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THE POTENTIAL REGULATORY CHALLENGES OF INCREASINGLY AUTONOMOUS MOTOR VEHICLES¹

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1. The opinions and conclusions expressed in this Article are those of the authors and not necessarily those of the United States Department of Transportation (DOT) or the National Highway Traffic Safety Administration (NHTSA).

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INTRODUCTION

While talking about the regulation of fully autonomous² motor vehicles—cars that can drive themselves—might seem premature, some of the technologies that will make autonomous motor vehicle operation possible are already appearing in vehicles. Indeed, the first demonstrations of some of these technologies date as far back as 1939.³ Recent research by companies, such as Google,⁴ and the Grand and

2. This Article generally uses the term “autonomous,” instead of the term “automated.” We have chosen to use the term “autonomous” because it is the term that is currently in more widespread use (and thus is more familiar to the general public). However, the latter term is arguably more accurate. “Automated” connotes control or operation by a machine, while “autonomous” connotes acting alone or independently. Most of the vehicle concepts (that we are currently aware of) have a person in the driver's seat, utilize a communication connection to the cloud or other vehicles, and do not independently select either destinations or routes for reaching them. Thus, the term “automated” would more accurately describe these vehicle concepts.

3. General Motors' (GM) 1939–40 New York World's Fair exhibit entitled “Futurama” was one of the early examples of an autonomous vehicle concept. Its concept involved automated vehicles traveling in dedicated lanes and being guided safely through traffic by radio control signals from a traffic control tower. See RANDAL O'TOOLE, *GRIDLOCK: WHY WE'RE STUCK IN TRAFFIC AND WHAT TO DO ABOUT IT* 189–91 (2009).

4. Google has developed a small fleet of autonomous vehicles that rely on video cameras, radar sensors, laser range finders, and maps collected by the company and are always manned with a driver trained to take over by disengaging cruise control when necessary. Sebastian Thrun, *What We're Driving At*, OFFICIAL GOOGLE BLOG (Oct. 9, 2010, 12:00 PM),

Urban Challenges⁵ sponsored by the Defense Advanced Research Programs Agency (DARPA) have sought to develop autonomous driving technologies further with an eye toward large-scale civilian and military deployment. Notwithstanding the steady progress being made, systems designed to assume complete control from the driver, including the performance of safety critical operations, are not yet feasible as they are incapable at this stage in their technological development of resolving and navigating through all of the many different driving scenarios that might arise. Although there are many technical challenges that must be overcome before vehicles can drive themselves reliably in all scenarios, many autonomous driving technologies are being incorporated into vehicles sold today for use in discrete scenarios. In the near future, more and more vehicles will be equipped with various autonomous driving technologies, creating the potential for large safety and mobility (i.e., congestion reduction) benefits. The mobility benefits would, in turn, have fuel consumption and carbon dioxide emission reduction benefits.

Government actions can influence the extent and the speed with which autonomous driving technologies are adopted. For example, in the most recent revision of the New Car Assessment Program (NCAP),⁶ the National Highway Traffic Safety Administration (NHTSA) initiated the practices of making recommendations to consumers regarding those advanced crash avoidance technologies that the agency deemed most promising (based on existing data regarding

<http://googleblog.blogspot.com/2010/10/what-were-driving-at.html>. Sebastian Thrun is a Google Vice President and Fellow, and a Research Professor at Stanford University. *Sebastian Thrun*, STANFORD.EDU, <http://robots.stanford.edu/index.html> (last visited May 13, 2012). As of late March 2012, the mileage total had reached 200,000 miles. GOOGLE+, <https://plus.google.com/u/0/116899029375914044550/posts/MVZBmrnzDio#116899029371168990293/posts/MVZBmrnzDio> (last visited Oct. 9, 2012).

5. See Defense Advanced Research Projects Agency, *History*, DARPA.MIL, <http://www.darpa.mil/About/History/Archives.aspx> (last visited Oct. 9, 2012) (listing archival material relating to these challenges).

6. NCAP enables the agency to publish comparative safety information, which encourages manufacturers to voluntarily improve safety in their vehicles. See NAT'L HIGHWAY TRAFFIC SAFETY ADMIN., DOT HS 810 698, THE NEW CAR ASSESSMENT PROGRAM SUGGESTED APPROACHES FOR FUTURE PROGRAM ENHANCEMENTS (2007), available at <http://www.safercar.gov/staticfiles/DOT/safercar/pdf/810698.pdf>.

their effectiveness) and of identifying those vehicles that are equipped with these systems.⁷ In addition, NHTSA has publicly announced that it will work toward a decision⁸ in 2013 on whether to initiate rulemaking to mandate and set performance requirements for various advanced crash avoidance technologies whose effectiveness could be increased through vehicle-to-vehicle (V2V) communications.⁹ As the United States government agency responsible for the safety of new motor vehicles, NHTSA will inevitably play a vital role in monitoring, encouraging, conducting research regarding and, as necessary, regulating autonomous driving technologies through the application of the agency's authority over motor vehicles and motor vehicle equipment. As motor vehicles incorporating these technologies become an increasingly larger part of the overall fleet of vehicles in operation, the crash data are expected to begin to show the significant safety benefits of these technologies. Where needed to address safety risks arising from any of the vehicles with these technologies, the agency will take appropriate action. NHTSA has broad authority to regulate these new technologies and currently has various regulatory tools/methods that can be applied in addressing these new potential challenges.

With this perspective in mind, this Article begins with a brief overview of some of the autonomous driving technologies

7. See Press Release, NHTSA, Auto Safety Agency Unveils List of Vehicles to be Tested as Part of Revamped Safety Ratings Program (Oct. 13, 2011), available at <http://www.nhtsa.gov/About+NHTSA/Press+Releases/2011/ci.NHTSA+Announces+Model+Year+2012+Vehicles+to+be+Rated+Under+Government+5-Star+Safety+Ratings+Program.print>.

8. See NAT'L HIGHWAY TRAFFIC SAFETY ADMIN., NHTSA VEHICLE SAFETY AND FUEL ECONOMY RULEMAKING AND RESEARCH PRIORITY PLAN 2011–2013 (2011), available at http://www.nhtsa.gov/staticfiles/rulemaking/pdf/2011-2013_Vehicle_Safety-Fuel_Economy_Rulemaking-Research_Priority_Plan.pdf.

9. Vehicle-to-Vehicle Communications for Safety is the wireless exchange of data between nearby vehicles that offers the opportunity for significant safety improvements. By exchanging vehicle-based data regarding position, speed, and location (at a minimum), V2V communications enables a vehicle to: sense threats and hazards with a 360-degree awareness of the position of other vehicles and the threat or hazard they present; calculate risk; issue driver advisories or warnings; or take pre-emptive actions to avoid and mitigate crashes. *Connected Vehicles Applications: Vehicle to Vehicle (V2V) Communications for Safety*, RESEARCH & INNOVATIVE TECH. ADMIN. (Aug. 16, 2012, 12:02 PM), <http://www.its.dot.gov/research/v2v.htm> [hereinafter *Connected Vehicles Applications*].

(including advanced crash avoidance technologies) that lead to the autonomous motor vehicle. Then, this Article reviews NHTSA's regulatory authority and explores the possible role that the agency might play in the implementation of autonomous driving technologies. Afterward, the Article evaluates some of the challenges of developing and drafting appropriate and effective standards for these new technologies, investigating defects, and encouraging voluntary adoption of safety technologies (through programs like NCAP). In these sections, we conclude that (while additional research and information will likely be necessary) many of the current methods used by NHTSA can still be applied to these advanced technologies.

I. TODAY'S ADVANCED TECHNOLOGIES MAKE AUTONOMOUS MOTOR VEHICLES POSSIBLE

It is important to understand at the outset that autonomous driving technologies do not represent a far-fetched, futuristic concept. There is a continuum of these technologies, and many of them are already available today.¹⁰ As current advanced crash avoidance technologies become more developed and are able to work in conjunction with each other, vehicles will increasingly become able to drive autonomously.¹¹

A. *Progressing from Driver Monitoring and Control to Vehicle Monitoring and Control*

For the purposes of this Article, we will be using the NHTSA approach to defining the different levels of autonomy¹² (see below). In NHTSA's research, the agency has

10. For example, as lane-keeping technology and adaptive cruise control mature, these two technologies could theoretically work together to enable a vehicle to drive autonomously in a lane of a limited access highway. See Damon Lavrinc, *Next Audi Flagship Will Drive Autonomously in Traffic Jams*, AUTOBLOG (Jan. 12, 2012, 12:31 PM), <http://www.autoblog.com/2012/01/12/next-audi-flagship-will-drive-autonomously-in-traffic-jams/> (Audi's new system that will enable autonomous driving in traffic jam situations).

11. See Bill Howard, *The Almost-Self-Driving Lincoln Won't Let You Drive Hands-off*, EXTREMETECH (Nov. 29, 2011, 2:13 PM), <http://www.extremetech.com/extreme/107037-the-almost-self-driving-lincoln-won%E2%80%99t-let-you-drive-hands-off> (describing how automakers are linking current crash avoidance technologies to achieve low level automation).

12. For its own internal purposes, NHTSA uses the term "automation"

used five categories to describe different levels of autonomy. These levels are shown in the following table.

	Level 0	Level 1	Level 2	Level 3	Level 4	
Human	Non-Auto.	Auto.-Assist'd	Monitor'd Auto.	Cond'l Auto.	Full Auto.	Computer

1. *Non-Automated*

In this category, the human is in complete and sole fundamental control of the vehicle at all times. While current vehicles (without any advanced crash avoidance technologies) can be included in this category, vehicles with warning systems that assist drivers also fall into this category. Vehicles equipped with these technologies will not assume control for any driving tasks, but will provide additional information to the driver and/or warn the driver of situations requiring immediate attention. Navigational global positioning systems (GPS) are an example of a currently available technology which provides information useful to the overall task of driving, and potentially highly valuable to V2V communications.¹³ Lane Departure Warning (LDW) is an example of a currently available warning technology.¹⁴ This technology alerts the driver when his or her vehicle begins to drift out of the lane of travel.¹⁵ Like other information and

instead of “autonomy” for the reasons explained in *supra* note 2.

13. At the heart of V2V communications is a basic application known as the *Here I Am* data message. See *Connected Vehicles Applications*, *supra* note 9. This message can be derived using non-vehicle-based technologies such as GPS to identify location and speed of a vehicle, or vehicle-based sensor data wherein the location and speed data is derived from the vehicle’s computer and is combined with other data such as latitude, longitude, or angle to produce a richer, more detailed situational awareness of the position of other vehicles. *Id.*

14. Lane Departure Warning is currently available on Infiniti and Mercedes Benz models among others. *E-Class Sedan*, MERCEDES-BENZ USA, <http://www.mbusa.com/mercedes/vehicles/class/features/class-E/bodystyle-SDN/vehicle-safety> (last visited Oct, 9, 2012); *Infiniti M: Specifications and Options*, INFINITI USA, <http://www.infiniti.com/m/specs-options> (last visited Oct, 9, 2012).

15. NAT’L HIGHWAY TRAFFIC SAFETY ADMIN., DOT HS 811 405, ADVANCED CRASH AVOIDANCE TECHNOLOGIES (ACAT) PROGRAM – FINAL REPORT OF THE VOLVO-FORD-UMTRI PROJECT: SAFETY IMPACT METHODOLOGY FOR LANE DEPARTURE WARNING – METHOD DEVELOPMENT AND ESTIMATION OF BENEFITS

warning technologies, a LDW system does not intervene to prevent the driver from departing the lane.¹⁶ It merely monitors the lane markings on the roadway to determine whether the vehicle is keeping within its current driving lane.¹⁷ LDW systems can also warn the driver if lane markings cannot be detected or if the system malfunctions.¹⁸

2. *Automation-Assisted*

The “automation-assisted” category still leaves the driving authority squarely with the driver. However, under limited normal driving or crash imminent circumstances, technologies in this category will take control away from the driver. An example of this type of technology is the electronic stability control (ESC). ESC systems use automatic computer-controlled braking of individual wheels to assist a driver in maintaining control in critical driving scenarios 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).¹⁹ Another advanced example of automation-assisted driving is a lane-keeping system that will actively steer a vehicle back toward the center of its lane when the system detects that the vehicle is drifting into an adjacent lane or is on a collision course with a vehicle in an adjacent lane.²⁰

14 (2010), available at <http://www.nhtsa.gov/DOT/NHTSA/NVS/Crash%20Avoidance/Technical%20Publications/2010/811405.pdf> [hereinafter NHTSA, ACAT PROGRAM].

16. *Id.*

17. *Id.*; FED. MOTOR CARRIER SAFETY ADMIN., CONCEPT OF OPERATIONS AND VOLUNTARY OPERATIONAL REQUIREMENTS FOR LANE DEPARTURE WARNING SYSTEMS ON-BOARD COMMERCIAL MOTOR VEHICLES (2005), available at <http://www.fmcsa.dot.gov/facts-research/research-technology/report/lane-departure-warning-systems.htm>.

18. *Id.*

19. Federal Motor Vehicle Safety Standards; Electronic Stability Control Systems; Control and Displays, 72 Fed. Reg. 17,236 (Apr. 6, 2007) (final rule) (codified at 49 C.F.R. pt. 571). NHTSA issued a notice of proposed rulemaking on May 23, 2012, proposing to require ESC on all vehicles with a gross vehicle weight rating over 26,000 pounds. Federal Motor Vehicle Safety Standards; Electronic Stability Control Systems for Heavy Vehicles, 77 Fed. Reg. 30766 (proposed May 23, 2012) (to be codified 49 C.F.R. pt. 571), available at <http://www.gpo.gov/fdsys/pkg/FR-2012-05-23/pdf/2012-12212.pdf>.

20. NHTSA, ACAT PROGRAM, *supra* note 15, at 14. NHTSA is currently conducting research on advanced braking technologies that utilize forward-looking sensors to detect impending crashes and assist the driver in avoiding or

3. *Monitored Automation*

The “monitored automation” category is the first category in which the technology will share the driving responsibility with the driver. However, in this category, the human driver is expected to be ready to take control of the vehicle at all times. Thus, the autonomous technology is only able to assume the responsibility of driving when the conditions permit. For example, some vehicles on the market today are available with automatic parallel parking systems. This type of technology differs from automation-assisted driving technologies because the driver gives a general command to the vehicle (e.g., “park in this space”) and the vehicle effectuates that command by assuming control of the steering and making the necessary steering calculations.²¹ Another potential example is the combination of adaptive cruise control with lane-keeping. The combination of these two technologies would potentially enable vehicles to proceed down the freeway with little or no input from the driver. However, depending on the level of sophistication in this system, drivers might still be required to intervene at any moment (e.g., lane markings disappear and the vehicle can no longer position itself in the center of the lane).

4. *Conditional Automation*

In this category, the technology is sufficiently reliable such that the human driver is able to completely cede the driving responsibility to the autonomous driving system under certain circumstances. This category differs from “monitored automation” systems as drivers using “conditional automation” systems would not need to be able to assume control of the vehicle within a moment’s notice. In theory, the vehicle would be able to warn the driver of an impending condition sufficiently in advance so that the driver can safely

mitigating these crashes. See Advanced Braking Technologies that Rely on Forward-Looking Sensors; Request for Comments, 77 Fed. Reg. 39561 (July 3, 2012) (soliciting comment on test protocols used to evaluate sensor based dynamic braking systems and the performance of these systems), available at <http://www.gpo.gov/fdsys/pkg/FR-2012-07-03/pdf/2012-16250.pdf>.

21. See Doug Newcomb, *Self-Parking Systems Comparison Test*, EDMUNDS INSIDE LINE (Nov. 26, 2010), <http://www.insideline.com/features/self-parking-systems-comparison-test.html>.

take control. However, the drivers would be expected to be available to take control when so warned.

5. *Full Automation*

As the final category in the above diagram, “full automation” driving encompasses all of the systems necessary for the vehicle to perform automatically and independently all driving tasks in all driving scenarios. This vehicle would integrate various technologies from the previous three categories to perform all driving tasks such that a person is no longer driving. An example of a technology in this category would be a vehicle that is capable of bringing the driver anywhere. The only driver input would be the destination. The vehicle would be responsible for all driving decisions and actions during travel.

B. *Connected Vehicle Technologies Can Reinforce and Complement Autonomous Technologies*

As an added dimension, it is important to note that the technologies on the continuum (stretching from today’s advanced crash avoidance technologies to tomorrow’s autonomous driving system) can use different methods for obtaining information to make judgments about a vehicle’s surroundings (such as through the use of sensors or communications with other vehicles/infrastructure).²²

Thus, an “autonomous motor vehicle” is a concept distinct from a “connected vehicle” (a vehicle which communicates with other vehicles or infrastructure). A vehicle can perform autonomous driving functions without communicating with other vehicles, and a connected vehicle might have the ability to receive information and relay it to the driver, but might not have the ability to drive autonomously. For example, the lane departure warning safety function described above could be accomplished through the use of only sensors/cameras or it

22. See, e.g., Kathleen Doheny, *Technology Aimed at Helping Drowsy Drivers Stay Awake*, EDMUNDS.COM (Jan. 12, 2012) <http://www.edmunds.com/car-safety/technology-aimed-at-helping-drowsy-drivers-stay-awake.html> (stating that current forward collision warning and lane departure warning systems often use cameras and sensors). See also *Connected Vehicles Applications*, supra note 9 (listing the various safety applications being researched for vehicle-to-vehicle communications, which includes forward collision warnings and lane change warnings).

could be accomplished through the use of a communication between vehicles identifying each vehicle's position and heading.²³ Further, as evidenced by Google's autonomous motor vehicle project, autonomous driving can be possible through the use of cameras and sensors without any vehicle communications apart from map updates.²⁴ While communications can be an enabling technology which can provide an effective means to augment or supplant the same functions of vehicle sensors and cameras, future deployment of autonomous motor vehicles or vehicles with advanced crash avoidance technologies (such as lane departure warnings) can occur independent of vehicle communications.

NHTSA has been exploring the use of vehicle communications as a way to complement or (in some scenarios) act as an alternative for sensor-based detection for advanced crash avoidance systems.²⁵ The research concept is that vehicles would transmit safety-related information (e.g., location, direction and speed) to each other so as to enable each vehicle to identify potential conflicts (i.e., collisions). After these conflicts are identified, vehicles could issue warnings for the driver or possibly take evasive or preemptive action in order to avoid or at least mitigate a crash.²⁶ The research explores various types of crash scenarios that can be addressed through V2V communications and identifies seven crash scenarios that could be effectively addressed by this technology (such as forward collision, lane departure, and intersection movement assist).²⁷ From these studies, it appears that vehicle communications have the potential to act

23. See Doheny, *supra* note 22.

24. See John Markoff, *Smarter Than You Think: Google Cars Drive Themselves, in Traffic*, N.Y. TIMES, Oct. 10, 2010, at A1, available at <http://www.nytimes.com/2010/10/10/science/10google.html>.

25. See NAT'L HIGHWAY TRAFFIC SAFETY ADMIN., DOT HS 811 492A, VEHICLE SAFETY COMMUNICATIONS APPLICATIONS (VSC-A) FINAL REPORT xi (2011), available at <http://www.nhtsa.gov/DOT/NHTSA/NVS/Crash%20Avoidance/Technical%20Publications/2011/811492A.pdf> [hereinafter NHTSA, VSC-A FINAL REPORT].

26. See NAT'L HIGHWAY TRAFFIC SAFETY ADMIN., DOT HS 811 373, USDOT CONNECTED VEHICLE RESEARCH PROGRAM: VEHICLE-TO-VEHICLE SAFETY APPLICATION RESEARCH PLAN 1 (2011), available at <http://www.nhtsa.gov/DOT/NHTSA/NVS/Crash%20Avoidance/Technical%20Publications/2011/811373.pdf>.

27. See NHTSA, VSC-A FINAL REPORT, *supra* note 25, at xii.

not only as an enabling technology for autonomous motor vehicles, but also as a technology that can enhance an autonomous motor vehicle's ability to identify potential problems and take appropriate actions to avoid them. V2V communications have the potential to provide additional information to the autonomous motor vehicle (covering areas beyond the range of the on-board sensors) and enable more robust performance of autonomous driving technologies.

While there is a significant degree of overlap between what vehicles can achieve using sensor-based crash avoidance technologies and what vehicles can achieve using V2V communications, there are some areas in which the capabilities of these systems differ. Sensor-based technologies might have a greater capacity to avoid single vehicle crashes because V2V communications rely on the presence of other vehicles to avoid crashes while sensors have the ability to operate independently of other vehicles. Sensor-based technologies might enable a vehicle to determine its location more accurately in some settings, e.g., urban areas with tall buildings.²⁸ Conversely, V2V communications might be able to prevent crashes that sensor-based crash avoidance technologies cannot because V2V communications systems can communicate information beyond the range of sensor-based technologies.²⁹

As discussed below in the next section, legal issues that apply to autonomous motor vehicles and connected vehicles are closely related.

II. NHTSA'S GENERAL AUTHORITY OVER MOTOR VEHICLE SAFETY

Congress enacted the National Traffic and Motor Vehicle Safety Act (the "Safety Act" or "the Act") in 1966 with the purpose of reducing deaths and injuries as a result of motor vehicle crashes and non-operational safety hazards

28. Jesse Levinson and Sebastian Thrun, Stanford University, 2010 IEEE International Conference on Robotics and Automation: Robust Vehicle Localization in Urban Environments Using Probabilistic Maps (May 3-8, 2010).

29. An example of such a scenario is an intersection crash for which V2V communications might be able to provide a warning that another vehicle is about to enter the intersection at a high rate of speed but a sensor-based system may not be able to provide such a warning because of the angle involved and the limited range of the sensors.

attributable to motor vehicles.³⁰ The Act, as amended, is now codified as 49 U.S.C. §§ 30101 *et seq.*

To accomplish this purpose, the Act authorizes NHTSA to use several major tools to address motor vehicle safety concerns associated with motor vehicles³¹ and motor vehicle equipment.³² The Act authorizes the agency to set motor vehicle safety standards for new motor vehicles and motor vehicle equipment and requires the recall and remedy of vehicles and equipment that do not comply with the standards in place at the time of manufacture.³³ It also authorizes NHTSA to conduct investigations about possible safety defects and requires the recall and remedy of motor vehicles and motor vehicle equipment determined to have a safety defect. We will briefly introduce each tool below.

The Act mandates that the standards to be issued by NHTSA be “practicable, meet the need for motor vehicle safety and [be] stated in objective terms.”³⁴ In order to issue a standard, NHTSA must determine that the vehicle or item of equipment falls under NHTSA’s authority (i.e., is a motor vehicle or item of motor vehicle equipment within the meaning of the Act), that there is a safety need, and that the standard will meet that need. The Act also establishes a self-certification framework for ensuring compliance with the safety standards. Under this framework, NHTSA establishes performance standards³⁵ for motor vehicles and motor vehicle equipment to which manufacturers of these products are required to certify that their products conform. NHTSA does not certify or approve products.

The agency does not regulate the actions of vehicle owners, the operation of motor vehicles on public roads or the maintenance and repair of vehicles-in-use. Further, NHTSA

30. H.R. REP. NO. 89-1776, at 10 (1966).

31. *See* 49 U.S.C. § 30102(a)(6) (2006).

32. *See* § 30102(a)(7).

33. Manufacturers must certify that their products comply with the applicable Federal Motor Vehicle Safety Standards (FMVSS) at the time of manufacture.

34. 49 U.S.C. § 30111(a) (2006).

35. H.R. REP. 89-1719, at 15 (1966) (stating that, while Congress intended to protect the public from “inherently dangerous designs,” Congress did not intend for motor vehicle safety standards to directly address issues of vehicle design).

has only limited authority to prevent after-market modifications that remove or reduce the effectiveness of the federally-required safety features of a vehicle. While various types of commercial entities are prohibited by the Act from making such modifications to motor vehicles owned by other parties, vehicle owners may modify their own vehicles.³⁶ Further, NHTSA does not have authority to require retrofitting of older vehicles with new safety equipment unless the vehicle is a commercial vehicle.³⁷ Thus, NHTSA works with the States regarding the making of periodic inspections to ensure that certain basic safety equipment on vehicles remains intact and functional after vehicles cease to be new, i.e., after their first sale for purposes other than resale.³⁸

Manufacturers are obligated to recall and remedy without charge motor vehicles and motor vehicle equipment that are determined to fail to comply with one of the agency's standards or to contain a defect that poses an unreasonable risk to motor vehicle safety.³⁹ If NHTSA makes the determination, it must do so through a process that allows the affected manufacturer a chance to be heard.⁴⁰ In almost all cases, however, the determination is made by the manufacturer (although often after the agency has initiated an investigation).⁴¹

36. The Safety Act expressly prohibits motor vehicle repair businesses from "mak[ing] inoperative any part of a device or element of design installed on or in a motor vehicle or motor vehicle equipment in compliance with an applicable [FMVSS]." See 49 U.S.C. § 30122(b) (2006).

37. See 49 C.F.R. § 1.95(c) (2010) (delegating to NHTSA, in coordination with the Federal Motor Carrier Safety Administration (FMCSA), the powers vested in the Secretary of Transportation by subchapter III of chapter 311 of title 49 of the United States Code to promulgate safety standards for commercial motor vehicles and equipment subsequent to initial manufacture).

38. To aid the States in conducting inspections of used vehicles, 49 U.S.C. § 30126 directed NHTSA to establish safety standards for the inspection of used vehicles. See 49 U.S.C. § 30126 (2006). Pursuant to that direction, NHTSA established standards to be used by the States in conducting inspections. See 49 C.F.R. pt. 570 (2010).

39. 49 U.S.C. §§ 30118, 30120 (2006).

40. § 30118(b).

41. See Christopher Jensen, *2010 a Record Year for 'Voluntary' Recalls*, N.Y. TIMES WHEEL BLOG (Jan. 20, 2011, 11:33 AM), <http://wheels.blogs.nytimes.com/2011/01/20/2010-a-record-year-for-voluntary-recalls/>.

In addition to setting mandatory vehicle safety standards to which vehicles must be certified, NHTSA also conducts the New Car Assessment Program (NCAP) that generates and provides the public with comparative performance ratings to encourage vehicle manufacturers to improve the safety of their vehicles voluntarily. Since 1979, NHTSA has been giving safety ratings to certain new vehicles through NCAP.⁴² Currently, “NHTSA rates a sample of new vehicles that are predicted to have high sales volume, those that have been structurally redesigned, or those with improved safety equipment.”⁴³ Those vehicles are assigned a rating from one to five stars (lowest to highest) based on their success in frontal and side crash tests and in rollover resistance tests.⁴⁴ In the crash tests, anthropomorphic dummies are placed in the test vehicles. The dummies are equipped with accelerometers that measure the forces to which the dummies are subjected in those tests. Vehicles with body structures, energy absorbing materials and restraint systems that are relatively more effective in managing the crash forces receive higher scores.

NCAP ratings are made publicly available and vehicle manufacturers may advertise these ratings, thus providing an incentive to achieve higher ratings. High NCAP scores are widely used by vehicle manufacturers in advertising to demonstrate to potential buyers the safety attributes of the vehicles they produce. Thus, through providing the public with objective information on the relative safety performance of new vehicles, NCAP has been successful in achieving its purpose of creating consumer awareness of those differences, thereby creating market forces that prompt vehicle manufacturers to make added safety improvements to their

42. U.S. GOV'T ACCOUNTABILITY OFFICE, GAO-05-370, VEHICLE SAFETY: OPPORTUNITIES EXIST TO ENHANCE NHTSA'S NEW CAR ASSESSMENT PROGRAM 8 (2005).

43. See *NHTSA 5-Star Ratings FAQ*, SAFERCAR.GOV, <http://www.safercar.gov/FAQ> (last visited Oct. 22, 2012).

44. NHTSA's NCAP program has been publishing comparative consumer information on frontal crashworthiness of new vehicles since 1979, on side crashworthiness since 1997, and on rollover resistance since January 2001. Consumer Information Regulations; Federal Motor Vehicle Safety Standards; Rollover Resistance, 66 Fed. Reg. 3388 (Jan. 12, 2001) (Response to Comments, Notice of Final Decision).

vehicles.⁴⁵ Additionally, as a result of recent amendments by the Moving Ahead for Progress in the 21st Century Act—“MAP-21,”⁴⁶ the agency may require that additional types of NCAP information be displayed on the “Monroney label,” which is affixed to the side window of new automobiles.⁴⁷ Thus, consumers have this safety information at the point of sale

Recently, NHTSA has begun under the NCAP Program to note online the presence in vehicle models of three types of voluntarily-installed crash avoidance systems: electronic stability control, lane departure warning and forward collision warning. In order to have one of these crash avoidance systems listed on NCAP website (safercar.gov) for a vehicle model, the manufacturer must design the system so that it meets the minimum performance criteria established by the agency for that type of system.

III. NHTSA’S BROAD AUTHORITY OVER AUTONOMOUS DRIVING TECHNOLOGIES AND EQUIPMENT

The vehicle technologies that make autonomous operation possible are vastly different than those that existed when the Safety Act was enacted in 1966. Then, the vehicle operating systems were largely mechanical and controlled by the driver via mechanical inputs and linkages. Components and systems were either designed into the vehicle at the time

45. U.S. GOV’T ACCOUNTABILITY OFFICE, *supra* note 42, at 2.

46. Moving Ahead for Progress in the 21st Century Act of 2012, Pub. L. No. 112-141, 126 Stat. 405 (2012), available at <http://www.gpo.gov/fdsys/pkg/BILLS-112hr4348enr/pdf/BILLS-112hr4348enr.pdf>.

47. In 2005, Congress enacted the Safe, Accountable, Flexible, Efficient Transportation Equity Act: A Legacy for Users (SAFETEA-LU), requiring automobile manufacturers to disclose NCAP ratings for new vehicles on Monroney labels as of September 1, 2007. Pub. L. No. 109-59, § 10307, 119 Stat. 1941 (current version at 15 U.S.C. § 1232(g)–(h) (2006)). This requirement was modified by the recent enactment of MAP-21. Pub. L. No. 112-141, § 31315, 126 Stat. 405. The amendment permits the agency to require ratings for additional aspects of safety performance on the Monroney labels. *Id.* Monroney labels are the labels placed on new automobiles with the manufacturer’s suggested retail price and other consumer information, as required in 15 U.S.C. §§ 1231–1233 (2006). On www.safercar.gov, NHTSA supplements the label information by indicating whether any one or more of three recommended advanced technology features (ESC, FCW, and LDW) comes as standard or optional equipment on particular vehicle models. *NHTSA 5-Star Ratings FAQ*, *supra* note 43.

of original manufacture or were later attached to or physically carried in the vehicle. Sensing of a vehicle's performance and the roadway environment was done solely by the driver. Today, an increasing number of vehicle functions are electronic. These functions can be activated and controlled automatically by electronic control units. Further, they can rely on electrical inputs from the driver or on information relayed from on-board sensors. Increasingly, those on-board sensors monitor vehicle performance and the roadway environment. The operation of those units can be substantially altered by post-manufacture software updates. In addition, advances in communications technology have made it possible for nomadic devices with vehicle-related applications to be brought into the vehicle. Furthermore, devices located outside the vehicle can be used to affect and even control vehicle functions—including safety ones.

NHTSA's statutory authority over motor vehicles and motor vehicle equipment would allow the agency to establish safety standards applicable to vehicles that are originally manufactured with autonomous capabilities and to aftermarket equipment that could be added to vehicles that were not originally manufactured as autonomous vehicles so as to convert them into autonomous vehicles.

The Safety Act gives NHTSA authority over new motor vehicles and motor vehicle equipment. The Act defines a "motor vehicle" as "a vehicle driven or drawn by mechanical power and manufactured primarily for use" on public roads.⁴⁸ The definition of "motor vehicle equipment" is broader and thus effectively establishes the limit of the agency's authority under the Safety Act:

- (A) any system, part, or component of a motor vehicle as originally manufactured;
- (B) any similar part or component manufactured or sold for replacement or improvement of a system, part, or

48. 49 U.S.C. § 30102 (a)(6) (2006). The definition of "motor vehicle" includes trailers, but generally excludes vehicles that only use public roads for a limited duration to travel between worksites; vehicles that run exclusively on rails are also excluded from the definition of motor vehicle. See § 30102 (a)(7) ("'[M]otor vehicle' means a vehicle driven or drawn by mechanical power and manufactured primarily for use on public streets, roads, and highways, but does not include a vehicle operated only on a rail line.").

component, or as an accessory or addition to a motor vehicle; or

(C) any device or an article or apparel, including a motorcycle helmet and excluding medicine or eyeglasses prescribed by a licensed practitioner, that—

(i) is not a system, part, or component of a motor vehicle; and

(ii) is manufactured, sold, delivered, or offered to be sold for use on public streets, roads, and highways with the apparent purpose of safeguarding users of motor vehicles against risk of accident, injury, or death.⁴⁹

NHTSA's authority to issue safety standards that apply to new motor vehicles would enable the agency to establish standards applicable to vehicles that were originally manufactured with autonomous capabilities.⁵⁰ This authority would also extend to the individual pieces of equipment that are installed in new autonomous vehicles to enable these vehicles to drive autonomously.⁵¹ NHTSA could also establish safety standards that apply to equipment used to equip vehicles (not originally manufactured as autonomous vehicles) with autonomous technology using the agency's authority over equipment that is sold as replacements or

49. See § 30102 (a)(7)(C); MAP-21, Pub. Law. 112-141, § 31201, 126 Stat. 405, available at <http://www.gpo.gov/fdsys/pkg/BILLS-112hr4348enr/pdf/BILLS-112hr4348enr.pdf>. Congress added subparagraph (C) to the statutory definition of "motor vehicle equipment" in 1970 when it amended the definition in order to clarify the Department's authority over additional objects such as motorcycle helmets. See S. REP. NO. 91-559, at 5 (1970). However, Congress did not seek to limit the extension of the Department's authority only to motorcycle helmets and instead utilized the broad terms "device, article, and apparel" to describe the universe of objects that are within the agency's authority. See *id.* Acknowledging the concerns of those who authored the House version of the amendatory language that utilizing the terms "device, article, and apparel" might unduly extend the Department's authority to objects that have only a tangential relation to motor vehicle safety, the conference committee added a use restriction. See *id.* Congress relaxed this use restriction in the statutory definition of "motor vehicle equipment" as part of the amendments to the Safety Act in MAP-21. See MAP-21, Pub. Law. 112-141, § 31201, 126 Stat. 405. Thus, the Department's regulatory authority under subparagraph (C) is limited to those devices, articles, or apparel that are used for "the apparent purpose of safeguarding users of motor vehicles against risk of accident, injury, or death." See *id.* (emphasis added).

50. 49 U.S.C. §§ 30102 (a)(6), 30111.

51. § 30102 (a)(7)(A).

improvements to a motor vehicle.⁵²

NHTSA's authority over these groups of items: (1) systems, parts, and components installed or included in a vehicle, (2) replacements and improvements to those systems, parts and components, and (3) accessories and additions to motor vehicles is very broad. Their status as motor vehicle equipment does not depend on the type of technology or its mode of control (mechanical or electronic) or whether an item is tangible or intangible.⁵³ Thus, the transition from mechanical to electromechanical systems has had no significant effect on the extent of NHTSA's authority over motor vehicle performance. NHTSA will continue to have regulatory authority over all the systems, parts and components installed on new motor vehicles under the Safety Act as motor vehicle control systems become increasingly electronic and then increasingly automated.

A. Motor Vehicles Originally Manufactured as Autonomous Vehicles

This part of the definition of "motor vehicle equipment" includes all systems, parts, and components that are installed in or accompany a motor vehicle as it is originally manufactured.⁵⁴ In essence, this authorizes the agency to regulate anything that is included with the motor vehicle at the time it is produced for sale to a member of the public. "System, part, or component" is broad language that encompasses a large universe of items that can be considered

52. § 30102 (a)(7)(B).

53. See, e.g., *Drive-by-Wire™ Throttle System*, HONDA, <http://automobiles.honda.com/crosstour/features.aspx?Feature=dbw> (last visited Oct. 9, 2012) (detailing the drive-by-wire system currently available on the Honda Crosstour). An example of an electromechanical system is a drive-by-wire system, which is currently used in various vehicle models. *Id.* It substitutes electronic linkages and electromechanical actuators for the traditional mechanical linkages between driver controls (steering wheel, brake pedal, and accelerator pedal) and the associated vehicle operating systems. *Id.* Instead of the driver's hands turning the steering wheel, which in turn could move a rack and pinion mechanical link to the wheels, the driver's turning of the steering wheel would send an electrical command to the wheels and the vehicle would turn the wheels accordingly. *Id.* NHTSA would consider such a system, including the electrical signals used to relay commands, to be motor vehicle equipment.

54. "Motor vehicle equipment means—any system, part, or component of a motor vehicle as originally manufactured." § 30102 (a)(7)(A).

motor vehicle equipment.⁵⁵

The agency has already given some consideration to the application of subparagraph (A) of the definition of “motor vehicle equipment” to novel technologies. A recent example of a new technology that the agency has considered to be an item of motor vehicle equipment is an in-vehicle communications system (such as OnStar).⁵⁶ OnStar is available on many new General Motors models. As an item that is usually⁵⁷ installed as original equipment for the purposes of providing various functions, such as emergency notification and turn-by-turn navigation,⁵⁸ the device is considered by the agency to be a system, part, or component installed in motor vehicles as originally manufactured. As discussed above, sensors and other equipment that allow autonomous technology to function would be considered “motor vehicle equipment” by virtue of these items’ being installed in a new motor vehicle at the time of manufacture (in the same manner as OnStar).

B. Aftermarket Autonomous Technologies

The definition of “motor vehicle equipment” also gives great breadth to NHTSA’s authority to issue safety standards and the manufacturers’ obligation to recall noncompliant or defective equipment and devices that are not part of the

55. A system is “a regularly interacting or interdependent group of items forming a unified whole . . . : a group of devices or artificial objects or an organization forming a network especially for distributing something or serving a common purpose.” *System*, MERRIAM-WEBSTER, <http://www.merriam-webster.com/dictionary/system> (last visited Oct. 9, 2012). A part is “one of the often indefinite or unequal subdivisions into which something is or is regarded as divided and which together constitute the whole.” *Part*, MERRIAM-WEBSTER, <http://www.merriam-webster.com/dictionary/part> (last visited Oct. 9, 2012). A component is “a constituent part: INGREDIENT.” *Component*, MERRIAM-WEBSTER, <http://www.merriam-webster.com/dictionary/component?show=0&t=1337029662> (last visited Oct. 9, 2012).

56. See Letter from Anthony M. Cooke, Chief Counsel, NHTSA to Ashley G. Alley, Office of General Counsel, Gov’t Accountability Office (July 19, 2007), available at <http://isearch.nhtsa.gov/files/GAO%20telematics%20Sept%2013.htm>.

57. OnStar is currently available as an aftermarket device. See Althea Chang, *Aftermarket OnStar Available to Non-GM Vehicles on Sunday*, FORBES.COM (July 23, 2011, 5:55 AM), <http://www.forbes.com/sites/altheachang/2011/07/23/aftermarket-onstar-available-to-non-gm-vehicles-on-sunday/>.

58. See *id.*

vehicle as originally manufactured, but are purchased by motor vehicle users in the after-market.⁵⁹ The agency's jurisdiction over after-market equipment is significant in regard to autonomous driving technologies because providers of advanced crash avoidance and autonomous driving technologies might wish to market these technologies for installation on used vehicles. Further, any after-market software updates to the autonomous driving system or software enabling other devices to connect to the autonomous driving system would be considered "motor vehicle equipment" under this part of the definition.

The statutory language separates the items covered by this part of the definition into two groups: (1) those that are a "replacement or improvement" and (2) those that are an "accessory or addition." Thus, for discussion purposes, we have restated subparagraph (B) of the statutory definition to aid readers in understanding the criteria that govern the determination of whether an item qualifies as a "replacement or improvement" or as an "accessory or addition." As restated, subparagraph (B) reads:

- (B) any similar part or component manufactured or sold
- for replacement or improvement of a system, part, or component, or
 - as an accessory or addition to a motor vehicle;

The following paragraphs will discuss each of the above groups of items and the associated requirements from the statutory text. It is important to note that, while the criteria for those items over which NHTSA possesses regulatory authority by virtue of subparagraph (B) of the definition of "motor vehicle equipment" are different from the criteria for items that fall under subparagraph (A) of the definition,⁶⁰ both subparagraph (A) and (B) begin with the same pool of items (system, parts, or components).⁶¹ In essence, NHTSA

59. See § 30102 (a)(7)(B) (covering replacements, improvements, accessories, and additions).

60. Part (A) restricts system, parts, and components by the time during which they are attached to motor vehicle. See § 30102 (a)(7)(A). Part (B) has different restrictions as will be discussed in the paragraphs that follow. See § 30102 (a)(7)(B).

61. Part (A) defines the universe of objects as "system, parts, or components," while part (B) begins with "similar parts or components." § 30102

possesses regulatory authority under subparagraph (A) of the definition of “motor vehicle equipment” over items that are systems, parts, or components on new motor vehicles.⁶² Subparagraph (B) of the definition of “motor vehicle equipment” gives NHTSA regulatory authority over the same or similar systems, parts, or components sold in the aftermarket and installed in used vehicles.⁶³

1. *Replacements and Improvements*

An autonomous driving system would be considered motor vehicle equipment regardless of whether it is offered to consumers as original equipment on a new motor vehicle or as an after-market replacement of or improvement to original equipment. NHTSA’s regulatory authority over items that are sold as “replacement[s] or improvement[s] of a system, part, or component” allows the agency to regulate autonomous technology installed as aftermarket equipment.⁶⁴ Installing autonomous technology on a vehicle that was not originally manufactured as an autonomous vehicle would necessitate extensive modification to the vehicle.⁶⁵ The items used to convert a used vehicle to an autonomous vehicle would be considered improvements to a motor vehicle.⁶⁶

This part of the definition of “motor vehicle equipment” is also applicable to software installed on vehicles. For example, a manufacturer could issue software updates for existing autonomous driving systems. Regardless of where the software is located (i.e., on what type of hardware), the

(a)(7)(A)–(B). As most all parts of a vehicle can need replacement, it does not seem accurate to consider the “replacements,” “improvements,” “accessories,” or “additions,” in part (B) to be a narrower set of objects as in part (A). *See id.*

62. § 30102 (a)(7)(A).

63. § 30102 (a)(7)(B).

64. *Id.*

65. *See* Sebastian Thrun & Chris Urmson, Keynote Presentation at IROS 2011 (Sept. 29, 2011), *available at* <http://www.youtube.com/watch?v=z7ub5Doyapk> (explaining how the Google self-driving car achieves autonomous driving). The Google self-driving car offers an example of the extensive modifications that would be necessary to convert a vehicle that was not originally manufactured as an autonomous vehicle to one capable of autonomous driving. *See id.*

66. § 30102 (a)(7)(B). It is likely that items used to convert a vehicle that was not originally manufactured as an autonomous vehicle to one capable of autonomous operation could also qualify as additions to a motor vehicle. *See id.*

software itself would be subject to the Safety Act and could be subject to a safety standard should there be a sufficient safety need for one. If a software update were delivered to a consumer (such as updated maps or enhanced decision-making algorithms), the software itself would be considered a replacement or improvement under the first half of subparagraph (B) of the definition.

2. *Accessories and Additions*

Items that are considered “motor vehicle equipment” because they are accessories or additions to motor vehicles differ from the items we have discussed above. Unlike items that are considered to be replacements or additions, items that are considered to be accessories or additions are not necessarily as closely related to the systems, parts and components originally installed in new motor vehicles (in the sense that these items potentially do not duplicate the functions of original equipment).

The dictionary definition of “addition” seems to imply that an “addition” to the motor vehicle is an item that becomes united or joined with a motor vehicle.⁶⁷ In other words, it is not an item which can be freely carried into and out of the vehicle.

The dictionary definition of “accessory” states that an accessory is a secondary item which adds some value or function (such as additional convenience or effectiveness) to the original item.⁶⁸ While such a definition does not contemplate that an item’s becoming a part of (or physically attached) to the motor vehicle in order to be regarded as an accessory (as such an interpretation would make “accessory” duplicative of the term “addition”), this definition does seem to imply some sort of use of the item in conjunction with the

67. An addition is “a part added (as to a building or residential section)” and add means “to join or unite so as to bring about an increase or improvement.” *Addition*, MERRIAM-WEBSTER, <http://www.merriam-webster.com/dictionary/addition> (last visited Oct. 9, 2012); *Add*, MERRIAM-WEBSTER, <http://www.merriam-webster.com/dictionary/add> (last visited Oct. 9, 2012).

68. An accessory can be “a thing of secondary or subordinate importance: ADJUNCT” or “an object or device not essential in itself but adding to the beauty, convenience, or effectiveness of something else.” *Accessory*, MERRIAM-WEBSTER, <http://www.merriam-webster.com/dictionary/accessory> (last visited Oct. 9, 2012).

motor vehicle. Thus, an item could be an “accessory” under subparagraph (B) of the statutory definition of “motor vehicle equipment” if a substantial portion of its expected use were in conjunction with motor vehicles.⁶⁹

Given that a system, part, or component might be intangible and electronic, and given that an item can be an accessory to a motor vehicle under subparagraph (B) as long as a substantial portion of its expected use is in conjunction with a motor vehicle, certain types of software can be regarded as an accessory and thus are “motor vehicle equipment.” For example, a software application that could be installed on a cell phone for the purpose of enabling the phone user to perform such vehicle-related functions as starting/stopping or locking/unlocking a motor vehicle through manipulating the controls on the phone would be considered an accessory to the motor vehicle even if the cell phone itself is not.⁷⁰ Other applications can perform

69. One practical consideration in the agency’s deciding whether to exercise this authority with respect to a particular type of object would be whether another federal agency was authorized, able and inclined to regulate the safety of that object effectively.

70. Our conclusion that software can be an item of motor vehicle equipment is reinforced by the recent enactment of MAP-21. In that Act, Congress implicitly recognized this fact when it directed NHTSA to examine the need for safety standards with regard to electronic systems in passenger motor vehicles. See Pub. L. No.112-141, §§ 31401-02, 126 Stat. 405. Separately, NHTSA is not the only agency contemplating how its statutory authority may apply to software. The Food and Drug Administration (FDA) is also considering adopting an interpretation of its statutory authority that would subject software installed on mobile devices to regulation under the Federal Food, Drug, and Cosmetic Act, 21 U.S.C §§ 301 et seq. (2006). See Draft Guidance for Industry and Food and Drug Administration Staff; Mobile Medical Applications; Availability, 76 Fed. Reg. 43689 (July 21, 2011) [hereinafter FDA Draft Guidance] (announcing the availability of the FDA’s proposed application of the agency’s regulatory authority to software applications installed on mobile devices), available at <https://www.federalregister.gov/articles/2011/07/21/2011-18537/draft-guidance-for-industry-and-food-and-drug-administration-staff-mobile-medical-applications>. The FDA’s draft guidance would treat software installed on mobile devices as a regulated device under the Federal Food, Drug, and Cosmetic Act, 21 U.S.C §§ 301 et seq. (2006), if the software met the definition of “device” contained in the Act and is either “used as an accessory to a regulated medical device or transforms a mobile platform into a regulated medical device.” FDA Draft Guidance, *supra*. The term “device” is defined in the Federal Food, Drug and Cosmetic Act, as:

an instrument, apparatus, implement, machine, contrivance, implant, in vitro reagent, or other similar or related article, including any component, part, or accessory, which is . . . recognized in the official

functions related to on-road vehicle operation. An example is a software application that uses the camera function on a smart phone placed on a vehicle's dashboard to detect and recognize vehicles on the road ahead and provide forward collision warnings.

IV. SAFETY STANDARDS: STATUTORY REQUIREMENTS AND ADDRESSABLE ASPECTS OF PERFORMANCE

While NHTSA's authority over autonomous driving systems is quite broad, the agency is still faced with the challenge of determining the appropriate instances for and effective ways of regulating autonomous driving technologies (whether functioning individually or in combination) using the existing statutory framework. Under the Safety Act, NHTSA's standards must be performance-oriented.⁷¹ Further, the standards are required to be practicable, objective, and meet the need for safety.⁷² This section does not attempt a comprehensive identification and resolution of the possible regulatory issues that can arise with the advent of increasingly complex autonomous driving technologies. Instead, it attempts to illustrate possible regulatory challenges and their solutions by first providing an overview of the current statutory framework for establishing standards and then applying that framework to a few technical areas

National Formulary, or the United States Pharmacopeia, or any supplement to them, [] intended for use in the diagnosis of disease or other conditions, or in the cure, mitigation, treatment, or prevention of disease, in man or other animals, or [] intended to affect the structure or any function of the body of man or other animals, and which does not achieve its primary intended purposes through chemical action within or on the body of man or other animals and which is not dependent upon being metabolized for the achievement of its primary intended purpose.

21 U.S.C. § 321(h) (2006).

71. See 49 U.S.C. § 30102(a)(8) (defining "motor vehicle safety" as "the performance of a motor vehicle . . . in a way that protects the public against unreasonable risk of accidents occurring because of the design, construction, or performance of a motor vehicle"); see § 30102(a)(9) (defining "motor vehicle safety standard" as "a minimum standard for motor vehicle or motor vehicle equipment performance." See S. REP. NO. 89-1301, at 2713-14 (1966) (stating that motor vehicle standards issued by NHTSA should specify a minimum level of safety performance).

72. See 49 U.S.C. § 30111(a) (establishing requirements for NHTSA to follow when issuing motor vehicle safety standards).

with foreseeable regulatory issues. The technical areas examined in this section include the following:

- *Minimum Standards and Testing for Software Performance*: As vehicle systems employ artificial intelligence to accomplish multiple (or all) driving tasks, how can the agency help to ensure that the autonomous driving systems accomplish their tasks in a reliable, accurate, and timely fashion?
- *Security and Privacy of Vehicle Systems*: Public acceptance and activation of autonomous driving technologies will depend substantially on the ability of those technologies to perform reliably and safely and without compromising the privacy of drivers. As autonomous driving systems will be increasingly integrated with other devices through wireless interfaces, how can the agency help to protect vehicle systems from malicious hacking and tampering? In addition, how can it help protect the information received, generated and sent by autonomous vehicles and ensure that drivers may freely move without being tracked?
- *User Interfaces with Autonomous Driving Systems*: As some vehicle systems might become automated before others, some communication between the vehicle and the driver about those automated systems would be necessary. How can the agency help to ensure that the driver has a proper understanding of whether the vehicle is responsible or whether the driver is responsible for any given driving task at any given moment?

With these questions in mind, this section attempts to illustrate the challenges confronting NHTSA in addressing these safety issues using performance standards that are both objective and practicable. During the course of this analysis, we conclude that (although additional research might be required) many of NHTSA's current approaches to writing performance requirements and test procedures that address real world scenarios can be effectively applied to autonomous driving technologies. Further, we note that connected vehicles and autonomous motor vehicles are closely-related (but distinct) concepts, and thus many of the challenges in regulating autonomous motor vehicles and connected motor vehicles are quite similar.

*A. Requirements and Considerations Applicable to Safety Standards**1. Performance-Oriented*

NHTSA's regulatory authority would allow the agency to issue safety standards that regulate the performance of autonomous vehicles. While NHTSA is directed to establish performance standards, the case law and the legislative history indicate that when necessary to promote safety, NHTSA can be quite specific in drafting its performance standards and may require or preclude the installation of certain equipment. In the Safety Act, the Secretary is directed to issue motor vehicle safety standards. "Motor vehicle safety standards" are defined as "minimum standard[s] for motor vehicle or motor vehicle equipment performance."⁷³ The cases have reinforced this concept by determining that NHTSA is "generally charged"⁷⁴ with setting performance standards, instead of becoming directly involved in questions of design.⁷⁵ The legislative history further illustrates that NHTSA's standards are to "[specify] the required minimum safe performance of vehicles but not the manner in which the manufacturer is to achieve the specified performance."⁷⁶ An example cited in the legislative history points to "a building code which specifies the minimum load-carrying characteristics of the structural members of a building wall, but leaves the builder free to choose his own materials and design."⁷⁷

Although the Safety Act directs NHTSA to issue performance standards, Congress understood that the agency may preclude certain designs through these performance standards. "Motor vehicle safety," is defined in the Safety Act as the performance of a motor vehicle in a way that protects the public from unreasonable risks of accident due to (among other things) the design of the motor vehicle.⁷⁸ The legislative

73. *Id.*; see also § 30102(a)(9) (emphasis added).

74. *Washington v. Dept. of Transp.*, 84 F.3d 1222, 1224 (10th Cir. 1996) (citations omitted).

75. *Id.* at 1224 (citations omitted).

76. S. REP. NO. 89-1301, at 2713-14 (1966).

77. *Id.*

78. See § 30102(a)(8) ("'Motor vehicle safety' means the performance of a motor vehicle or motor vehicle equipment in a way that protects the public

history is clear that this language is not intended to afford the agency the authority to promulgate design standards, “but merely to clarify that the public is to be protected from inherently dangerous designs which conflict with the concept of motor vehicle safety.”⁷⁹ This clarification is evidence that Congress recognized that performance standards inevitably have an impact on the design of a motor vehicle.⁸⁰

The courts have further elaborated on the framework established by Congress and have recognized that, when necessary to achieve a safety purpose, NHTSA can be quite specific in establishing performance standards even if certain designs will be precluded. For example, the Sixth Circuit found that an agency provision permitting rectangular headlamps, but only if they were of certain specified dimensions, was not an invalid design restriction and “serve[d] to ensure proper headlamp performance,” reasoning that “the overall safety and reliability of a headlamp system depends to a certain extent upon the wide availability of replacement lamps, which in turn depends upon standardization.”⁸¹ Thus, the court found it permissible for the agency to establish very specific requirements for headlamps even though it would restrict design flexibility.⁸²

Further, the cases indicate that NHTSA can establish standards to require the installation of certain specific equipment on vehicles and establish performance standards for that equipment. For example, the Tenth Circuit found in *Washington v. DOT* that “NHTSA’s regulatory authority extends beyond the performance of motor vehicles per se, to particular items of equipment.”⁸³ In that case, the validity of NHTSA’s Federal Motor Vehicle Safety Standard (FMVSS)

against unreasonable risk of accidents occurring because of the design, construction, or performance of a motor vehicle.”).

79. See H.R. REP. NO. 89-1919, at 2732 (1966).

80. Courts have also recognized this truth. See *Chrysler Corp. v. Dept. of Transp.*, 515 F.2d 1053, 1058–59 (6th Cir. 1975); see also *Washington*, 84 F.3d at 1224 (stating “the performance-design distinction is much easier to state in the abstract than to apply definitively-so . . . This is particularly true when, due to contingent relationships between performance requirements and design options, specification of the former effectively entails, or severely constrains, the latter.”).

81. *Chrysler Corp.*, 515 F.2d at 1058–59.

82. See *id.*

83. *Washington*, 84 F.3d at 1222, 1225 (citations omitted).

No. 121 requiring ABS systems on air-braked vehicles was challenged as “imposing design specifications rather than performance criteria.”⁸⁴ The court’s conclusion was based not only on the fact that prior courts had upheld NHTSA’s standards requiring particular equipment,⁸⁵ but also on the fact that Congress had recognized NHTSA’s former rulemakings and left NHTSA’s authority unchanged when it codified the Safety Act in 1994.⁸⁶

Thus, in summary, NHTSA is required to issue performance standards when regulating motor vehicles and motor vehicle equipment. However, NHTSA is able to be quite specific in establishing performance standards and may preclude certain designs that are contrary to the interests of safety. Further, NHTSA may require the installation of certain equipment and establish performance standards for that equipment.

2. *Meeting the Need for Safety*

As required by the Safety Act, standards issued by the agency must “meet the need for motor vehicle safety.”⁸⁷ As “motor vehicle safety” is defined in the statute as protecting the public against “unreasonable risk” of accidents, death, or injury,⁸⁸ the case law indicates that there must be a nexus between the safety problem and the standard.⁸⁹ However, a

84. *Id.* at 1223.

85. *See id.* at 1225 (citing *Chrysler Corp. v. Rhodes*, 416 F.2d 319, 3222, 3222 n.4) (1st Cir. 1969) (“motor vehicles are required to have specific items of equipment . . . these enumerated items of equipment are subject to specific performance standards,” including lamps and reflective devices requiring “specific items of equipment”); *Wood v. Gen. Motors Corp.*, 865 F.2d 395, 417 (1st Cir. 1988) (“requiring seat belts or passive restraints . . . has elements of a design standard”); *Automotive Parts & Accessories Ass’n v. Boyd*, 407 F.2d 330, 332 (D.C. Cir. 1968) (“factory equipped . . . head restraints which meet specific federal standards”).

86. *See Washington*, 84 F.3d at 1225.

87. *See* 49 U.S.C. § 30111(a).

88. 49 U.S.C. § 30102(a)(8) (2006) (emphasis added).

89. *See, e.g., National Tire Dealers Ass’n v. Brinegar*, 491 F.2d 31, 35–37 (D.C. Cir. 1974) (stating that the administrative record did not support a significant nexus between motor vehicle safety and requiring retread tires to have permanent labels because there was no showing that a second-hand owner would be dependent on these labels and no showing as to how often such situations would arise); *see also H&H Tire Co. v. Dept. of Transp.*, 471 F.2d 350, 354–55 (7th Cir. 1972) (expressing doubt that the standard met the need for safety because there was little evidence that the required compliance tests

standard need not address safety by direct means.

In upholding NHTSA's authority to issue a safety standard requiring standardized vehicle identification numbers (VINs), the Fourth Circuit Court of Appeals found that a FMVSS requiring VINs met the need for motor vehicle safety by such indirect means as reducing errors in compiling statistical data on motor vehicle crashes (in order to aid research to understand current safety problems and support future standards, to increase the efficiency of vehicle recall campaigns, and to assist in tracing stolen vehicles).⁹⁰

3. *Objective*

A standard is objective if it specifies test procedures that are "capable of producing identical results when test conditions are exactly duplicated" and performance requirements whose satisfaction is "based upon the readings obtained from measuring instruments as opposed to the subjective opinions."⁹¹ The requirement that standards be stated in objective terms matches the overall statutory scheme requiring that manufacturers self-certify that their motor vehicles or motor vehicle equipment are in compliance with the relevant FMVSSs.⁹² In order for this statutory scheme to work, the agency and the manufacturer must be able to obtain the same result from identical tests in order to objectively determine the validity of the manufacturer's certification.⁹³

Using those two elements of objectivity (capable of producing identical results and compliance based on measurements not subjective opinion), the Sixth Circuit Court of Appeals found that the test procedure in question in early version of FMVSS No. 208 was not objective because the test dummy specified in the standard for use in compliance

would ensure that retreaded tires would be capable of performing safely under modern driving conditions).

90. See *Vehicle Equip. Safety Comm'n v. NHTSA*, 611 F. 2d 53, 54 (4th Cir. 1979).

91. See *Chrysler Corp. v. Dept. of Transp.*, 472 F.2d 659, 676. See also *Paccar, Inc. v. Nat'l Highway Traffic Safety Admin.*, 573 F.2d 632, 644 (9th Cir. 1978).

92. See 49 U.S.C. § 30115(a) (2006).

93. See *Chrysler Corp.*, 472 F.2d at 675.

testing did not give consistent and repeatable results.⁹⁴ The court in this case was unconvinced that the standard met the objectivity requirements even though NHTSA based its test procedure on a test dummy in a voluntary automotive industry standard (Society of Automotive Engineers (SAE) Recommended Practice J963). The court rejected NHTSA's explanation that, although J963 "may not provide totally reproducible results,"⁹⁵ "dummies conforming to the SAE specifications are the most complete and satisfactory ones presently available."⁹⁶ Further, the court rejected NHTSA's reasoning that, in the event that the agency's test results were different from those of the manufacturers because of the difference in the test dummies, NHTSA's test results would not be used to find non-compliance,⁹⁷ stating that "there is no room for an [] agency investigation [] in this procedure" that enable the agency to compare results of differing tests.⁹⁸

Other courts have also reached similar conclusions. The Ninth Circuit Court of Appeals, relying on the same reasoning adopted by the Sixth Circuit, found that a compliance road test specifying the use of surfaces specifically rated with quantifiable numbers (defining the "slickness" of the surfaces) was objective despite "[t]he fact that it is difficult to create and thereafter maintain a road surface with a particular coefficient of friction does not render the specified

94. The court stated,

The record supports the conclusions that the test procedures and the test device specified . . . are not objective in at least the following respects: (1) The absence of an adequate flexibility criteria for the dummy's neck; the existing specifications permit the neck to be very stiff, or very flexible, or somewhere in between, significantly affecting the resultant forces measured on the dummy's head. (2) Permissible variations in the test procedure for determining thorax dynamic spring rate (force deflection characteristics on the dummy's chest) permit considerable latitude in chest construction which could produce wide variations in maximum chest deceleration between two different dummies, each of which meets the literal requirements of SAE J963. (3) The absence of specific, objective specifications for construction of the dummy's head permits significant variation in forces imparted to the accelerometer by which performance is to be measured.

See id. at 676–78.

95. *See id.* at 677.

96. *See id.*

97. *Id.* at 677–78.

98. *Id.* at 678–79.

coefficient any less objective.”⁹⁹ In this case, both NHTSA and the manufacturer would perform road tests on surfaces with identically rated friction coefficients.¹⁰⁰ In a later case, the Sixth Circuit upheld NHTSA’s decision not to incorporate a test suggested by a commenter for wheelchair crashworthiness performed with a “test seat” which “shall be capable of resisting significant deformation during a test” as not sufficiently objective.¹⁰¹ In the absence of language quantifying how much deformation is significant, terms such as “significant deformation” do not provide enough specificity to remove the subjective element from the compliance determination process.

4. *Practicable*

In general, the practicability of a given standard involves a number of considerations. The majority of issues concerning the practicability of a standard arise out of whether the standard is technologically and economically feasible. An additional issue is whether the means used by manufacturers to comply with a standard will be accepted and correctly used by the public.

i. Technological Practicability

Significant technical uncertainties in meeting a standard might lead a court to find that a standard is not practicable. For example, the Sixth Circuit Court of Appeals upheld NHTSA’s decision to amend FMVSS No. 222 to include requirements for wheelchair securement and occupant restraint on school buses with a static¹⁰² compliance test instead of a dynamic test,¹⁰³ noting that the administrative

99. See *Paccar, Inc. v. Nat’l Highway Traffic Safety Admin.*, 573 F.2d 632, 644 (9th Cir. 1978), *cert. denied*, 439 U.S. 862 (1978).

100. See *id.* (stating that the “skid number method of testing braking capacity meets the [objectivity] definition. Identical results will ensue when test conditions are exactly duplicated. The procedure is rational and decisively demonstrable. Compliance is based on objective measures of stopping distances rather than on the subjective opinions of human beings.”).

101. *Simms v. Nat’l Highway Traffic Safety Admin.*, 45 F.3d 999, 1007–08 (6th Cir. 1995).

102. Static testing tests the strength of individual components of the wheelchair separately, while dynamic testing subjects the entire wheelchair to simulated real-world crash conditions. See *Simms*, 45 F.3d at 1001.

103. See *id.* at 1006–08. Petitioners argued that NHTSA had acted

record showed that this particular dynamic test was underdeveloped and had many unresolved technical problems.¹⁰⁴ The court noted that it is not practicable “[t]o attempt to fashion rules in an area in which many technical problems have been identified and no consensus exists for their resolution”¹⁰⁵ In another example, the Ninth Circuit Court of Appeals found a compliance test procedure using a specified friction (“slickness”) coefficient to be impracticable due to technical difficulties in maintaining the specific slickness test condition. As mentioned above, the Ninth Circuit found the specified coefficient test condition to be objective.¹⁰⁶ However, the court found that this standard was not practicable due to the technical difficulties in maintaining this specific test condition. Thus, the cases show that when significant technical uncertainties and difficulties exist in a standard promulgated by NHTSA, those portions of the standard can be considered impracticable under the Safety Act.

However, the requirement that standards be technologically feasible does not require that the technology to be used to comply with a new standard be fully developed and tested when the standard is promulgated. The Sixth

unlawfully in promulgating standards for the securement of wheelchairs on school buses based only on “static” instead of “dynamic” testing. *Id.* Static testing tests the strength of the individual components of a securement device. *See id.* Dynamic testing is a full systems approach that measures the forces experienced by a human surrogate (test dummy) in simulated crash that replicates real world conditions and assesses the combined performance of the vehicle and the securement device. *See id.*

104. *Id.* at 1005–07. NHTSA agreed that dynamic testing is the preferred approach (because it more fully and accurately replicates the real world conditions in which the desired safety performance is to be provided), but explained that it was not practicable at that time to adopt dynamic testing because there was:

- (1) [N]eed to develop an appropriate test dummy; (2) need to identify human tolerance levels for a handicapped child; (3) need to establish test conditions; (4) need to select a “standard” or surrogate wheelchair; (5) need to establish procedures for placing the wheelchair and test dummy in an effective test condition; and (6) need to develop an appropriate test buck to represent a portion of the school bus body for securement and anchorages.

Id. at 1005.

105. *Id.* at 1010–11.

106. *Paccar, Inc. v. Nat’l Highway Traffic Safety Admin.*, 573 F.2d 632, 644 (9th Cir. 1978).

Circuit upheld a NHTSA standard requiring “Complete Passive Protection,” that includes the required use of airbags as standard equipment, by a future date, rejecting petitioner’s contention that standards cannot require nonexistent technology.¹⁰⁷ Relying on the legislative history of the Safety Act, the court found that the agency “is empowered to issue safety standards which require improvements in existing technology or which require the development of new technology, and is not limited to issuing standards based fully on devices already fully developed.”¹⁰⁸ Thus, while technological feasibility is a significant part of determining whether a given standard can be considered practicable, the agency is fully empowered to issue technology-driving standards when it is appropriate to do so.

ii. Economic Practicability

A standard can be considered impracticable by the courts due to economic infeasibility. This consideration primarily involves the costs imposed by a standard.¹⁰⁹ In the instances in which a court has been called upon to assess whether a standard is economically feasible, typically with respect to an industry composed largely of relatively small businesses, the courts have asked whether or not the cost would be so

107. See *Chrysler Corp. v. Dept. of Transp.*, 472 F.2d 659, 666, 671–75 (6th Cir. 1972). Stages one and two required vehicle manufactures to provide “Complete Passive Protection,” or one of two other options on vehicles manufactured between January 1, 1972, and August 14, 1973, for stage one, and after August 15, 1972, stage two. See *id.* at 666–67. Stage 3, requiring solely “Complete Passive Protection” was required by August 15, 1975. *Id.* at 667.

108. *Id.* at 673. In making its decision, the court stated

[I]t is clear from the Act and its legislative history that the Agency may issue standards requiring future levels of motor vehicle performance which manufacturers could not meet unless they diverted more of their resources to producing additional safety technology than they might otherwise do. This distinction is one committed to the Agency’s discretion, and any hardships which might result from the adoption of a standard requiring . . . a great degree of developmental research, can be ameliorated by the Agency under The section [that] allows the Secretary to extend the effective date beyond the usual statutory maximum of one year from the date of issuance, as he has done [here].

Id. at 673.

109. See, e.g., *Nat’l Truck Equip. Ass’n v. Nat’l Highway Traffic Safety Admin.*, 919 F.2d 1148, 1153–54 (6th Cir. 1990); *Ctr. for Auto Safety v. Peck*, 751 F.2d 1336, 1343 (D.C. Cir. 1985) (panel opinion by Circuit Judge Scalia).

prohibitive that it could cause significant harm to a well-established industry. In essence, this consideration generally establishes a non-quantified outer limit of the costs that can be reasonably imposed upon regulated entities. If compliance with the standard is so burdensome, i.e., costly, so as to create a significant harm to a well-established industry, courts have generally found that the standard is impracticable in its application to that industry.

iii. Public Acceptance and Use

Finally, a standard might not be considered practicable if the public were not expected to accept and correctly use the technologies installed in compliance with the standard. When considering passive restraints such as automatic seatbelts, the D.C. Circuit stated that “the agency cannot fulfill its statutory responsibility [in regard to practicability] unless it considers popular reaction.”¹¹⁰ While the agency argued in that case that public acceptance is not one of the statutory criteria that the agency must apply, the court disagreed.¹¹¹ The court reasoned that, “without public cooperation there can be no assurance that a safety system can ‘meet the need for motor vehicle safety.’”¹¹² Thus, as a part of the agency’s considerations, a standard issued by the agency will not be considered practicable if the technologies installed pursuant to the standard are so unpopular that there is no assurance of sufficient public cooperation to meet the safety need that the standard seeks to address.¹¹³

B. Autonomous Performance: Minimum Standards and Methods of Ensuring Compliance

As we have mentioned above, autonomous driving systems can employ a variety of hardware (such as sensors/cameras/communications devices) and complex

110. See *Pac. Legal Found. v. Dept. of Transp.*, 593 F.2d 1338, 1345–46 (D.C. Cir.), *cert. denied*, 444 U.S. 830 (1979).

111. See *id.*

112. See *id.*

113. Pursuant to concerns about public acceptance of various seat belt designs, NHTSA issued a final rule in 1981 adding seat belt comfort and convenience requirements to Standard No. 208, Occupant Crash Protection. Federal Motor Vehicle Safety Standards; Improvement of Seat Belt Assemblies, 46 Fed. Reg. 2064 (Jan. 8, 1981) (codified at 49 C.F.R. 571).

software—capable of assisting or even replacing the driver’s senses and intelligence—for an increasing number of driving tasks. Today, vehicles are already beginning to incorporate software designed to issue warnings to the driver regarding conditions (e.g., potential crashes with other vehicles) in the immediate surrounding area or even automatically brake the vehicle on behalf of the driver to avoid or at least mitigate potential crashes.¹¹⁴ NHTSA will need to develop methods of ensuring a minimum level of safety performance, as it does for more traditional automotive technologies, if it determines that any of these technologies lead to a significant safety benefit or have potential to create safety issues.

This task will become increasingly complex as autonomous driving systems are designed for the potentially limitless variety of real-world stimuli, conditions, and scenarios. In response to these factors, a vehicle’s sensors must acquire the appropriate information, its software must intelligently interpret this information, and the vehicle must take the appropriate and timely actions. In response to general concerns about increasingly capable and complex electronic systems, NHTSA arranged for the National Academy of Sciences (NAS) to conduct a study and make recommendations for addressing the challenges posed by those systems. NAS’s report recommends that NHTSA become more familiar with and proactive in responding to those complex challenges.¹¹⁵ The report highlights many of the same challenges in regulating electronic control systems discussed in this Article.¹¹⁶ The report also contains several

114. See, e.g., *Reward 2010 - Mercedes-Benz PRE-SAFE Brake*, EURO NCAP, http://www.euroncap.com/rewards/mercedes_benz_pre_safe_brake.aspx (last visited Oct. 9, 2012) (describing briefly the Mercedes-Benz PRE-SAFE system—available on the E-Class—as a system which issues warnings and is able to brake autonomously in certain situations).

115. See Press Release, Nat’l Acad. of Sci., Unintended Acceleration Controversy Reveals Need for NHTSA to Anticipate Safety Challenges From Automotive Electronics, Says New Report (Jan. 18, 2012), available at <http://www8.nationalacademies.org/onpinews/newsitem.aspx?RecordID=13342>.

116. See generally TRANSP. RESEARCH BD., *THE SAFETY PROMISES AND CHALLENGES OF AUTOMOTIVE ELECTRONICS: INSIGHTS FROM UNINTENDED ACCELERATION* 117–34 (2012), available at http://www.nap.edu/catalog.php?record_id=13342 (describing the extent to which electronic control systems are incorporated into new vehicles and recommending strategies to improve the safety of electronic systems in motor vehicles). The Transportation Research Board is an affiliate of the National Academy of Sciences. *Id.* at iii.

recommendations to NHTSA regarding the agency's efforts to ensure the safety of electronic control systems.¹¹⁷ NHTSA is reviewing these recommendations and will consider how adopting the recommendations could improve the way in which NHTSA seeks to ensure the safety of these systems.¹¹⁸ While NHTSA will seek to conduct additional research in the area of electronics, many of the methods NHTSA currently uses to help to ensure that its standards adequately promote safety under real world conditions will still be applicable to these technologies.¹¹⁹

1. *Technical Issue: Ensuring that Autonomous Motor Vehicles Can Handle a Broad Array of Real-World Driving Conditions*

In earlier sections of this Article, we discussed the idea of a continuum of autonomous driving technologies. We recognized in that section that the implementation of autonomous driving technologies will likely be implemented in stages, thus allowing the vehicle to assume progressively more driving tasks over time. With warning systems and other advanced crash avoidance technologies (such as forward collision warning and automatic emergency braking), the vehicle software is performing relatively simple functions because it has comparatively less responsibility. For example, with a crash imminent braking or a forward collision warning system, the vehicle software is only required to detect the vehicle in front and warn the driver (or intervene with braking) when the distance to the forward vehicle decreases at a rate greater than a certain threshold, indicating that a collision is likely.

117. *Id.*

118. Press Release, Nat'l Highway Traffic Safety Admin., NHTSA Statement on NAS Report on Electronic Control Systems (Jan. 18, 2012), available at <http://www.nhtsa.gov/About+NHTSA/Press+Releases/2012/NHTSA+Statement+on+NAS+Report+on+Electronic+Control+Systems>.

119. Several of the recommendations contained in National Academy of Science report on electronic control systems pertained to increasing NHTSA's familiarity with manufacturers' quality assurance processes and technical expertise in automotive electronics. See TRANSP. RESEARCH BD., *supra* note 116, at 117–34 (recommending strategies for NHTSA to regulate the safety of electronic control systems).

These calculations are relatively simple and made under controlled circumstances. While it is never completely straightforward to construct an objective and practicable standard which adequately anticipates and incorporates the appropriate test variables, one can imagine a standard that requires manufacturers to certify that their vehicles have collision braking when tested under controlled conditions on a test track. Such a test procedure could require, for example, that when a vehicle is proceeding at 50 mph on a straight test track and encounters a 40 mph lead vehicle in the same lane on the test track, it automatically reduces its speed to match that of the 40 mph lead vehicle. Additional test scenarios might also be specified to help to ensure that the vehicle can adequately respond under various emergency braking situations. One scenario might, for example, utilize a completely stationary lead vehicle in the same lane. Another scenario might utilize a vehicle rapidly decelerating from fifty mph to zero mph. The test conditions under each of these scenarios would need to be defined in great detail in order to help to ensure that the results are consistent when the test conditions are duplicated.

Collision imminent braking and forward collision warning are merely one small set of functions that contribute toward achieving a motor vehicle with full automation. In order to ensure that a motor vehicle with full automation provides an appropriate level of minimum performance, the agency's test or tests might need to evaluate the vehicle's software decision-making in many different potential crash scenarios.

2. Potential Solution: Supplementing Track Tests with Diagnostic Tools to Evaluate Vehicles in a Wide Range of Scenarios

One potential solution for ensuring that NHTSA's performance standards adequately address the ability of the increasingly autonomous motor vehicle to make correct decisions and perform reliably when assuming a substantial number of driving responsibilities is to utilize multiple tests that make use of the agency's ability to use ranges of values, representative test conditions, and test devices. As previously discussed, the Safety Act requires standards to be stated in objective terms and case law indicates that this

means a standard which is capable of producing identical results when the test conditions are exactly duplicated and is based upon readings obtained by measuring instruments.¹²⁰ In accomplishing these goals and the goals of addressing the safety need while ensuring practicability of the standard, NHTSA has often utilized ranges, selected representative test conditions, or utilized specific test devices.

NHTSA often utilizes a range of possible test values in order to ensure that a standard is not only stated objectively, but also practicable and addresses the safety need. In such situations, the agency has indicated in the Code of Federal Regulations (CFR) that these are the set of possible values or conditions that the agency may test at and that the manufacturer must certify that its vehicle will meet the requirements in the standard when tested to any of those test conditions within the specified range.¹²¹ For example, in FMVSS No. 208, entitled "Occupant Crash Protection," vehicles are crashed into a barrier at any speed up to 35 mph.¹²² The agency specified a range of speed conditions to help to ensure that protection is provided for a wide range of crash severity levels.

Similarly, a range of test conditions could be utilized in order to ensure that the autonomous motor vehicle can handle multiple conditions. For example, if NHTSA was to test an autonomous motor vehicle's ability to accurately avoid pedestrians at an intersection, the agency could define a test intersection (e.g., four way intersection controlled by traffic light) and present the vehicle with various test objects defined so as to replicate the appearance of a pedestrian to the vehicle's sensors. In such a test, ranges of values could be utilized to make the test more representative of the possibly erratic trajectory of a pedestrian. For example, the standard could establish that the pedestrian test object could begin at any point within a defined area in the intersection and proceed at any vector at any speed up to 10 mph. Such a

120. *Chrysler Corp. v. Dept. of Transp.*, 472 F.2d 659, 675 (6th Cir. 1972).

121. See Explanation of Usage 49 C.F.R. § 571.4 (2011) (explaining that the use of the word "any," in connection with a range of values or set of items means that any one of those values within the specified range may be selected for testing).

122. 49 C.F.R. § 571.208, para. S5.1.1(b)(2) (2011).

range of conditions would help to ensure that the vehicle would adequately detect and avoid any potential pedestrians within a defined range of possibilities.

In addition, the agency utilizes representative test conditions in order to ensure that the test is not only rationally linked to the safety need, but also objective and repeatable. In these instances, the test does not attempt to evaluate the vehicle's performance under all possible conditions that might occur in the real world. Instead, these tests establish conditions such that it is rational to conclude that if vehicles are able to meet the requirements of the standard when subjected to the test procedures and conditions specified in the standard, the vehicles will perform well in the vast majority of real world conditions they can be expected to encounter. One example of the agency's utilizing this method is in FMVSS No. 220, "School Bus Rollover Protection." In this standard, the agency's test specifies using a flat plate to apply a uniformly distributed force to the school bus roof.¹²³ This direct and top-down roof crush test condition arguably does not correspond exactly to the actual conditions that a school bus will be exposed to when it is involved in a rollover crash because most rollovers do not involve the application of a force directly perpendicular to the vehicle chassis. However, as the excellent safety record of school buses demonstrates, the representative test condition used in FMVSS No. 220 does enable school buses to withstand rollover crash forces better in the real world.¹²⁴

Similarly, a representative test condition (or set of representative test conditions) could be utilized to assess an autonomous vehicle's performance under the vast majority of likely crash scenarios. Using the forward collision warning/collision imminent braking example from earlier in this section, the agency could utilize a set of representative conditions (such as matching the speed of a lead vehicle traveling at 40 mph, a stopped lead vehicle, and a rapidly decelerating lead vehicle) in order to ensure that the test

123. See 49 C.F.R. § 571.220 para. S5.

124. Federal Motor Vehicle Safety Standards; Denial of Petition for Rulemaking; School Buses, 76 Fed. Reg. 53102, 53104 (Aug. 25, 2011) (discussing that school bus passengers are generally less likely to be fatally injured in a crash).

vehicle can adequately respond in the various possible real world forward collision scenarios. Although NHTSA might be unable to test the vehicle's forward collision avoidance capabilities under *all* possible forward collision scenarios, NHTSA might be able to establish a set of test conditions such that it would be rational to conclude that because a vehicle can adequately handle the defined test conditions, it should be able to handle the vast majority of likely real world conditions.

Using the same logic, NHTSA might be able to ensure adequate minimum electronic systems performance of autonomous motor vehicles by establishing various tests designed to ensure the minimum performance of representative safety features. As mentioned earlier in this Article, an autonomous motor vehicle is a vehicle which integrates the functionality of many different autonomous driving technologies. For example, an autonomous motor vehicle would likely need to incorporate the functions of a forward collision warning/collision imminent braking system and the pedestrian avoidance system described above. While the agency might be unable to practicably test a given autonomous motor vehicle model's ability to appropriately react to the full gamut of possible crash scenarios, the agency would likely still be able to ensure that—whatever autonomous driving system is used by the manufacturer—the vehicle is able to appropriately react to a defined set of crash scenarios (such as pedestrian avoidance and forward collision avoidance).

NHTSA would also be able to test the performance of software and electronic control systems by requiring the use of a specific test device in the agency's compliance test. NHTSA often utilizes test devices in order to determine compliance with FMVSSs. For example, FMVSS No. 208, "Occupant Crash Protection," utilizes specified anthropomorphic test dummies in evaluating compliance with the agency's airbag and crashworthiness requirements.¹²⁵ The CFR contains a detailed description of the test dummies and other similar devices that are used to measure the amount of crash force that would be exposed to a person in a

125. See, e.g., 49 C.F.R. §. 571.208, paras. S5.1.1(b), S6, S14.5.

crash.¹²⁶ Further, FMVSS No. 208 contains specific injury criteria which establish the permissible amount of crash force that can be exposed to the test dummy's head, neck, chest, etc.¹²⁷ Using the test procedure defining the crash conditions in conjunction with the aforementioned test dummies, the agency can establish an objective minimum performance requirement on the necessary level of protection for a vehicle occupant during a crash.

In a similar fashion, test devices can be utilized for ensuring a minimum level of software and electronic systems performance. As we noted in earlier sections of this Article, NHTSA's authority extends to motor vehicle equipment, regardless of whether it is a physical/mechanical item, or an intangible piece of software. Similarly, test devices in the future might include software programs designed to expose the faults in logic or coding of software used in vehicles. When NHTSA enlisted NASA's assistance in investigating possible software or electronic issues that might lead to unintended acceleration in a vehicle, NASA utilized various source code analysis software designed to detect coding errors and logic model checking.¹²⁸ In a similar fashion, one can imagine a standard in which a specific diagnostic (simulation) software (or set of diagnostic software) capable of producing objective results is specified in the regulatory text for use in evaluating the quality of the source code or logic processing of a software component of a motor vehicle. While the analysis conducted by NASA for the unintended acceleration investigation was very extensive, a simplified and less extensive version might be possible as part of a standard for electronic systems. Using a software diagnostic tool is analogous to NHTSA's current practice of using physical test devices such as anthropomorphic test dummies to determine compliance with a safety standard.

126. See Anthropomorphic Test Devices, 49 C.F.R. pt. 572 (describing in detail the various test devices that are used by the agency).

127. See 49 C.F.R. § 571.208, para. S6.

128. See NASA ENG'G & SAFETY CTR., TI-10-00618, TECHNICAL ASSESSMENT REPORT: NAT'L HIGHWAY TRAFFIC SAFETY ADMIN. TOYOTA UNINTENDED ACCELERATION INVESTIGATION - APPENDIX A, available at http://www.nhtsa.gov/staticfiles/nvs/pdf/NASA_FR_Appendix_A_Software.pdf (stating that NASA used Coverity, CodeSonar, and Uno to check for coding errors and Spin and Swarm to check the logic model).

As using diagnostic software only tests the coding and logic of the vehicle's software component, it does not enable a regulatory agency to test many other aspects of the performance that would be critical in autonomous driving systems. While using diagnostic software would enable NHTSA to determine if the software will make the correct decisions given a certain set of input data, additional testing would be required to ensure that a vehicle's sensors are providing accurate information about the surrounding environment so that the vehicle can effectively execute the software's commands. Thus, utilizing diagnostic software tests in conjunction with other tests utilizing ranges of values and representative tests conditions (as described above) might afford more comprehensive protection. Defining a set of tests as described above can enable the agency to ensure objective and practicable standards. By utilizing the ability to define ranges of values, sets of representative test conditions, and test devices, the agency should be able to ensure a minimum level of electronic systems performance in a sufficient number of crash scenarios so as to rationally conclude that the tested vehicles will be able to appropriately react to the majority of likely crash scenarios.

C. Vehicle Computer System Security and Privacy—Their Impact on Safety Effectiveness and/or Public Acceptance

The increased prevalence of electronic components in vehicles leads to unique challenges regarding the security of vehicle systems. Not only are electronic systems being developed that can assist (or replace) the driver's senses and decision-making functions, electronic systems are already being used to replace traditionally mechanical components of the vehicle.¹²⁹ This increased permeation of electronic components into the motor vehicle could expose the vehicle to new safety issues if persons can gain access to these electronic components and can manipulate how these components issue commands or otherwise interact with the vehicle. Through the increased use of wireless connections (whether as a medium for V2V safety communications or for other, non-safety related purposes), it is well demonstrated

129. See, e.g., *Drive-by-Wire™ Throttle System*, *supra* note 53.

that it is possible to obtain unauthorized access to a vehicle's systems without physical access to the vehicle.¹³⁰ As autonomous driving systems assume more and more driving tasks, there is an increasing potential for a person with unauthorized access to create significant safety issues. Further, these risks are aggravated by the increasingly connected nature of these vehicles because increased connectivity (especially wireless) exposes vehicles to more sources of potential bad actors.

If electronic and autonomous vehicle control systems are vulnerable to unauthorized access, the safety effectiveness of autonomous vehicle systems would suffer. This loss of effectiveness would reduce public confidence in and use of those systems, leading to still further loss of safety benefits. We have noted in this Article that public acceptance is an important aspect to be considered when evaluating the practicability (and effectiveness) of a safety standard.¹³¹ Making autonomous driving systems secure from unauthorized intrusion and modification would be an important element of a comprehensive effort to instill trust in the public regarding those technologies. Further, seeking to

130. Researchers from USC and Rutgers were able to obtain unauthorized access to a vehicle's systems through the wireless tire pressure monitoring systems. See Peter Bright, *Cars Hacked Through Wireless Tire Sensors*, ARS TECHNICA (Aug. 10, 2010, 1:20 PM), <http://arstechnica.com/security/news/2010/08/cars-hacked-through-wireless-tyre-sensors.ars>. This wireless intrusion into the vehicle followed another demonstration in which researchers were able to disable the brakes and the engine of a vehicle through physically accessing the OBD-II diagnostic port. See Robert McMillan, *Car Hackers Can Kill Brakes, Engine, and More*, PC WORLD (May 13, 2010, 11:20 PM), http://www.pcworld.com/businesscenter/article/196293/car_hackers_can_kill_brakes_engine_and_more.html.

131. See *Pac. Legal Found. v. Dept. of Transp.*, 593 F.2d 1338, 1345–46 (D.C. Cir.), *cert. denied*, 444 U.S. 830 (1979). In addition to including cyber security requirements in a standard to ensure that a particular standard is practicable, NHTSA would also be able to issue cyber security standards on an independent basis. See *Clifton v. Fed. Election Comm'n*, 114 F.3d 1309, 1312 (1st Cir. 1997). This is consistent with the principle of administrative law that agencies are authorized to promulgate rules reasonably related to achieving the purpose of the statute granting the rulemaking authority. *Id.* Because standards aimed at enhancing the security of electronic systems on motor vehicles would maintain the level of effectiveness of the safety features controlled by those electronic systems, NHTSA would be authorized able to promulgate such standards because they would be reasonably related to promoting motor vehicle safety. See *id.*

ensure that the security of these autonomous driving systems is protected only in ways that give due regard to the privacy concerns of the general public would likewise be crucial to securing public acceptance and ensuring the practicability of any potential standard. For example, it is important that the transmission of the “Here I am” message by motor vehicles in a V2V environment be accomplished in ways that do not reveal personal information.

1. *Technical Issue: Sources and Modes of Attack Are Unknown, Unpredictable, and Likely to Be Ever-Changing*

One significant challenge in establishing standards to address unauthorized access to electronic control systems in vehicles is the rapid pace at which this area of technology evolves and the many possible interfaces that can serve as potential portals for intrusion. Unlike the products released by the original equipment manufacturers that generally adhere to a multi-year product cycle, the methods utilized by potential bad actors are constantly evolving. While automakers might begin issuing software updates to their vehicles instead of waiting for the next product cycle,¹³² such updates are unlikely to be as unpredictable and numerous as the possible changes in tactics used by unknown members of the general public seeking to gain unauthorized access to vehicle systems regardless of the security measures used. As developing and publishing a rule can often take more than a year¹³³ and major revisions to FMVSSs can often contain multi-year phase-in schedules,¹³⁴ it can be extremely difficult

132. Ford has issued an update to its vehicles already on the market that utilize the MyFordTouch system. See Sharon Silke Carty, *Ford Tries to Resuscitate Its Image with a Bunch of Thumb Drives*, AOL AUTOS (Nov. 7, 2011), <http://autos.aol.com/article/ford-tries-to-resuscitate-image/>. Customers are able to update their MyFordTouch system by either bringing the vehicle to a Ford dealership or using a USB flash drive they receive from Ford in the mail. *Id.*

133. See Jerry L. Mashaw, *Improving the Environment of Agency Rulemaking: An Essay on Management, Games, and Accountability*, in YALE LAW SCHOOL FACULTY SCHOLARSHIP SERIES 200 (1994), available at http://digitalcommons.law.yale.edu/cgi/viewcontent.cgi?article=2167&context=fs_s_papers (“roughly 1.5 person years per agency”).

134. See, e.g., Advanced Air Bag Final Rule, 65 Fed. Reg. 30,680, 30,718 (May 12, 2000).

for regulatory agencies to properly identify the relevant security risks of electronic in-vehicle systems and anticipate the potential security breaches that can occur over the next few years. Unlike the past, when vehicle systems were largely mechanical and subject to the automakers' multi-year product cycle, establishing standards to address the security concerns of electronic systems is far less predictable.

2. *Legal and Practical Issues: Providing Protection from Unauthorized Intrusions into Autonomous Driving Systems*

While the potential security risks with automotive electronic systems are unpredictable, there might be certain areas in which the agency's authority to address security issues¹³⁵ could be used in ways that contribute toward ensuring a minimum level of protection. However, coordinated action by NHTSA and other entities (such as state governments) might provide the most comprehensive protection. In their article discussing the security of vehicle electronic systems, Dennis K. Nilsson and Ulf E. Larson opine that the priority areas for action in the immediate future should be ensuring that external sources of information for the vehicle are authenticated and that interfaces that are exposed to those external sources are properly guarded against unwanted intrusions.¹³⁶ However, as the authors note, there are significant challenges to ensuring that vehicle electronic system interfaces are guarded against unwanted intrusions in automotive applications because many of these applications (such as crash imminent safety applications) have little time to spare for firewalls or other protective measures.¹³⁷

135. The agency's authority to address security issues was recognized by Congress' inclusion in MAP-21 of a provision directing NHTSA to consider the need for establishing safety standards to prevent unauthorized access to the electronic systems in passenger motor vehicles. See Pub. L. No. 112-141, § 31402, 126 Stat. 405.

136. See DENNIS K. NILSSON & ULF E. LARSON, A ROADMAP FOR SECURING VEHICLES AGAINST CYBER ATTACKS, available at http://varma.ece.cmu.edu/Auto-CPS/Nilsson_Chalmers.pdf. See also STEPHEN CHECKOWAY ET AL. COMPREHENSIVE EXPERIMENTAL ANALYSES OF AUTOMOTIVE ATTACK SURFACES, available at <http://www.autosec.org/pubs/cars-usenixsec2011.pdf>.

137. See *id.*

Ensuring that external sources of information are authenticated and trusted has been a major focus for the Department in its connected vehicle research.¹³⁸ The program envisions a system which uses certificates to ensure that sources of information entering into a vehicle are trusted sources of information. It is not difficult to imagine a standard that requires vehicles to accept only information accompanied by authenticated security certificates in a certain fashion or update them at specified intervals. As mentioned earlier, NHTSA is required to establish performance standards but can be quite specific in establishing such standards in order to meet the need for safety. In this instance, the nature of the safety need (ensuring that each source of information for the vehicle's electronic systems is a trusted source) would necessitate quite detailed management of certificates and that all vehicles are able to communicate with the certifying entity or entities.

Finally, while NHTSA's authority extends to the vehicle equipment used to ensure security from unauthorized vehicle access, NHTSA's authority to prevent after-market modifications to motor vehicles is limited.¹³⁹ Specifically, NHTSA has the authority to prevent manufacturers, distributors, dealers and motor vehicle repair businesses from making modifications to motor vehicles that would take the motor vehicle out of compliance with an FMVSS (that the vehicle was certified as compliant with at the time the vehicle was manufactured).¹⁴⁰ However, private owners of motor

138. See RESEARCH & INNOVATIVE TECH. ADMIN., CERTIFICATE MANAGEMENT ENTITY SLIDE SHOW, available at http://www.its.dot.gov/meetings/pdf/BAH_CME_Webinar.pdf. In the Department's connected vehicle program, vehicles are intended to communicate a safety message to each other in order to enable various advanced safety functions. See *Vehicle-to-Vehicle (V2V) Communications for Safety*, U.S. DEP'T OF TRANSP.: RESEARCH & INNOVATIVE TECH. ADMIN., http://www.its.dot.gov/factsheets/v2v_factsheet.htm (last visited June 3, 2012). Thus, one important issue being explored is how to ensure that each vehicle transmitting safety information is a reliable source of information. See *id.*

139. As mentioned above in Part II, the Safety Act expressly prohibits motor vehicle repair businesses from "mak[ing] inoperative any part of a device or element of design installed on or in a motor vehicle or motor vehicle equipment in compliance with an applicable [FMVSS] . . ." 49 U.S.C. § 33012(b) (2006). However, private owners of motor vehicles are not precluded from making these after-market modifications under this provision of the Act. See *id.*

140. See *id.*

vehicles are not bound under the provision of the Act which allows NHTSA to preclude after-market modifications to motor vehicles in violation of an established FMVSS.¹⁴¹ While NHTSA may establish tamper-resistance requirements in FMVSSs to discourage private owners from modifying or disabling the safety features in their own vehicles, the agency does not have direct authority to prohibit owners from taking such actions.¹⁴² NHTSA also does not have the direct authority to require vehicle owners to maintain safety systems on their vehicles.

Thus, while NHTSA may preclude certain types of actors from modifying or providing services to the public that modify vehicle security systems (e.g., requiring a vehicle to accept certificates to authenticate it as a trustworthy source of information), state governments or other entities would have the authority to take action to directly ensure that the vehicle users on their roads have properly maintained their vehicles so that they can participate in the security infrastructure.¹⁴³ NHTSA could require that manufacturers ensure that new autonomous vehicles are equipped with the latest system security updates at the point of sale. States could complement the Federal action by requiring that drivers continue to update their vehicle's security software. Further, the states could more directly ensure that vehicle owners do not disable or tamper with an autonomous vehicle's security systems. NHTSA may be able to establish fairly specific standards regarding a vehicle's minimum level of cyber security protection. However, addressing many of the other aspects of cyber security performance may require other entities to act in conjunction with NHTSA in order to provide an appropriate minimum level of protection.

141. *See id.*

142. Contrast this provision with the parallel provision in the Clean Air Act, 42 U.S.C. § 7522(a)(3)(A) (2006). That provision prohibits "any person" from removing or rendering inoperative any device or element of design installed on or in a new or used motor vehicle or motor vehicle engine in compliance with Federal regulations issued under the Clean Air Act. *Id.*

143. While NHTSA has established vehicle use standards, *see, e.g.*, 49 C.F.R. pt. 570 (2009), these standards do not (by themselves) establish requirements upon any person. *See* 49 C.F.R. pt. 570.3. Instead, NHTSA works with the states (through vehicle inspection programs) to apply these requirements. *See id.*

3. *Privacy Issues: Data and Locational Privacy*

As we discussed in previous sections of this Article, one aspect of ensuring that a standard is practicable involves ensuring that the public will accept and use the technologies being installed to meet that standard.¹⁴⁴ While the vulnerability of autonomous driving systems to security threats has the potential to affect public acceptance, steps to reduce that vulnerability can also affect public acceptance. This point can be illustrated by an example drawn from efforts to address system vulnerabilities in implementing vehicle-to-vehicle communications systems. One potential measure for addressing security concerns entails each vehicle's being issued unique security certificates. To implement a system for certificating each transmitter of information to a vehicle to ensure that the transmitter is a trusted source might raise concerns regarding the impact of certificating on the privacy of the participants in this network. Specifically, the broadcasting of a unique security certificate by each vehicle has raised concerns that the system could be used to track individual drivers. These concerns should be taken into account and addressed in making decisions about whether and how to implement such a system. Otherwise, such a system could reduce the public's acceptance of vehicles equipped to send and receive vehicle-to-vehicle communications. Autonomous vehicles that do not use vehicle-to-vehicle communications might nevertheless also present privacy concerns. To the extent that an autonomous driving system relies on GPS to determine its location its position on the road and relative to the map, this reliance could cause concerns about the possibility of tracking (as the existence of a device that generates location information might enable the recordation of such information).¹⁴⁵

With this in mind, the Department's connected vehicle program has conducted research into the methods available

144. *See Pac. Legal Found. v. Dept. of Transp.*, 593 F.2d 1338, 1345–46 (D.C. Cir.), *cert. denied*, 444 U.S. 830 (1979).

145. Brief for Owner-Operator Independent Drivers Association, Inc. as Amici Curiae Supporting Respondents at 5–8, *United States v. Jones*, 132 S. Ct. 945 (2012) (No. 10-1259) (protesting regulations requiring that certain trucks be equipped with GPS devices).

for ensuring both the security of connected vehicles and the privacy of the individuals who use these systems. The Department has examined the possibility of separating the functions used to create these security certificates to ensure anonymity of the users and the reliability of the information.¹⁴⁶

Finally, we note that privacy concerns for autonomous driving systems (and public acceptance of these systems) are not limited to system security functions. While we have described in the preceding two paragraphs how addressing potential risks in system security might lead to increased concern regarding the protection of private information, privacy concerns are not limited to efforts aimed at addressing system security risks. Any FMVSS aimed at requiring advanced crash avoidance technologies or autonomous driving systems would involve the potential for more sophisticated measuring (and potentially recording) of safety relevant information regarding the driver's behavior (such as direction, speed, etc.). Thus, any such FMVSS would need to reflect careful consideration of the potential collections of information that might be required under the FMVSS. Any such FMVSS should consider whether such information needs to be collected and what safeguards would be in place to protect this information once it is collected. Through this analysis, an FMVSS might be more likely to be practicable because the public might be more willing to accept advanced technologies (such as autonomous driving technologies) when the public is assured that their private information will be protected.

D. Human Machine Interface

The human machine interface (HMI), for the purposes of this Article, represents the process by which the vehicle and driver interact and communicate with each other. The interaction between the driver and the vehicle becomes increasingly relevant with the adoption of advanced crash avoidance technologies and autonomous driving technologies. In the future, the driver will likely not only be exposed to an increasing amount of messages/warnings from the vehicle,

146. See generally *supra* note 138.

but also be sharing the driving task with the vehicle. Because the human driver can only respond to a finite amount of information, at some point additional information collected by the vehicle will only be useful if it is used to assist the driver with vehicle control. Further, because the vehicle is unlikely to be able to handle *all* driving conditions in the immediate future, the ability of the driver to quickly and correctly interpret communications from the autonomous vehicle is of paramount importance. Thus, timely, accurate, clear, and non-distracting communications between the driver and the vehicle is an issue of increasing importance with the progressive incorporation of these technologies in motor vehicles.

1. *Technical Issue: Quickly and Smoothly Transferring Control Between Driver and Vehicle*

As the vehicle increasingly assists or takes over for the human driver (particularly for the performance of safety critical functions) ensuring safety will likely require that a human be ready and able to step in and assume control of vehicle direction and speed with little or even no advance notice. This means that the driver should not only remain ready to assume driving tasks, but also should understand the interface that the vehicle uses to communicate with the driver. The increased sharing of the driving responsibility contributes significantly to the amount of information that needs to be communicated between the vehicle and the driver and the level of sophistication of that information. How can the vehicle ensure that the driver is ready and able to take over the driving task should the driver's expertise be required? How will the driver receive the relevant information regarding the potential safety hazards around the vehicle? Will the driver experience information overload? How should the messages be prioritized? How will the vehicle communicate with the driver that he or she needs to assume control? The ability of a vehicle to communicate this information and to interact with the driver is critical in the implementation of these technologies.

Even as vehicles increasingly warn, intervene and even assume driving responsibility, there are still many scenarios that will likely require the driver to assume control of the vehicle in the foreseeable future. Given the current state of

technology autonomous driving systems are generally not capable of correctly assessing and handling all driving scenarios—especially atypical ones, i.e., those that depart from those ordinarily encountered in real-world road conditions. For example, an autonomous motor vehicle might be able to sense a stoplight color and make the correct decision on whether to stop or go. However, difficulties might arise when that vehicle encounters a traffic light that is not functioning due to a power outage in the area or a traffic officer giving hand signals at an intersection. Additionally, heavy rain or snow could interfere with an autonomous motor vehicle's ability to determine correctly the status of a traffic light. In addition, these systems, like any other systems, presumably can be expected to malfunction on occasion. In these situations, the vehicle must be able to recognize the malfunction and then alert the driver that the autonomous driving system is not functioning and that the driver must again assume driving responsibility. The vehicle design and the communications between the vehicle and the driver must allow the driver to safely accomplish this transition from vehicle to driver control.

2. *Potential Solution: Standardizing the HMI to Ensure Consistent Messages and Method of Operation and Encourage Appropriate Driver Engagement*

While additional research would be necessary to determine the level of safety need and whether a standardized HMI and other minimum performance requirements would be able to address that need, NHTSA has the authority to require these elements in vehicle equipment in order to ensure that the driver can safely assume control of the vehicle. Although NHTSA does not directly regulate driver behavior, the agency could influence the extent of driver involvement in the driving task using the agency's regulatory authority over vehicle performance.¹⁴⁷ For

147. While NHTSA may not be able to regulate the driver, NHTSA may be able to indirectly influence the behavior of the driver through requiring the use of new technologies which detect whether drivers are paying attention to the driving task. *See, e.g.*, Howard, *supra* note 11. NHTSA also has numerous non-regulatory initiatives and programs that are intended to, and do, influence driver behavior. One example of this is the agency's Driver Distraction

example, NHTSA would be able to issue performance standards or mandate particular items of motor vehicle equipment¹⁴⁸ to ensure that vehicles are consistent in their communications to the driver. Further, NHTSA could exercise this authority by requiring the vehicle to encourage a certain level of driver involvement in the driving task.¹⁴⁹

Standardization of communications between the vehicle and the driver, and the manner in which the driver assumes driving responsibility from the vehicle could also encourage a reasonable level of driver involvement and afford a greater likelihood of a smooth transition of the driving responsibility from the autonomous driving system to the driver. Such standardization could also help ensure that drivers will understand the communications or warnings from the vehicle regardless of which vehicle they are in.

One method to accomplish these goals is by requiring that the HMI of autonomous driving systems possess specific standardized elements (i.e., alerts, signals, telltales, switches) that make it possible for any driver to understand the information being presented by a given vehicle. While standardizing this interaction between the driver and the autonomous driving system might constrain vehicle design to some degree, it is within the agency's authority to issue performance standards to require the standardization of the process as well as any warning lamps or other warning devices to the extent necessary to achieve a safety objective.¹⁵⁰

In situations in which standardization of a particular process or vehicle feature will lead to an increase in overall safety (as it will decrease the likelihood that drivers might not understand the communications from the vehicle) NHTSA has the authority under the Safety Act to issue standards

Guidelines. See Visual-Manual NHTSA Driver Distraction Guidelines for In-Vehicle Electronic Devices, 77 Fed. Reg. 11,200 (Feb. 24, 2012), available at <https://www.federalregister.gov/articles/2012/02/24/2012-4017/visual-manual-nhtsa-driver-distraction-guidelines-for-in-vehicle-electronic-devices>.

148. "NHTSA's regulatory authority extends beyond the performance of motor vehicles per se, to particular items of equipment." *Washington v. Dept. of Transp.*, 84 F.3d 1222, 1225 (10th Cir. 1996) (citing examples).

149. See e.g., *Howard*, *supra* note 11.

150. See *Chrysler Corp. v. Dept. of Transp.*, 515 F.2d 1053 (6th Cir. 1975) (upholding as within NHTSA's authority under the Safety Act the agency's rulemaking prescribing requirements that particular headlamps must comply with specific measurements stated in inches).

that (because of the specificity of the performance required) might constrain design.¹⁵¹ Such a standard could enable drivers to clearly understand autonomous driving systems and the scenarios in which the system would require the driver to take control of the vehicle. Should the safety need arise, the agency might require additional research to determine the most effective form of standardized warning that can urge a driver to retake control of an autonomous motor vehicle. However, this regulatory tool is available to NHTSA and is one method that can be used to ensure that the driver and autonomous driving system understand each other.

E. Retrospective Review to Assess the Effect of New Technologies on Benefits of Existing Standards

In addition to the aforementioned issues, NHTSA's rules are reviewed pursuant to the requirements of Executive Orders 12866 (Regulatory Planning and Review)¹⁵² and 13563 (Improving Regulation and Regulatory Review).¹⁵³ Both Executive Orders instruct federal agencies to conduct cost benefit analyses of proposed and final rules in order to help ensure that agencies use the least burdensome methods to achieve the regulatory end.¹⁵⁴ Both also instruct the agencies to revise their regulations as circumstances change. Section 5 of EO 12866 provides:

Sec. 5. In order to . . . determine whether regulations promulgated by the executive branch of the Federal Government have become unjustified or unnecessary as a result of changed circumstances . . . , each agency shall submit to OIRA a program, consistent with its resources and regulatory priorities, under which the agency will periodically review its existing significant regulations to determine whether any such regulations should be modified or eliminated so as to make the agency's regulatory program more effective in achieving the regulatory objectives, less burdensome, or in greater

151. *See id.* (holding that standardization of a particular piece of equipment on a vehicle is not inconsistent with the mandate in the Safety Act that safety standards not dictate vehicle design).

152. Exec. Order No. 12,866, 3 C.F.R. 638 (1994).

153. Exec. Order No. 13,563, 3 C.F.R. 215 (2012).

154. *See id.*

alignment with the President's priorities and the principles set forth in this Executive order.

Section 6 of E.O. 13563 directs the federal agencies to conduct a retrospective review of all existing rules periodically.¹⁵⁵ The purpose of this requirement is to ensure that existing rules are analyzed to determine whether they are outmoded, ineffective or excessively burdensome and whether or not these rules should be modified or repealed.¹⁵⁶

If, as anticipated, the advanced crash avoidance technologies and autonomous driving systems significantly reduce or mitigate a variety of types of crashes without resulting in any significant unintended consequences, the benefits associated with many current safety standards are likely to decrease. Since the costs of compliance would be generally unaffected, while the lives saved and injuries reduced or avoided would decrease, the cost per equivalent life saved by these standards would presumably increase. Thus, in conducting reviews of its safety standards, NHTSA would need to consider how the changes in the estimated benefits of each standard affects the cost per equivalent life saved and decide whether any of the standards should be amended. For example, if autonomous driving systems were capable of assuming the driving task and avoiding many of the crashes at speeds higher than a certain speed (such as 20 or 30 mph), then as the percentage of vehicles equipped with those systems increased, it would become increasingly appropriate for the agency to consider whether there was a need to amend the requirements of various crashworthiness standards to reflect changing risks to occupant safety.¹⁵⁷

Similarly, safety measures that might be appropriate during the early and middle stages of the progression from driver-controlled vehicles to fully automated vehicles appear likely to cease to be needed once the end stage is reached. In the former stages, when control is being transferred back and

155. *See id.* at 217.

156. *See id.*

157. Crashworthiness standards are standards that address the ability of a vehicle to protect its occupants in a crash. *See Crashworthiness*, NHTSA.GOV, <http://www.nhtsa.gov/cars/rules/CrashWorthy/> (last visited Oct. 21, 2012); *Crashworthiness*, NHTSA.GOV, <http://www.nhtsa.gov/Research/Crashworthiness> (last visited Oct. 20, 2012). In contrast, crash avoidance standards are intended to help avoid or at least mitigating crashes.

forth between the driver and the vehicle as the vehicle passes through different driving environments, the ability of the driver and the vehicle to anticipate and seamlessly handle the transfers of control will be of great safety importance. Human factors considerations regarding such matters as advance warning of impending transfers of control to the driver, situational awareness, compensating behaviors, and effects of increasing automation on driver skills might necessitate NHTSA's adopting appropriate regulatory and non-regulatory measures. However, once the progression is completed, the significance of the human factor considerations will decline substantially because control will remain with the vehicle throughout each trip. The need for any regulatory measures adopted to address human factors issues in the early and middle stages will theoretically have substantially disappeared by the time of the final stage. At that point, the two orders would require the agency to assess whether those regulatory measures should be modified or repealed and take appropriate action based on the results of that assessment.

V. RECALL AND REMEDY OF MOTOR VEHICLES AND EQUIPMENT WITH SAFETY DEFECTS

Under the Safety Act, a manufacturer's obligation to recall motor vehicles and motor vehicle equipment determined by the manufacturer or NHTSA to have a safety-related defect¹⁵⁸ is separate and distinct from its obligation to recall motor vehicles and motor vehicle equipment determined by the manufacturer or NHTSA to fail to comply with an applicable safety standard that is in effect at the time of manufacture.¹⁵⁹ The obligation to recall, which includes

158. 49 U.S.C. § 30118 (2006) (directing the Secretary to require the notification, recall and remedy of any motor vehicle or motor vehicle equipment he or she determines to contain a safety defect or to fail to comply with a safety standard and requiring a manufacturer to notify consumers of any motor vehicle or motor vehicle equipment the Secretary determines to contain a safety defect or to fail to comply with a safety standard). *Id.* § 30120 (requiring manufacturers of vehicles and motor vehicle equipment to recall and remedy a safety defect or noncompliance with a safety standard free of charge).

159. *See* § 30120; *United States v. Chrysler Corp.*, 158 F.3d 1350, 1351 (D.C. Cir. 1998) (NHTSA "may seek the recall of a motor vehicle *either* when a vehicle has 'a defect related to motor vehicle safety' *or* when a vehicle 'does not comply

the provision of a remedy without charge, defective motor vehicles and motor vehicle equipment is not dependent upon the agency's prior issuance of a standard addressing the type of performance in which a defect has been found.

Thus, notwithstanding the absence of a safety standard for a particular advanced crash avoidance technology or autonomous driving system, the agency could respond to a safety problem posed by a vehicle with one of those technologies or systems by ordering a recall if it could show that there is a defect and that the defect poses an unreasonable risk to motor vehicle safety.¹⁶⁰ Determining whether one of the technologies or systems is defective would present many of the same challenges that the agency would face in developing and issuing safety standards for these technologies and systems.

A. *Definition of Defect*

A defect "includes any defect in performance, construction, a component, or material of a motor vehicle or motor vehicle equipment."¹⁶¹ It also includes a defect in design.¹⁶² NHTSA can establish the existence of a defect in vehicles or equipment in a variety of ways. NHTSA frequently focuses its investigations on defects in performance. It can identify a broken part of a vehicle or

with an applicable motor vehicle safety standard.'").

160. See § 30120.

161. § 30102(a)(2).

162. In *United States v. Gen. Motors Corp. (Wheels)*, 518 F.2d 420, 432 (D.C. Cir. 1975), the court recognized the linkages between the term defect and motor vehicle safety, and the defect and the remedy. Both the motor vehicle safety definition and the remedy provision refer to design defects. The term "motor vehicle safety" refers to unreasonable risk of accidents occurring because of the "design, construction, or performance" of a motor vehicle. *Wheels*, 518 F.2d at 432. In view of the linkage, design defects are actionable. Indeed, the *Wheels* court recognized this in its discussion of the 1974 amendments to the Safety Act:

The remedy without charge requirement is intended to require manufacturers to correct at their expense defects in the performance, design, or construction of their products which relate to motor vehicle safety. It is not intended that manufacturers be required to make corrections if they can establish that the condition requiring correction results from the abuse of their products or the failure to adequately maintain them.

Id. at 436.

present evidence of a number of occurrences that are indicative of problematic performance to establish a defect. For example, vehicles or items of equipment have incidences of failure of performance and that the failure could not have been caused by ordinary wear and tear.¹⁶³

In addition to showing the existence of a defect, to compel a recall NHTSA must also show that the defect is related to motor vehicle safety. As defined in the Safety Act, motor vehicle safety means “the performance of a motor vehicle or motor vehicle equipment in a way that protects the public against unreasonable risk of accidents occurring because of the design, construction, or performance of a motor vehicle, and against unreasonable risk of death or injury in an accident, and includes nonoperational safety of a motor vehicle.”¹⁶⁴ This definition encompasses crash avoidance, crashworthiness and nonoperational safety. The concept of an unreasonable risk to motor vehicle safety is broad.¹⁶⁵ For example, a defect poses an “unreasonable risk to motor vehicle safety” if the defect results in a fire that creates a potentially hazardous situation to the driver and can be reasonably expected to occur again in the future.¹⁶⁶ Defects that cause a driver to lose control of a motor vehicle even at low speeds can pose an unreasonable risk to motor

163. *Wheels*, 518 F.2d at 432 (holding that NHTSA is not required to prove that the vehicle performance failures occurred during normal use, the agency may establish a *prima facie* case of defect by showing a significant number of failures). After NHTSA has established a defect, the manufacturer may attempt to establish, “as an affirmative defense, that the failures were attributable to gross and unforeseeable owner abuse or unforeseeable neglect of vehicle maintenance.” *Id.*

164. 49 U.S.C. § 30102(a)(8).

165. See *United States v. Gen. Motors Corp. (Pitman Arms)*, 561 F.2d 923, 928–29 (D.C. Cir. 1977) (stating that in addition to proving the presence of a defect in the vehicle, NHTSA must show that the defect is related to motor vehicle safety to initiate a recall). Motor vehicle safety is defined “as the performance of a motor vehicle or motor vehicle equipment in a way that protects the public against unreasonable risk of accidents occurring because of the design, construction, or performance of a motor vehicle.” § 30102(a)(8).

166. *United States v. Gen. Motors Corp. (Carburetors)*, 565 F.2d 754, 758 (D.C. Cir. 1977) (finding that a defect that caused gasoline to leak out of the carburetor onto the engine block creating a fire in the engine compartment posed an “unreasonable risk to motor vehicle safety”); see also *Pitman Arms*, 561 F.2d at 929 (holding that a failure of the vehicle’s steering system that caused the driver to lose control of the vehicle was an “unreasonable risk to motor vehicle safety”).

vehicle safety.¹⁶⁷

Take the following hypothetical example. A vehicle equipped with an advanced crash avoidance technology is experiencing a considerable rate of forward collisions. NHTSA would need to prove that the vehicle with that system was defective and that the defect posed an unreasonable risk to motor vehicle safety in order to require the manufacturer to initiate a recall and remedy the vehicle in question.

B. Establishing a Defect

Even when attempting to show a defect in a complex electronic system, the agency can point to failures in performance of a vehicle to establish the defect.¹⁶⁸ The agency does not need to identify a specific programming, engineering or mechanical error to show a defect in a complex autonomous or advance crash avoidance system such as the forward collision avoidance system in the hypothetical discussed above.¹⁶⁹ In the event that an algorithm controlling a safety-critical-vehicle system failed to make the correct determination in circumstances that likely would occur in the real world, the agency would be able to point to that failure as a way of establishing the existence of a defect.¹⁷⁰ The agency would not need to establish the defect by pointing to a specific error in the algorithm flowchart or coding. As an easy example, if the agency could point to some nontrivial performance failure in a crash imminent braking system—such as the system’s engaging the throttle, instead of the brake, when the vehicle detected that a crash was imminent—to establish that the system was defective, the agency would not need to offer an engineering explanation for the defect.¹⁷¹

167. *Pitman Arms*, 561 F.2d at 929.

168. *Id.* Viewed another way, the agency does not need to prove causation in the tort sense.

169. *United States v. Gen. Motors Corp. (X-Cars)*, 841 F.2d 400, 413 (D.C. Cir. 1988).

170. *United States v. Gen. Motors Corp. (Wheels)*, 518 F.2d 420, 432 (D.C. Cir. 1975).

171. In September 2011, Kia recalled Sorento models from 2007 and 2008 because the vehicles’ occupant classification system was misclassifying adult passengers and deactivating the passenger side airbags. Jonathan Welch, *Recall Roundup: Kia, Subaru Report Airbag and Moonroof Flaws*, WALL ST. J. BLOG (Sept. 16, 2011, 9:00 AM), <http://blogs.wsj.com/drivers->

The agency would then be able to issue a recall order assuming as is likely it could also establish that the defect posed an unreasonable risk to motor vehicle safety.

1. *Identifying Defects from Performance Failures*

In the case of defects with electronic control systems, being able to point to a failure in performance in lieu of a specific error in the software coding is important when the agency is attempting to show that these systems are defective. Investigating electronic control systems in an attempt to uncover specific errors in software coding that could be causing a certain performance failure is very time-consuming and expensive.

In response to reports of unintended acceleration in Toyota vehicles equipped with electronic throttle controls, NHTSA arranged to employ the expertise of the National Aeronautics and Space Administration (NASA) to conduct a study of the software that controlled the system to determine if the software contained any errors that could have caused the accelerator control system to malfunction.¹⁷² NHTSA provided NASA with vehicles purchased from consumers who had filed complaints of unintended acceleration with the agency.¹⁷³ The resulting NASA study lasted ten months and cost \$1.5 million.¹⁷⁴ During the course of the study, amongst

seat/2011/09/16/recall-roundup-kia-subaru-report-airbag-and-moonroof-flaws/. See also NAT'L HIGHWAY TRAFFIC SAFETY ADMIN., OFFICE OF DEFECT INVESTIGATION RESUME (EA-017) (2011), available at <http://www-odi.nhtsa.dot.gov/acms/cs/jaxrs/download/doc/UCM404705/INCLA-EA09017-1909.PDF> (summarizing NHTSA's investigation of the Sorento's occupant classification system). This is an example of a defect in an electronic control system that provided evidence of the failure in performance. See *id.* When the occupant classification system misclassified an occupant, a warning light would go on indicating that the passenger side air bag was deactivated showing that the system was not functioning as intended. *Id.*

172. See generally NASA ENG'G & SAFETY CTR., NHTSA TOYOTA UNINTENDED ACCELERATION INVESTIGATION (2011), available at http://www.nhtsa.gov/staticfiles/nvs/pdf/NASA-UA_report.pdf (examining whether any design deficiencies in the Toyota Electronic Throttle Control System Intelligent could cause unintended acceleration).

173. See *id.* at 19 (describing NASA's methodology used in studying reports of unintended acceleration in Toyota vehicles).

174. See Peter Whoriskey, *Report Clears Toyota Electronics*, WASH. POST, Feb. 9, 2011, at A1 (reporting NASA's efforts in investigating the link between electronic throttle control systems and unintended acceleration).

many other activities, NASA examined 280,000 lines of software code and subjected the test vehicles to magnetic radiation in an attempt to develop an explanation for the reported incidents of unintended acceleration.¹⁷⁵ NASA conducted a fault tree analysis in order to eliminate possible explanations of unintended acceleration.¹⁷⁶ NASA also used logic models to investigate whether the software that controlled the electronic throttle controls contained errors that could lead to unintended acceleration.¹⁷⁷

If NHTSA needed to provide an engineering explanation for every defect in advanced crash avoidance technologies or autonomous driving systems, its defect investigations might consume the same amount of time and resources used during the agency's investigation of unintended acceleration. This would significantly limit the agency's ability to induce or require manufacturers to recall vehicles with defective systems. That would, in turn, hinder the agency's efforts to ensure the continuing safety of motor vehicles.¹⁷⁸

2. *Challenges of Showing Defects from Performance Failures Alone*

Now assume that the failure in performance of the advanced crash avoidance technology discussed in the hypothetical above were not something so obvious as the system's engaging the throttle when it should be engaging the brake. In order to determine if a vehicle were defective, NHTSA would ordinarily first identify performance failures in specific vehicles or components. NHTSA often looks to the agency's consumer complaints database and Early Warning Reporting database to identify patterns of performance

175. *Id.*

176. See NASA ENG'G & SAFETY CTR., *supra* note 172, at 72 (describing the system level failures in the throttle control system that would need to occur in order for a vehicle to experience unintended acceleration).

177. A logic model explores all the possible responses of a system given a set of inputs in an attempt to elicit responses that lead to software errors. See NASA ENG'G & SAFETY CTR., *supra* note 128, at 10.

178. See *United States v. Gen. Motors Corp. (Wheels)*, 518 F.2d 420, 438 (D.C. Cir. 1975) (stating that requiring NHTSA to show that every performance failure was not attributable to owner abuse could have the effect of undermining the importance that Congress placed on the agency's ability to order recalls of defective vehicles).

failures involving a particular vehicle, vehicle component or system that could be attributed to a defect.¹⁷⁹

Once the agency has identified a series of performance failures in vehicles with an advanced crash avoidance technology or autonomous driving system, it might be challenging for the agency to show that these failures were a product of a defect (and refute a manufacturer's contention of driver error or some other external factor).¹⁸⁰ While the agency does not need to provide an engineering explanation in order to show a defect, it can be difficult to show the underlying performance failure relying on consumer complaints alone.¹⁸¹ Because there are many factors that influence forward collisions (the failure and performance that would point to a defect in a crash imminent braking system), it is unclear whether in various circumstances the differences in crash rates or consumer complaints would be a sufficient means for establishing the failure in performance present in the hypothetical failure of the advanced crash avoidance technology.

Some of the target crash scenarios that advanced crash avoidance technologies are designed to mitigate include head-

179. See, e.g., *United States v. Gen. Motors Corp. (X-Cars)*, 841 F.2d 400, 407 (D.C. Cir. 1988) (explaining that NHTSA based its claim of a performance defect in the X-car's brake system on the volume of consumer complaints that the agency received regarding premature rear wheel lock-up); Reporting of Early Warning Information, 72 Fed. Reg. 29,435 (May 29, 2007) (to be codified at 49 C.F.R. pt. 579) (stating that historically NHTSA identified defects primarily by analyzing consumer complaints). The Transportation Recall Enhancement, Accountability, and Documentation (TREAD) Act, Pub. L. No. 106-414, required NHTSA to issue rules to establish an early warning reporting system to assist the agency in identifying defects in a more expedited manner. Transportation Recall Enhancement, Accountability, and Documentation (TREAD) Act, Pub. L. No. 106-414 (2000) (current version at 49 U.S.C. §§ 30101–30170 (2006)). NHTSA requires manufacturers of vehicles and equipment to notify the agency of notices to dealers and consumers concerning defective equipment, foreign recalls initiated by the manufacturer, incidences involving the death, injury, and property damage, consumer complaints, and warranty claims attributable to a specific vehicle component. 49 C.F.R. pt. 579 (2010).

180. See *Ctr. for Auto Safety, Inc. v. Lewis*, 685 F.2d 656, 663 (D.C. Cir. 1982) (citing the difficulties that the Department of Transportation would have faced in proving a defect because the interaction between the driver and the vehicle was a critical factor in the complained performance failure).

181. See *X-Cars*, 841 F.2d at 413 (stating that when NHTSA attempts to show a defect through circumstantial evidence, the trial court can take into account the absence of an engineering explanation in determining whether the vehicle is defective).

on collisions with vehicles travelling in the opposite direction, rear-end collisions with a vehicle that is stopped, decelerating or travelling at a lower speed, collisions with vehicles making a left turn, collisions with vehicles going straight through a vertical junction and collisions with vehicles executing other turning maneuvers.¹⁸² Because crashes can be attributed to a variety of factors or driver error of the second vehicle involved in the crash a higher crash rate of a particular vehicle model alone might not indicate a failure in performance amounting to a defect.¹⁸³

In situations in which the agency is attempting to show a defect in performance that arguably can be attributable to external factors, manufacturers would likely question the complaints, arguing that consumers would have difficulty determining whether the failure should be attributed to the vehicle.¹⁸⁴ This seems especially likely when the performance failure complained of involves a complex system and the agency cannot point to physical or engineering evidence of failure.¹⁸⁵ On the other hand, if a number of drivers explained that a vehicle went haywire, and these problems could not fairly be attributed to the driver or another vehicle, the agency would not face a particularly difficult burden.

In the case of the hypothetical failure of the advanced crash avoidance technology discussed above that was causing an increased number of forward collisions, the manufacturer of the vehicle might argue that vehicle speed dictated by the

182. See ANA MARIA EIGEN & WASSIM G. NAJM, DETAILED ANALYSIS OF TARGET CRASHES FOR PRE-CRASH SENSING APPLICATIONS (2009), available at <http://www-nrd.nhtsa.dot.gov/pdf/esv/esv21/09-0248.pdf> (identifying crashes from the National Automotive Sampling System's Crashworthiness Data System that could be mitigated using forward crash avoidance technologies).

183. The World Health Organization identifies excessive speed (either exceeding the speed limit or driving too fast for conditions), driver impairment or distraction, environmental factors (visibility and road conditions), vehicle condition and road design as the leading causes of motor vehicle crashes. WORLD HEALTH ORG., WORLD REPORT ON ROAD TRAFFIC INJURY PREVENTION 76–88 (Margie Peden et al. eds., 2004), available at <http://whqlibdoc.who.int/publications/2004/9241562609.pdf>.

184. See *X-Cars*, 841 F.2d at 412–13 (in the context of brake lock up, questioning whether consumers could determine with any degree of accuracy what caused the performance failure complained of in that case).

185. See *id.* at 412 (stating that, in order to demonstrate that a defect exists, NHTSA must show that performance failure complained of is attributable to the vehicle instead of the driver or road conditions).

driver, driver error, road conditions, or behavior of other vehicles could have prevented the advanced crash avoidance technology from functioning as intended. In fact, because many of the crashes that a crash imminent braking system is intended to avoid involve a second vehicle, it is likely that there would be disputed reconstructions of crashes and conflicting views on what went wrong.¹⁸⁶

Because of the number of complex factors that could lead to a forward collision, it might be difficult for the driver to explain the circumstances and interactions that gave rise to a crash and for experts to determine whether the crash should be attributable to a failure in the vehicle's advanced crash avoidance technologies or some other factor that prevented the vehicle's systems from avoiding the crash.¹⁸⁷ While advanced crash avoidance technologies and autonomous driving systems are designed to correct for some of the driver related factors that contribute to crashes, for multiple vehicle crashes driver error could be present in the second vehicle and speed and environmental factors could still be crash contributors.¹⁸⁸ In view of the number of variables, it could be challenging for NHTSA to identify the defect and require the manufacturer to initiate a recall.¹⁸⁹

3. *Identifying the Cause of the Performance Failure: Methods and Tools*

NHTSA's traditional method of identifying defects might benefit from additional information to help uncover performance failures in advanced crash avoidance technologies and autonomous driving systems. While some failures in the performance of algorithms that control these

186. See EIGEN & NAJM, *supra* note 182.

187. See WORLD HEALTH ORG., *supra* note 183.

188. See Tyler Cowen, *Can I See Your, License, Registration and C.P.U.?*, NYTIMES.COM (May 28, 2011), <http://www.nytimes.com/2011/05/29/business/economy/29view.html> (discussing the potential safety benefits of advanced crash avoidance and autonomous technologies); *see also* Interview with Larry Page, Co-Founder, Google, & Eric Schmidt, CEO, Google, Question and Answer at Zeitgeist Americas 2011 (Sept. 27, 2011), *available at* <http://www.youtube.com/watch?v=srI6QYfi-HY> (highlighting the capabilities of the Google autonomous car). In the interview, Larry Page and Eric Schmidt state that the Google autonomous car has better minimum capabilities than most human drivers. *Id.*

189. *Ctr. for Auto Safety, Inc. v. Lewis*, 685 F.2d 656, 663 (D.C. Cir. 1982).

systems might be evident (and thus manifest themselves in consumer complaints or Early Warning Reporting databases), other performance failures that vehicles experience might be more difficult to identify. The likelihood of multiple failures in performance increases as the information provided by the vehicle's sensors are linked to an ever-expanding number of vehicle functions controlled by the vehicle's onboard computers. If shortcomings in design impact several aspects of vehicle performance such as braking, acceleration, and steering, it might be more difficult for the agency to identify a pattern of performance failures by examining consumer complaints or the Early Warning Reporting database, making it difficult for the agency to isolate the defect.¹⁹⁰

In order for the agency to identify defects and order recalls of defective vehicles in a timely manner, the agency's traditional strategy might benefit from additional tools for identifying failures in performance of advanced crash avoidance technologies and autonomous driving systems that pose an unreasonable risk to motor vehicle safety. One way in which NHTSA would be able to determine if these systems were functioning correctly at the time of a crash would be for the system to record the vehicle functions and actions taken by the computer control system prior to the crash. NHTSA currently relies on event data recorders (EDRs) that collect information about vehicle speed, throttle position, seatbelt status and airbag deployment in investigating defects.¹⁹¹ The

190. See TRANSP. RESEARCH BD., *supra* note 116, at 78 (stating that if the failure in performance caused by a defect cannot be traced to the failure of a clearly identifiable component, the Early Warning Reporting database may not be helpful in alert NHTSA to the existence of the defect).

191. NHTSA has issued requirements to standardize the information collected by EDRs. 49 C.F.R. pt. 563 (2010). The agency does not currently mandate that vehicles weighing 5500 pounds and less be equipped with an EDR. *Id.* at pt. 563.3. Manufacturers currently install EDRs on light vehicles on a voluntary basis. One of the recommendations contained in the National Academy of Science report on electronic vehicle control systems was to ensure that all new motor vehicles contain EDRs. TRANSP. RESEARCH BD., *supra* note 116, at 7. The report states that EDRs will help NHTSA detect electronic failures and intermittent electronic faults that leave no physical evidence of a defect. *Id.* According to NHTSA's research and rulemaking priority plan, the agency plans on issuing a proposal to require all new motor vehicles weighing 5500 pounds and less be equipped with an EDR. NHTSA VEHICLE SAFETY AND FUEL ECONOMY RULEMAKING AND RESEARCH PRIORITY PLAN 20 (2011), available at http://www.nhtsa.gov/staticfiles/rulemaking/pdf/2011-2013_Vehicle

agency uses the information from EDRs to determine the factors that contribute to crashes and to monitor the performance of safety systems.¹⁹² The role of EDRs can be potentially expanded in the future in order to provide superior information regarding the potential causes of performance failures. Both NHTSA and the manufacturers would be able to use the data collected about the behavior of these autonomous driving systems to improve the algorithms that control these systems and enhance the systems' response to avoid collisions caused by driver error.¹⁹³ However, as discussed above, the agency would need to consider the privacy implications of any such expansion and to examine what steps could be taken to protect privacy.

4. *Application of NHTSA's Defect Authority to Aftermarket Equipment*

As noted above, NHTSA's authority to investigate defects applies to manufacturers of motor vehicle equipment¹⁹⁴ (as well as motor vehicles).¹⁹⁵ NHTSA applies the same test to determine whether a defect is present in an item of motor vehicle equipment as it does when investigating defects in motor vehicles.¹⁹⁶ The Safety Act generally gives NHTSA the ability to order recalls of autonomous driving technologies

_Safety-Fuel_Economy_Rulemaking-Research_Priority_Plan.pdf.

192. Event Data Recorders, 71 Fed. Reg. 50998 (Aug. 28, 2006) (to be codified at 49 C.F.R. pt. 563).

193. See James K. Kuchar & Ann C. Drumm, *The Traffic Alert and Collision Avoidance System*, 16 LINCOLN LAB. J. 277, 283–88 (2007) (studying strategies that could enhance the performance of aircraft collision avoidance systems to avoid collisions in situations in which the pilot of one aircraft ignores the direction provided by the collision avoidance system).

194. Reading the terms “motor vehicle” and “replacement equipment” together, NHTSA's defects authority generally extends to the items that are considered “motor vehicle equipment.” See *supra* note 158.

195. 49 U.S.C. § 30118 (2006). The manufacturer can be an entity other than the original equipment manufacturer. Persons who make changes to motor vehicles (that are otherwise certified as compliant with applicable FMVSSs) before the first sale are considered alterers of the motor vehicle with responsibilities to certify compliance with relevant FMVSSs. See 49 C.F.R. pt. 567, available at <http://www.ecfr.gov/cgi-bin/text-idx?c=ecfr&sid=8c691a99067d5d687f819dceaafd8e5&rgn=div5&view=text&node=49:6.1.2.3.35&idno=49#49:6.1.2.3.35.0.7.7>. Further, in certain circumstances, modifications of used vehicles are regarded as resulting in the manufacture of a new motor vehicle. See 49 C.F.R. 571.7(e) and (f).

196. See *id.*

because of defects present in the components of those technologies or because of defects attributable to the improper installation of the technology by an alterer. In order to establish a defect, NHTSA must show a significant number of performance failures.¹⁹⁷ Under the Safety Act, the presence of a defect is not dependent on the source of the performance failure leading to an unreasonable risk to motor vehicle safety.¹⁹⁸ Thus, a defect can be based on the improper assembly of a motor vehicle or motor vehicle equipment.¹⁹⁹ As the components of autonomous driving technology are motor vehicle equipment, NHTSA would be able to use the methods discussed above to order a recall of autonomous driving technology installed (as aftermarket equipment) on a vehicle that was not originally manufactured as an autonomous vehicle.²⁰⁰

Because of the potential benefits of autonomous driving technology and the potential demand for the technology by consumers, it is likely that some manufacturers of autonomous driving technology will seek to convert vehicles that were not originally manufactured as autonomous vehicles to equip them with autonomous driving capabilities. If the autonomous driving technologies are not properly installed in the aftermarket by an alterer, it is possible that the improper installation could be considered to have created a defect if it posed an unreasonable risk to motor vehicle safety. If NHTSA could establish a significant number of performance failures caused by the improper installation of aftermarket autonomous driving technology, the agency

197. *United States v. Gen. Motors Corp. (Wheels)*, 518 F.2d 420, 432 (D.C. Cir. 1975).

198. *See* § 30102(a)(2) (defining defect as including any “defect in performance, construction, a component or material of a motor vehicle or motor vehicle equipment”); *see also Wheels*, 518 F.2d at 432 (stating that the presence of a defect can be established based exclusively on the performance of the vehicle or equipment).

199. *See United States v. Gen. Motors Corp. (Carburetors)*, 565 F.2d 754, 756 (D.C. Cir. 1977) (stating that the defect at issue in the case was caused by the improper installation of a fuel inlet plug into a carburetor). The improper installation of the fuel inlet plug into the carburetor during manufacturing was not isolated to a small number of vehicles. *Id.* General Motors disclosed 665 fires in 1965 and 1966 Chevrolet and Buick models during the course of the litigation. *Id.*

200. *See* § 30102(a)(2).

would be able to order the recall of that technology. In such a situation, NHTSA could argue that it was reasonably foreseeable that the autonomous driving technology would be improperly installed and that the technology was defective because of the number of performance failures.²⁰¹

NHTSA's ability to order the recall of motor vehicle equipment because of a defect in the installation of the equipment is also important to the agency's efforts to promote vehicle-to-vehicle communications. Because the benefits of any vehicle-to-vehicle communications system depend on the penetration of the technology into the on road vehicle fleet, aftermarket installations of vehicle-to-vehicle communications technology is crucial to increasing the penetration of the technology and maximizing its full safety benefits. NHTSA's ability to order the recall of motor vehicle equipment because of a defect in the installation of that equipment will help ensure that aftermarket installations of autonomous driving and vehicle-to-vehicle communications technologies are implemented in a safe manner.

C. *Establishing Unreasonable Risk*

In addition to identifying a defect, NHTSA needs to show that the defect poses an unreasonable risk to motor vehicle safety in order to induce or (if necessary) require a manufacturer to conduct a recall. The courts likely will look at the threatened harm and the frequency of it. Courts will not require a high frequency when the threat is substantial.²⁰² In some cases, it will be easy to establish that a defect in an advanced crash avoidance technology or autonomous driving system poses an unreasonable risk to motor vehicle safety. The hypothetical of the defect in a crash imminent braking system that caused the vehicle to accelerate, instead of braking, when a collision was imminent would increase danger to the occupants of a vehicle equipped with the defective system, as well as to the occupants of other vehicles, and be considered an unreasonable risk to motor vehicle

201. *Wheels*, 518 F.2d at 438 (stating that NHTSA can establish a defect based on performance failures caused by "reasonably-to-be-expected" abuse).

202. *Carburetors*, 565 F.2d at 758; *United States v. Gen. Motors Corp. (Pitman Arms)*, 561 F.2d 923, 928–29 (D.C. Cir. 1977).

safety.²⁰³ The high likelihood that this defect would not only cause a frontal collision, but also increase its severity would be considered a severe harm. A defect of this nature would make the vehicle more dangerous than if the vehicle were not equipped with the crash imminent braking system in the first place.

Whether a given defect represents an unreasonable risk to motor vehicle safety might not always be so clear as in the hypothetical described above. Determining whether a defective advanced crash avoidance technology or autonomous driving system poses a likelihood of harm might depend on the functionality of the system as well as driver reliance on that system. To the extent that a system only provides warnings to the driver and does not cause the vehicle to take any corrective action itself, driver reliance on the system might be a significant issue.

If driver reliance on an autonomous driving system were high, the failure of that system would have greater safety consequences. In the case of a full or close to full automation driving system, a failure of that system that would make it necessary for the driver to take control of the vehicle would likely pose an unreasonable risk to motor vehicle safety.²⁰⁴ Having become accustomed to relying upon the autonomous driving system, drivers might not be able to reacquire situational awareness (i.e., awareness of the potential for crashes in the immediate driving environment) in a very short period of time and take control of their vehicle quickly enough when the system fails.²⁰⁵

It is possible that drivers might come to rely on the autonomous driving system to such an extent that they will not respond when presented with a situation in which the autonomous driving system is no longer in control of the

203. See *Pitman Arms*, 561 F.2d at 928 (stating that a “commonsense” approach should be used when determining if a defect poses an unreasonable risk to motor vehicle safety).

204. See Joan Lowry, “Automation Addiction” *Damaging Pilots’ Flying Skills: Report*, THE HUFFINGTON POST (Aug. 30, 2011, 7:48 AM), available at http://www.huffingtonpost.com/2011/08/30/automation-addiction-dama_0_n_942604.html (examining how increased reliance on automated flight systems has impacted pilots’ ability to fly without the aid of the automated system).

205. See *id.* (discussing incidents in which the automated flight controls failed and the pilot was unable to regain control of the aircraft).

vehicle.²⁰⁶ Several factors would compound the risks created by the failure of an autonomous driving system. One is a sudden failure. Another is failure that occurs without the driver being given any indication that it has occurred. Drivers in the latter situation would likely not realize that the autonomous driving system is no longer in control of the vehicle until it is too late to avoid a collision.

Even if the root cause of a defect might be more difficult to ascertain than in the era when vehicle systems were primarily mechanical, NHTSA generally needs only to point to a performance failure to establish a defect. As driver reliance on advanced crash avoidance technologies and autonomous driving systems increases, so will the risk of harm from the failure of these systems. While NHTSA might need additional data and tools to help determine whether there is a failure of performance in connection with certain types of defects in these systems, the agency will still be able to point to performance failures of these systems as grounds for ordering recalls of defective vehicles.

VI. COMPARATIVE SAFETY PERFORMANCE INFORMATION PROGRAMS

A. *Role of the New Car Assessment Program (NCAP) in Encouraging Autonomous Motor Vehicle Features*

Public awareness of differences in the relative safety performance characteristics between different vehicle models through NCAP has helped foster consumer demand for safety and strongly encourages manufacturers to build motor vehicles that exceed the minimum performance requirements in the FMVSSs. NHTSA has recognized that “the success of the NCAP requires change if manufacturers are to be continually challenged to make voluntary safety improvements to their vehicles.”²⁰⁷ Thus, NHTSA will strive to continually update NCAP as necessary to continue to “incentiv[ize] and encourage *accelerated deployment* of these

206. *See generally id.*

207. NAT'L HIGHWAY TRAFFIC SAFETY ADMIN., DOT HS 810 698, THE NEW CAR ASSESSMENT PROGRAM SUGGESTED APPROACHES FOR FUTURE PROGRAM ENHANCEMENTS 3 (2007).

new, advanced technologies.”²⁰⁸

As advanced crash avoidance technologies are increasingly electronic and continue to advance along the continuum toward full automation, the foreseeable future challenges confronting NCAP will be assessing and publicizing the benefits of these advanced technologies that are continuously and rapidly evolving. In addition, many of these technologies possess a high level of variation in design and composition of safety applications between manufacturers. Thus, determining which of these technologies offer the most promise in addressing the most frequently occurring crash scenarios might be challenging. While these new technologies might have great safety benefit, there might be little information and real-world data to provide a basis for evaluating the existence of a safety benefit and to serve as the basis for NHTSA recommending the technology to consumers through NCAP.

In developing ratings for NCAP, NHTSA is not bound by the same statutory requirements that apply when the agency issues FMVSSs.²⁰⁹ This gives the agency more flexibility in devising NCAP rating criteria and methodologies. Through NCAP, NHTSA could promote a technology that has evident safety benefits but which the agency is not yet prepared to require as a part of an FMVSS.

B. Current NCAP

NCAP provides vehicle crashworthiness information to consumers through a rating system based on one to five stars (five being the highest rating). Every year, NCAP rates the crashworthiness of selected vehicle models²¹⁰ and provides a

208. Consumer Information: New Car Assessment Program, 73 Fed. Reg. 40,016, 40,033 (July 11, 2008) (emphasis added).

209. The statute authorizing NCAP directs NHTSA to maintain a program for providing information to consumers on the damage susceptibility and crashworthiness of vehicles in order to assist consumers in purchasing vehicles. See 49 U.S.C. § 32302 (2006).

210. For MY 2012, NCAP will “provide consumer safety information on approximately 81 percent of model year 2012 passenger vehicles sold in the United States, while rollover tests will provide information on 92 percent of the 2012 fleet.” *NHTSA Announces Model Year 2012 Vehicles to be Rated Under Government 5-Star Safety Ratings Program*, NEWS (U.S. Dep’t of Transp., Washington, D.C.), Oct. 13, 2011, at 1, available at <http://www.nhtsa.gov/staticfiles/communications/pdf/nhtsa1711.pdf>. This

vehicle safety score (VSS) star rating. The VSS is derived from a particular vehicle's combined success on three testing criteria: frontal crash, side crash, and rollover resistance. In addition to the overall VSS, NCAP provides independent star ratings for the subject vehicle's success during each one of the three crashworthiness tests.

NCAP also provides information to the public about selected advanced crash avoidance technologies. NHTSA selects crash avoidance technologies for inclusion in NCAP's crash avoidance ratings program based on technical maturity of the technology, the availability of the technology in the current fleet, and the availability of safety effectiveness data for the technology.²¹¹ NHTSA has selected three advanced crash avoidance technologies to be recommended and promoted through NCAP: Electronic Stability Control (ESC), Forward Collision Warning (FCW), and Lane Departure Warning (LDW).²¹² These three technologies are currently the only advanced crash avoidance technologies that meet the agency's criteria for inclusion in NCAP.²¹³

Because vehicles equipped with ESC have been available for some time, NHTSA was able to rely on real-world data to establish ESC's effectiveness. In contrast, FCW and LDW are relatively new technologies with limited available real-world data. In estimating the safety benefits of these two technologies, NHTSA relied on data from large scale field operational tests (FOTs). NHTSA believes "that the FOT results for FCW and LDW are applicable for estimating real-world safety benefits since these technologies were evaluated in the same real-world driving environment in which they would be deployed."²¹⁴ NHTSA also used FOT data and other

means "NHTSA will rate 74 vehicles for the FY 2012 model year . . ." *Id.*

211. See CONSUMER INFORMATION; NEW CAR ASSESSMENT PROGRAM, 73 Fed. Reg. at 40,016–40,017, 40,033.

212. *Id.* at 40,017.

213. *Id.*

214. *Id.* at 40,033. In general, in an FOT, the major variables impacting a technology's safety benefits, including differences in individual driving styles and behavior, system performance, and driver acceptance, are taken into account. Likewise, critical safety incidents (i.e., near-crash incidents that occur during the FOT) data are recorded and evaluated to determine if the technology provided a safety benefit in terms of critical incident reduction. Assuming a proportional relationship between near-crash events and actual crashes, critical incident data are further evaluated using statistical methods to estimate crash

agency research to develop test procedures and minimum performance criteria in order to validate that technologies purporting to be FCW or LDW in fact have the requisite performance capabilities.²¹⁵ Following its evaluation, NHTSA concluded that (at that time) it did not yet have enough data to recommend other technologies such as “collision mitigation braking systems, lane-keeping assist systems, and side object detection technologies.”²¹⁶

Unlike for traditional crash test ratings, NHTSA does not provide vehicle model specific comparative individual or overall ratings for advanced crash avoidance technologies as it does for a vehicle model’s crashworthiness.²¹⁷ The current NCAP does not rate the crash avoidance capabilities of individual vehicles because NHTSA’s current test procedures have not been designed to comparatively rate the effectiveness of different manufacturers’ advanced crash avoidance systems.²¹⁸ Instead, the agency established performance tests to verify that a particular vehicle model has systems that possess the minimum qualities and characteristics of these technologies.²¹⁹ A vehicle model’s NCAP crashworthiness ratings are supplemented by a symbol or symbols indicating which of the three recommended advanced crash avoidance technologies are installed on that model.

C. Estimating the Safety Benefits of New Technology as Early as the Pre-Production Stage

As advanced crash avoidance technologies are rapidly developing, NHTSA is seeking new ways to estimate safety benefits of these technologies. In addition to using the field operational tests discussed above to identify safety benefits of emerging technologies earlier, NHTSA has initiated the

reduction benefits. In the field tests for FCW and LDW systems, NHTSA provided technical management and the Volpe National Transportation Systems Center performed an independent evaluation to estimate safety benefits which included rigorous statistical analysis. *Id.*

215. *Id.*

216. *Id.*

217. *Id.* at 40,034.

218. *Id.*

219. *Id.*

Advanced Crash Avoidance Technologies (ACAT I²²⁰) research program, in conjunction with vehicle manufacturers, to develop standardized methodologies to evaluate the effectiveness of advanced technologies in mitigating specific types of vehicle crashes; and to develop and demonstrate objective tests that can verify the safety impact of a real system.²²¹

To accomplish this goal, the agency has focused on developing methodologies for estimating safety benefits of systems at the pre-production stage by extrapolating the results of laboratory tests.²²² NHTSA has developed a common framework that can be tailored to evaluating the safety benefits of each different crash avoidance technology. This framework includes identifying crash scenarios that the technology is designed to mitigate.²²³ The methodologies rely on computer models, human factors research, and performance tests.²²⁴ Four research groups have created

220. Art Carter, Presentation at the SAE Government/Industry Meeting: The Advanced Crash Avoidance Technologies Program (Feb. 4, 2009), *available at* <http://www.sae.org/events/gim/presentations/2009/artcarter1.pdf>.

221. NHTSA's objective for the ACAT program is to develop a methodology for estimating the potential effectiveness of advanced safety technologies intended to assist drivers in avoiding crashes. U.S. DEP'T OF TRANSP.: NAT'L HIGHWAY TRAFFIC SAFETY ADMIN., DOT HS 811 088, ADVANCED CRASH AVOIDANCE TECHNOLOGIES PROGRAM: ANNUAL REPORT 1 (2009) [hereinafter ANNUAL REPORT], *available at* <http://www.nhtsa.gov/DOT/NHTSA/NRD/Multimedia/PDFs/Crash%20Avoidance/2009/811088.pdf>; U.S. DEP'T OF TRANSP.: NAT'L HIGHWAY TRAFFIC SAFETY ADMIN., DOT HS 811 454H, ADVANCED CRASH AVOIDANCE TECHNOLOGIES PROGRAM: FINAL REPORT OF THE HONDA-DRI TEAM (2011) [hereinafter HONDA-DRI TEAM], *available at* <http://www.nhtsa.gov/DOT/NHTSA/NVS/Crash%20Avoidance/Technical%20Publications/2011/811454H.pdf>. NHTSA's prior experience indicates that the effectiveness of advanced safety technologies in reducing crashes is not well understood. ANNUAL REPORT, *supra*, at 1; HONDA-DRI TEAM, *supra*. ACAT is targeted at developing some of the tools needed for calculating the estimated benefit of these technologies in relation to the crashes they are intended to prevent. ANNUAL REPORT, *supra*, at 1; HONDA-DRI TEAM, *supra*.

222. See ARTHUR A. CARTER ET AL., SAFETY IMPACT METHODOLOGY (SIM): EVALUATION OF PRE-PRODUCTION SYSTEMS 1 (2009), *available at* <http://www-nrd.nhtsa.dot.gov/pdf/esv/esv21/09-0259.pdf>. In addition "to form[ing] the basis for regulatory evaluations of potential new requirements[,] new SIMs for pre-production systems can be used: "1) as part of the design process of new systems, 2) to evaluate the performance of pre-production systems before marketing, 3) to provide guidance to safety advocates, such as NHTSA, on new safety improvements" *Id.*

223. *Id.* at 4.

224. See *id.*

methodologies within NHTSA's framework for evaluating different crash avoidance technologies or "countermeasures" including the Advanced Collision Mitigation Braking System Countermeasure, Lane Departure Collision Countermeasures, Pre-collision Safety System Countermeasures, and Backing-Collision Countermeasures.²²⁵

D. Future Role for NCAP in Promoting Advanced Crash Avoidance Technologies

As more advanced crash avoidance technologies are introduced into the new vehicle fleet and demonstrate safety benefits, NHTSA will be able to decide whether to continue its current approach of informing consumers of the presence of advanced crash avoidance technologies on a vehicle model or to begin comparatively rating vehicle models based on their overall ability to avoid crashes. To some extent, the agency's approach will depend on how the driving public views advanced crash avoidance technologies. Recent focus groups conducted by the agency suggest that drivers have yet to understand the potential of these technologies.²²⁶ Different consumers might also place different values on advanced crash avoidance technologies and autonomous driving systems, based on personal preferences and driving habits. In recommending advanced crash avoidance technologies, the agency might need to take into account how different driving habits and preferences might impact consumers' choices about purchasing vehicles equipped with these technologies.

If the agency chooses to continue to promote advanced crash avoidance technologies by presenting information about individual technologies in the same manner as is currently used on the NCAP website, the agency will need to develop benefit estimates and decide which technologies to list at a pace that equals the rate of their penetration into the new vehicle fleet. As these technologies on vehicles will increasingly operate in tandem, it might be challenging for NHTSA to determine how to apportion the credit among the linked technologies for the benefits they generate. If different manufacturers use different combinations of technologies to

225. *See id.* at 5–8.

226. *Id.*

address similar crash scenarios, the problem of providing information that differentiates between available technologies will increase. As the number of crash avoidance technologies increases, however, the number of beneficial technologies recommended by the agency might increase to the point at which consumers could become confused by the number of technologies recommended by the agency.²²⁷ Accordingly, the agency might need to shift its approach and rate a vehicle's overall ability to avoid crashes as it currently does for a vehicle's crashworthiness in order to provide consumers with meaningful information and to encourage continued innovation.

VII. NHTSA'S STANDARDS WILL LIKELY INFLUENCE OR BE INFLUENCED BY LARGER PUBLIC POLICY CHOICES

NHTSA inevitably will play a role in influencing the manner and pace with which autonomous driving systems are developed and introduced. Even issues relating to driver behavior, vehicle maintenance, and vehicle system tampering are likely to be influenced by NHTSA's research and regulatory activities as autonomous driving systems become more advanced and assume greater driving responsibilities.

Issues related to driver behavior and maintenance of vehicles on public roads are generally the domain of state and local governments. Several States, most recently California, have adopted laws governing the testing and operation of autonomous vehicles on public roads.²²⁸

227. *See id.* (explaining that consumers found it difficult to make sense of potential NCAP rating involving multiple check marks, star ratings, or grading scales even when a reference key is provided).

228. *See, e.g.*, NEV. REV. STAT. §§ 482A.30, 482A.100 (2012) (defining autonomous technology and directing the Department of Motor Vehicles to issuing regulations authorizing the operation and testing of autonomous vehicles); FLA. STAT. § 316.85 (2012) (establishing requirements for autonomous vehicles registered in the state and testing requirements).

On September 25, 2012, the Governor of California signed legislation expressly authorizing the testing on public roads of autonomous vehicles as long as their driver's seat is occupied by a licensed driver. *See* 2012 Cal. Stat. 91. This legislation requires the California Department of Motor Vehicles (DMV) to issue, not later than January 1, 2015, regulations establishing a process for manufacturers of autonomous vehicles to submit applications to operate autonomous vehicles on public roads for purposes other than testing. *See id.* The legislation prohibits the operation of autonomous vehicles on public roads for non-testing purposes until the DMV approves the application of a

As the prevalence and sophistication of autonomous driving technology increases, NHTSA might find it appropriate to issue new FMVSSs to address the performance of those technologies. For example, NHTSA could influence the scenarios in which autonomous motor vehicles are allowed to operate in autonomous mode through a vehicle safety standard. It would be possible for NHTSA to issue standards requiring that an autonomous motor vehicle only function in autonomous mode at certain speeds or only on roads sensed to be limited access highways.²²⁹

Further, autonomous driving systems might significantly increase the importance of motor vehicle maintenance in ensuring vehicle safety. It is possible that an autonomous motor vehicle's ability to avoid crashes will depend on consistent software updates and hardware upkeep to ensure that the vehicle's autonomous driving system will have the necessary information to make decisions about its surroundings. Further, failure to maintain a vehicle's autonomous driving systems can potentially have consequences for other road users (especially in a connected vehicle environment). In this situation, the utility of the autonomous driving systems and the ability of the systems to

manufacturer of autonomous vehicles pursuant to those regulations. *See id.* The legislation defines the term "autonomous vehicle manufacturer" as (1) a person who manufactures vehicles originally equipped with autonomous technology or (2) a person that modifies a vehicle by equipping the vehicle with autonomous technology so as to convert it into an autonomous vehicle. *See id.*

The legislation requires autonomous vehicle manufacturers wishing to obtain permission from the DMV for the operation of their autonomous vehicles on public roads for non-testing purposes to submit an application to the DMV certifying that their autonomous vehicles meet all applicable Federal motor vehicle safety standards, have certain capabilities that enable the driver to retake control of the vehicle when it is in autonomous mode, are able to notify the driver when the vehicle is in autonomous mode, and can capture and store from the autonomous technology sensor data for the period thirty seconds prior to a crash. *See id.* Finally, the legislation requires the DMV to notify the legislature if any manufacturer submits an application for permission to operate an autonomous vehicle on public roads without the presence of a driver inside the vehicle. *See id.*

229. NHTSA has issued several safety standards that, while not applicable to used vehicles, affect the operation of a vehicle. The agency can issue standards with explicit requirements for when required safety systems must be active and when these systems may not be active. *See* FMVSS No. 108, Lamps, Reflective Devices, and Associated Equipment, 49 C.F.R. § 571.108, para. S5.1.4 (2009) (prescribing activation and deactivation requirements for school bus lamps).

safely operate would depend on whether the vehicle owner updates the vehicle's software and maintains the vehicle's systems in a timely manner. It is possible that NHTSA could work with states and issue standards to ensure that vehicle owners updated the software that controls autonomous driving systems by issuing used vehicle standards.²³⁰

In addition, adopting these technologies might also increase the importance of preventing vehicle owners from tampering with autonomous driving systems. As autonomous driving systems control an increasing number of vehicle functions it is possible that some drivers might want to alter the decision-making process of the autonomous motor vehicle's computer or otherwise alter the way in which the autonomous motor vehicle behaves.²³¹ The likelihood of such behavior might increase if, for example, federal or state governments chose to require autonomous driving systems be activated under certain conditions. The agency is able to prevent manufacturers, distributors, dealers, or motor vehicle repair businesses from disabling required safety devices installed on vehicles.²³² However, this authority does not prevent owners from making changes that would disable a safety system in their own vehicles.²³³ While the agency might discourage system tampering by establishing a standard that requires autonomous driving systems to have a certain level of tamper-resistance, additional statutory authority or coordinated action with state and local governments would be required in order to legally prevent owners from tampering with these systems.

NHTSA will have a variety of choices about the role it plays in influencing the manner and pace with which autonomous motor vehicles are adopted. NHTSA could choose to promote autonomous driving technologies by including these technologies in NCAP, by requiring that

230. See, e.g., 49 U.S.C. § 30126 (2006).

231. See Sarah Aue & Frank Douma, *ITS and Locational Privacy: Suggestions for Peaceful Coexistence*, 78 J. TRANSP. L. LOGISTICS & POL'Y 89, 111 (2011) (describing efforts of vehicle owners to remove ignition interlock devices that prevented the vehicle from starting if the driver did not have the belt fastened that manufacturers installed on vehicles to meet the passive restraint requirements in FMVSS No. 208).

232. 49 U.S.C. § 30122 (2006).

233. *Id.*

voluntarily installed autonomous driving technologies meet specific performance requirements, by requiring that certain autonomous driving technologies be installed in motor vehicles as mandatory equipment or by defining the types of driving environments or conditions in which vehicles will be permitted to function in autonomous mode. These decisions will be based on factors such as the maturity of technologies, the safety benefits to be gained from the use of these technologies, the cost of obtaining those benefits, and the extent to which these technologies function without unintended safety consequences.

CONCLUSION

The advanced crash avoidance technologies and autonomous driving systems being incorporated into motor vehicles today represent an exciting trend. There is a great potential for autonomous driving technologies to yield significant safety benefits. Autonomous driving technologies offer the promise of mitigating the greatest risk factor on the highway today—unsafe actions by human drivers. While many of these technologies were not envisioned at the time Congress passed the Safety Act, one can see through the analysis in this Article that many of the currently available regulatory tools can be effectively applied to these new technologies. Although NHTSA would likely need to act in conjunction with other entities in order to address some aspects of the concerns with privacy, security, and external vehicle connections and vehicle maintenance of advanced crash avoidance technologies and autonomous driving systems in used vehicles, NHTSA's authority is broad enough to address a wide variety of issues affecting the safety of vehicles equipped with these technologies and systems. Whether, when and how NHTSA exercises its authority to regulate autonomous vehicles depends on the results of on-going research, on the gathering and analyzing of information relating to the developing, testing and eventual introducing of those vehicles and on policy choices that have yet to be made by the agency and the Department of Transportation. However, as autonomous vehicle technologies develop, it is likely that NHTSA will continue to conduct research, eventually develop appropriate performance requirements and test procedures, and actively utilize alternatives to direct

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regulation such as comparative performance information in partnership with stakeholders, including manufacturers, consumer groups and the states.