



April 1, 2021

Dr. Steven Cliff,
Acting Administrator,
National Highway Traffic Safety Administration
U.S. Department of Transportation
West Building, Ground Floor, Room W12-140
1200 New Jersey Avenue S.E.
Washington, D.C. 20590

Dear Acting Administrator Cliff,

Aurora appreciates the opportunity to respond to the National Highway Traffic Safety Administration's (NHTSA) Advanced Notice of Proposed Rulemaking (ANPRM) on the development of a framework for Automated Driving System (ADS) safety (Docket No. NHTSA-2020-0106). Aurora welcomes the opportunity to comment on how a framework developed by NHTSA should ensure motor vehicle safety, including methods for assessing manufacturers' efforts to ensure safety, while also providing sufficient flexibility for new and effective safety innovations.

Aurora's mission is to deliver the benefits of self-driving technology safely, quickly, and broadly. We are building the Aurora Driver, a platform that combines hardware, software, and data services that allows vehicles to move people and goods safely and efficiently through the world. When complete, the Aurora Driver will enable a transportation ecosystem, bringing together automakers, truck manufacturers, logistics services, mobility services, and fleet management providers to deliver the benefits of self-driving technology to a wide segment of the population.

There were 36,096 fatalities in motor vehicle crashes in the U.S. in 2019¹ and that number is projected to have increased in 2020²; that status quo is not acceptable. We're motivated to build this technology because we want to reduce crashes, injuries, and fatalities. Safety is our first priority when it comes to developing the Aurora Driver. You can see that in everything we do, from the people we hire to the way we develop and test our technology.

At Aurora, our technology is continuously evolving, and we are simultaneously expanding and refining our safety case, safety management system, and safety culture. Furthermore, the industry is actively developing consensus standards and best practices related to ADS safety through a variety of collaborative efforts.

Aurora acknowledges that collecting the necessary data, and assisting with the development of industry standards to support a performance-based regulatory framework for ADS safety, will require at least 5-10 years of focused activities by the Agency. In preparation for future regulatory action, we believe NHTSA could best support ADS development by providing guidance, conducting research, and fostering collaboration among ADS developers, partner agencies, and stakeholders.

We recommend that NHTSA continue developing a performance-based regulatory framework for ADS safety by considering a variety of approaches to objectively test and evaluate ADSs at the vehicle level. We strongly support NHTSA's efforts to develop a technology-neutral approach to guiding and regulating self-driving technology and to ensure a level playing field for all self-driving technology developers.

Our response generally addresses the key questions cited in the ANPRM and is structured as follows:

¹ NHTSA, 2019 Roadway Fatalities Report, <https://www.nhtsa.gov/press-releases/roadway-fatalities-2019-fars>

² NHTSA, Traffic Safety Facts, <https://crashstats.nhtsa.dot.gov/Api/Public/ViewPublication/813004>

- Aurora's Approach to Self-Driving;
- Aurora's Safety Framework;
- Industry Standards Activities for ADS;
- Potential Research Topics for ADS;
- Administrative Mechanisms; and
- Streamlining the FMVSS Exemptions.

Aurora's Approach to Self-Driving

We founded Aurora because we saw the opportunity to safely accelerate the adoption of self-driving technology. We're building a robust transportation ecosystem by partnering with automakers, truck manufacturers, transportation networks, and fleet management companies to deliver the benefits of our technology broadly. At the core of this ecosystem is the Aurora Driver, our self-driving technology that combines hardware, software, and data services to enable vehicles to move people and goods safely through the world.

Our mission is to deliver the benefits of self-driving technology safely, quickly, and broadly. Safety is at the core of everything we do—we take an enterprise approach to safety, integrating safety considerations into all facets of the business. This holistic approach ensures that safety is ingrained throughout the entire process, from initial concept to deployment.

The Aurora Driver is designed to be vehicle-agnostic, meaning it can be deployed across a variety of vehicle platforms and in various settings, from Class 8 trucks delivering goods on rural roads to passenger vehicles conducting ride-sharing in dense urban settings. This multi-industry and unified-platform approach to deploying self-driving technology demonstrates the need for a coordinated federal framework for ADS safety. Aurora strongly believes that federal, state, and local government agencies are our partners when it comes



to safely and successfully deploying self-driving vehicle technology.

Aurora's Safety Framework

Aurora prioritizes safety throughout our culture, processes, programs, training, partnerships, and technology. We are creating robust safety cases to manage our product development and deployment, and we promote a positive safety culture that is supported by our leadership, core values, and employee engagement.

A safety case framework provides a generalized structured approach to addressing safety issues implicated by self-driving technology across various development stages and use cases. It typically incorporates safety elements from federal and state guidance, industry standards and best practices, and the organization's internally developed requirements, including policies, test results, and procedures. Taken together, these elements provide a clear and defensible argument that the ADS is acceptably safe. The safety case is also a useful tool to evaluate a company's overall efforts to promote safety by providing insight into the organization's safety culture and the development process. Aurora believes that a safety case is an approach that can help a developer understand how different aspects of safety are considered and implemented in their development and deployment efforts.

At Aurora, we believe that a clearly documented argument—along with the full complement of supporting claims, sub-claims, and verified evidence for all claims—is the most sensible and comprehensive approach to demonstrating the safety of the ADS. In the near-term, we are implementing an internal safety case framework to ensure that our safety management system and our engineering and development of the Aurora Driver are aligned with our safety goals. We are incorporating both published and emerging industry best practices and standards in our development and testing processes.

We are committed to sharing our safety case framework with stakeholders, including



NHTSA, the industry, and the general public, and intend to engage in technical discussions with the agency and its partners. It is important that we continue building a safety case framework collaboratively while the technology is in development.

Organizational Safety Management Approach

Aurora's organizational safety management approach focuses on four key components: a detailed Safety Risk Management structure, a robust Safety Assurance program, disciplined documentation of our Safety Policy, and strong execution of our Safety Promotions and Education programs. These components shape employee engagement and, most importantly, our engineering decisions to control risk while promoting a positive safety culture. Each component plays an important role in cultivating a strong and effective company-wide safety program.

A safety management system (SMS) ensures effective safety controls are developed and remain in place to manage safety risk and to mitigate the risk of our on-road operations. Stand-alone practices, like a standard about the way engineers might build a specific part of a vehicle, can't guarantee the safety of all of the components that an organization-wide safety approach should encompass. This is why the scope of the SMS goes beyond engineering safety practices that ensure proper testing and reliability of individual components.

Industry Standards Activities for ADS

Aurora believes that the development of ADS technologies should follow a similar trajectory as past innovative automotive technologies, like air bags, where the research and development of key concepts precedes the development of industry consensus standards. Ultimately, these industry consensus standards should be used as the basis to develop



specific ADS Federal Motor Vehicle Safety Standards (FMVSS).

We appreciate that NHTSA highlighted the following ADS safety assurance approaches in the ANPRM:

- Engineering measures, which use system level testing to establish safety performance; and
- Process measures, which seek to manage safety risk in the design, development, and testing of ADS.

We support the work being done to advance the state of the art in safety assurance by developing safety models and metrics. To date the publicly available work on the safety efficacy of these models and metrics has been mostly theoretical (i.e., formal mathematical proofs) and not fully supported by the available data. NHTSA should consider supporting research into how these metrics could be applied across a variety of operational design domains (ODDs) and identify gaps in how these safety models and metrics link to ADS safety.

Two additional activities that should be considered in the category of engineering measures include the Automated Vehicle Safety Consortium (AVSC) and the IEEE P2846 Working Group.

- AVSC has developed six best practices, which cover terminology and key concepts that help align the industry and contribute to a framework for ADS safety. Furthermore, the most recent “Best Practice on Metrics and Methods for Assessing Safety Performance of Automated Driving Systems (ADS)”³ identifies a foundational set of common, system-level metrics that can be used as part of an ADS developer's aggregate safety performance assessment.

³ AVSC, Best Practices, <https://avsc.sae-itc.org/#roadmap>

- The IEEE P2846, “Assumptions for Models in Safety-Related Automated Vehicle Behavior,”⁴ Working Group is developing a standard that will describe the minimum set of reasonable assumptions used in foreseeable scenarios to be considered for road vehicles in the development of safety-related models that are part of an ADS. This standard will promote industry consensus on the key road user attributes that ADS should consider to operate safely.

Aurora agrees that the process measures NHTSA identifies in the ANPRM, which include ISO 26262, ISO 21448, and UL 4600, all have a role to play in the safe development of ADSs. At Aurora, our safety processes and analysis are consistent with and informed by aspects of ISO 26262 and ISO 21448; however, these standards are not solely sufficient to ensure safety for a level 4 ADS. For example, ISO 26262 provides a valuable foundation for our internal analyses at the component level, but it does not sufficiently identify and control hazards for a system of systems, like the Aurora Driver, as well as unique hazards present in the defined ODD. Also, in recognition of the challenges associated with developing ADSs, both ISO 21448 and UL 4600 are currently going through an update cycle with new versions anticipated in 2021. Parts of the standards are currently combined with our own internally-developed processes and analyses to ensure the safe design and development of the Aurora Driver.

We leverage aspects of UL 4600 as part of our safety case framework, and we expand on areas that are not sufficiently developed in the standard or are absent. For example, we believe testing the Aurora Driver with trained vehicle operators is an important part of the progression toward full and safe autonomy. UL 4600 is predominantly focused on driverless operations, whereas we believe the safety case framework for ADS development must also include the organization’s progression through supervised operations.

NHTSA requests comments on how these three standards could be used as part of a safety

⁴ IEEE SA, P2846, <https://sagroups.ieee.org/2846/>

assessment framework by the Agency. In Aurora's view, these standards are helpful for developers, but in their current form they are not performance-based and lack objective criteria and tests that could be used to verify conformance under NHTSA's existing self-certification approach. Further, a significant amount of interpretation is needed by each ADS developer in order to apply these standards to their specific ADS use case (e.g., goods delivery or rideshare). NHTSA could provide more direction on the potential utility of these standards and whether they could be used as part of a framework for ADS safety.

Gaps in ADS Industry Standards

The current state of the technology is characterized by controlled testing and localized deployments in select cities and states, which will then be followed by widespread deployment and commercialization. As such, gaining industry consensus on best practices and standards is currently challenging; however, the industry continues to move forward in specific technical areas where broad consensus can be achieved. Despite that progress, the current standards (covered in the previous section) have technical gaps, and the existing best practices and standards do not cover all necessary substantive areas. Some topical areas we have identified with key technical gaps include:

- **Vulnerable Road User Interactions:** This is a challenging area for ADS developers in terms of the behavioral assumptions, potential communications with vulnerable road users (VRUs), and optimal ADS behavior. There is still much work to be done to explore how VRU interaction research can support safety, equity, and mobility goals.
- **Safety Performance Metrics:** While there has been some work in the industry to identify potential performance metrics, there is still much work to be done to demonstrate that these potential metrics are strong leading indicators of safety performance.
- **Remote Assistance:** Standards do not yet address the role of remote driving, remote

assistance, and remote monitoring in regards to ensuring the safety performance of an ADS, especially in light of emerging telecommunications technologies.

At Aurora, we will continue to identify these gaps and work through various industry standards development organizations to develop potential industry standards or best practices. For example, we are members of AVSC and participate in industry standards development activities with SAE, IEEE, and Underwriter's Laboratories. These gaps also present an opportunity for NHTSA to leverage federal research funding to help accelerate, inform, and seed the development of industry best practices and standards.

Potential Research Topics for ADS

There are several areas where we believe NHTSA could help address common challenges across the industry through the focused application of federal research initiatives. In this section we propose potential research areas for consideration.

Emerging Standards Framework and Gap Analysis

NHTSA could identify and organize emerging standards, which would provide valuable insights to ADS developers interested in participating in or leveraging insights from the standards development process. Developing an organizational structure for the various standards activities (e.g., one that is aligned with the Voluntary Safety Self Assessment (VSSA) safety design elements⁵) or various industry categorizations (beyond process and engineering measures) would provide greater clarity to both industry and government stakeholders. A by-product of the organizational approach is that it would better facilitate the identification of potential gaps among the various ADS standards. This activity would also inform potential future NHTSA research topics, based on the gaps identified and the

⁵ NHTSA, Automated Driving Systems: A Vision for Safety 2.0, https://www.nhtsa.gov/sites/nhtsa.dot.gov/files/documents/13069a-ads2.0_090617_v9a_tag.pdf

rate at which industry activities are filling those gaps.

Reasonable and Foreseeable Assumptions Regarding Other Road Users

NHTSA should focus on research that will accelerate the adoption and utilization of the IEEE P2846 standard. This standard is intended to identify a set of safety-relevant driving scenarios that an autonomous vehicle may encounter in operations on public roads, and within each scenario, what minimum set of assumptions must be considered to increase driving safety. As described in the P2846 Status Report⁶, the minimum set of reasonably foreseeable assumptions defined by this standard includes properties of other road users, such as velocity v , heading h , rate of change of the heading angle \dot{h} , braking capabilities β , and response times ρ .

While IEEE P2846 will identify a minimum set of assumptions that are defined by specific parameters regarding the motion of other road users, it will not identify the ranges of specific parameter values that could be considered reasonable and foreseeable for an ADS developer. NHTSA research could accelerate industry efforts by focusing on two specific areas that would support adoption and utilization of this standard:

- Utilize historical field operational test data collected by the U.S. Department of Transportation (DOT) to identify observed ranges of values to inform ADS developers in establishing motion profiles for specific categories of road users (e.g., pedestrians, bicycles, scooters, and motorcycles).
- Conduct research that would explore potential processes for establishing a reasonable range of parameter values for a specific use case and ODD and

⁶ IEEE, P2846 Status Report, <http://sagroups.ieee.org/2846/wp-content/uploads/sites/124/2021/02/IEEE-P2846-Status-Report-2-July-December.pdf>

demonstrate the process through a reference implementation.

Industry-Government Collaborative Roadmap

Developing a framework for ADS safety would benefit from a coordinated approach between industry and the federal government. While other entities may have tried to implement this, they lack the convening power of NHTSA. As such, NHTSA could consider collaboratively developing, with ADS developers and industry stakeholders, a roadmap that captures and helps coordinate the multitude of concurrent activities underway, including:

ADS Emerging Standards

Numerous standards development organizations continue to evolve and mature a set of standards that support ADS safety. Leaders from relevant committees, working groups, and task forces could provide valuable insights regarding the scope and timing of key products from their organizations that NHTSA could then publish or reference.

ADS Developer Internal Safety Frameworks

Aurora and other ADS developers are developing safety case frameworks and safety determination processes and publicly sharing those approaches, which contribute to the state-of-the-art for ADS safety. NHTSA could summarize these initiatives for broad awareness in their comprehensive roadmap and also further evaluate the utility of these approaches in future research activities.

Federal-Led Research Agenda

Multi-modal research activities aimed at addressing common challenges facing all industry developers of ADS could inform the framework for ADS safety. The results of this key research would inform the foundational standards, as well as support the



validation of internal ADS developer safety frameworks.

Federal-Led Voluntary Initiatives

The progression of voluntary initiatives, such as updates to the NHTSA AV guidance and the evolution of the VSSA and the AV Test program should also be included in the federal research roadmap. These initiatives provide important opportunities for the industry to collaborate. NHTSA should continue to enhance these programs based on feedback from the industry.

The development of such a roadmap, with appropriate input from industry, would inform NHTSA's regulatory strategy regarding ADS safety as well as prove to be a valuable tool for industry. Also, both industry and government could more accurately determine where research gaps exist and coordinate additional efforts to dedicate resources towards addressing and closing those gaps.

Administrative Mechanisms

Aurora appreciates NHTSA's decision to explore consideration of alternative or complementary mechanisms for managing risks and facilitating agency safety oversight. Prior to developing an ADS-specific FMVSS, we believe there are several ways the agency can continue maintaining safety oversight of the ADS industry, while also pursuing the necessary research, data, and industry knowledge that would serve as the foundation for any eventual FMVSSs. Specifically, NHTSA can strengthen the VSSA, which could improve public awareness and confidence in ADS technology. The Agency can facilitate collaboration externally with ADS developers and internally with its partner agencies. Additionally, NHTSA can promote and coordinate a national effort to standardize road rules, which will benefit all road users.

Strengthening the Voluntary Safety Self Assessment

We appreciate NHTSA's and the U.S. DOT's continuing development of AV policy, beginning with publication of the first "Federal Automated Vehicles Policy" in September 2016 and continuing through AVS 2.0, AV 3.0, AV 4.0, and the "Automated Vehicles Comprehensive Plan" published in January 2021. The Department's commitment to continuing the conversation on AV policies and regulations ensures ADS developers and related stakeholders share in the responsibility of developing this technology in a safe, trustworthy, and transparent manner.

The NHTSA guidance (AV 1.0⁷ and 2.0⁸) identifies ADS safety design elements and establishes the VSSA as a tool for ADS developers to use to communicate with the Agency on the safety of their systems. To date 27 ADS developers have submitted a VSSA to NHTSA for publication in their VSSA Index, including Aurora. This guidance has been a valuable tool for ADS developers since its publication in 2017, as evidenced by the number of submissions and updates. In the four years since its publication, the technology, industry standards, and best practices have advanced substantially. Given how rapidly the self-driving landscape is evolving, NHTSA should revisit these elements and consider revising or updating them.

We specifically recommend the following updates or revisions:

- Incorporate new elements and strengthen existing elements based on new development standards and best practices. For example, the Fallback element could provide additional guidance regarding how to assess the effectiveness of minimum risk conditions in the event of a fault or failure.

⁷ NHTSA, Federal Automated Vehicle Policy

<https://www.transportation.gov/AV/federal-automated-vehicles-policy-september-2016>

⁸ NHTSA, Automated Driving Systems: A Vision for Safety 2.0,

https://www.nhtsa.gov/sites/nhtsa.dot.gov/files/documents/13069a-ads2.0_090617_v9a_tag.pdf



- Elements should reference key best practices and standards as applicable, such as the six published AVSC Best Practices⁹, which cover safety drivers, ODD lexicon, emergency responder interactions, event data collection, and safety metrics.
- Develop a chapter or element in coordination with the Federal Motor Carrier Safety Administration (FMCSA) that focuses on specific considerations for heavy vehicles.
- Incorporate an Organizational Approach to Safety (i.e., a Safety Management System) element, which aligns with a best practice from AVSC.

Collaborating with ADS Developers

We appreciate NHTSA's continued willingness to engage with and provide leadership to the ADS developer community. We recommend that NHTSA convene town halls, technical meetings, and other collaborative activities among ADS developers, relevant safety advocacy groups, first responders, and local and state agencies to address key challenges facing both industry and government stakeholders. We recommend these activities occur quarterly in various locations around the U.S. (perhaps aligned with the NHTSA regional offices) to ensure broad participation. Each of these activities could focus on key themes relevant to the Agency and ADS developers, such as safety metrics, vulnerable road users, safety management system implementation, and first responder interactions. These activities would also provide a good venue to build and update a collaborative roadmap for ADS development (as discussed earlier in this response).

Collaborating with Partner Agencies

The U.S. DOT's previous guidance on automated vehicle policy has highlighted the role of numerous federal agencies in AV policy and deployment, including NHTSA, FMCSA, and the Federal Highway Administration's (FHWA) automated vehicle research efforts and an analysis of potential regulatory barriers to deployment. With the growing awareness of the

⁹ AVSC, Best Practices, <https://avsc.sae-itc.org/#roadmap>

importance of ADS for trucking, we believe that increased collaboration and coordination between these three agencies could be especially beneficial to support industry's efforts in addressing and solving some of the challenges unique to self-driving trucks.

While NHTSA has the authority to regulate the safety performance of Class 8 heavy-duty trucks, there are still many additional operational challenges that companies will likely face when removing a human driver from the cabin. For example, the requirement for Class 8 trucks to stop periodically at weigh stations for inspections poses challenges for a self-driving truck, which would need to navigate varying and changing instructions from attendants and inspectors. NHTSA could support an FMCSA effort to provide clear guidance on how states should handle weigh stations and inspections for level 4 ADSs. Furthermore, collaborative research activities between the agencies would help address some of the key barriers identified in the "Review of the Federal Motor Carrier Safety Regulations for Automated Commercial Vehicles."¹⁰

These are a few examples of where NHTSA's collaboration with FMCSA, FHWA, and other appropriate agencies could result in more clear and consistent safety requirements that would provide ADS developers with increased direction and certainty.

Coordinating a National Effort to Standardize Road Rules

There is a patchwork of road rules that exist across the country. Right now, self-driving technology is being tested in limited jurisdictions (our vehicles are on the roads in California, Pennsylvania, and Texas), so programming individual state road rules into our system is challenging but not crippling. When we and other self-driving companies want to enter all 50 states and thousands of cities, that task becomes much harder because different rules

¹⁰ FMCSA, Review of the Federal Motor Carrier Safety Regulations for Automated Commercial Vehicles

<https://www.fmcsa.dot.gov/research-and-analysis/technology/review-federal-motor-carrier-safety-regulations-automated>

require us to create different ODDs where our vehicles can safely operate.

A common set of road rules would accelerate the deployment of ADS-equipped vehicles by reducing the complexity of the ODDs that a developer has to address in their development and testing regime. Increased standardization across ODDs increases the transferability of the ADS from one ODD to another ODD that has the same defining characteristics. This streamlining would also benefit human drivers as they travel across states.

Aurora will always make sure that our vehicles operate safely regardless of the jurisdiction, but we also must ensure that our vehicles are capable of complying with all state and local traffic laws. We encourage the U.S. DOT, specifically NHTSA and FHWA, to foster the development of model road rules that states and cities could enact to ensure that all drivers, whether human or autonomous, are subject to substantially similar rules wherever they are in the United States.

We intend to continue identifying, tracking, and supporting efforts to standardize road rules. For example, we appreciate FHWA's recent efforts to update the Manual on Uniform Traffic Control Devices, which includes an acknowledgment of ADS and an intention to understand the need to standardize on-vehicle dynamic message displays. We will continue to engage with the U.S. DOT, NHTSA, FMCSA, and FHWA, along with other stakeholders to make it easier and safer for ADSs to navigate our nation's complex roadways.

Streamlining the FMVSS Exemption Process

Unlike traditional FMVSS that have clear, controlled test procedures, protocols, and pass/fail criteria, testing and validating the efficacy of an ADS is highly dependent on the ODD for which it is designed. Industry is still working to scale an ADS that demonstrates proficiency in multiple ODDs, since so much of the system's performance depends on knowledge of the roadway infrastructure, weather, and other road users within defined geographic



boundaries.

One regulatory challenge that complements the ADS regulations discussion is the FMVSS exemption process. Aurora believes that NHTSA should establish a process whereby industry may take a proactive role in identifying and aligning on common exemptions. Such a process could help NHTSA determine which exemptions are appropriate and receive broader input on their safety. It would be helpful if NHTSA published a list of areas under investigation for FMVSS exemption to help streamline the process for all developers pursuing the same or similar exemptions. Several challenges for passenger vehicles that have been discussed for exemptions include side mirrors and manual turn signals, which are designed to assist human drivers but are not needed by an ADS.

Closing Remarks

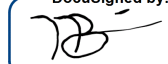
As discussed throughout, we are committed to safely developing and deploying the Aurora Driver and to ensuring NHTSA and all of our stakeholders are confident with our approach. We strongly encourage NHTSA to develop an approach to regulating self-driving technology that is technology neutral and establishes a level playing field for all developers of self-driving technology to ensure that safety-focused, innovative, job-creating companies like Aurora are not disadvantaged.

We plan to continue engaging with NHTSA and other regulators on ways that ADS developers can help promote transparency and accountability as ADSs continue to develop. We believe that ADS regulations are ultimately necessary, and we encourage NHTSA to initiate the necessary research that would serve as the foundation to enable a thoughtful, collaborative, performance-based regulatory approach. We intend to help the industry and NHTSA further clarify the capabilities of this technology and how regulations will safely support, rather than inhibit, the continued advancement of ADSs.



We believe NHTSA can take a proactive approach by focusing on the various suggestions we have outlined. We encourage NHTSA to work closely with FMCSA and FHWA to ensure all ADS guidelines, requirements, and regulations are clear, consistent, and serve to enable the safe deployment of ADS. We thank NHTSA again for providing us with an opportunity to comment on this ANPRM, and we look forward to continuing the conversation on this important topic.

Best regards,

DocuSigned by:

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Nat Beuse

VP of Safety