieces of information in the literature and media were particularly helpful with ODD identification and taxonomy definition, including the following.

- **Descriptions in the product literature**
  - In some cases, ODDs have been explicitly defined in the product literature and through prototype testing and deployment materials, especially roadway types and speeds.

- **Videos**
  - Videos provide visual documentation of vehicles being tested in specific domains (e.g., weather conditions, physical infrastructure, shared road users, etc.), which serves as the basis for inferring the potential ODDs for these ADS features.
  - Videos range from official marketing material to product research and testing videos to independent videos of released products for many different ADS features that are being tested or introduced by OEMs.

- **Perception systems**
  - Sensor suites drive ODD boundaries and limitations (e.g., dusty conditions hinder cameras more than radar). The perceptions systems proposed for the different ADS features were considered when identifying ODDs.

- **Testimonials**
  - Anecdotal reports provide insights into what features of the environment are important, especially reports of systems having trouble with specific ODDs, including poor lane markings, hill crests/curves, etc.
• ODDs from other domains
  o ODDs from other domains inform categorization and approach (e.g., aviation includes airspace classes and transitions, presence of ground crews, workload on operator, etc.).

Influences for Defining the ODD Framework

The literature revealed several early efforts to define and frame ODDs. The concepts put forth are not in complete agreement and take the form of everything from public policy to industry guidelines to research. This section discusses sources that were influential in advancing the framework put forth in this report.

Automated Driving Systems 2.0 – A Vision for Safety

The USDOT definition of ODD is given in Federal guidance and is adopted for the purposes of this report. The definition indicates that ODD should be identified by the manufacturer, and includes example ODD categories.

Entities are encouraged to define and document the Operational Design Domain (ODD) for each ADS available on their vehicles as tested or deployed for use on public roadways, as well as document the process and procedure for assessment, testing, and validation of ADS functionality with the prescribed ODD.

The definition goes on to describe how the ODD’s boundary influences ADS operation.

The ODD would include the following information at a minimum to define each ADS’s capability limits/boundaries: Roadway types (interstate, local, etc.) on which the ADS is intended to operate safely; Geographic area (city, mountain, desert, etc.); Speed range; Environmental conditions in which the ADS will operate (weather, daytime/nighttime, etc.); and other domain constraints (NHTSA, 2017a).

2016 SAE J3016

SAE J3016 has been adopted by USDOT and defines and describes ODDs. The concepts put forth in J3016 are adopted in this research and are consistent with USDOT’s policy. ODD is not explicitly related to level of driving automation, except that for L5, the ODD is described as “unlimited.”

J3016 provides the following definition of ODD: “The specific conditions under which a given driving automation system or feature thereof is designed to function, including, but not limited to, driving modes.”

J3016 also provides example categories (see Figure 8).

An ODD may include one or more driving modes. For example, a given ADS may be designed to operate a vehicle only on fully access-controlled freeways and in low-speed traffic, high-speed traffic, or in both driving modes.3
There have been questions and critiques regarding J3016. For example, the National Society of Professional Engineers (Austin, 2016) commented that:

The operational design domains proposed in SAE J3016 are overly broad and do not adequately reflect the myriad of subdomains a vehicle may be required to enter and exit in the course of a single route within an overall domain (e.g., toll roads).

Another question that has arisen is whether the concept of an “unlimited” ODD at L5 should be taken to the extreme (e.g., whiteout snow conditions) or whether it is limited in practice (e.g., to the same level as a reasonable human driver). SAE J3016 is currently working on an update to the document in conjunction with ISO that will clarify several points, including concepts that relate to ODDs.

**California Policy**

Similar to USDOT and SAE International, California draft regulations (CA DMV, 2017) describe a concept for ODD that defines the boundary between ADS and human operation, and state that the ODD is to be specified by the manufacturer.

[The manufacturer] shall identify in the application the operational design domain in which the subject autonomous vehicles are designed to operate and certify that the vehicles are designed to be incapable of operating in the autonomous mode in areas outside of the disclosed ODD.
The policy goes on to note that ODD elements can be identified as subtractive:

…identify any commonly occurring or restricted conditions including but not limited to: snow, fog, black ice, wet road surfaces, construction zones, and geo-fencing by location or road type, under which the vehicles are either designed to be incapable of operating or unable to operate reliably in the autonomous mode and certify that the vehicles are designed to be incapable of operating in autonomous mode under those conditions.

It also discusses the relationship with local legal codes within the geographically defined ODD:

…a reference to the ordinances or resolutions from local authorities that specifies the operational design domains within the jurisdiction of the local authorities that the vehicles may be operated.

In support of the California policy, California PATH conducted an analysis (University of California PATH Program, 2016) that gathered expert feedback on “areas of operation,” which were defined as Rural, Urban, and Freeway/Highway. This classification scheme was found to be too blunt and indiscriminate and was replaced by ODD. This analysis also identified the challenge of handling the wide range of environmental, weather, and lighting conditions, and suggested using a complementary functional safety plan to address difficult-to-quantify scenarios.

**PEGASUS Project**

The PEGASUS Project is aimed at “establishing generally accepted quality criteria, tools and methods, as well as scenarios and situations for the release of highly automated driving functions (Winner, Wachenfeld, & Junietz, 2016).” The effort is focused on highway driving, and the PEGASUS research team has identified several elements of a scene that pertain to ODD, including traffic infrastructure (e.g., lanes, regulations, geometry), environmental conditions (e.g., surface grip from wetness, light, sun, fog, sensor obstacles), and traffic (Hungar, 2017).

**Others Referenced**

While not central to this analysis, influences from other industries were considered. These include aviation and the Department of Defense.

The aviation industry manages operational domains for traffic in the national airspace and space flight. Airspace volumes are designated into several classes, which specify operational characteristics and procedures. To operate in certain airspace domains, airplanes may be required to have certain equipage (e.g., transponders), and pilots may need to follow certain procedures (e.g., instrumented flight rules versus visual flight rules). These operational domain designations are influenced by complexity of the airspace and potential risks. For automobiles, ODD is similarly influenced by complexity (e.g., speed, traffic level), risks, equipage (e.g., sensors), and procedures (e.g., toll lanes).
NASA’s missions operate in a limited domain that help to constrain design; for example, missions that are restricted to specific geographic areas or types of objects that may be encountered (Wang & Hussein, 2012). For automated flight systems, there are certain domain considerations, such as air traffic, hazardous weather, terrain, and other obstructions and safety maneuvers (Hayhurst, Maddalon, Miner, DeWalt, & McCormick, 2006).

The DOD considers operating domains for the design and use of unmanned systems; for example, roadways, littoral areas, forested areas, and various operating speeds (National Research Council, 2005).

Guiding Principles

Several guiding principles were developed based on the literature to identify and characterize the ODDs:

- **Need for an ODD taxonomy** – A large variety of ODD dimensions exist, and a structure is needed to organize categories and facilitate discussion of system requirements, capabilities, and testing.

- **Account for variations in operational environments** – ODDs may vary in nature. Some can be predetermined (e.g., roadway type), while others change in time (e.g., traffic conditions). Some can be divided into discrete categories (e.g., signage), while others vary along a continuous scale and may be difficult to quantify (e.g., rain, light, fog).

- **Define what constitutes “operational scenario”** – An operational scenario is described in part by a set of ODD characteristics that describe the environment in which the feature is designed to perform.

- **Identify ODD boundaries** – ODD defines where the ADS can and cannot operate. ODD limits may vary by sub-trip or operational scenario due to confounding variables (e.g., weather and illumination), non-deterministic software, design and testing, etc. (Bojarski, et al., 2016)

- **Identify Current ODD State (Self-Awareness)** – An ADS feature should be able to identify whether it is within the ODD and detect and respond to system engagement and disengagement restrictions (University of California PATH Program, 2016). This may include identifying transitions between certain ODD states (e.g., roadway type).

Defining an ODD Taxonomy

While the literature provided many examples of ODD elements, no classification framework was identified. This work takes an initial step towards developing a taxonomy to organize the many ODD elements identified in research. This ODD taxonomy takes the form of a hierarchy of categories and subcategories, each with definitions and, where appropriate, gradations. This taxonomy is meant to be descriptive, not normative, as it is envisioned that these elements may be organized into several different groupings. The taxonomy offers a structured approach to organize and identify various ODDs for ADS features, especially when there are several different
possible combinations. Figure 9 shows the broad range of top-level categories and immediate subcategories.

Figure 9. ODD Classification Framework With Top-Level Categories and Immediate Subcategories

The hierarchy extends into multiple sublevels, as shown in Figure 10. The “Environmental Conditions” category was divided into four subcategories: weather, illumination, particulate matter, and road weather. Weather is further subdivided into rain, temperature, wind, and snow. For this research project, it was helpful to further subdivide rain into gradations to capture the data that were collected on ADS features. For example, some ADS features had been tested in light rain, while others had been tested in heavy rain. Although the application of this taxonomy has been useful in the context of this research project, further research and stakeholder engagement would be beneficial in refining and objectively quantifying the categories and gradations.
ODD CATEGORY DESCRIPTIONS

Physical Infrastructure

Physical infrastructure refers to facilities and systems that serve a country, city, or area and enable its economy to function. Physical infrastructure is typically characterized by technical structures, such as roads, bridges, tunnels, water supply, sewers, electrical grids, telecommunications, etc., that are for the most part interrelated. ADS features may depend on such infrastructure elements, which are a critical part of the ODD environment. Subcategories of the main physical infrastructure elements are listed below; illustrative photos are provided in Figure 11.

Roadway Types

- Divided highway, undivided highway, arterial, urban, rural, parking, multi-lane, single lane, high-occupancy vehicle (HOV) lane, on/off ramps, emergency evacuation routes, one-way, turn-only lanes, private roads, reversible lanes, intersections (signaled, U-turns, 4-way/2-way stop, roundabout, merge lanes, turn-only lanes, crosswalk, toll plaza, railroad crossing) (FHWA, 2012).

Roadway Surfaces

- Asphalt, concrete, mixed, grating, brick, dirt, gravel, scraped road, partially occluded, speed bumps, potholes, grass (Gibbons, 1999).
**Roadway Edges**

- Line markers, temporary line markers, shoulder (paved or gravel), shoulder (grass), concrete barriers, grating, rails, curb, cones (Sage, 2016).

**Roadway Geometry**

- Straightaways, curves, hills, lateral crests, corners (regular, blind corners), negative obstacles, lane width (Huang, 2010).

![Figure 11. Examples of Physical Infrastructure Elements](image)

**Operational Constraints**

There are several operational constraints that need to be considered when designing and testing ADS applications. These include elements such as dynamic changes in speed limits, traffic characteristics, construction, etc. For example, an ADS entering a school zone is subjected to lower speed limits and must respond appropriately to ensure the safety of its passengers and other road users. Some examples of the operational constraints are listed below. Illustrative photos are provided in Figure 12.

**Speed Limit**

- Minimum and maximum speed limit (absolute, relative to speed limit, relative to surrounding traffic) (Elpern-Waxman, 2016).
Traffic Conditions

- Minimal traffic, normal traffic, bumper-to-bumper/rush-hour traffic, altered (accident, emergency vehicle, construction, closed road, special event) (University of California PATH Program, 2016).

![Traffic Conditions Diagram](image)

Figure 12. Examples of Operational Constraints

Objects

For an ADS to properly navigate within an ODD, it must detect and respond to certain objects, which is referred to as OEDR. OEDR is the focus of Chapter 4, but is discussed here in the context of identifying objects that can reasonably be expected to exist within the ODD. For example, a pedestrian may be expected at an intersection but rarely on a freeway. Examples of objects and descriptions are provided in the text below and in Figure 13.

Signage

- Signs (e.g., stop, yield, pedestrian, railroad, school zone, etc.), traffic signals (flashing, school zone, fire department zone, etc.), crosswalks, railroad crossing, stopped buses, construction signage, first responder signals, distress signals, roadway user signals, hand signals (FHWA, 2012).
**Roadway Users**


**Non-roadway User Obstacles/Objects**

- Animals (e.g., dogs, deer, etc.), shopping carts, debris (e.g., pieces of tire, trash, ladders), construction equipment, pedestrians, cyclists

![Figure 13. Examples of Objects](image)

**Environmental Conditions**

Environmental conditions play a crucial role in the safe operation of a variety of ADS applications, and pose one of the biggest challenges to deployment, particularly early deployment. The environment can impact visibility, sensor fidelity, vehicle maneuverability, and communications systems. Today, ADS technologies are tested most often in clear, rather than adverse, weather conditions. On average, there are over 5.7 million vehicle crashes each year. Approximately 22 percent of these crashes—nearly 1.3 million—are weather-related (Erdman, 2015). Weather-related crashes are defined as crashes that occur in adverse weather (i.e., rain, sleet, snow, fog, severe crosswinds, or blowing snow/sand/debris) or on wet, snowy, or icy pavement. Weather acts through visibility impairments, precipitation, high winds, and temperature extremes to affect driver capabilities, vehicle performance (i.e., traction, stability,
and maneuverability), pavement friction, roadway infrastructure, crash risk, traffic flow, and agency productivity (FHWA, 2017a). It is thus important to consider a variety of environmental conditions as part of the ODD. A few of these conditions are described below, and examples are shown in Figure 14.

**Weather**

- Wind, rain, snow, sleet, temperature
- On freeways, light rain or snow can reduce average speed by 3 to 13 percent. Heavy rain can decrease average speed by 3 to 16 percent. In heavy snow, average freeway speeds can decline by 5 to 40 percent. Free-flow speed can be reduced by 2 to 13 percent in light rain and by 6 to 17 percent in heavy rain. Snow can cause free-flow speed to decrease by 5 to 64 percent. Speed variance can fall by 25 percent during rain (FHWA, 2017c).

**Weather-induced Roadway Conditions**

- Standing water, flooded roadways, icy roads, snow on road
- Capacity reductions can be caused by lane submersion due to flooding and by lane obstruction due to snow accumulation and wind-blown debris. Road closures and access restrictions due to hazardous conditions (e.g., large trucks in high winds) also decrease roadway capacity (FHWA, 2017).

**Particulate Matter**

- Fog, smoke, smog, dust/dirt, mud
- Low visibility can cause speed reductions of 10 to 12 percent. Visibility distance is reduced by fog and heavy precipitation, as well as wind-blown snow, dust, and smoke. Low-visibility conditions cause increased speed variance, which increases crash risk. Each year, over 38,700 vehicle crashes occur in fog. Over 600 people are killed, and more than 16,300 people are injured in these crashes annually (FHWA, 2017b).

**Illumination**

- Day (sun: overhead, back-lighting, and front-lighting), dawn, dusk, night, street lights, headlights (regular and high-beam), oncoming vehicle lights (overhead lighting, back-lighting, and front-lighting) (FHWA, 2017a).
Connectivity

Connectivity and automation are increasingly being integrated into cars and trucks with the objective of improving safety, mobility, and providing a better driving experience. Connectivity is an enabling technology that may define where an ADS feature can operate. For example, low-speed shuttles may depend on traffic light signal phase and timing messages to reduce the dependence on sensors alone to detect the signal. Other operational examples include eco-approach and departure or coordinated ACC (Michel, Karbowski, & Rousseau, 2016). Connectivity constitutes a communications link between other vehicles, road users, remote fleet management operators, and physical and digital infrastructure elements. Some of these elements are described below. Illustrative photos are provided in Figure 15.

**Vehicles**

- V2V communications (e.g., DSRC, Wi-Fi), emergency vehicles

**Traffic Density Information**

- Crowdsourced data (e.g., Waze) and V2I

**Remote Fleet Management System**

- A vehicle may be supported by an operations center that can perform remote operation. (Aljaafreh et al., 2011)
Infrastructure Sensors and communications

- Work zone alerts, vulnerable road user, routing and incident management, GPS, 3-D high-definition maps (Ellichipuram, 2016), pothole locations, weather data, data on the cloud, etc.

Zones

ADS features may be limited spatially by zones. The boundaries of these zones may be fixed or dynamic, and conditions that define a boundary may be based on complexity, operating procedures, or other factors. One example is work zones, which can confuse ADS as the road configuration (pavement markings and new lane alignments) differs from typical conditions. In a work zone, cones may replace double yellow lines, bollards may replace curbs, and construction worker hand signals may overrule traffic lights. These cues designed for human drivers can challenge advanced computer systems (Marshall, 2017). There are several other types of zones that are important to consider as potential elements of an ODD (see text below and Figure 16).

Geo-fencing (Crosbie, 2017)

- Central business districts, school campuses, and retirement communities (for example, CityMobil2 is fixed route and includes < 20 mph (CityMobil2, 2013) routes both on-road and off-road on pedestrian walkways).
Traffic Management Zones

- May include temporary lane closures, dynamic traffic signs, variable speed limits, temporary or non-existent lane markings, human-directed traffic, loading/unloading zones

School/Construction Zones

- Dynamic speed limit, erratic pedestrian and vehicular behaviors (Marshall, 2017)

Regions/States

- Any legal, regulatory, enforcement, tort, or other considerations (e.g., following distance, licensing, etc.) (Bomey & Zambito, 2017)

Interference Zones

- Tunnels, parking garages, dense foliage, limited GPS due to tall buildings, atmospheric conditions

Figure 16. Examples of Zones

ODD Identification for ADS Features

The ODD taxonomy lends itself to serving as a checklist for identifying the ODD of an ADS feature. A comprehensive ODD checklist was generated based on the ODD taxonomy described above. To demonstrate a potential application of the checklist, the checklist was filled out for three theoretical ADS features. The generic L3 Conditional Traffic Jam Drive, L3 Conditional
Highway Drive and L4 Highly Automated Vehicle/TNC features were selected. The results are presented in Appendix A. It should be noted that currently the manufacturer would determine the ODD for a feature, and the ODD may vary for similar ADS features. The theoretical features presented here are purely demonstrative, not representative of any commercially marketed ADS feature. An excerpt of the checklist for L3 Conditional Traffic Jam Drive is shown in Table 11, with the other ODD categories presented in the Appendix. Additional supporting material is provided in Appendix A.

Table 11. Extract from ODD Checklist Defined for a Generic L3 Conditional Automated Traffic Jam Drive Feature

<table>
<thead>
<tr>
<th>ODD CHECKLIST: L3 Conditional Traffic Jam Drive</th>
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<tr>
<td><strong>PHYSICAL INFRASTRUCTURE</strong></td>
</tr>
<tr>
<td><strong>Roadway Types</strong></td>
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<tr>
<td>Divided highway</td>
</tr>
<tr>
<td>Undivided highway</td>
</tr>
<tr>
<td>Arterial</td>
</tr>
<tr>
<td>Urban</td>
</tr>
<tr>
<td>Rural</td>
</tr>
<tr>
<td>Parking (surface lots, structures, private/public)</td>
</tr>
<tr>
<td>Managed lanes (HOV, HOT, etc.)</td>
</tr>
<tr>
<td>On-off ramps</td>
</tr>
<tr>
<td>Emergency evacuation routes</td>
</tr>
<tr>
<td>Intersections</td>
</tr>
<tr>
<td><strong>Roadway Surfaces</strong></td>
</tr>
<tr>
<td>Asphalt</td>
</tr>
<tr>
<td>Concrete</td>
</tr>
<tr>
<td><strong>Roadway Edges &amp; Markings</strong></td>
</tr>
<tr>
<td>Lane markers</td>
</tr>
<tr>
<td>Temporary lane markers</td>
</tr>
<tr>
<td>Shoulder (paved or gravel)</td>
</tr>
<tr>
<td>Shoulder (grass)</td>
</tr>
<tr>
<td>Lane barriers</td>
</tr>
<tr>
<td>Rails</td>
</tr>
<tr>
<td><strong>OPERATION CONSTRAINTS</strong></td>
</tr>
<tr>
<td>Speed Limits</td>
</tr>
<tr>
<td>Minimum speed limit</td>
</tr>
<tr>
<td>Maximum speed limit</td>
</tr>
<tr>
<td>Traffic Conditions</td>
</tr>
<tr>
<td>Traffic density</td>
</tr>
</tbody>
</table>
SUMMARY

The ODD defines when and where a vehicle is designed to function. This chapter reviewed the ODD literature, developed an ODD taxonomy, as reconciled with the OEM’s current definitions, and identified ODDs for ADS features. The ODD framework presented here lays the foundation for Chapter 4 (OEDR) and Chapter 5 (Scenarios).

To test a vehicle’s ability to operate safely, ODD is considered in test development and execution. Scenarios consider a combination of ODD elements that can be used to describe conditions for test cases and scenarios; for example, a highway with a concrete surface with a light mist. Test facilities are limited in their ability to re-create certain ODDs (e.g., urban environments, hill crests) and may need to be upgraded with new infrastructure to support testing. Some ODD elements are difficult to quantify and re-create (e.g., weather), and may be addressed through functional safety design practices and on-road testing. Other examples of ODDs are shown in Figure 17. A figure showing the significance of ODD relative to levels of driving automation from SAE J3016 is reproduced in Figure 18.

Figure 17. Other Examples of ODD
There are several aspects to consider to expand upon the defined ODD characteristics. Comparisons with other ODD characterizations and working with OEMs to develop a consensus for definitions could improve the robustness of this taxonomy. Further investigation of ODD boundary conditions, and how ADS can detect these boundaries will be important to understanding disengagement events. For example, a minimal risk maneuver might differ based on on-board sensor configuration and availability of shoulders. Further, potential events like a leaf obstructing a sensor or bird excrement on a windshield obstructing line of sight when the driver is involved in part of the driving task need to be taken into account. There is thus a need to consider a more exhaustive list and potential classifiers for MRCs and other non-roadway users. Automation experts in both automotive and aviation industries have cautioned that the differences in ODD between automobiles and airplanes are so significant that the cross-learning opportunities are quite limited. Finally, monitoring the reports from the PEGASUS project in Europe is suggested.
CHAPTER 4. OBJECT AND EVENT DETECTION AND RESPONSE CAPABILITIES

OVERVIEW

This chapter describes the identification of OEDR capabilities that enable ADS to function safely within their prescribed operational ODD. OEDR refers to “the subtasks of the DDT that include monitoring the driving environment (detecting, recognizing, and classifying objects and events and preparing to respond as needed) and executing an appropriate response to such objects and events (i.e., as needed to complete the DDT and/or DDT fallback”; SAE International, 2016). OEDR capabilities will play a key role in developing sample tests for ADS.

Tactical maneuver behaviors were identified in Chapter 2 for conceptual ADS features. These behaviors largely focus on the elements of the DDT related to real-time functions specified in SAE J3016 (SAE International, 2016). These behaviors notionally represent the control-related tasks that are used as the ADS navigates to reach its prescribed destination. While performing these tactical maneuver behaviors, ADS will inevitably interact with a variety of static and dynamic physical objects that may alter how these behaviors are executed. SAE J3016 identifies the following real-time functions as elements of the DDT related to addressing these interactions with objects.

- Object and event detection, recognition, and classification
- Object and event response

These functions can be generalized under the term OEDR. OEDR represents the ability of the ADS feature to detect any circumstance that is immediately relevant to the driving task and implement an appropriate response. One of the factors that determines the level of driving automation of an ADS is whether the human driver or ADS is responsible for monitoring the driving environment. ADS, which are the focus of this report, range from SAE International L3 through L5, which means that the ADS feature is completing all aspects of monitoring the driving environment.

The elements of the ADS functional architecture shown in Figure 3 that are specifically relevant to OEDR generally include hardware and software components that support the following.

- Sensing (e.g., radar, laser scanners, cameras, etc.)
- Perception (e.g., road feature classification, object segmentation and classification, etc.)
- World modeling (e.g., persistent data mapping, dynamic obstacle tracking, and prediction, etc.)
- Navigation and planning (e.g., path planning and motion control commands to implement responses)

The sensing and perception elements of the architecture specifically support detection of relevant objects. World modeling supports the aggregation of perception and other information to identify and understand events that may occur through interactions with those objects. Navigation and
planning supports determination of the appropriate response to those events and interactions, and the generation of control commands to implement that response.

**APPROACH**

Three of the generic ADS features identified in Chapter 2 were selected for this OEDR analysis. This allowed for an evaluation of a cross-section of operating environments and conditions, as well as driving scenarios. The three features selected were the following.

- L3 Conditional Automated Traffic Jam Drive
- L3 Conditional Automated Highway Drive
- L4 Highly Automated Vehicle/TNC

These features were selected to provide a cross-sectional representation of the wide variety of ODDs presented in Chapter 3. The L3 Conditional Automated Traffic Jam Drive feature can generally be expected to function in low-speed, stop-and-go traffic in areas where traffic jams are common (e.g., highways, urban roads). The L3 Conditional Automated Highway Drive feature can generally be expected to function on higher speed roads (e.g., highways, limited access freeways) with typical levels of traffic. The L4 Highly Automated Vehicle/TNC feature can generally be expected to function in denser urban areas at low to moderate speeds and be exposed to a wide variety of interactions with other vehicles and vulnerable road users. These features were also selected based on their expected timeline for availability to the public. The two L3 features were considered near-term ADS that will likely become available in the next few years. The L4 feature was considered a mid-term ADS, albeit one that is currently the subject of significant research.

Using these selected conceptual ADS features from Chapter 2 and the notional ODDs identified in Chapter 3 and expanded upon in Chapter 7. Appendix A for the selected features, this chapter will review the process undertaken to identify notional capabilities for OEDR for ADS. This process can be broken down into the following steps.

- Review the literature to evaluate and leverage prior research.
- Identify notional operational descriptions for features.
- Perform analysis to identify baseline ODDs.
- Perform driving scenario analysis.
- Perform analysis to identify OEDR behaviors and corresponding responses.
The development of a notional, representative ConOps supported the identification of normal driving scenarios for each ADS feature. The operations descriptions explain the intended use of each feature and the circumstances in which it may be used. The operations descriptions are launching points for identifying the operational needs of each feature, including its OEDR capabilities.

Following the evaluation of the operational needs of the selected ADS features, a focusing exercise established baseline ODDs for each feature to further refine the analysis to identify OEDR capabilities for the three selected features. This exercise served to frame the OEDR analysis to account for the potential variability of certain ODD elements, as well as the substantial number of combinations and permutations of ODD elements. It is reasonable to expect that different organizations developing similar ADS features will generate unique designs and implementations, and thus will ultimately define different ODDs for their respective systems. For example, Vendor A designs and develops an L3 Traffic Jam Drive feature that can only operate on limited access highways where there are no pedestrians or pedalcyclists; while Vendor B designs an L3 Traffic Jam Drive feature with similar control capabilities but that also works on arterials and urban streets where pedestrians and pedalcyclists may be present. Similarly, there can be great diversity of abilities within specific categories of the ODD. For example, Vendor A’s Traffic Jam Drive feature may be capable of operating only in light rain, while Vendor B’s Traffic Jam Drive feature can operate in both light and heavy rain (light and heavy rain are treated purely qualitatively for the purposes of this example). A well-defined ODD helps to determine the OEDR capabilities that may be necessary and, as such, these
baseline ODDs delineate the attributes of the ODD for each selected feature for the purposes of identifying OEDR capabilities. It should also be noted again that the developing OEMs and entities ultimately define the ODD for their respective features and, as such, these baseline ODDs are intended to be notional and descriptive, rather than normative. The baseline ODDs also serve to support the development of sample test scenarios and procedures described in Chapter 5.

With the ODD baselines established for each feature, a survey and analysis of the driving scenarios that fall out of the operations descriptions led to the identification of relevant objects and interactions that the ADS could encounter. These objects and events are derived from an evaluation of normal driving scenarios for a given ADS feature operating in its ODD, including:

- Expected hazards (e.g., vehicles, pedestrians, etc.);
- Unspecified/unexpected events (e.g., construction zones, emergency vehicles, etc.); and
- Key infrastructure elements (e.g., traffic signs and signals, road markings, etc.).

Prior work conducted by California PATH to define behavioral competencies (Nowakowski, Shladover, Chan, & Tan, 2015) informed this evaluation of driving scenarios. Table 12 reproduces a working list of critical driving maneuvers identified by PATH across a variety of driving environments. The driving environments correspond to certain attributes of the ODD at a high level. This list produced by PATH served as a starting point that was extended and refined based on the hierarchical ODD taxonomy developed in Chapter 3.

<table>
<thead>
<tr>
<th>Critical Driving Maneuvers</th>
<th>Freeway</th>
<th>Rural Highway</th>
<th>City Streets</th>
<th>Valet Parking</th>
<th>Low-Speed Shuttles</th>
</tr>
</thead>
<tbody>
<tr>
<td>Detect System Engagement/Disengagement Conditions Including Limitations by Location, Operating Condition, or Component Malfunction</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Detect &amp; Respond to Speed Limit Changes (Including Advisory Speed Zones)</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td></td>
<td>✓</td>
</tr>
<tr>
<td>Detect Passing and No Passing Zones</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Detect Work Zones, Temporary Lane Shifts, or Safety Officials Manually Directing Traffic</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Detect and Respond to Traffic Control Devices</td>
<td></td>
<td>✓</td>
<td>✓</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Detect and Respond to Access Restrictions such as One-Way Streets, No-Turn Locations, Bicycle Lanes, Transit Lanes, and Pedestrian Ways</td>
<td></td>
<td></td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
</tbody>
</table>

Table 12. California PATH Minimum Behavioral Competencies (Nowakowski, Shladover, Chan, & Tan, 2015)
Next, the evaluation of driving scenarios estimated the risk associated with the various objects and events. This risk analysis helps to prioritize scenarios for testing and evaluation. Risk is qualitatively estimated by considering the likelihood of an event or interaction occurring, and the resulting severity of the ADS incorrectly responding to the interaction (e.g., a response that results in a collision with the object). This analysis also used NHTSA pre-crash data for prioritizing scenarios. The prioritization was based on frequency of occurrence and severity (number resulting in injuries or fatalities) (Najm, Smith, & Yanagisawa, 2007). Table 13 shows pre-crash data for two-vehicle light-vehicle crashes involving manually driven vehicles. Following the development of the working list of tactical maneuver behaviors in Chapter 2, the list of objects and events was refined into a working list of OEDR behaviors that notionally represent a set of testable perception-related scenarios.

Control actions were then identified to support safe responses to the identified combinations of objects and events. These actions are seated in the tactical maneuver behaviors identified in Chapter 2 and PATH behavioral competencies reproduced in Table 12 above. The control action options are further informed by a task decomposition exercise. This decomposition, in some cases, breaks the behaviors down into their more specific control-related actions. The National

<table>
<thead>
<tr>
<th>Critical Driving Maneuvers</th>
<th>Freeway</th>
<th>Rural Highway</th>
<th>City Streets</th>
<th>Valet Parking</th>
<th>Low-Speed Shuttles</th>
</tr>
</thead>
<tbody>
<tr>
<td>Perform High Speed Freeway Merge</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Perform a Lane Change or Lower Speed Merge</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Park on the Shoulder or Transition the Vehicle to a Minimal Risk State (Not Required for SAE L3)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Navigate Intersections &amp; Perform Turns</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Navigate a Parking Lot &amp; Locate Open Spaces</td>
<td></td>
<td></td>
<td></td>
<td>✓</td>
<td></td>
</tr>
<tr>
<td>Perform Car Following Including Stop &amp; Go and Emergency Braking</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Detect &amp; Respond to Stopped Vehicles</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Detect &amp; Respond to Intended Lane Changes/Cut-Ins</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Detect &amp; Respond to Encroaching Oncoming Vehicles</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Detect &amp; Respond to Static Obstacles in Roadway</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Detect &amp; Respond to Bicycles, Pedestrians, Animals, or Other Moving Objects</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Detect Emergency Vehicles</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table 13: Pre-crash data for two-vehicle light-vehicle crashes involving manually driven vehicles.
Institute of Standards and Technology 4D/RCS Reference Model Architecture for Unmanned Vehicle Systems was leveraged (Barbera, Horst, Schlenoff, & Aha, 2004) for this analysis.

Table 13. Pre-Crash Scenarios of Two-Vehicle Light-Vehicle Crashes (Najm, Smith, & Yanagisawa, 2007)

<table>
<thead>
<tr>
<th>No.</th>
<th>Scenario</th>
<th>Frequency</th>
<th>Rel. Freq.</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Lead Vehicle Stopped</td>
<td>792,000</td>
<td>20.46%</td>
</tr>
<tr>
<td>2</td>
<td>Vehicles Turning at Non-Signalized Junctions</td>
<td>419,000</td>
<td>10.83%</td>
</tr>
<tr>
<td>3</td>
<td>Lead Vehicle Decelerating</td>
<td>347,000</td>
<td>8.96%</td>
</tr>
<tr>
<td>4</td>
<td>Vehicles Changing Lanes - Same Direction</td>
<td>295,000</td>
<td>7.62%</td>
</tr>
<tr>
<td>5</td>
<td>Straight Crossing Paths at Non-Signalized Junctions</td>
<td>252,000</td>
<td>6.52%</td>
</tr>
<tr>
<td>6</td>
<td>Running Red Light</td>
<td>233,000</td>
<td>6.02%</td>
</tr>
<tr>
<td>7</td>
<td>Vehicles Turning - Same Direction</td>
<td>220,000</td>
<td>5.68%</td>
</tr>
<tr>
<td>8</td>
<td>LTAP/OD⁴ at Signalized Junctions</td>
<td>205,000</td>
<td>5.29%</td>
</tr>
<tr>
<td>9</td>
<td>Lead Vehicle Moving at Lower Constant Speed</td>
<td>186,000</td>
<td>4.82%</td>
</tr>
<tr>
<td>10</td>
<td>LTAP/OD at Non-Signalized Junctions</td>
<td>181,000</td>
<td>4.68%</td>
</tr>
<tr>
<td>11</td>
<td>Backing Up Into Another Vehicle</td>
<td>131,000</td>
<td>3.38%</td>
</tr>
<tr>
<td>12</td>
<td>Vehicles Not Making a Maneuver - Opposite Direction</td>
<td>94,000</td>
<td>2.43%</td>
</tr>
<tr>
<td>13</td>
<td>Vehicles Drifting - Same Direction</td>
<td>91,000</td>
<td>2.35%</td>
</tr>
<tr>
<td>14</td>
<td>Following Vehicle Making a Maneuver</td>
<td>74,000</td>
<td>1.92%</td>
</tr>
<tr>
<td>15</td>
<td>Control Loss Without Prior Vehicle Action</td>
<td>52,000</td>
<td>1.33%</td>
</tr>
<tr>
<td>16</td>
<td>Vehicles Parking - Same Direction</td>
<td>47,000</td>
<td>1.21%</td>
</tr>
<tr>
<td>17</td>
<td>Running Stop Sign</td>
<td>43,000</td>
<td>1.12%</td>
</tr>
<tr>
<td>18</td>
<td>Evasive Action Without Prior Vehicle Maneuver</td>
<td>37,000</td>
<td>0.95%</td>
</tr>
<tr>
<td>19</td>
<td>Vehicle Turning Right at Signalized Junctions</td>
<td>34,000</td>
<td>0.89%</td>
</tr>
<tr>
<td>20</td>
<td>Control Loss With Prior Vehicle Action</td>
<td>26,000</td>
<td>0.68%</td>
</tr>
<tr>
<td>21</td>
<td>Non-Collision Incident</td>
<td>25,000</td>
<td>0.64%</td>
</tr>
<tr>
<td>22</td>
<td>Lead Vehicle Accelerating</td>
<td>16,000</td>
<td>0.41%</td>
</tr>
<tr>
<td>23</td>
<td>Vehicles Making a Maneuver - Opposite Direction</td>
<td>13,000</td>
<td>0.33%</td>
</tr>
<tr>
<td>24</td>
<td>Evasive Action With Prior Vehicle Maneuver</td>
<td>8,000</td>
<td>0.21%</td>
</tr>
<tr>
<td>25</td>
<td>Vehicle Failure</td>
<td>8,000</td>
<td>0.20%</td>
</tr>
<tr>
<td>26</td>
<td>Animal Crash Without Prior Vehicle Maneuver</td>
<td>6,000</td>
<td>0.14%</td>
</tr>
<tr>
<td>27</td>
<td>Road Edge Departure Without Prior Vehicle Maneuver</td>
<td>3,000</td>
<td>0.08%</td>
</tr>
<tr>
<td>28</td>
<td>Pedestrian Crash Without Prior Vehicle Maneuver</td>
<td>2,000</td>
<td>0.05%</td>
</tr>
<tr>
<td>29</td>
<td>Road Edge Departure With Prior Vehicle Maneuver</td>
<td>2,000</td>
<td>0.04%</td>
</tr>
<tr>
<td>30</td>
<td>Pedestrian Crash With Prior Vehicle Maneuver</td>
<td>1,000</td>
<td>0.02%</td>
</tr>
<tr>
<td>31</td>
<td>Pedalcyclist Crash Without Prior Vehicle Maneuver</td>
<td>1,000</td>
<td>0.02%</td>
</tr>
<tr>
<td>32</td>
<td>Other</td>
<td>28,000</td>
<td>0.73%</td>
</tr>
</tbody>
</table>

⁴ *Left Turn Across Path/Opposite Direction
FINDINGS

Baseline ODDs

The ODD checklists referenced in Chapter 3 and the samples presented in Appendix A notionally represent the ODDs for ADS features based on available data. The baseline ODDs are similarly summarized here for the selected ADS features.

**L3 Conditional Automated Traffic Jam Drive Feature**

For the L3 Conditional Automated Traffic Jam Drive feature, a notional operational use case of a driver on a limited-access highway or urban arterial road encountering slow, stop-and-go traffic that is expected to persist for a period of time was considered. As described in Chapter 2, this feature implements lateral and longitudinal control to maintain the current lane of travel and a safe following distance behind an immediate lead vehicle. This will likely rely on a combination of cameras for lane tracking and radar for lead vehicle ranging.

**Table 14. L3 TJD Baseline ODD – Physical Infrastructure**

<table>
<thead>
<tr>
<th>ODD Elements</th>
<th>Examples</th>
</tr>
</thead>
<tbody>
<tr>
<td>Roadway Types</td>
<td>Interstates, freeways, divided highways undivided highways, arterials, urban, bridges, multi-lane, single-lane, one-way, tunnels</td>
</tr>
<tr>
<td>Roadway Surfaces</td>
<td>Asphalt, concrete, mixed</td>
</tr>
<tr>
<td>Roadway Edges and Markings</td>
<td>Lane markers, temporary lane markers, concrete barriers, curbs, cones</td>
</tr>
<tr>
<td>Roadway Geometry</td>
<td>Straight, curves, hills</td>
</tr>
</tbody>
</table>

**Table 15. L3 TJD Baseline ODD – Operational Constraints**

<table>
<thead>
<tr>
<th>ODD Elements</th>
<th>Examples</th>
</tr>
</thead>
<tbody>
<tr>
<td>Minimum Speed Limit</td>
<td>0 kph (0 mph)</td>
</tr>
<tr>
<td>Maximum Speed Limit</td>
<td>59 kph (37 mph) (notionally)</td>
</tr>
<tr>
<td>Traffic Density</td>
<td>Immediate lead vehicle</td>
</tr>
</tbody>
</table>

**Table 16. L3 TJD Baseline ODD – Environmental Conditions**

<table>
<thead>
<tr>
<th>ODD Elements</th>
<th>Examples</th>
</tr>
</thead>
<tbody>
<tr>
<td>Weather</td>
<td>Clear, calm</td>
</tr>
<tr>
<td>Weather-induced Roadway Conditions</td>
<td>Dry</td>
</tr>
<tr>
<td>Illumination</td>
<td>Day, dawn/dusk</td>
</tr>
</tbody>
</table>

**Table 17. L3 TJD Baseline ODD - Connectivity**

<table>
<thead>
<tr>
<th>ODD Elements</th>
<th>Examples</th>
</tr>
</thead>
<tbody>
<tr>
<td>Digital Infrastructure</td>
<td>Optional to determine if inside or outside of zone (e.g., geofence, infrastructure zone)</td>
</tr>
</tbody>
</table>
Table 18. L3 TJD Baseline ODD - Zones

<table>
<thead>
<tr>
<th>ODD Elements</th>
<th>Examples</th>
</tr>
</thead>
<tbody>
<tr>
<td>Regions/States</td>
<td>Adhere to State/local laws</td>
</tr>
<tr>
<td>School/Construction</td>
<td>Construction zones</td>
</tr>
</tbody>
</table>

**L3 Conditional Automated Highway Drive Feature**

For the L3 Conditional Automated Highway Drive feature, a notional use case of a driver on a limited access highway encountering nominal, free-flow traffic conditions allowing for high-speed driving was considered. The feature implements lateral and longitudinal control to maintain the current lane of travel, achieve the specified speed, and if necessary alter that speed to follow an immediate lead vehicle at a safe following distance. This feature may also implement automatic lane changing, potentially initiated by the occupant activating a turn signal or automatically to maintain the target speed if it is safe and prudent to do so.

Table 19. L3 HWD Baseline ODD – Physical Infrastructure

<table>
<thead>
<tr>
<th>ODD Elements</th>
<th>Examples</th>
</tr>
</thead>
<tbody>
<tr>
<td>Roadway Types</td>
<td>Interstates, freeways, divided highways undivided highways, arterials, urban, bridges, multi-lane, single-lane, one-way, tunnels</td>
</tr>
<tr>
<td>Roadway Surfaces</td>
<td>Asphalt, concrete, mixed</td>
</tr>
<tr>
<td>Roadway Edges and Markings</td>
<td>Lane markers, temporary lane markers, concrete barriers, curbs, cones</td>
</tr>
<tr>
<td>Roadway Geometry</td>
<td>Straight, curves, hills</td>
</tr>
</tbody>
</table>

Table 20. L3 HWD Baseline ODD – Operational Constraints

<table>
<thead>
<tr>
<th>ODD Elements</th>
<th>Examples</th>
</tr>
</thead>
<tbody>
<tr>
<td>Minimum Speed Limit</td>
<td>72 kph (45 mph) (notionally)</td>
</tr>
<tr>
<td>Maximum Speed Limit</td>
<td>112 kph (70 mph) (notionally)</td>
</tr>
<tr>
<td>Traffic Density</td>
<td>Minimal, normal</td>
</tr>
</tbody>
</table>

Table 21. L3 HWD Baseline ODD – Environmental Conditions

<table>
<thead>
<tr>
<th>ODD Elements</th>
<th>Examples</th>
</tr>
</thead>
<tbody>
<tr>
<td>Weather</td>
<td>Clear, calm</td>
</tr>
<tr>
<td>Weather-induced Roadway Conditions</td>
<td>Dry</td>
</tr>
<tr>
<td>Illumination</td>
<td>Day, dawn/dusk</td>
</tr>
</tbody>
</table>

Table 22. L3 HWD Baseline ODD - Connectivity

<table>
<thead>
<tr>
<th>ODD Elements</th>
<th>Examples</th>
</tr>
</thead>
<tbody>
<tr>
<td>Digital Infrastructure</td>
<td>Optional to determine if inside or outside of zone</td>
</tr>
</tbody>
</table>
Table 23. L3 HWD Baseline ODD - Zones

<table>
<thead>
<tr>
<th>ODD Elements</th>
<th>Examples</th>
</tr>
</thead>
<tbody>
<tr>
<td>Regions/States</td>
<td>Adhere to State/local laws</td>
</tr>
<tr>
<td>School/Construction</td>
<td>Construction zones</td>
</tr>
<tr>
<td>Interference</td>
<td>Urban canyons</td>
</tr>
</tbody>
</table>

**L4 Highly Automated Vehicle/TNC Feature**

For the L4 Highly Automated Vehicle/TNC feature, a use case of an unmanned TNC vehicle being hailed by a passenger in a dense urban area was considered.

Table 24. L4 HAV/TNC Baseline ODD – Physical Infrastructure

<table>
<thead>
<tr>
<th>ODD Elements</th>
<th>Examples</th>
</tr>
</thead>
<tbody>
<tr>
<td>Roadway Types</td>
<td>Arterials, urban, bridges, multi-lane, single-lane, one-way, turn-only, rail crossings, bridges, bicycle lanes, crosswalks, tunnels</td>
</tr>
<tr>
<td>Roadway Surfaces</td>
<td>Asphalt, concrete, mixed</td>
</tr>
<tr>
<td>Roadway Edges and Markings</td>
<td>Lane markers, temporary lane markers, concrete barriers, curbs, cones</td>
</tr>
<tr>
<td>Roadway Geometry</td>
<td>Straight, curves, hills, varying lane widths</td>
</tr>
</tbody>
</table>

Table 25. L4 HAV/TNC Baseline ODD – Operational Constraints

<table>
<thead>
<tr>
<th>ODD Elements</th>
<th>Examples</th>
</tr>
</thead>
<tbody>
<tr>
<td>Minimum Speed Limit</td>
<td>0 kph (0 mph)</td>
</tr>
<tr>
<td>Maximum Speed Limit</td>
<td>72 kph (45 mph) (notionally)</td>
</tr>
<tr>
<td>Traffic Density</td>
<td>Minimal, normal, heavy</td>
</tr>
</tbody>
</table>

Table 26. L4 HAV/TNC Baseline ODD – Environmental Conditions

<table>
<thead>
<tr>
<th>ODD Elements</th>
<th>Examples</th>
</tr>
</thead>
<tbody>
<tr>
<td>Weather</td>
<td>Clear, calm</td>
</tr>
<tr>
<td>Weather-induced Roadway Conditions</td>
<td>Dry</td>
</tr>
<tr>
<td>Illumination</td>
<td>Day, dawn/dusk</td>
</tr>
</tbody>
</table>

Table 27. L4 HAV/TNC Baseline ODD - Connectivity

<table>
<thead>
<tr>
<th>ODD Elements</th>
<th>Examples</th>
</tr>
</thead>
<tbody>
<tr>
<td>Digital Infrastructure</td>
<td>Optional digital map, optional GPS</td>
</tr>
</tbody>
</table>
Table 28. L4 HAV/TNC Baseline ODD - Zones

<table>
<thead>
<tr>
<th>ODD Elements</th>
<th>Examples</th>
</tr>
</thead>
<tbody>
<tr>
<td>Geofencing</td>
<td>CBDs, school campuses, communities, fixed routes</td>
</tr>
<tr>
<td>Traffic Management Zones</td>
<td>Temporary road/lane closures, dynamic traffic signs, human-directed traffic, loading/unloading zones, temporary lane markers</td>
</tr>
<tr>
<td>Regions/States</td>
<td>Adhere to State/local laws</td>
</tr>
<tr>
<td>School/Construction</td>
<td>School/construction zones</td>
</tr>
<tr>
<td>Interference</td>
<td>Urban canyons, tunnels, foliage</td>
</tr>
</tbody>
</table>

**Baseline OEDR Behaviors**

The developed baseline ODDs were used to identify important objects and events that ADS could feasibly encounter within those ODDs. Those relevant objects and events are presented for the selected ADS features. The events of interest are based on some manner of interaction between the subject ADS and an identified object. Figure 20 shows a notional depiction of how some events were categorized in the vicinity immediately around the ADS. Interactions with obstacles were indicated as occurring in a frontal, side, or rear zone. The tables presented below include a notional set of objects and events that an ADS could encounter in a baseline ODD. The events in bold type represent interactions that were used for test development in Chapter 5. Some of the events were considered lower priority for testing for safety assessment, as they did not fall within the immediate collision zone around the subject vehicle (SV). Potential maneuver and control actions that the ADS could implement in response to the objects and events were also identified.

![Figure 20. Notional Crash-Relevant Zones](image-url)
### Table 29. L3 TJD Summary of Roadway User Events

<table>
<thead>
<tr>
<th>Objects</th>
<th>Events/Interactions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vehicles (e.g., cars, light trucks, heavy trucks, buses, motorcycles)</td>
<td>Lead vehicle decelerating (frontal), lead vehicle stopped (frontal), lead vehicle accelerating (frontal), changing lanes (frontal/side), cutting in (adjacent), turning (frontal), encroaching opposing vehicle (frontal/side), encroaching adjacent vehicle (frontal/side), entering roadway (frontal/side), cutting out (frontal)</td>
</tr>
<tr>
<td>Pedestrians</td>
<td>Crossing road – inside crosswalk (frontal), crossing road – outside crosswalk (frontal), walking on sidewalk/shoulder</td>
</tr>
<tr>
<td>Pedalcyclists</td>
<td>Riding in lane (frontal), riding in adjacent lane (frontal/side), riding in dedicated lane (frontal/side), riding on sidewalk/shoulder, crossing road – inside crosswalk (frontal/side), crossing road – outside crosswalk (frontal/side)</td>
</tr>
</tbody>
</table>

### Table 30. L3 TJD Summary of Non-Roadway User Events

<table>
<thead>
<tr>
<th>Objects</th>
<th>Events/Interactions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Animals(^5)</td>
<td>Static in lane (frontal), moving into/out of lane (frontal/side), static/moving in adjacent lane (frontal), static/moving on shoulder</td>
</tr>
<tr>
<td>Debris(^6)</td>
<td>Static in lane (frontal)</td>
</tr>
<tr>
<td>Other dynamic objects (e.g., shopping carts)</td>
<td>Static in lane (frontal/side), moving into/out of lane (frontal/side)</td>
</tr>
</tbody>
</table>

### Table 31. L3 TJD Summary of Signs and Signals Events

<table>
<thead>
<tr>
<th>Objects</th>
<th>Events/Interactions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Traffic signs(^7)</td>
<td>Stop, yield, speed limit, crosswalk, railroad crossing, school zone</td>
</tr>
<tr>
<td>Traffic signals(^7)</td>
<td>Intersection, railroad crossing, school zone</td>
</tr>
<tr>
<td>Vehicle signals</td>
<td>Turn signals</td>
</tr>
</tbody>
</table>

---

\(^{5}\) Animals that may have safety impacts, such as causing physical damage to ADS or harm to its occupants (e.g., deer, moose)  
\(^{6}\) Debris that may have safety impacts, such as causing physical damage to ADS or harm to its occupants (e.g., large tires)  
\(^{7}\) Compliant with the Manual on Uniform Traffic Control Devices
### Table 32. L3 TJD Summary of Other Objects of Interest

<table>
<thead>
<tr>
<th>Objects</th>
<th>Events/Interactions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Emergency vehicles</td>
<td>Lights and sirens activated (frontal/side), passing on shoulder (side/rear), encroaching, driving wrong direction (frontal/side), violating precedence/right-of-way (frontal/side/rear)</td>
</tr>
<tr>
<td>School buses</td>
<td>Lights and signs activated (frontal), stopped in lane or adjacent lane (frontal/side), stopped in opposing/undivided lane (frontal/side)</td>
</tr>
</tbody>
</table>

### L3 Conditional Automated Highway Drive Feature

### Table 33. L3 HWD Summary of Roadway User Events

<table>
<thead>
<tr>
<th>Objects</th>
<th>Events/Interactions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vehicles (e.g., cars, light trucks, heavy trucks, buses, motorcycles)</td>
<td>Lead vehicle decelerating (frontal), lead vehicle stopped (frontal), lead vehicle accelerating (frontal), changing lanes (frontal/side), cutting in (adjacent), turning (frontal), encroaching opposing vehicle (frontal/side), encroaching adjacent vehicle (frontal/side), entering roadway (frontal/side), cutting out (frontal)</td>
</tr>
<tr>
<td>Pedestrians</td>
<td>Crossing road (frontal), walking on shoulder</td>
</tr>
<tr>
<td>Pedalcyclists</td>
<td>Riding in lane (frontal), riding in adjacent lane (frontal/side), riding in dedicated lane (frontal/side), riding on shoulder, crossing road (frontal/side)</td>
</tr>
</tbody>
</table>

### Table 34. L3 HWD Summary of Non-Roadway User Events

<table>
<thead>
<tr>
<th>Objects</th>
<th>Events/Interactions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Animals(^5)</td>
<td>Static in lane (frontal), moving into/out of lane (frontal/side), static/moving in adjacent lane (frontal), static/moving on shoulder</td>
</tr>
<tr>
<td>Debris(^6)</td>
<td>Static in lane (frontal)</td>
</tr>
<tr>
<td>Other dynamic objects (e.g., shopping carts)</td>
<td>Static in lane (frontal/side), moving into/out of lane (frontal/side)</td>
</tr>
</tbody>
</table>

### Table 35. L3 HWD Summary of Signs and Signals Events

<table>
<thead>
<tr>
<th>Objects</th>
<th>Events/Interactions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Traffic signs(^7)</td>
<td>Stop, yield, <strong>speed limit</strong>, railroad crossing, school zone</td>
</tr>
<tr>
<td>Traffic signals(^7)</td>
<td>Intersection (at grade), railroad crossing, school zone</td>
</tr>
<tr>
<td>Vehicle signals</td>
<td>Turn signals</td>
</tr>
</tbody>
</table>
### Table 36. L3 HWD Summary of Other Objects of Interest

<table>
<thead>
<tr>
<th>Objects</th>
<th>Events/Interactions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Emergency vehicles</td>
<td>Lights and sirens activated (frontal/side), passing on shoulder (side/rear), encroaching, driving wrong direction (frontal/side), violating precedence/right-of-way (frontal/side/rear)</td>
</tr>
<tr>
<td>School buses</td>
<td>Lights and signs activated (frontal), stopped in lane or adjacent lane (frontal/side), stopped in opposing/undivided lane (frontal/side)</td>
</tr>
</tbody>
</table>

**L4 Highly Automated Vehicle/TNC Feature**

### Table 37. L4 HAV/TNC Summary of Roadway User Events

<table>
<thead>
<tr>
<th>Objects</th>
<th>Events/Interactions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vehicles (e.g., cars, light trucks, heavy trucks, buses, motorcycles)</td>
<td>Lead vehicle decelerating (frontal), lead vehicle stopped (frontal), lead vehicle accelerating (frontal), changing lanes (frontal/side), cutting in (adjacent), turning (frontal), encroaching opposing vehicle (frontal/side), encroaching adjacent vehicle (frontal/side), parking (frontal/side), entering roadway (frontal/side), cutting out (frontal)</td>
</tr>
<tr>
<td>Pedestrians</td>
<td>Crossing road – inside crosswalk (frontal), crossing road – outside crosswalk (frontal), walking on sidewalk/shoulder</td>
</tr>
<tr>
<td>Pedalcyclists</td>
<td>Riding in lane (frontal), riding in adjacent lane (frontal/side), riding in dedicated lane (frontal/side), riding on sidewalk/shoulder, crossing road – inside crosswalk (frontal), crossing road – outside crosswalk (frontal)</td>
</tr>
</tbody>
</table>

### Table 38. L4 HAV/TNC Summary of Non-Roadway User Events

<table>
<thead>
<tr>
<th>Non-roadway Users</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Animals(^5)</td>
<td>Static in lane (frontal), moving into/out of lane (frontal/side), static/moving in adjacent lane (frontal), static/moving on shoulder</td>
</tr>
<tr>
<td>Debris(^5)</td>
<td>Static in lane (frontal)</td>
</tr>
<tr>
<td>Other dynamic objects (e.g., shopping carts)</td>
<td>Static in lane (frontal/side), moving into/out of lane (frontal/side)</td>
</tr>
</tbody>
</table>
Table 39. L4 HAV/TNC Summary of Signs and Signals Events

<table>
<thead>
<tr>
<th>Signs and Signals</th>
<th>Traffic signs(^7)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Traffic signs(^7)</td>
<td>Stop, yield, speed limit, crosswalk, railroad crossing, school zone, access restriction (e.g., one-way), work zone</td>
</tr>
<tr>
<td>Traffic signals(^7)</td>
<td>Intersection, railroad crossing, school zone</td>
</tr>
<tr>
<td>Vehicle signals</td>
<td>Turn signals</td>
</tr>
</tbody>
</table>

Table 40. L4 HAV/TNC Summary of Other Objects and Events of Interest

<table>
<thead>
<tr>
<th>Other Objects of Interest</th>
<th>Lights and sirens activated (frontal/side/rear), passing on shoulder (side/rear), encroaching (frontal/side/rear), driving wrong direction (frontal/side/rear), violating precedence/right-of-way (frontal/side/rear)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Emergency vehicles</td>
<td>Lights and signs activated (frontal/side), stopped in lane or adjacent lane (frontal/side), stopped in opposing/undivided lane (frontal/side)</td>
</tr>
<tr>
<td>School buses</td>
<td>Cones, barrels, safety officials (e.g., handheld signs, flags, or hand signals)</td>
</tr>
<tr>
<td>Other traffic control devices(^7)</td>
<td></td>
</tr>
</tbody>
</table>

Table 41 shows a summary of the objects and events highlighted in bold from the preceding tables, generalized into a working list of OEDR behavior capabilities. While not directly related to a specific object, operating outside of the defined ODD was also identified as an important event for OEDR, and is relevant to all of the selected features. These OEDR behaviors are intended to be a companion to the list of tactical maneuver behaviors identified and presented in Chapter 2. These OEDR behaviors provided the basis for the development of preliminary tests in Chapter 5. As previously mentioned, several other attempts have been made to develop similar sets of behaviors and conditions that are important, including the California PATH program behavioral competency analysis (Nowakowski, Shladover, Chan, & Tan, 2015) and NHTSA pre-crash scenario analysis (Najm, Smith, & Yanagisawa, 2007). Waymo also recently released a voluntary safety self-assessment that included a list of behavioral competencies above and beyond those included in the PATH analysis (Waymo, 2017b). A comparison of the behavior combined list of OEDR behaviors and tactical maneuver behaviors from Chapter 2 with those from the PATH, NHTSA, and Waymo analyses is provided in Appendix D.
Table 41. OEDR Behavior Capabilities

<table>
<thead>
<tr>
<th>Detect &amp; Respond to Speed Limit Changes</th>
<th>Detect &amp; Respond to Relevant School Buses</th>
</tr>
</thead>
<tbody>
<tr>
<td>Detect &amp; Respond to Encroaching, Oncoming Vehicles</td>
<td>Detect &amp; Respond to Relevant Emergency Vehicles</td>
</tr>
<tr>
<td>Perform Vehicle Following</td>
<td>Detect &amp; Respond to Relevant Pedestrians</td>
</tr>
<tr>
<td>Detect &amp; Respond to Relevant Stopped Vehicles</td>
<td>Detect &amp; Respond to Relevant Pedalcyclists</td>
</tr>
<tr>
<td>Detect &amp; Respond to Relevant Lane Changes/Cut-ins</td>
<td>Detect &amp; Respond to Relevant Animals</td>
</tr>
<tr>
<td>Detect &amp; Respond to Relevant Static Obstacles in Lane</td>
<td>Detect &amp; Respond to Relevant Vehicle Cut-out/Reveal</td>
</tr>
<tr>
<td>Detect &amp; Navigate Work Zones</td>
<td>Detect &amp; Respond to Relevant Vehicle Roadway Entry</td>
</tr>
<tr>
<td>Detect &amp; Respond to Relevant Safety Officials</td>
<td>Detect &amp; Respond to Relevant Adjacent Vehicles</td>
</tr>
<tr>
<td>Detect &amp; Respond to Relevant Access Restrictions</td>
<td>Detect &amp; Respond to ODD Boundary Transition</td>
</tr>
<tr>
<td>Detect &amp; Respond to Relevant Dynamic Traffic Signs</td>
<td></td>
</tr>
</tbody>
</table>

The detection of objects and events may occur in multiple ways. ADS will likely employ a suite of perception sensors—potentially to include some combination of radar, lidar, cameras, and ultrasonic sensors—that can support detection and recognition of many of these objects and events. This path relies on supporting algorithms to parse and interpret the data provided by those sensors. V2V and V2I communications capability, via DSRC or other technology, can also support detection and recognition in some capacity. If available, SAE J2735 Basic Safety Messages include information on vehicle position, speed, and heading that could supplement or augment measurements taken by an ADS’s onboard perception sensors. Other data, such as intersection signal, phase, and timing data could be broadcast through digital infrastructure to provide information on the state of a traffic signal. Furthermore, many prototype ADS under development rely on onboard, high-fidelity digital maps that have been collected and optimized a priori. These maps may include three-dimensional information about static objects and infrastructure, including the roadway itself. Maps may also include important navigation metadata, such as the number of lanes on a road segment and other important lane characteristics (e.g., directionality, left turn, bus-only), speed limits, and presence of traffic control devices or markings (e.g., stop signs, traffic signals, crosswalks). This map information can similarly be used to supplement or augment an ADS’s onboard sensor data (or vice versa) or could be used independently to support the detection of certain objects and events. No assumptions regarding the mechanism for implementing detection were made when compiling the list of objects and events.

Assuming an ADS has correctly detected a safety-critical object or event, it then implements an appropriate response. The response will ideally be a stable control action or maneuver that allows the ADS to maintain a safe avoidance distance from all relevant obstacles in the immediate crash vicinity, and that continues to follow the applicable rules and etiquette of the road, to the best extent possible. The identified responses that notionally fit these criteria include:
Follow Vehicle – Implement lateral and/or longitudinal control actions to maintain a safe\(^8\) following distance from an immediate lead vehicle, while continuing to follow the current lane of travel.

Accelerate – Implement longitudinal control actions to increase speed, as appropriate and lawful.

Decelerate – Implement longitudinal control actions to decrease speed, as appropriate.

Stop – Implement longitudinal control actions to decelerate in a safe and stable manner to a complete stop.

Yield – Relinquish right-of-way to another road user.

Change Lane – Implement longitudinal and/or lateral control actions to shift into an adjacent lane.
  - Abort Lane Change – Cancel the maneuver to shift into an adjacent lane (remain in or return to original lane).

Pass – Implement longitudinal and/or lateral control actions to shift into an adjacent lane to accelerate to desired speed.
  - Abort Pass – Cancel maneuver to shift into an adjacent lane (remain in or return to original lane).

Turn – Implement lateral and longitudinal control actions to transition from current road/lane to connecting road/lane.

Shift Within Lane – Implement lateral and/or longitudinal control actions such that the ADS does not follow the center (or near-center) of the current lane but remains fully within the current lane.

Shift Outside of Lane – Implement lateral and/or longitudinal control actions such that the ADS partially or fully moves outside of the current lane of travel (i.e., one or more wheels cross the lane boundary).

Move Out of Travel Lane/Park – Implement lateral and longitudinal control actions such that the ADS fully exits the current active lane of travel onto a shoulder or parking lane and stops.

Transition to MRC:
  - Return Control to Fallback-ready User – Return longitudinal and lateral control to human occupant/driver (while providing sufficient warning).
  - ADS Implements Minimal Risk Maneuver – Implement lateral and/or longitudinal control actions to achieve a minimal risk condition (see Chapter 6).

These control actions and maneuvers represent a variety of options for an ADS to respond to objects and events of interest. Table 42 through Table 53 show mappings of these responses to the objects and events identified in Table 29 through Table 40. Again, these mappings are intended to be notional rather than normative. It should also be noted again that, as an ADS’s ODD will be specified by the OEM or developer, some of these objects and events may fall outside the final ODD. These cases may be captured by the event representing operation outside of the ODD, for which the appropriate response may likely be to transition to an MRC.

\(^8\) Could be defined by State or local regulations, but notionally should ensure vehicle can decelerate safely to avoid a collision.
### L3 Conditional Automated Traffic Jam Drive Feature

**Table 42. L3 TJD Response Mapping - Roadway Users**

<table>
<thead>
<tr>
<th>Event</th>
<th>Response</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lead vehicle decelerating</td>
<td>Follow vehicle, decelerate, stop</td>
</tr>
<tr>
<td>Lead vehicle stopped</td>
<td>Decelerate, stop</td>
</tr>
<tr>
<td>Lead vehicle accelerating</td>
<td>Accelerate, follow vehicle</td>
</tr>
<tr>
<td>Lead vehicle turning</td>
<td>Decelerate, stop</td>
</tr>
<tr>
<td>Vehicle changing lanes</td>
<td>Yield, decelerate, follow vehicle</td>
</tr>
<tr>
<td>Vehicle cutting in</td>
<td>Yield, decelerate, stop, follow vehicle</td>
</tr>
<tr>
<td>Vehicle entering roadway</td>
<td>Follow vehicle, decelerate, stop</td>
</tr>
<tr>
<td>Opposing vehicle encroaching</td>
<td>Decelerate, stop, shift within lane, shift outside of lane</td>
</tr>
<tr>
<td>Adjacent vehicle encroaching</td>
<td>Yield, decelerate, stop</td>
</tr>
<tr>
<td>Lead vehicle cutting out</td>
<td>Accelerate, decelerate, stop</td>
</tr>
<tr>
<td>Pedestrian crossing road – inside crosswalk</td>
<td>Yield, decelerate, stop</td>
</tr>
<tr>
<td>Pedestrian crossing road – outside of crosswalk</td>
<td>Yield, decelerate, stop</td>
</tr>
<tr>
<td>Pedalcyclist riding in lane</td>
<td>Yield, follow</td>
</tr>
<tr>
<td>Pedalcyclist riding in dedicated lane</td>
<td>Shift within lane&lt;sup&gt;9&lt;/sup&gt;</td>
</tr>
<tr>
<td>Pedalcyclist crossing road – inside crosswalk</td>
<td>Yield, decelerate, stop</td>
</tr>
<tr>
<td>Pedalcyclist crossing road – outside crosswalk</td>
<td>Yield, decelerate, stop</td>
</tr>
<tr>
<td>Lead vehicle decelerating</td>
<td>Follow vehicle, decelerate, stop</td>
</tr>
<tr>
<td>Lead vehicle stopped</td>
<td>Decelerate, stop</td>
</tr>
<tr>
<td>Lead vehicle accelerating</td>
<td>Accelerate, follow vehicle</td>
</tr>
</tbody>
</table>

**Table 43. L3 TJD Response Mapping - Non-Roadway Users**

<table>
<thead>
<tr>
<th>Event</th>
<th>Response</th>
</tr>
</thead>
<tbody>
<tr>
<td>Debris static in lane</td>
<td>Decelerate, stop</td>
</tr>
<tr>
<td>Dynamic object in lane</td>
<td>Decelerate, stop</td>
</tr>
<tr>
<td>Dynamic object moving into/out of lane</td>
<td>Decelerate, stop</td>
</tr>
</tbody>
</table>

**Table 44. L3 TJD Response Mapping - Other Events of Interest**

<table>
<thead>
<tr>
<th>Event</th>
<th>Response</th>
</tr>
</thead>
<tbody>
<tr>
<td>Operating outside of ODD</td>
<td>Transition to MRC (fallback-ready user)</td>
</tr>
</tbody>
</table>

<sup>9</sup> Could be informed by State or local regulations.
### L3 Conditional Automated Highway Drive Feature

#### Table 45. L3 HWD Response Mapping - Roadway Users

<table>
<thead>
<tr>
<th>Event</th>
<th>Response</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lead vehicle decelerating</td>
<td>Follow vehicle, decelerate, stop, change lane, pass</td>
</tr>
<tr>
<td>Lead vehicle stopped</td>
<td>Decelerate, stop, change lane, pass</td>
</tr>
<tr>
<td>Lead vehicle accelerating</td>
<td>Accelerate, follow vehicle</td>
</tr>
<tr>
<td>Lead vehicle turning</td>
<td>Decelerate, stop, change lane, pass</td>
</tr>
<tr>
<td>Vehicle changing lanes</td>
<td>Yield, decelerate, follow vehicle</td>
</tr>
<tr>
<td>Vehicle cutting in</td>
<td>Yield, decelerate, stop, follow vehicle, change lane</td>
</tr>
<tr>
<td>Vehicle entering roadway</td>
<td>Follow vehicle, decelerate, stop, change lane, pass</td>
</tr>
<tr>
<td>Opposing vehicle encroaching</td>
<td>Decelerate, stop, shift within lane, shift outside of lane, change lane</td>
</tr>
<tr>
<td>Adjacent vehicle encroaching</td>
<td>Yield, decelerate, stop, shift within lane, shift outside of lane, change lane</td>
</tr>
<tr>
<td>Lead vehicle cutting out</td>
<td>Accelerate, decelerate, stop</td>
</tr>
<tr>
<td>Pedestrian crossing road – inside crosswalk</td>
<td>Yield, decelerate, stop</td>
</tr>
<tr>
<td>Pedestrian crossing road – outside of crosswalk</td>
<td>Yield, decelerate, stop</td>
</tr>
<tr>
<td>Pedalcyclist riding in lane</td>
<td>Yield, follow, change lane, pass</td>
</tr>
<tr>
<td>Pedalcyclist riding in dedicated lane</td>
<td>Shift within lane, change lane</td>
</tr>
<tr>
<td>Pedalcyclist crossing road – inside crosswalk</td>
<td>Yield, decelerate, stop</td>
</tr>
<tr>
<td>Pedalcyclist crossing road – outside crosswalk</td>
<td>Yield, decelerate, stop</td>
</tr>
</tbody>
</table>

#### Table 46. L3 HWD Response Mapping - Non-Roadway Users

<table>
<thead>
<tr>
<th>Event</th>
<th>Response</th>
</tr>
</thead>
<tbody>
<tr>
<td>Animal static in lane</td>
<td>Decelerate, stop, change lane, pass, shift within lane, shift outside of lane</td>
</tr>
<tr>
<td>Animal moving into/out of lane</td>
<td>Decelerate, stop, change lane, pass, shift within lane, shift outside of lane</td>
</tr>
<tr>
<td>Debris static in lane</td>
<td>Decelerate, stop, change lane, pass, shift within lane, shift outside of lane</td>
</tr>
<tr>
<td>Dynamic object in lane</td>
<td>Decelerate, stop, change lane, pass, shift within lane, shift outside of lane</td>
</tr>
<tr>
<td>Dynamic object moving into/out of lane</td>
<td>Decelerate, stop, change lane, pass, shift within lane, shift outside of lane</td>
</tr>
</tbody>
</table>

#### Table 47. L3 HWD Response Mapping - Signs and Signals

<table>
<thead>
<tr>
<th>Event</th>
<th>Response</th>
</tr>
</thead>
<tbody>
<tr>
<td>Speed limit change</td>
<td>Accelerate, decelerate</td>
</tr>
</tbody>
</table>

---

10 Could be informed by State or local regulations.
Table 48. L3 HWD Response Mapping - Other Events of Interest

<table>
<thead>
<tr>
<th>Event</th>
<th>Response</th>
</tr>
</thead>
<tbody>
<tr>
<td>Operating outside of ODD</td>
<td>Transition to MRC (fallback-ready user)</td>
</tr>
</tbody>
</table>

**L4 Highly Automated Vehicle/TNC Feature**

Table 49. L4 HAV/TNC Response Mapping - Roadway Users

<table>
<thead>
<tr>
<th>Event</th>
<th>Response</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lead vehicle decelerating</td>
<td>Follow vehicle, decelerate, stop, change lane, pass</td>
</tr>
<tr>
<td>Lead vehicle stopped</td>
<td>Decelerate, stop, change lane, pass</td>
</tr>
<tr>
<td>Lead vehicle accelerating</td>
<td>Accelerate, follow vehicle</td>
</tr>
<tr>
<td>Lead vehicle turning</td>
<td>Decelerate, stop, change lane, pass</td>
</tr>
<tr>
<td>Vehicle changing lanes</td>
<td>Yield, decelerate, follow vehicle</td>
</tr>
<tr>
<td>Vehicle cutting in</td>
<td>Yield, decelerate, stop, follow vehicle, change lane</td>
</tr>
<tr>
<td>Vehicle entering roadway</td>
<td>Yield, decelerate, stop, change lane, pass</td>
</tr>
<tr>
<td>Vehicle cutting out</td>
<td>Accelerate, decelerate, stop, change lane, pass</td>
</tr>
<tr>
<td>Opposing vehicle encroaching</td>
<td>Decelerate, stop, shift within lane, shift outside of lane, change lane</td>
</tr>
<tr>
<td>Adjacent vehicle encroaching</td>
<td>Yield, decelerate, stop, shift within lane, shift outside of lane, change lane</td>
</tr>
<tr>
<td>Lead vehicle cutting out</td>
<td>Accelerate, decelerate, stop</td>
</tr>
<tr>
<td>Lead vehicle parking</td>
<td>Decelerate, stop, change lane, pass</td>
</tr>
<tr>
<td>Pedestrian crossing road – inside crosswalk</td>
<td>Yield, decelerate, stop</td>
</tr>
<tr>
<td>Pedestrian crossing road – outside of crosswalk</td>
<td>Yield, decelerate, stop</td>
</tr>
<tr>
<td>Pedalcyclist riding in lane</td>
<td>Yield, follow, change lane, pass</td>
</tr>
<tr>
<td>Pedalcyclist riding in adjacent lane</td>
<td>Yield, shift within lane</td>
</tr>
<tr>
<td>Pedalcyclist riding in dedicated lane</td>
<td>Shift within lane$^{11}$, change lane</td>
</tr>
<tr>
<td>Pedalcyclist crossing road – inside crosswalk</td>
<td>Yield, decelerate, stop</td>
</tr>
<tr>
<td>Pedalcyclist crossing road – outside crosswalk</td>
<td>Yield, decelerate, stop</td>
</tr>
</tbody>
</table>

Table 50. L4 HAV/TNC Response Mapping - Non-Roadway Users

<table>
<thead>
<tr>
<th>Event</th>
<th>Response</th>
</tr>
</thead>
<tbody>
<tr>
<td>Animal static in lane</td>
<td>Decelerate, stop, change lane, pass, shift within lane, shift outside of lane</td>
</tr>
<tr>
<td>Animal moving into/out of lane</td>
<td>Decelerate, stop, change lane, pass, shift within lane, shift outside of lane</td>
</tr>
<tr>
<td>Debris static in lane</td>
<td>Decelerate, stop, change lane, pass, shift within lane, shift outside of lane</td>
</tr>
<tr>
<td>Dynamic object in lane</td>
<td>Decelerate, stop, change lane, pass, shift within lane, shift outside of lane</td>
</tr>
<tr>
<td>Dynamic object moving into/out of lane</td>
<td>Decelerate, stop, change lane, pass, shift within lane, shift outside of lane</td>
</tr>
</tbody>
</table>

$^{11}$ Could be informed by State or local regulations.
Table 51. L4 HAV/TNC Response Mapping - Signs and Signals

<table>
<thead>
<tr>
<th>Event</th>
<th>Response</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stop sign</td>
<td>Decelerate, stop</td>
</tr>
<tr>
<td>Yield sign</td>
<td>Decelerate, yield, stop</td>
</tr>
<tr>
<td>Speed limit sign</td>
<td>Accelerate, decelerate</td>
</tr>
<tr>
<td>Crosswalk sign</td>
<td>Decelerate, yield, stop</td>
</tr>
<tr>
<td>Railroad crossing</td>
<td>Decelerate, yield, stop</td>
</tr>
<tr>
<td>School zone</td>
<td>Decelerate, yield, stop</td>
</tr>
<tr>
<td>Access restriction</td>
<td>Stop, turn, change lane, transition to MRC (ADS), move out of travel lane/park</td>
</tr>
<tr>
<td>Work zone</td>
<td>Decelerate, yield, change lane, shift within lane, shift outside of lane</td>
</tr>
<tr>
<td>Intersection signals</td>
<td>Decelerate, stop, accelerate, yield, turn</td>
</tr>
<tr>
<td>Railroad crossing signal</td>
<td>Decelerate, stop</td>
</tr>
<tr>
<td>School zone signal</td>
<td>Decelerate, yield, stop</td>
</tr>
</tbody>
</table>

Table 52. L4 HAV/TNC Response Mapping - Other Objects of Interest

<table>
<thead>
<tr>
<th>Event</th>
<th>Response</th>
</tr>
</thead>
<tbody>
<tr>
<td>Emergency vehicle (active) static</td>
<td>Decelerate, yield, stop, change lane, pass, shift within lane, shift outside of lane</td>
</tr>
<tr>
<td>Emergency vehicle (active) passing</td>
<td>Decelerate, yield, stop, change lane, shift within lane, shift outside of lane</td>
</tr>
<tr>
<td>Emergency vehicle (active) encroaching</td>
<td>Decelerate, yield, stop, change lane, shift within lane, shift outside of lane</td>
</tr>
<tr>
<td>Emergency vehicle (active) driving wrong direction</td>
<td>Decelerate, yield, stop, change lane, shift within lane, shift outside of lane</td>
</tr>
<tr>
<td>Emergency vehicle (active) violating precedence</td>
<td>Decelerate, yield, stop</td>
</tr>
<tr>
<td>School bus (active) stopped in lane</td>
<td>Yield, stop</td>
</tr>
<tr>
<td>School bus (active) stopped in adjacent lane</td>
<td>Yield, stop</td>
</tr>
<tr>
<td>School bus stopped in opposing/undivided lane</td>
<td>Yield, stop</td>
</tr>
<tr>
<td>Other traffic control devices</td>
<td>Dependent on scenario configuration</td>
</tr>
</tbody>
</table>

Table 53. L4 HAV/TNC Response Mapping for Other Events of Interest

<table>
<thead>
<tr>
<th>Event</th>
<th>Response</th>
</tr>
</thead>
<tbody>
<tr>
<td>Operating outside of ODD</td>
<td>Transition to MRC (fallback-ready user or ADS)</td>
</tr>
</tbody>
</table>

SUMMARY

This chapter identified a set of baseline ODDs for the selected ADS features to frame the analysis of driving scenarios and the identification of OEDR capabilities. Relevant objects and events that an ADS could reasonably be expected to encounter within its ODD were then

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12 Any of the listed responses could be appropriate for temporary or alternative traffic control devices (e.g., hand signals, flags), depending on the situation and context.
identified. These objects and events were generalized into a set of 19 OEDR-related behaviors for further evaluation. A number of the potential control-related actions an ADS could implement in response to the objects and events were also identified. The responses were then mapped to the identified key objects and interactions. While ADS features brought to market may inevitably have specified ODDs that differ from the baselines, the OEDR capabilities identified using these baselines capture a significant cross-section of potential OEDR-related behaviors. The baseline ODDs and OEDR capabilities will serve to inform and drive the construction of a flexible testing framework, and specific tests that can be performed within that framework in Chapter 5.
CHAPTER 5. PRELIMINARY TESTS AND EVALUATION METHODS

OVERVIEW

This chapter describes the development of preliminary tests and evaluation methods to support the assessment of ADS for safe deployment. This builds on findings reported in Chapter 2, Chapter 3, and Chapter 4. The test methods and procedures were developed using engineering judgments, previous test procedure development experience, functional requirements, and use cases. The test framework and procedures developed gave special consideration to achieving repeatability, reliability, and practicality. Lastly, many challenges associated with testing ADS and further research needed to help address these challenges were identified. Challenges included those related to the technology itself as well as test execution. While this task did not involve any actual testing, the findings may inform future physical and virtual tests.

The current automotive certification landscape in the United States involves OEMs and suppliers to self-certify that each piece of regulated equipment and each regulated vehicle is compliant with relevant Federal Motor Vehicle Safety Standards. NHTSA’s authority includes the ability to select vehicles and equipment to verify compliance with these standards, and to pursue enforcement actions when it finds a noncompliance or defect posing a safety risk. To support this, NHTSA’s Office of Vehicle Safety Compliance audits and verifies compliance, and its Office of Defects Investigation explores safety issues to determine if a safety-related defect exists. No assumptions about the structure of the future automotive certification landscape that includes ADS were made. Rather, the aim was to develop an example of a flexible evaluation framework and common test scenarios. The resulting framework focuses on common test scenarios that can be leveraged and applied across multiple testing techniques.

A goal was to develop the framework such that it could be used for testing in a variety of ways, including:

- Black-box testing – The functionality of the system is tested, while the internal design and implementation of the system are largely unknown or unexposed to the tester.
- White-box testing – The internal structure or workings of a system are tested as opposed to its overall functionality.

An example of black-box testing in the context of an ADS assessment would be to evaluate its obstacle avoidance capabilities. In this example, the test may involve positioning a large static obstacle along an ADS’s intended route and observing its ability to avoid a collision with the object while continuing to navigate to its desired destination. In this case, only the resulting navigation outcome is evaluated to answer one primary question:

- Did the ADS avoid the obstacles in a safe and stable manner?
An example of white-box testing in the same context would involve measuring the outputs of one or more of the ADS’s perception and navigation algorithms to answer a multitude of questions, potentially including:

- At what range did the ADS detect the obstacle?
- Did the ADS correctly classify the type of obstacle?
- Did the ADS correctly estimate the location of the obstacle?
- Did the ADS correctly estimate the size of the obstacle?
- How quickly did the ADS decide to react?
- How stable was the control response?

In some cases, black-box testing may be sufficient for safety verifications of ADS or other systems; however, there is significant value in answering the questions associated with white-box testing. Answering these questions supports a deeper understanding of the performance bounds of a system. A goal was to establish a testing framework that could benefit and support government and industry with both black-box and white-box testing, as ADS are developed and deployed.

**APPROACH**

To identify appropriate methods to evaluate ADS, a review and assessment of existing testing methods and tools was performed. This evaluation served to develop an understanding of how testing is currently being executed for vehicles capable of various levels of automation. It also served to identify potential gaps in this existing testing framework, which led to the identification of additional and modified tools and methods to fill those gaps and help create a testing framework. This assessment included a meeting with crash avoidance test engineers at NHTSA’s Vehicle Research and Testing Center in Ohio to discuss their current testing of vehicles capable of SAE International L1 and L2 driving automation. Findings from the previous tasks were presented and initial thoughts on the steps to develop a useful set of test methods and actual tests were provided.

A common test scenario framework that could be used broadly across the various testing methods and tools was then established. This framework built upon the findings of the previous tasks to include the principal elements of ADS operation (tactical maneuver, ODD, and OEDR) that have a direct impact on their overall safety. Each of these elements can be viewed as an input or integrated component in the overall test scenario. The framework was developed in such a way that it could be used for both black-box and white-box testing. Each of the core scenario components can be applied similarly for both black-box and white-box analyses; the differences come in the ability to inject inputs and take output measurements at various levels within the system under test. As part of this analysis, key interfaces where this injection and measurement could take place were identified.

With this scenario framework established, notional test procedures for a subset of the important scenarios were developed. The structure of the procedures was based on prior tests related to
connected-vehicle technology (Howe, Xu, Hoover, Elsasser, & Barickman, 2016). Aspects of these procedures include the following.

- Test subject and purpose
- Test personnel, facilities, and equipment
- Test scenario
  - Inputs
  - Initial conditions
  - Execution
  - Data measurement and metrics

Several guiding principles were identified to support the development of the testing framework and the test procedures themselves.

- Testing variables should be isolated, not integrated
- Test environments should be characterized or controlled for test repeatability
- Test metrics should not contain inherent thresholds
- Test methods should allow for sufficient dynamic range
- Tests should be conducted at the lowest level of integration possible
- Low-level tests should help create boundary conditions for high-level integrated system tests
- Parameterization of testing variables and conditions should focus on a “reasonable worst case”

Finally, challenges associated with testing ADS were identified. ADS add a significant level of complexity to a base vehicle platform that can make their assessment more difficult in many ways. These challenges were broken down into two main categories: (1) challenges associated with developing tests and metrics, and (2) challenges associated with test execution.
FINDINGS

Testing Architecture

Available literature and reports on current ADS testing activities conducted by both government and industry were reviewed. The review identified several ways that these tests are primarily being conducted.

- Modeling and simulation (M&S)
- Closed-track testing
- Open-road testing

These three techniques offer a multifaceted testing architecture with varying degrees of test control, and varying degrees of fidelity in the test environment. In many cases, two or more of these techniques can be used in parallel or in an iterative fashion to progressively evaluate a complex system such as an ADS.
**Modeling and Simulation**

M&S rely on a virtual environment with virtual agents to generate knowledge about an ADS’s behavior without the need for a physical vehicle and actual testing in the real world. The base vehicle platform and the underlying ADS components need to be modeled physically and/or mathematically to the extent that the behavior of the virtual system can mimic that of the real system to the desired degree of fidelity. Similarly, the virtual environment in which the ADS will be operating is modeled to the desired degree of fidelity. The higher the fidelity of these models, the more closely they represent the actual nature of the vehicle or environment, which results in more substantive data for analysis.

Simulation testing provides several advantages:

- **Controllability** – Simulation affords an unmatched ability to control many aspects of a test.
- **Predictability** – Simulation is designed to run as specified, so there is little uncertainty as to how the test will run.
- **Repeatability** – Simulation allows a test to be run many times in the same fashion, with the same inputs and initial conditions.
- **Scalability** – Simulation allows for generation of a large number and type of scenarios.
- **Efficiency** – Simulation includes a temporal component, which allows it to be sped up faster than real time so that many tests can be run in a relatively short amount of time.

These features are important for the testing of complex systems. Simulation may also serve as a relatively cheaper option for initial testing, as opposed to building up one or more fully functional test vehicles. Simulation environments are also faster to implement and deploy and may be able to test a broader range of conditions.

There are several approaches to M&S that may be applied to support the validation and verification of ADS with existing tools. Examples of the applications are discussed in this section and described more expansively in Appendix B. Appendix B also includes a breakdown of tools by functional area.

Several subfields within the field of M&S that could be used for ADS testing were identified.

- Software-in-the-loop (SIL) simulation
- Hardware-in-the-loop (HIL) simulation
- Vehicle-in-the-loop (VIL) simulation

SIL simulation might be viewed as a traditional simulation system where a subset or all of the underlying ADS software is incorporated into the modeled vehicle to drive the physical response to stimuli. This could include processing modeled sensor data that then feed into world-modeling, decision-making, and motion-planning algorithms. The output of the motion-planning algorithm could be fed into the vehicle model to then induce the virtual vehicle’s motion.
HIL simulation incorporates some level of physical hardware and equipment into the simulation environment to provide real data inputs and processing for some parts of the system. For example, an actual radar may be tied into the simulation to provide live range data for the virtual ADS to process and enact a response to, or an actual electronic control unit could be tied into the virtual system to study how the physical production-intent hardware functions. Alternatively, a real heavy-duty vehicle pneumatic brake actuation system could be installed on a static stand and tied into the simulator (Salaani, Mikesell, Boday, & Elsasser, 2016). The brake signals generated by the virtual ADS model could be sent to the brake system to collect data to understand the actual dynamic response to certain conditions and stimuli.

Finally, VIL simulation can allow for a somewhat more integrated test and analysis by leveraging the production-intent vehicle and subsystems. The ADS platform could be placed on a roller test bench, such as a chassis-dynamometer, to allow physical actuation of the steering, throttle, and brake systems to get the wheels rolling and turning, while the vehicle remains in place. The simulation system could be tied into both the roller bench and the vehicle itself. The interface with the vehicle could allow for injection of sensor data to simulate terrain and objects and injection of map data to support routing and decision-making, among other things. The interface with the roller bench could facilitate simulation of road surface conditions (e.g., roughness, traction loss). Alternatively, virtual scenarios and objects could be injected into a real-world test environment, with the actual ADS running on a track and reacting to the virtual scenarios (Kallweit, Prescher, & Butenuth, 2017). Communications infrastructure, such as DSRC, could be integrated into the simulation to provide V2V or V2I data exchange to inject these virtual objects or scenarios.

Figure 23 shows a generalized ADS simulation architecture diagram. The diagram calls out external inputs that could be simulated and injected into a test, inputs that can otherwise be controlled or measured, as well as outputs that can be measured. The nature of the simulation (e.g., white-box versus black-box) could allow for other interfaces for data injection and measurement.
M&S testing offers several additional benefits to address some of the challenges associated with testing ADS. The magnitude of the number of scenarios an ADS could encounter, along with the magnitude and variability of the components that make up a scenario (e.g., ODD, OEDR), likely present an impractical set of test cases. M&S can be leveraged to inform testing requirements and prioritize test scenarios for additional testing using the other techniques of the proposed testing architecture. Simulation can be used as a tool to assess the impact of the sensitivity of ODD and OEDR to the accuracy of ADS. The wide variety of test case parameters (e.g., sensor errors, types of intersections, types of objects) can be varied efficiently to estimate the potential associated risk. This can inform the development of risk profiles that can help prioritize those parameters and scenarios. Additionally, simulation can easily allow for fault injection to test failure modes and the ADS’s responses to those failures.

Several disadvantages also exist to the use of M&S. It is difficult to model systems and physical properties with full-fidelity, which may impact how well the simulation environment mimics the real world. There is also a wide variety of commercially available simulation tools, as well as vendor-developed tools, with distinctive features and capabilities. This presents challenges to perform comparisons of results across the different tools.
Figure 24. Modeling and Simulation Used to Inform Test Requirements and Prioritize Test Scenarios

Closed-Track Testing

Running tests in a real-world environment is an important component of assessing ADS. Putting physical vehicles through a gamut of lifelike scenarios allows for an evaluation of full system performance that may not be practical using M&S techniques. Rather than presenting virtual objects and environments to a vehicle that is modeled with potentially limited fidelity, as is the case in simulation, physical testing presents real obstacles or obstacle surrogates to a production-level vehicle using actual sensors and software running on target platforms. Testing in a closed-track or road-course setting is one way to achieve such lifelike testing conditions.

Many organizations developing ADS technology either have their own closed-access proving grounds or have access to similar proving grounds through partnerships. Independent proving grounds also exist. Additionally, USDOT recently designated 10 proving ground pilot sites to encourage ADS testing and data sharing (USDOT, 2017). Teams with expertise in CV and ADS technology and with available test facilities to support evaluation of those technologies, including closed test tracks, have organized these proving ground pilot sites across the country to meet those goals.

Track testing provides a few advantages compared to M&S or open-road testing.

- **Controllability** – Track testing allows for control over many of the test variables, including certain aspects of ODD and OEDR.
- **Improved fidelity** – Track testing involves functional, physical ADS and lifelike obstacles and environmental conditions.
- **Transferability** – Track testing scenarios can be replicated in different locations.
- **Repeatability** – Track testing allows for multiple iterations of tests to be run in the same fashion, with the same inputs and initial conditions.
Conversely, closed-track testing also suffers from several drawbacks that present challenges to its utility in assessing and evaluating ADS.

- **Prolonged and costly** – Track testing can take a significant amount of time to set up and execute, resulting in elevated costs.
- **Limited variability** – Track testing facility infrastructure and conditions may be difficult to modify to account for a wide variety of test variables (e.g., ODD conditions).
- **Personnel and equipment needs** – Track testing may need specialized test equipment (e.g., obstacle objects, measurement devices, safety driver).
- **Potentially hazardous** – Track testing with physical vehicles and real obstacles presents a potentially uncertain and hazardous environment to the test participants (e.g., safety driver and experiment observers).

Figure 25 shows a generalized ADS track testing architecture diagram. The diagram calls out external inputs and conditions that could be controlled or measured during a test, as well as outputs that could be measured. The nature of the test (e.g., white-box versus black-box) could allow for different interfaces for data injection and measurement. In a black-box testing scenario, the primary measured output is the navigation outcome, which could include an OEDR-related response as described in Chapter 4. Alternatively, a white-box testing scenario could incorporate measurement at a number of other points within the architecture, including the outputs of sensor-fusion, decision-making, and motion-planning stages. This proposed white-box scenario presents additional challenges, such as gaining access to necessary subsystem interfaces for relevant data collection. It should be noted that elements of the real-world environment, including environmental conditions (e.g., road geometry, road surface, and infrastructure) and temporal-spatial motions of objects, can largely be controlled in track settings. Other conditions, such as weather and ambient lighting, cannot necessarily be controlled. It should also be noted that, regardless of whether some of those conditions can be controlled and replicated or not, the sheer variability of some ODD and OEDR-related conditions (e.g., quality of lane markers, amount of rain or snow, roughness of road, orientation of objects and infrastructure) may make testing completeness intractable. Prioritization of testing scenarios based on risk profiles was identified as a key factor in test scenario selection.
Open-Road Testing

Public roads offer a “real-world laboratory” to support testing and evaluation of ADS. Several entities are actively testing prototype ADS in public, open-road settings to support ongoing development and refinement (General Motors, 2016), (Krok, 2017), (Guardian, 2015), (Lomas, 2017). In addition to allowing a full performance assessment of the prototype systems, public roads expose the systems to an extremely wide variety of real-world conditions related to ODD and OEDR that would not be feasible with established closed test tracks.

However, open-road testing for ADS also has several drawbacks.

- **Lack of controllability** – Public-road scenarios do not afford much, if any, control over ODD and OEDR conditions.
- **Lack of replicability** – Public-road scenarios are difficult to replicate exactly in different locations.
- **Lack of repeatability** – Public-road scenarios are difficult to repeat exactly over multiple iterations.
- **Limited scalability** – Public-road scenarios may not scale up well, as ADS may require additional data, such as *a priori* digital maps.

Figure 26 represents a notional ADS test architecture for open-road testing. It is important to note that very few of the system inputs are controllable or known. Little to no control exists over the primary system inputs (e.g., environmental conditions and real-world information). This testing technique may present a reasonable and critical “final step” for evaluating systems further along in the development process.
Efforts have been, and currently are, underway to provide guidance to developing organizations on the safe testing and validation of ADS, including in public-road settings (SAE International, 2015; NHTSA, 2016a). Some States have investigated similar guidance or, in some cases, legislation that governs the testing and deployment of ADS on public roads within their State boundaries (Nowakowski, Shladover, Chan, & Tan, 2015). Since 2012, 41 States and districts have considered such legislation (National Conference of State Legislatures, 2017), although the degree to which this legislation addresses some of the primary concerns is uncertain and/or varied. In California, which has a considerable number of companies testing ADS on public roads, the California Department of Motor Vehicles requires those companies to submit annual disengagement reports that detail the number of autonomous miles driven, and the number and nature of safety driver interventions per test vehicle (State of California Department of Motor Vehicles, 2017).

**Test Scenarios**

The previous chapters summarized several important functional components that drive the safe deployment of ADS, and the next chapter will summarize a final important component. The following components were identified as collectively making up the core aspects of a common ADS test scenario.

- Tactical maneuver behaviors
- ODD elements
- OEDR capabilities
- Failure mode behaviors
Tactical maneuver behaviors relate to the immediate control-related tasks the ADS is executing as part of the test (e.g., lane following, lane change, turning). The relevant ODD elements generally define the operating environment in which the ADS is navigating during the test (e.g., roadway type, traffic conditions, or environmental conditions). OEDR capabilities relate directly to the objects and events the ADS encounters during the test (e.g., vehicles, pedestrians, traffic signals). Finally, some tests may include injection or simulation of errors or faults that induce failures at various stages within the ADS’s functional architecture. Failure modes will be discussed in more detail in Chapter 6.

Test scenarios can be composed of one or more elements of each of these core components, visualized as the individual dimensions of the multidimensional test matrix in Figure 27. Each of these components may be included in a checklist identifying the aspects of each category that are incorporated in a given test.

Figure 27. ADS Test Scenario Matrix

For example, a sample ADS test scenario for the L4 Highly Automated Vehicle/TNC feature may be notionally described by the items indicated in Table 54. In this scenario, the primary tactical maneuver behavior is the ADS performing a low-speed merge into an adjacent lane. The primary OEDR behavior under test is detecting and responding to other vehicles in the target adjacent lane. The nominal ODD conditions place the test on a straight, flat arterial road with non-degraded lane markers, nominal traffic, and a maximum speed limit of 72 kph (45 mph). The test occurs during the day with clear and dry conditions, and the ADS is functioning as designed.

This method of specifying a scenario descriptor could be established as a series of checklists: one checklist for each dimension of the scenario test matrix shown in Figure 27. This multidimensional checklist approach would provide the high-level structure of the scenario test.
The underlying components of each category are then further defined and quantified to fully develop an actionable set of scenario test procedures. For example, the tactical maneuver behavior could be further specified to indicate the direction of the lane change and how it will be induced (e.g., shift to adjacent left lane due to upcoming left turn). The ODD elements could be further specified to indicate radius of curvature and pitch for the test road, time of day and sun position at which the test will be conducted, and presence of surrounding infrastructure, if any. The OEDR behaviors could be further specified to indicate the number of obstacle vehicles and their initial conditions (e.g., positions, speeds, orientations) and trajectories during the test. Failure mode components could be further specified to indicate the exact failure that will be induced (e.g., GPS receiver failure), as well as how and when it will be induced (e.g., unplugging coaxial cable between GPS antenna and receiver after ADS has begun moving and before it begins changing lanes).

Additional information is necessary to further set the stage for the actual execution of the tests, including vehicles (subject and object vehicles) and their roles. General test procedures were modeled on prior tests conducted by NHTSA for CV technology, specifically a test for an FCW system for commercial vehicles (Howe, Xu, Hoover, Elsasser, & Barickman, 2016). Aspects of those test procedures include the following.

- Ambient conditions
- Sample test personnel
- Sample test facilities
- Sample test equipment
- Sample test scenario
  - Description
  - Purpose
  - Sample initial conditions
  - Sample metrics
A more detailed sample set of test scenarios and procedures for the selected generic features, including performing low-speed lane changes or merges, are outlined in Appendix C. Each of these scenarios was generated for one of the selected generic features by identifying the elements of the proposed test matrix in Figure 27. The procedures define a test for a single scenario. There are numerous relevant scenarios related to an ADS performing a low-speed merge, some of which are shown in Figure 28, as well as most of the other behaviors. In these scenario visualizations, the ADS is highlighted in green. These scenarios show a hypothetical progression of testing, starting with a simple case with no vehicles in the adjacent lane and iteratively getting more complex to a situation where the vehicles in the adjacent lane are spaced such that there is insufficient room for the ADS to safely merge.

![Figure 28. Sample Low-Speed Merge Test Scenarios](image)

The scenario framework described here is flexible enough to support the definition of test scenarios that can apply to simulation, closed-track, and open-road testing. Some elements of the test procedures described above are more relevant to closed-track or open-road testing; however, those elements can likely be modified or ignored for simulation-based testing (e.g., test personnel, test facilities). The core components of the scenarios (tactical maneuver behaviors, ODD, OEDR behaviors, failure mode behaviors) lend themselves well to configuration for all legs of the testing architecture. They also lend themselves well to defining scenarios for both black-box and white-box testing. One of the significant differences for white-box testing will be identifying key interfaces for data measurement to support performance metrics for evaluation that may otherwise be unavailable for black-box testing techniques.

The framework can be leveraged to facilitate a progression of testing, where certain conditions are modified to increase complexity (e.g., speeds and trajectories of the subject vehicle and obstacles). This type of test progression supports identification of behavior and performance...
boundaries and limits. Furthermore, the scenario framework lends itself well to constructing combinations or sequences of scenarios to extend an ADS evaluation to include more comprehensive operational tests. Testing of specific scenarios or behaviors, while important, may have limited utility in assessing the safe operation of an ADS. Combining scenarios into operational tests provides a means to evaluate the system and assess the test space.

Testing Challenges

The previous sections in this chapter have identified a framework to develop ADS scenario tests, and the methods to execute those tests. While this framework provides a flexible means to conduct ADS evaluation, the challenges associated with these evaluations are numerous. This section builds off prior work to identify several key challenges associated with testing ADS (Koopman & Wagner, 2016). The list of challenges presented is not comprehensive but is rather intended to provide an initial working list.

Two primary categories of challenges to consider when developing and conducting tests were identified: (1) challenges associated with ADS technology, and (2) challenges associated with test execution.

Challenges associated with ADS technology focus on some of the characteristics of the technology and the underlying implementations of the integrated hardware and software systems:

- **Probabilistic and non-deterministic algorithms** – To meet some of the temporal needs related to ADS decision-making, many developers are leveraging algorithms that rely on heuristics or probability to provide a “best guess” relatively quickly. This leaves the system open to making incorrect decisions or decisions that vary from one iteration to the next, even when presented with identical or near-identical conditions. This lack of a repeatable system output emphasizes that new testing methodologies may be needed. Probabilistic and non-deterministic algorithms are often used when the State space is extremely large or even unbounded, making complete testing of all conditions virtually impossible.

- **Machine learning algorithms** – Many developers are also leveraging algorithms, such as convolutional neural networks, that allow the system to learn from experience as it is exposed to new conditions and scenarios. This similarly could result in the ADS responding differently in tests with similar or identical situations.

- **Digital mapping needs** – Some prototype ADS (typically L4 or L5 systems) use a priori digital map information for localization and obstacle mapping. This effectively limits the geographic areas in which the ADS can function, and subsequently be tested.

- **Regression testing** – The advent of over-the-air updates to software and firmware will allow ADS developers to push out new features and fix defects rapidly. These updates could potentially have significant impacts on overall system performance that may augment or even invalidate prior test results.
The challenges associated with the execution of tests on ADS highlight the expansiveness of the conditions that vehicles may encounter and handle with minimal, if any, input or guidance from a human. These challenges, among others, include:

- **Testing completeness** – The number of tests or miles driven (Kalra & Paddock, 2016) required to achieve statistical significance to claim safe operation could be staggering.
- **Testing execution controllability** – Without a driver to direct the vehicle, new tools or methods may be needed to direct the ADS to conduct the test in the desired manner (e.g., follow desired route/trajectory, force encounters with objects).
- **Testing scalability** – It will be difficult to achieve significant coverage of the variety and combination of conceivable test conditions, particularly related to ODD and OEDR.
- **Unknown or unclear constraints/operating conditions** – There are a substantial number of real-world corner cases (e.g., missing lane markers, missing signage) that may present the ADS with a situation in which it does not have all the necessary information. The appropriate response may be clear (e.g., transition to MRC); however, identifying and testing against all those corner cases may be intractable.
- **Degraded testing** – Testing against ideal conditions provides a good starting point but establishing tests against even “reasonable worst case” scenarios (e.g., degraded lane markers, rain, snow, shadows) will be cumbersome.
- **Infrastructure considerations** – Changes to key infrastructure elements (e.g., road surface, lane markings, signs) may have substantial impacts on ADS performance.
- **Laws and regulations** – Driving laws vary within and across State lines, can change, and in some cases and to a certain extent are open to interpretation. Successful tests against certain laws and regulations may not be transferable.
- **Assumptions** – Establishing tests with certain assumptions or expectations (e.g., other vehicles obey rules of road and follow driving etiquette) may oversimplify the scenarios such that they are unrealistic or lose value from an assessment standpoint.

**International ADS Testing Programs**

A few international programs related to ADS testing that may be relevant or complement the goals of this research were identified.

*AdaptIVe*

The AdaptIVe Automated Driving project, which recently concluded, involved 28 partners from eight different countries in Europe to further applications for automated driving through collaborative development and testing (AdaptIVe, 2017). The program addressed SAE International L1 through L4 systems, and evaluated other aspects of automated driving, including human factors and legal issues. The AdaptIVe project evaluated several scenarios that were categorized as the following.
• Close-distance scenarios – garage parking (L3), stop-and-go traffic (L3), safe stop (L4)
• Urban scenarios – city chauffeur (L3), safe stop (L4)
• Highway scenarios – lane change (L3), lane/vehicle following (L3), safe stop (L4)

The program also addressed evaluation methods for ADS for four key areas.

• Technical assessment – performance of ADS features
• User-related assessment – interaction between user and ADS features
• In-traffic assessment – effects of ADS on surrounding traffic and non-users
• Impact assessment – effects of ADS features on safety and environmental aspects

**PEGASUS**

Previously referenced in Chapter 3, the PEGASUS Project has goals of:

• Defining standardized procedures for ADS testing and experimentation in simulation, on test stands, and in real environments;
• Developing a continuous and flexible tool chain to safeguard automated driving;
• Integrating tests in the development process at an early stage; and
• Creating a cross-manufacturer method for safeguarding highly automated driving functions.

The program involves 17 partners, including OEMs, Tier 1 suppliers, test labs, and scientific institutes. An important aspect of the program is the identification and generation of scenarios at various levels of abstraction. Furthermore, the program seeks to implement some of these scenario tests using simulation, closed-track testing, and open-road testing, and seeks to identify formal performance metrics for those test techniques. Similar to this work, a subset of available ADS features was selected for analysis and testing.

**SUMMARY**

This task identified and developed an example of a flexible testing framework for ADS, as well as preliminary tests and procedures. The framework leverages existing testing techniques, namely M&S, closed-track testing, and open-road testing. Each of these techniques has advantages and disadvantages for assessing the performance of ADS features, but when used together in a potentially iterative process, they can provide a comprehensive evaluation framework. M&S can provide significant coverage of a wide variety of test conditions in an efficient manner. M&S can be used to perform test variable sensitivity analyses and can help to prioritize scenarios for further evaluation. Closed-track testing uses physical systems and objects to set up lifelike scenarios in a controlled setting. Open-road testing affords an opportunity to assess full system performance in a real-world, unpredictable, and uncontrollable environment.

This chapter established a flexible ADS test scenario framework that built on the other key testing components identified in this research—tactical maneuver behaviors, ODD elements,
OEDR behaviors, and failure mode behaviors. This framework identified a multidimensional approach to specifying the key test scenario data inputs, based on those four test components. This framework is flexible enough to add or modify specific items within those components, as new maneuvers or OEDR behaviors are identified, and allows for the efficient design of new tests. The flexibility of the framework is also manifest in that it can be used for all the testing techniques mentioned above. High-level test procedures are proposed for a set of sample scenarios to further define how tests could be executed and what data to collect to measure performance.

Several challenges were identified with the assessment of ADS that could be categorized as challenges associated with the ADS technology itself and challenges associated with executing tests on ADS. To a certain extent, the testing architecture and scenario framework can be leveraged to address some of those challenges. The chapter also described international research programs that share the common goal of finding ways to assess the performance of ADS.
CHAPTER 6. FAIL-OPERATIONAL AND FAIL-SAFE MECHANISMS

OVERVIEW

This chapter describes an assessment approach to FO and FS mechanisms for an ADS. ADSs will use FO and FS mechanisms when the system does not function as intended. These mechanisms enable an ADS to attain an MRC that removes the vehicle and its occupants from harm’s way, to the best extent possible. Defining, testing, and validating FO and FS strategies for achieving an MRC are important steps in ensuring the safe operation and deployment of ADS.

MRC is defined in SAE J3016 as:

A condition to which a user or an ADS may bring a vehicle after performing the DDT fallback in order to reduce the risk of a crash when a given trip cannot or should not be completed.

SAE J3016 further states:

At level 3, given a DDT performance-relevant system failure in the ADS or vehicle, the DDT fallback-ready user is expected to achieve a minimal risk condition when s/he determines that it is necessary.

At levels 4 and 5, the ADS is capable of automatically achieving a minimal risk condition when necessary (i.e., due to ODD exit, if applicable, or a DDT performance-relevant system failure in the ADS or vehicle). The characteristics of automated achievement of a minimal risk condition at levels 4 and 5 will vary according to the type and extent of the system failure, the ODD (if any) for the ADS feature in question, and the particular operating conditions when the system failure or ODD exit occurs. It may entail automatically bringing the vehicle to a stop within its current travel path, or it may entail a more extensive maneuver designed to remove the vehicle from an active lane of traffic and/or to automatically return the vehicle to a dispatching facility.

As described in Chapter 5, the sample test framework includes failure mode behavior as one important high-level dimension in defining test scenarios and procedures. The efforts undertaken in this task help to frame how failure mode behavior plays into that larger testing architecture, with the goal of evaluating an ADS feature’s ability to achieve an MRC.

APPROACH

As stated previously, the appropriate failure mitigation strategy and resulting MRC is largely dependent on the type and nature of failures the ADS experiences. To this end, an understanding of potential ADS failure modes is necessary. As such, a high-level failure analysis was performed. The results of this analysis informed the assessment of FO and FS mechanisms. A variety of failure and hazard analysis techniques exist, including fault tree analysis, system FMEA, FMECA, system-theoretic process analysis, and HazOp. System FMEA was identified and selected as an initial approach to develop the high-level analysis needed to identify potential
failures in each subsystem of the representative functional architecture, as well as their causes and impacts.

FMEA analyses typically occur early in the design phase of a system, or potentially iteratively throughout the design, development, and testing phases. The general goal is to attempt to identify and correct or address potential malfunctions before the system is available to customers. An FMEA can generally be broken down into the following steps.

1. Identify potential failure modes
2. Identify potential causes and effects of those failure modes
3. Prioritize the failure modes based upon risk
4. Identify an appropriate corrective action or mitigation strategy

In this process, existing reports and literature on ADS failures, including from the Defense Advanced Research Projects Agency Grand and Urban Challenges (DARPA, 2008), as well as engineering judgments and prior experience in ADS development and testing were leveraged and considered. It was assumed that a detailed failure analysis employing a range of techniques noted above has been performed on the base vehicle platform, and therefore efforts were focused on components specifically related to the ADS. This allowed for a deeper dive into the ADS functional architecture presented in Figure 3. A more detailed architecture diagram, which is a working diagram from the SAE International ORAD committee, provided the basis for the high-level FMEA and is shown in Figure 2. Furthermore, failures that could have safety implications, as opposed to failures that are merely an inconvenience, were prioritized.

A notional FMEA worksheet was used to perform the analysis, a summary of which is shown in Table 55. The components of that worksheet are described as follows.

- **Architecture Elements** – System/subsystem from ADS functional architecture (e.g., sensors – radar)
- **Function** – Purpose the element serves (e.g., acquire range data to obstacles)
- **Failure Modes** – Possible ways the element can fail (e.g., hardware failure – loss of power)
- **Potential Causes** – Potential reasons failure occurred (e.g., power cable disconnected)
- **Potential Effects** – Potential downstream implications of failure (e.g., object segmentation algorithm fails to identify lead vehicle, resulting in collision with lead vehicle)
- **Occurrence (O)** – Measure of the likelihood the failure will occur
- **Severity (S)** – Measure of the severity of the effects if the failure did occur
- **Detectability (D)** – Measure of the ability of the system to detect the failure
- **Risk Priority Number (RPN)** – Overall measure of risk associated with failure, composed of occurrence (O), severity (S), and detectability (D): \( RPN = O \cdot S / D \)
- **Process Controls** – Methods or actions to eliminate or mitigate failure
Table 55. Notional Worksheet for ADS FMEA

<table>
<thead>
<tr>
<th>Architecture Elements</th>
<th>Function</th>
<th>Failure Modes</th>
<th>Potential Causes</th>
<th>Potential Effects</th>
<th>Occurrence</th>
<th>Severity</th>
<th>Detectability</th>
<th>RPN</th>
</tr>
</thead>
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<td>Sensors</td>
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<tr>
<td></td>
<td>Radar</td>
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</tr>
</tbody>
</table>

This worksheet includes quantitative measures of occurrence, severity, and detectability to ultimately prioritize the failure modes according to their significance and risk. For this analysis, the types of failures and their impacts were of more interest than their overall risk; however, the team completed the exercise for completeness. The three metrics were evaluated on a notional 0-10 scale, with larger values indicating failures occurring more frequently, with higher severity, and with higher detectability. Values for each were assigned based on research team discussion and insight.

The failure modes and their implications in relation to the ADS tactical maneuver behaviors identified in Chapter 2 and the OEDR behaviors identified in Chapter 5 were highlighted and summarized. As these behaviors are common across many of the ADS features, this then provided a similar mapping between failure modes and those features.

The last step outlined in the FMEA procedure above was completed to identify conceptual FO and FS mechanisms to mitigate identified failures. FS mechanisms are employed when the ADS cannot continue to operate due to a significant failure. When this type of failure occurs, the system should fail in a predictable, controlled manner to the MRC. FO mechanisms are employed when a failure occurs, but the ADS is still able to operate, albeit potentially with reduced capabilities or only for a limited duration. A variety of potential FS and FO options for ADS, as well as advantages, disadvantages, and potential limitations for each were identified and described.

The test architecture and framework from Chapter 5 was revisited to incorporate testing and validating failure mode behavior. The comprehensive testing architecture presented includes options for M&S, closed-track testing, and open-road testing. Inducing failures to evaluate an ADS’s response adds a level of complexity and risk that may necessitate modified approaches or procedures to execute tests.

Several other programs and ongoing activities related to failure mitigation techniques for ADS were identified. USDOT’s Functional Safety Analysis of Automated Lane Centering Controls (Brewer & Najm, 2015) program also includes analysis of failure modes, and the SAE International ORAD committee is currently discussing failure strategies for ADS.
FINDINGS

Failure Modes and Effects

The FMEA was broken down by architecture subsystems to identify potential key failures at each step through the ADS “pipeline.”

- Sensing and communication
- Perception
- Navigation and control
- HMI

Sensing and Communication

Failures related to sensing and communication focus on hardware and software related to exteroception, proprioception, and communication. Sensors related to exteroception acquire data about the external environment around the vehicle. Some examples of exteroceptive sensors include radar, lidar, cameras, and ultrasonics. Sensors related to proprioception acquire data about the internal state of the vehicle, most commonly to support localization. Some examples of proprioceptive sensors include GPS, inertial measurement units, gyroscopes, wheel speed sensors, compasses, steering wheel sensors, and brake pedal sensors. Communication equipment, such as DSRC, cellular technology (3G/4G/LTE/5G), Wi-Fi, and Bluetooth, provides wireless one-way or two-way transmission of data with other roadway users or with infrastructure. The data acquired through communication could include information on other vehicles or roadway users (individual roadway users or larger traffic volumes and patterns), as well as information on relevant incidents, warnings, or infrastructure changes/updates (e.g., traffic accidents, emergency vehicles, and temporary construction zones).

Failure modes associated with exteroceptive sensors include loss of power, loss of data connection, internal hardware failures, and emitter/receiver fouling (e.g., mud, dirt). Failure modes associated with proprioceptive sensors similarly include loss of power, loss of data connection, internal hardware failures, and poor calibration/alignment. Failure modes associated with communication equipment similarly include loss of power, loss of data connection, internal hardware failure, and loss of external signal. Additionally, many of these sensors need software drivers that process the raw data coming from each sensor into data that are more ADS-friendly. These software drivers may fail, or may fail to produce the data at the desired rate, although this may similarly be caused by an internal fault or failure of the equipment itself.

The downstream effects of exteroceptive sensor failures could lead to the ADS failing to detect and track relevant obstacles (e.g., fails to segment or classify another vehicle), or the ADS inaccurately characterizing relevant obstacles (e.g., incorrectly estimates position or shape of object). The effects of proprioceptive sensor failures could lead to the ADS failing to accurately estimate its internal state (e.g., relative and/or absolute position, orientation, speed). The effects of communication equipment failures could lead to the ADS failing to account for or act on
relevant warnings or updates (e.g., fails to detect and react to lane closure). These failures ultimately lead to the ADS being unable to perceive and model the surrounding environment accurately.

**Perception**

Failures associated with perception focus primarily on software algorithms related to sensor processing, localization, and world modeling. Sensor processing involves algorithms to support perception field segmentation (near-field/mid-field/far-field), roadway/terrain segmentation and classification, and object segmentation and classification. Localization involves algorithms for absolute and relative state estimation. World modeling involves algorithms to aggregate information from digital maps and other static and dynamic obstacle maps into a common coordinate frame, as well as incorporating known traffic rules and other virtual information (e.g., geo-fencing).

Failure modes associated with sensor processing include failing to model or detect the information for which the sensor was designed or providing suboptimal results. Failure modes associated with localization include failing to estimate the state of the ADS, or more likely providing an inaccurate estimate. Failure modes associated with world modeling include failing to appropriately combine and register the disparate data into a cohesive model or map, or more likely providing a suboptimal model or map. Failure modes for these perception tasks also include typical software failures, such as memory corruption, control flow errors, or calculation errors. Similarly, these algorithms will be running on computing hardware, which could experience any of a number of failures, including internal hardware failures, loss of power, or loss of data connection.

The downstream effects of failures associated with sensor processing could lead to the ADS ignoring undetected objects or roadway features or misinterpreting them. The effects of failures associated with localization include the ADS losing track of its position and/or orientation and being unable to safely navigate. The failures associated with world modeling lead to the system misrepresenting the environment in which the ADS is operating. This could also include the ADS failing to recognize that it is crossing an ODD or OEDR operational boundary. In general, these failures could lead to the ADS making suboptimal or unsafe navigation decisions.

**Navigation and Control**

Failures associated with navigation focus primarily on software algorithms related to mission planning, maneuver/trajectory planning, and steering and speed control. Mission planning involves algorithms to derive a high-level route for the ADS to follow from its initial location to a desired destination, potentially to include roads to follow and turns to take, and potentially considering travel time or distance. Maneuver and trajectory planning involve algorithms to iteratively determine appropriate and safe motions that allow the ADS to make progress along its high-level route. This includes determining the appropriate tactical maneuver behaviors identified in Chapter 2, such as lane following, lane switching, merging, navigating intersections,
and executing U-turns, as well as the optimal paths for the vehicle to follow to execute those behaviors and the appropriate and safe speeds at which to follow the prescribed path. Steering control involves algorithms to convert the initial, near-field segments of those paths into control inputs to the steering actuator. Speed control involves algorithms to convert the target speed along the desired trajectory into control inputs to the ADS throttle and brake actuators.

Failure modes associated with mission planning include algorithm failures where the high-level route is not generated (e.g., missing connection in digital map), or an inefficient or suboptimal route is generated (e.g., route is not the shortest distance or duration possible). Failures associated with maneuver planning include algorithm failures where a necessary maneuver is not planned (e.g., turn not recognized) or an incorrect or inappropriate maneuver is planned (e.g., incorrect lane change planned before upcoming turn). Failures associated with trajectory planning include algorithm failures where a feasible trajectory is not found to implement a maneuver (e.g., path to execute lane change not generated, even if a feasible one exists, and vehicle continues in current lane), or the trajectory generated is incorrect or suboptimal. Failures associated with steering and speed control include algorithm failures where control inputs are not generated or are incorrect or suboptimal in relation to the planned trajectory.

The effects of failures associated with mission planning may include the ADS being unable to reach its desired destination or following an inefficient route to get there. Effects of failures associated with maneuver planning include the ADS getting stuck or needing to recalculate its mission route, or potentially executing unsafe maneuvers. Effects of failures associated with trajectory planning include the ADS getting stuck, or potentially following unsafe paths. Effects of failures associated with steering and speed control include the ADS not accurately following its planned path, or not safely and stably maintaining the target speed. These lower-level navigation failures could have dire consequences in cases where the vehicle is navigating in complex environments around many dynamic obstacles, ultimately leading to collisions.

**Human-Machine Interface**

Failures associated with the vehicle interface focus on hardware and software failures related to visual displays or audible or tactile warnings that may otherwise be necessary to facilitate an operator takeover. The HMI is crucial for occupied ADS where the occupant may need to perform the functions of a fallback-ready user in the event of a major failure. The HMI provides information about the state of the environment, as well as the internal state of the system and its ability to function as intended. If any of this information is not provided, or the information provided is incorrect, the operator may either fail to retake control of the vehicle when necessary or may lack vital information or context to facilitate a safe takeover.

Failure modes associated with the HMI include internal hardware failures such as a display, speaker, or tactile mechanism not functioning as intended (e.g., display screen dies, steering wheels fails to vibrate). They also include software failures related to the presentation of relevant
data or warnings for the operator (e.g., misrepresenting automation status, not issuing an audible warning of imminent collision).

Downstream effects of these failures include a delay in an operator retaking control of the vehicle when requested, or the operator being uninformed that a takeover is necessary. Alternatively, the operator could successfully retake control, but could make poor decisions based on the misrepresentation or lack of data provided. These types of failures may be mitigated in L4 systems, as the ADS achieves the MRC; however, for a L3 system, these types of failures could be pertinent to safety.

Summary

In general, many of the ADS failure modes described above could be attributed to failures of information. These were summarized into three primary categories as failures attributed to:

- No data – Information is absent altogether
- Inadequate quality data – Information is of poor or degraded quality
- Latent data – Information is delayed or old

For each of these three categories, the temporal nature of the failure is also a key component to the resolution. Information failures can be transient/intermittent or persistent. Intermittent or transient data failures may be mitigated by filtering or the recursive nature of many of the elements of the functional architecture. They may also be more difficult to detect. Persistent data failures may be more severe but are also likely to manifest themselves relatively quickly and be easier to detect. Many ADS architectures will provide robustness to some of these failures by fusing and filtering data from multiple sources (e.g., fusing data from a suite of perception sensors, filtering data from multiple relative and absolute localization sensors, extended Kalman filters). This robustness may still have a limited functional time horizon in the event of persistent errors or failures (e.g., state estimation drift accumulation).

The progression or propagation of failures through the ADS architecture also presents a challenge. Small errors or faults that occur early in the pipeline (e.g., sensing failures) may ultimately develop into more significant errors or faults at the end of the pipeline (e.g., the perception system does not identify an adjacent vehicle, resulting in the navigation subsystem generating a trajectory that leads to a collision). Similarly, small simultaneous errors in disparate subsystems could potentially lead to unintended or undesired emergent behavior. Providing confidence or other measures of quality for output data at each step along the pipeline could support identification of faults or failures early and allow for mitigation.

The effects of these failures were summarized into four primary categories, although each may build off the others.

- Suboptimal performance (e.g., hugging one side of a lane, driving slower than allowed, taking an inefficient route or trajectory)
- Unexpected/unpredictable behavior (e.g., sudden acceleration/deceleration, erratic steering oscillation)
- Unsafe behavior (e.g., driving out of desired lane, not reacting to relevant obstacles)
- Collisions

Failures that result in suboptimal performance may mostly be benign and be more of an inconvenience than a safety concern, although it may still be beneficial to identify and quantify them. Failures that result in unexpected or unsafe behavior or collisions are certainly a safety concern and need to receive careful consideration when developing a failure response strategy.

Like the vastness of potential ODDs presented in Chapter 3, a wide variety of failure modes are possible at each stage of the ADS functional architecture. Coupling this with the extensive combination and propagation space of failures presents a significant challenge to deploying ADS safely. The nature and extent of a single failure or sequence of failures plays a key role in determining the appropriate failure response.

**ADS Behavior Mapping**

After completing the FMEA for the ADS architecture, the various failure modes and effects were summarized and mapped to the relevant tactical maneuver and OEDR behaviors for the three down-sampled ADS features (L3 Traffic Jam Drive, L3 Highway Drive, and L4 Highly Automated Vehicle/TNC). This notionally provides a mapping from the specific failures identified in the FMEA, to the generalized failures summarized in the previous section, to the behaviors implemented by various ADS features.

This exercise could be extended to the other features identified in Chapter 2. A more thorough analysis and mapping could eventually provide a means to identify potential failure effects that are manifested in the testing architecture outlined in Chapter 5. For example, if an ADS under test could not safely and continuously maintain its specified lane, the test team could follow the detailed mapping back to identify possible root causes (e.g., relative localization solution instability caused by intermittent power failure in camera tasked with detecting and tracking lane markers).

**Table 56. L3 Traffic Jam Drive Failure Mode/Effects Summary**

<table>
<thead>
<tr>
<th>Behavior Failure</th>
<th>Effects</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fail to maintain lane</td>
<td>Impact adjacent vehicle or infrastructure</td>
</tr>
<tr>
<td>Fail to maintain safe following distance</td>
<td>Impact lead vehicle</td>
</tr>
<tr>
<td>Fail to detect and respond to maneuvers by other vehicles</td>
<td>Impact lead or adjacent vehicles</td>
</tr>
<tr>
<td>Fail to detect relevant obstacles in or near lane</td>
<td>Impact obstacles</td>
</tr>
<tr>
<td>Fail to identify ODD/OEDR boundary</td>
<td>Operate outside of ODD/OEDR capabilities</td>
</tr>
</tbody>
</table>
Table 57. L3 Highway Drive Failure Mode/Effects Summary

<table>
<thead>
<tr>
<th>Behavior Failure</th>
<th>Effects</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fail to maintain lane</td>
<td>Impact adjacent vehicle or infrastructure</td>
</tr>
<tr>
<td>Fail to maintain safe following distance</td>
<td>Impact lead vehicle</td>
</tr>
<tr>
<td>Fail to maintain appropriate/safe speed</td>
<td>Exceed speed limit, lose stability, impact lead vehicle</td>
</tr>
<tr>
<td>Fail to detect and respond to maneuvers by other vehicles</td>
<td>Impact lead or adjacent vehicles</td>
</tr>
<tr>
<td>Fail to detect relevant obstacles in or near lane</td>
<td>Impact obstacles</td>
</tr>
<tr>
<td>Fail to identify ODD/OEDR boundary</td>
<td>Operate outside of ODD/OEDR capabilities</td>
</tr>
</tbody>
</table>

Table 58. L4 Highly Automated Vehicle/TNC Failure Mode/Effects Summary

<table>
<thead>
<tr>
<th>Behavior Failure</th>
<th>Effects</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fail to maintain lane</td>
<td>Impact adjacent vehicle or infrastructure</td>
</tr>
<tr>
<td>Fail to maintain safe following distance</td>
<td>Impact lead vehicle</td>
</tr>
<tr>
<td>Fail to maintain appropriate/safe speed</td>
<td>Exceed speed limit, lose stability, impact lead vehicle</td>
</tr>
<tr>
<td>Fail to maneuver appropriately/safely (e.g., lane change, intersection)</td>
<td>Impact vehicles or infrastructure</td>
</tr>
<tr>
<td>Fail to detect and respond to maneuvers by other vehicles</td>
<td>Impact lead or adjacent vehicles</td>
</tr>
<tr>
<td>Fail to detect relevant obstacles in or near lane</td>
<td>Impact obstacles</td>
</tr>
<tr>
<td>Fail to obey traffic rules and etiquette</td>
<td>Impact vehicles</td>
</tr>
<tr>
<td>Fail to recognize and respond to nonstandard hazards (e.g., work zones, emergency vehicles)</td>
<td>Navigate unsafely, impact obstacles</td>
</tr>
<tr>
<td>Fail to identify ODD/OEDR boundary</td>
<td>Operate outside of ODD/OEDR capabilities</td>
</tr>
</tbody>
</table>

Failure Mitigation Strategies

Based on the general failure modes identified, potential failure mode responses and strategies were identified. This effort focused on FS strategies for cases where the ADS cannot continue to operate due to a significant failure, and FO strategies for cases where the ADS could continue to operate even in the face of a failure.

**Fail-Safe Mechanisms**

The primary goal of an FS strategy is to rapidly achieve an MRC where the vehicle and occupants are safe. Three candidate FS mechanisms were considered for further evaluation.

- Transition to fallback-ready user control
- Safely stop in lane of travel
- Safely move out of travel lane and stop
For L3 systems, requesting intervention by a fallback-ready user may be the primary FS strategy. This assumes that an operator is present and attentive to the HMI. Furthermore, there is an assumption that the information being provided by the ADS through the HMI is appropriate to reengage the operator. A challenge with this strategy is providing sufficient warning to the operator before an intervention is needed. Prior studies have shown that the timing of this warning in L2 and L3 systems can be substantial, depending on the nature of the event and the alert provided (Blanco et al., 2015). Furthermore, the ADS feature needs to continue to function until that transition occurs. Additional questions and challenges arise if the user is not fallback-ready (e.g., asleep and does not notice intervention request). This intervention request may also be a feasible FS strategy for a L4 system, again assuming a fallback-ready user is present, and the necessary information is available; however, L4 systems can achieve the MRC in the event an operator is unavailable or fails to act.

The strategy of stopping in the current lane of travel is a debated approach with the technical and policy community. In this case, the ADS may rapidly but safely decelerate to a stop while maintaining its current lane. The actions and time needed are minimal; however, there is considerable disagreement as to whether this is a safe state for the vehicle, its occupants, and other road users. The ODD and driving conditions play a role in answering this question. For example, stopping in an active lane of travel on a lower-speed urban road with good visibility may be a relatively safe condition, whereas stopping in an active lane of travel on a higher-speed rural highway after a blind curve may not fit the intent of a safe state. The frequency, nature, and extent of the failure also play into answering that question. For example, if one or more of the ADS’s primary sensors fails and it cannot detect adjacent obstacles, stopping in an active lane of travel may be safer than attempting to maneuver out of the travel lanes to stop. Remote fleet management integration could further support this strategy if a remote operator could be hailed to assist in maneuvering the vehicle to a safe state.

Finally, an ADS maneuvering safely out of the active roadway and stopping/parking presents an appealing FS mechanism. The frequency, nature, and extent of the failures, as well as the initial driving conditions, again play a role in determining if this is a viable strategy. For example, if the vehicle is in a middle lane of a large freeway, a complicated set of maneuvers conducted over a substantial period of time may be necessary to shift one or more lanes around adjacent traffic to be able to merge onto a shoulder or safe area to achieve the MRC. If one or more of its primary sensors has failed or if no shoulder or safe harbor is available, then this strategy may be impractical.

**Fail-Operational Mechanisms**

FO strategies allow the ADS to continue to function, even in the event of one or more failures. It is important to note that this operation may only be supported for a limited duration, or potentially with a reduced set of capabilities. Three primary FO mechanisms were considered for further analysis.
• Hardware/software redundancy
• Adaptive compensation
• Degraded operations
  o Reduced top speed
  o Reduced level of automation
  o Reduced ODD
  o Reduced maneuver capabilities
  o Reduced OEDR capabilities

Integrating redundant hardware or software, which is more of a design strategy, provides backups for critical pieces of equipment or logical processes. For example, multiple identical ECUs running a steering control application could be installed on an ADS. In the event the primary ECU experienced a hardware failure, a logic mechanism could trigger the system to begin responding to outputs from the secondary ECU. This strategy may improve reliability and robustness from an operational standpoint so as to allow the ADS to continue to function. However, this strategy increases cost, complexity, and potentially the “footprint” of the ADS feature (e.g., needs additional power and cabling, takes up additional space).

Adaptive compensation allows an ADS subsystem to compensate for a failure in one or more components by relying more on other complementary components or processes, if available. For example, if a GPS receiver suffers a hardware failure and is providing noisy or intermittent data, the state estimation system could potentially reduce the weight of the GPS data and increase the weight on other available sensors (e.g., IMU, wheel-speed sensors) to continue to provide a robust, filtered solution. This strategy may work particularly well for subsystems that already fuse data from multiple sources (e.g., perception and localization), although possibly not for others. It is also possible that this compensation technique is only effective for a limited amount of time (e.g., state estimator drift could cause vehicle to lose track of its absolute position over time if GPS or other absolute data are not acquired). This strategy may become less practical as developers seek to minimize components on their ADS to move to market.

Finally, a variety of degraded modes of operation exist that could allow an ADS to continue to function after a failure. Operating at a reduced speed is a useful tool for mitigating faults or failures that are associated with constrained resources (e.g., network bandwidth, processing power, processing latency/lag). This strategy provides the ADS additional time to evaluate a scenario and make navigation decisions; however, it may be impractical or unsafe in some driving scenarios (e.g., freeway, HOV lane). Operating at a reduced level of automation is another option, albeit one that may shift responsibility of one or more aspects of the DDT or fallback performance (e.g., reduction from L4 to L3 implies a fallback-ready user is available). This strategy may include emphasis on driver state monitoring, if applicable, to ensure that the operator is attentive and aware of the circumstances. It may therefore be impractical for ADS features without a defined driver (e.g., L4 or L5 Highly Automated Vehicle/TNC feature, automated delivery vehicle). Operating with a reduced ODD further limits the conditions and domains in which the ADS can function (e.g., daytime only, low-speed only).
SUMMARY

This task considered and analyzed potential failure modes for a generic ADS, and possible failure mitigation strategies. A high-level system FMEA was performed to identify failure modes and their implications for the primary subsystems within the ADS functional architecture. Failures were primarily related to failures of information resulting from both physical and logical faults and errors. The failure modes were generalized according to the severity of their effects, and mapped to the tactical maneuver behaviors and OEDR behaviors identified in Chapter 2 and Chapter 4, respectively, as well as to the down-selected ADS features.

Potential mechanisms that allow ADS to either fail safely when a critical failure occurs such that the vehicle cannot continue to function as designed, or fail operationally when a failure occurs such that the vehicle can continue to function, were identified and evaluated. FS strategies generally attempt to achieve an MRC as efficiently as possible, while FO strategies generally attempt to continue to perform the primary elements of the DDT, albeit potentially for a limited duration or with a reduced set of capabilities. The identified FS and FO strategies each have advantages and disadvantages. A hierarchy of these mechanisms may be necessary, as the appropriate failure mitigation strategy will largely depend on the nature and extent of the failures, as well as the initial conditions present when the failure occurs.

The test scenario framework and testing architecture were revisited to incorporate evaluation of failure response into the proposed architecture, as described in Chapter 5. Failure mode behavior lends itself to being included as a fourth dimension in the test scenario framework (shown in Figure 27). M&S may be well-suited to efficiently and effectively evaluate the wide variety of potential failure modes an ADS could experience, as well as the wide variety of initial conditions in which it could fail. Common root causes of some failure modes, including noise and latency, can be modeled for virtual testing. Fault injection and failure analysis can occur safely in a virtual environment, but they present hazards when using real systems during closed-track or open-road testing. Furthermore, M&S can support failure mode analysis early and iteratively through the ADS design and development process, long before prototype test vehicles or systems are available.
CHAPTER 7. SUMMARY AND CONCLUSIONS

A functional testing architecture and framework is an approach to support the safe deployment of ADS and evaluate and assess their performance. This report describes an example of a testing architecture and a scenario-based test framework. Efforts focused on the testing of ADS (SAE International L3–L5), where the ADS is fully capable of all aspects of the DDT. To facilitate the identification of the testing architecture and framework, common and relevant operational components for ADS were identified and evaluated, specifically these:

- ADS features
- ODD
- OEDR
- FO and FS strategies

Prototype ADS that have been conceived or that are currently under development were surveyed. A working list of 24 such proprietary systems were identified by performing a literature review and interacting with stakeholders and categorized into seven generic ADS features. Three of these generic features were down-selected to focus the remaining analyses. Potential ODDs for ADS were surveyed and identified, and a hierarchical ODD taxonomy was developed. An ADS’s ODD is specified by the developing entity, but this taxonomy provides an early step in establishing an example of a common language that could be used. Important obstacles and events that ADS are likely to encounter within their ODD and potential response maneuvers and actions were surveyed and identified. The objects and events were derived from an evaluation of the expected normal driving scenarios for the given ADS features. Potential mitigation strategies that an ADS could employ in the event of a failure were also identified and evaluated. Both FO and FS strategies were identified and assessed for cases where the ADS can or cannot continue to function as intended.

The primary contribution of this report is the conceptual development of a test scenario framework that incorporates elements of each of these operational components. The framework uses a checklist-type approach to identify high-level scenario tests by specifying relevant tactical maneuvers, ODD, OEDR, and potential failures. Each of these components are then further specified to develop a comprehensive set of procedures for a given scenario test. The scenario framework lends itself well to being applied across the three testing techniques identified for the testing architecture (M&S, closed-track testing, and open-road testing), although specific test procedures and implementations will vary, depending on the technique and tools used. This test scenario framework and the sample test procedures developed can provide a launching point to more comprehensive ADS test development and ultimately, test execution. Figure 29 shows a sample ADS test scenario visualization, with the principal elements notionally specified. (In this figure, POV stands for principal other vehicle.)
The expansiveness of conceivable ODD, OEDR, and failure conditions presents a significant challenge to achieving comprehensive testing, even considering the test scenario framework identified during this project and described in this report. The concept of risk associated with driving scenarios, notionally based on probability and severity of occurrence, has helped focus the analyses of ODD, OEDR, and failure modes to identify an appropriate testing process. A “reasonable worst case” approach may prove sufficient for general safety assessments; however, it is necessary to extend testing beyond the reasonable cases to understand the performance boundaries and limitations of ADS. This report also identifies M&S capabilities and tools as a potential approach to addressing the expansiveness of these test components, as well as their potential combinations. M&S provide a number of features and advantages that make it suitable to play a role in this type of testing.

- Highly repeatable and reliable
- Rapid and inexpensive compared to other testing techniques
- Able to cover a wide range of scenarios and conditions efficiently
- Allow for assessment of impact of the sensitivity of those scenarios and conditions on ADS performance
- Allow for variance of test parameters to support estimation of risk
- Able to establish integrity of ADS subsystems to reduce overall system testing requirements
- Well-suited for certain types of fault injection
## APPENDIX A. OPERATIONAL DESIGN DOMAIN SAMPLES

### L3 CONDITIONAL TRAFFIC JAM DRIVE

<table>
<thead>
<tr>
<th>PHYSICAL INFRASTRUCTURE</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Roadway Types</strong></td>
<td></td>
</tr>
<tr>
<td>Divided highway</td>
<td>Y</td>
</tr>
<tr>
<td>Undivided highway</td>
<td></td>
</tr>
<tr>
<td>Arterial</td>
<td></td>
</tr>
<tr>
<td>Urban</td>
<td>N</td>
</tr>
<tr>
<td>Rural</td>
<td></td>
</tr>
<tr>
<td>Parking (surface lots, structures, private/public)</td>
<td></td>
</tr>
<tr>
<td>Bridges</td>
<td></td>
</tr>
<tr>
<td>Multi-lane/single lane</td>
<td></td>
</tr>
<tr>
<td>Managed lanes (HOV, HOT,(^{13}) etc.)</td>
<td>Y</td>
</tr>
<tr>
<td>On-off ramps</td>
<td></td>
</tr>
<tr>
<td>Emergency evacuation routes</td>
<td></td>
</tr>
<tr>
<td>One way</td>
<td></td>
</tr>
<tr>
<td>Private roads</td>
<td></td>
</tr>
<tr>
<td>Reversible lanes</td>
<td>If barriers present</td>
</tr>
<tr>
<td>Intersection Types</td>
<td></td>
</tr>
<tr>
<td>- signaled</td>
<td></td>
</tr>
<tr>
<td>- U-turns</td>
<td></td>
</tr>
<tr>
<td>- 4-way vs. 3-way vs. 2-way</td>
<td></td>
</tr>
<tr>
<td>- stop sign</td>
<td></td>
</tr>
<tr>
<td>- roundabout</td>
<td></td>
</tr>
<tr>
<td>- merge lanes</td>
<td></td>
</tr>
<tr>
<td>- left turn across traffic, one-way to one-way</td>
<td></td>
</tr>
<tr>
<td>- right turn</td>
<td></td>
</tr>
<tr>
<td>- multiple turn lane</td>
<td></td>
</tr>
<tr>
<td>- crosswalk</td>
<td></td>
</tr>
<tr>
<td>- toll plaza</td>
<td></td>
</tr>
<tr>
<td>- railroad crossing</td>
<td></td>
</tr>
<tr>
<td>Other</td>
<td></td>
</tr>
<tr>
<td><strong>Roadway Surfaces</strong></td>
<td></td>
</tr>
<tr>
<td>Asphalt</td>
<td></td>
</tr>
<tr>
<td>Concrete</td>
<td>Y</td>
</tr>
<tr>
<td>Mixed</td>
<td></td>
</tr>
<tr>
<td>Grating</td>
<td></td>
</tr>
<tr>
<td>Brick</td>
<td>n/a</td>
</tr>
<tr>
<td>Dirt</td>
<td></td>
</tr>
</tbody>
</table>

\(^{13}\) HOT- high occupancy toll
<table>
<thead>
<tr>
<th>Gravel</th>
<th>Scraped road</th>
<th>Partially occluded</th>
<th>Speed bumps</th>
<th>Potholes</th>
<th>Grass</th>
<th>Other</th>
</tr>
</thead>
</table>

**Roadway Edges & Markings**

<table>
<thead>
<tr>
<th>Lane markers</th>
<th>Clear markers</th>
</tr>
</thead>
<tbody>
<tr>
<td>Temporary lane markers</td>
<td>N</td>
</tr>
<tr>
<td>Shoulder (paved or gravel)</td>
<td>Limited to divided highway</td>
</tr>
<tr>
<td>Shoulder (grass)</td>
<td>Limited to divided highway</td>
</tr>
<tr>
<td>Lane barriers</td>
<td>Barrier, concrete or metal</td>
</tr>
<tr>
<td>Grating</td>
<td>Y</td>
</tr>
<tr>
<td>Rails</td>
<td>Barrier, concrete or metal</td>
</tr>
<tr>
<td>Curb</td>
<td>N</td>
</tr>
<tr>
<td>Cones</td>
<td>N</td>
</tr>
<tr>
<td>Other</td>
<td></td>
</tr>
</tbody>
</table>

**Roadway Geometry**

| Straightaways                  | Y                                     |
| Curves                         |                                       |
| Hills                          |                                       |
| Lateral crests                 | n/a                                   |
| Corners (Regular, Blind)       |                                       |
| Negative obstacles             |                                       |
| Lane width                     |                                       |
| Other                          |                                       |

**OPERATION CONSTRAINTS**

**Speed Limits**

| Minimum Speed Limit            | 0 mph                                 |
| Maximum Speed Limit            | < 37 mph                              |
| Relative to Surrounding Traffic| n/a                                   |
| Other                          |                                       |

**Traffic Conditions**

<p>| Traffic density                | Only heavy traffic with preceding vehicle to follow and convoy in adjacent lane |
| Altered (Accident Emergency vehicle, Construction, Closed road, Special event) | n/a |
| Other                          |                                       |</p>
<table>
<thead>
<tr>
<th>OBJECTS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Signage</td>
</tr>
<tr>
<td>Signs (e.g., stop, yield, pedestrian, railroad, school zone, etc.)</td>
</tr>
<tr>
<td>Traffic Signals (regular, flashing, school zone, fire dept. zone)</td>
</tr>
<tr>
<td>Crosswalks</td>
</tr>
<tr>
<td>Railroad crossing</td>
</tr>
<tr>
<td>Stopped buses</td>
</tr>
<tr>
<td>Construction signage</td>
</tr>
<tr>
<td>First responder signals</td>
</tr>
<tr>
<td>Distress signals</td>
</tr>
<tr>
<td>Roadway user signals</td>
</tr>
<tr>
<td>Hand signals</td>
</tr>
<tr>
<td>Other</td>
</tr>
<tr>
<td>Roadway Users</td>
</tr>
<tr>
<td>Vehicle types (cars, light trucks, large trucks, buses, motorcycles, wide-load, emergency vehicles, construction or farming equipment, horse-drawn carriages/buggies)</td>
</tr>
<tr>
<td>Cars, trucks</td>
</tr>
<tr>
<td>Stopped vehicles</td>
</tr>
<tr>
<td>Other automated vehicles</td>
</tr>
<tr>
<td>Pedestrians</td>
</tr>
<tr>
<td>Cyclists</td>
</tr>
<tr>
<td>Other</td>
</tr>
<tr>
<td>Non-Roadway Users Obstacles</td>
</tr>
<tr>
<td>Animals (e.g., dogs, deer, etc.)</td>
</tr>
<tr>
<td>Shopping carts</td>
</tr>
<tr>
<td>Debris (e.g., pieces of tire, trash, ladders)</td>
</tr>
<tr>
<td>Other</td>
</tr>
<tr>
<td>ENVIRONMENTAL CONDITIONS</td>
</tr>
<tr>
<td>Weather</td>
</tr>
<tr>
<td>Wind</td>
</tr>
<tr>
<td>Rain</td>
</tr>
<tr>
<td>Snow</td>
</tr>
<tr>
<td>Sleet</td>
</tr>
<tr>
<td>Temperature</td>
</tr>
<tr>
<td>Other</td>
</tr>
<tr>
<td>Weather-Induced Roadway Conditions</td>
</tr>
<tr>
<td>Standing Water</td>
</tr>
<tr>
<td>Flooded Roadways</td>
</tr>
<tr>
<td>Icy Roads</td>
</tr>
<tr>
<td>Snow on Road</td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td>Particulate Matter</td>
</tr>
<tr>
<td>-------------------------------------------</td>
</tr>
<tr>
<td>Fog</td>
</tr>
<tr>
<td>Smoke</td>
</tr>
<tr>
<td>Smog</td>
</tr>
<tr>
<td>Dust/Dirt</td>
</tr>
<tr>
<td>Mud</td>
</tr>
<tr>
<td>Other</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Illumination</th>
<th>Other</th>
</tr>
</thead>
<tbody>
<tr>
<td>Day (sun: Overhead, Back-lighting and Front-lighting)</td>
<td>No information available at this time</td>
</tr>
<tr>
<td>Dawn</td>
<td></td>
</tr>
<tr>
<td>Dusk</td>
<td></td>
</tr>
<tr>
<td>Night</td>
<td></td>
</tr>
<tr>
<td>Street lights</td>
<td></td>
</tr>
<tr>
<td>Headlights (Regular &amp; High-Beam)</td>
<td></td>
</tr>
<tr>
<td>Oncoming vehicle lights (Overhead Lighting, Back-lighting &amp; Front-lighting)</td>
<td>No information available at this time</td>
</tr>
<tr>
<td>Other</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>CONNECTIVITY</th>
<th>Other</th>
</tr>
</thead>
<tbody>
<tr>
<td>V2I and V2V communications</td>
<td>May have V2I to warn if driver incapacitated</td>
</tr>
<tr>
<td>Emergency vehicles</td>
<td>N</td>
</tr>
<tr>
<td>Other</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Remote Fleet Management System</th>
<th>Other</th>
</tr>
</thead>
<tbody>
<tr>
<td>Does the system require an operations center?</td>
<td>N</td>
</tr>
<tr>
<td>Does remote operation expand ODD or support fault handling?</td>
<td></td>
</tr>
<tr>
<td>Other</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Infrastructure Sensors</th>
<th>Other</th>
</tr>
</thead>
<tbody>
<tr>
<td>Work zone alerts</td>
<td></td>
</tr>
<tr>
<td>Vulnerable road user</td>
<td>N</td>
</tr>
<tr>
<td>Routing and incident management</td>
<td></td>
</tr>
<tr>
<td>Other</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Digital Infrastructure</th>
<th>Other</th>
</tr>
</thead>
<tbody>
<tr>
<td>GPS</td>
<td>Y</td>
</tr>
<tr>
<td>3-D Maps</td>
<td>Y</td>
</tr>
<tr>
<td>Pothole Locations</td>
<td></td>
</tr>
<tr>
<td>Weather Data</td>
<td>No information available at this time</td>
</tr>
<tr>
<td>Infrastructure Data</td>
<td></td>
</tr>
<tr>
<td>Other</td>
<td></td>
</tr>
<tr>
<td>ZONES</td>
<td></td>
</tr>
<tr>
<td>-------------------------------------------</td>
<td>--------------------------------------</td>
</tr>
<tr>
<td><strong>Geofencing</strong></td>
<td></td>
</tr>
<tr>
<td>CBDs</td>
<td>No information available at this time</td>
</tr>
<tr>
<td>School Campuses</td>
<td></td>
</tr>
<tr>
<td>Retirement Communities</td>
<td></td>
</tr>
<tr>
<td>Fixed Route</td>
<td></td>
</tr>
<tr>
<td>Other</td>
<td></td>
</tr>
<tr>
<td><strong>Traffic Management Zones</strong></td>
<td></td>
</tr>
<tr>
<td>Temporary Closures</td>
<td>No information available at this time</td>
</tr>
<tr>
<td>Dynamic Traffic Signs</td>
<td></td>
</tr>
<tr>
<td>Variable Speed Limits</td>
<td></td>
</tr>
<tr>
<td>Temporary or Non-Existant Lane Marking</td>
<td></td>
</tr>
<tr>
<td>Human-Directed Traffic</td>
<td></td>
</tr>
<tr>
<td>Loading and Unloading Zones</td>
<td></td>
</tr>
<tr>
<td>Other</td>
<td></td>
</tr>
<tr>
<td><strong>School/construction zones</strong></td>
<td></td>
</tr>
<tr>
<td>Dynamic speed limit</td>
<td>No information available at this time</td>
</tr>
<tr>
<td>Erratic pedestrian</td>
<td></td>
</tr>
<tr>
<td>Vehicular behaviors</td>
<td></td>
</tr>
<tr>
<td>Other</td>
<td></td>
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<td>Enforcement Considerations</td>
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<td>Tort</td>
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<tr>
<td><strong>Interference Zones</strong></td>
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<tr>
<td>Tunnels</td>
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<tr>
<td>Dense Foliage</td>
<td></td>
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## L3 CONDITIONAL HIGHWAY DRIVE

### ODD CHECKLIST: L3 Conditional Highway Drive

<table>
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<tr>
<th>PHYSICAL INFRASTRUCTURE</th>
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<td><strong>Roadway Types</strong></td>
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<td>Divided highway</td>
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<tr>
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<td><strong>Roadway Surfaces</strong></td>
</tr>
<tr>
<td>Asphalt</td>
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<tr>
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**Roadway Edges & Markings**

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<thead>
<tr>
<th>Description</th>
<th>Status</th>
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<tbody>
<tr>
<td>Lane markers</td>
<td>Clear</td>
</tr>
<tr>
<td>Temporarily lane markers</td>
<td>N</td>
</tr>
<tr>
<td>Shoulder (paved or gravel)</td>
<td>Limited</td>
</tr>
<tr>
<td>Shoulder (grass)</td>
<td>Limited</td>
</tr>
<tr>
<td>Lane barriers</td>
<td>Y</td>
</tr>
<tr>
<td>Grating</td>
<td>Y</td>
</tr>
<tr>
<td>Rails</td>
<td>Y</td>
</tr>
<tr>
<td>Curb</td>
<td>N</td>
</tr>
<tr>
<td>Cones</td>
<td>N</td>
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**Roadway Geometry**

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<thead>
<tr>
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<tr>
<td>Straightaways</td>
<td>Y</td>
</tr>
<tr>
<td>Curves</td>
<td></td>
</tr>
<tr>
<td>Hills</td>
<td></td>
</tr>
<tr>
<td>Lateral crests</td>
<td>n/a</td>
</tr>
<tr>
<td>Corners (Regular, Blind)</td>
<td></td>
</tr>
<tr>
<td>Negative obstacles</td>
<td></td>
</tr>
<tr>
<td>Lane width</td>
<td></td>
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<td>Other</td>
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**OPERATION CONSTRAINTS**

**Speed Limits**

<table>
<thead>
<tr>
<th>Description</th>
<th>Status</th>
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</thead>
<tbody>
<tr>
<td>Minimum Speed Limit</td>
<td>0 mph</td>
</tr>
<tr>
<td>Maximum Speed Limit</td>
<td>Speed limit (55-70 mph)</td>
</tr>
<tr>
<td>Relative to Surrounding Traffic</td>
<td>n/a</td>
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<td>Other</td>
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**Traffic Conditions**

<table>
<thead>
<tr>
<th>Description</th>
<th>Status</th>
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</thead>
<tbody>
<tr>
<td>Traffic density</td>
<td>No traffic restrictions</td>
</tr>
<tr>
<td>Altered (Accident Emergency vehicle, Construction, Closed road, Special event)</td>
<td>n/a</td>
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<tr>
<td>Other</td>
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**OBJECTS**

**Signage**

<table>
<thead>
<tr>
<th>Description</th>
<th>Status</th>
</tr>
</thead>
<tbody>
<tr>
<td>Signs (e.g., stop, yield, pedestrian, railroad, school zone, etc.)</td>
<td></td>
</tr>
<tr>
<td>Traffic Signals (regular, flashing, school zone, fire dept. zone)</td>
<td></td>
</tr>
<tr>
<td>Crosswalks</td>
<td></td>
</tr>
<tr>
<td>Railroad crossing</td>
<td></td>
</tr>
<tr>
<td>Other</td>
<td>N</td>
</tr>
<tr>
<td>Roadway Users</td>
<td>Vehicle types (cars, light trucks, large trucks, buses, motorcycles, wide-load, emergency vehicles, construction or farming equipment, horse-drawn carriages/buggies)</td>
</tr>
<tr>
<td>---------------</td>
<td>----------------------------------------------------------------------------------------------------------------------------------</td>
</tr>
<tr>
<td>Stopped vehicles</td>
<td>N</td>
</tr>
<tr>
<td>Other automated vehicles</td>
<td>Y</td>
</tr>
<tr>
<td>Pedestrians</td>
<td>N</td>
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<tr>
<td>Cyclists</td>
<td>N</td>
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<tr>
<td>Other</td>
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<table>
<thead>
<tr>
<th>Non-Roadway Users Obstacles</th>
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<tbody>
<tr>
<td>Animals (e.g., dogs, deer, etc.)</td>
<td>Y</td>
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<tr>
<td>Shopping carts</td>
<td></td>
</tr>
<tr>
<td>Debris (e.g., pieces of tire, trash, ladders)</td>
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<td>Other</td>
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<table>
<thead>
<tr>
<th>ENVIRONMENTAL CONDITIONS</th>
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<tr>
<td>Weather</td>
<td></td>
</tr>
<tr>
<td>Wind</td>
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<tr>
<td>Rain</td>
<td>No information available at this time, but potentially may include mild rain and typical temperatures</td>
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<tr>
<td>Snow</td>
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<tr>
<td>Sleet</td>
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<td>Temperature</td>
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<tr>
<th>Weather-Induced Roadway Conditions</th>
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<tr>
<td>Standing Water</td>
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<tr>
<td>Flooded Roadways</td>
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<tr>
<td>Icy Roads</td>
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<td>Snow on Road</td>
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<td>Other</td>
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<table>
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<td>Fog</td>
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<td>Smoke</td>
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<td>Smog</td>
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<td>Dust/Dirt</td>
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<td>Mud</td>
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<td><strong>Illumination</strong></td>
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<td>------------------</td>
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<tr>
<td>Day (sun: Overhead, Back-lighting and Front-lighting)</td>
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<tr>
<td>Dawn</td>
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</tr>
<tr>
<td>Dusk</td>
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<tr>
<td>Night</td>
<td></td>
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<tr>
<td>Street lights</td>
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<tr>
<td>Headlights (Regular &amp; High-Beam)</td>
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<tr>
<td>Oncoming vehicle lights (Overhead Lighting, Back-lighting &amp; Front-lighting)</td>
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<tr>
<td><strong>Vehicles</strong></td>
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<tr>
<td>V2I and V2V communications</td>
<td>May have V2I to warn if driver incapacitated</td>
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<tr>
<td>Emergency vehicles</td>
<td>N</td>
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<tr>
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<tbody>
<tr>
<td>Does the system require an operations center?</td>
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<tr>
<td>Does remote operation expand ODD or support fault handling?</td>
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<thead>
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<td>Routing and incident management</td>
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<td>3-D Maps</td>
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<td>Pothole Locations</td>
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<td>Weather Data</td>
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<tbody>
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<td>CBDs</td>
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<td>School Campuses</td>
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<td>Retirement Communities</td>
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<tr>
<td>------------------------------------------------</td>
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<tr>
<td>Temporary Closures</td>
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<tr>
<td>Dynamic Traffic Signs</td>
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<tr>
<td>Variable Speed Limits</td>
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<tr>
<td>Temporary or Non-Existent Lane Marking</td>
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<td>Human-Directed Traffic</td>
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<tr>
<td>Loading and Unloading Zones</td>
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<td>Other</td>
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<td>School/construction zones</td>
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<td>Vehicular behaviors</td>
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<tr>
<th><strong>OBJECTS</strong></th>
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<tbody>
<tr>
<td><strong>Signage</strong></td>
</tr>
<tr>
<td>Signs (e.g., stop, yield, pedestrian, railroad, school zone, etc.)</td>
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<tr>
<td>Traffic Signals (regular, flashing, school zone, fire dept. zone)</td>
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<tr>
<td>Crosswalks</td>
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<tr>
<td>Railroad crossing</td>
</tr>
<tr>
<td>Roadway Users</td>
</tr>
<tr>
<td>---------------</td>
</tr>
<tr>
<td>Stopped buses</td>
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<td>Construction signage</td>
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<tr>
<td>First responder signals</td>
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<td>Distress signals</td>
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<td>Roadway user signals</td>
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<td>Hand signals</td>
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<tr>
<td>Other</td>
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<tr>
<td>Vehicle types (cars, light trucks, large trucks, buses, motorcycles, wide-load, emergency vehicles, construction or farming equipment, horse-drawn carriages/buggies)</td>
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<td>Other automated vehicles</td>
</tr>
<tr>
<td>Pedestrians</td>
</tr>
<tr>
<td>Cyclists</td>
</tr>
<tr>
<td>Other</td>
</tr>
<tr>
<td>Non-Roadway Users Obstacles</td>
</tr>
<tr>
<td>Animals (e.g., dogs, deer, etc.)</td>
</tr>
<tr>
<td>Shopping carts</td>
</tr>
<tr>
<td>Debris (e.g., pieces of tire, trash, ladders)</td>
</tr>
<tr>
<td>Other</td>
</tr>
<tr>
<td>ENVIRONMENTAL CONDITIONS</td>
</tr>
<tr>
<td>Weather</td>
</tr>
<tr>
<td>Wind</td>
</tr>
<tr>
<td>Rain</td>
</tr>
<tr>
<td>Snow</td>
</tr>
<tr>
<td>Sleet</td>
</tr>
<tr>
<td>Temperature</td>
</tr>
<tr>
<td>Other</td>
</tr>
<tr>
<td>Weather-Induced Roadway Conditions</td>
</tr>
<tr>
<td>Standing Water</td>
</tr>
<tr>
<td>Flooded Roadways</td>
</tr>
<tr>
<td>Icy Roads</td>
</tr>
<tr>
<td>Snow on Road</td>
</tr>
<tr>
<td>Other</td>
</tr>
<tr>
<td>Particulate Matter</td>
</tr>
<tr>
<td>Fog</td>
</tr>
<tr>
<td>Smoke</td>
</tr>
<tr>
<td>Smog</td>
</tr>
<tr>
<td>Dust/Dirt</td>
</tr>
<tr>
<td>Mud</td>
</tr>
<tr>
<td>Other</td>
</tr>
</tbody>
</table>
### Illumination

<table>
<thead>
<tr>
<th>Time</th>
<th>Requirement</th>
</tr>
</thead>
<tbody>
<tr>
<td>Day (sun: Overhead, Back-lighting and Front-lighting)</td>
<td></td>
</tr>
<tr>
<td>Dawn</td>
<td>Y</td>
</tr>
<tr>
<td>Dusk</td>
<td></td>
</tr>
<tr>
<td>Night</td>
<td></td>
</tr>
<tr>
<td>Street lights</td>
<td></td>
</tr>
<tr>
<td>Headlights (Regular &amp; High-Beam)</td>
<td></td>
</tr>
<tr>
<td>Oncoming vehicle lights (Overhead Lighting, Back-lighting &amp; Front-lighting)</td>
<td>No information available at this time</td>
</tr>
<tr>
<td>Other</td>
<td></td>
</tr>
</tbody>
</table>

### Connectivity

#### Vehicles

<table>
<thead>
<tr>
<th>Requirement</th>
</tr>
</thead>
<tbody>
<tr>
<td>V2I and V2V communications</td>
</tr>
<tr>
<td>No definitive information; connectivity is being tested by many potential implementers</td>
</tr>
<tr>
<td>Emergency vehicles</td>
</tr>
<tr>
<td>No information available</td>
</tr>
<tr>
<td>Other</td>
</tr>
</tbody>
</table>

#### Remote Fleet Management System

<table>
<thead>
<tr>
<th>Requirement</th>
</tr>
</thead>
<tbody>
<tr>
<td>Does the system require an operations center?</td>
</tr>
<tr>
<td>No information available at this time</td>
</tr>
<tr>
<td>Does remote operation expand ODD or support fault handling?</td>
</tr>
<tr>
<td>No information available at this time</td>
</tr>
<tr>
<td>Other</td>
</tr>
</tbody>
</table>

#### Infrastructure Sensors

<table>
<thead>
<tr>
<th>Requirement</th>
</tr>
</thead>
<tbody>
<tr>
<td>Work zone alerts</td>
</tr>
<tr>
<td>No information available at this time</td>
</tr>
<tr>
<td>Vulnerable road user</td>
</tr>
<tr>
<td>No information available at this time</td>
</tr>
<tr>
<td>Routing and incident management</td>
</tr>
<tr>
<td>Other</td>
</tr>
</tbody>
</table>

#### Digital Infrastructure

<table>
<thead>
<tr>
<th>Requirement</th>
</tr>
</thead>
<tbody>
<tr>
<td>GPS</td>
</tr>
<tr>
<td>No information available at this time</td>
</tr>
<tr>
<td>3-D Maps</td>
</tr>
<tr>
<td>No information available at this time</td>
</tr>
<tr>
<td>Pothole Locations</td>
</tr>
<tr>
<td>Other</td>
</tr>
<tr>
<td>Weather Data</td>
</tr>
<tr>
<td>Infrastructure Data</td>
</tr>
<tr>
<td>Other</td>
</tr>
</tbody>
</table>

### Zones

<table>
<thead>
<tr>
<th>Requirement</th>
</tr>
</thead>
<tbody>
<tr>
<td>CBDs</td>
</tr>
<tr>
<td>Y</td>
</tr>
<tr>
<td>School Campuses</td>
</tr>
<tr>
<td>No information available at this time</td>
</tr>
<tr>
<td>Retirement Communities</td>
</tr>
<tr>
<td>No information available at this time</td>
</tr>
<tr>
<td>Fixed Route</td>
</tr>
<tr>
<td>Other</td>
</tr>
<tr>
<td>Traffic Management Zones</td>
</tr>
<tr>
<td>-----------------------------------------------</td>
</tr>
<tr>
<td>Temporary Closures</td>
</tr>
<tr>
<td>Dynamic Traffic Signs</td>
</tr>
<tr>
<td>Variable Speed Limits</td>
</tr>
<tr>
<td>Temporary or Non-Existent Lane Marking</td>
</tr>
<tr>
<td>Human-Directed Traffic</td>
</tr>
<tr>
<td>Loading and Unloading Zones</td>
</tr>
<tr>
<td>Other</td>
</tr>
</tbody>
</table>

| School/construction zones                      |          |
| Dynamic speed limit                           |          |
| Erratic pedestrian                            | No information available at this time |
| Vehicular behaviors                            |          |
| Other                                          |          |

| Regions/States                                 |          |
| Legal/Regulatory                               |          |
| Enforcement Considerations                     | No information available at this time |
| Tort                                           |          |
| Other                                          |          |

| Interference Zones                             |          |
| Tunnels                                        | No information |
| Parking Garage                                 | Y        |
| Dense Foliage                                  |          |
| Limited GPS                                    | No information |
| Atmospheric Conditions                         |          |
| Other                                          |          |
APPENDIX B. MODELING AND SIMULATION FOR SCENARIO TESTING

As described in Chapter 5, M&S could offer a good basis for scenario testing of ADS. Simulation-based tests feature highly repeatable and reliable testing platforms due to the controlled environments established by the models. Additionally, software-based simulation provides a rapid and inexpensive testing platform. In addition, certain types of M&S enable controlled testing of micro- to macro-scale models (e.g., vehicle subsystems or a large-scale transportation network, respectively). The modular nature of M&S tools makes them suitable for the testing of systems or subsystems or both.

ADSs are complex, with multiple subsystems interacting with each other. Modeling transportation networks enables the testing of ADS in their entirety and individual subsystems under different operational environments. Such M&S-based methods are increasingly becoming the industry method of choice for certain types of testing of ADS and ADS subsystems before they go into the field for controlled-environment and open-road field tests.14

Consider the functional diagram of an ADS. As shown in Figure 30 below, a typical ADS consists of five modules/processes which are active as an iterative list that is enacted at a high frequency.

![Figure 30. Simplified ADS Functional Flow Diagram](image)

The modules/processes are:

1. Sensing – A variety of sensors, such as radar, lidar, etc., detect external stimuli and communicate with external agents, such as other vehicles, the cloud environment, and infrastructure.
2. Perception and Mapping – High-accuracy localization and output from sensing and communication are used to understand the externalities that the vehicle is subject to.

---

14 For example, Alphabet’s Waymo has been using a custom-designed simulation system named “Carcraft,” to test its self-driving vehicle software under different operational characteristics and detection parameters. Similarly, automated driving OEMs use software such as Cognata to conduct “virtual tests” of its systems prior to deploying the code for on-road tests.
3. Develop World Model – A world model is developed based on the perception and mapping that defines the persistent and transient state of the vehicle.

4. Navigation/Planning Decisions – Navigation and planning are performed based on the path-planning algorithms defined within the ADS.

5. Vehicle Dynamics and Control – Vehicle dynamic and control processes take place as a consequence of navigation and planning decisions and trajectory calculations.

Please note that this set of iterative processes represents a simplified ADS and that each of the processes consists of smaller processes and subsystems. M&S may be a suitable method to test the entire system or individual subsystems and is being used effectively by industry to continuously improve driving algorithms. Applications of M&S in testing of ADS are numerous and are supported by different types of simulation:

1. Parameter characterization – By simulating a range of operational parameters such as visibility, sensing, communication delay, and world model completeness, this kind of testing will help evaluate the parameters that form the ODD of the ADS.

2. Subsystem testing – Based on the functional diagram, M&S can be used to test different subsystems. For example, a sensor fusion simulation tool can be used to assess how noises in the provided sensor data transform to the developed world model and associated ADS actions.

3. Decision modules – M&S can also be used to perform system testing under different operational conditions to allow testing of the entire ADS based on its navigation decisions under each event.

4. Fault detection – M&S can also be used to evaluate a system or subsystem’s ability to recognize and respond to faults or failures.

Some of these use cases are described further below.

**Parameter Characterization**

To support the validation and verification of ADS, it is vital to understand the range of operational parameters that form the system’s ODD. Full-range parameter testing will help to determine that range and is conducted through Monte Carlo simulations of different parameters that define an ODD. For example, the range of visibility under which the machine-vision algorithm can confidently parse the sensor data can be assessed by providing sensor cloud data that emulates different levels of lighting.

**Subsystem Testing**

As discussed in Chapter 5, the modular nature of simulations allows SIL and HIL simulations. These are excellent options when conducting subsystem testing, where components of a fully known simulation setup are replaced with testable subsystems. For example, to test the navigation and path-planning algorithms, an SIL system can be configured where the path-planning algorithms interact with a variety of world models and provide output to the vehicle dynamics models. By assessing the stability of the models to deal with different situations, subsystem testing can be done to support overall performance assessment.
HIL tests can be performed, for example, to assess how sensors react to identifying objects (such as sign boards and pedestrians under different lighting conditions) by how they translate to the development of world models. Conducting subsystem testing involves emulating an ADS as a modular system that is representative of the feature. Several simulation programs exist that can be used to emulate components of a typical ADS. Some examples are provided in the following table.

**Table 59. Simulation Software Examples**

<table>
<thead>
<tr>
<th>Simulated ADS Process</th>
<th>Simulation Type</th>
<th>Description</th>
<th>Example Software Applications</th>
</tr>
</thead>
<tbody>
<tr>
<td>1a, 2</td>
<td>Sensor Fusion</td>
<td>Represents applications that emulate sensor data when an environment is presented to them. The sensor data could be developed either in the form of vector graphics or as a sensor point cloud.</td>
<td>MATLAB ADS Toolbox</td>
</tr>
<tr>
<td>1b</td>
<td>V2V/V2I Communication</td>
<td>Represents applications that emulate communications interaction between vehicles and other infrastructure elements so that parameters such as latency and error rates can be incorporated into data packets.</td>
<td>Riverside Modeler, OMNET, etc.</td>
</tr>
<tr>
<td>3</td>
<td>Simulate World Models</td>
<td>Represents applications that emulate the world model, either based on sensor data or from a known environment.</td>
<td>Cognata, MATLAB ADS</td>
</tr>
<tr>
<td>5</td>
<td>Vehicle Dynamics</td>
<td>Represents applications that emulate the physical characteristics of a vehicle when subject to path-planning and navigation decisions.</td>
<td>Simulink, CarSim, etc.</td>
</tr>
<tr>
<td>Process</td>
<td>Transportation Network Modeling</td>
<td>Represents applications that can emulate V2V, V2I, and vehicle-to-pedestrian interaction with respect to the navigation of each of the elements in a transportation network.</td>
<td>Vissim, Aimsun, TransModeler, etc.</td>
</tr>
</tbody>
</table>

**Fault Detection**

As discussed in Chapter 6, ADS may be prone to a wide variety of faults that could lead to the system not performing as expected or intended. Many types of errors can be modeled and incorporated into a virtual environment to induce faults or failures (e.g., sensor noise, hardware failure). M&S can be used to efficiently and safely replicate a significant amount of the potential faults and failures, and therefore allow for analysis of the ADS’s implemented failure mitigation strategies. Critical failures can be induced to elicit an FS response, while non-critical failures can be induced to elicit an FO response.
APPENDIX C. SAMPLE TEST PROCEDURES

PERFORM LANE CHANGE/LOW-SPEED MERGE

ODD Characteristics

- Multi-lane divided highway (or similar)
- Asphalt or concrete
- Straight, flat
- Clear lane markers
- Clear sky, dry, daylight

OEDR Characteristics

- Optional object vehicles

Failure Behaviors

- None

Test Protocol

Vehicle Platforms

Subject Vehicle– The vehicle equipped with the ADS feature being tested.

Principal Other Vehicles– The primary object vehicles for which the detection and response of the subject vehicle are being tested.

Vehicle Roles

The SV is a light-duty vehicle equipped with an ADS feature that is being evaluated.

The POVs are other fully functional (operational brake lights, etc.) light-duty vehicles (e.g., sedan, SUVs, pickup trucks, etc.) or vehicle surrogates. If a vehicle surrogate is used, it would ideally be frangible and should possess similar mobility and detection characteristics as a regular light-duty vehicle.

- Ability to be towed or remotely controlled to follow the test course
- Ability to achieve test speeds
- Similar visual appearance
- Similar radar and/or lidar reflectivity
### Test Scenarios

Table 60. Perform Lane Change Test Scenarios

<table>
<thead>
<tr>
<th>Maneuver</th>
<th>SV Speed kph (mph)</th>
<th>POV(^{15}) Speed kph (mph)</th>
<th>Location of POV_1</th>
<th>Location of POV_2</th>
<th>Location of POV_3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Baseline 15</td>
<td>24 (15)</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
</tr>
<tr>
<td>PLC_B_15</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Baseline 25</td>
<td>40 (25)</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
</tr>
<tr>
<td>PLC_B_25</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Baseline 35</td>
<td>56 (35)</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
</tr>
<tr>
<td>PLC_B_35</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Simple Positive 15</td>
<td>24 (15)</td>
<td>24 (15)</td>
<td>Rear bumper 6 m</td>
<td>N/A</td>
<td>N/A</td>
</tr>
<tr>
<td>PLC_SP_15</td>
<td></td>
<td></td>
<td>(20 ft) in front of SV front bumper</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Simple Positive 25</td>
<td>40 (25)</td>
<td>40 (25)</td>
<td>Rear bumper 6 m</td>
<td>N/A</td>
<td>N/A</td>
</tr>
<tr>
<td>PLC_SP_25</td>
<td></td>
<td></td>
<td>(20 ft) in front of SV front bumper</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Simple Positive 35</td>
<td>56 (35)</td>
<td>56 (35)</td>
<td>Rear bumper 6 m</td>
<td>N/A</td>
<td>N/A</td>
</tr>
<tr>
<td>PLC_SP_35</td>
<td></td>
<td></td>
<td>(20 ft) in front of SV front bumper</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Complex Positive 15</td>
<td>24 (15)</td>
<td>24 (15)</td>
<td>Rear bumper 8 m</td>
<td>Front bumper 25 ft (8 m) behind SV rear bumper</td>
<td>N/A</td>
</tr>
<tr>
<td>PLC_CP_15</td>
<td></td>
<td></td>
<td>(25 ft) in front of SV front bumper</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Complex Positive 25</td>
<td>40 (25)</td>
<td>40 (25)</td>
<td>Rear bumper 8 m</td>
<td>Front bumper 25 ft (8 m) behind SV rear bumper</td>
<td>N/A</td>
</tr>
<tr>
<td>PLC_CP_25</td>
<td></td>
<td></td>
<td>(25 ft) in front of SV front bumper</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Complex Positive 35</td>
<td>56 (35)</td>
<td>56 (35)</td>
<td>Rear bumper 8 m</td>
<td>Front bumper 25 ft (8 m) behind SV rear bumper</td>
<td>N/A</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>(25 ft) in front of SV front bumper</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Simple Negative 15</td>
<td>24 (15)</td>
<td>24 (15)</td>
<td>Rear bumper ≤ 5 m</td>
<td>Front bumper even</td>
<td>Front bumper ≤</td>
</tr>
<tr>
<td>PLC_SN_15</td>
<td></td>
<td></td>
<td>(15 ft) in front of SV front bumper</td>
<td>with SV front bumper</td>
<td>15 ft (5 m) behind SV rear bumper</td>
</tr>
<tr>
<td>Simple Negative 25</td>
<td>40 (25)</td>
<td>40 (25)</td>
<td>Rear bumper ≤ 6 m</td>
<td>Front bumper even</td>
<td>Front bumper ≤</td>
</tr>
<tr>
<td>PLC_SN_25</td>
<td></td>
<td></td>
<td>(20 ft) in front of SV front bumper</td>
<td>with SV front bumper</td>
<td>20 ft (6 m) behind SV rear bumper</td>
</tr>
<tr>
<td>Simple Negative 35</td>
<td>56 (35)</td>
<td>56 (35)</td>
<td>Rear bumper ≤ 8 m</td>
<td>Front bumper even</td>
<td>Front bumper ≤</td>
</tr>
<tr>
<td>PLC_SN_35</td>
<td></td>
<td></td>
<td>(25 ft) in front of SV front bumper</td>
<td>with SV front bumper</td>
<td>25 ft (8 m) behind SV rear bumper</td>
</tr>
</tbody>
</table>

\(^{15}\) Principal other vehicle
Test Scenario Sample Visualizations

![Figure 31. Merge Test Scenario](image)

General Procedures

*Ambient Conditions*

- The ambient temperature shall be between 0 °C (32 °F) and 38 °C (100 °F).
- The maximum wind speed shall be no greater than 10 m/s (22 mph).
- Tests should not be performed during periods of inclement weather. This includes, but is not limited to, rain, snow, hail, fog, smoke, or ash.
- Unless specified otherwise, the tests shall be conducted during daylight hours with good atmospheric visibility (defined as an absence of fog and the ability to see clearly for more than 5,000 m). The test shall not be conducted with the vehicle oriented into the sun during very low sun angle conditions (the sun is oriented 15 degrees or less from horizontal), where low sun angles degrade forward visibility for the test vehicle operators.
- Unless stated otherwise, all tests shall be conducted such that there are no overhead signs, bridges, or other significant structures over, or near, the testing site. Each trial shall be conducted with no vehicles, obstructions, or stationary objects within one lane width of either side the vehicle path.
**Personnel**

A test execution team would include an SV safety driver, an experimenter, and one or more POV operators, and potentially external observers. The team would typically coordinate using person-to-person radios for communication.

The SV safety driver would be skilled in the operation of the ADS feature under test. This skill and knowledge would include familiarity with the ADS feature user interface, activation and deactivation procedures, and potential failure modes. The safety driver must be capable of disengaging the ADS feature under test and bringing the vehicle to a minimal risk state, if the experiment approaches or reaches an unsafe state.

The experimenter observes and directs execution of each test trial and would typically be in the SV as the test is executed. The experimenter would also be knowledgeable of the operation of the ADS feature under test to determine if it is functioning properly. The experimenter records test conditions and test trial notes, and judges apparent test trial validity. The experimenter might also operate the data acquisition system and other test equipment.

The POV operator would hold a valid driver’s license and be comfortable operating the POVs. The POV operator would be responsible for positioning the POVs for each trial. If the POV is a vehicle surrogate, the POV operator would be knowledgeable of its construction and mobility and be able to position and control the surrogate for the prescribed trials.

The other observers may be responsible for operating external data collection equipment (e.g., video recording of test execution, etc.).

**Test Data and Equipment**

Relevant data listed below should be collected to support the metrics identified for each test scenario/trial. Options for equipment to collect the individual data elements are also provided.

- Vehicle Positions (SV and POVs): GPS/inertial navigation system (< X cm RMS, 95% confidence interval)
- Vehicle Speeds (SV and POVs): GPS/INS, estimated from position information
- Ranges (closest points between SV and POV): lidar, radar, estimated from position information
- Turn signal status
- Ambient Conditions:
  - Temperature: thermometer (°C, °F)
  - Wind Speed: anemometer (mph, kph)
  - Precipitation: range gauge (in/h, cm/h)
  - Time: clock
  - Sun position: manual observation
- Test Documentation: camera
- Experimenter Notes
**Test Facility**

For performing lane change competency tests, the test facility is a straight, flat, and level roadway that includes one driving lane, whose surface is constructed of asphalt or concrete, and whose driving lane is at least 12 ft wide and delineated by lane markings visible to the vehicle operators. The only exceptions to this may be for tests where the roadway is curved instead of straight. The length of the roadway will be sufficient to allow the ADS feature under test to establish and maintain a specified lane and speed, and to allow the SV to stop or exit the course, if applicable. The length of the test course is at least greater than the maximum SV perception range, or 105 m, whichever is greater.

**Scenario Test: PLC_Comp_15 – Straight Road, Complex, 15 mph**

**Scenario Description**

A vehicle equipped with an ADS feature is driving along a straight urban street with multiple lanes. It is approaching a necessary turn and needs to change lanes to position itself in the appropriate lane to make the turn.

**Test Subject and Purpose**

The subject of this test is an ADS feature whose specified ODD includes operation on improved urban roads with other traffic vehicles. The test determines the ability of the ADS feature to change lanes in the presence of other traffic vehicles.

**Initial Conditions**

The SV will initially be static in the prescribed positions and orientations.

The POVs will initially be static in the prescribed positions ahead of the SV in an adjacent lane. The leading edge of POV_2 will be approximately 3 m behind the trailing edge of POV_1.

**Test Velocities**

The steady state velocities of the SV and POV are specified for each trial or set of trials.

**Metrics**

**Disengagements**

A disengagement is defined as the SV safety driver deactivating the ADS feature being evaluated and taking manual control of the SV. The location and manner of the disengagement should be included in the experimenter’s notes.
Separation Distances
The separation distances are the distances between the SV and each of the POVs. The minimum separation distances (closest approach) should be identified, as well as the separation distances being observed as a continuum.

Signal Status
Signal status is the activation state of the SV turn signal, to be measured at a periodic rate to determine when the signal is activated and deactivated.

Execution of Procedure
1. The POVs are positioned in the center of the right lane of the test road at their specified locations.
2. The SV is positioned in the center of a left lane of the test road immediately adjacent to POV_2.
3. The SV is given a target destination in the right lane at the end of the test course.
4. The SV’s navigation system is activated to begin traversing the course.
5. As the SV begins moving, the POVs simultaneously begin accelerating to the specified steady state velocity while maintaining the approximate separation distance.
6. Each trial ends when the SV successfully changes lanes to merge between POV_1 and POV_2 and stops at the target destination, or the SV driver must intervene.
7. After the end of the trial, the SV driver disengages the ADS feature (if it is not already disengaged).

Trial Validity
An individual trial is valid if during the trial:

1. The velocity of the POVs did not exceed ±X kph from the specified steady state velocities.
2. The separation distance between the POVs did not exceed ±X m from the specified separation distance.
3. The POVs did not deviate from the specified lane.

NOTE: Other trial validity requirements might include GPS coverage requirements.

Evaluation Metrics
A trial is successful if the SV:

- Successfully accelerates and merges between the two POVs with a minimum separation distance of ≥X m with each POV.
- Successfully decelerates and merges behind POV_2 with a minimum separation distance of ≥X m with POV_2.
- Successfully accelerates and merges ahead of POV_1 with a minimum separation distance of ≥X m with POV_1 and does not exceed Y kph of the specified speed limit.
PERFORM VEHICLE FOLLOWING

ODD Characteristics

- Multi-lane divided highway (or similar)
- Asphalt or concrete
- Straight/curved, flat
- Clear lane markers
- Clear sky, dry, daylight

OEDR Characteristics

- Lead object vehicle

Failure Behaviors

- None

Test Protocol

Vehicle Platforms

Subject Vehicle– The vehicle equipped with the ADS feature being tested.

Principal Other Vehicle– The primary object vehicle for which the detection and response of the SV are being tested.

Vehicle Roles

The SV is a light-duty vehicle equipped with an ADS feature that is being evaluated.

The POV is another fully functional (operational brake lights, etc.) light-duty vehicle (e.g., sedan, SUV, pickup truck, etc.) or vehicle surrogate. If a vehicle surrogate is used, it would ideally be frangible and should possess similar mobility and detection characteristics as a regular light-duty vehicle.

- Able to be towed or remotely controlled to follow the test course
- Able to achieve test speeds
- Similar visual appearance
- Similar radar and/or lidar reflectivity
### Test Scenarios

**Table 61. Vehicle Following Test Scenarios**

| Maneuver                | SV Speed kph (mph) | POV Speed kph (mph) | Initial Headway; m (ft)
|-------------------------|--------------------|---------------------|------------------------
| Straight 25, slower speed | 40 (25)            | 32 (20)             | > 30 (> 100)           
| VF_S_25_Slow            |                    |                     |                        
| Straight 45, slower speed | 72 (45)            | 64 (40)             | > 68 (> 225)           
| VF_S_45_Slow            |                    |                     |                        
| Straight 65, slower speed | 105 (65)           | 96 (60)             | > 105 (> 345)          
| VF_S_55_Slow            |                    |                     |                        
| Curve 25, slower speed  | 40 (25)            | 32 (20)             | > 30 (> 100)           
| VF_C_25_Slow            |                    |                     |                        
| Curve 45, slower speed  | 72 (45)            | 64 (40)             | > 68 (> 225)           
| VF_C_45_Slow            |                    |                     |                        
| Curve 65, slower speed  | 105 (65)           | 96 (60)             | > 105 (> 345)          
| VF_C_65_Slow            |                    |                     |                        |

**Test Scenario Sample Visualizations**

![Figure 32. Vehicle Following Test Scenario](image-url)
General Procedures

Ambient Conditions

- The ambient temperature shall be between 0 °C (32 °F) and 38 °C (100 °F).
- The maximum wind speed shall be no greater than 10 m/s (22 mph).
- Tests should not be performed during periods of inclement weather. This includes, but is not limited to, rain, snow, hail, fog, smoke, or ash.
- Unless specified otherwise, the tests shall be conducted during daylight hours with good atmospheric visibility (defined as an absence of fog and the ability to see clearly for more than 5,000 m). The test shall not be conducted with the vehicle oriented into the sun during very low sun angle conditions (the sun is oriented 15 degrees or less from horizontal), where low sun angles degrade forward visibility for the test vehicle operators.
- Unless stated otherwise, all tests shall be conducted such that there are no overhead signs, bridges, or other significant structures over, or near, the testing site. Each trial shall be conducted with no vehicles, obstructions, or stationary objects within one lane width of either side the vehicle path.

Personnel

A test execution team would include an SV safety driver, an experimenter, a POV operator, and potentially external observers. The team would typically coordinate using person-to-person radios for communication.

The SV safety driver would be skilled in the operation of the ADS feature under test. This skill and knowledge would include familiarity with the ADS feature user interface, activation and deactivation procedures, and potential failure modes. The safety driver must be capable of disengaging the ADS feature under test and bringing the vehicle to a minimal risk state, if the experiment approaches or reaches an unsafe state.

The experimenter observes and directs execution of each test trial and would typically be in the SV as the test is executed. The experimenter would also be knowledgeable of the operation of the ADS feature under test to determine if it is functioning properly. The experimenter records test conditions and test trial notes and judges apparent test trial validity. The experimenter might also operate the data acquisition system and other test equipment.

The POV operator would hold a valid driver’s license and be comfortable operating the POV. The POV operator would be responsible for following the prescribed lane at the prescribed speed for each trial. If the POV is a vehicle surrogate, the POV operator would be knowledgeable of its construction and mobility and be able to position and control the surrogate for the prescribed trials.

The other observers may be responsible for operating external data collection equipment (e.g., video recording of test execution, etc.).
Test Data and Equipment

Relevant data listed below should be collected to support the metrics identified for each test scenario/trial. Options for equipment to collect the individual data elements are also provided:

- Vehicle Positions (SV and POV): GPS/INS (< X cm root mean square (RMS) error, 95% confidence interval)
- Vehicle Speeds (SV and POV): GPS/INS, estimated from position information
- Ranges (following distance between SV and POV): lidar, radar, estimated from position information
- Ambient Conditions:
  - Temperature: thermometer (°C, °F)
  - Wind Speed: anemometer (mph, kph)
  - Precipitation: range gauge (in/h, cm/h)
  - Time: clock
  - Sun position: manual observation
- Test Documentation: camera
- Experimenter Notes

Test Facility

For vehicle-following competency tests, the test facility is a straight, flat, and level roadway that includes one driving lane, whose surface is constructed of asphalt or concrete, and whose driving lane is at least 12 ft wide and delineated by lane markings visible to the vehicle operators. The only exceptions to this may be for tests where the roadway is curved instead of straight. The length of the roadway will be sufficient to allow the ADS feature under test to establish and maintain a specified lane and speed before encountering the POV, and to allow the SV to stop or exit the course, if applicable. The length of the test course is at least greater than the maximum SV perception range, or 105 m, whichever is greater. The test course should be a single lane so as not to allow the SV to change lanes to maneuver around the POV (if that is a capability of the ADS feature.)

Scenario Tests: VF_S_25_Slow – Straight Road, POV Slower than SV

Scenario Description

A vehicle equipped with an ADS feature is driving along a straight highway or urban road with one or more lanes. It approaches a slower moving lead vehicle in the same lane from behind.

Test Subject and Purpose

The subject of this test is an ADS feature whose specified ODD includes operation on improved roads with other traffic vehicles. The test determines the ability of the ADS feature to maintain a safe following distance behind another traffic vehicle.
**Initial Conditions**

The SV will initially be static in the prescribed positions and orientations.

The POV will initially be static in the prescribed positions ahead of the SV.

**Test Velocities**

The steady state velocities of the SV and POV are specified for each trial or set of trials.

**Metrics**

**Disengagements**
A disengagement is defined as the SV safety driver deactivating the ADS feature being evaluated and taking manual control of the SV. The location and manner of the disengagement should be included in the experimenter’s notes.

**Following Distance**
The following distance is the distance between the leading edge (front bumper) of the SV and the trailing edge (rear bumper) of the POV. The minimum following distance (closest approach) should be identified, as well as the following distance being observed as a continuum.

**Deceleration Rate**
The deceleration rate is the rate of change of speed of the vehicle (presuming that the vehicle slows down in this case). Ideally, the rate of change would be smooth, as opposed to an abrupt deceleration as the SV approaches the POV.

**Execution of Procedure**

1. The POV is positioned in the center of a lane of the test road at the specified starting location.
2. The SV is positioned in the center of a lane of the test road at the specified initial headway.
3. The SV is given a target destination at the end of the test course such that it will remain in the lane as it traverses the course and reaches the specified speed.
4. The SV’s navigation system is activated to begin traversing the course.
5. The POV accelerates to and maintains the specified speed while maintaining the specified lane.
6. The SV approaches the POV at the specified speed (higher than the POV speed) in the specified lane.
7. Each trial ends when the SV successfully stops at the target destination, or the SV driver must intervene.
8. After the end of the trial, the SV driver disengages the ADS feature (if it is not already disengaged).
**Trial Validity**

An individual trial is valid if during the trial:

1. The velocity of the SV did not exceed ±X kph from the specified steady state velocity before the POV came within its perception horizon.
2. The velocity of the POV did not exceed ±X kph from the specified steady state velocity.
3. The POV did not deviate from the specified lane.
4. The yaw rate of the POV did not exceed ±X degrees/s.

*NOTE: Other trial validity requirements might include GPS coverage requirements.*

**Evaluation Metrics**

A trial is successful if the SV remains within its prescribed lane and reduces its speed to maintain a safe, speed-dependent following distance behind the POV for the remaining length and duration of the trial.
MOVE OUT OF TRAVEL LANE/PARK

ODD Characteristics

- Multi-lane arterial street (or similar)
- Asphalt or concrete
- Straight, flat
- Clear lane markers
- Clear sky, dry, daylight

OEDR Characteristics

- Optional object vehicles

Failure Behaviors

- None

Test Protocol

Vehicle Platforms

Subject Vehicle– The vehicle equipped with the ADS feature being tested.

Principal Other Vehicles– The primary object vehicles for which the detection and response of the SV are being tested.

Vehicle Roles

The SV is a light-duty vehicle equipped with an ADS feature that is being evaluated.

The POVs are other fully functional (operational brake lights, etc.) light-duty vehicles (e.g., sedan, SUV, pickup truck, etc.) or vehicle surrogates. If a vehicle surrogate is used, it would ideally be frangible and should possess similar mobility and detection characteristics as a regular light-duty vehicle:

- Ability to be towed or remotely controlled to follow the test course
- Ability to achieve test speeds
- Similar visual appearance
- Similar radar and/or lidar reflectivity
### Test Scenarios

Table 62. Move Out of Travel Lane Test Scenarios

<table>
<thead>
<tr>
<th>Maneuver</th>
<th>SV Speed kph (mph)</th>
<th>POV Speed kph (mph)</th>
<th># of POVs</th>
<th>Location of POV_1</th>
<th>Location of POV_n</th>
<th>Length of “Parking” Zone m (ft)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Simple Positive 15 MOTL_Simp_15</td>
<td>24 (15)</td>
<td>0 (0)</td>
<td>1</td>
<td>Rear bump. 12 m (40 ft) beyond Int_1</td>
<td>Front bump. ≥24 m (80 ft) before Int_2</td>
<td>24 (80)</td>
</tr>
<tr>
<td>Simple Positive 25 MOTL_Simp_15</td>
<td>40 (25)</td>
<td>0 (0)</td>
<td>1</td>
<td>Rear bump. 12 m (40 ft) beyond Int_1</td>
<td>Front bump. ≥24 m (80 ft) before Int_2</td>
<td>24 (80)</td>
</tr>
<tr>
<td>Complex Positive 15 MOTL_Comp_15</td>
<td>24 (15)</td>
<td>0 (0)</td>
<td>≥ 2</td>
<td>Rear bump. 11 m (35 ft) beyond Int_1</td>
<td>Front bump. 6 m (20 ft) before Int_2</td>
<td>24 (80)</td>
</tr>
<tr>
<td>Complex Positive 25 MOTL_Comp_25</td>
<td>40 (25)</td>
<td>0 (0)</td>
<td>≥ 2</td>
<td>Rear bump. 11 m (35 ft) beyond Int_1</td>
<td>Front bump. 6 m (20 ft) before Int_2</td>
<td>24 (80)</td>
</tr>
<tr>
<td>Negative 15 MOTL_Neg_15</td>
<td>24 (15)</td>
<td>0 (0)</td>
<td>≥ 2</td>
<td>Rear bump. 6 m (20 ft) beyond Int_1</td>
<td>Front bump. 6 m (20 ft) before Int_2</td>
<td>≤ 3 (10)</td>
</tr>
<tr>
<td>Negative 25 MOTL_Neg_25</td>
<td>40 (25)</td>
<td>0 (0)</td>
<td>≥ 2</td>
<td>Rear bump. 6 m (20 ft) beyond Int_1</td>
<td>Front bump. 6 m (20 ft) before Int_2</td>
<td>≤ 3 (10)</td>
</tr>
</tbody>
</table>

*Int = Intersection, bump. = bumper
Test Scenario Sample Visualizations

Figure 33. Move Out of Travel Lane/Park Test Scenario

General Procedures

Ambient Conditions

- The ambient temperature shall be between 0 °C (32 °F) and 38 °C (100 °F).
- The maximum wind speed shall be no greater than 10 m/s (22 mph).
- Tests should not be performed during periods of inclement weather. This includes, but is not limited to, rain, snow, hail, fog, smoke, or ash.
- Unless specified otherwise, the tests shall be conducted during daylight hours with good atmospheric visibility (defined as an absence of fog and the ability to see clearly for more than 5,000 m). The test shall not be conducted with the vehicle oriented into the sun during very low sun angle conditions (the sun is oriented 15 degrees or less from horizontal), where low sun angles degrade forward visibility for the test vehicle operators.
- Unless stated otherwise, all tests shall be conducted such that there are no overhead signs, bridges, or other significant structures over, or near, the testing site. Each trial shall be conducted with no vehicles, obstructions, or stationary objects within one lane width of either side the vehicle path.
**Personnel**

A test execution team would include an SV safety driver, an experimenter, a POV operator, and potentially external observers. The team would typically coordinate using person-to-person radios for communication.

The SV safety driver would be skilled in the operation of the ADS feature under test. This skill and knowledge would include familiarity with the ADS feature user interface, activation and deactivation procedures, and potential failure modes. The safety driver must be capable of disengaging the ADS feature under test and bringing the vehicle to a minimal risk state, if the experiment approaches or reaches an unsafe state.

The experimenter observes and directs execution of each test trial and would typically be in the SV as the test is executed. The experimenter would also be knowledgeable of the operation of the ADS feature under test to determine if it is functioning properly. The experimenter records test conditions and test trial notes, and judges apparent test trial validity. The experimenter might also operate the data acquisition system and other test equipment.

The POV operator would hold a valid driver’s license and be comfortable operating the POVs. The POV operator would be responsible for positioning the POVs for each trial. If the POV is a vehicle surrogate, the POV operator would be knowledgeable of its construction and mobility and be able to position and control the surrogate for the prescribed trials.

The other observers may be responsible for operating external data collection equipment (e.g., video recording of test execution).

**Test Data and Equipment**

Relevant data listed below should be collected to support the metrics identified for each test scenario/trial. Options for equipment to collect the individual data elements are also provided:

- Vehicle Positions (SV and POVs): GPS/INS (< X cm root mean square error, 95% confidence interval)
- Vehicle Speeds (SV and POVs): GPS/INS, estimated from position information
- Ranges (closest points between SV and POV): lidar, radar, estimated from position information
- Turn signal status
- Ambient Conditions:
  - Temperature: thermometer (°C, °F)
  - Wind Speed: anemometer (mph, kph)
  - Precipitation: range gauge (in/h, cm/h)
  - Time: clock
  - Sun position: manual observation
- Test Documentation: camera
- Experimenter Notes
**Test Facility**

For moving out of travel lane competency tests, the test facility is a straight, flat, and level roadway that includes one driving lane, whose surface is constructed of asphalt or concrete, and whose driving lane is at least 3.6 m (12 ft) wide and delineated by lane markings visible to the vehicle operators. The only exceptions to this may be for tests where the roadway is curved instead of straight. A curb of standard height 0.09 to 0.18 m (4 to 8 in) shall be located on the right edge of the right lane of the test road. The length of the roadway will be sufficient to allow the ADS feature under test to establish and maintain a specified lane and speed before encountering the parking area, and to allow the SV to stop or exit the course, if applicable. The length of the test course is at least greater than the maximum SV perception range, or 105 m, whichever is greater.

**Scenario Tests: MOTL_Comp_15 – Straight Road, Complex, 15 mph**

**Scenario Description**

A vehicle equipped with an ADS feature is driving along a straight urban street with one or more lanes. It needs to move out of the active travel lanes to a parking area to allow passengers to embark or disembark.

**Test Subject and Purpose**

The subject of this test is an ADS feature whose specified ODD includes operation on improved urban roads with other vehicle traffic. The test determines the ability of the ADS feature to move out of active travel lanes to park in a safe and timely manner.

**Initial Conditions**

The SV will initially be static in the prescribed positions and orientations.

The POVs will initially be static in the prescribed positions ahead of the SV. The leading edge of POV_2 will be approximately 80 ft behind the trailing edge of POV_1, allowing sufficient space for the SV to maneuver and park.

**Test Velocities**

The steady state velocities of the SV and POV are specified for each trial or set of trials.

**Metrics**

**Disengagements**

A disengagement is defined as the SV safety driver deactivating the ADS feature being evaluated and taking manual control of the SV. The location and manner of the disengagement should be included in the experimenter’s notes.
Separation Distances
The separation distances are the distances between the SV and each of the POVs. The minimum separation distances (closest approach) should be identified, as well as the separation distances being observed as a continuum.

The separation distance at stop is also measured and represents the distance between the SV and each of the POVs when the SV has come to a complete stop in its parking position.

Deceleration Rate
The deceleration rate is the rate of change of speed of the vehicle (presumed that the vehicle slows down in this case). Ideally the rate of change would be smooth, as opposed to an abrupt deceleration as the SV reaches the parking location.

Execution of Procedure
1. The POVs are positioned in the center of the parking lane (right lane) of the test road at their specified locations.
2. The POVs’ engines are turned off and are placed in park with their emergency brakes activated.
3. The SV is positioned in the center of a lane of the test road at the specified initial headway.
4. The SV is given a target “park” destination between the leading edge of POV_1 and the trailing edge of POV_2.
5. The SV’s navigation system is activated to begin traversing the course.
6. The SV approaches the POVs at the specified speed (higher than the POV speed) in the specified lane.
7. Each trial ends when the SV successfully stops at or near the target destination (between the POVs) and shifts to park, or the SV driver must intervene.
8. After the end of the trial, the SV driver disengages the ADS feature (if it is not already disengaged).

Trial Validity
An individual trial is valid if during the trial:

1. The velocity of the SV did not exceed ±X kph from the specified steady state velocity before the POV came within its perception horizon.
2. The velocity of the POVs did not exceed ±X kph from the specified steady state velocities.

NOTE: Other trial validity requirements might include GPS coverage requirements.
**Evaluation Metrics**

A trial is successful if the SV:

- Remains within its prescribed lane before reaching the parking area.
- Enters the parking lane with a moving separation distance of $\geq X$ m with each POV.
- Stops with separation distance at stop of $\geq X$ m with each POV.
- Shifts to park upon stopping in the parking lane.
DETECT AND RESPOND TO SCHOOL BUSES

ODD Characteristics

- Multi-lane divided highway (or similar)
- Asphalt or concrete
- Straight, flat
- Clear lane markers
- Clear sky, dry, daylight

OEDR Characteristics

- Object school bus

Failure Behaviors

- None

Test Protocol

Vehicle Platforms

Subject Vehicle– The vehicle equipped with ADS feature being tested.

Principal Other Vehicle– The primary object vehicle for which the detection and response of the SV are being tested.

Vehicle Roles

The SV is a light-duty vehicle equipped with an ADS feature that is being evaluated.

The POV is a “Type C” school bus, also known as a “conventional” school bus, with a gross vehicle weight rating of more than 4,535 kg (10,000 pounds), designed to carry more than ten persons. The bus has functioning onboard traffic control devices, including warning lights and articulating stop signs. Alternatively, a school bus surrogate can be used. If a bus surrogate is used, it would ideally be frangible and should possess similar mobility and detection characteristics as a regular light-duty vehicle.

- Similar visual appearance
- Similar radar and/or lidar reflectivity
- Similar traffic control devices
Test Scenarios

Table 63. School Bus Test Scenarios

<table>
<thead>
<tr>
<th>Maneuver</th>
<th>SV Speed kph (mph)</th>
<th>POV Speed kph (mph)</th>
<th>Initial Headway; m (ft)$^1$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Same Direction 25</td>
<td>40 (25)</td>
<td>0</td>
<td>&gt; 30 (&gt; 100)</td>
</tr>
<tr>
<td>SB_SD_25</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Same Direction 45</td>
<td>72 (45)</td>
<td>0</td>
<td>&gt; 68 (&gt; 225)</td>
</tr>
<tr>
<td>SB_SD_45</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Same Direction 65</td>
<td>105 (65)</td>
<td>0</td>
<td>&gt; 105 (&gt; 345)</td>
</tr>
<tr>
<td>SB_SD_55</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Opposing Direction 25</td>
<td>40 (25)</td>
<td>0</td>
<td>&gt; 30 (&gt; 100)</td>
</tr>
<tr>
<td>SB_OD_25</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Opposing Direction 45</td>
<td>72 (45)</td>
<td>0</td>
<td>&gt; 68 (&gt; 225)</td>
</tr>
<tr>
<td>SB_OD_45</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Opposing Direction 65</td>
<td>105 (65)</td>
<td>0</td>
<td>&gt; 105 (&gt; 345)</td>
</tr>
<tr>
<td>SB_OD_65</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Test Scenario Sample Visualizations

Figure 34. School Bus Test Scenarios

General Procedures

Ambient Conditions

- The ambient temperature shall be between 0 °C (32 °F) and 38 °C (100 °F).
• The maximum wind speed shall be no greater than 10 m/s (22 mph).
• Tests should not be performed during periods of inclement weather. This includes, but is not limited to, rain, snow, hail, fog, smoke, or ash.
• Unless specified otherwise, the tests shall be conducted during daylight hours with good atmospheric visibility (defined as an absence of fog and the ability to see clearly for more than 5,000 m). The test shall not be conducted with the vehicle oriented into the sun during very low sun angle conditions (the sun is oriented 15 degrees or less from horizontal), where low sun angles degrade forward visibility for the test vehicle operators.
• Unless stated otherwise, all tests shall be conducted such that there are no overhead signs, bridges, or other significant structures over, or near, the testing site. Each trial shall be conducted with no vehicles, obstructions, or stationary objects within one lane width of either side the vehicle path.

**Personnel**

A test execution team would include an SV safety driver, an experimenter, and a POV operator. The team would typically coordinate using person-to-person radios for communication.

The SV safety driver would be skilled in the operation of the ADS feature under test. This skill and knowledge would include familiarity with the ADS feature user interface, activation and deactivation procedures, and potential failure modes. The safety driver must be capable of disengaging the ADS feature under test and bringing the vehicle to a minimal risk state, if the experiment approaches or reaches an unsafe state.

The experimenter observes and directs execution of each test trial and would typically be in the SV as the test is executed. The experimenter would also be knowledgeable of the operation of the ADS feature under test to determine if it is functioning properly. The experimenter records test conditions and test trial notes, and judges apparent test trial validity. The experimenter might also operate the data acquisition system and other test equipment.

The POV operator would be skilled in the operation of the other object vehicles, in this case a Class C school bus. The POV operator would position the POV for each trial and would activate and deactivate the necessary POV features (bus lights and signs). If the POV is a vehicle surrogate, the POV operator would be knowledgeable of its construction and mobility and be able to position the surrogate and operate its traffic control devices for the prescribed trials.

**Test Data and Equipment**

Relevant data listed below should be collected to support the metrics identified for each test scenario/trial. Options for equipment to collect the individual data elements are also provided.

- Vehicle Positions (SV and POV): GPS/INS (< X cm root mean square error, 95% confidence interval)
- Ranges (closest points between SV and POVs): lidar, radar
• Ambient Conditions:
  o Temperature: thermometer (°C, °F)
  o Wind Speed: anemometer (mph, kph)
  o Precipitation: range gauge (in/h, cm/h)
  o Time: clock
  o Sun position: manual observation
• Test Documentation: camera
• Experimenter Notes

**Test Facility**

For school bus competency tests, the test facility is a straight, flat, and level roadway that includes two or more adjacent driving lanes and one or more opposing driving lanes, whose surface is constructed of asphalt or concrete, and whose driving lanes are at least 3.6 m (12 ft) wide and delineated by lane markings visible to the vehicle operators. The only exceptions to this may be for tests where the roadway is curved instead of straight. The length of the roadway will be sufficient to allow the ADS feature under test to establish and maintain a specified lane and speed before interaction with the POV and to allow the SV to stop or exit the course after passing the POV, if applicable. The length of the test course is at least greater than the maximum SV perception range, or 105 m, whichever is greater.

**SCENARIO TESTS: SB_OD_25_Straight – Opposing Direction in Adjacent Lanes, Straight Road**

**Scenario Description**

A vehicle equipped with an ADS feature is driving along a straight, undivided, multilane highway. It approaches a school bus that is stopped in an opposing lane, with lights and signs activated, to allow students to disembark.

**Test Subject and Purpose**

The subject of this test is an ADS feature whose specified ODD includes operation in areas where interaction with a school bus with activated traffic control devices is reasonably expected. The test determines the ability of the ADS feature to respond to the bus’s traffic control devices by stopping in a safe and timely manner.

**Initial Conditions**

The SV and POV will initially be static in the prescribed positions and orientations.

**Test Velocities**

The steady state velocities of the SV and POV are specified for each trial or set of trials.
**Metrics**

**Disengagements**
A disengagement is defined as the SV safety driver deactivating the ADS feature being evaluated and taking manual control of the SV. The location and manner of the disengagement should be included in the experimenter’s notes.

**Separation Distance at Stop**
Separation distance at stop is defined as the distance between the leading edge of the SV and a plane extending from the leading edge of the POV when the SV has come to a complete stop.

**Execution of Procedure**

1. The POV is positioned in the center of the opposing lane of test road.
2. The POV’s engine remains running and the POV is placed in park with the emergency brake activated.
3. The POV’s traffic control devices are activated (lights on and signs extended).
4. The SV is positioned in the center of the left lane of the test road at the specified initial headway distance behind the POV.
5. The SV is given a target destination at the end of the test course such that it will remain in the left lane as it traverses the course and reaches the specified speed.
6. The SV’s navigation system is activated to begin traversing the course.
7. Each trial ends when the SV successfully stops, or the SV driver must intervene.
8. After the end of the trial, the SV driver disengages the ADS feature (if it is not already disengaged).

**Trial Validity**
An individual trial is valid if during the trial:

1. The SV did not deviate from its specified lane (wheels crossing lane boundaries).
2. The velocity of the SV did not exceed ±X kph from the specified velocity.
3. The yaw rate of the SV did not exceed ±X degrees/s.
4. The POV did not deviate from the specified velocity by more than 0.1 kph.
5. The POV’s traffic control devices remained active for the entirety of the trial.

*NOTE: Other trial validity requirements might include GPS coverage requirements.*

**Evaluation Metrics (Performance Metrics – Pass/Fail Criteria)**
A trial is successful if the SV stops before its leading edge (front bumper) crosses a hypothetical plan extending horizontally from the leading edge (front bumper) of the POV.
DETECT AND RESPOND TO ENCROACHING ONCOMING VEHICLES

Test Protocol

Vehicle Platforms

Subject Vehicle– The vehicle equipped with ADS feature being tested.

Principal Other Vehicle– The primary object vehicle for which the detection and response of the SV are being tested.

Vehicle Roles

The SV is a light-duty vehicle equipped with an ADS feature that is being evaluated.

The POV is another fully functional (operational brake lights, etc.) light-duty vehicle (e.g., sedan, SUV, pickup truck, etc.) or vehicle surrogate. If a vehicle surrogate is used, it would ideally be frangible and should possess similar mobility and detection characteristics as a regular light-duty vehicle:

- Ability to be towed or remotely controlled to follow the test course
- Ability to achieve test speeds
- Similar visual appearance
- Similar radar and/or lidar reflectivity

Test Scenarios

Table 64. Encroaching Opposing Vehicle Test Scenarios

<table>
<thead>
<tr>
<th>Maneuver</th>
<th>SV Speed kph (mph)</th>
<th>POV Speed kph (mph)</th>
<th>Initial Headway; m (ft)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Straight 25/20</td>
<td>40 (25)</td>
<td>32 (20)</td>
<td>&gt; 30 (&gt; 100)</td>
</tr>
<tr>
<td>EOV_S_25_20</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Straight 45/40</td>
<td>72 (45)</td>
<td>64 (40)</td>
<td>&gt; 68 (&gt; 225)</td>
</tr>
<tr>
<td>EOV_S_45_40</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Straight 65/60</td>
<td>105 (65)</td>
<td>96 (60)</td>
<td>&gt; 105 (&gt; 345)</td>
</tr>
<tr>
<td>EOV_S_65_60</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Curve 25/20</td>
<td>40 (25)</td>
<td>32 (20)</td>
<td>&gt; 30 (&gt; 100)</td>
</tr>
<tr>
<td>EOV_C_25_20</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Curve 45/40</td>
<td>72 (45)</td>
<td>64 (40)</td>
<td>&gt; 68 (&gt; 225)</td>
</tr>
<tr>
<td>EOV_C_45_40</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Curve 65/60</td>
<td>105 (65)</td>
<td>96 (60)</td>
<td>&gt; 105 (&gt; 345)</td>
</tr>
<tr>
<td>EOV_C_65_60</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Test Scenario Sample Visualizations

Figure 35. Encroaching, Oncoming Vehicle Test Scenario

General Procedures

Ambient Conditions

- The ambient temperature shall be between 0 °C (32 °F) and 38 °C (100 °F).
- The maximum wind speed shall be no greater than 10 m/s (22 mph).
- Tests should not be performed during periods of inclement weather. This includes, but is not limited to, rain, snow, hail, fog, smoke, or ash.
- Unless specified otherwise, the tests shall be conducted during daylight hours with good atmospheric visibility (defined as an absence of fog and the ability to see clearly for more than 5,000 m). The test shall not be conducted with the vehicle oriented into the sun during very low sun angle conditions (the sun is oriented 15 degrees or less from horizontal), where low sun angles degrade forward visibility for the test vehicle operators.
- Unless stated otherwise, all tests shall be conducted such that there are no overhead signs, bridges, or other significant structures over, or near, the testing site. Each trial shall be conducted with no vehicles, obstructions, or stationary objects within one lane width of either side the vehicle path.
**Personnel**

A test execution team would include an SV safety driver, an experimenter, a POV operator, and potentially external observers. The team would typically coordinate using person-to-person radios for communication.

The SV safety driver would be skilled in the operation of the ADS feature under test. This skill and knowledge would include familiarity with the ADS feature user interface, activation and deactivation procedures, and potential failure modes. The safety driver must be capable of disengaging the ADS feature under test and bringing the vehicle to a minimal risk state, if the experiment approaches or reaches an unsafe state.

The experimenter observes and directs execution of each test trial and would typically be in the SV as the test is executed. The experimenter would also be knowledgeable of the operation of the ADS feature under test to determine if it is functioning properly. The experimenter records test conditions and test trial notes, and judges apparent test trial validity. The experimenter might also operate the data acquisition system and other test equipment.

The POV operator would hold a valid driver’s license and be comfortable operating the POV. The POV operator would be responsible for following the prescribed lane at the prescribed speed for each trial. If the POV is a vehicle surrogate, the POV operator would be knowledgeable of its construction and mobility and be able to position and operate the surrogate for the prescribed trials.

The other observers may be responsible for operating external data collection equipment (e.g., video recording of test execution).

**Test Data and Equipment**

Relevant data listed below should be collected to support the metrics identified for each test scenario/trial. Options for equipment to collect the individual data elements are also provided.

- Vehicle Positions (SV and POV): GPS/INS (< X cm root mean square error, 95% confidence interval)
- Vehicle Speeds (SV and POV): GPS/INS, estimated from position information
- Ranges (following distance between SV and POV): lidar, radar, estimated from position information
- Ambient Conditions:
  - Temperature: thermometer (°C, °F)
  - Wind Speed: anemometer (mph, kph)
  - Precipitation: range gauge (in/h, cm/h)
  - Time: clock
  - Sun position: manual observation
- Test Documentation: camera
- Experimenter Notes
Test Facility

For vehicle-following competency tests, the test facility is a straight, flat, and level roadway that includes one or more driving lanes and one opposing lane, whose surface is constructed of asphalt or concrete, and whose driving lanes are at least 3.6 m (12 ft) wide and delineated by lane markings visible to the vehicle operators. The only exceptions to this may be for tests where the roadway is curved instead of straight. The length of the roadway will be sufficient to allow the ADS feature under test to establish and maintain a specified lane and speed before encountering the POV, and to allow the SV to stop or exit the course, if applicable. The length of the test course is at least greater than the maximum SV perception range, or 105 m, whichever is greater.

SCENARIO TESTS: EOV_S_45_40 – Straight Road, 45 mph, 40 mph Opposing Vehicle

Scenario Description

A vehicle equipped with an ADS feature is driving along a straight highway with one or more lanes. Another moving vehicle is approaching in an opposing lane of travel and begins to drift into the SV’s lane of travel such that a collision would occur if the SV did not react.

Test Subject and Purpose

The subject of this test is an ADS feature whose specified operational design domain includes operation on multidirectional, undivided, improved roads with other vehicle traffic. The test determines the ability of the ADS feature to detect an opposing vehicle that is encroaching into its lane to the extent that a collision would occur if the SV did not implement an avoidance maneuver.

Initial Conditions

The SV will initially be static in the prescribed positions and orientations.

The POV will be static in the prescribed positions and orientations.

Test Velocities

The steady state velocities of the SV and POV are specified for each trial or set of trials.

Metrics

Disengagements
A disengagement is defined as the SV safety driver deactivating the ADS feature being evaluated and taking manual control of the SV. The location and manner of the disengagement should be included in the experimenter’s notes.

Avoidance Distance
The avoidance distance is the minimum distance between the SV and POV.
Deceleration Rate
The deceleration rate is the rate of change of speed of the vehicle (presumed that the vehicle slows down in this case).

Yaw Rate
The yaw rate is defined as the rate of change of the heading of the vehicle.

Execution of Procedure

1. The POV is positioned in the opposing lane of the test road with its left (driver’s side) tires entirely over the center dividing lane markers in the SV’s lane.
2. The SV is positioned in the center of a lane of the test road at the specified initial headway.
3. The SV is given a target destination at the end of the test course such that it will remain in the lane as it traverses the course and reaches the specified speed.
4. The SV’s navigation system is activated to begin traversing the course.
5. The POV begins driving in the opposing direction and maintains a trajectory parallel to the center of the opposing lane, with its left (driver’s side) entirely over the center dividing lane markers, in the SV’s lane.
6. The SV and POV approach each other in opposing directions at the specified speeds.
7. Each trial ends when a collision occurs or is avoided, or if the SV driver disengages the ADS Feature.
8. After the end of the trial, the SV driver disengages the ADS Feature (if it is not already disengaged).

Trial Validity
An individual trial is valid if during the trial:

1. The velocity of the SV did not exceed ±X kph from the specified steady state velocity before the POV came within its perception horizon.
2. The velocity of the POV did not exceed ±X kph from the specified velocity for the duration of the trial.
3. The left (driver’s side) wheels of the POV remained fully in the SV’s lane for the duration of the trial.

NOTE: Other trial validity requirements might include GPS coverage requirements.

Evaluation Metrics
A trial is successful if the SV either:

- Maneuvers fully into an available adjacent lane and avoids a collision with the POV.
- Maneuvers fully onto an available shoulder and avoids a collision with the POV.
- Maneuvers to shift within its lane (potentially partially entering an available adjacent lane or shoulder) and avoids a collision with the POV.
- Decelerates rapidly to mitigate an imminent collision with the POV.
DETECT AND RESPOND TO PEDESTRIANS

Test Protocol

Vehicle Platforms

Subject Vehicle– The vehicle equipped with ADS feature being tested.

Vehicle Roles

The SV is a light-duty vehicle equipped with an ADS feature that is being evaluated.

Other Definitions

Pedestrian Surrogate– A human surrogate that is attached to a self-propelled or freewheeling mobile base. The surrogate would ideally be frangible and with similar mobility and detection characteristics.

- Ability to be towed or remotely controlled to follow prescribed course
- Similar articulation of joints (if applicable)
- Similar visual appearance
- Similar radar and/or lidar reflectivity
## Test Scenarios

Table 65. Pedestrian Test Scenarios

<table>
<thead>
<tr>
<th>Maneuver</th>
<th>SV Speed kph (mph)</th>
<th>PS Speed kph (mph)</th>
<th>Initial Headway; ft (m)¹</th>
</tr>
</thead>
<tbody>
<tr>
<td>In Crosswalk Straight 25</td>
<td>40 (25)</td>
<td>5 (3)</td>
<td>&gt; 30 (&gt; 100)</td>
</tr>
<tr>
<td>Ped_Crosswalk_S_25</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>In Crosswalk Straight 45</td>
<td>72 (45)</td>
<td>5 (3)</td>
<td>&gt; 68 (&gt; 225)</td>
</tr>
<tr>
<td>Ped_Crosswalk_S_45</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>In Crosswalk/Sign Straight 25</td>
<td>40 (25)</td>
<td>5 (3)</td>
<td>&gt; 30 (&gt; 100)</td>
</tr>
<tr>
<td>Ped_Crosswalk_Sign_S_25</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>In Crosswalk/Sign Straight 45</td>
<td>72 (45)</td>
<td>5 (3)</td>
<td>&gt; 68 (&gt; 225)</td>
</tr>
<tr>
<td>Ped_Crosswalk_Sign_S_45</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>In No Crosswalk Straight 25</td>
<td>40 (25)</td>
<td>5 (3)</td>
<td>&gt; 30 (&gt; 100)</td>
</tr>
<tr>
<td>Ped_NoCrosswalk_S_25</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>In No Crosswalk Straight 45</td>
<td>72 (45)</td>
<td>5 (3)</td>
<td>&gt; 68 (&gt; 225)</td>
</tr>
<tr>
<td>Ped_NoCrosswalk_S_45</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Entering Crosswalk Straight 25</td>
<td>40 (25)</td>
<td>5 (3)</td>
<td>&gt; 30 (&gt; 100)</td>
</tr>
<tr>
<td>Ped_Crosswalk_S_25</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Entering Crosswalk Straight 45</td>
<td>72 (45)</td>
<td>5 (3)</td>
<td>&gt; 68 (&gt; 225)</td>
</tr>
<tr>
<td>Ped_Crosswalk_S_45</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Entering Crosswalk/Sign Straight 25</td>
<td>40 (25)</td>
<td>5 (3)</td>
<td>&gt; 30 (&gt; 100)</td>
</tr>
<tr>
<td>Ped_Crosswalk_Sign_S_25</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Entering Crosswalk/Sign Straight 45</td>
<td>72 (45)</td>
<td>5 (3)</td>
<td>&gt; 68 (&gt; 225)</td>
</tr>
<tr>
<td>Ped_Crosswalk_Sign_S_45</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**NOTE:** Further iterations of tests could have pedestrians coming from different directions.
Test Scenario Sample Visualizations

Figure 36. Pedestrian Test Scenario

General Procedures

*Ambient Conditions*

- The ambient temperature shall be between 0 °C (32 °F) and 38 °C (100 °F).
- The maximum wind speed shall be no greater than 10 m/s (22 mph).
- Tests should not be performed during periods of inclement weather. This includes, but is not limited to, rain, snow, hail, fog, smoke, or ash.
- Unless specified otherwise, the tests shall be conducted during daylight hours with good atmospheric visibility (defined as an absence of fog and the ability to see clearly for more than 5,000 m). The test shall not be conducted with the vehicle oriented into the sun during very low sun angle conditions (the sun is oriented 15 degrees or less from horizontal), where low sun angles degrade forward visibility for the test vehicle operators.
- Unless stated otherwise, all tests shall be conducted such that there are no overhead signs, bridges, or other significant structures over, or near, the testing site. Each trial shall be conducted with no vehicles, obstructions, or stationary objects within one lane width of either side the vehicle path.

*Personnel*

A test execution team would include an SV safety driver, an experimenter, a PS operator, and potentially external observers. The team would typically coordinate using person-to-person radios for communication.
The SV safety driver would be skilled in the operation of the ADS feature under test. This skill and knowledge would include familiarity with the ADS feature user interface, activation and deactivation procedures, and potential failure modes. The safety driver must be capable of disengaging the ADS feature under test and bringing the vehicle to a minimal risk state, if the experiment approaches or reaches an unsafe state.

The experimenter observes and directs execution of each test trial, and would typically be in the SV as the test is executed. The experimenter would also be knowledgeable of the operation of the ADS feature under test to determine if it is functioning properly. The experimenter records test conditions and test trial notes, and judges apparent test trial validity. The experimenter might also operate the data acquisition system and other test equipment.

The PS operator would be responsible for positioning and controlling the pedestrian surrogate. The PS operator would be knowledgeable of its construction and mobility, and be able to position and operate the surrogate for the prescribed trials.

The other observers may be responsible for operating external data collection equipment (e.g., video recording of test execution, etc.).

**Test Data and Equipment**

Relevant data listed below should be collected to support the metrics identified for each test scenario/trial. Options for equipment to collect the individual data elements are also provided:

- Vehicle Positions (SV): GPS/INS (< X cm root mean square error, 95% confidence interval)
- Pedestrian Surrogate Position: GPS/INS (< X cm root mean square error, 95% confidence interval)
- Vehicle Speeds (SV): GPS/INS, estimated from position information
- Pedestrian Surrogate Speed: GPS/INS, estimated from position information
- Ranges (between SV and PS): lidar, radar, estimated from position information
- Ambient Conditions:
  - Temperature: thermometer (°C, °F)
  - Wind Speed: anemometer (mph, kph)
  - Precipitation: range gauge (in/h, cm/h)
  - Time: clock
  - Sun position: manual observation
- Test Documentation: camera
- Experimenter Notes

**Test Facility**

For pedestrian competency tests, the test facility is a straight, flat, and level roadway that includes one or more driving lanes, whose surface is constructed of asphalt or concrete, and whose driving lanes are at least 12 ft wide and delineated by lane markings visible to the vehicle.
operators. The only exceptions to this may be for tests where the roadway is curved instead of straight. The length of the roadway will be sufficient to allow the ADS feature under test to establish and maintain a specified lane and speed before encountering the PS, and to allow the SV to stop or exit the course, if applicable. The length of the test course is at least greater than the maximum SV perception range, or 105 m, whichever is greater.

For some of the tests, crosswalk markings and pedestrian crossing signs will be present. The crosswalk markings will fully traverse the test road perpendicularly to the travel lanes. The signs will be installed outside of the travel lanes, on the shoulder or similar area. Signs and markings will adhere to the Manual on Uniform Traffic Control Devices (MUTCD.)

SCENARIO TESTS: Ped_Crosswalk_Sign_S_25 – Crosswalk Markings and Signs, Straight, 25 mph

Scenario Description

A vehicle equipped with an ADS feature is driving along a straight urban road with one or more lanes. The vehicle approaches a crosswalk in which a pedestrian is crossing the road.

Test Subject and Purpose

The subject of this test is an ADS feature whose specified ODD includes operation on roadways where it may reasonably be expected that pedestrians could enter the roadway. The test determines the ability of the ADS feature to detect and yield to the pedestrian in the roadway (leveraging markings and signs, if available).

Initial Conditions

The SV will initially be static in the prescribed positions and orientations.

The PS will be static in the prescribed positions and orientations.

Test Velocities

The steady state velocities of the SV and PS are specified for each trial or set of trials.

Metrics

Disengagements
A disengagement is defined as the SV safety driver deactivating the ADS feature being evaluated and taking manual control of the SV. The location and manner of the disengagement should be included in the experimenter’s notes.
Separation Distance
The separation distances are the distances between the SV and the PS. The minimum separation distance (closest approach) should be identified, as well as the separation distance being observed as a continuum.

Deceleration Rate
The deceleration rate is the rate of change of speed of the vehicle (presumed that the vehicle slows down in this case).

Execution of Procedure
1. The PS is positioned outside of the test course travel lanes, adjacent to the marked crosswalk.
2. The SV is positioned in the center of a lane of the test road at the specified initial headway.
3. The SV is given a target destination at the end of the test course such that it will remain in the lane as it traverses the course and reaches the specified speed.
4. The SV’s navigation system is activated to begin traversing the course.
5. When the SV approaches within X meters of the crosswalk, the PS is set into motion to traverse the crosswalk, such that it is fully in the crosswalk.
6. Each trial ends when a collision occurs or is avoided by the SV slowing down and/or stopping, or if the SV driver disengages the ADS feature.
7. After the end of the trial, the SV driver disengages the ADS feature (if it is not already disengaged).

Trial Validity
An individual trial is valid if during the course of the trial:

1. The velocity of the SV did not exceed ±X kph from the specified steady state velocity before the PS came within its perception horizon.
2. The velocity of the PS did not exceed ±X kph from the specified velocity for the duration of the trial.
3. The PS was actively moving through the lanes of travel in the direction of the SV’s course (e.g., the PS was not still approaching the active travel lanes and had not already exited the relevant side of the road).
4. The PS remained inside of the crosswalk bounds for the duration of its traversal.

NOTE: Other trial validity requirements might include GPS coverage requirements.

Evaluation Metrics
A trial is successful if the SV slows down and/or stops to yield to the PS until it has exited the active travel lanes. If multiple lanes are available, the SV should not attempt a lane change to go around the PS (neither in front of, nor behind).
APPENDIX D. BEHAVIOR COMPETENCY COMPARISON

This section describes an analysis conducted after the main body of research for this project had been completed. This addendum seeks to clarify the concept of ADS Behavioral Competencies, due to the existence of several embodiments of this concept found in the literature.

Several pieces of research have sought to define and catalogue the behavioral competencies of ADS. In this document, we provide a framework for ADS behavioral competencies in the context of developing ADS test scenarios. Furthermore, this document provides a notional condensed list of ADS behavioral competencies that represents findings from research by the NHTSA testable cases and scenarios for ADS research project, Waymo’s Voluntary Safety Self-Assessment, California PATH at the Institute of Transportation Studies at University of California, Berkeley, and NHTSA pre-crash scenarios.

In this work, it was helpful to think of a test case in four dimensions.

- Tactical Maneuver Behaviors
- ODD Elements
- OEDR Behaviors
- Failure Mode Behaviors

This summary uses the three categories for behaviors (tactical maneuvers, OEDR, and failure mode) as a means of summarizing research findings. It should be noted that each behavioral competency can be necessary in multiple ODDs. For example, lane changes may take place on highways or low speed urban environments. The development of a test scenario will depend both on the behavioral competency being tested, as well as the ODD in which that competency is expected to perform.

It should also be noted that the SAE International ORAD Committee has an active task force on behaviors and maneuvers that is seeking to harmonize the terms and definitions for behavioral competencies. The work of this task force is intended to support the definition of ADS test scenarios, which will benefit from a harmonized approach to cataloguing behavioral competencies, and providing an ontology of OEDR, tactical maneuver, and failure mode behaviors, as well as ODD for each behavior.

The multiple behavioral competencies based on the literature and analysis from this project were condensed into a single list. This list may not be complete, but does attempt to incorporate all behavioral competencies from the four major literature sources that were reviewed. The behavioral competencies listed here provide a high-level description, but the development of a test scenario will require significant additional definition of ODD, narrative and purpose, trajectory information, traffic control devices, and other aspects described in the full report.
<table>
<thead>
<tr>
<th>Categories of Behavioral Competencies</th>
<th>Specific Behavioral Competencies</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Tactical Maneuvers</strong></td>
<td></td>
</tr>
<tr>
<td>Parking</td>
<td>• Navigate a parking lot, locate spaces, make appropriate forward and reverse parking maneuvers</td>
</tr>
<tr>
<td>(Note: ODD may include parking garages, surface lots, parallel parking)</td>
<td></td>
</tr>
</tbody>
</table>
| Lane Maintenance & Car Following     | • Car following, including stop and go, lead vehicle changing lanes, and responding to emergency braking  
• Speed maintenance, including detecting changes in speed limits and speed advisories  
• Lane centering  
• Detect and respond to encroaching vehicles  
• Enhancing conspicuity (e.g., headlights)  
• Detect and respond to vehicles turning at non-signalized junctions |
| (Note: ODD may include high and low speed roads) |                                  |
| Lane Change                          | • Lane switching, including overtaking or to achieve a minimal risk condition  
• Merge for high and low speed  
• Detect and respond to encroaching vehicles  
• Enhancing conspicuity (e.g., blinkers)  
• Detect and respond to vehicles turning at non-signalized junctions  
• Detect and respond to no passing zones |
| (Note: ODD may include high and low speed roads) |                                  |
| Navigate Intersection                | • Navigate on/off ramps  
• Navigate roundabouts  
• Navigate signalized intersection  
• Detect and respond to traffic control devices  
• Navigate crosswalk  
• U-Turn  
• Car following through intersections, including stop and go, lead vehicle changing lanes, and responding to emergency braking  
• Navigate rail crossings  
• Detect and respond to vehicle running red light or stop sign  
• Vehicles turning - same direction  
• LTAP/OD at signalized junction and non-signalized junction  
• Navigate right turn at signalized and non-signalized junctions |
<p>| (Note: ODD may include signalized and non-signalized junctions) |                                  |
| Navigate Temporary or Atypical Condition | • Detect and respond to work zone or temporary traffic patterns, including construction workers directing traffic |</p>
<table>
<thead>
<tr>
<th>OEDR Capabilities</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>OEDR: Vehicles</strong></td>
</tr>
<tr>
<td>Detect and respond to encroaching, oncoming vehicles</td>
</tr>
<tr>
<td>Vehicle following</td>
</tr>
<tr>
<td>Detect and respond to relevant stopped vehicle, including in lane or on the side of the road</td>
</tr>
<tr>
<td>Detect and respond to lane changes, including unexpected cut-ins</td>
</tr>
<tr>
<td>Detect and respond to cut-outs, including unexpected reveals</td>
</tr>
<tr>
<td>Detect and respond to school buses</td>
</tr>
<tr>
<td>Detect and respond to emergency vehicles, including at intersections</td>
</tr>
<tr>
<td>Detect and respond to vehicle roadway entry</td>
</tr>
<tr>
<td>Detect and respond to relevant adjacent vehicles</td>
</tr>
<tr>
<td>Detect and respond to relevant vehicles when in forward and reverse</td>
</tr>
</tbody>
</table>

| **OEDR: Traffic Control Devices and Infrastructure** |
| Detect and respond to speed limit changes or advisories |
| Detect and respond to relevant access restrictions, including one-way streets, no-turn locations, bicycle lanes, transit lanes, and pedestrian ways (See MUTCD for more complete list)) |
| Detect and respond to relevant traffic control devices, including signalized intersections, stop signs, yield signs, crosswalks, and lane markings (potentially including faded markings) (See MUTCD for more complete list) |
| Detect and respond to infrastructure elements, including curves, roadway edges, and guard rails (See AASHTO Green Book for more complete list) |

| **OEDR: Vulnerable Road Users, Objects, Animals** |
| Detect and respond to relevant static obstacles in lane |
| Detect and respond to pedestrians, pedalcyclists, animals in lane or on side of road |

<table>
<thead>
<tr>
<th>Failure Modes</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>ODD Boundary</strong></td>
</tr>
<tr>
<td>Detect and respond to ODD boundary transition, including unanticipated weather or lighting conditions outside of vehicle's capability</td>
</tr>
</tbody>
</table>

| **Degraded Performance/ Health Monitoring, Including Achieving Minimal Risk Condition** |
| Detect degraded performance and respond with appropriate fail-safe/fail-operational mechanisms, including detect and respond to conditions involving vehicle, system, or component-level failures or faults (e.g., power failure, sensing|
failure, sensing obstruction, computing failure, fault handling or response)
- Detect and respond to vehicle control loss (e.g., reduced road friction)
- Detect and respond to vehicle road departure
- Detect and respond to vehicle being involved in incident with another vehicle, pedestrian, or animal
- Non-collision safety situations, including vehicle doors ajar, fuel level, engine overheating

Failure Mitigation Strategy
- Detect and respond to catastrophic event, for example flooding or debilitating cyber attack

Based on the four literature sources reviewed, the research team developed a side by side comparison of the behavioral competencies identified in each. Table 67 is divided into categories that help compare similar competencies.

Table 67. Comparison of Behavior Competency Analyses

<table>
<thead>
<tr>
<th>Categories of Behavioral Competencies</th>
<th>NHTSA Testable Cases</th>
<th>Waymo Voluntary Safety Self-Assessment</th>
<th>California PATH Behavior Competencies</th>
<th>NHTSA Pre-Crash Scenarios</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Tactical Maneuvers</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
| Parking                              | ● Parking            | ● Navigate a Parking Lot and Locate Spaces
                                          ● Make Appropriate Reversing Maneuvers
                                          ● Detect and Respond to Encroaching Oncoming Vehicles
                                          ● Perform Car Following (Including Stop and Go) | ● Navigate a Parking Lot and Locate Open Spaces
                                          ● Detect & Respond to Speed Limit Changes (Including Advisory Speed Zones) | ● Vehicles Parking |
| Lane Maintenance & Car Following    | ● Car Following
                                          ● Speed Maintenance
                                          ● Lane Centering
                                          ● Enhancing Conspicuity (headlights) | ● Detect and Respond to Speed Limit Changes and Speed Advisories
                                          ● Detect and Respond to Encroaching Oncoming Vehicles
                                          ● Perform Car Following (Including Stop and Go) | ● Perform Car Following Including Stop & Go and Emergency Braking
                                          ● Detect & Respond to Speed Limit Changes (Including Advisory Speed Zones) | ● Lead Vehicle Stopped
                                          ● Vehicles Turning at Non-Signalized Junctions
                                          ● Lead Vehicle Decelerating
                                          ● Vehicles Changing Lanes
                                          ● Straight Crossing paths at Non-Signalized Junctions |
| Lane Change (e.g., overtake, merge) | • Lane Switching/Overtaking  
  • Enhancing Conspicuity (e.g., blinkers)  
  • Merge (high & low speed) | • Perform High-Speed Merge (e.g., Freeway)  
  • Perform Low-Speed Merge  
  • Move Out of the Travel Lane and Park (e.g., to the Shoulder for Minimal Risk)  
  • Detect and Respond to Encroaching Oncoming Vehicles  
  • Detect Passing and No Passing Zones and Perform Passing Maneuvers  
  • Perform Lane Changes | • Detect Passing and No Passing Zones  
  • Perform High Speed Freeway Merge  
  • Perform a Lane Change or Lower Speed Merge  
  • Park on the Shoulder or Transition the Vehicle to a Minimal Risk State (Not Required for SAE L3) | • Vehicles Turning at Non-Signalized Junctions  
  • Vehicles Changing Lanes  
  • Straight Crossing paths at Non-Signalized Junctions |
| --- | --- | --- | --- | --- |
| Navigate Intersection:  
  • Type: Signalized, Non-signalized, Roundabout, Rail Crossing  
  • Turn: Left/Right/Straight | • Navigate On/Off Ramps  
  • Roundabouts  
  • Intersection (left, right, straight)  
  • Crosswalk  
  • U-Turn | • Perform Car Following (Including Stop and Go)  
  • Navigate Intersections and Perform Turns  
  • Navigate Roundabouts  
  • Navigate Railroad Crossings | • Navigate Intersections & Perform Turns  
  • Detect and Respond to Traffic Control Devices  
  • Navigate Intersections & Perform Turns | • Running Red Light  
  • Vehicles Turning - Same Direction  
  • LTAP/OD at Signalized Junction  
  • LTAP/OD at Non-Signalized Junction  
  • Running Stop Sign  
  • Vehicle Turning Right at Signalized Intersection |
| Navigate Temporary or A-Typical Condition | • Detect and Respond to Workzone  
  • N-Point Turn  
  • Detect and Respond to Relevant Safety Officials | • Detect and Respond to Work Zones and People Directing Traffic in Unplanned or Planned Events  
  • Follow Police/First Responder Controlling Traffic (Owring or Acting as Traffic Control Device)  
  • Follow Construction Zone Workers Controlling Traffic Patterns (Slow/Stop Sign Holders)  
  • Respond to Citizens Directing Traffic After a Crash  
  • Detect/Respond to Detours and/or Other | • Detect Work Zones, Temporary Lane Shifts, or Safety Officials Manually Directing Traffic |
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<td>• Navigate Around Unexpected Road Closures (e.g., Lane, Intersection, etc.)</td>
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- Detect and Respond to Encroaching Oncoming Vehicles
- Detect and Respond to Locked Out Vehicles
- Vehicle Following
- Detect and Respond to Relevant Stopped Vehicle
- Detect and Respond to Lane Changes/Cut-ins
- Detect and Respond to Cut-outs/Reveals
- Detect and Respond to School Buses
- Detect and Respond to Emergency Vehicles
- Detect and Respond to Vehicle Roadway Entry
- Detect and Respond to Relevant Adjacent Vehicles

- Detect and Respond to Encroaching Oncoming Vehicles
- Detect and Respond to Stopped Vehicles
- Detect and Respond to Lane Changes
- Detect and Respond to Emergency Vehicles
- Yield for Law Enforcement, EMT, Fire, and Other Emergency Vehicles at Intersections, Junctions, and Other Traffic Controlled Situations
- Provide Safe Distance From Vehicles, Pedestrians, Bicyclists on Side of the Road
- Detect and Respond to Lead Vehicle
- Detect and Respond to a Merging Vehicle
- Detect and Respond to Motorcyclists
- Detect and Respond to School Buses
- Detect and Respond to Vehicles Parking in the Roadway

- Detect Emergency Vehicles
- Detect & Respond to Stopped Vehicles
- Detect & Respond to Intended Lane Changes/Cut-Ins
- Detect & Respond to Encroaching Oncoming Vehicles

- Running Red Light
- Lead Vehicle Moving at Lower Constant Speed
- Backing Up Into Another Vehicle
- Vehicles Not Making A Maneuver - Opposite Direction
- Vehicles Drifting - Same Direction
- Following Vehicle Making Maneuver
- Running Stop Sign
- Lead Vehicle Accelerating
- Vehicles Making a Maneuver - Opposite Direction
| OEDR: Traffic Control Devices & Infrastructure | Follow Driving Laws  
Detect and Respond to Speed Limit Changes  
Detect and Respond to Relevant Access Restrictions  
Detect and Respond to Relevant Dynamic Traffic Signs | Detect Traffic Signals and Stop/Yield Signs  
Respond to Traffic Signals and Stop/Yield Signs  
Detect and Respond to Access Restrictions (One-Way, No Turn, Ramps, etc.)  
Make Appropriate Right-of-Way Decisions  
Follow Local and State Driving Laws  
Detect and Respond to Temporary Traffic Control Devices  
Detect/Respond to Detours and/or Other Temporary Changes in Traffic Patterns  
Detect and Respond to Faded or Missing Roadway Markings or Signage | Detect and Respond to Access Restrictions such as One-Way Streets, No-Turn Locations, Bicycle Lanes, Transit Lanes, and Pedestrian Ways  
Detect and Respond to Traffic Control Devices  
Detect and Respond to Relevant Static Obstacles in Lane  
Detect and Respond to Pedestrians, Pedalcyclists, Animals |  
| |  
| OEDR: Vulnerable Road Users (VRU), Objects, Animals | Detect and Respond to Relevant Static Obstacles in Lane  
Detect and Respond to Pedestrians, Pedalcyclists, Animals | Detect and Respond to Static Obstacles in the Path of the Vehicle  
Yield to Pedestrians and Bicyclists at Intersections and Crosswalks  
Provide Safe Distance From Vehicles, Pedestrians, Bicyclists on Side of the Road  
Detect and Respond to Pedestrians in Road (Not Walking Through Intersection or Crosswalk)  
Provide Safe Distance from Bicyclists Traveling on Road (With or Without Bike Lane)  
Detect and Respond to Animals | Detect & Respond to Static Obstacles in Roadway  
Detect & Respond to Bicycles, Pedestrians, Animals, or Other Moving Objects |
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<td>• Detect and Respond to Unanticipated Weather or Lighting Conditions Outside of Vehicle's Capability (e.g., rainstorm)</td>
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Navigating the Development and Design of Automated Vehicles

February 7, 2019

Driver assistance technologies have evolved from aiding the driver in very specific situations (e.g., electronic stability control) to automating a broader range of driving tasks (e.g., adaptive cruise control and lane-keeping systems). While recent demonstrations of automated vehicles support the possibility that even limited automation can provide safety benefits compared to fully manual driving, many challenges remain. For example, while automated vehicle (AV) designers may assume drivers will perform their allocated roles and maintain vigilance during automated driving, recent incidents have demonstrated the frailty of such assumptions. These include drivers watching videos, sleeping, and generally failing to pay attention to the driving task during automated driving. Research conducted in the wake of such incidents suggests that the public’s tolerance for crashes and fatalities in AVs is likely to be much less than that for manual driving.

Such incidents also serve as a reminder that AVs can change the nature of driving and the role of the driver (including safety drivers used during road testing of AVs), often in unanticipated ways. Similar outcomes were common during initial implementations of automation in the aviation and process control industries, but many questions remain. What are the attentional, decision-making, and physical requirements that AVs place on the driver, and what design features are needed to support those requirements? Recent design guidance for the human-machine interface (HMI) for automated vehicles produced by the U.S. Department of Transportation provides only limited answers to these questions. How can human factors researchers help manufacturers design AV technology in a way that meets driver expectations, is easy-to-use, and generates the required levels of system safety and public trust in AVs? The following strategies can help address some of the challenges with imperfect automation, guide the AV industry towards a driver-centric approach to AV design, and produce more effective driver-vehicle interactions.

Embrace a collaborative approach to the development of the AV and the design of the HMI. Partial automation requires various types and amounts of driver involvement (especially Level 2 & 3 automation). With lower levels of automation, the driver is still required to maintain awareness of the driving environment in case the automation must transfer control back to the driver. Living with imperfect automation means the driver cannot be isolated from on-going responsibilities for monitoring the roadway, making decisions, and controlling the vehicle. These responsibilities must be shared between the AV system and the driver using an interdependent, collaborative approach to driver-vehicle interactions.

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promotes readiness, appropriate expectations, situation awareness, driver trust, and effective mental models of the AV’s operations.

Provide engaging feedback. The key to successful AV-driver collaborations is to incorporate an HMI that facilitates flexible, interactive communications with the driver on all aspects of the driving task. The lack of feedback and meaningful, on-going interactions with the system is a major cause of drivers being “out-of-the-loop.” Feedback is also a key component of the process by which drivers develop and update their mental model of the AV’s functionality. Feedback could include information about system capabilities and limitations, ongoing trip status, discrepancies between predicted and actual conditions, cues for key elements in the environment, changes in the status of the automation, countdowns to waypoints, and predictive information.

Measure and maintain effective driver engagement. Under imperfect automation, securing effective driver engagement is crucial to avoiding conflicts and crashes. Engagement includes acquiring and processing the roadway information necessary for successful monitoring and safe driving. A measure of effective engagement is whether the driver is looking at specific scene elements that support the strategic and tactical objectives of the driving task. Is the driver glancing at mirrors, relevant guide signs, traffic control devices, lane markings, other vehicles, and latent hazards? In short, is the driver looking at the right things at the right times? A collaborative AV will help drivers monitor the environment and draw their attention to relevant scene elements. Although coarse “eyes on the road” measurements are currently used as proxies for driver engagement, flexible eye-tracking technologies, sensors with machine vision capabilities, and real-time vehicle-to-infrastructure communications can now be used to provide better information about driver engagement levels and even help predict the driver’s readiness to take control of the vehicle.

Incorporate attention management strategies. Attention management is an on-going process by which an AV system can help the driver allocate and focus attention across competing objectives, activities, decisions, and sources of information. An attention management system could help shape driver behaviors and improve situation awareness. It would include real-time monitoring of the driver, as well as a design approach that encourages safe activities and restricts unsafe ones; e.g., the strategic use of alerts, provisional access to system features, and system-initiated lockouts from distracting technology. Beyond real-time monitoring and feedback, support for appropriate management of driver attention could be provided in various ways, including the careful design of marketing messages and training materials.

Exponent has been involved in the development of advanced vehicle technologies and driver assistance systems for over a decade. Today, we are actively investigating advanced driver assistance systems (ADAS), as well as connected vehicle and automated vehicle design. What sets Exponent apart is our ability to offer a multi-disciplinary team of Ph.D.-level engineers, scientists, and human factors experts, along with our newly minted Phoenix User Research Center (PURC), attached to our automotive testing facilities at the Test and Engineering Center to quickly and seamlessly integrate with in-house teams to address a client’s human factors needs throughout the design and development of advanced vehicle technologies, including AVs.

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Automated Vehicles: How Safe is Safe Enough?

October 16, 2018

The connected and automated vehicle industry is growing rapidly. Last year, a study from Intel and Strategy Analytics estimated that driverless vehicles could represent $7 trillion of economic activity annually by 2050.\(^1\) Achieving this market size will require each manufacturer to answer critical questions about whether its product is safe enough. While a consensus answer has yet to emerge, our history of development in transportation suggests that it will be a function of three key criteria: regulatory demand, consumer acceptance, and a manufacturer’s tolerance for risk. Above all, stakeholders must have confidence that every automated vehicle on the road reliably performs to the agreed upon safety performance standards or negative societal, individual, and business consequences will be the result.

Traditionally, an automotive manufacturer creates a testing program for a new vehicle by looking to regulations and their experience—drawing upon a variety of scripted scenarios that have historically been useful predictors of vehicle safety and coupling these with reliability and performance testing to assess the overall safety of the product. With an automated vehicle, these scripted scenarios do not exist, and the idea that a vehicle design has a set of performance and safety characteristics that can be assessed once while the vehicle is “new” and thereafter remain constant throughout its design life is flawed. The recent surge in the development of automated vehicle technology is taking us toward automated driving systems (ADSs) that are not only designed by exposing the algorithms that control system behavior to curated collections of training data and having the algorithms learn from these data—but to ADSs that continue to learn throughout the entire product lifecycle and across entire deployed fleets. This leads to the open question of whether and how frequently to re-test the automated vehicle as its ADS is incrementally modified: At what point do the original test results no longer apply?

It is tempting to think that a vehicle under the control of a continuously learning ADS that successfully navigates a certain number of miles travelled is on the right path to demonstrating a “safe enough” level of performance. But this metric, while easy to calculate, can be a weak predictor of future performance. The ADS in an automated car is entrusted with making the correct decisions to navigate a vehicle from point A to point B; however, it is the quality, quantity, and type of decisions made in this process that reflect ADS performance. Instead of a digital metric indicating success or failure while navigating the user-selected (or algorithm-selected?) route, a more appropriate approach may be to borrow an idea from risk analysis and look at the exposure a vehicle experiences while travelling from A to B, as well as the margin available to the system while navigating that risk. Instead of vehicle miles travelled, consider the following:

- What kind of interactions/decisions were experienced/made? Were there any “edge” cases experienced, or did the ADS only experience “conventional” scenarios?
- How many interactions/decisions were experienced/made?
- With what margin or opportunity for future action was each decision made?

By looking at each of these three questions, it is possible to gain insight into the coverage of the operational domains that the testing/training covers as well as the robustness of the performance estimate. When it comes to safety, consumers are likely to trust an automated vehicle when it performs significantly better than their own driving abilities. It is not enough for a vehicle to consistently turn right or left and stop at traffic signals when needed. Can the vehicle turn left onto a street that is hosting a parade and adjust accordingly? Can it adapt to a malfunctioning stoplight or follow a police officer’s instructions that are contrary to what the light is indicating? Manufacturers of automated vehicles must demonstrate that their products can mitigate safety risk across a myriad of real-world interactions. Failure to do so can jeopardize consumer trust, limit commercial viability, and impact human lives.

Whereas other industries—or even the conventional transportation industry—may look to well-defined regulatory standards for guidance, the automated vehicle industry is immersed in a rapidly evolving, piecemeal regulatory framework. Automated vehicle regulations currently vary from state to state with limited consistency across locations and only a very general federal strategy for harmonization. As a result, innovators must take the first step in self-certifying that their products are safe enough to be on the road. Manufacturers must be able to say, “I know where the bar is regarding safety, and here is where I am with respect to that bar.” This requires a strong understanding of the different regulatory environments within the United States and prospective global markets.

Manufacturers of automated vehicles often partner with third parties to help them navigate the above complexities. Exponent offers a fully integrated team of engineers, human factors specialists, and regulatory experts that can help manufacturers answer the question of “How safe is safe enough?” With over fifty years of safety experience, start-ups and traditional vehicle manufacturers alike can find a partner in Exponent for their automated vehicle needs.

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The development and deployment of automated vehicles has the potential to transform mobility and the transportation system as we know it. Traditional vehicle manufacturers and component suppliers and technology companies alike, including start-ups, are racing to develop and deploy automated vehicles. This progress comes with a critical challenge: the speed of innovation has outpaced the ability of regulators to update safety standards and has pushed industry to explore best practices for automated vehicles. Innovators who plan to bring automated vehicles to market must navigate the fluid and complex regulatory landscape, and prepare a comprehensive, often anticipatory, regulatory strategy as part of the product launch. Failure to do so could restrict wide-scale consumer access and ultimately limit commercial viability.

The regulatory landscape for the automated vehicle industry is still in its infancy. Automated vehicle regulations currently vary from state to state and federal regulations and policy are in flux. Prior to the development of automated vehicles, the regulating role of the U.S. federal government vs. state governments was clearly defined. The National Highway Traffic Safety Administration (NHTSA) developed Federal Motor Vehicle Safety Standards (FMVSS) to which manufacturers self-certified their vehicles, and the states registered vehicles, licensed drivers, and conducted driver testing. As automated driving systems take on more of the driving task, the boundaries between these roles will continue to blur. The deployment of automated vehicles will require significant collaboration between federal and state agencies and the private sector.

The U.S. Department of Transportation (DOT) and NHTSA have recently issued guidance documents to reaffirm the federal government’s authority in this area. In an upcoming rulemaking, NHTSA plans to update the FMVSS standards to better accommodate the certification of automated vehicles. This update may explore revamping the approach to developing safety standards but will still likely follow the self-certification path. Given the rate and diversity of automated vehicle technology development, the safety standards will need to continue to be performance based (i.e., technology neutral) and be flexible to accommodate new automated vehicle technology developments and capabilities.

Manufacturers and developers of automated driving systems will need to account for several considerations when building a regulatory strategy. First, manufacturers and developers are not overly constrained by current FMVSS standards when it comes to developing vehicles with lower levels of automation (e.g., Society of Automotive Engineers (SAE) Levels 1 and 2). Challenges to certification will likely arise for higher levels of automation (e.g., SAE Levels 4 and 5) that depart from conventional vehicle designs (e.g., alternative cabin layouts). In these instances, manufacturers and developers can request exemptions from current FMVSS standards. These exemptions can enable manufacturers and developers to get a vehicle into the market, but they are limited to small-scale deployments of up to 2,500 vehicles, and approval is on a case-by-case basis. NHTSA is currently evaluating ways to streamline the exemption process and will likely be seeking public comment on an updated process.
In addition, manufacturers and developers may consider collaborating with others in the industry to develop best practices and/or voluntary standards. In the U.S. DOT’s recently released “Preparing for the Future of Transportation: Automated Vehicles 3.0 (AV 3.0)” guidance document, the U.S. DOT states that it is “identifying and supporting the development of automation-related voluntary standards developed through organizations and associations, which can be an effective non-regulatory means to advance the integration of automation technologies.” Manufacturers and developers who collaborate with one another can take advantage of this opportunity by sharing best practices and bringing forward ideas for how voluntary and FMVSS standards can be evolved.

Finally, manufacturers and developers can explore bringing both consumers and regulators into the dialogue of “How safe is safe enough?” Should an automated vehicle only be as safe as a human driver, or should the bar be set considerably higher? Should industry measure vehicle safety at the individual level or the societal level? 37,113 Americans lost their lives on the road in 2017.1 Is that the number to improve upon, or is it something else? Related to this is the notion of consumer expectation - consumers should not assume that automated vehicles will successfully mitigate 100% of accidents. Complete reduction of all road-related fatalities could theoretically be achieved in the future, but due to complex interactions between automated vehicles and human-driven vehicles, pedestrians, and other road users in addition to varying road conditions and unforeseen phenomena, getting to this future will not be achieved overnight. It’s important that the automated vehicle industry continues the dialogue with both consumers and regulators alike to help set appropriate safety expectations.

Manufacturers and developers of automated driving systems can benefit from collaborating with third parties to build and execute effective regulatory strategies. Exponent offers a fully integrated team of engineers, human factors specialists, and regulatory experts that can support the process from start to finish. Exponent’s diverse experience with the U.S. DOT, NHTSA and other federal and state agencies can help manufacturers and developers secure and prepare for discussions with regulators. Exponent can also facilitate discussion across industry collaborators to help move the regulatory framework forward.

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Human factors analysis in the automated vehicle industry has evolved as quickly as the industry itself. Five years ago, much of the human factors focus was on the impact that advanced driver-assistance systems (ADAS) (e.g., adaptive cruise control, collision warning and mitigation systems, lane keeping, etc.) would have on drivers. Our own studies showed that driver behavior changed in the presence of these technologies (Moorman et al. 2017), with drivers spending more time looking inside the vehicle when certain ADAS technologies were active (Crump et al. 2017). As vehicle automation has progressed past ADAS technologies, and as fully automated vehicles are entering the roadways, the focus of human factors efforts has similarly expanded to include design and safety considerations at these higher levels of automation and the broader interactions of the technology with drivers and the transportation infrastructure. Human factors scientists are poised to support automated vehicle manufacturers as they make decisions about driver performance and training, vehicle interaction with infrastructure and pedestrians, and how safe is “safe enough.”

One of the primary areas where human factors can best be leveraged is in assessing the changing role of the driver, who will have very different responsibilities in an SAE Level 2 vehicle than in a Level 4 or 5 (Click here for SAE Automation Level Definitions). In a highly, but not fully, automated vehicle, what should/could the operator in the driver’s seat be doing? What are the capabilities and limitations of human performance that will affect that person’s ability to interact with or take over from the automation as needed? A human factors understanding is critical to answering both of these questions, and the March 2018 fatality involving a self-driving ride-share vehicle illustrates the importance of answering them correctly.

Optimizing a strategy to appropriately inform the public of automated vehicle capabilities as well as to educate users on how to interact with the automation is another area where human factors has an important role. Many investigations of incidents involving highly automated and SAE Level 2 vehicles have shown confusion between the expectations of the driver and the actual capabilities of the technology. It is certainly dangerous when people indicate “I thought the car was going to do X, and it did Y instead.” Confusion with new vehicle technologies is not a new problem, and recent data support the idea that the public does not have a clear picture of what automated vehicle technologies can and cannot do (Hoyos et al. 2018). Education also plays a role in the interaction of pedestrians and vehicles. Pedestrians often rely on eye contact with drivers of conventional vehicles to ensure they are safe to cross the street. How might a pedestrian receive this acknowledgment from an automated vehicle? Human factors evaluation can help manufacturers understand how best to take advantage of learned behavior and implant some of the necessary human tendencies for safe driving into highly automated vehicles.

Finally, human factors assessments and analysis can help automated vehicle manufacturers answer the critical question of “How safe is safe enough?” This question, roughly translated to “what level of risk or safety factor
The Role of Human Factors in the Development of Automated Vehicles

is acceptable to the public” or “what is the public’s risk tolerance”, is not a new one. In fact, it is a question that goes right to the roots of this company: one of our founders, Alan Tetelman, co-authored a white paper in 1977 titled “How Safe is Safe Enough?” discussing exactly these issues in the context of automobiles and general industrial products. In the automated vehicle space, manufacturers have regularly touted headlines about the number of miles driven or the rate of accidents per million miles driven and have held that out as a measure of safety. While miles driven and accident rates are important data points, from a human factors perspective, we can also consider public perception and the risk tolerance of the population that will interact in any way with vehicle automation. This is in line with one of Dr. Tetelman’s main points: the context of use of a product is not as straightforward as looking at one metric. To that effect, experts are increasingly asking whether a more sufficient denominator for vehicle safety should be incidents per mile driven, incidents per difficult scenario encountered, or some more complex melding of various metrics to paint a comprehensive picture of safety. Automated vehicle manufacturers can leverage human factors insight to evaluate how issues that are traditionally problematic for human drivers might translate to an automated vehicle. Engineers can then pair boundary case scenarios along with closed-course track testing, simulator data, computer modeling, and Monte Carlo simulations to determine how a vehicle will respond in each situation and whether it is ultimately safe enough for market deployment.

Over the next several years, despite continued advances in, and pushes towards, higher levels of vehicle automation, as long as there are still people interacting with a complicated system, the ability of human factors scientists to inform design and safety decisions will only grow as manufacturers’ ability to collect, store, and use relevant data sets continues to improve. For example, today’s manufacturers can leverage mobile eye tracking and perceptual data to evaluate alternative cabin configurations and help minimize the risk of vestibular disturbance for riders. Manufacturers can also leverage over-the-air updates and data tracking to investigate the cause of adverse incidents involving automated vehicles and help understand the behavior of the driver. Moving forward, the industry will see continued advancements in the ease of obtaining this type of actionable data from both people and vehicles. Manufacturers can expect to use these data to inform important research and design decisions that optimize the comfort, safety, and overall consumer acceptance of automated vehicles. Furthermore, if vehicles of the future are going to be less focused on driving performance and more on the ride experience, then leveraging human factors and user experience expertise to assess the quality, comfort, enjoyment, and overall usability of the vehicle will be an essential part of the product lifecycle.

While automated vehicle manufacturers often employ in-house human factors teams, many also turn to independent third parties for enhanced human factors support. What sets Exponent apart is our ability to offer a multidisciplinary team of Ph.D.-level engineers, scientists, and human factors experts along with our newly minted Phoenix User Research Center (PURC), attached to our automotive testing facilities at the Test and Engineering Center to quickly and seamlessly integrate with in-house teams to address a client’s human factors needs across the entire automated vehicle lifecycle.

References


Modern Event Data Recorders and How They Impact Accident Reconstruction

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WHAT IS AN EDR?
WHAT DO THE MODULES DO?
How Does An EDR Work?

• Wake up algorithm (Algorithm Enable)
  – Manufacturer and vehicle dependent
    • Between 1 and 2 G’s
    • 5 mph Delta-V longitudinal or lateral

• Where is it located?
WHAT DATA IS COLLECTED?

Retrieves and interprets what the manufacturer authorizes
Pre-Crash Data

- Vehicle Speed Indicated
- Brake On/Off
- Accelerator Pedal %
- Engine RPM
- Steering Angle
- Engine Throttle %
- ABS Activity
- Traction Control
- Air Temperature
- Stability Control Metrics
- Transmission Gear
- Cruise Control
- Wheel Speed
- Yaw Rate
**CRASH DATA**

- Longitudinal Delta-V
- Lateral Delta-V
- Acceleration
- Roll Angle
- Seatbelt Status
- Remote Sensors
- Time
  - Delta-V
  - Pretensioner
  - Bag Deployment
How Is EDR Data Obtained?

Data Link Connector (DLC)

Direct to Module - Vehicle

Direct to Module - Bench
How much data is collected?

- It depends on the manufacturer and model year

- Crash Data
  - 0 to 80 milliseconds before crash
  - 0 to 300 milliseconds after crash
  - 1 to 10 millisecond intervals

- Pre-Crash Data
  - 5 seconds before crash
  - 0.1 to 1 second intervals

- PCM Data
  - 10 to 20 seconds before crash
  - 2.5 to 5 seconds after crash
  - 0.2 second intervals

- Stability Control Data
  - 0 to 5 seconds
  - 0.1 to 0.5 second intervals

NHTSA Crash Investigation Sampling System (CISS)
Is The Data From The Crash?

- Downloaded = Yes, must analyze to determine if crash related

- Crash location, date, time and VIN were deemed non-essential by NHTSA in 2006

- Insufficient duration

- Power loss

- Maximum vehicle performance may trigger event
HOW IS THE DATA PRESERVED?

• What stays?
  – Deployment events
  – Most recent events
  – Storage for multiple events (example)
    • 4 frontal
    • 4 side
    • 6 pre-crash

• What gets overwritten?
  – Non-Deployment events

• How long does the data last?
  – Non-Deployment may be cleared after 250 ignition cycles
CAN THE DATA BE LOST OR ALTERED?

• Data Loss
  – Key cycles to overwrite non-deployment events
  – Fire damage (chip can be tested)
  – Physically lose the module

• Reprogramming
  – Requires physical access inside the module
  – Not going to be done on scene
  – Not easy
HOW DO WE INTERPRET THE DATA?

• Vehicle Speed
  – How is it measured?
  – Change in tire outer diameter with no reprogramming
  – Boundary conditions

• Data Clipping

• Data Resolution
  – Sensor limitations

• Sensor Positions

NHTSA Crash Investigation Sampling System (CISS)
HOW ACCURATE IS THE DATA? (PER NHTSA 49 CFR PART 563)

- Acceleration, +/-10%
- Delta-V, +/-10%
- Speed, +/-1 km/h
- Steering, +/-5%
- Deployment Time, +/-2 milliseconds
Early Generation CDR Report vs. More Recent CDR Report

NHTSA Crash Investigation Sampling System (CISS)

Report = 6 Pages

Report = 34 Pages

NHTSA Crash Investigation Sampling System (CISS)
EDR Usage In Both Civil And Criminal Cases?

• How are EDRs used in both?

• What are the implications for in house engineers of manufacturers asked to provide testimony in criminal cases regarding EDR data?
In What Kind Of Auto PL Litigation Can EDRs Be Used?

• Unintended acceleration

• Airbag and restraints defect claims

• Handling and stability

• Virtually any case involving an accident reconstruction

• Driver Assist Technology (DAT)
What Kind Of Litigation Does EDR Invite?

• Spoliation issues?

• Privacy violations?
WHAT EVIDENTIAL ISSUES ARE ASSOCIATED WITH EDR USAGE AT TRIAL?

• Chain of custody?

• Reliability of data?

• Data “interpretation”?

• Can data be manipulated?

• Garbage in, garbage out?
HELPFUL LINKS

• Federal Regulations re: EDRs (49 CFR 563)
  – https://www.law.cornell.edu/cfr/text/49/part-563

• NHTSA Event Data Recorder Web Site

• NHTSA Withdrawal of Proposed Rule Pertaining to EDRs

• IIHS “Q and A” regarding EDR
  – https://www.iihs.org/iihs/topics/t/airbags/qanda#event-data-recorders

• Consumer Reports article on EDRs
INTERESTING VIDEOS RELATED TO EDR

• Fox News clip when NHTSA proposed mandatory EDR rule came out in 2012
  – https://www.youtube.com/watch?v=UsiTy6kEFQw

• Compilation of UA accidents
  – https://www.youtube.com/watch?v=cOWdWHSgl-4

• Taiwanese cop prevents “fake” pedestrian claim because of EDR
  – https://www.youtube.com/watch?v=AOZFjcdRCe8
QUESTIONS?
INTRODUCTION:

The performance of seatbacks in rear impacts has been a subject of litigation for many years, often involving large verdicts. Over the years, there appears to be a trend for seats, on average, to become stronger. Specifically, has this trend affected seatback litigation and if so how? Generally, what are the primary plaintiff and defense positions in this type of litigation?

PLAINTIFFS POSITIONS

Every year thousands of deaths and serious injuries occur in rear-end crashes. As a result of the significant number of fatalities and injuries, protecting occupants in rear impact collisions is an important motor vehicle safety issue. The role of the front seat in rear impact safety has been discussed at length in the engineering literature and seat back strength has remained a subject of automotive defect litigation over the last 35 years.

The dynamics of a rear end crash and the occupant kinematics associated with seat back cases are well understood. When a vehicle is hit from behind the vehicle struck in the rear is accelerated forward. While, the occupants inside the struck vehicle based on their own inertia, tend to stay in their position prior to the collision force acting on them. As the floorpan and hence the seats are accelerated forward, the seatbacks interact with the occupant and the occupant loads the seatback.

The greater the severity of the crash and the heavier the occupant’s torso, the greater the load on the seatback. In more severe crashes, the loads imposed on the seat back can rotate or bend the seat back backwards. When the seatback has rotated beyond 45 degrees from vertical, the ability of the seatback to contain the occupant degrades and the occupant may ramp or slide up the seatback resulting in rearward excursion off of the seat.

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2 See *DAVID C. VIANO, ROLE OF THE SEAT IN REAR CRASH SAFETY* (2002); *See also* Bibliography: Rear Impact, Seatback and Head Restraint References, attached as Appendix 1.
Automotive manufacturers, experts and counsel for both manufacturers and injured consumers agree that the seat plays an important role in occupant protection in rear crashes. However, there is an on-going debate regarding how the seatback should perform in a rear impact crash.

The view generally adopted by most manufacturers is that the front seat must be designed to absorb energy by yielding in a severe rear impact crash. Proponents of this view argue that a yielding seatback increases occupant ridedown and enhances occupant protection.

The other view, often adopted by safety advocates and counsel for injured consumers argues that the seatback should be strong and remain relatively upright throughout a severe rear end crash to reduce the incidence of front seat occupants impacting rear occupants, or ramping up into the rear interior or being ejected out the rear window.

This paper is written for lawyers and others interested in seat back litigation. Its purpose is to identify the battle lines from the perspective of advocates, to compare and contrast the positions of both sides and to address the trend towards increasing rigidity of modern automotive seat design. The statements and positions in this paper are not intended to reflect the views or position of any manufacturer, client, or expert retained by the authors.

**Plaintiffs’ Position:**

The arguments advanced by advocates for injured consumers in seat back litigation have been consistent for the last three decades. Consider the following excerpts quoted directly from a press release by an organization that was known as the Institute for Injury Reduction:

> Each year some 1,200 people die in rear-end car accidents, and many thousands are terribly injured. A large number of these deaths and injuries - probably the great majority - are caused by the partial or total failure of the restraint systems that should be protecting car occupants in rear-end impacts.
To most of us, the term "restraint systems" means seat belts and air bags. Most motorists know that seat belts and air bags, when properly designed, are able to provide protection in front-end crashes at and even above speeds in the 30-40 mph range. However, few of us know what kind of restraint protection should be expected and provided in rear-end crashes.

That is because most car companies and the National Highway Traffic Safety Administration, which talk a great deal about "buckling up for safety," have remained silent about rear-end crash protection. Perhaps they are ashamed to talk about the subject. Given their outrageous neglect of occupant protection in rear-end accidents, they should be.

In a front-end crash, when the vehicle's forward movement is abruptly stopped by a collision, seat belts keep the occupants from hurtling forward. Air bags do the same thing. The objective is to maintain the occupant in an upright position and to prevent her or his body from bashing into hard surfaces, other occupants inside the car or from being hurted out of the car.

When a car is hit from the rear, the forces move in the opposite direction. The car is abruptly propelled forward, and occupants are thrown backwards. The objective of a restraint system is just the same as in a frontal crash, but in the opposite direction. It is to maintain the occupant in an upright position and to prevent his or her body from striking hard surfaces or other people in the car, such as rear seat passengers, and to prevent the occupant from being ejected out the rear windows or doors.4

In current seatback failure cases, the position of the Plaintiffs remains largely unchanged from what it was 30 years ago. The Plaintiff is likely to claim:
- the seatback failed at a level far below human tolerance
- the seatback failed and allowed the occupant to ramp out of the seat
  - the ramped occupant is then injured from rear seat contact
  - the ramped occupant then injures a rear seat occupant (typically a child)
  - a ramped occupant then is out of position for a subsequent frontal and gets injured from interaction with the seat belt
  - a ramped occupant gets over or around the seat back and gets an extension spinal injury

4 Statement of Benjamin Kelley, Institute for Injury Reduction, Seat Collapse in Rear Impacts (May 14, 1993).
The Plaintiff’s position is bolstered when a broken component or part is linked to one of the issues identified above.

Finally, the Plaintiff will demonstrate the profound insufficiency of FMVSS 207 to the extent it is part of the auto manufacturer’s mantra that the vehicle “met all Federal Motor Vehicle Safety Standards.”

In many seatback failure cases, the most compelling evidence for the Plaintiff is the collapsed seat and/or any broken components. Showing the collapsed seatback, showing how the stock seat yields/collapses in rear impact testing, comparing the stock seat’s performance to a strong seat and providing a few other similar incidents (OSIs) are the basic foundation of a Plaintiff’s seatback failure case. Much of the other proof often introduced by the Plaintiff is offered to undermine the stock defenses that manufacturers have asserted in seatback failure cases.

DEFENSE POSITIONS

Nothing in this world is perfect, and no seat design can prevent all injuries in all accidents. Manufacturers have an obligation to design a seat that is reasonably safe in the most common real world accidents—not the outliner accidents.

As applied to seat back strength, how strong is too strong? Seat backs by design yield rearward in rear end impact, absorbing energy of crash that would otherwise be inflicted upon occupant. The extensive testing and crash evidence developed over the past decades demonstrates that when real world factors are contemplated (i.e. the most common types of crashes, out of position occupants, an aging population), a yielding seat provides for greater occupant protection than a stiffer, non-yielding seat.

This is not to say that a stiffer seat is inherently more dangerous—it can have reasonable applications. But when manufacturers are designing seats to meet their obligations, the means by which they can reduce the risk of severe injury for occupants is the yielding seat.

Defense Analysis Supporting the Use of Yielding Seats Over Stiffer Seats:

- Testing and literature support the conclusion that that yielding seats should be used in modern vehicles rather than stiffer, non-yielding seats. The reasons for this conclusion are two-fold:
  - (1) Stiffer seats are more dangerous than yielding seats in other more common crashes, including low speed rear end collisions; and
  - (2) Stiffer seats present increased risks of certain serious injuries in high speed rear end crashes which are mitigated or eliminated by use of yielding seats.

- Testing and modeling that conclude that stiffer seats are safer than yielding seats fail to account of important real-world factors, were improperly executed, and should not be relied up on to assess crash injury risks. David C. Viano & Chantal S. Parenteau, Stiff versus Yielding Seats: Analysis of Matched Rear Impact Tests, SAE International (2007).

- When out of position occupancy is accounted for, there is evidence to suggest that a stiffer seat increases the risk of severe injury to the occupant. David C. Viano & Chantal S. Parenteau, *Influence of Seating Position on Dummy Responses with ABTS Seats in Severe Rear Impacts*, SAE International (2009).

- There must be consideration of the lower neck in assessing the risk of injury in a rear impact. Looking at only the upper neck, head, and check provides only a partial view of the occupant response, and any conclusion derived therefrom is dubious.

- When developing predictive models, there must be an evaluation of both injury and non-injury collisions. Because obtaining such data is difficult, if not impossible, predictive models bases based on such data may not be reliable.
  - There is an obvious problem with relying on injuries at issue in litigation. No one litigates non-injury cases, and there may be little record where injuries are minor. The data pool from litigation is skewed.

- (1) *Stiffer Seats Are More Dangerous in Common Crashes*
  - Manufacturers cannot account for every possible variable that could exist with regard to rear end collisions when designing seats. There needs to be a prioritization of protecting occupants in the most common (i.e. foreseeable) rear end collisions while also accounting for occupant safety in extreme crash circumstances.
    - The most common (vast majority) rear end crashes are low to medium speed rear end collisions. Testing has shown that ATDs have lower biomechanical responses in yielding seats than in stiffer seats in low to medium speed rear sled testing (7-17 mph delta-V). David C. Viano et al., *Stiff versus Yielding Seats: Analysis of Matched Rear Impact Tests*, SAE International (2007).
  - Extensive testing was done by the Insurance Institute for Highway Safety which did rear sled tests with All-Belts-To-Seats (“ABTS”) and conventional seats, and the results clearly showed that there were significantly higher risks with the ABTS seat in low-speed rear crashes. David C. Viano et al., *Stiff versus Yielding Seats: Analysis of Matched Rear Impact Tests*, SAE International (2007).
    - The IIHS tests show that more rigid ABTS seats involve significantly higher neck tension, rearward shear force, and extension moments than matched conventional seats. Overall the ABTS seats applied more load on the head and spine, and had less control of neck kinematics with higher

- IIHS rear sled tests with Sebring ABTS and Hyundai Accent seats specifically show that the loads on the occupant were significantly greater in the Sebring ABTS seat. David C. Viano et al., *Stiff versus Yielding Seats: Analysis of Matched Rear Impact Tests*, SAE International (2007). The upper neck responses of the dummy were more than 2-times that in the Accent seat and this demonstrates a significantly greater risk of whiplash to disabling spinal injury and death in the stiff ABTS seat. David C. Viano et al., *Stiff versus Yielding Seats: Analysis of Matched Rear Impact Tests*, SAE International (2007). The risk would even be greater for those with spinal for those with degenerative spinal conditions such as stenosis or other disorders that limit tolerable neck extension and shear loading. David C. Viano et al., *Stiff versus Yielding Seats: Analysis of Matched Rear Impact Tests*, SAE International (2007).
The bottom line is that there are significantly higher risks for serious-to-fatal injury with stiffer seats in low speed crashes.

- In very-low speed crashes, older occupants as well as occupants with spine disease, deformation, or degeneration can suffer spinal cord injuries in stiffer seats that may not occur with normal adults.
    - This fact will become increasingly more important as populations age and as there are increasing numbers of older drivers on the road.
- Fairly recent studies have shown that there are significantly higher forces on an occupant’s neck in an ABTS seat compared to a conventional seat in the same model vehicle.
  - Although ABTS seats have reasonable applications, when it comes to the most common real world impacts (low speed crashes with less than 15 mph delta-V), conventional seats are superior in reducing the risk of whiplash and more severe injuries. David C. Viano & Chantal S. Parenteau, *BioRID Dummy Responses in Matched ABTS and Conventional Seat Tests on the IIHS Rear Sled*, Traffic Injury Prevention (2013).

(2) Stiffer Seats Increase the Risk of Serious Injuries in High Speed Crashes

- Summary of Safety Issues Related to FMVSS No. 207, Seating Systems, NHTSA (September 1992): if a seating system is too stiff, injuries could be increased in a rear impact collision because of the exacerbation of several problems, including:
  - occupant rebound off the seat back into the frontal components;
  - ramping of the occupant into the roof of the vehicle;
  - direct contact with the seat back; and
  - phasing problems between the neck/back body regions contacting the head restraint and the seat back.
- Recent studies have shown that modern seats (model year 2000 and older) provide lower biomechanical responses in 25 mph delta-V rear sled tests than older seats (pre-model year 2000) and seats with ABTS designs. David C. Viano et al., *Occupant Responses in Conventional and ABTS Seats in High-Speed Rear Sled Tests*, Taylor & Francis Group (2017).
  - This is consistent with an increase in the seat strength in yielding seats along with changes in design that permit improved pocketing of an occupant and increase the height of a headrest while decreasing its distance from the occupant’s head.
  - ABTS designs were created and used when stiffer seats were the go-to choice for vehicle manufacturers.
Peer reviewed literature and studies conclude that stiffer, upright seats increase the risks for older occupants with spinal degenerative changes because yielding of the seatback lowers forces on the neck. David C. Viano et al., *Occupant Responses in Conventional and ABTS Seats in High-Speed Rear Sled Tests*, Taylor & Francis Group (2017).

- This is especially true in lower speed accidents which account for 15% of all serious injuries in rear impacts and involves a unique risk in those with spinal degenerative changes. David C. Viano et al., *Occupant Responses in Conventional and ABTS Seats in High-Speed Rear Sled Tests*, Taylor & Francis Group (2017).

- Testing by Viano & Parenteau in 2011 demonstrates that the lower neck extension moment was 102% higher (range 38%-187%, p < 0.05) in the ABTS compared to conventional seats. Upper neck tension was 44% higher (range 24%-94%, p < 0.05) and the upper neck rearward shear force was 75% higher (range 17%-156%, p < 0.05). See Figure 78 below, Page 341 of BioRID Dummy Responses in Matched ABTS and Conventional Seat Tests on the IIHS Rear Sled.
Testing with a 95% male dummy showed that an ABTS seat supported the head, neck, and torso fairly well; however, when the dummy was out of place such that the forces of the testing caused the head and upper to wrap around the rigid seat back resulted in higher biomechanical responses. David C. Viano et al., *Influence of Seating Position on Dummy Responses with ABTS Seats in Severe Rear Impacts*, SAE International (2009).

- This means that occupants are at increased risk of injury when the strength of the seat exceeds the extension tolerance of the spine and the upper body, head, or neck is unsupported (as the result of an off-set crash or out of position occupants).

- Accordingly, even in specific high speed crashes, stiffer seats often would not prevent the injuries allegedly sustained as a result of a using a yielding seat design. Case specific evidence may include:
  - Evidence that the accident forces were so high that that the interaction between rear seat and front seat occupants was caused by or exacerbated by this forward excursion.
  - Evidence that rear seat occupants were out of position or improperly restrained (by the vehicle belts or child or booster seats), which caused or exacerbated the front and rear interactions.
  - Evidence including testing that the forces were so great that an alleged “safer alternative design” would not have done better.
  - Evidence that the forces were overwhelming, as “everyone”, front and rear seat occupants were so badly hurt that the injuries in the particular case were not due to a “yielding” seat.
In short, when designing a seat, manufacturers must consider (1) all foreseeable types of crashes, (2) all occupants (including age, weight, and concomitant physical characteristics), (3) the safety of unbelted occupants, and (4) the safety of out of position occupants. Thus, the defense of yielding seat cases requires the careful use of general evidence concerning seat design and testing and specific evidence of performance and causation in a particularly case. Further details, photographs, videos, and other exhibits will be presented and discussed during the presentation.
Powell J, Palacin R.

Passenger stability within moving railway vehicles: Limits on maximum longitudinal acceleration.

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Passenger Stability Within Moving Railway Vehicles: Limits on Maximum Longitudinal Acceleration

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Abstract
Increasing the acceleration and deceleration of trains within a railway network can improve the performance of the system. However, the risk of passengers losing their balance and falling is also increased. The purpose of this paper is therefore to examine the effect of longitudinal vehicle accelerations on passenger safety and comfort. The literature review brings together two separate disciplinary areas, considering the effects of acceleration on balance from a physiological/kinesiological perspective, as well as looking at the results of previous empirical studies on the levels of acceleration that railway passengers will tolerate. The paper also describes an experiment carried out on the Tyne and Wear Metro, which gathered data on typical acceleration levels to compare against the findings of the literature review. It was found that both the magnitude of the accelerations and their rate of change (jerk) are important. The results also suggest that there may be scope to improve the trade-off between journey times, energy consumption and passenger comfort by fine control of the acceleration/jerk profile. This is particularly relevant to urban rail systems, as they typically feature relatively high acceleration and deceleration. However, the findings for passenger comfort are equally applicable to conventional regional and intercity services.

Keywords
Passenger safety · Passenger comfort · Longitudinal acceleration · Braking · Jerk

1 Introduction

An increase in the level of acceleration and deceleration achieved by a train allows a reduction of journey time (and a potential increase in railway system capacity), or alternatively a reduction in energy use for a given journey time. However, higher levels of longitudinal acceleration can compromise passenger comfort, and ultimately safety too if they are sufficient to cause passengers to lose their balance.

This has been highlighted as a significant cause of injury for bus passengers [10], with research suggesting that ‘accelerations that are commonly encountered in practice appear to be impossible to endure without support [such as handgrips]’ [7]. Although bus accelerations are typically higher than trains, passengers in a railway vehicle are more likely to be standing unsupported, or moving around within the vehicle. In Great Britain, the Rail Safety and Standards Board estimate that around 15% of on-board harm in the railway network in the last 10 years (measured by fatalities and weighted injuries) can be attributed to ‘injuries attributable to sudden movements of the train due to lurching or braking’ [21].

The purpose of this paper is therefore to examine the effects on railway passengers of the longitudinal accelerations found in regular operation, and the relationship to comfort and safety.

2 Methodology and Paper Structure

The outline methodology of this paper consists of two parts. The literature review in Sect. 3 first examines the biological theory unpinning balance, and then reconciles this with the results of previous empirical studies into the limits of acceleration that passengers will tolerate.
Section 4 describes an experiment undertaken on the Tyne and Wear Metro to measure actual railway vehicle accelerations during regular operation, which are then compared against the findings from the literature, and some conclusions drawn in Sect. 5.

3 Passenger Balance and Stability

3.1 Physiology/Kinesiology

Balance in humans is an unconscious proprioceptive reaction, coordinated by the brain stem, supported by the cerebellum, visual cortex and basal ganglia. Information is obtained from the somatosensory system in the feet, the vestibular system in the inner ear and visual stimuli from the eyes [4]. The somatosensory system detects changes in pressure on the sole of the feet. When there is an imbalance between one foot and the other, it stimulates the muscles in the leg to contract so that the leg stiffens to oppose the increased pressure. The vestibular system consists of the semicircular canals and the otolith organs, and movement of fluid within each of these is detected by cells that stimulate the central nervous system. The semicircular canals provide a static response (effectively measuring position), and so help to stimulate corrective or predictive body movements such a stepping. The otolith organs provide a dynamic response and so control reflex reactions, such as flexing the body to change position. Finally, visual stimuli from the eyes provide an extra frame of reference to help determine position more accurately.

Following the above, three different strategies can be identified for retaining balance under the influence of an external acceleration. Where the acceleration is small, contracting the leg muscles and bending the ankle is sufficient to react against the external acceleration and keep the body balanced; this is known as ankle strategy. If the acceleration magnitude is greater, the body must change position to prevent falling, also bending at the hip. This is known as hip strategy, and requires a longer time for the muscles to actuate. Finally, the applied acceleration may be large enough that one or more steps must be taken to avoid falling; this is the stepping strategy.

Unconscious control of these strategies is a negative feedback system, therefore both the magnitude of the external acceleration and its rate of change (jerk) are important [31]. This implies that both strength and sensing/actuation times of the body’s muscles and nervous system must be considered when investigating the case of passengers balancing within a moving vehicle.

Where the jerk is very high, passengers will not have sufficient time to react, and their behaviour can be approximated by a static rigid body. This will topple when the line of action of the resultant force (due to external accelerations acting on it) lies outside of the base of support. This force will act through the body’s centre of gravity, and for an average human this is approximately located at 54% of their height, in line with the front of their knee/ankle joints in a normal standing posture [24, 30].

The minimum time for muscles to react against external forces is typically 0.12–0.13 s [2, 17], and for the body to make larger movements to retain balance takes around 1 s [25]. These figures may be considered to approximate the cases of the ankle and hip strategies respectively.

For a lower jerk level, the maximum tolerable acceleration is greater as the muscles have more time to actuate and resist the force. Where the jerk is very low, the strength of the individual will be the only important human factor, as the acceleration is changing slowly enough for the body to fully react and change posture as required.

Within a given population, there will be significant variation in the ability of individual passengers to balance under the influence of a given level of acceleration and jerk, in accordance with their physiology [4]. This variation means that it is difficult to set universal acceleration/jerk limits for passenger safety. It also means that, depending on their individual reactions to maintain balance, different passengers will have different perceptions of how uncomfortable a particular level of acceleration/jerk is.

3.2 Review of Previous Experimental Work

Empirical research into the levels of longitudinal acceleration that passengers will tolerate can be broadly classified into subjective and objective studies. A review was carried out by Hoberock [13] that included a mixture of both types, partly based on the work of Gebhard [9].

Subjective studies typically use questionnaires and interviews with study participants in order to establish how comfortable different acceleration profiles are for different people. A study by British Railways [16] was carried out to determine the effects on passengers of quasi-static lateral accelerations due to track curvature. For standing passengers, 0.1 g was given the approximate limit that could be attained without discomfort, and around 0.12 g was defined as uncomfortable. Values for seated subjects were somewhat higher, and it was also noted that lower levels of jerk increased the aforementioned acceleration limits. These values were found to have reasonable agreement with previous research in Britain [27] and by South African Railways [22]. The paper also demonstrated that passenger comfort on curves was generally a more limiting case than safety against derailment, and this formed the basis for British track design standards [6].
Hoberock also reported on similar experiments carried out by Japanese National Railways to assess passenger comfort during braking [18, 19], which also considered the effects of jerk. A later study [28] also included an evaluation of whether a given level of deceleration was acceptable to passengers, in addition to the assessments of comfort. It was noted that that the comfort ratings and the acceptability of different decelerations did not always correlate.

This research has been developed further by the Railway Technical Research Institute (RTRI) in Japan. Hiroaki [11] used questionnaires to examine the effect of high jerk values on the acceptability of different levels of acceleration. Curves for the acceptability of different levels of acceleration/jerk were produced, and an example for a group made up of regular commuters is illustrated in Fig. 1. Other curves were presented for occasional regional/intercity travellers, and the acceptability of a given acceleration/jerk level varied significantly depending on the type of passenger and journey being undertaken.

Overall, the variability in the methods of the subjective studies highlighted in this section means that they can only provide a general indication of what can be defined as acceptable or unacceptable levels, especially given the sensitivity of results to individuals’ opinions or interpretations. Nonetheless, these studies confirm that both jerk and acceleration influence passenger comfort and stability, and also that unsupported standing passengers facing the direction of the vehicle’s acceleration have the lowest tolerance.

Objective studies seek a quantifiable measure of people’s reactions to external accelerations, rather than relying on their perception and opinion, and two significant studies were detailed by Hoberock. Hirshfeld [12] reported on their perception and opinion, and two significant studies highlighted in this section means that they can only provide a general indication of what can be defined as acceptable or unacceptable levels, especially given the sensitivity of results to individuals’ opinions or interpretations. Nonetheless, these studies confirm that both jerk and acceleration influence passenger comfort and stability, and also that unsupported standing passengers facing the direction of the vehicle’s acceleration have the lowest tolerance.

Objective studies seek a quantifiable measure of people’s reactions to external accelerations, rather than relying on their perception and opinion, and two significant studies were detailed by Hoberock. Hirshfeld [12] reported on a series of experiments intended to determine the effects of longitudinal acceleration on the loss of balance of standing passengers, as part of a wider design programme for the standardised PCC streetcars in the USA. Participants in the study stood on a platform that moved with variable acceleration profiles, and the average value of acceleration at which they either took a step or grabbed a handrail was measured. The study confirmed that different levels of jerk (for the same acceleration) influence the retention of balance, and that unsupported forward-facing passengers were least tolerant, losing their balance at an average of 0.13 g. The combined average for all unsupported standees was 0.165 g, increasing to 0.23 g with an overhead strap for support and 0.27 g with a vertical grab rail.

The experiments carried out by Browning [3] had similar objectives and methodology, although as part of a programme looking at the design of moving pedestrian walkways. The results were categorised in terms of the observed movement of the participants by an expert panel and presented in terms of acceleration against rise time (where jerk equals acceleration divided by rise time). Curves were produced for the approximate limits for each of the observed movement categories, and these are illustrated in Fig. 2.

Based on both the subjective and objective studies, Hoberock’s principal conclusion was that it is difficult to set conclusive limits on acceleration and jerk, as passenger’s reactions strongly depend on the individual concerned. A range was nonetheless suggested for maximum permissible accelerations of 0.11–0.15 g as an outline guide, with jerk limited to 0.30 g/s.

A more recent review [8] proposed ‘large movement’ in Browning’s results to be approximately equivalent to Hirshfeld’s case of passengers either stepping or requiring external support. The review also included acceleration values at which seated passengers start to be dislodged from their seats, based on the results of Abernethy et al. [1]. A limit for transverse (forward- or backward-facing) seats was given as 2.45 m/s², well above the guidelines for standing passengers, but a lower limit of 1.4 m/s² was given for longitudinal (side-facing) seats.

RTRI have also carried out further experimental studies that combine subjective and objective approaches [15], investigating the jerk limits required for high deceleration levels to be acceptable to passengers. The two graphs in Fig. 3 illustrate the data points and fitted curves for acceptability (left) and the ability of passengers to retain their balance (right) with four jerk levels.

A different type of experiment was carried out by Kamper et al. [14], in which the postural stability of a small group of wheelchair users with tetraplegia or paraplegia was examined under the influence of quasi-static accelerations typically found in road vehicles. 95% of the participants were able to retain balance within the wheelchair at an acceleration of 0.126 g, and the average at which balance was lost was around 0.22 g. Balance retention was improved with a lower level of jerk.
Finally, Sari [23] considered the likelihood of passengers walking within railway vehicles falling under the influence of low frequency (0.5–2 Hz) lateral oscillations. Although not directly applicable to this paper, as the accelerations are transient and the passengers are already in motion, it nonetheless provides a useful point of reference for comparison. A range of accelerations between 0.1 and 2.0 m/s² were tested across the range of frequencies. As may be expected, balance was generally lost at a lower acceleration level than the results for standing or seated passengers highlighted in this paper. Likewise, it was reported that results also varied with frequency of the oscillations, effectively the rate of change of these accelerations.

3.3 Current Practice

Although guideline figures for the safe limits of longitudinal accelerations in railway vehicles are used when specifying rolling stock, the source of the values is often unclear and can vary significantly [5, 20, 29]. Table I provides some examples from main line and light rail vehicles in Great Britain, from data provided by vehicle manufacturers/operators.

Note that some values given are estimates and should be taken as representative rather than exact. The values are the absolute maxima, and the average values achieved during braking in regular service are typically rather lower—this is illustrated further in Sect. 4 for the Tyne and Wear Metro. The operators also noted that emergency track brakes (indicated by an asterisk * in Table 1) are used as a last resort, as experience has shown their use carries a high risk of passenger injury.

3.4 Findings

Passenger safety becomes an issue when the acceleration/jerk levels require passengers to take one or more steps to retain balance (the stepping strategy), as this introduces the risk of falling. Passenger comfort is a more subjective measure, but may be considered quantitatively as how
close a particular individual is to their own limit of balance. This correlation is not exact however.

The RTRI studies [11, 15] provide an overview of the acceptability of acceleration/jerk for a population, while the results from Browning [3] provide some insight into the effects on individuals. There is a distinct change in the response at a rise time of around 1 s, and it is proposed that this is due to the unconscious change from ankle strategy to hip strategy. For low values of jerk, or high values that correspond to a rise time of less than 0.12 s, the acceleration value becomes independent of the jerk. It is instead related only to the strength of individual passengers for low values of jerk, or their posture and location of their centre of gravity for high values.

There is considerable variation between the perceptions and stability of different individuals however. This can be observed in the scatter in the results of Fig. 3, and more generally by the differences in the findings of the studies reviewed. It is therefore not possible to set precise passenger limits for longitudinal acceleration for passenger safety. Nonetheless, it can be concluded that previously suggested guidelines of 1.1 to 1.5 m/s² are reasonable—this is reflected in the current railway practice illustrated by Table 1. The values also suggest that passengers are likely to be more tolerant of discomfort on short metro-type service by comparison with intercity/regional services.

<table>
<thead>
<tr>
<th>Vehicle</th>
<th>Maximum acceleration (m/s²)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Traction</td>
</tr>
<tr>
<td>Class 390 Pendolino (intercity EMU)</td>
<td>0.37</td>
</tr>
<tr>
<td>Class 156 Super Sprinter (regional DMU)</td>
<td>0.75</td>
</tr>
<tr>
<td>Class 323 (suburban EMU)</td>
<td>0.99</td>
</tr>
<tr>
<td>London Underground 1992 tube stock</td>
<td>1.3</td>
</tr>
<tr>
<td>Tyne and Wear Metrocar</td>
<td>1.0</td>
</tr>
<tr>
<td>Manchester tram (Ansaldo T-68)</td>
<td>1.3</td>
</tr>
<tr>
<td>Sheffield Supertram (Siemens-Duweg)</td>
<td>1.3</td>
</tr>
<tr>
<td>Croydon tram (Bombardier FLEXITY)</td>
<td>1.2</td>
</tr>
<tr>
<td>Nottingham tram (Bombardier)</td>
<td>1.2</td>
</tr>
</tbody>
</table>

The Tyne and Wear Metrocars are towards the upper end of the range of accelerations given in Table 1. The Metro infrastructure consists of old railway alignments converted to Metro use, a new tunnel through Newcastle upon Tyne city centre (built specifically for the Metro), and sections of track shared with current heavy rail services. It therefore also features a range of curvature and gradient values typical of railway systems, including the highest values likely to be found on railway infrastructure. Although on-street tram systems can feature more extreme accelerations, passenger behaviour in trams is likely to be more similar to buses than railway vehicles. The Metro therefore provides a good case study for the purposes of this paper.

4.2 Experimental Methods

An afternoon peak time diagram was chosen for acceleration measurements, running empty from South Gosforth depot to Regent Centre, then in passenger service from Regent Centre to Pelaw and Pelaw to Monkseaton, before returning empty back to the depot.

The equipment consisted of three triaxial accelerometers with a range of ±18 g and a multi-channel data acquisition system with a sample rate of 128 Hz. This was set up within the depot in the B carriage of Metrocar 4007, on the double seat adjacent to the innermost door set (door 5). One accelerometer was glued to the overhead grab rail, one glued to the seat back, and one placed on a metal plate on the seat, sited so that passenger interference would be minimal. These are illustrated in Fig. 4. The accelerometers were calibrated by rotating through ±90° before final placement, effectively a 2 g inversion. The track in the depot where the equipment was installed was close to straight and level, minimising any offset in the readings (due to track geometry) during calibration.

During the test, a log was kept of arrival and departure times at each station, any other significant events (such as signal checks) and approximate passenger loadings. Notes
were also taken throughout the journey to qualitatively describe the comfort level at different locations.

4.3 Results

Figure 5 illustrates an example set of results for the accelerations measured in the longitudinal, lateral and vertical directions during the tests. The profile illustrated here includes section of running on old main line railway alignments, the tunnel designed specifically for Metro trains and track shared with heavy rail services.

Given that passengers may stand facing in any direction within the vehicle, the resultant of the lateral and longitudinal acceleration was calculated for each measured point and filtered to remove high frequency vibration in order to give the maximum quasi-static acceleration in the horizontal plane. For a static body, a vertical acceleration changes the effective weight (but not mass) of the body, changing the point at which it will topple. This mechanism was assumed to also apply to the cases of ankle and hip strategy, and the resultant horizontal plane acceleration was modified accordingly. The corresponding jerk for each measured point was then obtained by dividing the change in quasi-static acceleration between adjacent points by the sample time.

The wide variation in assessments of passenger comfort between different studies has already been noted. Therefore, the acceleration/jerk pairs from the measured data were compared against the proposed curves in both Figs. 2 and 3. There were several locations where the measured acceleration/jerk pairs were highlighted as problematic by these methods, and these matched up well with the subjective observations on comfort recorded during the test. These locations were therefore analysed to look for patterns that might suggest how to improve passenger comfort.

4.4 Discussion

The majority of the cases where acceleration/jerk levels were outside the proposed limits were found to be when the train was stopping at a station, as it came to a standstill. By definition, the jerk approaches infinity at the moment speed equals zero when stopping, and therefore a lower acceleration magnitude is necessary. It is common driving practice to reduce the braking effort demanded as the train comes to
Fig. 5 Sample acceleration profile
a standstill to address this. Sone and Ashiya [26] provide an example of how pure electric braking (rheostatic or regenerative, using three phase AC traction motors) can achieve superior passenger comfort in this respect.

The worst case measured was when traction power was cut off at a relatively low speed while accelerating, in order to meet a speed restriction. The Tyne and Wear Metrocars have camshaft resistance control of DC traction motors, and although the first couple of camshaft steps limit the jerk when power is first applied, power is cut off abruptly by contactors when the combined power/brake controller is returned to neutral. As in the previous case, this results in a large jerk. However, the camshaft control also means that driver has less control over the level of tractive effort by comparison with braking, and for relatively low speeds the train’s acceleration will be close to its maximum level. This situation occurs far less often than station stops, but passengers are less likely to be able to predict and anticipate it, and the subjective observations on the Metro suggest it is also the most likely reason for passengers making large movements to correct their balance.

There were also a few cases where the train changed immediately from accelerating to braking, or where the driver was moving the controller frequently between discrete brake notches while decelerating. This can be observed in Fig. 5, where the negative longitudinal accelerations during braking show significantly more variation than the positive longitudinal accelerations. The locations at the cases highlighted generally also coincided with specific infrastructure features that influence the acceleration and jerk levels, such as sharp curves and their associated transitions, which increased the lateral acceleration and jerk. Automatic Train Operation (ATO) can mitigate this variation and provides a more consistent control of braking effort, improving passenger comfort.

Overall, resultant quasi-static accelerations were routinely observed approaching 1.4 m/s². The majority of these cases were found to be acceptable by both the qualitative observations during the test and the quantitative data collected—the locations identified as problematic were not necessarily the locations with a high acceleration level, but in all cases did involve a high value of jerk.

5 Conclusions

Passenger tolerance to longitudinal accelerations varies significantly between different individuals, according to their physiology and psychology. The acceptability of a given level of acceleration depends strongly on the rate of change of the acceleration (jerk).

Acceleration and jerk limits are typically given as single figures in rolling stock specifications. However, this paper suggests that there may be scope to improve the trade-off between journey times, energy consumption and passenger comfort by fine control of the acceleration/jerk profile. ATO and electric braking (using three phase AC traction motors) are likely to be a prerequisite for the level of control required however.

This research is particularly applicable to urban rail systems, as they typically operate vehicles at higher acceleration and deceleration levels than conventional regional or intercity passenger trains. However, passengers on regional or intercity services are likely to expect a higher level of comfort than urban rail passengers, and control of the jerk then becomes important in this respect.

Acknowledgments The authors would like to thank Dr Kazuma Nakai of RTRI for his assistance with the Japanese research and helpful suggestions for the paper, and Nexus for the opportunity to carry out experimental work on the Tyne and Wear Metro (the work described here was carried out when the Metro was managed as an integrated system, prior to train operations being split from infrastructure and contracted separately).

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References

18. Matsudaira T (1960) Dynamics of high speed rolling stock. Railway Technical Research Institute, Quarterly Reports, (Special Issue), pp 57–65
22. SAR (1948) Superelevations and maximum permissible speeds on curves. Research Circular No. 25.027, South African Railways
LESSONS LEARNED IN JURY SELECTION
MOCK JURIES
SHADOW JURIES
TRUMP JURORS
AND JURY CONSULTANTS

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LESSONS LEARNED IN JURY SELECTION
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AND JURY CONSULTANTS

By
Jeff Patterson and Luke Spencer

I. Introduction

We have all had our experiences with jury research, and we have all experienced push-back from our clients due to the cost of jury research. Some of us push back on jury research ourselves, due to our conceit that we know jurors as well as any psychologist. This resistance from client and trial lawyer sometimes obscures the value of jury research. If the amount in controversy is high enough, and if your client can tolerate the cost, some of it is extremely worthwhile. This paper explores the different types of jury research, mistakes made and lessons learned by the authors, and our experience in the following types of jury research:

1. Focus Groups
2. Mock Trials
3. Jury Selection
4. Shadow Juries

Finally, we will acknowledge a phenomenon some defense lawyers are struggling with: The Paradox of Trump Jurors.

II. Choosing the Right Vendor

We have had extensive experience with jury consultants both in the context of patent litigation in East Texas and years of pattern litigation. Because of the high exposure of both types of litigation, our clients have found jury research to be worth the money, but it is extremely important to find the right consultant. As with all service industries, some consultants provide more value than others.
Because of competition in the jury research market and cost constraints of our clients, jury researchers are cutting prices -- and cutting corners. For instance, with focus groups and mock trials, the consultants will simply orchestrate the logistics of the exercise. Some do not provide written reports at the end of the exercise, or if they do provide a written report, it is boiler plate and devoid of insight. The exercise may be good exercise for the lawyers, forcing us to prepare and practice our arguments, and may provide a marketing opportunity to perform for our clients, but a good jury consultant will provide more: they will provide a work product that provides analysis and insights that help you tailor your arguments, your style, and your strategy.

After several disappointing exercises, I retained Jason Bloom from Dallas to run a mock trial for pattern litigation plaguing our client. As of this writing, we have engaged in eight similar exercises. During our initial conversations about this challenging case, Jason asked me to come to his office to deliver my opening statement to him, one-on-one. I hate arguing to one person; it is artificial and threatens to kill my soul. But I did it, and half-way through the opening, he interrupted me, engaged in a brainstorming session, and then asked me to continue. At the end of the opening, he took my slide deck, rearranged it, eliminated portions I mistook as important, and significantly changed/improved my approach. This is what we should expect from jury consultants; not simply hiring jurors and orchestrating the exercise.

In contrast, another consultant completed the exercise and asked, “You don’t care about the report, do you?” She clearly didn’t want to provide that, although it was included in her proposal. The report not only summarizes the jury feedback, but provided insights and recommendations of the consultant. Her question suggested she wanted to minimize effort and that her report would not add value. She was correct. Her report was boilerplate and told us nothing we did not know.

III. Focus Groups

Focus groups tend to be one-day exercises where the consultant hires 16 to 24 jurors. One lawyer delivers a “clopening” for the Plaintiff; a second provides one for Defendant. The plaintiff gets a rebuttal. There is very little time for witness testimony, although it is possible to provide a 10 minute video clip of a few witnesses just for the benefit of testing first impressions. Time restraints also force the lawyers’ arguments to be concise and simplified. Focus groups are ideal for testing themes, arguments, and strategies. For instance:

- Do we want to argue contributory negligence, blame the plaintiff, blame the plaintiff’s lawyers?
• Do we want to blame the Federal Government for excessive regulation?
• Do we want to test the likeability of the advocates?
• Do we want to test the timeline or other graphics we want to use?

Focus groups are ideal for such discrete testing. They are not ideal for predicting the outcome of a future trial. As we all know, trials are complex and unpredictable, bullets are flying, the dynamics are changing, and the barrage of evidence and argument over ten days is entirely different than a presentation of that same information over a few hours. Still, the focus group can be valuable for these specific purposes.

The advantages of focus groups are that they are economical, with a cost ranging from $40,000 to $60,000. You can and should do the focus group in the trial venue or a simulated venue. Simulated venues can approximate the jurisdiction in terms of demographics, but they may miss the culture entirely. Closer is better.

The downside of focus groups, of course, is that time is limited and that it is necessary to dumb down the presentation. Another downside to any jury research is that the feedback from the jurors may not be pleasant for the trial attorney. Many trial lawyers have been burned by nasty comments from jurors delivered orally in deliberation or in writing. Lawyers have a tendency to be negative and critical, and may forget all compliments and remember only insults. Those may include, but not be limited to:

• Arrogant
• Cocky
• Showboaty
• Disorganized
• Snarky
• Mean
• Resting bitch face, and my favorite:
• “It’s not that he did anything wrong; he just sucks as a lawyer”

To engage in jury research, one needs thick skin.

IV. Mock Trials

Some clients are unhappy with focus groups because they do not simulate trials and are generally not predictive of the outcome. For those clients, we run mock trials that can last two or three days. We have openings, closings, rebuttal, and video excerpts of plaintiff and defense witnesses and between. Sometimes we summarize the meaning of the testimony presented at the beginning and end of the day.
A survey is taken of the jurors after each presentation -- lawyers and witnesses. That way we can harvest spontaneous impressions from the jurors throughout the 2 or 3 days. Some vendors provide the jurors with meters so they can register their impressions throughout the argument or testimony, and produce graphs that coordinate with the specific words. The latter is silly. Jurors come to decisions based on cumulative impressions.

After closings are done, the jurors will be split into smaller jury panels for separate deliberations. We typically use three groups of eight, but some projects involve up to eight groups. Closed circuit video will enable the clients, consultants, and lawyers to switch from room to room, observing deliberations. This generally leads trial lawyers to despair, the conclusion that there is no hope for humanity, that the jury system is a terrible idea, and that jurors generally cannot follow a line of logic. But it also provides a reality check and reminds us that we lawyers live in an insulated world surrounded by educated and somewhat rational people. The rest of the world is not like this. Hence, we must use other techniques to persuade.

After deliberations, the jury panels reconvene for a group session. The focus group moderator may ask them pointed questions, allow them to ask the lawyers questions, and challenge the leadership of strong jurors. This group session sometimes yields surprising results that do not arise in the deliberations. The dynamic of a large group of jurors speaking is different than that of a smaller panel.

As with focus groups, mock trials are useful for testing the strength of witness testimony (either live or through video depositions), testing the advocacy of the attorneys, testing the good and bad facts, and testing the trial themes.

The benefit of a mock trial over a focus group is that you have more time. You can test many more issues, many more people, and lots of graphics. The jurors have more time to absorb and digest the information thrown at them, and a mock trial is more predictive of the outcome than a focus group.

The downside of a mock trial is expense. These can run from $100,000 to $150,000 so trial lawyers better be prepared. It is very expensive if you botch the exercise.

Another downside to any jury research is that someone must argue for the other side. I often take this role if the client allows it. It is a good exercise that forces me to see the case from Plaintiff’s perspective. It often gives an advantage to the Plaintiff, which helps with deliberations (see more below). But more than one client has been dismayed
that I could argue so effectively for the other side. It feels disloyal to them, so it’s best to warn them in advance.

At the end of the day, the real objective of the focus group or mock trial is to eliminate some of the guesswork surrounding how a jury will feel and process certain issues in your case. Sometimes, these exercises serve as lightning rods that help create an effective strategy for the case. But you have to remember, these social science experiments can be garbage in-garbage out. Below are practical tips for successful mock trial:

*Practice tip #1: Location, Location, Location…*

One of the more disturbing discoveries from our recent experiences is the importance of the correct venue. Sometimes economics and convenience dictates that one venue may be sufficient to cover three different venues – if they are all “red state” venues, for instance. Or if they are all in urban areas. We have come to believe that our communities are losing their individuality since they are all exposed to the same national news, movies and music. This can be a major mistake. Even if your mock director believes he can replicate the political, educational, ethnic, racial, religious, and economic demographics of the actual venue, it is better to test in the venue or an adjacent venue. The lesson that we learned: if you are going to spend the money, don’t mock the wrong area.

It may be more convenient or cost-effective to mock a similarly situated suburb. However, we saw vastly different results on the same issues in cities only hours apart. For instance, Cedar Rapids, Iowa and Omaha, Nebraska have some similarities and are a mere four-hour car ride apart. Demographically the venues were similar, and yet the themes that resonated in each city were surprisingly different. We saw significant differences in Houston and Dallas as well, while presenting the same facts, lawyers, witnesses and documents.

Note that some judges have standing orders that jury research cannot be performed in the venue where the case is pending (e.g., Marshall, Texas). This is because mock jurors may discuss it with others, or appear on a venire panel and disclose it. In this case we have no choice but to choose an adjacent and similar venue.

*Practice tip #2: Winning isn’t everything*

Often times, our innate competitive nature as attorneys can lead to a critical misstep in mock trials -- namely, trying too hard to win. You are in a room with your
client watching, and it is only natural to want to impress your client, and give her the confidence to try the case. This is NOT a proper goal for mock trial. The real goal is to present a balanced case which will result in a robust deliberation. This is how we learn from the exercise. If most of the mock jurors agree with you, the discussion will be tepid and you learn nothing. Consequently, you should make sure you put on a strong case for both sides, and even put your thumb on the scale to balance the sides. Do NOT choose a weaker advocate for your adversary. Recruit one of your talented partners to perform if you think a younger associate may tilt the scale.

Additionally, trial lawyers are competitive and you will be tempted to ambush the other side with a new argument or new evidence, or play a prank, or cheat. Although highly entertaining, do NOT do that under any circumstance. Unlike a trial, this is a controlled test. Tossing a grenade in a mock trial can skew the results, destroy any benefit that the exercise could have, and waste all the money and time your client has spent.

In short, the lessons learned from a close loss may be far more valuable than a lopsided victory. Explain this upfront to your client and set the expectations. Tell them not to be shocked that you can advocate so well for the opposing side. If you are a client, don’t waste your money, make the most of the mock, and insist that your attorney’s advocate as hard as the opposing side will at the real trial.

Practice tip #3: Even a three-day mock is not predictive

Winning the mock does not mean that you will win the case. Like a focus group, many of the issues that arise during trial cannot be simulated at a mock trial. For instance, Plaintiff may change his/her theme or strategy. Your witness may lay an egg. Your judge may surprise you with her rulings. Your jury may not match the demographics of the venue. In a recent trial, our jurors included six women and two men; Four of the women were 73 or older. I had never seen that before. Finally, the drumbeat of the themes has a cumulative effect over ten days that cannot be replicated even in a three day mock. Telling a lie 30 times may cause some jurors to believe the lie, when they did not believe it the first three times.

V. Jury Selection

I have given CLEs on jury selection and have always prided myself on being talented at voir dire. I previously believed that by having a one-on-one conversation with each of the first 18 jurors, I can identify those who are like-minded or right-minded and strike others. In the course of pattern of litigation, we have used a consultant to
help us strike the jury in a few trials. I have been surprised and humbled at the value a
good consultant can provide to this process. Generally, the lawyer performing voir dire
is also thinking about opening and the first day or two of witnesses. He may not have
time to review the juror profiles or questionnaires thoroughly. While he is performing
during voir dire, he may miss things that are said, or subtle body language, in the venire
panel. The consultant can focus all her energies on those things and lessen some of the
burden for the trial lawyer.

During the strike process, I have been methodical about considering each juror,
making lists of pros and cons, and prioritizing whom to strike. In my last two trials, our
consultant immediately provided his list of strikes. I wanted to discuss them. He did
not. After reviewing my notes and doing my own analysis, I came to the same
conclusion that he did. When the jury was in the box, he predicted the foreperson. Two
weeks hence we learned he was right. I was surprised and humbled on each occasion.

The cost of this is that of another timekeeper for about two days plus expenses.
Probably $6-8,000.

VI. Shadow Jurors

In the last two trials we have used shadow jurors. Our consultant hires between
cfive and eight mock jurors to sit in the gallery and observe the trial from start to finish.
The jurors do not know which side is paying them. They have a handler who meets
with them each evening and harvests their information. The handler has no interaction
with the trial lawyers at any point. Each evening around 8 p.m., we get the handler’s
report in a concise summary. We see the shadow jurors’ impressions of all those who
spoke: lawyers and witnesses. We see their questions and confusion. After a few days,
handler will ask about the jurors’ leanings for plaintiff or defendant. The questions get
more specific toward the end of the trial where they might ask about negligence, gross
negligence, or fraud.

There are a number of advantages for a shadow jury. First, the jurors will ask
questions or make comments that tip off the trial lawyer and allow him to respond to
those questions or comments the next day in testimony or argument. Second, the jurors
give real time feedback on how the attorneys are perceived. For instance, the jurors
might say, “He objects too much”, “What is he hiding?”, or “He seems mean”, etc. This
allows us to alter our style on the spot. Third, I saw an unexpected benefit at the last trial
with a shadow jury. The shadow jury picked up on our judge frowning, shaking his
head, messaging his bias to the jury. I pointed this out to the judge on a break in
chambers, and his behavior immediately changed.
One last word of warning, shadow juries are often, but not always predictive of the outcome. We harvest their impressions without deliberation. We usually have a smaller number. It’s easier for shadow jurors to say “No” to a Plaintiff than it is for real jurors. Shadow jurors don’t have the same feel-good incentive to make Plaintiff rich, or to punish the Defendant. Seeing a shadow jury tracking for the defense each day can instill false confidence, but that is not necessarily a bad thing.

VII. Trump Jurors

Over the past year and half, our firm has interacted with jurors and/or mock jurors an average of once a month. As we do a significant amount of pattern litigation, the issues are often very similar and the venues are across the country. This work has given us a unique perspective on jury selection in the current political climate and a chance to re-evaluate our juror profiles.

The traditional axiom of defense lawyers is that white, conservative, Republican jurors are better for the defense. This has always been a simplistic and lazy and racist belief. With the recent trends in politics and growing anger towards “the system” and the status quo, we believe the axiom is not only simplistic, but it is dangerous.

What I call Trump jurors are white, conservative and Republican, but are not necessarily good for the defense. They tend to be cynical, angry, distrustful, and have a strong desire to exercise power and disrupt the status quo, which may include institutions and corporations.

Jury psychologists have long postulated that emotions control how facts are perceived. Jury consultant Jason Bloom often preaches that you cannot change emotion with facts. That is especially true today. How do Trump Jurors perceive facts? Do they believe there are no facts? Do they think the justice system is not a search for the truth or that it’s all rigged? Are they willing to disbelieve facts in order to assert their will? If the anger, distrust, and suspicion are directed at your company, it can be dangerous – punitive damages dangerous. Parsing through the prospective jurors’ predispositions in voir dire to determine if they reason by emotion as opposed to analysis becomes critical.

We have seen firsthand how emotions can control one’s view of facts. We have seen good facts become bad facts. For example, in a case where our client was accused of fraudulent misrepresentation and breach of warranty, one of the facts that we believed was the best fact is that we always paid our warranty claims – no questions asked. A person that commits fraud surely does not take care of his victim like this, right? Wrong. When the jurors had a negative predisposition to our client, the good fact became a bad
fact. These jurors concluded that this behavior is an admission of guilt. “Why would they pay so easily?” “What are they hiding?”

We have also seen bad facts become good facts. A bad fact: high employee turnover. Many employees involved in the program are no longer with the company. We were concerned they would assume they were terminated as a result of the fraud, and see that as an admission. They did conclude this, but thought it indicated that our company must have a lot of integrity in only keeping employees that comport with its values.

In short, we have learned that the defense lawyer’s axiom that republican jurors are favorable has been shaken in recent years and is now unreliable. Demographics are no longer as predictive; thus striking a jury is far more complex than some believed, and a jury consultant can be helpful in identifying the risky jurors in the pool.

And we have learned that a trial lawyer needs to be sure he/she is on the right side of emotion, so he/she does not end up on the wrong side of the verdict.

VIII. Conclusion

The landscape of jury research continues to evolve. Sometimes this is because jurors are evolving, as we see with Trump jurors or Millennial jurors. Sometimes we evolve because our cases get big enough to afford jury research. Sometimes we evolve because our confidence in our old practice gives way to humility and new techniques. Our ethical duty to represent our clients zealously demands that we be open to such evolution. If used correctly, focus groups, mock trials, shadow juries, and jury consultants can be effective tools for achieving the best result for the client.
“Tips on Cross Examination from the Perspective of Defense Counsel”

By Jervonne Newsome

Tip #1: Be the Director

The director of a movie sees the end from the beginning. He or she knows the story they want to tell. Don’t be tempted to accept the story as the plaintiff has framed it. Develop your own story line, your own characters, your own heroes! The plaintiff has a story to tell but so does the defendant. Cross-examination is not just a time to impeach or discredit the witness. It’s an integral time to tell your story! Your client is not the big bad wolf. If we would have heard a different story about the three little pigs and how it was actually the three little pigs who antagonized the wolf and bullied the wolf until the wolf just acted in retaliation, then we would no longer be able to see the wolf as the villain. We have created a new character. If we would have heard a different version of the David and Goliath story, would we feel the same about Goliath?

In other words, find a way to use cross-examination to inject your idea of who the main players are and their responsibility. Don’t wait until you put on the defense. By then the jury has already identified with the plaintiff’s story. The jurors, just like the audience at the movies, seek to identify with someone. And more often than not, they identify with the plaintiff. Why? Because most of the time the jurors find it hard to identify with a company that has no face and no one sitting in the chair.

Tip #2: Humanize the Defendant Company

The primary challenge in these types of cases is that you have an injured plaintiff up against a multi-million dollar company whose only face is its logo. The goal throughout trial is to humanize the defendant. How do you do that? You do it the same way that the director of a number-one box office movie does: by emphasizing the human qualities of the perceived villain. For example, in a movie, you might see a flashback into the villain’s life showing the villain being abused or showing the villain have an emotional/traumatic experience. Directors have determined that the greatest movies are those whereby sympathy is created for the perceived villain early on in the movie, making the audience have to constantly go back and forth on who they can trust and who they believe. The same thing goes on in a trial. The defense attorney must find moments throughout the trial, and specifically on cross-examination whereby he or she can humanize the defendant. Here are a few topics to inject throughout your cross.

- Pioneer, industry leader in safety, IIHS ratings, dutifully serving U.S.’s appetite for affordable and safe cars, creating jobs/feeding families.
- Hired additional employees to engineering and design department for purposes of efficiency and safety.
• Community oriented/ gives back.
• Customers rank the company pretty high in terms of most dependable.

You can inject these topics by asking the following questions.

• Did you know . . .
• Would you agree with me that . . .

Another way to humanize your client is to use specific names where possible instead of the company name or “representative of X company”. For example, when discussing one of the company witnesses, try to use his or her real name along with the company name in order to bring life to the company image. You are trying to get the jury to see, “we are not just a company, we are people.”

Tip #3: Land Punches with the Expert

Remember, a plaintiff in a product liability case against an automaker is usually deceased or horribly injured; so, count on a sympathetic jury. Do not plan on beating up the plaintiff (as in other cases). It’s not a winning strategy. Instead, focus on landing as many punches as you can with the expert.

The following questions will be helpful in showing that the expert is a hired gun who intentionally focuses his career on testifying for plaintiffs in product liability cases.

Mr. Expert, you’ve provided expert testimony in over 200 product liability cases, correct?

Yes.

In those 200 plus cases, you only testified in support of the plaintiffs in those matters, correct?

Yes.

So out of your 20 years of experience in the automobile industry, you’ve never provided expert testimony on behalf of the defendant?

No, I haven’t.

The following question challenges the expert’s qualifications.

Mr. Expert, in the 200 plus product liability cases for which you’ve provided expert testimony on behalf of plaintiffs, only 2 of those cases were seatbelt cases, correct?

Yes.

The following question is helpful to challenge the data (or lack thereof) that the expert relies on.

You didn’t review XYZ did you?
No, I did not.

Here, you have successfully challenged the expert’s ability to be trusted with the specific matters in this case. Keep in mind, you might also break this question down a bit further. For example, you can continue a line of questioning that further distinguishes this case from the matters upon which Mr. Expert testified before. Remember, land as many punches as you can through this simple line of questioning.

Also, keep in mind that, every instance of something going wrong should be told in the context of the number of vehicles purchased, miles driven, etc. So, the event complained of becomes 1:1 million. To be clear, no death or injury is statistically insignificant, but that 999,999 had no issue is a big point to display to the jurors. Be sure to point that out when crossing the expert. It will show that perhaps he is not seeing the big picture.

Tip #4: If you do the work, you do not have to come off as a jerk.

As mentioned before, in a product liability case, the plaintiff is pinned as the victim of some horrific act by the big bad company and has already gained the sympathy of the jurors. So how do you effectively combat the plaintiff in a way that gets the dramatic effect you want for your side of the story?

Use your questions to create the dramatic effect you are looking for along with something visual for the juror to focus on. Think about that great movie you just saw last weekend. It was not necessary for the character to yell “I love you” at the top of his lungs for you to gather from the context, the scenery, and his physical affection towards his wife, that he is madly in love with his wife. Thus, not ever cross has to be loud or aggressive, particularly if you are crossing a plaintiff who just lost her arm from a car fire. Being a jerk will not serve any purpose but to discredit you and your client. You simply have to create drama in a different way. Do the work. Don’t be a jerk.

To illustrate, there is a popular scene from the movie “My Cousin Vinny” where Cousin Vinny uses a bunch of photos to challenge witness’s alleged identification of the suspects. During that scene, Cousin Vinny merely walks through all of the photos with the witness and ask what the items reflect, knowing that the witness will have to admit that the photos reveal that there were a lot of items obstructing the witness’ view of the store where the crime occurred. With a calm, conversational tone, Cousin Vinny got the witness to question his own identification of the suspects. The witness ultimately admitted that it is possible he was mistaken. Importantly, by creating a dramatic effect by placing each of the photos on the ledge in front of the witness during his questioning, Cousin Vinny did not have to yell or engage in any aggressive argumentative dialogue with the witness. Cousin Vinny remained the good guy.

What props can you use on cross of a plaintiff? Use an easel that lists what plaintiff says she can prove. And cross out what is questionable.

Ask a question to which plaintiff’s answer will permit you to cross something out. “So, you are not sure that anything Defendant did was the actual cause of your back pain because your back
pain pre-existed the car accident, right?” When Plaintiff answers that she is not entirely sure, cross out that allegation on the white board.

Also, to create drama you should ask questions whereby the jury can draw the conclusion you are making.

Ms. Plaintiff, isn’t true that the first treatment you received for your back after the accident was on May 15, 2017?

Yes.

That’s six days after the date of the accident, right?

Yes.

In fact, on the date of the accident, you declined any emergency services, right?

That’s right, for some reason I wasn’t in much pain until a few days later.

Here, you might feel the urge to draw the conclusion for the jury and ask one final question such as, “so you waited six days to seek treatment, right?” This type of question will only draw another explanation from the plaintiff and you will lose ground. A better final question would be:

So, six days after the accident you went to see your physician, Mr. Doctor, right? Yes. And you never received any emergency services of any kind related to the accident, right? Right. And your treatment with Mr. Doctor consisted of a visit once a month for only four months, right?” That’s correct.

Another way to approach the plaintiff is to use any prior pleadings whereby the plaintiff may have originally blamed other parties for her injury before casting blame on the defendant company. For example, plaintiff’s original pleading may have pointed to the driver of the other vehicle as the primary offender. If so, do not be afraid to show that during cross-examination by using the prior pleading as an admission by party opponent. This will show the jury that it is possible that plaintiff may be blaming the company because the company has deeper pockets. In other words, the jury will begin to draw the inference that plaintiff’s lawsuit may have been contrived out of greed and not premised on the fact that the company actually did something wrong.

Again, do the work and you don’t have to be a jerk.

Tip #5: Highlight the Human Component

Whether you are a Nascar driver who lives on the edge or you are enjoying a nice peaceful flight in the sky, your safety can always be compromised by human error. There are things that we still have to do in order to ensure our safety no matter what. So, what does this mean in terms of cross-examination? Even if you have a perfect witness who has no bias and whose credibility is superb, no one can deny the probability of human error. For example, let’s say that you decide
to cross-examine the plaintiff who’s 5-year-old is now paralyzed from the waist down from a car accident she was involved in with plaintiff driving. Plaintiff claims that her seatbelt malfunctioned and now is suing Hyundai. Here is a line of questioning that will highlight the possibility of human error.

Ms. Plaintiff, I just want to run through what a typical day looks like when you take your daughter to school every morning.

Your daughter has to ride in a car seat right?

When she gets in the car, you help her to buckle up her seatbelt, right?

But there’s also a harness that she has to strapped into in the car seat?

Now can you tell the jury what exactly you do when you help her get buckled in?

When you get to the school do you let her out?

So, your daughter unbuckles her car seat harness to get out?

You do this every school day, you buckle her in and she unbuckles herself when she wants to get out?

Here, you have shown that perhaps the problem is not the seatbelt but the fact that the little girl prematurely unbuckled her car seat harness before the impact. In other words, take an approach that shows he possibility that there was some human error involved that may have gone unnoticed, even if you have no actual proof that such error occurred. The jury will simply draw a conclusion in your favor.

Tip #6: Use the Reverse Reptilian Approach

Many of you have heard of what is referred to as the “Reptile Approach”. Basically, this approach attempts to prey on the survival and protective instincts of the juror to influence the juror to render a verdict in favor of the plaintiff. How is this done? The plaintiff’s attorney tries his or her case in way that forces the juror to focus on the defendant's actions and how those actions could have grave impact on the safety of the community and more specifically, the juror and his or her own family. The jurors will feel a since of obligation to protect.

There are two ways to combat this theory and, in fact, use it against the plaintiff. First, on behalf of the company, you can ignite the juror’s instinct to protect the world against irresponsible plaintiffs who endanger the lives of others. Look at the following line of questioning.

- Mr. Doe, you would agree that it is never ok to needlessly endanger yourself or your co-workers?

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1 The questions in this section of the paper are excerpts from an article written by Kyle J. White titled “Can Defense Lawyers Co-Opt the Reptile Strategy?” http://www.gwblawfirm.com/can-defense-lawyers-co-opt-reptile-strategy/.
• And your employer gives you safety information which tells you how to avoid needless danger to yourself and your coworkers?

• And the plant where you work has people from the community come in to look around every now and then – students, employees’ spouses, customers, etc.?

• And you are never allowed to needlessly endanger visitors to the plant?

• And the safety information your employer gives you is meant to protect visitors to the plant from danger as well, correct?

• And you know that if you ignore safety information provided by your employer, you could endanger yourself and your coworkers, and any visitors?

• So, you must not ignore that safety information?

• And if that safety information is in writing when you get it, you should read it?

• Part of the safety information that your company gives you when you are training tells you to inspect the equipment before your shift?

• Because it is important to make sure the equipment is working properly before you operate it?

• Because if the equipment is not working properly, you, your coworkers, or visitors could be endangered?

• And there was a label on the equipment that said to read the entire operator’s manual, correct?

• And the safety information your company gave you told you to read the entire operator’s manual for the equipment, correct?

• And you admit that you did not read the section of the owner’s manual that told you to inspect the fuel valve?

Another way to combat the Reptilian Approach is to hone in on how responsible and safe the company has been in developing its product. See the following line of questioning.

• You would agree that when a company tries to make its product safer, the company is doing something good, correct?

• And the government occasionally enacts safety regulations that companies must follow so that products are safer for people to use?

• So, when a company follows those safety regulations, users of the product in the community are safer?

• A manufacturer of children’s toys must comply with a number of federal safety regulations?
• A manufacturer of children’s toys must comply with ASTM F963-11?

• And that requires children’s toys to be tested for compliance with the toy safety standards?

• And the goal of that regulation is for the product to be safer for people to use?

• So when a manufacturer tests its products for compliance with the toy safety standards, the manufacturer has done something that makes its product safer?

• And in this case, ABC Company tested the product to ensure compliance with toy safety standards?

• And the testing must by conducted by a consumer product safety commission accepted laboratory?

• And requiring a community product safety commission accepted laboratory is meant to make the testing more reliable, and that would enhance customer safety?

• So when ABC decided to comply with the requirement to use a CPSC accepted laboratory for its testing, it did something that made its product safer?

Tip #7: Never Pass Up a Chance to Cross

Declining to cross examine any witness, even an irrelevant witness, will not sit well with a jury. Juries will automatically assume that the witness is credible since his or her testimony is not challenged. Additionally, the jurors will think that your decision to forgo cross examination means that you simply could not combat anything the witness said. Jurors expect you to deal with every witness called in the case. Your failure to question will not show strength; it is more likely to be interpreted as weakness.

Many if not all of the witnesses in any case have at least some information that helps both sides. The truth of this is evident in how we agonize whether to put the witness on the stand at all: we weigh the help we will get on direct examination against damage we may suffer on cross-examination. Thus, the second technique of cross-examination is to question a witness not to impeach credibility, but instead to extract the favorable facts the witness knows. This technique is sometimes called hitchhiking, because the examiner climbs aboard the adversary’s bandwagon and rides as far as he can in his own direction.

This technique is especially important because in the minds of the jurors, there are never two cases being presented, one for the plaintiffs and one for the defendants. For the jurors, there is only one case. And all of the attorneys for all of the parties are held responsible for everything in the case – no matter when it arises – and all are expected to advocate their case through their

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2 The tips described in this section are attributable to and wholly derived from the tips and advice illustrated in the white paper and presentation titled Landing Punches on Cross Examination by Trey Cox and Eric Pinker of Lynn, Pinker, Cox, & Hurst LLP. To learn more about their incredible practice, please visit www.lynnllp.com.
examinations, regardless of which lawyer called the witness to the stand. And this is true regardless of whether the attorney happens to be conducting direct or cross-examination. Because every witness called to the stand has a great potential for providing at least some helpful information to the cross-examiner’s case.

Basically, the jury will now have to question whether the facts are more helpful to the plaintiff or the defendant. If you set your questions up right and use the right tone, you may sway the jurors to thinking that the facts are good for the defendant.

Another reason to cross examine a witness is to limit the witness’s testimony. This type of examination is designed to demonstrate that the witness’ testimony and the cross-examiner’s theme and theory of the case can live together in the same lawsuit. In this way, the examiner side-steps the testimony by demonstrating that the witness is not on a collision course with the cross-examiner’s central theme. This technique is actually used more frequently and successfully than impeachment. An example would be:

**Am I correct that you never personally witnessed Ms. Plaintiff buckle in her daughter to the car seat?**

That’s correct.

**Conclusion**

In conclusion, counsel for the defense must seize every opportunity to tell the story of the Defendant Company even it that means stealing the show from plaintiff on cross. Never simply rely on being aggressive and a jerk. There are other ways to create drama and gain the credibility of the jury. Tell the David and Goliath story that the jurors never heard.
CROSS EXAMINATION IN A PRODUCT LIABILITY CASE

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Plaintiff has a story to tell

Does the Defendant?
MAKE YOUR POINTS AND THEN SIT DOWN

THIS IS ASPIRATIONAL AND NOT ALWAYS REALITY
CREDIBILITY AND INTEGRITY MUST COME FIRST

- Your Client
- Your Case
- You
PREPARATION, PREPARATION, PREPARATION

4 years of perspiration cannot be made up for by 10 seconds of inspiration in the court room
If you do the work, you don’t have to be a jerk.
Organization and document preparation are key.
Tip #1

Be the Director
Villain or Hero
CONTROL AND COMMAND OF THE WITNESS AND THE COURT ROOM

- Stay Calm
- Do Not Get Angry
- Do Not Ask the Judge For Help
- Control over the Facts and Evidence
- If you don’t look like you are being effective then you are not being effective
- Do Not Be Afraid

WE’VE GOT TO KEEP OUR COMPOSURE!!!
WHAT TO ACCOMPLISH

• SAFETY RULES
• VIOLATION OF THE RULES IS A DANGER TO THE PUBLIC
• FIND A AGREEMENT
• EMPHASIZE FACTS THAT HELP YOUR CASE
• QUALIFICATIONS
  • TRAINING
  • EDUCATION
• BIAS
• OTHER NEGLECTED INCIDENTS
• BUILD YOUR THEMES
EXPERTS

- Pre-Determined Opinions - Web Page
- Multiple Cases Same Opinions
- Corporate Rep and Expert Disagree
- Lack of Testing their own opinion or yours
- Put opinions to the test in the court room
- Ask about areas outside of expertise
- Use their strong beliefs to your advantage (Tort reform)
- Earnings and work for Defense
- Make them pay for their mistakes
Tip #2

Humanize your Client
CONSTRUCTIVE CROSS-EXAM

- Build your themes
- Build your damages
- Find agreement
- Build up your witnesses
- Never lose sight of your case
DESTRUCTIVE CROSS EXAM

- Undermine defense case
- Undermine credibility
  - How much do they bill and for what
- Bias
- Direct v. Collateral Attack
TAKE WITNESS OUT
OF HIS/HER
COMFORT ZONE

- Demonstratives
- Flip Charts
- Checklists
- Models
- Bring Them Off the Stand
- Timelines
- Be Creative
Use props for silent dramatic effects
Tip #3

Land Punches with the Expert
BIAS
Inadequate qualifications
Insufficient facts and data
Ford Explorer Throttle Stick Timeline

Fall 1996
Ford first aware of throttle problem

January 1997
Ford issues SSM re: throttle defect

March 1997
Ford manufactures Rebekah’s Explorer

May 1997
Ford implements Owner and Dealer Notification Programs

May 1999
Rebekah purchases 1997 Ford Explorer

March 2000
Rebekah has Explorer serviced at dealership

March 21, 2000
Ford letter mentioning hot stick/sudden surges sent to dealers

November 10, 2000
Rebekah is critically injured in collision caused by throttle malfunction

December 22, 2000
Ford letter to NHTSA - institutes recall

April 2001
Rebekah receives recall letter

May 1999
Ford implements Owner and Dealer Notification Programs

May 1999
Rebekah purchases 1997 Ford Explorer

May 1999
Ford implements Owner and Dealer Notification Programs

May 1999
Rebekah purchases 1997 Ford Explorer

FORD HAS MORE THAN 4 YEARS OF KNOWLEDGE BEFORE REBEKAH’S ACCIDENT
Hitchhiking and Limiting
QUESTIONS WHERE THE ANSWER DOES NOT MATTER
Ah ha!
THE POINT IS ALWAYS TO BUILD YOUR CASE

• Build your case
• Attack theirs
• Undermine credibility of witness
• Build credibility of your witnesses
Tip #4
Highlight the Human Component
Tip #5
Use the Reverse Reptilian Approach
OTHER THINGS TO ACCOMPLISH DURING CROSS

Safety Rules
Violation of the Rules is a Danger to the Public
Find a Agreement
Emphasize Facts that Help Your Case

Qualifications
• Training
• Education
Bias
Other Negligent Incidents
Build your Themes
Tip #6

Never Pass Up A Chance To Cross
Does the expert have the qualifications they say they do

- Check CV
- Check Degrees
- Check Schools
AND NOW...
PERSONAL JURISDICTION


- No general jurisdiction in Texas over Michelin in action brought by owner of used automobile who alleged that she was involved in a rollover accident in Mexico as a result of the failure of the automobile's right back tire. Manufacturer was not incorporated in Texas, nor was it headquartered there.

- Specific Jurisdiction
  - (1) Minimum Contacts: Even though vehicle and tires were used rather than new, there was “an uninterrupted, albeit indirect, flow of one stream of commerce foreseeably bringing an item into a forum targeted by Michelin,” and the forum was one in which manufacturer should have reasonably expected to be subject to litigation.
  - (2) Substantial Connection: Evidence that the used tire was originally sold in Texas and then resold in Texas created a strong enough nexus to support specific jurisdiction.
The Ford F-150 was not designed, manufactured, sold, or serviced by Ford in New Mexico.
- The District Court found specific jurisdiction.

The Court of Appeals upheld the finding of jurisdiction but on different grounds:
- Ford consented to general jurisdiction in New Mexico by complying with the state’s statute requiring registration to do business in the state.
- The Court distinguished *Daimler* (2014) by reasoning that California’s registration statute does not require corporations to consent to general jurisdiction.
- “Whether consent to jurisdiction is inherent in corporate registration depends on language of the forum state’s registration statute itself or on how a state court has construed it.”

*But see Jeffs v. Ford Motor Co.*, 2018 IL App (5th) 150529-U, 2018 WL 3466965 (reversing trial court’s holding that it had general jurisdiction over Ford because Ford consented to doing business in Illinois).
On appeal, the Kims again challenged the trial court's denial of their motion in limine to exclude evidence of industry custom and practice.

The Court of Appeal rejected the challenge. In so doing, it identified tension between [one] line of appellate decisions ... which have stated that such evidence is irrelevant and inadmissible in a strict products liability action, and [another line of cases] which held that evidence that the product complied with trade association industry standards was an appropriate factor to consider in the risk-benefit analysis.
▪ By “industry custom and practice,” we refer to the use of the challenged design within the relevant industry—“what is done”—as opposed to so-called “‘state of the art’” evidence, which concerns “what can be done” under present technological capacity.

▪ The critical question is whether evidence of industry custom and practice has a tendency to prove or disprove any fact that is of consequence to the proper weighing of the risks and benefits of the challenged design.
Evidence of industry custom and practice sometimes does shed light not just on the reasonableness of the manufacturer's conduct in designing a product, but on the adequacy of the design itself.

The risk-benefit test calls on juries to consider whether a design is safe enough, given “the relative complexity of design decisions and the trade-offs that are frequently required in the adoption of alternative designs.”

Depending on the circumstances, evidence of other manufacturers' design decisions may aid the jury's understanding of these complexities and trade-offs, and thus may provide some assistance in determining whether the manufacturer has balanced the relevant considerations correctly.
Plaintiffs objected to what they referred to as “[t]rue industry custom evidence”: “evidence that ‘nobody does it,’ that ‘every body does it,’ or that the defendant's product is no more dangerous than others on the market.”
This category of evidence may, depending on the circumstances, be admissible. It is not clear why we would cordon off this category of evidence from, for example, the category of industry standards promulgated by trade associations.

Such industry custom and practice evidence may be relevant in a strict liability design defect case—even if not dispositive—for much the same reason as industry standards evidence: because it illuminates “the relative complexity of design decisions and the trade-offs that are frequently required in the adoption of alternative designs.”
Lockout mechanisms for distracted driving

*Meador v. Apple, Inc.*, 911 F.3d 260 (5th Cir. 2018)
Plaintiffs alleged that receipt of a text message triggers in the recipient “an unconscious and automatic, neurobiological compulsion to engage in texting behavior.”

No Texas case has addressed whether a smartphone manufacturer should be liable for a user’s torts because the neurobiological response induced by the phone is a substantial factor in her tortious acts. To our knowledge, informed by submissions to us, no court in the country has yet held that, and numerous courts have declined to do so.
To our minds, the closest analogy offered by Texas law is so-called dram shop liability: the liability of commercial purveyors of alcohol for the subsequent torts or injuries of the intoxicated customers they served.

The law development that has occurred places the onus of distracted driving on the driver alone.

We cannot say that Texas law would regard a smartphone’s effect on a user as a substantial factor in the user’s tortious acts.
Because we decline to consider “neurobiological compulsion” a substantial factor under Texas law, we conclude that the iPhone 5 could not be a cause in fact of the injuries in this case.

Consequently, it is unnecessary to consider the issues of concurrent and superseding causation on which Appellants have focused their arguments.
▪ Garrett Wilhelm was driving on the interstate, and, while driving, was using the FaceTime application on his Apple iPhone 6 Plus. Traveling at highway speed, Wilhelm crashed into the Modisettes’ car, which had stopped due to police activity.

▪ The Modisettes alleged that the car accident “occurred ... when a driver, distracted while using the ‘FaceTime’ application on an Apple iPhone 6 Plus during operation of his motor vehicle, collided at highway speed with [their] stationary motor vehicle and caused severe physical and emotional injuries to [them],” and that Apple’s failure to design the iPhone “to ‘lock out’ the ability of drivers to utilize the ‘FaceTime’ application on the Apple iPhone while driving a motor vehicle, ... resulted in the[ir] injuries.”
The Modisettes alleged that Apple had wrongfully failed to implement in the iPhone 6 Plus a safer alternative design that would have automatically prevented drivers from utilizing FaceTime while driving at highway speed (lockout technology). The Modisettes also alleged that Apple had failed to warn users that the iPhone “was likely to be dangerous when used or misused in a reasonably foreseeable manner.”

The Modisettes alleged that Apple “had a legal duty to ... use due care in the design, manufacture, and sale of its iPhone 6 Plus” and that Apple had “breached that duty by failing to use reasonable care to design and manufacture [the phone] with the safer, alternative ‘lock-out’ technology it had already developed to prevent the use of its pre-installed ‘FaceTime’ application during a driver’s operation of a motor vehicle.”
We conclude that the Modisettes’ claims for general and gross negligence, negligent products liability, negligent infliction of emotional distress, and public nuisance fail because Apple did not owe the Modisettes a duty of care. We base this determination on two considerations: first, the tenuous connection between the Modisettes’ injuries and Apple’s design of the iPhone 6 Plus without lockout technology; and, second, the burden to Apple and corresponding consequences to the community that would flow from such a duty. We also determine that the Modisettes’ claims for strict products liability, intentional infliction of emotional distress, and loss of consortium fail for lack of proximate cause.
In particular, we conclude, first, that there was not a “close” connection between Apple’s conduct and the Modisettes’ injuries and, second, that “the extent of the burden to [Apple] and consequences to the community of imposing a duty to exercise care with resulting liability for breach” would be too great if a duty were recognized.

For the Modisettes to be injured, they had to stop on a highway due to police activity; Wilhelm had to choose to use his iPhone while driving in a manner that caused him to fail to see that the Modisettes had stopped; and Wilhelm had to hit the Modisettes’ car with his car, an object heavy enough to cause the Modisettes’ severe injuries. It was Wilhelm’s conduct of utilizing FaceTime while driving at highway speed that directly placed the Modisettes in danger. Nothing that Apple did induced Wilhelm’s reckless driving.
In addition to concluding that the connection between the Modisettes’ injuries and Apple’s design of the iPhone weighs against a duty of care on the part of Apple, we determine that the burden a contrary conclusion would place upon cell-phone manufacturers and the consequences to the community strongly militate toward finding that Apple had no duty to the Modisettes even if their injuries were foreseeable.
Taking the Modisettes’ properly pleaded allegations as true, it appears to us that the first amended complaint pleaded facts sufficient to establish that Apple’s design of the iPhone 6 Plus without its patented lockout technology was a cause in fact of the Modisettes’ injuries because it was “a necessary antecedent” of the accident.

As a matter of practical necessity, legal responsibility must be limited to those causes which are so close to the result, or of such significance as causes, that the law is justified in making the defendant pay.”

Although Apple’s manufacture of the iPhone 6 Plus without the lockout technology was a necessary antecedent of the Modisettes’ injuries (as was the police activity that slowed traffic on the interstate that day), those injuries were not a result of Apple’s conduct. Rather, Wilhelm caused the Modisettes’ injuries when he crashed into their car while he willingly diverted his attention from the highway.
The Modisettes also contend that product misuse “is an affirmative defense for which Apple bears the burden of proof.” Although we agree that product misuse is an affirmative defense, it bears on whether a third party’s misuse of a product was the “superseding cause of injury that absolves a tortfeasor of his or her own wrongful conduct [because] the misuse was so highly extraordinary as to be unforeseeable.”

We do not conclude here that Wilhelm’s use of the iPhone while driving was unforeseeable. Rather, we determine that the gap between Apple’s design of the iPhone and the Modisettes’ injuries is too great for the tort system to hold Apple responsible.
Lessons from *Nester v. Textron, Inc.*, 888 F.3d 151 (5th Cir. 2018).
Lessons from *Nester v. Textron, Inc.*, 888 F.3d 151 (5th Cir. 2018).

- Using a pattern jury charge will not be abuse of discretion even if it does not match the current state of the law.
- A later-occurring OSI is admissible to show evidence of defect even if not notice of defect.
- A company’s analysis of a dissimilar incident can be relevant evidence of a safer alternative design – even if the incident itself is inadmissible.
- A district court is not bound by state law in determining whether to bifurcate.
Malfunction Theory
The Pittses argue that they presented sufficient evidence to show that defectively designed circuitry was the proximate cause of the electrical malfunction that ultimately caused Pitts’ injuries.

According to the Pittses, [their expert] testified with sufficient certainty that the electrical malfunction was caused by one of several possible reasons, all of which could be attributed to design defects that created an unreasonable danger of an electrical malfunction.
The expert stated that one of six or more possibilities could have been the cause of the accident. While some of the initial report’s “possibilities” could possibly be connected to the affidavit’s “unreasonably dangerous” elements of the design, others cannot.

We need not decide in this case if the Pittses were required to eliminate all possible nondesign causes in order to create a material issue of fact, because even if they were not, the evidence’s logical sequence of cause and effect was lacking. In other words, [the expert] did not opine with a requisite degree of certainty that any of the “possibilities” was the one that caused the malfunction.
The Pittses rely on what is known as the malfunction theory to support the causation prong of this claim.... They assert that in lieu of proving a specific manufacturing defect, the malfunction theory allows them to circumstantially prove an unspecified defect in the lift.

The malfunction theory is narrow in scope. The theory simply provides that it is not necessary for the plaintiff to establish a specific defect so long as there is evidence of some unspecified dangerous condition or malfunction from which a defect can be inferred—the malfunction itself is circumstantial evidence of a defective condition.
The Pittses have pointed to evidence of specific design defects in the lift that possibly caused an electrical malfunction; but, later, in an effort to forward his manufacturing defect theory, relied on the malfunction theory by generally asserting that a flaw in the lift’s circuitry caused this electrical malfunction. For this reason, the malfunction theory is inapplicable in this case and the district court did not err in refusing to apply it.
Lessons from *Smith v. Chrysler Group, LLC*, 909 F.3d 744 (5th Cir. 2018).

- 2013 Jeep Wrangler: Vehicle Fire
- Spoliation
  - Chrysler was never given the opportunity to inspect or preserve the Jeep.
  - Without a finding that the plaintiff acted in bad faith in failing to preserve the Jeep, a sanction was not warranted.
- Available physical evidence:
  - Photos of the scene.
  - Autopsy revealed Mr. Smith had a blood carbon-monoxide level of 17%.
Lessons from *Smith v. Chrysler Group, LLC*, 909 F.3d 744 (5th Cir. 2018).

- Cursory reference to new information is not enough to warrant a supplemental expert report after the designation deadline.
- Evidence that purportedly allows an expert to exclude defects other than the recall condition is not enough to conclude that the recall condition more likely than not caused the accident.
  - “This conclusion tells us only that the Jeep in question here did not have the same defect as other Jeeps that caught fire. That is, the new evidence allows him to eliminate a fire connected to these other Jeep defects. It does not allow us to conclude that Mr. Smith’s Jeep had a defect nor that the alleged defect could cause a fire, or more particularly, whether it could cause the fire that caused this crash.”
- An accident reconstructionist could not show causation. “The absence of expert testimony from a fire expert is critical.”
What U.S. Lawyers Need to Know About Canadian Class Actions Law and Practice

April 3, 2019

American Bar Association  Tort Trial & Insurance Practice Section
2019 Emerging Issues in Motor Vehicle Product Liability Litigation

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What U.S. Lawyers Need to Know About Canadian Class Actions Law and Practice

As more companies enter the international market, attorneys often find themselves in situations where they are asked to represent or counsel clients that have been sued in foreign jurisdictions. The purpose of this article is to provide an overview of Canadian class action law and practice and explain some of the key differences between Canadian and U.S. law and jurisprudence for those practitioners who represent clients that may be subject to Canadian jurisdiction.

The Canadian Legal System

The legal system in Canada is different from that of the U.S. in that there are two different systems that may apply, one grounded in common law and the other in civil law.

In all Canadian provinces and territories except for Québec, the common law system rules. This legal system is based on the British model. There are numerous similarities with the U.S. system, but also some significant differences, which will be discussed below.

In Québec, on the other hand, private civil matters are regulated under the civil law system based on the French model. Unlike the common law, the civil law system is codified. The Civil Code of Québec is the comprehensive guide which covers all areas of private civil law. The class action rules are in the Code of Civil Procedure.

Class Action Law and Procedure

A “statement of claim” is the originating document under the common law. A motion for certification starts the process towards certifying the case as a class action. A statement of claim needs to be personally served. Generally, for a corporation, that means a copy must be given to an officer, director or agent of the corporation or someone who appears to be in control of management of the place of business. If your company operates in Ontario, for example, then the statement of claim can be provided to a representative of the company who operates there.

In Québec, the rules of service are now governed by a new Code of Civil Procedure promulgated in 2016. The new Code of Civil Procedure incorporated the provisions of the Hague Convention on the Service Abroad of Judicial and Extrajudicial Documents in Civil or Commercial Matters. This means that a motion for authorization to institute a class action, usually drafted in French or in English, the two officials languages of Québec, must be translated, for example, into Japanese if it is served on a Japanese corporation whose head office is in Japan. Before 2016, a plaintiff could ask the permission to serve the proceeding, in French or in English, and those permissions were granted ex parte as a matter of course. This is no longer the case.

In the recent class action Francis Lévesque v. Nissan Canada Inc. et al.\(^1\) involving a Japanese car manufacturer, Nissan, the Japanese parent, the U.S. and the Canadian subsidiaries of Nissan were sued. The Japanese parent was not served with the motion in Japanese in accordance with the rules of the Hague Convention, only the American and the Canadian corporations were appropriately served (in English). In dismissing the motion for authorization to institute a class

\(^{1}\) 2019 QCCS 609.
action, the judge remarked that service on the Japanese parent had not been done in accordance with the rules of procedure, and that the motion for authorization was thus considered not served on the Japanese corporation.

The issue of service is thus of paramount importance and one must be careful not to consent to service inadvertently.

It is important to note that in Québec, “authorization” to institute a class action is similar to certification. The criteria used by the Court to authorize the institution of a class action are set out in article 575 of the Code of Civil Procedure:

575. The court authorizes the class action and appoints the class member it designates as representative plaintiff if it is of the opinion that

1. the claims of the members of the class raise identical, similar or related issues of law or fact;

2. the facts alleged appear to justify the conclusions sought;

3. the composition of the class makes it difficult or impracticable to apply the rules for mandates to take part in judicial proceedings on behalf of others or for consolidation of proceedings; and

4. the class member appointed as representative plaintiff is in a position to properly represent the class members.

The word “authorization” is used instead of certification in Québec because there is no underlying action which is going to be certified as a class proceeding. If the motion for authorization to institute a class action is not granted, then the matter ends there.

It is important to note that the Supreme Court of Canada, in Infineon Technologies AG v. Option consommateurs, has recently reiterated that the evidentiary threshold under article 575 of the Code of Civil Procedure for authorization is low, and even lower than in the common law provinces.

However, in most provinces outside of Québec, there is a formal process set out in legislation to obtain certification of class actions, much like the U.S. system.

Two Official Languages - English and French

There are two official languages in Canada - English and French. A large percentage of the class actions occur in Ontario and proceedings can be in either English or French. However, if English is the primary language spoken by the defendant, then the defendant has the right to conduct its defense in English. Similarly, proceedings in the courts of Québec can be in either French or English.

2 2013 SCC 59.
In Ontario, rulings at the Court of Appeal in Ontario are in English but rulings of the Supreme Court of Canada and the Federal Courts of Canada are issued in both English and French⁴.

In Québec, some rulings of the Court of Appeal of Québec may at some point be translated into English, for example, in matters of corporate law⁴.

**Case Management of Class Actions**

In the case of a Québec class action, there will often be a notice of hearing accompanying the motion for authorization to institute a class action. The notice will state that the defendant must appear in court in eight weeks. The hearing, however, is purely pro forma. Neither the petitioner nor the respondent appear in court on that date. The clerk of the Superior Court, upon seeing that the file is an “- 06 file” - a motion for authorization to institute a class action - will bring the file to the Justice in charge of the Class Action Chamber (for the south of the province of Québec), currently Justice Chantal Chatelain.

Normally the coordinating judge will wait a few weeks in order to allow respondents the time to select a law firm to represent them. When appearances, now called answers in Québec, from law firms are filed in the court record, she then sends a letter to the lawyers asking the following questions:

1) Have there been any other similar class actions brought in any of the other Canadian provinces?

2) If so, will there be a request to suspend the Québec proceedings in favour of another jurisdiction? Do you have an objection to the jurisdiction of the Superior Court to hear this dispute? This question is asked because, in some substantive areas of law, such as pension and benefits or employment law, the jurisdiction to hear the dispute belongs to another tribunal or agency. See for example *Bisaillon v. Concordia University*⁵. Objections to the subject-matter jurisdiction of the Superior Court are normally adjudicated *in limine litis*. If there is an objection to the subject-matter jurisdiction of the Superior Court, there will usually be a hearing devoted only to this question. This is not common.

3) What, if any, preliminary applications do the parties intend on filing prior to the authorization hearing? In most cases, at this point, defense counsel will disclose whether or not they are considering filing an application for permission to adduce relevant evidence or to examine the petitioner as per article 574 of the Code of Civil Procedure which states that “the judge may allow relevant evidence to be submitted.”

Once the lawyers have responded to these questions, the coordinating judge then assigns the case to be “case managed.” In Québec, since September 1st, 2018, a group of 10 judges have been designated to hear all of the class action authorization requests in the south of the province of Québec. This was done in response to the significant increase in those districts of the filing of requests to authorize class actions. Indeed, there are currently more than 350 class actions

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⁵  For more information on this topic see [http://jugements.qc.ca](http://jugements.qc.ca).

[2006] 1 S.C.R. 666
pending before the court in those districts. Referred to as the “Group of 10,” these judges are assigned by the coordinating judge to “case manage” class actions all the way through the authorization hearing, including hearing and deciding on any preliminary motions. If authorized, the class actions are then distributed to all available judges of the Superior Court of Québec. Each judge in the Group of 10 is assigned approximately 15 to 20 files to manage per year, with the result being that all preliminary motions and the authorization hearing are now generally completed within a period of not more than six months and often less. This is a drastic change to the situation prior to the creation of the Group of 10, where the hearing on authorization would often proceed more than one year from the filing of appearances.

Once assigned to a case management judge, a case management conference, generally by conference call, is scheduled and the questions regarding the existence of other similar class actions, jurisdiction and preliminary questions are debated.

In general, class actions are also case managed in the rest of Canada. It depends on the procedural rules, size and sophistication of the jurisdiction. In Canada’s largest city, Toronto, there are several class action case management judges who have developed a high level of knowledge in understanding and managing such cases. In other parts of the country, there is either no case management because the rules do not provide for it, or the community is too small to have such specialized judges.

Under the common law, once a claim is filed, counsel usually consult with one another with respect to dates for arguing the motion for certification. Sometimes a motion is filed first and counsel will discuss dates afterwards.

Quite often, with the exception of the province of Québec, a substantial period of time may elapse between the filing of the statement of claim and the actual motion for certification. How much time will depend on the complexity and magnitude of the case, but on average it may take between eight and twelve months.

In Ontario, the period may be longer due to recent developments in the law. Some judges require that certain procedural motions be filed and decided in advance of the certification motion and therefore, the date for the certification motion is necessarily pushed back. In addition, it is now a requirement to file a statement of defense prior to the certification hearing. Also, objections to jurisdiction must be asserted at the outset, certainly before any defense is filed. Similar to the Québec system, a motion would need to be brought to argue jurisdiction at the outset. The motion itself does not mean that the responding party has submitted to the jurisdiction. But no other steps may be taken without risking “attorning” or waiving one’s right to challenge jurisdiction.

**National Class vs. Provincial Class**

A primary difference between the U.S. and Canadian systems is that, unlike the U.S. federal court system, the Canadian Federal Court has very limited jurisdiction set by statute. As a result, 99% of all Canadian class actions, including national ones, are argued in provincial superior court.
courts across the country. The Federal Court generally hear matter related only to competition law and claims against the federal government.

Indeed, in cases where a class action against the government is filed in Federal Court but, as the case progresses and, other non-governmental entities are joined as defendants, the Federal Court will lose jurisdiction and the proceeding must move to the appropriate provincial superior court.

Whether asking for a national class in a provincial court is unconstitutional is an issue that has not yet been brought squarely before the Supreme Court of Canada. But the reality is that it happens frequently and not just in relation to national classes, but international classes as well. For example, people who reside in the U.S. may opt into a Canadian class action. In order to have a national class action, the provincial court will be asked to certify a class of residents and non-residents. Depending on the province, the rules for identifying resident and non-resident members of the class may differ. There are provinces that require residents to send notice of their intention to opt-out of a certified class action, but non-residents to opt in.

Multiple Class Actions

Defendants may find themselves facing multiple class actions filed in different provinces, for example both in Ontario and Québec, each of which seek certification or authorization of a national class. This can indeed be a problem. In fact, though unlikely, a defendant could find itself facing class actions in all 13 jurisdictions at once (ten provinces, two territories and under federal jurisdiction). This multi-jurisdictional aspect can become a significant issue of cost and complexity to the defendant, and often requires the strategic consideration of requests to suspend certain of the proceedings in favour of one jurisdiction. While such consideration and requests are common, they raise complex issues of law and such requests are not always granted by the courts seized with such questions. Strategic and legal considerations are important for defendants facing multijurisdictional class actions in Canada.

Ideally, a defendant should aim to be in as few jurisdictions as possible and preferably select a jurisdiction with the most favourable laws given the claims. In terms of settlement, if there is to be one, the defendant would want to settle with the plaintiffs’ lawyer who can give the best and most comprehensive coverage, with as few legal fees as possible.

Motions to Adduce Relevant Evidence

In Québec, a respondent to an application for authorization to institute a class action does not have the right to file a formal, written contestation to the motion. Owing to the fact that the application for authorization to institute a class action does not need to be supported by an affidavit from the petitioner, it follows that the respondent does not have the absolute right to examine the petitioner or to contradict the facts. The application for permission to adduce relevant evidence is the procedural vehicle that must be used to present the other side of the story.

While a motion to adduce relevant evidence would raise due process concerns in the U.S., a challenge was made in Québec on similar grounds, but failed. In New York Life Insurance
Company v. Vaughan\textsuperscript{7}, New York Life Insurance argued that the system contemplated by article 1002 (now article 574) of the Code was inconsistent with section 23 of the Charter of Human Rights and Freedoms that guarantees the right to a full, fair and public hearing. The Court of Appeal did not accept that argument.

In practice, therefore, defense counsel discloses to the petitioner’s lawyers that there will be a request for permission to examine the petitioner. The more experienced the lawyers, the more likely it is that they will not resist the attempt to examine the client. Some plaintiffs’ lawyers, mostly inexperienced or ideological types, refuse, which means defense counsel must ask the court for permission in order to conduct the examination. More recently, such requests have come under increased scrutiny by the courts who carefully examine the relevance and necessity of such requests and sometimes refuse them for absence of relevance to its consideration of the authorization criteria and the allegations of the motion for the authorization of class action, which are assumed to be true for the purpose of authorization.

That said, in some cases, judges do accept that the respondent has the right to ask questions to the potential class representative to check, for instance, if he or she is in a conflict of interest. If, for example, the petitioner's client is a milk producer and wants to act on behalf of a class of milk product consumers, a conflict of interest exists.\textsuperscript{8} That would not satisfy the criteria of article 575(4) of the Code of Civil Procedure.

In the rest of Canada, under the common law, no such right to examine the petitioner's client exists. Instead there is a duty to disclose relevant documents during the proceedings. However, in class action matters, this will usually only occur if certification is granted and then only with respect to the common issues certified.

**Questions about the Class**

In common law jurisdictions, questions about size, geography and adequacy of the representative class come up at the certification stage. Even then, such concerns may not be resolved at that time. There may be a separate hearing to determine the opt-in, opt-out forms and notice to the class, and all that relates to the size and location of the class.

In Québec, on the other hand, questions about the geographical limits of a class are usually considered to be appropriate at the notice of authorization stage. A class must not be defined in a circular fashion. The courts will want to work with a class definition that is ascertainable and will allow questions on that issue. Also, a defendant can usually ask questions to the proposed class representative to verify whether they are an adequate representative or whether there is a conflict with the interests of the class.

**Questions About the Merits of the Case**

There is no merit-based analysis in Canadian common law jurisdictions at the certification stage. This is perhaps the biggest distinction between the U.S. and Canada (outside of Québec). The first stage of certification is whether there is a reasonable cause of action - similar to a motion to

\textsuperscript{7} [2003] J.Q. no 89 (QC CA)

\textsuperscript{8} See, e.g. Bouchard v. Agropur coopérative [2006] J.Q. no 11396 (QC CA)
dismiss for failure to state a claim. While this suggests a more merit-based analysis, it is simply a determination of whether petitioners have asserted a legally cognizable claim under Canadian law. Whether the case actually has merit is not a consideration during the certification process.

The primary disputes in Canadian certification motions generally fall into four categories:

1) Is there a cause of action?

2) Is there commonality? The question as to whether there are enough common threads between the plaintiffs such that the case ought to be certified and proceed in some common manner, is a significant defense tool.

3) Is there a preferable procedure? In other words, is there an alternative way to proceed other than a class action that would be better suited to resolving the dispute.

4) Is the proposed representative an adequate representative of the class?

In Québec, the test for demonstrating a cause of action is set in article 575(2) of the Code of Civil Procedure: “The facts alleged appear to justify the conclusions sought.” In other words, petitioners have a relatively light evidentiary burden. Indeed, the burden is one of demonstration, not proof. Plaintiffs only have to demonstrate that they have an arguable case or an “appearance of right” assuming the facts that they have alleged are true at this stage of the proceeding. Only vague or general allegations or unsupported opinions or hypotheses are not deemed to be true for the purposes of a motion for the authorization to institute a class action.

**Jury Trials**

An additional difference between the U.S. and Canadian systems is that jury trials in civil cases in Canada are rare. Indeed, in Québec there are no juries allowed in civil matters, period. In the rest of Canada, under the common law, both the certification hearing and the trial of the main issues are usually heard by a judge alone.

In Canada, there is no constitutional right to a jury in a civil trial. Any party may request a jury, but a judge has broad discretion to deny such a request if they feel that the legal or factual issues are too complex. The practical result is that jury trials in complex civil matters under the common law are extremely rare. While the common issues trial may theoretically be heard before a jury, the likelihood of such an occurrence is slim to none. The few class actions that have proceeded to trial thus far have been determined by a judge alone.

**Punitive Damages**

In Canada, punitive damages which are awarded are often fairly conservative by U.S. standards. This said, in Québec punitive damage awards on the rise and can be awarded even in the absence of an award of compensatory damages. In the decision *Biondi v. Syndicat des cols bleus regroupés de Montréal (SCFP-301)*, the Superior Court of Québec ordered the Syndicat des cols bleus regroupés de Montréal (Union) to pay $2M CAD ($1.5M USD) in punitive damages.

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9 2016 QCCS 83.
to the class resulting from the delay of the City of Montréal (City) to de-ice sidewalks of downtown Montréal during the illegal strike of the members of the Union in the winter of 2004. This award was upheld by the Québec Court of Appeal.

Class actions are changing the landscape of amounts awarded as punitive damages in Québec. This said, punitive damage awards remain an exceptional measure and courts are reluctant to award significant amounts under this head of damages. Indeed, in the recent decision of Vidéotron v. Girard,¹⁰ Vidéotron, a leading Québec telecommunications company, appealed a Superior Court judgment that had partially allowed a class action against it, resulting in Vidéotron being condemned to pay $6.4M CAD ($4.8M USD) in compensatory damages and $1M CAD ($750k USD) in punitive damages for having made misleading representations to consumers about Local Program Improvement Fund (“LPIF”) fees. While Vidéotron was unsuccessful in reversing the lower court’s findings of liability, the Court of Appeal did review the punitive damages awarded, reducing them to $200k USD ($150k USD).

This being said, class actions often lead to claims for punitive damage and courts will not hesitate to grant substantial punitive damages in order to sanction serious and intentional violations of a right protected by the Québec Charter of Human Rights and Freedoms or of another law providing for the award of punitive damages, such as the Consumer Protection Act. The amount of punitive damage awards in class actions becomes more significant for defendants given the junction of all class members’ claims in a single proceeding. Unlike many cases in the U.S., however, punitive damages are not calculated as a factor of the revenue of the defendant and as a result punitive awards are often lower and less frequent than in the U.S.

Judiciary

Another significant difference between the U.S. and Canada is that in Canada, all judges are appointed, not elected. Furthermore, there is no formal ratification process, although some timid efforts are being made to introduce such a process for Supreme Court of Canada judges. Generally, the judicial appointment process is kept neutral from politics, and Canadian judges are expected to avoid politics so as not to appear biased in certain cases.

Conclusion

While on paper it may appear easier to obtain class action certification in Canada due to the lack of a merits-based analysis during the certification stage, Canadian courts tend to be more conservative than U.S. courts. In addition, with the exception of perhaps the province of Québec, there are generally fewer petitions for class certification in Canada. This is probably due to the fact that Canada is generally not as litigious a jurisdiction as the U.S. An additional factor is that costs can be more readily awarded against a plaintiff, although that depends on the jurisdiction (some provinces do not allow for costs against a losing plaintiff in a class action). In Ontario, which has much of the class action activity in Canada, costs can be awarded against the plaintiff and operates as a significant disincentive to seek class certification. Also, damage awards in Canada are not as high as those in the U.S., so motivation to launch a class action is also not as strong. Finally, novel arguments of law and creative fact scenarios tend to be less successful in Canada.

¹⁰ 2018 QCCA 767.
Owing to the complexities and differing rules involved in Canadian class actions and the increased prevalence of cross-border actions, U.S. lawyers should seek guidance from Canadian counsel experienced in multi-jurisdictional and cross-border class actions. Navigating the various rules and regulations, some of which have been described in this article, can become quite complex.

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Automotive Class Actions in Canada

Steven Rosenhek
Fasken, Toronto

Noah Boudreau
Fasken, Montreal

April 4, 2019
The Canadian Landscape for Automotive Class Actions

1. Copycat cases
2. Product liability
3. Relatively easy to certify
4. No MDL
5. Coordination important – timing
Federal v. Provincial Jurisdiction

- Federal jurisdiction narrow
- No MDL
Pre-Certification Motions

- Jurisdiction
- Summary judgment
- Partial summary judgment discouraged
- Statement of Defence not required
Court Timetable – Case Management

- Broad discretionary powers
- Timing of certification
- Leave to appeal rarely granted
Discovery

• No pre-certification discovery
Certification

Test for Certification

• A class shall be certified if:
  a) the pleadings disclose a cause of action;
  b) there is an identifiable class;
  c) the claims or defences of the class members raise common issues of fact or law;
  d) a class proceeding would be the preferable procedure; and
  e) there is a representative plaintiff or defendant who would adequately represent the interests of the class

  s. 5(1) Class Proceedings Act, 1992 (Ontario)
Certification (cont’d)

- No merits determination
- “Some basis in fact”
Certification (cont’d)

a) Pleadings disclose cause of action
   • very low threshold
   • assuming facts as pleaded are true, claims have a chance of success at trial
   • must be “plain and obvious” that pleadings do not disclose a cause of action
b) Identifiable class

- two or more class members
- class must be defined by objective criteria that has rational relationship with proposed common issues
c) Common issues

- issues of fact or law in common to all class members
- must establish some factual basis in support of common issues and a rational connection between class definition and the proposed common issues
- common question can exist even if the answer given to the question might vary from one class member to another
Certification (cont’d)

- some basis in fact – must show some evidence of commonality across the class
- not required to lead evidence establishing existence of common issues
- common issues do not need to predominate over individual issues
d) Preferable procedure

• Two requirements:
  i. whether class action would be “fair, efficient and manageable method of advancing the claim”;
  and
  ii. whether class action would be preferable to another reasonably available means of resolving class members’ claims
Certification (cont’d)

• assessed in light of judicial economy, access to justice and behaviour modification
• broader approach than Federal Rule 23(b)(3)
Certification (cont’d)

e) Representative plaintiff

- fairly and adequately represent interests of class
- produce plan that includes workable method of advancing the proceedings on behalf of class
- considerable flexibility in favour of plaintiffs
Settlement

- Generally on par with US – 10% rule
Costs

• Loser pay rule
Quebec: Canada’s Class Action Paradise

Noah Boudreau
Fasken, Montreal
Low Threshold for Authorization (Certification)

“(…)The Quebec approach to authorization is more flexible than the one taken in the common law provinces, although the latter provinces do generally subscribe to an interpretation that is favourable to the class action.”

- Vivendi Canada Inc. v. Dell’Aniello, [2014] 1 SCR 3
Low Threshold for Authorization (Certification)

- Authorization criteria are framed broadly and are liberally interpreted by judges.
- Plaintiff does not need a direct cause of action or legal relationship with each of the defendants, permitting industry-wide class actions.
- Less costly to institute a class action in Québec (fonds d’aide aux recours collectifs).
Pro-Consumer Legislation

- Who is the Quebec consumer?
  - Not a reasonably prudent and diligent person
  - Not a well-informed person
  - Not experienced at detecting falsehoods or subtleties in commercial representations
Implied Warranties and Legal Presumptions

- Sellers (manufacturers, distributors, suppliers) are deemed to warrant that products are free from latent defects.
- Statutory warranties of quality, fitness and durability in consumer contracts.
- Defects are legally presumed to have existed at the time of the sale if the product malfunctions or deteriorates prematurely.
- Impossible to limit one’s liability for defective products.
Punitive Damages

• Punitive damages can be awarded even if contractual remedies or compensatory damages are not.

• No need to demonstrate bad faith of the defendant – lax, passive or ignorant behavior will suffice.
Quebec’s Class Action Paradise

Standard of an arguable case

Implied warranties and legal presumptions

Credulous and inexperienced buyers

Autonomous punitive damages
## Some Statistics

<table>
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</tbody>
</table>
## More Statistics

### Class Actions in the Automotive Industry

<table>
<thead>
<tr>
<th>Year</th>
<th>Authorized</th>
<th>Refused</th>
</tr>
</thead>
<tbody>
<tr>
<td>2019</td>
<td>2</td>
<td>1*</td>
</tr>
<tr>
<td>2018</td>
<td>8**</td>
<td>0</td>
</tr>
<tr>
<td>2017</td>
<td>2</td>
<td>0</td>
</tr>
<tr>
<td>2016</td>
<td>2</td>
<td>0</td>
</tr>
</tbody>
</table>

* Plaintiff discontinued his case on the eve of the hearing, but judge refused authorization anyway.

** 4 settlements
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2019 EMERGING ISSUES IN MOTOR VEHICLE PRODUCT LITIGATION

Examining Recent Autonomous Vehicle Litigation Matters and Lessons Learned for the Future

Thomas N. Vanderford, Jr.
April 4, 2019

Hyundai Motor America
Overview of Automated Driving Technology

Automated (Driver Assistance) vs. Autonomous
Gradual shift from Level 1 to higher levels.
SAE Automation Levels

SOCIETY OF AUTOMOTIVE ENGINEERS (SAE) AUTOMATION LEVELS

0  No Automation  
Zero autonomy; the driver performs all driving tasks.

1  Driver Assistance  
Vehicle is controlled by the driver, but some driving assist features may be included in the vehicle design.

2  Partial Automation  
Vehicle has combined automated functions, like acceleration and steering, but the driver must remain engaged with the driving task and monitor the environment at all times.

3  Conditional Automation  
Driver is a necessity, but is not required to monitor the environment. The driver must be ready to take control of the vehicle at all times with notice.

4  High Automation  
The vehicle is capable of performing all driving functions under certain conditions. The driver may have the option to control the vehicle.

5  Full Automation  
The vehicle is capable of performing all driving functions under all conditions. The driver may have the option to control the vehicle.
<table>
<thead>
<tr>
<th>Level 0</th>
<th>No Automation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Level 1</td>
<td>Driver Assistance</td>
</tr>
<tr>
<td>Level 2</td>
<td>Partial Automation</td>
</tr>
<tr>
<td><strong>Level 3</strong></td>
<td>Conditional Automation: <em>Driver must be ready to take control of the vehicle at all time with notice</em></td>
</tr>
</tbody>
</table>
| Level 4 | Vehicle performs all functions under *certain conditions*  
  - The driver may have the option to control the vehicle |
| Level 5 | Vehicle performs all functions under *all conditions*  
  - The driver may have the option to control the vehicle |

**SAE Automation Levels**

**MICHIGAN STATE UNIVERSITY**
Overview of Automated Driving Technology

• Examples of new driver assistance technology
  • Adaptive cruise control
  • Automatic emergency braking
  • Lane-keeping technology
  • Blind spot detection
  • Forward collision warnings
  • Highway autopilot with lane changing
  • Traffic jam autopilot
  • Autonomous valet parking
  • Urban autopilot
  • Driver attention alert
  • Electronic Stability Control (ESC)
Hyundai Level 4 Test Drive

- 118 Miles
- Seoul to Pyeongchang, South Korea
- Fleet (two Genesis G80i, 3 Nexo SUV’s)
- Level 4 – National Highway Traffic Safety Administration – “designed to perform all safety critical driving functions and monitor roadway conditions for an entire trip” within the “operational design domain” of the vehicle. The driver may have the option to take control of the vehicle
You will see:

- Lane changing
- Tunnels without GPS signals
- Vehicle passing
- Interchange, junction driving
- Tollgates
- Pedestrian recognition
- Traffic light recognition
Who will get self driving cars on road first?

- Many companies in this space
- Very fast moving
- All over the World: U.S., Europe, and Asia
- All OEM’s working on autonomous vehicles
- Many strategic partnerships
  - Honda $2 billion investment in GM’s Cruise, partnering “to speed up development of self-driving cars.”
Companies in this Space

- ZF TRW
- Bosch (NVIDIA AI brain)
- Continental (Lidar Systems)
- Delphi (Intel)
- Samsung (Harman International)
- Uber (deals with Daimler, Volvo)
- Intel (Mobileye – $15 billion deal)
- Apple
- Nvidia (with Uber)
- Baidu (Apollo) (office in Sunnyvale, testing permit in California)
- Huawei (Roadrunner)
- nuTonomy (MIT, Singapore)
Auto companies are linking up with each other and tech giants to advance driverless-car technology. A rundown of some of the active collaborations.
Difference in Philosophies: Tesla vs. GM

• **Tesla**
  - Autopilot – promise to stretch the boundaries of technology?
  - Can be used on all roads

• **GM**
  - Super Cruise – places limits on man and machine (limited to 130,000 miles of pre-mapped roads; facial recognition to monitor driver alertness, three stage haptic warnings (now on CTS) (more conservative)
Autonomous Vehicles

- Most OEM’s quickly adding new driver assistance technologies
- Partially automated systems pass control back and forth between vehicle and driver
- Allow driver to cede control of the car but be ready to resume command at a moments notice
- Plaintiffs will allege that these systems could give drivers a false sense of confidence
- Allegations that drivers are lulled into complacency
PREPARING FOR THE FUTURE OF TRANSPORTATION
Waymo Safety Report

“On the Road to Fully Self Driving”

- Waymo (Google)
- October 12, 2017 Report
- Different approach
- Level 3 could be dangerous
- Skip Level 3, directly to Level 4
- Human drivers “not monitoring the roadway carefully enough to safely take control when needed.”
Waymo Safety Report
“On the Road to Fully Self Driving”

• “During our internal testing, we found that human drivers overtrusted the technology and were not monitoring the roadway carefully enough to be able to take control when needed.”

• “As driver assist features become more advanced, drivers are often asked to transition from passenger to driver in a matter of seconds, often in challenging or complex situations with little context of the scene ahead . . . . [The] more tasks a vehicle is responsible for, [the] more complicated and vulnerable this moment of transition becomes.”

• “Avoiding this ‘handoff problem’ is . . . why Waymo is working on fully self driving vehicles. Our technology takes care of all the driving, allowing passengers to stay passengers.”

• Waymo’s approach inconsistent with approach of most OEM’s, including Tesla.
Recent Headlines: Crashes

- January 22, 2018, Tesla into fire truck, Culver City, California.
- March 18, 2018, Uber self driving vehicle hit and killed pedestrian in Tempe, Arizona (case already settled).
- March 23, 2018, Tesla Model X collided with highway barrier near Mountain View, CA, fatally injuring driver.
- September 4, 2018, Utah driver who slammed into stopped firetruck sues Tesla. Model S on autopilot.
- Each incident: a human was at the wheel and could have taken control.
Uber Crash in Tempe, Arizona
Tesla Crash in Mountain View, California
Tesla Crash in Salt Lake City, Utah

Elon Musk @elonmusk - May 14, 2018
It’s super messed up that a Tesla crash resulting in a broken ankle is front page news and the ~40,000 people who died in US auto accidents alone in past year get almost no coverage
washingtonpost.com/business/tesla...

Elon Musk @elonmusk
What’s actually amazing about this accident is that a Model S hit a fire truck at 60mph and the driver only broke an ankle. An impact at that speed usually results in severe injury or death.
1:57 PM - May 14, 2018
86.4K 13.2K people are talking about this
‘Confused’ Tesla on autopilot runs off N.J. highway, crashes into signs, driver tells cops

Updated Feb 11, 3:25 PM; Posted Feb 11, 6:23 AM

A self-driving Tesla that ran off Route 1 Sunday in New Brunswick is hauled away. (Submitted photo)
A Tesla Motors Inc. Model S 90D shown in Washington in 2016.
Drew Angerer/Bloomberg via Getty Images

News

Tesla Crashed Into Home When Park-Assist Failed, Suit Says (1)

Posted Feb. 14, 2019, 6:42 AM; Updated Feb. 15, 2019, 7:57 AM
In May 2016, there was a fatal crash involving a Tesla Model S equipped with Autopilot that underrode a tractor trailer in Williston, Florida.

Tesla camera system used Mobileye’s EyeQ3 processing chip

Complex or unusual vehicle shapes can present proper classifications of targets/threats

In June 2016, NHTSA ODI opened a Preliminary Evaluation (PE16-007) into the performance of the Autopilot mode and the Automatic Emergency Braking (AEB) on the Tesla Model S
• 2015 Tesla Model S
• Tractor trailer
• Data from Tesla indicated:
  • Autopilot in use
  • Tesla cruise control speed was set for 74 mph
  • No driver interaction since last setting of cruise control ~2 minutes before crash
  • No electronic or physical evidence of pre-collision evasive action by either vehicle
Truck Overview
Truck Damage
Tesla Damage
Autosteer is intended for use only on highways and limited-access roads with a fully attentive driver. When using Autosteer, hold the steering wheel and be mindful of road conditions and surrounding traffic. Do not use Autosteer on city streets, in construction zones, or in areas where bicyclists or pedestrians may be present. Never depend on Autosteer to determine an appropriate driving path. Always be prepared to take immediate action. Failure to follow these instructions could cause serious property damage, injury or death.
Tesla Investigation

• NHTSA found no defects in the design or performance of the AEB or Autopilot systems.

• With respect to AEB, NHTSA concluded that the May 2016 crash conditions exceeded the limits of the AEB capabilities at that time.
  - In particular, AEB systems in 2016 could not reliably work in all crossing-type crashes.

• With respect to Autopilot, NHTSA classified it as “Level 2” automation, which requires full attention of the driver to monitor the environment and take control if necessary.
  - Original Autopilot had a series of escalating warnings if it did not detect the driver’s hands on the steering wheel. After about 30 seconds, the vehicle will begin to slow down until the driver’s hands reengage the steering wheel.
  - In August 2016, Tesla sent out an Over-the-Air (OTA) update to shorten the time to begin the deceleration and to “strike out” the Autopilot for the remainder of that driving cycle entirely.
NHTSA found no defects in the operation of the Model S’s Autopilot, but did note the potential for driver confusion about the status of the mode.

NHTSA issued a Special Order to obtain information about what types of driver misuse and driver distraction were considered during Model S development.

NHTSA’s conclusion: It appears that Tesla’s evaluation of driver misuse and its resulting actions addressed the unreasonable risk to safety that may be presented by such misuse.

But NHTSA cautioned: Driver misuse in the context of semi-autonomous vehicles is an emerging issue and the agency intends to continue its evaluation and monitoring of this topic, including best practices for handling driver misuse as well as driver education.
Lessons from the Tesla Investigation

• NHTSA is serious about requiring manufacturers to take into account human-machine interface, and the potential for driver distraction and driver misuse when designing automated features for vehicles.

• From the Investigation Closing Report:

“While drivers have a responsibility to read the owner’s manual and comply with all manufacturer instructions and warnings, the reality is that drivers do not always do so. Manufacturers therefore have a responsibility to design with the inattentive driver in mind. See Enforcement Guidance Bulletin 2016-02: Safety-Related Defects and Automated Safety Technologies, 81 Fed. Reg. 65705.”
Proposed HAV Accident Victim Compensation System

“Automated Vehicles and Manufacturers Responsibility for Accidents: A New Legal Region for a New Era,” by Professors Kenneth Abraham (UVA) and Robert L. Rabin (Stanford)

- New legal regime will need to govern the era of automated vehicles
- Article to be published in University of Virginia Law Review
- Proposes elimination of tort liability for accidents and exclusively involving Highly Automated Vehicles (“HAV”) in favor of new “Manufacturers Enterprise Liability (“MER”) system
Current Environment

• Long transition to Level 4, Level 5
• 95% there, last 5% very difficult
• Driver assistance and accident avoidance technology will be phased in
• Warnings, disclaimer’s and driver education now critically important
• Much litigation will be focused on warnings
• Eventually, algorithms will be blamed
How safe should we expect self driving cars to be?

• Question: Expected to completely avoid fatalities or good enough to reduce them?

• Senator Blumenthal Tesla test drive left him “frightened.”

• Elon Musk: Critics of autonomous cars “killing people” by writing negative articles. Media doesn’t discuss 1.2 million deaths in “manual crashes.”

• 37,133 deaths in U.S. in 2016.

• New driver assistance technologies will make cars safer and will reduce fatality rate.

• But . . . there will be accidents.
With human error taken out of the picture, automakers and auto suppliers are going to find they become unwilling participants in a new blame game. It’s as if the car and its components will take on all of the liability borne by the driver in the past. If an accident happens, it’s because of a failure of a car part. That’s a new role for many suppliers.
New Product Liability Litigation

• But . . . same law.

• Failure to warn.
  - Warnings and disclaimers regarding new technology.
  - NHTSA $\rightarrow$ design with distracted driver in mind.

• Risk utility test.
  - Each new technology makes car overall “safer”.

• Consumer expectation test.