AMERICAN ASSOCIATION OF STATE HIGHWAY AND TRANSPORTATION OFFICIALS

AASHTO

TESTIMONY OF

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REGARDING

Deployment of Connected and Automated Vehicles; Implications for Highway System Infrastructure

BEFORE THE

Committee on Environment and Public Works of the United States Senate

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INTRODUCTION

Chairman Barrasso, Ranking Member Carper, and Members of the Committee, thank you for the opportunity to appear today and address implications for our highway infrastructure from deployment of connected and automated vehicles (CAVs).

My name is Bill Panos, and I serve as Director and CEO of the Wyoming Department of Transportation (WYDOT) and as Chair of the Committee on Transportation System Operations of the American Association of State Highway and Transportation Officials (AASHTO). I appear today on behalf of Wyoming and AASHTO, which represents the state departments of transportation (state DOTs) of all 50 States, Washington, D.C., and Puerto Rico.

I became Director of WYDOT in 2015 after 37 years leading private and public sector organizations, including engineering and leadership positions with the TRW Corporation, the Commonwealth of Massachusetts, the State of Washington, and local government.

Our testimony today emphasizes the following points, beginning with safety:

- Safety has been and always will be the ultimate priority for state DOTs, including as they invest in and manage infrastructure relating to CAV deployment;
- Both connected and automated vehicles are in our future;
- The highway infrastructure investment implications of deploying connected and automated vehicles must be recognized and addressed, including by ensuring that capital investments in infrastructure related to CAVs are eligible uses of funds under the Federal-aid highway program;
- Nationwide interoperability, including further deployment of Dedicated Short Range Communications (DSRC), is essential;
- We should achieve increased collaboration between technology developers, vehicle manufacturers, and federal, state and local agencies; and
- More federal resources should be provided for research in this area.

SAFETY HAS BEEN AND ALWAYS WILL BE THE ULTIMATE PRIORITY FOR STATE DOTS, INCLUDING AS THEY INVEST IN AND MANAGE HIGHWAY INFRASTRUCTURE RELATING TO CAV DEPLOYMENT

Safety is the most important consideration for AASHTO and state DOTs respecting highway infrastructure and the emerging deployment of CAVs. These new technologies have the potential to decrease crashes and fatalities significantly and positively influence the safety of not only vehicle occupants, but also highway maintenance and construction workers, bicyclists, and pedestrians. While the prospect for safety improvement is exciting, we are also acutely aware that this is truly innovative technology and there are still uncertainties surrounding it. Attention to safety is, of course, part of the discussion. Today we are focusing on these developments as they relate to infrastructure, including investments in infrastructure.

So, there are a wide range of issues related to CAV deployment and infrastructure to consider. Inherent in having infrastructure is that it has to be built, which means there are highway construction zones. So, among the questions highway owners are considering are:

- How will an automated driving system (ADS) navigate a temporary work zone?
- How will it handle variable speed limits (speed limits are frequently reduced in construction zones)?
- There are many other issues, including issues concerning fleets with mixed automation capabilities. Some of the more frequently raised issues are:
    - What are the signage and striping issues?
    - What advisories from DSRC enabled infrastructure would be helpful to automated vehicles and improve safety?

A better understanding of how these systems work, and the results of on-road testing showing how ADS equipped vehicles sense and respond to non-ADS equipped vehicles, would provide infrastructure agencies with useful information about how to plan infrastructure for the future. State DOTs are ready and willing to work with all stakeholders in addressing such safety issues.

But while noting these technical issues, we have not lost sight of the potential for these vehicles reduce crashes and fatalities, perhaps greatly.

BOTH CONNECTED AND AUTOMATED VEHICLES ARE IN OUR FUTURE; WHAT STATES ARE DOING NOW

There are many reasons why we are anticipating deployment of these innovative technologies. One is simply the outstanding capacity and innovative capabilities of many people in many companies. Others include consumer demand and the potential for increased safety, as human error is a factor in so many crashes. Also, many that are less mobile, such as senior citizens and people with disabilities, see CAVs as a tremendous boost to their mobility and quality of life. So, for a variety of reasons, the deployment is coming.

As the owners of a significant amount of the highway transportation infrastructure, state DOTs are at the forefront of preparing for deployment of CAVs, including ensuring that the current infrastructure is in a state of good repair such that any vehicle can operate on it in a safe and effective manner. In addition, many state DOTs are starting to plan, design, deploy, operate, and maintain the technology needed for CAVs, including vehicles equipped with ADS and vehicles connected to each other and the infrastructure.

For those who may be skeptical that investment needs in this area are growing, let me emphasize that a connected vehicle need not be an automated vehicle. Cars that are being driven by people are increasingly connected and equipped with electronics that can receive data from DSRC enabled equipment installed in or near the roadway. Such signals help a vehicle "see" in the snow or fog and provide other information. We can develop and deploy roadside infrastructure that can assist both ADS equipped vehicles and increasingly advanced non-ADS equipped vehicles.

AASHTO's member DOTs believe that establishing a strong foundation for CAVs requires robust connectedness for vehicle-to-vehicle (V2V) and vehicle-to-infrastructure (V2I) communication. The overwhelming support for the development and deployment of connected vehicle technologies is evident in the significant commitment that the states and local agencies have made in leading, supporting, and fostering the deployment and testing of CAV systems. To date, 33 locations in the US, including in my home state of Wyoming, are deploying connected vehicle technologies under sponsorship of the United State Department of Transportation (USDOT), and 17 locations are deploying the technologies without sponsorship from USDOT. Combined, this represents 72,000 vehicles on the road and 65,000 devices installed on the infrastructure.

Let me illustrate further by discussing an example.

In Wyoming, to improve safety along the 402 miles of Interstate 80 in my state, the Wyoming Department of Transportation is implementing a USDOT pilot program using DSRC enabled technology to connect vehicles to infrastructure and to other vehicles.

This corridor along the southern section of Wyoming is prone to winter crashes affecting both commercial and private vehicles. It is subjected to some of the most extreme winter weather conditions—especially blowing snow and vehicle blow overs—of any highway on the U.S. interstate system. From October 2015 to September 2016, more than 1,600 crashes occurred on I-80 in Wyoming, resulting in 18 fatalities and 271 injuries. During this period, all or parts of I-80 were closed to all vehicles for a total of over 1,500 hours—impacting not only travelers but also the trucks that make up roughly 55 percent of the state's total annual traffic stream and carry more than 32 million tons of freight across the state each year.

The Wyoming pilot program will test applications, such as advanced forward collision warnings, to let travelers know of crashes ahead. It will also provide: immediate situational awareness warnings about weather alerts, speed restrictions, parking availability, and so forth; detailed and

current work zone warnings; specialized spot weather impact warnings for ice, fog, and other hazards; and notifications from disabled vehicles.

Pilot testing with WYDOT vehicles such as highway patrol cars and snowplows occurred last winter. We will analyze this season's data, and test with commercial vehicles next winter. Other sites under the federal pilot program will test hot, humid weather (Tampa, Florida) and congestion (New Jersey/New York City) applications.

INFRASTRUCTURE INVESTMENT IMPLICATIONS OF DEPLOYING CONNECTED AND AUTOMATED VEHICLES MUST BE RECOGNIZED AND ADDRESSED

We turn now to the infrastructure implications of the emerging deployment of CAVs.

Currently, state DOTs (and other infrastructure owners) are uncertain, at least at a detailed level, which roadway characteristics are critically important to the safe and efficient operation of ADS. Aspects of ADS have been developed in the absence of significant collaboration between the infrastructure owners and technology developers. Thus, state DOTs want a clearer consensus on infrastructure needs from the technology developers.

We know some of the developers' needs in a general way. Industry has filed comments at USDOT that signage and lane marking and striping are important. One state has responded to this concern by going from 4-inch to 6-inch stripes to help the technology developers with their sensors and lane departure warning systems. Other states, however, are not as willing to modify their lane striping widths because this is seen as a major investment. They may, however, stripe more frequently, to maintain visibility. In most cases striping is a maintenance activity, not a capital activity eligible under the Federal highway program.

However, any increase in maintenance would not be without implications for a state DOT's or other transportation agency's overall budget and its ability to make other needed infrastructure investments. In these scenarios, there would be less available for capital expenditures on transportation infrastructure.

Further underscoring our interest in working with the developers, it is not clear how critical lane striping is to ADS, as many systems are not dependent upon them. Further, the relevance of striping may be limited in environments that are not ideal such as construction zones or when snow or ice obscures the lines.

Beyond striping, if ADS equipped vehicles have sensors that could be adversely impacted by poor or intermittent ride quality, that could place upward pressure on the already high need for investment in maintaining and improving pavement quality.

While respecting the developers' abilities to work to address CAV operations within today's infrastructure, AASHTO recommends and strongly desires more collaborative dialogue between the infrastructure owners and the technology developers as to infrastructure. This dialogue would

include work to better define the roadway characteristics and infrastructure elements that are critical to the efficient and safe deployment of CAVs. One approach would be to discuss and publish a list of existing data on roadway characteristics that the state DOTs can readily provide to the technology developers. This list will help the technology developers with near-term ADS applications and encourage them to identify additional data that they will need to successfully develop ADS. The state DOTs need consensus from the technology developers about what data and information is needed and that it be consistent among all technology developers. Otherwise, the state DOTs are continuing to chase the technology requirements.

In addition, there has been discussion about the consistent application of the FHWA Manual on Uniform Traffic Control Devices (MUTCD) and its ability to provide consistency throughout the United States. While conformance to MUTCD already takes place, many states and localities provide exceptions to the MUTCD for various reasons. Strict adherence to the MUTCD may be desirable from the perspective of ADS developers, but the reality is that there will always be exceptions that must be accounted for. In addition to these exceptions, there will also be instances of storms or incidents knocking down and damaging signage along the roadway, and snow and debris can obscure lane stripes. State DOTs aim to repair and replace damaged signs and striping as quickly as possible, but may not be able to do so on a timeline needed by technology that relies on signage and striping alone for ADS operations.

Another priority is the deployment of ADS and more robust connected vehicle infrastructure in rural environments. State DOTs and many counties own the rural highways which, due to their longer routes, need different solutions, such as more reliance on cellular technology. As there are rural areas of the nation that still do not have adequate cell phone service, we need to ensure rural connectivity in deployment of CAVs.

We view the potential highway capital costs associated with CAV deployment, such as V2I and related signage, as already eligible uses of a state's apportioned funds under the Federal-aid Highway Program. However, to the extent that any type of highway capital cost related to servicing CAVs comes to the attention of the Committee as not eligible under the current program, the additional eligibility should be provided.

State DOTs are committed to maintaining their assets in as good a condition as possible given the resources available to them. At this point, state DOTs do not know what, or if, minimum conditions are needed for ADS to operate effectively or what the minimum condition levels should be. The state DOTs look forward to working with other public and private sector partners in updating the practical meaning of state of good repair in a world of deployed CAVs.

As noted earlier, providing alerts to CAVs as to weather, traffic, work zones and other advisories has implications for investment in DSRC enabled equipment deployments as part of the infrastructure. Simply put, because we want our vehicles to have such information, we will need to invest to make that possible.

And, importantly, there are potential savings from deployment of CAVs. Some see the potential for narrower lanes or shoulders, for example, due to more precise driving by ADS vehicles.

Also, there is the potential for improved throughput. ADS equipped vehicles may need shorter separation between vehicles. CAVs may also be able to take better advantage of improved traffic light technology to improve vehicle throughput. More specifically, AASHTO is supporting a national traffic signal phasing and timing (SPaT) program that heavily leverages V2V and similar technologies to improve traffic flow and reduce crashes. Through the SPaT Challenge, AASHTO is hoping to achieve the deployment of V2I infrastructure with SPaT broadcasts at roadway intersections in at least one corridor or network in each of the 50 states and Washington, DC by January 2020. Individual states are also working to comprehensively improve traffic signals in similar ways.

NATIONWIDE INTEROPERABILITY, INCLUDING FURTHER DEPLOYMENT OF DEDICATED SHORT RANGE COMMUNICATIONS, IS ESSENTIAL

In general, state DOTs see significant benefits—in both directions—from sharing with developers detailed digital maps and dynamic traffic information such as alerts about nearby vehicles, pedestrians and bicyclists, weather, and lane availability associated with incidents and construction projects. To achieve these benefits would involve the two-way exchange of data between the vehicles and infrastructure. Some of the data discussions needed to achieve this are going on through the development of Society of Automotive Engineers (SAE) standards, the Connected Vehicle Pooled Fund Study, and the V2I Deployment Coalition.

Information exchange must address connectivity between the vehicles and the roadside infrastructure. Without the digital infrastructure and data, ADS operability that is reliant on information from roadside equipment would essentially become non-functional. AASHTO believes that vehicle connectivity enhances and expands the safety and mobility benefits of ADS by providing information that the vehicle sensors cannot "see" and important redundancy of information that the sensors can "see." When dealing with life-safety issues, redundancy can be a solution, not a problem.

In discussing some of the technical aspects of interoperability, let me note that our purpose is not to comment on vehicle-specific issues, but to describe the background against which a state or other infrastructure owner would decide to make an infrastructure investment by deploying DSRC enabled equipment along a road.

Digital infrastructure at its basic level includes the hardware and software associated with applications and communications, and is typically identified as being either on-board equipment if it’s contained within the vehicle or road side equipment if it exists as part of the roadway network. Both applications and communications can be defined to exist in environments described as isolated (i.e., a remote roadside weather information system), local (i.e., signal system on a corridor), area wide (i.e., capturing vehicle responses in adverse driving conditions such as activating windshield wipers or having automatic braking systems engaged and sharing that information with other vehicles or roadside units within a designated area), regional (cellular wireless access, sharing traveler information) or even global (GPS) infrastructure.

This digital infrastructure serves as the conduit by which data can be consumed and acted upon by the ADS. So, standards for both infrastructure and vehicle would make this work, especially when dealing with different original equipment manufacturers.

Two interfaces for V2I information transfers are available today: 4GLTE for non-time-critical data and dedicated short range communication (DSRC) for low-latency applications. We believe both approaches need to be leveraged, and both should use the same data definitions and standards in SAE J2735. The challenge with cellular data, to date, has been that most of the transmissions have been through corporate-specific clouds (generally not open to data sharing between various manufacturers) and are based on a fee-for-service arrangement, limiting the data to those willing and able to pay the fee. We believe this is not the appropriate model to facilitate broad increases in safety for all users.

The advantage of DSRC is that it is very fast, which is essential for many safety applications, and is fee-free. We applaud the USDOT for spending considerable effort developing, testing, and proving the DSRC medium, including encouraging its use in many test beds and deployments. Because of its benefits, we encourage a continuation of support for this medium. While other mechanisms, such as 5G, promise great advantages, we encourage the USDOT to require that those data transmissions be company-agnostic (available to all vehicle brands and types), free from user fees, and fully backwards compatible with current messages. If this is not the case, safety benefits will be limited, and the large investments currently being made by government in available technologies will be diminished. So, we see interoperability across technologies as essential.

Regarding data transmission, it should be in a format that can be easily consumed on multiple fronts for sharing without any need for translation. In the scenario where the on board equipment provides information to the road side equipment, that information should be easily translated to other potential users or applications (i.e., traffic operations centers or advanced traffic management systems). Beyond data format, specific kinds of information that would enhance safe and efficient operations would include those associated with service packages identified in the national architecture, such as weather, construction, maintenance, road conditions, and advisories.

While we believe accelerating ADS deployment would best be determined by the system developers, it would be helpful to infrastructure owners to have in advance of deployment a solid understanding of an ADS operation design domain. For example, if the relationship between the algorithms and the mechanical systems controlling the dynamic driving functions has operational limits (i.e., can't assume steering control at certain speeds and/or under certain road conditions or terrain), that should be shared with other users so they too would know when they're approaching being beyond their respective design limits well in advance of it occurring. More collaboration among public sector agencies and private sector developers would better address this.

In terms of types of operations data needed by ADS, there are numerous examples, including roadway characteristics (pavement type, geometric design, condition), signal phasing and timing, work zone information (when, where, duration, type), incidents information, weather conditions, and current traffic characteristics (speed, volume, type).

On the other hand, ADS could provide valuable transportation planning data, such as ridership, occupancy, origin/destination, and, potentially, roadway maintenance data (pavement/paint/sign condition). If original equipment manufacturers were able to provide this type of information at the individual vehicle level, state DOTs may be able to redirect significant resources for other purposes such as better maintaining the infrastructure rather than data collection.

To elaborate, a significant amount of variable information and data could be provided to ADS by state DOTs. But it needs to be done in a way that connects effectively to the vehicle. For example:

- Is it enough to know the beginning and end of work zone location or does it also need to include more data due to construction or maintenance activities? For example, work zone configuration can change multiple times in a day and can be affected by weather conditions.
- How much information does the vehicle need and how detailed is that information? This also has implications for setting up and operating work zones.
- For weather-related roadway impacts such as standing water, snow, and wind impacts, how much detail must be provided to an ADS vehicle?
- As to vertical or horizontal limitations such as low bridges and temporary wire crossings, how would the infrastructure best provide that information?

State DOTs need to understand the data needs of the ADS and how to provide data in a consistent format, frequency and reliability that meets the needs of ADS. However, with hundreds of thousands of lane miles to cover, providing fast, up-to-date data can be an expensive, technical challenge.

State DOTs support nationwide interoperability while still maximizing flexibility and cost effectiveness for ADS technology developers and transportation agencies and minimizing threats to cybersecurity and/or privacy. In general, maximizing flexibility and cost effectiveness must include a consideration for standards that are open source (allowing for improvements), as well as establishing data definitions and associated priorities of those definitions, and identifying what's needed for operational functionality and what's not needed.

ACHIEVE INCREASED COLLABORATION BETWEEN TECHNOLOGY DEVELOPERS, VEHICLE MANUFACTURERS, AND FEDERAL, STATE AND LOCAL AGENCIES

Infrastructure owners and operators want more information from the automakers about what infrastructure elements they need in order to be successful. The advent of ADS and connected technology represents a new paradigm in the relationship between these two segments of the

transportation community. We recognize that automakers work in a very competitive environment, and may be challenged to reach consensus on their needs. Similarly, road agencies range in size and capability and don't often speak with a uniform voice. However, if we are to provide infrastructure that supports these new technologies, both physical and digital infrastructure, clearer guidance from the automaker industry would be helpful. There are examples of this collaboration taking place now, such as the V2I Deployment Coalition and AASHTO's Cooperative Automated Transportation (CAT) Coalition, but this collaboration should be greatly expanded to include broader and active participation from the private sector as well as more public sector agencies.

We see three key areas where infrastructure owners should work more closely with ADS developers. First, is standard-setting. AASHTO appreciates that it is not efficient for vehicle manufacturers to have to address a patchwork of state-based policies, laws and regulations that are not consistent or coordinated with each other. In addition, USDOT needs to be actively involved in engaging the public and private sectors in developing national standards for infrastructure and ADS because requirements for infrastructure readiness should be the same across state boundaries so an ADS vehicle can function well anywhere in the country. We ask for consensus from the technology developers and the infrastructure owners to develop these needed standards.

With this being said, it is important to AASHTO that any policy, laws, regulations or guidance do not disrupt the current authority given to states to license the driver of the vehicle or the registration of vehicles. Historically, the regulation concerning the design, construction, and performance of a motor vehicle is a federal obligation that has been under the oversight of the National Highway Traffic Safety Administration (NHTSA) through the Federal Motor Vehicle Safety Standards. The licensing of motor vehicle operators, registration of vehicles, and enforcement of traffic laws has been the domain of states. The development of ADS has the potential to disrupt this separation of design versus operation whereby motor vehicles are no longer driven by a person but by the ADS, and important questions about design, regulation, and certification of complex computer systems must be addressed. The state DOTs believe that these questions, and many others, will be most effectively addressed collaboratively among Federal, state, public and private stakeholders. Already, there are examples of this cooperation happening on a regional basis. For example, the I-95 Corridor Coalition, comprised of 16 states along I-95, has begun to broach this issue by bringing states together to discuss regional strategy and bridge the gap by forming a regional group to establish a regional path forward.

Second, it is important that this engagement be done in partnership with state and local agencies and other private sector partners who own and operate the transportation infrastructure. There are existing structures in place—such as the V2I Deployment Coalition, the Connected Vehicle Pooled Fund Study, and the Collision Avoidance Metrics Partnership—that bring together state and local DOT representatives, research partners, USDOT, auto industry, original equipment manufacturers, and technology vendors. In addition, we would like to see more engagement from non-traditional, original equipment manufacturers.

Finally, in addition to supporting the dialogue with technology developers and asset owners, AASHTO recommends additional federal funding for building new testbeds and maintaining existing ones, with the industry and technology developers testing their hardware and applications on such testbeds. This will enable infrastructure owners and technology developers to better understand each other's requirements. That should lead to better standards and, ultimately, better infrastructure.

A particular and important example of the need for States to understand the operations, so that they can provide better infrastructure, is in the area of data provided via dedicated short range communications (DSRC), which is discussed elsewhere in this statement.

PROVIDE ADDITIONAL FEDERAL RESOURCES FOR RESEARCH

Before closing, let us touch on research needs in this area. Already, there are many research and deployment activities underway in information interface needs and standards, such as SAE J2735 messages, new message standards, equipment deployment and interoperability. At AASHTO, these developments are occurring in a number of places, including the:

- V2I Deployment Coalition,
- Cooperative and Automated Transportation Coalition,
- National Operations Center of Excellence, and
- NCHRP 20-102: Impacts of Connected Vehicles and Automated Vehicles on State and Local Transportation Agencies.

Of particular note concerning existing research activities is the NCHRP 20-102 task order contract administered by the Transportation Research Board. The purposes of this contract are to: identify critical issues associated with connected vehicles and automated vehicles that state and local transportation agencies and AASHTO will face; conduct research to address those issues; and conduct related technology transfer and information exchange activities. This program has been instrumental in moving forward with deployment of connected and automated vehicles. Projects have covered a wide breadth of issues ranging from impacts of regulation and policies on Connected and automated vehicle introduction in transit operations (Task 02) to the implication of automated vehicle on motor vehicle codes (Task 07) to data management strategies (Task 14). Funded under the National Cooperative Highway Research Program supported by the Federal-aid Highway Program, it is imperative that USDOT continues to fund and participate in these critical research projects.

Additionally, the transportation industry has been developing needed data standards and interface requirements. For example, the nature of the data to be shared has been well (but not completely) defined in the SAE J2735 and related standards. Definitions of the Basic Safety Message, the Traveler Information Message, the Signal Phase and Timing Message, and the map geometry messages, among others, include many of the needed elements. Both the automakers and the infrastructure owners and operators are currently working on a Basic Infrastructure Message to define some of the elements of information that can be provided from the infrastructure, such as

information contained on static and dynamic roadway signs, modification in roadway geometry due to construction and maintenance activities, and locations of traffic crashes and incidents. We encourage a continued collaboration through standards bodies like the SAE to define and refine these elements in a way that benefits both the automakers and the infrastructure agencies. Infrastructure owners and operators will similarly make beneficial use of dynamic vehicle response information - indications of localized weather, slippery or uneven roadway surfaces, sudden vehicle movements, etc., and we encourage automakers to provide this kind of information.

Finally, roadway design documents, such as the AASHTO "Green Book" and the Manual on Uniform Traffic Control Devices (MUTCD) will need to be updated to reflect the findings of ADS and connected vehicle research. Collaboration between federal research entities and operator organizations is essential to moving this process forward in a way that doesn't inhibit these technological advancements and the resulting safety benefits.

CONCLUSION

In conclusion, CAVs are in our future and we want the infrastructure to be ready and safer than it has ever been when they are deployed. If deployed properly, this technology will save lives. We hope the information we have presented today will assist the Committee in its efforts to achieve an infrastructure that helps harness the full potential of CAVs, including improving safety, enhancing mobility, and reducing the environmental impact of surface transportation systems.

AASHTO and the state DOTs appreciate the opportunity to present their views to the Committee today.