Desi Ujkashevic, Global Director
Automotive Safety Office
Sustainability, Environment & Safety Engineering

Fairlane Plaza South, Suite 400
330 Town Center Drive
Dearborn, MI 48126-2738

August 28, 2019

Ms. Heidi King
Deputy Administrator
National Highway Traffic Safety Administration
1200 New Jersey Avenue S.E., West Building
Washington D.C. 20590-0001

RE: Advanced Notice of Proposed Rulemaking (ANPRM)*:* Removing Regulatory Barriers for Vehicles with Automated Driving Systems.
Docket No. NHTSA-2019-0036

Dear Ms. King:

Ford Motor Company (Ford), a domestic manufacturer and importer of motor vehicles with offices at One American Road, Dearborn, Michigan 48126-2798, submits the following response supporting NHTSA efforts to address regulatory barriers for vehicles equipped with automated driving systems through the subject ANPRM.

Ford appreciates NHTSA's leadership and efforts in identifying and addressing the regulatory barriers for the deployment of ADS-equipped vehicles through a request for comments[1] earlier last year and this ANPRM. We also support the agency's plans in continuously improving guidance[2] on other emerging safety areas for ADS-equipped vehicles.

Ford was built on the belief that freedom of movement drives human progress. It is a belief that has always fueled our passion to create great cars and trucks and drives our commitment today as well, to become the world's most trusted mobility company, designing smart vehicles for a smart world that help people move more safely, confidently, and freely.

[1] https://www.federalregister.gov/documents/2018/01/18/2018-00671/removing-regulatory-barriers-for-vehicles-with-automated-driving-systems
[2] https://www.nhtsa.gov/vehicle-manufacturers/automated-driving-systems#automated-driving-systems-av-30

The benefits of autonomous technology are substantial, including the potential to save lives, expand mobility, and make transportation more efficient.

We have announced our intent to deploy an SAE Level 4[3]-capable ADS-equipped vehicle for commercial application in mobility services early in the next decade. Ford is investing in an autonomous future and working to provide mobility solutions for transportation challenges affecting communities across the country and around the world.

Ford is a member of the Alliance of Automobile Manufacturers (the Alliance) and participated in the development of their response to this ANPRM. The responses herein supplement those provided by the Alliance. Our key takeaways are summarized below:

- NHTSA will need to work closely with AV developers to acquire and stage vehicles for compliance verification testing.
- Both the Test mode with pre-programmed execution and Test mode with external control methods hold promise for assessing crash avoidance standards. Ford conducted testing for FMVSS 126 and FMVSS 135 with these methods and we have shared the results in Appendices 2 and 3, respectively, to demonstrate the potential for compliance certification with these alternative methods.
- Simulation is an important tool for vehicle development today and should continue to be a compliance option for future AV requirements.
- Ford is aligned with the Alliance comments on technical documentation and the use of surrogate vehicles with human control and believes they are viable options for compliance certification.
- Ford recommends that the assessment of the driving capability of the ADS remain as part of NHTSA's guidance or be considered as part of future rulemaking.

At Ford, the safety of our customers and the integrity of our products are a primary focus. NHTSA's ANPRM is an important step to establish a pathway to aid in the efficient deployment of ADS equipped vehicles and related services, provide certainty for manufacturers, and more importantly enhance safety for all Americans. We thank NHTSA for the opportunity to provide input and look forward to collaborating with the agency as it plans to address the regulatory barriers for ADS-equipped vehicles. If you have questions regarding these comments, please contact Gurunath Vemulakonda (email: gvemulak@ford.com or phone: 313-323-9582).

Sincerely,

Desi Ujkashevic

[3] Taxonomy and Definitions for Terms Related to Driving Automation Systems for On-Road Motor Vehicles J3016_201609 (https://www.sae.org/standards/content/j3016_201609/)

Attachments:

1. Appendix 1 – Comments and Response to Questions Regarding Possible Approaches to Revising Crash Avoidance Test Procedures.
2. Appendix 2: FMVSS Compliance example for Test Mode with Programmed Execution
3. Appendix 3: FMVSS Compliance Example with Test Mode with External Controls

Appendix 1 – Comments and Response to Questions Regarding Possible Approaches to Revising Crash Avoidance Test Procedures

6) *What other potential revisions or additions to terms, in addition to 'driver' are necessary for crash avoidance standards that NHTSA should consider defining or modifying to better communicate how the agency intends to conduct compliance verification of ADS vehicle.*

   In the context of ADS-DV equipped vehicles without manual controls, there are several terms in the regulations that need to be redefined to accommodate new innovative concepts. Ford recommends updates in the following areas.

   a. Driver vision
      i. Provide an alternative to the definition of information that is "seen" by driver (e.g., FMVSS101, 111, 138) to accommodate the ADS.
   b. Driver visibility
      i. Since a driver eyellipse (e.g., FMVSS111 RVC image size measurement), cannot be estimated for an ADS-DV, an alternative method for object detection needs to be identified.
   c. Driver interaction with or specific mention of controls
      i. Ignition and gear state change (e.g., FMVSS114)
      ii. Brake throttle override (e.g., FMVSS124)
      iii. Steering wheel angle measurement for conducting ESC (e.g., FMVSS126)
      iv. Application of parking and service brake (e.g., FMVSS135 Foot activated brake control)

   Specific references to manual controls need to be generalized to the action required, e.g., brake activation.

11) *What research or data exists to show that the compliance test method would adequately maintain the focus on ADS-DV safety? What modifications of the safety standards would be necessary to enable the use of the test method?*

   The designs of the ADS-equipped vehicles can vary with each developer; and it is up to the AV developer to demonstrate that the safety intent of the regulation can be met for the selected test method(s). Certain test methods may lend themselves better to standard verification than others.

   - Normal ADS-DV operation: The ODD for the ADS-equipped vehicle may have some limitations but this approach could address test methods for FMVSS138, 141, and 114 that require the vehicle to be driven from point A to point B. While there is not enough research available, the key challenge with this method is to request granular driving tasks. The standards could be modified to eliminate specific references to driving controls (see response to Q6 above).
   - Test Mode with Pre-Programmed Execution (TMPE) can be applicable for FMVSS124, 126,135, 138, and 141, with slight modifications to the metrics that reference driving controls. Appendix 2 provides an approach supported by data to demonstrate how the test method can maintain the focus on ADS-DV safety for FMVSS126.

- Test Mode with External Control (TMEC) can be applicable for FMVSS124, 135, 138, and 141. Appendix 3 provides an approach supported by data to demonstrate how the test method can maintain the focus on ADS-DV safety for FMVSS135.
- Simulation: Useful for verifying algorithms or for checking the robustness of the test results by simulating test variability for most test methods. It is a challenge to develop well-correlated models without production representative hardware.
- Technical Documentation for System Design and/or Performance approach could be used to describe the communication to the ADS for test methods that need to demonstrate communication of warnings and telltales to a human driver. Technical documentation can also be used to supplement other test methods.
- Use of Surrogate Vehicle with Human Controls: Not all AVs will have a sister vehicle platform with conventional human controls, but AV prototypes could likely be equipped with human controls during the development phase. This approach would allow a conventional verification approach for test procedures with vehicle performance requirements, for e.g., FMVSS124, 126,135, 138, and 141

12) *What design concepts are vehicle manufacturers considering relating to how an ADS-DV passenger/operator will interface with, or command (e.g., via verbal or manual input), the ADS to accomplish any driving task within its ODD? Please explain each design concept and exactly how each would be commanded to execute on-road trips.*

We have stated in our VSSA (Voluntary Safety Self-Assessment), “Initially, self-driving vehicles will work best […] where vehicles are accessed and shared versus owned and driven. They will operate as part of a mobility service accessed through a smartphone app for either moving people or delivering goods.” We plan for an app interface to be the primary means for riders to request rides, including selecting their desired destination. There may additionally be an interface (e.g. a touchscreen interface) within the vehicle for modifying the destination from what was originally requested.

13) *Are there specific challenges that will be encountered with this kind of approach for vehicle compliance verification? Please be specific and explain each challenge*

Setting up an ADS-equipped vehicle for compliance verification at a test facility will be a challenge for NHTSA or the test contractor, since ADS-DVs deployed as part of a ride-hail application are likely to operate only as directed by a fleet operator within specific mapped geofenced regions.

Additionally, there may need to be modifications to the current test requirements to facilitate testing that does not exceed ODD limitations for certain vehicles.

Given these anticipated ODD limitations, the agency should and the AV developers will need to work together to obtain pursue testing at non-OEM test facilities.

14) *Will all ADS-DVs without traditional manual controls be capable of receiving and acting upon simple commands not consisting of a street address based destination, such as "drive forward or backwards a distance of 10 feet and stop"; "shift from park to drive and accelerate to 25 mph"; "drive up onto a car hauler truck trailer"; etc.? Please explain projected challenges for ADS-DVs without traditional manual controls to complete discrete driving commands and tasks.*

Our initial AV will not have an interface for humans inside or outside of the vehicle to give it such directions. The ADS will be responsible for deciding when, where, and how it is appropriate to drive. We anticipate this will be true for our future AVs as well. We do not foresee interfaces beyond a method of giving the vehicle a destination. Thus, testing requirements like in S6 of FMVSS 114 that require operating the gear selection control, applying the parking brake, driving the vehicle a short distance up an incline, etc. may be difficult or impossible to perform with this method. To perform such testing, NHTSA and AV manufacturers will need to work together to pursue alternatives that would not be available otherwise.

27) *Could a means of manual control be developed that would allow NHTSA to access the system for compliance testing but not allow unauthorized access that could present a security or safety risk to an ADS-DV?*

Offering an access point with a device, such as a TMEC, potentially creates a vulnerability. To mitigate that vulnerability, the access point shouldn't be active during the entire vehicle life. It is more secure if the AV developer activates the access point in response to a NHTSA request. This could be accomplished with software that could be sent to a vehicle wirelessly after NHTSA provides the AV developer with the VIN of the vehicle they would like to test. This could also be accomplished with hardware by "keying" TMEC hardware to the specific vehicle NHTSA has commandeered through an electronic authentication. This "keyed" TMEC hardware would then be provided to the testing facility by the AV developer.

28) *Is it reasonable to assume any geofence-based operating restrictions could be suspended while an external controller intended to assess FMVSS compliance is connected to the ADS-DV?*

While it may be possible to suspend geo-fenced operations, it may not be appropriate to test the vehicle outside of its operational limits(e.g., max speed allowed).

29) *Are there other considerations NHTSA should be aware of when contemplating the viability of using an external controller-based vehicle certification?*

For functional and cybersecurity reasons, this approach is feasible only with OEM participation. OEMs will need to inform third-party labs how to configure a TMEC to interact with their vehicle and the OEM will need to authenticate/authorize the use of a TMEC in the vehicle. If these conditions can be accommodated, this method has the potential to be an effective and safe way to perform existing FMVSS 100 series test methods on L4+ AVs.

30) *How can simulations be used to assess FMVSS compliance?*

Simulation has become an important tool for vehicle development and has allowed automakers to drastically decrease both development cost and time, and it is possible to determine compliance with a validated simulation model.

For the long term, simulation may be a useful tool for compliance testing of future regulations related to ADS OEDR performance when combined with closed-track physical testing. A far greater number of tests can be run with the combination of physical tests and validated simulation than with only physical testing given the same time frame.

Appendix 2: FMVSS Compliance example for Test Mode with Programmed Execution

FMVSS 126
Requirement

The stated purpose of FMVSS 126 is to "*reduce the number of deaths and injuries that result from crashes in which the driver loses directional control of the vehicle, including those resulting in vehicle rollover*"[4]. Sections 6.3.5 and 7 require the use of an automated steering machine to run test procedures that include dynamic driving requirements. These requirements are not compatible with AVs that do not offer a lateral control device that can accommodate the automated steering machine defined in S6.3.5.

The compliance issue identified under FMVSS 126 results from a difference in how a human driver and the ADS interface with the ESC system. The underlying functionality of the ESC systems are identical between the manual and AV modes.

The ESC system on an AV functions the same as it does on non-AV vehicles. The system calculates the expected yaw rate based on vehicle velocity (wheel speed) and steering demand (pinion angle sensor), compares that to the actual yaw rate (yaw rate sensor), and applies brake pressure to the corner(s) of the vehicle when there is a large discrepancy.

Figures 3-5 show the results of a sine with dwell test conducted on a development surrogate vehicle using Test Mode with Programmed Control strategy. Steering commands used during testing were identical to the steering commands that are typically sent to the automated steering machine. Instead of sending the commands to the automated steering machine, which would then turn a steering wheel, the commands were sent to the electric power steering system directly. This was done using a laptop computer and a real-time prototyping ECU (dSpace MicroAutobox II) to emulate steering and torque commands as illustrated in Figure 1.

[4] 49 C.F.R. § 571.126 – S2

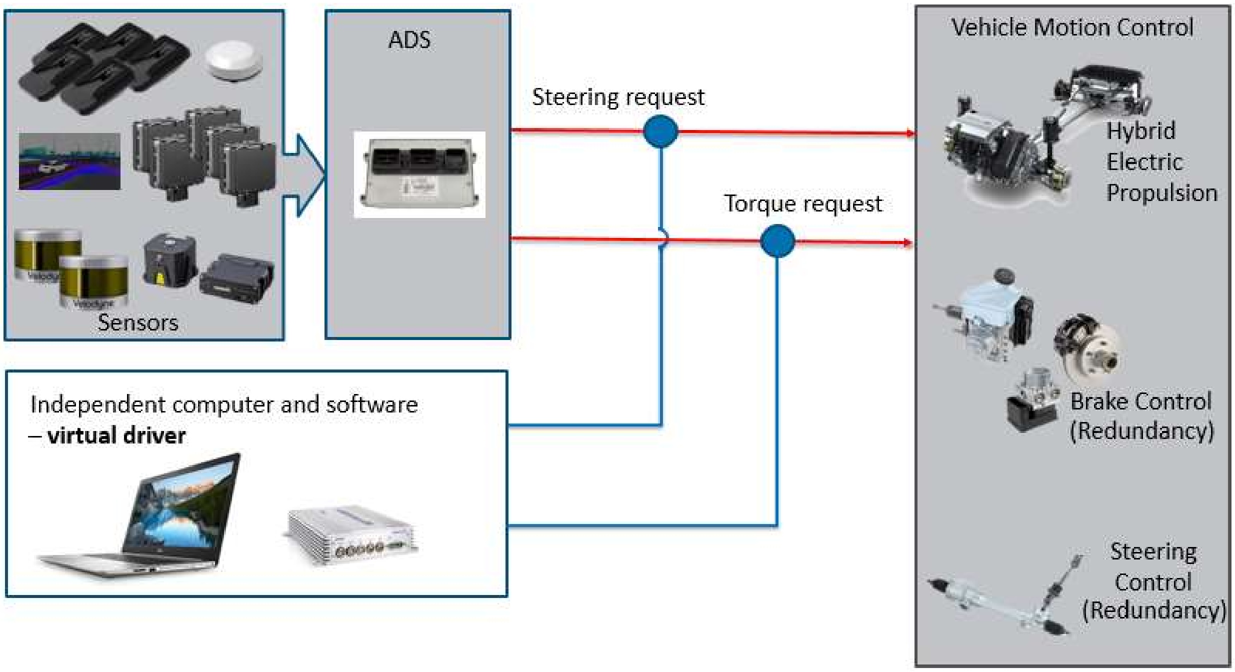

Figure 1 - 126 Testing Instrumentation

The commands/signals are configured, such that, the vehicle and associated modules interpret these commands as coming from the ADS. During the alternative test method, the steering wheel angle was not measured or used. Instead, steering pinion angle was used in the slowly increasing steer test to determine the amount of pinion angle that results in a lateral acceleration of 0.3g. As a result, the steering amplitude factor used in the alternative sine with dwell test was also based on pinion angle. Figure 2 demonstrates that pinion angle and steering wheel angle are highly correlated, thus supporting using pinion angle as a substitute for steering wheel angle. Both pinion/steering wheel angle and rack travel were measured to confirm the vehicle response to the steering input. In Figures 3-5, the steering wheel amplitude factor during the alternative test method (blue data) is referring to the pinion gear angle amplitude factor. Other steering metrics, such as steering rack travel, could also be used as a substitute for steering wheel angle, provided that they correlate well with steering inputs.

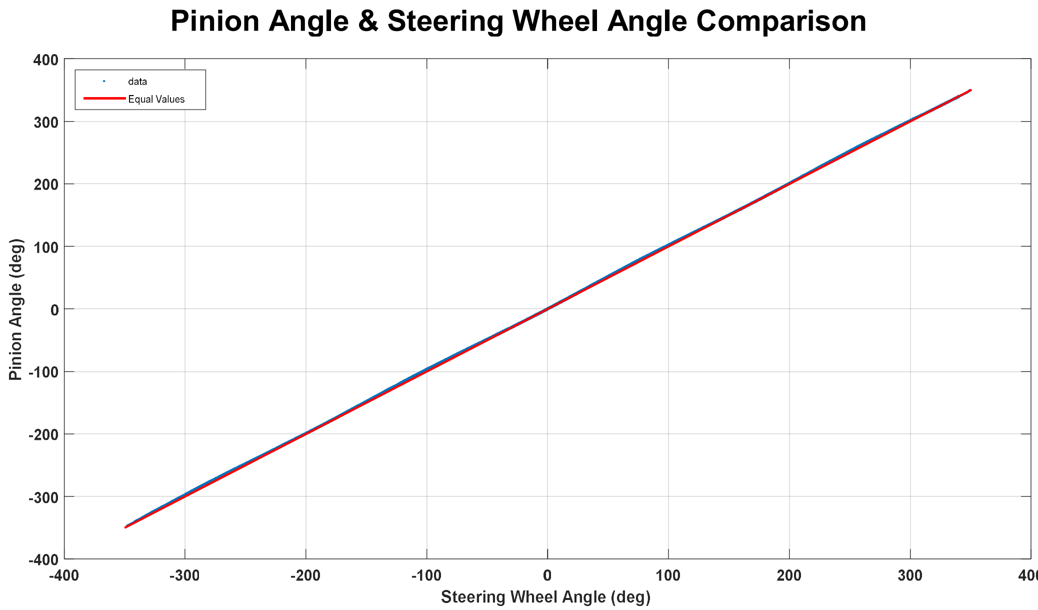

Figure 2 - Pinion vs Steering Wheel Angle

The surrogate vehicle was equipped with traditional controls, including pedals and a steering wheel. This vehicle was tested using the regulated test procedure and the alternative test procedure mentioned above. Figures 3-5 highlight the results of the performance requirements defined in S5.2 for both test methods. In addition to criteria defined in the regulation, the vehicle response with ESC turned off is shown for both methods to demonstrate that the improvement in vehicle response due to ESC is true whether the ADS is active or not.

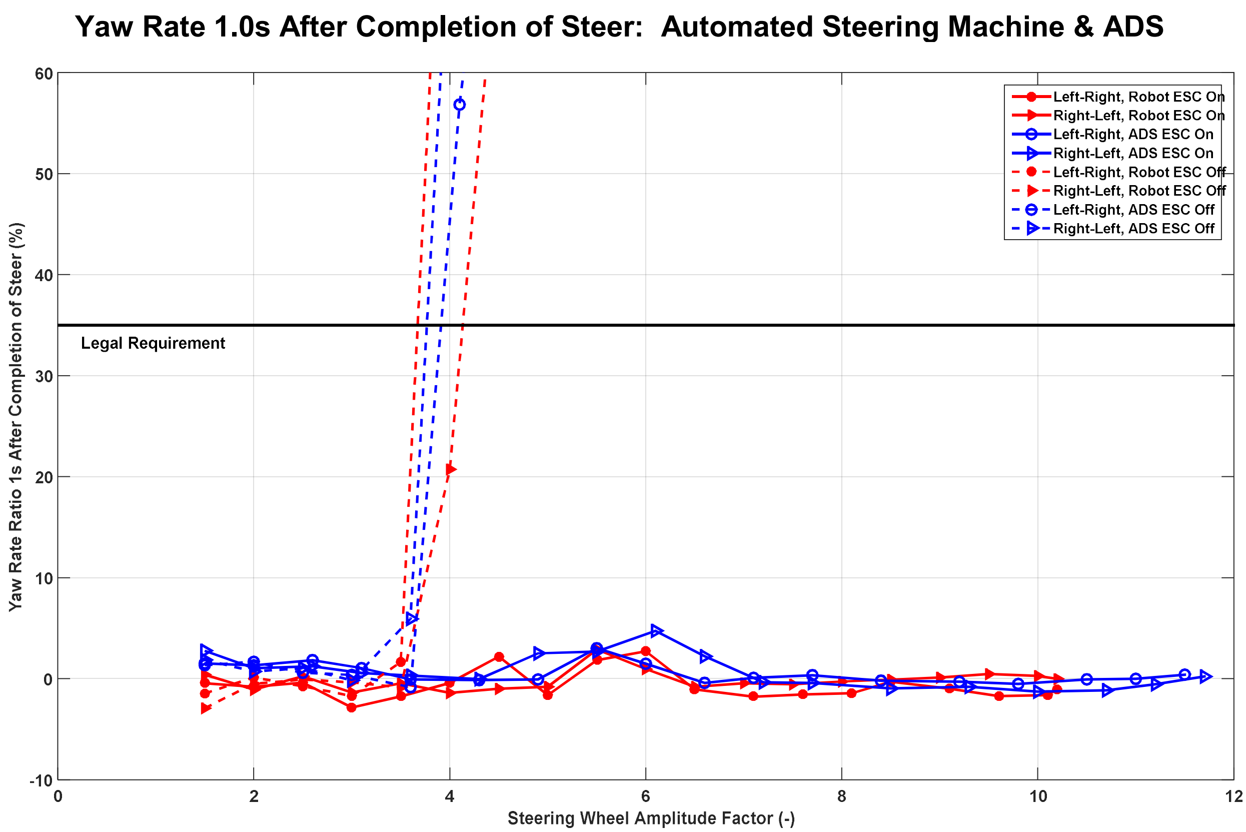

Figure 3 - Yaw Rate 1.0 seconds after steer

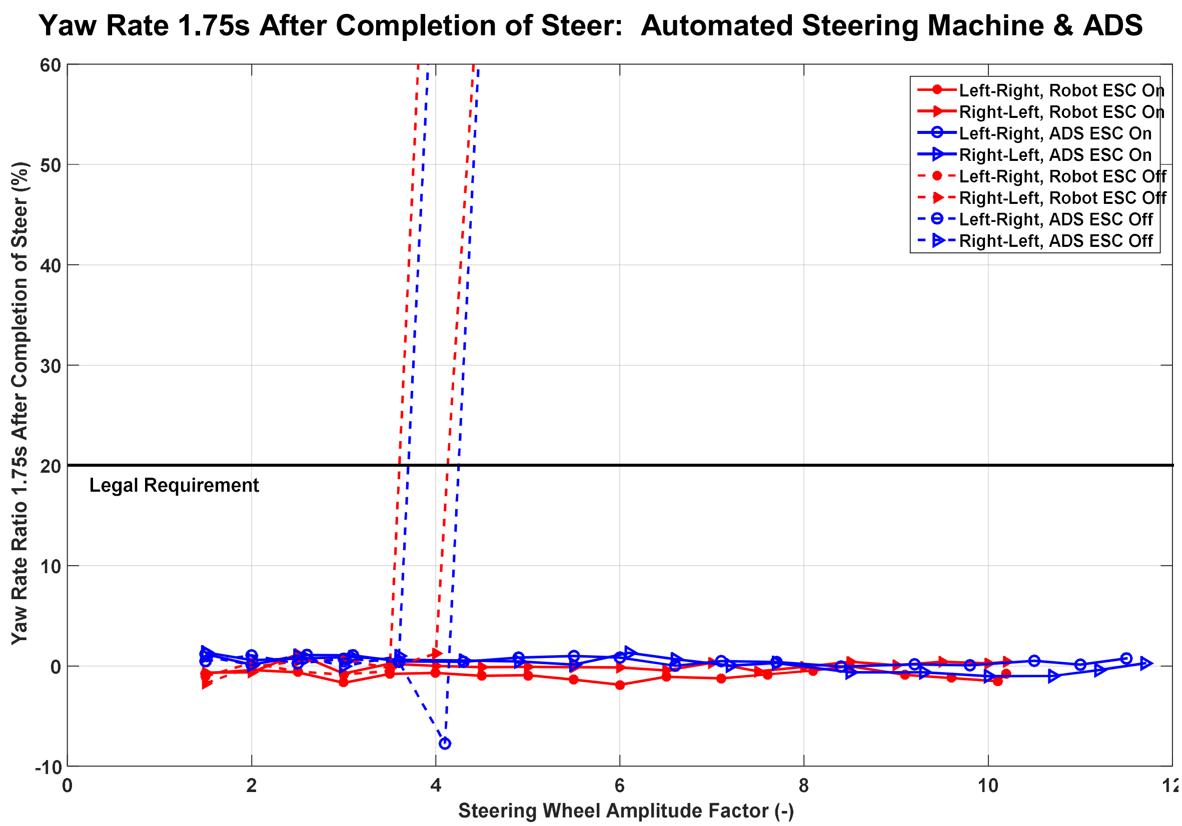

Figure 4 - Yaw Rate 1.75 seconds after steer

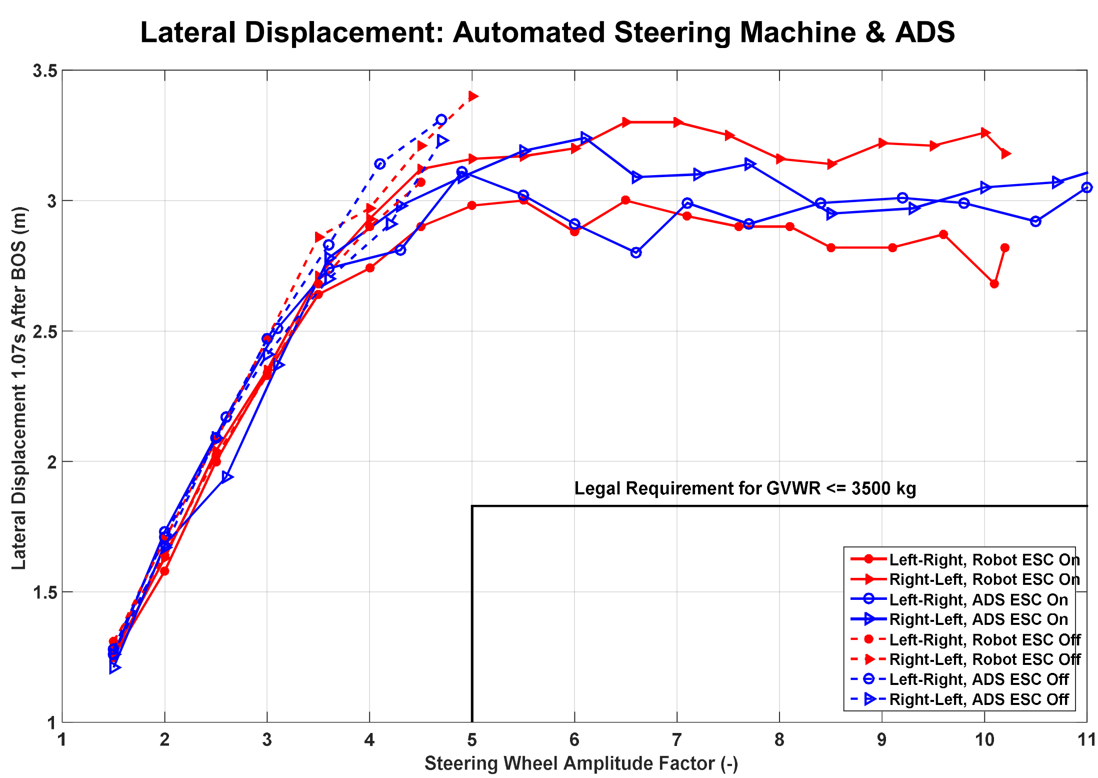

Figure 5 - Lateral Displacement Comparison

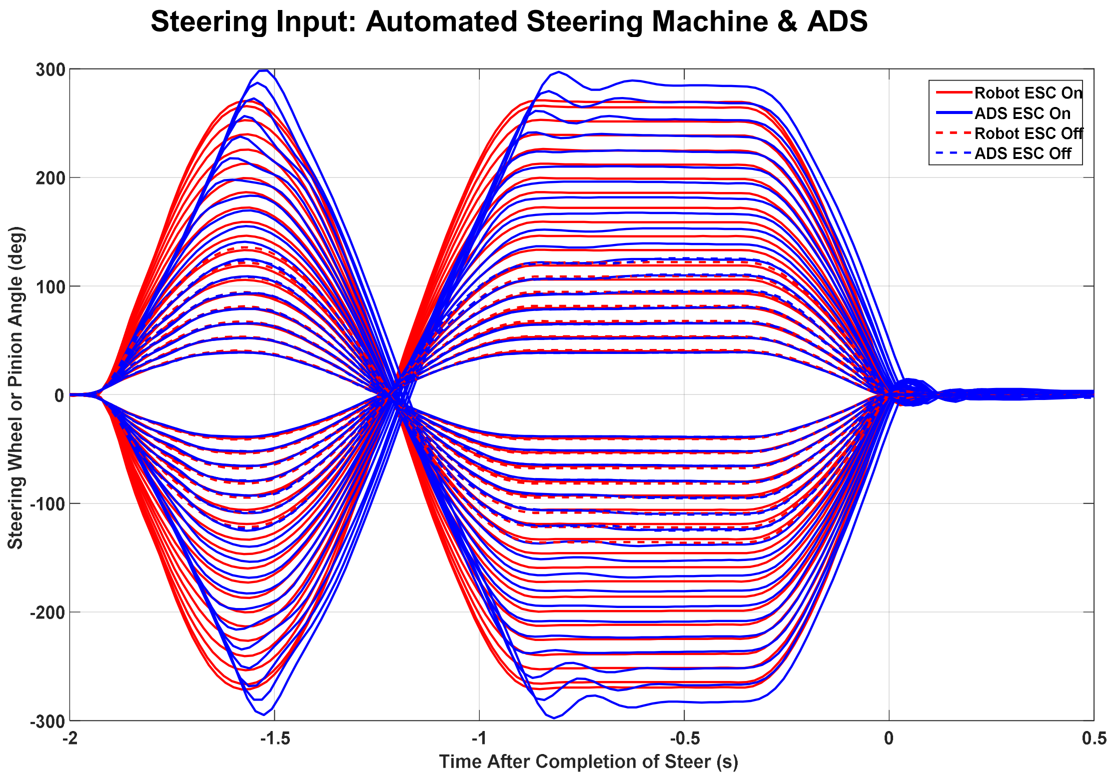

Figure 6 - Steering Input Comparison

The results for the yaw rate 1.0s after completion of steer are very similar between the two methods and demonstrate an average difference of 1.1%. The lateral displacement 1.07s after the beginning of steer also provided very similar results with an average difference of 0.6%. The yaw rate 1.75s after completion of steer provided an average difference of 1.0% between the two methods. The similarity of the performance metrics is expected since the same vehicle, with the same ESC calibration, and similar steering commands were used for both test methods.

While the alternative test procedure provided similar results to the traditional method, the two test methods are not identical. The steering input between the two methods differ, as demonstrated in Figure 6 - Steering Input Comparison. Despite these differences in steering input, the outputs of the tests including. yaw rate and lateral displacement. are very similar. The differences in the steering input do not cause a difference in vehicle response. The data presented demonstrates that in severe steering events, at the vehicles maximum steering ability, the electronic stability control system can intervene and cause the vehicle yaw rate and lateral displacement to be within the limits defined in FMVSS 126.

Based on the results shown in Figures 3-5 it is possible to demonstrate the compliance of the ESC system to FMVSS 126 using the TMPE method, even though there are some minor differences between the steering inputs as shown in Figure 6.

Appendix 3: FMVSS Compliance Example with Test Mode with External Controls

FMVSS 135

Requirement

The stated purpose of FMVSS 135 is to "*ensure safe braking performance under normal and emergency driving conditions*"[5]. Section S5.3.1 requires a foot control for actuating the service brakes and a parking brake that is actuated by either a hand or foot. Section S7 describes test procedures that are conducted by dynamically driving the vehicle and applying certain amount of force to the brake pedal. These requirements are not compatible with AVs that do not offer these regulated controls during AV operation.

The FMVSS 135 compliance issue results from the difference between how a human driver and the ADS interface with the underlying brake system.

When ADS is active, there will not be a foot control for actuating the service brakes as required in S5.3.1. There will also not be a hand or foot control for actuating the parking brake as required in S5.3.1. The ADS will control both latitudinal and longitudinal motion of the vehicle including braking by sending electronic signals to the brake control module which will activate the service brakes and the parking brake. Road test procedures defined in S7 cannot be conducted when the ADS is active because the test personnel cannot apply the service brakes and parking brake as required in S7. By conducting both a traditional road test sequence as defined in S7 and by utilizing the alternate test procedure with external controls, we can demonstrate that the performance requirements defined in S7 are met.

Table 1: FMVSS 135 Summary Results shows the results of various brake performance tests conducted on a development surrogate vehicle using an external test controller (summarized in Figure 7 below) and traditional controls.

[5] 49 C.F.R. § 571.135 – S2

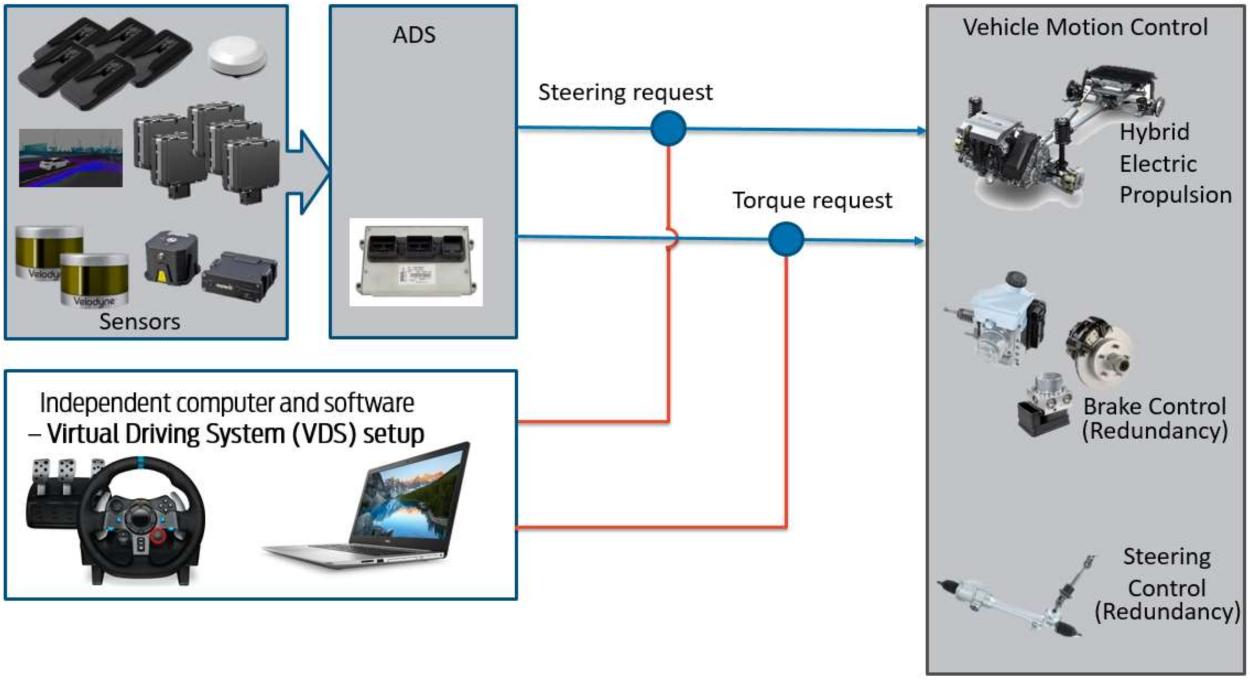

Figure 7: Setup for Test Mode with External Control

Table 1: FMVSS 135 Summary Results

FMVSS Section	Test Name/Type	Federal Requirement (meters)	Performance in Manual Mode (meters)	Performance With External Controller (meters)
7.5	Cold Effectiveness at GVW	70	45	44
7.5	Cold Effectiveness at LLVW	70	44	44
7.7	Stops with Engine off	70	46	45
7.8	Failed Antilock & Failed Proportioning @ GVW	85	60	61
7.8	Failed Antilock & Failed Proportioning @ LLVW	85	70	60
7.8	Failed Antilock @ GVW	85	62	61
7.8	Failed Antilock @ LLVW	85	64	59
7.10	Hydraulic Circuit Failure (LF & RR) LLVW	168	88	88
7.10	Hydraulic Circuit Failure (RF & LR) LLVW	168	93	93

FMVSS Section	Test Name/Type	Federal Requirement (meters)	Performance in Manual Mode (meters)	Performance With External Controller (meters)
7.10	Hydraulic Circuit Failure (LF & RR) GVW	168	87	88
7.10	Hydraulic Circuit Failure (RF & LR) GVW	168	83	85
7.11	Inoperative Brake Power Unit	168	84	84
7.12	Parking Brake Hill hold @ 20% Grade Up	Hold For 5 minutes	EPB Held	EPB Held
7.14	Parking Brake Hill hold @ 20% Grade Down	Hold For 5 minutes	EPB Held	EPB Held
7.14	Hot Performance Req #1 (Manual Mode)	68	44	N/A
7.14	Hot Performance Req #2	89	44	47
7.16	Recovery Performance (Manual Mode)	60	43	N/A
7.14	Hot Performance Req #1 (AV Mode)	66	N/A	47
7.16	Recovery Performance (AV Mode)	58	N/A	43

Based on the results from the tests we can conclude that using an external test controller can be a viable option to demonstrate the performance of the brake system for compliance with FMVSS 135.