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April 28, 2021

Dr. Steven Cliff, Ph.D.
Acting Administrator
National Highway Traffic Safety Administration
1200 New Jersey Avenue, SE
Washington, DC 20590

Re: Advance Notice of Proposed Rulemaking on *Framework for Automated Driving System Safety,* Docket No. NHTSA 2020-0106

Dear Acting Administrator Cliff:

Waymo LLC ("Waymo") respectfully submits these comments in response to the Advance Notice of Proposed Rulemaking ("ANPRM") on a *Framework for Automated Driving System Safety*, published by the National Highway Traffic Safety Administration ("NHTSA") on December 3, 2020.[1]

Waymo believes that NHTSA has demonstrated significant insight and flexibility in presenting the range of possible approaches the agency is considering with regard to the very complicated subject of automated driving system[2] ("ADS") safety. Waymo fully agrees with NHTSA in recognizing the need to balance the ADS safety regulatory approach with the need to allow continued innovation, especially due to rapid evolution of ADS technology. To achieve such balance, Waymo recommends in these comments that NHTSA take a phased regulatory approach to ADS safety that is commensurate with real-world safety needs, promotes innovation, and ensures a reasonable level of ADS safety. This phased approach would include the issuance of a new ADS "safety case" Federal Motor Vehicle Safety Standard ("FMVSS").

Indeed, NHTSA itself articulates in the ANPRM why the traditional, more prescriptive approach to

[1] 85 FR 78058 (2020).

[2] "AUTOMATED DRIVING SYSTEM (ADS). The hardware and software that are collectively capable of performing the entire DDT [Dynamic Driving Task] on a sustained basis, regardless of whether it is limited to a specific operational design domain (ODD); this term is used specifically to describe a level 3, 4, or 5 driving automation system." J3016 Taxonomy and Definitions for Terms Related to Driving Automation Systems for On-Road Motor Vehicles (June 2018) ("J3016") at 3.2.

drafting FMVSS with detailed test requirements may be premature for ADS safety. The ANPRM further suggests that an effective ADS safety framework may need to include a phased regulatory approach, a range of non-regulatory actions, and a novel way of thinking about the agency's role in regulating automated technologies, which Waymo wholly agrees with. Although performance of the entire dynamic driving task[3] ("DDT") by the ADS may present hazards not present in human driving, such hazards can be appropriately identified and addressed by NHTSA via a phased regulatory approach that includes a safety case FMVSS. This can also be done in a way that recognizes and does not delay the important safety benefits likely to flow from the ADS's avoidance of common human driving errors.

Before expanding on our recommendation for a phased regulatory approach (*see page 7*) and before answering the specific questions posed in the ANPRM, Waymo will address some general points that provide context for our comments.

Waymo's ADS and Operations

Waymo is the world's most experienced developer of ADSs, which, when installed in a vehicle, can perform the entire DDT without human intervention. Waymo develops and has deployed on public roads the Waymo Driver™, our SAE Level 4[4] ADS. Unlike the Waymo Driver today, when Waymo began as the Google self-driving car project in 2009, our early testing of driving automation systems relied on human intervention for safety. That early work, however, convinced us that we would never achieve our safety goals if our technology relied on a human driver. That is why we shifted in 2013 to solely focus on developing a Level 4 ADS that does not rely on a human driver for any reason.

Waymo currently operates our AVs primarily in Arizona, California, and Texas, with additional testing in several other states including Florida, Michigan, New Mexico, Ohio, and Washington. In Metro Phoenix, our fleet of hybrid electric Chrysler Pacifica AVs has been transporting passengers and deliveries in various types of ADS-operated service since 2017. In October of 2020, we introduced fully autonomous vehicles (i.e., rider-only Level 4 vehicles with no human

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[3] "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, and including without limitation: Lateral vehicle motion control via steering(operational); Longitudinal vehicle motion control via acceleration and deceleration (operational); Monitoring the driving environment via object and event detection, recognition, classification, and response preparation (operational and tactical); Object and event response execution (operational and tactical); Maneuver planning (tactical); and Enhancing conspicuity via lighting, signaling and gesturing, etc. (tactical)." J3016 at 3.13.

[4] "LEVEL or CATEGORY 4 - HIGH DRIVING AUTOMATION. 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." J3016 at 5.5.

driver) into our public Waymo One™ ride-hailing service within our Metro Phoenix operational design domain[5] ("ODD"). Today, anyone in our service territory can hail a ride on our Waymo One app, and a completely empty minivan operated by the Waymo Driver will pick them up to take them to their destination. To date, Waymo has compiled over 20 million ADS-driven miles on public roads operating in over 25 cities, including 74,000 fully autonomous miles as of October 2020.

In addition to installing the Waymo Driver on various passenger vehicle platforms, we are also developing our ADS to be used for delivering goods, including via heavy-duty, Class 8 commercial motor vehicles. After more than a decade of deep autonomous driving experience, we have applied that expertise to Class 8 trucks, which pose unique challenges for automation. For instance, a heavy-duty truck has very different handling characteristics from a passenger vehicle.

Waymo's Safety Methodologies and Performance

Over the last several years, Waymo has continued to refine the methodologies it uses to address the safety of its ADS. In October of 2020, we published *Waymo's Safety Methodologies and Safety Readiness Determinations* ("Waymo's Methodologies paper"), which explains how Waymo works to ensure the safety of its ADS and operations by using multiple, complementary methodologies that we continuously improve. These safety methodologies, which draw on well established engineering processes and address new safety challenges specific to ADS-equipped vehicle ("AV") technology, provide a firm foundation for safe deployment of the Waymo's Level 4 ADS.

Thus far, our Level 4 testing and deployment have compiled a very strong safety record. For example, we recently analyzed our AVs' performance in our Metro Phoenix ODD.[6] Our paper covered autonomous operations with an autonomous specialist (Waymo's term for our test driver) behind the steering wheel from calendar year 2019, plus 65,000 miles of fully autonomous operation without a specialist behind the steering wheel from 2019 through the first nine months of 2020. The paper provided a detailed analysis of every actual crash from a dataset of more than 6.1 million real-world miles of autonomous driving in Waymo's ODD, and also of every simulated, counterfactual (i.e., "what if") collision or contact that might have occured during those miles.

The paper found that every single collision, both real and simulated, was of low severity. The data further showed that actions by other agents, namely human-related deviations from traffic rules

[5] "OPERATIONAL DESIGN DOMAIN (ODD). Operating conditions under which a given driving automation system or feature thereof is specifically designed to function, including, but not limited to, environmental, geographical, and time-of-day restrictions, and/or the requisite presence or absence of certain traffic or roadway characteristics." J3016 at 3.22.

[6] *Waymo Public Road Safety Performance Data*, October 2020.

and safe driving performance, contributed significantly to the 47 events (18 actual and 29 simulated, one during driverless operation). Nearly all the actual and simulated events involved one or more road rule violations or other incautious behavior by another agent, including all eight of the most severe events involving actual or expected airbag deployment. The Waymo Driver experienced zero actual or simulated collision-relevant contacts in the NHTSA "road departure, fixed object, rollover" single-vehicle collision typology (which account for 27% of all US roadway fatalities). While rear-end collisions are one of the most common collision modes for human drivers, the Waymo Driver recorded only a single front-to-rear striking collision (simulated) and that event involved an agent cutting in and immediately braking.

In a March 2021 report[7] ("Waymo's Fatal Crash Study"), Waymo performed simulated crash reconstruction using available crash data to analyze how its ADS would have performed had it been controlling either the initiator or responder vehicle in 72 actual fatal crashes that occurred in the period 2008 through 2017 in the current geographic ODD of the Waymo One fully autonomous ride-hailing service in Metro Phoenix. The results of these simulations showed that the Waymo Driver was successful in avoiding *every* collision when replacing the crash initiator (i.e., the road user who made the initial, unexpected maneuver leading to a collision). Replacing the driver reacting (i.e., the responder) to the actions of the crash initiator with the Waymo Driver resulted in an estimated 82% of simulations[8] where a collision was avoided and an additional 10% of simulations where the collision severity was mitigated (i.e., a reduction in crash-level serious injury risk). The remaining 8% of simulations with the Waymo Driver in the responder role had a similar outcome to the original collision. All of these "unchanged" collisions (i.e., those in which the Waymo Driver would not have avoided or mitigated the collision) involved both the original vehicle and the Waymo Driver being struck in the rear in a front-to-rear configuration.

In both of these reports, Waymo noted the analytical challenges and methodological limitations of its analysis. However, even considering those factors, these studies illustrate the enormous potential of ADS-equipped vehicles to improve traffic safety, particularly where an ADS is developed using rigorous, best-in-class safety methodologies.

General Considerations on the ADS Safety Framework

The ANPRM seeks comment on NHTSA's concept that the agency should focus on four primary ADS functions (sensing, perception, planning, control). Waymo believes that the suggested categorization of functions is useful as a starting point for analytical purposes Of course, the

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[7] *Waymo Simulated Driving Behavior in Reconstructed Fatal Crashes within an Autonomous Vehicle Operating Domain*, March 2021.

[8] For the 72 crashes, Waymo ran 91 total simulations because some of the crashes involved two vehicle actors, and some involved one vehicle actor, such as when a vehicle actor struck a pedestrian.

ADS's prediction capability with regard to anticipated actions of other road users, which is closely related to perception and planning, warrants consideration. Moreover, because ADS safety depends on the effective and integrated performance of all of those functions to perform the DDT, we think that integrated performance needs to be fully considered as well. Also, as the ANPRM notes, there are additional dimensions of ADS safety beyond those four functions. For example, the DDT includes certain non-control functions such as enhancing conspicuity; and monitoring field performance is also an important element of ADS safety that can help ensure needed adjustments. To address the gamut of ADS safety considerations, Waymo's Methodologies paper breaks down our safety framework into three broad areas -- hardware, behavior, and operations -- in order to cover all dimensions of ADS safety. NHTSA may wish to consider such a broad framework that encompasses the functions it has identified and additional factors relevant to ADS safety.

As NHTSA develops its ADS safety framework, Waymo suggests that effort would be aided by distinguishing between two very different use cases: (1) AV operation in a centrally managed fleet, including fleets operated by the ADS manufacturer; and (2) AVs sold or leased to the public for personal use. Historically, NHTSA has not had to consider these different deployment paths in crafting its regulatory approach because the agency's primary focus was on vehicles sold or leased to the public. And even those sold for fleet use were not differentiated in terms of safety.

When it comes to AVs, however, the timing of regulatory action, the nature of the safety need, and the selection of appropriate measures to address ADS safety may differ significantly for these two different use cases. Centrally-managed AV fleets are already operating on public roads today under circumstances in which the entity managing the fleet has complete and constant oversight of the vehicles, enabling immediate knowledge and prompt remediation of safety issues. On the other hand, AVs are not available for sale or lease to consumers at this time, and when they are, the extent and nature of manufacturer control and oversight may vary and trigger different regulatory considerations.

Another important general consideration NHTSA should keep in mind is the very important difference between ADS-equipped vehicles (i.e., those with systems in SAE Levels 3 through 5) and vehicles with lower level driving automation systems.[9] The safety needs and possible regulatory approaches concerning those two broad groupings of vehicle automation are very different. In addition, even among ADS-equipped vehicles, the specific requirements that might be appropriate for a Level 3 system (e.g., related to transition to control by a human driver to perform a fallback) may have no relevance to higher levels of automation.

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[9] Comments already submitted in the docket by National Transportation Safety Board Chairman Robert L. Sumwalt delineate some of these distinctions and possible regulatory approaches. Comment NHTSA-2020-0106-0617.

Waymo appreciates the ANPRM's effort to draw a distinction between "process" and "engineering" measures to ensure and assess ADS safety in order to facilitate discussion and comment. However, we believe the ANPRM draws too binary a contrast between "process" and "engineering" measures, potentially overlooking the extent to which these measures interrelate and can be blended in a single FMVSS. The process measures the agency cites (ISO 26262, SOTIF, and UL 4600) are themselves *engineering* practices designed to help ensure and document that appropriate attention is given to all relevant safety aspects in the development and deployment of a system. Application of those processes may include methods of measuring performance, which the ANPRM refers to as engineering measures. Process and engineering measures to ensure safety substantially overlap. The more relevant distinction is between measures that prescribe engineering practices (which may include validation of ADS safety performance) and measures that prescribe specific test metrics and procedures.

Voluntary Mechanisms

The ANPRM asks whether voluntary mechanisms should continue to play a role as part of the agency's ADS safety framework. NHTSA's AV guidance to date[10] has been very helpful in facilitating AV development, focusing stakeholders on the most important elements of ADS safety, and clarifying federal and state roles in ADS safety. In 2017, Waymo was the first company to publish and submit a Vehicle Safety Self-Assessment ("VSSA") as recommended by NHTSA's AV guidance.[11] Waymo was pleased to see that many companies involved in the AV industry followed suit by submitting their own VSSAs in the following years.

NHTSA's New Car Assessment Program ("NCAP") may someday play a role in the agency's ADS framework. NCAP is designed to inform consumers in making a choice about which new car to buy based on an objective rating of its safety, and the program is a proven success that has been duplicated around the world. However, NCAP tests concerning new technologies are typically not developed until after those technologies have been introduced into the marketplace for sale or lease. Of course, AVs (i.e., vehicles equipped with an ADS) may not be sold or leased to the public in the U.S. for some time. Rather, vehicles with Level 3 and Level 4 ADSs are today being tested or deployed in fleet services, often operated by the ADS manufacturer. Of course, devising NCAP tests that would effectively measure ADS safety would require the same level of research that devising such tests for inclusion in an FMVSS would require. Moreover, Level 1 and 2 Advanced Driver Assistance Systems ("ADAS") are already sold to consumers, and NCAP has not yet been updated to address those automation levels, which may logically be the agency's NCAP priority.

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[10] For example, see *Automated Vehicles 3.0*, U.S. Department of Transportation (2019).
[11] *Waymo Safety Report*, updated in September 2020.

While NCAP may not be well suited to address the current and near-term ADS safety needs, we believe that NCAP may someday play an important role in guiding consumers on the purchase of AVs. In the meantime, the agency may draw helpful ideas on possible test procedures concerning AVs from developments underway in Euro NCAP.

Regulatory Mechanisms

Reporting requirements

In these still-early years of AV testing and deployment, uniform reporting on certain factors may provide the agency, the public, and industry with important information to help guide safe ADS development and help shape the regulatory framework by defining the safety need. NHTSA's AV Test Initiative, which encourages voluntary reporting on certain subjects, is a very important first step in this direction. The site provides useful information on the test location, vehicle type, road type, etc. of several ADS manufacturers. As the ANPRM notes, NHTSA currently requires reporting of certain information from ADS manufacturers who receive exemptions from FMVSSs, but such reporting covers only very few ADS operators.

Waymo recommends against including ADS disengagements or "near misses" in any potential mandatory reporting requirements. Disengagements, of course, are an expected part of ADS development and, standing alone, provide little or no useful information on safe performance. Near misses are very hard to define uniformly and could indicate either outstanding safety performance (e.g., the ADS's avoidance of a crash in a severe cut-in situation) or ADS performance in need of some adjustment, but such adjustments are the stuff of ADS development, not government regulation, and should be adequately accounted for in the ADS manufacturer's safety case (as discussed below).

Phased Approach to Regulation of ADS Safety

Rather than trying right now to prematurely develop traditional, more prescriptive regulations for ADS, Waymo believes that NHTSA can pursue a phased regulatory approach to ADS safety that will be: (1) achievable with the agency's current knowledge, resources, and current regulatory authority; (2) commensurate with the safety need as determined through the various phases; and (3) consistent with the need to allow for continued innovation in AV technology. Carefully crafted mandatory mechanisms, if properly sequenced, can increase public confidence in AVs, provide NHTSA with valuable information to inform its work relating to ADS safety, identify possible safety problems, and provide manufacturers with uniform expectations concerning their regulatory obligations.

The agency itself notes in the ANPRM the need for a phased regulatory approach to address the complex matter of ADS safety:

> *NHTSA expects a phased approach to regulation of those aspects of safety performance that may necessitate regulation, given limited agency resources and the constantly evolving technology and business models involved in ADS development. NHTSA would need to phase its responses in several ways. To avoid implementing ineffective or counterproductive measures, the Agency would need to set priorities and allocate its resources accordingly. [page 78073]*

The ANPRM makes very clear what an unparalleled and difficult task it would be to develop a traditional FMVSS on ADS safety that included a comprehensive set of scenario-based tests and test metrics suitable for compliance confirmation testing performed by NHTSA for every possible permutation of SAE automation level, ADS feature, ODD, and vehicle type. Such an approach could actually have the unintended consequence of encouraging manufacturers to design to such specific tests, which could lessen their overall focus on avoiding unreasonable risk. The ANPRM notes:

> *The traditional approach to standard drafting is one where NHTSA specifies the desired performance in great detail, and may also include requirements to lessen the likelihood and mitigate the consequences of failure. . . . Applying this approach to the myriad unique combinations of technologies that may be developed to perform the four critical functions of an ADS could prove quite challenging. [page 78072]*

At this stage of ADS development and early deployment, comprehensive regulation could unnecessarily delay the delivery of significant improvements in traffic safety. The ANPRM recognizes this risk. For example, Waymo's Fatal Crash Study indicated that, had Waymo Driver controlled the vehicles involved in certain fatal crashes within its Metro Phoenix ODD, nearly all of those crashes would likely not have occurred.[12] A landmark study by RAND has similarly warned against delaying ADS deployment while seeking perfect ADS safety metrics.[13]

Specifically, Waymo recommends that NHTSA develop an FMVSS for ADS safety in distinct phases, starting with a requirement for a safety case including standard elements that demonstrate certain minimum ADS performance capabilities relevant to the ODD of the ADS, followed by later phases in which, for example, more detailed scenario-based tests may be prescribed. Only a phased approach to an FMVSS seems reasonable in the near term given the

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[12] *Waymo Simulated Driving Behavior in Reconstructed Fatal Crashes within an Autonomous Vehicle Operating Domain*, March 2021.
[13] *The Enemy of Good, Estimating the Cost of Waiting for Nearly Perfect Automated Vehicles* (RAND, 2017).

immensity of the regulatory task, actual safety need, and agency resources. A phased approach also aligns with the phased deployment of AVs, which is and will continue to scale gradually.

The ANPRM sets out the basic requirements that any FMVSS must meet, which are based on various provisions of the National Traffic and Motor Vehicle Safety Act ("Safety Act") 49 U.S.C. Chapter 301. A review of those criteria shows that an FMVSS can take various forms and need not include detailed scenario-based tests and test metrics, as discussed in more detail in the section below on statutory requirements for an FMVSS.

First Phase: A Safety Case FMVSS

Waymo believes that the logical, first phase of rulemaking for ADS safety should be a "safety case" FMVSS, which would be both a process and engineering measure. A safety case is "a structured argument, supported by a body of evidence that provides a compelling, comprehensible and valid case that a system is, or will be, adequately safe for a given application in a given environment."[14] A safety case FMVSS should require documentation of the ADS manufacturer's use of a comprehensive engineering process that: (1) analyzes potential hazards relevant to the safety of an ADS; (2) explains how relevant safety requirements were developed and how the system's performance was validated against those requirements; and (3) substantiates how the validated system has been demonstrated to protect against unreasonable safety risks.

Use of safety cases as a basis for certification of safety-critical systems is common in several industries:

> *The development of a safety case has become common practice for the certification of safety-critical systems in the nuclear, defense, oil and gas, and rail domains. Indeed, the development and acceptance of a safety case is a key element of safety regulation in many safety-critical sectors.*[15]

The ultimate purpose of a safety case is to ensure: (1) thorough analysis and documentation that the system's safety risks have been comprehensively and properly identified; (2) that the level of each risk has been evaluated; (3) that appropriate methods have been used to validate disposition of each risk commensurate with its level of risk; and (4) that the technical documentation as a

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[14] *NASA System Safety Handbook Volume 2: System Safety Concepts, Guidelines, and Implementation Examples* at 117, citing U.K. Ministry of Defence, Defence Standard 00-56, "Safety Management Requirements for Defence Systems," London, UK. 2007.2.61.

[15] *Hierarchical Safety Cases* (at p. 4) (NASA, 2012) Ewen Denney, Ganesh Pai, and Iain Whiteside. NASA/TM–2012–216481.

whole supports the conclusion that overall system risk is at an acceptable level, i.e., the system is free from unreasonable risk.[16]

A safety case generally includes a similar structure: very specific safety goals of the system are articulated and evidence is presented to support argumentation that each goal has been met. As such, an FMVSS-required safety case would go much further than a voluntary safety self-assessment (VSSA) as recommended by NHTSA guidance.[17] A VSSA is a descriptive document explaining how an ADS manufacturer has addressed certain subjects suggested by NHTSA. Rather, as we envision it, an ADS safety case would be a detailed engineering document that thoroughly covers the actual systems engineering methodologies used, hazards identified and addressed, validation tests performed, and specific evidence to support a manufacturer's safety claims and its conclusion that an ADS has an acceptable level of risk.[18]

A safety case FMVSS would require manufacturers of ADS-equipped vehicles and ADS manufacturers that add their ADS to previously certified vehicles to prepare a safety case for the ADS at particular junctures of the ADS's development (*see discussion below*). The vehicle or ADS manufacturer would self-certify that the safety case addressed all of the elements prescribed by the new FMVSS and that the safety case supported a conclusion that the ADS would not present an unreasonable risk to safety. The safety case itself would, of course, be made available to NHTSA upon the agency's request.[19]

Waymo believes that a first-phase FMVSS consisting of a required safety case for the ADS would provide a regulatory approach that meets the current need with regard to ADS safety, protect the public against unreasonable safety risks in ADS deployment, and provide NHTSA with extremely valuable information on which it could build the next phases of its ADS regulatory framework.

Description of an ADS Safety Case FMVSS

Identifying what specific elements should be required in an ADS safety case FMVSS is a topic for further discussion and consideration, and the agency should seek input from ADS manufacturers

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[16] Helpful papers on the basics of a safety case include: *Building a Preliminary Safety Case: An Example from Aerospace*, Kelly, T. et al.
[17] *Automated Driving Systems 2.0: A Vision for Safety* , NHTSA, September 2017.
[18] In the world of ADS safety, Underwriters Laboratories ("UL") and Edge Case Research have produced ANSI/UL 4600, *Standard for Evaluation of Autonomous Products*, which applies safety case methodology specifically to the evaluation of systems at SAE Levels 3 through 5 (i.e., ADSs). Waymo does not believe that NHTSA should prescribe the use of UL 4600. Rather, we think that NHTSA could require ADS manufacturers to produce a safety case by clearly specifying the necessary elements to ensure a thorough and rigorous argument is supported by the appropriate compelling evidence.
[19] If a safety case is provided to NHTSA, the protection afforded to confidential business information would apply. See 49 CFR Part 512.

and other expert stakeholders. However, at a high level, a safety case would define the scope of the ADS's operation and include both ADS performance elements and process elements. Waymo offers the following list of elements for consideration as potential options for inclusion in a safety case FMVSS:

ADS Description, Intended Use, Vehicle Platform, and ODD

- The ADS's level of automation with reference to SAE J3016, with an explanation of how the design intent fits the definition of that level
- Description of the ADS's hardware and software elements, including its sensor suite
- Explanation of how the ADS performs essential functions, including sensing, perception, prediction, planning and control
- The intended use case (e.g., on-demand passenger service, freight delivery, sale or lease of vehicles to the public, etc.)
- Identification and description of the vehicle platform(s) on which the ADS is used
- If the ADS is added to a previously certified vehicle, measures taken to ensure that addition of the ADS does not take the vehicle out of compliance with other applicable FMVSSs
- Adjustments made to any manual controls (even if required by another FMVSS) to prevent unsafe interference with the ADS's performance of the driving task
- A complete ODD description
    - Explanation of controls in place to ensure the ADS operates only within its ODD and detects conditions not within its ODD
    - Details of the process to be used for expanding the ADS's ODD

Engineering Processes

- The hazard analysis and other analytical methodologies used to guide the design and assess the performance of the ADS to ensure the absence of unreasonable risk, including specific references to any industry standards relied on in whole or part[20]
- Methods used to assess and address the ADS's cybersecurity protections

[20] The most prominent examples of such methodologies are: ISO 26262: 2018, *Road Vehicles--Functional Safety*; ISO/PAS 21448: 2019, *Road Vehicles--Safety of the Intended Functionality ("SOTIF")*; and *SystemsTheoretic Process Analysis*. For a discussion of how Waymo applies these methodologies see *Waymo's Safety Methodologies and Safety Readiness Determinations*. Another potentially useful standard, currently under development, is IEEE P2846, *Assumptions for Models in Safety-Related Automated Vehicle Behavior*, which describes the minimum set of reasonable assumptions used in foreseeable scenarios to be considered for road vehicles in the development of safety-related models for automated driving systems.

ADS Performance Competencies (including evidence supporting safety claims in each area)

- Basic behavioral competencies of the ADS
- Crash avoidance capabilities with regard to other vehicles
- Crash avoidance capabilities with regard to vulnerable road users ("VRUs")
- How the ADS detects other road users in conditions relevant to its ODD, including VRUs and emergency vehicles
- Fail safe and failure mitigation strategies
    - How the ADS is capable of detecting faults that would affect the ability of the ADS to perform the DDT safely
    - If L3 ADS: how the ADS safely transfers control to a human driver when fallback is necessary
    - If L4 or 5 ADS: how the ADS achieves a minimal risk condition when necessary

Performance Testing and Results

- Description of testing conducted to validate all of the ADS performance competencies, including simulation, closed course, and on-road testing, with description of test methods and metrics, ODD-relevant scenarios, and summary of test results (voluminous test documentation can be referenced rather than included)
    - Where testing was performed using simulation, describe the simulation tool(s) used and method(s) used to validate the simulation tools
    - Where testing was performed at the component level (e.g., on sensor components), describe outcomes and relevance to overall system performance
- Description of the processes that will be used to validate updates to the ADS software and hardware

ADS Life Cycle Safety

- Description of risk management and field safety reporting processes in place to identify ADS safety problems that surface during public road operation and to remediate such problems
    - If the use case includes sale or lease of AVs to the public, the measures taken and planned to ensure: (1) the user's full understanding of the ADS's capabilities and the human driver's role, if any; and (2) information related to how possible ADS safety problems will be detected and promptly conveyed to and addressed by the vehicle manufacturer
    - If the use case includes fleet service, whether the fleet operator will be the

vehicle manufacturer, ADS manufacturer, or a third entity, and how information related to ADS safety problems will be detected and promptly conveyed to the vehicle manufacturer, ADS manufacturer, and/or fleet operator

- Explanation of how the manufacturer's safety governance and safety management system ensure the safety case is updated when appropriate

Preparation of a thorough safety case is not a simple matter and requires significant resources. A safety case is not merely a description of items such as those listed above; a safety case includes evidence supporting the safety claims in each subject area.

Accordingly, a requirement to prepare a safety case would need to be tailored carefully to apply only when needed, and not at every change in software, hardware, or ODD element. Rather, how such changes in software, hardware, and ODD elements are effectuated in accordance with sound safety principles would be part of the safety case itself. For example, a revised safety case would not be needed simply to expand the ODD, or even to offer the service in a different but similar ODD using the same vehicle platform; instead, the safety case would be required to explain the process used to address safety in such situations involving incremental expanded use of the same fundamental ADS. Waymo, for example, has explained the process it uses to help ensure that such changes are based on a rigorous analytical process.[21]

Moreover, because testing and evaluation of ADSs involve frequent adjustments in the ADS and related processes, a safety case should not be required during testing and evaluation phases. Instead, NHTSA should consider triggers for requiring safety cases such as introducing a new ADS-equipped vehicle model for sale or lease, using an AV to provide service to the public for the first time, or introducing a new ADS that involves a step up in SAE automation levels from a previous version of the ADS.

A vehicle manufacturer that had already sold or leased AVs or an ADS manufacturer that had introduced a passenger, freight, or delivery service using AVs by the date that the new FMVSS is issued should have a reasonable amount of time (e.g., a minimum of 18 months) from that date to prepare a safety case meeting the requirements of the FMVSS. Assuming the FMVSS would allow sufficient lead time between its issuance and its effective date (as is the norm for any new FMVSS), if a company deployed AVs after the FMVSS is in effect without having a safety case that covers the required points, its deployment would be noncompliant with the FMVSS.

A vehicle or ADS manufacturer would certify that the ADS covered by the safety case complies with the safety case FMVSS, i.e., that the safety case addresses all the required subjects,

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[21] *Waymo's Safety Methodologies and Safety Readiness Determinations*.

accurately reflects the processes used, and that all tests summarized in the safety case were successfully performed. Such certification, and the safety case itself, would be made available to NHTSA on request. If the safety case is submitted to the agency, the manufacturer could choose to seek protection of confidential business information through NHTSA's normal process under 49 CFR Part 512.

As with any matter covered by self-certification under the FMVSSs, NHTSA could ask questions of the vehicle or ADS manufacturer and seek further information, including specific documentation of particular test results. NHTSA could also determine that the safety case did not meet the specific requirements of the FMVSS and apply remedies for noncompliance.

Of course, the contemplated sale, lease, or fleet operation of AVs would not be dependent on NHTSA's approval of the safety case. The self-certification concept enshrined in NHTSA's statutory authority does not contemplate or authorize the agency to require pre-approval before deployment of a vehicle or motor vehicle equipment. The combination of the self-certification system, including the agency's risk-based compliance verification process, and NHTSA's exercise of its authority to address safety defects in vehicles and equipment that may arise in operation has worked effectively for decades. Waymo's recommended regulatory mechanism does not entail any change to that system.

A Safety Case FMVSS Could Meet All Statutory Requirements for FMVSS

Waymo recommends above that NHTSA consider issuing a proposed rule that would create a new ADS safety case FMVSS. Waymo believes that such a rule, if articulated appropriately, could meet all the statutory requirements to qualify as an FMVSS.

The Safety Act defines "motor vehicle safety standard" as "a minimum standard for motor vehicle or motor vehicle equipment performance."[22] A fundamental point is that the Act defines "motor vehicle safety," as performance that protects against "unreasonable risk of accidents occurring because of the design, construction, or performance of a motor vehicle" and unreasonable risk of death or injury in an accident.[23] Therefore, a standard that provides an objective basis for ensuring that the performance of a subject vehicle or system will protect against such unreasonable risk can be considered an FMVSS regardless of whether it contains traditional scenario-based tests. NHTSA has acknowledged this principle previously, when it prescribed an FMVSS that, rather than requiring a specific scenario-based test, instead requires the manufacturer to document how its

[22] 49 U.S.C. § 30102(10).
[23] 49 U.S.C. § 30102(9).

electronic stability control system can achieve acceptable performance in a particular type of situation.[24]

The Safety Act also provides that "[e]ach standard shall be practicable, meet the need for motor vehicle safety, and be stated in objective terms."[25] In issuing FMVSSs, NHTSA must consider certain factors, including "relevant available motor vehicle safety information" and "whether a proposed standard is reasonable, practicable, and appropriate for the particular type of motor vehicle or motor vehicle equipment for which it is prescribed."[26]

Combining these requirements, a standard will qualify as an FMVSS if it: (1) articulates a minimum standard of motor vehicle or equipment performance that protects against unreasonable risk of accidents, death, and injury; (2) meets the need for motor vehicle safety as it may be determined by "relevant available vehicle safety information"; and (3) is reasonable, practicable, objective, and appropriate for the particular type of vehicle or equipment to which it applies.

Accordingly, NHTSA could embody a safety case approach in an FMVSS, an approach increasingly used in certification of safety-critical systems.[27] The agency could state the required elements of a safety case in objective terms that are reasonable and practicable, as suggested in the preceding section. The required elements, which as noted above could include performance elements in addition to scope and process elements, can also be stated so that the safety case adequately demonstrates the minimum ADS performance sufficient to protect against an unreasonable risk of accidents and death and injury in such accidents. A manufacturer's safety case would necessarily include evidence of performance testing and test results demonstrating that the ADS is free of unreasonable risk to safety, likely supported by internationally accepted methodologies for identifying and avoiding unreasonable risk utilized by the manufacturer.[28]

Issuance of an FMVSS on ADS safety need not await the completion of the extensive research that will likely be needed to develop the specific, scenario-based tests and test procedures typical of a traditional FMVSS for the full range of ADS-equipped vehicles. Such tests would need

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[24] We refer to the requirement to make available upon agency request sufficient documentation of an electronic stability control system's understeer capability rather than conducting a specific test. 49 CFR 571.126, S5.6.
[25] 49 U.S.C. § 30111(a).
[26] 49 U.S.C. § 30111(b).
[27] We have noted above (*at page 9*) the use of safety cases to support certification in the defense, nuclear, oil and gas, railroad and aerospace industries. Other regulatory bodies are also considering inclusion of a required safety case in their ADS regulatory schemes. For example, see *Automated Vehicles: Consultation Paper 3 - A regulatory framework for automated vehicles*, issued jointly by the UK Law Commission and Scottish Law Commission (December 2020), pages 115-122.
[28] For example, ISO 26262 defines "functional safety" as "the absence of unreasonable risk," and SOTIF (ISO/PAS 21448) defines an acceptable level of safety for road vehicles as the absence of unreasonable risk.

to be ODD-specific, which increases the complexity of applying the traditional FMVSS approach.[29] The ANPRM notes the difficulty of developing such ODD-specific rules and getting them through the rulemaking process while ADS technology is still evolving:

> *The nature and requirements of the rulemaking process may challenge the Agency's efforts to amend existing FMVSS and develop, validate, and establish new FMVSS quickly enough to enable the Agency to keep pace with the expected rapid rate of technological change. Some aspects of the process are inherent and, thus, unavoidable, such as the often lengthy period needed for preparatory research to develop and validate performance metrics and test procedures and for the rulemaking process to propose, take and consider comment, and eventually adopt the metrics and procedures.*[30]

The ANPRM goes on to express the need for a fresh approach to how an FMVSS can be written:

> *What may be needed, then, is a new approach to structuring and drafting standards that places greater reliance on more general, but still objective, specifications of the types and required levels of performance.*[31]

Waymo believes that an ADS safety case FMVSS would embody such a new approach and would be responsive to the actual safety need with regard to ADS safety. In determining the current need for such an ADS FMVSS, crashes involving automated systems below SAE Level 3[32] should *not* be considered; they involve driver-dependent systems and, if regulated, should be regulated separately based on the distinguishable safety need.

Actual ADS-equipped vehicles are a very small percentage of the vehicle population and their numbers are likely to increase relatively slowly but steadily for several years. ADS-equipped vehicles have an excellent safety record to date. Waymo's recent papers on our AVs' actual and simulated crashes -- all of low severity -- in their ODD and on the simulated performance of our ADS in fatal crashes that had occurred over several years in that ODD demonstrate that current ADS testing and deployment warrant a regulatory response commensurate with the relatively low safety risk they present, especially when the potential safety benefits are weighed. An FMVSS

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[29] On p. 78071, the ANPRM notes the need to tailor ADS safety standards to the ODD of the ADS: "NHTSA believes that the critical relationship between the safety of an ADS's design and the vehicle's decision-making system makes it necessary to evaluate the safety of ADS performance considering appropriate and well-defined ODD (for any system below Level 5)."
[30] ANPRM at 78071.
[31] ANPRM at 78071.
[32] The NTSB's recent submission in this docket (NHTSA-2020-0106-0617) includes references to four such crashes (three involving fatalities) involving Level 2 Tesla systems.

requiring preparation of an ADS safety case is both prudent and proportional to the actual safety need faced by NHTSA.

While the contours of a safety case FMVSS would need to be the subject of further discussion and development, Waymo believes it is clear that the agency has ample authority to issue a safety case FMVSS under existing law, and we encourage the agency to exercise that authority.

Subsequent Regulatory Phases

As discussed earlier in our comments, a phased approach to NHTSA's ADS regulatory framework that evolves over time to match the actual ADS safety need and that does not outrun the agency's resources seems most reasonable. We have recommended a safety case FMVSS as the most reasonable first phase for regulatory action on ADS safety. Subsequent phases may include developing a traditional FMVSS for ADS safety that includes a set of scenario-based tests and test metrics suitable for compliance confirmation. However, an all-purpose, holistic, traditional form FMVSS for ADS safety may be infeasible. The prospect of moving such a comprehensive regulatory undertaking through the research, notice and comment, and final rule processes required for U.S. rulemaking leads to a reasonable conclusion that a traditional form FMVSS for ADS would take several years to complete.[33]

Such a holistic approach may not be necessary for ensuring ADS safety. One option would be for NHTSA to develop a select set of performance tests and metrics to address just a relatively small number of the most critical subjects that the agency decides are most important from a safety perspective.[34]

The ANPRM notes that the agency must consider efficiency in the face of the limitless number of possible scenarios that could be subject to testing with regard to ADS safety:

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[33] The UNECE's Working Party 29 has embarked on such a comprehensive regulatory task and, despite the commendable and dedicated efforts of multiple governments (including the U.S. through NHTSA's representatives) and a variety of non-governmental organizations (including representatives from industry and academia) over the last 18 months, the process is moving slowly due to the complexity of the task. See *Revised Framework document on automated/autonomous vehicles*, ECE/TRANS/WP.29/2019/34/Rev.2; New Assessment/Test Method for Automated Driving (NATM) Master Document; WP.29-183-05; *Informal Working Group on Functional Requirements for Automated Vehicles (FRAV) Progress Report*, GRVA-09-28. Waymo does not believe that developments at UNECE are sufficiently mature at this time to provide NHTSA with an adequate basis to develop traditional scenario-based performance tests for ADSs.

[34] Candidates for such a limited, initial set of traditional performance tests may include these ADS capabilities: detection and response to vulnerable road users likely to be present in any ODD involving surface streets; a Level 3 system's transfer of control back to the human driver when necessary; a Level 4 system's ability to achieve a minimal risk condition; the ADS's ability to detect the limits of its ODD and respond correctly; the ADS's ability to detect and respond to the most likely fault conditions; or the ADS's ability to detect and respond to emergency vehicles.

> *Efficiency— Given that there is neither enough time nor resources for the Agency to develop physical test procedures for all conceivable driving scenarios, an effort should be made to determine which physical tests have the greatest likelihood to minimize safety risk in an effective manner. [page 78073]*

For each critical aspect of performance, NHTSA could state high-level, results-focused, technology neutral requirements. The agency could glean insights from the safety cases prepared in accordance with a first-phase FMVSS on which aspects of performance are most critical and how to create scenarios for and conduct related tests.

Some of these requirements could be validated by NHTSA by riding in the vehicle within its ODD, like a human driver's test, and some (e.g., fault response) could be demonstrated on a closed course. Still others might best be validated using simulation.

Waymo believes that virtual testing through simulation will have to be part of any such regime, given the technical, logistical, and financial difficulty involved in doing physical tests to validate performance in many scenarios that may be critical for the ADS's performance of the entire DDT in its ODD. Among the many regulatory challenges is how best to validate the use of simulation tools that are themselves used to validate safe performance in some scenarios.

Where physical tests are appropriate, NHTSA may be able to perform confirmatory testing on some of these requirements by obtaining vehicles from manufacturers and testing them itself. However, the agency would also need to be willing to perform tests at the manufacturer's facility and perhaps with the cooperation of the manufacturer. All Level 3 and 4 ADSs will have ODDs that may be difficult and costly to replicate beyond the actual ODD or manufacturer test facility. Tests performed with the cooperation of the manufacturer at its facility and/or on public roads in the appropriate ODD can be designed to be every bit as objective and repeatable as a test conducted at a NHTSA facility or contractor's test site.[35]

The establishment of an advisory committee to recommend how to approach subsequent rulemaking phases may also be helpful. Representatives of industry, safety advocates, and other knowledgeable groups might be able to reach consensus recommendations that address the full spectrum of ADS safety. Such a committee might logically have two wings, one focused on

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[35] Waymo shared its views on how to address compliance verification testing for ADS-dedicated vehicles in earlier comments to NHTSA (*see* NHTSA-2019-0036-0083). While those comments were focused on such testing for AVs that are not equipped with traditional manual controls, much of what Waymo wrote is relevant also for AVs that are equipped with traditional manual controls.

non-commercial AVs and one focused on automated commercial motor vehicles (where the interest groups and issues may differ from the non-commercial setting).

Waymo appreciates the opportunity to offer our views on this thoughtful rulemaking. Developing a framework for ADS safety is a reasonable next step in the agency's regulatory approach for AVs. If it takes a prudent, phased approach, NHTSA simultaneously can identify and safeguard against potential safety risks, increase public confidence in AVs, provide manufacturers with necessary regulatory certainty, and advance the considerable safety and mobility benefits this technology can provide the American public. Despite filing after this proceeding's comment deadline, we hope that the agency will give our comments all due consideration.

Sincerely,

/s/ Daniel Smith
Daniel Smith
Assistant General Counsel (Regulatory)

/s/ David Quinalty
David Quinalty
Head of Federal Policy and Government Affairs

/s/ Allison Drutchas
Allison Drutchas
Senior Counsel, Product and Regulatory

Appendix A. Responses to Specific Questions

Note: In the answers below, "explained above" indicates that the subject is addressed in the text of these comments preceding these responses.

Questions About a Safety Framework

- Question 1. Describe your conception of a Federal safety framework for ADS that encompasses the process and engineering measures described in this document and explain your rationale for its design.
    - Answer: Explained above.
- Question 2. In consideration of optimum use of NHTSA's resources, on which aspects of a manufacturer's comprehensive demonstration of the safety of its ADS should the Agency place a priority and focus its monitoring and safety oversight efforts and why?
    - Answer: Explained above. In short, Waymo believes that an FMVSS requiring a safety case for the ADS should be the agency's priority.
- Question 3. How would your conception of such a framework ensure that manufacturers assess and assure each core element of safety effectively?
    - Answer: Explained above. A safety case is designed to do just that.
- Question 4. How would your framework assist NHTSA in engaging with ADS development in a manner that helps address safety, but without unnecessarily hampering innovation?
    - Answer: Explained above. A phased approach to regulation would address the safety need without hampering innovation.
- Question 5. How could the Agency best assess whether each manufacturer had adequately demonstrated the extent of its ADS' ability to meet each prioritized element of safety?
    - Answer: Explained above. A safety case would allow NHTSA to assess whether the manufacturer had adequately demonstrated the ADS's performance capabilities. NHTSA could seek additional documentation of those capabilities as necessary.
- Question 6. Do you agree or disagree with the core elements (i.e., "sensing," "perception," "planning" and "control") described in this document? Please explain why.
    - Answer: Explained above.
- Question 7. Can you suggest any other core element(s) that NHTSA should consider in developing a safety framework for ADS? Please provide the basis of your suggestion.
    - Answer: Explained above.
- Question 8. At this early point in the development of ADS, how should NHTSA determine whether regulation is actually needed versus theoretically desirable? Can it be done effectively at this early stage and would it yield a safety outcome outweighing the associated risk of delaying or distorting paths of technological development in ways that

might result in forgone safety benefits and/or increased costs?

- Answer: Explained above. We think a phased approach to regulation in which the regulatory burden imposed in each phase is commensurate with the safety need would not interfere with delivery of the substantial safety benefits that ADS deployment promises to bring.

- Question 9. If NHTSA were to develop standards before an ADS-equipped vehicle or an ADS that the Agency could test is widely available, how could NHTSA validate the appropriateness of its standards? How would such a standard impact future ADS development and design? How would such standards be consistent with NHTSA's legal obligations?
  - Answer: Explained above. Agency testing of any Level 3 or 4 system may need to occur in that system's actual ODD or at the manufacturer's test site. Such tests can be just as objective as tests performed at NHTSA's own test sites.
- Question 10. Which safety standards would be considered the most effective as improving safety and consumer confidence and should therefore be given priority over other possible standards? What about other administrative mechanisms available to NHTSA?
  - Answer: Explained above in the discussions of a first phase and subsequent regulatory phases.
- Question 11. What rule-based and statistical methodologies are best suited for assessing the extent to which an ADS meets the core functions of ADS safety performance? Please explain the basis for your answers. Rule-based assessment involves the definition of a comprehensive set of rules that define precisely what it means to function safely, and which vehicles can be empirically tested against. Statistical approaches track the performance of vehicles over millions of miles of real-world operation and calculate their probability of safe operation as an extrapolation of their observed frequency of safety violations. If there are other types of methodologies that would be suitable, please identify and discuss them. Please explain the basis for your answers.
  - Answer: No set of rules currently exists that could be used to comprehensively test ADS safety. However, a safety case thoroughly examines the processes and metrics used by the manufacturer/developer in designing and validating the safety of its ADS. As later phases of an ADS safety FMVSS are developed, scenario-based tests can be devised to include relevant metrics for successful performance of each test. Statistical methods relying on lagging indicators of ADS performance will have to await sufficient mileage accumulation to produce meaningful measures.
- Question 12. What types and quanta of evidence would be necessary for reliable demonstrations of the level of performance achieved for the core elements of ADS safety performance?
  - Answer: Please see the answer to Questions 5 and 11.
- Question 13. What types and amount of argumentation would be necessary for reliable

and persuasive demonstrations of the level of performance achieved for the core functions of ADS safety performance?

- Answer: Explained above. A safety case approach includes argumentation and evidence to support each safety claim made with regard to the ADS. The types and amount of evidence would vary with each particular aspect of safety.

B. Question About NHTSA Research

- Question 14. What additional research would best support the creation of a safety framework? In what sequence should the additional research be conducted and why? What tools are necessary to perform such research?
  - Answer: Useful areas of research include: methods for validation of simulation tools used to validate ADS safety performance; research into the most likely types of ADS failure or intended function shortcomings that could lead to high severity crashes; and research to determine how the agency might facilitate representative crash reconstructions for use in simulation, as was done in Waymo's paper on simulated driving behavior in its ODD.[36]

C. Questions About Administrative Mechanisms

- Question 15. Discuss the administrative mechanisms described in this document in terms of how well they meet the selection criteria in this document.
  - Answer: Explained above.
- Question 16. Of the administrative mechanisms described in this document, which single mechanism or combination of mechanisms would best enable the Agency to carry out its safety mission, and why? If you believe that any of the mechanisms described in this document should not be considered, please explain why.
  - Answer: Explained above.
- Question 17. Which mechanisms could be implemented in the near term or are the easiest and quickest to implement, and why?
  - Answer: Explained above. An FMVSS focused on the elements of a required ADS safety case would be the quickest mandatory mechanism to ensure that ADSs do not present unreasonable risks to safety. Subsequent phases could add more traditional requirements if the safety need requires such measures in later years.
- Question 18. Which mechanisms might not be implementable until the mid or long term but might be a logical next step to those mechanisms that could be implemented in the near term, and why?
  - Answer: Explained above. Scenario-based testing, perhaps limited to critical scenarios, could be a logical next step in the future after a safety case FMVSS.

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[36] *Waymo Simulated Driving Behavior in Reconstructed Fatal Crashes within an Autonomous Vehicle Operating Domain*, March 2021.

- Question 19. What additional mechanisms should be considered, and why?
    - Answer: Explained above.
- Question 20. What are the pros and cons of incorporating the elements of the framework in new FMVSS or alternative compliance pathways?
    - Answer: Explained above.
- Question 21. Should NHTSA consider an alternative regulatory path, with a parallel path for compliance verification testing, that could allow for flexible demonstrations of competence with respect to the core functions of ADS safety performance? If so, what are the pros and cons of such alternative regulatory path? What are the pros and cons of an alternative pathway that would allow a vehicle to comply with either applicable FMVSS or with novel demonstrations, or a combination of both, as is appropriate for the vehicle design and its intended operation? Under what authority could such an approach be developed?
    - Answer: Explained above. An FMVSS requiring an ADS safety case is an alternative regulatory path that could allow for flexible demonstrations of competence with respect to the core functions of ADS safety performance. The research needed to support a more traditional scenario-based compliance verification testing approach could occur in parallel with the implementation of a safety case FMVSS, eventually leading to a more traditional FMVSS to supplement a safety case FMVSS if necessary to address the actual safety need.

D. Questions About Statutory Authority

- Question 22. Discuss how each element of the framework would interact with NHTSA's rulemaking, enforcement, and other authority under the Vehicle Safety Act.
    - Answer: Explained above. We believe that an FMVSS requiring a comprehensive ADS safety case is consistent with the Safety Act.
- Question 23. Discuss how each element of the framework would interact with Department of Transportation Rules concerning rulemaking, enforcement, and guidance.
    - Answer: Every alternative Waymo recommends is consistent with current DOT rules and guidance.
- Question 25. If you believe that any of the administrative mechanisms described in this document falls outside the Agency's existing rulemaking or enforcement authority under the Vehicle Safety Act or Department of Transportation regulations, please explain the reasons for that belief.
    - Answer: We do not believe that any of the mechanisms described in the ANPRM fall outside NHTSA's authority.
- Question 24. If your comment supports the Agency taking actions that you believe may fall outside its existing rulemaking or enforcement authority, please explain your reasons for that belief and describe what additional authority might be needed.

- Answer: We do not support or recommend any agency actions that fall outside NHTSA's current authority and have explained above how our recommended approach (starting with a safety case FMVSS) fits within that authority.