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49 CFR Parts 571 and 585

Federal Motor Vehicle Safety Standards; Electronic Stability Control Systems; Controls and Displays; Final Rule

DEPARTMENT OF TRANSPORTATION

National Highway Traffic Safety Administration

49 CFR Parts 571 and 585

[Docket No. NHTSA–2007–27662]

RIN 2127–AJ77

Federal Motor Vehicle Safety Standards; Electronic Stability Control Systems; Controls and Displays

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

ACTION: Final rule.

SUMMARY: As part of a comprehensive plan for reducing the serious risk of rollover crashes and the risk of death and serious injury in those crashes, this document establishes a new Federal motor vehicle safety standard (FMVSS) No. 126 to require electronic stability control (ESC) systems on passenger cars, multipurpose passenger vehicles, trucks, and buses with a gross vehicle weight rating of 4,536 Kg (10,000 pounds) or less. ESC systems use automatic computer-controlled braking of individual wheels to assist the driver in maintaining control in critical driving situations in which the vehicle is beginning to lose directional stability at the rear wheels (spin out) or directional control at the front wheels (plow out).

Preventing single-vehicle loss-of-control crashes is the most effective way to reduce deaths resulting from rollover crashes. This is because most loss-of-control crashes culminate in the vehicle leaving the roadway, which dramatically increases the probability of a rollover. Based on the best available data, drawn from crash data studies, NHTSA estimates that the installation of ESC will reduce single-vehicle crashes of passenger cars by 34 percent and single vehicle crashes of sport utility vehicles (SUVs) by 59 percent, with a much greater reduction of rollover crashes. NHTSA estimates that ESC has the potential to prevent 71 percent of the passenger car rollovers and 84 percent of the SUV rollovers that would otherwise occur in single-vehicle crashes.

NHTSA estimates that ESC would save 5,300 to 9,600 lives and prevent 156,000 to 238,000 injuries in all types of crashes annually once all light vehicles on the road are equipped with ESC systems. The agency further anticipates that ESC systems would substantially reduce (by 4,200 to 5,500) the more than 10,000 deaths each year on American roads resulting from rollover crashes.

Manufacturers equipped about 29 percent of model year (MY) 2006 light vehicles sold in the U.S. with ESC, and intend to increase the percentage to 71 percent by MY 2011. This rule requires installation of ESC in 100 percent of light vehicles by MY 2012 (with exceptions for some vehicles manufactured in stages or by small volume manufacturers). Once all light vehicles in the fleet have ESC, of the overall projected annual 5,300 to 9,600 highway deaths and 156,000 to 238,000 injuries prevented by stability control systems installed either voluntarily or under this rulemaking, we would attribute 1,547 to 2,534 prevented fatalities (including 1,171 to 1,465 involving rollover) to this rulemaking, in addition to the prevention of 46,896 to 65,801 injuries by increasing the percentage of light vehicles with ESC from 71 percent to 100 percent.

DATES: *Effective Date:* This final rule is effective June 5, 2007. The incorporation by reference of certain publications listed in the rule is approved by the Director of the Federal Register as of June 5, 2007.

Compliance Date: Consistent with the phase-in commencing September 1, 2008, all new light vehicles must be equipped with an ESC system that meets the requirements of the standard by September 1, 2011, with the following exceptions. Vehicle manufacturers need not meet the standard's requirements for control and display requirements for the ESC malfunction indicator telltale and ''ESC Off'' switch and telltale (if provided) until September 1, 2011 (*i.e.*, at the end of the phase-in), and vehicles produced by final-stage manufacturers and alterers must be equipped with a compliant ESC system (including the control and display requirements) by September 1, 2012. However, manufacturers may voluntarily certify vehicles to FMVSS No. 126 and earn carry-forward credits for compliant vehicles, produced in excess of the phase-in requirements, that are manufactured between June 5, 2007, and the conclusion of the phase-in.

Petitions for Reconsideration: If you wish to submit a petition for reconsideration of this rule, your petition must be received by May 21, 2007.

ADDRESSES: Petitions for reconsideration should refer to the docket number above and be submitted to: Administrator, Room 5220, National Highway Traffic Safety Administration, 400 Seventh Street, SW., Washington, DC 20590.

See the **SUPPLEMENTARY INFORMATION** portion of this document (Section VI; Rulemaking Analyses and Notice) for DOT's Privacy Act Statement regarding documents submitted to the agency's dockets.

FOR FURTHER INFORMATION CONTACT: For non-legal issues, you may call Mr. Patrick Boyd, Office of Crash Avoidance Standards (Telephone: 202–366–6346) (Fax: 202–366–7002).

For legal issues, you may call Mr. Eric Stas, Office of the Chief Counsel (Telephone: 202–366–2992) (Fax: 202–366–3820).

You may send mail to both of these officials at National Highway Traffic Safety Administration, 400 Seventh Street, SW., Washington, DC 20590.

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I. Executive Summary

As part of a comprehensive plan [1] that seeks to reduce the serious risk of rollover crashes and the risk of death and serious injury in those crashes, and that includes a number of complementary rulemaking actions, this rule establishes Federal Motor Vehicle Safety Standard (FMVSS) No. 126, *Electronic Stability Control Systems*, which requires passenger cars, multipurpose passenger vehicles (MPVs), trucks, and buses that have a gross vehicle weight rating (GVWR) of 4,536 kg (10,000 pounds) or less to be equipped with an ESC system that meets the requirements of the standard. ESC systems use automatic, computer-controlled braking of individual wheels to assist the driver in maintaining control (and the vehicle's intended heading) in situations where the vehicle is beginning to lose directional stability (*e.g.*, where the driver misjudges the severity of a curve or over-corrects in an emergency situation). In such situations (which occur with considerable frequency), intervention by the ESC system can assist the driver in preventing the vehicle from leaving the roadway, thereby preventing fatalities and injuries associated with crashes involving vehicle rollover or collision with various objects (*e.g.*, trees, highway infrastructure, other vehicles).

Based upon current estimates regarding the effectiveness of ESC systems, we believe that an ESC standard could save thousands of lives each year, providing potentially the greatest safety benefits produced by any safety device since the introduction of seat belts. The following discussion highlights the research and regulatory efforts that have culminated in this safety standard.

Since the early 1990's, NHTSA has been actively engaged in finding ways to address the problem of vehicle rollover, because crashes involving rollover are responsible for a disproportionate number of fatalities and serious injuries (over 10,000 of the 33,000 fatalities of vehicle occupants in 2004). Although various options were explored, the agency ultimately chose to add a rollover resistance component to its New Car Assessment Program (NCAP) consumer information program in 2001. In response to NCAP's market-based incentives, vehicle manufacturers made modifications to their product lines to increase their vehicles' geometric stability and rollover resistance by utilizing wider track widths (typically associated with passenger cars) on many of their newer sport utility vehicles (SUVs) and by making other improvements to truck-based SUVs during major redesigns (*e.g.*, introduction of roll stability control). This approach was successful in terms of reducing the much higher rollover rate of SUVs and other high-center-of-gravity vehicles, as compared to passenger cars. However, manipulating vehicle configuration alone cannot entirely resolve the rollover problem (particularly when consumers continue to demand vehicles with greater carrying capacity and higher ground clearance).

Accordingly, the agency began exploring technologies that could confront the issue of vehicle rollover from a different perspective or line of inquiry, which led to today's final rule. We believe that the ESC requirement offers a complementary approach that may provide substantial benefits to drivers of both passenger cars and LTVs (light trucks/vans). Undoubtedly, keeping vehicles from leaving the roadway is the best way to prevent deaths and injuries associated with rollover, as well as other types of

[1] 70 FR 49223, at 49229 (August 23, 2005).

crashes. Based on its crash data studies, NHTSA estimates that the installation of ESC systems will reduce single vehicle crashes of passenger cars by 34 percent and single vehicle crashes of sport utility vehicles (SUVs) by 59 percent. Its effectiveness is especially great for single-vehicle crashes resulting in rollover, where ESC systems were estimated to prevent 71 percent of passenger car rollovers and 84 percent of SUV rollovers in single vehicle crashes (*see* Section V).

In short, we believe that preventing single-vehicle loss-of-control crashes is the most effective way to reduce rollover deaths, and we believe that ESC offers considerable promise in terms of meeting this important safety objective while maintaining a broad range of vehicle choice for consumers. In fact, among the agency's ongoing and planned rulemakings, it is the single most effective way of reducing the total number of traffic deaths. It is also the most cost-effective of those rulemakings.

We note that this final rule also satisfies the recent mandate in section 10301 of the Safe, Accountable, Flexible, Efficient Transportation Equity Act: A Legacy for Users of 2005 (SAFETEA–LU).[2] That provision requires the Secretary of Transportation to ''establish performance criteria to reduce the occurrence of rollovers consistent with stability enhancing technologies'' and to ''issue a proposed rule * * * by October 1, 2006, and a final rule by April 1, 2009.'' In light of the tremendous life-saving potential anticipated to be associated with a requirement for ESC to be standard equipment on all light vehicles, the agency determined that, consistent with its mission to save lives, prevent injuries and reduce economic costs due to road traffic crashes, it was important to issue a final rule as soon as possible and accelerate the rate of installation. Accordingly, today's final rule is being published well in advance of the statutory deadline under SAFETEA–LU.

The balance of this notice discusses (1) The background regarding the size of the safety problem, the agency's comprehensive response to rollover-related safety problems, the agency's mandate under SAFETEA–LU, and ESC systems as a countermeasure to address single-vehicle crashes and rollovers (*see* Section II); (2) the agency's September 2006 NPRM for ESC and public comments on that proposal (*see* Section III); (3) the requirements and implementation of the final rule, including a detailed discussion regarding resolution of the issues raised in public comments (*see* Section IV); and (4) costs and benefits associated with the final rule (*see* Section V). However, before turning to this more detailed analysis, we summarize the key points of the final rule, including the requirements for ESC systems under FMVSS No. 126, lead time and phase-in, differences between the final rule and the NPRM, and the anticipated impacts of the final rule.

A. Requirements of the Final Rule

After careful consideration of all available information, including the public comments, the agency has decided to adopt in the ESC final rule most of the elements of the proposed rule. Consistent with SAFETEA–LU, NHTSA is requiring all light vehicles to be equipped with an ESC system with, at the minimum, the capabilities of current production systems. We believe that a requirement for such ESC systems is desirable in terms of both ensuring technological feasibility and providing the desired safety benefits in a cost-effective manner. Although vehicle manufacturers have been increasing the portion of the light vehicle fleet equipped with ESC, we believe that given the relatively high cost of this technology, a mandatory standard is necessary to maximize the safety benefits associated with electronic stability control, and is required by SAFETEA–LU.

In order to realize these benefits, we have decided to require vehicles to be equipped with an ESC system meeting definitional requirements and to pass a dynamic test. The definitional requirements specify the necessary elements of a stability control system that is capable of both effective oversteer and understeer intervention. These requirements are necessary due to the extreme difficulty in establishing tests adequate, by themselves, to ensure the desired level of ESC functionality in a variety of circumstances.[3] The test that we are adopting is necessary to ensure that the ESC system is robust and meets a level of performance at least comparable to that of current ESC systems. This approach is similar to the one we took, for similar reasons, in 1995 in mandating antilock brakes for medium and heavy vehicles pursuant to the Intermodal Surface Transportation Efficiency Act (ISTEA) of 1991.[4]

These requirements are summarized below:

• Consistent with the definition of ESC contained in a voluntary consensus standard, the Society of Automotive Engineers[5] (SAE) Surface Vehicle Information Report J2564 (rev. June 2004), we are requiring vehicles covered under the standard to be equipped with an ESC system that:

(1) Augments vehicle directional stability by applying and adjusting the vehicle brake torques individually to induce a correcting yaw moment to a vehicle;

(2) Is computer-controlled, with the computer using a closed-loop

[2] Pub. L. 109–59, 119 Stat. 1144 (2005).

[3] An equipment requirement is necessary because it would be almost impossible to devise a single performance test that could not be met through some action by the manufacturer other than providing an ESC system. Establishing a battery of performance tests to achieve our intended results is not possible at this time because we have not been able to develop a practical, repeatable limit-understeer test, and there are no applicable tests in vehicle dynamics literature. Although the agency has undertaken its own preliminary research efforts related to understeer, the complexity of such research would require several years of additional work before any conclusions could be reached regarding an ESC understeer performance test.

Given this, the agency determined that it had three available options: (1) Delay the ESC final rule and conduct research and development; (2) drop the understeer requirement and amend the standard once an ESC performance test is developed; or (3) include a requirement for understeer as part of the definition of ''ESC System,'' along with requiring specific components that will permit the system to intervene in excessive understeer situations.

The agency eliminated the first and second options on the grounds of safety.

The agency believes that the third option, adopting an understeer requirement as part of the definition of ''ESC System,'' along with a requirement for specific equipment suitable for that purpose, will accomplish the purposes of the statutory mandate. Such requirement is objective in terms of explaining to manufacturers what type of performance is required and the minimal equipment necessary for that purpose. The agency can verify that the system has the necessary hardware and logic for understeer mitigation. Since the necessary components for effective understeer intervention are already present on all ESC systems, we believe that manufacturers are highly unlikely to decrease their ESC systems' understeer capabilities simply because the standard does not have a specific test for understeer. The agency believes that its chosen approach will ensure that vehicle manufacturers maintain understeer intervention as a feature of the ESC system, without delaying the life-saving benefits of the ESC rule. In the meantime, the agency will conduct additional research in the area of ESC understeer intervention and consider taking additional action, as appropriate.

Even with an understeer test, the ultimate practicability of a standard without an equipment requirement remains in doubt because of the possible large number of test conditions that would be required.

[4] 60 FR 13216 (March 10, 1995).

[5] The Society of Automotive Engineers is an association of engineers, business executives, educators, and students who share information and exchange ideas for advancing the engineering of mobility systems. SAE currently has over 90,000 members in approximately 97 countries. The organization's activities include development of standards, events, and technical information and expertise used in designing, building, maintaining, and operating self-propelled vehicles for use on land or sea, in air or space. *See http://www.sae.org.*

algorithm[6] to limit vehicle oversteer and to limit vehicle understeer;

(3) Has a means to determine vehicle yaw rate[7] and to estimate its sideslip[8] or the time derivative of sideslip;

(4) Has a means to monitor driver steering input;

(5) Has an algorithm to determine the need, and a means to modify engine torque, as necessary, to assist the driver in maintaining control of the vehicle, and

(6) Is operational over the full speed range of the vehicle (except at vehicle speeds less than 15 km/h (9.3 mph) or when being driven in reverse).

• The ESC system, as defined above, is also required to be capable of applying brake torques individually at all four wheels and to have an algorithm that utilizes this capability.[9] Except for the situations specifically set forth in part (6) of the definition of ''ESC System'' above, the system is also required to be operational during all phases of driving, including acceleration, coasting, and deceleration (including braking). It is also required to be capable of activation even if the anti-lock brake system or traction control system is also activated.

• In order to ensure that a vehicle is equipped with an ESC system that meets the definition of ''ESC System'' under S4, the final rule requires vehicle manufacturers to submit, upon the request of NHTSA's Office of Vehicle Safety Compliance, ESC system technical documentation as to when understeer intervention is appropriate for a given vehicle (*see* S5.6). Specifically, NHTSA may seek information such as a system diagram that identifies all ESC components, a written explanation describing the ESC system's basic operational characteristics, a logic diagram supporting the explanation of system operations, and a discussion of the pertinent inputs to the vehicle computer or calculations within the computer and how its algorithm uses that information and controls ESC system hardware to limit vehicle understeer.

• We are also requiring vehicles covered under the standard to meet a performance test. It must satisfy the standard's stability criteria and responsiveness criterion when subjected to the sine with dwell steering maneuver test. This test involves a vehicle's coasting at an initial speed of 50 mph while a steering machine steers the vehicle with a steering wheel pattern as shown in Figure 2 of the regulatory text. The test maneuver is then repeated over a series of increasing maximum steering angles. This test maneuver was selected over a number of other alternatives because we decided that it has the best set of characteristics, including severity of the test, repeatability and reproducibility of results, and the ability to address lateral stability and responsiveness.

The maneuver is severe enough to produce spinout for most vehicles without ESC. The stability criteria for the test measure how quickly the vehicle stops rotating after the steering wheel is returned to the straight-ahead position. A vehicle that continues to rotate for an extended period after the driver steers straight is out of control, which is what ESC is designed to prevent. The quantitative stability criteria are expressed in terms of the percent of the peak yaw rate after maximum steering that persists at a period of time after the steering wheel has been returned to straight ahead. They require that the vehicle yaw rate decrease to no more than 35 percent of the peak value after one second and that it continue to drop to no more than 20 percent after 1.75 seconds. Since a vehicle that simply responds very little to steering commands could meet the stability criteria, a minimum responsiveness criterion is applied to the same test.

• Because the benefits of the ESC system can only be realized if the system is functioning properly, we are requiring that a telltale be mounted inside the occupant compartment in front of and in clear view of the driver. The ESC malfunction telltale is required to illuminate after the occurrence of one or more malfunctions that affect the generation or transmission of control or response signals in the vehicle's ESC system. Such telltale must remain continuously illuminated for as long as the malfunction(s) exists, whenever the ignition locking system is in the ''On'' (''Run'') position.

• In certain circumstances, drivers may have legitimate reasons to disengage the ESC system or limit its ability to intervene, such as when the vehicle is stuck in sand/gravel, is being used while equipped with snow chains, or is being run on a track for maximum performance. Accordingly, under this final rule, vehicle manufacturers may include a driver-selectable switch that places the ESC system in a mode in which it does not satisfy the performance requirements of the standard (*e.g.*, ''sport'' mode or full-off mode). However, if the vehicle manufacturer chooses this option, it must ensure that the ESC system always returns to the fully-functional default mode at the initiation of each new ignition cycle, regardless of the mode the driver had previously selected (with certain exceptions for low speed off-road axle/transfer case selections that turn off ESC, but cannot be reset electronically). If the vehicle manufacturer chooses this option, it must also provide an ''ESC Off'' control and a telltale that is mounted inside the occupant compartment in front of and in clear view of the driver. Such telltale must remain continuously illuminated for as long as the ESC is in a mode that renders it unable to meet the performance requirements of the standard, whenever the ignition locking system is in the ''On'' (''Run'') position.

• We are not requiring the ESC system to be equipped with a roll stability control system. Roll stability control systems involve relatively new technology. There is currently an insufficient body of data to judge the efficacy of such systems. However, the agency will continue to monitor the development of these systems.

B. Lead Time and Phase-In

In order to provide the public with what are expected to be the significant safety benefits of ESC systems as rapidly as possible, compliance with this final rule is set to commence on September 1, 2008. That date marks the start of a three-year phase-in period. Subject to the special provisions discussed below, NHTSA has decided to require compliance in accordance with the following schedule: 55 percent of a vehicle manufacturer's light vehicles manufactured during the period from September 1, 2008 to August 31, 2009; 75 percent of those manufactured during the period from September 1, 2009 to August 31, 2010; 95 percent of those manufactured during the period from September 1, 2010 to August 31, 2011, and all light vehicles thereafter.

For the reasons discussed in detail in Section IV.B of this notice, we believe that it is practicable for vehicle manufacturers to meet the requirements of the phase-in discussed above, subject

[6] A ''closed-loop algorithm'' is a cycle of operations followed by a computer that includes automatic adjustments based on the result of previous operations or other changing conditions.

[7] ''Yaw rate'' means the rate of change of the vehicle's heading angle measured in degrees/second of rotation about a vertical axis through the vehicle's center of gravity.

[8] ''Sideslip'' means the arctangent of the lateral velocity of the center of gravity of the vehicle divided by the longitudinal velocity of the center of gravity.

[9] The standard was developed based on new vehicles produced in 2005 and 2006. The definition of ESC is limited to four-wheel ESC systems because existing two-wheel ESC systems are not capable of understeer invention or four-wheel automatic braking during an intervention, even though these systems also produced substantial (but lesser) benefits.

to the exceptions below. Because ESC is so cost-effective and has such high benefits in terms of potential fatalities and injuries that may be prevented, the agency has decided that it is important to require ESC installation in light vehicles as quickly as possible. Given the product plans we have from six vehicle manufacturers, and the desire to provide manufacturers with flexibility by having a carry-forward provision, we have chosen the most aggressive phase-in alternative that we believe is reasonable (*i.e.*, 55/75/95%). In doing so, we have carefully considered the financial and technological practicability of the final rule (in keeping with our statutory mandate), while at the same time facilitating ESC installation in the light vehicle fleet as expeditiously as possible.

With the above said, the agency has decided that it is appropriate to provide the following exceptions to the phase-in. First, we have decided to defer the standard's requirements related to the ESC telltales and controls until the end of the phase-in (*i.e.*, September 1, 2011 for most manufacturers; September 1, 2012 for final-stage manufacturers and alterers). Although vehicle manufacturers generally commented that they could bring their ESC systems into full compliance (including the control and telltale requirements), they stated that additional lead time would be necessary to accomplish those changes, suggesting that they could do so by the end of the phase-in. As a complicating matter, vehicle manufacturers and their trade associations explained that even though most current ESC systems would largely meet the performance requirements of the proposed standard, manufacturers' inability to meet the proposed control and display requirements would prevent them from earning the carry-forward credits needed to comply with the ESC phase-in schedule. Our analysis demonstrates that the safety benefits associated with early introduction of ESC systems, even without standardized controls and displays, far outweigh the benefits of delaying the standard until all systems can fully meet the control and display requirements (*see* FRIA's lead time/phase-in discussion). Accordingly, we believe that it is preferable to move rapidly to implement the standard, but to delay the compliance date only for the ESC control and telltale requirements.

As proposed, vehicle manufacturers may earn carry-forward credits for compliant vehicles, produced in excess of the phase-in requirements, which are manufactured between the effective date of the final rule and the conclusion of the phase-in period.[10]

This final rule excludes small volume manufacturers (*i.e.*, manufacturers producing less than 5,000 vehicles for sale in the U.S. market in one year) from the phase-in, instead requiring those manufacturers to fully comply with the standard beginning on September 1, 2011.

In addition, consistent with the policy set forth in NHTSA's February 14, 2005 final rule on certification requirements for vehicles built in two or more stages and altered vehicles (70 FR 7414), final-stage manufacturers and alterers are excluded from the requirements of the phase-in and are permitted an additional one year for compliance (*i.e.*, until September 1, 2012). However, final-stage manufacturers and alterers may voluntarily certify compliance with the standard prior to this date.

C. Differences Between the Final Rule and the Notice of Proposed Rulemaking

As noted above, NHTSA has decided to adopt most of the provisions in the NPRM as part of this final rule. We made a number of changes in response to the public comments on the NPRM. The main differences between the NPRM and the final rule involve an increase in the percentages of FMVSS No. 126-compliant vehicles that must be produced during the phase-in period, a delay in the requirements for standardized symbols and acronyms for ESC controls and displays until the end of the phase-in, and the inclusion of engine control as part of the standard's definition of ''ESC system.''

The following points briefly describe the main differences between the NPRM and this final rule.

- In order to increase fleet installation of life-saving ESC systems, the phase-in schedule for ESC is being accelerated to require 55 percent phase-in in the first year, 75 percent in the second year, and 95 percent in the third year, rather than the 30 percent, 60 percent, and 90 percent schedule that was proposed (*see* S8.1, S8.2, and S8.3 in the regulatory text of this final rule).
- The effective date for the requirement to use standardized symbols and acronyms as well as certain malfunction detection and ''ESC Off'' control functions has been moved to the end of the phase-in period. This was done in recognition of the fact that manufacturers will be relying on the carry-forward and compliance credits for vehicles in current production that pass all the ESC performance requirements, but currently lack the standardized controls and displays features proposed in the NPRM (*see* S5.3.1, S5.3.2; S5.3.4; S5.3.9; S5.4.2; S5.5.2; S5.5.3; S5.5.6).
- The definition of ''ESC System'' has been changed to require ESC systems with engine control, a feature that allows the ESC system to reduce vehicle speed during an intervention by cutting engine power as well as by brake application (*see* S4 ESC (5)). It was a feature on most vehicles in the crash data analysis and on all the vehicles in the ESC cost study.
- The definition of ''ESC System'' has been changed to delete the word ''as appropriate'' from the description of when the system must intervene to mitigate vehicle understeer (*see* S4 ESC (2)). Instead, in order to ensure that a vehicle is equipped with an ESC system that meets the definition of ''ESC System'' under S4, we have decided to require vehicle manufacturers to submit, upon the request of NHTSA's Office of Vehicle Safety Compliance, ESC system technical documentation as to when understeer intervention is appropriate for a given vehicle (*see* S5.6). Specifically, NHTSA may seek information such as a system diagram that identifies all ESC components, a written explanation describing the ESC system's basic operational characteristics, a logic diagram supporting the explanation of system operations, and a discussion of the pertinent inputs to the vehicle computer or calculations within the computer and how its algorithm uses that information and controls ESC system hardware to limit vehicle understeer.[11]
- The ''ESC System'' definition and performance requirements have been changed to refer to generating brake torques at all four wheels individually, rather than applying individual brakes, so that the action of regenerative braking by electric motors is included (*see* S4 ESC (1); S5.1.1).
- The definition of ''ESC System'' has been further changed to recognize that some systems operate by estimating the time derivative of side slip, rather than by measuring side slip directly. The final rule also defines the low speed threshold for ESC operation as 15 km/h (*see* S4 ESC (3), (6)).
- The responsiveness criterion has been changed to a two-stage criterion with a lower lateral displacement requirement for large vehicles (*i.e.*, ones

[10] We note that carry-forward credits may not be used to defer the mandatory compliance date of September 1, 2011 for all covered vehicles.

[11] We note here that we anticipate that much of this information is proprietary and would be submitted under a request for confidential treatment pursuant to 49 CFR Part 512.

over 7,716 pounds GVWR). It is applied during tests with a peak commanded steering angle of five times or greater than the steering wheel angle necessary to produce 0.3g steady-state lateral acceleration. This is a change from applying it simply for tests with steering wheel angles greater than 180 degrees. It compensates for the slower steering gear ratios of large vehicles. (*see* S5.2; S5.2.3; S6.3.5).

- Low-speed four-wheel-drive (4WD) modes that have the side effect of turning off ESC and that are selected by mechanical controls that cannot be automatically reset electrically are excluded from the requirement for automatic ESC restoration at the next ignition cycle (*see* S5.4.1).
- Under the final rule, outriggers will be used for testing of trucks, MPVs, and buses, and the maximum weight and roll moment of inertia are also specified for outriggers (*see* S6.3.4).
- The ESC malfunction detection test procedure has been modified to include a short driving and turning procedure so that ESC systems with self-diagnostics requiring vehicle motion can accomplish their function (*see* S7.10.2).

D. Impacts of ESC and of the Final Rule

Based on its analysis of the best available data, NHTSA estimates that ESC—both installed voluntarily and under this regulatory mandate—will save 5,300 to 9,600 lives and prevent 156,000 to 238,000 injuries in all types of crashes annually once all light vehicles on the road are equipped with ESC systems. A large portion of these savings will come from preventing large numbers of rollover crashes. ESC systems will substantially reduce (by 4,200 to 5,500) the more than 10,000 deaths that occur on American roads each year as a result of rollover crashes.

Manufacturers installed ESC in about 29 percent of model year (MY) 2006 light vehicles sold in the U.S., and intend to increase the percentage of ESC installation in light vehicles to 71 percent by MY 2011. This rule accelerates that rate of installation by requiring a 100 percent installation rate by MY 2012 (with exceptions for some vehicles manufactured in stages or by small volume manufacturers). We took that step because, in response to public comments and our review of vehicle manufacturers' production plans, we determined that it is practicable to increase the percentage of new light vehicles that must comply with Standard No. 126 under the phase-in, thereby accelerating the benefits expected to be provided by ESC systems.

As the discussion below demonstrates, ESC not only has a very significant life-saving and injury-preventing potential in absolute terms, but it also achieves these benefits in a very cost-effective manner vis-à-vis other agency rulemakings. ESC offers consistently strong benefits and cost-effectiveness across all types of light vehicles, including passenger cars, SUVs, vans, and pick-up trucks. Of the 5,300 to 9,600 highway deaths and 156,000 to 238,000 MAIS 1–5 injuries that we project will be prevented annually for all types of crashes once all light vehicles on the road are equipped with ESC, we attribute 1,547 to 2,534 prevented fatalities (including 1,171 to 1,465 involving rollover) to this rulemaking, in addition to the prevention of 46,896 to 65,801 injuries.

The agency estimates that the production-weighted, average cost per vehicle to meet the proposed standard's requirements will be $58 ($90.3 per passenger car and $29.2 per light truck).[12] These are incremental costs over the manufacturers' MY 2011 plans for installation of ABS, which is expected to be installed in almost 93 percent of the light vehicle fleet, and ESC, which is expected to be installed in 71 percent of the light vehicle fleet. Vehicle costs are estimated to be $368 (in 2005$) for anti-lock brakes (ABS) and an additional $111 for ESC, for a total system cost of $479 per vehicle. The total annual vehicle cost of this regulation, based on ESC installation beyond manufacturers' planned percentages, is expected to be approximately $985 million.

In terms of cost-effectiveness, this final rule is expected to save 1,547 to 2,534 lives and prevent 46,896 to 65,801 injuries at a cost of $0.18 to $0.33 million per equivalent life saved at a 3 percent discount rate and $0.26 to $0.45 million at a 7 percent discount rate.

The final rule is highly cost-effective even when passenger cars are considered alone. The passenger car portion of the final rule will save 945 lives and prevent 32,196 injuries at a cost of $0.38 million per equivalent life saved at a 3 percent discount rate and $0.50 at a 7 percent discount rate.

II. Background

A. Overview of the Safety Problem

The following discussion explains the nature and scope of the safety problem which the agency seeks to address through this rulemaking for ESC, based upon our analysis of recent single-vehicle crash and rollover statistics. About one in seven light vehicles involved in police-reported crashes collides with something other than another vehicle. However, the proportion of these single-vehicle crashes increases steadily with increasing crash severity, and almost half of serious and fatal injuries occur in single-vehicle crashes. We can describe the relationship between crash severity and the number of vehicles involved in the crash using information from the agency's crash data programs. We limit our discussion here to ''light vehicles,'' which consist of passenger cars, multipurpose passenger vehicles (MPVs), trucks, and buses with a gross vehicle weight rating (GVWR) of 4,536 kilograms (10,000 pounds) or less.[13]

The 2000–2005 data from the National Automotive Sampling System (NASS) Crashworthiness Data System (CDS) and 2005 data from the Fatality Analysis Reporting System (FARS) were combined to estimate the current target population for this rulemaking. It includes 27,680 people who were killed as occupants of light vehicles (both single-vehicle and multi-vehicle crashes). Over half of these (15,191) occurred in single-vehicle crashes. Of these, 8,596 occurred in rollovers. About 1.0 million injuries (AIS 1–5) occurred in crashes that could be affected by ESC, almost 458,000 in single vehicle crashes (of which almost half were in rollovers). Multi-vehicle crashes that could be affected by ESC accounted for 12,485 fatalities and almost 547,000 injuries.

Rollover crashes are complex events that reflect the interaction of driver, road, vehicle, and environmental factors. We can describe the relationship between these factors and the risk of rollover using information from the agency's crash data programs.

According to 2005 data from FARS, 10,836 people were killed as occupants in light vehicle rollover crashes, which represents 34 percent of all occupants killed that year in crashes. Of those, 8,769 were killed in single-vehicle rollover crashes. Seventy-four percent of the people who died in single-vehicle rollover crashes were not using a seat belt, and 61 percent were partially or completely ejected from the vehicle (including 50 percent who were completely ejected). FARS shows that 55 percent of light vehicle occupant fatalities in single-vehicle crashes involved a rollover event.

[12] We note that the costs for passenger cars are higher because a greater portion of those vehicles require installation of ABS in addition to ESC.

[13] For brevity, we use the term ''light trucks'' in this document to refer to multipurpose passenger vehicles (*e.g.*, vans, minivans, and SUVs), trucks, and buses with a GVWR of 4,536 kilograms (10,000 pounds) or less.

Using data from the 2000–2004 NASS CDS files, we estimate that 266,000 light vehicles were towed from a police-reported rollover crash each year (on average), and that 29,000 occupants of these vehicles were seriously injured. Of these 266,000 light vehicle rollover crashes, 219,000 were single-vehicle crashes. Sixty-one percent of those people who suffered a serious injury in a single-vehicle tow-away rollover crash were not using a seat belt, and 52 percent were partially or completely ejected (including 41 percent who were completely ejected). Estimates from NASS CDS indicate that 82 percent of tow-away rollovers were single-vehicle crashes, and that 88 percent (197,000) of the single-vehicle rollover crashes occurred after the vehicle left the roadway. An audit of 1992–96 NASS CDS data showed that about 95 percent of rollovers in single-vehicle crashes were tripped by mechanisms such as curbs, soft soil, pot holes, guard rails, and wheel rims digging into the pavement, rather than by tire/road interface friction as in the case of untripped rollover events.

B. The Agency's Comprehensive Response to Rollover

As mentioned above, this final rule for ESC is but one part of the agency's comprehensive plan to address the issue of vehicle rollover. The following discussion provides background on NHTSA's comprehensive plan to reduce rollover crashes. In 2002, the agency formed an Integrated Project Team (IPT) to examine the rollover problem and to make recommendations on how to reduce rollovers and to improve safety when rollovers nevertheless occur. In June 2003, based on the work of that team, the agency published a report titled, ''Initiatives to Address the Mitigation of Vehicle Rollover.'' [14] The report recommended improving vehicle stability, ejection mitigation, roof crush resistance, as well as road improvements and behavioral strategies aimed at consumer education.

Since then, the agency has been working to implement these recommendations as part of its comprehensive agency plan for reducing the serious risk of rollover crashes and the risk of death and serious injury when rollover crashes do occur. It is evident that the most effective way to reduce deaths and injuries in rollover crashes is to prevent the rollover crash from occurring. This final rule adopting a new Federal motor vehicle safety standard for electronic stability control systems is one key part of that comprehensive agency plan.

Moreover, we note that the agency also published a notice of proposed rulemaking in the **Federal Register** in August 2005, seeking to upgrade our safety standard on roof crush resistance (FMVSS No. 216); that notice, like the present one, contains an in-depth discussion of the rollover problem and the countermeasures which the agency intends to pursue as part of its comprehensive response to the rollover problem (*see* 70 FR 49223 (August 23, 2005)).

C. Congressional Mandate Under Section 10301 of the Safe, Accountable, Flexible, Efficient Transportation Equity Act: A Legacy for Users of 2005

During the course of the ongoing agency's research into ESC systems, Congress passed the Safe, Accountable, Flexible, Efficient Transportation Equity Act: A Legacy for Users of 2005 (SAFETEA–LU).[15] Section 10301 of that Act contains legislative mandates for the agency to initiate a number of rulemakings, including ones for rollover prevention and occupant ejection prevention. In relevant part, that provision states:

> (a) In General.—The Secretary [of Transportation] shall initiate rulemaking proceedings, for the purpose of establishing rules or standards that will reduce vehicle rollover crashes and mitigate deaths and injuries associated with such crashes for motor vehicles with a gross vehicle weight rating of not more than 10,000 pounds.
>
> (b) Rollover Prevention.—One of the rulemaking proceedings initiated under subsection (a) shall be to establish performance criteria to reduce the occurrence of rollovers consistent with stability enhancing technologies. The Secretary shall issue a proposed rule in this proceeding by rule by October 1, 2006, and a final rule by April 1, 2009.

This SAFETEA–LU mandate is consistent with the agency's efforts under its Comprehensive Rollover Safety Program (discussed above). The agency's research efforts had already identified electronic stability control systems as a mature and effective technology which has had adequate time to be analyzed in both the scientific literature, as well as by NHTSA researchers. These research results strongly suggest that fleet-wide installation of ESC systems should yield tremendous benefits in terms of the prevention of fatalities and injuries. Although the agency considered other potential ''stability enhancing technologies,'' there was no evidence to demonstrate that they would meet the need for motor vehicle safety (*see* Section IV.C.3 below). Accordingly, the agency has determined that adopting a requirement for installation of ESC systems in light vehicles would be consistent with the statutory mandate under section 10301 of SAFETEA–LU. Under our interpretation of that statutory provision, Congress provided the agency discretion to evaluate various stability enhancing technologies and to adopt a requirement for a system that the agency determines would best reduce the occurrence of rollovers. The agency agrees with Congress regarding the tremendous life-saving potential associated with ESC as a proven stability enhancing technology, and because of the agency's prior efforts, it was possible to publish today's final rule well in advance of the statutory deadline under SAFETEA–LU.

As this final rule makes clear, the agency has decided to implement the statutory mandate contained in section 10301 of SAFETEA–LU through promulgation of a Federal motor vehicle safety standard for ESC pursuant to 49 U.S.C. Chapter 301, *Motor Vehicle Safety*. Adoption of an FMVSS for ESC meets the statutory directive to ''establish performance criteria'' consistent with stability enhancing technologies. Furthermore, this approach is consistent with the agency's implementation of the statutory mandate for tire pressure monitoring systems contained in section 13[16] of the Transportation Recall Enhancement, Accountability, and Documentation (TREAD) Act.[17]

D. Electronic Stability Control as a Countermeasure to Address Single-Vehicle Crashes and Rollovers

General Principles of ESC System Operation

Although Electronic Stability Control (ESC) systems have been known by a number of different trade names such as Vehicle Stability Control (VSC), Electronic Stability Program (ESP), StabiliTrak and Vehicle Stability Enhancement (VSE), their function and performance are similar. They are systems that use computer control of individual wheel brakes to help the driver maintain control of the vehicle during extreme maneuvers by keeping the vehicle headed in the direction the driver is steering even when the vehicle nears or reaches the limits of road traction.

When a driver attempts an ''extreme maneuver'' (*e.g.*, one initiated to avoid

[14] *See* Docket Number NHTSA 2003–14622–1.

[15] Pub. L. 109–59, 119 Stat. 1144 (2005).

[16] *See* 49 U.S.C. 30123 note (2003).

[17] Pub. L. 106–414, 114 Stat. 1800 (2000).

a crash or due to misjudgment of the severity of a curve), the driver may lose control if the vehicle responds differently as it nears the limits of road traction than it does during ordinary driving. The driver's loss of control can result in either the rear of the vehicle ''spinning out'' or the front of the vehicle ''plowing out.'' As long as there is sufficient road traction, a highly skilled driver may be able to maintain control in many extreme maneuvers using countersteering (*i.e.*, momentarily turning away from the intended direction) and other techniques. However, average drivers in a panic situation in which the vehicle is beginning to spin out would be unlikely to countersteer to regain control.

ESC uses automatic braking of individual wheels to adjust the vehicle's heading if it departs from the direction the driver is steering. Thus, it prevents the heading from changing too quickly (spinning out) or not quickly enough (plowing out). Although it cannot increase the available traction, ESC affords the driver the maximum possibility of keeping the vehicle under control and on the road in an emergency maneuver using just the natural reaction of steering in the intended direction.

Keeping the vehicle on the road prevents single-vehicle crashes, which are the circumstances that lead to most rollovers. However, if the speed is simply too great for the available road traction, even a vehicle with ESC will unavoidably drift off the road (but not spin out). Furthermore, ESC cannot prevent road departures due to driver inattention or drowsiness rather than loss of control.

How ESC Prevents Loss of Vehicle Control

The following explanation of ESC operation illustrates the basic principle of yaw stability control, but it does not attempt to explain advanced refinements of the yaw control strategy described below that use vehicle sideslip (lateral sliding that may not alter yaw rate) to optimize performance on slippery pavements.

An ESC system maintains what is known as ''yaw'' (or heading) control by determining the driver's intended heading, measuring the vehicle's actual response, and automatically turning the vehicle if its response does not match the driver's intention. However, with ESC, turning is accomplished by applying a brake force at a single wheel rather than by steering input. (The uneven brake force from braking only one wheel creates a yaw torque or moment that rotates the vehicle around a vertical axis.)

Speed and steering angle measurements are used to determine the driver's intended heading. The vehicle response is measured in terms of lateral acceleration and yaw rate by onboard sensors. If the vehicle is responding in a manner corresponding to driver input, the yaw rate will be in balance with the speed and lateral acceleration.

The concept of ''yaw rate'' can be illustrated by imaging the view from above of a car following a large circle painted on a parking lot. One is looking at the top of the roof of the vehicle and seeing the circle. If the car starts in a heading pointed north and drives half way around circle, its new heading is south. Its yaw angle has changed 180 degrees. If it takes 10 seconds to go half way around the circle, the ''yaw rate'' is 180 degrees per 10 seconds or 18 deg/sec. If the speed stays the same, the car is constantly rotating at a rate of 18 deg/sec around a vertical axis that can be imagined as piercing its roof. If the speed is doubled, the yaw rate increases to 36 deg/sec.

While driving in a circle, the driver notices that he must hold the steering wheel tightly to avoid sliding toward the passenger seat. The bracing force is necessary to overcome the lateral acceleration that is caused by the car following the curve. The lateral acceleration is also measured by the ESC system. When the speed is doubled the lateral acceleration increases by a factor of four if the vehicle follows the same circle. There is a fixed physical relationship between the car's speed, the radius of its circular path, and its lateral acceleration.

The ESC system uses this information as follows: Since the ESC system measures the car's speed and its lateral acceleration, it can compute the radius of the circle. Since it then has the radius of the circle and the car's speed, the ESC system can compute the correct yaw rate for a car following the path. Of course, the system includes a yaw rate sensor, and it compares the actual measured yaw rate of the car to that computed for the path the car is following. If the computed and measured yaw rates begin to diverge as the car that is trying to follow the circle speeds up, it means the driver is beginning to lose control, even if the driver cannot yet sense it. Soon, an unassisted vehicle would have a heading significantly different from the desired path and would be out of control either by oversteering (spinning out) or understeering.

When the ESC system detects an imbalance between the measured yaw rate of a vehicle and the path defined by the vehicle's steering wheel angle, speed, and lateral acceleration, the ESC system automatically intervenes to turn the vehicle. The automatic turning of the vehicle is accomplished by uneven brake application rather than by steering wheel movement. If only one wheel is braked, the uneven brake force will cause the vehicle's heading to change. Figure 1 shows the action of ESC using single wheel braking to correct the onset of oversteering or understeering. (Please note that all Figures discussed in this preamble may be found at the end of the preamble, immediately preceding the proposed regulatory text.)

- *Oversteering.* In Figure 1 (bottom panel), the vehicle has entered a left curve that is extreme for the speed it is traveling. The rear of the vehicle begins to slide which would lead to a vehicle without ESC turning sideways (or ''spinning out'') unless the driver expertly countersteers. In a vehicle equipped with ESC, the system immediately detects that the vehicle's heading is changing more quickly than appropriate for the driver's intended path (*i.e.*, the yaw rate is too high). It momentarily applies the right front brake to turn the heading of the vehicle back to the correct path. It will also cut engine power to gently slow the vehicle and, if necessary, apply additional brakes (while maintaining the uneven brake force to create the necessary yaw moment). The action happens quickly so that the driver does not perceive the need for steering corrections. Even if the driver brakes because the curve is sharper than anticipated, the system is still capable of generating uneven braking if necessary to correct the heading.
- *Understeering.* Figure 1 (top panel) shows a similar situation faced by a vehicle whose response as it nears the limits of road traction is to slide at the front (''plowing out'' or understeering) rather than oversteering. In this situation, the ESC system rapidly detects that the vehicle's heading is changing less quickly than appropriate for the driver's intended path (*i.e.*, the yaw rate is too low). It momentarily applies the left rear brake to turn the heading of the vehicle back to the correct path. Again, it will also cut engine power to gently slow the vehicle and, if necessary, apply additional brakes (while maintaining the uneven brake force to create the necessary yaw moment).

While Figure 1 may suggest that particular vehicles go out of control as either vehicles prone to oversteer or vehicles prone to understeer, it is just as likely that a given vehicle could require both understeer and oversteer interventions during progressive phases

of a complex avoidance maneuver such as a double lane change.

Although ESC cannot change the tire/road friction conditions the driver is confronted with in a critical situation, there are clear reasons to expect it to reduce loss-of-control crashes, as discussed below.

In vehicles without ESC, the response of the vehicle to steering inputs changes as the vehicle nears the limits of road traction. All of the experience of the average driver is in operating the vehicle in its ''linear range'', *i.e.*, the range of lateral acceleration in which a given steering wheel movement produces a proportional change in the vehicle's heading. The driver merely turns the wheel the expected amount to produce the desired heading. Adjustments in heading are easy to achieve because the vehicle's response is proportional to the driver's steering input, and there is very little lag time between input and response. The car is traveling in the direction it is pointed, and the driver feels in control. However, at lateral accelerations above about one-half ''g'' on dry pavement for ordinary vehicles, the relationship between the driver's steering input and the vehicle's response changes (toward oversteer or understeer), and the lag time of the vehicle response can lengthen. When a driver encounters these changes during a panic situation, it adds to the likelihood that the driver will lose control and crash because the familiar actions learned by driving in the linear range would not be the correct steering actions.

However, ordinary linear range driving skills are much more likely to be adequate for a driver of a vehicle with ESC to avoid loss of control in a panic situation. By monitoring yaw rate and sideslip, ESC can intervene early in the impending loss-of-control situation with the appropriate brake forces necessary to restore yaw stability before the driver would attempt an over correction or other error. The net effect of ESC is that the driver's ordinary driving actions learned in linear range driving are the correct actions to control the vehicle in an emergency. Also, the vehicle will not change its heading from the desired path in a way that would induce further panic in a driver facing a critical situation.

Besides allowing drivers to cope with emergency maneuvers and slippery pavement using only ''linear range'' skills, ESC provides more powerful control interventions than those available to even expert drivers of non-ESC vehicles. For all practical purposes, the yaw control actions with non-ESC vehicles are limited to steering. However, as the tires approach the maximum lateral force sustainable under the available pavement friction, the yaw moment generated by a given increment of steering angle is much less than at the low lateral forces occurring in regular driving [18]. This means that as the vehicle approaches its maximum cornering capability, the ability of the steering system to turn the vehicle is greatly diminished, even in the hands of an expert driver. ESC creates the yaw moment to turn the vehicle using braking at an individual wheel rather than the steering system. This intervention remains powerful even at limits of tire traction because both the braking force of the individual tire and the reduction of lateral force that accompanies the braking force act to create the desired yaw moment. Therefore, ESC can be especially beneficial on slippery surfaces. While a vehicle's possibility of staying on the road in a critical maneuver ultimately is limited by the tire/pavement friction, ESC maximizes an ordinary driver's ability to use the available friction.

Overview of ESC Effectiveness in Preventing Single-Vehicle and Rollover Crashes

Crash data studies conducted in the U.S., Europe, and Japan indicate that ESC is very effective in reducing single-vehicle crashes. Studies of the behavior of ordinary drivers in critical situations using the National Advanced Driving Simulator also show a very large reduction in instances of loss of control when the vehicle is equipped with ESC. Based on its crash data studies, NHTSA estimates that ESC will reduce single vehicle crashes of passenger cars by 34 percent and single vehicle crashes of SUVs by 59 percent. NHTSA's latest crash data study also shows that ESC is most effective in reducing single-vehicle crashes that result in rollover. ESC is estimated to prevent 71 percent of passenger car rollovers and 84 percent of SUV rollovers in single vehicle crashes. It is also estimated to reduce some multi-vehicle crashes but at a much lower rate than its effect on single vehicle crashes. The following discussion explains in detail the research finding upon which the agency has relied in determining the anticipated effectiveness of ESC systems.

Electronic stability control can directly reduce a vehicle's susceptibility to on-road untripped rollovers as measured by the ''fishhook'' test that is part of NHTSA's NCAP rollover rating program. The direct effect is mostly limited to untripped rollovers on paved surfaces. However, untripped on-road rollovers are a relatively infrequent type of rollover crash. In contrast, the vast majority of rollover crashes occur when a vehicle runs off the road and strikes a tripping mechanism such as soft soil, a ditch, a curb or a guardrail.

We expect that requiring ESC to be installed on light trucks and passenger cars would result in a large reduction in the number of rollover crashes by greatly reducing the number of single-vehicle crashes. As noted previously, over 80 percent of rollovers are the result of a single-vehicle crash. The purpose of ESC is to assist the driver in keeping the vehicle on the road during impending loss-of-control situations. In this way, it can prevent the exposure of vehicles to off-road tripping mechanisms. We note, however, that this yaw stability function of ESC is not direct ''rollover resistance'' and cannot be measured by the NCAP rollover resistance rating.

Although ESC is an indirect countermeasure to prevent rollover crashes, we believe it is the most powerful countermeasure available to address this serious risk. Effectiveness studies by NHTSA and others worldwide [19] estimate that ESC reduces single vehicle crashes by at least a third in passenger cars and perhaps reduces loss-of-control crashes (*e.g.*, road departures leading to rollovers) by an even greater amount. In fact, NHTSA's latest data study that is discussed in this section found a reduction in single-vehicle crashes leading to rollover of 71 percent for passenger cars and 84 percent for SUVs. Thus, ESC can reduce the numbers of rollovers of all vehicles, including lower center of gravity vehicles (*e.g.*, passenger cars, minivans and two-wheel drive pickup trucks), as

[18] Liebemann *et al.*, (2005) Safety and Performance Enhancement: The Bosch Electronic Stability Control (ESP), 19th International Technical Conference on the Enhanced Safety of Vehicles (ESV), Washington, DC.

[19] Aga M, Okada A. (2003) Analysis of Vehicle Stability Control (VSC)'s Effectiveness from Accident Data, 18th International Technical Conference on the Enhanced Safety of Vehicles (ESV), Nagoya.

Dang, J. (2004) Preliminary Results Analyzing Effectiveness of Electronic Stability Control (ESC) Systems, Report No. DOT HS 809 790. U.S. Dept. of Transportation, Washington, DC.

Farmer, C. (2004) Effect of Electronic Stability Control on Automobile Crash Risk, Traffic Injury Prevention Vol. 5:317–325.

Kreiss J-P, *et al.* (2005) The Effectiveness of Primary Safety Features in Passenger Cars in Germany. 19th International Technical Conference on the Enhanced Safety of Vehicles (ESV), Washington, DC.

Lie A., *et al.* (2005) The Effectiveness of ESC (Electronic Stability Control) in Reducing Real Life Crashes and Injuries. 19th International Technical Conference on the Enhanced Safety of Vehicles (ESV), Washington, DC.

well as of the higher center of gravity vehicle types (*e.g.*, SUVs and four-wheel drive pickup trucks). ESC can affect both crashes that would have resulted in rollover as well as other types of crashes (*e.g.*, road departures resulting in impacts) that result in deaths and injuries.

Human Factors Study on the Effectiveness of ESC

A study by the University of Iowa using the National Advanced Driving Simulator demonstrated the effect of ESC on the ability of ordinary drivers to maintain control in critical situations.[20] A sample of 120 drivers equally divided between men and women and between three age groups (18–25, 30–40, and 55–65) was subjected to the following three critical driving scenarios. The ''Incursion Scenario'' forced drivers to attempt a double lane change at high speed (65 mph speed limit signs) by presenting them first with a vehicle that suddenly backs into their lane from a driveway and then with another vehicle driving toward them in the left lane. The ''Curve Departure Scenario'' presented drivers with a constant radius curve that was uneventful at the posted speed limit of 65 mph followed by another curve that appeared to be similar but that had a decreasing radius that was not evident upon entry. The ''Wind Gust Scenario'' presented drivers with a sudden lateral wind gust of short duration that pushed the drivers toward a lane of oncoming traffic. The 120 drivers were further divided evenly between two vehicles, an SUV and a midsize sedan. Half the drivers of each vehicle drove with ESC enabled, and half drove with ESC disabled.

In 50 of the 179 test runs performed in a vehicle without ESC, the driver lost control. In contrast, in only six of the 179 test runs performed in a vehicle with ESC, did the driver lose control. One test run in each ESC status had to be aborted. These results demonstrate an 88 percent reduction in loss-of-control crashes when ESC was engaged. The study also concluded that the presence of an ESC system helped reduce loss of control regardless of age or gender, and that the benefit was substantially the same for the different driver subgroups in the study. Because of the obvious danger to participants, an experiment like this cannot be performed safely with real vehicles on real roads. However, the National Advanced Driver Simulator provides extraordinary verisimilitude with the driver sitting in a real vehicle, seeing a 360-degree scene and experiencing the linear and angular accelerations and sounds that would occur in actual driving of the specific vehicle.

Crash Data Studies of ESC Effectiveness

There have been a number of studies of ESC effectiveness in Europe and Japan beginning in 2003.[21] All of them have shown large potential reductions in single-vehicle crashes as a result of ESC. However, the sample sizes of crashes of vehicles new enough to have ESC tended to be small in these studies. A preliminary NHTSA study published in September 2004 [22] of crash data from 1997–2003 found ESC to be effective in reducing single-vehicle crashes, including rollover. Among vehicles in the study, the results suggested that ESC reduced single vehicle crashes in passenger cars by 35 percent and in SUVs by 67 percent. In October 2004, the Insurance Institute for Highway Safety (IIHS) released the results of a study of the effectiveness of ESC in preventing crashes of cars and SUVs. The IIHS found that ESC is most effective in reducing fatal single-vehicle crashes, reducing such crashes by 56 percent. NHTSA's later peer-reviewed study [23] of ESC effectiveness found that ESC reduced single vehicle crashes in passenger cars by 34 percent and in SUVs by 59 percent, and that its effectiveness was greatest in reducing single vehicle crashes resulting in rollover (71 percent reduction for passenger cars and an 84 percent reduction for SUVs). It also found reductions in fatal single-vehicle crashes and fatal single-vehicle rollover crashes that were commensurate with the overall crash reductions cited. ESC reduced fatal single-vehicle crashes in passenger cars by 35 percent and in SUVs by 67 percent and reduced fatal single-vehicle crashes involving rollover by 69 percent in passenger cars and 88 percent in SUVs.

(a) NHTSA's preliminary study

In September, 2004, NHTSA issued an evaluation note on the *Preliminary Results Analyzing the Effectiveness of Electronic Stability Control (ESC) Systems*. The study evaluated the effectiveness of ESC in reducing single vehicle crashes in various domestic and imported cars and SUVs. It was based on Fatality Analysis Reporting System (FARS) data from calendar years 1997–2003 and crash data from five States that reported partial Vehicle Identification Number (VIN) information in their data files (Florida, Illinois, Maryland, Missouri, and Utah) from calendar years 1997–2002. The data were limited to mostly luxury vehicles because ESC first became available in 1997 in luxury vehicles such as Mercedes-Benz and BMW. The analysis compared specific make/models of passenger cars and SUVs with ESC versus earlier versions of the same make/models, using multi-vehicle crash involvements as a control group.

The passenger car sample consisted of mainly Mercedes-Benz and BMW models (61 percent). Mercedes-Benz installed ESC in certain luxury models in 1997 and had made it standard equipment in all their models (except one) by 2000. BMW also installed ESC in certain 5, 7, and 8 series models as early as 1997 and had made it standard equipment in all their models by 2001. The passenger car sample also included some luxury GM cars, which constituted 23 percent of the sample, and a few cars from other manufacturers. GM cars where ESC was offered as standard equipment are the Buick Park Avenue Ultra, the Cadillac DeVille, Seville STS and SLS, the Oldsmobile Aurora, the Pontiac Bonneville SSE and SSEi, and the Chevrolet Corvette. The SUV make/models in the study with ESC include Mercedes-Benz (ML320, ML350, ML430, ML500, G500, G55 AMG), Toyota (4Runner, Landcruiser), and Lexus (RX300, LX470).

The first set of analyses used multi-vehicle crash involvements as a control group, essentially assuming that ESC has no effect on multi-vehicle crashes. Specific make/models with ESC were compared with earlier versions of similar make/models using multi-vehicle crash involvements as a control group, creating 2x2 contingency tables as shown in Tables 1 and 2. The study found that single vehicle crashes were reduced by

$$1 - \{(699/1483)/(14090/19444)\} = 35 \text{ percent}$$

for passenger cars and by 67 percent for SUVs (Table 1). Similarly, fatal single vehicle crashes were reduced by 30 percent in cars and by 63 percent in SUVs (Table 2). Reductions of single vehicle crashes in passenger cars and SUVs were statistically significant at the .01 level, as evidenced by chi-square statistics exceeding 6.64 in each 2x2 contingency table (Table 1). Reductions of fatal single vehicle crashes are

[20] Papelis *et al.* (2004) Study of ESC Assisted Driver Performance Using a Driving Simulator, Report No. N04–003–PR, University of Iowa.

[21] See Footnote 10.

[22] Dang, J. (2004) Preliminary Results Analyzing Effectiveness of Electronic Stability Control (ESC) Systems, Report No. DOT HS 809 790. U.S. Dept. of Transportation, Washington, DC.

[23] Dang, J. (2006) Statistical Analysis of The Effectiveness of Electronic Stability Control (ESC) Systems, U.S. Dept. of Transportation, Washington, DC (publication pending peer review). A draft version of this report, as supplied to peer reviewers, has been placed in the docket for this rulemaking.

statistically significant at the .01 level in SUVs and at the .05 level in passenger cars with chi-square statistic greater than 3.84 (Table 2).

TABLE 1.—EFFECTIVENESS OF ESC IN REDUCING SINGLE VEHICLE CRASHES IN PASSENGER CARS AND SUVS

[Preliminary study with 1997–2002 crash data from five States]

	Single vehicle crashes	Multi-vehicle crashes (control group)
Passenger Cars		
No ESC	1483	19444
ESC	699	14090
Percent reduction in single vehicle crashes in passenger cars with ESC	35%	
Approximate 95 percent confidence bounds	29% to 41%	
Chi-square value	84.1	
SUVs		
No ESC	512	6510
ESC	95	3661
Percent reduction in single vehicle crashes in SUVs with ESC	67%	
Approximate 95 percent confidence bounds	60% to 74%	
Chi-square value	104.4	

TABLE 2.—EFFECTIVENESS OF ESC IN REDUCING FATAL SINGLE VEHICLE CRASHES IN PASSENGER CARS AND SUVS

[Preliminary study with 1997–2003 FARS data]

	Fatal single vehicle crashes	Fatal multi-vehicle crashes (control group)
Passenger Cars		
No ESC	186	330
ESC	110	278
Percent reduction in fatal single vehicle crashes in passenger cars with ESC	30%	
Approximate 95 percent confidence bounds	10% to 50%	
Chi-square value	6.0	
SUVs		
No ESC	129	199
ESC	25	103
Percent reduction in fatal single vehicle crashes in SUVs with ESC	63%	
Approximate 95 percent confidence bounds	44% to 81%	
Chi-square value	16.1	

NHTSA has now updated and modified last year's report, extending it to model year 1997–2004 vehicles—and to calendar year 2004 for the FARS analysis and calendar year 2003 for the State data analysis. Nevertheless, even as of 2004, a large proportion of the vehicles equipped with ESC were still luxury vehicles. Moreover, only passenger cars and SUVs had been equipped with ESC—no pickup trucks or minivans.

The State databases included crash cases from California (2001–2003), Florida (1997–2003), Illinois (1997–2002), Kentucky (1997–2002), Missouri (1997–2003), Pennsylvania (1997–2001, 2003), and Wisconsin (1997–2003). The FARS database included fatal crash involvements from calendar years 1997 to 2004. The extra year of exposure and the availability of data from more states significantly increased the sample size of crashes of vehicles with ESC. In the preliminary study, the state crash database contained 699 single-vehicle crashes of cars with ESC and 95 single-vehicle crashes of SUVs with ESC. The FARS database contained 110 single-vehicle crashes of cars with ESC and 25 single-vehicle crashes of SUVs with ESC. For the updated study, the state crash database contains 2,251 single-vehicle crashes of cars with ESC and 553 single-vehicle crashes of SUVs with ESC, and the FARS database of fatal single-vehicle crashes contains 157 and 47 crashes respectively, for passenger cars and SUVs with ESC.

The larger sample of crashes in the updated study facilitated a new analysis of the effectiveness of ESC on specific subsets of single-vehicle crashes (SV run-off-road crashes and SV crashes resulting in rollover). It also facilitated the use of a more focused control group of crashes that were unlikely to be affected by ESC so that a new analysis of the effect of ESC on multi-vehicle crashes could be undertaken.

The basic analytical approach was to estimate the reduction of crash involvements of the types that are most likely to have benefited from ESC—relative to a control group of other types of crashes where ESC is unlikely to have made a difference in the vehicle's involvement. Crash types taken as the new control group (non-relevant involvements because ESC would in almost all cases not have prevented the crash) were crash involvements in which a vehicle:

(1) Was stopped, parked, backing up, or entering/leaving a parking space prior to the crash,

(2) Traveled at a speed less than 10 mph,

(3) Was struck in the rear by another vehicle, or

(4) Was a non-culpable party in a multi-vehicle crash on a dry road.

The types of crash involvements where ESC would likely or at least possibly have an effect are:

(1) All single vehicle crashes, except those with pedestrians, bicycles, or animals (SV crashes).

(2) Single vehicles crashes in which a vehicle ran off the road (SV ROR) and hit a fixed object and/or rolled over.

(3) Single vehicles crashes in which a vehicle rolled over (SV Rollover), mostly a subset of SV ROR.

(4) Involvements as a culpable party in a multi-vehicle crash on a dry or wet road (MV Culpable).

(5) Collisions with pedestrians, bicycles, or animals (Ped, Bike, Animal).

In the updated study we performed the state data analysis separately for each state. Then we used the median of the estimates from the seven states as the best indicator of the central tendency of the data, and the variation of the seven states as a basis for judging statistical significance and estimating confidence bounds. The results of this analysis are presented in Table 3.

TABLE 3.—UPDATED STUDY—MEAN EFFECTIVENESS OF ESC IN REDUCING CRASHES IN PASSENGER CARS AND SUVS BASED ON SEPARATE ANALYSES OF 1997–2003 CRASH DATA FROM SEVEN STATES

	SV Crashes	SV ROR	SV Rollover	MV Culpable	Ped, bike, animal
Passenger Cars					
Mean percent reduction of listed crash type in passenger cars with ESC.	34%	46%	71%	11%	34%.
Approximate 90 percent confidence bounds	20% to 46%	35% to 55%	60% to 78%	4% to 18%	5% to 55%.
SUVs					
Mean percent reduction of listed crash type in SUVs with ESC.	59%	75%	84%	16%	−4% not statistically significant.
Approximate 90 percent confidence bounds	47% to 68%	68% to 80%	75% to 90%	7% to 24%	−28% to 15%.

Fatal crashes were analyzed separately using the FARS database as was done in the preliminary study, but larger sample sizes were possible because of an additional year of data. The results are given in Table 4.

TABLE 4.—UPDATED STUDY—EFFECTIVENESS OF ESC IN REDUCING FATAL CRASHES OF PASSENGER CARS AND SUVS BASED ON 1997–2004 FARS DATA

	SV Crashes	SV ROR	SV Rollover	MV Culpable	Ped, bike, animal	Control group
Passenger Cars						
No ESC	223	217	36	176	46	166
ESC	157	154	12	156	69	181
Percent reduction of listed crash type in passenger cars with ESC.	35%	36%	69%	19% not statistically significant.	38% not statistically significant.	
Approximate 90 percent confidence bounds.	20% to 51%	19% to 51%	52% to 87%	−2% to 39%	−87% to 12%.	
Chi-square value	8.58	8.17	12.45	1.82	2.14.	
SUVs						
No ESC	197	191	106	108	56	153
ESC	47	38	9	48	40	109
Percent reduction of listed crash type in SUVs with ESC.	67%	72%	88%	38%	0% not statistically significant.	
Approximate 90 percent confidence bounds.	55% to 78%	62% to 82%	81% to 95%	16% to 60%	−40% to 40%.	
Chi-square value	29.57	36.44	42.4	4.89	0.00.	

The effectiveness of ESC in reducing fatal single-vehicle crashes is similar to the effectiveness in reducing single-vehicle crashes from state data that included mostly non-fatal crashes. In the case of fatal crashes as well, the effectiveness of ESC in reducing single-vehicle rollover crashes was particularly high. The effectiveness of ESC in reducing fatal culpable multi-vehicle crashes of SUVs was also higher than in the analysis of state data, while the parallel analysis of multi-vehicle crashes of passenger cars did not achieve statistical significance.

The updated study of ESC effectiveness yielded robust results. The analysis of state data and a separate analysis of fatal crashes both reached similar conclusions on ESC effectiveness. ESC reduced single vehicle crashes of passenger cars by 34 percent and single vehicle crashes of

SUVs by 59 percent. The separate analysis of only fatal crashes supported the analysis of state data that included mostly non-fatal crashes. Therefore, the overall crash reductions demonstrated a significant life-saving potential for this technology. The effectiveness of ESC in reducing SV crashes shown in the latest data (Tables 3–4) is similar to the results of the preliminary analysis.

The effectiveness of ESC tended to be at least as great and possibly even greater for more severe crashes. Furthermore, the effectiveness of ESC in reducing the most severe type of crash in the study, the single-vehicle rollover crash, was remarkable. ESC reduced single-vehicle rollover crashes of passenger cars by 71 percent and of SUVs by 84 percent. This high level of effectiveness also carried over to fatal single-vehicle rollover crashes.

The benefits presented in Section V were calculated on the basis of the single-vehicle crash and single-vehicle rollover crash effectiveness results of Table 3 for reductions in non-fatal crashes and of Table 4 for reductions in fatal crashes. The single-vehicle rollover crash effectiveness results were applied only to first harmful event rollovers with the lower single-vehicle crash effectiveness results applied to all other rollover crashes for a more conservative benefit estimate.

III. September 2006 Notice of Proposed Rulemaking (NPRM) and Public Comments

A. The NPRM

As noted above, NHTSA published an NPRM on September 18, 2006 that proposed to establish FMVSS No. 126, *Electronic Stability Control Systems* (71 FR 54712). Specifically, it proposed to require passenger cars, multipurpose passenger vehicles, trucks, and buses with a GVWR of 4,536 kg (10,000 pounds) or less to be equipped with an ESC system that meets the requirements of the standard. As proposed, the vehicle would be required to meet a definitional requirement (*i.e.*, specifying the necessary elements of a stability control system that would be capable of both effective oversteer and understeer intervention) and to pass a dynamic performance test. These requirements are necessary due to the extreme difficulty in establishing a test adequate to ensure the desired level of ESC functionality.[24] The test is necessary to ensure that the ESC system is robust and meets a level of performance at least comparable to that of current ESC systems.

The NPRM included the following points, which highlighted the key provisions of the proposed requirements. However, for a more complete discussion—including detailed information on the proposal, as well as various potential performance tests (for both lateral stability and vehicle responsiveness) and regulatory alternatives considered by the agency—interested persons are encouraged to consult the NPRM.

• Consistent with the industry consensus definition of ESC contained in the Society of Automotive Engineers (SAE) Surface Vehicle Information Report J2564 (rev. June 2004), we proposed to require vehicles covered under the standard to be equipped with an ESC system that:

(1) Augments vehicle directional stability by applying and adjusting the vehicle's brakes individually to induce correcting yaw torques to a vehicle;

(2) Is computer-controlled, with the computer using a closed-loop algorithm[25] to limit vehicle oversteer and to limit vehicle understeer when appropriate;

(3) Has a means to determine vehicle yaw rate[26] and to estimate its sideslip[27];

(4) Has a means to monitor driver steering input, and

(5) Is operational over the full speed range of the vehicle (except below a low-speed threshold where loss of control of the vehicle is unlikely).

• The proposed ESC system, as defined above, would also be required to be capable of applying all four brakes individually and to have an algorithm that utilizes this capability. The system would also be required to be operational during all phases of driving, including acceleration, coasting, and deceleration (including braking), and it would be required to remain operational when the antilock brake system or traction control system is activated.

• We also proposed to require vehicles covered under the standard to satisfy the standard's stability criteria and responsiveness criterion when subjected to the Sine with Dwell steering maneuver test. This test involves a vehicle coasting at an initial speed of 50 mph while a steering machine steers the vehicle with a steering wheel pattern as shown in Figure 2 of the NPRM. The test maneuver is then repeated over a series of increasing maximum steering angles. This test maneuver was selected over a number of other alternatives, because we tentatively decided that it has the most optimal set of characteristics, including severity of the test, repeatability and reproducibility of results, and the ability to address lateral stability and responsiveness.

The maneuver is severe enough to produce spinout for most vehicles without ESC. The stability criteria for the test measure how quickly the vehicle stops turning after the steering wheel is returned to the straight-ahead position. A vehicle that continues to turn for an extended period after the driver steers straight is out of control, which is what ESC is designed to prevent. The stability criteria are expressed in terms of the percent of the peak yaw rate after maximum steering that persists at a period of time after the steering wheel has been returned to straight ahead. The criteria require that the vehicle yaw rate decrease to no more than 35 percent of the peak value after one second and that it continues to drop to no more than 20 percent after 1.75 seconds. Since a vehicle that simply responds very little to steering commands could meet the stability criteria, a minimum responsiveness criterion is applied to the same test. It requires that the ESC-equipped vehicle must move laterally at least 1.83 meters (half a 12 foot lane width) during the first 1.07 seconds after the initiation of steering (a discontinuity in the steering pattern that is convenient for timing a measurement).

• Because the benefits of the ESC system can only be realized if the system is functioning properly, we proposed to require a telltale be mounted inside the occupant compartment in front of and in clear view of the driver and be identified by the symbol shown for ''ESC Malfunction Telltale'' in Table 1 of FMVSS No. 101, *Controls and Displays.* The ESC malfunction telltale would be required to illuminate not more than two minutes after the occurrence of one or more malfunctions that affect the generation or transmission of control or response signals in the vehicle's ESC system.

[24] Without an equipment requirement, it would be almost impossible to devise a single performance test that could not be met through some action by the manufacturer other than providing an ESC system. Even a battery of performance tests still might not achieve our intended results, because although it might necessitate installation of an ESC system, we expect that it would be unduly cumbersome for both the agency and the regulated community.

[25] A ''closed-loop algorithm'' is a cycle of operations followed by a computer that includes automatic adjustments based on the result of previous operations or other changing conditions.

[26] ''Yaw rate'' means the rate of change of the vehicle's heading angle measured in degrees/second of rotation about a vertical axis through the vehicle's center of gravity.

[27] ''Sideslip'' means the arctangent of the lateral velocity of the center of gravity of the vehicle divided by the longitudinal velocity of the center of gravity.

Such telltale would be required to remain continuously illuminated for as long as the malfunction(s) exists, whenever the ignition locking system is in the ''On'' (''Run'') position. (Vehicle manufacturers would be permitted to use the ESC malfunction telltale in a flashing mode to indicate ESC operation.)

• In certain circumstances, drivers may have legitimate reasons to disengage the ESC system or limit its ability to intervene, such as when the vehicle is stuck in sand/gravel or when the vehicle is being run on a track for maximum performance. Accordingly, under this proposal, vehicle manufacturers would be permitted to include a driver-selectable switch that places the ESC system in a mode in which it would not satisfy the performance requirements of the standard (*e.g.*, ''sport'' mode or full-off mode). However, if the vehicle manufacturer chooses this option, it would be required to ensure that the ESC system always returns to a mode that satisfies the requirements of the standard at the initiation of each new ignition cycle, regardless of the mode the driver had previously selected. Furthermore, the manufacturer would be required to provide an ''ESC Off'' switch and a telltale that are mounted inside the occupant compartment in front of and in clear view of the driver and which are identified by the symbol or text shown for ''ESC Off'' in Table 1 of FMVSS No. 101. Such telltale would be required to remain continuously illuminated for as long as the ESC is in a mode that renders it unable to meet the performance requirements of the standard, whenever the ignition locking system is in the On (''Run'') position.

• We did not propose to require the ESC system to be equipped with a roll stability control function (or a separate system to that effect). Roll stability control systems involve relatively new technology, and we decided that there is currently insufficient data to judge the efficacy of such systems. However, the agency stated that it will continue to monitor the development of roll stability control systems. The NPRM also stated that vehicle manufacturers may supplement the ESC system we are proposing to require with a roll stability control system/feature.

In order to provide the public with the expected significant safety benefits of ESC systems as rapidly as possible, the NPRM proposed to require all light vehicles covered by this standard to be equipped with a FMVSS No. 126-compliant ESC system by September 1, 2011 (subject to the exception below). The agency proposed that compliance would commence on September 1, 2008, subject to the following phase-in schedule: 30 percent of a vehicle manufacturer's light vehicles manufactured during the period from September 1, 2008 to August 31, 2009 would be required to comply with the standard; 60 percent of those manufactured during the period from September 1, 2009 to August 31, 2010; 90 percent of those manufactured during the period from September 1, 2010 to August 31, 2011, and all light vehicles thereafter.

The NPRM stated that in order to encourage early compliance, the agency proposed that vehicle manufacturers would be permitted to earn carry-forward credits for compliant vehicles, produced in excess of the phase-in requirements, which are manufactured between the effective date of the final rule and the conclusion of the phase-in period. However, under the proposal, beginning September 1, 2011, all covered vehicles would be required to comply with the standard, without regard to any earlier carry-forward credits.

We proposed to exclude multi-stage manufacturers and alterers from the requirements of the phase-in and to extend by one year the time for compliance by those manufacturers (*i.e.*, until September 1, 2012). This NPRM also proposed to exclude small volume manufacturers (*i.e.*, manufacturers producing less than 5,000 vehicles for sale in the U.S. market in one year) from the phase-in, instead requiring such manufacturers to fully comply with the standard on September 1, 2011.

International Discussions of a Potential Global Technical Regulation on ESC

Based upon the agency's analysis of available research, we believe that the benefits of ESC are more broadly applicable than to just the U.S. driving environment. Instead, we believe that ESC has the potential to greatly benefit road users in all parts of the world. Therefore, throughout the development of its ESC proposal, NHTSA made particular efforts to keep other governments informed on the progress of its rulemaking. The agency accomplished this through several bilateral exchanges, as well as through its role in the United National World Forum for the Harmonization of Vehicle Regulations (WP.29) in Geneva, Switzerland.

Specifically, the United States negotiated the placement of electronic stability control systems on the Program of Work of WP.29 under the 1998 Global Agreement,[28] in order to formalize and facilitate information exchange on this topic. Since early 2005, agency officials have provided formal presentations on the ESC rulemaking to WP.29 and its specialized subsidiary body for stability control systems four times during formal session meetings. More recently, in November 2006, the NHTSA Administrator delivered remarks at the 140th session of WP.29, in which she outlined the benefits of this new technology and encouraged the Forum to pursue the development of a Global Technical Regulation (GTR) for ESC. The proposal[29] was met with great interest and was accepted by several of the government representatives in attendance. The representatives were especially impressed that the benefits of ESC technology are well-corroborated through several studies conducted independently around the world. Formal work to develop a GTR on electronic stability control is expected to begin in 2007.

B. Summary of the Public Comments on the NPRM

NHTSA received comments on the September 18, 2006 NPRM from a variety of interested parties, including seven automobile manufacturers and their trade associations,[30] nine suppliers of automobile equipment and their trade association,[31] four safety advocacy organizations,[32] and two other interested organizations.[33] Comments

[28] Although commonly referred to as the 1998 Global Agreement, this provision is more formally titled the ''1998 Agreement Concerning the Establishing of Global Technical Regulations for Wheeled Vehicles, Equipment and Parts which can be Fitted and/or be Used on Wheeled Vehicles.''

[29] *See http://www.unece.org/trans/doc/2007/wp29/ECE-TRANS-WP29-2007-17e.doc.*

[30] Comments were received from the following automobile manufacturers and related trade associations: (1 and 2) Alliance of Automobile Manufacturers and Association of International Automobile Manufacturers (joint comments); (3) Honda Motor Co. Ltd. and American Honda Motor Co., Inc.; (4) Nissan North America, Inc.; (5) Porsche Cars North America, Inc.; (6) Toyota Motor North America, Inc., and (7) Verband der Automobilindustrie.

[31] Comments were received from the following automobile equipment suppliers and their trade associations: (1) BorgWarner Torq Transfer Systems, Inc.; (2) Continental Automotive Systems; (3) Delphi Corporation; (4) Motor & Equipment Manufacturers Association; (5) Oxford Technical Solutions, Ltd.; (6) RLP Engineering; (7) Robert Bosch Corporation; (8) Specialty Equipment Market Association, and (9) TRW Automotive.

[32] Comments were received from the following safety advocacy organizations: (1) Advocates for Highway and Auto Safety; (2) Consumers Union; (3) Insurance Institute for Highway Safety, and (4) Public Citizen.

[33] Comments were received from the following other interested organizations: (1) National Mobility Equipment Dealers Association, and (2) SUVOA.

were also received from eight individuals. All of these comments may be found in Docket No. NHTSA–2006–25801.

Although certain of the comments from individuals objected to the ESC proposal (on the grounds of cost, newness of the technology, and concerns that it inappropriately may wrest vehicle control from the driver during critical situations), the overwhelming majority of the commenters supported establishing a safety standard for ESC systems as required equipment on new light vehicles. Instead, the difference of opinion among the commenters involved the stringency of the standard (including a requirement for advanced features), the test procedures (including need for understeer performance requirements), and the proposed lead time and phase-in for implementing the new standard. Other topics included making the ''ESC System'' definition more performance-based, lateral responsiveness criteria, ESC performance requirements, ESC malfunction detection requirements, ESC telltale requirements, system disablement and the ''ESC Off'' switch, test procedures, impacts on the aftermarket, comments on the preliminary regulatory impact analysis (PRIA), ESC outreach efforts, and other topics. The following discussion summarizes the main issues raised by these public comments and the positions expressed on these topics. A more complete discussion of the public comments is provided under Section IV.C, which provides an explanation of the agency rationale for the requirements of the final rule and addresses related public comments by issue.

IV. The Final Rule and Response to Public Comments

A. Summary of the Requirements

After careful consideration of the public comments on the NPRM, this final rule establishes FMVSS No. 126, *Electronic Stability Control Systems.* Specifically, it requires passenger cars, multipurpose passenger vehicles, trucks, and buses with a gross vehicle weight rating of 4,536 Kg (10,000 pounds) or less to be equipped with an ESC system that meets the requirements of the standard, in order to assist the driver in maintaining control in critical driving situations in which the vehicle is beginning to lose directional stability at the rear wheels (spin out) or directional control at the front wheels (plow out). Subject to the phase-in schedule and the exceptions below, compliance with the requirements of the final rule commences for covered vehicles manufactured on or after September 1, 2008 (*i.e.*, MY 2009).

The following points highlight the key provisions of the final rule.

- Consistent with the industry consensus definition of ESC contained in the Society of Automotive Engineers (SAE) Surface Vehicle Information Report J2564 (rev. June 2004), we are requiring vehicles covered under the standard to be equipped with an ESC system that:

(1) Augments vehicle directional stability by applying and adjusting the vehicle brake torques individually to induce a correcting yaw moment to a vehicle;

(2) Is computer-controlled, with the computer using a closed-loop algorithm [34] to limit vehicle oversteer and to limit vehicle understeer;

(3) Has a means to determine vehicle yaw rate [35] and to estimate its sideslip [36] or the time derivative of sideslip;

(4) Has a means to monitor driver steering input;

(5) Has an algorithm to determine the need, and a means to modify engine torque, as necessary, to assist the driver in maintaining control of the vehicle, and

(6) Is operational over the full speed range of the vehicle (except at vehicle speeds less than 15 km/h (9.3 mph) or when being driven in reverse).

- The ESC system as defined above is also required to be capable of applying brake torques individually at all four wheels and to have an algorithm that utilizes this capability. Except for the situations specifically set forth in part (6) of the definition of ''ESC System'' above, the system is also required to be operational during all phases of driving, including acceleration, coasting, and deceleration (including braking), and it is required to be capable of activation even if the anti-lock brake system or traction control system is also activated.
- In order to ensure that a vehicle is equipped with an ESC system that meets the definition of ''ESC System'' under S4, the final rule requires vehicle manufacturers to submit, upon the request of NHTSA s Office of Vehicle Safety Compliance, ESC system technical documentation as to when understeer intervention is appropriate for a given vehicle (*see* S5.6). Specifically, NHTSA may seek information such as a system diagram that identifies all ESC components, a written explanation describing the ESC system's basic operational characteristics, a logic diagram supporting the explanation of system operations, and a discussion of the pertinent inputs to the vehicle computer or calculations within the computer and how its algorithm uses that information and controls ESC system hardware to limit vehicle understeer.
- We are also requiring vehicles covered under the standard to meet performance tests. It must satisfy the standard s stability criteria and responsiveness criterion when subjected to the Sine with Dwell steering maneuver test. This test involves a vehicle coasting at an initial speed of 50 mph while a steering machine steers the vehicle with a steering wheel pattern as shown in Figure 2 of the regulatory text. The test maneuver is then repeated over a series of increasing maximum steering angles. This test maneuver was selected over a number of other alternatives, because we decided that it has the most optimal set of characteristics, including severity of the test, repeatability and reproducibility of results, and the ability to address lateral stability and responsiveness.

The maneuver is severe enough to produce spinout for most vehicles without ESC. The stability criteria for the test measure is how quickly the vehicle stops turning after the steering wheel is returned to the straight-ahead position. A vehicle that continues to turn for an extended period after the driver steers straight is out of control, which is what ESC is designed to prevent. The quantitative stability criteria are expressed in terms of the percent of the peak yaw rate after maximum steering that persists at a period of time after the steering wheel has been returned to straight ahead. The criteria require that the vehicle yaw rate decrease to no more than 35 percent of the peak value after one second and that it continues to drop to no more than 20 percent after 1.75 seconds. Since a vehicle that simply responds very little to steering commands could meet the stability criteria, a minimum responsiveness criterion is applied to the same test. It requires that an ESC-equipped vehicle with a GVWR of 7,716 pounds or less must move laterally at least 6 feet during the first 1.07 seconds after the initiation of steering (a discontinuity in the steering pattern that is a convenient point for timing a

[34] A ''closed-loop algorithm'' is a cycle of operations followed by a computer that includes automatic adjustments based on the result of previous operations or other changing conditions.

[35] ''Yaw rate'' means the rate of change of the vehicle's heading angle measured in degrees/second of rotation about a vertical axis through the vehicle's center of gravity.

[36] ''Sideslip'' means the arctangent of the lateral velocity of the center of gravity of the vehicle divided by the longitudinal velocity of the center of gravity.

measurement). It also requires that a heavier vehicle with a GVWR up to 10,000 pounds must move at least 5 feet laterally in the same maneuver for specified steering angles.

• Because the benefits of the ESC system can only be realized if the system is functioning properly, we are requiring a telltale be mounted inside the occupant compartment in front of and in clear view of the driver and be identified by the symbol or text shown for ''ESC Malfunction Telltale'' in Table 1 of FMVSS No. 101, *Controls and Displays.* The ESC malfunction telltale is required to illuminate after the occurrence of one or more malfunctions that affect the generation or transmission of control or response signals in the vehicle's ESC system. Such telltale must remain continuously illuminated for as long as the malfunction(s) exists, whenever the ignition locking system is in the ''On'' (''Run'') position. (Vehicle manufacturers are permitted to use the ESC malfunction telltale in a flashing mode to indicate ESC operation.)

• In certain circumstances, drivers may have legitimate reasons to disengage the ESC system or limit its ability to intervene, such as when the vehicle is stuck in sand/gravel, using snow chains, or when the vehicle is being run on a track for maximum performance. Accordingly, under this final rule, vehicle manufacturers may include a driver-selectable control that places the ESC system in a mode in which it would not satisfy the performance requirements of the standard (*e.g.*, ''sport'' mode or full-off mode). However, if the vehicle manufacturer chooses this option, it must ensure that the ESC system always returns to the fully-functional default mode at the initiation of each new ignition cycle, regardless of the mode the driver had previously selected (with certain exceptions for low speed off-road axle/transfer case selections that turn off ESC but cannot be reset electronically). The manufacturer is required to provide an ''ESC Off'' control and a telltale that are mounted inside the occupant compartment in front of and in clear view of the driver and which are identified by the symbol or text shown for ''ESC Off'' in Table 1 of FMVSS No. 101 or the text ''ESC Off.'' Such telltale must remain continuously illuminated for as long as the ESC is in a mode that renders it unable to meet the performance requirements of the standard, whenever the ignition locking system is in the ''On'' (''Run'') position.

B. Lead Time and Phase-in

In order to provide the public as rapidly as possible with what are expected to be the significant safety benefits of ESC systems, NHTSA has decided to require all light vehicles covered by this standard to be equipped with a FMVSS No. 126-compliant ESC system by September 1, 2011 (with certain exceptions discussed below). This implementation date for full, mandatory compliance is the same as that proposed in the NPRM and is consistent with our stated intention to have 90 percent of the subject fleet equipped with ESC in the 2011 model year that starts September 1, 2010. The agency continues to believe that this schedule for full implementation of the safety standard for ESC is appropriate, in order to provide manufacturers adequate lead time to make necessary production changes. September 1, 2008 marks the start of a three-year phase-in period for FMVSS No. 126.

However, in response to public comments and upon further review of the production plans [37] voluntarily submitted by vehicle manufacturers, we have determined that it would be practicable to increase the percentage of new light vehicles that must comply with Standard No. 126 under the phase-in, thereby accelerating the benefits expected to be provided by ESC systems. Because ESC is so cost-effective and has such high benefits in terms of potential fatalities and injuries that may be prevented, the agency agrees that it is important to require ESC installation in light vehicles as quickly as possible. Accordingly, under this final rule, we are requiring the following phase-in schedule for FMVSS No. 126: 55 percent of a vehicle manufacturer's light vehicles manufactured during the period from September 1, 2008 to August 31, 2009 would be required to comply with the standard; 75 percent of those manufactured during the period from September 1, 2009 to August 31, 2010; 95 percent of those manufactured during the period from September 1, 2010 to August 31, 2011, and all light vehicles thereafter. (This compares to the NPRM's proposal for a 30/60/90/all phase-in schedule over the same time periods.)

In order to ensure the financial and technological practicability of the final rule (in keeping with our statutory mandate), while at the same time facilitating ESC installation in the light vehicle fleet as expeditiously as possible, the agency analyzed the product plans submitted by six vehicle manufacturers, whose combined production accounts for approximately 87 percent of the new light vehicle fleet.[38] As explained in Chapter VII of the FRIA, we examined three different potential phase-in schedules to find the right balance among these competing concerns. Based upon this product plan information and the desire to provide manufacturers with flexibility by having a carry forward provision, we have chosen the most aggressive phase-in alternative that we believe is reasonable (*i.e.,* 55/75/95%).

Two factors were controlling in making the decision as to which alternative to choose: (1) The ability of manufacturers to change vehicles from being equipped with optional ESC to standard ESC for MY 2010 and MY 2011; and (2) Not forcing any manufacturer to install ESC in any make/model for which it was not planned to be at least an option. The agency did not believe there was enough lead time to redesign a make/model to include ESC by MY 2009. While there may be enough time to redesign such a make/model to include ESC by MY 2010, given the carry forward provisions this was not necessary for any of the six manufacturers for MY 2010. The second consideration became a factor once again in MY 2011, in not going beyond 95 percent (thereby obviating the costly need to redesign and develop tooling for a few vehicle lines which will not be produced in MY 2012).

In general, we anticipate that vehicle manufacturers will be able to meet the requirements of the standard by installing ESC system designs currently in production (*i.e.*, ones available in MY 2006). Except for possibly some low-production-volume vehicles with infrequent design changes (addressed below), NHTSA believes that most other vehicles can reasonably be equipped with ESC within three to four model years. We have determined that the majority of vehicle manufacturers would be able to meet the first two years of the revised phase-in schedule, without revising their current

[37] In April 2006, NHTSA sent letters to seven vehicle manufacturers requesting voluntary submission of information regarding their planned production of ESC-equipped vehicles for model years 2007 to 2012. Six manufacturers responded with product plans containing confidential information. These agency letters and manufacturer responses (with confidential information redacted) may be found in Docket No. NHTSA–2006–25801.

[38] We note that manufacturers' product plans have continued to evolve during the course of this rulemaking. For example, in a September 13, 2006 press release, Ford Motor Company announced that 100 percent of its light vehicle fleet would have ESC as standard equipment by MY 2010 (*see http://www.consumeraffairs.com/news04/2006/09/ford_stability.html*). The agency has carefully considered such developments in setting the phase-in schedule for this final rule.

production plans for ESC-equipped vehicles, given available phase-in credits under the rule. For the other manufacturers, they will have to increase production of ESC-equipped vehicles to comply with this accelerated phase-in schedule, but the available lead time is sufficient to allow for orderly planning for this increase and to achieve full implementation. Furthermore, we do not believe that the final rule's phase-in should pose ESC supply problems; public comments from vehicle manufacturers and ESC suppliers did not raise any such supply concerns, and our analysis of vehicle manufacturers' production plans suggest that the selected phase-in schedule will result in an installation rate increase of only a few percentage points in any year of the phase-in. Overall, we have determined that the final rule's phase-in schedule may be accomplished without disruptive changes in manufacturer and supplier production processes.[39]

After outlining the general parameters of the phase-in for FMVSS No. 126, we now turn to a number of exceptions or exclusions from the phase-in intended to address certain classes of vehicle manufacturers that may require additional time to achieve compliance and to address certain ESC components that may pose problems for a broader range of manufacturers in the short term. As an initial matter, we now understand from the public comments that vehicle manufacturers currently employ a variety of approaches for ESC controls and telltales, many of which would not meet the requirements of the agency's proposal. As a complicating matter, vehicle manufacturers and their trade associations explained that even though most current ESC systems would largely meet the performance requirements of the proposed standard, manufacturers' inability to meet the proposed control and display requirements would prevent them from earning the carry-forward credits needed to comply with the NPRM's aggressive phase-in schedule. Vehicle manufacturers generally commented that they could bring their ESC systems into full compliance (including the control and telltale requirements) by the end of the phase-in, and they argued that it is the performance of the ESC systems themselves, not the messages provided by the controls and telltales, that impart safety benefits under the standard.

After consideration of the numerous manufacturer comments on this issue, we have decided to defer the standard's requirements related to the ESC telltales and controls until the end of the phase-in (*i.e.*, September 1, 2011 for most manufacturers; September 1, 2012 for final-stage manufacturers and alterers); however, at that point, all covered vehicles must meet all relevant requirements of the standard (*i.e.*, no additional phase-in for the control and telltale requirements). Manufacturers are encouraged to voluntarily install compliant ESC controls and displays prior to the mandatory compliance date. Our rationale for this change from our proposal is as follows.

We now understand that standardizing ESC controls and telltales will involve substantial design and production changes and that additional lead time will be required to effect those changes. In addition, our analysis demonstrates that the safety benefits associated with early introduction of ESC systems, even without standardized controls and displays, far outweigh the benefits of delaying the standard until all systems can fully meet the control and display requirements (*see* FRIA's lead time/phase-in discussion). We do not believe that implementation of the entire standard should be delayed until technical changes related to the ESC controls and telltales can be fully resolved, because they would deny the public the safety benefits of ESC systems in the meantime. Accordingly, we believe that it is preferable to move rapidly to implement the standard, but to delay the compliance date only for the ESC control and telltale requirements.

This final rule also excludes small volume manufacturers (*i.e.*, manufacturers producing less than 5,000 vehicles for sale in the U.S. market in one year) from the phase-in, instead requiring such manufacturers to fully comply with the standard on September 1, 2011. This exclusion should facilitate implementation for low-production-volume vehicles with infrequent design changes.

Consistent with the policy set forth in NHTSA's February 14, 2005 final rule on certification requirements for vehicles built in two or more stages and altered vehicles (70 FR 7414), final-stage manufacturers and alterers are excluded from the requirements of the phase-in and are permitted an additional one year for compliance (*i.e.*, until September 1, 2012). However, final-stage manufacturers and alterers may voluntarily certify compliance with the standard prior to this date.

Vehicle manufacturers may earn carry-forward credits for compliant vehicles, produced in excess of the phase-in requirements, which are manufactured between the effective date of the final rule and the conclusion of the phase-in period. (We note that carry-forward credits may not be used to defer the mandatory compliance date of September 1, 2011 for all covered vehicles.) The final rule also includes phase-in reporting requirements for ESC systems (contained in Subpart I of 49 CFR Part 585) which are consistent with the phase-in schedule discussed above.

C. Response to Public Comments by Issue

As noted previously, public comments on the September 2006 NRPM for ESC raised a variety of issues with the NPRM's proposed requirements. Each of these topics will be discussed in turn, in order to explain how these comments impacted the agency's determinations in terms of setting requirements for this final rule.

Major Issues

1. Approach of the ESC NPRM

Subject to the phase-in schedule set forth in S8, the NPRM for ESC proposed to require new vehicles covered by Standard No. 126 to be equipped with an ESC system that meets the requirements specified in S5 under the test conditions specified in S6 and the test procedures specified in S7 of this standard (*see* S5, *Requirements*). The proposed standard would apply to passenger cars, multipurpose passenger vehicles, trucks, and buses with a gross vehicle weight rating of 4,536 kilograms (10,000 pounds) or less (*see* S3.1, *Application*).

NHTSA also noted that the ESC proposal would implement the provision in section 10301 of SAFETEA–LU, which requires the Secretary of Transportation to ''establish performance criteria to reduce the occurrence of rollovers consistent with stability enhancing technologies'' and to issue a final rule by April 1, 2009.

A number of commenters on the NPRM raised issues regarding the general approach taken by the agency in terms of its proposal for ESC. These comments are discussed immediately below.

(a) ESC Mandate vs. ESC Standardization

Mr. Kiefer urged NHTSA to adopt specifications for standardization of ESC systems that manufacturers voluntarily choose to install, rather than mandating

[39] We note that the agency has considered the possibility that external forces (*e.g.*, increases in gasoline prices, changing consumer preferences) might affect demand for specific types of vehicles, such as SUVs, which have higher ESC penetration. Such concerns provided further reason for the agency to adopt a phase-in schedule that included a provision for carry-forward credits.

installation at this time. The commenter stated that this approach would provide a trial period during which the ESC requirements could be evaluated, prior to fleet-wide installation.

We believe Mr. Kiefer's suggested approach falls short in light of the advanced state of development of ESC systems. Moreover, our analysis of the real-world experience with ESC to date indicates that a rulemaking mandate for it will save thousands of lives each year on American roadways. Our analyses also indicate that a mandate for ESC will be among the most cost-effective of NHTSA's rules ever. Moreover, the agency is not aware of any significant operational problems for ESC systems now in millions of vehicles on the American roads, nor have ESC suppliers or vehicle manufacturers indicated that there are such problems. Under these circumstances, there is no reason to delay proceeding to a mandate for this life-saving technology to be on all light vehicles.

(b) ESC as Part of a Comprehensive Rollover Safety Program

The comments of Advocates for Highway and Auto Safety (Advocates) included a lengthy discussion of what it perceives to be the agency's failure to carry out a comprehensive rollover crash safety plan. Public Citizen similarly argued that the ESC rulemaking should be part of a comprehensive rollover plan, and in particular, it objected to the proposal's failure to include a requirement for roll stability control (cited as currently in production on the Volvo XC–90). According to Public Citizen, a requirement for roll stability control would lead SUVs to be equipped with roll sensors, which it argued would in turn enhance safety features critical for ejection mitigation such as seatbelt pretensioners, advanced window glazing, and side impact airbags.

As we have stated in the past and in the NPRM for this rule, the agency adopted such a comprehensive plan in June 2003, which envisions agency efforts (several of which are currently underway) to improve vehicle stability, ejection mitigation, roof crush resistance, as well as road improvements and behavioral strategies aimed at consumer education. The relevant legislative provisions contained in SAFETEA–LU are fully consistent with the agency's ongoing efforts to prevent rollover crashes and to reduce their severity when they do occur.

Our analysis demonstrates that ESC systems can have a major positive impact in terms of preventing loss of control and keeping the vehicle on the roadway, thereby preventing rollovers. Regarding our decision not to propose a requirement for roll stability control, the agency made this determination because there is little data available to assess whether that feature actually provides any additional safety benefits, given that it appears that some current systems add this feature to ESC. Note that we believe that current systems that include roll stability control will satisfy the requirements for ESC. Under 49 U.S.C. 30111, a safety standard must be practicable, meet the need for motor vehicle safety, and be stated in objective terms; in setting the standard, relevant, available motor vehicle safety information must be considered. In this case, the dearth of information about roll stability control effectively precludes the agency from adopting a roll stability requirement, because it is not possible to determine whether this technology meets the need for safety. At the same time, this rule does not establish any barriers to automakers' adding roll stability control to ESC systems, nor to customers' demanding it. The issue of roll stability control and other ESC features is discussed in further detail in Section IV.C.3 of this document.

Impact on Other NHTSA Rulemakings

Advocates argued that the ESC NPRM and accompanying PRIA should take into account that rulemaking's impact on the agency's proposal [40] to upgrade FMVSS No. 216, *Roof Crush Resistance.* The commenter stated that the ESC benefits assessment is incomplete because it does not discuss how some unknown portion of fatalities due to roof crush will not occur as a result of ESC intervention to keep the vehicle on the road (*i.e.*, by preventing the rollover crash entirely), and it makes essentially the same point regarding the roof crush NPRM.

The agency agrees that the ESC rule would impact the agency's rulemaking to amend FMVSS No. 216, *Roof Crush Resistance.* The benefits estimated in the PRIA for FMVSS No. 216, which accompanied the NPRM published on August 23, 2005 (70 FR 49223), reflect the impacts of ESC penetration into the fleet at that time. As a general matter, the impact of ESC on FMVSS No. 216 should be addressed in the regulatory analyses for FMVSS No. 216 rather than in the ESC rule. Generally, the agency's approach for estimating the actual benefits of any rulemaking is to adjust the benefits of a later rule to take into account the impacts of earlier rules. Therefore, for the ESC rulemaking, the PRIA and this FRIA estimated the overall benefits of the ESC rule and only address the impacts of prior rulemakings on this current rule. The impact of ESC on other future rulemakings would be addressed in those future rules respectively. The benefits of future rules, including the roof crush rulemaking, will reflect the installation of ESC in the vehicle fleet.

(c) Need for Common Terminology

According to Consumers Union, vehicle manufacturers currently utilize a variety of acronyms and proprietary trade names to identify their ESC systems, which in turn make it more difficult for consumers to know what to ask for when shopping for a vehicle. To limit consumer confusion, Consumers Union urged NHTSA to require uniform terminology for how ESC systems are identified, so as to facilitate vehicle-to-vehicle comparisons. The organization recommended use of the nomenclature ''ESC'' and the term ''Electronic Stability Control,'' which presumably already have broad consumer recognition. A similar comment was provided by Mr. Petkun. These commenters also argued that the agency should require the automobile industry and dealerships to provide training for sales staff so that they may better educate and more accurately advise potential buyers about the value of an ESC system.

The agency appreciates the importance of providing consumers with clear information regarding vehicle safety features to use when deciding which vehicle to purchase, because we believe that such information serves a safety need (consistent with the agency's motor vehicle information mandate under 49 U.S.C. Chapter 323, *Consumer Information*). However, we do not believe it is necessary to pursue the use of common terminology for ESC, for the following reasons. The primary concern engendering calls for common terminology involved a consumer's ability to know whether a given vehicle is equipped with ESC or some other similar-sounding device (*e.g.*, a manufacturer's name for traction control), but that concern has essentially been eliminated by this final rule, which mandates installation of a compliant ESC system on all light vehicles by the end of the phase-in period. Absent that concern, there is no need for NHTSA to dictate how companies market their products.

2. The Definition of ''ESC System'' as the Basis of the Standard

As noted above, the NPRM proposed to require installation of an ESC system

[40] 70 FR 49223 (August 23, 2005).

that meets the definition contained in paragraph S4 of the standard, as well as the requirements of S5.1, *Required Equipment.* The proposed definition of ''ESC System'' specified certain features that must be present on that equipment, including that it be capable of applying all four brakes individually and have a computer using a closed-loop algorithm to limit vehicle oversteer and to limit vehicle understeer when appropriate. In addition, the system must have a means to determine the vehicle's yaw rate and to estimate its side slip, as well as a means to monitor driver steering inputs. Furthermore, the ESC system must be operational during all phases of driving including acceleration, coasting, and deceleration (including braking), except when the driver has disabled ESC or the vehicle is below a low speed threshold where loss of control is unlikely, and it must remain operational when the antilock brake system or traction control system is activated. The ESC system must also meet the proposed performance requirements for lateral stability and vehicle responsiveness (*see* S5.2).

BorgWarner Torq Transfer Systems, Inc. (BorgWarner) stated that the proposed standard should not mandate a specific solution in terms of how an ESC system would operate (*i.e.*, requiring a brake-base system), but instead it should adopt a performance standard that would encourage development of new and potentially improved technologies, ones which may provide more benefits and/or be more cost-effective than brake-based ESC systems. The commenter stated that it is ultimately the forces at the road/tire interface that are adjusted by the ESC, regardless of how that is accomplished. Accordingly, BorgWarner stated its opposition to the definition of ''ESC System'' as the basis of the standard because ''* * * other systems such as effective design of suspension and steering geometry, active steering, active suspension, AWD active yaw control, torque vectoring yaw control, [and] electronically controlled axle differentials may increase the vehicle's stability threshold such that loss of control is not imminent within the scope of the proposed testing procedure.''

Delphi Corporation (Delphi) stated that there are currently various alternative technologies in various stages of development that may substitute for brake-based ESC systems. According to the commenter, these include active steering systems (Active Front Steer, Active Rear Steer, Steer by Wire, Electric Power Steering), active drivetrains (Active Differentials, Electronic Limited Slip Differentials, Electric Motor/Generator Devices for Propulsion/Braking), and active suspensions (Active Stabilizer Bars, Active Dampers, Active Springs). Delphi added that while brake-based ESC systems are usually restricted to limit-handling conditions, other technologies (such as those mentioned above) can operate across a range of linear-handling to limit-handling (*i.e.*, nonlinear-handling) conditions.[41] The commenter stated that alternative technologies such as Active Front Steer and Active Rear Steer may actually prevent the vehicle's tires from reaching total saturation in the first place, thereby avoiding unstable and unresponsive situations.

Delphi also stated that systems using a combination of steering and braking actuation are more responsive and are not necessarily more objectionable to drivers because they are more predictive in their operation. Accordingly, Delphi recommended modifying the ESC definition in the regulatory text to permit any actuator device that can influence the tire/road forces to achieve improvements in vehicle stability and responsiveness.[42]

RLP Engineering expressed concern that the NPRM's ''equipment requirements'' (*i.e.*, definition of an ''ESC system'') is based upon current component technology and methodology, which could become outdated. Instead of specifying components, the commenter recommended that the agency state certain objectives and required outcomes, namely requiring means and methods of detecting impending vehicle instability and subsequent means and methods for actively engaging appropriate countermeasures. RLP Engineering argued that such an approach would allow for advancement in the state of the art and elimination of obsolete vehicle componentry (with the potential for cost reduction).

According to the Alliance of Automobile Manufacturers (Alliance) and the Association of International Automobile Manufacturers (AIAM), for some electric or hybrid vehicles, the industry expects that the appropriate ESC braking torques could be provided directly through the vehicle's propulsion system (regenerative braking) without the need to apply the friction brake, as done by current ESC systems. The commenters stated that such systems would potentially provide enhanced safety benefits in terms of more rapid and precise applied braking intervention, as well as longer service life for the vehicle's friction brakes.[43]

After careful consideration of the comments, we have decided to retain the approach set forth in the NPRM (with certain modifications), which would make the requirements associated with the definition of ''ESC System'' the primary basis of the standard. Our reasoning for this decision is as follows.

The agency's intention in the context of this ESC rulemaking has been to spread the proven safety benefits of current ESC systems across the light vehicle fleet. Available information shows that current brake-based ESC systems are effective and meet the need for motor vehicle safety. The agency is not aware of and commenters have not provided any information to demonstrate the efficacy of the ESC-related technologies specified in their comments as an alternative to brake-based ESC systems.

Furthermore, it is possible for a vehicle without ESC to be optimized to avoid spin-out in the narrowly defined conditions of the ESC oversteer intervention test (especially if the standard is silent on understeer) but to lack the advantages of ESC under other conditions. The agency has determined that it is not currently feasible to develop a comprehensive battery of tests that could substitute for the knowledge of what equipment constitutes ESC, and it remains to be seen if such approach

[41] ''Linear-handling'' describes the conditions that average drivers usually face. Drivers are accustomed to a range of lateral acceleration in which a given steering wheel movement produces a proportional change in the vehicle's heading, so that one knows with some degree of certainty where the vehicle will go when the wheel is turned a certain amount.

''Nonlinear-handling'' is at the edge of, and beyond, the range of lateral acceleration to which drivers are normally accustomed (*i.e.*, above about one-half ''g'' on dry pavement for ordinary vehicles). In such situations, the relationship between the driver's steering input and the vehicle's response changes, and the lag time of the vehicle's response can lengthen.

[42] Specifically, the commenter suggested modifying paragraphs S4 and S5.1.1 of the proposed standard to read as follows:

S4 Definitions (1) ''* * * augments vehicle directional stability by applying and adjusting the wheel forces to induce correcting yaw torques to a vehicle;''

S5.1.1 ''Is capable of *dynamically adjusting all four wheel forces* and has a control algorithm that utilizes this capability.''

[43] In order to accommodate such technology, the Alliance/AIAM recommended modifying S4 (definition of ''ESC system'') and S5.1.1 of the proposal to read as follows:

S4, *Electronic Stability Control System or ESC System* * * *

(1) That augments vehicle directional stability by applying and adjusting vehicle brake *torques* individually to induce a correcting yaw *moment* to a vehicle.

S5.1.1 Is capable of applying brake *torques* individually to *all four wheels* and has a control algorithm that utilizes this capability.

would ever be practical to set a purely performance-based standard that would ensure that manufacturers provide at least current ESC systems. Therefore, we have concluded that the standard's definition of ''ESC System'' is necessary in order to ensure that light vehicles have the attributes of ESC systems that produced the large reduction of single-vehicle crashes and rollovers in our crash data study (as discussed in detail in Section II.D). We note that a similar approach of defining heavy truck ABS, rather than depending solely on performance requirements, has been successful under FMVSS No. 121, Air Brake Systems. The following discussion explains the identified obstacles to a strictly performance-based approach.

Among the challenges associated with developing a performance test for ESC, the agency notes that manufacturers develop ESC algorithms using tests whose conditions are generally not repeatable (*e.g.*, icy surfaces which change by the minute, wet/slippery surfaces which are not repeatable day-to-day) and through simulation. Manufacturers also use hundreds of conditions requiring weeks of testing for a given vehicle. However, it is not practicable to use these approaches as part of a safety standard. Furthermore, the agency cannot use subjective tests to determine compliance with a safety standard.

It is possible to overcome these limitations by adopting the standard's definition of ''ESC System,'' which is based on a Society of Automotive Engineers definition of what ESC is, and which includes those elements that account for the cost of those systems. There is no reason to believe that manufacturers will incur all the costs of the ESC equipment and capabilities required by the standard's definition and then just program the system to achieve limited operation restricted to the test conditions of the standard. The standard's definitional requirement for ''ESC System'' requires, at a minimum, the equipment and capabilities of existing ESC system designs. This translates into the substantial fatality and injury benefits provided by existing ESC systems.

Without the definition of ''ESC System,'' it would not be feasible to comprehensively assess the operating range of resulting devices, particularly for understeer intervention, that might be installed in compliance with the safety standards. If manufacturers were to only optimize the vehicle so as to pass only a few highly-defined tests, there public would not receive the full safety benefits provided by current ESC systems.[44]

Under this topic, we also note the comment from the Alliance/AIAM about test variability (in the responsiveness portion of the oversteer intervention test). Even under test conditions chosen for high repeatability, these commenters maintain that the performance requirements must be decreased to allow a larger margin of compliance. Such margins of compliance would make a very weak standard if based solely on tests that would be considerably less repeatable than those we are using.

The Delphi comment also lists a number of systems and components that can influence wheel forces and suggests that it should be permissible for the definition of ESC to be satisfied by systems that can generate wheel force (*i.e.*, a requirement more open than compelling a system that must operate through brake forces). However, the commenter did not provide any data to show the effectiveness of such systems, as would demonstrate that they meet the need for motor vehicle safety and that it would be appropriate to substitute them for proven brake-based ESC systems. We believe there are good reasons for the safety standard at least initially to be based on braking forces (noting that we have changed the definition to include all ''braking'' torques at the wheels (*i.e.*, regenerative braking by an electric motor as well as the action of friction brakes)). While some of the devices mentioned by BorgWarner and Delphi could create yaw moments (for ESC interventions) by driving torques,[45] yaw moments created by braking torques have an advantage in critical situations because they also cause the vehicle to slow down.

These commenters also mention a number of steering-related concepts as an alternative means of meeting the standard's requirements. Specifically, Delphi stated that active steering interventions (in a vehicle that combines steering and braking in its ESC) could operate at driving conditions well below critical levels of tire saturation (where steering interventions lose their power) and produce a more responsive vehicle. While active steering may be useful in certain situations, the steering interventions may not be very helpful at or near the limit of traction, which is arguably the critical situation at the heart of this rulemaking. Again, braking forces have an advantage over steering forces because they can create a more powerful yaw intervention when the vehicle is at the limit of traction.[46]

We understand that manufacturers of a small number of luxury cars are beginning to add active steering to ESC, as described by Delphi, which are very refined vehicle systems that are carefully designed so as to not annoy their drivers. We clarify that the standard in no way prohibits the addition of refinements to vehicles that retain the ability to create yaw moments with brake torques when necessary. The vehicles in question retain the brake-based ESC as the backstop for stability, because the brake interventions which are more noticeable to drivers retain their power in situations where the transparent steering interventions might not be powerful enough. Without data to assess the effectiveness of these potential alternative operating features for ESC (which commenters did not provide), we have decided that it would not be appropriate at this time to abandon the requirement for brake torque-based systems which have proven benefits, in favor of concepts that have not yet demonstrated any safety benefits, much less the enormous benefits associated with current brake torque-based ESC systems.

We acknowledge that in requiring ESC as it now exists and has proven to be beneficial, we may be indirectly impacting hypothetical future technological innovations. We have to balance the benefits of saving thousands of lives a year by requiring ESC systems with the capabilities of current ESC systems, against the loss of savings in the future provided by some even more advanced ESC technologies. In this case, we believe that the opportunity to save this many lives must be selected. Should new advances lead to forms of ESC different than those currently required by this standard, interested parties can petition the agency to modify the regulation. We also note that

[44] The U.S. Environmental Protection Agency (EPA) experienced problems with heavy duty diesel manufacturers' production of engines that met EPA standards during laboratory testing under EPA procedures but were turned off under highway driving conditions. On October 22, 1998, the Department of Justice and EPA announced a settlement with seven major diesel engine manufacturers. Accordingly, we do not believe that the industry's ability to circumvent the requirements of the standard is a theoretical one, as would permit us to forgo a definition for ''ESC System.''

[45] ''Driving torque'' is a force applied by the engine through the drive train in order to make a particular wheel turn faster than the others—similar to ''braking torques'' which brakes one wheel to make it turn slower than the others. Either force can be utilized by an ESC system to change the heading of the vehicle, although braking torque has the added benefit of helping slow the vehicle down.

[46] Liebemann *et al.*, Safety and Performance Enhancement: The Bosch Electronic Stability Control (ESP), 2005 ESC Conference.

the vehicle manufacturers who are the directly regulated parties have not opposed using the definition for ''ESC System'' as the primary requirement of the standard, and some have actively supported it. We interpret this to mean that the vehicle manufacturers are not aware of any feasible alternative approach for providing efficacious electronic stability control in the near future, other than the approach described in the definition.

3. Stringency of the Standard

The NPRM proposed in S4 to require installation of an ESC system that: (1) Is capable of applying all four brakes individually and has a control algorithm that utilizes this capability; (2) is operational during all phases of driving including acceleration, coasting, and deceleration (including braking), except when the driver has disabled ESC or the vehicle is below a low speed threshold where loss of control is unlikely, and (3) remains operational when the antilock brake system or traction control system is activated (*see* S5.1). The ESC system also would have to meet the proposed performance requirements for lateral stability and vehicle responsiveness (*see* S5.2).

Advocates expressed strong support for a mandate that ESC be provided on all light vehicles, but it urged the agency to adopt a more stringent standard in the final rule. Specifically, Advocates argued that the proposed requirements for ESC intervention to increase lateral stability and to restore proper directional heading are sub-optimal. The commenter also objected to what it characterized as the ''minimal standard'' that would be set by the proposal, one which effectively accommodates the lowest level of all existing ESC system designs and performance, rather than pushing for state-of-the-art technology. According to the commenter, the proposal would grandfather in all existing ESC designs, even though not all ESC systems have the same level of capabilities.

Advocates also requested that the rule require certain operating functions present on many current ESC systems (*e.g.*, automatic speed reduction achieved by automatic braking and engine de-powering/engine control, traction control, automatic steering, roll stability control), even though the agency based its benefits assessment in the PRIA by ''piggybacking'' onto these more robust ESC systems. The commenter stated that these additional features, which the agency suggests have some positive safety value, make some unknown (*i.e.*, unquantified) contribution to the anticipated reduction in deaths, injuries, and crash severity associated with the ESC rulemaking. Advocates added that the PRIA's estimated benefits may be inflated because, given the more truncated requirements of the proposed standard, there is no assurance that manufacturers will continue to install more complex ESC systems, a result that would detract from ESC as an advanced safety technology.

In addition, Advocates urged that the agency continue its efforts to reconcile ESC intervention with effective roll stability control systems, characterizing the latter as the only means to directly intervene to prevent imminent rollover (as compared to ESC's indirect contributions through oversteer and understeer intervention). Although the commenter seemed to acknowledge that incorporation of roll stability control requirements may not be possible immediately, it stated that the agency should eventually include performance specifications for this function as part of FMVSS No. 126.

Consumers Union expressed general support for the ESC rulemaking, stating that stability control systems should be standard equipment on all vehicles, especially sport utility vehicles (SUVs). It further stated that, since 1998, it has conducted tests on 179 vehicles equipped with ESC systems, but it has found considerable variability in the level of performance across the systems provided. The commenter stated that better ESC systems act decisively but not prematurely, whereas other systems can be slow to react, help only in certain situations, and intervene too frequently during normal driving. Accordingly, Consumers Union recommended that NHTSA's standard should be modeled after the ESC systems found to be ''best performers,'' which it characterized as ones that are intrusive and very evident in ''at the limit'' testing (*i.e.*, at the point at which loss of vehicle control may be imminent), but less so during routine driving.

In addition, Consumers Union stated that ESC calibration should be adjusted to match the type of vehicle for which the system has been developed so that it complements vehicle and driver characteristics (*e.g.*, a more intrusive system for a minivan than for a sports sedan).

Specifically, Consumers Union stated that the NPRM's proposed steering response 1.07 seconds after the initiation of steering (minimum of 6 feet from the center line) is not aggressive enough, and accordingly, the commenter reasoned that it could allow manufacturers to fit low grip tires and slow steering to improve performance under the standard's test procedures. Consumers Union expressed concern that manufacturers may seek to reduce costs by developing cheaper, less sophisticated ESC systems which may pass all the requirements of the standard, but which may be relatively less effective in terms of saving lives.

Public Citizen commented that the agency's ESC proposal is incomplete because it does not deal with the full set of technologies which make up many current ESC systems, instead proposing a more limited yaw stability standard. (Public Citizen also argued that the agency assessed benefits in the PRIA on these more advanced ESC systems). For example, Public Citizen noted that the Alliance of Automobile Manufacturers made a presentation to NHTSA in which it described a number of current features [47] on ESC systems, including yaw stability,[48] traction control, ABS,[49] brake assist, active steering, body roll control,[50] vehicle roll stability control, corner brake control,[51] and electronic damping control.[52] Public Citizen specifically asked why the agency considered traction control to be only a ''convenience feature.''

According to Public Citizen, the ESC equipment requirements are already out-of-date and will be obsolete by the time a final rule is published. The commenter argued that the proposal would mislead consumers into thinking that they are purchasing a true ESC system using the latest technology. Public Citizen stated that because the agency's proposal would accept the

[47] We note that many of the ESC-related features cited by the commenters may serve similar or complementary functions, which may vary to some extent from vehicle to vehicle. However, to the extent possible, we have tried to generally explain our understanding of these technologies either in footnotes or the textual discussion of this document.

[48] ''Yaw stability'' means an electronic stability control system of the type required by new FMVSS No. 126 and explained in section II.D of this preamble.

[49] ''ABS'' means anti-lock braking system, a system that controls rotational wheel slip in braking by sensing individual wheel speeds and adjusting brake actuating forces in response to those signals. ABS provides many of the components necessary for ESC.

[50] ''Body roll control'' is a utilization of electronic damping control to stiffen the body roll resistance in a curve to provide a more level ride.

[51] ''Corner brake control'' (CBC) is designed to improve vehicle stability *during a braking event* by adjusting the brake line pressure applied to the individual wheels. It is a refinement of ABS with some similarity to ESC, except that CBC intervention requires the driver to apply force to the brake pedal, whereas ESC interventions occur regardless of whether the driver has applied the brakes.

[52] ''Electronic damping control'' is an electronic system of shock absorbers having electrically-controllable damping rates (stiffness) and a control module to operate them as a system.

least extensive of current ESC technologies, it would merely ratify the *status quo* and not ''reduce'' rollover deaths as Congress required under SAFETEA–LU. The organization stated that the agency cannot rely upon an unenforceable expectation that vehicle manufacturers will continue to provide advanced ESC systems, and it expressed concern that some vehicle manufacturers might actually strip out certain ESC-related features on low-cost vehicles, thereby actually degrading vehicle safety. In contrast, Public Citizen argued that the agency should exert a ''technology forcing'' influence with respect to vehicle safety improvements. Thus, Public Citizen argued that the ESC proposal would not go far enough to improve vehicle safety.

Public Citizen stated that the two studies of the effectiveness of ESC system prepared by NHTSA, which used Fatality Analysis Reporting System (FARS) data for 1997–2004 and State registration data for 1997–2003, surveyed a time period during which ESC technology was a relatively new technology. As a result, Public Citizen argued that those studies were confounded by small sample sizes and that the results, therefore, make it nearly impossible to support statistically significant claims regarding specific ESC configurations or to separate out the components which the agency decided not to include in its proposal. Again, Public Citizen commented that the PRIA for the ESC NPRM counts the benefits of more extensive ESC technologies, without counting the full costs for those systems. It argued that more properly, the agency should have measured the benefit of a yaw control system, which is more in line with the requirements of the agency's proposal.

In response to these comments requesting that the agency require additional features found on some ESC systems, we have decided to incorporate a requirement for ESC engine control but not to require other system components at this time. Although discussed in detail immediately below, the following summarizes our rationale for this decision.

As a preliminary matter, we find no merit in Public Citizen's arguments that the NPRM's proposed ESC requirements fail to satisfy the requirements of the statutory mandate under SAFETEA–LU. As discussed previously, the statute provided the agency with discretion to adopt performance criteria for technologies consistent with stability enhancing technologies. Our research identified ESC systems as the most effective of these technologies, and our proposal was based upon the definition for ''ESC System'' promulgated by the Society of Automotive Engineers, a group which is broadly representative of industry experts. Furthermore, the Verband der Automobilindustrie (VDA), an association of German vehicle manufacturers, acknowledged that NHTSA's definition corresponds to modern ''state-of-the-art'' ESC systems. The proposal also established performance criteria in the form of tests for lateral stability and vehicle responsiveness (*see* Section IV.C.4 and the Appendix for a discussion of the agency's efforts to develop a performance test for understeer). Accordingly, this final rule meets the requirements of SAFETEA–LU.

As discussed above, under 49 U.S.C. 30111, a safety standard must be practicable, meet the need for motor vehicle safety, and be stated in objective terms; in setting the standard, relevant, available motor vehicle safety information must be considered. With the exception of engine control, all of the other ESC-related components lack supporting data to assess their effectiveness and to determine whether such technologies meet the need for safety. The commonality of design for ESC systems that were represented in the agency's crash data study focused on individual brake application and engine control, and we note that in its comments, VDA stated that the agency's proposed definition for ''ESC system'' captures the state-of-the-art. Again, even though certain later ESC designs incorporate some additional features, it was not possible to determine the safety benefits, if any, of these features because these features were not available on any of the ESC-equipped vehicles in the crash data study. Also, some of those features are directed at comfort and convenience rather than safety (as explained below). We do not believe that there is good reason to postpone the proven life-saving benefits of basic ESC systems until such time as the agency can conduct the necessary research to assess the panoply of related components. Accordingly, we believe that it is not necessary to specify additional components as part of the standard's definition for ''ESC system,'' but instead, we leave it to the discretion of vehicle manufacturers to tailor the features of their individual ESC systems to the needs of a given vehicle. We note that the rule does not limit manufacturers' ability to develop, install, and advertise stability control systems that go beyond its requirements.

At the time of the agency's analysis, the U.S. crash data available to NHTSA to evaluate the benefit of ESC did not include vehicles newer than 2003. However, the ESC systems of the vehicles that were part of the agency's analysis proved extraordinarily effective, reducing single-vehicle crashes from 34 to 59 percent and reducing rollover in single-vehicle crashes (the crash type leading to over 80 percent of rollovers) from 71 to 84 percent. The results were statistically significant and in agreement with studies by other parties worldwide as cited in the NPRM. The rule requires ESC systems at least as capable as those that produced this extremely high level of demonstrated, real-world benefits at a reasonable cost to the public. It does not simply ''grandfather'' all existing ESC systems, and the performance criteria were developed using contemporary new vehicles produced in 2005 and 2006. The basis of the standard is a definition of ESC that specifically excludes existing two-wheel ESC systems because they are not capable of understeer invention or four-wheel automatic braking during an intervention, even though these systems also produced substantial (but lesser) benefits.

Engine Control

''Engine control'' means the ability of an ESC system to determine the need, and a means to modify engine torque, as necessary, to assist the driver in maintaining control of the vehicle.

The commenters argued that the benefit assessment included the contributions of ESC engine control. We have considered this comment and agree that ESC engine control was a feature on most vehicles in the crash data analysis and on all the vehicles in the ESC cost study. Because ESC engine control is likely to have influenced the estimated benefits reported in the PRIA, we are amending the ''ESC System'' definition in the standard to include a requirement for engine control based on the definition contained in SAE Surface Vehicle Information Report J2564:

> The system must have an algorithm to determine the need, and a means to modify engine torque, as necessary, to assist the driver in maintaining control of the vehicle.

Other Features

The commenters also claimed that the benefit assessment included the contributions of such features as automatic braking, traction control, active steering, brake assist, and roll stability control and that the standard would not achieve the expected benefits with the required ESC systems. However, we have determined that it is not necessary to make additional modifications related to the other features cited by commenters. We have

also decided that the commenters' recommendations regarding the test criteria are likewise unnecessary. We address each of these topics in turn below.

Automatic Braking

''Automatic braking'' involves the application of other brakes in addition to the brake required to generate the necessary yaw torque (as described in the explanation of ESC operation in Section II.D), along with a heavier application at the initial brake location to maintain the yaw torque.

A requirement for automatic braking would be redundant, because that feature is simply the application of other brakes in addition to the brake already required to generate the necessary yaw torque. All of the hardware required for this operation is already included in the definition of ''ESC System.'' Automatic braking is just one of the strategies invoked by the basic operating software of ESC, but the circumstances when it is called for and the severity of the braking are determined when ESC is tuned for a specific vehicle. Making ESC a requirement will not reduce the use of automatic braking. If anything, use of ESC on a much greater number of vehicles will lead to more sophisticated basic software being delivered to vehicle manufacturers by suppliers.

Traction Control

''Traction control'' reduces engine power and applies braking to a spinning drive wheel in order to transfer torque to the other drive wheel on the axle.

The commenters are mistaken in attributing ESC benefits to traction control. Traction control provides mobility in starting on slippery surfaces, but it offers no improvement in lateral stability beyond that already provided by ESC with engine control. ESC already reduces engine power when lateral instability is detected, and there is no further assistance that traction control could add.

Active Steering

''Active steering'' is a computer-controlled function that allows steering of the front axle (and possibly the rear) independent of driver input to maintain stability. As mentioned in Section IV.C2 above, active steering interventions are not as powerful as ESC brake interventions in limit situations. (Our observations lead us to believe that active steering is being used to delay the onset of ESC interventions as a driver satisfaction feature.)

Active steering did not affect our estimation of benefits because none of the vehicles in our data study were equipped with that feature. Also, only one of the new vehicles in our research to develop an oversteer test had this recently introduced feature. This vehicle was also the only new vehicle in our research that failed the oversteer test criteria. Ironically, this vehicle was equipped with more cutting edge technology than the rest of the new test vehicles.

Brake Assist

''Brake assist'' causes a maximum brake application if the driver presses the brake pedal very quickly in a manner indicative of panic braking, even if the driver is hesitant to brake hard.

Similarly, the benefits we have attributed to ESC based upon our research have nothing to do with brake assist. It is a feature that predates ESC on the European vehicles in our test group that had it. Brake assist is not part of the ESC system; it does not affect yaw stability, and it was present on both the non-ESC control vehicles and the ESC-equipped vehicles in our study. NHTSA is examining the merits of brake assist separately from its ESC research.

Roll Stability Control

''Roll stability control'' senses the vehicle's body roll angle and applies high brake force to the outside front wheel to straighten the vehicle's path and reduce lateral acceleration if the roll angle indicates probable tip-up.

Roll stability control was not responsible for the huge reduction in rollovers in single-vehicle crashes of 71 percent for cars and 84 percent for SUVs. None of the vehicles in the crash data study had roll stability control. The crash data study was a study of the benefits of yaw stability control. The first vehicle with roll stability control was the 2003 Volvo XC90 (cited by Public Citizen) which was not in our data study because it was a new vehicle without a non-ESC version that could serve as a control vehicle. It is also a low-production-volume vehicle that would have produced very few crash counts in the 1997–2003 crash data of our study. A similar roll stability control system was used on high-volume Ford Explorers starting in 2005, and eventually there will be enough Explorer data to evaluate the effectiveness of roll stability control. The agency will track the rollover rate of vehicles equipped with roll stability control through analysis of State-generated crash data and evaluate its effectiveness once a sufficient sample size becomes available (*i.e.*, approximately three to four years).

However, because our data study showed yaw stability control reducing rollovers of SUVs by 84% by reducing and mitigating road departures, and because on-road untripped rollovers are much less common events, the target population of crashes that roll stability control could possibly prevent may be very small. If and when roll stability control can be shown to be cost-effective, then it could be a candidate for inclusion in the standard in subsequent rulemaking.

In addition, the countermeasure of roll stability control systems is at least theoretically not benign. It reduces lateral acceleration by turning the vehicle away from the direction the driver is steering for at least a short distance. As noted previously, several individual commenters expressed strong dissatisfaction that we were proposing a mandatory safety device in which the driver yields at least some measure of vehicle control to a computer. This was an inaccurate criticism of the pure yaw stability control system we proposed, because such system would help the vehicle go in the direction the driver is steering. ESC engine control does require the system to override the driver's throttle control which was a specific complaint of some commenters. However, requiring systems that actually countermand the driver's steering control requires a high level of justification, a hurdle which roll stability control cannot yet surmount due to the newness of the technology and the corresponding lack of available data.

Test Criteria

In terms of future manufacturer actions, we note that Consumers Union criticized the test criteria as too weak to ensure that manufacturers will not create cheaper, less sophisticated systems that rely on poor tire traction or a reduced steering ratio to meet the performance test. To preclude such actions, we established criteria for vehicle responsiveness as well as lateral stability (*see* discussion under Section IV.C.5).

Also, we do not agree with Consumers Union's assertions that the standard's test criteria are weak. The commenters offered no recommendations in terms of how test severity could be improved. As carefully explained in the NPRM, the agency knows of no test more suited for quantifying an ESC system's ability to mitigate excessive oversteer while simultaneously facilitating the assessment of lateral displacement capability. Every vehicle we have evaluated using the lateral stability performance criteria has demonstrated

profound differences between tests performed with fully enabled and fully disabled ESC. Thus, this test clearly distinguishes vehicles with properly tuned ESC systems from comparable vehicles not so equipped.

4. Understeer Requirements

Under the proposed requirement that vehicles be equipped with ESC systems meeting the proposed definition of ''ESC System,'' a system must be ''computer controlled with a computer using a closed-loop algorithm to limit vehicle oversteer and to *limit vehicle understeer when appropriate*'' (emphasis added). The NPRM did not propose a separate performance requirement for understeer. (All current ESC designs that NHTSA has studied appear to already include provisions for mitigating excessive understeer.)

BorgWarner suggested that it is inconsistent for the ESC proposal to state that the system must meet an understeer requirement without defining a test or set of criteria to objectively measure compliance. Accordingly, BorgWarner stated that the agency should either include a performance requirement for understeer or eliminate the understeer requirement. The commenter suggested that the agency could amend the standard at a later date, once the parameters of the understeer performance requirement and associated test procedure have been developed.

Delphi stated that while it supports the eventual incorporation of an understeer performance requirement into the ESC standard, the commenter believes that adoption of the agency's proposal would yield significant safety benefits and that the agency should proceed quickly to a final rule. Accordingly, Delphi suggested leaving an understeer performance requirement for a separate future rulemaking. Delphi reasoned that, ultimately, an ESC system facing an extreme understeer situation must avoid overreaction that produces oversteer (excess yaw and side slip, which may lead to off-road tripped rollover) or produces excessive lateral acceleration that may induce on-road untripped rollover.

Advocates faulted the NPRM, on both safety and legal grounds, for not proposing specific performance requirements for ESC understeer intervention. The commenter argued that because the agency has identified understeer intervention as one of the necessary elements for an ESC system, it is obligated to establish performance requirements (including appropriate test procedures), without which the understeer requirement is unenforceable. Otherwise, the commenter stated that some manufacturers might supply ESC systems that do not adequately compensate for understeer loss of control circumstances, arguing that there are already vast differences in tuning among various ESC systems. Advocates predicted that failure of the agency to specify understeer performance requirements would maintain or expand differences between ESC performance from one vehicle make or model to another and could cause the standard to forgo prevention of additional fatalities and injuries. Furthermore, Advocates argued that since SAFETEA–LU directs the agency to establish performance *criteria* for stability enhancing technologies (*i.e.*, noting the plural nature of that statutory provision, which Advocates suggested requires something more than an oversteer *criterion* alone), including the understeer component that the agency has determined to be a necessary part of ESC systems from a safety perspective is also required from a legal perspective.

Consumers Union expressed concern that the agency's proposal does not assess an ESC-equipped vehicle's ability to reduce understeer through the standard's test procedures. The commenter inquired as to what percentage of the fatalities to be addressed by the standard are caused by understeer as opposed to oversteer, but the organization stated that it nevertheless believes that understeer is an issue that should be addressed by the agency.

IIHS expressed its agreement with the agency's approach to provide both a definition of an ESC system and a performance requirement for such systems. However, because the proposed ESC performance test does not fully address understeer, IIHS cautioned the agency to monitor the performance of ESC-equipped vehicles to ensure that they continue to be effective.

Public Citizen also objected to the omission of a performance test for understeer intervention, stating that the agency has not addressed the understeer performance criteria used by industry or the potential loss of benefits that would be attributed to the failure to develop understeer performance criteria. According to Public Citizen, the agency should explain on the record the available test procedures for understeer that it examined and explain why those procedures are inadequate. The commenter stated that the agency itself has identified understeer intervention as an important component of the ESC system, but without any performance criteria, neither the agency nor the consumer will have any sense of the effectiveness of the system in that regard. Accordingly, the commenter argued that the NPRM is inadequate to meaningfully address rollover fatalities as required by the statute, so it demanded a supplemental notice of proposed rulemaking (SNPRM) to correct these perceived deficiencies.

Although Mr. Sparhawk agreed that ESC systems are likely to provide substantial benefits, he raised two issues for resolution in the final rule. Mr. Sparhawk argued that NHTSA has not established an adequate record to justify adoption of an equipment requirement or to explain why development of a performance test for understeer was too difficult and too cumbersome for the agency and the regulated community. The commenter stated that the justification provided by the agency for not including an understeer test as part of the ESC proposal requires further factual and analytical development.

Mr. Sparhawk questioned how, without an understeer test, the agency can determine whether that aspect of the ESC system has the desired level of functionality or whether the system will always function as expected. (The commenter cited NHTSA's June 2003 report titled ''Initiatives to Address the Mitigation of Vehicle Rollover,'' which noted system-to-system variability in terms of ESC performance.)

The commenter also stated that numerous understeer tests have been developed in Asia, Europe, and North America, so the record should explain that these tests do exist, why they are inadequate, and the urgent need to move to a final rule even before the understeer issue can be fully resolved. Otherwise, one might ask why the agency simply did not wait for additional data on this key element before proceeding with its rulemaking. In addition, the commenter asked the agency to explain the factors, elements, or processes used by the agency to determine when any battery of tests is too difficult for incorporation in a regulation. Mr. Sparhawk also argued that there is no provision in the statute permitting the agency to consider burden on the agency or the regulated community as a factor when prescribing a safety standard.

As background for the reader, all light vehicles (including passenger cars, pickups, vans, minivans, crossovers, and sport utility vehicles) are designed to understeer[53] in the linear range of

[53] Although Appendix 1 provides a technical definition of ''understeer,'' in lay terms it is probably best described as the normal condition of

Continued

lateral acceleration,[54] although operational factors such as loading, tire inflation pressure, and so forth can in rare situations make them oversteer in use. This is a fundamental design characteristic. Understeer provides a valuable, and benign, way for the vehicle to inform the driver of how the available roadway friction is being utilized, insofar as the driver can ''feel'' the response of the vehicle to the road as the driver turns the steering wheel. Multiple tests have been developed to quantify linear-range understeer objectively, including SAE J266, ''Steady-State Directional Control Test Procedures for Passenger Cars and Light Trucks,'' and ISO 4138, ''Road vehicles—Steady state circular test procedure.'' These tests help vehicle manufacturers design their vehicles with an appropriate amount of understeer for normal linear-range driving conditions. Tests such SAE J266 and ISO 4138 simply measure the small constant reduction in vehicle turning (in comparison to the geometric ideal for a given steering angle and wheelbase) that characterizes linear range understeer at relatively low levels of lateral acceleration. This is much different from limit understeer in loss-of-control situations where even large increases in steering to avoid an obstacle create little or no effect on vehicle turning.

In the linear range of handling, ESC should never activate. ESC interventions occur when the driver's intended path (calculated by the ESC control algorithms using a constant linear range understeer gradient) differs from the actual path of the vehicle as measured by ESC sensors. Since this does not occur while driving in the linear range, ESC intervention will not occur. Therefore, ESC has no effect upon the linear-range understeer of a vehicle.

Our response to the comments is explained in more detail in Appendix 1, below. In overview, the agency recognizes that understeer intervention is one of the core functions of an ESC system, a feature common to all current production systems. The agency examined the available research for a potential ESC understeer test, but such research did not address understeer in the context of loss-of-control situations. Understeer tests in the literature (such as SAE J266 and ISO 4138) focus on linear range understeer properties and are not relevant to the operation of ESC, as explained above.

Because there are no suitable tests of limit understeer performance in existence, NHTSA undertook its own preliminary research efforts related to understeer. However, the complexity of such research would require several years of additional work before any conclusions could be reached regarding an ESC understeer performance test. A principal complication is that manufacturers often program ESC systems for SUVs to avoid understeer intervention altogether on dry roads because of concern that the intervention could trigger tip-up or make the oversteer control of some vehicles less certain in high-speed situations. This common understanding of how current ESC systems operate related to understeer has also been observed in the course of NHTSA's research; this principle was discussed in the NPRM, and no commenter disagreed with this operational understanding.

We believe it would be unwise to disregard manufacturers' exercise of caution in this circumstance, particularly in view of the remarkable reduction in rollover crashes of SUVs that manufacturers have achieved with current ESC strategies. Respect for the manufacturer's discretion in understeer strategies is the reason why we added ''when appropriate'' to the NPRM's proposed requirement for understeer intervention in the ''ESC System'' definition, which was modeled on the SAE definition. As a result, tests of understeer intervention would have to be conducted on low-coefficient of friction (''low-coefficient'') surfaces.

There are two kinds of low-coefficient test surfaces: (1) Those involving water delivery to the pavement and pavement sealing compounds such as Jennite to reduce the friction of wet asphalt, and (2) those involving water delivery to inherently slick surfaces such as basalt tile pads. Repeatable pavement watering is confounded by factors like time between runs, wind, slope, temperature, and sunlight. Jennite itself is not very durable, resulting in the coefficient changing with wear. Simply wetting the same surface used for the oversteer test would not produce a surface slippery enough to ensure that SUVs would intervene in understeer. Basalt tile is extremely expensive, as evidenced by the lack of large enough basalt test pads anywhere in the country for this kind of testing. Moreover, the coefficient of friction of basalt pads is extremely low, almost as low as glare ice. Causing manufacturers to optimize understeer intervention at extremely low coefficients like this may create overly-aggressive systems that compromise oversteer control on more moderate low-coefficient surfaces. Given the practicability problems of repeatable low-coefficient testing, the need for compliance margins expressed by the Alliance (*see* Section IV.C.5) would likely result in very low criteria.

Development of specific performance criteria is also problematic. In the oversteer performance test, the difference between the maximum yaw rate achieved and the zero when the vehicle is steered straight at the end of the maneuver is large and readily obvious. In contrast, the difference between understeer and the ultimate controlled drift, which is the most any ESC system can deliver when there is simply not enough traction for the steering maneuver, is difficult to differentiate. Also, the kind of optical instrumentation that a test would use to measure possible metrics in an understeer test such as body and wheel slip angles does not function reliably for tests on wet surfaces. There is a real question whether NHTSA can ever create criteria for understeer intervention that would be both stringent enough for testing and universal enough to be applied on cars and SUVs without upsetting legitimate design compromises.

In light of the above, the agency determined that it had three available options: (1) Delay the ESC final rule until such time as the agency's research was completed and an understeer performance test could be developed; (2) drop the understeer requirement from the proposed definition of ''ESC System'' and amend the standard at a future date once an ESC performance test is developed; or (3) include a requirement for understeer as part of the definition of ''ESC System,'' along with requiring specific components that will permit the system to intervene in excessive understeer situations (*e.g.*, capability to brake at four wheels individually which is necessary for both oversteer and understeer intervention) and requiring that manufacturers make available to the agency, upon request,

most cars for everyday driving. Light vehicles are designed to be slightly understeer in normal driving situations, because being understeer provides both stability (the vehicle is not hugely affected by, *e.g.*, small gusts of wind) and lateral responsiveness (*e.g.*, the vehicle is able to respond to the driver's sudden decision to avoid an obstruction in the roadway by turning the wheel quickly).

[54] The ''linear range of lateral acceleration'' is referred to in other parts of the preamble as ''linear-handling'' and ''linear range,'' and in very basic terms describes the normal situation of everyday driving, where a given turn by the driver of the steering wheel causes an expected amount of turn of the vehicle itself, because the vehicle is operating at the traction levels to which most drivers are accustomed. As the limits of the accustomed traction levels are approached (elsewhere called ''limit-handling''), the vehicle begins to enter non-linear range, in which the driver cannot predict the movement of the vehicle given a particular turn of the steering wheel, as on a slippery road or a sharp curve, where the driver can turn the wheel a great deal and get little response from the skidding vehicle.

sufficient engineering documentation to demonstrate the ESC system's capability to limit understeer.

The agency quickly decided to eliminate the option of delaying the ESC rulemaking, because of the extremely high life-saving potential of this rulemaking. To do so would run counter to the agency's mission.

Similarly, the agency decided that eliminating the understeer requirement from the rule and deferring its adoption until the completion of future research would also run counter to safety. As discussed in Section II.D, understeer intervention is one of the key beneficial features in current ESC systems, and we did not want to set a requirement that did not ensure the substantial benefits of current ESC systems.

That left the agency with the third option (which we have retained in this final rule) of adopting an understeer requirement as part of the definition of ''ESC System,'' along with a requirement for specific equipment suitable for that purpose. Such requirement is objective in terms of explaining to manufacturers what type of performance is required and the minimal equipment necessary for that purpose. The rule also requires that the manufacturer must submit to NHTSA, upon request, the engineering documentation necessary to demonstrate the system's understeer capability (*see* S5.6).

Specifically, in order to ensure that a vehicle is equipped with an ESC system that meets the definition of ''ESC System'' under S4, NHTSA's Office of Vehicle Safety Compliance (OVSC) may ask the vehicle manufacturer to provide a system diagram that identifies all ESC components, a written explanation describing the ESC system's basic operational characteristics, and a logic diagram supporting the explanation of system operations. In addition, regarding mitigation of understeer, OVSC may request a discussion of the pertinent inputs to the vehicle computer or calculations within the computer and how its algorithm uses that information and controls ESC system hardware to limit vehicle understeer. (In appropriate cases in the context of an enforcement proceeding, NHTSA might ask for additional data, including the results of a manufacturer's understeer testing.) We note here that we anticipate that much of the above information is proprietary and would be submitted under a request for confidential treatment.

In sum, the agency believes that the above information will permit the agency to understand the operation of the ESC system and to verify that the system has the necessary hardware and logic for mitigating excessive understeer. This ensures that vehicle manufacturers are required to provide understeer intervention as a feature of the ESC systems, without delaying the life-saving benefits of the ESC rule (including those attributable to understeer intervention). In the meantime, the agency will conduct additional research in the area of ESC understeer intervention and considering taking additional action, as appropriate.

The Vehicle Safety Act requires that FMVSS be stated in objective terms. NHTSA believes that the understeer requirement is objective, even without a specific performance test. The definition of ''ESC System'' requires not only an understeer capability (part (2) of the definition), but also specific physical components that allow excessive understeer mitigation (part (1) of the definition). Based on agency evaluation of ESC-equipped vehicles so far, we have identified both the hardware and the algorithms necessary for an ESC-equipped vehicle to be able to mitigate excessive understeer, as described in S5.1 of the standard and more fully in the Appendix.

We note that in the proposed regulatory text, NHTSA defined ESC as including an algorithm that would ''limit vehicle understeer as appropriate,'' which was intended to ensure the mitigation of excessive understeer already performed by existing ESC systems when the vehicle has entered the non-linear range and to prevent any backsliding of the technology. However, based upon the concern for objectivity, we have decided to delete the words ''when appropriate'' in paragraph (2) of the definition of ''ESC System'' in S4. We believe that the provision for ESC system technical documentation contained in S5.6 provides a clearer picture as to when understeer intervention is appropriate for a given vehicle.

Thus, NHTSA plans to enforce the understeer requirement via a two part process: Ensuring that vehicles have all of the hardware needed to limit vehicle understeer (as required by FMVSS No. 126), and checking engineering documentation (*i.e.*, logic/system diagrams and other information discussed above) provided by the vehicle manufacturers upon request to show that the ESC system is capable of addressing vehicle understeer.

Regarding Consumers Union's question about what percentage of the fatalities to be addressed by the standard are caused by understeer as opposed to oversteer, we cannot quantify this from the available data. This is because it is exceedingly difficult to determine during or after an accident whether it was caused by oversteer or understeer, when both frequently occur at the same time during accidents.

In conclusion, while NHTSA would like to include a performance standard for understeer intervention in FMVSS No. 126, we do not know of any suitable performance tests for excessive understeer mitigation. We are unwilling to forgo the large safety benefits that ESC will provide to the American public in the near future just because we might, some years from now, be able to produce a more refined standard. If, in the future, we see ways to amend FMVSS No. 126 in a manner that would increase motor vehicle safety, NHTSA would consider undertaking additional rulemaking at that time.

5. Lateral Responsiveness Criteria

The NPRM proposed that under each test performed under the test conditions of S6 and the test procedure of S7.9, the vehicle would be required to satisfy the responsiveness criterion of S5.2.3 during each of those tests conducted with a steering amplitude of 180 degrees or greater. Specifically, proposed paragraph S5.2.3 provides that lateral displacement of the vehicle center of gravity with respect to its initial straight path must be at least 1.83 m (6 feet) when computed 1.07 seconds after initiation of steering. The NPRM further proposed that the computation of lateral displacement is performed using double integration with respect to time of the measurement of lateral acceleration at the vehicle center of gravity (*see* S5.2.3.1) and that time t=0 for the integration operation is the instant of steering initiation (*see* S5.2.3.2).

The VDA expressed support for the agency's proposed requirements for ''Metric Stability.'' The commenter confirmed that in similar testing by its members, measured lateral accelerations and the subsequent double integration for the lateral displacements showed similar values to those tested during the agency's development of the NPRM. It stated that its testing showed that all passenger cars reached the proposed limit of 1.83 m after 1.07 s, although SUVs were more borderline. The commenter also stated that the required lateral displacement for proposed steering wheel angles above 180 degrees was easily reachable for passenger cars, although more difficult to achieve for larger, heavier vehicles with more indirect steering ratios. According to the VDA, the accuracy of the lateral acceleration integration, up to 1.07 s after initiation of steering, is a sufficient

and reproducible measurement procedure.

The VDA supported the agency's requirement of stability criteria using yaw rate measured 1 sec and 1.75 sec after the end of steering. However, the VDA offered a recommendation regarding the proposed responsiveness test procedure. Specifically, the commenter urged the responsiveness metric to include the influence of steering ratios and possibly vehicle weight.

Regarding parameters that may influence test results, the VDA stated that it did not conduct detailed tests to examine factors such as proving grounds, test track surface, slope, ambient climatic conditions, or brake temperatures. The commenter stated that this was not possible in its testing, because each vehicle manufacturer member carried out its own testing on its own test track. Accordingly, the VDA recommended that the agency should adopt the Alliance's recommendations that take into account relevant tolerances and influencing parameters.

The Alliance and AIAM stated their understanding that NHTSA's intention in proposing a responsiveness metric as part of the ESC rulemaking was not to change the basic responsiveness characteristics of the current fleet of vehicles without ESC (which they argue are satisfactory from a safety standpoint), but to prevent vehicle manufacturers from inappropriately suppressing the vehicle's natural level of responsiveness in order to enhance stability when the ESC system is activated. In support of this view, the commenters also pointed out that in the NPRM, the agency stated its expectation that approximately 98 percent of current ESC-equipped vehicles would comply with the proposal. However, the Alliance/AIAM argued that given the observed variability inherent in vehicle testing, the proposed responsiveness metric and criteria would not provide manufacturers with a sufficient margin to ensure compliance for a number of vehicles (primarily long wheelbase pick-ups and stretched limousines) being tested without ESC (*i.e.*, in a base handling state).

The Alliance/AIAM comments of November 17, 2006 presented considerable detail on three potential sources of variability: (1) Track variability; (2) temperature variability, and (3) run-to-run variability. While none of the 62 vehicles tested by NHTSA or the Alliance actually failed the proposed responsiveness criterion, the Alliance/AIAM attributed the success of some of the vehicles to test conditions (ambient temperature and test track) that were at the favorable end of the variability range. However, the commenters argued that for compliance testing purposes, manufacturers would have to certify that the vehicles would pass the performance test at the least favorable end of the variability range. Therefore, the Alliance/AIAM perceived the proposed responsiveness criterion as very demanding because of the large margin of compliance that would be necessary for certification, taking into account the sources of test variability.

The Alliance/AIAM proposed several alternative responsiveness criteria in their November 17, 2006 comments in order to address the problem of insufficient compliance margins that the commenters attributed to the inherent level of test variability. These suggestions were based on lowering the lateral displacement criteria from 6 feet to 4.5 feet (in a range determined according to the test weight of the vehicle) or increasing the time for the vehicle to reach the 6-foot displacement. On December 21, 2006, the Alliance/AIAM submitted a supplemental comment introducing the ideas of replacing the fixed steering angle of 180 degrees used in the test with a normalized steering angle that takes into account differences in vehicle steering ratio and using the GVWR of the vehicle rather than the test weight to create a cut-off point to qualify larger vehicles for a reduced displacement criteria. The supplemental comment did not suggest reducing the stringency of the responsiveness test of the NPRM as much as the previous comment. Since NHTSA wants to preserve the stringency of the responsiveness test as much as possible, it considered the supplemental comment rather than the original comment in trying to address the concerns of the Alliance and AIAM.

The Alliance/AIAM supplemental comment stressed the effect of GVWR and of steering ratio differences between vehicles on a reasonable criterion for lateral displacement in NHTSA's Sine with Dwell test maneuver. It used NHTSA's proposed criterion of 6 feet of lateral displacement for vehicles with a GVWR of 5,500 pounds or less, but the commenters suggested a small reduction to 5.5 feet for vehicles over 5,500 pounds GVWR and up to 10,000 pounds GVWR. The supplemental comment also suggested using a normalized steering wheel angle (that would account for differences in steering ratios between vehicles) rather than simply 180 degrees of steering wheel rotation as the minimum amount of steering for responsiveness tests. The steering wheel angle would be normalized by dividing the first peak steering wheel angle by the steering wheel angle at 0.3g determined by the slowly increasing-steer test (thereby expressing the amount of steering as a unitless number or scalar rather than in degrees). The Alliance/AIAM suggested that the responsiveness criteria should be applied for tests using a normalized steering wheel angle of 5.0 or greater.

NHTSA agrees with Alliance/AIAM comment regarding the use of the normalized steering wheel angle of 5.0 as the minimum steering input for applying the responsiveness test criteria. The performance test in the NPRM already includes the procedure for normalizing the steering wheel angle and calls for performing the Sine with Dwell maneuver at normalized steering wheel angles including 5.0, 5.5, 6.0, and 6.5, at which points responsiveness would be measured. For contemporary light vehicles, our data indicate that, on average, a normalized steering wheel angle of 5.0 is about 180 degrees. However, the heavier trucks and vans in the weight class with a GVWR up to 10,000 pounds tend to have slower steering ratios, which means that 180 degrees of rotation for those vehicles produces less steering motion of the front wheels than for cars (*e.g.*, a normalized steering wheel angle of 5.0 averages approximately 147 degrees for passenger cars, 195 degrees for SUVs, and 230 degrees for pickups). Since these are the vehicles whose inherent chassis properties limit responsiveness, the test becomes very difficult to pass if they are also tested at lower effective steering angles at the front wheels. Thus, the use of normalized steering wheel angles will remove a systematic disadvantage for trucks in the test procedure.

In response to the Alliance/AIAM comment's suggestion for applying the normalized steering angles to the first actual peak steering wheel angles measured during the test, we believe that there are problems with such an approach. Figure 2 of the regulatory text shows the ideal steering profile of the Sine with Dwell maneuver used to command the steering machine. A steering machine is utilized because it turns the steering wheel in the test vehicles with far greater precision and repeatability than is possible for a human driver. However, the power steering systems of some vehicles do not permit the steering machines to accomplish the desired steering profile. For the reasons discussed below, we believe the normalized steering angle should be based on the commanded angle of a steering machine (which replaces driver input during the test) with a high steering effort capacity

rather than on the measured maximum steering angle achieved by the machine.

The Alliance/AIAM also suggested that NHTSA should specify a maximum steering torque capacity of 50 to 60 Nm for steering machines to reduce the variability caused by the choice of steering machine and to assure manufacturers that the tests would be carried out with powerful machines to maximize the steering input during the responsiveness test. NHTSA is specifying (in S6.3.5 of the final rule) that the steering machine used for the Sine with Dwell maneuver must be capable of applying steering torques between 40 and 60 Nm at steering wheel velocities up to 1200 degrees per second. This is a more rigorous specification than simply a maximum torque range that does not include speed capability, and it prevents NHTSA from conducting compliance tests with some of the less powerful machines in use by test facilities.

However, even a robust steering machine cannot maintain the commanded steering profile with some vehicle power steering systems. Some of the electric power steering systems are especially marginal in that their power assistance diminishes at high steering wheel velocities. In the case of vehicle power steering limitations, the first steering angle peak in Figure 2 cannot be met, but the second peak as well as the frequency of the wave form are usually achieved. Thus, marginal vehicle power steering does not likely reduce the severity of the oversteer intervention part of the test, but it will reduce the steering input that helps the vehicle satisfy the responsiveness criteria. If NHTSA were to use the actual steering angle rather than the commanded steering angle as the normalized steering angle for the responsiveness test, it could create the unacceptable situation of vehicles that could not be tested for compliance, because the test would not allow for their evaluation. For example, if the steering machine could not achieve a normalized steering wheel angle of 5.0 even when commanded to a normalized angle of 6.5 because of vehicle limitations, the vehicle could not be said to fail, no matter how poor its performance.

Therefore, the agency has decided to use the commanded steering profile (using an assuredly robust steering machine), rather than the measured steering profile, to calculate the normalized steering wheel angle used to assess compliance with our lateral displacement requirement. We do not believe that this creates a practical problem. At this time, the larger vehicles have reasonably powerful steering systems that should enable them to achieve actual peak steering angles within at least 10 degrees of the commanded peak. Furthermore, under this approach to defining the steering input, the lateral displacement required for large vehicles would be reduced to 5 feet rather than the 5.5 feet requested in the Alliance/AIAM supplemental comment (with its somewhat higher measured steering angle). The weaker electric power steering systems discussed above are typically found on cars, and cars tend to be responsive enough to pass the 6-foot lateral displacement criterion at normalized steering wheel angles of less than 5.0. Therefore, S5.2 of the proposed standard has been revised to read as follows:

S5.2 Performance requirements. During each test performed under the test conditions of S6 and the test procedure of S7.9, the vehicle with the ESC system engaged must satisfy the stability criteria of S5.2.1 and S5.2.2, and it must satisfy the responsiveness criterion of S5.2.3 during each of those tests conducted with a commanded steering wheel angle of 5A or greater, where A is the steering wheel angle computed in S7.6.1.

As noted above, the NPRM included a responsiveness criterion that specified a minimum lateral movement of 6 feet during the first 1.07 seconds of steering during the Sine with Dwell maneuver. The purpose of the criterion was to limit the loss of responsiveness that could occur with unnecessarily aggressive roll stability measures incorporated into the ESC systems of SUVs. This is a real concern, as our research has demonstrated that one such system reduced the lateral displacement capability of a mid-sized SUV below that attainable with a 15-passenger van, multiple unloaded long wheelbase diesel pickups, and even a stretched wheelbase limousine.

A heavy-duty pickup truck understeers strongly in this test because of its long wheelbase and because it is so front-heavy under the test condition. The ESC standard is not intended to influence the inherent chassis properties of these vehicles (which were tested without ESC), because low responsiveness in the unloaded state is the consequence of a chassis with reasonable inherent stability in the loaded state. The standard must avoid causing vehicles to be designed with chasses that are unstable at GVWR and rely on ESC in normal operation. NHTSA is also aware that some very large vans with a high center of gravity, such as 15-passenger vans, rely on their ESC system to reduce responsiveness because of special concerns for loss of control and rollover. While it is necessary to respect the responsiveness limitations appropriate to large vehicles with commercial purposes, there is no need for lighter vehicles designed for personal transportation, including SUVs, to give up so much of the object avoidance capability of their chassis when tuning the ESC system.

NHTSA agrees with the Alliance/AIAM comment suggesting a lower responsiveness criterion for vehicles with higher GVWRs, but we disagree with the 5,500-pound GVWR break point suggested by the commenters. Some large passenger cars, such as the Mercedes-Benz S-class, have GVWRs near this level. With this break point, minivans like the Honda Odyssey and midsize SUVs like the Toyota 4Runner and Jeep Cherokee would be considered to have the same limitations as 15-passenger vans and trucks with a GVWR of 10,000 lbs. We believe a more representative break point was established by Standard No. 135, *Light Vehicle Brake Systems*, at a GVWR of 3,500 kg (7,716 pounds). Accordingly, S5.2.3 of the proposed standard has been revised to read as follows:

S5.2.3 The lateral displacement of the vehicle center of gravity with respect to its initial straight path must be at least 1.83 m (6 feet) for vehicles with a GVWR of 3,500kg (7,716 lb) or less, and 1.52 m (5 feet) for vehicles with a GVWR greater than 3,500 kg (7,716 lb) when computed 1.07 seconds after the Beginning of Steer (BOS). BOS is defined in S7.11.6.

6. Definition of ''ESC System'' and Required Equipment

As noted above, the NPRM proposed to require installation of an ESC system that: (1) Is capable of applying all four brakes individually and has a control algorithm that utilizes this capability; (2) is operational during all phases of driving including acceleration, coasting, and deceleration (including braking), except when the driver has disabled ESC or the vehicle is below a low speed threshold where loss of control is unlikely, and (3) remains operational when the antilock brake system or traction control system is activated (see S5.1). The ESC system must also meet the proposed performance requirements for lateral stability and vehicle responsiveness (*see* S5.2).

Under S4 of the proposal, an ''ESC System'' is defined as a system that has all of the following attributes: (1) That augments vehicle directional stability by applying and adjusting the vehicle brakes individually to induce correcting yaw torques to a vehicle; (2) that is computer-controlled with the computer using a closed-loop algorithm to limit

vehicle oversteer and to limit vehicle understeer when appropriate; (3) that has a means to determine the vehicle's yaw rate and to estimate its side slip; (4) that has a means to monitor driver steering inputs, and (5) that is operational over the full speed range of the vehicle (except below a low-speed threshold where loss of control is unlikely).

According to the VDA, it supports the definition for ''ESC system'' included in the agency's proposal which ''corresponds to modern state-of-the-art ESC systems.''

(a) Clarification of Performance Expectations

Delphi expressed support for the approach in the agency's ESC proposal to combine an ESC definitional requirement with a performance requirement (*i.e.*, a lane change maneuver at 50 mph conducted on a dry surface), until such time as the agency can conduct relevant research into ESC operation on slippery surfaces and/or for extreme understeer condition, which may support future requirements under an amended standard. However, Delphi did recommend that the agency include an explicit statement in the final rule about the performance expectations across all operating conditions. Specifically, Delphi suggested that the final rule should state that a vehicle with ESC should be equally or more stable and equally or more responsive than a vehicle without ESC, across all speeds, road surface frictions, and maneuvers. The commenter also stated that improvements in handling stability should not significantly reduce handling responsiveness, and visa-versa.

We agree that, to the extent possible, improvements in handling stability should not significantly reduce handling responsiveness, and visa-versa. To ensure that this goal is achieved, the standard includes a test with responsiveness criteria (discussed in Section IV.C.5) that requires ESC-equipped vehicles to demonstrate an acceptable practical level of lateral displacement capability in response to a specified amount of steering.

(b) Clarification of Threshold Speed

In their comments, the Alliance/AIAM agreed with that portion of the NPRM providing that ESC systems are not required to be operational at very low speeds, even though the system is technically ''on.'' However, the commenters argued that the proposed language in the definition of ''ESC System'' under S4 stating ''except below a speed threshold where loss of control is unlikely'' is not objective and could lead to uncertainty in compliance testing. Accordingly, the commenters recommended revising the relevant portion of that definition to read as follows: ''That is operational over the full speed range of the vehicle (*except at vehicle speeds less than 20 mph*).''

As reflected in the NPRM, we originally thought that it would be appropriate to provide flexibility by leaving determination of a ''low-speed threshold where the loss of control is unlikely'' to the discretion of vehicle manufacturers and ESC suppliers. However, we have decided to grant the industry's request that we increase the specificity of S4 by providing a explicit threshold speed below which the ESC system need not operate. The Alliance/AIAM suggested a low-speed threshold of 20 mph.

To determine an appropriate low-speed threshold, NHTSA must consider three factors:

1. ESC should not be active when the vehicle's Antilock Brake System (ABS) is not active. If the vehicle's ESC was active but the ABS was inactive, then ESC brake applications could result in one or more of the vehicle's wheels locking up. While one wheel locking up may not cause safety problems, if two or more wheels lock up, the vehicle may experience lateral instability. Even at low speeds, this situation may result in a safety problem.

2. All ABSs must have a low-speed threshold below which the ABS becomes inactive. Otherwise, it would be impossible to use the vehicle's brakes to bring a vehicle to a complete stop, because the ABS would keep activating and releasing the brakes when the driver tried to stop. FMVSS No. 135 does not currently contain performance requirements for ABSs; therefore, that standard does not set a low-speed threshold for them. However, S7 of FMVSS No. 135 does indicate that wheel lock-ups below a low-speed threshold are not a safety concern. *See* S7.1.3(e), S7.2.1(d), and S7.2.3(d) of FMVSS No. 135. Lock-ups at vehicle speeds above 15 km/h can cause safety problems.[55] Similarly, ECE Regulation 13–H,[56] which does contain performance requirements for ABSs, sets a low-speed threshold of 15 km/h (9.3 mph).

3. ESC systems obtain much of their information about the state of the vehicle from the ABS's wheel-speed sensors. At low vehicle speeds, the ABS wheel-speed sensors rotate more slowly, which could create unacceptable amounts of noise in the data sent to ESC. The European standard (ECE Regulation No. 13–H) shows that sensor data of acceptable quality can be obtained at speeds down to 15 km/h (9.3 mph), although certain changes may be required for some current ESC systems offered in the U.S. market.

Based on the preceding analysis, and in order to promote consistency with other FMVSSs and relevant international regulations, we have decided upon 15 km/h (9.3 mph) as the appropriate low-speed threshold above which ESC must be active. Accordingly, paragraphs S4 and S5.1.2 of the regulatory text have been revised to read as follows:

S4, ESC Definition, Part 6—(6) That is operational over the full speed range of the vehicle (except at vehicle speeds less than 15 km/h (9.3 mph) or when being driven in reverse). * * *

S5.1.2 Is operational during all phases of driving including acceleration, coasting, and deceleration (including braking), except when the driver has disabled ESC, the vehicle speed is below 15 km/h (9.3 mph), or the vehicle is being driven in reverse.

Please note that these changes to the regulatory text provisions related to when the vehicle is driven in reverse arise from our response to another public comment discussed under Section IV.C.6(f) below.

(c) Estimation of Sideslip—Request to Add Derivative

Although the comments of Honda Motor Co. Ltd. and American Honda Motor Co., Inc. (Honda) agreed that, in order to ensure proper operation, it is necessary for the ESC system to determine the vehicle's yaw rate (*i.e.*, spin), it did not agree that manufacturers should be required to measure vehicle sideslip directly. The commenter stated that manufacturers should be permitted to utilize other available status variables for estimating the spin of a vehicle. Accordingly, Honda recommended modifying the definition of ''Electronic Stability Control System'' in S4, specifically by revising the third part of that definition as follows: ''(3) That has a means to determine the vehicle's yaw rate and to estimate its sideslip *or side slip derivative*.'' As accompanying clarification, Honda recommended further clarification to state, ''*Sideslip or*

[55] *See* Snyder *et al.*, ''NHTSA Light Vehicle ABS Performance Test Development'' (NHTSA Technical Report), DOT HS 809 747 (June 2005), at 47. Available at *http://www-nrd.nhtsa.dot.gov/vrtc/ca/capubs/ABSperformancefinalreport.pdf.*

[56] United Nations Economic Commission for Europe, Regulation No. 13–H, ''Approval of Passenger Cars with Regard to Braking, Rev. 2, World Forum for Harmonization of Vehicle Regulations (WP.29 ECE R13–H), May 11th 1998. Available at *http://www.unece.org/trans/main/wp29/wp29regs1–20.html.*

side slip angle means the arctangent of the lateral velocity of the center of gravity of the vehicle divided by the longitudinal velocity of the center of gravity.''

The Alliance/AIAM made a similar comment, arguing that many current ESC systems do not measure sideslip directly, but instead use a mathematical derivative with respect to time in order to determine the vehicle's sideslip. Accordingly, the Alliance/AIAM recommended revising the ''ESC System'' definition in S4 by revising the third requirement of that definition as follows: ''(3) That has a means to determine the vehicle's yaw rate and to estimate its side slip *or side slip derivative with respect to time*.''

The agency concurs with these comments. Because side slip and the derivative of side slip angle are intimately mathematically related, when one of these values is known, it is then possible to determine the other. This change will not have any impact on safety, because it merely permits a key value for ESC operation to be determined by alternate means. Accordingly, we have decided to modify the relevant portion of the ''ESC System'' definition in S4 to read as follows:

(3) That has a means to determine the vehicle's yaw rate and to estimate its side slip or side slip derivative with respect to time.

(d) Request for Alternate Transducers

RLP Engineering recommended changes to the proposed definition of ''ESC System,'' particularly the requirement for the system to have a ''means to determine vehicle yaw rate and to estimate side slip.'' According to the commenter, vehicle instability occurs only when there is tire sideslip, not necessarily when there is vehicle sideslip. RLP Engineering stated that detection of instability involves determination of the amount of tire sideslip and in which wheel(s) it is occurring (with front tire sideslip corresponding to understeer and rear tire sideslip corresponding to oversteer). The commenter stated that vehicle yaw rate sensors may or may not be relevant to determining tire sideslip, and in any event, there may be other and potentially better ways to determine vehicle stability. For example, RLP Engineering stated that a means of detecting tire sideslip directly within a wheel assembly may eliminate the need for a yaw rate sensor. It also stated that it could be possible for tire sideslip to occur in the absence of vehicle sideslip, such as in an extreme understeer condition. Accordingly, RLP Engineering recommend that the agency modify the definition of ''Electronic Stability Control System'' in S4, specifically by revising the third part of that definition to read as follows: ''(3) That has a means to estimate *tire contact patch* sideslip.''

RLP Engineering made a similar comment regarding the portion of the ''ESC System'' definition pertaining to requirement (4) that the ESC system have ''a means to monitor driver steering inputs * * *.'' The commenter stated that current ESC systems use steering wheel angle data as one information component in estimating the intended path of a vehicle, as compared to its actual path. However, it again commented that if there is a means of detecting tire sideslip directly within a wheel assembly, there may be no need for the steering wheel angle sensor. Therefore, the commenter recommended deleting requirement (4) from the proposed definition of ''ESC System.''

When defining the ESC hardware and software requirements for the proposed FMVSS No. 126, we attempted to specify technology known to be effective in reducing real world crashes. Contemporary ESC systems meet all the requirements of S4, but they do not necessarily estimate the sideslip of the tire contact patch. As it happens, NHTSA has yet to see an effective technology for measuring the sideslip of the tire contact patch. While we are encouraged to learn of new technologies that may improve vehicle safety, quantifying their effectiveness is not possible until crash data become available, even if one would theoretically expect the alternative technology to affect vehicle performance in a similar manner as the proven technology.

Therefore, we do not concur with RLP Engineering's suggested revisions to S4. We have no effectiveness data for ESC-type systems that estimate the sideslip of the tire contact patch instead of determining the vehicle's yaw rate, or estimating the vehicle's sideslip, and monitoring the driver's steering inputs. Until crash data exist for such systems, we are not willing to treat them as equivalent to compliant ESC systems under FMVSS No. 126, which have demonstrated that they can save thousands of lives each year.

(e) Interaction With Other Vehicle Systems

Although proposed paragraph S5.1.3 states, ''Remains operational when the antilock brake system or traction control system is activated,'' the Alliance/AIAM stated that on current vehicles, these systems tend not to be functionally separate but instead are integrated into a single system. In order to allow subsystem arbitration to occur as needed to optimize ESC performance, the commenters recommended modifying paragraph S5.1.3 as follows: ''Remains *capable of activation even if* the antilock brake system or traction control system is *also* activated.''

The agency agrees with the Alliance/AIAM recommendations on this issue. Anti-lock brakes, traction control, and ESC systems all utilize the vehicle's brake control system to accomplish their intended stability enhancement goals. It is imperative that the vehicle's design logic for activation of these systems be integrated so that these systems can work in unison together addressing vehicle instabilities. Accordingly, we are amending S5.1.3 in the manner suggested by the commenters.

(f) ESC Operation in Reverse

The Alliance/AIAM, Robert Bosch Corporation (Bosch), Continental Automotive Systems (Continental), Delphi, and Nissan North America, Inc. (Nissan) all requested that the final rule not require ESC operability when the vehicle is driven in reverse, a functionality not presently part of current ESC systems and one which the commenters do not believe is a necessary part of the ESC rulemaking. Commenters further stated that requiring ESC operation in reverse would necessitate costly changes to current ESC systems.

In response, we note that the agency never intended the ESC system to be operable when the vehicle is being driven in reverse. We agree that requiring operation in reverse would necessitate costly changes to current ESC systems with no anticipated safety benefit. Our belief is that the main safety problems while the vehicle is operating in reverse are backing into/over pedestrians, backing over edges (drop-offs), and backing into inanimate objects (*e.g.*, other vehicles, buildings). ESC is not expected to help prevent any of these types of crashes.

Furthermore, vehicles are rarely driven rapidly in reverse. Therefore, the provision in S5.1.2 that ESC need not function when ''the vehicle speed is below 15 km/h (9.3 mph)'' means that ESC would typically not have to be active when the vehicle is in reverse. Requiring ESC to be active for those rare times when the vehicle is backing rapidly would be unreasonable, especially since having an active ESC in this situation would not improve safety.

Accordingly, the relevant provisions of the regulatory text have been revised to read as follows:

S4, ESC Definition, Part 6—(6) That is operational over the full speed range of the vehicle (except at vehicle speeds less than 15km/h (9.3 mph) or when being driven in reverse). * * *

S5.1.2 Is operational during all phases of driving including acceleration, coasting, and deceleration (including braking), except when the driver has disabled ESC, the vehicle speed is below 15 km/h (9.3 mph), or the vehicle is being driven in reverse.

Please note that the changes to the regulatory text about vehicle speeds less than 15km/h (9.3 mph) have been provided in response to another public comment discussed under Section IV.C.6(b) above.

7. ESC Performance Requirements

(a) Definition for ''Lateral Acceleration''

The Alliance/AIAM and Honda recommended that the agency include a definition in S4 of the final rule for the term ''lateral acceleration,'' suggesting use of the following definition from SAE J670e: ''*Lateral Acceleration—The component of the vector acceleration of a point in the vehicle perpendicular to the vehicle x axis (longitudinal) and parallel to the road plane.*''

The Alliance/AIAM stated that the NPRM does not define a method of determining lateral acceleration at the vehicle's center of gravity (Aycg). In response, the commenters recommended that, in the final rule, the agency should specify that the accelerometers be placed on the centerline of the vehicle and on the floor between the front and rear seat whenever possible (or as close to that location as possible). With respect to Aycg, the commenters requested that the agency incorporate the following formula into the standard:

$$\mathbf{Aycg = \underbrace{(Aym - \sin(roll)/\cos(roll))}_{\text{Measurement \& Roll Correction}} + \underbrace{(CF * yaw_acceleration * X)}_{\text{Longitudinal Location Correction}}}$$

Where:

Aycg = the calculated lateral acceleration at the CG of the vehicle (g);

Aym = the acceleration as measured by the body-mounted accelerometer (g);

Roll = the roll angle of the body with respect to the ground (degrees);

Yaw_acceleration = the first derivative of yaw rate with respect to time (degrees/second);

X = the longitudinal distance between the accelerometer and vehicle center-of-gravity (m);

CF = 1.78×10^{-3} (unit conversion factor)

The term ''lateral acceleration'' is used in the regulation text and so the agency has decided to add a definition to section S4. The agency will use the definition as recommended by the Alliance/AIAM and provided in SAE J670E, *Vehicle Dynamics Terminology* (rev. July 1976):

Lateral Acceleration means the component of the vector acceleration of a point in the vehicle perpendicular to the vehicle x axis (longitudinal) and parallel to the road plane.

The formula for computing lateral acceleration suggested by the commenters is an abbreviated version of what NHTSA has been using for many years. A qualitative description of NHTSA's methods for determining the corrected lateral acceleration have been included in a new section S7.11 of the final rule that deals with data processing. A complete suite of the equations used by NHTSA (*i.e.*, those applicable to not only lateral acceleration, but for longitudinal acceleration as well), are provided in the laboratory test procedure. Additionally, these equations have been incorporated into the Common Data Processing Kernel described in Section IV.C.7(e)(vi).

(b) Lateral Displacement Calculation

Regarding calculation of lateral displacement, paragraphs S5.2.3.1 and S5.2.3.2 of the proposal stated that such calculation would use double integration with respect to time of the measurement of lateral acceleration at the vehicle center of gravity (where time, t = 0, for the integration operation is the instant of steering initiation), as expressed by the following formula:

$$\text{Lateral Displacement} = \iint Ay_{C.G.}\,dt$$

Delphi agreed that, given the short interval of time in the initial phase of the lane change maneuver, it is reasonable to use double integration of measured lateral acceleration to approximate the vehicle's actual lateral displacement. Still, the commenter argued that the two are technically not exactly equivalent, because lateral acceleration is measured in the coordinate frame of the vehicle, whereas lateral displacement is in the fixed reference frame of the road (*i.e.*, the surface of the earth). According to the commenter, the vehicle frame can rotate with respect to the earth frame, leading

to an error in the double integration method. Thus, Delphi stated that it should be expected that there will always be a small error in calculation of a vehicle's lateral displacement due to coordinate system differences. Nevertheless, Delphi commented that this error is likely to be small enough to be insignificant when compared to the actual displacement encountered during a particular test maneuver, given that the vehicle's rotation is small (less than 20 degrees) in the early stage of the lane change maneuver. However, the commenter seemed to suggest that the agency should somehow acknowledge and account for such error as part of the ESC performance requirement.

We agree with Delphi's comment stating the double integration method used to calculate lateral displacement may produce a small error compared to actual displacement encountered during a particular test maneuver. However, like Delphi, we believe that because the integration interval is short (since lateral displacement is assessed 1.07 seconds after initiation of the maneuver's steering inputs), the integration errors are expected to be so small as to be negligible. Therefore, we do not believe that any changes to the regulatory text are needed to account for this inaccuracy.

(c) Yaw Rate Calculation

The NPRM set forth the following stability criteria for ESC systems. The yaw rate measured one second after completion of the sine with dwell steering input (time $T_0 + 1$ in Figure 1) must not exceed 35 percent of the first peak value of yaw velocity recorded after the beginning of the dwell period ($\dot{\psi}_{Peak}$ in Figure 1) during the same test run (*see* S5.2.1), and the yaw rate measured 1.75 seconds after completion of the Sine with Dwell steering input must not exceed 20 percent of the first peak value of yaw velocity recorded after the beginning of the dwell period during the same test run (*see* S5.2.2).

The Alliance and AIAM requested a modification to the yaw rate ratio calculation methodology set forth in S5.2.1 and S5.2.2, which specify that '' * * * first peak value of yaw velocity recorded after the beginning of the dwell period. * * * '' The commenters stated that the first peak often occurs near the start of the dwell, and it can actually occur *before* the start of the dwell. In order to account for this possibility and to ensure that the calculation is correct and consistent in all cases, the Alliance/AIAM comments recommended revising the relevant language of S5.2.1 and S5.2.2 as follows: '' * * * first peak value of yaw velocity recorded after the *steering wheel angle changes sign (between first and second peaks)* * * * ''

According to Honda, the proposed rule would require that the tested vehicle suppress the yaw rate after completion of the Sine with Dwell steering input within the specified performance requirements, one of which is that the yaw rate may not exceed the specified threshold. Honda stated that the agency itself has acknowledged that in certain instances, negative yaw rates may be produced and measured. Thus, Honda recommended modifying S5.2.1 and S5.2.2 to specify that the measurement is for the ''absolute value of yaw rate'' (rather than simply ''yaw rate,'' as proposed), in order ensure that any negative yaw rate is included in the standard's yaw rate calculation.

We agree with the Alliance/AIAM comment on this issue. Because their proposed regulatory language better expresses what NHTSA intended, we have decided to modify paragraphs S5.2.1 and S5.2.2 to read as follows:

S5.2.1 The yaw rate measured one second after completion of the sine with dwell steering input (time $T_0 + 1$ in Figure 1) must not exceed 35 percent of the first peak value of yaw rate recorded after the steering wheel angle changes sign (between first and second peaks) ($\dot{\psi}_{Peak}$ in Figure 1) during the same test run, and

S5.2.2 The yaw rate measured 1.75 seconds after completion of the sine with dwell steering input must not exceed 20 percent of the first peak value of yaw rate recorded after the steering wheel angle changes sign (between first and second peaks) during the same test run.

However, we do not agree with Honda's comment. A negative yaw rate ratio can only be achieved when the yaw rate measured at a given instant in time is in an opposite direction of the second yaw rate peak, which can have a much different meaning than the absolute value of identical magnitude. Although it is very unlikely, taking the absolute value of the yaw rate at 1.0 or 1.75 seconds after completion of steer could cause a compliant vehicle be deemed non-complaint if the respective yaw rate ratios are large enough. For example, if at 1.75 seconds after completion of steer a vehicle produces a yaw rate ratio of −21 percent, the vehicle would be in compliance with our proposed lateral stability criteria. However, if the absolute value of the yaw rate ratio were used (21 percent), the vehicle's performance would be non-compliant.

Requiring a provision that prevents a negative yaw rate ratio does not simplify the data analysis process, and can only confound interpretation of the test data. We see no reason to accept this recommendation from Honda.

(d) Temperature and Pavement Specifications

As part of the Alliance/AIAM comment regarding the effect on the margin of compliance for the responsiveness criterion (S5.2.3) of the observed variability inherent in vehicle testing, the parties made specific suggestions about the temperature and pavement specifications (S6) for the test.

The NPRM proposed that the ambient temperature for testing would be between 0 °C (32 °F) and 40 °C (104 °F) (*see* S6.1.1).

According to the Alliance/AIAM comments, their research demonstrates that responsiveness is reduced at higher temperatures, which is typical of vehicles with all-season tires. It recommended that testing should be conducted in a range of 50 °F to 104 °F, in order to reduce the temperature sensitivity effect demonstrated at low temperatures. The Alliance/AIAM comments stated that if this more restricted temperature range is multiplied by the temperature sensitivity of the relatively sensitive test vehicle examined, the maximum change in lateral displacement due to temperature variability should be limited to 0.3 to 0.4 feet.

NHTSA understands the Alliance/AIAM suggestion to be a comment on the general desirability of reducing sources of variability in vehicle testing, because its suggestion would have the effect of preventing NHTSA compliance testing at temperatures that favor a vehicle's chance of passing the test. However, it also has the disadvantage of reducing the length of the testing season for NHTSA's potential compliance test contractors located in colder States. We agree with the goal of better repeatability but prefer a minimum temperature of 7 °C (45 °F) for the sake of practicability. We believe that conducting testing down to 7 °C (45 °F) will still prevent the low temperature effects which the commenters seek to address and will not impact our ability to evaluate the performance of ESC systems. Accordingly, we are amending S6.1.1 to read as follows:

S6.1.1 The ambient temperature is between 7 °C (45 °F) and 40 °C (104 °F).

The NPRM proposed the following specifications for the road test surface (*see* S6.2). The test would be conducted on a dry, uniform, solid-paved surface (*i.e.*, without irregularities and undulations such as dips and large cracks) (*see* S6.2.1). As proposed, the road test surface would be required to produce a peak friction coefficient (PFC)

of 0.9 ± 0.05 when measured using an American Society for Testing and Materials (ASTM) E1136 standard reference test tire, in accordance with ASTM Method E 1337–90, at a speed of 64.4 km/h (40 mph), without water delivery (*see* S6.2.2). The proposal also specified that the test surface would have a consistent slope between level and 2% and that all tests are to be initiated in the direction of positive slope (uphill) (*see* S6.2.3).

The Alliance/AIAM argued that the actual surfaces of many of the test facilities used to develop the supporting performance data (test facility characteristics provided in a table in the comments) would not meet the specifications in the standard. The commenters argued that the proposed requirement in S6.2.3 that ''all tests are to be initiated in the direction of positive slope (uphill)'' is unduly restrictive and would preclude the use of a number of test tracks where the slope runs either perpendicular or diagonal to the length of the track, because such tracks would not provide enough room to run the test. The commenter also stated that their review suggested that most test tracks have a slope of 1 percent or less. Accordingly, the Alliance/AIAM recommended that in the final rule, the agency should modify S6.2.3 as follows to tighten the proposed 2 percent maximum slope restriction to 1 percent and to eliminate the direction requirement. More importantly, the commenters argued that the lower end of the peak friction coefficient range was not representative of the test facilities used in the research. Therefore, the Alliance/AIAM recommended increasing the nominal specification from 0.9 ± 0.05 to 0.95 ± 0.05.

In response to these comments, we note that NHTSA based its surface coefficient specification on FMVSS No. 135, *Light Vehicle Brake Systems*, which simply specifies a peak friction coefficient (PFC) of 0.9. While it is unlikely that any facility has exactly that PFC, NHTSA's compliance testing for Standard No. 135 is performed on a surface with a PFC somewhat higher than the specification which creates a margin for clear enforcement, and manufacturers who are assuring themselves of compliance may wish to test on a surface slightly below the specification to create a compliance margin for themselves. In attempting to increase objectivity by putting a tolerance on the 0.9 PFC, the NPRM created the possibility of compliance tests for Standard No. 126 being performed on lower coefficient surfaces than those for Standard No. 135. That was not NHTSA's intention, and we are changing the specification to match that in Standard No. 135, using the same compliance testing conventions.

We are also reducing the maximum slope tolerance which eliminates the need for a directional specification. We agree that most test tracks have a slope of 1 percent or less, which is so slight that a directional specification is unnecessary—in effect, there is no uphill to worry about. Accordingly, we are amending S6.2.2 and S6.2.3 to read as follows:

S6.2.2 The road test surface must produce a peak friction coefficient (PFC) of 0.9 when measured using an American Society for Testing and Materials (ASTM) E1136–93 (1993) standard reference test tire, in accordance with ASTM Method E 1337–90 (rev. 1996), at a speed of 64.4 km/h (40 mph), without water delivery. These standards are here incorporated by reference as explained in S3.2 above.

S6.2.3 The test surface has a consistent slope between level and 1%.

(e) Data Processing Issues

In order to ensure consistent calculation of lateral displacement, the Alliance and AIAM recommended specification of the following details related to data processing in the regulatory text for FMVSS No. 126.

(i) Determination of Beginning of Steering

The Alliance/AIAM comments recommended that the start of steering be defined as the moment when the ''zeroed'' steering wheel angle (SWA) passes through 5 degrees. The commenters stated that this modification is important to ensure that the start of steering is determined to accurately and consistently calculate performance metrics for the Sine with Dwell test.

The process used by NHTSA to identify ''beginning of steering'' uses three steps. In the first step, the time when steering wheel velocity that exceeds 75 deg/sec is identified. From this point, steering wheel velocity must remain greater than 75 deg/sec for at least 200 ms. If the condition is not met, the next time steering wheel velocity that exceeds 75 deg/sec is identified and the 200 ms validity check is applied. This iterative process continues until the conditions are satisfied. In the second step, a zeroing range defined as the 1.0 second time period prior to the instant the steering wheel velocity exceeds 75 deg/sec (*i.e.*, the instant the steering wheel velocity exceeds 75 deg/sec defines the end of the ''zeroing range'') is used to zero steering wheel angle data. In the third step, the first instance the filtered and zeroed steering wheel angle data reaches −5 degrees (when the initial steering input is counterclockwise) or +5 degrees (when the initial steering input is clockwise) after the end of the zeroing range is identified. The time identified in Step 3 is taken to be the beginning of steer.

The agency agrees that an unambiguous reference point to define the start of steering is necessary in order to ensure consistency when computing the performance metrics measured during compliance testing. The practical problem is that typical ''noise'' in the steering measurement channel causes continual small fluctuations of the signal about the zero point, so departure from zero or very small steering angles does not indicate reliably that the steering machine has started the test maneuver. NHTSA's extensive evaluation of zeroing range criteria (*i.e.*, that based on the instant a steering wheel rate of 75 deg/sec occurs) has confirmed that the method successfully and robustly distinguishes the initiation of the Sine with Dwell steering inputs from the inherent noise present in the steering wheel angle data channel. As such, the agency has incorporated the 75 deg/sec criterion described above plus the commenter's suggestion of the 5 degree steering measurement into S7.11, a new section on data processing added to the final rule in response to comments. The value for time at the start of steering, used for calculating the lateral responsiveness metrics described in Section IV.C.7(b), is interpolated.

(ii) Determination of End of Steering

The Alliance/AIAM recommended defining the end of steering event as the first occurrence of the ''zeroed'' steering wheel angle crossing zero degrees after the second peak of steering wheel angle. The commenters stated that this modification is important to ensure that the end of steering is determined to accurately and consistently calculate some of the performance metrics for the Sine with Dwell test.

The agency agrees that an unambiguous point to define the end of steering is also necessary for consistency in computing the performance metrics measured during compliance testing. The agency has incorporated the commenter's suggestion of the first occurrence of the ''zeroed'' steering wheel angle crossing zero degrees after the second peak of steering wheel angle in S7.11, a new section on data processing added to the final rule. While signal noise results in continual zero crossings as long the data is being sampled, the first zero crossing after the steering wheel has begun to

return to the zero position is a logical end to the steering maneuver.

(ii) Removing Offsets

The Alliance/AIAM comments recommended that, given the potential for the accelerometers used in the measurement of lateral displacement to drift over time, the agency should use the data one second before the start of steering to ''zero'' the accelerometers and roll signal.

Prior to the test maneuver, the driver must orient the vehicle to the desired heading, position the steering wheel angle to zero, and be coasting down (*i.e.*, not using throttle inputs) to the target test speed of 50 mph. This process, known as achieving a ''quasi-steady state,'' typically occurs a few seconds prior to initiation of the maneuver, but can be influenced by external factors such as test track traffic, differences in vehicle deceleration rates, etc. Any zeroing performed on test data must be performed after a quasi-steady state condition has been satisfied, but before the maneuver is initiated. The proposed zeroing duration of one second provides a good combination of sufficient time (*i.e.*, enough data is present so as to facilitate accurate zeroing of the test data) and performability (*i.e.*, the duration is not so long that it imposes an unreasonable burden on the driver). For past research, NHTSA has used zeroing intervals between 0.5 and 1.0 seconds. Our experience has shown the use of a 0.5 second interval is usually sufficient; however, the 1.0 second is more conservative and therefore preferred. We do not believe zeroing intervals longer than one second will improve the zeroing accuracy.

(iv) Use of Interpolation

According to the Alliance/AIAM, there are several events in the calculation of performance metrics that require determining the time and/or level of an event, including: (1) Start of steering; (2) 1.07 or 1.32 seconds after the start of steering; (3) end of steering; (4) 1 second after the end of steering, and (5) 1.75 seconds after the end of steering. The commenters recommended using interpolation for all of these circumstances, because such practice provides more consistent results and is less sensitive to differing sampling rates than other approaches (*e.g.*, choosing the sample that is closest in time to the desired event). Interpolation is a way of computing the exact time that the continuous steering signal crossed zero, even though the digital samples did not coincide with the exact zero point, but rather consisted of one sample slightly before the time of zero-crossing and one slightly after.

In determining specific timed and measured data points, the agency agrees with the Alliance and AIAM that the method of interpolation provides the most consistent results. Therefore, the agency will use this method during post data processing, as specified in S7.11.

(v) Method for Determining Peak Steering Wheel Angle

The Alliance/AIAM stated that because metrics for responsiveness are specified by steering wheel angle (SWA), a method for determining the actual SWA needs to be specified in the final rule for ESC. The commenters recommended using the first measured peak SWA, as it is the peak that directly influences the responsiveness measurement.

For the reasons discussed in our response to public comments on our lateral responsiveness criteria, we have decided in the final rule to define the torque capacity of the steering machine used in the responsiveness test and to use the commanded peak steering angle, rather than the measured peak steering angle, as the indication of tests in which the vehicle must meet the responsiveness criteria (*see* Section IV.C.5).

(vi) Need for a Common Data Processing Kernel

According to the Alliance/AIAM, data processing methods have a significant impact on the results that are generated. The commenters stated that as a longer-term objective, the agency should work with interested parties to develop and incorporate into the standard (either directly or by reference) detailed algorithms for processing of data and stability/responsiveness metric calculations. The Alliance/AIAM commented that a similar procedure is already in place in other safety standards (*e.g.*, FMVSS No. 208).

The agency agrees that data processing methods can have a significant impact on the results generated. To address this issue we have added necessary data processing details to the regulation text of the standard and plan to include in the compliance test procedure the MATLAB code used for post-processing critical yaw rate and lateral displacement performance data.

(f) ESC Initialization Period

Delphi stated that most ESC systems typically require a short initialization period after the start of each new ignition cycle, during which time the ESC system is not operational. The commenter stated that during this period, the ESC performs diagnostic checks and sensor signal correlation updates. Delphi commented that the duration of this ESC initialization interval may depend upon several factors, including distance traveled, speed, and/or signal magnitudes.

In response to other comments, we have modified S5.1.2 to clarify that ESC does not need to be active when the vehicle speed is below 15 km/h (9.3 mph). Therefore, the ESC manufacturer has a short period of time, from the time the vehicle's ignition is turned on to the time when the vehicle speed first exceeds 15 km/h (9.3 mph) to initialize ESC. The process of initializing ESC is, in many ways, similar to the process of initializing ABS. ABS systems typically have completed their initialization by the time the vehicle reaches speeds of 5 km/h (3.1 mph) to 9 km/h (5.6 mph). Therefore, NHTSA believes that allowing up to a speed of 15 km/h (9.3 mph) should be adequate to initialize ESC.

Honda, Continental and the Alliance/AIAM have pointed out that some types of diagnostic checks cannot be performed unless the vehicle is making turns or traveling at relatively high speeds. We have modified S7.10 to accommodate these types of diagnostic checks, as explained in the answer to Issue 8(b) below, ''Practicability Problems with Malfunction Detection.'' However, our expectation is that the ESC manufacturer can assume that the ESC has not malfunctioned and make the system operational once driving situations occur that permit these diagnostic checks to be performed.

(g) ESC Calibration

Mr. Petkun commented that the agency should require ESC systems to be calibrated to activate ''at the precise moment that the vehicle may go out of control.'' The commenter also suggested that the ESC system should be matched to the type of vehicle and complement driver characteristics; for example, Mr. Petkun stated that a minivan's ESC might be tuned to respond to vehicle movements at a slightly earlier point than an ESC system on a sports coupe or sedan.

With respect to Mr. Petkun's first comment, it is important to recognize that determining when ESC intervention must occur is a complicated balance of effectiveness and intrusiveness. Loss of control is not usually a binary condition. As such, one of the challenges of designing ESC control algorithms is how to anticipate when a loss-of-control situation may occur. More conservative algorithms may be tuned to activate sooner than those

allowing the vehicle to achieve higher slip angles prior to activation. However, the longer an intervention is delayed, the more aggressive it must typically be later in the maneuver in order to still be effective. Therefore, determining when intervention should occur is a decision not only based on achieving good ESC performance, but also how sensitive individual drivers may be to the manner in which the intervention occurs. Although NHTSA has no way of resolving this subjective dilemma (an issue for each vehicle manufacturer and its ESC vendor to resolve), we can objectively assess how effective the final tuning is on a vehicle's lateral stability and responsiveness using the Sine with Dwell test maneuver and our ESC performance criteria.

In regards to Mr. Petkun's second comment, our discussions with ESC suppliers and vehicle manufacturers indicate that while different vehicles may use much of the same modular ESC hardware, the software controlling how each system operates contains make/model specific information. One way to ensure that the ESC software has been appropriately adapted to a particular make/model is to perform test track performance evaluations. We believe the Sine with Dwell maneuver, and the lateral stability and responsiveness performance criteria that evaluate the test output, provide an excellent way of assessing ESC system performance for all light vehicles. Regardless of whether the driver is operating a minivan or a sports car, we believe the vehicle's ESC should perform in an effective manner, quantified by successfully satisfying our minimum performance standards.

Other Issues

8. ESC Malfunction Detection Requirements

Under paragraph S5.3, *ESC Malfunction*, the NPRM proposed that the vehicle must be equipped with a telltale that provides a warning to the driver not more than two minutes after the occurrence of one or more malfunctions that affect the generation or transmission of control or response signals in the vehicle's electronic stability control system. The proposal also set forth the following additional requirement related to ESC malfunction detection.

Specifically, the ESC malfunction telltale would be required to be mounted inside the occupant compartment in front of and in clear view of the driver (*see* S5.3.1) and be identified by the symbol shown for ''ESC Malfunction Telltale'' in Table 1 of Standard No. 101 (49 CFR 571.101) (*see* S5.3.2). The ESC malfunction telltale would be required to remain continuously illuminated under the conditions specified in S5.3 for as long as the malfunction(s) exists, whenever the ignition locking system is in the ''On'' (''Run'') position (*see* S5.3.3), and except as provided in paragraph S5.3.5, each ESC malfunction telltale must be activated as a check of lamp function either when the ignition locking system is turned to the ''On'' (''Run'') position when the engine is not running, or when the ignition locking system is in a position between ''On'' (''Run'') and ''Start'' that is designated by the manufacturer as a check position (*see* S5.3.4). The ESC malfunction telltale need not be activated when a starter interlock is in operation (*see* S5.3.5). The ESC malfunction telltale must extinguish after the malfunction has been corrected (*see* S5.3.6).

Under the proposal, manufacturers would be permitted to use the ESC malfunction telltale in a flashing mode to indicate ESC operation (*see* S5.3.7).

As discussed below, several commenters raised a variety of concerns regarding operation of the ESC malfunction indicator (with malfunction telltale-related issues addressed later in this document under section IV.C.9, *ESC Telltale Requirements*).

(a) Types of Malfunctions To Be Detected

In its comments, Nissan objected to the use of the term ''any ESC component'' in the ESC malfunction detection portion of the standard's proposed test procedures (*see* S7.10.1), because the company believes that the term is not objective and is overly broad. Nissan stated that there are certain vehicle components which may be considered part of the ESC system, but whose failure would not impact the ability of the vehicle to meet the performance requirements specified under S5.2. The company used the example of a malfunction of the ESC off switch, the disconnection of which, it argued, would not ''affect the generation or transmission of control or response signals in the vehicle's electronic stability control system.'' Accordingly, Nissan argued that the agency should specify which components it deems to be part of the ESC system for malfunction testing purposes.

Unless a suitable resolution can be found to the ''any ESC component'' issue identified by Nissan, the company argued that the agency should delay the effective date for the ESC malfunction detection requirements until the end of the phase-in. Otherwise, Nissan again stated that it may not be able to garner sufficient carry-forward credits to meet the certification requirements of the phase-in.

Likewise, Toyota Motor North America, Inc. (Toyota) commented on a particular problem regarding ESC malfunction detection that could affect its phase-in compliance and carry-forward credits. Specifically, the difficulty is encountered because Toyota's ESC electronic control unit (ECU) is integrated into the vehicle's ABS ECU. According to the commenter, the problem involves the proposed test procedures under S7.10.1, which provide for ''simulate[ing] one or more ESC malfunction(s) by disconnecting the power source to any ESC component, or disconnecting any electrical connection between ESC components.'' As its vehicles are currently designed with a single ABS/ESC ECU, Toyota stated that if the power source is disconnected, only the vehicle's ABS malfunction lamp will illuminate, not the ESC malfunction telltale (although the company anticipates meeting the requirements of S7.10.1 for all other types of ESC malfunctions). Although Toyota stated its belief that illumination of the ABS malfunction lamp would be sufficient to warn drivers of a loss of function to the entire ABS/ESC system, it agreed that it would be possible to redesign its system to meet the proposed requirements of S7.10.1. However, Toyota projects that it will not be possible to resolve this problem until the end of the phase-in period.

In response to the concerns of Nissan and Toyota, we would start by noting that the agency has delayed the effective date of the controls and displays aspects of the ESC standard to the end of the phase-in in response to a number of similar comments. Stated another way, the ESC system must meet the malfunction detection requirements of the standard, according to the final rule's general phase-in schedule, but it need not signal the driver in a standardized fashion until the end of the phase-in. This delay in the effective date for the controls and displays requirements of the rule includes the ''ESC Off'' control and telltale, thereby resolving one specific concern raised by Nissan related to its ability to earn carry-forward credits.

As to the broader issue of which vehicle components are subject to ESC malfunction testing, we believe that a rule of reason applies. Simply stated, if a vehicle malfunction were to ''affect the generation or transmission of control or response signals in the vehicle's electronic stability control system,'' it must be detectable by the ESC system.

In other words, if the malfunction impacts the functionality of the ESC system, the ESC system must be capable of detecting it. For shared or connected components, a malfunction need only be detected to the extent it may impact the ESC system's operation. This is precisely the same malfunction requirements currently established for tire pressure monitoring systems (TPMS) under FMVSS No. 138. We see no reason why such a requirement, which is appropriate in the TPMS context, would be considered overly broad here. Furthermore, manufacturers are in a better position than the agency in terms of knowing the vehicle components involved in ESC operation.

As a specific example for the sake of clarity, we would consider the disconnection of the ''ESC Off'' switch to be a malfunction suitable for simulation under the standard, because it directly impacts ESC operability (even though a manufacturer voluntarily provides such a switch). However, we would not consider the disconnection of an ancillary function such as a hill-holding aid that may be controlled by a shared ESC computer to be a fault in the ESC system itself.

We are aware that because this final rule accelerates the phase-in schedule for ESC, it also creates greater pressure on manufacturers to earn carry-forward credits by installing compliant ESC systems as soon as possible. Again, because we think it is more important to have operating ESC systems sooner, we are moving the effective date of the standardization aspects of controls and displays to the end of the phase-in period. The specific difficulties recited by the commenters are analogous to the temporary lack of standardization that we find preferable to an overall phase-in delay. Therefore, we have decided to address these manufacturers' identified concerns in the following fashion. The test of the malfunction indicator calls for disconnecting various components to simulate a fault that should be detected. To reiterate the problems, when the power to the electronic control unit of some Toyota ESC systems is disconnected, the ABS malfunction telltale illuminates but the ESC malfunction telltale does not (because the control unit operates both systems), and disconnection of the optional ''ESC Off'' switch on some Nissan vehicles will not cause the malfunction telltale to illuminate. It has been the industry practice to provide a separate ESC malfunction telltale, in order to make consumers aware when this important safety device is potentially unavailable, but public comments have demonstrated that some additional time is necessary to standardize ESC malfunction telltale operation. We do not believe that vehicles with these minor deviations in the malfunction indicator should be disqualified for phase-in credit.

One solution would be to move the provision for malfunction detection to the later effective date of the telltales and controls standardization. However, it is not necessary to relax the important requirement for a malfunction warning to avoid complicating the phase-in of ESC. Instead, we have decided to insert a very narrow temporary exception under paragraph S5.3.9 to address the specific malfunction testing issues brought forward by Nissan and Toyota:

S.5.3.9 Prior to September 1, 2011, a disconnection of the power to the ESC electronic control unit may be indicated by the ABS malfunction telltale instead of the ESC malfunction telltale, and a disconnection of the ''ESC Off'' control need not illuminate the ESC malfunction telltale.

(b) Practicability Problems With Malfunction Detection

Under paragraph S7.10, *ESC Malfunction Detection*, the proposed test procedures for FMVSS No. 126 state that one or more ESC malfunction(s) would be simulated by disconnecting the power source to any ESC component, or disconnecting any electrical connection between ESC components (except for electrical connections for the telltale lamp(s)) (*see* S7.10.1). The proposed test procedures further provide, that with the vehicle stationary and the ignition locking system in the ''Lock'' or ''Off'' position, activate the ignition locking system to the ''On'' (''Run'') position and verify that within two minutes of activating the ignition locking system, the ESC malfunction indicator illuminates in accordance with S5.3 (*see* S7.10.2).

TRW Automotive expressed concern that the ESC malfunction detection portion of the test procedures, as currently drafted, may pose a safety hazard to test technicians. Specifically, TRW Automotive stated that paragraph S7.10 does not indicate that the vehicle is to be turned off before ''disconnecting the power source to any ESC component,'' and paragraph S7.10.4 merely states, ''Restore the ESC system to normal operation and verify that the telltale has extinguished.'' The commenter recommended that those two provisions be modified to explicitly state that the vehicle is to be in the ''off'' state prior to disconnecting or restoring the ESC system.

Honda stated that its understanding of S7.10 is that this portion of the test procedure will be conducted with the vehicle stationary. However, Honda stated that vehicle motion is necessary for the system to be able to detect certain ESC malfunctions (e.g., damage to the pulser of the wheel speed sensor) and to later extinguish the telltale once the malfunction is corrected (similar comment provided by Bosch, Continental). Accordingly, Honda sought clarification that testing conducted pursuant to S7.10 will involve only those malfunctions amenable to detection based upon static activation and deactivation.

Continental argued that some malfunctions are not time-based, but instead require comparisons of sensor outputs generated when the vehicle is driven. Accordingly, the commenter recommended elimination of the requirement that ESC malfunctions be detected within two minutes of occurrence, even if the vehicle is parked. Instead, Continental urged adoption of the following language: ''*The vehicle must be equipped with a telltale that provides a warning to the driver when one or more malfunctions occur that affect the generation or transmission of control or response signals in the vehicles electronic stability control system.*'' (Similar comments were provided by Bosch and Delphi.)

Similarly, the Alliance/AIAM commented that the proposed test procedure may be inadequate to detect a full range of electrical component failures, because some of these malfunctions cannot be detected when the vehicle is stationary. Instead, the commenters suggested that the agency adopt a more robust ESC malfunction test that would allow the engine to be running and the vehicle to be in motion as part of the diagnostic evaluation. To this end, the commenters suggested that the agency replace the existing provisions at S7.10.2 and S7.10.3 with the following language:

S7.10.2 *With the vehicle initially stationary and the ignition locking system in the ''Lock'' or ''Off'' position, activate the ignition system to the ''Start'' position and start the engine. Place the vehicle in a forward gear and obtain a steady speed of 30 mph ± 5 mph. Drive the vehicle for at least two minutes, including at least one left and one right turning maneuver. Verify that within two minutes of obtaining this steady speed, the ESC malfunction indicator illuminates in accordance with 5.3.*

S7.10.3 *Stop the vehicle, deactivate the ignition locking system to the ''Off'' of ''Lock'' position. After a five-minute period, activate the vehicle's ignition locking system to the ''Start'' position and start the engine. Verify that the ESC malfunction indicator again illuminates to signal a malfunction and*

remains illuminated, as long as the engine is running or until the fault is corrected.

NHTSA agrees with TRW Automotive that it is always prudent to make the disconnections and connections of ESC components with the power turned off, even though the components are generally powered by low-voltage DC current and the risk of harm to the vehicle would be greater than the risk to the technicians. Accordingly, we have amended paragraph S7.10.1 as follows, but we do not think the reminder need be repeated in S7.10.4 in view of other changes to its language being made.

S7.10.1 Simulate one or more ESC malfunction(s) by disconnecting the power source to any ESC component, or disconnecting any electrical connection between ESC components (with vehicle power off). When simulating an ESC malfunction, the electrical connections for the telltale lamp(s) are not to be disconnected.

NHTSA does not agree with Honda that S7.10 should be limited to only those malfunctions amenable to detection based upon static activation and deactivation. Our purpose in writing S7.10.2 was to ensure that ESC malfunctions would be detected within a reasonable time of starting to drive. The language proposed by the Alliance/AIAM conforms to our original intent, while clarifying that the vehicle should be driven during the proposed two-minute period so that the parts of its malfunction detection capability which depend on vehicle motion can operate. Accordingly, we are adopting the language suggested by the Alliance/AIAM for S7.10.2 and S7.10.3. We believe that this change also addresses the comment by Continental that malfunction detection is not a time-based function but one that requires certain driving motions to make ESC self-testing possible.

(c) Monitoring When System Is Off

Honda sought clarification of the proposed standard to ensure that there is not an unintended requirement for the ESC system to maintain constant monitoring even when the ignition key is in the ''off'' position. Accordingly, Honda recommended modifying S5.3.6 to read as follows: ''The ESC malfunction telltale must extinguish *at the initiation of the next ignition cycle* after the malfunction has been corrected.'' Honda also recommended modifying S7.10.4 to state: ''*Deactivate the ignition locking system to the ''off'' or ''lock'' position.* Restore the ESC system to normal operation and verify that the telltale has extinguished.''

Honda is correct that the agency does not expect the ESC system to maintain monitoring capability with vehicle turned off. However, we do not believe that it is necessary to restrict the extinguishing of the telltale to the exact instant of the initiation of the next ignition cycle. Therefore, we are amending paragraphs S5.3.6 (now S5.3.7) and S7.10.4 to read as follows:

S5.3.7 The ESC malfunction telltale must extinguish at the next ignition cycle after the malfunction has been corrected. * * *

S7.10.4 Deactivate the ignition locking system to the ''off'' or ''lock'' position. Restore the ESC system to normal operation, activate the ignition system to the ''Start'' position and start the engine. Verify that the telltale has extinguished.

(d) Minimum Performance Level

BorgWarner commented that the proposed ESC standard should set a defined minimum performance level for a vehicle when the ESC system is deactivated (i.e., ''off'') or when there is an ESC malfunction (which again may result in a failure mode of ESC ''off''). The commenter stated that unless this is done, negative safety consequences may arise under conditions where a driver is not aware of the vehicle's baseline stability behavior. BorgWarner argued that establishing a minimum stability performance level for a deactivated ESC system would be analogous to the minimum performance standard which the agency adopted for ABS ''foundation'' brake performance in the event ABS is deactivated due to a system malfunction.

NHTSA considers ESC to be a safety feature added to vehicles whose basic chassis properties have been designed to match their intended purposes. Our discussion in Section IV.C.5 (Lateral Responsiveness Criteria) is based upon the expectation by both NHTSA and the industry that ESC will not cause changes in the basic chassis properties of vehicles. We expect that ESC activations will be rare events in panic situations and that drivers will not depend upon the ESC system in the ordinary operation of the vehicle. In the case of an ESC malfunction or failure, the ESC telltale warns the driver that the ESC system is non-operational and may require repair. However, pending the repair, the driver would be no more at risk than a person driving an older car without ESC. Unless future developments prove these assumptions to be false, there is no need for additional ''minimum performance'' requirements on base vehicles equipped with ESC.

9. ESC Telltale Requirements

(a) ESC Telltale

As noted above, paragraph S5.3 of the ESC proposal would require each ESC system to include an ESC malfunction telltale mounted inside the occupant compartment in front of and in clear view of the driver (*see* S5.3.1) and identified by the symbol shown for ''ESC Malfunction Telltale'' in Table 1 of Standard No. 101 (49 CFR 571.101) (*see* S5.3.2). The ESC malfunction telltale would be required to remain continuously illuminated under the conditions specified in S5.3 for as long as the malfunction(s) exists, whenever the ignition locking system is in the ''On'' (''Run'') position (*see* S5.3.3), and except as provided in paragraph S5.3.5, each ESC malfunction telltale must be activated as a check of lamp function either when the ignition locking system is turned to the ''On'' (''Run'') position when the engine is not running, or when the ignition locking system is in a position between ''On'' (''Run'') and ''Start'' that is designated by the manufacturer as a check position (*see* S5.3.4). The ESC malfunction telltale need not be activated when a starter interlock is in operation (*see* S5.3.5). The ESC malfunction telltale must extinguish after the malfunction has been corrected (*see* S5.3.6). Under the proposal, manufacturers would be permitted to use the ESC malfunction telltale in a flashing mode to indicate ESC operation (*see* S5.3.7).

Several commenters raised specific issues pertaining to the ESC malfunction telltale, which are set forth and addressed below.

(i) Telltale Symbol Text Enhancement

Although Advocates supported use of the ISO symbol, it argued that the telltale should also include the abbreviation ''ESC,'' because that would allow drivers to better understand that their vehicle is equipped with an ESC system.

NHTSA shares the Advocates' concern regarding the importance of promoting drivers' understanding of ESC and whether or not their vehicle is equipped with ESC. However, we believe that augmenting the ESC malfunction telltale by adding the word, ''ESC,'' is unlikely to address that concern. As explained in the NPRM, NHTSA's research so far indicates that most drivers do not yet understand what ''ESC'' means. Insofar as drivers will have to learn the precise meaning of any telltale offered by manufacturers to convey the idea of ESC, NHTSA does not believe it necessary at this time to specifically require a telltale that

includes both the symbol and the acronym. We have no evidence that both together will convey a greater benefit than either alone. Additionally, no other FMVSS has required both a symbol and a text term together for a telltale, so for the sake of consistency we are reluctant to do so now. We believe that the ESC malfunction telltale symbol and substitute ''ESC'' text can effectively be used interchangeably. We also believe that most drivers become increasingly familiar with the meaning of instrument panel telltales over time, and we expect that this will be the case with ESC telltales and substitute text, as well.

Furthermore, NHTSA is sensitive to vehicle manufacturers' stated concern that limited instrument panel area is available for locating telltales. Paragraph S5.2.3 of FMVSS No. 101, *Controls and Displays*, states that ''[s]upplementary symbols, words, or abbreviations may be used at the manufacturer's discretion in conjunction with any symbol, word, or abbreviation specified in Table 1 or Table 2.'' Based on the above provision, augmenting the ISO symbol with the text ''ESC'' is permissible, provided that it does not violate the locational requirement contained in the definition of ''adjacent'' as specified in S4 of FMVSS No. 101.[57]

Therefore, for the reasons stated above, NHTSA believes that it is not necessary to require addition of the text ''ESC'' to the ESC malfunction telltale.

(ii) Telltale Symbol Alternative: Substitute Text

The Alliance/AIAM asked the agency to permit the use of the symbol ''ESC'' without the ISO symbol, as an alternative to the proposed symbol when the warning is provided by the vehicle's message/information center. These commenters argued that this approach is consistent with other FMVSS No. 101 Table 1 indicators. (Porsche Cars North America, Inc. (Porsche) made a similar comment.)

NHTSA agrees with the commenters that the general approach of FMVSS No. 101 is to provide flexibility to vehicle manufacturers via alternative text terms for telltales. Moreover, as the concept of ESC becomes more widely understood by drivers, we expect that offering the option of using the text term ''ESC,'' as opposed to manufacturer-specific ESC system acronyms, will facilitate driver recognition of the telltale. This promotes consistency in the telltale field, where there currently is little. Therefore, NHTSA has decided to permit use of the term ''ESC'' at the manufacturer's discretion instead of the ISO symbol. As a result, we are modifying S5.3.2 to read as follows:

S5.3.2 Effective September 1, 2011, must be identified by the symbol shown for ''ESC Malfunction Telltale'' or the specified words or abbreviations listed in Table 1 of Standard No. 101 (49 CFR 571.101);

In the event that the text alternative for the ESC malfunction telltale is presented via the vehicle's message/information center (defined as a ''common space'' under S4 of FMVSS No. 101), the conditions of S5.5.2 and S5.5.5 of FMVSS No. 101 (set forth below) must be met. While not specified in the proposed regulatory text, NHTSA believes it is necessary to modify S5.5.2 and S5.5.5 of FMVSS No. 101 to place restrictions on the use of the ESC telltale in a common space. The amended language reads as follows:

S5.5.2 The telltales for any brake system malfunction required by Table 1 to be red, air bag malfunction, low tire pressure, electronic stability control malfunction, passenger air bag off, high beam, turn signal, and seat belt must not be shown in the same common space.* * *

S5.5.5 In the case of the telltale for a brake system malfunction, air bag malfunction, side air bag malfunction, low tire pressure, electronic stability control malfunction, passenger air bag off, high beam, turn signal, or seat belt that is designed to display in a common space, that telltale must displace any other symbol or message in that common space while the underlying condition for the telltale's activation exists.

Therefore, when presenting the ESC malfunction telltale in a vehicle's common space display, the malfunction telltale must not appear in the same common space as any of the other listed telltales under paragraph S5.5.2 of FMVSS No. 101, and, when activated, it must displace any another message or symbol in its common space as long as the ESC malfunction condition exists, as required under paragraph S5.5.5 of FMVSS No. 101. For example, in the event that a failure of the ABS led to an ESC malfunction, both malfunctions would be required to be indicated to the driver and must be presented in separate common spaces.

(iii) Waiver of Yellow Color Requirement for ESC Telltale When Message/Information Center Is Used

The Alliance/AIAM asked the agency to waive the yellow color requirement when ESC malfunction indications are provided by the vehicle's message/information center, due to the difficulty associated with providing color in a message/information center (regardless of whether a text or symbol is used).

The use of message/information centers for presentation of ESC malfunction information is permissible to the extent that the requirements of FMVSS No. 101 are met (*see* 49 CFR 571.101 and discussion in Section IV.C.9(a)(ii) immediately above). The intent of the color requirements specified in Table 1 of FMVSS No. 101 is that the color yellow be used to communicate to the driver a condition of compromised performance of a vehicle system that does not require immediate correction. The International Standards Organization (ISO) in its standard titled, ''Road Vehicles—Symbols for controls, indicators, and tell-tales'' (ISO 2575:2004(E)), agrees with this practice through its statement of the meaning of the color yellow as ''yellow or amber: Caution, outside normal operating limits, vehicle system malfunction, damage to vehicle likely, or other condition which may produce hazard in the longer term.''

In the context of ESC, the agency purposely chose to associate indication of an ESC system malfunction with a yellow, cautionary warning to the driver. NHTSA believes that this requirement must be maintained in order to properly communicate the level of urgency with which the driver must seek to remedy the malfunction of this important safety system.

Furthermore, this policy is consistent with the agency's decision in our September 7, 2005 final rule responding to petitions for reconsideration of the Tire Pressure Monitoring System (TPMS) final rule, in which petitioners raised the identical issue of waiving the yellow color requirement for TPMS malfunctions and low tire pressure warnings when presented via a message/information center (*see* 70 FR 53079 (Sept. 7, 2005)). Therefore, NHTSA has decided to deny the request for waiver of the yellow color requirement for the ESC malfunction telltale or substitute text when a message/information center is used.

(iv) Telltale Illumination Strategy

Nissan stated that its current ESC systems utilize a telltale control logic that illuminates the ''ESC Off'' telltale

[57] Paragraph S4 of FMVSS No. 101 (49 CFR 571.101 S4) provides:

S4. *Definitions.*

Adjacent, with respect to a control, telltale or indicator, and its identifier means:

(a) The identifier is in close proximity to the control, telltale or indicator; and

(b) No other control, telltale, indicator, identifier or source of illumination appears between the identifier and the telltale, indicator, or control that the identifier identifies.

whenever the ESC malfunction telltale is illuminated. Nissan reasoned that this illumination strategy provides a clear message to the driver that the malfunctioning ESC system may not be able to perform normally and would therefore be ''off'' within the meaning of the standard's performance requirements of S5.4, *ESC Off Switch and Telltale* (*i.e.,* the system is in a mode that does not meet the requirements of S5.2, *Performance Requirements*). The commenter sought clarification that this telltale illumination strategy is permissible under the proposed ESC standard. (A similar comment was provided by the Alliance/AIAM.)

Nissan has correctly interpreted the regulatory text to indicate that when an ESC malfunction situation exists, manufacturers may choose to illuminate the ''ESC Off'' telltale (per Table 1 of FMVSS No. 101) or display ''ESC Off'' text in a message/information center in addition to illuminating the separate ESC malfunction telltale to emphasize to the driver that ESC functionality has been reduced due to the failure of one or more ESC components.

However, we believe that it is important to clarify here that the reverse situation (*i.e.*, illuminating the ESC malfunction telltale in addition to the ''ESC Off'' telltale when ESC has been manually switched off by the driver) is prohibited, unless an actual ESC malfunction condition exists. In such situations, an ESC system actively disengaged by the driver through an appropriate control is not malfunctioning, but is instead functioning properly. Furthermore, such an illumination strategy could cause driver confusion, which may in turn decrease confidence in the ESC system.

(v) Telltale Extinguishment

TRW Automotive urged NHTSA to clarify paragraph S5.3.6 of its proposal, which provides, ''The ESC malfunction telltale must extinguish after the malfunction has been corrected.'' The commenter argued that this provision may cause confusion, because it could be interpreted as implying that all ESC malfunctions will require corrective action by a third party (*e.g.*, dealership, repair shop). Instead, TRW Automotive stated that there are numerous examples of situations in which outside intervention is not required to return the ESC system to normal operation, such as where a sensor may become temporarily inactive but subsequently returned to service. Accordingly, the company recommended revising S5.3.6 as follows: ''The ESC malfunction telltale must extinguish after *the ESC system has determined* the malfunction *no longer exists.*''

We clarify that in paragraph S5.3.6 of the NPRM, NHTSA did not intend to imply that all ESC malfunctions require corrective action by a third party. However, TRW Automotive's suggested language is problematic, because, unlike the agency's proposed language, it sets no requirement for the ESC system to actually determine and recognize that the malfunction no longer exists. Therefore, NHTSA has decided to retain the proposed requirement set forth in paragraph S5.3.6 without revision as part of this final rule.

(vi) Telltale Location

Consumers Union argued that, if the agency does decide to adopt a requirement for a visual warning of ESC activation, the standard should require an appropriate telltale in that vehicle's ''instrument cluster'' where its message would be more prominent, rather than in the vehicle's center console (*i.e.*, where the radio and climate control mechanisms are normally located).

In paragraph S5.3.1 of the NPRM for FMVSS No. 126, NHTSA proposed to require that the ESC malfunction telltale ''[m]ust be mounted inside the occupant compartment in front of and in clear view of the driver.'' In addition, paragraph S5.1.2 of FMVSS No. 101 requires that ''telltales and indicators * * * must be located so that, when activated, they are visible to the driver under the conditions of S5.6.1 and S5.6.2'' (*i.e.*, the driver has adapted to the ambient light roadway conditions and is properly restrained by the seat belts). NHTSA believes that these existing requirements are sufficiently stringent to ensure that vehicle manufacturers will locate the ESC malfunction telltale in a reasonable location, so the agency has decided that it is not necessary to specify that the ESC telltale must be located within the instrument panel area.

(vi) Use of ESC Malfunction Telltale To Indicate Malfunctions of Related Systems/Functions

The Alliance/AIAM commented that NHTSA should allow manufacturers to use the ESC malfunction indicator to indicate the malfunction of any ESC-related system, including traction control, trailer stability assist, corner brake control, and other similar functions that use throttle and/or individual wheel torque control to operate and which share common components with the ESC system. The commenters stated that this approach would be directly analogous to the position the agency has taken with respect to the frontal air bag readiness indicator required by S4.5.2 of FMVSS No. 208, *Occupant Crash Protection.* The commenters quoted a letter from NHTSA to Porsche dated July 30, 1996, stating, ''Since the dealer or repair business can inform the owner which system is malfunctioning, it does not matter that the indicator does not make that distinction.''

NHTSA understands the commenters' concerns regarding space limitations in the instrument panel for incorporation of additional telltales. While the International Standards Organization in its standard titled, ''Road Vehicles—Symbols for controls, indicators, and tell-tales'' (ISO 2575:2004(E)), specifies telltales for ''traction control'' and ''traction control off or not available,'' we agree that our established position noted by the commenter in relation to air bags may be similarly applied here. We believe that a single malfunction telltale that relates to a vehicle's stability-related safety systems generally is sufficiently informative for the driver, and it should be effective in conveying to the driver that a malfunction has occurred which may require diagnosis and service by a repair facility. Thus, we are revising Table 1 of FMVSS No. 101 to include a note referring to the ESC malfunction telltale that states:

> This symbol may also be used to indicate the malfunction of related systems/functions including traction control, trailer stability assist, corner brake control, and other similar functions that use throttle and/or individual torque control to operate and share common components with the ESC system.

(b) ''ESC Off'' Indication

If the vehicle manufacturer chooses to install a driver-selectable control (an ''ESC Off'' control) that places the ESC system in a mode that does not satisfy the performance requirements of the standard, then the proposal would require the manufacturer to provide an ''ESC Off'' telltale to alert the driver when the vehicle has been placed in such a mode (*see* S5.4.2). Specifically, the NPRM proposed that the ''ESC Off'' switch and telltale must be identified by the symbol shown for ''ESC Off'' in Table 1 of Standard No. 101 (49 CFR 571.101) (*see* S5.4.3), and the telltale must be mounted inside the occupant compartment in front of and in clear view of the driver (*see* S5.4.4). The ESC telltale symbol indicating ''ESC Off'' proposed by NHTSA consists of the ISO symbol J.14 with the English word, ''Off,'' beneath it. No text substitution for the ''ESC Off'' telltale was offered as part of the proposal.

It further proposed that the ''ESC Off'' telltale remain continuously illuminated

for as long as the ESC is in a mode that renders it unable to satisfy the requirements of S5.2.1, S5.2.2 and S5.2.3 (*see* S5.4.5), and except as provided in paragraph S5.4.7, each ''ESC Off'' telltale must be activated as a check of lamp function either when the ignition locking system is turned to the ''On'' (''Run'') position when the engine is not running, or when the ignition locking system is in a position between ''On'' (''Run'') and ''Start'' that is designated by the manufacturer as a check position (*see* S5.4.6). The ''ESC Off'' telltale would not need to be activated when a starter interlock is in operation (*see* S5.4.7). The ''ESC Off'' telltale would be required to extinguish after the ESC system has been returned to its fully functional default mode (*see* S5.4.8).

Several commenters raised specific issues pertaining to the ESC Off control and telltale, which are set forth and addressed below.

(i) ''ESC Off'' Symbol Alternative: Use of Text

In their comments, the Alliance/AIAM asked the agency to permit the use of the text ''ESC Off'' without the ISO symbol (J.14) to indicate that the ESC system has been switched off. The commenters argued that such approach is consistent with other FMVSS No. 101 Table 1 indicators.

Pursuant to the discussion in Section IV.C.9(a)(ii) above, NHTSA has decided to revise S5.4.3 (now S5.4.2 and S5.5.2) to permit use of the term ''ESC Off'' at the manufacturer's discretion as follows:

S5.4.2 Effective September 1, 2011, a control whose only purpose is to place the ESC system in a mode in which it will no longer satisfy the performance requirements of S5.2.1, S5.2.2 and S5.2.3 must be identified by the symbol shown for ''ESC Off'' in Table 1 of Standard No. 101 (49 CFR 571.101) or the text, ''ESC Off'' as listed under ''Word(s) or Abbreviations'' in Table 1 of Standard No. 101 (49 CFR 571.101); * * *

S5.5.2 Effective September 1, 2011, the ''ESC Off'' telltale must be identified by the symbol shown for ''ESC Off'' in Table 1 of Standard No. 101 (49 CFR 571.101) or the text, ''ESC Off'' as listed under ''Word(s) or Abbreviations'' in Table 1 of Standard No. 101 (49 CFR 571.101).

(ii) Waiver of Yellow Color Requirement When ''ESC Off'' Is Indicated Via Message/Information Center Text

In their comments, the Alliance/AIAM requested a waiver of the yellow color requirement when ''ESC Off'' indications are provided via the vehicle's message/information center, due to the difficulty associated with providing color in a message/information center. (Porsche made a similar comment.)

As explained in Section IV.C.9(a)(iii) above, the use of message/information centers for presentation of required ESC information is permissible to the extent that the requirements of FMVSS No. 101 are met (*see* 49 CFR 571.101 and discussion in Section IV.C.9(a)(ii) immediately above). The intent of the color requirements specified in Table 1 of FMVSS No. 101 is that the color yellow be used to communicate to the driver a condition of compromised performance of a vehicle system that does not require immediate correction. The International Standards Organization in its standard titled, ''Road Vehicles—Symbols for controls, indicators, and tell-tales'' (ISO 2575:2004(E)), agrees with this practice through its statement of the meaning of the color yellow as ''yellow or amber: Caution, outside normal operating limits, vehicle system malfunction, damage to vehicle likely, or other condition which may produce hazard in the longer term.''

NHTSA believes that operating ESC in a mode other than ''full on'' qualifies as a condition of ''compromised performance.'' Therefore, NHTSA believes that the yellow color requirement must be maintained in order to properly communicate the condition of potentially decreased safety to the driver. Accordingly, NHTSA has decided to deny the request for waiver of the yellow color requirement for the ''ESC Off'' telltale or substitute text when a message/information center is used. As noted in Section IV.C.9(a)(iii), this decision is consistent with the identical issues raised in petitions for reconsideration of the TPMS rule.

(iii) ''ESC Off'' Telltale Clarification

The Alliance/AIAM recommended that the final rule should clarify that the ''ESC Off'' telltale can be illuminated whenever the ESC system is in a mode other than the fully active system, even if, at that level, the system would meet the requirements of FMVSS No. 126.

As discussed above, paragraph S5.4 of the NPRM proposed to require that the ''ESC Off'' telltale must remain continuously illuminated for as long as the ESC is in a driver-selected mode that renders it unable to satisfy the requirements of S5.2.1, S5.2.2 and S5.2.3 (*see* S5.4.5). In their comments, the Alliance/AIAM suggested that manufacturers should be permitted to use the ''ESC Off'' telltale to alert the driver that the system is in a mode less than fully active, regardless of whether it could meet the requirements of S5.2.1, S5.2.2 and S5.2.3 at that level. After careful consideration, NHTSA agrees that permitting vehicle manufacturers to employ an illumination strategy as suggested by the Alliance/AIAM may help to remind drivers when their vehicle's ESC system has been placed in a mode of less than maximal effectiveness and to encourage them to rapidly return the system to fully-functional status. Certain modifications to the regulatory text are required to achieve this result, because S5.3.1(e) of FMVSS 101 reads, ''A telltale must not emit light except when identifying the malfunction or vehicle condition it is designed to indicate, or during a bulb check.'' Accordingly, it is necessary to add the following new paragraph S5.5.5 (renumbering subsequent paragraphs):

Notwithstanding S5.3.1(e) of 49 CFR 571.101, the vehicle manufacturer may use the ''ESC Off'' telltale to indicate an ESC level of function other than the fully functional default mode even if the vehicle would meet S5.2.1, S5.2.2 and S5.2.3 at that level of ESC function.

(iv) ''ESC Off'' Telltale Strategy

Porsche sought clarification that the following ESC telltale illumination strategy would be permissible: If the ESC is deactivated by the driver, illuminate the ESC symbol in the instrument panel (by which we assume Porsche means the ESC malfunction symbol and not the ''ESC Off'' symbol), provide a ''PSM OFF'' message in the message/information center, and illuminate a yellow light-emitting diode (LED) in the ''ESC Off'' button which is in clear view of the driver.

In response to Porsche's comment, we note that paragraph S5.3 of the NPRM states that the ESC malfunction telltale shall be illuminated ''* * * after the occurrence of one or more malfunctions.'' Manual disablement of the ESC by the driver does not constitute an ESC malfunction. Furthermore, paragraph S5.3.1(e) of FMVSS 101 requires, ''A telltale must not emit light except when identifying the malfunction or vehicle condition it is designed to indicate, or during a bulb check.'' Thus, the ESC malfunction telltale can only be used when a malfunction exists.

NHTSA is concerned that if the ESC malfunction telltale were permitted to be presented simultaneously with the ''ESC Off'' telltale, drivers would be unable to distinguish whether the system had been switched off or whether a malfunction had occurred. Therefore, presentation of the ESC malfunction telltale in addition to an ''ESC Off'' indication when ESC has been disabled via the driver-selectable

control and no system malfunction exists is prohibited.

(v) Use of Two-Part Telltales

Porsche stated that vehicle manufacturers should be permitted the flexibility to use two adjacent telltales, one containing the ISO symbol for the proposed yellow ESC malfunction indicator and another yellow telltale with the word ''Off.'' Porsche stated that given the limited space available on the instrument clusters in their vehicles, this dual-purpose combination should be permissible. The Alliance/AIAM offered the same comment, arguing that this approach would increase efficiency by allowing one lamp to be illuminated to indicate ESC malfunction and both to be illuminated to indicate that the system has been turned off or placed in a mode other than the ''full on'' mode.

NHTSA acknowledges the commenters'' concerns regarding limited instrument panel area available for locating telltales. However, we are not adopting the commenters' recommendation, because allowing a two-part telltale in such manner would create conflicting regulatory requirements, as discussed below.

Indication of a malfunction condition must always be the predominant visual indication provided to the driver by a telltale. As a result, if a two-part ESC telltale were used and an ESC malfunction occurred, only the malfunction portion of the telltale could be illuminated. Paragraphs S5.4.2 and S5.4.3 of the proposed regulatory text state that a telltale consisting of the symbol for ''ESC Off'' or substitute text (as indicated in Table 1 of FMVSS No. 101) must be illuminated when a control input to the ESC switch (*i.e.*, control) has been made by the driver to put the vehicle into a non-compliant ESC mode. If a two-part telltale were used, and an ESC malfunction condition occurred after the ESC had been turned off by the driver, the malfunction indication would take precedence over the ''off'' indication, thereby requiring that the ''off'' portion of the two-part telltale be extinguished. This situation would be in conflict with S5.4.2 of the proposed regulatory text. Due to this conflict, NHTSA has decided to deny the request to permit use of a two-part ESC telltale.

(vi) Conditions for Illumination of the ''ESC Off'' Telltale: Speed

The Alliance/AIAM sought clarification that the ''ESC Off'' telltale (if provided) need not illuminate when the vehicle is traveling below the low-speed threshold at which the ESC system becomes operational.

We note that under paragraph S5.1.2, NHTSA's proposal states that the ESC system must be ''* * * operational during all phases of driving including acceleration, coasting, and deceleration (including braking), except when the driver has disabled ESC or when the vehicle is below a speed threshold where loss of control is unlikely.'' Thus, NHTSA's proposal provides that the ESC system need not be functional when the vehicle is traveling at low speeds.

Paragraph S5.4.2 of FMVSS No. 126 requires the vehicle manufacturer to illuminate the ''ESC Off'' telltale when the ''vehicle has been put into a mode that renders it unable to satisfy the requirements of S5.2.1, S5.2.2 and S5.2.3.'' Driving a vehicle at low speeds does not equate with the vehicle operator actively using a driver-selectable control that places the ESC system ''into a mode in which it will not satisfy the requirements of S5.2,'' as stated in S5.4. Therefore, NHTSA believes that the proposed language does not imply that the ''ESC Off'' telltale must be illuminated when the vehicle is traveling at low speeds and is sufficiently clear in defining the conditions under which the ''ESC Off'' telltale must be illuminated. As a result, NHTSA has determined that no revisions to the proposed regulatory language are necessary to address this issue.

(vii) Conditions for Illumination of the ''ESC Off'' Telltale: Direction

The Alliance/AIAM, Bosch, Continental, Delphi, and Nissan commented that the final rule should be modified to clarify that there is no need to illuminate the ''ESC Off'' telltale when the vehicle is driven in reverse, because triggering the telltale under those circumstances could result in driver confusion.

As discussed under Section IV.C.6(f) above, NHTSA did not intend to require the ESC system to be operable when the vehicle is driven in reverse, because such a requirement would necessitate costly changes to current ESC systems with no anticipated safety benefit. Furthermore, we have decided in the final rule to modify the regulatory language in S4 of FMVSS No. 126 to clarify that ESC is intended to function ''over the full speed range of the vehicle (except at vehicle speeds less than 15km/h (9.3 mph) or when being driven in reverse). In such instances, the ESC system has not been turned off, but instead, it has encountered a situation in which, by regulation, the ESC system need not operate; once the vehicle is returned to forward motion at a speed above the minimum threshold, one would presume that the ESC system would return to normal operation automatically.

Requiring the ''ESC Off'' telltale to illuminate frequently (given that reversing the vehicle and low-speed driving are routine occurrences) would certainly be perceived as a nuisance by drivers and might even be mistaken for a system malfunction. Furthermore, we note that paragraph S5.4.2 of the NHTSA proposal comes under the heading and is in the context of the ''ESC Off'' Switch and Telltale (*see* S5.4). Those provisions already stated that the ''ESC Off'' indicator must be illuminated when the ESC system is manually disabled (*i.e.*, placed in a non-compliant mode) by the driver via the ''ESC Off'' switch. For these reasons, the agency does not believe that any change to the regulatory text is necessary to clarify that the ''ESC Off'' telltale need not be illuminated when the vehicle is in reverse gear.

(c) Alerting the Driver of ESC Activation

As noted above, paragraph S5.3.7 of the NPRM stated that manufacturers may use the ESC malfunction telltale in a flashing mode to indicate ESC operation. However, as was also stated in the NPRM, NHTSA has not identified any safety need that would justify a requirement for provision of an ESC activation indicator to alert the driver that the ESC system is intervening during a loss-of-control situation.[58] The NPRM also stated that the agency does not recommend use of an auditory indication of ESC activation.[59]

(i) Visual and Auditory Indications of ESC Activation

Regarding the issue of provision of an indication of ESC activation to the driver, commenters offered a variety of viewpoints. In overview, the Alliance/AIAM expressed support for a visual telltale. Consumers Union and Toyota expressed support for both visual and auditory indications. Advocates expressed support for a steady-burning telltale, and Public Citizen stated that an activation telltale is unnecessary and potentially distracting to the driver. These comments are summarized in detail below.

The Alliance/AIAM expressed support for allowing the ESC telltale to be used, at the manufacturer's option, to indicate an ESC operating or ''intervention'' event to the driver.

Consumers Union challenged the agency's data suggesting that visual and

[58] 71 FR 54729 (Sept. 18, 2006).

[59] *Id.*

audible warnings to the driver when the ESC system has been activated provide little or no safety benefit. The organization stated that testing by its own engineers suggested that such warnings are helpful, in that they may alert drivers earlier regarding slippery road conditions, thereby causing the driver to slow down in anticipation of a potential hazard. Accordingly, Consumers Union requested that the agency either include a requirement for visual and audible warnings of ESC operation in the final rule or at least conduct additional research before deciding to exclude such requirement.

In its comments, the Advocates stated that NHTSA should allow ESC telltales to be lit or not lit at the manufacturer's discretion when ESC intervenes, but, if lit, the telltale should not be allowed to flash. The commenter cited the agency's own study, which it interpreted as suggesting that flashing illumination increases driver distraction. The commenter also faulted the agency for making a tentative determination that a flashing ESC telltale was not shown to result in a measurable consequence in terms of roadway departures, arguing that the agency should have disclosed that the portion of the November 2005 study [60] upon which it relied had data from only 20 subjects in a driving simulator. The Advocates opined that this small sample size results in low statistical power for generalization.

The Advocates also expressed concern that a flashing telltale could elicit a panic reaction in some drivers or be confused with an ESC malfunction (since an increasing number of telltales are being wired to flash to indicate malfunction of the given system). The commenter expressed concern that ESC is not an ''automatic'' technology, in that it will only attempt to correct the vehicle's path if the driver is actively steering. The Advocates argued that if a driver panics and fails to even attempt to steer the vehicle, then the ESC system cannot intervene to compensate for a loss of lateral stability.

The Advocates argued that there is no support in the rulemaking record for allowing the ESC telltale to flash, but instead, that approach is arbitrary in that it contradicts the contrary evidence presented in NHTSA's own limited study (*i.e.*, one showing increased eye glance distributions away from the roadway). Instead, the commenter characterized this issue as the agency again seeking to permit continuation of certain current, suboptimal ESC systems. For these reasons, the commenter argued that a flashing ESC telltale could be detrimental to safety, so this aspect of the agency proposal should be reconsidered.

Public Citizen commented that NHTSA's position on telltales is sound. Public Citizen stated its belief that a telltale for ESC activation indication is unnecessary and argued that its position is supported by NHTSA's own study, which did not show such indicators to provide any benefit. Further, Public Citizen stated concern that an ESC activation telltale may create a distraction for drivers or lead to annoyance, which may cause drivers to deactivate the ESC system.

Toyota asked whether their current strategy of providing both visual (flashing) and auditory indications of ESC activation indication would be permissible. The commenter correctly stated NHTSA research results as showing that there were increased road departures and the average glance time was approximately twice as long for participants presented with an auditory-only indication of ESC activation as compared to those presented with a steady-burning telltale, flashing telltale, or no telltale. Toyota postulated that those responses resulted from the driver searching for a visual indicator to explain the meaning of the auditory indicator. Toyota noted that the NHTSA study did not test a condition in which an auditory indication of ESC activation is presented in addition to the flashing ESC telltale, as they currently provide in their vehicles, and, therefore, the commenter believes that NHTSA's recommendation not to use an auditory indicator refers to an auditory-only indication, and not to a system such as Toyota's that provides both visual and auditory indications to the driver.

After careful consideration of the numerous public comments raising this issue, the agency has decided to retain the approach toward ESC activation warnings presented in the NPRM for the reasons that follow. In a survey conducted in the early phases of NHTSA's human factors research relating to ESC,[61] we examined 28 vehicles equipped with ESC systems and found that all manufacturers appeared to provide a visual indication of ESC activation. The study found that a majority of vehicle manufacturers provided such indication using a symbol, while a few indicated ESC activation using text. Each vehicle examined that used a symbol to indicate ESC activation did so by flashing the telltale. Owner's manuals examined typically indicated that the purpose of the flashing telltale was to inform the driver that the ESC was ''active'' or ''working.''

As discussed in NHTSA's proposal, the safety need for an ESC activation indicator to alert the driver during an emergency situation that ESC is intervening is not obvious. It would seem that with ESC, as with anti-lock brake systems, vehicle stability would be increased regardless of whether feedback was provided to inform the driver that a safety system had intervened. No data have been provided to NHTSA to suggest that safety benefits are enhanced by alerting the driver of ESC activations. Nevertheless, the agency's current research on the topic of ESC activation warnings supports the NPRM's current approach (with which the Alliance/AIAM and Public Citizen agree) that an ESC activation indication should neither be prohibited nor required, as explained below.

The results of recent NHTSA research [62] neither show that alerting a driver to ESC activation provides a safety benefit, nor that it may prove to be a source of distraction that could lead to adverse safety consequences. Our research shows that drivers presented with the flashing telltale were more likely to glance at the instrument panel and that these drivers typically glanced at the panel twice, rather than just once as for the steady-burning telltale or no telltale. Insofar as a flashing telltale draws a driver's attention away from the road, where we believe it should be during an emergency loss-of-control situation, we cannot logically require it. Although the Consumers Union commented that ''their own testing resulted in [their] engineers finding these warnings were helpful and alerted them earlier in their driving to the possibility of slippery conditions before an emergency situation may occur,'' the commenter provided no indication of whether the telltale flashed because of the activation of the ESC system itself, or due to other traction control interventions, which are often connected with the ESC telltale. NHTSA agrees that it makes sense to alert drivers to slick road conditions when the driver is operating the vehicle on the roadway in a generally straight path, but disagrees that it would make sense to draw the driver's attention away from the road when they are in the midst of assessing a crash-imminent situation and attempting to avoid a collision.

While NHTSA's research to date showed that drivers looked at a flashing

[60] Mazzae, E. *et al., The Effectiveness of ESC and Related Telltales: NADS Wet Pavement Study,* (Telltale Study) DOT HS 809 978, NHTSA (November 2005) (Docket No. NHTSA–2006–25801–7).

[61] *Id.*

[62] *Id.*

telltale twice as often, this did not result in significantly different rates for loss of control, road departures, and collisions than with steady-burning telltales or no telltales. Thus, despite the logical risk of looking away from the road during an ESC-worthy maneuver, we found no apparent detriment from the increased glances at a flashing telltale. NHTSA therefore cannot agree with Advocates' comment that NHTSA should allow ESC telltales to be lit or not lit at the manufacturer's discretion when ESC intervenes, but that lit telltales should not be allowed to flash, because the flashing might lead to driver distraction or panic. Currently available research results are insufficient to support prohibition of the existing practice of providing a visual indication of ESC activation, but neither do they support requiring it. Although Consumers Union engineers have performed their own informal study, the agency does not consider their results (without data being provided), to offer sufficient justification for requiring a visual indication of ESC activation.

Consumers Union requested that the agency either include a requirement for visual and audible warnings of ESC operation in the final rule, or at least conduct additional research before deciding to exclude such a requirement. Advocates also criticized the small sample size of NHTSA's existing research in this area. To both commenters, we respond that, while the existing research had statistically valid sample sizes, additional research is underway to examine driver behavior and crash-imminent situation outcomes as a function of whether a flashing ESC telltale is presented during ESC activation, versus presentation of the icon immediately following ESC activation. Data from this research are being analyzed, and NHTSA hopes that the study results will further clarify which strategy for notifying the driver of ESC activation is least likely to negatively impact the driver's response to a loss-of-control situation. However, unless additional research provides strong, statistically-valid evidence of a benefit or detriment associated with presentation of an ESC activation indication, we will not require or prohibit such an indication.

To NHTSA's knowledge, Toyota is the only manufacturer that currently presents both a visual and an auditory indication of ESC activation. As Toyota correctly pointed out, NHTSA's recent ESC study measured a negative consequence of the presentation of an auditory-only indicator of ESC activation, statistically significant for older drivers in terms of road departures. Approximately twice as many road departures were observed for participants presented with the auditory ESC activation indication as compared to those who were presented with a steady-burning telltale, flashing telltale, or no telltale. For this reason, NHTSA recommended against using an auditory ESC activation indicator in its proposal. Toyota postulated that increased instrument panel glances resulted from the driver searching for a visual indicator to explain the meaning of the auditory indicator. Given that study results showed drivers presented with no visual or auditory indication of ESC activation exhibited instrument panel glances lasting half the duration of those observed in conjunction with presentation of the Toyota auditory ESC indicator, one can only assume that the auditory alert produced the longer glance durations. Toyota has not provided any data to substantiate its apparent assertions that providing simultaneous visual and auditory indicators would result in: (1) Instrument panel glances of similar duration to those observed in the NHTSA study for participants presented with only a visual indicator, and (2) fewer road departures, as were observed in the other ESC activation indication conditions.

Consistent with its research, NHTSA believes that auditory indications of ESC activation are not necessary and provide no apparent safety benefit. However, while NHTSA has conducted research showing that an auditory indication of ESC activation elicits longer instrument panel glances and may be associated with an increase in road departures, we do not consider these results from a single, simulator study to provide sufficient justification to prohibit use of an auditory ESC indicator. Therefore, while we would discourage Toyota's use of an auditory ESC activation warning, even when combined with a visual indication, current data do not justify a prohibition of such approach.

(ii) Flashing Telltale as Indication of Intervention by Related Systems/Functions

Honda and the Alliance/AIAM requested permission to flash the ESC malfunction telltale to indicate the intervention of other related systems, including traction control and trailer stability assist function. Honda reasoned that these functions are directly related to the ESC system and that the driver would experience the same sensations from the braking system actuator and throttle control triggered by operation of these related systems, as they would in the event of ESC activation. In addition to keeping the driver informed, Honda also reasoned that this strategy would aid in minimizing the number of telltales used for related functions. The commenter proposed revising paragraph S5.3.7 as follows: ''The manufacturer may use the ESC malfunction telltale in a flashing mode to indicate ESC operation, *or to indicate operation of functions directly related to stability control such as a traction control program.''*

Because NHTSA is not requiring an ESC activation indication, if vehicle manufacturers choose to provide one, they may use it to indicate interventions by additional related systems in their discretion. We expect that manufacturers would explain the meaning and scope of the activation indication in the vehicle owner's manual, consistent with facilitating consumer understanding of important vehicle safety features.

(d) Bulb Check

Except when a starter interlock is in operation, the NPRM proposed to require that each ESC malfunction telltale and each ''ESC Off'' telltale must be activated as a check of lamp function either when the ignition locking system is turned to the ''On'' (''Run'') position when the engine is not running, or when the ignition locking system is in a position between ''On'' (''Run'') and ''Start'' that is designated by the manufacturer as a check position (*see* S5.3.4 and S5.5.6).

(i) Waiver of Bulb Check for Message/Information Centers

Regarding the NPRM's proposed bulb check requirements, the Alliance/AIAM stated that while such requirements are appropriate for traditional telltales, those requirements are not appropriate for vehicle message/information centers which do not use bulbs and are illuminated whenever the vehicle is operating. According to the commenters, if there were a problem of this type, it would be readily apparent because the entire message/information center would be blank. Therefore, the Alliance/AIAM requested that in the final rule, the agency exclude ESC system status indications provided through a message/information center from the standard's bulb check requirements. (Porsche provided a similar comment on this issue.)

As indicated in paragraphs S5.3.4 and S5.5.6, any ESC status information presented via a telltale must have a bulb check performed for that telltale. However, NHTSA agrees with the commenters that a bulb check is not

relevant or necessary for the type of display technology utilized for information/message centers. Presumably, if an information/message center experiences a problem analogous to one which would be found by a telltale's bulb check, the entire message center would be non-operational, a situation likely to be rapidly discovered by the driver. Therefore, we have decided to waive the bulb check requirement under FMVSS No. 126 for ESC system status indications provided via a message/information center. In response to these comments, we are adding new paragraphs S5.3.6 and S5.5.8 as follows:

S5.3.6 The requirement S5.3.4 does not apply to telltales shown in a common space.
* * *

* * * * *

S5.5.8 The requirement S5.5.6 does not apply to telltales shown in a common space.

(ii) Clarification Regarding Bulb Check

TRW Automotive recommended that as part of the final rule, the agency clarify that under paragraph S7.2, *Telltale bulb check*, of the proposed test procedures, the bulb check for the ESC malfunction telltale and ESC Off telltale (if provided) may be performed by any vehicle system and is not required to be conducted by the ESC system itself. According to TRW Automotive, many vehicle systems are able to perform this function, and most current vehicles are designed such that the instrument panel controls the telltales. Thus, the commenter recommended that the last sentence of S7.2 (consistent with paragraphs S5.3.4 and S5.4.6) be revised to read as follows: ''The ESC malfunction telltale must be activated as a check of lamp function for the ESC malfunction telltale, and if equipped, the ''ESC Off'' telltale, as specified in S5.3.4 and S5.4.6.''

NHTSA is not concerned with the precise mechanism of how the bulb check for an ESC-related telltale is accomplished, provided that this performance requirement is met. Accordingly, we have decided to modify S7.2 by adopting the language recommended by TRW Automotive.

10. System Disablement and the ''ESC Off'' Control

Under paragraph S5.4, the NPRM proposed to permit manufacturers to provide a driver-selectable switch that places the ESC system in a mode in which it will not satisfy the performance requirements of the standard. However, if an ''ESC Off'' switch is provided, the vehicle's ESC system must always return to a mode that satisfies the requirements of the standard at the initiation of each new ignition cycle, regardless of what mode the driver had previously selected (*see* S5.4.1). If the system has more than one mode that satisfies these requirements, the default mode must be the mode that satisfies the performance requirements by the greatest margin (*see* S5.4.1).

Under the proposal, if an ''ESC Off'' switch is provided, the vehicle manufacturer must also provide a telltale indicating that the vehicle has been put into a mode that renders it unable to satisfy the requirements of the standard (*see* S5.4.2). The ''ESC Off'' switch and telltale must be identified by the symbol shown for ''ESC Off'' in Table 1 of Standard No. 101 (49 CFR 571.101) (*see* S5.4.3). (For further details of the telltales and symbols for the ''ESC Off'' switch and telltale (and issues relating thereto), see section IV.C.9 above.)

Commenters raised a number of issues regarding these provisions pertaining to system disablement and the ''ESC Off'' switch. Most commenters agreed that there may be a need to disengage the ESC system in certain driving situations (*e.g.*, to gain traction in snow, mud). General comments on this issue (*e.g.*, appropriateness and reach of the system disablement provision) are discussed immediately below, followed by more detailed, technical comments.

(a) Provision of an ''ESC Off'' Control

In its comments, IIHS supported inclusion of an ESC off switch, because it agreed that there are situations in which the system would need to be disabled (*e.g.*, initiating movement in deep snow). IIHS also supported the proposal to have a default mode of ''on'' for the ESC each time the vehicle is started.

Mr. Petkun supported the proposal's tentative decision to permit vehicle manufacturers to install ESC off switches, stating that a driver may need to disable the ESC system when a vehicle is stuck in a deformable surface such as mud or snow, or when a compact spare tire, tires of mismatched sizes, or tires with chains are installed on the vehicle. He agreed that vehicle manufacturers should provide an easily identifiable telltale to indicate when the vehicle has been placed in a mode that completely disables the ESC system.

In contrast to the comments above, the Advocates stated that the proposal's policy for ESC on-off switches is too liberal and may place motorists at risk. Although it agreed that there may be justification for temporary ESC disablement where the vehicle needs full longitudinal tire traction for negotiating mud, gravel, or snow, the commenter did not support ESC disablement for the purpose of increasing ''driving enjoyment'' (similar comment from Public Citizen). The organization was particularly skeptical of the rationale related to racing, arguing that this small minority of drivers can disable their ESC systems by other (unspecified) means. The Advocates' comments suggested that ESC disablement could result in the loss of benefits of an active ESC system for long distances or considerable periods of time until the start of the next ignition cycle. Furthermore, Advocates expressed concerns that turning off the ESC system could also disable ABS operation, thereby negatively impacting vehicle safety.

In addition, the Advocates made an analogous argument that NHTSA's sister agency, the Federal Motor Carrier Safety Administration (FMCSA), issued a report [63] in 2005 which recommended that in no case should drivers of vehicles greater than 10,000 pounds GVWR be allowed to disable a Vehicle Stability System (either roll stability control or ESC). The commenter argued that this is another reason for the agency to reconsider the ease with which a driver could use an ESC disabling switch for vehicles under 10,000 pounds GVWR.

Advocates suggested that it may be unnecessary to permit ESC disablement, if ESC systems can operate in conjunction with vehicle traction control systems. According to the Advocates, if the agency continues to believe that ESC disablement switches should be permitted, disablement should require either: (1) A long switch engagement period, or (2) sequential switch engagement actions.

Despite the reservations of some commenters, NHTSA continues to believe that provision of a control for temporarily disabling ESC will enhance safety. The rationale for this position is detailed below.

First, we acknowledge that driving situations exist in which ESC operation may not be helpful, most notably in conditions of winter travel (*e.g.*, driving with snow chains, initiating movement in deep snow). ESC determines the speed at which the vehicle is traveling via the wheel speeds, rather than using an accelerometer or other sensor. While NHTSA is only requiring ESC to operate at travel speeds of 15 kph (9.3 mph) and greater, some manufacturers may choose to design their ESC systems to operate

[63] A. Houser, J. Pierowicz, *Concept of Operations and Voluntary Operational Requirements for Vehicular Stability Systems (VSS) On-Board Commercial Motor Vehicles*, FMCSA–MCRR–05–006 (July 2005).

at lower speeds. Thus, drivers trying to work their way out of being stuck in deep snow may induce wheel spinning that implies a high enough travel speed to engage the ESC to intervene, thereby hindering the driver's ability to free the vehicle.

Second, NHTSA is concerned that if a control is not provided to permit drivers to disable ESC when they choose to, some drivers may find their own, permanent way to disable ESC completely. This permanent elimination of this important safety system would likely result in the driver losing the benefit of ESC for the life of the vehicle. However, as currently designed, ESC systems retain some residual safety benefits when they are ''switched off'' and they also become operational again at the next ignition cycle of the vehicle. NHTSA feels that provision of this type of temporary ''ESC Off'' control is the best strategy for dealing with such situations.

While we acknowledge FMCSA's recommendation that drivers of vehicles with a GVWR greater than 10,000 pounds should not be permitted to disable a Vehicle Stability System, those vehicles generally have very different handling characteristics than the light vehicles subject to today's final rule. Furthermore, the operators of those vehicles in many cases may be expected to have different motivations for driving (*i.e.*, driving for personal reasons, rather than work reasons). Accordingly, we do not believe that the referenced FMCSA recommendation would alter the identified safety need discussed above to allow vehicle manufacturers to include an ''ESC Off'' control on certain light vehicles equipped with an ESC system.

In response to Advocates' suggestion that it may be unnecessary to permit ESC disablement if ESC systems can operate in conjunction with traction control, NHTSA does not believe that ESC disablement should be prohibited on this basis. This rule mandates ESC, not traction control, for new vehicles. For vehicles equipped with ESC but not with traction control, ESC disablement may be necessary in certain situations, as described above. Mandating traction control as well as ESC, as Advocates' suggestion would entail, is beyond the scope of this rulemaking.

(b) Switch for Complete ESC Deactivation

Consumers Union stated that for certain sporty models, NHTSA could permit a separate mode (perhaps activated with a switch) which would give the driver discretion to completely disable the ESC for race track use (similar comments by Mr. Cheah and Mr. Kiefer). Mr. Kiefer added that this disablement mechanism, which would fully and permanently disable the vehicle's ESC system, should shut down any vehicle subsystem that intervenes in the vehicle's performance, although he agreed that exceptions may be warranted (*e.g.*, where the driver wishes to keep ABS operative).

The proposed regulatory text states that the ''manufacturer may include a driver-selectable switch that places the ESC system in a mode in which it will not satisfy the performance requirements'' specified by NHTSA (*see* S5.4 of the NPRM). Because NHTSA is permitting, rather than requiring such a switch and is not specifying the extent to which ESC function must be reduced via the switch, manufacturers have the freedom to provide drivers with a switch that has the ability to completely disable ESC. Thus, NHTSA believes that the regulatory text as originally drafted sufficiently addresses the commenters' concerns regarding this issue.

(c) ESC Operation After Malfunction and ''ESC Off'' Control Override

Honda expressed concern that when an ESC malfunction is detected, some drivers may respond by pressing the ESC Off control (if one is provided). According to Honda, not all ESC malfunctions may render the system totally inoperable, so there may be benefits to ensuring that the system remains active in those cases. Thus, the commenter urged the agency to permit manufacturers to disable the ESC Off control in those instances where an ESC malfunction has been indicated. Honda recommended adding a new provision to S5.4 stating, ''*Operation of the ESC off switch may be disabled when the ESC malfunction telltale is illuminated.*''

In addition, Honda's comments also stated that the company's current ESC system designs contain a logic that permits the system to override the ''ESC Off'' control in certain appropriate situations (*e.g.*, when the TPMS system detects low tire pressure or a TPMS system malfunction such as when a spare tire is in use). Honda argued that at such times, the benefits of ESC operational availability are more important than the ability to disable the system. The company further argued that because the ESC Off control is permitted at the vehicle manufacturer's option, the manufacturer should be accorded discretion to appropriately limit the operation of that off control.

We agree with the commenter's reasoning on both of these issues. It was never the agency's intention to require that just because the manufacturer permits the ESC system to be disabled under some circumstances, the manufacturer must allow it to be disabled at *all* times. If the vehicle manufacturer believes a situation has occurred in which it should not be possible to turn ESC off, then the manufacturer should be permitted to override the operation of the ''ESC Off'' control. Honda's example of an ESC system malfunction after which the driver triggers the ''ESC Off'' switch is illustrative of such a situation; in such cases, the vehicle operator presumably had desired to maintain ESC functionality while driving, so the driver's action to turn the system off arguably reflects a reflex reaction that the system is unavailable and must be shut down, rather than a reasoned decision to forgo any residual ESC benefits that might remain in spite of the malfunction.

Similarly, it was not the agency's intention to require the ESC system to remain disabled if the vehicle manufacturer believes a situation has occurred in which ESC should again become functional. We do not believe that any changes to the regulatory text are necessary regarding this issue.

(d) Default to ''ESC On'' Status

Although Consumers Union acknowledged that there may be certain situations in which ESC disablement may be appropriate (*e.g.*, vehicles stuck in snow or mud), it did not support the proposed requirement that the ESC system be permitted to remain disabled until the next ignition cycle (*i.e.*, default mode upon vehicle start-up be ESC ''on''). The commenter argued that the driver may inadvertently forget to reengage the ESC for the remainder of the current trip by turning the ignition off and then on again. Thus, Consumers Union recommended that the standard should require that, once disabled, the ESC system must again become operational once the vehicle has reached a speed of 25 mph.

Public Citizen expressed support for a default setting of ''on'' for ESC systems at the start of each ignition cycle (similar comment by Mr. Petkun). However, Public Citizen argued that waiting for the next ignition cycle to require reengagement of the ESC system needlessly compromises potential safety benefits. Accordingly, Public Citizen urged the agency to consider other alternatives, such as a time-delay reminder to re-enable the system or some other means of automatic re-enablement.

In response to these comments, we note that while paragraph S5.4.1 of the

proposed regulation states that ''[t]he vehicle's ESC system must always return to a mode that satisfies the requirements of S5.1 and S5.2 at the initiation of each new ignition cycle,'' manufacturers have the freedom to equip their vehicles with ESC systems that return to a compliant mode sooner, based upon an automatic speed trigger or timeout.

As discussed in Section IV.C.10(a) above, NHTSA noted two situations in which drivers may desire to turn off ESC, specifically when a vehicle is stuck in the snow and when a driver chooses to engage in sporty driving or racing. The latter of these two situations is the only one that warrants a potentially more prolonged delay of ESC re-enablement until the next ignition cycle. However, if the agency were to require automatic reengagement of a fully-functional ESC mode after a certain time delay or upon the vehicle reaching a certain speed threshold, many vehicle operators might face a considerable obstacle if they wished to continue engaging in sports driving. As mentioned above, we believe that there could be safety disbenefits associated with sports drivers who try to permanently disable the ESC system themselves.

Nevertheless, NHTSA believes that many vehicle manufacturers will equip vehicles that are not of a ''sport'' class with ESC systems that automatically re-engage the operation of the ESC system based on some threshold reached during the ignition cycle. Given our assessment of the situation, NHTSA does not believe it necessary or advisable to specify more stringent requirements for returning ESC to a compliant mode.

(e) Operation of Vehicle in 4WD Low Modes

The Alliance/AIAM, Bosch, Continental, Delphi, and Nissan all stated that there are certain situation in which the ESC system would not be able to default to ''on'' status at the start of a new ignition cycle. As an example, Bosch stated that there are certain vehicle operational modes in which the driver intends to optimize traction, not stability (*e.g.*, 4WD-locked high, 4WD-locked low, locking front/rear differentials). The commenters argued that an exception should be made in FMVSS No. 126 for when drivers select ESC modes for four-wheel drive low, has locked the vehicle's differentials, or has placed the vehicle in other special off-road chassis modes. According to the commenters, transition to one of these modes is mechanical and cannot be automatically reverted to ''on'' status at the start of each new ignition cycle.

The commenters suggested that this approach would be consistent with safety because the operating conditions for these vehicle modes tend to involve low-speed driving. The Alliance/AIAM added that in those cases, the ESC ''Off'' telltale should be illuminated, in order to remind the driver of the ESC system's status as being unavailable. Bosch recommended modifying paragraph S5.4.1 to read as follows: ''The vehicle's stability control system must always return to a mode which satisfies the requirements of S5.1 and S5.2 at the initiation of each new ignition cycle, regardless of the mode the driver had previously selected, except if that mode was specifically for enhanced traction during low-speed, off-road driving.''

We agree with the commenters that when a vehicle has been intentionally placed in a mode specifically intended for enhanced traction during low-speed, off-road driving via mechanical means (*e.g.*, levers, switches) and in this mode ESC is always disabled, it is not sensible to require the ESC system to be returned to enabled status just because the ignition has been cycled. In these situations, keeping the ESC disabled and illuminating the ESC ''Off'' telltale, in order to remind the driver of the ESC system's status as being unavailable, makes more sense. We agree with the comment that making this change to the regulatory text should have no substantial effect on safety because the operating conditions for these vehicle modes tend to involve low-speed driving.

In revising the regulatory text pertaining to this issue, we have adopted Bosch's recommended language, except that a clause has been added to limit applicability to situations where the vehicle's mode transition is accomplished via mechanical means. We note that if the vehicle's mode transition is accomplished via electronic means, then the vehicle can reset itself to a normal traction mode, and the ESC to active status, with each ignition cycle. Accordingly, paragraph S5.4.1 has been revised to read as follows:

S5.4.1 The vehicle's ESC system must always return to a mode that satisfies the requirements of S5.1 and S5.2 at the initiation of each new ignition cycle, regardless of what mode the driver had previously selected, except if that mode is specifically for enhanced traction during low-speed, off-road driving and is entered by the driver using a mechanical control that cannot be automatically reset electrically. If the system has more than one mode that satisfies these requirements, the default mode must be the mode that satisfies the performance requirements of S5.2 by the greatest margin.

(f) ''ESC Off'' Control Requirements

Under paragraph S5.4.3 of the NPRM, the agency proposed to require the ''ESC Off'' control, if present, to be identified by the symbol shown for ''ESC Off'' in Table 1 of Standard No. 101 (*i.e.*, the ISO symbol J.14 with the English word ''Off'').

(i) Labeling of the ''ESC Off'' Control

While the Alliance/AIAM agreed that the ''ESC Off'' control should be identified, they argued that vehicle manufacturers should be granted flexibility in terms of how to identify the ''ESC Off'' control. The commenters stated that it is not necessary to standardize the identification of the control because vehicle manufacturers have been providing drivers with more detailed feedback on the ESC operating mode when the system is in other than the default ''full on'' mode. If the agency understands the comment correctly, the Alliance and AIAM are suggesting that because vehicle manufacturers are providing a telltale that would illuminate whenever the system is in a mode other than ''full on,'' they should be permitted discretion to optimize control labeling in ways that would facilitate driver understanding of variable ESC modes (*i.e.*, permitting a message other than ''ESC Off'').

NHTSA shares the commenters' concern for ensuring driver understanding of ESC status. We also agree that it would be beneficial to encourage drivers to select ESC modes other than ''full on'' only when driving conditions warrant. We feel that standard control labeling of an actual ''ESC Off'' control must be maintained and, therefore, manufacturers must identify the ''ESC Off'' control using the specified ''ESC Off'' symbol or ''ESC Off'' text (which may be supplemented with other text and symbols). However, we are distinguishing between an actual ''ESC Off'' control (*i.e.*, one whose function is to put the ESC system in a mode in which it no longer satisfies the requirements of an ESC system, and which accordingly must bear the required ''ESC Off'' labeling) and two other possible types of controls (which would not be required to bear the ''ESC Off'' labeling).

The first control to be clarified as excluded is one which has a different primary purpose (*e.g.*, a control for the selection of low-range 4WD that locks the axles), but which must turn off the ESC system as a consequence of an operational conflict with the function that it controls. In this case, such control would be made confusing by adding ''ESC Off'' to its functional label.

Nevertheless, in such situations, the ''ESC Off'' telltale must illuminate to inform the driver of ESC system status.

The second control to be clarified as excluded is one that changes the mode of ESC to a less aggressive mode than the default mode but which still satisfies the performance criteria of Standard No. 126. In such cases, the manufacturer may label such a control with an identifier other than ''ESC Off,'' and the manufacturer is permitted, but not required, to use the ''ESC Off'' telltale beyond the default mode to signify lesser modes that still satisfy the test criteria.

Accordingly, paragraph S5.4 has been rewritten to address which vehicle controls must be identified with the ''ESC Off'' symbol or ''ESC Off'' text.

(ii) Location of the ''ESC Off'' Control

Nissan stated its understanding that by including the optional ESC off switch in Table 1 of FMVSS No. 101, *Controls and Displays*, such switch is subject to the requirement of S5.3.2.1 that the control be visible to a restrained driver. However, the commenter requested that vehicle manufacturers be provided flexibility in the placement of the ESC off switch for the following reasons. First, Nissan believes that the ESC off switch would be infrequently used during normal driving. Second, the location of the ESC off switch would help ensure that disabling of the ESC reflects a deliberate act by the driver. Accordingly, Nissan requested that the final rule exclude the ESC off switch from the visibility requirements of FMVSS No. 101.

For the reasons that follow, the agency has decided that the ''ESC Off'' switch location must meet the requirements of FMVSS No. 101 S5.1.1, which states that ''[t]he controls listed in Table 1 and in Table 2 must be located so that they are operable by the driver under the conditions of S5.6.2 [*i.e.*, while properly restrained by the seat belt].'' The commenter correctly understood the intent of FMVSS No. 101, in noting the implicit requirement that both telltales and controls be located such that they are visible to a belted driver. We believe that hand-operated controls should be mounted where they are easily visible to the driver so as to minimize visual search time, because safety may be diminished the longer a driver's vision and attention are diverted from the roadway. Furthermore, relative consistency of location across vehicle platforms will promote easy identification of the switch when drivers encounter a new vehicle. Therefore, NHTSA believes that, consistent with S5.1.1 of FMVSS No. 101, it is necessary to require the ''ESC Off'' switch to be located in a position where it is visible to a belted driver.

11. Test Procedures

(a) Accuracy Requirements

Honda requested that the agency specify accuracy requirements for the following measurement instruments used in the ESC test procedures: (1) Yaw rate sensor; (2) steering machine, and (3) lateral acceleration sensor. The commenter stated that such specifications would assist in the self-certification process and the agency's own compliance testing.

The agency has decided that it is not necessary to include sensor specifications as part of the regulatory text of FMVSS No. 126. NHTSA is including these sensor specifications in the NHTSA Laboratory Test Procedures for Standard No. 126. The Laboratory Test Procedures provide detailed instructions to personnel conducting compliance testing for the agency, including test equipment to be used and the limitations on equipment output variability. Including the acceptable equipment output variability parameters in the test procedures does not affect the substance of the standard's requirements, and helps the agency respond as needed to factors affecting the availability of test equipment. The Laboratory Test Procedures will be made available to the public prior to the initiation of FMVSS No. 126 compliance testing, but for those interested, we note here that the sensor specifications of the instrumentation used by the agency's ESC research program and currently planned for use in the compliance testing program are as follows:

Yaw rate: Range ±100 degrees/s; Nonlinearity ≤0.05% of full scale.

Steering machine encoder: Range ±720 degrees; Resolution ±0.10 degrees (combined resolution of the encoder and D/A converter).

Accelerometers: Range ±2 g; Nonlinearity <50μg/g.[2]

The agency emphasizes that there is considerable precedent on the question of what belongs in the regulatory text as compared to what belongs in the compliance test procedure. For example, neither FMVSS No. 138 (*Tire Pressure Monitoring Systems*) nor FMVSS No. 139 (*New Pneumatic Radial Tires for Light Vehicles*) contain accuracy requirements in the standard, but rather include them in the test procedures.

Given how the agency knows that manufacturers design their vehicles to pass compliance tests (*i.e.*, with some margin to allow for test inaccuracy), we anticipate that manufacturers should have no difficulty complying with specifications contained in the test procedures rather than in the standard itself. Manufacturers may base their margins on their own estimates of the repeatability and reproducibility of the Sine with Dwell test. NHTSA has recently completed a major round-robin study with industry examining the reproducibility and repeatability of the test. Industry, as well as NHTSA, has all of the raw data, and as the results are evaluated, we believe that manufacturers will have more than sufficient information to make these decisions.

(b) Tolerances

Under paragraph S7.4, *Brake Conditioning*, the NPRM's proposed test procedures call for the vehicle to undertake a series of stops from either 56 km/h (35 mph) or 72 km/h (45 mph) in order to condition the brakes prior to further testing under the standard (*see* S7.4). In addition, the NPRM called for the vehicle to undertake several passes with sinusoidal steering at 56 km/h (35 mph) to condition the tires (*see* S7.5).

Honda recommended that the agency outline specific tolerances for vehicle speed and deceleration to condition the tires and brakes prior to compliance testing, thereby helping to ensure consistent test conditions.

The agency has decided not to make additional changes to the tire and brake conditioning provisions of the regulatory text based upon Honda's recommendations, because, for the reasons discussed below, we believe the details currently specified in the proposed regulatory text for FMVSS No. 126 are sufficient. The intent of tire conditioning is to wear away mold sheen and to help bring the tires up to test temperature. Minor fluctuations in the vehicle speeds specified in S7.5.1 and S7.5.2 should not have any measurable effect on these objectives. Similarly, we believe minor fluctuations in the maneuver entrance speeds and deceleration specifications provided in S7.4.1 through S7.4.4 will not adversely affect the brake conditioning process. Accordingly, we believe that the commenter's recommended tolerances for vehicle speed and deceleration are unnecessary.

(c) Location of Lateral Accelerometer

Honda recommended that the final rule's test procedures should include detailed specifications on how to calculate lateral acceleration. According to Honda, the NPRM proposed to require calculation of lateral

displacement of the vehicle's center of gravity based upon lateral acceleration of the vehicle's center of gravity. However, the commenter stated that for some vehicles, it may not be possible to install a lateral acceleration sensor at the location of the vehicle's actual center of gravity; in those cases, it reasoned, a correction factor will be necessary to accommodate this different sensor positioning.

We agree with Honda's comment that it may not be possible to install a lateral acceleration sensor at the location of the vehicle's actual center of gravity. For this reason, it is important to provide a coordinate transformation to resolve the measured lateral acceleration values to the vehicle's center of gravity location. The specific equations used to perform this operation, as well as those used to correct lateral acceleration data for the effect of chassis roll angle, will be incorporated into the laboratory test procedure.

(d) Calculation of Lateral Displacement

As noted above, the NPRM proposed that under each test performed under the test conditions of S6 and the test procedure of S7.9, the vehicle would be required to satisfy the responsiveness criterion of S5.2.3 during each of those tests conducted with a steering amplitude of 180 degrees or greater. Specifically, proposed paragraph S5.2.3 provides that lateral displacement of the vehicle center of gravity with respect to its initial straight path must be at least 1.83 m (6 feet) when computed 1.07 seconds after initiation of steering. The NPRM further proposed that the computation of lateral displacement is performed using double integration with respect to time of the measurement of lateral acceleration at the vehicle center of gravity (*see* S5.2.3.1) and that time t=0 for the integration operation is the instant of steering initiation (*see* S5.2.3.2).

Oxford Technical Solutions, Ltd. (Oxford) commented that the proposed ESC test procedures require refinement, because it believes that the same vehicle, when tested at different facilities and by different engineers, may experience differences in lateral displacement of up to 60 cm. Specifically, Oxford identified what it perceived to be problems with the proposed test procedures' computation of lateral displacement and also the repeatability of those procedures.

Regarding lateral displacement computation, Oxford argued that integrating the accelerometer into a rotating reference frame does not compute actual lateral displacement, because with this technique, a vehicle that rotates more (*i.e.*, achieves a higher yaw angle compared to the original straight driving line) will yield a different result, even if the displacement is the same. Although the commenter acknowledged the need to set some value as part of the test (*e.g.*, 1.83 meters, as proposed), it suggested using some term to prevent confusion, such as ''NHTSA Displacement,'' ''ESC Displacement,'' or ''Spin Displacement.'' On this point, Oxford recommended consideration of the following language:

> The ''Spin Displacement'' is a double-integration of a lateral accelerometer over a period of 1.071 seconds and the value has to be 1.83m. The test must be conducted uphill on your VDA to within 5 degrees of the uphill direction. The VDA should have an angle of no more than 2 degrees. The lateral acceleration must be measured to an accuracy of 0.03m/s2, including roll effects. Therefore roll must be measured to an accuracy of 0.2 degrees relative to gravity. The accelerometer must have a linearity and scale factor better than 0.3% and a bandwidth larger than 25 Hz.

Regarding repeatability, Oxford stated that up to 60 cm of difference in lateral displacement could result from small differences in the conduct of testing, including:

- Use of a true lateral displacement measurement (*i.e.*, GPS), as opposed to the proposed accelerometer technique, could result in a 6 cm difference.
- Failure to do a roll correction for the acceleration could result in up to an 18 cm difference.
- Variation for the linearity error of a low-cost accelerometer could result in up to a 2 cm difference.
- Depending upon the rainwater run-off angle of the road, there could be up to a 6 cm difference.
- Variations in the mounting angle of the accelerometer in the vehicle may result in about a 9 cm difference.
- If there is a 20 ms timing error in acquisition, this could result in about an 8 cm difference.
- For accelerometers with a 10 Hz bandwidth, as compared to a wide bandwidth, there could be a difference of about 20 cm.
- There may also be some variation in the natural drift of vehicles, which can vary by about 40 cm over 100 m. This may affect the results by a few centimeters in the 20 m traveled during the test. (Changing the tires, keeping the same tire model, would yield yet a different result.)

Oxford also suggested that the test should be based upon ''spin velocity'' rather than ''spin displacement.'' The commenter reasoned that this approach would render timing less important, because spin velocity at 1.071 seconds is roughly constant, and it argued that measurements of ''spin velocity'' would be easier to repeat.

Technically speaking, as Oxford points out, the lateral displacement evaluated under the proposed ESC rule is not the ''lateral displacement of the vehicle's center of gravity,'' but an approximation of this displacement. In the context of the proposal, the location of the vehicle's center of gravity corresponds to the longitudinal center of gravity, measured when the vehicle is at rest on a flat, uniform surface.

The lateral displacement metric, as defined in the ESC NPRM, is based on the double integration of accurate lateral acceleration data. Lateral acceleration data are collected from an accelerometer, corrected for roll angle effects, and resolved to the vehicle's center of gravity using coordinate transformation equations. The use of accelerometers is commonplace in the vehicle testing community, and installation is simple and well understood. Although the use of GPS-based measurements for vehicle dynamics testing is increasing, achieving high dynamic accuracy requires differential post-processing (a process the agency has found to be time-consuming), a real-time differential service, or real-time kinematics base station correction of the data. Each of these options introduces significant cost and complexity to the testing effort. However, the system described by Oxford is approximately forty times more expensive than the calculation method prescribed by the final rule.

For the purposes of the ESC performance criteria, we believe use of a calculated lateral displacement metric provides a simple, reasonably accurate, and cost-effective way to evaluate vehicle responsiveness. Since the integration interval is short (recall that lateral displacement is assessed 1.07 seconds after initiation of the maneuver's steering inputs), integration errors are expected to be small. Recent improvements to the agency's data processing routines include refined signal offset and zeroing strategies that should minimize the confounding effects these factors may have on the test output, thereby ensuring repeatable results.

These NHTSA-developed routines used to calculate lateral displacement during data post-processing will be made publicly available, in order to ensure that vehicle manufacturers and ESC suppliers know exactly how the responsiveness of their vehicle's (or customer's vehicles) will be evaluated. If the sensors used to measure the

vehicle responses are of sufficient accuracy, and have been installed and configured correctly, use of the analysis routines provided by NHTSA are expected to minimize the potential for performance discrepancies among NHTSA and industry test efforts. The specifications of the accelerometers used by NHTSA are: (1) Bandwidth >300 Hz, (2) non-linearity <50 μg/g², (3) resolution ≤10 μg, and (4) output noise ≤7.0mV. An overview of all NHTSA instrumentation used during Sine with Dwell tests is provided in Table 5.

TABLE 5.—NHTSA SENSOR SPECIFICATIONS

Data measured	Type	Range	Manufacturer	Accuracy	Model No.
Steering Wheel Angle	Angle Encoder	±720 degrees	Automotive Testing, Inc.	±0.10 degrees[1]	Integral with ATI Steering Machine.
Longitudinal, Lateral, and Vertical Acceleration.	Multi-Axis Inertial Sensing System.	Accelerometers: ±2g Angular Rate Sensors: ±100°/s.	BEI Technologies, Inc. Systron Donner Inertial Division.	Accelerometers:<50μg/g[2] [2]. Angular Rate Sensors: ≤0.05%.	MotionPak Multi-Axis Inertial Sensing System MP–1.
Left and Right Side Vehicle Ride Height.	Ultrasonic Distance Measuring System.	4–40 inches	Massa Products Corp.	0.25% of maximum distance.	M–5000/220 kHz.
Vehicle Speed	Radar Speed Sensor	0.1–125 mph	B+S Software und Messtechnik.	0.1 mph	DRS–6.

[1] Combined resolution of the encoder and D/A converter.
[2] Non-linearity specifications.

(e) Maximum Steering Angle

For the Sine with Dwell test, the NPRM proposed to provide that ''[t]he steering amplitude of the final run in each series is the greater of 6.5A or 270 degrees.'' (*See* S7.9.4)

Toyota expressed concern that S7.9.4 may allow the steering angle to be too large for vehicles that have a large steering gear ratio. Toyota stated its belief that the upper limit of an average driver's steering velocity is approximately 1000°/sec; thus, the steering angle is 227° under a Sine with Dwell condition with a frequency of 0.7 Hz. Similarly, Toyota stated that the steering angle of 270° is equal to the steering velocity of 1188°/sec, a value that exceeds the average driver's steering velocity. Therefore, Toyota recommended revising S7.9.4 to state: ''The steering amplitude of the final run in each series is 270 degrees.''

NHTSA disagrees with Toyota's recommendation. Our own studies have shown that human drivers can sustain handwheel rates of up to 1189 degrees per second for 750 milliseconds. This steering rate corresponds to a steering angle magnitude of approximately 303 degrees.[64]

We concede that the method used to determine maximum Sine with Dwell steering angles can produce very large steering angles. Of the 62 vehicles used to develop the Sine with Dwell performance criteria, the vehicle requiring the most steering was a 2005 Ford F250. This vehicle required a maximum steering angle of 371 degrees (calculated by multiplying the average steering angle capable of producing a lateral acceleration of 0.3g in the Slowly Increasing Steer maneuver times a steering scalar of 6.5). Use of this steering wheel angle required an effective steering wheel rate of 1454 degrees per second, a magnitude well beyond the steering capability of a human driver.

Although we do not believe the maximum steering angle specified in S7.9.4 should be revised in the precise manner recommended by Toyota, we do believe revision of that specification is necessary. As such, we have updated the specification in S7.9.4 to read as follows:

S7.9.4 The steering amplitude of the final run in each series is the greater of 6.5A or 270 degrees, provided the calculated magnitude of 6.5A is less than or equal to 300 degrees. If any 0.5A increment, up to 6.5A, is greater than 300 degrees, the steering amplitude of the final run shall be 300 degrees.

(f) Vehicle Test Weight

Under S6.3.2, the NPRM proposed that the vehicle is to be loaded with the fuel tank filled to at least 75 percent of capacity, an total interior load of 168 kg (370 lbs) comprised of the test driver, approximately 59 kg (130 lbs) of test equipment (automated steering machine, data acquisition system and the power supply for the steering machine), and ballast as required by differences in the weight of test drivers and test equipment.

TRW Automotive commented that the proposed vehicle test conditions for vehicle weight leave only 240 pounds as the maximum driver test weight. The commenter suggested that the total interior load should be increased to 400 pounds, thereby permitting a maximum driver test weight of 270 pounds. According to TRW Automotive, this modification should not result in a substantive change to the intent of the regulation or test results, but it would provide greater flexibility in testing by accommodating a broader weight variance between drivers.

The Alliance/AIAM recommended modifying S6.3.2 to clarify the location where ballast (if required) is to be placed in the vehicle. The commenters recommended substituting the following language:

S6.3.2 *Test Weight.* The vehicle is loaded with the fuel tank filled to at least 75 percent of capacity, and total interior load of 168 kg (370 lbs.) comprised of the test driver, approximately 59 kg (130 lbs.) of test equipment (automated steering machine, data acquisition system and power supply for the steering machine), and ballast as required by differences in the weight of test drivers and test equipment. Where required, ballast shall be placed on the floor behind the passenger front seat or if necessary in the front passenger foot well area.

In regard to the TRW Automotive comment, given that the weight of a 95th percentile male is 225 pounds,[65]

[64] As background, the frequency of the sinusoidal curve used to command the Sine with Swell maneuver steering input is 0.7 Hz. Use of this frequency causes the time from the completion of the initial steering input (the first peak) to the completion of the steering reversal (the second peak) to take approximately 714 ms, regardless of the commanded steering angle magnitude. We have performed multiple studies using double-lane change maneuvers to evaluate the upper limit of human driver steering capability, and we have found the results listed above. *See* Forkenbrock, Garrick J. and Devin Elsasser, ''An Assessment of Human Driver Steering Capability,'' NHTSA Technical Report, DOT HS 809 875, October 2005. Available at *http://www-nrd.nhtsa.dot.gov/vrtc/ca/capubs/NHTSA_forkenbrock_driversteeringcapabilityrpt.pdf.*

[65] Schneider, L.W., Robbins, D.H., Pflug, M.A., and Synder, R.G., ''Development of Anthropometrically Based Design Specifications for

we believe that the maximum allowable weight allocated for the test driver, as presently specified in the NPRM for FMVSS No. 126, is conservative and should not impose an unreasonable testing burden on parties performing ESC compliance tests. As such, in this final rule, we are retaining the total interior load of 168 kg (370 lbs) specified in S6.3.2.

In response to the Alliance/AIAM comment, we note that the standard does require ballast to be added to a test vehicle, if necessary, to account for varying weights of test drivers and test equipment. We agree with the Alliance/AIAM comment additional clarification of where the ballast shall be positioned is necessary. The agency has decided to provide further direction in the standard's test procedure to ensure required ballast is appropriately placed in the vehicle. We concur with the Alliance/AIAM recommendation, as it provides a reasonable way to evenly distribute the load of the driver, steering machine, and test equipment. Additionally, we also acknowledge the very abrupt vehicle motions imposed by the Sine with Dwell maneuver are capable of dislodging and/or relocating unsecured ballast while testing. So as to maximize driver safety, we have revised S6.3.2 to read:

S6.3.2 *Test Weight.* The vehicle is loaded with the fuel tank filled to at least 75 percent of capacity, and total interior load of 168 kg (370 lbs.) comprised of the test driver, approximately 59 kg (130 lbs.) of test equipment (automated steering machine, data acquisition system and power supply for the steering machine), and ballast as required by differences in the weight of test drivers and test equipment. Where required, ballast shall be placed on the floor behind the passenger front seat or if necessary in the front passenger foot well area. All ballast shall be secured in a way that prevents it from becoming dislodged during test conduct.

(g) Data Filtering

According to the Alliance/AIAM, NHTSA usually incorporates specifications for its data filtering method as part of its test report (presumably referring to the agency's laboratory test procedure). However, the commenters argued that given the potential for different filtering methods to significantly influence final results, the agency should specify its data filtering methods directly in FMVSS No. 126.

The Alliance/AIAM recommended the following filtering protocol for all channels (except steering wheel angle and steering wheel velocity): (a) Create a six-pole, low-pass Butterworth filter with a 6 Hz cut-off frequency, and (b) filter the data forwards and backwards so that no phase shift is induced. For the steering wheel angle channel, the commenters recommended using the same protocol, but with a 10 Hz cut-off frequency. For steering wheel velocity, the Alliance/AIAM recommended adoption of a specific calculation described in Appendix 1 of their comments.

Data filtering methods can have a significant impact on final test results used for determining vehicle compliance with FMVSS No. 126. The agency agrees with the Alliance/AIAM that the same filtering and processing protocols must be followed in order to ensure consistent and repeatable test results. Therefore, the agency has decided to add a new paragraph S7.11 to the test procedures section of the final rule's regulatory text in order to specify critical test filtering protocols and techniques to be used for test data processing, as described in greater detail above in Section IV.C.7(e), *Data Processing Issues.*

(h) Outriggers

Under the proposed test condition in S6 of the NPRM, paragraph S6.3.4 provides, ''Outriggers must be used for tests of Sport Utility Vehicles (SUVs), and they are permitted on other test vehicles if deemed necessary for driver safety.''

According to the Alliance/AIAM, although the use of outriggers may be appropriate, the final rule should explicitly clarify the vehicle classes that are to be equipped with outriggers under the standard and set forth the design specifications for those devices. The organizations suggested that requiring outriggers on sport utility vehicles and ''other test vehicles if deemed necessary for driver safety'' is too open-ended. The commenters argued that such clarification is necessary because outriggers can influence vehicle dynamics in the subject tests. Thus, the Alliance/AIAM recommended revising S6.3.4 to read as follows: ''Outriggers *meeting the specifications of [cite section]* must be used for tests of *trucks, multipurpose vehicles, and buses.''*

The agency agrees that the use of outriggers has the potential to influence vehicle dynamics during ESC testing. Therefore, in order to reduce test variability and increase the repeatability of test results, the agency is revising paragraph S6.3.4 in this final rule to specify that outriggers are to be used on all vehicles other than passenger cars. Furthermore, the agency has decided to include maximum weight and roll moment of inertia specifications for outriggers in paragraph S6.3.4, and we will also make available the detailed design specifications for the outriggers used by the agency as part of the NHTSA compliance test procedure for FMVSS No. 126.

(i) Ambient Temperature Range

Under the proposed test condition in S6 of the NPRM, paragraph S6.1.1 provides, ''The ambient temperature is between 0 °C (32 °F) and 40 °C (104 °F).''

In their comments, the Alliance/AIAM stated that their analysis has demonstrated test variability due to temperature. The Alliance/AIAM comments also suggested that certain high performance tires could enter their ''glass transition range'' [66] which could introduce further variability at near-freezing temperatures. For these reasons, the commenters expressed concern that the lower bound of the proposed ambient test range is too low. Accordingly, the Alliance/AIAM recommended increasing the lower bound of the temperature range to 50 degrees F. In addition to reducing test variability, the commenters stated that their proposed modification to the temperature portion of the test procedures would permit virtually year-round testing at certain facilities (*e.g.*, DRI Bakersfield), reduce burdens associated with confirming compliance at low temperatures, and avoid complications of snow and ice during testing.

A vehicle's ESC system is designed for and expected to address stability issues over a wide range of various environmental conditions. Testing conducted by Alliance/AIAM member companies indicates that lateral displacement for vehicles equipped with all-season tires varies with fluctuating ambient temperatures. According to the Alliance/AIAM, the data indicate that lateral displacement for test vehicles equipped with all-season tires increases as the ambient temperature decreased, suggesting that the displacement requirement could be met more easily at lower ambient

an Advanced Adult Anthropomorphic Dummy Family—Volume 1—Procedures, Summary Findings, and Appendices,'' The University of Michigan Transportation Research Institute Report UMTRI–83–53–1, December 1983, Table 2–5 at 20.

[66] We note that this is Alliance/AIAM's term, not NHTSA's. We believe they are referring to a rubber chemistry issue (*i.e.*, that all rubbery polymers turn into glassy solids at characteristic low temperatures), which vary depending on the polymer composition of the tires. The Alliance/AIAM seem to assert that because of their composition, for certain high performance tires, the ''glass transition range'' (*i.e.*, the temperature range between the glass temperature and the onset of fully rubber-like response) may include some of the lower bound of the proposed ambient test range.

temperatures. However, this same relationship was not manifest for test vehicles equipped with high performance tires. (Some high-performance tires are not designed for operation under freezing conditions, and the performance variability of these tires under cold ambient temperatures is unknown, because in our repeatability studies, we only test tires in the temperature ranges in which they are designed to operate.) The Alliance recommended minimizing potential test variability by reducing the specified test condition ambient temperature range. To minimize test variability the agency has decided to increase the lower bound of the temperature range for compliance testing to 45 degrees F. The agency believes that 7 °C (45 °F) is appropriate because it is low enough to increase the length of the testing season at multiple testing sites, and also represents the low end of the relevant temperature range for at least one brand of high performance tires of which the agency is aware.

(j) Brake Temperatures

In their comments, the Alliance/AIAM stated that several of their member companies assessed the affect of brake pad temperatures on ESC test results, particularly given the potential for drivers to use heavy braking between test runs. Included in their comments were charts based upon their research that purported to demonstrate variance in testing due to brake pad temperature would be an artifact of the test methodology, not a reflection of expected ESC performance in the real world. Therefore, in order to minimize non-representative test results, the Alliance/AIAM comments recommended that the standard's test procedures should specify a minimum of 90 seconds between test runs in order to allow sufficient time for cooling of the brake pads.

The test procedure specified in the NPRM did not address brake temperature issues that may arise from heavy braking between test runs. Because the agency agrees that excessive brake temperatures may have an effect on ESC test results, a minimum wait time between test runs has been incorporated into the test procedure to ensure brake temperatures are not excessive. We believe that 90 seconds, as proposed by the Alliance/AIAM, is a reasonable lower bound for the allowable time between runs. Note that the procedure specified in the NPRM does specify a maximum wait time of 5 minutes between test runs to ensure that the brakes and tires remain at operating temperatures, a feature we believe is important since compliance test procedures endeavor to simulate real world driving conditions. For these reasons, the allowable range of time between Sine with Dwell tests will be 90 seconds to 5 minutes.

(k) Wind Speed

Under the proposed test condition in S6 of the NPRM, paragraph S6.1.2 provides, ''The maximum wind speed is no greater than 10 m/s (22 mph).''

The Alliance/AIAM expressed concern that the proposed maximum wind speed for testing (10 m/s (22mph)) could impact the performance of certain vehicle configurations (*e.g.*, cube vans, 15-passenger vans, vehicles built in two or more stages). The commenters estimated that a cross wind at 22 mph could reduce lateral displacement at 1.07 s by 0.5 feet, compared to the same test conducted under calm conditions. Accordingly, the Alliance/AIAM recommended revising S6.1.2 to reduce the maximum allowable wind speed to 5 m/s (11 mph), a figure consistent with other regulatory requirements (*e.g.*, FMVSS No. 135, *Light Vehicle Brake Systems*) and ISO 7401.

The agency agrees that wind speed could have some impact on the lateral displacement for certain vehicle configurations, including large sport utility vehicles and vans. However, we also believe that reducing the maximum wind speed to 5 m/s (11 mph) can impose additional burdens on our test labs by restricting the environmental conditions under which testing can be conducted. With these considerations in mind, we have decided to modify S6.1.2 to reduce the wind speed requirement as recommended to 5 m/s (11 mph) for multipurpose passenger vehicles (including SUVs, vans, and trucks), but to keep the specified wind speed for passenger cars at 10 m/s (22 mph). This change will reduce test variability for those vehicles expected to be most effected by wind speed and to minimize any additional burdens on test laboratories.

We note that if we set the wind speed requirement at 5 m/s (11 mph) for all light vehicles, that would unduly limit the number of days on which NHTSA could perform compliance testing, and we further believe that wind speed up to 10 m/s (22 mph) would not have an appreciable impact on the testing of passenger cars due to their smaller side dimensions.

(l) Rounding of Steering Wheel Angle at 0.3 g

Under the proposed test procedure in S7 of the NPRM, paragraph S7.6.1 provides, ''From the Slowly Increasing Steer tests, the quantity ''A'' is determined. ''A'' is the steering wheel angle in degrees that produces a steady state lateral acceleration of 0.3 g for the test vehicle. Utilizing linear regression, A is calculated, to the nearest 0.1 degrees, from each of the six Slowly Increasing Steer tests. The absolute value of the six A's calculated is averaged and rounded to the nearest degree to produce the final quantity, A, used below.''

The Alliance/AIAM recommended against rounding the steering wheel angle measurement at 0.3 g to the nearest whole number, because such methodology potentially increases variability across test runs. As demonstrated in a table included in their submission, the commenters stated that such an approach could also increase steering wheel angle variability at a scalar of 5.0 (where the proposed responsiveness metric starts) by a factor of five. They also argued that rounding to that proposed level of precision (*i.e.*, to a whole number) does not simplify programming or control of the steering robot. Therefore, in order to eliminate this source of test variability, the Alliance/AIAM recommended rounding the steering wheel angle at 0.3 g to the nearest 0.1 degrees.

The agency agrees with the Alliance and AIAM recommendation to round the steering wheel angle at 0.3 g to the nearest 0.1 degree, and we have modified the final rule's regulatory text accordingly. Rounding to this level is not expected to complicate programming of the automated steering controller and will decrease the variability in the number of required test runs.

(m) Vehicle Speed Specification for the Slowly Increasing Steer Test

In their comments, the Alliance/AIAM questioned whether the proposal's failure to specify a vehicle speed for the slowly-increasing-steer test was an oversight. The commenters recommended adopting specifications for a test speed of 80 ± 1 km/h, which is consistent with the speed for the Sine with Dwell test.

We agree that a speed tolerance should be specified for the Slowly Increasing Steer test, and we have determined that it should be the same as the speed tolerance specified for the Sine with Dwell test. However, we note that in this final rule, the proposed Sine with Dwell test speed tolerance has been revised to better reflect the manner in which testing is performed; as revised, the speed tolerance is 80 ± 2 km/h (50 ±1 mph). This speed tolerance

will also be applicable to the Slowly Increasing Steer maneuver.

(n) Alternative Test Procedures

Public Citizen stated that in the NPRM, the agency noted that there is a trade-off between lateral stability and intervention magnitude, but the commenter challenged the agency's determination as to where the appropriate balance should be set. Public Citizen stated that the agency should provide an assessment of other available alternative test procedures and the agency's rationale for not adopting those procedures. The commenter further argued that the test procedures which the agency did propose may be inadequate, particularly if errors in measurement would allow vehicles to pass the performance test.

We believe an appropriate balance between lateral stability and intervention magnitude is one in which a light vehicle is in compliance with the evaluation criteria of FMVSS No. 126, both in terms of lateral stability and responsiveness. Development of these criteria was the result of hundreds of hours of testing and data analysis. We are confident these criteria provide an extremely effective way of objectively assessing whether the lateral stability of ESC-equipped vehicle is adequate.

We believe the responsiveness criteria proposed for use in FMVSS 126, that a vehicle must achieve at least 6 feet (5 feet for vehicles with a GVWR of greater than 3500 kilograms) of lateral displacement when the Sine with Dwell maneuver is performed with normalized steering angles (normalized steering wheel angles account for differences in steering ratios between vehicles) greater than 5.0, adequately safeguards against implementation of overly aggressive ESC systems, even those specifically designed to mitigate on road untripped rollover (*i.e.*, systems that may consider stability more important than path following capability). Achieving acceptable lateral stability is very important, but should not be accomplished by grossly diminishing a driver's crash avoidance capability.

Intervention intrusiveness can refer to how the vehicle manufacturer and its ESC vendor ''tune'' an ESC system for a particular make/model, specifically how apparent the intervention is to the driver. We do not believe it is appropriate to dictate this form of intervention magnitude, as it can be an extremely subjective specification. As long as a vehicle's ESC (1) Satisfies our hardware and software definitions and (2) allows the vehicle to comply with our lateral stability and responsiveness performance criteria, we believe intervention intrusiveness should be a tuning characteristic best specified by the vehicle/ESC manufacturers.

In response to the Public Citizen statement regarding maneuver selection, we evaluated twelve test maneuvers before ultimately selecting the Sine with Dwell maneuver to assess ESC performance. As explained below, this evaluation was performed in two stages, an initial reduction from twelve maneuvers to four, then from four to one.

The first stage began with identification of three important attributes: (1) High maneuver severity (''maneuver severity''); (2) capability to produce highly repeatable and reproducible results using inputs relevant to real-world driving scenarios (''face validity''); and (3) ability to effectively evaluate both lateral stability and responsiveness (''performability''). To quantify the extent to which each maneuver possessed these attributes, adjectival ratings ranging from ''Excellent'' to ''Fair'' were assigned to each of the twelve maneuvers, for each of the three maneuver evaluation criteria. Of the twelve test maneuvers, only four received ''Excellent'' ratings [67] for each of the maneuver evaluation criteria—the Increasing Amplitude Sine (0.7 Hz), Sine with Dwell (0.7 Hz), Yaw Acceleration Steering Reversal (YASR; 500 deg/sec), and Yaw Acceleration Steering Reversal with Pause (YASR with Pause; 500 deg/sec steering rate).

Stage two of the maneuver reduction process used data from 24 vehicles (a sampling of sports cars, sedans, minivans, small and large pickup trucks, and sport utility vehicles intended to represent a majority of the vehicles presently sold in the United States) to compare the maneuver severity, face validity, and performability of the four maneuvers selected in the first stage. The ability of the four maneuvers to satisfy these three evaluation criteria were compared and rank ordered.

Of the four candidate maneuvers, we concluded the Sine with Dwell and YASR with Pause were the top performers in terms of evaluating the lateral stability component of ESC functionality. However, due to the fact that the Sine with Dwell maneuver required smaller steering angles to produce spinouts for five of the ten vehicles evaluated with left-right steering, and for two of the ten vehicles with right-left steering (with the remaining thirteen tests using the same steering angles), we assigned the Sine with Dwell maneuver a higher maneuver severity ranking than that assigned to the YASR with Pause maneuver.

Generally speaking, the Increasing Amplitude Sine and YASR maneuvers required the most steering to produce spinouts, regardless of direction of steer. However, the Increasing Amplitude Sine maneuver also produced the lowest normalized second yaw rate peak magnitudes, implying the maneuver was the least severe for most of the 24 test vehicles used for maneuver comparison. For this reason, we assigned the worst severity ranking to the Increasing Amplitude Sine maneuver.

Each of the four candidate maneuvers possessed inherently high face validity since they were each comprised of steering inputs similar to those capable of being produced by a human driver in an emergency obstacle avoidance maneuver. However, of the four maneuvers, we believed the Increasing Amplitude Sine maneuver possessed the best face validity. Conceptually, the steering profile of this maneuver was the most similar to that expected to be used by real drivers,[68] and even with steering wheel angles as large as 300 degrees, the maneuver's maximum effective steering rate was a very reasonable 650 deg/sec. For these reasons, the Increasing Amplitude Sine maneuver received the top face validity rating.

The two YASR maneuvers received the same face validity ratings, just lower than that assigned to the Increasing Amplitude Sine. The YASR steering profiles were comprised of very reasonable 500 deg/sec steering rates; however, their sharply defined, trapezoidal shapes reduce their similarity to inputs actually used by drivers in real world driving situations. The steering profile of the Sine with Dwell was deemed very reasonable; however, the maneuver can require steering rates very near what we believe is the maximum capability of a human driver.

[67] The adjectival ratings used to rate the test maneuvers were ''Excellent,'' ''Good,'' and ''Fair,'' with ''Excellent'' being the best and ''Fair'' being the worst. We considered an ''Excellent'' maneuver as one capable of adequately demonstrating whether a vehicle was, or was not, equipped with an ESC system that satisfied a preliminary version of our minimum performance criteria. Conversely, a maneuver assigned a ''Fair'' rating was unable to adequately demonstrate whether vehicles evaluated by NHTSA were, or were not, equipped with ESC systems capable of satisfying the preliminary minimum performance criteria.

[68] In an obstacle avoidance scenario, it is clearly conceivable that the second steering input may be larger than the first input. If the first steering input induces overshoot, the driver's reversal will need to be equal to the first steering input plus enough steering to combat the yaw overshoot.

The performability of the Sine with Dwell and the Increasing Amplitude Sine maneuvers were deemed to be excellent. These maneuvers are very easy to program into the steering machine, and their lack of rate or acceleration feedback loops simplifies the instrumentation required to perform the tests. Conversely, the YASR maneuvers require the use of specialized equipment (an angular accelerometer), and these maneuvers required an acceleration-based feedback loop that was sensitive to the accelerometer's signal-to-noise ratio near peak yaw rate. Testing demonstrated that large steering angles can introduce dwell time variability capable of adversely reducing maneuver severity and test outcome.

After considering the totality of the test result from our evaluation of the candidate maneuvers and for the reasons stated above, the agency concluded that the Sine with Dwell maneuver offers the best combination of maneuver severity, face validity, and performability. Additional details of the maneuver selection process are available in an Enhanced Safety of Vehicles (ESV) technical paper [69] and an NHTSA technical report.[70]

Turning to the statement in Public Citizen's comments regarding the implication of measurement errors, the commenter stated that ''* * * the error in measurements would allow vehicles to pass that did not even meet the * * * standard of the proposal.'' This comment is in response to comments made by Brendan Watts from Oxford Technologies, a company that sells highly accurate (and very expensive) instrumentation.[71] Many of the concerns expressed by Mr. Watts (stressing the importance of using accurate accelerometers and sound data processing techniques) are not specifically applicable to the manner in which we (NHTSA) will be performing our ESC compliance tests, in that such concerns have already been addressed by the agency. For example, the accelerometers that will be used in ESC compliance tests are more accurate than those Mr. Watts indicated may compromise test accuracy. We appreciate the data processing concerns expressed by Mr. Watts (*e.g.*, correcting lateral acceleration for the effects of roll angle, or addressing offset from the vehicle's center of gravity), but again, our post-processing routines already contain algorithms to resolve such concerns.

We note that all test track evaluations inherently contain some degree of output variability, regardless of what aspect of vehicle performance they are being used to evaluate. In the context of ESC compliance, we concede this variability could result in a marginally non-compliant vehicle passing the proposed test, but it is important to recognize these situations would only affect a very small population of vehicles, and that that effect of instrumentation and/or calculation errors is likewise believed to be very small. Since the performance of most contemporary vehicles resides far enough away from the proposed compliance thresholds, we believe it is extremely unlikely that measurement complications will be solely responsible for having the performance of a non-compliant vehicle be deemed acceptable.

(o) Representativeness of Real World Conditions

Mr. Kiefer questioned the adequacy of the agency's proposed ESC test procedures. Specifically, the commenter questioned how many tests are necessary to ensure that the system is robust, and how many different configurations of tires, loading, and trailering are needed to be representative of real world driving.

Mr. Cheah also questioned whether it would be feasible for the ESC test procedures' controlled conditions to adequately represent real world conditions. He argued that even though an ESC system may increase safety under certain conditions, in other cases, it may add ''unpredictable and unusual characteristics to the vehicle.''

NHTSA has reviewed many crash data studies quantifying real world ESC effectiveness.[72] Regardless of the origin of the data used for these studies (*i.e.*, whether from the United States, Germany, Japan, France, Sweden, etc.), all reported or estimated that ESC systems provide substantial benefits in ''loss of control'' situations (*see* Section II.D). These studies reported that ESC is expected to be particularly effective in situations involving excessive oversteer, such as ''fishtailing'' or ''spinout'' which may result from sudden collision avoidance maneuvers (*e.g.*, lane changes or off-road recovery maneuvers).

We note that the Sine with Dwell maneuver is specifically designed to excite an oversteer response from the vehicle being evaluated. While this maneuver has been optimized for the test track (because objectivity, repeatability, and reproducibility are necessary elements of a regulatory compliance test), it is important to recognize that multiple studies have indicated that the steering angles and rates associated with the Sine with Dwell maneuver are within the capabilities of actual drivers, not just highly trained professional test drivers.

NHTSA does not know of any ''unpredictable and unusual characteristics'' imparted by any ESC system on the vehicle in which it is installed. ESC interventions occur in extreme driving situations where the driver risks losing control of the vehicle, not during ''normal'' day-to-day driving comprised of relatively small, slow, and deliberate steering inputs. In these extreme situations, the driver must still operate the vehicle by conventional means (*i.e.*, use of steering and/or brake inputs are still required to direct the vehicle where the driver wants it to go); however, the mitigation strategies used by ESC to suppress excessive oversteer and understeer help improve the driver's ability to successfully retain control of the vehicle under a broad range of operating conditions.

The load configuration used during the conduct of our ESC performance tests is known as the ''nominal'' load configuration, consisting of a driver and test equipment. This configuration approximates a driver and one front seat occupant. We believe this configuration is highly representative of how the majority of vehicles driven on our nation's roadways are loaded. Our analyses, based on results from a database [73] comprised of 293,000 single-vehicle crashes, indicate that the average number of passenger car occupants involved in a single-vehicle crash was 1.48 occupants per vehicle. Results for pickups, sport utility vehicles, and vans were similar (1.35,

[69] Forkenbrock, Garrick J., Elsasser, Devin, O'Harra, Bryan C., ''NHTSA's Light Vehicle Handling and ESC Effectiveness Research Program,'' ESV Paper Number 05–0221, June 2005. (Docket No. NHTSA–2006–25801–5)

[70] Forkenbrock, Garrick J., Elsasser, Devin, O'Harra, Bryan C., Jones, Robert E., ''Development of Electronic Stability Control (ESC) Performance Criteria,'' NHTSA Technical Report, DOT HS 809 974, September 2006. Available at *http://www-nrd.nhtsa.dot.gov/pdf/nrd-01/esv/esv19/05-0221-O.pdf.*

[71] The comments made by Mr. Watts are specifically addressed in Section IV.C.11(d) of this document.

[72] *See* 71 FR 54712, 54718 (Sept. 18, 2006) footnote 11.

[73] Data were analyzed for the development of the rollover NCAP star ratings criteria. It is data for six States: Florida (1994–2001), Maryland (1994–2000), Missouri (1994–2000), North Carolina (1994–1999), Pennsylvania (1994–1997), and Utah (1994–2000). Only single-vehicle crashes for 100 make-models were included. Please consult the Rollover NCAP portion of the NHTSA Web site for further information (*http:///www.nhtsa.dot.gov*).

1.54, and 1.81 occupants per vehicle, respectively).

We believe it is important for an objective test procedure to be applicable to all light vehicles (*i.e.*, vehicles with a GVWR of 10,000 pounds or less). The use of multiple load configurations was considered, but there are an infinite number of ways drivers can potentially load their vehicles, and not all vehicles can be subjected to the same load configurations.

Although we do believe it is important to understand how vehicle loading can influence ESC effectiveness and presently have research programs designed to objectively quantify those effects, we believe requiring ESC on all light vehicles will save thousands of lives per year. Accordingly, we do not believe it is appropriate to delay the present mandate for ESC, and to thereby fail to maximize the benefits of this requirement, pending the outcome of this additional research. In sum, we believe that the available data strongly support our decision to mandate ESC installation on all light vehicles at this time.

12. Lead Time and Phase-in

In preparing its ESC proposal, the agency carefully considered the lead time necessary for expedient yet practicable incorporation of this important safety device. With minor exceptions discussed below, NHTSA proposed in the NPRM to require all light vehicles covered by this standard to be equipped with a FMVSS No. 126-compliant ESC system by September 1, 2011 (*see* 8.4). However, the agency proposed to extend by one year the time for compliance by multi-stage manufacturers and alterers (*i.e.*, until September 1, 2012) (*see* S8.8).

In terms of the phase-in for ESC, the agency proposed that compliance would commence on September 1, 2008, which would mark the start of a three-year phase-in period (*see* S8.1 to S8.4). Subject to the special provisions discussed below, the agency proposed the following phase-in schedule for FMVSS No. 126: 30 percent of a vehicle manufacturer's light vehicles manufactured during the period from September 1, 2008 to August 31, 2009 would be required to comply with the standard; 60 percent of those manufactured during the period from September 1, 2009 to August 31, 2010; 90 percent of those manufactured during the period from September 1, 2010 to August 31, 2011, and all light vehicles thereafter.

The agency proposed to exclude multi-stage manufacturers and alterers from the requirements of the phase-in and instead require full implementation at the special mandatory compliance date applicable to those manufacturers (*i.e.*, September 1, 2012) (*see* S8.8). The NPRM also proposed to exclude small volume manufacturers (*i.e.*, manufacturers producing less than 5,000 vehicles for sale in the U.S. market in one year) from the phase-in, instead requiring such manufacturers to fully comply with the standard on September 1, 2011 (*see* S8.7).

Under our proposal, vehicle manufacturers would be permitted to earn carry-forward credits for compliant vehicles, produced in excess of the phase-in requirements, which are manufactured between the effective date of the final rule and the conclusion of the phase-in period (*see* S8.5). In the NPRM, we noted that carry-forward credits would not be permitted to be used to defer the mandatory compliance date for all covered vehicles.

(a) Lead Time for ESC Telltale(s)

Vehicle manufacturers and their representatives generally did not object to the lead time provided for meeting the proposed ESC performance requirements, although they did request additional lead time to meet the control and telltale requirements. For example, the Alliance/AIAM comments argued that there is currently a lack of uniformity among ESC systems in terms of their labeling and telltales, such that most existing systems would not meet those requirements. In fact, the Alliance and AIAM stated that none of their members' ESC systems would fully meet the proposed requirements. As a result, they suggested that these ESC systems may not be fully compliant with the standard and, therefore, may be ineligible for carry-forward credits under the standard.

These commenters also argued that current ESC systems have a variety of special-purpose operating modes which may require specific context-related labeling. According to the commenters, these modes are not fully ''off'' and provide varying degrees of ESC intervention, but they will generally not comply with the proposal's ''full on'' performance requirements. The Alliance/AIAM stated that in some cases, an ESC system may have more than one of these special-purpose modes, so they requested that manufacturers be given flexibility in terms of how relevant information is presented to vehicle operators.

Accordingly, the Alliance/AIAM requested that the effective date for the ESC control and telltale requirements proposed to be contained in FMVSS Nos. 101 and 126 be postponed until the end of the phase-in (*i.e.*, September 1, 2011), with early compliance permitted, as was done in the agency's TPMS rulemaking. The commenters also requested that ESC-equipped vehicles produced prior to that date which meet all other requirements of the standard be permitted to earn carry-forward credits under FMVSS No. 126 and the ESC phase-in reporting provisions of 49 CFR Part 585, because many manufacturers will need to use such carry-forward credits to meet the agency's aggressive phase-in schedule.

Honda stated that although it expects its ESC systems to already meet the proposed performance requirements, additional lead time is necessary to meet the proposed control and telltale requirements for ESC. As a result of the proposal, the commenter stated that every Honda and Acura vehicle would require a redesign of its instrument panel to accommodate the proposed telltale symbol and sizing (*i.e.*, a vertical layout, which differs from the company's current horizontal layout). According to Honda, the necessary tooling changes to the instrument panel assemblies and required reprogramming, testing, and validation to the electronic control unit would involve significant cost; Honda estimated these costs to range from $17,000 to $170,000 per model, with a total expenditure of over $1 million.

Honda stated that in its proposal, the agency stated its expectation that approximately 98 percent of the ESC systems in current vehicles would already comply with the proposed requirements, and the remaining two percent would only require slight tuning. However, the commenter argued that the agency must have been focusing on the ESC performance requirements, because very few vehicles currently in production meet the proposed control and telltale requirements. Looking beyond the issue of cost, Honda stated that it would be difficult to make these changes in line with the proposed phase-in schedule.

According to Honda, its request for a delay in implementation of the ESC control and telltale requirements is consistent with the approach adopted by NHTSA in its rulemaking establishing FMVSS No. 138, *Tire Pressure Monitoring Systems* (TPMS). Honda stated that this approach would allow the public to receive the immediate benefit of ESC systems, while providing the industry adequate time to ensure compliance with the entire regulation. Therefore, Honda requested lead time until the end of the phase-in period (*i.e.*, September 1, 2011) to meet the proposed control and telltale

requirements. Alternatively, the company requested that the entire phase-in be delayed, beginning three years after publication of the final rule to establish FMVSS No. 126, in order to provide adequate lead time.

Nissan stated that depending upon the design of the vehicle and the extent of the changes required, it would require an additional ten months to three years of lead time in order to meet the control and telltale requirements in the ESC proposal. Thus, Nissan also requested that the agency delay the effective date of the ESC control and telltale requirements until the end of the phase-in (*i.e.*, September 1, 2011) (similar comment provided by the Toyota). Nissan stated that without an extension of the lead time for the control and telltale requirements, its current systems would not be eligible for the carry-forward credits upon which the company plans to rely in order to meet the aggressive phase-in schedule for ESC. The commenter further noted that the control and telltale requirements would not impact the dynamic performance of the ESC system and that the company has not received any reports of consumer confusion associated with its current ESC telltales and symbols.

Porsche also requested additional lead time to meet the proposed control and telltale requirements for ESC, citing the company's longer-than-average product life cycles which present unique challenges in terms of meeting standard phase-in schedules. The commenter stated that the telltale systems for its vehicles have already been developed, and it had planned on keeping those systems unchanged until the next product cycle (mid-2012 for some models). Porsche stated that the proposed ESC off telltale requirements would substantially disrupt this existing telltale production strategy. Accordingly, Porsche requested either an extension for compliance with the ESC-related control and display requirements for all manufacturers until September 1, 2012, or alternatively, it requested an extension from those requirements until that date for any manufacturer which would be able to equip 100 percent of their fleet with vehicles meeting the ESC performance requirements by September 1, 2008 (a schedule Porsche expects to meet).

According to the VDA, indicator symbols and indicator algorithms for current ESC systems vary considerably across different vehicle manufacturers. The commenter stated that implementing the proposed telltale requirements within the proposed phase-in schedule would involve considerable effort, particularly in light of the long lead times associated with changes to vehicle cockpit designs. Therefore, the VDA recommended extending the lead time provided for implementing the ESC telltale requirements and to accord vehicle manufacturers flexibility in terms of ESC telltale designs for special modes (*e.g.*, ones for deep snow, snow chains).

In order to provide the public as rapidly as possible with what are expected to be the significant safety benefits of ESC systems, NHTSA has decided to require all light vehicles covered by this standard to be equipped with a FMVSS No. 126-compliant ESC system by September 1, 2011 (with certain exceptions discussed below). Consistent with our proposal, September 1, 2008 marks the start of a three-year phase-in period for FMVSS No. 126.

After consideration of the numerous manufacturer comments on this issue, we have decided to defer the standard's requirements related to the ESC telltales and controls until the end of the phase-in (*i.e.*, September 1, 2011 for most manufacturers; September 1, 2012 for final-stage manufacturers and alterers); however, at that point, all covered vehicles must meet all relevant requirements of the standard (*i.e.*, no additional phase-in for the control and telltale requirements). This approach is consistent with vehicle manufacturers' request for additional lead time until the end of the phase-in to bring their ESC systems into full compliance (including the control and telltale requirements). Manufacturers are encouraged to voluntarily install compliant ESC controls and displays prior to the mandatory compliance date. Our rationale for this change from our proposal is as follows.

We now understand from the public comments that vehicle manufacturers currently employ a variety of approaches for ESC controls and telltales, many of which would not meet the requirements of the agency's proposal, and that standardization of ESC controls and telltales will involve substantial design and production changes. We further understand from the comments that manufacturers' inability to meet the proposed control and display requirements would prevent them from earning the carry-forward credits, even though these ESC systems might otherwise meet the performance requirements of the standard. Vehicle manufacturers' inability to earn carry-forward credits would likely jeopardize their ability to meet the standard's phase-in schedule.

We agree that it is the performance of the ESC systems themselves that impart safety benefits under the standard, and our analysis demonstrates that the safety benefits associated with early introduction of ESC systems, even without standardized controls and displays, far outweigh the benefits of delaying the standard until all systems can fully meet the control and display requirements (*see* FRIA's lead time/phase-in discussion). We do not believe that implementation of the entire standard should be delayed until technical changes related to the ESC controls and telltales can be fully resolved, because they would deny the public the safety benefits of ESC systems in the meantime. Accordingly, we believe that it is preferable to move rapidly to implement the standard, but to delay the compliance date only for the ESC control and telltale requirements.

On a related matter, commenters pointed out that vehicle manufacturers may earn carry-forward credits for compliant vehicles, produced in excess of the phase-in requirements, which are manufactured between the effective date of the final rule and the conclusion of the phase-in period. In clarification, we would note that vehicles that meet the performance requirements of FMVSS No. 126, but do not meet the control and telltale requirements of the standard prior to the end of the phase-in are eligible for carry-forward credits and may be counted as part of the manufacturer's required production under the phase-in.

In response to the comments of the Alliance/AIAM and the VDA that the agency should accord vehicle manufacturers flexibility in terms of ESC telltale designs for special modes, we acknowledge that resolution of this issue is another factor supporting our decision to provide additional lead time for manufacturers to meet the ESC control and telltale requirements. However, in terms of the substantive issue of what message should be provided by those controls and telltale, this is a substantive matter which we are addressing under the public comment response for ESC telltales (*see* Section IV.C.9 of this document).

(b) Phase-in Schedule

Advocates for Highway and Auto Safety argued that in light of vehicle manufacturers' current high level of installation of advanced ESC systems, the agency should accelerate is proposed timetable (similar comment by IIHS). Advocates argued that this acceleration should occur in terms of both the interim percentages within the

phase-in and the date for mandatory full compliance in order to bring this important safety feature to the whole market more quickly. The Advocates suggested that full implementation should occur by September 1, 2010 (*i.e.*, one year earlier than proposed in the NPRM) (similar comment by Consumers Union, Mr. Petkun). Specifically, Advocates recommended adoption of the following implementation schedule for installation of ESC in the final rule:

- 40 percent of model year (MY) 2008 light vehicles by September 1, 2008.
- 70 percent of MY 2009 light vehicles by September 1, 2009.
- 100 percent of MY 2010 light vehicles by September 1, 2010.
- 100 percent of light vehicles produced by multi-stage manufacturers, alterers, and small volume manufacturers by September 1, 2011.

Advocates argued that its recommended phase-in schedule would be both realistic and achievable, because it would be consistent with the projected ESC installation rates predicted by vehicle manufacturers and the agency. The commenter also stated that given that the proposal would effectively permit compliance by currently existing ESC systems, a protracted phase-in schedule is unnecessary.

Consumers Union stated that it would like to see the phase-in be vehicle-type-specific. It recommended that ESC first be required on all SUVs, followed by small cars (which the commenter stated tend to be driven by younger, less experienced drivers), and then on family and upscale sedans (which the commenter stated tend to be driven by older, more experienced drivers).

Public Citizen argued that because ESC components are already well-defined and familiar to manufacturers, extensive research and development for these systems is not required, and that given the important life-saving potential of ESC technology, the agency should not provide a phase-in schedule slower than what the industry is already planning (citing statements by Ford, General Motors, and DaimlerChrysler). In addition, Public Citizen also suggested that the agency should consider adopting a more aggressive phase-in schedule for ESC on new light trucks and SUVs, because of these vehicles' higher propensity to roll over.

In order to provide the public as rapidly as possible with what are expected to be the significant safety benefits of ESC systems, NHTSA has decided to require all light vehicles covered by this standard to be equipped with a FMVSS No. 126-compliant ESC system by September 1, 2011 (with certain exceptions discussed below), with September 1, 2008 marking the start of a three-year phase-in. This implementation date for full, mandatory compliance is the same as that proposed in the NPRM. The agency continues to believe that this schedule for full implementation of the safety standard for ESC is appropriate, in order to provide manufacturers adequate lead time to make necessary production changes. Even though vehicle manufacturers are currently introducing ESC systems into an increasing percentage of their new vehicle fleets, that does not mean that these complex systems can be incorporated into vehicles without significant developmental efforts to tune them to and to incorporate them into a specific vehicle design.

However, in response to public comments and upon further review of the production plans voluntarily submitted by vehicle manufacturers, we have determined that it would be practicable to increase the percentage of new light vehicles that must comply with Standard No. 126 under the phase-in, thereby accelerating the benefits expected to be provided by ESC systems. Because ESC is so cost-effective and has such high benefits in terms of potential fatalities and injuries that may be prevented, the agency agrees that it is important to require ESC installation in light vehicles as quickly as possible. Accordingly, under this final rule, we are requiring the following phase-in schedule for FMVSS No. 126: 55 percent of a vehicle manufacturer's light vehicles manufactured during the period from September 1, 2008 to August 31, 2009 would be required to comply with the standard; 75 percent of those manufactured during the period from September 1, 2009 to August 31, 2010; 95 percent of those manufactured during the period from September 1, 2010 to August 31, 2011, and all light vehicles thereafter. (This compares to the NPRM's proposal for a 30/60/90/all phase-in schedule over the same time periods.)

In order to ensure the financial and technological practicability of the final rule (in keeping with our statutory mandate), while at the same time facilitating ESC installation in the light vehicle fleet as expeditiously as possible, the agency analyzed the product plans submitted by six vehicle manufacturers, whose combined production accounts for approximately 87 percent of the new light vehicle fleet. As explained in Chapter VII of the FRIA, we examined three different potential phase-in schedules to find the right balance among these competing concerns. Based upon this product plan information and the desire to provide manufacturers with flexibility by having a carry forward provision, we have chosen the most aggressive phase-in alternative that we believe is reasonable (*i.e.*, 55/75/95%).

Two factors were controlling in making the decision as to which alternative to choose: (1) The ability of manufacturers to change vehicles from being equipped with optional ESC to standard ESC for MY 2010 and MY 2011; and (2) Not forcing any manufacturer to install ESC in any make/model for which it was not planned to be at least an option. The agency did not believe there was enough lead time to redesign such a make/model to include ESC by MY 2009. While there may be enough time to redesign a make/model to include ESC by MY 2010, given the carry forward provisions this was not necessary for any of the six manufacturers for MY 2010. The second consideration became a factor once again in MY 2011, in not going beyond 95 percent (thereby obviating the costly need to redesign and develop tooling for a few vehicle lines which will not be produced in MY 2012).

In general, we anticipate that vehicle manufacturers will be able to meet the requirements of the standard by installing ESC system designs currently in production (*i.e.*, ones available in MY 2006), and most vehicle lines would likely experience some level of redesign over the next three to four years, thereby providing an opportunity to incorporate an ESC system during the course of the manufacturer's normal production cycle. Except for possibly some low-production-volume vehicles with infrequent design changes (addressed below), NHTSA believes that most other vehicles can reasonably be equipped with ESC within three to four model years. Furthermore, we do not believe that the final rule's phase-in should pose ESC supply problems; public comments from vehicle manufacturers and ESC suppliers did not raise any such supply concerns, and our analysis of vehicle manufacturers' production plans suggest that the selected phase-in schedule will result in an installation rate increase of only a few percentage points in any year of the phase-in. Overall, we have determined that the final rule's phase-in schedule may be accomplished without disruptive changes in manufacturer and supplier production processes.

As noted immediately above, we have decided to defer the standard's requirements related to the ESC telltales and controls until the end of the phase-

in (*i.e.*, September 1, 2011 for most manufacturers; September 1, 2012 for final-stage manufacturers and alterers.

We have modified the final rule's phase-in reporting requirements for ESC systems (contained in Subpart I of 49 CFR Part 585) in a manner consistent with the phase-in schedule discussed above.

We have decided not to adopt the suggestion by Consumers Union that the agency should specify phase-in requirements for ESC by vehicle type. We note that vehicle manufacturers have already been moving aggressively to include ESC systems in high-center-of-gravity vehicles (*e.g.*, SUVs). Furthermore, we are concerned that such action would amount to unwarranted agency intervention into the details of manufacturers' production plans. It is unclear how such intervention might impact implementation of the standard and installation of ESC systems overall. Given these concerns, we have decided not to change our traditional approach of affording vehicle manufacturers flexibility in terms of how (*i.e.*, with which models) they will meet a safety standard's phase-in requirements.

13. Impacts on the Aftermarket

The Specialty Equipment Market Association (SEMA), an aftermarket trade association representing the specialty automotive industry, expressed support for the ESC rulemaking as an important advance for automotive safety. However, the organization expressed concern regarding the interaction of ESC systems with products manufactured by its members (many of which are small businesses), arguing that current ESC systems seem to be largely vehicle-specific. According to SEMA, many of their members' products (*e.g.*, wheels, tires, suspension systems), installed either for repair or replacement of existing equipment, also increase motor vehicle safety, so it is imperative that these products remain available to consumers and that they operate in unison with the ESC system.

SEMA explained that as a new and evolving technology, ESC systems could potentially be impacted by the installation of a variety of other automotive products (*e.g.*'' wheels, tires, suspension systems, drive gear sets, brake parts/systems) during the life of the vehicle. The commenter cited the potential for such modifications to deactivate the ESC system, to cause its premature failure, or to reduce its effectiveness. However, SEMA stated its impression that neither vehicle manufacturers, ESC suppliers, nor the agency have answers to questions regarding ESC interaction with other equipment and systems, and SEMA is not aware of any available data on this topic or related testing. It argued that, as drafted, the agency's proposal fails to contemplate the full range of downstream consequences associated with the required ESC installation. According to SEMA, the dearth of knowledge about how ESC systems will operate in conjunction with common vehicle modifications is a fundamental flaw in the agency's rulemaking.

In terms of its impact on automotive aftermarket manufacturers and the vehicle service industry, SEMA stated that there is a significant difference between voluntary installation of the ESC system and its mandatory installation under a Federal safety standard. Specifically, SEMA referred to the statutory prohibitions on manufacturing/selling/importing noncomplying motor vehicles and equipment (49 U.S.C. 30112) and on making safety devices and elements inoperative (49 U.S.C. 30122). Violations of these provisions can result in substantial civil penalties. Accordingly, the commenter cautioned the agency to fully investigate how the ESC rule will impact the aftermarket industry prior to establishing a mandatory safety standard.

SEMA's recommended solution is to either: (1) Delay issuance of a final rule until the interaction between ESC systems and aftermarket components is better understood, or (2) require ESC systems to be capable of adapting to subsequent vehicle modifications or otherwise be capable of being modified by installers to accommodate aftermarket equipment. According to SEMA, the agency should not feel rushed to issue a final rule, given that vehicle manufacturers are already ahead of NHTSA's proposed phase-in schedule and that the statute only requires issuance of a final rule by April 1, 2009.

In response, NHTSA emphasizes that we are issuing a final rule on ESC systems before the statutory deadline (*i.e.*, April 2009) because of the tremendous safety benefits that we believe an ESC standard can achieve. If, as anticipated, an ESC standard can save thousands of lives each year, clearly we should establish that standard as soon as possible. As noted above, ESC systems were installed on approximately 29 percent of MY 2006 light vehicles, and that percentage was expected to rise to 71 percent by MY 2011, consistent with manufacturers' production plans. However, given ESC's estimated high effectiveness rate in preventing single-vehicle crashes (34 percent for passenger cars and 59 percent for SUVs) and rollovers (71 percent for passenger cars and 84 percent for SUVs), the agency decided that it was imperative to mandate ESC to ensure that *all* drivers receive the benefit of this important safety device (*i.e.*, to close the gap between manufacturers' planned installation rates and the requirement for ESC systems to be standard equipment on all light vehicles). For every year that the final rule is delayed (assuming consistent lead time and the same phase-in), we estimate that 1,547–2,534 lives would be lost and 46,896–65,801 injuries would occur over the lifetime of that model year fleet due to lower ESC installation rates (*see* FRIA Executive Summary, E–2 .[74]) We believe that result is unacceptable. Thus, NHTSA will not delay the issuance of this final rule simply because the statute allows us more time.

Furthermore, NHTSA disagrees that the final rule should be delayed because it does not analyze all possible ''downstream consequences'' or impacts on the aftermarket community to SEMA's satisfaction. As discussed in Section IV.C.14 below, even though NHTSA has no legal obligation to analyze the impacts of a rulemaking on entities not directly regulated by the rule, we are nevertheless concerned about the impact our rules have on all affected parties. Accordingly, we have considered the effects that the ESC final rule might have on aftermarket motor vehicle equipment manufacturers and the motor vehicle service industry. The agency is not aware of any significant compatibility problems between ESC systems and other vehicle equipment, and SEMA has not provided any evidence to substantiate such problems, either in its comments or in a subsequent meeting[75] with the agency. So at this point, delay of the final rule would be based upon a speculative concern. Furthermore, we note that with any complex system, the agency cannot

[74] Although the benefit calculation is based on the annual impact for a full, on-road vehicle fleet, it would also represent the lifetime savings for a given model year's fleet.

[75] On January 10, 2007, SEMA officials and other representatives of the aftermarket industry met with agency staff to discuss their concerns with the potential impact of the ESC final rule on their businesses, consistent with SEMA's November 17, 2006 comments. However, despite the passage of almost two months, the industry representatives were still unable to provide any information regarding the nature and scope of the identified problem with aftermarket modifications impacting ESC system functionality, When asked, the industry representatives were not able verifiably identify any modifications that would or would not cause failure of the ESC systems. (For a record of this meeting, *see* Docket No. NHTSA–2006–25801–55.).

hypothesize on all possible interactions between required safety technologies and different vehicle equipment.

Therefore, for all these reasons, NHTSA will not delay the final rule until all possible interactions are known and documented, because that would frustrate the agency's purpose of saving lives as soon as possible. However, NHTSA recognizes that ESC systems vary from vehicle to vehicle, and that additional information will help the agency and industry to better understand how ESC systems interact with other vehicle equipment and systems. NHTSA will continue to monitor the data and testing information we receive on this issue, and we encourage all interested parties to share relevant information with the agency and the public as it becomes available. Additionally, should we later find significant safety risks associated with the interaction between ESC systems and other equipment and systems (whether aftermarket or otherwise), NHTSA will work toward adjusting the ESC standard to address these possible problems.

Furthermore, NHTSA disagrees that it should require ESC systems to be capable of adapting to subsequent vehicle modifications, because we question the feasibility and practicability of such a requirement due to the varied and voluminous nature of the aftermarket vehicle equipment market. Likewise, NHTSA is not mandating a requirement that ESC systems be capable of being modified by installers to accommodate aftermarket equipment. NHTSA does not believe that such a requirement is necessary, given that the agency has not been presented with any evidence of a safety problem or a compatibility problem between ESC and other vehicle systems or equipment, and given the tendency for the market to respond to consumer demands that sufficient information be provided to permit third party vehicle servicing. Nonetheless, NHTSA strongly encourages SEMA and its members to develop relationships with vehicle and ESC system manufacturers to research and find solutions to these questions.

(a) System Adaptability and Sharing ESC Information

In describing the need for an ESC system to be ''adjustable'' to subsequent modifications (such as ones permitting enhanced towing capacity), SEMA stated that the ESC system should be sufficiently flexible to allow for relocated vehicle centers of gravity,[76] and changes in roll rate, lateral acceleration, and related dynamics (*e.g.*, changes that may accompany installation of an aftermarket suspension system). SEMA called upon NHTSA to require ESC systems with ''adaptive learning'' capabilities, such that the ESC systems recognize subsequent vehicle modifications and make corresponding adjustments so that the vehicle is not taken out of compliance with FMVSS No. 126. In addition, the commenter stated that the agency should require a reprogrammability requirement as part of the final rule, in order to ensure ongoing ESC functionality after subsequent vehicle modifications.

Furthermore, SEMA called for original equipment manufacturers (both ESC suppliers and vehicle manufacturers) to share relevant ESC information with aftermarket manufacturers (*e.g.*, providing access to software used for ESC calibration). The commenter stated that aftermarket on-board computer re-programming companies will also need access to this information. SEMA commented that inability of these aftermarket manufacturers to gain access to ESC on-board communications software may render installers of these products unable to determine methods for keeping the ESC system operational. According to SEMA, ESC manufacturer estimates suggest that aftermarket suppliers will need to operate within three percent of the ESC's predetermined control level, something currently beyond a majority of legal aftermarket products. Because these aftermarket businesses have no knowledge of the operational limits of typical ESC systems, SEMA argued that these businesses need to understand ESC systems' failure modes, as well as the test protocols and standard for compliance (if any), in order to understand the design parameters within which the aftermarket parts must comply and to provide practical objectives for their own products to meet.

NHTSA does not agree that requiring ESC systems to have ''adaptive learning'' capabilities or to be reprogrammable after all subsequent vehicle modifications is necessary or appropriate at this time. In its comments, SEMA has provided no evidence that current ESC systems are even capable of the ''adaptive learning'' or reprogramming, how that would be accomplished, or the cost of achieving such capability if it is possible.[77] (The agency is not aware of any ESC systems with an adaptive learning capability of the type suggested by SEMA.) The requirements NHTSA has decided to mandate through this final rule are already being met by the vast majority of ESC-equipped vehicles in current production. NHTSA cannot mandate equipment or performance requirements without any indication that complying with them would even be possible.

NHTSA agrees with the commenter that sharing of information between vehicle and ESC manufacturers and aftermarket businesses is important, but we do not believe that a requirement that OEMs share ESC information is necessary at this time. Vehicle and ESC system manufacturers undoubtedly realize that aftermarket alterations of vehicles that could affect ESC systems are happening and will continue to happen. NHTSA believes that OEMs will recognize it to be in their best interest to share as much non-proprietary information as possible with the aftermarket sales industry to avoid rendering ESC systems ineffective through subsequent vehicle alterations. Again, NHTSA strongly encourages OEMs and the aftermarket sales industry to work together in this regard, but for now, mandating such cooperation is beyond the scope of this rulemaking.

Furthermore, we agree that consumers and the motor vehicle industry (OEM, aftermarket, and service/repair) should be vigilant in avoiding alterations which could render ESC systems inoperative or lessen their effectiveness. We note that, as mentioned, we do not yet have any reliable information on what these ESC-degrading alterations might be and what effects they might have. Still, to the extent they become aware of problems, as one possible measure, vehicle manufacturers might consider alerting purchasers to alterations that reasonably could render ESC systems inoperative or lessen their effectiveness. We believe that, to the extent needed, vehicle manufacturers are in the best position to communicate specific statements and to make recommendations about which alterations may reasonably be expected to impact ESC systems adversely.

[76] We should note that these modifications identified by SEMA, particularly any that would elevate the vehicle's center of gravity, might affect the stability of the vehicle and raise safety issues that are distinct from those addressed by an ESC system.

[77] In a January 10, 2007 with the agency, SEMA and other representatives of the aftermarket industry stated that TRW Inc. has designed an ESC system capable of adaptive learning regarding changes in tire sizes (*see* Docket No. NHTSA–2006–25801–55). However, even such system would not be expected to be capable of adaptive learning of the numerous aftermarket modifications that could potentially impact the vehicle's ESC system.

(b) ''Make Inoperative'' Prohibition

SEMA argued that, provided the ESC malfunction lamp does not illuminate, installers of aftermarket equipment should not be required to undertake additional action to confirm that the vehicle remains in compliance with FMVSS No. 126. Stated another way, SEMA asserted that if the ESC malfunction telltale does not illuminate, the manufacturer, distributor, dealer, or motor vehicle repair business should be able to assume that the ESC system is operating properly and that the vehicle modifications in question have not violated the ''make inoperative'' prohibition of 49 U.S.C. 30122. The commenter stated that for the agency to hold otherwise would place an impossible burden on the aftermarket industry and have a strong negative impact on many small businesses. According to SEMA, installers generally lack knowledge as to the changes made to vehicles before they arrive at their shops, given the countless possibilities.

Thus, SEMA recommended that NHTSA state in the final rule that when a vehicle has been modified and the malfunction telltale has not been disabled, one may assume that the vehicle remains in compliance with FMVSS No. 126 and that there has been no violation of the ''make inoperative'' prohibition (49 U.S.C. 30122). SEMA reasoned that if the ESC malfunction telltale does illuminate, it will have served its purpose of alerting the consumer as to a potential compatibility problem, thereby permitting corrective action to be taken. The commenter stated that NHTSA has adopted an identical approach for two other safety standards—FMVSS No. 110, *Tire Selection and Rims for Motor Vehicles with a GVWR of 4,536 Kilograms (10,000 Pounds) or Less*, and FMVSS No. 138, *Tire Pressure Monitoring Systems*.

NHTSA recognizes that in previous rules (*e.g.*, TPMS [78]), we have allowed vehicle modifiers to assume that a vehicle remains in compliance with the relevant FMVSS if a malfunction telltale has not illuminated, but we decline to do so again for the ESC standard for the reasons that follow. SEMA has provided no evidence to establish that aftermarket modifications have already caused ESC system malfunctions or any indication whether such malfunction did or did not illuminate the ESC telltale.

In most cases, we expect that replacement of motor vehicle equipment, such as tire and rims, with replacement or aftermarket equipment of the same size would not impact ESC functionality or result in ''make inoperative'' problems. Replacement of worn or damaged equipment with similar equipment would likely constitute a large majority of instances of aftermarket product usage. However, NHTSA believes that there may well be modifications to vehicles that negatively impact the ESC system without causing the telltale to illuminate (*e.g.*, changing the steering ratio through modification to tie rods and steering arms). It would not be consistent with the agency's safety mission to require drivers to unwittingly forgo the life-saving benefits of ESC, without any indication that the system is malfunctioning due to subsequent vehicle modifications. Therefore, we have decided not to grant SEMA's request. However, NHTSA will seek relevant information, monitor this situation, and take appropriate action as necessary. And again, NHTSA encourages SEMA and its members to develop relationships with vehicle and ESC system manufacturers to research and find solutions to these questions.

In the meantime, persons who modify vehicle may assume that their actions have made the ESC system inoperative if those action result in the ESC malfunction telltale being illuminated or, regardless of whether the telltale illuminates, they know based upon other sources of information that their actions are likely to make the system inoperative.

(c) Pass-Through Certification

Delphi stated that the NPRM indicated that final-stage manufacturers and alterers can rely on the original manufacturer's certification of ESC compliance, provided they make no modifications to a vehicle's brake system. Delphi commented that this cautionary statement by the agency is too narrow, suggesting that there should be clarification that any major modification to the vehicle's dynamic characteristics (*e.g.*, handling, propulsion) may influence ESC operation. According to Delphi, a brake-based ESC system is designed and ''tuned'' or ''calibrated'' for a specific vehicle configuration with a specific dynamic response character (with such character being determined by factors such as mass, distribution of mass, size (length, width, height), tires, suspension/steering geometry, and suspension/steering components, among others, such as likely driving characteristics and conditions). Delphi stated that brake-based ESC systems are designed to accommodate routine variations, but not major modifications affecting a vehicle's handling character. The commenter stated that major modifications of that nature could result in improper operation of the ESC system, causing either unwanted braking or a failure to intervene when needed. Delphi further recommended that the final-stage manufacturer or alterer should consult with the original manufacturer and/or the ESC supplier to determine whether there is a need for adjustments to the vehicle's ESC system in response to the subsequent modifications.

NHTSA recognizes that many different subsequent vehicle modifications have the potential to affect the ability of an ESC system to perform as originally designed. The agency agrees that vehicle/ESC manufacturers and final-stage manufacturers and alterers should communicate as to the effects that subsequent vehicle modifications may have on ESC systems, and we strongly encourage such communication to ensure proper functioning of the ESC system. As with other vehicle technologies that may be affected by final stages of manufacturing or subsequent alterations, NHTSA also encourages OEMs to be in contact with final-stage manufacturers and alterers, to the extent possible, to ensure that the certification of their vehicles under the ESC standard is not compromised.

14. Compliance With Relevant Legal Requirements

(a) Regulatory Flexibility Act

SEMA argued that NHTSA's Regulatory Flexibility Analysis did not consider how the rule would potentially impact manufacturers, installers, and retailers of aftermarket products that would have the potential to interact with the ESC system when installed on the vehicle. The commenter stated that the agency is obligated under the Regulatory Flexibility Act to consider all reasonable alternatives for crafting the least burdensome rule. SEMA suggested that the agency's analysis was inadequate because it did not also focus on the aftermarket industry. Mr. Sparhawk also argued that the NPRM failed to adequately analyze the reasonably foreseeable impacts of the proposed ESC requirement on small businesses, as required by the

[78] We believe that the TPMS rulemaking is distinguishable from the present ESC rulemaking, because for TPMS, the agency had a reasonable degree of certainty that the malfunction indicator would be able to detect any aftermarket modifications (*e.g.*, installation of replacement tires) likely to affect the system's operation. In contrast, given the complexity of the ESC system and the greater number of modifications with the potential to impact its proper functioning, we do not have the same level of confidence that the driver would be accurately informed of the ESC system's status in all cases.

Regulatory Flexibility Act, because it does not consider the impacts on vehicle repair businesses, instead only addressing the effects of the proposal on large manufacturers.

In response, we note that NHTSA is not required to perform a regulatory flexibility analysis for entities not directly impacted by its rulemaking. In its 2003 publication titled ''A Guide for Government Agencies: How to Comply with the Regulatory Flexibility Act'' (''RFA Guide''), the Small Business Administration states that ''[t]he courts have held that the RFA requires an agency to perform a regulatory flexibility analysis of small entity impacts only when a rule directly regulates them.'' [79] The cases cited by the RFA Guide indicate that a rule ''directly regulates'' only the entities to which the rule applies—for example, electric utilities but not independent electricity cooperatives in a FERC rate-setting regulation,[80] or automobile manufacturers but not aftermarket businesses in an EPA ''deemed-to-comply'' rule.[81] In *Motor & Equipment Mfrs. Ass'n* v. *Nichols*, the DC Circuit described the distinction as follows: ''The RFA itself distinguishes between small entities subject to an agency rule, to which its requirements apply, and those not subject to the rule, to which the requirements do not apply.'' [82]

This final rule establishes performance and equipment requirements for ESC systems. The only entities subject to these requirements are vehicle manufacturers and manufacturers of ESC systems. NHTSA has already analyzed the potential impacts of the rule on these directly affected entities, as the final regulatory flexibility analysis (contained within the FRIA) makes clear. Nothing in this rule subjects the entities described by SEMA and Mr. Sparhawk to NHTSA's regulation.

With that said, although NHTSA has no obligation to perform a regulatory flexibility analysis to consider the potential impacts of this final rule on such non-directly regulated entities, we are nevertheless concerned about the impact our rules have on all affected parties. Again, we have considered the effects that the ESC final rule might have on aftermarket motor vehicle equipment manufacturers and the motor vehicle service industry. The agency is not aware of any significant compatibility problems between ESC systems and other vehicle equipment. However, we note that with any complex system, the agency cannot hypothesize on all possible interactions between required safety technologies and different vehicle equipment. Again, we do not believe it appropriate to delay this final rule for ESC systems and the significant safety benefits accompanying them on the basis of speculative arguments regarding compatibility problems for which there is no evidence; we believe that this is particularly so in light of the substantial number of vehicles currently equipped with ESC systems—some portion of which it is expected would have had aftermarket modifications of the types suggested by SEMA—and given that there has been no indication of any problem to date. However, to the extent information suggesting such a problem exists, the agency will carefully consider it.

(b) Executive Orders 12866 and 13258

SEMA stated that Executive Order 12866 (Regulatory Planning and Review), as amended by Executive Order 13258, requires agencies to write all rules in plain language, and it also stated that the Administrative Procedure Act (APA) requires agencies to include issues of consequence within a rulemaking and to provide the opportunity for public comment. SEMA argued that the agency's ESC proposal did not properly assess the impact of the ESC rule on the aftermarket community and that any such impacts (*e.g.*, how the ''make inoperative'' prohibition applies to their activities) should be stated in plain language in the rule.

NHTSA agrees that agencies are required to write rules in plain language and to address and provide an opportunity for public comment on the substance of the rulemaking, as well as its impact. However, for the reasons discussed in the response to the Regulatory Flexibility Act comment above, NHTSA disagrees that it is obligated to assess the indirect impact of the ESC rule on the aftermarket community (entities described by SEMA) or state any such impacts in the rule. Nevertheless, because we are concerned about the impact our rules have on all affected parties, we have considered the effects that the ESC final rule might have on aftermarket motor vehicle equipment manufacturers and the motor vehicle service industry. Again, the agency is not aware of any significant compatibility problems between ESC systems and other vehicle equipment.

(c) Vehicle Safety Act

SEMA asserted that NHTSA's proposed rule does not meet the practicability requirement of the Safety Act, because it could ''potentially lead to millions of [subsequently-modified] vehicles whose compliance with the ESC standard would be unknown.'' SEMA also argued that the rule could ''deny consumers the right to accessorize their vehicles with products that may provide additional safety benefits beyond the ESC systems.''

NHTSA disagrees with these comments. SEMA has provided no evidence that the final rule is impracticable under the Safety Act. Vehicles currently include many complex systems, and aftermarket suppliers are able to produce products compatible with those systems; similarly, motor vehicle repair businesses are currently able to obtain sufficient information to perform their work. We do not believe that the situation with ESC will be any different, and NHTSA anticipates that the aftermarket community will be able to work with OEMs and dealers as the phase-in progresses to avoid SEMA's concern. Additionally, this final rule in no way denies consumers the right to modify their vehicles. Individual vehicle owners are not regulated under the Vehicle Safety Act nor under this final rule, and SEMA provided no evidence that these products would be incompatible with ESC systems.

15. ESC Outreach Efforts

(a) ESC Test Procedures Workshop

Honda requested that the agency consider sponsoring a workshop on the ESC test procedures once a final rule has been issued, similar to the one the agency conducted for the TPMS standard. The commenter suggested that such a workshop would be useful to provide manufacturers the opportunity to understand important details of the test procedure and to clarify questions in a practical, hands-on setting.

NHTSA agrees with this suggestion and will plan to have a workshop on the ESC test procedures in the near future.

[79] Office of Advocacy, United States Small Business Administration, ''A Guide for Government Agencies: How to Comply with the Regulatory Flexibility Act,'' 2003, p. 20.

[80] *Mid-Tex Electric Cooperative, Inc.* v. *Federal Energy Regulatory Commission* (FERC), 773 F.2d 327, 341 (DC Cir. 1985) (stating that ''Congress did not intend to require that every agency consider every indirect effect that any regulation might have on small businesses in any stratum of the national economy.'').

[81] *Motor & Equipment Mfrs. Ass'n* v. *Nichols*, 142 F.3d 449, 467 (DC Cir. 1998) (holding that ''Because the deemed-to-comply rule did not subject any aftermarket businesses to regulation, EPA was not required to conduct a flexibility analysis as to small aftermarket businesses. It was only obliged to consider the impact of the rule on small automobile manufacturers subject to the rule, and it met that obligation.'').

[82] *Id.*, fn 18, at 467 (describing 5 U.S.C. 603(b)(3) and (4)).

Details of this ESC workshop will be announced in a separate **Federal Register** notice at least 30 days prior to the scheduled date of the meeting.

(b) Public Information Campaign

SUVOA, an association representing owners of sport utility vehicles, pick-up trucks, and vans, encouraged the agency to undertake a strong public information campaign as part of the final rule for ESC. According to SUVOA, consumers need to understand how newly required safety equipment such as ESC works and how it enhances the safety of their vehicles, and automobile dealerships and their salespeople should similarly be educated regarding the lifesaving benefits of ESC. SUVOA offered to work with the agency to contribute to such communications efforts.

NHTSA's principal public information portals are its main agency Web site (*www.nhtsa.dot.gov*), the Safercar.gov Web site, and its publication ''Buying a Safer Car.'' In these information sources, consumers can already obtain information about what ESC systems do and which vehicles were equipped with ESC systems in 2005, 2006, and 2007. However, we agree with SUVOA about the general desirability of increased public information which could possibly drive demand for ESC systems during the phase-in period. We applaud the efforts of General Motors and Bosch in particular to educate dealers and salesman about ESC, and we encourage other interested parties to help spread the message regarding the important benefits provided by ESC systems.

16. Miscellaneous Issues

(a) Linking Brake Light Illumination to ESC Activation

Consumers Union suggested that whenever the vehicle's ESC system is activated and intervenes, the vehicle's brake lights should be automatically illuminated in order to alert motorists to the rear of potentially slippery conditions and of a slowing vehicle ahead (similar comment by Mr. Petkun). The commenter urged the agency to undertake whatever ancillary amendments to other safety standards that may be necessary to effectuate this change (*e.g.*, possible amendments to FMVSS No. 105, *Hydraulic and Electric Brake Systems*, and FMVSS No. 108, *Lamps, Reflective Devices, and Associated Equipment*).

In our May 26, 2000 letter of interpretation [83] to Mr. C. Thomas Terry of General Motors, NHTSA has already established a policy regarding stop lamps and technologies that make use of the vehicles brakes (including ESC), and we intend to follow that interpretation with regard to FMVSS No. 126, as discussed below. Under our interpretation letter to Mr. Terry, only when a vehicle system operates in a way that is analogous to the driver using the brakes to slow the vehicle should the stop lamps activate. We believe that it is not desirable to change the meaning of the stop lamp signal. Traction control, for example, applies one brake on an axle at a time to limit wheel spin for the purpose of accelerating rather than decelerating the vehicle, so in such cases, stop lamps should not be activated. Adaptive cruise control, on the other hand, uses brakes in the same way as the driver and should activate the stop lamp.

We understand that vehicle manufacturers consider the duration and mode of ESC operation to determine whether to activate the stop lamps (to avoid confusing blinks), but whenever the system augments the reduction of engine power with braking intended to further slow the vehicle (as opposed to a very short application of a single brake simply to change the vehicle's heading), brake lamp activation would be expected to occur.

(b) Vehicles With Dual Wheels on the Rear Axle

According to the Alliance/AIAM, there are a small number (unspecified) of incomplete vehicles with a GVWR of 10,000 pounds or less that are equipped with dual wheels on the rear axle (''dualies''), which are typically completed as commercial vehicles. The commenters stated that these vehicles require their own unique ESC calibration. Based upon the small number of ''dualies'' and their unusual calibration needs, the Alliance/AIAM requested that the agency exclude these vehicles from the present ESC rulemaking and instead consider them as part of any subsequent ESC rulemaking for heavy trucks (a category in which dualies' ESC systems arguably more appropriately belong).

In light of the agency's statutory mandate under section 10301 of SAFETEA–LU, NHTSA does not believe it has the authority to exempt any vehicles with a GVWR of 10,000 pounds or less from the requirements of the Standard No. 126. Accordingly, this final rule applies to passenger cars, multipurpose vehicles, trucks and buses with a gross vehicle weight rating of 4,536 Kg (10,000 pounds) or less, as originally proposed.

(c) ESC Operation With Towed Trailers

According to Mr. Feldhus, ESC systems must be required to have on/off controls for vehicles capable of towing a trailer, because current ESC systems do not communicate with the trailer when intervening to maintain stability. He stated that because the ESC-equipped towing vehicle's brake lights do not activate, the aftermarket trailer's brake controllers cannot participate. He further stated that towing vehicles dive and trailer hitches rise during heavy braking, so unless care is taken, a two-to-four ton trailer could lift and overpower the towing vehicle. Thus, Mr. Feldhus stated that the agency should not mandate ESC systems until such time as it evaluates such effects using special trailer test rigs that have motor-controlled swinging masses and numerous hitch combinations. He also suggested additional tests simulating air disturbance from oncoming trucks on two-lane roads. Ultimately, Mr. Feldhus recommended adopting specific pass/fail towing criteria that vehicle manufacturers must meet, as part of any safety standard for ESC.

We have no evidence supporting the supposition that ESC intervention will adversely affect the safety of a vehicle hauling a trailer, nor has any vehicle or ESC manufacturer told us that lack of communication between a tow vehicle and trailer will negatively affect ESC functionality. ESC systems operate in extreme driving situations where a loss of control is anticipated (*i.e.*, excessive oversteer or understeer situations). On some vehicles with high centers of gravity, ESC may also intervene during impending on-road, untripped rollover situations. In each of these loss-of-control situations, we do not believe ESC stabilization of the tow vehicle would result in a subsequent loss of trailer stability. Accordingly, we see no reason to revise the regulatory text regarding this issue.

However, tow vehicle/trailer safety is an area of ongoing interest to NHTSA, and the agency always welcomes information on ways new technology can improve it. For example, some ESC systems are now being offered with trailer stabilization assist (TSA) control algorithms. These algorithms are specifically designed to help mitigate yaw oscillations that can occur when the vehicle/trailer system is being operated in certain driving situations. These systems operate by using the tow vehicle ESC system to automatically brake the tow vehicle in a way that suppresses the trailer yaw oscillations before they become so large that a loss of control is evident. Evaluating TSA

[83] *See http://isearch.nhtsa.gov/files/21281.ztv.html.*

effectiveness is an area of research presently under consideration at NHTSA.

(d) Wheelchair-Accessible Vehicles

The National Mobility Equipment Dealers Association (NMEDA) commented that ESC system sensors are normally located under one of the front row seats. NMEDA argued that because ESC systems are position-sensitive, their relocation is likely to affect the accuracy, performance, and effectiveness of those systems. (The commenter pointed to the fact that yaw rate and sideslip are functions of the vehicle center of gravity, and also, the ESC's horizontal plane of reference will likely be altered when an ESC system is relocated, further altering its performance.) The organization expressed concern that whenever the system sensors must be moved in the process of modifying vehicles to make them accessible to the disabled, the ESC system could generate potentially dangerous and unpredictable vehicle responses under certain driving conditions.

Therefore, NMEDA recommended that the final rule should require an original equipment manufacturer to provide a means to permanently deactivate an ESC system for vehicles manufactured, altered, or modified after first sale to accommodate persons with disabilities. According to NMEDA, it would be possible to ensure that the ESC system is not accidentally activated by equipping the vehicle with a permanent, key-operated ''off'' mechanism and an associated warning lamp (similar to one provided on an air bag deactivation system). Alternatively, NMEDA stated that the agency could specify in the final rule that third parties are permitted to permanently deactivate the ESC system on vehicles that are manufactured, altered, or modified after first sale to be accessible to persons with disabilities.

In response to the commenter's concerns about vehicles modified to make them accessible to disabled individuals, NHTSA believes that no change is necessary as part of the ESC final rule. Parties who must certify that their vehicles are in compliance with Federal motor vehicle safety standards prior to first retail sale should have the capability to ensure the functionality of the ESC system installed in their vehicles. However, aftermarket modifiers who adapt vehicles for persons with disabilities would not likely be able to move ESC components without some level of assistance from vehicle manufacturers or ESC system suppliers.

We strongly urge OEMs to work with vehicle modifiers to identify alternative locations or other modification methods so that the benefits of ESC may be retained for drivers of adapted vehicles. The number of vehicles that are popular for adaptations for persons with disabilities is quite limited, and we believe it is practical for manufacturers to provide assistance to modifiers who must remove OEM seats, supply alternative seats, or modify floors, so that the modifiers may relocate ESC components in a way that preserves the proper functioning of the system. (We understand that General Motors already provides some technical assistance to those adapting its vans for disabled persons.) NHTSA would be willing to host a technical session to be attended by OEM engineers, ESC manufacturer engineers, and representatives of aftermarket modifiers to facilitate this discussion.

In addition, NHTSA will consider whether it is necessary to add language to 49 CFR 595 Subpart C, *Vehicle Modifications to Accommodate People With Disabilities*, to exempt the modifier from the ''make inoperative'' prohibition of 49 U.S.C 30122, as it applies to FMVSS No. 126 in the event that: (1) The ESC sensor must be moved in the modification of a vehicle after first retail sale to accommodate a person with a disability, and (2) the OEM has not provided an alterative position.

V. Benefits and Costs

A. Summary

This section summarizes our analysis of the benefits, costs, and cost per equivalent life saved as a result of the ESC requirements contained in this final rule. As noted previously, the life- and injury-saving potential of ESC is very significant, both in absolute terms and when compared to prior agency rulemakings. We anticipate that this final rule for ESC, compared to a baseline of manufacturers' plans of having 71 percent of the light vehicle fleet with ESC by MY 2011, will save 1,547 to 2,534 lives and cause a reduction of 46,896 to 65,801 MAIS 1–5 injuries annually once all passenger vehicles have ESC. This compares favorably with the Regulatory Impact Analyses for other important rulemakings such as FMVSS No. 208 mandatory air bags (1,964 to 3,670 lives saved), FMVSS No. 214 side impact protection (690 to 1,030 lives saved [84]), and FMVSS No. 201 upper interior head impact protection (870 to 1,050 lives saved). The ESC final rule is expected to also save $376 to $535 million annually in property damage and travel delay (undiscounted). The total cost of this final rule is estimated to be $985 million.

The ESC final rule is extremely cost-effective. The cost per equivalent life saved is expected to range from $0.18 to $0.33 million at a 3 percent discount and $0.26 to $0.45 million at a 7 percent discount. Again, the cost-effectiveness for ESC compares favorably with the Regulatory Impact Analyses for other important rulemakings such as FMVSS No. 202 head restraints safety improvement ($2.61 million per life saved), FMVSS No. 208 center seat shoulder belts ($3.39 to $5.92 million per life saved), FMVSS No. 208 advanced air bags ($1.9 to $9.0 million per life saved), and FMVSS No. 301 fuel system integrity upgrade ($1.96 to $5.13 million per life saved).

For a more complete discussion of the benefits and costs associated with this rulemaking for ESC, please consult the Final Regulatory Impact Analysis (FRIA), which is available in the docket for this rulemaking.

B. ESC Benefits

As discussed in detail in Chapter IV (Benefits) of the FRIA, we anticipate that, when all light vehicles have ESC, this rulemaking would prevent 67,466 to 90,807 crashes (1,430 to 2,354 fatal crashes and 66,036 to 88,453 non-fatal crashes). Preventing these crashes entirely is the ideal safety outcome and would translate into 1,547 to 2,534 lives saved and 46,896 to 65,801 MAIS 1–5 injuries prevented.

The above figures include benefits related to rollover crashes, a subset of all crashes. However, in light of the relatively severe nature of crashes involving rollover, ESC's contribution toward mitigating the problem associated with this subset of crashes should be noted. We anticipate that this rulemaking would prevent 35,680 to 39,387 rollover crashes (1,076 to 1,347 fatal crashes and 34,604 to 38,040 non-fatal crashes). This would translate into 1,171 to 1,465 lives saved and 33,001 to 36,420 MAIS 1–5 injuries prevented in rollovers.

In addition, preventing crashes would also result in benefits in terms of travel delay savings and property damage savings. We estimate that this rulemaking would save $376 to $535

[84] Note that estimates for the FMVSS No. 214 rulemaking are from the agency's preliminary regulatory analysis that accompanied the notice of proposed rulemaking. When the final rule is published, the revised regulatory analysis will reflect the impact of today's ESC final rule, which will reduce the benefit of the FMVSS No. 214 rule.

million, undiscounted,[85] in these two categories ($240 to $269 million of this savings is attributable to prevented rollover crashes).

We further note that this rule also has the effect of causing all light vehicles to be equipped with anti-lock braking systems (ABS) as a foundation for ESC. We anticipate some level of benefits from improved brake performance on vehicles not currently equipped with ABS, but have not attempted to quantify them. However, the potential benefits of ABS did not influence our effectiveness estimates for ESC, because all of the non-ESC control vehicles in the study already had ABS. The measure of unquantified benefits relates to situations where the ABS system activates (but the ESC system does not need to) on vehicles that were not previously equipped with ABS.

C. ESC Costs

In order to estimate the cost of the additional components required to equip every vehicle in future model years with an ESC system, assumptions were made about future production volume and the relationship between equipment found in anti-lock brake systems (ABS), traction control (TC), and ESC systems. We assumed that in an ESC system, the equipment of ABS is a prerequisite. Thus, if a passenger car did not have ABS, it would require the cost of an ABS system plus the additional incremental costs of the ESC system to comply with an ESC standard. We assumed that traction control (TC) was not required to achieve the safety benefits found with ESC. We estimated a future annual production of 17 million light vehicles consisting of nine million light trucks and eight million passenger cars.

An estimate was made of the MY 2011 installation rates of ABS and ESC. It served as the baseline against which both costs and benefits are measured. Thus, the cost of the standard is the incremental cost of going from the estimated MY 2011 installations to 100 percent installation of ABS and ESC. The estimated MY 2011 installation rates are presented in Table 6.

TABLE 6.—MY 2011 PREDICTED INSTALLATIONS

[Percent of the light vehicle fleet]

	ABS	ABS + ESC
Passenger Cars	86	65
Light Trucks	99	77

[85] The present discounted value of these savings ranges from $247 to $436 million (based on 3 percent and 7 percent discount rates).

Based on the assumptions above and the data provided in Table 6, Table 7 presents the percent of the MY 2011 fleet that would need these specific technologies in order to equip all light vehicles with ESC.

TABLE 7.—PERCENT OF THE LIGHT VEHICLE FLEET REQUIRING TECHNOLOGY TO ACHIEVE 100% ESC INSTALLATION

	None	ABS + ESC	ESC only
Passenger Cars	65	14	21
Light Trucks	77	1	22

The cost estimates developed for this analysis were taken from tear down studies that contractors have performed for NHTSA. This process resulted in estimates of the consumer cost of ABS at $368 and the incremental cost of ESC at $111. Thus, it would cost a vehicle that does not have ABS currently, $479 to meet the requirements of this final rule. Combining the technology needs in Table 7 with the cost above and assumed production volumes yields the cost estimate in Table 8 for the ESC standard. Thus, for example, the average cost for passenger cars, including both those that require installation of an ESC system and those that already have it, is $90.

TABLE 8.—SUMMARY OF VEHICLE COSTS FOR THE ESC STANDARD

[2005$]

	Average vehicle costs	Total costs (millions)
Passenger Cars	$90.3	$722.5
Light Trucks	29.2	262.7
Total	58.0	985.2

In summary, Table 8 shows that requiring electronic stability control and anti-lock brakes will increase the cost of new light vehicles on average by $58, totaling $985 million annually across the new light vehicle fleet.

In addition, we note that this final rule is expected to add weight to vehicles and consequently to increase their lifetime use of fuel. Most of the added weight is for ABS components and very little is for the ESC components. Since 99 percent of light trucks are predicted to have ABS in MY 2011, the weight increase for light trucks is less than one pound and is considered negligible. The average weight gain for passenger cars is estimated to be 2.13 pounds, resulting in 2.6 more gallons of fuel being used over the lifetime of these vehicles. The present discounted value of the added fuel cost over the lifetime of the average passenger car is estimated to be $2.73 at a 7 percent discount rate and $3.35 at a 3 percent discount rate.

We have not included in these cost estimates, allowances for ESC system maintenance and repair. Although all complex electronic systems will experience component failures from time to time necessitating repair, our experience to date with existing systems is that their failure rate is not outside the norm. Also, there are no routine maintenance requirements for ESC systems.

VI. Regulatory Analyses and Notices

A. Vehicle Safety Act

As noted above, the agency is implementing the ESC language in SAFETEA–LU through promulgation of a Federal motor vehicle safety standard for ESC pursuant to 49 U.S.C. Chapter 301, *Motor Vehicle Safety*. Thus, in developing this final rule for ESC, the agency carefully considered the statutory requirements of both SAFETEA–LU and 49 U.S.C. Chapter 301.

Under 49 U.S.C. Chapter 301, *Motor Vehicle Safety* (49 U.S.C. 30101 *et seq.*), the Secretary of Transportation is responsible for prescribing motor vehicle safety standards that are practicable, meet the need for motor vehicle safety, and are stated in objective terms.[86] These motor vehicle safety standards set the minimum level of performance for a motor vehicle or motor vehicle equipment to be considered safe.[87] When prescribing such standards, the Secretary must consider all relevant, available motor vehicle safety information.[88] The Secretary also must consider whether a standard is reasonable, practicable, and appropriate for the type of motor vehicle or motor vehicle equipment for which it is prescribed and the extent to which the standard will further the statutory purpose of reducing traffic accidents and associated deaths.[89] The responsibility for promulgation of

[86] 49 U.S.C. 30111(a).
[87] 49 U.S.C. 30102(a)(9).
[88] 49 U.S.C. 30111(b).
[89] *Id.*

Federal motor vehicle safety standards has been delegated to NHTSA.[90] We describe below our consideration of these provisions.

First, in preparing this document, the agency carefully evaluated available research, testing results, and other information related to ESC technology. The agency performed extensive research on its own and made use of research performed by the Alliance of Automobile Manufacturers and its member companies, plus research from Hyundai/Kia. We also performed analyses of ESC using actual crash data to determine the effectiveness of ESC in reducing single-vehicle crashes and rollovers. Furthermore, the agency carefully considered all of the public comments submitted on the NPRM for ESC, along with any accompanying data, and responded to such information as part of this final rule. In sum, this document reflects our consideration of all relevant, available motor vehicle safety information.

Second, to ensure that the ESC requirements are practicable, the agency research and the industry research documented the capabilities of current ESC systems and dynamic performance of model year 2005 vehicles equipped with them. ESC is a developed technology that is currently available on a wide variety of vehicle types and models. We have concluded that all current production vehicles equipped with ESC systems are capable of complying with the equipment requirements, that all but one current vehicle model are capable of complying with the performance tests, and that only minor software tuning would be required to bring that vehicle model into compliance. In sum, we believe that this final rule is practicable for fleet-wide implementation, in that it may be implemented with existing technology and is quite cost-effective, given its potential to prevent thousands of deaths and injuries each year, particularly those associated with single-vehicle crashes leading to rollover.

Third, the regulatory text following this preamble is stated in objective terms in order to specify precisely what equipment constitutes an ESC system, what performance is required, and how performance is tested under the standard. The final rule's definition of an ''ESC System'' is based on a voluntary consensus definition developed by the Society of Automotive Engineers (SAE). The rule also includes performance requirements and test procedures for the timing and intensity of the oversteer intervention by the ESC system (*i.e.*, a lateral stability criterion) and the responsiveness of the vehicle (*i.e.*, a vehicle responsiveness criterion). This test procedure involves a precisely-defined steering pattern performed by a robotic steering machine under a defined set of test conditions (*e.g.*, ambient temperature, road test surface, vehicle load, vehicle speed). Performance is defined by objective measurements of yaw rate and lateral acceleration taken by scientific instruments at precise times with reference to the steering pattern. The standard's test procedures carefully delineate how such testing is conducted.

Historically, the agency has striven to set motor vehicle safety standards that are as performance-based as possible, but we have interpreted our mandate as permitting the adoption of more specific regulatory requirements when such action is in the interest of safety. In the present case, the agency cannot specify a practicable and repeatable dynamic understeer performance test at this time. As discussed in Section IV.C.4 above, there is no available test for effective understeer intervention in non-linear-handling, loss-of-control situations, and the agency's own research efforts were not able to identify a broadly applicable test for understeer that would ensure intervention by the ESC system in all appropriate cases. However, as the court held in *Chrysler Corporation* v. *DOT*,[91] NHTSA may specify equipment requirements as part of an FMVSS where development of a performance standard alone would not be practicable or meet the need for motor vehicle safety. Such is the case here, thereby necessitating our adoption of a definitional requirement for an ESC system (based upon the definition in SAE J2564) that has the components/capabilities for effective understeer (and oversteer) intervention, consistent with current production systems. However, the agency will continue its research effort pertaining to ESC understeer intervention and will consider amending the standard in the future, as appropriate.

In light of the above, the agency believes that the regulatory requirements and test procedures in this final rule are sufficiently objective and would not result in any uncertainty as to whether a given vehicle satisfies the requirements of the ESC standard.

Finally, we believe that this final rule is reasonable and appropriate for motor vehicles subject to the applicable requirements. As discussed elsewhere in this notice, the agency is addressing Congress' concern about rollover crashes resulting in fatalities and serious injuries. Under section 10301 of SAFETEA–LU, Congress mandated installation of stability enhancing technologies in new vehicles to reduce rollovers. NHTSA has determined that ESC systems meeting the requirements of this final rule offer an effective countermeasure to rollover crashes and to other single-vehicle and certain multi-vehicle crashes. Accordingly, we believe that this final rule is appropriate for vehicles subject to these provisions because it furthers the agency's objective of preventing deaths and serious injuries, particularly those associated with rollover crashes.

B. Executive Order 12866 and DOT Regulatory Policies and Procedures

Executive Order 12866, ''Regulatory Planning and Review'' (58 FR 51735, October 4, 1993), provides for making determinations whether a regulatory action is ''significant'' and therefore subject to Office of Management and Budget (OMB) review and to the requirements of the Executive Order. The Order defines a ''significant regulatory action'' as one that is likely to result in a rule that may:

(1) Have an annual effect on the economy of $100 million or more or adversely affect in a material way the economy, a sector of the economy, productivity, competition, jobs, the environment, public health or safety, or State, local, or Tribal governments or communities;

(2) Create a serious inconsistency or otherwise interfere with an action taken or planned by another agency;

(3) Materially alter the budgetary impact of entitlements, grants, user fees, or loan programs or the rights and obligations of recipients thereof; or

(4) Raise novel legal or policy issues arising out of legal mandates, the President's priorities, or the principles set forth in the Executive Order.

We have considered the impact of this action under Executive Order 12866 and the Department of Transportation's regulatory policies and procedures. This action has been determined to be economically significant under the Executive Order, and it is also a subject of congressional interest and a mandate under section 10301 of SAFETEA–LU. The agency has prepared and placed in the docket a Final Regulatory Impact Analysis. This rulemaking action is also significant within the meaning of the

[90] 49 U.S.C. 105 and 322; delegation of authority at 49 CFR 1.50.

[91] 515 F.2d 1053 (6th Cir. 1975) (*holding* that NHTSA's specification of dimensional requirements for rectangular headlamps constitutes an objective performance standard under the Vehicle Safety Act).

Department of Transportation's Regulatory Policies and Procedures (44 FR 11034; February 26, 1979). Accordingly, this rulemaking document was reviewed by the Office of Management and Budget under Executive Order 12866, ''Regulatory Planning and Review.'' The agency has estimated that compliance with this rule would cost approximately $985 million per year and have net benefits as high as $11.4 billion per year. Thus, this rule would have greater than a $100 million effect.

C. Regulatory Flexibility Act

Pursuant to the Regulatory Flexibility Act of 1980 (5 U.S.C. 601 *et seq.*, as amended by the Small Business Regulatory Enforcement Fairness Act (SBREFA) of 1996), whenever an agency is required to publish a notice of rulemaking for any proposed or final rule, it must prepare and make available for public comment a regulatory flexibility analysis that describes the effect of the rule on small entities (*i.e.*, small businesses, small organizations, and small governmental jurisdictions). However, no regulatory or flexibility analysis is required if the head of an agency certifies that the rule will not have a significant economic impact on a substantial number of small entities. SBREFA amended the Regulatory Flexibility Act to require Federal agencies to provide a statement of the factual basis for certifying that a rule will not have a significant economic impact on a substantial number of small entities.

NHTSA has considered the effects of this rulemaking action under the Regulatory Flexibility Act and has included a final regulatory flexibility analysis in the FRIA. This analysis discusses potential regulatory alternatives that the agency considered that would still meet the identified safety need of reducing the occurrence of rollovers through stability enhancing technologies. Alternatives considered included (a) Applying the standard to light trucks but not to passenger cars and (b) permitting front-wheel-only ESC systems that are incapable of understeer intervention. The first alternative was rejected because passenger car ESC systems would save 945 lives and reduce 32,196 injuries annually at a cost per equivalent fatality that would easily justify a separate rule for passenger cars. The second alternative was rejected because front-wheel-only ESC systems would prevent 30 percent fewer single-vehicle crashes without producing a large cost saving.

To summarize the conclusions of that analysis, the agency believes that the final rule will have a significant economic impact on a substantial number of small businesses. There are currently four small domestic motor vehicle manufacturers in the United States, each having fewer than 1,000 employees. Although the cost for an ESC system is relatively high, we believe that these manufacturers should be able to pass the associated costs on to purchasers without decreasing sales volume, because the demand for the high-end, luxury vehicles produced by these manufacturers tends to be inelastic and the increase in total vehicle cost is expected to be only 0.2–1.1 percent.

There are a significant number of final-stage manufacturers and alterers likely to be impacted by the final rule for ESC, some of which buy incomplete vehicles. However, final-stage manufacturers and alterers typically do not modify the brake system of the vehicle (the modification most likely to impact ESC), so the original manufacturer's certification of the ESC system should pass through for these vehicles. To the extent other subsequent vehicle modifications have the potential to affect the ability of an ESC system to perform as originally designed, we encourage vehicle/ESC manufacturers and final-stage manufacturers and alterers to communicate as to the effects that subsequent vehicle modifications may have on ESC systems in order to ensure continued proper functioning. As with other vehicle technologies that may be affected by final stages of manufacturing or subsequent alterations, NHTSA also encourages OEMs to be in contact with final-stage manufacturers and alterers, to the extent possible, to ensure that the certification of their vehicles under the ESC standard is not compromised. We believe that increased costs associated with ESC will impact all such final-stage manufacturers and alterers equally, and that such costs will be passed on to consumers. Furthermore, we have no reason to believe that an average cost of $90 per passenger car and $29 per truck will cause a significant decline in overall vehicle sales.

We do not expect manufacturers of ESC systems to be classified as small businesses.

The agency also received public comments from SEMA and Mr. Sparhawk arguing that the agency is bound to address the indirect effects that this regulation would have on installers of aftermarket vehicle equipment and motor vehicle repair businesses.

Although our response to these commenters is discussed more fully under Section IV.C.14(a), we repeat that this final rule establishes performance and equipment requirements for ESC systems and that the only entities subject to and directly affected by these requirements are vehicle manufacturers and manufacturers of ESC systems. Nothing in this rule subjects the entities described by SEMA and Mr. Sparhawk to NHTSA's regulation. However, NHTSA nevertheless considered the effects that the ESC final rule might have on aftermarket motor vehicle equipment manufacturers and the motor vehicle service industry, and based upon that analysis, the agency is not aware of any significant compatibility problems between ESC systems and other vehicle equipment. Although the agency will continue to monitor this issue, we do not believe it appropriate to delay this final rule for ESC systems and the significant safety benefits accompanying them on the basis of speculative arguments regarding compatibility problems for which there is no evidence.

D. Executive Order 13132 (Federalism)

NHTSA has examined today's final rule pursuant to Executive Order 13132 (64 FR 43255, August 10, 1999) and concluded that no additional consultation with States, local governments, or their representatives is mandated beyond the rulemaking process. The agency has concluded that the rule does not have federalism implications, because the rule does not have ''substantial direct effects on the States, on the relationship between the national government and the States, or on the distribution of power and the responsibilities among the various levels of government.''

Further, no consultation is needed to discuss the preemptive effect of today's rule. NHTSA rules can have preemptive effect in at least two ways. First, the National Traffic and Motor Vehicle Safety Act contains an express preemptive provision: ''When a motor vehicle safety standard is in effect under this chapter, a State or a political subdivision of a State may prescribe or continue in effect a standard applicable to the same aspect of performance of a motor vehicle or motor vehicle equipment only if the standard is identical to the standard prescribed under this chapter.'' 49 U.S.C. 30102(b)(1). In addition, we note that this final rule establishing a safety standard for electronic stability control systems was mandated by Congress, pursuant to section 10301 of SAFETEA–LU. It is this statutory command that preempts State law, not today's

rulemaking, so consultation would be inappropriate.

In addition to the express preemption noted above, the Supreme Court has also recognized that State requirements imposed on motor vehicle manufacturers, including sanctions imposed by State tort law, can stand as an obstacle to the accomplishment and execution of a NHTSA safety standard. When such a conflict is discerned, the Supremacy Clause of the Constitution makes their State requirements unenforceable. *See Geier* v. *American Honda Motor Co.*, 529 U.S. 861 (2000). NHTSA has not outlined such potential State requirements in today's rulemaking, however, in part because such conflicts can arise in varied contexts, but it is conceivable that such a conflict may become clear through subsequent experience with today's standard and test regime. NHTSA may opine on such conflicts in the future, if warranted. *See id.* at 883–86.

E. Executive Order 12988 (Civil Justice Reform)

With respect to the review of the promulgation of a new regulation, section 3(b) of Executive Order 12988, ''Civil Justice Reform'' (61 FR 4729, February 7, 1996) requires that Executive agencies make every reasonable effort to ensure that the regulation: (1) Clearly specifies the preemptive effect; (2) clearly specifies the effect on existing Federal law or regulation; (3) provides a clear legal standard for affected conduct, while promoting simplification and burden reduction; (4) clearly specifies the retroactive effect, if any; (5) adequately defines key terms; and (7) addresses other important issues affecting clarity and general draftsmanship under any guidelines issued by the Attorney General. This document is consistent with that requirement.

Pursuant to this Order, NHTSA notes as follows. The preemptive effect of this rule is discussed above. NHTSA notes further that there is no requirement that individuals submit a petition for reconsideration or pursue other administrative proceeding before they may file suit in court.

F. Executive Order 13045 (Protection of Children From Environmental Health and Safety Risks)

Executive Order 13045, ''Protection of Children from Environmental Health and Safety Risks'' (62 FR 19855, April 23, 1997), applies to any rule that: (1) Is determined to be ''economically significant'' as defined under Executive Order 12866, and (2) concerns an environmental, health, or safety risk that the agency has reason to believe may have a disproportionate effect on children. If the regulatory action meets both criteria, the agency must evaluate the environmental health or safety effects of the planned rule on children, and explain why the planned regulation is preferable to other potentially effective and reasonably feasible alternatives considered by the agency.

Although the rule for ESC has been determined to be an economically significant regulatory action under Executive Order 12866, the problems associated with loss of vehicle control equally impact all persons riding in a vehicle, regardless of age. Consequently, this final rule does not involve a decision based on environmental, health, or safety risks that disproportionately affect children and would not necessitate further analyses under Executive Order 13045.

G. Paperwork Reduction Act

Under the Paperwork Reduction Act of 1995 (PRA), a person is not required to respond to a collection of information by a Federal agency unless the collection displays a valid OMB control number. The Department of Transportation is submitting the following information collection request to OMB for review and clearance under the PRA.

Agency: National Highway Traffic Safety Administration (NHTSA).

Title: Phase-In Production Reporting Requirements for Electronic Stability Control Systems.

Type of Request: Routine.

OMB Clearance Number: 2127-New.

Form Number: This collection of information will not use any standard forms.

Affected Public: The respondents are manufacturers of passenger cars, multipurpose passenger vehicles, trucks, and buses having a gross vehicle weight rating of 4,536 Kg (10,000 pounds) or less. The agency estimates that there are about 21 such manufacturers.

Estimate of the Total Annual Reporting and Recordkeeping Burden Resulting from the Collection of Information: NHTSA estimates that the total annual hour burden is 42 hours.

Estimated Costs: NHTSA estimates that the total annual cost burden, in U.S. dollars, will be $2,100. No additional resources would be expended by vehicle manufacturers to gather annual production information because they already compile this data for their own uses.

Summary of Collection of Information: This collection would require manufacturers of passenger cars, multipurpose passenger vehicles, trucks, and buses with a gross vehicle weight rating of 4,536 Kg (10,000 pounds) or less to provide motor vehicle production data for the following three years: September 1, 2008 to August 31, 2009; September 1, 2009 to August 31, 2010; and September 1, 2010 to August 31, 2011.

Description of the Need for the Information and the Proposed Use of the Information: The purpose of the reporting requirements will be to aid NHTSA in determining whether a manufacturer has complied with the requirements of Federal Motor Vehicle Safety Standard No. 126, *Electronic Stability Control Systems*, during the phase-in of those requirements. In the NPRM, NHTSA requested comments on the agency's estimates of the total annual hour and cost burdens resulting from this collection of information. No comments were received on this issue.

H. National Technology Transfer and Advancement Act

Section 12(d) of the National Technology Transfer and Advancement Act of 1995 (NTTAA), Public Law 104–113, section 12(d) (15 U.S.C. 272) directs NHTSA to use voluntary consensus standards in its regulatory activities unless doing so would be inconsistent with applicable law or otherwise impractical. Voluntary consensus standards are technical standards (*e.g.*, materials specifications, test methods, sampling procedures, and business practices) that are developed or adopted by voluntary consensus standards bodies, such as the Society of Automotive Engineers (SAE). The NTTAA directs NHTSA to provide Congress, through OMB, explanations when the agency decides not to use available and applicable voluntary consensus standards. The NTTAA does not apply to symbols.

The equipment requirements of this standard are based (with minor modifications) on the SAE Surface Vehicle Information Report on Automotive Stability Enhancement Systems J2564 Rev JUN2004 that provides an industry consensus definition of an ESC system. However, there is no voluntary consensus standard for ESC that contains any specifications for a performance test.

The agency has also incorporated by reference two standards developed by the American Society for Testing and Materials (ASTM) in order to provide specifications for road test surface conditions for use in the standard's test procedures. These are: (1) ASTM E1337–90 (rev. 1996), *Standard Test Method for Determining Longitudinal*

Peak Braking Coefficient of Paved Surfaces Using a STD Reference Test Tire; and (2) ASTM E1136–93, *Standard Specification for a Radial Standard Reference Test Tire* (1993).

I. Unfunded Mandates Reform Act

Section 202 of the Unfunded Mandates Reform Act of 1995 (UMRA) requires Federal agencies to prepare a written assessment of the costs, benefits, and other effects of proposed or final rules that include a Federal mandate likely to result in the expenditure by State, local or tribal governments, in the aggregate, or by the private sector, of more than $100 million in any one year (adjusted for inflation with base year of 1995, currently $122 million in 2005 dollars). Before promulgating a rule for which a written statement is needed, section 205 of the UMRA generally requires NHTSA to identify and consider a reasonable number of regulatory alternatives and adopt the least costly, most cost-effective, or least burdensome alternative that achieves the objectives of the rule. The provisions of section 205 do not apply when they are inconsistent with applicable law. Moreover, section 205 allows NHTSA to adopt an alternative other than the least costly, most cost-effective or least burdensome alternative if we publish with the final rule an explanation why that alternative was not adopted.

This final rule is not expected to result in the expenditure by State, local, or tribal governments, in the aggregate, of more than $122 million annually, but it will result in the expenditure of that magnitude by vehicle manufacturers and/or their suppliers.

As noted above, this rulemaking is being promulgated pursuant to section 10301 of the Safe, Accountable, Flexible, Efficient Transportation Equity Act: A Legacy for Users of 2005 (SAFETEA–LU). As part of this final rule, the agency is presenting not only its regulatory approach for ESC, but also the regulatory alternatives it considered; we also present a detailed discussion of the costs and benefits associated with the rule (*see* the FRIA and also Section V of this document).

In terms of regulatory alternatives considered, the agency analyzed three possibilities: (1) Limiting the standard's applicability to light trucks and vans (LTVs); (2) permitting use of 2-channel ESC systems; and (3) three different potential phase-in schedules.[92] The following briefly explains the conclusions that the agency reached in analyzing these available alternatives.

Although the first alternative reduces overall costs of the regulation and increases cost-effectiveness (based upon the higher propensity for LTVs to roll over), the agency rejected it because our analysis showed that requiring ESC for passenger cars would save 945 lives and reduce 32,196 non-fatal injuries. These benefits were substantial in their own right (a net benefit of $4.7 billion at a 3 percent discount rate and $3.7 billion at a 7 percent discount rate). Further, ESC was found to be highly cost-effective for passenger cars alone ($0.38 million at a 3 percent discount rate and $0.50 million at a 7 percent discount rate).

Although the second alternative would have reduced the cost of the regulation by approximately $10 per vehicle, the agency rejected that alternative because the agency's research showed a potentially enhanced safety benefit from 4-channel ESC systems, as compared to 2-channel systems, and also because of the strong industry trend toward providing 4-channel systems. A more detailed analysis of the regulatory alternatives considered by the agency may be found in the FRIA (*see* FRIA Chapter VII).

In terms of the alternative phase-in schedules, the agency analyzed a number of potential alternatives to identify the schedule that would facilitate ESC installation in the light vehicle fleet as expeditiously as possible, while at the same time ensure the financial and technological practicability of the final rule (in keeping with our statutory mandate). To this end, the agency analyzed the product plans submitted by six vehicle manufacturers, whose combined production accounts for approximately 87 percent of the new light vehicle fleet. As explained in Chapter VII of the FRIA, we examined three different potential phase-in schedules to find the right balance among these competing concerns.

Two factors were controlling in making the decision as to which alternative to choose: (1) The ability of manufacturers to change vehicles from being equipped with optional ESC to standard ESC for MY 2010 and MY 2011; and (2) Not forcing any manufacturer to install ESC in any make/model for which it was not planned to be at least an option. The agency did not believe there was enough lead time to redesign such a make/model to include ESC by MY 2009. While there may be enough time to redesign a make/model to include ESC by MY 2010, given the carry forward provisions, this was not necessary for any of the six manufacturers for MY 2010. The second consideration became a factor once again in MY 2011, in not going beyond 95 percent (thereby obviating the costly need to redesign and develop tooling for a few vehicle lines which will not be produced in MY 2012).

Based upon this product plan information and the desire to provide manufacturers with flexibility, we chose the most aggressive phase-in alternative with a carry forward provision that we believe is reasonable (*i.e.*, 55/75/95%). (We note that the estimates below are compared to a baseline of the NPRM's proposed phase-in schedule of 30/60/90% with carry-forward credits.) Although the 55/75/95% phase-in alternative was not the least costly (expected to increase total compliance costs by $295 million), it was nevertheless very cost-effective ($0.394 to $0.640 million per equivalent life saved at a 3 percent discount rate; $0.496 to $0.802 million per equivalent life saved at a 7 percent discount rate). Further, this alternative also had the potential to substantially increase the number of prevented fatalities (336–550) and injuries (10,174–14,276) over the lifetime of the three model years in the phase-in period. Although the 55/75/95% without carry-forward credits alternative theoretically had higher benefits and was more cost-effective, the agency determined that based upon available product plan information, it may not be practical for manufacturers to achieve such high installation rates in such a short timeframe without carry-forward credits. Accordingly, the agency believes that the alternative chosen will provide the highest achievable level of incremental benefits among the schedules with a carry-forward provision, a feature the agency determined was necessary for reasonable implementation of the standard.

Accordingly, in light of the substantial benefits in terms of fatalities and injuries prevented (discussed at length in the FRIA and elsewhere in this document), the agency decided to adopt an ESC requirement for all light vehicles, even though this alternative was not the least costly, most cost-effective, or least burdensome available. In light of the demonstrated effectiveness of ESC in preventing single-vehicle crashes (including rollovers), the agency decided that it would be inappropriate to not make the

[92] As explained in Chapter VII of the FRIA, the agency assessed the following potential phase-in schedules for ESC: (A) 30%/60%/90% with carry forward credits (as proposed in the NPRM); (B) 55%/75%/95% with carry forward credits; and (C) 55%/75%/95% without carry forward credits.

life-saving benefits of ESC available to all vehicle occupants and in the shortest timeframe that the agency determined to be both reasonable and practicable. As noted previously, we have determined that the final rule's phase-in schedule may be accomplished without disruptive changes in manufacturer and supplier production processes.

In addition, as part of the public comment process, the agency's NPRM also invited suggestions regarding ways to promote flexibility and to minimize costs of compliance, while achieving the safety purposes of SAFETEA–LU. The overwhelming majority of public comments supported the ESC rulemaking and offered no suggested substitute. However, commenters did suggest numerous technical changes that might be characterized as promoting flexibility or minimizing costs. Each such issue is addressed in this final rule.

J. National Environmental Policy Act

NHTSA has analyzed this rulemaking action for the purposes of the National Environmental Policy Act. The agency has determined that implementation of this action would not have any significant impact on the quality of the human environment.

K. Regulation Identifier Number (RIN)

The Department of Transportation assigns a regulation identifier number (RIN) to each regulatory action listed in the Unified Agenda of Federal Regulations. The Regulatory Information Service Center publishes the Unified Agenda in April and October of each year. You may use the RIN contained in the heading at the beginning of this document to find this action in the Unified Agenda.

L. Privacy Act

Please note that anyone is able to search the electronic form of all comments received into any of our dockets by the name of the individual submitting the comment (or signing the comment, if submitted on behalf of an association, business, labor union, etc.). You may review DOT's complete Privacy Act Statement in the **Federal Register** published on April 11, 2000 (Volume 65, Number 70; pages 19477–78) or you may visit *http://dms.dot.gov.*

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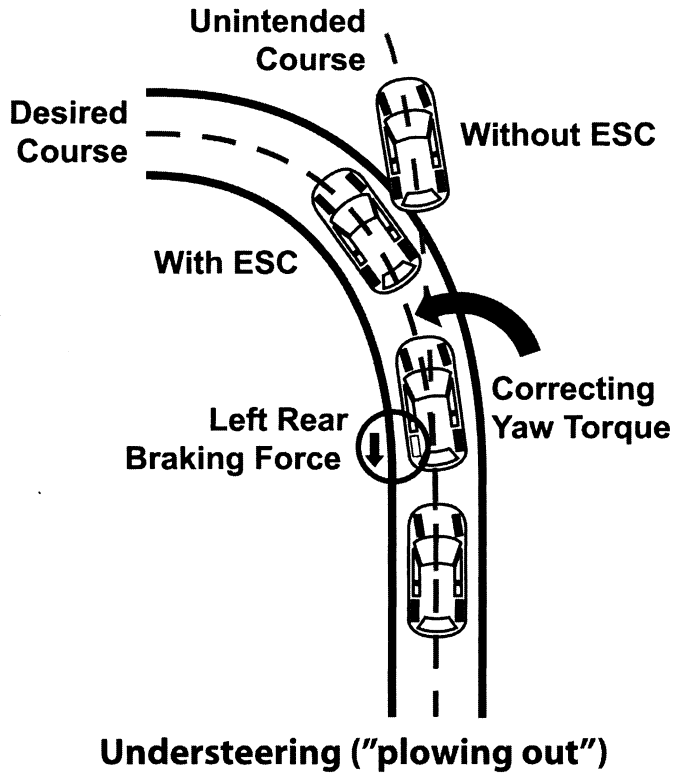
Figure to Preamble



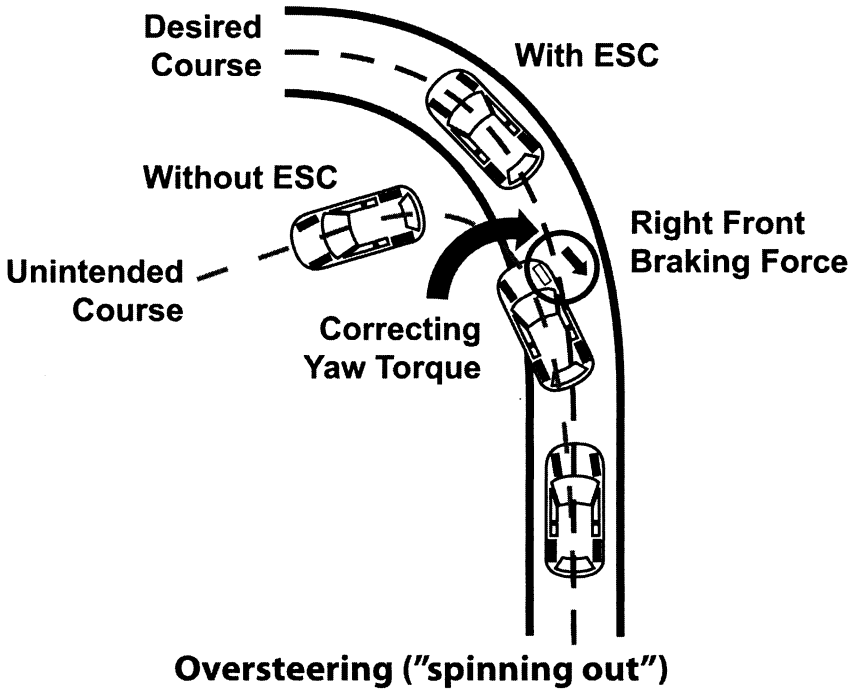


Figure 1. ESC Interventions for Understeering and Oversteering

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List of Subjects in 49 CFR Parts 571 and 585

Imports, Incorporation by reference, Motor vehicle safety, Report and recordkeeping requirements, Tires.

■ In consideration of the foregoing, NHTSA is amending 49 CFR parts 571 and 585 as follows:

PART 571—FEDERAL MOTOR VEHICLE SAFETY STANDARDS

■ 1. The authority citation for part 571 continues to read as follows:

Authority: 49 U.S.C. 322, 30111, 30115, 30117, and 30166; delegation of authority at 49 CFR 1.50.

■ 2. Section 571.101 is amended by revising the section heading, S5.5.2, S5.5.5, and Table 1 to read as follows:

§ 571.101 Standard No. 101; Controls and displays.

* * * * *

S5.5.2. The telltales for any brake system malfunction required by Table 1 to be red, air bag malfunction, low tire pressure, electronic stability control malfunction, passenger air bag off, high beam, turn signal, and seat belt must not be shown in the same common space.

* * * * *

S5.5.5. In the case of the telltale for a brake system malfunction, air bag malfunction, side air bag malfunction, low tire pressure, electronic stability control malfunction, passenger air bag off, high beam, turn signal, or seat belt that is designed to display in a common space, that telltale must displace any other symbol or message in that common space while the underlying condition for the telltale's activation exists.

* * * * *

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Table 1
Controls, Telltales, and Indicators with Illumination or Color Requirements [1]

Column 1 ITEM	Column 2 SYMBOL	Column 3 WORDS OR ABBRE-VIATIONS	Column 4 FUNCTION	Column 5 ILLUMIN-ATION	Column 6 COLOR
Highbeam [2]	[3,5]	—	Telltale	—	Blue or Green [4]
Turn signals [2]	[3,6]	—	Control	—	—
			Telltale	—	Green [4]
Hazard warning signal	[3]	Hazard	Control	Yes	—
		—	Telltale [7]	—	—
Position, side marker, end-outline marker, identification, or clearance lamps	[3] [8]	Marker Lamps or MK Lps [8]	Control	Yes	—
Windshield wiping system		Wiper or Wipe	Control	Yes	—
Windshield washing system		Washer or Wash	Control	Yes	—
Windshield washing and wiping system combined		Washer-Wiper or Wash-Wipe	Control	Yes	—
Windshield defrosting and defogging system		Defrost, Defog or Def.	Control	Yes	—
Rear window defrosting and defogging system		Rear Defrost, Rear Defog, Rear Def., or R-Def.	Control	Yes	—

Table 1
Controls, Telltales, and Indicators with Illumination or Color Requirements [1]

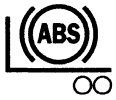
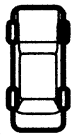
Column 1 ITEM	Column 2 SYMBOL	Column 3 WORDS OR ABBREVIATIONS	Column 4 FUNCTION	Column 5 ILLUMINATION	Column 6 COLOR
Brake system malfunction	—	Brake	Telltale	—	Red[4]
Antilock brake system malfunction for vehicles subject to FMVSS 105 or 135	—	Antilock, Anti-lock, or ABS [9]	Telltale	—	Yellow
Malfunction in Variable Brake Proportioning System	—	Brake Proportioning [9]	Telltale	—	Yellow
Regenerative brake system malfunction	—	RBS or ABS/RBS [9]	Telltale	—	Yellow
Malfunction in antilock system for vehicles other than trailers subject to FMVSS 121	—	ABS or Antilock [9]	Telltale	—	Yellow
Antilock brake system trailer fault for vehicles subject to FMVSS 121		Trailer ABS or Trailer Antilock	Telltale	—	Yellow
Brake Pressure (for vehicles subject to FMVSS 105 or 135)	—	Brake Pressure [9]	Telltale	—	Red[4]
Low brake fluid condition (for vehicles subject to FMVSS 105 or 135)	—	Brake Fluid [9]	Telltale	—	Red[4]
Parking brake applied (for vehicles subject to FMVSS 105 or 135)	—	Park or Parking Brake [9]	Telltale	—	Red[4]
Brake lining wear-out condition (for vehicles subject to FMVSS 135)	—	Brake Wear [9]	Telltale	—	Red[4]
Electronic Stability Control System Malfunction (manufacturer may use this telltale in flashing mode to indicate ESC operation. See FMVSS 126.)		ESC [10]	Telltale	—	Yellow
Electronic Stability Control System "OFF"		ESC OFF	Control	Yes	—
			Telltale	—	Yellow

Table 1
Controls, Telltales, and Indicators with Illumination or Color Requirements [1]

Column 1 ITEM	Column 2 SYMBOL	Column 3 WORDS OR ABBREVIATIONS	Column 4 FUNCTION	Column 5 ILLUMINATION	Column 6 COLOR
Fuel Level	or	Fuel	Telltale	—	—
			Indicator	Yes	—
Engine oil pressure	11	Oil	Telltale	—	—
			Indicator	Yes	—
Engine coolant temperature	11	Temp	Telltale	—	—
			Indicator	Yes	—
Electrical charge		Volts or Charge or Amp	Telltale	—	—
			Indicator	Yes	—
Engine stop	—	Engine Stop [12]	Control	Yes	—
Automatic vehicle speed (cruise control)	—	—	Control	Yes	—
Speedometer	—	MPH, or MPH and km/h [13]	Indicator	Yes	—
Heating and Air conditioning system	—	—	Control	Yes	—
Automatic transmission control position *(park)* *(reverse)* *(neutral)* *(drive)*	—	P R N D [14]	Indicator	Yes	—
Heating and/or air conditioning fan	or	Fan	Control	Yes	—
Low Tire Pressure (including malfunction) (See FMVSS 138)	[15]	Low Tire [15]	Telltale	—	Yellow

Table 1
Controls, Telltales, and Indicators with Illumination or Color Requirements [1]

Column 1 ITEM	Column 2 SYMBOL	Column 3 WORDS OR ABBRE-VIATIONS	Column 4 FUNCTION	Column 5 ILLUMIN-ATION	Column 6 COLOR
Low Tire Pressure (including malfunction) that identifies involved tire (See FMVSS 138)	 [15]	Low Tire [15]	Telltale	—	Yellow
Tire Pressure Monitoring System Malfunction (See FMVSS 138) [16]	—	TPMS [15, 17]	Telltale	—	Yellow

Notes:

1. An identifier is shown in this table if it is required for a control for which an illumination requirement exists or if it is used for a telltale for which a color requirement exists. If a line appears in column 2 and column 3, the control, telltale or indicator is required to be identified, however the form of the identification is the manufacturer's option. Telltales are not considered to have an illumination requirement, because by definition the telltale must light when the condition for its activation exists.
2. Additional requirements in FMVSS 108.
3. Framed areas of the symbol may be solid; solid areas may be framed.
4. Blue may be blue-green. Red may be red-orange.
5. Symbols employing four lines instead of five may also be used.
6. The pair of arrows is a single symbol. When the controls or telltales for left and right turn operate independently, however, the two arrows may be considered separate symbols and be spaced accordingly.
7. Not required when arrows of turn signal telltales that otherwise operate independently flash simultaneously as hazard warning telltale.
8. Separate identification not required if function is combined with master lighting switch.
9. Refer to FMVSS 105 or FMVSS 135, as appropriate, for additional specific requirements for brake telltale labeling and color. If a single telltale is used to indicate more than one brake system condition, the brake system malfunction identifier must be used.
10. This symbol may also be used to indicate the malfunction of related systems/functions, including traction control, trailer stability assist, corner brake control, and other similar functions that use throttle and/or individual torque control to operate and share common components with ESC.
11. Combination of the engine oil pressure symbol and the engine coolant temperature symbol in a single telltale is permitted.
12. Use when engine control is separate from the key locking system.
13. If the speedometer is graduated in both miles per hour and in kilometers per hour, the scales must be identified "MPH" and "km/h", respectively, in any combination of upper- and lowercase letters.
14. The letters 'P', 'R', 'N', and 'D' are considered separate identifiers for the individual gear positions. Their locations within the vehicle, and with respect to each other, are governed by FMVSS 102. The letter 'D' may be replaced by another alphanumeric character or symbol chosen by the manufacturer.
15. Required only for FMVSS 138 compliant vehicles.
16. Alternatively, either low tire pressure telltale may be used to indicate a TPMS malfunction. See FMVSS 138.
17. Required only for vehicles manufactured on or after September 1, 2007.

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■ 3. Section 571.126 is added to read as follows:

§ 571.126 Standard No. 126; Electronic stability control systems.

S1. *Scope.* This standard establishes performance and equipment requirements for electronic stability control (ESC) systems.

S2. *Purpose.* The purpose of this standard 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.

S3. *Application and Incorporation by Reference.*

S3.1 *Application.* This standard applies to passenger cars, multipurpose passenger vehicles, trucks, and buses with a gross vehicle weight rating of 4,536 kilograms (10,000 pounds) or less, according to the phase-in schedule specified in S8 of this standard.

S3.2 *Incorporation by reference.* ASTM E1337–90 (Reapproved 1996), Standard Test Method for Determining Longitudinal Peak Braking Coefficient of Paved Surfaces Using a STD Reference Test Tire, and ASTM E1136–93 (1993), Standard Specification for a Radial Standard Reference Test Tire, are incorporated by reference in S6.2.2 of this section. The Director of the Federal Register has approved the incorporation by reference of this material in accordance with 5 U.S.C. 552(a) and 1 CFR Part 51. Copies of ASTM E1337–90 (rev. 1996) and ASTM E1136–93 (1993) may be obtained from the ASTM Web site at *http://www.astm.org*, or by contacting ASTM, 100 Barr Harbor Drive, West Conshohocken, PA 19428–2959. Copies of ASTM E1337–90 (Reapproved 1996) and ASTM E1136–93 (1993) may be inspected at NHTSA's Office of Rulemaking, 400 Seventh Street, SW., Washington, DC 20590, or at the National Archives and Records Administration (NARA). For information on the availability of this material at NARA, call 202–741–6030, or go to: *http://www.archives.gov/federal_register/code_of_federal_regulations/ibr_locations.html.*

S4. *Definitions.*

Ackerman Steer Angle means the angle whose tangent is the wheelbase divided by the radius of the turn at a very low speed.

Electronic Stability Control System or ESC System means a system that has all of the following attributes:

(1) That augments vehicle directional stability by applying and adjusting the vehicle brake torques individually to induce a correcting yaw moment to a vehicle;

(2) That is computer controlled with the computer using a closed-loop algorithm to limit vehicle oversteer and to limit vehicle understeer;

(3) That has a means to determine the vehicle's yaw rate and to estimate its side slip or side slip derivative with respect to time;

(4) That has a means to monitor driver steering inputs;

(5) That has an algorithm to determine the need, and a means to modify engine torque, as necessary, to assist the driver in maintaining control of the vehicle, and

(6) That is operational over the full speed range of the vehicle (except at vehicle speeds less than 15 km/h (9.3 mph) or when being driven in reverse).

Lateral Acceleration means the component of the vector acceleration of a point in the vehicle perpendicular to the vehicle x axis (longitudinal) and parallel to the road plane.

Oversteer means a condition in which the vehicle's yaw rate is greater than the yaw rate that would occur at the vehicle's speed as a result of the Ackerman Steer Angle.

Sideslip or side slip angle means the arctangent of the lateral velocity of the center of gravity of the vehicle divided by the longitudinal velocity of the center of gravity.

Understeer means a condition in which the vehicle's yaw rate is less than the yaw rate that would occur at the vehicle's speed as result of the Ackerman Steer Angle.

Yaw rate means the rate of change of the vehicle's heading angle measured in degrees/second of rotation about a vertical axis through the vehicle's center of gravity.

S5. *Requirements.* Subject to the phase-in set forth in S8, each vehicle must be equipped with an ESC system that meets the requirements specified in S5 under the test conditions specified in S6 and the test procedures specified in S7 of this standard.

S5.1 *Required Equipment.* Vehicles to which this standard applies must be equipped with an electronic stability control system that:

S5.1.1 Is capable of applying brake torques individually to all four wheels and has a control algorithm that utilizes this capability.

S5.1.2 Is operational during all phases of driving including acceleration, coasting, and deceleration (including braking), except when the driver has disabled ESC, the vehicle speed is below 15 km/h (9.3 mph), or the vehicle is being driven in reverse.

S5.1.3 Remains capable of activation even if the antilock brake system or traction control system is also activated.

S5.2 *Performance Requirements.* During each test performed under the test conditions of S6 and the test procedure of S7.9, the vehicle with the ESC system engaged must satisfy the stability criteria of S5.2.1 and S5.2.2, and it must satisfy the responsiveness criterion of S5.2.3 during each of those tests conducted with a commanded steering wheel angle of 5A or greater, where A is the steering wheel angle computed in S7.6.1.

S5.2.1 The yaw rate measured one second after completion of the sine with dwell steering input (time $T_0 + 1$ in Figure 1) must not exceed 35 percent of the first peak value of yaw rate recorded after the steering wheel angle changes sign (between first and second peaks) ($\dot{\psi}_{Peak}$ in Figure 1) during the same test run, and

S5.2.2 The yaw rate measured 1.75 seconds after completion of the sine with dwell steering input must not exceed 20 percent of the first peak value of yaw rate recorded after the steering wheel angle changes sign (between first and second peaks) during the same test run.

S5.2.3 The lateral displacement of the vehicle center of gravity with respect to its initial straight path must be at least 1.83 m (6 feet) for vehicles with a GVWR of 3,500kg (7,716 lb) or less, and 1.52 m (5 feet) for vehicles with a GVWR greater than 3,500 kg (7,716 lb) when computed 1.07 seconds after the Beginning of Steer (BOS). BOS is defined in S7.11.6.

S5.2.3.1 The computation of lateral displacement is performed using double integration with respect to time of the measurement of lateral acceleration at the vehicle center of gravity, as expressed by the formula:

$$\text{Lateral Displacement} = \iint Ay_{C.G.}dt$$

S5.2.3.2 Time t = 0 for the integration operation is the instant of steering initiation, known as the Beginning of Steer (BOS). BOS is defined in S7.11.6.

S5.3 *ESC Malfunction.* The vehicle must be equipped with a telltale that provides a warning to the driver of the occurrence of one or more malfunctions that affect the generation or transmission of control or response signals in the vehicle's electronic stability control system. The ESC malfunction telltale:

S5.3.1 As of September 1, 2011, must be mounted inside the occupant

compartment in front of and in clear view of the driver;

S5.3.2 As of September 1, 2011, must be identified by the symbol shown for ''ESC Malfunction Telltale'' or the specified words or abbreviations listed in Table 1 of Standard No. 101 (49 CFR 571.101);

S5.3.3 Except as provided in paragraph S5.3.4, the ESC malfunction telltale must illuminate only when a malfunction(s) exists and must remain continuously illuminated under the conditions specified in S5.3 for as long as the malfunction(s) exists, whenever the ignition locking system is in the ''On'' (''Run'') position; and

S5.3.4 As of September 1, 2011, except as provided in paragraph S5.3.5, each ESC malfunction telltale must be activated as a check of lamp function either when the ignition locking system is turned to the ''On'' (''Run'') position when the engine is not running, or when the ignition locking system is in a position between ''On'' (''Run'') and ''Start'' that is designated by the manufacturer as a check position.

S5.3.5 The ESC malfunction telltale need not be activated when a starter interlock is in operation.

S5.3.6 The requirement S5.3.4 does not apply to telltales shown in a common space.

S5.3.7 The ESC malfunction telltale must extinguish at the next ignition cycle after the malfunction has been corrected.

S5.3.8 The manufacturer may use the ESC malfunction telltale in a flashing mode to indicate ESC operation.

S5.3.9 Prior to September 1, 2011, a disconnection of the power to the ESC electronic control unit may be indicated by the ABS malfunction telltale instead of the ESC malfunction telltale, and a disconnection of the ''ESC Off'' control need not illuminate the ESC malfunction telltale.

S5.4. *ESC Off and Other System Controls.* The manufacturer may include an ''ESC Off'' control whose only purpose is to place the ESC system in a mode in which it will no longer satisfy the performance requirements of S5.2.1, S5.2.2 and S5.2.3. Manufacturers may also provide controls for other systems that have an ancillary effect upon ESC operation. Controls of either kind that place the ESC system in a mode in which it will no longer satisfy the performance requirements of S5.2.1, S5.2.2 and S5.2.3 are permitted, provided that:

S5.4.1 The vehicle's ESC system must always return to a mode that satisfies the requirements of S5.1 and S5.2 at the initiation of each new ignition cycle, regardless of what mode the driver had previously selected except if that mode is specifically for enhanced traction during low-speed, off-road driving and is entered by the driver using a mechanical control that cannot be automatically reset electrically. If the system has more than one mode that satisfies these requirements, the default mode must be the mode that satisfies the performance requirements of S5.2 by the greatest margin.

S5.4.2 As of September 1, 2011, a control whose only purpose is to place the ESC system in a mode in which it will no longer satisfy the performance requirements of S5.2.1, S5.2.2 and S5.2.3 must be identified by the symbol shown for ''ESC Off'' in Table 1 of Standard No. 101 (49 CFR 571.101) or the text, ''ESC Off'' as listed under ''Word(s) or Abbreviations'' in Table 1 of Standard No. 101 (49 CFR 571.101).

S5.4.3 A control for another system that has the ancillary effect of placing the ESC system in a mode in which it no longer satisfies the performance requirements of S5.2.1, S5.2.2 and S5.2.3 need not be identified by the ''ESC Off'' identifiers in Table 1 of Standard No. 101 (49 CFR 571.101), but the ESC status must be identified by the ''ESC Off'' telltale in accordance with S5.5.

S5.5 *ESC Off Telltale*

S5.5.1 The vehicle manufacturer must provide a telltale indicating that the vehicle has been put into a mode that renders it unable to satisfy the requirements of S5.2.1, S5.2.2 and S5.2.3, if such a mode is provided.

S5.5.2 As of September 1, 2011, the ''ESC Off'' telltale must be identified by the symbol shown for ''ESC Off'' in Table 1 of Standard No. 101 (49 CFR 571.101) or the text, ''ESC Off'' as listed under ''Word(s) or Abbreviations'' in Table 1 of Standard No. 101 (49 CFR 571.101).

S5.5.3 As of September 1, 2011, the ''ESC Off'' telltale must be mounted inside the occupant compartment in front of and in clear view of the driver.

S5.5.4 The ''ESC Off'' telltale must remain continuously illuminated for as long as the ESC is in a mode that renders it unable to satisfy the requirements of S5.2.1, S5.2.2 and S5.2.3, and

S5.5.5 Notwithstanding S5.3.1(e) of 49 CFR 571.101, the vehicle manufacturer may use the ''ESC Off'' telltale to indicate an ESC level of function other than the fully functional default mode even if the vehicle would meet S5.2.1, S5.2.2 and S5.2.3 at that level of ESC function.

S5.5.6 As of September 1, 2011, except as provided in paragraph S5.5.7 and S5.5.8, each ''ESC Off'' telltale must be activated as a check of lamp function either when the ignition locking system is turned to the ''On'' (''Run'') position when the engine is not running, or when the ignition locking system is in a position between ''On'' (''Run'') and ''Start'' that is designated by the manufacturer as a check position.

S5.5.7 The ''ESC Off'' telltale need not be activated when a starter interlock is in operation.

S5.5.8 The requirement S5.5.6 does not apply to telltales shown in a common space.

S5.5.9 The ''ESC Off'' telltale must extinguish after the ESC system has been returned to its fully functional default mode.

S5.6 *ESC System Technical Documentation.* To ensure a vehicle is equipped with an ESC system that meets the definition of ''ESC System'' in S4, the vehicle manufacturer must make available to the agency, upon request, the following documentation:

S5.6.1 A system diagram that identifies all ESC system hardware. The diagram must identify what components are used to generate brake torques at each wheel, determine vehicle yaw rate, estimated side slip or the side slip derivative and driver steering inputs.

S5.6.2 A written explanation describing the ESC system basic operational characteristics. This explanation must include a discussion on the system's capability to apply brake torques at each wheel and how the system modifies engine torque during ESC system activation. The explanation must also identify the vehicle speed range and the driving phases (acceleration, deceleration, coasting, during activation of the ABS or traction control) under which the ESC system can activate.

S5.6.3 A logic diagram that supports the explanation provided in S5.6.2.

S5.6.4 Specifically for mitigating vehicle understeer, a discussion of the pertinent inputs to the computer or calculations within the computer and how its algorithm uses that information and controls ESC system hardware to limit vehicle understeer.

S6. *Test Conditions.*

S6.1 *Ambient conditions.*

S6.1.1 The ambient temperature is between 7 °C (45 °F) and 40 °C (104 °F).

S6.1.2 The maximum wind speed is no greater than 10 m/s (22 mph) for passenger cars and 5 m/s (11 mph) for multipurpose passenger vehicles, trucks and buses.

S6.2 *Road test surface.*

S6.2.1 The tests are conducted on a dry, uniform, solid-paved surface. Surfaces with irregularities and undulations, such as dips and large cracks, are unsuitable.

S6.2.2 The road test surface must produce a peak friction coefficient (PFC) of 0.9 when measured using an American Society for Testing and Materials (ASTM) E1136–93 (1993) standard reference test tire, in accordance with ASTM Method E 1337–90 (Reapproved 1996), at a speed of 64.4 km/h (40 mph), without water delivery. (These standards are here incorporated by reference as explained in S3.2 above.)

S6.2.3 The test surface has a consistent slope between level and 1%.

S6.3 *Vehicle conditions.*

S6.3.1 The ESC system is enabled for all testing.

S6.3.2 *Test Weight.* The vehicle is loaded with the fuel tank filled to at least 75 percent of capacity, and total interior load of 168 kg (370 lbs) comprised of the test driver, approximately 59 kg (130 lbs) of test equipment (automated steering machine, data acquisition system and the power supply for the steering machine), and ballast as required by differences in the weight of test drivers and test equipment. Where required, ballast shall be placed on the floor behind the passenger front seat or if necessary in the front passenger foot well area. All ballast shall be secured in a way that prevents it from becoming dislodged during test conduct.

S6.3.3 *Tires.* The vehicle is tested with the tires installed on the vehicle at time of initial vehicle sale. The tires are inflated to the vehicle manufacturer's recommended cold tire inflation pressure(s) specified on the vehicle's placard or the tire inflation pressure label. Tubes may be installed to prevent tire de-beading.

S6.3.4 *Outriggers.* Outriggers must be used for testing trucks, multipurpose passenger vehicles, and buses. Vehicles with a baseline weight under 2,722 kg (6,000 lbs) must be equipped with ''standard'' outriggers and vehicles with a baseline weight equal to or greater than 2,722 kg (6,000 lbs) must be equipped with ''heavy'' outriggers. A vehicle's baseline weight is the weight of the vehicle delivered from the dealer, fully fueled, with a 73 kg (160 lb) driver. Standard outriggers shall be designed with a maximum weight of 32 kg (70 lb) and a maximum roll moment of inertia of 35.9 kg-m^2 (26.5 ft-lb-sec^2). Heavy outriggers shall be designed with a maximum weight of 39 kg (86 lb) and a maximum roll moment of inertia of 40.7 kg-m^2 (30.0 ft-lb-sec^2).

S6.3.5 *Automated steering machine.* A steering machine programmed to execute the required steering pattern must be used in S7.5.2, S7.5.3, S7.6 and S7.9. The steering machine shall be capable of supplying steering torques between 40 to 60 Nm (29.5 to 44.3 lb-ft). The steering machine must be able to apply these torques when operating with steering wheel velocities up to 1200 degrees per second.

S7. *Test Procedure.*

S7.1 Inflate the vehicles' tires to the cold tire inflation pressure(s) provided on the vehicle's placard or the tire inflation pressure label.

S7.2 *Telltale bulb check.* With the vehicle stationary and the ignition locking system in the ''Lock'' or ''Off'' position, activate the ignition locking system to the ''On'' (''Run'') position or, where applicable, the appropriate position for the lamp check. The ESC malfunction telltale must be activated as a check of lamp function, as specified in S5.3.4, and if equipped, the ''ESC Off'' telltale must also be activated as a check of lamp function, as specified in S5.5.6. The telltale bulb check is not required for a telltale shown in a common space as specified in S5.3.6 and S5.5.8.

S7.3 *''ESC Off'' control check.* For vehicles equipped with an ''ESC Off'' control, with the vehicle stationary and the ignition locking system in the ''Lock'' or ''Off'' position, activate the ignition locking system to the ''On'' (''Run'') position. Activate the ''ESC Off'' control and verify that the ''ESC Off'' telltale is illuminated, as specified in S5.5.4. Turn the ignition locking system to the ''Lock'' or ''Off'' position. Again, activate the ignition locking system to the ''On'' (''Run'') position and verify that the ''ESC Off'' telltale has extinguished indicating that the ESC system has been reactivated as specified in S5.4.1.

S7.4 *Brake Conditioning.* Condition the vehicle brakes as follows:

S7.4.1 Ten stops are performed from a speed of 56 km/h (35 mph), with an average deceleration of approximately 0.5 g.

S7.4.2 Immediately following the series of 56 km/h (35 mph) stops, three additional stops are performed from 72 km/h (45 mph).

S7.4.3 When executing the stops in S7.4.2, sufficient force is applied to the brake pedal to activate the vehicle's antilock brake system (ABS) for a majority of each braking event.

S7.4.4 Following completion of the final stop in S7.4.2, the vehicle is driven at a speed of 72 km/h (45 mph) for five minutes to cool the brakes.

S7.5 *Tire Conditioning.* Condition the tires using the following procedure to wear away mold sheen and achieve operating temperature immediately before beginning the test runs of S7.6 and S7.9.

S7.5.1 The test vehicle is driven around a circle 30 meters (100 feet) in diameter at a speed that produces a lateral acceleration of approximately 0.5 to 0.6 g for three clockwise laps followed by three counterclockwise laps.

S7.5.2 Using a sinusoidal steering pattern at a frequency of 1 Hz, a peak steering wheel angle amplitude corresponding to a peak lateral acceleration of 0.5–0.6 g, and a vehicle speed of 56 km/h (35 mph), the vehicle is driven through four passes performing 10 cycles of sinusoidal steering during each pass.

S7.5.3 The steering wheel angle amplitude of the final cycle of the final pass is twice that of the other cycles. The maximum time permitted between all laps and passes is five minutes.

S7.6 *Slowly Increasing Steer Test.* The vehicle is subjected to two series of runs of the Slowly Increasing Steer Test using a constant vehicle speed of 80 ± 2 km/h (50 ± 1 mph) and a steering pattern that increases by 13.5 degrees per second until a lateral acceleration of approximately 0.5 g is obtained. Three repetitions are performed for each test series. One series uses counterclockwise steering, and the other series uses clockwise steering. The maximum time permitted between each test run is five minutes.

S7.6.1 From the Slowly Increasing Steer tests, the quantity ''A'' is determined. ''A'' is the steering wheel angle in degrees that produces a steady state lateral acceleration (corrected using the methods specified in S7.11.3) of 0.3 g for the test vehicle. Utilizing linear regression, A is calculated, to the nearest 0.1 degrees, from each of the six Slowly Increasing Steer tests. The absolute value of the six A's calculated is averaged and rounded to the nearest 0.1 degrees to produce the final quantity, A, used below.

S7.7 After the quantity A has been determined, without replacing the tires, the tire conditioning procedure described in S7.5 is performed immediately prior to conducting the Sine with Dwell Test of S7.9. Initiation of the first Sine with Dwell test series shall begin within two hours after completion of the Slowly Increasing Steer tests of S7.6.

S7.8 Check that the ESC system is enabled by ensuring that the ESC malfunction and ''ESC Off'' (if provided) telltales are not illuminated.

S7.9 *Sine with Dwell Test of Oversteer Intervention and*

Responsiveness. The vehicle is subjected to two series of test runs using a steering pattern of a sine wave at 0.7 Hz frequency with a 500 ms delay beginning at the second peak amplitude as shown in Figure 2 (the Sine with Dwell tests). One series uses counterclockwise steering for the first half cycle, and the other series uses clockwise steering for the first half cycle. The vehicle is provided a cool-down period between each test run of 90 seconds to five minutes, with the vehicle stationary.

S7.9.1 The steering motion is initiated with the vehicle coasting in high gear at 80 ±2 km/h (50 ±1 mph).

S7.9.2 In each series of test runs, the steering amplitude is increased from run to run, by 0.5A, provided that no such run will result in a steering amplitude greater than that of the final run specified in S7.9.4.

S7.9.3 The steering amplitude for the initial run of each series is 1.5A where A is the steering wheel angle determined in S7.6.1.

S7.9.4 The steering amplitude of the final run in each series is the greater of 6.5A or 270 degrees, provided the calculated magnitude of 6.5A is less than or equal to 300 degrees. If any 0.5A increment, up to 6.5A, is greater than 300 degrees, the steering amplitude of the final run shall be 300 degrees.

S7.9.5 Upon completion of the two series of test runs, post processing of yaw rate and lateral acceleration data is done as specified in S7.11.

S7.10 *ESC Malfunction Detection.*

S7.10.1 Simulate one or more ESC malfunction(s) by disconnecting the power source to any ESC component, or disconnecting any electrical connection between ESC components (with the vehicle power off). When simulating an ESC malfunction, the electrical connections for the telltale lamp(s) are not to be disconnected.

S7.10.2 With the vehicle initially stationary and the ignition locking system in the ''Lock'' or ''Off'' position, activate the ignition locking system to the ''Start'' position and start the engine. Place the vehicle in a forward gear and obtain a vehicle speed of 48 ± 8 km/h (30 ± 5 mph). Drive the vehicle for at least two minutes including at least one left and one right turning maneuver. Verify that within two minutes of obtaining this vehicle speed the ESC malfunction indicator illuminates in accordance with S5.3.

S7.10.3 Stop the vehicle, deactivate the ignition locking system to the ''Off'' or ''Lock'' position. After a five-minute period, activate the vehicle's ignition locking system to the ''Start'' position and start the engine. Verify that the ESC malfunction indicator again illuminates to signal a malfunction and remains illuminated as long as the engine is running or until the fault is corrected.

S7.10.4 Deactivate the ignition locking system to the ''Off'' or ''Lock'' position. Restore the ESC system to normal operation, activate the ignition system to the ''Start'' position and start the engine. Verify that the telltale has extinguished.

S7.11 *Post Data Processing—Calculations for Performance Metrics.* Yaw rate and lateral displacement measurements and calculations must be processed utilizing the following techniques:

S7.11.1 Raw steering wheel angle data is filtered with a 12-pole phaseless Butterworth filter and a cutoff frequency of 10Hz. The filtered data is then zeroed to remove sensor offset utilizing static pretest data.

S7.11.2 Raw yaw rate data is filtered with a 12-pole phaseless Butterworth filter and a cutoff frequency of 6Hz. The filtered data is then zeroed to remove sensor offset utilizing static pretest data.

S7.11.3 Raw lateral acceleration data is filtered with a 12-pole phaseless Butterworth filter and a cutoff frequency of 6Hz. The filtered data is then zeroed to remove sensor offset utilizing static pretest data. The lateral acceleration data at the vehicle center of gravity is determined by removing the effects caused by vehicle body roll and by correcting for sensor placement via use of coordinate transformation. For data collection, the lateral accelerometer shall be located as close as possible to the position of the vehicle's longitudinal and lateral centers of gravity.

S7.11.4 Steering wheel velocity is determined by differentiating the filtered steering wheel angle data. The steering wheel velocity data is then filtered with a moving 0.1 second running average filter.

S7.11.5 Lateral acceleration, yaw rate and steering wheel angle data channels are zeroed utilizing a defined ''zeroing range.'' The methods used to establish the zeroing range are defined in S7.11.5.1 and S7.11.5.2.

S7.11.5.1 Using the steering wheel rate data calculated using the methods described in S7.11.4, the first instant steering wheel rate exceeds 75 deg/sec is identified. From this point, steering wheel rate must remain greater than 75 deg/sec for at least 200 ms. If the second condition is not met, the next instant steering wheel rate exceeds 75 deg/sec is identified and the 200 ms validity check applied. This iterative process continues until both conditions are ultimately satisfied.

S7.11.5.2 The ''zeroing range'' is defined as the 1.0 second time period prior to the instant the steering wheel rate exceeds 75 deg/sec (*i.e.*, the instant the steering wheel velocity exceeds 75 deg/sec defines the end of the ''zeroing range'').

S7.11.6 The Beginning of Steer (BOS) is defined as the first instance filtered and zeroed steering wheel angle data reaches −5 degrees (when the initial steering input is counterclockwise) or +5 degrees (when the initial steering input is clockwise) after time defining the end of the ''zeroing range.'' The value for time at the BOS is interpolated.

S7.11.7 The Completion of Steer (COS) is defined as the time the steering wheel angle returns to zero at the completion of the Sine with Dwell steering maneuver. The value for time at the zero degree steering wheel angle is interpolated.

S7.11.8 The second peak yaw rate is defined as the first local yaw rate peak produced by the reversal of the steering wheel. The yaw rates at 1.000 and 1.750 seconds after COS are determined by interpolation.

S7.11.9 Determine lateral velocity by integrating corrected, filtered and zeroed lateral acceleration data. Zero lateral velocity at BOS event. Determine lateral displacement by integrating zeroed lateral velocity. Zero lateral displacement at BOS event. Lateral displacement at 1.07 seconds from BOS event is determined by interpolation.

S8. Phase-in schedule.

S8.1 *Vehicles manufactured on or after September 1, 2008, and before September 1, 2009.* For vehicles manufactured on or after September 1, 2008, and before September 1, 2009, the number of vehicles complying with this standard must not be less than 55 percent of:

(a) The manufacturer's average annual production of vehicles manufactured on or after September 1, 2005, and before September 1, 2008; or

(b) The manufacturer's production on or after September 1, 2008, and before September 1, 2009.

S8.2 *Vehicles manufactured on or after September 1, 2009, and before September 1, 2010.* For vehicles manufactured on or after September 1, 2009, and before September 1, 2010, the number of vehicles complying with this standard must not be less than 75 percent of:

(a) The manufacturer's average annual production of vehicles manufactured on or after September 1, 2006, and before September 1, 2009; or

(b) The manufacturer's production on or after September 1, 2009, and before September 1, 2010.

S8.3 *Vehicles manufactured on or after September 1, 2010, and before September 1, 2011.* For vehicles manufactured on or after September 1, 2010, and before September 1, 2011, the number of vehicles complying with this standard must not be less than 95 percent of:

(a) The manufacturer's average annual production of vehicles manufactured on or after September 1, 2007, and before September 1, 2010; or

(b) The manufacturer's production on or after September 1, 2010, and before September 1, 2011.

S8.4 *Vehicles manufactured on or after September 1, 2011.* All vehicles manufactured on or after September 1, 2011 must comply with this standard.

S8.5 *Calculation of complying vehicles.*

(a) For purposes of complying with S8.1, a manufacturer may count a vehicle if it is certified as complying with this standard and is manufactured on or after June 5, 2007, but before September 1, 2009.

(b) For purpose of complying with S8.2, a manufacturer may count a vehicle if it:

(1) (i) Is certified as complying with this standard and is manufactured on or after June 5, 2007, but before September 1, 2010; and

(ii) Is not counted toward compliance with S8.1; or

(2) Is manufactured on or after September 1, 2009, but before September 1, 2010.

(c) For purposes of complying with S8.3, a manufacturer may count a vehicle if it:

(1)(i) Is certified as complying with this standard and is manufactured on or after June 5, 2007, but before September 1, 2011; and

(ii) Is not counted toward compliance with S8.1 or S8.2; or

(2) Is manufactured on or after September 1, 2010, but before September 1, 2011.

S8.6 *Vehicles produced by more than one manufacturer.*

S8.6.1 For the purpose of calculating average annual production of vehicles for each manufacturer and the number of vehicles manufactured by each manufacturer under S8.1 through S8.4, a vehicle produced by more than one manufacturer must be attributed to a single manufacturer as follows, subject to S8.6.2:

(a) A vehicle that is imported must be attributed to the importer.

(b) A vehicle manufactured in the United States by more than one manufacturer, one of which also markets the vehicle, must be attributed to the manufacturer that markets the vehicle.

S8.6.2 A vehicle produced by more than one manufacturer must be attributed to any one of the vehicle's manufacturers specified by an express written contract, reported to the National Highway Traffic Safety Administration under 49 CFR Part 585, between the manufacturer so specified and the manufacturer to which the vehicle would otherwise be attributed under S8.6.1.

S8.7 *Small volume manufacturers.*

Vehicles manufactured during any of the three years of the September 1, 2008 through August 31, 2011 phase-in by a manufacturer that produces fewer than 5,000 vehicles for sale in the United States during that year are not subject to the requirements of S8.1, S8.2, S8.3, and S8.5.

S8.8 *Final-stage manufacturers and alterers.*

Vehicles that are manufactured in two or more stages or that are altered (within the meaning of 49 CFR 567.7) after having previously been certified in accordance with Part 567 of this chapter are not subject to the requirements of S8.1 through S8.5. Instead, all vehicles produced by these manufacturers on or after September 1, 2012 must comply with this standard.

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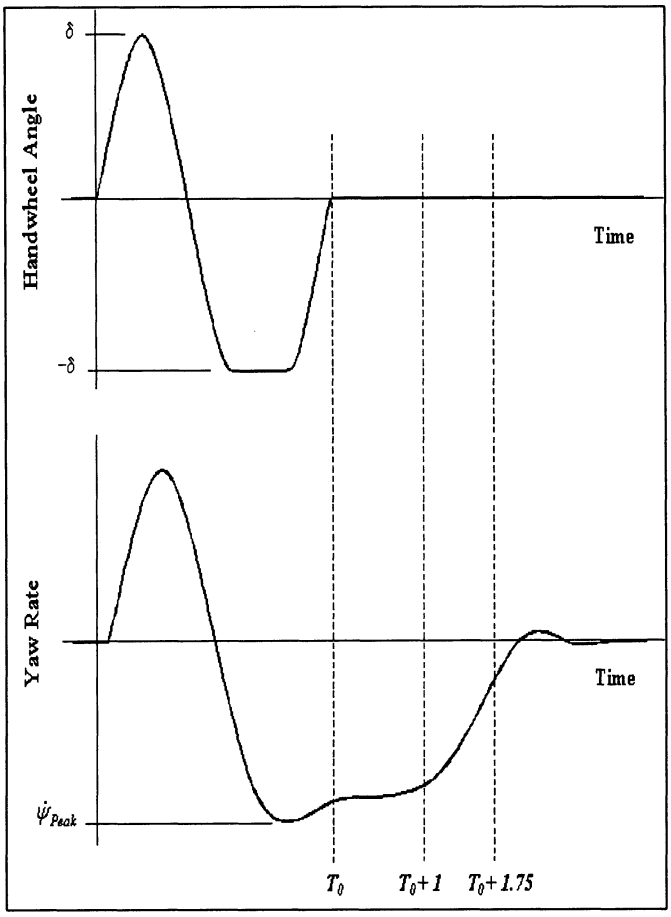


Figure 1. Steering wheel position and yaw velocity information used to assess lateral stability.

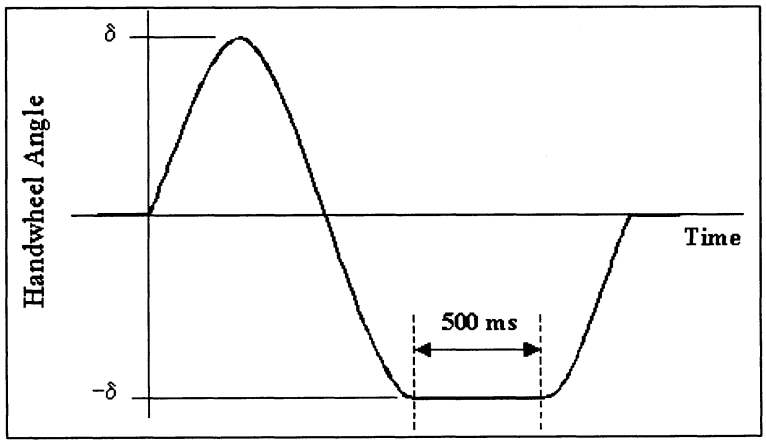


Figure 2. Sine with Dwell steering profile.

PART 585—PHASE-IN REPORTING REQUIREMENTS

■ 4. The authority citation for part 585 continues to read as follows:

Authority: 49 U.S.C. 322, 30111, 30115, 30117, and 30166; delegation of authority at 49 CFR 1.50.

■ 5. Subpart H is added and reserved.

■ 6. Subpart I is added to read as follows:

Subpart I—Electronic Stability Control System Phase-In Reporting Requirements

Sec.
585.81 Scope.
585.82 Purpose.
585.83 Applicability.
585.84 Definitions.
585.85 Response to inquiries.
585.86 Reporting requirements.
585.87 Records.
585.88 Petition to extend period to file report.

Subpart I—Electronic Stability Control System Phase In Reporting Requirements

§ 585.81 Scope.

This subpart establishes requirements for manufacturers of passenger cars, multipurpose passenger vehicles, trucks, and buses with a gross vehicle weight rating of 4,536 kilograms (10,000 pounds) or less to submit a report, and maintain records related to the report, concerning the number of such vehicles that meet the requirements of Standard No. 126, *Electronic stability control systems* (49 CFR 571.126).

§ 585.82 Purpose.

The purpose of these reporting requirements is to assist the National Highway Traffic Safety Administration in determining whether a manufacturer has complied with Standard No. 126 (49 CFR 571.126).

§ 585.83 Applicability.

This subpart applies to manufacturers of passenger cars, multipurpose passenger vehicles, trucks, and buses with a gross vehicle weight rating of 4,536 kilograms (10,000 pounds) or less. However, this subpart does not apply to manufacturers whose production consists exclusively of vehicles manufactured in two or more stages, and vehicles that are altered after previously having been certified in accordance with part 567 of this chapter. In addition, this subpart does not apply to manufacturers whose production of motor vehicles for the United States market is less than 5,000 vehicles in a production year.

§ 585.84 Definitions.

For the purposes of this subpart:

Production year means the 12-month period between September 1 of one year and August 31 of the following year, inclusive.

§ 585.85 Response to inquiries.

At any time prior to August 31, 2011, each manufacturer must, upon request from the Office of Vehicle Safety Compliance, provide information identifying the vehicles (by make, model, and vehicle identification number) that have been certified as complying with Standard No. 126 (49 CFR 571.126). The manufacturer's designation of a vehicle as a certified vehicle is irrevocable. Upon request, the manufacturer also must specify whether it intends to utilize carry-forward credits, and the vehicles to which those credits relate.

§ 585.86 Reporting requirements.

(a) *General reporting requirements.* Within 60 days after the end of the production years ending August 31, 2009, August 31, 2010, and August 31, 2011, each manufacturer must submit a report to the National Highway Traffic Safety Administration concerning its compliance with Standard No. 126 (49 CFR 571.126) for its passenger cars, multipurpose passenger vehicles, trucks, and buses with a gross vehicle weight rating of less than 4,536 kilograms (10,000 pounds) produced in that year.

Each report must—

(1) Identify the manufacturer;

(2) State the full name, title, and address of the official responsible for preparing the report;

(3) Identify the production year being reported on;

(4) Contain a statement regarding whether or not the manufacturer complied with the requirements of Standard No. 126 (49 CFR 571.126) for the period covered by the report and the basis for that statement;

(5) Provide the information specified in paragraph (b) of this section;

(6) Be written in the English language; and

(7) Be submitted to: Administrator, National Highway Traffic Safety Administration, 400 Seventh Street, SW., Washington, DC 20590.

(b) *Report content.*

(1) *Basis for statement of compliance.* Each manufacturer must provide the number of passenger cars, multipurpose passenger vehicles, trucks, and buses with a gross vehicle weight rating of 4,536 kilograms (10,000 pounds) or less, manufactured for sale in the United States for each of the three previous production years, or, at the manufacturer's option, for the current production year. A new manufacturer that has not previously manufactured these vehicles for sale in the United States must report the number of such vehicles manufactured during the current production year.

(2) *Production.* Each manufacturer must report for the production year for which the report is filed: the number of passenger cars, multipurpose passenger vehicles, trucks, and buses with a gross vehicle weight rating of 4,536 kilograms (10,000 pounds) or less that meet Standard No. 126 (49 CFR 571.126).

(3) *Statement regarding compliance.* Each manufacturer must provide a statement regarding whether or not the manufacturer complied with the ESC requirements as applicable to the period covered by the report, and the basis for that statement. This statement must include an explanation concerning the use of any carry-forward credits.

(4) *Vehicles produced by more than one manufacturer.* Each manufacturer whose reporting of information is affected by one or more of the express written contracts permitted by S8.6.2 of Standard No. 126 (49 CFR 571.126) must:

(i) Report the existence of each contract, including the names of all parties to the contract, and explain how the contract affects the report being submitted.

(ii) Report the actual number of vehicles covered by each contract.

§ 585.87 Records.

Each manufacturer must maintain records of the Vehicle Identification Number for each vehicle for which information is reported under § 585.86(b)(2) until December 31, 2013.

§ 585.88 Petition to extend period to file report.

A manufacturer may petition for extension of time to submit a report under this Part. A petition will be granted only if the petitioner shows good cause for the extension and if the extension is consistent with the public interest. The petition must be received not later than 15 days before expiration of the time stated in § 585.86(a). The filing of a petition does not automatically extend the time for filing a report. The petition must be submitted to: Administrator, National Highway Traffic Safety Administration, 400 Seventh Street, SW., Washington, DC 20590.

Issued: March 22, 2007.

Nicole R. Nason,

Administrator.

[**Note:** The Following Appendix Will Not Appear in the Code of Federal Regulations.]

APPENDIX: Technical Explanation in Response to Comments on Understeer

This appendix explains NHTSA's reasoning regarding the issue raised by public comment on *Understeer Requirements,* as discussed in the Response to Comments section of the Final Rule (*see* Section IV.C.4). This is an area of ongoing research by vehicle dynamics researchers involving concepts that are beyond what is usually discussed in a first-year graduate-school-level course on vehicle dynamics. We have done our best to address this subject in a way that will be easily understandable by the general reader. Nevertheless, some aspects of the following discussion are unavoidably fairly technical.

Explanation of Linear and Non-Linear Understeer

First, we wish to clarify what we mean by linear and non-linear range understeer since some of the commenters did not appear to understand the fundamental issues associated with the agency's decision to include an understeer requirement in the definition of ESC System.

Understeer has proven to be an extremely useful concept for characterizing the lateral response of a vehicle. Section III.A, *How ESC Prevents Loss of Vehicle Control*[93] of the Notice of Proposed Rulemaking (NPRM) attempts to explain the concepts of understeer and oversteer to the reader in non-technical terms. However, the full scientific definitions of understeer and oversteer are presented here in order to lay the technical groundwork for the discussions that follow.

Many alternative definitions of understeer have been developed. The Society of Automotive Engineers' (SAE) definitions of understeer and its opposite, oversteer, taken from SAE J670e,[94] are:

''9.4.7 UNDERSTEER/OVERSTEER GRADIENT—The ratio of the *steering wheel angle gradient* to the *overall steering ratio* quantity obtained by subtracting the *Ackerman steer angle gradient* from the ratio of the *steering wheel angle gradient* to the *overall steering ratio.*''

''9.4.9 UNDERSTEER—A vehicle is understeer at a given *trim*[95] if the ratio of the *steering wheel angle gradient* to the *overall steering ratio* is greater than the *Ackerman steer angle gradient.*''

''9.4.10 OVERSTEER—A vehicle is oversteer at a given *trim* if the ratio of the *steering wheel angle gradient* to the *overall steering ratio* is less than the *Ackerman steer angle gradient.*''

SAE J670e defines ''steering wheel angle gradient'' and ''Ackerman steer angle gradient'' as follows:

''9.4.5 STEERING WHEEL ANGLE GRADIENT—The rate of change in the *steering wheel angle* with respect to change in steady state lateral acceleration on a level road at a given *trim* and test conditions.''

''Note 14 ACKERMAN STEER ANGLE GRADIENT is equal to the wheelbase divided by the square of the vehicle speed (rad/ft/sec^2).''

Consider the linear range of vehicle handling. The linear range is defined as the region of handling where the lateral acceleration versus steering wheel angle gain remains approximately constant (meaning that the understeer gradient is essentially constant).[96] The boundaries of the linear range depend upon the friction of the surface being driven on. The linear range occurs for lateral accelerations between 0.1 and 0.4g on a high friction surface such as dry asphalt or concrete. For a slippery, moderately low friction surface such as a wet road, the linear range would be lower, perhaps between lateral accelerations of 0.05 and 0.2g (depending upon the surface of the road), while on ice the limits of the linear range would be still lower.

All light vehicles (including passenger cars, pickups, vans, minivans, crossovers, and sport utility vehicles) are designed to understeer in the linear range of lateral acceleration, although operational factors such as loading, tire inflation pressure, and so forth can in rare situations make them oversteer in use. This is a fundamental design characteristic. Understeer provides a valuable, and benign, way for the vehicle to inform the driver of how the available roadway friction is being utilized. Multiple tests have been developed to objectively quantify linear-range understeer, including SAE J266 and ISO 4138.

In the linear range of handling, ESC should never activate. ESC interventions occur when the driver's intended path (calculated by the ESC control algorithms using a constant linear range understeer gradient) differs from the actual path of the vehicle as measured by ESC sensors. Since by definition, this relationship is not violated while driving in the linear range, ESC intervention will not occur. Therefore, ESC has no effect upon the linear-range understeer of a vehicle.

Solving the linear range differential equations of motion for what the Millikens[97] refer to as the ''Elementary Automobile'' or ''bicycle'' model reveals that the understeer gradient has some very interesting mathematical properties.

First, the solutions to the linear range differential equations of motion are unconditionally stable[98] provided that the understeer gradient is positive (*i.e.*, the vehicle is understeer). For an oversteer vehicle,[99] solutions to the linear range differential equations of motion become unstable if the vehicle's speed exceeds the critical speed. The value of the critical speed depends upon the degree of oversteer the vehicle exhibits (and on other vehicle properties); however, a vehicle with reasonable amounts of oversteer can easily exceed the critical speed and become unstable during normal driving.

What does it mean when the solutions to the linear range differential equations of motion become unstable? It means that as soon as the unstable vehicle encounters a disturbance input (and in real driving, disturbance inputs such as small wind gusts or small bumps in the road occur very frequently), the actual solutions of the differential equation will rapidly diverge from the nominal solutions. In the real world, this means that the driver can no longer control the unstable vehicle by using the steering wheel. The unstable vehicle generally will rotate rapidly about a vertical axis (spin) and may change its direction of motion regardless of what the driver does with the steering wheel. From the safety point of view, a vehicle becoming unstable often has severe negative consequences, ranging from road departure to sideways impacts with off-road obstacles to tripped rollover.

Returning to the mathematical properties of the understeer gradient, we find that it also is a key parameter in determining the lateral responsiveness[100] of the vehicle. According to the solutions to the linear range differential equations of motion, the more a vehicle understeers, the less lateral responsiveness it will have (assuming, of course, that all other parameters are held constant).

For a vehicle to be safe, it must have adequate lateral responsiveness. Vehicles with too little lateral responsiveness will not be able to successfully maneuver around pedestrians, vehicles, or other objects that

[93] 71 FR 54712, 54716–54718 (Sept. 18, 2006).

[94] SAE J670e, ''Vehicle Dynamics Terminology,'' SAE Recommended Practice, Issued by the SAE Vehicle Dynamics Committee July 1952, last revised July 1976.

[95] For the reader's reference, ''trim'' is roughly defined as the vehicle's weight distribution at a given time. For example, loading the vehicle's trunk changes the trim.

[96] A less technical way of describing ''linear range'' would be the normal situation of everyday driving, where a given turn by the driver of the steering wheel causes an expected amount of turn of the vehicle itself, because the vehicle is operating at the traction levels to which most drivers are accustomed.

[97] Milliken, W.F., and Milliken, D.L., p. 144, ''Race Car Vehicle Dynamics,'' SAE International, 1995

[98] ''Unconditionally stable'' for a motor vehicle means that, regardless of the weight distribution, suspension configuration, tire cornering stiffness, or vehicle speed (provided the vehicle can be modeled by the Elementary Automobile or ''bicycle'' model), the vehicle will return to straight ahead driving after enough time (usually only a couple of seconds) has passed after the return of the steering wheel to the straight ahead position.

[99] A simple test illustrates the concepts of understeer and oversteer. A vehicle is driven around a circle at a constant speed, then the speed is slowly increased. If the vehicle tends to go off the outside of the circle so that the driver must increase steering to maintain the circle, then the vehicle is considered to be an understeer vehicle. If the vehicle tends to go off the inside of the circle so that the driver must reduce steering to maintain the circle, then the vehicle is considered to be an oversteer vehicle. Understeer and oversteer can affect the stability of a vehicle; however, just because a vehicle is an oversteer vehicle does not mean that it is uncontrollable. A more detailed discussion of understeer and oversteer and their impact on stability and control is contained in (a) William F. Milliken and Douglas L. Milliken, ''Simplified Steady State Stability and Control,'' Chapter 5, and ''Simplified Transient Stability and Control,'' Chapter 6 in *Race Car Vehicle Dynamics* (Warrendale, PA: Society of Automotive Engineers, 1995) 123–229 and 231–277; and (b) Thomas D. Gillespie, ''Rollover,'' Chapter 9 in *Fundamentals of Vehicle Dynamics* (Warrendale, PA: Society of Automotive Engineers, 1992) 309–333.

[100] Lateral responsiveness is defined here as how much a vehicle moves sideways in a given amount of time due to a specified rotation of the steering wheel.

may suddenly intrude into the roadway. They will also be more difficult to steer around turns in the road, requiring the driver to initiate steering earlier than for vehicles with adequate lateral responsiveness.

A safe vehicle, then, requires both stability and adequate lateral responsiveness. In the linear range of handling, this is achieved by having the vehicle understeer to a moderate degree. This explains why all light vehicles are designed to understeer in the linear range of lateral acceleration.

Next, consider driving situations that are outside of the linear range of handling. In this situation, the differential equations of motion, even for the ''Elementary Automobile'' or ''bicycle'' model become non-linear, complicated, and beyond the ability of humans to solve analytically. Vehicle dynamics simulations have been developed that use numerical integration to predict the vehicle trajectories. Unfortunately, the prediction of vehicle trajectories is insufficient to determine the stability of the vehicle, although it can be used to determine the lateral responsiveness of the vehicle.

To determine the stability of the solutions of the non-linear range differential equations of motion, the ''Method of Liapunov'' [101] is used. The Method of Liapunov consists of linearizing the non-linear differential equations about an operating point of the vehicle. Liapunov proved that the stability of the solutions of the linearized differential equations about an operating point is the same as the stability of the original non-linear differential equations about that same operating point. The term that determines the stability of the solutions of the linearized differential equations about an operating point is called the non-linear understeer gradient. However, unlike the linear understeer gradient, the non-linear understeer gradient is no longer constant. It will vary as a function of the vehicle's lateral acceleration.

Just as is the case for the linear range vehicle, for a vehicle to be safe at an operating point in the non-linear range, we must have both stability and adequate lateral responsiveness. Again, this is achieved by designing the vehicle to understeer to a moderate degree. However, for reasons that are explained below, it is impossible to attain this desirable condition over the entire non-linear operating range of the vehicle.

What NHTSA Means by Mitigating Excessive Understeer

All motor vehicles are limited as to how sharply they can turn. This fact has important implications for the non-linear understeer/oversteer of vehicles.

The behavior of a vehicle when turning as sharply as possible is referred to as the limit behavior of the vehicle. For vehicles with four wheels and two axles, there are exactly four possible limit behaviors. Each of these cases, and its implications for limit understeer/oversteer are discussed below.

Case 1—The vehicle plows out. For this case, how sharply the vehicle can turn is limited by the friction between the roadway and the tires on the vehicle's front axle. When the tires on the vehicle's front axle are producing as much side force as the road/tire friction permits, we say that the vehicle's front tires are saturated. When the front tires saturate before the rear tires, the vehicle continues to travel forward in as tight a curve as it can manage. The turn will not become tighter, even if the driver turns the steering wheel requesting a sharper turn. We call this behavior vehicle plow-out. While from a safety point of view it is never good for a vehicle to reach limit behavior, plow-out is the most benign form of limit behavior. Mathematically, plow-out corresponds to the non-linear understeer gradient remaining positive and becoming infinite at the limit of handling.

Case 2—The vehicle drifts out. For this case, the tires on both the vehicle's front and rear axles saturate at exactly the same time. Drift-out is extremely rare; it is very hard to saturate both axles at the same time. When drift-out occurs, the vehicle continues to travel forward in as tight a curve as it can manage (similar to plow-out) except that the vehicle will slowly (far more slowly than for Case 3, below) rotate about its vertical axis. Due to this slow rotation of the vehicle, from a safety point of view drift-out is not as benign as plow-out but it is better than spin-out (Case 3, below). Mathematically, drift-out corresponds to the non-linear understeer gradient remaining positive and becoming infinite at the limit of handling.

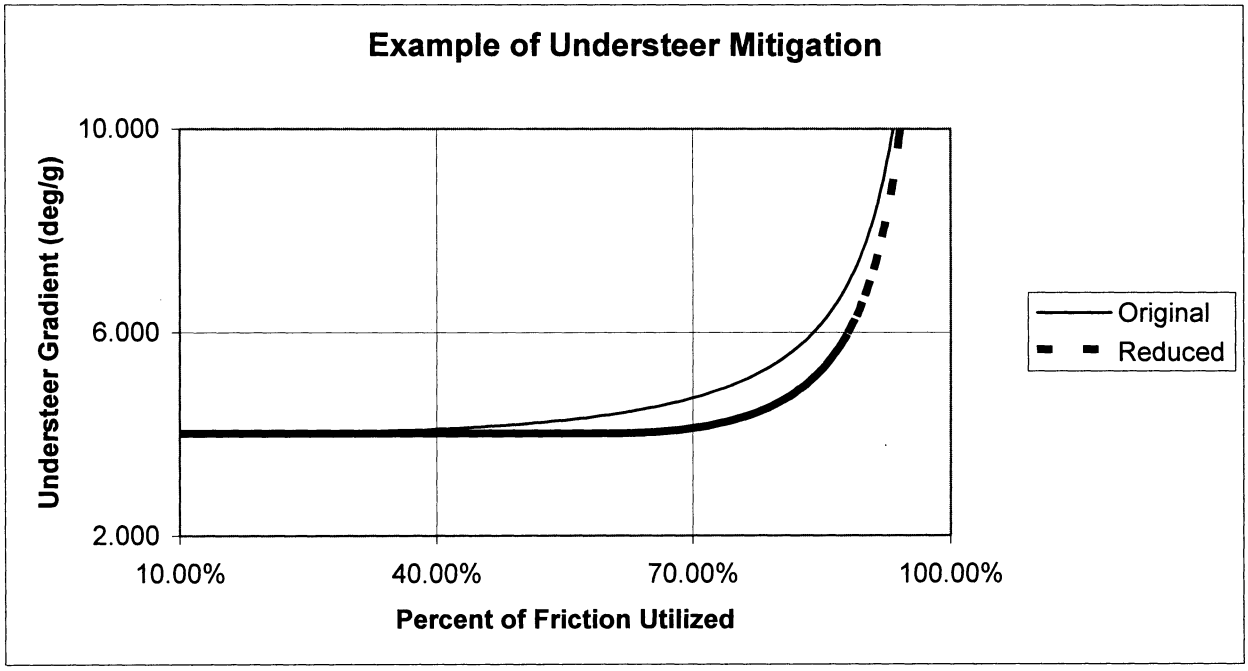
Case 3—The vehicle spins out. For this case, the tires on the vehicle's rear axle saturate first. When spin-out occurs, the vehicle continues to travel forwards in a curve while the rear of the vehicle rapidly rotates about its vertical axis. From the safety point of view, vehicle spin-out is very bad with negative consequences ranging from road departure to sideways impacts with off-road obstacles to tripped rollover. Mathematically, spin-out corresponds to the non-linear understeer gradient becoming negative and infinite (*i.e.*, the vehicle oversteers to an extreme degree) at the limit of handling.

Case 4—The vehicle rolls over. For this case, the tires on the vehicle's front and rear axles do not reach saturation. Instead, before the friction limit is reached, the vehicle's tires leave the roadway and the vehicle rotates rapidly about its longitudinal axis onto its side or roof. From the safety point of view, vehicle rollover is the worst type of limit behavior. It is also the only type of limit behavior in which the vehicle's behavior at the limit does not determine the non-linear understeer gradient at the limit of handling. Either understeer or oversteer, and by any amount, is possible for this case.

Summarizing the above cases, at the limit of handling a vehicle's understeer gradient will either be positive and infinite (plow-out and drift-out), negative and infinite (spin-out), or not determined (rollover). While both spin-out and rollover are major safety concerns, this discussion is concerned with mitigating excessive understeer. Therefore, in the following discussion, we will only deal with the case in which a vehicle's understeer gradient is positive and infinite at the limit of handling. Vehicles that behave in this manner are called ''terminally understeering.''

A terminally understeering vehicle's understeer gradient will then be a positive constant in its linear range and positive and infinite at the limit of handling. Between the upper limit of the linear handling range and the limit of handling, the non-linear understeer gradient will be positive and monotonically increasing. (Vehicles with local maxima in their non-linear understeer gradient usually become terminally oversteer although we are not aware of any proofs that this must occur.) Figure 1 shows a typical understeer gradient curve for a hypothetical vehicle without ESC (the curve marked ''Original''). The goal of mitigating excessive understeer is to use the ESC to reduce the non-linear understeer gradient over the range from 40 to 95 percent friction utilization to closer to the linear range understeer gradient. The curve marked ''Reduced'' in Figure 1 shows a hypothetical example of mitigation of excessive understeer.

[101] Birkhoff, G. and Rota, G.C., pp 134–136, ''Ordinary Differential Equations,'' Blaisdell Publishing Company, 1969.



Need for Care in Mitigating Excessive Understeer

Conceptually, the idea of ESC understeer mitigation makes good physical sense. In a situation where the vehicle does not sufficiently respond to the driver's steering input (*e.g.*, ''plowing'' when the driver attempts to steer around a corner), the automatic application of single-wheel braking torque to reduce understeer and increase the vehicle's lateral responsiveness, thereby tightening the turning radius, seems like a logical course of action. NHTSA researchers have participated in ESC demonstrations specifically designed to showcase understeer mitigation effectiveness, and acknowledge that in *certain driving situations, performed with certain vehicles, at certain vehicle speeds,* the technology can suppress excessive understeer, thereby improving the driver's ability to control the vehicle. However, truly understanding both what understeer mitigation can and, equally importantly, cannot do, is deceptively complicated. In fact, there are certain situations where understeer mitigation could potentially produce safety disbenefits if not properly tuned.

The technique used for mitigating excessive understeer is to apply unbalanced vehicle braking so as to generate an oversteering moment. Clearly, if too much oversteering moment is generated, then the vehicle may oversteer and spin out with obvious negative safety consequences.

Another possible problem with understeer mitigation is that reducing the non-linear understeer gradient increases the lateral responsiveness of the vehicle. This increases the lateral acceleration the vehicle can attain. For vehicles with low static stability factors and/or soft (in roll) suspensions, this may result in untripped rollover. Keep in mind that the idea of roll stability control (RSC) is to prevent untripped rollover by momentarily inducing excessive understeer, thereby reducing the lateral responsiveness of the vehicle and decreasing the lateral acceleration. Excessive understeer mitigation acts like anti-RSC. Based on this concern, ESC manufacturers generally do not perform understeer mitigation on high-coefficient-of-friction pavements for vehicles for which untripped rollover is possible (sport utility vehicles, pickup trucks, full sized vans).

For the reasons discussed above, understeer mitigation must be performed with great care. Too much mitigation can create safety problems (spin out or rollover).

Problems With Performance Tests for Mitigating Excessive Understeer

All current ESC designs that NHTSA has studied appear to include provisions for mitigating excessive understeer. How do we know this? We know this from driving these vehicles in the sort of maneuvers in which understeer mitigation should be performed and evaluating the resultant vehicle performance.

How are ESC algorithms for mitigating excessive understeer developed? Designers use a combination of analysis, vehicle dynamics simulation, and evaluation based on engineering judgment to develop the algorithms.

NHTSA cannot rely upon analysis, vehicle dynamics simulation, or evaluation based on engineering judgment for ensuring compliance with NHTSA regulations. We need a performance test, one that is objective, repeatable, generates reproducible results, is practicable to perform, and has acceptable face validity (*i.e.*, passing the test must enhance safety).

Tests designed to measure linear range understeer gradient (*e.g.* SAE J266 and ISO 4138) are not suitable to evaluate an ESC's understeer mitigation performance. ESC interventions occur when the driver's intended path differs from the actual path of the vehicle, as discussed above. Since this relationship is not violated during linear range driving, by the definition of linear range, ESC intervention will not occur. Without intervention, assessment of ESC performance is not possible.

NHTSA has carefully examined the existing vehicle dynamics literature including both the SAE and ISO standards. We have been unable to find any test designed to measure the non-linear understeer gradient over the full non-linear range of vehicle handling. A variety of theoretical difficulties make it unlikely that such test will ever be developed.

In order for ESC understeer mitigation to occur during a non-linear understeer mitigation scenario, differences between the calculated and actual paths of the vehicle must exceed a manufacturer-specified allowable threshold. NHTSA knows of no existing test protocol capable of objectively evaluating non-linear understeer mitigation. (Note that this is a somewhat different problem than that of measuring the non-linear understeer gradient over the full non-linear range of vehicle handling. The theoretical problems referred to above do not prevent the development of an objective test for evaluating non-linear understeer mitigation.)

What are the principal challenges to developing a suitable, objective, non-linear understeer mitigation performance test?

Dry Test Challenges

Understeer mitigation is only possible for vehicles that are designed to exhibit non-linear and terminal understeer. Although a reduction of understeer may allow the tires of these vehicles to better utilize the available friction, the subsequent increase in maximum lateral acceleration capacity is not desirable for all vehicles. Some vehicles, particularly those with low static stability factors such as sport utility vehicles, or those having soft (in roll) suspensions, understeer

designed into the chassis helps reduce the risk of on-road untripped rollover. By attempting to remove understeer, it is possible ESC could increase the likelihood of on-road untripped rollover.[102] Discussions with ESC manufacturers have indicated that tests performed on a high friction surface at moderate to high speeds may not trigger any understeer intervention from this type of vehicles' ESC systems. For this reason, NHTSA has concluded that it would be inappropriate to require that understeer mitigation occur in situations where vehicles are being operated on high friction surfaces at high speeds.

Unfortunately, the specific details of this potential compromise are not fully understood. NHTSA does not know of any vehicle whose understeer mitigation algorithms induce on-road untripped rollover, and therefore has no test data to objectively quantify the extent to which understeer mitigation may increase the likelihood of on-road untripped rollover beyond that realized with the same vehicle evaluated with ESC disabled. Nevertheless, if NHTSA were to require that understeer mitigation effectiveness be evaluated using a test performed on a dry high coefficient surface, the potential for achieving good understeer control on the test track at the expense of compromised real world driving safety cannot be ignored.

NHTSA notes that ESC systems containing rollover mitigation control (RSC) algorithms present another reason that understeer mitigation should not be evaluated on high friction surfaces. To create a state of non-linear understeer for testing purposes, large steering wheel angles and rates must be inputted. For vehicles with RSC, these severe inputs may be interpreted as a threat to the vehicle's roll stability. If RSC intervention occurs, the effect will be a brief period of substantially increased understeer, where no understeer mitigation would occur. Although NHTSA has no crash data quantifying the safety benefits of RSC, we do not want to preclude implementation of RSC technology as the result of an inappropriate understeer mitigation test.

In summary, performing tests designed to evaluate ESC understeer mitigation technology on dry, high friction surfaces presents too many problems. NHTSA then considered whether it could mandate such tests on low friction surfaces, as discussed below.

Wet Test Challenges

So as to avoid the problems associated with testing on dry, high-friction surfaces, NHTSA believes that ESC understeer mitigation performance testing must be performed on a low-friction test surface such as wet Jennite or wet basalt tiles. Use of low friction surfaces, where peak coefficient of friction would be expected to range between 0.3 and 0.5, would prevent the development of lateral accelerations capable of inducing on-road untripped rollover. This fact alone resolves many of the issues that plague the use of high friction surfaces for understeer mitigation assessment. NHTSA does not expect any adverse repercussions for requiring a properly tuned ESC to invoke understeer mitigation on low friction surfaces, regardless of vehicle type. Furthermore, since on-road untripped rollover is not expected, RSC intervention should not confound understeer mitigation assessment on low friction surfaces, as activation of such interventions should not occur.

Unfortunately, low friction tests have historically been plagued with high test variability when compared to otherwise equivalent tests performed on high friction surfaces. They can also be confounded by hydroplaning, and can be difficult-to-impossible to perform within the confines of the relatively small low friction test pads available at the various proving grounds. Resolution of these matters is imperative if understeer mitigation effectiveness is to be objectively assessed.

NHTSA performed numerous low-friction tests during the 2006 testing season. Most of these tests were based on the ''ramp steer'' maneuver, a test NHTSA believes is its best candidate for objectively evaluating ESC understeer mitigation performance. This maneuver uses a steering ramp (input at one of eight steering velocities) from zero to a target steering wheel angle, a brief pause, and a return of the steering wheel back to zero degrees. Using the ramp steer maneuver, data were collected during tests performed with three passenger cars, one sports car, three sport utility vehicles, and one 15-passenger van. To compare how the maneuver output might change as a function of surface, tests were performed on the Transportation Research Center's (TRC) Vehicle Dynamics Area Jennite pad, and on the General Motors Milford Proving Grounds basalt tile pad. Results from this testing will be provided in a detailed technical report, to be released spring 2007.

NHTSA is presently evaluating two ways to reduce factors contributing to test variability on low friction surfaces, specifically in the realm of improved water delivery and optimized water delivery-to-test-conduct timing. Preliminary results from NHTSA's 2006 understeer mitigation research indicated similar variability for tests performed on Jennite and basalt. From a logistics standpoint, this is important since basalt test pads of dimensions appropriate for use in understeer mitigation are not common. NHTSA knows of only one basalt pad capable of supporting understeer mitigation tests (located at the General Motors Milford Proving Grounds), and considers even the dimensions of this pad to be only marginally adequate. Construction of a new basalt facility capable of supporting ramp steer tests is cost-prohibitive for NHTSA, as such facilities cost millions of dollars. TRC's Jennite pad is also marginal for understeer mitigation testing. Again, increasing the size of the TRC Jennite pad will be extremely expensive, although not to the extent a basalt facility would be.

In short, resolution of low friction testing issues is the topic of ongoing research, and the primary challenge in the development of an objective and repeatable way of assessing light vehicle understeer mitigation effectiveness. However, there are many issues that remain to be resolved, ranging from a lack of large-enough test surfaces to possible performance criteria before NHTSA could have a suitable low coefficient of friction understeer mitigation performance test.

Based on preliminary results from NHTSA's 2006 understeer mitigation research, we have investigated two possible types of low coefficient of friction understeer mitigation performance tests. The easier type of test to perform will be called the Understeer Presence test, the more difficult type, the Full Understeer Performance test.

The Understeer Presence test would check that a vehicle is equipped with an ESC system that will limit vehicle understeer in at least some conditions. We are fairly confident that this test can be developed with one to two years of research. The drawback of this test is that it will accomplish nothing more than providing a means for NHTSA to check that a vehicle meets the understeer mitigation requirements of FMVSS 126. It is not clear that this test will be as robust as the method (see discussion below) that NHTSA intends to use in the absence of this test to check compliance with the understeer mitigation portion of FMVSS 126. In other words, having this test will do nothing to improve vehicle safety beyond the understeer requirement presently specified in FMVSS No. 126. Based on this fact, NHTSA's has no plans at this time to expend further effort to develop the Understeer Presence test.

The Full Understeer Performance test would actually impose further understeer mitigation requirements beyond those currently specified in FMVSS 126. We hope, but do not know, that these additional understeer mitigation requirements would further enhance vehicle safety. Unfortunately, development of the Full Understeer Performance test is expected to take at least five years and require provision of substantial financial resources.

To summarize the above discussion, we do not know of any existing objective performance tests for understeer mitigation. We believe that it is not appropriate to perform an understeer mitigation performance test on a dry, high coefficient of friction test surface. NHTSA has been working on a low coefficient of friction understeer mitigation performance test and has found some approaches that its researchers believe to be promising. However, considerable work remains to develop such a performance test.

How NHTSA Will Enforce FMVSS No. 126 Requirements Without an Understeer Performance Test

The final regulatory text for FMVSS No. 126 requires light vehicles to be equipped with a system meeting the definition of ESC. A portion of the revised ESC definition from that standard is:

Electronic Stability Control System or ESC System means a system that has all of the following attributes:* * *

(2) That is computer controlled with the computer using a closed-loop algorithm to

[102] It is important to note that the braking action present during ESC understeer mitigation intervention will help slow the vehicle somewhat, decreasing the amount of energy available to produce rollover.

limit vehicle oversteer and to *limit vehicle understeer;* (emphasis added)* * *

Without having a performance test for understeer mitigation, how will NHTSA ensure that light vehicles are equipped with a system that will limit vehicle understeer under these circumstances? This will be accomplished through a two part process: ensuring that vehicles have all of the hardware needed to limit vehicle understeer (as required by FMVSS No. 126), and checking engineering documentation provided by the vehicle and ESC manufacturers that the ESC algorithm is capable of recognizing and limiting excessive understeer.

The regulatory text of FMVSS No. 126 includes S5.1 *Required Equipment.* Under this section, S5.1.1 mandates that light vehicles must have an ESC system as follows:

S5.1.1 Is capable of applying brake torques individually to all four wheels and has a control algorithm that utilizes this capability.

Having the capability of applying all four brakes individually is necessary to allow the ESC to limit vehicle understeer when appropriate. ESC systems have been developed (called two-channel ESC systems) that are capable of applying only the vehicle's front brakes. These two-channel ESC systems can prevent crashes from occurring in three of the four ways that four-channel ESC systems can prevent crashes, although perhaps not as well. Two-channel ESC can: (1) Prevent the vehicle from becoming oversteer and spinning out, (2) preventing untripped vehicle rollovers by using RSC-type algorithms, and (3) slow the vehicle down. What two-channel ESC cannot do is mitigate excessive understeer.

The development of an ESC algorithm is a large and complicated task. Development of the understeer mitigation portion of such an algorithm requires much analysis, vehicle dynamics simulation, and testing by engineers. We anticipate that ESC manufacturers will document the results of such analysis, simulation, and testing. This engineering documentation can be shown to NHTSA when it is necessary to demonstrate that an ESC algorithm is capable of limiting vehicle understeer when appropriate.

In summary, we believe that the requirement that all light vehicles be equipped with an ESC system capable of applying all four brakes individually, combined with the engineering documentation developed by ESC manufacturers, will be sufficient to enforce the understeer requirements of the ESC definition in FMVSS No. 126.

Responses to Other Understeer-Related Issues

One commenter stated that some manufacturers might supply ESC systems that do not adequately compensate for understeer loss of control circumstances, arguing that there are already vast differences in tuning among various ESC systems. They predicted that failure of the agency to specify understeer performance requirements would maintain or expand differences between ESC performance from one vehicle make or model to another and could cause the standard to forgo prevention of additional fatalities and injuries. The commenter did not provide any data to support this ''prediction.'' NHTSA will continue to monitor the safety performance of vehicles equipped with different ESC systems. If we do see safety related differences between ESC performances from one vehicle make or model to another, we will use the information to require safer ESC systems. Unfortunately, we do not know today, and are unlikely to know for the next several years, what understeer performance requirements would improve safety.

One commenter argued that since SAFETEA–LU directs the agency to establish performance *criteria* for stability enhancing technologies (*i.e.*, noting the plural nature of that statutory provision, which they suggested requires something more than an oversteer *criterion* alone), including the understeer component that the agency has determined to be a necessary part of ESC systems from a safety perspective is also required from a legal perspective. We do not agree with this comment. While SAFETEA–LU does direct the agency to establish performance *criteria* (which we agree is plural) for stability-enhancing technologies, having both lateral stability and lateral responsiveness *criteria* in the current FMVSS 126 fulfills this Congressional requirement without adding an understeer performance test.

Conclusions about Understeer Mitigation

Multiple commenters have requested that we include a performance test for excessive understeer mitigation in FMVSS 126. A number of other questions about understeer mitigation were also asked in these comments.

We have tried in our response to these comments to fully explain NHTSA's position on this important issue. Unfortunately, mitigation of excessive understeer is an extremely complex technical problem, so our response has been long and technical. In this final section of the response, we will try to summarize the results of the previous discussion.

First, excessive understeer mitigation involves the non-linear understeer gradient, a very different quantity than the linear understeer gradient (a calculation that is commonly mentioned in vehicle dynamics literature). While the non-linear understeer gradient shares many important properties with the linear understeer gradient, the non-linear gradient is both theoretically and practically a far more complex concept.

Figure 1, presented previously, probably gives the clearest idea as to what we mean by mitigation of excessive understeer. The goal is for ESC to change the non-linear understeer gradient of the vehicle from the higher to the lower curve.

For reasons that were explained, mitigation of excessive understeer must be performed with great care. Too much mitigation can create safety problems (spin out or rollover).

Tests designed to measure linear range understeer gradient (*e.g.* SAE J266 and ISO 4138) are not suitable to evaluate an ESC's understeer mitigation performance. ESC interventions occur when the driver's intended path (*i.e.*, that calculated by the ESC control algorithms) differs from the actual path of the vehicle (*i.e.*, as measured by ESC sensors). Since by definition, this relationship is not violated during linear range driving, ESC intervention will not occur. Without intervention, assessment of ESC performance is not possible.

NHTSA has carefully examined the existing vehicle dynamics literature including both the SAE and ISO standards. We have been unable to find any test designed to measure the non-linear understeer gradient over the full non-linear range of vehicle handling. A variety of theoretical difficulties make it unlikely that such test will ever be developed.

In order for ESC understeer mitigation to occur during a non-linear understeer mitigation scenario, differences between the calculated and actual paths of the vehicle must exceed a manufacturer-specified allowable threshold. NHTSA knows of no existing test protocol capable of objectively evaluating non-linear understeer mitigation. (Note that this is a somewhat different problem than that of measuring the non-linear understeer gradient over the full non-linear range of vehicle handling. The theoretical problems referred to above do not prevent the development of an objective test for evaluating non-linear understeer mitigation.)

Performing tests designed to evaluate ESC understeer mitigation technology on dry high friction surfaces presents too many problems. Rather, NHTSA believes it is much more appropriate to perform such tests on low friction surfaces.

NHTSA would like to include a performance standard for understeer mitigation in FMVSS No. 126. Unfortunately, we do not know of any existing objective performance tests for understeer mitigation. We believe that it is not appropriate to perform an understeer mitigation performance test on a dry, high coefficient of friction test. NHTSA has been working on a low coefficient of friction understeer mitigation performance test and has found some approaches that its researchers believe to be promising. However, considerable effort remains to develop such a performance test. Based on expected costs and benefits, NHTSA is not currently developing such a test.

Without having a performance test for understeer mitigation, how will NHTSA ensure that light vehicles are equipped with a system that will limit vehicle understeer when appropriate? This will be accomplished through a two part process: ensuring that vehicles have all of the hardware needed to limit vehicle understeer (as required by FMVSS No. 126), and checking engineering documentation provided by the vehicle and ESC manufacturers that the ESC algorithm is capable of limiting vehicle understeer when appropriate.

In conclusion, while NHTSA would like to include a performance standard for understeer intervention in FMVSS No. 126, we unfortunately do not know of any suitable performance tests for mitigation of excessive understeer. We are unwilling to forgo the

large safety benefits that ESC will provide to the American public in the near future just because we might, some years from now, be able to produce a better standard. If, in the future, we see ways to improve FMVSS No. 126 to increase motoring safety, NHTSA would at that time undertake another rulemaking activity to gain those benefits.

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