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NATIONAL HIGHWAY TRAFFIC SAFETY ADMINISTRATION

SAFETY PETITION

Submitted by

GENERAL MOTORS

PETITION UNDER 49 U.S.C. § 30113 AND 49 C.F.R. PART 555
TO ADVANCE SAFETY AND ZERO-EMISSION VEHICLES
THROUGH TECHNOLOGY THAT ACHIEVES THE SAFETY
PURPOSE OF THE FMVSS

January 11, 2018

USG 4708

GENERAL MOTORS

Paul Hemmersbaugh
Chief Counsel & Policy Director
Autonomous Vehicles &
Transportation as a Service

Jeffrey Massimilla
Vice President
Global Vehicle Safety &
Cybersecurity

Doug L. Parks
Vice President
Autonomous and Electric
Vehicle Programs

January 11, 2018

Ms. Heidi King
Deputy Administrator
National Highway Traffic Safety Administration
1200 New Jersey Avenue, S.E.
Washington, DC 20590

RE: Petition under 49 U.S.C. § 30113 and 49 C.F.R. Part 555 to advance safety and zero-emission vehicles through technology that achieves the safety purpose of the FMVSS

Dear Ms. King,

Please find enclosed General Motors' Safety Petition for our zero-emission autonomous vehicle.

Respectfully Submitted,

Doug Parks

Paul Hemmersbaugh

Jeffrey Massimilla

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Introduction

Pursuant to 49 U.S.C. § 30113 of the National Traffic and Motor Vehicle Safety Act ("Safety Act")[1] and 49 C.F.R. Part 555, General Motors, LLC ("GM"), a Delaware limited liability company, submits this petition for exemption ("Petition"). Through this Petition, GM seeks approval to advance safety and low-emission technology by introducing into commerce a limited number (2,500 or less per year) of GM's driverless zero-emission autonomous vehicle ("ZEAV"). GM's ZEAV achieves the purposes of the Federal Motor Vehicle Safety Standards ("FMVSS" or "Standards") through adaptations[2] necessary to enable self-driving operation. GM's ZEAV is designed to be fully self-driving for all trips, without a human driver and without human driver controls. Engineered with safety paramount, the ZEAV meets the safety purposes and objectives of all applicable FMVSS, directly complying with the vast majority of requirements in those Standards, and using advances in technology to meet the safety purposes of the remainder. In the ZEAV, GM has adapted driver controls and information requirements for operation exclusively by its automated driving system ("ADS") instead of a human, and has replaced the "driver seat" occupant protection system with a "passenger seat" occupant protection system meeting the performance requirements of relevant FMVSS for front passenger seats.

Granting this Petition will benefit the public in many ways—above all, by advancing safety. Self-driving technology, like that embodied in GM's ZEAV, has the potential to transform mobility and provide unprecedented vehicle safety. Because human error or behavior leads to 94 percent of vehicle crashes, technology that eliminates the human driver has the potential to save tens of thousands of lives and to avoid or mitigate hundreds of thousands of vehicle crashes every year in the United States alone.

Because of the significant life-saving potential of autonomous vehicles, government and industry should work together to eliminate unnecessary obstacles to deployment of this technology. Every day in the United States, more than 100 lives are lost in car crashes. Every day of delay in getting autonomous vehicles safely on American roads is a day in which we are losing lives that could be saved.[3] As the U.S. Department of Transportation ("DOT") has summarized,

> [T]he excitement around highly automated vehicles (HAVs) starts with safety. Two numbers exemplify the need. First, 35,092 people died on U.S. roadways in 2015 alone. Second, 94 percent of crashes can be tied to a human choice or error. An

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[1] Pub. L. No. 89-563, 80 Stat. 718 (1966) (codified as amended at 49 U.S.C. § 30101 *et seq.*).

[2] GM's adaptations replace certain conventional vehicle systems required by FMVSS with corresponding systems for autonomous vehicles, which achieve the safety purpose and effect of the Standards while advancing safety and low-emission technology.

[3] *See* Nidi Kalra and David G. Groves, *The Enemy of Good, Estimating the Cost of Waiting for Nearly Perfect Automated Vehicles*, Rand Corp. (2017), available at https://www.rand.org/pubs/research_reports/RR2150.html.

> important promise of HAVs is to address and mitigate that overwhelming majority of crashes. Whether through technology that corrects for human mistakes, or through technology that takes over the full driving responsibility, automated driving innovations could dramatically decrease the number of crashes tied to human choices and behavior.[4]
>
> Thanks to a convergence of technological advances, the promise of safer automated driving systems is closer to becoming a reality. From reducing crash-related deaths and injuries, to improving access to transportation, to reducing traffic congestion and vehicle emissions, automated vehicles hold significant potential to increase productivity and improve the quality of life for millions of people.[5]

Recently, NHTSA announced an initiative to remove unnecessary and inapplicable barriers to autonomous vehicles, particularly those like GM's ZEAV, which do not include human driver controls. Consistent with broader DOT efforts to enable innovation in transportation and vehicle safety, NHTSA announced that it seeks

> to identify any unnecessary regulatory barriers to Automated Safety Technologies, and for the testing and compliance certification of motor vehicles with unconventional automated vehicle designs, particularly those that are not equipped with controls for a human driver; e.g. steering wheel, brake or accelerator pedal. . . . in order to safely lay a path for innovative automated vehicle designs and technology.[6]

This Petition offers the opportunity to advance NHTSA's announced goals: to remove unnecessary and inapplicable regulatory barriers to the evaluation and deployment of an autonomous vehicle not equipped with human driver controls, and thereby to expedite the delivery of the promised safety and mobility benefits of autonomous vehicles to the American people. Granting this Petition would eliminate unnecessary obstacles to deployment of GM's ZEAV, primarily by authorizing functional and safety alternatives to requirements in the FMVSS

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[4] U.S. Department of Transportation and National Highway Traffic Safety Administration, *Federal Automated Vehicles Policy: Accelerating the Next Revolution in Roadway Safety* (2016) at 10, available at https://www.transportation.gov/sites/dot.gov/files/docs/AV%20policy%20guidance%20PDF.pdf.

[5] U.S. Department of Transportation and National Highway Traffic Safety Administration, *Automated Driving Systems 2.0: A Vision for Safety* (2017) at i, available at https://www.nhtsa.gov/sites/nhtsa.dot.gov/files/documents/13069a-ads2.0_090617_v9a_tag.pdf.

[6] U.S. Department of Transportation, *Removing Unnecessary Barriers to Automated Safety Technologies*, Report on DOT Significant Rulemakings Item 65 (NHTSA), RIN 2127-AL91 (October 2017). *See also* U.S. Department of Transportation and National Highway Traffic Safety Administration, *Removing Regulatory Barriers for Vehicles with Automated Driving Systems*, Docket No. NHTSA-2018-0009 (January 10, 2018) (requesting public comments "primarily" regarding "potential barriers to testing, compliance certification and compliance verification" for ADS-equipped vehicles that "lack controls for a human driver, e.g., steering wheel, brake pedal or accelerator pedal").

that are predicated on the presence of a human driver. An autonomous vehicle driven by an ADS can achieve the safety benefits of those FMVSS requirements with new technology systems and mechanisms that serve the same safety purposes as requirements for conventional vehicles. In this Petition, GM demonstrates that its ZEAV satisfies the safety purpose and intent of all FMVSS just as a certified, human-driven vehicle does. And because the ZEAV can help eliminate human error, drunk driving, and distracted driving, it offers safety potential beyond that of human-driven vehicles.

GM will introduce the ZEAV in a GM-controlled ride-share program using 2,500 or fewer vehicles per year. Through this program, in addition to gaining further experience in autonomous vehicle safety, GM will facilitate public exposure to and use of a new zero-emission vehicle, support the development of an industry creating thousands of jobs, and introduce new mobility options for Americans. And because GM's controlled deployment will require electric utility support for electric vehicle charging, the program will also encourage growth in infrastructure that supports low- and zero-emission vehicles. Through the deployment described in this Petition, GM's ZEAV will generate vital real-world experience and data to advance safety in future vehicles and validate use cases for zero-emission vehicles in urban mobility programs. As NHTSA moves forward with autonomous vehicle regulatory initiatives, data generated by GM's ZEAV program can provide valuable inputs and guideposts for future rulemaking.

GM seeks an "exemption" under two separate statutory provisions, 49 U.S.C. §§ 30113(b)(3)(B)(ii) and (iii). As this Petition makes clear, "exemption" is a term of art that is a misnomer in this context because GM does not seek to be "exempted" from any safety requirements. Rather, through this Petition, GM seeks authorization to satisfy the safety purpose and intent of certain FMVSS requirements and tests through different designs and systems. Because the ZEAV satisfies the requirements of both provisions, NHTSA may grant this Petition under either or both provisions.

<u>First</u>, under 49 U.S.C. § 30113(b)(3), NHTSA may issue an FMVSS exemption "on finding that—(A) an exemption is consistent with the public interest and this chapter or chapter 325 of this title (as applicable); and (B)…the exemption would make the development or field evaluation of a low-emission motor vehicle easier and would not unreasonably lower the safety level of that vehicle."[7] Thus, in order to justify an exemption, a petition under this provision must support three primary showings: the public interest showing; the low-emission showing; and the safety showing, as set forth in 49 U.S.C. § 30113(b)(3)(B)(iii). These provisions of § 30113(b)(3)(B)(iii) foster the same goals that GM pursues with this application: the development and prompt availability of new low-emission vehicles that improve consumer mobility and meet federal safety objectives embodied in the Safety Act. As demonstrated below, granting this Petition would make easier the development and field evaluation of GM's zero-emission autonomous vehicle,

[7] 49 U.S.C. § 30113(b)(3)(B)(iii).

and GM's proposed deployment program fully satisfies the three requirements of § 30113(b)(3)(B)(iii).

Second, this Petition also seeks an exemption on the independent basis that it will "make easier the development [and] field evaluation of new motor vehicle safety features."[8] Under 49 U.S.C. § 30113(b)(3), NHTSA may also issue an exemption "on finding that— (A) an exemption is consistent with the public interest and this chapter or chapter 325 of this title (as applicable); and (B)…the exemption would make easier the development or field evaluation of a new motor vehicle safety feature providing a safety level at least equal to the safety level of the standard."[9] Thus, under this provision, the Petition must support three primary showings: the public interest showing; the development and evaluation of a new safety feature showing; and the FMVSS safety showing, as set forth in 49 U.S.C. § 30113(b)(3)(B)(ii).

The discussion below supports findings that GM's proposed ZEAV deployment fully satisfies the three criteria of both §§ 30113(b)(3)(B)(ii) and (iii), and that NHTSA should therefore grant the Petition.[10]

In furtherance of this Petition, the discussion below contains:

- A description of GM's ZEAV program and the vehicle;
- A discussion of how the Petition should be evaluated under the Safety Act and NHTSA's regulations and procedures;
- A Standard-by-Standard description of how GM's ZEAV achieves the safety purposes of the affected human-driver based FMVSS requirements;
- An explanation of how granting this Petition will facilitate the development and field evaluation of a low-emission vehicle;
- A discussion of how granting this Petition will benefit the public interest; and
- A discussion of GM's plans for compliance with applicable FMVSS during and after the effective dates of the proposed exemption.

[8] 49 U.S.C. § 30113(b)(3)(B)(ii).
[9] 49 U.S.C. § 30113(b)(3)(B)(ii).
[10] The safety showings required to obtain an exemption under 49 U.S.C. § 30113(b)(3)(B)(ii) and (iii) are referred to hereinafter as the required "safety findings" or "safety showings."

Petition: Advancing Safety and Zero-Emission Vehicles Through Technologies That Achieve the Safety Purposes of FMVSS

I. GM's Zero-Emission Autonomous Vehicle Program

GM seeks authorization to deploy its fully self-driving ZEAV and to make it available to the public through on-demand mobility services provided in GM-controlled fleets. GM's ZEAV emerges from a convergence of GM's industry leadership in vehicle electrification, automation, and mobility services. It embodies an important step in safely advancing new low-emission mobility opportunities.

A. Leadership in Electrification

GM's new ZEAV is a product of GM's innovation and leadership in motor vehicle electrification. GM's ZEAV is built from the architecture of the award-winning Chevrolet Bolt EV, first introduced in Model Year 2017. The Bolt is the world's most affordable long-range zero-emission vehicle.[11] The Bolt's innovations, available at an affordable price, make the benefits of zero-emission vehicles available to more consumers than ever before.

Electrification innovations in GM's ZEAV, incorporated from the Bolt EV, are a product of the expertise GM developed while creating the Chevrolet Volt, which passed the 100,000-U.S.-sales milestone in 2016. The second-generation Chevrolet Volt, launched in 2015, features a 39 percent greater all-electric range, has stronger acceleration, and is 220 pounds lighter than its predecessor, launched in 2010. Like the Volt and the Bolt, GM's ZEAV will be part of GM's growing portfolio of electrified vehicles, which now also includes the new Chevrolet Malibu hybrid and the Cadillac CT6 plug-in hybrid electric vehicle. This electric vehicle portfolio will continue to grow, as GM recently announced that it intends to manufacture and sell 20 new electric vehicles by 2023.

[11] The 2017 Chevy Bolt EV offers an EPA estimated all-electric range of 238 miles on a full charge. The all-electric range of GM's ZEAV has not yet been determined.

B. Leadership in Automation

GM is also a pioneer in automated and emerging vehicle technology. GM's history includes leading developments in this field—from participating on the winning team at the 2007 Defense Advanced Research Projects Agency ("DARPA") challenge to designing, manufacturing, and selling vehicles with safety systems and advanced driver assistance features like adaptive cruise control, crash imminent braking, lane keep assist, and Super Cruise.

GM accelerated its vehicle automation efforts in early 2016 with the acquisition of Cruise Automation. With the addition of Cruise, GM gained deep software talent and additional autonomous vehicle expertise. In June of 2016, GM began testing autonomous Chevrolet Bolts on public roads under real-world conditions in San Francisco, California, and Scottsdale, Arizona. The GM fleet has grown to be one of the largest publicly tested fleets of autonomous vehicles in the world. We are now testing more than 50 ZEAVs on a daily basis and have added a third testing location in metro Detroit. This real-world testing, especially in the heart of San Francisco, challenges our vehicles to operate under dynamic, congested, and diverse conditions.[12]

GM and Cruise created the original prototypes for GM's ZEAV through a manual process of retrofitting a Chevrolet Bolt with self-driving controls and equipment. Last year, GM achieved a landmark manufacturing accomplishment by producing autonomous test vehicles on an assembly line at its Orion Assembly plant in Lake Orion, Michigan. Workers at Orion Assembly have already built a test fleet of 130 Bolt EVs equipped with fully autonomous (self-driving) technology. The new equipment includes LiDAR, radar, and camera sensors, along with state-of-the-art computerized vehicle control systems. To develop and produce these vehicles, GM has leveraged Michigan's talented pool of automotive workers and GM's proven manufacturing capabilities.

In addition to developing the technology, GM supports public policy that is necessary to facilitate advancements in safety, mobility, and low-emission vehicle technology. Regulators and legislators at the state and federal levels have recognized the efforts of GM and others in developing self-driving technologies and are now considering ways to foster the deployment of automated vehicles. GM is committed to being a full-fledged partner with policy makers in this process. We have had active dialogue with many cities across the U.S. to learn about their transportation system needs and to find ways that GM can help improve their future transportation solutions. At the federal level, GM Chairman and Chief Executive Officer Mary Barra is Co-Chair of DOT's Advisory Committee on Automation in Transportation. This committee "was established to serve as a critical resource for the Department in framing federal policy for

[12] *See* Kyle Vogt, *Why Testing Self-Driving Cars in SF Is Challenging but Necessary*, *Medium* (Oct. 3, 2017), available at https://medium.com/kylevogt/why-testing-self-driving-cars-in-sf-is-challenging-but-necessary-77dbe8345927.

the continued development and deployment of automated transportation" and to "assess the Department's current research, policy and regulatory support to advance the safe and effective use of autonomous vehicles."[13]

The combined efforts of GM, policy makers, and other technology and industry participants put America in the lead in a global race to develop and deploy autonomous vehicle technology and the safety advances that it will help to bring. While other countries actively explore ways to facilitate the development and deployment of autonomous vehicles, with this Petition, GM seeks to use available legal and regulatory tools to help the U.S. maintain its global leadership in autonomous vehicle technology.

C. Leadership in Mobility

In 2016, GM launched its shared mobility brand, Maven. Maven customers have traveled more than 160 million miles through Maven's three services: Maven City (car sharing), Maven Home (car sharing for communities, such as apartment buildings), and Maven Gig (car rental to drivers wishing to provide transportation services, such as through transportation network platforms). Maven's highly-personalized suite of mobility-on-demand services provides seamless access to transportation. Through its experience with Maven, GM continuously learns about the personal mobility solutions that customers want now and will seek in the future. This knowledge and GM's advances in electrification and autonomous technologies provide the building blocks for the next phase in the evolution of safe motor vehicle transportation: ZEAVs providing safer transportation, zero emissions, and accessible mobility services on American roads.

D. The Next Step: An Electrified and Automated Vehicle to Improve Safety and Advance Mobility

Urban centers throughout the country are searching for safe, accessible, and flexible mobility solutions that reduce congestion, reduce parking shortages, and help maintain air quality. In the search for such transportation solutions, each of the three elements described above—electrification, automation, and personalized mobility-on-demand services—shows immense potential. GM believes that the convergence of these three developments will foster significant improvements in vehicle safety and urban mobility. DOT has previously recognized some of these connections, observing that autonomous vehicles "may also have the potential to save energy and reduce air pollution from transportation through efficiency and by supporting vehicle electrification."[14]

[13] U.S. Department of Transportation, *Advisory Committee on Automation in Transportation (ACAT)*, available at https://www.transportation.gov/acat.
[14] *Federal Automated Vehicles Policy*, *supra* at 5.

GM's fully electric ZEAV combines electrification, automation, and personalized mobility-on-demand services. It is designed to operate in an urban fleet without a human driver. Passengers will connect with ZEAVs through their mobile devices. During each ride, passengers will experience in-vehicle features and design oriented toward human passengers, rather than human drivers. The ZEAV's robust cybersecurity measures, developed using the principles of security by design and privacy by design, will help to protect the safety, security, and privacy of passengers.

Electrification offers further advantages in automated vehicles providing mobility-on-demand services. GM electric vehicles have long service intervals for fluids, brake pads, and other features, reducing the maintenance burden for vehicles undergoing high mileage accumulation. And because electric drivetrains are more compact, electric vehicles can provide more spacious interiors than similarly-sized internal combustion engine vehicles.

GM's ZEAV will help bring new mobility options to cities and will put new zero-emission vehicles on the road. By exposing more of the public to zero-emission vehicles, GM's ZEAV will foster wider acceptance of electric vehicles. GM's ZEAV is a significant step in bringing the freedom of mobility to virtually anyone, including those currently lacking convenient transportation options.

Our ZEAV will meet the safety standards under either § 30113(b)(3)(B)(ii) or (iii) and provide our customers with safe transportation. And that is just the beginning. While we have been manufacturing vehicles for over a century, with our self-driving cars, GM is just getting started. We have not reached the limits of our self-driving technology or its capabilities to improve safety. We will continue to develop the car's computers so they operate faster, the car's sensors so they "see" better, and the car's safe driving skills to continually improve performance.

II. Designed to Be Safe and Self-Driving: Description of GM's Zero-Emission Autonomous Vehicle

This section provides an overview of how GM's ZEAV meets the safety purposes of all applicable FMVSS and provides safety at least equal to that of a vehicle that meets the human-driver-specific requirements of each affected FMVSS.

GM's new ZEAV is built from the architecture of our award-winning Chevrolet Bolt EV. The Bolt is certified to comply with all applicable FMVSS, and GM's ZEAV retains all of the Bolt's safety features applicable to a self-driving vehicle. With improvements to enable optimal operation at all times without a human driver, GM's vehicle meets the full intent of the FMVSS, but in some instances through designs and methods that the FMVSS do not yet contemplate. In particular, a number of FMVSS requirements were promulgated to protect or inform the driver. At present, these Standards assume that the driver will be a human being. In light of today's technological developments, this assumption no longer holds true. The adaptations described in this Petition allow GM's ZEAV to fulfill the underlying purposes of these Standards—to help to enable, protect, and inform the driver, the passengers, and other road users—when the "driver" is an ADS.

A. ZEAV Safety and the FMVSS

In the development of the ZEAV, safety is GM's foundation and guiding principle. GM's safety approach incorporates several industry benchmarks, including multiple analysis tools and standards from SAE International, the International Organization for Standardization, the Motor Industry Software Reliability Association, RCTA, Inc., and the U.S. Military. With these tools and standards, GM rigorously assesses system safety, cybersecurity, vehicle crashworthiness, and the operational design domain of the ZEAV.

Redundancy is an integral feature of the ZEAV's design. The vehicle's sensor systems and vehicle control systems are layered with built-in redundancies to help ensure that the vehicle can operate safely even if there is a component or system failure—GM's ZEAV has single-point, dual-point, and common cause failure response capabilities. Redundant software commands require verification before activating any critical controls. The ZEAV's computer system verifies that vehicle safety systems are functioning correctly, both before embarking on trips and during on-road operation.

The ZEAV's ADS control algorithms incorporate knowledge gained from millions of miles of on-road driver behavior data and a rigorous on-road testing and development program. Unlike many human drivers, the ADS is programmed to consistently follow traffic laws. ADS operation plans account for not only anticipated needs, such as routine maintenance, but also the unexpected. Response plans include detailed procedures for handling acute events—from remedying a part failure to reacting in the event of a collision. To further promote passenger safety and positive customer experience, the vehicle will maintain connectivity to a GM fleet operations center during rides. This will allow GM to monitor vehicle performance and will also allow passengers to connect with specially trained call-center operators through an in-vehicle communications system.

GM's ZEAV will not have a human driver. Instead, the ZEAV is a computer-driven vehicle. That is, the ADS (a computer-controlled system) controls all of the functions that a human driver would control in a conventional vehicle. The human occupants in GM's ZEAV will not have access to vehicle driving controls and will not perform the driving tasks referenced in the FMVSS. Thus, no occupant of the ZEAV meets the definition of "driver" in 49 C.F.R. § 571.3.[15] The ADS is the "driver," and the ADS will command the driving controls referenced in the FMVSS.[16]

[15] "*Driver* means the occupant of a motor vehicle seated immediately behind the steering control system." The passenger compartment of GM's ZEAV does not have a steering wheel or steering control system.

[16] This conclusion is consistent with NHTSA's February 4, 2016 Letter of Interpretation to Google.

With the ADS as the driver, there is no need for features designed to interface with a human driver, such as manual human driver controls (e.g., steering wheel, brake pedal, and accelerator pedal), human-driver-specific information systems (e.g., telltales and indicator lamps), human-driver-oriented visibility features (e.g., rearview mirrors), or human-driver-specific occupant protection (e.g., steering-wheel-mounted airbag). These features, which exist exclusively for the purpose of interfacing with a human driver, are required by some of the existing FMVSS. We refer to them in this Petition as the "human-driver-based requirements." These human-driver-specific features are not necessary in GM's ZEAV, which will never have a human driver. Instead, GM's ZEAV has control systems, information interfaces, and sensors that interface with the ADS and provide passenger occupant protection systems for all seating positions in the vehicle. These features allow the GM ZEAV to satisfy the safety purposes of human-driver-based requirements and enable GM to provide consumers with a new, safe, zero-emission mobility option.

B. Controls

In a conventional vehicle, the human driver controls include the steering wheel, accelerator pedal, brake pedal, transmission shift lever, turn signal activator, parking brake control, windshield wipers, and headlamp controls. These interfaces serve as inputs for the human driver's commands to the vehicle systems that control steering, acceleration, and braking and that activate turn signals and headlamps. While GM's ZEAV retains these vehicle control systems, it replaces the human control inputs with ADS control inputs to system controllers with associated actuators that enable the ADS to steer, accelerate, and brake the vehicle, as well as to activate the headlamps and turn signals. Responding to the control inputs from the ADS, these systems perform all necessary on-road vehicle driving functions. This, in combination with all of the other safety features discussed herein and those that meet the FMVSS (not discussed herein), enables the vehicle to fully satisfy the federal safety objectives embodied in the FMVSS and the safety showings required by §§ 30113(b)(3)(B)(ii) and (iii). This in turn eliminates the need for the human-driver-control interfaces. By removing human input from the formula, these changes provide the safety advantages of autonomous transportation while ensuring that passengers cannot interfere, purposefully or inadvertently, with the safe operation of the vehicle.

C. Vehicle Information

GM's ZEAV replaces audible and visual warnings, as well as other information displays meant for a human driver, with features and equipment supporting the ADS. In a conventional vehicle, audible and visual systems and displays provide feedback to the human driver, offering information to supplement what the human driver observes by watching the road and driving environment. A human driver can use the information conveyed by these systems to make decisions about the operation of the vehicle. GM's ZEAV provides the ADS with all of the same information provided to a human driver in a conventional motor vehicle. However, because indicators that are visible and audible to a human are not designed to provide information to an

ADS, the GM ZEAV meets the safety intent of the requirements for human-driver-based indicators through information interfaces providing the same information (and more) to the ADS, which in turn operates the vehicle systems and controls. Consequently, the ZEAV meets both the safety showings required by § 30113(b)(3)(B) and the safety objectives of the FMVSS.

D. External Information

Conventional vehicles have many features designed to make the external environment visible to the human driver—forward, to both sides, and rearward. GM's ZEAV has an array of sensors, including LiDAR, cameras, and radar, which provide the ADS with continuous 360-degree information on the environment outside the vehicle. Internal and external rearview mirrors are not necessary for the ADS. And while a human driver must avert her eyes from the forward direction to view reflections in the mirrors, the ADS, utilizing its suite of sensors, simultaneously receives information from all sides of the vehicle, at all times.

E. Occupant Protection

Finally, conventional vehicles have occupant protection systems specific to the driver seating position, such as a steering-wheel-mounted airbag. GM's ZEAV does not have a human driver and thus does not have a "driver" seating position. It also does not have a steering wheel, so requirements referencing either the (human) driver seating position or the steering wheel do not apply to GM's ZEAV. Instead, because every occupant of the ZEAV will be a passenger, including an occupant in the left front seat, the ZEAV's left front passenger seating position has an occupant protection system that mirrors occupant protection in the right front seat. To verify occupant protection, GM is using both computer simulation and physical crash tests of the ZEAV that include its integrated ADS computer, sensor, and control components.

As another safety measure, GM—not an individual purchaser or consumer—will control the operation of all ZEAVs manufactured under the exemption sought in this Petition. In particular, GM's ZEAV fleet will operate only within defined geographic boundaries, and limited to predefined speeds and weather conditions. GM's limitations on the operation of its ZEAV fleet will enhance safety—limited speeds eliminate events due to driving above the speed limit, and weather restrictions reduce occurrences of safety system activations due to weather-related road conditions. GM's program parameters will reduce the number of miles that the ZEAVs will be driven in higher-risk situations, so the ZEAV is not likely to encounter many of the risk scenarios that other vehicles encounter.

The following section describes how GM believes that NHTSA should evaluate safety under the Safety Act and its exemption provisions.

III. Evaluating Safety in a Petition for Exemption Under the Safety Act

In evaluating safety in this Petition, NHTSA should be guided by the approach to safety regulation crafted by Congress in the Safety Act and the time-and-experience-proven legal and regulatory tools provided by that Act. Throughout its history, NHTSA has never created a new Standard (or de facto Standard) before a new technology has entered commerce. Safety Act enforcement mechanisms have consistently facilitated safe deployment of vehicle systems of all kinds: new and traditional, unique and ubiquitous. As discussed further below, NHTSA's broad safety enforcement mechanisms have safely and successfully managed the introduction of numerous new vehicle technologies, including, among others, antilock brakes, electronic stability control, back-up cameras, collision imminent braking, and adaptive cruise control.

The Agency can apply those same established powers and tools to oversee the safe introduction of automated driving systems. By applying the legal framework established by Congress, NHTSA can safely facilitate, rather than impede, innovation and the development of autonomous vehicle technology. Such technology could begin saving lives and eliminating vehicle crashes as soon as GM's ZEAVs can be deployed.[17] Appropriate application of the Safety Act to this Petition can accelerate American progress toward a future with zero crashes.

The Safety Act creates two primary tools for ensuring motor vehicle safety: (i) the FMVSS and manufacturers' obligation to certify that vehicles meet or exceed applicable FMVSS and (ii) the manufacturer's obligation to avoid putting vehicles into commerce that pose an unreasonable risk to safety and to remedy any safety-related defects.[18] Part 555 petitions are within the ambit of FMVSS compliance. Each proposed exemption from an FMVSS should first be analyzed to determine whether the subject system or equipment achieves the safety purpose and intent of the Standard at issue.[19] If the subject system or equipment achieves the safety purpose and intent of the Standard (thus providing safety equal to that of a vehicle that directly complies with the Standard), then NHTSA should find that deployment of the system or equipment is consistent with the Safety Act.[20] If use of that system or equipment also satisfies the other two applicable findings, NHTSA should grant the requested exemption(s).

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[17] *See* Kalra and Groves, *supra*.

[18] 49 U.S.C. §§ 30112, 30118, 30120.

[19] In a number of instances, the Agency has granted exemptions even when the subject vehicle system or equipment does not achieve the purposes of the relevant FMVSS. In such cases, the Agency often cites mitigating factors and conditions of deployment that quell safety concerns about the vehicle. See, e.g., *Tesla*, 76 F.R. 60124, Docket No. NHTSA-2011-0110 (2011) (granting exemption from Standard No. 126, given vehicle's low center of gravity and low likelihood that vehicle will be used in rain or snow); *Kewet*, 60 F.R. 19444, Docket No. 92-58, Notice 2 (1995) (granting renewal of exemption from Standard No. 208, noting manufacturer's representations that lack of airbag was not a safety hazard due to vehicle's "low top speed and intended non-freeway use").

[20] 49 U.S.C. § 30113(b)(3)(B). Of course, if, during this process, NHTSA identifies a safety-related defect, then NHTSA can utilize the legal and regulatory tools under the Safety Act to address the identified defect.

A. NHTSA's Evaluation of Safety in Petitions for Exemption

Since 1968, the Safety Act has empowered NHTSA to grant exemptions[21] from FMVSS.[22] Over the years, NHTSA has evaluated numerous petitions for exemption, including at least 21 petitions seeking to facilitate the development or field evaluation of low-emission vehicles. In considering these petitions, the Agency has considered and granted an exemption on a Standard-by-Standard (or sometimes a paragraph-by-paragraph) basis.[23] With respect to each Standard for which exemption is sought, the Agency generally determines the safety intent or purpose of the Standard, assesses the manufacturer's approach to achieving that purpose, and then decides to grant or deny an exemption for that Standard (or portion thereof).

For example, NHTSA granted Clarity Group, Inc., an exemption from portions of six Standards to enable deployment of its electric cars and trucks.[24] In granting Clarity's petition, the Agency assessed the manufacturer's plans for addressing each of the six Standards, one at a time, finding that each noncompliance was "technical only."[25] For example, in granting an exemption from FMVSS Nos. 209 and 212, the Agency found that results of a 30 mph frontal barrier test conducted with a very similar (but not identical) vehicle achieved the safety purpose of these Standards.[26] In granting an exemption from FMVSS No. 103, the Agency reasoned that, at that time, "the test requirements of S4.2 and demonstration procedures of S4.3 were written for vehicles powered by internal combustion engines.… In a literal sense, it is impossible for an electric vehicle to test

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[21] Again, the term "exemption" is a misnomer that could be misleading in this context. GM is not seeking to be excused or exempted from the safety purpose or intent of any FMVSS.

[22] 90 P.L. 283, 82 Stat. 72 (Apr. 10, 1968); 92 P.L. 548, 86 Stat. 1159 (Oct. 25, 1972).

[23] *See, e.g., General Motors,* 58 F.R. 48421, Docket No. 93-39, Notice 2 (1993) (granting exemption from three FMVSS to enable deployment of zero-emission electric vehicle); *B.A.T.,* 58 F.R. 45549, Docket No. 93-36, Notice 2 (1993) (granting exemption from two FMVSS to enable deployment of low-emission, electric pickup trucks); *Mercedes-Benz,* 64 F.R. 29733, Docket No. NHTSA-98-3343, Notice 2 (1999) (granting exemption from five FMVSS under 49 U.S.C. § 30113(b)(3)(B)(iv) to enable deployment of vehicle manufactured to European specifications); *Chrysler*, 59 F.R. 65570, Docket No. 91-66, Notice 4 (1994) (granting renewal of exemption from three FMVSS to enable continued deployment of electric-powered multipurpose passenger vehicles). In some cases, this approach has led the Agency to grant an exemption from some of the Standards (or portions of Standards) from which the manufacturer sought exemption and not others. *See, e.g., Ford,* 58 F.R. 16907, Docket No. 93-01, Notice 2 (1993) (granting exemptions from 14 Standards to enable deployment of electric panel delivery van).

[24] *Clarity*, 57 F.R. 28765, Docket No. 91-51, Notice 2 (1992).

[25] Clarity also sought and was denied exemption from three other Standards, Nos. 101, 102, and 124. The Agency determined that Clarity likely misunderstood the requirements of FMVSS Nos. 101 and 124 and that the subject vehicles may have complied with those Standards. With respect to FMVSS No. 102, NHTSA rejected Clarity's argument that certain requirements do not apply to electric vehicles.

[26] *Clarity* (1992), *supra*.

according to S4.2 and S4.3, and an exemption is therefore required."[27] The Agency conducted a similar analysis for each of the other Standards included in Clarity's petition.

NHTSA has consistently declined to impose additional requirements on petitions beyond those imposed by the Safety Act and implementing regulations. For example, parties commenting on petitions for exemption have asked NHTSA to take other approaches to evaluating petitions for exemption, instead of or in addition to analyzing whether the subject vehicle or equipment achieves the purpose of the relevant Standard. Thus, in response to one petition, a commenter expressed concern that "exemptions may be given [to] entrepreneurs selling crudely-converted, unsafe vehicles."[28] The commenter argued that a manufacturer seeking an exemption for an electric vehicle should be required to show attempts to incorporate advanced technologies not required under then-existing FMVSS, such as "advanced electrical storage systems, energy efficient electrical controllers and motors, and light-weight, low-friction mechanisms." The Agency appropriately rejected this invitation, stating that "NHTSA will for the present reserve judgment on these questions, as these factors are currently not required by Part 555."[29]

B. How the Safety Act Addresses Technologies Not Yet Addressed in FMVSS

NHTSA's long-standing approach to addressing Part 555 petitions is through the application of the two pillars of the regulatory structure established by the Safety Act. Again, the Act protects the public by imposing two primary obligations on manufacturers introducing vehicles or equipment into commerce: (i) the obligation to certify that the vehicle or equipment complies with FMVSS and (ii) the obligations to avoid unreasonable risks to safety and to investigate and remedy safety-related defects.

<u>First</u>, with respect to specific systems addressed in FMVSS, the manufacturer must either certify that the system or equipment complies with applicable FMVSS or seek an exemption from

[27] Similarly, many of the Standards and tests that are the subject of this Petition cannot be satisfied in a "literal sense" because those Standards were written for, and in relation to, vehicles driven by humans. Applying those Standards and tests to a vehicle driven by an ADS is technically impossible. As in *Clarity* and other NHTSA precedents, here the Agency should consider the safety purpose of these Standards. If these purposes are satisfied, NHTSA should grant the Petition.

[28] *Jet Industries*, 41 F.R. 7545, Docket No. EX76-1, Notice 2 (1976) (granting exemption from seven FMVSS under 49 U.S.C. § 30113(b)(3)(B)(iii) to enable deployment of low-emission vehicles) (internal quotation marks omitted). *See also Clarity* (1992), *supra* (rejecting commenter's proposed test to grant a petition under § 30113(b)(3)(B)(iii) only if there is "clear evidence of conformance as fully as is practicable for an electrically powered vehicle" (internal quotation marks omitted) because applying this test would require determining what is "practicable" for each Standard, which is not required to uphold safety or the statute); *Solar Electric Engineering*, 57 F.R. 30997, Docket No. 91-61, Notice 2 (1992) (same comment and same NHTSA response as in *Clarity*).

[29] *Id.*

NHTSA.[30] If the manufacturer discovers that a vehicle fails to comply with an applicable Standard, it must initiate a recall to remedy the noncompliance.[31]

Second, if a vehicle or equipment contains a safety-related defect,[32] the manufacturer of the defective motor vehicle or equipment must conduct a recall to remedy the defect without charge to the vehicle owner.[33] Though the vast majority of recalls for safety-related defects are conducted voluntarily by manufacturers, the Safety Act also empowers NHTSA to conduct investigations and administrative proceedings, impose civil penalties, and order recalls to remedy defects.

Petitions for exemption fall within the scope of the manufacturer's first obligation, to certify that vehicles and equipment comply with FMVSS. While the FMVSS applicable to passenger cars cover a wide range and variety of vehicle systems, only a fraction of the total number of vehicle systems and components are addressed in those Standards. Safety of the remaining vehicle parts and systems not covered by FMVSS, including new technologies, is regulated through the Safety Act's duty to remedy safety-related defects.

Here, because there is no FMVSS specifically applicable to automated driving systems, a manufacturer is not required to certify that an ADS complies with any FMVSS. That is, while a vehicle manufacturer must certify that its vehicle complies with all applicable FMVSS before introducing the vehicle into commerce, it need not certify that the ADS itself meets any additional FMVSS, because presently there are no FMVSS that independently apply to an ADS. However, the ADS would be subject to the manufacturer's obligation to not introduce a system that creates an unreasonable risk to motor vehicle safety. And, an ADS also would be subject to the related obligation to remedy any safety-related defects that may be associated with the system.[34] To introduce the ZEAV into commerce, GM must certify that the vehicle complies with all applicable FMVSS or, as this Petition requests, obtain an exemption from any Standards with which it does not comply.

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[30] 49 U.S.C. §§ 30113 and 30115.
[31] 49 U.S.C. §§ 30118 and 30120.
[32] 49 U.S.C. § 30118.
[33] 49 U.S.C. § 30120.
[34] In contrast, there are FMVSS addressing specific vehicle systems (e.g., braking, lighting, occupant protection, among others). *See* Section IV below.

C. How New Vehicle Technologies Are Traditionally Introduced into Commerce

Historically, most new vehicle technologies have been introduced into commerce long before NHTSA has promulgated a Standard that applies to the new technology. In the absence of an applicable Standard, the Safety Act's requirement that manufacturers avoid putting a motor vehicle into commerce that creates an unreasonable risk to motor vehicle safety (and the corollary obligation to remedy safety-related defects) maintains motor vehicle safety. As the Agency explained in a guidance document issued in 2016, "[t]raditionally, only after new technology is developed and proven does the Agency establish new safety standards."[35] This regulatory approach began with the very first FMVSS, which became effective in 1968.[36] The original FMVSS were modeled after industry standards manufacturers had used to develop vehicles already on the roads at that time.

Since then, the introduction of new vehicle technologies and the eventual issuance of new Standards to address those technologies have followed a familiar paradigm. First, after robust testing and validation, manufacturers introduce new vehicle technologies into commerce. NHTSA then studies the new technology. Informed by real-world experience and analysis, the Agency promulgates a rule addressing the new technology—often years after its initial deployment. Through decades of applying this approach, the Agency has found that it "has yielded enormous safety benefits."[37] Indeed, this approach (i) avoids long delays before deployment of safety technology and innovations while the Agency researches and develops new regulations and (ii) allows the Agency and the public to benefit and learn from real-world experience with safety technologies to determine the need for and to better formulate the new Standards.

As one of many examples, in 1997, GM introduced electronic stability control ("ESC") on a number of Cadillac models. By 2006, an estimated 29 percent of all manufacturers' 2006 MY passenger vehicles were equipped with ESC.[38] Finding that this technology offered tremendous safety benefits, in 2007, NHTSA promulgated a rule requiring that all passenger vehicles be equipped with ESC—about 10 years after GM first introduced the technology into commerce. For nearly a decade, manufacturers deployed millions of vehicles with ESC on highways while there was no Standard addressing that vehicle system.

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[35] NHTSA Enforcement Guidance Bulletin 2016-02: *Safety-Related Defects and Automated Safety Technologies*, Docket No. NHTSA-2016-0040 at 4.

[36] *See, e.g.,* National Highway Traffic Safety Administration, *A Drive Through Time*, available at https://one.nhtsa.gov/nhtsa/timeline/index.html; DOT/Federal Highway Administration Notice Regarding Incomplete Motor Vehicles, 32 F.R. 16534, Docket No. 21, Notice 67-6 (Dec. 2, 1967).

[37] NHTSA Enforcement Guidance Bulletin 2016-02, *supra* at 4.

[38] National Highway Traffic Safety Administration, *Final Regulatory Impact Analysis: FMVSS No. 126, Electronic Stability Control Systems* (March 2007), available at https://one.nhtsa.gov/Laws-&-Regulations/Electronic-Stability-Control-(ESC)?ruleSortBy=fmvss&ruleOrder=asc.

During these years, the Safety Act obligations to avoid introducing vehicles or equipment that pose an unreasonable risk to safety and to remedy defects, protected the public from any unreasonable risk to safety that ESC might have posed. While it is difficult to calculate how many lives were saved by this technology in the years prior to the Agency's promulgation of a Standard, NHTSA crash data indicates that ESC drastically improved vehicle safety, for example, by reducing fatal single-vehicle crashes of passenger cars by 55 percent.[39]

A similar pattern of deployment, evaluation, and then rulemaking occurred prior to promulgation of many other Standards. For example, vehicles on the road had controls and displays before FMVSS No. 101 was adopted; vehicles had transmission shifters before FMVSS No. 102 was adopted; vehicles had defrosters before FMVSS No. 103 was adopted; vehicles had windshield washers and wipers before FMVSS No. 104 was adopted; and low-speed vehicles existed before FMVSS No. 500 was adopted.

Similarly, in evaluating petitions for exemption, NHTSA has declined to use the petition as a forum to determine the merits or promise of a new technology or vehicle design. Rather, the Agency has focused on how the new technology directly impacts the purposes of the existing Standards from which exemption is sought. For example, in its 2011 petition, Terrafugia sought exemption from four Standards to deploy the Transition®, a light sport aircraft that could also drive on public roads in the event that inclement weather prevented flying.[40] In granting this petition, NHTSA assessed Terrafugia's approach to achieving the purposes of the Standards. With respect to FMVSS No. 110, the Agency discussed Terrafugia's proposed plan to use tires and rims certified for motorcycles, not passenger-car rims and tires. The Agency only mentioned the fact that the Transition® was an airplane as it related to that particular Standard: Terrafugia was concerned that the additional weight of passenger-car tires and rims would affect the vehicle's airworthiness.

In granting Terrafugia's petition, the Agency did not address particularly unusual characteristics of a "roadable aircraft" not covered by FMVSS.[41] NHTSA did not, for example, attempt to create a new or de facto Standard to govern folded aircraft wings affixed to the sides of a vehicle.[42] Instead, the Agency relied on the duties to avoid unreasonable risks to safety and to remedy safety-related defects to regulate this feature. Nor did the Agency suggest that a new approach

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[39] *Tesla* (2011), *supra* (citing Sivinski, *Crash Prevention Effectiveness of Light-Vehicle Electronic Stability Control: An Update of the 2007 NHTSA Evaluation*, DOT HS 811 486 (June 2011)).
[40] *Terrafugia,* 76 F.R. 38270, Docket No. NHTSA-2010-0154 (2011) (granting petition for exemption under 49 U.S.C. § 30113(b)(3)(B)(i)).
[41] *Id.* at Section II (citing Terrafugia's description of the Transition® as "Roadable Aircraft").
[42] *Id*. at Section II.B (mentioning in passing "the exposed side area of the folded wings" in discussion of why Terrafugia decided to certify the airplane as a passenger car instead of as a motorcycle).

to evaluating a petition for exemption was required for "roadable aircraft." Instead, the Agency focused its inquiry entirely on the existing FMVSS to which the petition applied.[43]

The Agency took a similar approach to addressing Toyota's 2014 petition for exemption to deploy its fuel cell vehicles.[44] The subject fuel cell vehicles could not comply with S5.3 of FMVSS No. 305, which requires electrical isolation of major electrical components after specified crash tests. Citing the purpose of S5.3, to reduce the risk of high-voltage electrical shock, NHTSA granted the petition, largely because Toyota would "implement alternative safety measures to ensure the safety of the vehicle occupants and first responders will be protected from electric shock hazards after a crash."[45] Significantly, the Agency did not set a new or de facto Standard for fuel cell technologies or evaluate whether fuel cell technologies warrant a deviation from the Safety Act's approach to regulating new technologies.

D. Application of Time-Proven Approach to Automated Driving Systems

This long-established and successful paradigm of deployment of new technologies, evaluation, and then rulemaking should be followed with automated driving systems. While NHTSA has expressed its intent to engage in rulemaking related to automated driving technologies in the future,[46] the Agency has also expressed confidence in its enforcement authority as a tool for regulating automated driving systems today. As the Agency explained,

> While fully automated (self-driving) vehicles and other automated safety technologies may modify motor vehicle and equipment design, NHTSA's statutory enforcement authority is sufficiently general and flexible to keep pace with such innovation. The Agency has the authority to respond to a safety problem posed by new technologies in the same manner it is able to respond to safety problems posed by more established automotive technology and equipment, such as carburetors, the powertrain, vehicle control systems, and forward collision warning systems—by determining the existence of a defect that poses an unreasonable risk to motor vehicle safety and ordering the manufacturer to conduct a recall. This enforcement authority applies notwithstanding the presence or absence of an FMVSS for any particular type of advanced equipment or technology.[47]

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[43] *See generally id.*
[44] *Toyota,* 80 F.R. 101, Docket No. NHTSA-2014-0068 (2015) (granting petition for exemption under 49 U.S.C. § 30113(b)(3)(B)(iii)).
[45] *Id*. at Section VI(b).
[46] NHTSA Enforcement Guidance Bulletin 2016-02, *supra* at 4.
[47] *Id*. at 7 (internal citations omitted).

> Where a fully automated (self-driving) vehicle or other automated safety technology causes crashes or injuries, or poses other safety risks, the Agency will evaluate such technology through its investigative authority to determine whether the technology presents an unreasonable risk to safety. Similarly, should the agency determine that a fully automated (self-driving) vehicle or other automated safety technology has manifested a safety-related defect, and a manufacturer fails to act, NHTSA will exercise its authority to the fullest extent.[48]

E. Favorable Conditions in This Case Further Support Following Established Practice

In granting petitions for exemption, NHTSA has often taken into account the safety-favorable conditions under which vehicles operate. In particular, NHTSA has found that the following conditions (each of which applies at least in some manner to this Petition) support granting an exemption:

- Manufacturer would hold title to the vehicles;[49]
- Vehicles would be operated primarily in "urban environments" and at "low urban speeds";[50]
- Vehicles would have "low operating speeds" and be deployed in "urban use";[51]
- Speed "will not exceed 40 mph";[52] and
- It is unlikely that the vehicles would be driven in "rain, snow, or winter months."[53]

With respect to GM's proposed deployment of ZEAVs, there is especially good reason to rely on the Safety Act's legal and regulatory tools. Not only does GM's planned deployment align with the favorable criteria listed above, but GM will at all times maintain and control the ZEAVs. This approach will allow GM to closely monitor and address safety in every ZEAV deployed. If an incident were to occur, GM could promptly analyze the situation in depth and address it.

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[48] *Id*. at 13.
[49] *Ford* (1993), *supra* (granting exemption from Standards Nos. 115 and 209 in part because Ford's retention of title to the vehicles achieves the purposes of these Standards, i.e., to identify the vehicle or belt manufacturer in the event of a notification and remedy campaign).
[50] *Id.* (granting exemption from Standard No. 108 because the vehicles "will be operated primarily in urban environments with generally high ambient lighting" and from Standards Nos. 207 and 210 due to "low urban speeds at which [the vehicle] will be primarily operated").
[51] *Jet Industries* (1976), *supra*.
[52] *Kewet* (1995), *supra*. GM's ZEAVs will have not-to-exceed speeds, but they will not be limited to 40 mph, and their not-to-exceed speeds are expected to increase during the proposed exemption period.
[53] *Tesla* (2011), *supra*. GM's ZEAVs will be weather restricted, but their operational design domain for rain, snow, and winter driving is expected to expand during the proposed exemption period.

Common factors such as human driver behavior, consumer failure to maintain the vehicle, and consumer failure to repair the vehicle or obtain recall repairs will not be factors for the safety of GM-maintained-and-operated ZEAV fleets.

IV. Safety Showings for GM ZEAV Technology Advancements

The existing FMVSS requirements were drafted based on the assumption that all vehicles would be operated by human drivers. That underlying premise no longer holds—it should not forestall development and field evaluation of a promising self-driving, zero-emission vehicle, investment in advanced safety, or related high-tech jobs. In this section, we identify each of the relevant human-driver-based requirements in the FMVSS and explain how the ADS fulfills the safety purpose of the Standard or why the Standard logically does not apply when an ADS (and not a human) is the driver. We also explain why the ZEAV's replacement features fulfill the safety intent of the FMVSS, thus satisfying both the safety showings required under 49 U.S.C. § 30113(b)(3)(B) and federal safety objectives.[54]

The human-driver-based requirements in the FMVSS fall into four general categories:

1. **Controls and Displays:** GM's ZEAV will not be equipped with most of the human driver controls and displays specified or referenced in the FMVSS. The safety need for these controls and displays is obviated by the absence of a human driver. Additionally, the control interfaces to the ADS; GM's control of vehicles in deployment; and daily inspections and maintenance together provide assurance that the ZEAV will provide equivalent safety.

2. **Demonstration of Compliance:** A number of the FMVSS specify test procedures to assess compliance with the performance requirements of the Standards. Many of these test procedures assume the presence of a human driver or human driver controls in the front occupant compartment of the vehicle that are designed to be activated by a human driver. For example, Standard No. 135 specifies stopping distance and grade-holding requirements for light vehicle brake systems, and the demonstration procedures specified in the Standard assume a human driver and the use of manual service brake and parking brake controls. The ZEAV will not have a human driver or conventional human driver controls, but it will fully comply with the stopping distance and grade-holding performance requirements specified in Standard No. 135. Similarly, GM's ZEAV meets the functional requirements and purposes of other Standards discussed below, where specific human-driver-based test procedures do not apply.

[54] To reiterate, this Petition seeks authorization to use technology advancements for compliance with the safety purpose of relevant FMVSS under two different statutory provisions: 49 U.S.C. §§ 30113(b)(3)(B)(ii) and (iii). As this section demonstrates, GM's ZEAV satisfies the requirements of both provisions.

3. **Driver's Seating Position:** GM's ZEAV will not meet certain criteria specified in Standard No. 208 for the human driver (left front) seating position, such as those involving out-of-position test provisions and steering column interactions. Instead, the ZEAV will "mirror" the right front occupant restraint equipment in the left front occupant seating position. The performance of the occupant protection in the left front seating position will be crash tested in the ZEAV, including its integrated ADS computer, sensor, and control components, and it will meet the safety level of the occupant protection system in the right front seating position.

   A number of FMVSS reference the "driver's seat" and "driver-side." Because GM's ZEAV will not have a human driver or a driver's seat, GM has reasonably interpreted FMVSS references to the "driver's seat" as the front-most seat on the left side of the vehicle (facing forward) and "driver-side" as the left side of the vehicle.[55]

4. **Visibility Requirements:** GM's ZEAV will not be equipped with rearview mirrors or rear-vision camera display referenced in Standard No. 111. The ZEAV meets the safety purpose of this Standard with the electronic interfaces providing the ADS with comprehensive information from the ZEAV's suite of sensors, including multiple sensor views to the rear of the vehicle.

The following paragraphs itemize the requested FMVSS exemptions required to enable technology advancements in the ZEAV that achieve the safety purpose and intent of each of those FMVSS, while at the same time advancing safety and low-emission vehicle development. These paragraphs establish that these technology advancements meet the safety showings required under 49 U.S.C. § 30113(b)(3)(B) and that this Petition thus should be granted.

A. FMVSS No. 101: Controls and Displays

The purpose of Standard No. 101 is to ensure the accessibility, visibility, and recognition by a human driver "of motor vehicle controls, telltales and indicators,…to facilitate the proper selection of controls" and to reduce mistakes by the human driver when operating the vehicle.[56]

Paragraph S5.1.1 requires that the controls listed in Tables 1 and 2 be located so they are operable by the human driver. Paragraph S5.1.2 requires that the telltales and indicators in Tables 1 and 2 be visible to the human driver. Paragraphs S5.1.3, S5.2.1, S5.2.6, S5.2.8, S5.3.1, S5.3.2.1, and S5.4.1 require that the controls, telltales, and indicators listed in Tables 1 and 2 be identified by the specified symbol, word, abbreviation, and color and also meet illumination requirements. GM's ZEAV will not be equipped with most of the human-operated controls in the

[55] This is consistent with NHTSA's February 4, 2016 Letter of Interpretation to Google (*see, e.g.*, the discussion of Standard Nos. 201, 206, and 216a addressed at 20-23).
[56] 49 C.F.R. § 571.101, paragraph S2.

tables and will not have a human driver, so the location, visibility, symbols, color, and illumination requirements for controls, telltales, and indicators meant for a human driver, as written, do not apply.

In place of these human-driver-based telltales and indicators, GM's ZEAV has interfaces allowing the ADS to operate all of the applicable functions that the controls in Tables 1 and 2 operate, and to receive, monitor, and analyze as appropriate all of the information that the applicable telltales and indicators listed in Tables 1 and 2 provide. The attached Appendix II provides details on the communication networks within the ZEAV that provide data to, and transfer commands from, the ADS, furnishing the ADS with full access to the information and controls listed in Tables 1 and 2.[57] Appendix II also provides examples of ADS responses to relevant information that a conventional vehicle would provide to a driver through telltales. Further, the information and ADS responses in Appendix II illustrate that the ADS has access to the information and controls necessary to drive the ZEAV and is programmed with appropriate responses to maintain safety. Because it is equipped with functionally equivalent ADS interfaces in lieu of human interfaces, GM's ZEAV fully satisfies both the safety showings required by § 30113(b)(3)(B) and federal safety standard objectives.

B. FMVSS No. 102: Transmission Shift Lever Sequence, Starter Interlock, and Transmission Braking Effect

Standard No. 102 provides transmission shift position sequence, starter interlock, and transmission braking effect requirements to (i) reduce the likelihood of a human driver making shifting errors, (ii) prevent a human driver from inadvertently starting the vehicle when the transmission is in a drive position, and (iii) provide supplemental braking when the vehicle is traveling at speeds below 25 mph.[58] Paragraph S3.1.4 and its subparagraphs require that the shift lever sequence and position selected be displayed in view of the human driver. Because GM's ZEAV does not have a human driver, the intent of the requirement to display the transmission shift position is met by providing the transmission shift position information electronically to the ADS "driver." In all other respects, the vehicle meets the requirements of FMVSS No. 102. The attached Appendix II describes example behavior of the transmission shift control performed by the ADS. The example illustrates that the ADS (as the ZEAV's driver) takes into account appropriate information to perform transmission shift control in a safe and effective manner. Because the ADS has access to the transmission shift information that would otherwise be provided to a human driver and uses this information to safely perform the transmission shift

[57] Appendix II, along with technical detail provided herein and in Appendix I, provides record of the research, development, and testing establishing the innovative nature of the safety features and a detailed analysis establishing (i) that the safety level of the feature at least equals the safety level of the Standard, (ii) that the safety level of the vehicle is not lowered unreasonably by exemption from the Standard, and (iii) that the ZEAV is a low-emission motor vehicle.
[58] 49 C.F.R. § 571.102, paragraph S1.

control on the ZEAV, these features of GM's ZEAV fully satisfy both the safety showings required by § 30113(b)(3)(B) and federal safety objectives.

C. FMVSS No. 108: Lamps, Reflective Devices, and Associated Equipment

Standard No. 108 provides requirements for vehicles to adequately illuminate the roadway for the human driver and to make the vehicle's roadway presence conspicuous to other drivers.[59] Paragraph S9.1.1 requires self-cancellation of the turn signal operating unit. S9.3 and its subparagraphs provide requirements for the turn signal indicator, including visual feedback of the turn signal status to the human driver. Paragraph S9.4, its subparagraphs, and paragraph S9.5 relate to the headlamp beam switching device and indicator. These requirements all pertain to controls and information for a human driver. In addition, the ZEAV's radar and LiDAR do not rely on visible light, so operation of the additional upper beam headlamps is not necessary.

As Appendix II shows, GM's ZEAV has interfaces that allow the ADS to receive, monitor, and analyze the information otherwise provided by the telltales and indicators related to turn signals and headlamps, and to issue commands to control the headlamps and turn signals. Appendix II also provides examples of ADS responses to information about turn signal failure indicated under S9.3.6.

For self-cancellation of turn signals, GM's ZEAV does not have a steering wheel, so self-cancellation cannot be measured relative to rotation of a nonexistent steering wheel. Instead, the ADS will automatically cancel the turn signal after completion of the turning maneuver. The ADS interface to the lighting system will cause the ADS to control the headlamps and turn signals and to electronically receive information on their status. Appendix II includes examples of on-road turn signal operation in GM test vehicles, showing consistent operation of the turn signal activation and cancellation that meets the purpose of the Standard.

The requirements of S9.1.1, S9.3, S9.4, and S9.5 relating to human-driver-specific controls and information indicators are not necessary for the ADS to safely drive the vehicle. Appendix II illustrates the system design that causes the ADS to issue control commands to the headlamps and turn signals and to receive their status information. Appendix II also provides data on turn signal performance and control response to turn signal failure.

These changes fulfill the information and controls intent of Standard No. 108. These changes provide safety at least equal to the level of the Standard and therefore fully satisfy both the safety showings required by § 30113(b)(3)(B) and federal safety objectives.

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[59] 49 C.F.R. § 571.108, paragraph S2.

D. FMVSS No. 111: Rearview Visibility

Standard No. 111 contains requirements to provide the human driver with a clear and reasonably unobstructed view to the rear of the vehicle.[60] Paragraphs S5.1 through S5.4 and their subparagraphs set forth the requirements for the interior rearview mirror of unit magnification and for the outside rearview mirrors. Paragraph S5.5 sets forth the requirements for the rear-vision camera and associated display. These requirements are intended to provide a human driver with visibility to the rear of the vehicle, but are not necessary for the ZEAV's ADS to safely drive the vehicle. Instead of the interior rearview mirror, outside rearview mirrors, and rear camera display, GM's ZEAV includes rear-facing cameras, radar sensors, and LiDARs that continuously provide full rear-field-of-view information to the ADS.

The ZEAV's sensors provide overlapping coverage and diverse sensor-based environmental information to the ADS. Because different types of sensors operate through different mechanisms (camera, radar, and laser), one set of sensors validates and checks what other sets of sensors perceive (see the attached Appendix II for descriptions of sensors and the vehicle's field of perception). These sensors allow the ADS to perceive the vehicle's surroundings with significantly more breadth and detail than interior and exterior rearview mirrors provide to human drivers.

Thus the safety purpose of the mirror and rear camera display requirements of FMVSS 111 is met by the rear-facing sensor suite, which provides information to the ADS from its unobstructed sensor view to the rear of the vehicle. These changes provide safety at least equal to the level of the Standard and thus fully satisfy both the safety showings required by § 30113(b)(3)(B) and federal safety objectives.

E. FMVSS No. 114: Theft Protection and Rollaway Prevention

Standard No. 114 specifies performance requirements to reduce the incidence of crashes resulting from theft and accidental rollaway of the vehicle.[61] GM's ZEAV will comply with the performance requirements specified in paragraph S5 (and its subparagraphs).[62] Because the ZEAV will not be equipped with conventional human-operated controls for the parking brake, service brake, or transmission gear selection, the test procedures specified in paragraph S6 are not applicable. Appendix II illustrates how the ZEAV system design enables the ADS to electronically determine and control the brake system status, including the parking brake, service brake, and transmission gear selection. Because the ADS electronically interfaces with the ZEAV's braking and transmission control features in a manner that satisfies the performance

[60] 49 C.F.R. § 571.111, paragraph S2.
[61] 49 C.F.R. § 571.114, paragraph S1.
[62] Taking into consideration NHTSA's January 4, 2016, Letter of Interpretation to Samuel Campbell, III, BMW of North America, LLC.

requirements of Standard No. 114, it achieves the safety purpose of the Standard. Thus the GM ZEAV provides safety at least equal to the level of the Standard and fully satisfies both the safety showings required by § 30113(b)(3)(B) and federal safety objectives.

F. FMVSS No. 124: Accelerator Control Systems

Standard No. 124 establishes requirements for the return of the throttle to idle position when the driver removes actuating force from the accelerator control, or if the accelerator control system is disconnected, in order to reduce occurrences of unintended engine overspeed.[63] In GM's ZEAV, the ADS is the driver, and it regulates vehicle propulsion by providing a torque command to the motor speed controller. Appendix II provides details about how the ADS computers communicate with actuator controls. The ADS includes two independent software control commands to establish the desired level of motor torque (and associated vehicle propulsion). If the ADS commands zero torque, or if the independent software controls are inconsistent with each other, the system will provide zero motor torque in a manner that satisfies the time and temperature requirements of this Standard.[64] This approach, illustrated further in Appendix II, satisfies the safety purpose of this Standard—to protect against overspeed malfunctions. Thus the ZEAV provides safety at least equal to the level of the Standard and thus fully satisfies both the safety showings required by § 30113(b)(3)(B) and federal safety objectives.

G. FMVSS No. 126: Electronic Stability Control (ESC) System

Standard No. 126 provides requirements to reduce the incidence of driver loss of directional control of the vehicle.[65] GM's ZEAV will have an electronic stability control system that is functionally similar to that on the Chevrolet Bolt EV. However, the ZEAV will not have a steering wheel or brake or accelerator pedals and therefore cannot be tested using those controls as described in paragraph S5.2 and in paragraphs S7.6 through S7.9. The ADS electronically interfaces to steering, brake, and accelerator control systems, which have actuators that provide these control inputs. Appendix II provides additional information about these actuators and controls and describes how GM will run tests to ascertain the full functionality of the ESC system for the ZEAV before the first deployment of the vehicles. The ESC system will be operational when the ADS drives the vehicle and otherwise fully satisfies the performance requirements specified in S5.2.

GM's ZEAV does not have a human driver and thus does not have ESC malfunction and "off" telltales. Accordingly, it will not meet the specific requirements of paragraph S5.3 or the test

[63] 49 C.F.R. § 571.124, paragraph S1.
[64] *See* 49 C.F.R. § 571.124, paragraphs S4 and S5 and their respective subparagraphs. For example, paragraph S5.3 states, in part: "Maximum time to return to idle position shall be 3 seconds for any vehicle that is exposed to ambient air at −18 degrees Celsius to −40 degrees Celsius during the test or for any portion of the 12-hour conditioning period."
[65] 49 C.F.R. § 571.126, paragraph S2.

protocols that refer to these telltales, including in paragraphs S7.2, S7.3, S7.8, and S7.10. The telltale requirements are intended to provide information to a human driver, but GM's ZEAV does not have a human driver. So the ZEAV meets the safety purpose of the telltale requirements by providing the operational status of the ESC electronically to the ADS. Appendix II describes how the ADS provides a safe driving response to ESC malfunction information.

GM's ZEAV meets the safety intent of Standard No. 126 to reduce the potential incidence of loss of directional control of the vehicle, including from rollover, because (i) the ESC remains fully operational on GM's ZEAV and (ii) the ADS electronically receives and responds to the information that a human driver would receive through the telltales. Thus, the ZEAV provides safety at least equal to the level of the Standard and fully satisfies both the safety showings required by § 30113(b)(3)(B) and federal safety objectives.

H. FMVSS No. 135: Light Vehicle Brake Systems

The purpose of Standard No. 135 is to "ensure safe braking performance under normal and emergency driving conditions."[66] Paragraph S7 specifies test procedures for the service and parking brake systems. Paragraph S5.3.1 provides that service brakes must be activated by foot control and that the parking brake must be activated by either a hand or a foot control. Paragraphs S5.1.2, S5.5, and S5.5.5 set forth requirements for certain telltales. The purpose of these telltales is to alert a human driver when brake status and functionality may not be optimal and vehicle service may be required.

In GM's ZEAV, the ADS will control the brakes through commands to the brake control module. The vehicle thus controls applied braking force through actuators and thereby meets the performance requirements specified by the Standard. Appendix II describes the system that the ADS uses to communicate braking control to the brake control module. Because the ZEAV will not be equipped with an accelerator pedal, a service brake pedal, or manual parking brake controls, the tests in paragraph S7 and the operation of the controls by hand or foot as stated in S5.3.1 are not applicable. Instead, the ZEAV will undergo brake testing as described in Appendix II to demonstrate that it meets the performance requirements before GM initiates deployment of the vehicle.

Additionally, the ADS electronically receives the information that Standard No. 135 requires to be made available to a human driver (by the telltales specified in paragraphs S5.1.2, S5.5, and S5.5.5). Appendix II describes how the ADS responds to the same information to safely operate the vehicle. Thus, the intent of this Standard to provide braking information and control to the "driver" is met because (i) the ADS will activate the service and parking brake controls in lieu of a human driver and (ii) the ADS will receive the same information that would otherwise be provided to a human driver through telltales and will respond appropriately. In addition, the

[66] 49 C.F.R. § 571.135, paragraph S2.

ZEAV's braking system will satisfy the stopping distance and grade-holding performance requirements of Standard No. 135. Using its ADS controls and information interfaces, the ZEAV provides safety at least equal to the level of the Standard and fully satisfies the safety showings required by § 30113(b)(3)(B) and federal safety objectives.

I. FMVSS No. 138: Tire Pressure Monitoring Systems

Paragraphs S4.3 and S4.4 of Standard No. 138 set forth requirements for telltales warning of low tire pressure and malfunctions in the vehicle's tire pressure monitoring system.[67] These telltales alert a human driver in the driver seating position when tire pressure is low and when service of the tire pressure monitoring system is required. GM's ZEAV will not have a driver seating position and will not include tire pressure telltales visible to a vehicle occupant. Instead, the ADS will monitor the vehicle's tire pressure through an electronic interface, detect low tire pressure, and recognize malfunctions in the tire pressure monitoring system. The ADS will appropriately respond to low tire pressure conditions, as described in Appendix II, and will be able to communicate tire pressure status to GM (which will control maintenance and operation of the GM ZEAV fleets). Thus, the ZEAV provides safety at least equal to the level of the Standard and fully satisfies both the safety showings required by § 30113(b)(3)(B) and federal safety objectives.

J. FMVSS No. 141: Minimum Sound Requirements for Hybrid and Electric Vehicles

Standard No. 141 specifies performance requirements for pedestrian alert sounds emitted by electric and hybrid vehicles. In particular, paragraph S5 sets specific sound emission requirements for when the vehicle is in forward or reverse gear. GM will test and certify the ZEAV to meet these performance requirements in accordance with the phase-in schedule specified by Standard No. 141. But the ZEAV will not be equipped with a human-controlled gear selector for use in demonstrating compliance with the Standard. Appendix II describes how the ADS communicates with the gear selector control actuators. Responding to the gear selection, the ADS triggers the sound emission performance required by S5. Because GM's ZEAV will meet the performance requirements of the Standard, the vehicle fully satisfies both the safety showings required by § 30113(b)(3)(B) and federal safety objectives.

K. FMVSS No. 203: Impact Protection for the Driver from the Steering Control System

Paragraph S5.1 of Standard No. 203 sets the maximum permissible impact force exerted on the chest of a body block in accordance with SAE Recommended Practice J944 JUN80 and transmitted to the steering control system. The purpose of this Standard is to minimize the risk of chest, neck, or facial injury caused by interaction with the steering control system during a crash.[68] This requirement does not apply to GM's ZEAV because the vehicle will not be equipped with a

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[67] *See, also*, 49 C.F.R. § 571.138, paragraph S1.
[68] 49 C.F.R. § 571.203, paragraph S1.

steering wheel or column. Absence of the steering wheel and column eliminates the risk of chest, neck, or facial injury caused by the steering wheel and column that this Standard was intended to minimize. To verify occupant protection, GM began its crash testing with computer simulation tests of the ZEAV with its integrated ADS computer, sensor, and control components. GM has followed these computer simulation tests with physical crash tests of the integrated ZEAV, which will establish performance of the entire vehicle, including its ADS and all of its components. These tests will validate passenger occupant impact protection in all seating positions. As a result, this change provides safety at least equal to the level of the Standard and fully satisfies both the safety showings required by § 30113(b)(3)(B) and federal safety objectives.

L. FMVSS No. 204: Steering Control Rearward Displacement

Paragraph S4.2 of Standard No. 204 specifies limits on the rearward horizontal displacement of the steering control (i.e., steering wheel and steering column) in a 48 kph frontal crash, with the purpose of minimizing the risk of chest, neck, or head injury caused by the steering control system.[69] GM's ZEAV will not be equipped with a steering wheel or column extending into the occupant compartment. Absence of the steering wheel and column in the occupant compartment minimizes the risk of the type of chest, neck, or head injury caused by the steering control system that this Standard was intended to address. The absence of steering controls in the passenger compartment effectively provides safety at least equal to the level of the Standard and satisfies both the safety findings required by § 30113(b)(3)(B) and federal safety objectives. GM's computer simulation crash tests and subsequent physical crash tests of the integrated ZEAV are planned to validate occupant impact protection in all seating positions, including verifying that the left front seating position safety protection provides occupant protection comparable to that provided to the right front seat passenger.

M. FMVSS No. 207: Seating Systems

Paragraph S4.1 of Standard No. 207 provides that each vehicle must have a seat for the driver. This requirement does not apply to GM's ZEAV because there is no human driver, so all seats in the ZEAV will be passenger seats. All front passenger seats will have front passenger seat occupant protection, including airbags and seat belts. GM's computer simulation crash tests and subsequent physical crash tests of the integrated ZEAV are planned to validate occupant impact protection in all seating positions, including verifying that the left front seating position safety equipment provides occupant protection comparable to that of the right front seat passenger.

[69] 49 C.F.R. § 571.204, paragraph S1.

This fully satisfies both the safety showings required by § 30113(b)(3)(B) and federal safety objectives.

N. FMVSS No. 208: Occupant Crash Protection

Multiple in-position and out-of-position test procedures in Standard No. 208 (e.g., S10.3.1) define the positioning of anthropomorphic test devices ("ATDs" or "dummies") in the human "driver" seated position relative to controls, such as the steering wheel and pedals. These positioning requirements ensure that crash tests accurately represent the seating positions of human drivers in relation to such controls.

Because GM's ZEAV will not have a human driver, it will not be equipped with a steering wheel or pedals for the purposes of positioning ATDs. Therefore, the ZEAV design precludes tests using these specific procedures. Instead, the ZEAV will mirror the dummy-positioning provisions of the right front passenger seating position in the left front seating position, providing an occupant crash protection system for the left front seat comparable to that of the right front seat passenger. GM's proposed dummy positioning will achieve the purpose of the Standard (i.e., accurately representing the positions of actual occupants in the ZEAV) and therefore will satisfy both the safety showings required by § 30113(b)(3)(B) and federal safety objectives.

Paragraph S7.3 of Standard No. 208 provides that a seat belt assembly for the driver seating position must be equipped with a warning system that activates an audible signal or warning light, and it specifies requirements for such audible signals and lights. GM's ZEAV will not have the audible and visual warnings for a human driver specified by paragraph S7.3 because the vehicle will not have a human driver. Instead, the ADS will receive the status of passenger seat belt utilization through an electronic interface. The ADS will convey appropriate reminders and warnings to all vehicle occupants to fasten their seat belts prior to initiating a ride. This approach allows GM's ZEAV to meet the intent of this requirement and allows the vehicle to fully satisfy both the safety findings required by § 30113(b)(3)(B) and federal safety objectives.

Under paragraph S4.5.2 of Standard No. 208, an occupant protection system that deploys in the event of a crash must be equipped with a readiness indicator that monitors its own readiness and is "clearly visible from the driver's designated seating position." The purpose of this readiness indicator is to alert a driver when the airbags may not function properly and vehicle service may be required. In GM's ZEAV, there is no human driver, and the intent of the readiness indicator requirement is satisfied by providing the readiness indicator information to the ADS instead of a visible indicator to a human driver. GM will control operation of its fleets of ZEAVs, receive diagnostics from these vehicles (including occupant protection system readiness information), and determine whether conditions require further evaluation or repair. Appendix II indicates how the ADS will respond to the information provided by the readiness indicator as it safely drives the ZEAV. Thus, the ZEAV will achieve the safety purpose of Standard No. 208 by means other than an indicator visible to a human driver, fully satisfying both the safety showings required by § 30113(b)(3)(B) and federal safety objectives.

O. FMVSS No. 214: Side Impact Protection

Paragraph S12 of Standard No. 214 specifies driver dummy-positioning procedures for the driver seating position. A number of these procedures describe test dummy position in relation to the steering wheel and pedals. The positioning requirements are intended to ensure that crash tests accurately represent the seating positions of human drivers in relation to such controls.

GM's ZEAV will not be equipped with a steering wheel or pedals to reference in positioning dummies. Instead, GM will mirror the right front test dummy positioning in the left front seating position. GM has started computer simulation crash testing and will perform relevant physical crash tests of the vehicle with its integrated ADS computer, sensor, and control components to verify that occupant protection for the left front seating position is comparable to that for the right front seat passenger. GM's proposed dummy positioning will achieve the intent of the Standard (i.e., accurately representing the positions of actual occupants in the ZEAV) and therefore fully satisfies both the safety showings required by § 30113(b)(3)(B) and federal safety objectives, and provides safety at least equal to the level of the Standard.

P. FMVSS No. 226: Ejection Mitigation

Under paragraph S4.2.2 of Standard No. 226, human-driven vehicles equipped with an ejection mitigation countermeasure that deploys in the event of a rollover are required to have a readiness indicator that is "clearly visible from the driver's designated seating position." This readiness indicator alerts the driver when airbags may not function properly and vehicle service may be required.

In GM's ZEAV, there is no human driver, so no readiness indicator will be visible to a nonexistent human driver. The ADS will monitor the readiness of the roof rail airbags. Instead of an indicator light as described in S4.2.2, the ZEAV will meet the safety purpose of this requirement by monitoring the underlying conditions and alerting the fleet operator (GM) to any needed repairs. In addition, the ADS will respond to readiness indicator information as described in Appendix II, following context-specific procedures in the event that the readiness indicator information shows that monitored components of the ejection mitigation system are not operable. This approach fully satisfies both the safety showings required by § 30113(b)(3)(B) and federal safety objectives.

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In summary, GM's ZEAV will satisfy the safety purpose and intent of all FMVSS requirements. Thus, the vehicle will effectively meet all FMVSS safety requirements and provide "a safety level at least equal to the safety level of the [affected] standard[s]."[70] Accordingly, the ZEAV meets the safety showings required under both 49 U.S.C. §§ 30113(b)(3)(B)(ii) and (iii).

In addition, because the ZEAV provides safety at least equal to that afforded by direct compliance with affected FMVSS, it enables the development and field evaluation of new motor vehicle safety features, including (a) ADS control interfaces for the steering wheel, accelerator pedal, brake pedal, transmission shift lever, turn signal activator, parking brake control, windshield wipers, and headlamp controls; (b) information interfaces to provide the ADS with information and control responses; (c) an array of sensors, including LiDAR, cameras, and radar, that provide the ADS with continuous 360-degree information on the environment outside the vehicle; and (d) because all occupants of the ZEAV will be a passengers, including an occupant in the left front seat, a left front passenger seat occupant protection system that provides occupant protection comparable to that provided to the right front seat passenger.

The foregoing discussion demonstrates that this Petition to advance safety and zero-emission vehicles through technology advancements that achieve the safety purpose and intent of FMVSS satisfies two of the three statutory requirements for granting a petition under 49 U.S.C. § 30113(b)(3)(B)(ii). It would "make easier the development [and] field evaluation of a new motor vehicle safety feature" and "provid[e] a safety level at least equal to the safety level of the [affected] standard[s]."[71] The foregoing discussion also demonstrates that this Petition satisfies the safety showing required to grant a petition under 49 U.S.C. § 30113(b)(3)(B)(iii).[72] The second requirement for a petition under § 30113(b)(3)(B)(iii)—the low-emission showing—is addressed in the following section. And the third and final requirement for a petition under § 30113(b)(3)(B)(ii) or (iii)—consistency with the public interest—is addressed further below in Section VI.

[70] 49 U.S.C. § 30113(b)(3)(B)(ii).
[71] 49 U.S.C. § 30113(b)(3)(B)(ii).
[72] In addition to the safety showings required by § 30113(b)(3)(B), NHTSA may be interested in understanding GM's approach for ensuring that the ZEAV's ADS will safely drive when the ZEAVs are deployed in the GM-controlled fleet ride-share program. This topic is addressed in the attached Appendix III.

V. The Low-Emission Showing: Granting This Petition Will Facilitate the Development and Field Evaluation of a Low-Emission Vehicle

As discussed above, this Petition satisfies the safety requirements of both 49 U.S.C. §§ 30113(b)(3)(B)(ii) and (iii). The latter provision allows NHTSA to grant a petition if "the exemption would make the development or field evaluation of a *low-emission motor vehicle* easier and would not unreasonably lower the safety level of that vehicle" (emphasis added). As demonstrated below, granting the Petition would make the development and field evaluation of GM's low-emission vehicle (the ZEAV) easier.

First, 49 U.S.C. § 30113(a) defines a low-emission motor vehicle for purposes of this section as:

> a motor vehicle meeting the standards for new motor vehicles applicable to the vehicle under section 202 of the Clean Air Act (42 U.S.C. 7521) when the vehicle is manufactured and emitting an air pollutant in an amount significantly below one of those standards.

Section 202 of the Clean Air Act sets standards for emissions of greenhouse gases, including carbon dioxide, methane, and nitrous oxide. GM's ZEAV is an all-electric, zero-emission vehicle that does not utilize any form of combustion or emit any of the pollutants covered by § 202 of the Clean Air Act. As a zero-emission vehicle, GM's ZEAV is also a "low-emission motor vehicle."

Second, granting the Petition would make field evaluation of GM's ZEAV (a low-emission vehicle) easier. The ZEAV is unique among low-emission vehicles. While the ZEAV shares a platform with the Chevrolet Bolt, from a fuel economy perspective the ZEAV's zero-emission propulsion system will perform differently than that of the Bolt for at least two reasons. First, the ZEAV's high-performance computer system and array of sensors draw power from the power supply for the zero-emission propulsion system. Second, the ZEAV will be driven by the ADS, not a human driver. Granting this Petition will allow the study and real-world evaluation of the impact of these factors on the performance of the zero-emission propulsion system. This real-world field evaluation of the unique characteristics and performance of the zero-emission propulsion system will generate valuable data about advantages and disadvantages of incorporating the sophisticated computer and sensors of an ADS to a zero-emission platform. In addition, because the ZEAV will be used in a fully self-driving mobility-on-demand service, granting this Petition will allow GM to evaluate the impact of this use case on the performance of the zero-emission propulsion system. This data will in turn prove valuable in assessing further development of and investments in the ZEAV's technology. Because granting this Petition is necessary to allow deployment of the ZEAV in the first instance, granting this Petition clearly will make easier the development and field evaluation of the ZEAV, including systems and features affecting the ZEAV's zero-emission propulsion system and its performance.

Granting this Petition will encourage the development and introduction into commerce of ZEAVs (a subset of low-emission vehicles), by GM as well as other manufacturers. As explained, this

Petition targets the human-driver-based requirements of the FMVSS. Those requirements stand as an obstacle to deploying an autonomous zero-emission vehicle, namely, GM's ZEAV, as a new safety and mobility solution in American cities. Allowing GM to deploy its ZEAVs, which satisfy the safety purposes of those FMVSS requirements, will allow them to provide on-demand transportation services to passengers in urban areas. In the process, this exemption will enable GM and NHTSA to learn about a new type of zero-emission vehicle, the use of zero-emission vehicles as ride-share-dedicated vehicles, and the interplay of battery electric propulsion and automated driving systems. These and other advantages of GM's ZEAV are further discussed below.[73]

The remaining criterion for granting this Petition is that the exemption sought is consistent with the public interest. As demonstrated below, granting this Petition offers multifaceted benefits to the public by advancing safety, mobility, and the economy.

VI. The Public Interest Showing: Granting This Petition Will Benefit the Public Interest

The third and final showing necessary to grant a petition under both §§ 30113(b)(3)(B)(ii) and (iii) is that granting the petition is in the public interest.[74] Under 49 U.S.C. § 30113, NHTSA may grant an exemption petition upon making the requisite findings, including that "an exemption is consistent with the public interest."[75] The safety advances discussed above have the potential to save many lives and reduce motor vehicle crashes and injuries, providing tremendous benefit to the public. And we are just beginning to tap this potential of self-driving technology, which reinforces the importance of moving this technology forward. In addition, by enabling the operation of GM's ZEAV in fleets that provide personal mobility solutions, granting the Petition will support thousands of jobs, increase urban mobility options, foster public acceptance of both low-emission and autonomous vehicles, generate important real-world data, and inform future NHTSA action. Finally, as NHTSA has made clear, "it is manifestly in the public interest to accelerate the development of electrically driven vehicles. Electric vehicles can help reduce the reliance of the nation on oil and reduce greenhouse gas and other emissions. Moreover, development of electric vehicles contributes to the expansion of consumer choices."[76] These factors, discussed more fully below, provide a robust public interest showing.

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[73] As discussed in Appendix I: Low-Emission Finding, finding that granting this Petition would make the development and field evaluation of GM's low-emission vehicle easier is consistent with prior NHTSA decisions.
[74] GM has shown above that granting the Petition would serve the other two required factors under § 30113(b)(3)(B)(ii) (makes easier the evaluation of new motor vehicle safety feature and provides a safety level at least equal to the safety level of affected Standards) and § 30113(b)(3)(B)(iii) (makes evaluation of a low-emission vehicle easier and does not unreasonably lower the vehicle's safety level). Showing that the requested exemption is consistent with the public interest is the common third element of both provisions.
[75] 49 U.S.C. § 30113(b)(3)(A).
[76] *Think Technology AS*, 74 F.R. 40634, 40636, Docket No. NHTSA-2008-0152 (2009) (granting petition for temporary exemption).

A. Supporting U.S. Jobs and Investments in Autonomous Vehicle Development

GM's ZEAV program already is generating high-quality jobs across the United States. GM recently announced that it will add over 1,100 jobs to its autonomous vehicle business in California within the next five years. Beyond California, GM employees in Arizona, Michigan, and Georgia, among other locations across the United States, support GM's ZEAV development. For example, factory workers at GM's Orion Assembly plant will build the ZEAVs alongside GM's Chevrolet Bolt, while product engineers in Michigan develop the ZEAV vehicle architecture and GM IT workers in Georgia prepare necessary IT systems. Through these jobs, American workers gain invaluable skills and experience in a burgeoning high-technology field.

These jobs are just part of GM's larger investment in autonomous vehicle development, which GM anticipates will be about $600 million in 2017. At the same time, GM has also announced progress toward producing a profitable mass-market electric vehicle, which will add another dimension to the value placed on electric vehicles. GM's ZEAV will aid in these efforts by demonstrating additional design and usage options for electric vehicles.

GM's autonomous vehicle investment has a multiplier effect, driving additional investment by suppliers, competitors, and supporting industries. GM's efforts create a market for suppliers, such as those creating powerful in-vehicle computers and new sensors to enable autonomous vehicles, as well as for supporting services and infrastructure, such as vehicle charging stations. GM's investment in autonomous vehicle development also helps drive competition from other manufacturers and developers to begin or increase investment in autonomous technologies and related jobs.

Beyond supporting jobs needed for ZEAV development, production, components, and infrastructure, granting this Petition will facilitate the development of new mobility options for many people. In some instances, these new mobility options may be an important factor in a person's ability to accept and maintain a job that may otherwise be unavailable due to limited transportation options. And by creating new mobility options, GM's ZEAVs will also stimulate competition for safe and innovative mobility solutions for all people, including those who cannot or do not drive.

These and many similar investments in American jobs, mobility, and technology all rest on one common premise: a path to market for vehicles like GM's ZEAV. To encourage continued investment in American jobs and capital and to keep America competitive in this high-technology space, a regulatory environment conducive to the safe deployment of ZEAV technologies is essential. GM is committed to the safe introduction of ZEAVs and to amplifying the positive technological, economic, and mobility momentum its ZEAV program has generated. GM believes that the path forward for GM's ZEAV leads toward future investment in American jobs and technology to support zero-emission and autonomous vehicles.

B. Fostering Public Acceptance of Autonomous and Low-Emission Vehicles

GM's ZEAV is ideal for educating the public about the benefits of automated technology. Public acceptance is critical for broad realization of the safety and mobility benefits of autonomous vehicles. Through ZEAV ride-sharing fleets, all consumers—from the early adopter to the skeptic—will be able to experience automated vehicle technology firsthand, without significant individual financial commitment. While passengers experience automated vehicle technology for the first time, GM's ZEAV fleet may also allow them to take their first ride in an all-electric vehicle. In particular, passengers will learn through experience that battery electric vehicles are well suited for ride-share-dedicated use. Because it will enable exposure to this vehicle in a manner that allows consumers to pay only for the rides they want—without having to purchase the vehicle—GM's ZEAV is an ideal platform for educating the public about the benefits of both automated and zero-emission vehicle technologies.

C. Generating Valuable Real-World Data

The requested exemption will enable GM to collect valuable data to improve its ZEAVs, to design the next generation of safe and accessible ZEAVs, and to foster their public acceptance. Data collected under real-world conditions is essential for developing autonomous vehicle technologies. With this exemption, GM's ZEAV will face not only varying road conditions but also varying customer expectations and behaviors. The exemption requested under this Petition would allow the deployment of GM's ZEAVs in limited numbers (2,500 or less per year), constituting both a controlled deployment of this new technology and deployment at a scale large enough to generate meaningful learnings. GM will learn from larger-scale production of ZEAVs and will create opportunities to make autonomous vehicle safety technologies not built into conventional vehicles more affordable through scale. This in turn will generate valuable data to facilitate continual improvements in the safety, accessibility, and functionality of ZEAV technologies.

D. Informing Future NHTSA Action

If NHTSA grants this Petition, GM intends to share with NHTSA field safety performance data associated with its ZEAV deployment, including any crashes, property damage, injuries, or fatalities that may occur involving these vehicles. We will plan to provide this data, designated as confidential where appropriate, at the conclusion of the exemption period, but also may be able to provide interim reviews, if requested. For GM's ZEAV, this data will be representative of a vehicle that, as certified to meet the applicable FMVSS, includes its integrated ADS computer, sensor, and control components. GM also anticipates comparing its ZEAV crash statistics with relevant conventional vehicle statistics, where possible, and will share this analysis with the Agency as well. To discuss other learnings from the ZEAV deployment that may be of mutual interest to GM and the Agency, GM would be pleased to meet with the Agency during the exemption period.

GM's experience and data from its ZEAV deployment will inform the Agency's development of its regulatory framework for autonomous vehicles. Granting this Petition will facilitate the development and field evaluation of ZEAVs in real-world conditions, enabling the promulgation of future rules and policies grounded in real-world data and experience. This data and experience will provide invaluable inputs and guideposts for NHTSA as it navigates the coming period of dynamic technological change.

VII. Plans for Compliance During and After the Proposed Exemption Period

GM requests an exemption from the above-described FMVSS provisions for up to 2,500 vehicles per year for a period of two years. During the exemption period, GM intends to work with NHTSA and industry stakeholders on an FMVSS rulemaking to address new rules necessary to accommodate and foster autonomous vehicle technology and its myriad benefits. A new rulemaking could enable the manufacture and FMVSS certification of GM's ZEAV and similar vehicles, which could advance safe, low-emission mobility options. If that rulemaking is not completed during the two-year period of this requested exemption, then GM would likely request a renewal. GM will continue to operate vehicles produced during this period through their normal service life. GM does not intend to sell any of the exempted vehicles to individual consumers, but instead plans to deploy the vehicles in GM-owned-and-controlled fleets. Consistent with statutory limits, GM will not sell more than 2,500 exempted vehicles in the United States in any 12-month period under the authority sought in this Petition.

Conclusion

NHTSA has described its vision of a future in which technology helps people avoid crashes, citing autonomous technology's potential to significantly reduce highway fatalities by addressing the root cause of these tragic crashes: human error.[77] GM has adopted its own vision of a future with zero crashes, zero emissions, and zero congestion, and has invested in technology to advance these goals. NHTSA has repeatedly pointed to petitions for exemption as a regulatory tool to help safely bring autonomous technology to market.[78] GM provides this Petition evidencing its investments in technology that safely advances autonomous and low-emission vehicles and demonstrating that GM's ZEAV will be ready for safe, fully self-driving operation on public roads in GM-controlled ride-share fleets.

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[77] *Automated Driving Systems 2.0*, *supra* at i.

[78] *Id*. at 2. *See also Federal Automated Vehicles Policy*, *supra* at 7, 12, 13, 14, 48, 49, 52-62. *See also* NHTSA's February 4, 2016, Letter of Interpretation to Google.

NHTSA can play a key role in building and shaping a safer future by utilizing its regulatory tools to encourage, rather than hamper, the safe testing and deployment of automated vehicle technology. Granting this Petition is an important step in eliminating regulatory barriers that impede deployment of this promising technology. Granting this Petition will support innovation and promote public access to the safety, low-emission, mobility, and other benefits of such innovation. Granting this Petition also protects the American economy and its workers by fostering a regulatory environment that encourages investment and job growth in autonomous vehicle technologies and related fields.

This Petition meets all of the requirements set forth in 49 U.S.C. §§ 30113(b)(3)(B)(ii) and (iii) through technology that advances safety and zero-emission vehicles and achieves the safety purpose of the FMVSS requirements discussed above. GM respectfully requests that NHTSA grant this Petition exempting GM's self-driving ZEAV from the FMVSS cited above for a period of two years. GM thanks NHTSA for its consideration of this Petition and welcomes any questions or requests for additional information. Please direct such questions or requests to Doug Parks or Paul Hemmersbaugh (202) 775-5021.

Respectfully Submitted,

Doug Parks

Paul Hemmersbaugh

Jeffrey Massimilla

APPENDIX I: LOW-EMISSION FINDING

To grant a petition pursuant to 49 U.S.C. § 30113(b)(3)(B)(iii), NHTSA must find that an exemption would "make the development or field evaluation of a low-emission motor vehicle easier." In finding that an exemption satisfies this requirement, Agency decisions have determined that the proposed vehicle and deployment program would achieve one or more of five general objectives. Namely, the petitioner's proposed deployment would:

1. Facilitate the development and evaluation of data from road use of the vehicle and improve the petitioner's own expertise;[79]
2. Facilitate the development of future low-emission vehicle models or allow vehicles on the road while FMVSS-compliant systems are being developed;[80]
3. Demonstrate to the public the benefits and viability of low-emission vehicles;[81]
4. Help evaluate the market for low-emission vehicles;[82] or

[79] *See, e.g., B.A.T., Grant of Petition for Temporary Exemption From Federal Motor Vehicle Safety Standard No. 208*, 59 F.R. 39629 (August 3, 1994); *U.S. Electricar, Inc. [formerly Solar Electric Engineering], Grant of Petition for Renewal of Temporary Exemption From Five Federal Motor Vehicle Safety Standards*, 59 F.R. 39630 (August 3, 1994); *Ford Motor Company, Disposition of Petition for Temporary Exemption From Federal Motor Vehicle Safety Standards*, 58 F.R. 16907 (March 31, 1993); *Clarity, Grant of Petition for Temporary Exemption From Seven Federal Motor Vehicle Safety Standards*, 57 F.R. 28765 (June 26, 1992); *Carrozzeria Zagato, Petition for Temporary Exemptions from Motor Vehicle Safety Standards*, 39 F.R. 32774 (September 11, 1974); *Sebring-Vanguard, Petition for Temporary Exemptions from Motor Vehicle Safety Standards*, 39 F.R. 3710 (January 29, 1974).

[80] *See, e.g.*, *Greenkraft, Grant of Application for a Temporary Exemption From FMVSS No. 108*, 80 F.R. 12057 (March 5, 2015); *Toyota, Grant of Petition for Temporary Exemption from an Electrical Safety Requirement of FMVSS No. 305*, 80 F.R. 101 (January 2, 2015); *Wheego Electric Cars, Inc., Grant of Petition for Temporary Exemption From the Electronic Stability Control Requirements of FMVSS No. 126*, 77 F.R. 47915 (August 10, 2012); *Tesla, Grant of Petition for Temporary Exemption From the Electronic Stability Control Requirements of FMVSS No. 126*, 76 F.R. 60124 (September 28, 2011); *Think Technology AS, Grant of Application for a Temporary Exemption From the Advanced Air Bag Requirements of Federal Motor Vehicle Safety Standard No. 208*, 74 F.R. 40634 (August 12, 2009); *Chrysler Corporation, Grant of Application for Renewal of Temporary Exemption From Three Federal Motor Vehicle Safety Standards*, 59 F.R. 65570 (December 20, 1994); *General Motors Corp., Grant of Petition for Temporary Exemption From Federal Motor Vehicle Safety Standards*, 58 F.R. 48421 (September 15, 1993); *Kewet, Grant of Petition for Temporary Exemption From Federal Motor Vehicle Safety Standard No. 208*, 58 F.R. 7905 (February 10, 1993); *Solar Electric Engineering, Grant of Petition for Temporary Exemption From Five Federal Motor Vehicle Safety Standards*, 57 F.R. 30997 (July 13, 1992); *Chrysler Corporation, Grant of Petition for Temporary Exemption From Three Federal Motor Vehicle Safety Standards*, 57 F.R. 27507 (June 19, 1992); *Conceptor Industries, Grant of Petition for Temporary Exemption From Three Federal Motor Vehicle Safety Standards*, 54 F.R. 46318 (November 2, 1989); *Jet Industries, Petition for Temporary Exemptions from Motor Vehicle Safety Standards*, 41 F.R. 7545 (February 19, 1976).

[81] *See, e.g., Greenkraft* (March 5, 2015); *Wheego Electric Cars Inc.* (August 10, 2012); *Tesla* (September 28, 2011); *Wheego Electric Cars, Grant of Petition for Temporary Exemption from Certain Provisions of Federal Motor Vehicle Safety Standard (FMVSS) No. 208, Occupant Crash Protection,* 76 F.R. 7898 (February 11, 2011); *B.A.T.* (August 3, 1994); *Kewet* (February 10, 1993).

[82] *See, e.g.*, *Wheego Electric Cars* (February 11, 2011).

5. Expand consumer choices for low-emission vehicles.[83]

GM's proposed deployment program for the ZEAV achieves all of these objectives, each of which alone has been found sufficient to satisfy the low-emission vehicle development finding of § 30113(b)(3)(B)(iii). As to No. 1, granting this Petition will allow the deployment of vehicles in GM's ride-share program, from which GM will obtain on-road development and field evaluation data. As to No. 2, GM has announced plans to introduce 20 new all-electric vehicles by 2023—knowledge gained from the ZEAV's deployment will help GM develop aspects of these future vehicles, especially as they relate to potential ride-share and autonomous use cases. As to No. 3, the ZEAV's deployment in a ride-share program will introduce many members of the public to this zero-emission vehicle, and GM's ZEAV is an ideal platform for demonstrating to the public the benefits and viability of low-emission vehicles. As to No. 4, GM's ride-share program employing the ZEAV will seek to demonstrate the business viability of the ZEAV in the ride-share business. As to No. 5, making the ZEAV available provides consumers with a new choice for low-emission transportation.

Following are relevant excerpts from NHTSA's prior low-emission vehicle petition grants.

- ***Greenkraft, Inc.,* 80 F.R. 12057, 12060 (March 5, 2015)** (granting petition for exemption from headlamp standards of FMVSS No. 108 for LEV). "We have concluded that an exemption from the headlamp requirements of FMVSS No. 108 would make the development or field evaluation of a low-emission motor vehicle easier. Granting the exemption will allow Greenkraft to produce vehicles while the company designs a headlamp that complies with FMVSS No. 108. We believe that allowing Greenkraft to produce and sell vehicles during the exemption period will demonstrate to the public the environmental benefits and viability of CNG powered vehicles."

- ***Toyota Motor North America, Inc.*, 80 F.R. 101, 103 (January 2, 2015)** (granting petition for exemption from electrical safety requirement of FMVSS No. 305 for LEV). "Further, we believe that the temporary exemption would make easier the development of those vehicles. As Toyota stated in their petition, obtaining field information about new technologies (especially information about consumer reaction and real world performance) would facilitate Toyota's development and decisions on potential modifications to future versions of their FCVs [fuel cell vehicles]."

- ***Wheego Electric Cars, Inc.*, 77 F.R. 47915, 47916-17 (August 10, 2012)** (granting petition for exemption from the electronic stability control (ESC) requirements of FMVSS No. 126 for LEV). "We conclude that Wheego has shown that an exemption from the ESC

[83] *See, e.g., Wheego Electric Cars* (February 11, 2011); *Kewet* (February 10, 1993). *See also B.A.T.* (August 30, 1993 and August 3, 1994) (recognizing the additional purpose of supporting conversion entities that convert gasoline vehicles to electric vehicles, which is inapplicable here).

requirements would make the development or field evaluation of a low-emission motor vehicle easier. Specifically, we agree with Wheego that allowing continued production on a limited basis of additional LiFe models now under an exemption will make it easier for Wheego to design and produce future low emission vehicle models without an exemption.... We agree with Wheego that continued production of its vehicle will help to demonstrate to the U.S. public the capabilities of electric vehicles."

- ***Tesla Motors, Inc.*, 76 F.R. 60124, 60126 (September 28, 2011)** (granting petition for exemption from the electronic stability control (ESC) requirements of FMVSS No. 126 for LEV). "Tesla has shown that an exemption from the ESC requirements would make the development or field evaluation of a low-emission motor vehicle easier.… [W]e agree with Tesla that, by producing additional Roadster models, Tesla will be able to use data from computers installed on those vehicles to assist it in optimizing its battery design and vehicle software for future all-electric vehicle offerings… [Granting Tesla's petition] will help to demonstrate to the U.S. public the performance, range and capabilities of electric vehicles."

- ***Wheego Electric Cars, Inc.*, 76 F.R. 7898, 7901 (February 11, 2011)** (granting petition for exemption from advanced airbag requirements of FMVSS No. 208 for LEV). "NHTSA believes that the requested exemption would make the development or field evaluation of a low-emission motor vehicle easier. Wheego has stated that the LiFe will be one of the first affordable electric cars available in the United States. Wheego has also stated that allowing them into the market by granting the exemption will expand consumer choices and contribute to the development of electric cars in general by helping to evaluate the market for electric vehicles."

- ***Think Technology AS*, 74 F.R. 40634, 40636 (August 12, 2009)** (granting petition for exemption from advanced airbag requirements of FMVSS No. 208 for LEV). "Think explained that the exemption would, among other things, permit evaluation and further development of alternative battery concepts, evaluation and further development of vehicle systems based on real-world usage under U.S.-specific driving and storage conditions, and product evaluation through U.S. warranty analysis and customer feedback. We agree that the exemption would permit that company to engage in these activities, and thereby make the development or field evaluation of a low-emissions vehicle easier."

- ***Kewet Industri*, 60 F.R. 19444, 19445 (April 18, 1995)** (granting renewal petition for exemption from the automatic restraint requirements of FMVSS No. 208 for LEV). "[Kewet argued that] an exemption would promote learning and exchange of information between the Danish electric vehicle industry and the U.S. one. Finally, the El-Jet will demonstrate the commercial viability of a 'neighborhood electric vehicle.'… In consideration of the foregoing, it is hereby found that an extension of Kewet's exemption will facilitate the development and field evaluation of a low-emission motor vehicle."

- ***Chrysler Corporation*, 59 F.R. 65570, 65571 (December 20, 1994)** (granting petition for exemptions for LEV from certain portions of FMVSS No. 101, Controls and Displays; FMVSS No. 102, Transmission Shift Lever Sequence, Starter Lock, and Transmission Braking Effect; and FMVSS No. 105, Hydraulic Brake Systems). "It is manifestly in the public interest to accelerate the development of electrically-driven vehicles, not only to reduce reliance on oil, no matter where it originates, but also to reduce the level of harmful emissions in the environment. Because of the minimal impact on safety of the renewal of this exemption, NHTSA considers that an exemption is consistent with the objectives of Chapter 301. In consideration of the foregoing, it is hereby found that renewal of NHTSA Temporary Exemption No. 92-1 for a further two years would make the development or field evaluation of a low-emission vehicle easier."

- ***B.A.T. Incorporated*, 59 F.R. 39629, 39630 (August 3, 1994)** (granting petition for exemption from crash test requirements of FMVSS 208 for LEV). "As NHTSA noted in granting B.A.T.'s previous petition: '[I]t is manifestly in the public interest for small manufacturers to engage in the converting of internal combustion engines to electric power, and for this agency to take appropriate steps to encourage these endeavors, provided that they are consistent with motor vehicle safety.'… The exemption provided will allow the petitioner to broaden its product range from trucks to passenger cars, and contribute to the development of its expertise in vehicle conversion."

- ***U.S. Electricar, Inc. [formerly Solar Electric Engineering]*, 59 F.R. 39630, 39631 (August 3, 1994)** (granting renewal petition for exemptions for LEV from portions of FMVSS No. 103, Windshield Defrosting and Defogging Systems; FMVSS No. 105, Hydraulic Brake Systems; FMVSS No. 201, Occupant Protection in Interior Impact; FMVSS 204, Steering Control Rearward Displacement; and FMVSS No. 208, Occupant Crash Protection). "Under a renewed exemption, the company will continue its safety development and field evaluations with a view to ensuring that its vehicles fully comply before the end of the renewed exemption period…. Continued exemption of a low-emission motor vehicle facilitates its development and field evaluation and it remains in the public interest to do so."

- ***General Motors Corp.*, 58 F.R. 48421 (September 15, 1993)** (granting petition for exemptions for LEV from certain portions of FMVSS No. 201, Occupant Protection in Interior Impact; FMVSS No. 203, Impact Protection for the Driver from the Steering Control System; and FMVSS No. 208, Occupant Crash Protection). "Petitioner argued that…the data derived 'would facilitate the development of vehicles which would fully comply with FMVSS and satisfy the numerous requirements of potential buyers.'… Accordingly, in consideration of the foregoing, NHTSA finds that a temporary exemption will facilitate the development and field evaluation of a low-emission motor vehicle."

- ***B.A.T. Incorporated*, 58 F.R. 45549, 45550 (August 30, 1993)** (granting petition for exemption for LEV from FMVSS No. 204, Steering Control Rearward Displacement, and crash test requirements in FMVSS No. 208, Occupant Crash Protection). "Exemptions for conversions allow field evaluations by their purchasers and modifications by the converters that respond to the evaluations. Therefore, the Administrator finds in this instance that the exemptions requested will facilitate the development and field evaluation of low-emission motor vehicles, and that the exemptions requested are in the public interest and consistent with the objectives of the National Traffic and Motor Vehicle Safety Act."

- ***Ford Motor Company*, 58 F.R. 16907, 16909 (March 31, 1993)** (partially granting petition for exemptions for LEV from part or all of the following FMVSS: No. 101, Controls and Displays; No. 105, Hydraulic Brake Systems; No. 108, Lamps, Reflective Devices, and Associated Equipment; No. 115, Vehicle Identification Number; No. 120, Tire Selection and Rims for Motor Vehicles Other Than Passenger Cars; No. 204, Steering Column Rearward Displacement; No. 207, Seating Systems; No. 208, Occupant Crash Protection; No. 209, Seat Belt Assemblies; No. 210, Seat Belt Assembly Anchorages; No. 212, Windshield Mounting; No. 216, Roof Crush Resistance; No. 219, Windshield Zone Intrusion; and No. 301, Fuel System Integrity). "Manifestly, a program under which 105 vehicles are produced and leased to Ford's electric vehicle development partners is a program of field evaluations of low-emission vehicles that will be facilitated by a granting of Ford's petition."

- ***Kewet Industri*, 58 F.R. 7905, 7906** (**February 10, 1993)** (granting petition for exemption for LEV from the automatic restraint requirements of FMVSS No. 208). "The importation of the E1-Jet into the United States will allow its Danish manufacturer to judge its suitability for use on the public roads of the United States, and afford the opportunity for its further development. Its introduction into the growing fleet of electric vehicles in this country will provide consumers with an additional choice of an alternative low-emission motor vehicle…. In consideration of the foregoing, it is hereby found that the temporary exemption which Kewet has requested would facilitate the development or field evaluation of a low-emission motor vehicle."

- ***Solar Electric Engineering*, 57 F.R. 30997 (July 13, 1992)** (granting petition for exemptions for LEV from part or all of FMVSS No. 103, Windshield Defrosting and Defogging Systems; FMVSS No. 105, Hydraulic Brake Systems; FMVSS No. 201, Occupant Protection in Interior Impact; FMVSS No. 204, Steering Control Rearward Displacement; and FMVSS No. 208, Occupant Crash Protection). "The vehicle is per se a low-emission motor vehicle, and an exemption would facilitate its field evaluation and further development by the petitioner. Given the continuing concern over the environment, an exemption of such a vehicle is in the public interest…. For the foregoing reasons it is hereby found that a temporary exemption would facilitate the development and field evaluation of a low emission motor vehicle."

- ***The Clarity Group, Inc.*, 57 F.R. 28765 (June 26, 1992)** (partially granting petition for exemptions for LEV from part or all of the following FMVSS: No. 103, Windshield Defrosting and Defogging Systems; No. 105, Hydraulic Brake Systems; No. 208, Occupant Crash Protection; No. 212, Windshield Mounting; No. 219, Windshield Zone Intrusion; and No. 301, Fuel System Integrity). "According to the petitioner, an exemption would facilitate the development and field evaluation of a low emission motor vehicle by enabling the petitioner to advance 'the state of the art in electric vehicle traction systems through the application of electric vehicles in actual commercial uses', and deriving data from such uses…. It is also found that the vehicle for which petition is made is a low emission motor vehicle, and that an exemption would facilitate this manufacturer's development and field evaluation of low emission vehicles."

- ***Chrysler Corporation*, 57 F.R. 27507 (June 19, 1992)** (granting petition for exemptions for LEV from certain portions of FMVSS No. 101, Controls and Displays; FMVSS No. 102, Transmission Shift Lever Sequence, Starter Interlock, and Transmission Braking Effect; and FMVSS No. 105, Hydraulic Brake Systems). "Petitioner has argued that the exemption would enable it to develop the components of the vehicle to increase the efficiency and durability of future generations of electric vehicles. NHTSA concurs with this argument. In view of petitioner's recently-communicated desire to sell these vehicles, rather than destroy them, it is probable that an exemption would permit the use of the vehicles under varied conditions of climate and terrain, testing those components for durability and life."

- ***Solar Electric Engineering*, 57 F.R. 22860 (May 29, 1992)** (granting petition for exemptions for LEV from certain portions of FMVSS No. 103, Windshield Defrosting and Defogging Systems; FMVSS No. 105, Hydraulic Brake Systems; FMVSS No. 201, Occupant Protection in Interior Impact; FMVSS No. 204, Steering Control Rearward Displacement; and FMVSS No. 208, Occupant Crash Protection). "The vehicle is per se a low-emission motor vehicle, and an exemption would facilitate its field evaluation and further development by the petitioner. Given the continuing concern over the environment, an exemption of such a vehicle is in the public interest…. For the foregoing reasons it is hereby found that a temporary exemption would facilitate the development and field evaluation of a low emission motor vehicle."

- ***Conceptor Industries, Inc.*, 54 F.R. 46318 (November 2, 1989)** (granting petition for exemptions for LEV from part or all of FMVSS No. 105, Hydraulic Brake Systems; FMVSS No. 124, Accelerator Control Systems; and FMVSS No. 301, Fuel System Integrity). "NHTSA deems it important to encourage the search for propulsion systems that are viable alternatives to the internal combustion engine. Electrical propulsion is one such system…. The experience of Conceptor, with the encouragement and support of General Motors, could add to the sum of knowledge of electric vehicle technology. The agency believes that these factors would justify a finding that a temporary exemption will facilitate the development and field evaluation of a low-emission motor vehicle."

- ***Jet Industries, Ltd.*, 41 F.R. 7545, 7546** (**February 19, 1976)** (granting petition for exemptions for LEV from part or all of the following FMVSS: No. 101, Control, Location, Identification, and Illumination; No. 103, Windshield Defrosting and Defogging Systems; No. 104, Windshield Wiping and Washing Systems; No. 108, Lamps, Reflective Devices, and Associated Equipment; No. 119, New Pneumatic Tires for Vehicles Other Than Passenger Cars; No. 206, Door Locks and Door Retention Components; and No. 207, Seating Systems). "In granting temporary exemptions on the basis petitioner requested, it must be found that the exemption would facilitate the development and field evaluation of a low emission vehicle…. In this instance the petitioner hopes to sell and lease electric trucks in the United States for operation under varied conditions of climate and terrain, utilizing the data for future product improvement. Thus, it appears that an exemption will facilitate the development of a low emission motor vehicle within the intent of Congress."

- ***Carrozzeria Zagato*, 39 F.R. 32774** (**September 11, 1974)** (granting petition for exemptions for LEV from FMVSS No. 103, Windshield Defrosting and Defogging Systems; FMVSS No. 114, Theft Protection and Rollaway Protection; FMVSS No. 206, Door Locks and Door Retention Components; and FMVSS No. 208, Occupant Crash Protection). "NHTSA has determined that by allowing production and sale of an electric vehicle, the exemption would facilitate the development and field evaluation of a low emission vehicle."

- ***Sebring-Vanguard, Inc.*, 39 F.R. 3710 (January 29, 1974)** (granting petition for exemptions for LEV from certain portions of FMVSS No. 103, Windshield Defrosting and Defogging Systems; FMVSS No. 108, Reflective Devices; FMVSS No. 206, Door Locks and Door Retention Components; and FMVSS No. 208, Occupant Crash Protection). "NHTSA has determined that by allowing production and sale of an electric vehicle, the exemption would facilitate the development and field evaluation of a low emission vehicle."

APPENDIX II: SUPPLEMENTAL TECHNICAL INFORMATION

This Appendix II is part of GM's Petition under 49 U.S.C. § 30113 for exemption from certain FMVSS requirements for GM's fully self-driving, zero-emission autonomous vehicle, or ZEAV. This Appendix II provides additional explanation of how the ZEAV satisfies the safety findings required under both 49 U.S.C. § 30113(b)(3)(B)(ii) and (iii) and the federal safety objectives. This document is not a comprehensive description of GM's ZEAV, but provides a technical supplement to the Petition letter to which this Appendix II is attached. To the extent that NHTSA has questions related to items either covered or not covered in this document, GM welcomes dialogue to address those questions.

The details in this Appendix II include:

- An overview of the ZEAV's ADS and external sensor system;

- An explanation of how the ZEAV senses what is happening externally and ultimately processes and translates that information to control vehicle movement;

- Details of the ZEAV's robust and safety-focused architecture that enables connectivity, redundancy, and fail-operational and fail-safe functionality;

- Additional information and data related to the FMVSS discussed in the Petition letter and supporting the safety findings required under 49 U.S.C. § 30113(b)(3)(B)(ii) and (iii) and federal safety objectives;

- GM's approach to testing the ZEAV's ESC and service brake systems; and

- A description of how the vehicle will interact with its passengers in a ride-share deployment.

Overview

In GM's ZEAV, the ADS is a redundant, high-performance, computer-controlled system with fail-operational and fail-safe capabilities. The ADS includes two dual computer systems operating independently and simultaneously for self-driving decision making, each including an Automated Driving System Computer and an Advanced Driving Integration Module, connected by Ethernet networks and switches with diagnostics. An additional system, referred to as the Safety Co-Pilot, adds independent collision imminent braking capability. Ethernet, LVDS, and CAN networks connect the ADS to various sensors and vehicle systems. The ADS receives information from a diversified and redundant sensor system with a 360-degree view of the environment around the vehicle. The ZEAV's design integrates the ADS as part of a production vehicle, bringing advanced sensing and computing power while also allowing the ZEAV to include system components common to GM's Chevrolet Bolt. With this approach, the ZEAV benefits from both the new ADS technology and the integrity of existing Bolt systems. The ADS's high-power computing system ascertains the vehicle's precise location; detects, classifies, and predicts the behavior of objects around the vehicle multiple times per second; uses the object information along with map data and driving rules to plan the path of the vehicle; and interfaces with control systems to safely drive the vehicle. Key control components also have fail-operational and fail-safe capabilities. Diagnostics are built into sensors, networks, the high-power computers, and the actuator controls. The ADS responds to both normal and unexpected driving conditions, such as potential collisions, diagnostic failures, and system warnings. The vehicles will only be operated in a GM-controlled fleet, and, through remote connectivity, the fleet operations center will monitor the location and status of all vehicles in the fleet.

In developing this vehicle, GM used multiple System Safety analysis tools. In addition to internal GM tools, GM utilized tools and standards from SAE International, the International Organization for Standardization, the Motor Industry Software Reliability Association, RCTA, Inc., and United States Military Standards. The safety performance of the ZEAV is validated through computer modeling, laboratory testing, test road performance, and real-world mileage accumulation. The following pages provide additional information.

A. Vehicle Control System

1. External Sensors and Field of View

The ZEAV is equipped with an extensive array of camera, radar, and LiDAR sensors that provide 360 degrees of overlapping vision around the vehicle. To facilitate normal operation, the vehicle is equipped with short-range LiDARs, long-range LiDARs, short-range cameras, long-range cameras, traffic signal cameras, ultra-short-range radars, and additional radars (including three that articulate), each of which can be configured for long-range scans, mid-range scans, and dual long- and mid-range scans. These sensors are mounted at multiple locations on the exterior of the vehicle, including the front fascia area, the rear fascia area, a dedicated roof module, and outside rearview mirror locations. In addition to these sensors, the vehicle is equipped with two radars and one external-facing, interior-mounted camera dedicated to the Safety Co-Pilot system (described below). Finally, three cameras are mounted inside the occupant compartment. These three interior cameras do not typically operate during rides-in-progress, but are used to monitor door opening/closing protocols at the onset and conclusion of rides, and to assess the condition of the vehicle interior (e.g., items left behind) at the conclusion of rides. Cleaning devices are used to help maintain the operational capability of exterior-mounted sensors.

The LiDARs, cameras, and radars are used for a variety of tasks that support detecting the environment around the vehicle and enable the ADS to create a model of the world around the vehicle. Many tasks use diverse information from multiple sensor types. The ADS's computers perform these tasks using sophisticated processing to obtain a reliable understanding of objects and free space around the vehicle. Here are some examples of their functions:

> *The LiDARs* support localization of the vehicle using ground and height reflections, as well as other reflections. The LiDARs also support locating and identifying static and dynamic objects in space around the vehicle (e.g., bicycles, cars, and pedestrians), detecting ground debris and road conditions, and detecting the headings of moving objects on the road.
>
> *The cameras* aid in classifying objects and tracking them over time. They also support the identification of free space, among other things. They help differentiate various types of motor vehicles, pedestrians, bicycles, and free space. They identify road objects such as construction cones, barriers, and signs; identify objects such as street signs, streetlights, trees, and mailboxes; and read dynamic speed limit signs. They also identify attributes of other people and objects on the road, such as brake signals from cars, reverse lamps, turn signals, hazard lights, and emergency vehicles, and detect traffic light states and weather.
>
> *The radars* aid in a variety of functions, such as detecting the speed and distance of various objects. They are used to detect motor vehicles and bicycles nearby, as well as motor vehicles at long range, and to measure their speed and direction of travel. The articulating radars provide extra flexibility for a variety of situations. For example, during maneuvers such as left turns, articulating radars are directed to oncoming-traffic lanes to aid in the detection of potential objects in the upcoming maneuver space.

The following figures show an example field of view ("FOV") of the ZEAV's external sensor configuration. The multiple sensors with overlapping coverage provide diverse sensor-based environmental information to the ADS. This approach not only provides redundancy but also adds integrity through diversification. Because each type of sensor operates through a different mechanism (optical, radar, and laser measurements), the ZEAV software can check the validity of certain road users in a variety of environmental conditions (e.g., the presence or absence of pedestrians in a crosswalk). With this approach, diverse sensors complement each other to create a robust and fault-tolerant sensing suite that operates in a wide range of environmental and lighting conditions, providing high confidence that the ZEAV detects necessary road conditions and potential hazards.

Figure 1: LiDAR FOV

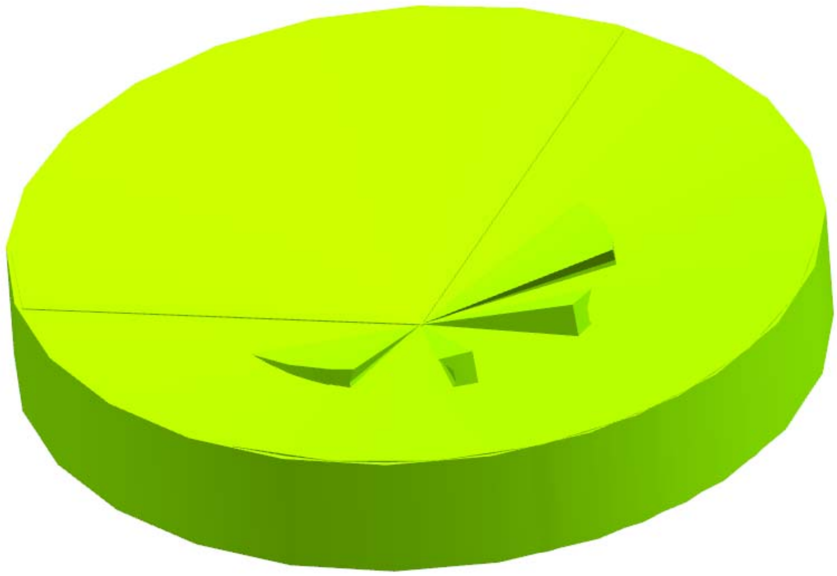


Figure 2: Cameras FOV

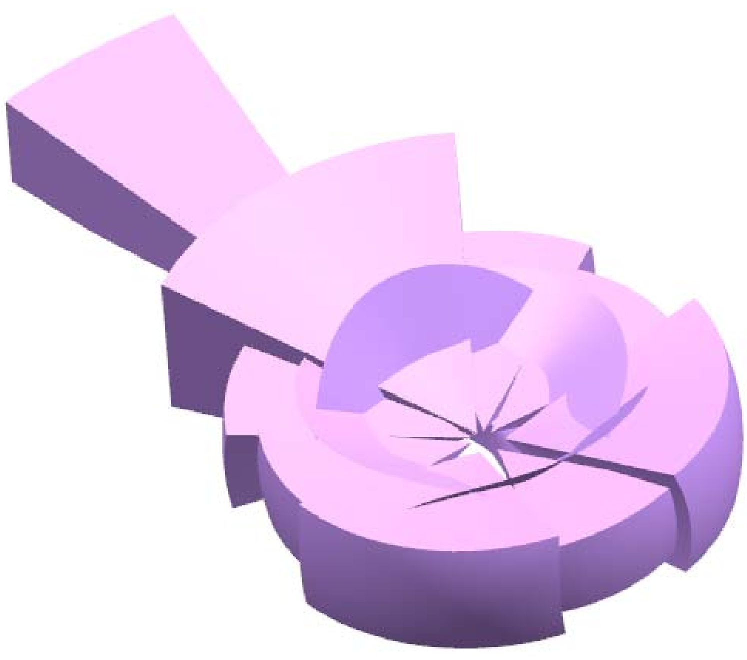
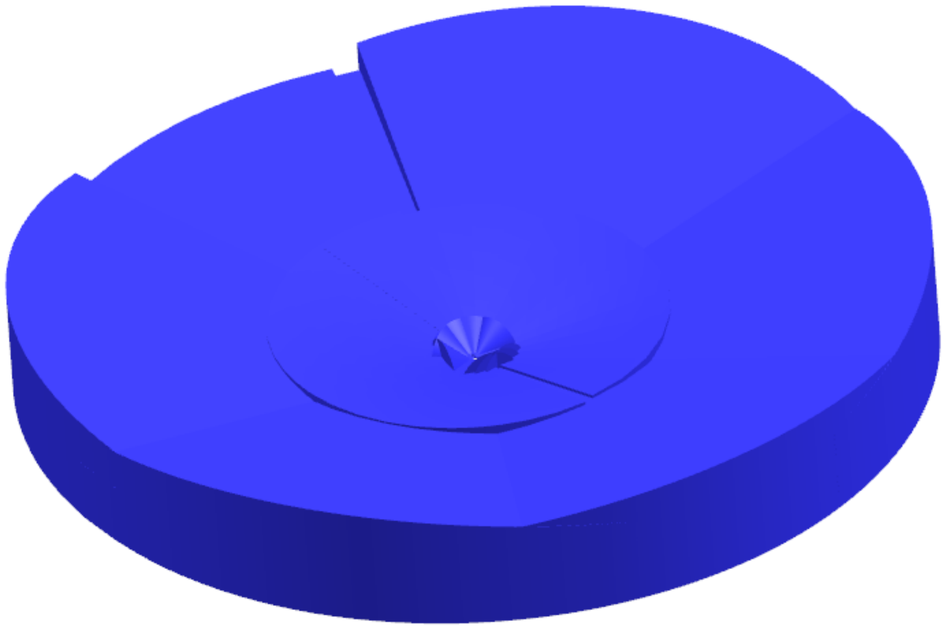


Figure 3: Radar FOV



As these figures illustrate, the cameras, radars, and LiDARs all provide capability for a complete 360-degree field of view to the computer driver. These figures illustrate how the ZEAV's sensors can be configured to provide comprehensive and overlapping fields of view that far exceed the field-of-view criteria specified in FMVSS No. 111 for rearview mirrors and rear-vision cameras.

2. <u>ADS Driver Operations</u>

The ADS performs a variety of operations that provide the necessary control to drive the ZEAV in real-world conditions. Three of these operations are performed by the Perception System, the Planning System, and the Controls System. The Perception System evaluates information about the environment outside the vehicle. The Planning System determines the path of the vehicle. And the Controls System operates the various vehicle control systems, controlling speed and direction so the vehicle follows the desired path.

a. Perception System

The Perception System receives information from the ZEAV's external sensors and is responsible for building a model of the world in three-dimensional space and over periods of time that can be used to plan a safe trajectory for the vehicle. Among other operations, this includes detecting and tracking motion and predicting future motion for relevant nearby objects like people, cyclists, and various motor vehicles. The model includes determining certainties and uncertainties related to the tracked objects and other attributes of the space around the vehicle. These certainties and uncertainties include those related to what can be detected, for example, due to weather conditions and due to occlusions by obstacles like cars in the vehicle's path.

Detecting an object means identifying an inanimate or moving object in space, segmenting it as a distinct object relative to the ground or other objects, and determining how much space it takes up (its size) and where it is located relative to the vehicle. Once the computer knows an object's location in space, it can measure its speed/kinematics and classify the object based on its motion, kinematic measurements, visual characteristics, location, and other considerations.

When the ADS combines the objects' many attributes with environmental and, if relevant, mapping information, it can *predict* what that object may do next. For example, the computers may detect a double parked vehicle on the other side of an intersection. The computers "see" that the vehicle is not moving and has hazard lights on with its doors open, and there is a bike on our right side also intending on going straight. Armed with extensive knowledge on how road users interact, the computers predict that the bicyclist is likely to move in front of our vehicle to go around the double-parked vehicle. So our vehicle will slow down to accommodate this predicted motion. If the computer detects a pedestrian, it similarly calculates potential paths of the person based on the person's current speed and direction and expected behavior. This supports crucial safe driving interactions between the vehicle and people in the vehicle's external environment.

b. Planning System

The Planning System determines the desired vehicle behavior in the world and is itself divided between three lower-level systems: the Route Planning System, the Maneuver Planning System, and the Motion Planning System. The Route Planning System uses GPS waypoints to determine a collection of road segments that optimally satisfy several routing conditions (traffic, road closures, trip length, vehicle capabilities, and all relevant road rules, among others) to create a route for the car to travel from trip origin to destination. Routes are chosen to optimize efficiency and safety and to route the car only on streets within the autonomous vehicle's capabilities (e.g., avoiding highways with speed limits in excess of the vehicle's maximum speed).

The Maneuver Planning System specifies what maneuvers need to be conducted during the trip. Its operations are based on rules of the road; where the vehicle is relative to the map; self-imposed rules based on interpretations of information about traffic controls, road markings, etc.; and predicted actions of other road users. Its primary job is to rationalize the dynamic world with the known mapped world into a set of movement constraints and barriers to ensure that the vehicle is driven in a collision-free, safe, and efficient manner. The Maneuver Planning System passes these constraints to the Motion Planning System to calculate the potential paths of the vehicle.

The Motion Planning System considers the dynamic and static constraints as well as current vehicle speed, trajectory, position, road condition (wet, raining, dry, etc.), and the vehicle's control capability (e.g., brake force available) when calculating vehicle paths. The Motion

Planning System solves for multiple potential paths to control the vehicle over the next several seconds and sends each of them back to the Maneuver Planning System. The Maneuver Planning System analyzes the potential paths and dynamic updates to the model of the three-dimensional space around the vehicle, including tracked objects, their predicted paths, free space, and the certainties and uncertainties. These potential paths are scored against each other, taking into account safety, efficiency, and comfort requirements, to determine what we call the "*final path*." This occurs multiple times per second. This allows the car to respond to unexpected changes on the road or faults that may occur in the hardware or software. For example, while preparing to change lanes to turn right at an intersection, another vehicle may aggressively cut into the destination lane. Planning already has an alternative route planned, such as to go around the city block instead of blocking its lane or making a lane change at the last second to make the turn. In the unlikely event of a sensor, hardware, or software failure, the ADS will adapt its functionality, in some cases entering a "Response State" (discussed below) and in other cases bringing the vehicle to a safe stop.

The *final path* is chosen and given to the Controls System to implement. The contingency plan for the event of a hardware or software failure is also passed on at all times.

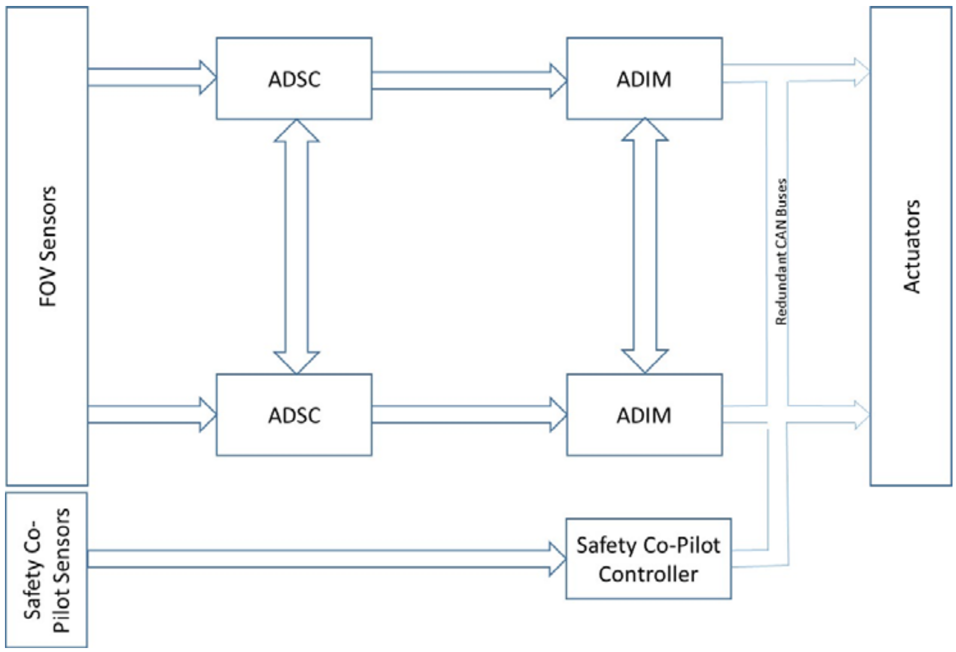
c. Controls System

The Controls System converts the *final path* from the planning system into a series of actuator commands for the steering, throttle, and brake actuators. The Controls System includes two main operations: first, it tracks the vehicle's intended position, represented by the *final path*, against its actual position, and generates a *local plan* to compensate for any position error; second, it processes the *local plan* and transforms it into the vehicle motion actuator commands so the vehicle follows the desired path.

3. ADSC Connectivity, Redundancy, and Fail-Safe

The ADS, along with its various network connections, is depicted in Figure 4. Figure 4 illustrates the connectivity of the external sensors and vehicle systems and sensors with the two Automated Driving System Computers ("ADSC"). The figure also illustrates the redundancy built into the system for fail-operational and fail-safe performance.

Figure 4: ADS Electrical Architecture

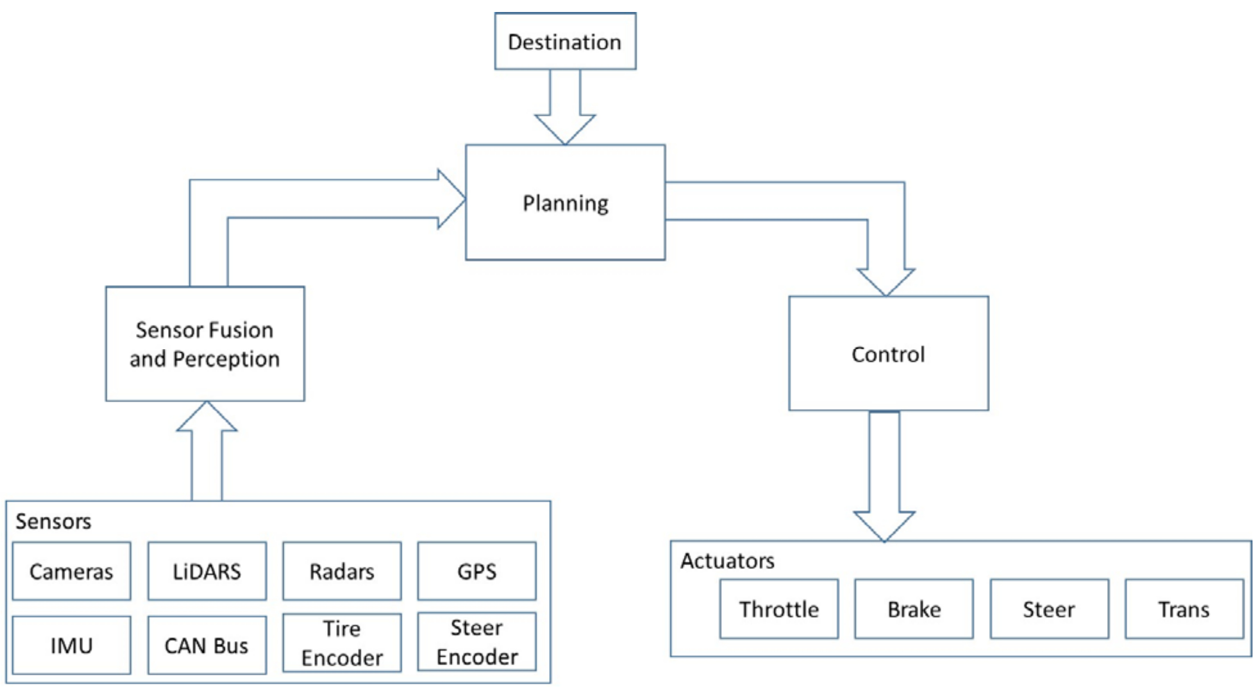


A significant portion of the sensor data is transmitted through Ethernet switches with diagnostic capabilities to the two ADSCs, located in the rear-hatch compartment of the ZEAV. Camera data is transmitted to the ADSCs through low-voltage differential signaling ("LVDS") buses. The two ADSCs are redundant to each other and have independent hardware, software, and 12V power supplies. One serves as the Primary ADSC and the other as the Secondary ADSC. Both ADSCs continuously process the sensor data inputs through their control algorithms to determine the appropriate path for the vehicle. The control information from the Primary ADSC is normally utilized, while the Secondary ADSC is available to assume this role within milliseconds if a fault is detected in the Primary ADSC. Each ADSC is connected via Ethernet connections and switches to another set of redundant computers, the Advanced Driving Integration Modules ("ADIM"). The ADSCs and ADIMs together, along with their network connections, comprise the computer control system for the ADS. Each ADIM independently monitors its associated ADSC for processing integrity. The ADIMs themselves are fail-silent modules (i.e., if they fail, they will not have the ability to send commands to the control modules) and have watchdogs monitoring their integrity.

Each ADSC uses feedback from the vehicle sensors and actuators to continuously communicate commands to its associated ADIM, transmitting path information many times per second. More particularly, each ADSC performs the Perception operations described above, as well as the Planning and the Path Follower portions of the Controls System operations. Each ADIM performs the Low Level Controls operations. The Planning and Controls System operations within the ADSCs and ADIMs are illustrated in Figure 5. With each updated *local plan*, the ADSC provides the longitudinal plan as a temporal discretized (over multiple seconds) set of desired accelerations, velocities, and travel trajectories and the lateral plan (steering angle) as a spatial discretized (over multiple seconds) set of optimal curvatures, headings, and cross track error trajectories. This *local plan* is transmitted to the ADIM to be translated into actuator commands by Low Level Controls.

Each ADIM sends the Low Level Control commands, as vehicle control signals, over the Control Area Network ("CAN") buses. As with the ADSCs, the information conveyed through the CAN buses from the Primary ADIM is utilized, while the information from the Secondary ADIM is utilized if a fault is detected in the Primary ADIM. More particularly, if a diagnostic fault of the primary ADIM is detected, the Primary ADIM will fail silent, and the secondary ADIM commands on the CAN buses will be utilized.

Figure 5: Planning and Control



The vehicle control commands on the CAN buses are read by the applicable vehicle control modules, specifically the Electric Power Steering Module ("EPSM"), the Electronic Brake Control Module ("EBCM"), the Engine Control Module ("ECM"), and the Electronic Shifter Module ("ESM"). The ZEAV is equipped with two redundant and independent control modules and actuators for the steering and braking functions.

The control modules then send commands to their respective hardware actuators to execute the desired vehicle controls. These actuators execute the commands in a similar manner to how they are executed in the base Chevrolet Bolt (non-autonomous) electric vehicle. For example, the braking commands from the EBCM for both the Bolt and the ZEAV activate regenerative braking (by placing the vehicle's electric motor in generator mode) when regenerative braking is available to provide the desired level of vehicle deceleration. A key distinction between the Bolt and the ZEAV is that the control signals for the Bolt are determined by the human driver inputs to conventional vehicle controls, while the control signals for the ZEAV are determined by the ADSCs and ADIMs (i.e., the ADS computer system that drives the vehicle).

In addition to the camera/radar/LiDAR sensor data described above, the ZEAV also monitors vehicle state data—e.g., vehicle speed, wheel speed, heading, yaw rate, selected transmission gear, etc. Also, standard vehicle data, such as data utilized for all relevant telltale functions in the FMVSS, is available to the ADS system through the CAN buses. In some cases, this vehicle data is utilized in a manner similar to use in conventional vehicles. In other cases, the data is used as input to the ADS for driving the vehicle, including taking into account responses to diagnostics such as those described in the Response States discussion below.

The ZEAV is also equipped with a Safety Co-Pilot to add independent collision imminent braking capability. The Safety Co-Pilot utilizes orthogonal software for object sensing from its own independent sensors (one camera and two radars) to intervene if it detects a forward crash-imminent situation. If the Safety Co-Pilot detects an imminent collision, it will direct the braking controller to bring the vehicle to a stop, the propulsion controller to invoke zero torque, and the gear selector to engage "Park" once vehicle speed drops below a low threshold value. In a Safety Co-Pilot event, the ADIMs will control steering commands. In addition, the ZEAV has response capability even if there is a total loss of communication with both ADIMs. In that case, the steering control will latch its last command. Commands from the Safety Co-Pilot always have priority over commands from the ADIMs.

4. Actuators, Actuator Redundancy, and Fail-Safe

Steering System: The steering system is fail-operational, with redundant controllers, actuators, and sensors. Even in the event of the complete loss of a single steering controller or actuator, the vehicle is able to maintain full lateral control and can drive safely. The steering controllers have safe rate limits and command validity checks to verify the integrity of the ADSC commands and maintain safe behavior. Additionally, the steering controllers have default fail-safe behavior when there is complete loss of communication with both of the ADIMs.

Brake System: The brake system is fail-operational, with redundant controllers, actuators, and sensors. Even in the event of the complete loss of a single brake controller or actuator, the vehicle is able to maintain safe lateral and deceleration control. The brake system works with the electric propulsion system to provide blended regenerative braking capability. To verify the integrity of the control commands and maintain safe behavior, the brake controllers have safe rate limits and command validity checks. Additionally, the brake controllers have default fail-safe behavior when there is complete loss of communication with both of the ADIMs.

Electric Propulsion and Shift-by-Wire Systems: The Electric Propulsion and Shift-by-Wire systems are carried-over systems from the production Chevy Bolt vehicle. Both of these systems have command validity checks to verify the integrity of the control commands and to maintain safe behavior.

All of the above safety-critical systems that support automated driving operations have fail-operational power and communication (i.e., independent and redundant mechanisms to continue operation in case of a single-point failure). Additionally, robust diagnostics operations monitor for potential latent failures. All actuator controllers that impact driving behavior are programmed with default fail-safe behaviors to account for the contingency of a complete loss of communication with both ADIMs.

5. Response States

The ADS continuously monitors the state of numerous vehicle systems and conditions, including and exceeding all of the underlying conditions corresponding to the telltales specified in the FMVSS. The ADS is programmed to respond to fault conditions and other anomalies according to a hierarchy appropriate to the specific condition for the ADS to safely operate the vehicle. Figure 6 shows the Response State categories used in the ZEAV.

Figure 6: Response States

Response State 1	Latent malfunction benign to the ADS. Maintain normal vehicle use until the end of the day (or until the next key cycle).
Response State 2	Tolerated malfunction in a safety system that maintains 100 percent vehicle performance for reduced scope of vehicle operation. Complete ride-in-progress implementing a predefined limit on maximum speed and maneuver set for this Response State; then return vehicle to the fleet service facility for repair.
Response State 3	Malfunction in a safety system that results in degraded vehicle performance. Gradually slow the vehicle to a stop while steering to a safe location at the side of the road. Engage "Park." Activate hazard flashers.
Response State 4	Loss of safety system functionality with no imminent collision. Gradually slow the vehicle to a stop while maintaining its steering position (e.g., within its lane of travel). Engage "Park." Activate hazard flashers.
Response State 5	Loss of safety system functionality with potential imminent collision. Aggressively slow the vehicle to a stop in its lane of travel. Engage "Park." Activate hazard flashers.

ZEAVs that enter any Response State will be either inspected by GM fleet management personnel when they return autonomously (Response States 1 and 2) or removed from the field and inspected at fleet management (Response States 3-5). For example, if a malfunction is detected in the service brake system or the ESC system as defined in FMVSS Nos. 135 and 126, respectively, the ADS will take the vehicle to Response State 3, gradually slowing it to a stop while steering to the side of the road. For this situation, a message will be transmitted to the vehicle occupants informing them that a malfunction that prevents completion of the ride has been detected and that alternative transportation will be sent. A service call to GM operators will also be initiated so they can explain the situation to vehicle occupants and respond to questions.

With respect to low tire pressure, the ADS will take the vehicle to either Response State 2 or Response State 3, depending on the degree of under-inflation. This approach implements the safety intent of the FMVSS-specified malfunction telltales, since the ADS takes immediate action appropriate to the severity of the underlying condition and does not depend on a human driver to respond to an illuminated malfunction telltale.

If there is a fault that may affect the ability of an airbag to deploy in the event of a crash, the ADS will take the vehicle to Response State 2, and a message will be provided to the occupants of a ride-in-progress. The message will indicate that a malfunction has been detected that could affect airbag deployment, and that the ride will be completed. Once the ride-in-progress is completed, the vehicle will be directed to the GM service facility for diagnosis and repair of the airbag fault prior to allowing additional customer rides. If occupants are uncomfortable with the airbag malfunction notification, they can talk to a remote support personnel and also have the choice to terminate the ride.

Some telltales prescribed in the FMVSS are status indicators, rather than malfunction indicators. Examples include transmission sequence and selected gear (FMVSS No. 102), turn signal and high-beam telltales (FMVSS No. 108), the ESC-off telltale (FMVSS No. 126), and the parking-brake-applied telltale (FMVSS No. 135). These status indicators themselves do not indicate the existence of a potential safety malfunction. That said, the ADS has full access through the CAN data buses to the information that these indicators would otherwise indicate to a human driver.

For example, the PRNDL display in a conventional vehicle provides to the human driver an indication of transmission state. In GM's ZEAV, the ADS constantly receives feedback of the transmission state through the CAN buses. Its programming takes this information into account. In another example, the ADS receives turn signal lamp function information through the CAN buses. This allows the ADS to maintain operational control of the turn signals (discussed further below) and to detect malfunctions, which are taken into account according to the response hierarchy listed above. In another example, the ADS operates with the ESC on at all times unless there is a detected malfunction, in which case the ESC may be turned off and the vehicle operates in Response State 3.

6. Additional Information About Controls and Displays (FMVSS No. 101)

The Tables 1 and 2 at the end of this Appendix II provide a brief description for each relevant control, telltale, and indicator in FMVSS No. 101 Tables 1 and 2. The description indicates how information with respect to each control or telltale/indicator is communicated to the ADS and, where appropriate, the Response State (Figure 6) that the ADS utilizes if a signal indicates a diagnostic that impacts driving operation.

7. Additional Information About Turn Signal Performance (FMVSS No. 108)

In FMVSS No. 108, S9.1.1 requires turn signal self-cancellation. The turn signal data in the table at the end of this Appendix II is taken from real-world turn signal operation in test vehicles on public roads. The test vehicles from which this data is taken have standard human control inputs allowing the human test drivers to take over control of the vehicle from the ADS, when necessary. The data in this table is from example right and left turns operated by the ADS without intervention by the human driver. In the turn signal data table, the lead distance is the distance from entry to the intersection, and the lead time is the time prior to reaching the intersection entry point at which the turn signal is activated. The trail distance is the distance from exiting the intersection, and the trail time is the time relative to reaching the intersection exit point at which the turn signal is cancelled. As the data shows, the ADS consistently operates the turn signals in anticipation of turns and cancels the turn signals upon exit from the turn intersection.

8. Example Transmission State Control (FMVSS No. 114)

The ZEAV provides the ADS with all the information necessary to understand the state of the transmission and operate the transmission gear shift controls. For example, using information available on the CAN buses, the ADIM will not shift the transmission out of "Park" unless all of the following conditions are met: The service brake is applied; all vehicle doors are closed; all occupants are buckled or they have dismissed the seat belt warnings using buttons on the in-vehicle tablets; an occupant has activated the "Start Ride" button or, if the vehicle is unoccupied, the fleet office has signaled a new destination to the vehicle; the ADSC has calculated a vehicle path; and the vehicle health manager has determined that there is no vehicle fault that would place the vehicle in a Response State 3, 4, or 5.

9. Operational Design Domain Limits

It is possible that the ZEAV will reach the limits of its operational design domain during a given ride. For example, the ZEAV may reach an unexpected construction zone with barriers or a cone configuration that it does not recognize. In these situations, the vehicle is programmed to stop and initiate a data communication with a specially trained operator who receives data, including external video, of the current situation. Using the data and predefined guidelines set by GM, the specially trained operator provides a domain extension to the vehicle to help define safe operating boundaries (e.g., permission to use the opposing traffic lane where cones are demarcating a new path of travel). The trained operator does not have control of the vehicle's object detection algorithms and cannot modify the object-avoidance functionality built into the ADS. Using the domain extension and the safety functionality built into the ADS, as well as the Perception, Planning, and Controls Systems, the ADS is able to continue operating.

10. <u>Data Recording</u>

Along with the traditional event data recorder described in FMVSR No. 563, the ZEAV also records terabytes of vehicle-specific data for subsequent download and analysis. This wealth of data provides the basis for refining autonomous vehicle control algorithms to enable future development and for diagnosing field incidents that may occur.

11. <u>Operational Performance Checks</u>

In operation, each vehicle will have operational checks pre-ride, during rides, and post-ride to verify the operational performance of vehicle safety systems. Diagnostic data will be sent to GM's operations center during vehicle operation. In addition to operational performance checks, the operations center monitors for potential hazardous weather and out-of-service roads. These activities allow GM to respond to operational issues and other potential issues appropriately and in a timely manner.

B. FMVSS Nos. 126 and 135 Testing Procedures

To test the performance of the ZEAV's ESC system, GM will use test ZEAVs that differ from the design subject to this Petition by including standard human driver controls, including steering, accelerator, and brake controls. GM will perform the testing required under FMVSS Nos. 126 and 135 utilizing these test vehicles with the driver's seat and controls. Because the ZEAV is equipped with brake and ESC hardware and software that are otherwise comparable to that in these test vehicles in all respects relevant to the performance requirements of FMVSS Nos. 126 and 135, GM intends to certify the performance requirements of these Standards based on these tests.

C. Validating an Integrated Vehicle

GM engineered the ADS and integrated it into the ZEAV prior to validation and certification to FMVSS. GM's relevant validation and testing to certification Standards utilizes the ZEAV as engineered with the ADS computer, sensor, controller, and actuator systems. For example, when GM conducts brake performance tests, those tests take into account content such as the autonomous vehicle actuators, controllers, and power supply components, all of which affect the vehicle weight and could impact vehicle braking performance. In addition, the ADS components are located in various parts of the vehicle, including the roof-mounted sensors, the exterior sensors, the rear-mounted computer system, and the added electrical components associated with the rear-mounted computer system and other electrical systems throughout the vehicle. These components become parts of the vehicle that could be impacted in a collision, and they are considered when measuring occupant protection. GM's crash testing and occupant protection validation utilizes ZEAVs with all of these integrated systems. With this approach, GM has developed its ZEAV as an autonomous vehicle certified to relevant Standards, not as a certified vehicle with ADS components added after certification.

D. Human-Machine Interface

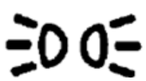
The ZEAV will provide on-demand transportation services in geo-fenced areas to customers who download a mobile application (app) and acknowledge a user agreement. When an authorized customer requests service, the vehicle will dispatch to the customer's location for pickup, transport the customer to her desired destination, and then depart for the next customer call for service.

The primary in-vehicle interface to riders is provided via three touch-screen tablets, one mounted in the front-center area of the instrument panel (for front seat occupants) and two mounted at the rear of the front seat headrests (for rear seat occupants). These touch-screen tablets enable riders to control the HVAC and radio, access general (static) information, and receive real-time status information pertinent to the current ride.

The ZEAV's user interfaces have been designed to make passengers feel comfortable. For example, passengers will be able to communicate in real time with remote support personnel. With the press of a button, passengers can ask any questions they may have. Support personnel may also initiate contact with vehicle occupants in certain circumstances, including if a vehicle crash is detected or if door opening/closing protocols are violated. Passengers may also be contacted if they leave an item in the vehicle at the conclusion of a ride. Through the tablets or through a hard button, passengers may choose to end the ride. While instructions will indicate that the hard button is for emergencies, passengers may use either the tablet or the hard button to end the ride at any time, for any reason.

APPENDIX II: Supplemental Technical Information

FMVSS Table 1

Item	Symbol	Words or Abbreviations	Function	Illumination	Color	Specifics of AV Function	AV Response to Underlying Condition
High beam		-	Telltale	-	-	Not applicable (N/A). ADS will not activate high-beam headlamps.	N/A
Turn signals		-	Control	-	-	When the path planning requires a turn or a lane change, each ADSC sends a command through the Ethernet bus and switches to its respective ADIM to activate the turn signal. Each ADIM then sends commands over the redundant CAN buses to the Body Control Module (BCM) to activate the relevant turn signal. The ADS repeats the process to cancel the turn signal when the Path Follower indicates that the turn or lane change is completed.	N/A
			Telltale	-	Green	The BCM monitors the turn signal circuit to identify when a turn signal outage is detected. When an outage is detected, the BCM sends a signal over the redundant CAN buses to the ADIMs to take action (see next column).	If an exterior turn signal lamp fails, the ADS takes the vehicle to Response State 2.
Hazard warning signal		**Hazard**	Control	Yes	-	The ADIM sends signals over the redundant CAN buses to the BCM to activate the hazard flasher signals, for example, when the ADIM takes the vehicle to Response State 3, 4, or 5.	N/A
		-	Telltale	-	-		
Position, side marker…		**Marker Lamps or MK Lps**	Control	Yes	-	N/A. ADS will not activate the position lamps independent of the low-beam headlamps.	N/A
Windshield wiping system		**Wiper or Wipe**	Control	Yes	-	When the rain sensor detects rain, it sends signals over the redundant CAN buses to the ADIMs, which then send commands over the	N/A

APPENDIX II: Supplemental Technical Information

FMVSS Table 1

Item	Symbol	Words or Abbreviations	Function	Illumination	Color	Specifics of AV Function	AV Response to Underlying Condition
						redundant CAN buses to the BCM to activate the wipers in low speed.	
Windshield washing system		**Washer or Wash**	Control	Yes	-	N/A	N/A
Wiper system combined		**Washer-Wiper or Wash-Wipe**	Control	Yes	-	N/A	N/A
Windshield defrosting and defogging system		**Defrost, Defog, or Def.**	Control	Yes	-	The ZEAV is equipped with a rider-operated defrost control via the computer tablets used to interface with the vehicle.	N/A
Rear window defrosting and defogging system		**Rear Defrost, Rear Defog, Rear Def., or R-Def.**	Control	Yes	-	N/A	N/A
Brake system malfunction	-	**Brake**	Telltale	-	Red	The Electronic Brake Control Module (EBCM) self-diagnoses its state of health and communicates the presence of a malfunction to the ADIMs via the redundant CAN buses.	When a service brake system malfunction is detected, the ADS takes the vehicle to Response State 3.
Antilock brake system malfunction …FMVSS 105 or 135	-	**Antilock, Anti-lock, or ABS**	Telltale	-	Yellow	The EBCM self-diagnoses its state of health and communicates the presence of a malfunction to the ADIMs via the redundant CAN buses.	When an ABS system malfunction is detected, the ADS takes the vehicle to Response State 3.
Malfunction in variable brake proportioning	-	**Brake Proportioning**	Telltale	-	Yellow	The EBCM self-diagnoses its state of health and communicates the presence of a malfunction to the ADIMs via the redundant CAN buses.	When an electronic brake proportioning malfunction is detected, the ADS takes the vehicle to Response State 3.

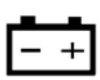
APPENDIX II: Supplemental Technical Information

FMVSS Table 1

Item	Symbol	Words or Abbreviations	Function	Illumination	Color	Specifics of AV Function	AV Response to Underlying Condition
Regenerative brake system malfunction	-	**RBS or ABS RBS**	Telltale	-	Yellow	The Engine Control Module (ECM) self-diagnoses its state of health and communicates the presence of a malfunction to the ADIMs via the redundant CAN buses.	When an RBS system malfunction is detected, the ADS takes the vehicle to Response State 2.
Malfunction in antilock system… FMVSS 121	-	**Antilock, Anti-lock, or ABS**	Telltale	-	Yellow	N/A	N/A
Antilock brake system trailer fault…FMVSS 121		**Trailer ABS or Trailer Antilock**	Telltale	-	Yellow	N/A	N/A
Brake Pressure… FMVSS 105 or 135	-	**Brake Pressure**	Telltale	-	Red	The EBCM self-diagnoses its state of health and communicates the presence of a malfunction to the ADIMs via the redundant CAN buses.	When a low service brake pressure is detected, the ADS takes the vehicle to Response State 3.
Low brake fluid condition …FMVSS 105 or 135	-	**Brake Fluid**	Telltale	-	Red	The EBCM self-diagnoses its state of health and communicates the presence of a malfunction to the ADIMs via the redundant CAN buses.	When low brake fluid is detected, the ADS takes the vehicle to Response State 3.
Parking brake applied…. FMVSS 105 or 135	-	**Park or Parking Brake**	Telltale	-	Red	The Electronic Park Brake Module provides feedback to the ADIMs when the parking brake has been set via the redundant CAN buses.	N/A
Brake lining wear-out… FMVSS 135	-	**Brake Wear**	Telltale	-	Red	In-vehicle diagnostics estimate brake wear.	When the diagnostics system estimates significant brake lining wear, the ADS takes the vehicle to Response State 3.
Electronic Stability Control		**ESC**	Telltale	-	Yellow	The EBCM self-diagnoses its state of health and communicates the presence of a	When ESC malfunction is detected, the ADS takes the vehicle to Response State 3.

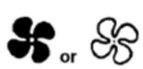
APPENDIX II: Supplemental Technical Information

FMVSS Table 1

Item	Symbol	Words or Abbreviations	Function	Illumination	Color	Specifics of AV Function	AV Response to Underlying Condition
system malfunction (manufacturer may use this telltale in flashing mode to indicate ESC operation; see FMVSS 126)						malfunction to the ADIMs via the redundant CAN buses.	
Electronic Stability Control System "OFF"		**ESC OFF**	Control	Yes	-	N/A	N/A
			Telltale	-	Yellow	N/A. ADS will not disable ESC, except due to a malfunction.	N/A
Fuel level		**Fuel**	Telltale	-	-	N/A	N/A
			Indicator	Yes	-	ADIMs monitor propulsion battery state of charge based on data provided through the redundant CAN buses and determine effective operating range. If low range is determined during a ride-in-progress, that ride is completed and no further rides are accepted. The vehicle returns to service facility for charging.	When low range is determined, the ADS takes the vehicle to Response State 2.
Engine oil pressure		**Oil**	Telltale	-	-	N/A	N/A
			Indicator	Yes	-	N/A	N/A
Engine coolant temperature		**Temp**	Telltale	-	-	N/A	N/A
			Indicator	Yes	-	N/A	N/A
Electrical charge		**Volts, Charge, or Amp**	Telltale	-	-	The BCM monitors the health of the 12V battery system and communicates any malfunction to the ADIMs via the redundant CAN buses. The Vehicle Integration Control	When the 12V electrical state of charge is low, the ADS takes the vehicle to Response State 2. When the electrical state of charge of the high-voltage propulsion system is low,
			Indicator	Yes	-		

APPENDIX II: Supplemental Technical Information

FMVSS Table 1

Item	Symbol	Words or Abbreviations	Function	Illumination	Color	Specifics of AV Function	AV Response to Underlying Condition
						Module monitors the health of the high-voltage propulsion system and communicates any malfunction to the ADIMs via the redundant CAN buses.	the ADS takes the vehicle to Response State 3.
Engine stop	-	**Engine Stop**	Control	Yes	-	N/A	N/A
Automotive vehicle speed (cruise control)	-	**-**	Control	Yes	-	N/A. The vehicle is not equipped with a traditional cruise control system. The ADS controls vehicle speed as described elsewhere in this Appendix II.	N/A
Speedometer	-	**MPH or MPH and km/h**	Indicator	Yes	-	N/A	N/A
Heating and air conditioning system	-	**-**	Control	Yes	-	Vehicle occupants have control of the HVAC system via the built-in computer tablets used to interface with the vehicle.	N/A
Automatic transmission control position (park) (reverse) (neutral) (drive)	-	**P R N D**	Indicator	Yes	-	The ETRS Module provides the selected transmission position to the ADIMs via the redundant CAN buses. The ADIMs provide this information to the ADSCs via the Ethernet network connections and switches.	N/A
Heating and/or air conditioning fan		**Fan**	Control	Yes	-	Vehicle occupants have control of the HVAC fan via the built-in computer tablets that the occupants use to interface with the vehicle.	N/A
Low tire pressure (including malfunction) (see FMVSS 138)		**Low Tire**	Telltale	-	Yellow	N/A	N/A

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FMVSS Table 1

Item	Symbol	Words or Abbreviations	Function	Illumination	Color	Specifics of AV Function	AV Response to Underlying Condition
Low tire pressure (including malfunction that identifies involved tire) (see FMVSS 138)		**Low Tire**	Telltale	-	Yellow	The Tire Pressure Monitoring System (TPMS) monitors the pressure of each of the tires and communicates low pressure to the ADIMs via the redundant CAN buses.	When a low tire pressure is sensed, the ADS takes the vehicle to Response State 2, or may take the vehicle to Response State 3 based on the degree of under-inflation.
Tire Pressure Monitoring System malfunction (see FMVSS 138)	-	**TPMS**	Telltale	-	Yellow	The TPMS self-monitors the health of the system and communicates a malfunction of the TPMS to the ADIMs via the redundant CAN buses.	When there is a TPMS malfunction, the ADS takes the vehicle to Response State 2.

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FMVSS Table 2 – Identifiers for Controls, Telltales and Indicators with No Color or Illumination Requirements

Item	Symbol	Words or Abbreviations	Specifics of AV Function	AV Response to Underlying Condition
Hand throttle control	-	**Throttle**	N/A	N/A
Engine start control	-	**Engine Start**	N/A	N/A
Manual choke control	-	-	N/A	N/A
Odometer	-	**Kilometers or km, if kilometers are shown. Otherwise, no identifier is required.**	N/A	N/A
Horn		**Horn**	The ADS has the ability to activate the horn by providing commands through the CAN buses.	N/A
Master lighting switch		**Lights**	N/A. Output from an ambient light sensor is communicated to the BCM via the redundant CAN buses; the BCM toggles between DRL and low-beam headlamps based on the ambient light conditions. As required by FMVSS 108, when the low beams are activated, the parking lamps, side markers, and tail lamps are also activated by BCM commands sent through the CAN buses.	N/A
Headlamps and tail lamps control	-	-	N/A	N/A
Low brake air pressure telltale… FMVSS 121	-	**Brake Air**	N/A	N/A
Seat belt unfastened telltale	 or 	**Fasten Belts or Fasten Seat Belts**	The status of the seat belt buckle at each designated seating position is monitored by the Sensing and Diagnostic Module. If an occupied seating position has an unbuckled belt, an audible and visual warning is provided to occupants via the tablets.	N/A

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Turn Signal Data Table

vin	time	turn direction	blinker	blinker on lead time seconds	blinker on lead distance feet	blinker off trail time seconds	blinker off trail distance feet	intersection
1G1FX6S05H40134EX	6/16/2017 9:30	left	left	14.80175638	101.241739	-0.05899668	0	NB DeHaro -> Mariposa
1G1FX6S06H40137EX	6/17/2017 8:13	left	left	10.66138291	100.7320489	-0.17391014	-3.70343663	NB DeHaro -> Mariposa
1G1FX6S06H40137EX	6/18/2017 21:26	left	left	10.77000403	100.9945178	0.017296076	0	NB DeHaro -> Mariposa
1G1FX6S05H40047EX	6/20/2017 12:22	left	left	10.69935822	99.06388587	-0.07369637	-2.02212754	NB DeHaro -> Mariposa
1G1FX6S05H40047EX	6/23/2017 12:32	left	left	51.9863205	105.3379893	0.071332455	2.008907361	NB DeHaro -> Mariposa
1G1FX6S09H40077EX	6/23/2017 15:29	left	left	14.08828545	98.17403206	-0.12031054	-1.19519579	NB DeHaro -> Mariposa
1G1FX6S00H40130EX	6/23/2017 19:07	left	left	12.60101557	99.81021218	0.024456739	0	NB DeHaro -> Mariposa
1G1FX6S05H40047EX	6/26/2017 12:16	left	left	10.51513934	96.31496423	-0.06851268	0	NB DeHaro -> Mariposa
1G1FX6S05H40047EX	6/26/2017 18:11	left	left	10.98054433	98.4360487	-0.00752902	0	NB DeHaro -> Mariposa
1G1FX6S04H40131EX	6/26/2017 21:19	left	left	10.20390558	98.5059641	-0.0246489	0	NB DeHaro -> Mariposa
1G1FX6S01H40075EX	6/27/2017 16:34	left	left	12.27106261	99.61696495	-0.01583385	0	NB DeHaro -> Mariposa
1G1FX6S01H40075EX	6/28/2017 17:00	left	left	10.6032896	96.5562936	-0.14473462	-3.95622131	NB DeHaro -> Mariposa
1G1FX6S04H40131EX	6/28/2017 20:42	left	left	24.07146263	102.3293094	-0.20483971	-4.41007157	NB DeHaro -> Mariposa
1G1FX6S02H40061EX	6/29/2017 18:25	left	left	11.53686643	97.57063452	-0.00105286	0	NB DeHaro -> Mariposa
1G1FX6S0XH40167EX	7/1/2017 12:45	left	left	10.80081892	99.86076399	-0.09371662	-2.22746561	NB DeHaro -> Mariposa
1G1FX6S00H40101EX	7/5/2017 17:51	left	left	11.64849281	100.4931784	-0.04130816	-1.48915321	NB DeHaro -> Mariposa
1G1FX6S00H40130EX	7/5/2017 23:05	left	left	15.42220545	100.4135361	0.110592604	0	NB DeHaro -> Mariposa
1G1FX6S00H40101EX	7/6/2017 11:24	left	left	10.55049109	97.12827027	0.014733315	0	NB DeHaro -> Mariposa
1G1FX6S09H40054EX	7/7/2017 12:24	left	left	13.60446167	100.5614562	-0.10353494	-1.66690483	NB DeHaro -> Mariposa
1G1FX6S04H40131EX	7/12/2017 15:35	left	left	10.23132181	99.29747585	-0.24584341	-4.26597836	NB DeHaro -> Mariposa
1G1FX6S09H40054EX	7/14/2017 12:27	left	left	19.71697593	98.05954913	-0.15423679	-1.83570385	NB DeHaro -> Mariposa
1G1FX6S06H40137EX	7/14/2017 14:59	left	left	10.07165384	99.1839176	-0.13850451	-3.64569067	NB DeHaro -> Mariposa
1G1FX6S00H40130EX	7/19/2017 17:46	left	left	9.936871052	97.71168122	0.013584614	0	NB DeHaro -> Mariposa
1G1FX6S09H40129EX	7/20/2017 10:57	left	left	10.3875885	101.9440924	-0.14527225	-1.78020208	NB DeHaro -> Mariposa
1G1FX6S05H40134EX	7/21/2017 8:54	left	left	10.50672436	99.02894841	-0.12169504	-4.11400461	NB DeHaro -> Mariposa
1G1FX6S09H40129EX	7/21/2017 11:20	left	left	9.870079994	100.4664928	0.083909512	2.089977107	NB DeHaro -> Mariposa
1G1FX6S01H40075EX	7/21/2017 11:22	left	left	11.33155847	96.06623708	-0.00589323	0	NB DeHaro -> Mariposa
1G1FX6S01H40075EX	7/21/2017 14:53	left	left	24.37003636	98.58517418	-0.06295943	0	NB DeHaro -> Mariposa
1G1FX6S06H40137EX	7/21/2017 18:04	left	left	12.8123014	99.27121656	-0.07058549	0	NB DeHaro -> Mariposa
1G1FX6S09H40077EX	7/21/2017 19:10	left	left	10.46516919	98.76685637	-0.04171848	0	NB DeHaro -> Mariposa

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Turn Signal Data Table

vin	time	turn direction	blinker	blinker on lead time seconds	blinker on lead distance feet	blinker off trail time seconds	blinker off trail distance feet	intersection
1G1FX6S06H40137EX	7/21/2017 20:35	left	left	10.8550663	99.7774613	0.115334511	2.211212824	NB DeHaro -> Mariposa
1G1FX6S09H40129EX	7/21/2017 23:25	left	left	9.833071709	98.52483775	-0.08316088	-1.75211685	NB DeHaro -> Mariposa
1G1FX6S05H40047EX	7/22/2017 9:34	left	left	10.61743832	98.8262738	0.115617752	1.681477425	NB DeHaro -> Mariposa
1G1FX6S01H40075EX	7/22/2017 17:40	left	left	10.74174976	99.93841289	-0.01200604	0	NB DeHaro -> Mariposa
1G1FX6S05H40047EX	7/22/2017 17:40	left	left	10.62534952	101.1798693	-0.05128312	0	NB DeHaro -> Mariposa
1G1FX6S06H40137EX	7/22/2017 21:26	left	left	10.40055609	101.62519	-0.05561447	0	NB DeHaro -> Mariposa
1G1FX6S06H40137EX	7/23/2017 6:58	left	left	10.35566187	101.3979295	-0.13384271	-2.197291	NB DeHaro -> Mariposa
1G1FX6S06H40137EX	7/23/2017 11:46	left	left	11.82947063	96.59576504	-0.10983324	-2.02973412	NB DeHaro -> Mariposa
1G1FX6S05H40047EX	7/23/2017 13:05	left	left	13.13393307	99.58990583	0.04070735	1.758951086	NB DeHaro -> Mariposa
1G1FX6S05H40047EX	7/23/2017 14:43	left	left	10.51344037	101.0575684	-0.07523441	0	NB DeHaro -> Mariposa
1G1FX6S00H40066EX	7/24/2017 18:23	left	left	11.59624124	99.06754159	-0.13401747	-2.21112249	NB DeHaro -> Mariposa
1G1FX6S02H40136EX	7/25/2017 23:06	left	left	10.20288467	99.1533894	-0.03976488	-2.2209043	NB DeHaro -> Mariposa
1G1FX6S00H40066EX	7/25/2017 23:21	left	left	10.22511649	95.50417397	-0.09402514	-2.22690904	NB DeHaro -> Mariposa
1G1FX6S03H40145EX	7/25/2017 23:27	left	left	9.991158009	96.47155547	-0.10414314	-2.2693683	NB DeHaro -> Mariposa
1G1FX6S01H40075EX	7/26/2017 18:06	left	left	10.25316	95.63089815	0.105382681	0	NB DeHaro -> Mariposa
1G1FX6S02H40136EX	7/26/2017 21:49	left	left	10.3160851	99.08183556	-0.10142064	-1.83576275	NB DeHaro -> Mariposa
1G1FX6S09H40054EX	7/26/2017 22:54	left	left	11.67694902	100.1490419	-0.15106249	-2.18575889	NB DeHaro -> Mariposa
1G1FX6S06H40137EX	7/28/2017 7:55	left	left	10.41516066	99.70949152	-0.1082201	-2.19408203	NB DeHaro -> Mariposa
1G1FX6S02H40136EX	7/28/2017 15:35	left	left	10.87403822	98.36410534	-0.14761686	-1.84796572	NB DeHaro -> Mariposa
1G1FX6S06H40137EX	7/29/2017 12:17	left	left	10.5466671	98.62103079	0.015791178	2.190681781	NB DeHaro -> Mariposa
1G1FX6S06H40137EX	8/1/2017 15:04	left	left	11.32875919	100.8386479	-0.09162545	-2.22518876	NB DeHaro -> Mariposa
1G1FX6S06H40056EX	8/1/2017 18:15	left	left	10.59219193	98.37276034	-0.09879756	-1.85000273	NB DeHaro -> Mariposa
1G1FX6S06H40137EX	8/1/2017 20:19	left	left	10.29112339	98.72860649	-0.12905407	-1.81732639	NB DeHaro -> Mariposa
1G1FX6S06H40056EX	8/2/2017 15:03	left	left	10.91123366	102.3606462	0.103040695	2.209161881	NB DeHaro -> Mariposa
1G1FX6S01H40075EX	8/2/2017 16:45	left	left	11.77220035	101.6415614	-0.17237806	-4.04020469	NB DeHaro -> Mariposa
1G1FX6S06H40056EX	8/2/2017 18:08	left	left	13.5095787	102.1773046	0.063839674	1.853288624	NB DeHaro -> Mariposa
1G1FX6S06H40137EX	8/3/2017 2:45	left	left	10.52893257	101.8419826	0.082564831	2.210004102	NB DeHaro -> Mariposa
1G1FX6S06H40137EX	8/3/2017 4:58	left	left	10.54868746	102.6587552	0.082067013	2.178069905	NB DeHaro -> Mariposa
1G1FX6S06H40062EX	8/3/2017 10:28	left	left	13.15427709	103.9299252	-0.27651215	-6.10890311	NB DeHaro -> Mariposa
1G1FX6S05H40047EX	8/3/2017 21:12	left	left	10.80419326	103.1017518	-0.30241799	-6.5662264	NB DeHaro -> Mariposa

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Turn Signal Data Table

vin	time	turn direction	blinker	blinker on lead time seconds	blinker on lead distance feet	blinker off trail time seconds	blinker off trail distance feet	intersection
1G1FX6S03H40064EX	8/5/2017 16:28	left	left	11.28262854	105.890762	-0.15942121	-4.09622368	NB DeHaro -> Mariposa
1G1FX6S03H40064EX	8/5/2017 21:16	left	left	10.90630245	103.3417155	-0.21029544	-2.20622963	NB DeHaro -> Mariposa
1G1FX6S05H40047EX	8/6/2017 18:29	left	left	10.8528738	104.7504144	-0.29595661	-4.06730783	NB DeHaro -> Mariposa
1G1FX6S06H40056EX	8/6/2017 21:20	left	left	11.19603133	104.2379461	-0.30829477	-6.34540305	NB DeHaro -> Mariposa
1G1FX6S03H40064EX	8/6/2017 21:22	left	left	11.07630277	105.0082569	-0.3707273	-5.86713019	NB DeHaro -> Mariposa
1G1FX6S05H40047EX	8/8/2017 18:23	left	left	10.7240541	105.172087	-0.24171185	-3.71858083	NB DeHaro -> Mariposa
1G1FX6S00H40066EX	8/10/2017 11:11	left	left	13.09378338	103.1518715	-0.15035105	-2.19158172	NB DeHaro -> Mariposa
1G1FX6S01H40075EX	6/28/2017 11:06	left	left	31.10466218	99.57819975	-0.30522633	-1.81281512	WB Hayes -> Gough
1G1FX6S03H40145EX	7/31/2017 23:36	left	left	4.93867898	97.95429823	-0.01118588	0	WB Hayes -> Gough
KL1FB6S0XGBIV0032	8/1/2017 1:56	left	left	3.850395918	97.02456764	-0.2046926	-3.83852559	WB Hayes -> Gough
1G1FX6S03H40145EX	8/1/2017 19:09	left	left	11.22707033	99.84595512	-0.23201776	-4.26791731	WB Hayes -> Gough
1G1FX6S03H40145EX	8/1/2017 19:09	left	left	11.42717195	101.5632781	-0.33211184	-6.5176247	WB Hayes -> Gough
1G1FX6S09H40054EX	8/3/2017 20:47	left	left	29.83602095	100.9540191	-0.36218023	-5.55222304	WB Hayes -> Gough
1G1FX6S03H40064EX	8/4/2017 17:11	left	left	29.05005765	106.3759628	-0.19879913	-3.8999135	WB Hayes -> Gough
1G1FX6S02H40136EX	8/7/2017 10:38	left	left	21.06055498	103.7990508	-0.19711685	-3.78514509	WB Hayes -> Gough
1G1FX6S09H40129EX	8/7/2017 10:32	left	left	5.866328478	106.0122162	-0.23214459	-4.34480079	WB Hayes -> Gough
1G1FX6S05H40047EX	8/9/2017 1:20	left	left	4.242732763	102.1881904	-0.33286262	-5.84242344	WB Hayes -> Gough
1G1FX6S01H40133EX	8/5/2017 13:57	right	right	41.36974287	106.1022363	-0.41203952	-6.66964465	WB 15th -> Potrero
1G1FX6S05H40047EX	8/5/2017 12:12	right	right	14.69130445	103.1794858	-0.2056756	-3.50606357	WB 15th -> Potrero
1G1FX6S03H40064EX	8/5/2017 14:48	right	right	11.17247343	101.8023949	-0.21829033	-3.34238166	WB 15th -> Potrero
1G1FX6S05H40047EX	8/5/2017 14:49	right	right	37.58400846	106.8808695	-0.20454192	-3.51060871	WB 15th -> Potrero
1G1FX6S03H40064EX	8/5/2017 16:44	right	right	40.30275869	101.5224485	-0.3595736	-6.64240103	WB 15th -> Potrero
1G1FX6S06H40056EX	8/5/2017 23:21	right	right	52.88964987	102.9573879	-0.30674648	-5.35939135	WB 15th -> Potrero
1G1FX6S03H40064EX	8/6/2017 6:48	right	right	5.598608494	105.8742225	-0.28983283	-5.0429117	WB 15th -> Potrero
1G1FX6S06H40056EX	8/6/2017 7:01	right	right	53.39396572	103.9973519	-0.37419486	-5.35765073	WB 15th -> Potrero
1G1FX6S05H40047EX	8/6/2017 7:20	right	right	41.69248843	106.5854496	-0.32903099	-3.80797683	WB 15th -> Potrero
1G1FX6S05H40047EX	8/6/2017 10:12	right	right	34.45599985	105.255774	-0.2533834	-3.2034202	WB 15th -> Potrero
1G1FX6S01H40075EX	8/6/2017 14:18	right	right	6.368715286	103.3616425	-0.37031627	-5.77719233	WB 15th -> Potrero
1G1FX6S05H40047EX	8/6/2017 14:44	right	right	8.090026855	103.7384426	-0.27116179	-5.49946759	WB 15th -> Potrero
1G1FX6S06H40056EX	8/6/2017 14:51	right	right	47.82409239	102.5837159	-0.13278198	-3.45648105	WB 15th -> Potrero

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vin	time	turn direction	blinker	blinker on lead time seconds	blinker on lead distance feet	blinker off trail time seconds	blinker off trail distance feet	intersection
1G1FX6S03H40064EX	8/6/2017 15:04	right	right	31.04058266	104.826136	-0.27633548	-3.38887136	WB 15th -> Potrero
1G1FX6S05H40047EX	8/6/2017 16:49	right	right	49.55390573	103.2131146	-0.3349781	-5.84812558	WB 15th -> Potrero
1G1FX6S06H40056EX	8/6/2017 20:13	right	right	56.30867052	106.3880613	-0.25799632	-5.66805234	WB 15th -> Potrero
1G1FX6S05H40047EX	8/6/2017 20:16	right	right	33.78151131	105.1294926	-0.21818471	-3.91080926	WB 15th -> Potrero
1G1FX6S06H40056EX	8/6/2017 23:28	right	right	35.21156549	99.58122241	-0.29691458	-3.96584778	WB 15th -> Potrero
1G1FX6S06H40062EX	8/7/2017 8:56	right	right	45.09824347	102.6592406	-0.15203786	-1.9252461	WB 15th -> Potrero
1G1FX6S00H40130EX	8/7/2017 9:40	right	right	24.24821186	105.2088235	-0.38640332	-5.74041874	WB 15th -> Potrero
1G1FX6S01H40133EX	8/7/2017 11:39	right	right	48.04594088	106.8389355	-0.183465	-3.87525353	WB 15th -> Potrero
1G1FX6S05H40047EX	8/7/2017 14:52	right	right	37.61333084	104.8490638	-0.13933301	-1.73268755	WB 15th -> Potrero
1G1FX6S03H40064EX	8/7/2017 15:06	right	right	41.93581676	104.8535638	-0.24576569	-4.11435138	WB 15th -> Potrero
1G1FX6S09H40077EX	8/7/2017 17:43	right	right	6.19338131	103.3209486	-0.21276307	-3.15438825	WB 15th -> Potrero
1G1FX6S02H40136EX	8/7/2017 17:47	right	right	46.1434257	102.1704022	-0.24834061	-3.61977171	WB 15th -> Potrero
1G1FX6S09H40129EX	8/7/2017 20:59	right	right	15.04172778	100.733474	-0.24201632	-5.83643632	WB 15th -> Potrero
1G1FX6S03H40064EX	8/8/2017 7:03	right	right	12.28411102	99.73108544	-0.33993626	-5.19538289	WB 15th -> Potrero
1G1FX6S03H40064EX	8/8/2017 15:08	right	right	44.70811796	105.2775705	-0.26013899	-5.90686849	WB 15th -> Potrero
1G1FX6S05H40047EX	8/8/2017 15:39	right	right	13.87015557	105.9126512	-0.25158954	-3.78324914	WB 15th -> Potrero
1G1FX6S03H40064EX	8/8/2017 23:13	right	right	5.143144131	102.4374285	-0.23534179	-3.42185663	WB 15th -> Potrero
1G1FX6S05H40047EX	8/8/2017 23:25	right	right	49.10963631	102.5493284	-0.16858673	-3.20533297	WB 15th -> Potrero
1G1FX6S06H40137EX	8/8/2017 23:55	right	right	33.85034037	100.7710042	-0.072721	0	WB 15th -> Potrero
1G1FX6S05H40047EX	8/9/2017 0:01	right	right	4.733023405	100.9371054	-0.27797937	-4.94870752	WB 15th -> Potrero
1G1FX6S03H40064EX	8/9/2017 1:33	right	right	46.40299463	102.5860732	-0.23555875	-3.46199936	WB 15th -> Potrero
1G1FX6S06H40056EX	8/9/2017 7:07	right	right	26.72175741	103.1950638	-0.38353682	-7.4507397	WB 15th -> Potrero
1G1FX6S03H40064EX	8/9/2017 12:31	right	right	21.47642708	103.1128076	-0.32072592	-5.79980441	WB 15th -> Potrero
1G1FX6S01H40133EX	8/9/2017 13:35	right	right	7.41862011	103.6805699	-0.33200407	-5.86493384	WB 15th -> Potrero
1G1FX6S06H40056EX	8/9/2017 20:31	right	right	40.70000219	103.6947023	-0.38724542	-5.56388936	WB 15th -> Potrero
1G1FX6S03H40064EX	8/9/2017 23:59	right	right	5.951725006	167.117795	-0.33686757	-5.28344403	WB 15th -> Potrero
1G1FX6S03H40064EX	8/10/2017 15:03	right	right	26.52575183	101.8325263	-0.20094419	-2.18975964	WB 15th -> Potrero
1G1FX6S06H40137EX	8/11/2017 7:29	right	right	39.8934598	98.98323105	0.020709991	1.589401148	WB 15th -> Potrero
1G1FX6S05H40047EX	8/12/2017 6:58	right	right	25.25502634	165.9703465	-0.29580975	-5.3285328	WB 15th -> Potrero
1G1FX6S06H40056EX	8/12/2017 12:13	right	right	57.05507898	168.4197728	-0.31839538	-5.35714112	WB 15th -> Potrero

APPENDIX II: Supplemental Technical Information

Turn Signal Data Table

vin	time	turn direction	blinker	blinker on lead time seconds	blinker on lead distance feet	blinker off trail time seconds	blinker off trail distance feet	intersection
1G1FX6S06H40137EX	8/12/2017 12:28	right	right	14.99187732	105.8281341	-0.34911704	-4.8346091	WB 15th -> Potrero
1G1FX6S05H40047EX	8/12/2017 20:32	right	right	58.52088213	106.1642785	-0.40397215	-5.64175315	WB 15th -> Potrero
1G1FX6S06H40056EX	8/13/2017 4:17	right	right	38.04609513	102.5469528	-0.23484159	-4.29171475	WB 15th -> Potrero
1G1FX6S03H40064EX	8/13/2017 6:49	right	right	6.314930439	106.6322211	-0.26479292	-5.30966505	WB 15th -> Potrero
1G1FX6S05H40047EX	8/13/2017 7:13	right	right	41.42897153	104.8210536	-0.31381273	-5.37754683	WB 15th -> Potrero
1G1FX6S05H40047EX	8/13/2017 14:43	right	right	36.40501833	105.6143522	-0.28944826	-3.76848485	WB 15th -> Potrero
1G1FX6S06H40137EX	8/13/2017 14:43	right	right	10.19981456	102.958929	-0.26662397	-3.69240802	WB 15th -> Potrero
1G1FX6S06H40056EX	8/13/2017 14:52	right	right	37.39478016	103.8993082	-0.12633419	-3.49400087	WB 15th -> Potrero

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APPENDIX III: AUTOMATED DRIVING SYSTEM AND INTEGRATED ZEAV SAFETY

Introduction

GM submits this Appendix III to provide NHTSA additional safety information supporting GM's Part 555 Petition regarding its fully self-driving, zero-emission autonomous vehicle, or ZEAV. The Petition seeks NHTSA's approval to use alternative means to achieve the safety purposes of certain FMVSS requirements under the Safety Act. This document will demonstrate how GM's safety assurance process for the ZEAV meets the Safety Act requirements.

As discussed in the Petition, the safety regulation approach crafted by Congress in the Safety Act and the time-and-experience-proven legal and regulatory tools provided by that Act should govern the Agency's evaluation of this Petition and the safety of GM's ZEAV. The Safety Act creates two primary tools for ensuring motor vehicle safety: (i) the FMVSS and manufacturer's obligation to certify that vehicles comply with the FMVSS; and (ii) the manufacturer's obligation to support vehicle safety by investigating and remedying safety-related defects.[1] Part 555 petitions are within the ambit of the first tool, FMVSS compliance. Each proposed exemption from a Standard should first be analyzed to determine whether the subject system or equipment achieves the safety purpose and intent of the Standard at issue. If the subject system or equipment (i) achieves the safety purpose and intent of the Standard, and (ii) meets the other requirements of the exemption statute, then NHTSA should grant the Petition.

Presently no FMVSS specifically apply to an automated driving system ("ADS"). However, this need not hinder the adoption of life-saving technologies. Safety of vehicle parts and systems not covered by FMVSS, including new technologies like the ADS, are regulated under the manufacturer's Safety Act obligation to investigate and remedy safety-related defects, and the proven legal and regulatory tools supporting that obligation. Through this obligation, the Safety Act makes OEMs like GM responsible for the safety of vehicles they manufacture.[2] A motor vehicle is safe if it does not present an unreasonable risk to motor vehicle safety.[3] Motor vehicle safety, in turn, 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, and against unreasonable risk of death or injury in an accident, and includes nonoperational safety of a motor vehicle.[4]

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[1] 49 U.S.C. §§ 30112, 30118, 30120.
[2] *See* 49 U.S.C. §§ 30118-30120 (motor vehicle manufacturer is obliged to maintain safety of motor vehicles it manufactures by identifying vehicle defects affecting vehicle safety and remedying those defects).
[3] *See id.*
[4] 49 U.S.C. § 30102(a)(8).

These manufacturer safety obligations apply equally to conventional vehicles and to autonomous vehicles and their ADS.[5] Thus, when deploying its ZEAV, GM is obliged to deploy vehicles that are safe, i.e. protect the public against unreasonable risk of accidents caused by design, construction, or performance of the vehicles. GM is intimately familiar with this safety obligation and is thoroughly committed to meeting that standard in its new ZEAV. Indeed, GM will not deploy its ZEAV unless it is satisfied that its ADS will drive safely, based on the processes summarized below.

GM has a century of experience—and over 50 years of experience under the Safety Act—designing, developing, and building automotive safety features. Those decades of experience and expertise serve as the foundation for developing the ZEAV's fully integrated safety systems. This Appendix III describes how, together, GM's ZEAV development, testing, safety validation, and deployment programs thoroughly incorporate safety into the vehicle and its self-driving systems. As the following discussion demonstrates, GM's Comprehensive Risk Management and Deeply Integrated safety systems make safety fundamental to the ZEAV throughout its development, from design to deployment. As GM's ZEAV program progresses, GM would be pleased to provide periodic, confidential updates to NHTSA.

[5] *See, e.g.,* Automated Driving Systems 2.0, A Vision for Safety at 3.

Executive Summary

GM designed, developed and validated the ZEAV to incorporate safety into all aspects of its operation. Two pillars of GM's development process that lead to automated safety operation are (1) Comprehensive Risk Management and (2) Deep Integration. Comprehensive Risk Management refers to the safety approach that GM applied to develop the ZEAV from the very start using system safety development processes that addressed all aspects of the self-driving vehicle operation. This approach uses a thorough analysis of potential problems to account for what could go wrong. Deep Integration means that the vehicle and ADS are built as one integral product so that the ADS's systems and those of the rest of the vehicle support each other through all aspects of operation.

Comprehensive Risk Management. For a highly automated vehicle, there are two primary sources of hazards. First, components or systems could break or malfunction. Second, the vehicle might encounter road hazards or other external factors that challenge safe, automated operation. GM used a rigorous hazard analysis to understand both of these categories and applied state-of-the-art safety engineering practices and cutting edge technologies to address them. By implementing Comprehensive Risk Management, GM solved potential problems by eliminating risks, or where eliminating them was not possible, responding to them in a safe way. For example, risks related to the possibility that a critical computer or its software might malfunction are eliminated by having a second computer ready to take over and continue safe operation. And, to address external hazards, GM's ZEAV validation process will make it a road-tested, experienced, and proven driver before GM deploys the vehicles on the road.

Deep Integration. By developing the ZEAV and its ADS as a single integrated vehicle, GM built ADS system safety into the vehicle development process making the ADS part of, not a separate add-on to, the vehicle. This "Deep Integration" of the ADS into the vehicle is critical because it enables evaluation and development opportunities not available in non-integrated systems to eliminate hazards. Some hazards are only identifiable by analysis of the ADS and the rest of the vehicle together as an integrated whole. By building the ZEAV as a single, integrated product, including the ADS, GM's iterative cycle of hazard analysis, design, development, testing, and design improvement all the way through final validation allowed early identification of integrated system hazards and early design of solutions to eliminate or minimize those hazards.

Furthermore, GM's combination of Deep Integration with the Comprehensive Risk Management approach allows us to meet two key performance objectives:

> *First*, no single-point-, plausible dual-point-, or common-cause-malfunctions cause safety hazards; and
>
> *Second*, the ADS's driving behavior demonstrates a statistical improvement to overall vehicle safety in the intended driving environment.

Together, GM's Deep Integration and Comprehensive Risk Management confer synergistic benefits that eliminate or mitigate risks of a self-driving vehicle.

Deployment in GM-Controlled Fleets. To introduce the ZEAV safely and to enable continuous learnings and improvements, GM intends to deploy its ZEAV in a GM-controlled fleet ride-share program. That controlled deployment will ensure the ZEAVs are driven within known, geo-fenced boundaries and under known operational conditions and constraints that apply to the entire fleet. GM will manage service and maintenance of the entire fleet so that the ZEAV's critical systems are operational and support safe on-road driving. In the event that an unexpected condition or circumstance arises, GM can respond promptly on a fleet-wide basis by, for example, updating software, limiting vehicle operating modes, making needed repairs, or removing vehicles from service. GM's fleet deployment program will introduce these vehicles safely to consumers in a manner that facilitates the further development, field evaluation, and improvement of its ZEAV.

GM's on-road testing of the ZEAV to obtain ADS performance data is ongoing. Presently, GM is expanding its on-road testing capacity and accelerating its acquisition of performance data. At this juncture, GM has made sufficient progress to (a) conclude that the approaches discussed herein will support a thorough evaluation of the ADS' safe driving capability; and (b) allow GM to determine when the vehicles will be road ready. GM will not deploy the ZEAV until it is satisfied with the safety and performance of the vehicle's ADS and other systems.

Because some of the foregoing topics are discussed in more detail in the Petition and Appendix II, this Appendix III will reference those documents where appropriate.

The discussion below addresses the following development, testing, validation, and deployment processes GM uses to make the ZEAV a safely operating automated vehicle:

1. **GM's Comprehensive Risk Management:**
   - ✓ **A rigorous System Safety process**
     - Implementing deterministic and probabilistic hazard analysis
   - ✓ **ZEAV system safety resulting from System Safety process**
     - Cybersecurity
     - Fail Operational, Fail Safe, Redundancy and Diagnostics
       - *Backup equipment, actuation, power, communication, and computers; redundant and diverse sensors; and high integrity diagnostics*
     - Statistically Significant Validation Testing
       - *Exposing the ADS to millions of miles of validation testing in the ZEAV's operational design domain*
       - *This testing exercises the systems and response capabilities of the vehicle in the expected operating environment*
2. **Deep Integration to enable Comprehensive Risk Management**
   - ✓ **Integrated Vehicle Safety Performance**
     - Crashworthiness, physical safety, and response of an integrated ADS and vehicle
     - Allows validation of the vehicle with integrated ADS for performance, response capabilities, and occupant protection

- Deep Integration supports addressing all relevant hazards throughout the product development cycle

3. **GM's Fleet Ride-Share Program**
   - ✓ **GM maintains control of the vehicles**
     - Fleet-wide maintenance, response, and update capabilities
     - Robust continuing support of development and evaluation of the ZEAV
   - ✓ **Deployed in known operating domain under recognized conditions**

ZEAV Safe Driving Capability

The following sections discuss how GM's development provides the ZEAV with the capabilities and experience to enable safe on-road operation across the variety of conditions and circumstances that may arise in its operational design domain.

1. Comprehensive Risk Management

In its safety development processes, GM identifies and thoroughly analyzes potential problems impacting safety (referred to as "hazards").[6] In implementing Comprehensive Risk Management, the hazards are analyzed during design, evaluated and re-analyzed during development, and tracked through the entire process. GM uses state-of-the-art safety engineering processes to define and track solutions to eliminate hazards, and where they cannot be eliminated, to minimize them to generate a safe result. Finally, GM utilizes validation necessary to provide safe operation of the ZEAV, both when something malfunctions, and when everything is operating as designed.

A benefit of GM's Comprehensive Risk Management approach is that the ZEAV effectively addresses potential safety hazards. The ZEAV is designed to continue operating properly even if there is a failure in a primary system—this is "fail-operational functionality." Fail-operational functionality is enabled by the ZEAV's back-up systems for all critical operations—this is "system redundancy." And in the unlikely event that both the back-up and primary systems fail, the ZEAV can bring itself to a safe stop—this is "fail-safe functionality."

To generate these safety benefits, GM's development process addresses two types of potential hazards: (i) faults or malfunctions of the hardware and software; and (ii) hazards in the driving environment encountered by the ADS when all systems are operating correctly. To address both of these types of hazards, GM's development process accounts for the roads and infrastructure on which the ZEAV will operate. For example, as a result of identifying and addressing hazards that may arise in the driving environment, GM's ZEAV has ample sensors allowing it to detect the roads, infrastructure, other cars, pedestrians, bicycles, motorcycles, and other road users on and around its intended path. The ZEAV also has computing power and computer control capabilities that, combined with the capabilities described above, support safe driverless automated

[6] As indicated above, the two primary sources of hazards are (1) components or systems could break or malfunction; and (2) the vehicle might encounter road hazards or other external factors that it does not know how to handle safely.

operation. Ultimately, the ZEAV development process enables the ZEAV to perform its mission: safe self-driving operation in its driving environment.

1.1 Rigorous Integration of System Safety into Vehicle Development

GM's System Safety development processes includes a continuous focus on identifying and resolving hazards to safety during the design, development, testing, and validation stages.

1.1.1 Preliminary Hazard Analysis

Preliminary hazard analysis identifies system hazards and risks beginning early in the design process, including a top-down analysis of those potential hazards and risks, as well as a system evaluation analysis. GM uses deterministic safety analysis to identify hazards due to faults and malfunctions with system components.[7] These are referred to as "unintended causal factors." GM uses probabilistic safety analysis to identify those hazards that could occur when all of the software, components, and systems are operating as intended. These are the road hazards or other external factors that the vehicle needs to know how to handle safely, and are referred to as "mission operational hazards." This thorough analysis allowed GM to develop the two key safety performance thresholds—(i) that no single-point, plausible dual-point, or common-cause malfunctions may cause safety hazards for the ZEAV; and (ii) that the ZEAV's driving behavior demonstrates a statistical improvement to overall vehicle safety in the intended driving environment.

Starting with these broad requirements, GM defined detailed, vehicle-level safety goals based on, and to address, identified hazards in order to mitigate safety risks so that the system is safe. GM will not deploy its ZEAV until these thresholds have been met.

1.1.2 Safety Analyses of the Vehicle Design

During the concept, design, testing, and validation stages, GM uses a variety of analytical tools to enable analysis of the vehicle design from different perspectives, using deductive, inductive, and exploratory analysis, enabling GM to obtain a thorough safety design evaluation. These various analytical tools are cornerstones of best-in-class engineering analysis. Below we highlight some of those tools and how GM uses them:

- *Deductive analysis* includes a fault tree analysis ("FTA"), which connects potential failures to their direct causes.

- *Inductive analysis* includes design failure mode and engineering analysis ("DFMEA"), which is a step-by-step approach to identifying all possible failures in a design.

- *Exploratory analysis* includes hazard and operability study ("HAZOP"), which identifies potential problems by analyzing the operations of a complex system.

[7] Including those caused by external sources.

- *Implementation into the product development process* includes using process hazard analysis at the concept stage to assess potential hazards, software HAZOP, system FTA and DFMEA during design, system functional interface analysis ("SFIA") and DFMEA during requirements definition, and DFMEA during implementation phases.

- *Requirements traceability analysis* manages the relationships between engineered systems and the safety thresholds and attendant requirements.

By implementing this last tool, requirements traceability analysis, GM's development process connects hazard elimination and minimization to the requirements, design, and validation of the vehicle, its systems, and its components. This traceability analysis allows GM to associate hazards to relevant software and hardware design, in turn allowing GM to set software and hardware integrity requirements. GM also uses root-cause analysis and regression test development throughout the ZEAV's development lifecycle. Robust simulation capabilities capture both anticipated and real experiences from design and development.

1.1.3 Applying the System Safety Process to the ZEAV

GM's system safety approach blends aspects of both MIL-STD-882[8] and ISO 26262[9] (in addition to other standards and analysis tools[10]). MIL-STD-882 emphasizes identifying hazards, hazard elimination, and managing the risks associated with the identified hazards. Where possible to do so, MIL-STD-882 prioritizes hazard elimination ("risk reduction precedence") over other strategies for risk reduction, such as the introduction of a safety mechanism. ISO 26262 emphasizes that system safety is achieved by the application of engineering process rigor for the level of safety criticality associated with the system or system component. Following these principles and methods, GM has implemented (a) a deterministic approach to validate unintended behaviors and (b) a probabilistic approach (as introduced in section 1.1.1) that provides both qualitative exposure of the ZEAV behavior in the intended environment and quantitative data with statistical significance.

A. Addressing Unintended Causal Factors

To address unintended causal factors, GM's system safety process implements redundant and fail-operational measures and systems in the design—including backup controllers, actuators, communication paths, and sensors. This approach addresses both random hardware failure risks as well as systematic design risks with the objective of eliminating single- or plausible dual-point and common-cause malfunctions, including dependent failures that can lead to safety hazards. GM uses verification and validation tests to confirm that the ZEAV meets this safety objective (and, in the event of faults or malfunctions, achieves a minimal risk condition).

[8] MIL STD 882 E, Department of Defense, Standard Practice, System Safety, 2012.
[9] ISO 26262 Road vehicles –Functional Safety, International Standard for Automotive E/E Systems, 2011.
[10] GM's development program includes use of multiple analysis tools and standards from the Society of Automotive Engineers, the International Organization for Standardization, the Motor Industry Software Reliability Association, RCTA, Inc., and United States Military Standards.

B. Addressing Mission Operational Hazards

To address mission operational hazards—those that are caused when no equipment or system fails and the software is functioning as intended—GM evaluates the performance abilities of all of the critical self-driving functions and the functions that support automated driving. This analysis includes both qualitative and quantitative evaluation of those functions and determines whether the self-driving operations have both the right skills and the proven experience to drive safely in the intended operating environment. This approach is called "safety of the intended function," or "SOTIF."

Because driving on the road inherently leads to unpredictable situations, GM's development approach includes processes that are suitable for a product facing unpredictability. These processes include test driving vehicles; evaluating the performance of the systems in test drives; improving the software and other systems to achieve the desired result; and then doing it all over again. Cross-functional teams participate in this process, with various subject matter experts bringing diverse operational goals to facilitate incorporation of all necessary features and characteristics into the ADS design. Through this process, which GM refers to as the "test-driven agile methodology," GM's ZEAV continuously improves its capabilities while incorporating Comprehensive Risk Management and Deep Integration goals.

GM utilizes test-driven agile methodology both to determine how well the ADS handles the driving tasks in its intended environment and to analyze the driving performance of the ADS against human driving. The former allows GM to evaluate qualitative exposure of the ZEAV in the intended environment and the latter allows GM to make quantitative comparisons with human drivers in the same environment. Test driven agile methodology uses real-world testing that exercises the ADS across the operational design domain to guide design, identify parameters that indicate performance, and define the next generation of tests. Robust regression testing provides that experiences during this iterative test process are captured and used to propagate continuous design improvements. The real-world testing and robust regression testing are paired with a top-down approach of cases that are unusual and stress system performance (edge cases) to identify performance requirements that must be evaluated in closed course testing and/or simulation. In other words, GM uses this process to identify the challenging driving skills that the ZEAV needs, and then tests the ZEAV on those skills. The resulting system is then further evaluated in real-world testing. Through many iterations, this process leads to testing that supports the quantitative analysis of driving performance and to confirm that the ADS is able to safely handle the wide variety of situations that can challenge the sensors, systems, and algorithms in the intended driving environment.

C. Role of Integrated Rapid Development Teams

In developing the ZEAV, GM itself controlled key aspects of critical systems development. Integrated software and hardware teams enable rapid iteration cycles and close integration between functional systems affecting both the ADS's decision-making core and the vehicle's other systems. GM developed the maps that the vehicle uses and the vehicle's ability to locate itself on the maps. GM also developed the way that the vehicle perceives road users and objects around it; how the vehicle plans motion in consideration of both road rules and dynamic and static object interactions; and how the vehicle controls its trajectory according to that path. While suppliers provide some hardware and software components, such as radars, cameras, brake controllers, and power supplies, GM develops, codes, and validates the novel logic and processing necessary for safe automated decision making. This allows GM to analyze, challenge, and evaluate the safety performance of key components efficiently and robustly. This also supports GM's efficient and effective integration of the ADS's computers with the conventional vehicle components and systems.

GM's approach adapts traditional automotive system engineering, safety, and validation practices to its ZEAV by layering in safety and development processes that support execution of the ADS's safe driving capabilities in its intended operating environment. Both the top-down safety analysis and the test drive agile methodology create tests and performance requirements. This combined methodology also uses the principles of data science to identify the variability experienced in the real world to enable full test coverage across the vehicle's operational design domain and between different aspects of that operational design domain. While initial design seeks to anticipate as much as is reasonably practicable, real world driving experiences are critical, propelling both design and requirements generation in parallel. Together, top-down design, test drive agile development, and the application of data science provide the building blocks for GM's AV development process and validating that the ZEAV is a road ready safe driver.

1.2 ZEAV System Safety

GM's ZEAV includes systems created and refined in the safety development process described above. GM's development of the ZEAV's systems will allow the vehicle to: operate safely on the roads on which the ZEAV will be deployed; avoid or minimize hazards; implement the characteristics necessary to protect the operation of the system, such as cybersecurity and fail-operational and fail-safe functionality; and prove the safety effectiveness of those systems and functions through road testing and validation.

More particularly, GM developed the ZEAV's systems to support safety for all of its critical operations in its intended self-driving environment. The ZEAV has sensor systems sufficient to detect the relevant environment around the vehicle and the computing power necessary to process the sensor data and make dynamic driving decisions. GM integrated the ADS with the vehicle control systems that provide necessary operational control of vehicle systems, redundancy of critical systems, and, where appropriate, fail-operational and fail-safe capabilities. The sensor system has a three-dimensional, 360-degree-view around the vehicle through LiDARs, cameras, and radars. These sensors, along with the vehicle's perception system, do something that humans cannot: they continually detect and categorize the vehicle's external environment in a 360-degree view around the ZEAV through multiple means, at all times. That is, the ZEAV detects each relevant object through multiple types of sensors, and continuously scans the environment around the vehicle. The ADS's computing system has complete redundancy in its computers and critical networks, with fail-operational capabilities, built-in watchdogs and validity checks, and fail-safe capabilities. The control system has redundancy built into critical control actuators; has fail-operational capabilities; and supports the fail-safe capabilities of the vehicle. These features are described in more detail in Appendix II.

In the ZEAV development process, GM has created robust physical systems that support the operations of the computer-driven ADS. The physical systems are engineered to perform the functions required of the ADS, and the ADS is engineered to safely direct the performance of its driving functions. These physical systems help the vehicle meet the key safety threshold that no single-, or plausible dual-point or common-cause-fault or malfunction leads to an unsafe condition.

The following sections discuss in more detail (1) cybersecurity; (2) fail-operational and fail-safe functionality; and (3) GM's approach to validating the ZEAV as a safe, road-ready driver.

1.2.1 Cybersecurity

Cybersecurity protects the operation of the self-driving system and other critical vehicle systems from malicious interference and supports high customer confidence in the ZEAV's operation and use.

GM's dedicated cybersecurity specialists are integrated with the self-driving vehicle development team to build cybersecurity into GM's System Safety engineering process. This team analyzes and addresses cybersecurity for all in-vehicle control systems, as well as any self-driving vehicle connected services (such as OnStar), mobile apps, and in-vehicle apps created for the self-driving experience. The development team utilizes integrated systems security engineering practices, and a "security-by-design" strategy, to address security requirements for the entire self-driving vehicle ecosystem.

As with other areas of the vehicle, thorough use of analysis and evaluation tools, such as software scans and threat models, drive design features that respond to the risks of cybersecurity. These features, based on a "defense-in-depth" approach, include a variety of mitigating controls, such as device registration, message authentication, secure programming and diagnostics, and intrusion detection and prevention systems for back-office and in-vehicle content. These in-vehicle defenses check for abnormalities within the vehicle electronics, across internal vehicle communication buses, as well as wireless communications into and out of the vehicles. During implementation and validation, GM uses additional tools, such as penetration testing, to verify that implementation meets our goals of eliminating and minimizing risks. In addition, GM's active fleet management process will allow service technicians to regularly monitor vehicles for security-related abnormalities. If needed during deployment, GM has robust incident response capabilities to monitor and address potential new cyber risks.

For GM, it is important to maintain and advance our cybersecurity capabilities, implement and advance cybersecurity guidelines and standards, and support the growth of industry cybersecurity practices. That is why GM works with many third parties on these activities, including our suppliers, joint ventures, various automotive and security consortia, government agencies, the security research community, and the Auto-ISAC. In addition, GM regularly assesses its security practices against guidance from NHTSA, NIST, Auto-ISAC and other industry experts.

1.2.2 Fail Operational, Fail Safe, Redundancy, and Diagnostics

The ZEAV can maintain safe operation in the event of a failure of a critical system component (fail-operational capability) and can safely bring the vehicle to a minimal risk condition when necessary (fail-safe capability). This capability results from GM's implementation of redundant systems with the capability to address potential behavioral and physical malfunctions. In addition, GM's Deep Integration approach (further described in section 2, below) enables GM to build robust, integrated diagnostics that support fail-operational and fail-safe functionality to determine response states[11] and to minimize the need for higher level response states that interfere with continued operation of the vehicle. These functions are supported by the following, and built to high integrity and ASIL D[12] requirements where appropriate:[13]

1. Redundant and technology diverse sensing strategy (radars, cameras, LiDARs)
2. Fail-operational computers to perceive, plan, and control the vehicle
3. Fail-operational steering and braking actuators
4. Fail-operational power with diverse technology power sources
5. Fail-operational signal distribution and communication
6. Safety monitors to verify the integrity of the ADS computers
7. Orthogonal and independent safety co-pilot to minimize risk of collisions with objects or pedestrians at all times
   - Has its own sensors, computers, controls, and communications
8. Safety strategy with diagnostics, plausibility, sanity, and rationality checks of safety critical inputs and outputs
   - Fault tolerance to single-, plausible dual-point, and common-cause malfunctions
   - Integrated diagnostics to take action before a vehicle function fails
   - Computer, sensor, communications, and actuator diagnostics to meet fault-tolerant time interval requirements
   - Vehicle performance diagnostics
   - Preventive vehicle maintenance (incorporating learnings from durability tests to inform plans for servicing components to minimize risk of field failure)
   - Design integrated for manufacturing first time quality
9. Transitions to a minimal risk state under functional degraded conditions
10. Automated control of the vehicle responsive to vehicle performance capabilities and stability under all intended driving conditions and adapts the control according to the driving situations
11. Pre- and post-operations checks of vehicle health with periodic vehicle maintenance inspections, service, and maintenance

[11] *Appendix II* describes the response states.
[12] Automotive Safety Integrity Level risk classification; see, SAE J2980, SAE Recommended Practice for ASIL Classification, 2014.
[13] See *Appendix II* for additional detail.

12. Remote fleet monitoring and emergency assistance to the ZEAV from the back office

1.2.3 ZEAV Road-Readiness Validation

GM's safety validation includes standard validation of the structural and functional systems. The safety validation also includes the SOTIF validation process for the ADS to verify and validate driving behavior in the intended operating environment.

A. Standard Validation Processes

Some of the standard validation processes:

- Evaluation of autonomous driving performance
- Vehicle, system, subsystem, and component level performance tests
- Requirements-based validation of systems, subsystems, and components
- Fault injection testing of safety critical control inputs, outputs, computation, and communication
- Validation of fail-over and minimal risk transitions within the fault-tolerant time interval
- Electromagnetic interference and electromagnetic compatibility testing, as well as other environmental element exposure tests (including temperature, humidity, RF, light energy)
- Durability tests
- Regression- and simulation-based software validation

B. SOTIF Validation Process

SOTIF includes both qualitative evaluation encompassing the intended operating domain exposure and quantitative evaluation providing a statistically powered analysis of driving capabilities. Some of the SOTIF validation processes include:

- Systematic exposure of the ADS to rigorously test all expected driving maneuvers under all expected driving conditions in the ODD
- Identifying and iteratively testing driving scenarios and edge cases that challenge the ADS
- Exercising the object and event detection and response capabilities of the ZEAV and its ability to identify environmental objects and situations that require a safe behavior response

C. ODD Exposure Testing, Validation, and Analysis

GM's ongoing validation of the ADS's driving performance will include millions of miles of testing on the roads, with the kinds of traffic and other driving challenges that the ZEAV will face in deployment. By road testing in the environments and conditions in which the ZEAV will be deployed, GM targets the ZEAV's operational design domain and ensures that the ADS's systems and response capabilities are thoroughly tested in that driving environment. This validation testing will allow GM to analyze (in a statistically valid way) the safety performance of the ADS. This analysis will allow GM to determine when the ADS is a safe driver and ready for driverless on-road operation.

GM's testing and validation program includes on-road testing with a test fleet of autonomous vehicles with human autonomous vehicle trainers ("AVTs") who can take-over driving from the ADS to prevent potential crashes. GM analyzes the take-over events to determine whether actual crashes were avoided and whether the ADS control software needs to be updated.

GM analyzes this record of ADS driving performance and human driving behavior as documented by existing human driving behavior studies and from new studies that GM is undertaking to characterize driving performance. These studies establish human driving behavior indicators and crash surrogates as a basis for understanding driver performance. This approach eliminates the need to rely on infrequent and tragic occurrences of traffic deaths and injuries to validate ADS behavior. Combining these driving performance characterizations with additional analysis, GM's program uses a data-driven analysis to determine how many miles the ADS should drive to establish that its driving performance will show a statistical improvement to overall vehicle safety.

1. GM's On-Road Testing of the ZEAV

On-road testing helps "train" the ZEAV safe driving capabilities of the ADS. During on-road testing, the AVT can take over control of driving from the ADS when the AVT determines that it is necessary or appropriate to do so. GM uses technology and AVT take-over events to establish crash "surrogates." That is, GM utilizes the prediction calculations of the ADS at the time of AVT take-over to identify and analyze those instances in which the vehicle likely would have crashed or failed to avoid a crash had the AVT not intervened. GM uses these virtual events (potential crashes avoided by AVT intervention), or "surrogate crashes," to analyze driving performance. More particularly, although the surrogate crashes did not actually occur on the road, GM's analysis counts them as crashes that would have happened and uses them to determine the performance of the ADS.

GM uses its on-road performance data, including miles driven, real crashes, and surrogate crashes, to build a statistically relevant analysis of the ADS's performance as a motor vehicle driver in the relevant driving environment. These analyses, combined with (i) an understanding of the causes of crashes; and (ii) the advantages that GM's ADS technology provides, will allow GM to determine—over the course of millions of miles of testing in the relevant operating domain with significant exercise of ADS sensor and response systems—that the ZEAV will drive safely.

GM uses the learnings from surrogate crashes to update the ADS software to avoid those types of crashes in the future. GM tests the updated software in simulations modeling surrogate crashes, and in other simulations to confirm that the updated ADS software accounts for the conditions and events leading to the surrogate crash, avoids such crashes, and does not degrade driving performance in the process. GM then tests the updated software in its on-road testing program.

In addition to analyzing on-road performance and crash surrogates, GM uses test tracks, staged encounters, test cases, and simulation to further validate the ZEAV's performance.

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2. Deep Integration to Obtain Comprehensive Risk Management

To enable Comprehensive Risk Management, GM has designed, developed, and tested the ZEAV's safety performance with the ADS as a fully integrated operating system of the vehicle using the fundamentals of Deep Integration. This Deep Integration, and the integrated development, testing, and validation it allows, is critical to the safety of GM's ZEAV. System performance and validation includes the vehicle with the integrated ADS, and all of the ADS's components. Conventional functions such as acceleration, braking, and steering are all calibrated and validated with the ADS components and system as part of the vehicle. Also, all of GM's critical testing and measures of safety performance include the ADS as part of the ZEAV. Occupant protection is designed and crash tested with the ADS components and system as part of the vehicle. And response states are determined and implemented based upon the vehicle with the fully integrated ADS.[14]

Further, as an integrated vehicle, the ZEAV has a single product lifecycle (including the ADS), allowing comprehensive understanding of service and maintenance needs throughout the

[14] See *Appendix II* for example Response States. For malfunctions that have the potential to lead to degraded operation, the AV will safely pull over to the road-side and turn the hazard lights on. During these conditions the vehicle health management system determines the minimal risk state and transitions the vehicle to a safe state. The ZEAV escalates response states only when necessary to achieve the minimal risk state for the driving situation.

operational life of the vehicle. This supports linking service and maintenance of the ADS with conventional vehicle systems, such as powertrain and braking systems. This enables the ADS to support lifecycle needs of other system components, and allows other system components to support lifecycle needs of the ADS. For example, if age or wear impacts vehicle performance, the ADS can take those changes into account. In addition, the ADS can enforce needed maintenance events that a human driver might be tempted to delay. Even further, the ZEAV obtains conventional benefits associated with integrated development, such as the ability to manage variability of individual components and the system as a whole, build quality into the entire integrated vehicle, and support more robust diagnostics. These benefits are more than what can be achieved with two separate products attached together at the end of two or more distinct manufacturing processes. Without Deep Integration, it would not be possible to conduct the level and rigor of safety validation that GM conducts for the ZEAV. In addition, the integrated development avoids conflicts resulting from separate and independent development of the vehicle and ADS, each according to its own unique requirements.

Deep Integration allows quality assurance, leading to performance integrity of the system by providing the opportunity to engineer production requirements and assembly processes during the vehicle development process. GM's fourth generation autonomous vehicle is the third generation that GM built in an assembly plant. In-plant assembly of the ADS along with the other vehicle components and systems facilitates consistent build quality, as well as opportunities to identify potential flaws in components early in the process. This use of Deep Integration supports Comprehensive Risk Management through assembly plant process consistency and quality control.

As discussed below in section 3, GM's vehicle design and deployment through a GM-controlled fleet ride-share program with proactive maintenance allows GM to identify and replace critical components at risk of failure. As a result of the fail-operational functionality, along with proactive maintenance, higher level response states will be rare. This result, enabled by Deep Integration, supports an important goal of GM's Comprehensive Risk Management approach—for each hazard, GM prioritizes hazard elimination (such as through fail-operational functionality) over hazard minimization (such as through fail-safe functionality).

2.1 Integrated Vehicle Safety Performance

The integrated ZEAV supports the design, development, and validation of the vehicle's safety performance. The ZEAV's body structure is based on the production Chevrolet Bolt EV and was built upon learnings from previous generations of high voltage vehicles and continued engineering development. GM conducted computer simulation and crash testing to analyze the structural integrity due to the addition of several new key systems to the ZEAV (for example, the sensor roof module, sensor cleaning and drying system, power back up system, and data management system). This work supported GM's integrated structure crashworthiness strategy for the ZEAV, including:

- Load paths to manage crash forces and protect occupant space during frontal, side, rear, and rollover crashes

- Battery housing structure to help protect battery internal space
- Vehicle floor reinforcements to distribute loads and maintain occupant space in a crash.

GM has completed appropriate crash simulations and initial crash testing of AV prototypes that show that all occupant protection safety requirements can be met. Additional crash testing is taking place to finalize the validation, with all sensors and computer systems present, to meet crashworthiness requirements for frontal, side, rear, and rollover crashes.

The following sections describe some additional safety benefits enabled or enhanced through the Deep Integration of the ADS into the ZEAV.

2.1.1 Protection of Occupants in the Vehicle

Seating: Because there will be no human driver, the ZEAV has no human driver controls, and the left front seat becomes another passenger seating position. All other seating positions are the same as the current Chevrolet Bolt EV.

Occupant Protection: GM designed the airbags and seatbelts for this left front passenger system to the same injury protection criteria as the right front passenger seat. Simulated crash testing to date shows that the occupant protection will be similar for both front passenger positions. This performance will be confirmed in physical crash tests prior to deployment.

2.1.2 Battery Safety

The ZEAV also incorporates battery safety measures. The ZEAV includes a reinforced structure for the battery compartment and two separate disconnects. The first disconnect is a human-operated disconnect located underneath the rear seat for use by service technicians. The second disconnect is a crash-safety system located forward of the battery, which cuts power in a collision, making it safer for first responders**.**

2.1.3 Child Protection

GM's ZEAV is designed to accommodate customers installing FMVSS certified child seats for children in the rear. The ZEAV will include safety belts and second row LATCH (lower anchors and top tethers for children). Both frontal passenger airbags (left side and right side) meet the FMVSS low-risk deployment requirements for child occupant protection.

2.1.4 Protection of other Road Users

The ZEAV's systems protect both the ZEAV occupants and other road users. Simulations and on-road testing show that the ZEAV can detect and react faster than a human when it senses a hazard around the perimeter of the vehicle. A combination of data collected from the ZEAV's 360-degree field of view is used to identify, track, and calculate the potential trajectories of objects, such as pedestrians and bicycles, in or around the road outside the vehicle. When the ZEAV senses a potential incursion from any incoming objects in its planned path, it first seeks to avoid a collision by changing its planned path taking the surrounding environment into consideration. If the ZEAV is not able to safely avoid an object in its path, it will come to complete stop.[15]

2.1.5 User Interactions with the ZEAV

The ZEAV includes features to assist passengers and other road users with both in-vehicle and remote communication capabilities. These include:[16]

- In-vehicle interactive screens that provide information to users relevant to their ride, such as destination and route
  - These screens are also able to display information about the road, such as relevant static (e.g., lanes) and dynamic (e.g., pedestrians) information, offering passengers information about the vehicle's planned path and surroundings
- Accommodations for hearing and visually impaired individuals so that vehicle functions are accessible to them
- Stop-request functionality that, at any time, allows riders to request a pullover and stop at the next safe place available (this can also be used for emergency pullover)
- Safety reminders to encourage passengers to buckle their seatbelts
- External signaling, such as turn signals, for indicating intentions to external actors
- Central monitoring of all vehicles and their operational status
- Post-crash notification and assistance
- Remote communication

3. Operational Checks and Fleet Management

GM will operate the ZEAVs that this Petition seeks permission to deploy only in a GM-controlled fleet program with ride-share services. This approach is an ideal way to introduce the ZEAV to consumers because it controls the operational design domain; limits the scenarios, conditions, and circumstances that the ZEAV will face; and provides GM access to the vehicles to continuously improve the technology. With full access to the entire fleet, GM will have the capability to rigorously evaluate the ZEAV's performance as well as to manage regular service and maintenance and prompt software updates.

GM's controlled fleet program will implement appropriate limitations and control over operation of each ZEAV. The ZEAVs will operate only in the design domain determined by GM, and they will not exceed design speed or travel on unmapped roads. The vehicles will drive only in pre-mapped areas for which GM fully understands the infrastructure and conditions that the vehicles will encounter. GM will know where all of the vehicles are at all times. If necessary, GM can provide updates to the entire fleet on short notice. And GM will be a central repository for data

[15] See Appendix II for further description of the ZEAV's perception and controls.
[16] See Appendix II for further descriptions.

collected from all of the ZEAVs. With GM's program, there are no concerns about vehicles in the hands of drivers who cannot be located.

Based upon these advantages, GM's intended fleet-based program will magnify the benefits of Part 555's purpose of supporting the development and field evaluation of new safety features and new low-emission vehicles in multiple ways. First, the fleet program does not have some of the limiting characteristics associated with vehicles sold at retail to individual consumers. Once vehicles are publicly sold, independent vehicle owners may not be in contact with, or have an incentive to facilitate feedback to or evaluation by the vehicle's manufacturer. This can result in limitations in the manufacturer's receipt and analysis of data supporting the development and field evaluation of the low-emission vehicle and safety features. GM's program not only eliminates the risk of minimal or delayed data for evaluation, it amplifies GM's ability to successfully field-evaluate these vehicles. GM's control of the vehicles provides the opportunity for pre- and post-operational checks that may be required for vehicle health. GM's control will also provide vehicle performance and data monitoring through remote communications and access to in-vehicle systems, allowing frequent access to vehicle performance data on a level unparalleled in a consumer sale model. Further, GM's fleet management provides GM the ability to quickly respond to any safety issues across the fleet.

Second, autonomous vehicles have advantages that allow continuous and efficient improvement of driving skills. GM's ride-sharing fleet approach maximizes the capacity to improve AV driving. By controlling the fleet, GM can implement vehicle updates to all vehicles in the fleet. Thus, not only does an ADS improve instantaneously with a new update, GM can update the entire fleet at the same time—when one ZEAV gets an improvement from the update, they all get the improvement. Unlike people, who need to be taught the same lesson individually and in some cases over a period of time, the ADS learns from the entire fleet's experience. As a result, the entire fleet of ZEAVs only needs to be programmed once to improve a targeted behavior.

The same factors discussed above that allow GM to quickly improve its ADS's automated driving also allow for continuous improvement of the entire fleet.

Third, building on the ability to efficiently obtain fleet-wide data and make fleet-wide improvements, GM's program maximizes the potential to assess the ZEAV's effect on NHTSA safety initiatives designed to protect Americans when they ride, drive, and walk. GM's fleet will be comprised of SAE Level 4 vehicles that offer no opportunity for a vehicle occupant to take over control of the dynamic driving task. Thus they will provide no opportunity for drunk, drugged, distracted, or drowsy driving. In addition, the ZEAV will operate with the seat belt enforcement function described in the Appendix II that can provide feedback on seatbelt use, further supporting NHTSA's safety goals. Further, GM's ZEAV has the ability not only to follow traffic laws, but to watch for other traffic participants, including pedestrians. Other traffic participants can be detected when they follow traffic laws, or when they break them, such as pedestrians jaywalking. GM's fleet program may help to develop data on the potential benefits of improved traffic participant detection, which may prove to be a valuable input in future safety initiatives.

There are still more safety benefits of deploying the ZEAV in a GM-controlled fleet program. GM's program includes operations to monitor roadway factors such as updates on road construction and other road hazards and to take these updates into account in operation of the ZEAVs. The ZEAVs will sense environmental factors, such as weather conditions and get additional information on weather from the fleet operations center. GM may use this information to manage vehicle routing during emergency conditions. This information helps ensure that the ZEAVs will only operate in their operational design domain and allows for adjustments based upon weather-related factors. The program therefore minimizes the impact of road and weather factors as potential hazards for the ZEAV operation.

Below are highlights of the advantages of fleet operations:

- Effective and efficient monitoring and collection of data supporting the development and field evaluation of the ZEAV
- Fleet-wide access for improvements and vehicle inspections and proactive service and maintenance
- Fleet learning capabilities – when software is updated, all vehicles receive the benefit
- Support of NHTSA safety initiatives, including elimination of impaired and distracted driving, pedestrian protection, and seat belt enforcement
- Remote communication of the ZEAV with the back office
- Fleet-wide ability to manage available routes and emergency response
- Fleet monitoring (during, pre-, post-ZEAV operations)

4. GM's Design, Development, Testing, and Validation Approach Using Comprehensive Risk Management and Deep Integration Addresses all 12 of NHTSA's Safety Elements

GM's safety development program employing the principles of Comprehensive Risk Management and Deep Integration summarized in this Appendix supports all 12 of NHTSA's ADS Safety Elements. System Safety is discussed in sections 1, 2 and 3. Operational Design Domain is discussed in sections 1.2, 1.2.3 and 1.2.4. Object and Event Detection and Response are covered in sections 1.2 and 1.2.3 and in Appendix II. Fallback is covered in section 1.2.2 and also in Appendix II. Validation methods are discussed throughout section 1. Human-machine interface is discussed in sections 2.1.5 and 3. Vehicle cybersecurity is discussed in section 1.2.1. Crashworthiness is discussed in sections 2.1.1, 2.1.2 and 2.1.3, as well as in Appendix II and in the Petition. Post-Crash ADS Behavior is supported by sections 1.1.3 and 1.2.2, and Appendix II—detected crashes lead to minimal risk conditions, the vehicle remaining on the scene when required by law, and two-way communication with the operations center is available if needed. Data recording is covered by section 3 and Appendix II. Consumer education and training are covered by section 2.1.5 and Appendix II. And federal, state and local laws are covered by section 1 as they relate to requirements for safe operation of the vehicle and by sections 1.1.3 and 1.2.2 as they relate to requirements such as remaining at the scene of an accident. A comprehensive discussion of how GM addresses NHTSA's 12 ADS Safety Elements is provided in GM's Voluntary Safety Self-Assessment.

Conclusion

This Appendix III demonstrates that GM has implemented a safety development and production process for the ZEAV that leverages Comprehensive Risk Management and Deep Integration. This approach accounts for potential safety hazards and risks attendant to self-driving operation, eliminates potential hazards where possible, and safely addresses the remainder. GM's safety-driven process for development and validation of the ZEAV also includes a data-driven road-readiness validation process that will demonstrate that GM's ZEAV is ready for safe, driverless, on-road operation. All of this shows that the ZEAV and its ADS meet the Safety Act's thresholds for driverless on-road operation

Acronyms

ADS – Automated Driving System

E/E – Electrical and Electronic

DFMEA – Design Failure Modes and Effects Analysis

FTA- Fault Tree Analysis

HAZOP Analysis – Hazard Operability Analysis

ODD- Operating Design Domain

OEDR – Object and Event Detection and Response

PHA – Preliminary Hazard Analysis

SOTIF – Safety of the Intended Function

ZEAV – Zero Emissions Autonomous Vehicle