Nuro, Inc.
1300 Terra Bella Ave., Suite 100
Mountain View, CA 94043

October 19, 2018

The Honorable Heidi King
Office of the Administrator
National Highway Traffic Safety Administration
1200 New Jersey Avenue SE
Washington, DC 20590

RE: Petition for Exemption from Certain Provisions of Federal Motor Vehicle Safety Standard, No. 500

Dear Deputy Administrator King,

On behalf of Nuro, Inc., I respectfully submit this petition for exemption from limited aspects of the Federal Motor Vehicle Safety Standards (FMVSS) No. 500 that are inapplicable to or otherwise inconsistent with our company's planned next-generation autonomous delivery robot, "R2X." We submit that these requirements would make the development or field evaluation of a low-emission vehicle easier and would not unreasonably lower the safety or impact protection level of that vehicle.

The information required by 49 CFR Part 555 is provided below. We would be pleased to provide any further information necessary to support your review of this petition.

Thank you for your time and consideration.

Respectfully,

Dave Ferguson
President and Co-Founder
Nuro, Inc.

1. Introduction and Background

A. Full Name and Address of Applicants

Nuro, Inc.
1300 Terra Bella Ave., Suite 100
Mountain View, CA 94043
Corporation organized under the laws of the State of Delaware

B. Nature of Business

Developer and Manufacturer of Managed Fleets of Advanced Robotics, Including Highly Autonomous Vehicles — Corporation — United States.

C. Summary of Requests for Exemption

Under the authority granted to the Secretary of Transportation in 49 USC § 30113, and as provided in 49 CFR 555, Nuro requests exemptions from the requirements of Federal Motor Vehicle Safety Standard (FMVSS) No. 500, on the basis that the alternatives proposed herein would make the development or field evaluation of a low-emission vehicle easier and would not unreasonably lower the safety or impact protection level of that vehicle. Specifically, Nuro requests exemptions from the following subsections of FMVSS No. 500:

- S.5(b)(6) An exterior mirror mounted on the driver's side of the vehicle and either an exterior mirror mounted on the passenger's side of the vehicle or an interior mirror;
- S.5(b)(8) A windshield that conforms to the Federal motor vehicle safety standard on glazing materials (49 CFR 571.205); and
- S.5(b)(11) The rear visibility requirement, as specified in paragraph S6.2 of FMVSS No. 111 (in part).

Nuro requests that NHTSA grant these exemptions for two years.

2. Statement of Public Interest

A. Device & Service Overview

Nuro has designed, prototyped, and extensively tested a low-speed, zero-emission, autonomous vehicle (AV).[1] This motor vehicle, code-named "R2X" during this pilot phase, is engineered from the ground up for short neighborhood trips and for the exclusive purpose of transporting and delivering goods.

Relative to other Automated Driving Systems (ADSs, SAE Level 3-4) NHTSA and the Department of Transportation (together "the Department") may have encountered, though it leverages many familiar technologies to traditional ADSs built on a traditional automobile chassis, R2X is a built-for-purpose vehicle (not a modified passenger car), and is not designed to transport

[1] Society of Automotive Engineers International, *Taxonomy and Definitions for Terms Related to Driving Automation Systems for On-Road Motor Vehicles,* (J3016_201609). Revised: 9/30/16c

people or accommodate a human driver. Instead, it is designed to be a fully autonomous,[2] driverless *and passengerless* platform.

While familiar to other road users given its resemblance to many Neighborhood Electric Vehicles (NEVs), the R2X presents a novel application of autonomous vehicle technology that permits a range of safety innovations.

Figure 1: Evaluation Prototype "R2X"

Nuro presently intends to partner with local retailers to provide last-mile delivery service for their goods and services. Summoned with an app or through a website by the consumer, the entire fleet will be owned and centrally managed by Nuro, rather than sold or leased to customers, providing the opportunity to comprehensively ensure the consistent and safe operation of these vehicles, and to consistently improve performance and service.

From the standpoint of regulatory classification, R2X meets the criteria for low speed vehicles (hereafter, "LSVs").[3] The Department has defined a LSV as having four wheels, a top speed between 20 and 25 mph, and a GVWR of less than 1,361 kilograms (3,000 pounds). R2X, under the test conditions and test procedure laid out in FMVSS No. 500, meets the speed requirement with a top speed of less than 25 mph.[4] R2X also has four wheels and a GVWR of less than 1,361 kilograms. Like the other LSVs considered in the original 1998 rulemaking, R2X offers "quieter transportation that does not pollute the air of the communities in which [it operates]."[5]

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[2] At present, R2X is designed to achieve Level 4 automation — managing all aspects of the dynamic driving task, but with built-in operational limitations to ensure optimal performance. These limitations are a function of the intended business use of the platform: low-speed operation, on marked and pre-mapped surface streets. It is also presently capable of teleoperation, or remote operation by a human backup driver. While future Nuro robots may exceed these imposed limitations and approach Level 5 automation, that unrestricted operation is not contemplated for R2X. Later sections detail the means of supervised, fallback, and other operation that would be a part of on-road testing of the vehicle.

[3] 49 C.F.R. 571.3.

[4] From the standpoint of other vehicles characterized in the FMVSS, R2X's footprint most closely resembles that of a golf cart or neighborhood electric vehicle — two well-understood vehicle categories with similar operational constraints.

[5] National Highway Traffic Safety Administration, Federal Motor Vehicle Safety Standards, 63 Fed. Reg. 33194, 33194 (June 17, 1998) (codified at 49 C.F.R. Pt. 571) (hereafter, "LSV rule").

B. Environmental Impact

The novelty of autonomous technology should not overshadow other major benefits of the R2X. When designing the R2X, Nuro chose to develop a vehicle that is fully electric, instead of choosing a hybrid or conventionally fueled vehicle, because of the additional efficiency and social benefit that comes with a battery-powered vehicle. A zero-emission vehicle, each R2X will replace potentially hundreds of trips, the vast majority of which utilize conventionally-fueled personal vehicles. The electricity that powers the R2X can come from a wide-variety of sources, including alternative fuels. The R2X has two compartments to enable batched or combined trips, plotting the most efficient routes from store to consumers, thereby lowering the energy and economic cost per mile for last mile transport.

To provide insights into the potential scale of R2X's environmental impact, consider that more than 20% of all privately-operated vehicle trips are people going to the store to shop, typically with only a single occupant in the car.[6] Deployed at scale to deliver products such as groceries, home goods, and hardware, R2X could replace the vast majority of these trips for an individual consumer, and reduce the total number of vehicle trips to and from any given retailer by combining similar trips into one and finding efficient routes, contributing to lower air and noise pollution and traffic congestion.

The grocery delivery segment is a prime example of the sort of impact the R2X can have on the environment. At least 90% of grocery trips are done via personal vehicles, the remaining approximately 10% are delivered by a variety of services, but most are still delivered by personal vehicles or heavy-duty delivery trucks.[7] The lower cost per mile of autonomous delivery robots, such as the R2X, combined with the ability to lower delivery fees, will incentivize more households to use delivery services and reduce environmental impact.

C. Safety Opportunities & Benefits

At Nuro, our goal is to produce robots that are as neighborly as they are helpful. Because of our unique footprint providing last-mile delivery to homes and businesses, Nuro's devices will be routinely visible to the consumer, accountable directly to the neighborhoods and communities in which they operate, and commercially successful only if they are regarded as safe and beneficial. We have engaged with a range of stakeholders in the communities where we plan to operate — including law enforcement agencies — to understand what is important to them, . For those reasons, core to the Nuro business model is the production of a vehicle that is designed to be uniquely safe, leveraging the particular benefits of providing goods delivery (rather than personal transport) to drive new innovations not possible with passenger vehicles. This philosophy permeates the company's approach to engineering.

From the standpoint of the car's autonomous driving system, the custom hardware implemented in R2X is among the industry's most advanced, incorporating 12 cameras providing high-definition, constant, and 360° views of the environment from various elevations and with overlapping vantages; top-mounted LIDAR to provide precise representations of the

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[6] Federal Highway Administration, National Household Travel Survey, 2017, https://nhts.ornl.gov.

[7] See, e.g., *Forbes*, https://www.forbes.com/sites/pamdanziger/2018/01/18/online-grocery-sales-to-reach-100-billion-in-2025-amazon-set-to-be-market-share-leader/ ("...estimates of online grocery's share of the total $641b U.S. grocery market vary, from 2% to 4.3% according FMI-Nielsen...").

surrounding area and movements; and on-board computing power capable of running all aspects of driving onboard and without the limitations of network connectivity. With respect to software, the system implements world-leading computer vision powered by advanced machine learning — capable of continual improvement.

We are proud of the steps that we are taking to ensure R2X delivers on our vision of meeting and, in many cases, exceeding applicable safety requirements. As just one example, while the FMVSS provides no performance specification for the braking system of NEVs, R2X features braking components that mirror the performance of full-speed passenger vehicles. Elsewhere as well, R2X leverages performance-standard-compliant hardware that is more commonly found on a full-speed vehicle, despite the fact R2X's operation will be exclusively below 25mph.

Nuro's unique application of exclusive goods transportation has also permitted safety innovations that are impossible or implausible in all existing production vehicles designed to carry passengers. As this petition will later detail, the absence of passengers not only precludes the need for a traditional glass windshield but offers an opportunity to replace it with a softer front-end featuring fewer hard edges, designed to minimize harm to pedestrians or other road users in the event of collision — while still possessing the appearance of a windshield so as not to confuse other road users about the vehicle's orientation. The same holds for side mirrors, where the lack of need for them to provide for driver visibility decreases the strike risk to pedestrians and other road users. The low weight of the vehicle — at roughly 2,500 lbs. unladen, dramatically lower than other cars and even electric vehicles in operation today — keeps its kinetic energy perhaps uniquely low among motor vehicles on the road, minimizing harm from potential impact or malfunction of any sort. It will be capable of emergency maneuvering or stopping that would not be plausible for a passenger-laden vehicle. Finally, in the unlikely event that the vehicle ever encounters an unavoidable collision scenario, it has the unique opportunity to prioritize the safety of humans, other road users, and occupied vehicles over its own contents and chassis. All these innovations are core to the company's vision of R2X as a uniquely safe presence on roads.

The vehicle is also designed with numerous redundancies and safety features. All driving and safety-critical systems are redundant, including backups for computing, steering, braking, and sensing systems. The system also checks for errors hundreds of times per second, ensuring all systems are operating safely. Where the system determines the a fail-safe mode is necessary, the vehicle will pull over to the closest available safe location possible; the onboard computer continuously maps multiple trajectories to a safe pullover spot, enabling pullover from trusted data even if a sensing system suddenly becomes faulty. As a further backup, R2X is also monitored remotely by experienced human operators who are extensively trained in the vehicle's systems. These operators prioritize safety, driving with caution and consideration. They can take control of R2X at any time and operate it remotely ("teleoperation" or "remote operation") should an issue arise, such as an unreliable sensor reading – provided the remote operator believes teleoperation would be safer. These operators can also take over after a pullover event, if appropriate given the circumstances. Further, R2X is designed to alert the safety driver of situations where teleoperation might be preferred, before it becomes necessary. To ensure reliable remote operation, Nuro uses several redundant, independent cellular connections with end-to-end encryption, and R2X's routing avoids areas with weak cellular connection, using custom-built maps. If necessary, the vehicle is also capable of full wireless

command override from central operations centers, and it hosts a number of other camera-based security features designed to minimize any dangerous intervention in its operation.

To help communicate the intent of Nuro's battery-powered vehicles to other road users, R2X is equipped with a sound generator that mimics an internal combustion engine, giving intuitive clues as to when the vehicle is accelerating, slowing down, or idling, along with standard lighting equipment such as turn signals and brake lights. We continue to research additional ways to communicate the vehicle's intent.

In pursuit of our goal to develop vehicles that are as natural and skilled at driving as their human counterparts (if not more), our top priority is and will always be the safety of all people in the roadway ecosystem.

D. Economic Opportunity & Jobs

Nuro's innovations also offer economic and consumer benefits. Once deployed at scale, Nuro's robot can enable many more businesses to offer affordable home delivery, including small businesses that today cannot afford to offer delivery at all. This could increase the volume of sales for local business and ultimately add jobs. It also would more evenly distribute operations throughout the day — meaning shorter wait times for goods, better planning for stores, and more reliable and predictable employment for workers.

To design and manufacture these vehicles, Nuro already employs over 200 people directly in the United States, and indirectly supports many more jobs through our partners located throughout the country. Numerous people will also participate in every delivery to pick-and-pack goods, supervise the vehicle fleet, and provide maintenance.

Nuro's ability to promote economic opportunity is dependent on producing a vehicle that, in meeting all the appropriate safety standards for its class, does not include extraneous technology that would add mass and expense without improving safety — such as those designed exclusively to safeguard passengers inside of a traditional passenger vehicle.

3. The Department's Recent Request for Comment on *Removing Regulatory Barriers for Vehicles With Automated Driving Systems* and announcement of forthcoming rulemakings

Parenthetically, Nuro notes the Department's recent Request for Comment (RFC)[8] on *Removing Regulatory Barriers for Vehicles With Automated Driving Systems* and the announcement, with the Department's recent guidance *Automated Vehicles 3.0: Prepared for the Future of Transportation*, that advanced notices of proposed rulemaking on this subject will be forthcoming. The request for comment and announcement of potential rulemakings are focused primarily on the regulatory barriers to traditional passenger vehicles with ADSs, including barriers in test procedures, definitions incommensurate with ADSs, or human-interface controls and notifications. As R2X is not a traditional passenger vehicle, action on this exemption petition need not await the final regulatory framework that will ultimately result from the Department's request for comment.

[8] Docket No. NHTSA-2018-0009

4. The Vehicle is a Low-Emission Vehicle as Defined by 49 U.S.C. 30113(a)

49 USC 30113(a) defines a low-emission vehicle as meeting the standard set by section 202 of the Clean Air Act, and "emitting an air pollutant in an amount significantly below one of those standards." The R2X is a zero-emission vehicle. It will emit no hydrocarbons, carbon monoxide, oxides of nitrogen, or particulate matter, which are four of the air pollutants regulated under the Clean Air Act. Its emissions are therefore significantly below the Clean Air Act standards.

5. A Temporary Exemption Would Not Unreasonably Degrade the Safety or Impact Protection of the Vehicle

Designing the vehicle with safety as a paramount concern, Nuro has taken significant steps to ensure compliance with all possible, relevant provisions of Federal law and regulation. Compliance also assists in our goal of ensuring that our vehicle naturally integrates with others in the transportation ecosystem, and is no more unusual to motorists than any standard NEV. Thus, within the FMVSS No. 500, for instance, R2X will comply with, *inter alia,* requirements pertaining to:

- Maximum Speed S5(a)
- Headlamps S5(b)(1)
- Front and rear turn signal lamps S5(b)(2)
- Taillamps S5(b)(3)
- Stop lamps S5(b)(4)
- Reflex reflectors: color and position S5(b)(5)
- Parking brake S5(b)(7)
- VIN S5(b)(9)
- Seat belts S5(b)(10)[9]

However, in this design process, Nuro encountered a limited number of circumstances in which the desired outcome of producing the safest possible vehicle for all road users came into direct conflict with FMVSS compliance. It is those cases on which Nuro seeks the Department's exemption on the basis that providing this exemption would make easier the field testing of a low-emission vehicle and would not unreasonably lower the safety or impact protection level of that vehicle.

While Nuro believes an exemption from these provisions would actually increase safety, any risk associated with the exemption would not be unreasonable in part because of the limited nature of Nuro's deployment. The requested exemption is temporary, lasting two years, and would be limited to no more than 2,500 vehicles in any 12-month period. In fact, under current plans, the number of R2X vehicles involved in an initial pilot on public roads would be few in number — [ ] through 2019 — to provide thorough evaluation of all aspects of their operation. While it is Nuro's intention to produce a later model of autonomous delivery vehicles at a larger scale, the company views complete confidence in their safe and reliable operation is a prerequisite to any possible expansion.

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[9] Section (b)(10) states the requirement for a "Type 1 or 2 seat belt assembly confirming to Sec. 571.209 of this part, Federal Motor Vehicle Safety Standard No. 209, *Seat belt* assemblies, installed at each designated seating position" (emphasis added). Because it does not accommodate a human driver or any passengers, R2X does not possess any designated seating positions requiring such seat belt assemblies.

Like other LSVs, R2X is also designed for a lower-risk operating environment, including through a maximum speed of 25-mph, lower mass than conventional passenger vehicles, and a typical concentration on neighborhood driving that results in fewer annual miles on the road. In addition, unlike other LSVs, R2X has built-in operational limitations that prevent it from operating except on marked and pre-mapped surface streets, and prevent it from violating traffic laws, including speed limits.

And, as described in detail above in the Statement of Public Interest, R2X has a number of safety features not present in other LSVs, ranging from its autonomous driving system to advanced braking components to a safety-enhanced front-end.

A detailed analysis follows for each specific provision of FMVSS No. 500 that Nuro is seeking exemption from.

In Detail: Exemption Requests Would Not Unreasonably Degrade the Safety or Impact Protection of the Vehicle

Nuro hereby requests exemption from the following provisions of the FMVSS No. 500 on Low-Speed Vehicles, 49 CFR Part 571.500:

I. S5(b)(6) An exterior mirror mounted on the driver's side of the vehicle and either an exterior mirror mounted on the passenger's side of the vehicle or an interior mirror,
II. S5(b)(8) A windshield that conforms to the Federal motor vehicle safety standard on glazing materials (49 CFR 571.205).
III. S5(b)(11) The rear visibility requirement, as specified in S6.2 of FMVSS No. 111.

I. S5(b)(6) An exterior mirror mounted on the driver's side of the vehicle and either an exterior mirror mounted on the passenger's side of the vehicle or an interior mirror.

R2X (1) possesses no operational need for physical mirrors to achieve rear- and side-visibility safety benefits intended with this mandate; (2) possesses a new and superior safety system that incorporates sensors dramatically exceeding operational visibility of other LSVs (and passenger vehicles) on the market, the testing of which would be in the public interest; and (3) would present unnecessary strike risk to passengers and other road users if forced to comply with this provision of the FMVSS. If exempted, R2X would differ from a vehicle that complies with the standard because it would have a sensor-based safety system and would not have exterior or interior mirrors.

<u>No Operational Need, Superior Visibility</u>
R2X is an advanced design autonomous vehicle, equipped with a self-driving system capable of performing all the functions of the human driver. Because this system does not have a human driver, or any passenger compartment, there is no need for the use of these mirrors in environmental detection, maneuvering, or other operation of the vehicle. Instead, the autonomous system relies on a series of sensors, including multiple cameras, radars, and LIDAR, to provide a perfect 360-degree, live image of the surrounding area. These sensors are always on when the vehicle is operating, and their information is continually processed by the

perception system — in contrast to a human driver who must remove his or her eyes from the forward picture in order to glance into a mirror. The sensing system has complete angles of visibility, overlapping within each system, and multiple overlapping (and therefore more redundant) means of providing that sensing. As an example, the following diagram provides an illustration of the complete angles of visibility available to the camera system.

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Figure 2: Visual Representation of Short and Long Range Cameras, Field of View, Top

FMVSS No. 500 does not state a performance standard for these side mirrors. However, to further document the safety benefits of Nuro's approach, it is worth noting the ways in which the system has durability, fail-safe, and redundancy features that considerably exceed visibility accorded by the mirrors prescribed by the FMVSS No. 500 S5(b)(6).

For durability, each camera — produced by the same manufacturer relied upon by passenger vehicle OEMs for their rear-view cameras — is waterproof, rated to International Electrotechnical Commission standard IP69K, rated for temperature exposure from -40° C to 85° C in operation. Combined with the LIDAR, these sensors provide visibility to the system that vastly exceed that available to any manned LSV driver. In the event of an outage or occlusion of any camera in any position (not just those providing rear visibility), the system can

immediately flag this fault. In such an event, the system is designed to rely first upon other cameras' significantly overlapping field of view; the LIDAR'S distance-and-motion tracking; and near-range radar — each providing 360° coverage — to navigate to safety and await repair. In addition, the system would be able to as a last-resort rely on extensive inch-by-inch mapping data of the operational environment kept onboard, as well as recent image memory in storage, to navigate to safety and await repair. Finally, a maximum operating speed of 25mph helps further ensure that any occlusion could be dealt with through safe deceleration. Further visibility benefits and specifications are articulated in the later section regarding 49 CFR 571.111 (rear-view visibility).

Unnecessary Risk Created by Compliance

Because these sensors provide superior operational benefit to a standard mirror, mirrors are not only unnecessary, but would actually create unnecessary risk for other road users — pedestrians in particular. As mentioned above, R2X has been designed with the safety of the ecosystem in mind, and this includes engineering designed to minimize the damage to others in the event of collision. R2X's planned operation in neighborhood environments makes protection for pedestrians especially important, and as other sections demonstrate, R2X has been engineered with particular attention to minimizing the physical harm in the event of a pedestrian strike. Several safety features provide for such a scenario. R2X's overall rounded contouring is engineered such that external objects coming into contact are more likely to glance off rather than suffer a perpendicular strike. Moreover, the highly deformable nature of the materials used for front and rear panels, as well as the "crumple zone" described in the subsequent section, minimize potential injury from a possible strike. The presence of a protruding mirror of any construction, particularly since unnecessary, would interfere with this impact-minimizing design. Such a protrusion would also increase the probability of a potential collision by creating an unnecessary strike risk in the event of inappropriately close proximity to pedestrians, bicyclists, or other road users.

For these reasons, excluding mirrors does not unreasonably degrade the safety or impact protection of the R2X vehicle.

II. S5(b)(8) A windshield that conforms to the Federal motor vehicle safety standard on glazing materials (49 CFR 571.205).

With respect to a windshield conforming to glazing standards in 49 CFR 571.205, Nuro seeks an exemption from this low-speed vehicle mandate on the basis that (1) R2X possesses no operational (driver or passenger) need for a forward windshield to provide the front visibility, passenger ejection, or passenger impact safety benefits intended with this mandate; (2) the inclusion of a compliant windshield (e.g. glass) would introduce avoidable risk in the event of a collision if instead R2X is able to (3) introduce a new and superior safety system designed to minimize the force of any impact, the testing of which would be in the public interest. If exempted, R2X would differ from a vehicle that complies with the standard because it would not have a windshield conforming to glazing standards and would have a new and superior front-end safety system, including rounded contouring, softer materials, and a "crumple zone."

No Operational Need, Superior Visibility

The intent of the FMVSS No. 500 S5(b)(8) mandate is to provide visibility to the driver of activities outside the vehicle, protect from environmental factors that might impair the driver's

vision or attention, and protect passengers inside the vehicle in the event of certain kinds of collisions or impacts from external objects. In the case of R2X, a windshield provides no benefit to the vehicle's ability to observe and react to its surroundings; no benefit of protection to driver or passengers (given their absence); and no protection from collisions that might otherwise be afforded by other materials that do not meet the glazing materials standard in FMVSS No. 205 . Thus, compliance with the windshield mandate provides no inherent safety benefit to driver or passengers.

R2X possess an equivalent or superior vantage to what a human might possess in a similarly-situated NEV. R2X is an advanced design autonomous vehicle, equipped with a self-driving system capable of performing all the functions of the human driver. Because this system does not have a human driver, or any passenger compartment, there is no need for a windshield providing visibility inside the vehicle to enable environmental detection, maneuvering, or other operation of the vehicle. Instead, the autonomous system relies on a series of sensors, including 12 high-definition cameras, radars, and one LIDAR, to provide a perfect 360-degree, live image of the surrounding area. Of particular note for this standard, the multiple angles of these overlapping sensors ensure the absence of "blind spots" in front of, behind, or around the vehicle itself — including immediately in front of the vehicle. Thus, in many instances, the front visibility afforded by these sensors would outperform visibility offered by compliant windshields on a number of vehicles in the LSV and other classes. These sensors are always on when the vehicle is operating, and their information is continually processed by the perception system. Figure 2, above, provides visual representations of the vehicle's field of view.

Unnecessary Risk Created by Compliance; Alternative Would Improve Overall Safety

At the same time, given the absence of operational need, compliance with this mandate would create unnecessary risk to other road users in the event of various kinds of potential collisions. Despite considerable progress in windshield technology designed to prevent undue harm to drivers or other road users in the event of a collision, windshields made of glass or other similar materials possess a rigidity that can cause harm in pedestrian or other collisions without breakage, and further risk of bodily harm in the event of shattering. By contrast, R2X's unique application and lack of passenger presents an opportunity to replace the rigid windshield with a nose-cone of different, softer materials that is designed to soften the force of any impact to an exterior body in the same manner as a "crumple zone" does for a driver or passenger. Together with the rounded contouring described above, this alternative pedestrian protecting front-end without a windshield would further improve safety performance.

Nuro recognizes that despite the diversity in styles, windshields provide a rough visual indication of the front of a vehicle, giving a useful visual cue to other drivers as to potential behavior. For that reason, as depicted in Figure 3, R2X's front will be equipped with a plate mimicking the visual appearance of a windshield. The result is a design that provides intuitive cues to other road users as to its behavior while reducing the risk of bodily harm to others.

Figures 3-4 — left, front view demonstrating visual similarity to windshield; right, rear view with reflectors and compliant brake lights

R2X's windshield- and window-less design, a result of its lack of occupants or a passenger compartment, minimize risk of injury from impact to glazing surfaces. The self-driving system relies on sensors and cameras that are not dependent on a windshield for visibility. Nuro's sensors, form factor, and low-top speed help minimize the risk of injury from accidents. For these reasons, excluding a compliant windshield does not unreasonably degrade the safety or impact protection of the R2X vehicle.

III. Exemption from parts of rear visibility requirements specified in paragraphs S6.2 of FMVSS No. 111 that are inapplicable to an electric vehicle without human occupants

FMVSS No. 500 requires that "low-speed vehicles shall comply with the rear visibility requirements specified in paragraphs S6.2 of FMVSS No. 111." FMVSS No. 111 requires that vehicles be able to display a rearview image meeting requirements outlined at S6.2.

R2X has a comprehensive sensing system capable of providing a "clear and reasonably unobstructed view" to the rear of the vehicle.[10] The autonomy system accesses this view at all times, including when in the reverse position. This sensing system is capable of meeting all the field of view and image size requirements of S6.2.1 and S6.2.2 after each durability test specified in S14.3.1, S14.3.2, and S14.3.3. The vehicle also will not reverse if the autonomy system or remote operator detects a person, animal, or object behind the vehicle. In addition, Nuro has developed a means for NHTSA to verify compliance with the standard by means of a remote operator. However, some of the testing procedures used to verify compliance with the standard, and some of the timing requirements, do not translate in a straightforward fashion to an autonomous vehicle. Specifically, Nuro requests exemption from the following requirements:

- In the timing requirements, the linger time and deactivation requirements (S6.2.4-5)
- In the testing procedures for the field of view requirement, the requirements for vehicle conditions related to the fuel tank, driver's seating position, and steering wheel (S14.1.2.2, S14.1.2.5, S14.1.7)

[10] 49 CFR 571.111.S.2.

- In the testing procedure for the image response time test, the requirements for opening the driver's door (S14.2)

When promulgating the rear-visibility rule, the Department explicitly considered excluding LSVs from the rule's applicability based on their superior visibility.[11] However, the Department noted that because model designs of LSVs differ across manufacturers in the extent of their rearview field of view, it would include LSVs within the scope of the rule, and LSV "manufacturers who believe that their vehicles are designed so as to enable drivers to avoid backover crashes without a rear visibility system . . . may petition for a temporary exemption under 49 CFR Part 555." Likewise, in interpreting FMVSS No. 111 in light of the emergence of autonomous vehicle technology, the Department has noted that manufacturers may "petition the agency for an exemption from these provisions."[12]

Nuro therefore requests an exemption from the subset of rear visibility requirements of FMVSS No. 111 S6.2 listed above, on the grounds that it would make the development or field evaluation of a low-emission vehicle easier and would not unreasonably lower the safety or impact protection level of R2X. As described below, R2X has a comprehensive rear view with no blind spots, including multiple cameras with overlapping fields of view, available to the self-driving system and to a remote operator during any backing event. Additionally, R2X's autonomy system acts on this information to stop when objects or people are in the rear view. This fulfills the standard's objective of providing "a clear and reasonably unobstructed view to the rear." Therefore, this exemption would not unreasonably lower the safety or impact protection level of R2X.

Field-of-View, Image Size, and Durability

As articulated above, R2X is an advanced design autonomous vehicle, equipped with a self-driving system capable of performing all the functions of the human driver.

The autonomous system itself relies on a series of sensors, including multiple cameras, radars, and LIDAR, to provide a perfect 360-degree, live image of the surrounding area. These sensors are always on when the vehicle is operating, and their information is continually processed by the perception system — in contrast to a human driver who must remove his or her eyes from the forward picture in order to glance at a rearview display.

Figure 1 (above) provides an overview of the range of visibility options, including rear-view visibility, available to the sensing system. Adding to those specifications, the below figures demonstrate R2X's ability to, via its onboard sensors, satisfy the field-of-view and image size tests articulated in S6.2.1 and S6.2.2:

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[11] National Highway Traffic Safety Administration, Federal Motor Vehicle Safety Standards; Rear Visibility, 79 Fed. Reg. 19178, 19197-98 (Apr. 7, 2014).

[12] NHTSA interpretation to Mr. Chris Urmson of Google, Feb. 2016, https://isearch.nhtsa.gov/files/Google%20--%20compiled%20response%20to%2012%20Nov%20%2015%20interp%20request%20--%204%20Feb%2016%20final.htm

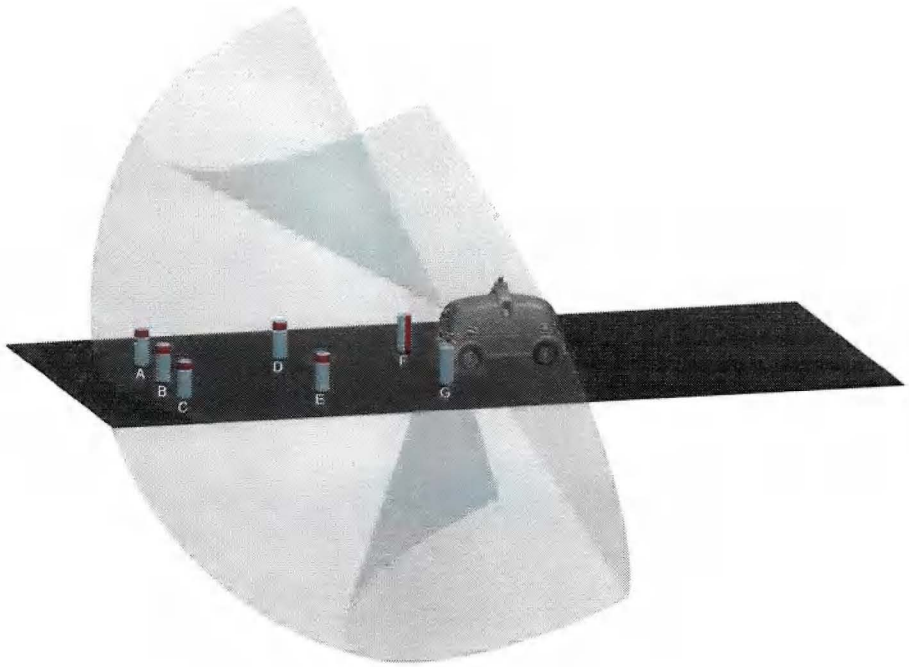

FIGURE 5: Visual Representation of Short Range, Wide Angle Camera (1x Body Rear) Single, Field of View, Side

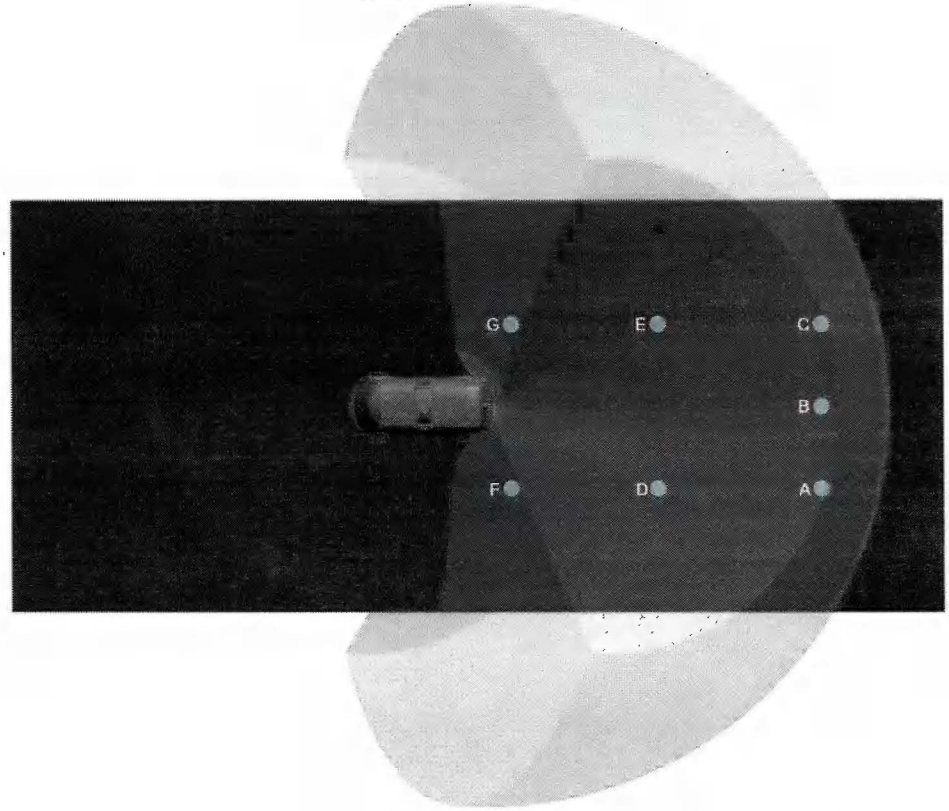

FIGURE 6: Visual Representation of Short Range, Wide Angle Camera (1x Body Rear) Single, Field of View, Top

R2X is further capable of satisfying the field of view and image size requirements following the durability test specified in S14.3.1, S14.3.2, and S14.3.3, utilizing those same sensors in the manner prescribed by these Sections.

A means for NHTSA to verify compliance with the standard is discussed below.

Timing and Nature of Display

FMVSS No. 111 S6.2.3-6.2.6 require an image to be displayed within 2 seconds of a backing event beginning, to always appear in the default position when beginning a backing event, and to avoid distracting the driver during forward operation. R2X's overlapping sensors described above are always on when the vehicle is operating, and their information is continually processed by the perception system — in contrast to a human driver who must remove his or her eyes from the forward picture in order to glance at a rear-view display. They provide the image immediately upon powering on the vehicle (less than 2 seconds), and do not move from the default view of a comprehensive rearview image. Thus, for the purpose of autonomous operation, the salient information that this section mandates the vehicle operator possess (live rearview image within specified parameters) is dutifully collected and processed (and indeed exceeded) by the on-board perception system.

In order to avoid driver distraction, the standard requires that the image display be deactivated when the direction selector is removed from the reverse position and after the backing event has ended (S6.2.4 and S6.2.5). Because R2X's autonomy system uses its rearview cameras during forward motion to gain a comprehensive understanding of its environment and avoid collisions with vehicles or objects approaching from the rear, deactivating the view to these cameras while in forward motion would significantly decrease the vehicle's safety. The purpose of the standard is satisfied because the autonomy system is capable of processing the information from all cameras without distraction. Nuro is therefore requesting an exemption from S6.2.4-5; this would not unreasonably lower the safety of the vehicle because the vehicle can process information from its front- and rear-facing sensors simultaneously, without distraction.

The Department's Estimation of the Probability of Avoiding Backover Crashes

In the Department's Regulatory Impact Analysis accompanying the final rear visibility rule, it included an analysis of the "probability of avoiding fatal backover crashes."[13] This analysis reviewed crash histories and available studies to estimate the probability that historic accidents would have occurred with different potential technologies, including mirrors, ultrasonic or radar sensors, or 130-degree or 180-degree cameras. The department considered three factors: "the percentage of cases found to be 'avoidable,' avoidability (factor f_A) [based on whether the pedestrian was believed to be within the rear visibility technology's field of view], the percentage of cases in which the system performs and provides the needed information (factor f_S), and the percentage of cases where drivers will recognize the information from the system and act appropriately to actually avoid a crash (factor f_{DR}) [driver reaction]."

[13] Office of Regulatory Analysis and Evaluation, National Center for Statistics and Analysis, NHTSA, *Final Regulatory Impact Analysis, Backover Crash Avoidance Technologies: FMVSS No. 111* (Mar. 2014), pg. 34 [RIA].

These same factors can be applied to R2X to show that it does not unreasonably lower vehicle safety, and in fact has a superior probability of avoiding backover crashes.

- Avoidability (f_A): The Department's analysis showed that in 90% of cases, the crash was avoidable or probably avoidable with the highest performance safety device, a camera with a 180-degree field of view, because the pedestrian was at some point in a zone that was visible by cameras. R2X's cameras have a 360-degree view, with no blindspot big enough for even a small child to stand in. In addition, this is supplemented by ultrasonic sensors, radar sensors, and LIDAR, which also provide redundant 360-degree view. Therefore, in 100% of cases, the pedestrian would be in R2X's field of view. Even if only a single camera were considered — the short-range, wide-angle camera at the rear of the vehicle — this single camera has a greater than 180-degree view (approaching 190-degrees at some heights), providing equivalent or greater visibility than the cameras prescribed in the standard.
- System performance (f_S): The Department notes that for cameras, "Fs is always equal to 100% because the camera always displays objects that are within the coverage area." As R2X features cameras meeting or exceeding the standard's requirements, this factor would also be 100% for R2X. In addition, R2X's redundant cameras and sensors provide additional backup, beyond what is present in standard passenger vehicles, in situations where a camera could become occluded.
- Driver reaction (f_{DR}): The Department conducted and reviewed studies of the rate that drivers react to the information provided by cameras and sensors and stop their vehicle's motion, and found that the driver acts to avoid the crash in 18% of cases where their vehicle uses sensors and 37% of cases where the vehicle uses cameras. Much as for a human driver, the process of "driver reaction" for an autonomous vehicle consists of two phases: perception and planning. First, the vehicle needs to detect an object within its field of view and identify that it is something that should not be backed over; for example, the software must correctly detect and identify a pedestrian in the road. Second, the vehicle must react appropriately, by halting the reverse motion or altering its path to avoid the object. One advantage of autonomous driving is that a computer will not make the human errors of forgetting to look at the screen or ignoring warning sounds, as the Department found happens more than half the time. To understand our system's current performance, we randomly selected 12 scenes[14] from our vehicle's case history over the last 2 months (which includes forward motion with the same perception and planning software as applies in reverse), where a pedestrian was proximate and in the vehicle's field of view, and simulated our current software's performance on the scene. In 100% of these cases, the vehicle successfully detected the pedestrian or object and avoided a crash. In cases where a remote operator controls the vehicle while reversing, the driver reaction would be the same or better than a human driver inside a passenger vehicle, because the remote operator will always be looking at the rear-view screen.

Based on this analysis, Nuro's vehicle has the potential to significantly improve safety compared to a standard vehicle complying with the rule. The Department's analysis and formula estimated

[14] This is consistent with the sample size used in the studies relied on by the Department in the Regulatory Impact Analysis (8 of the 14 studies relied on by the Department used an N of 7-14). RIA at 49-50.

that the 180-degree camera could prevent 24-33% of backover crashes; applying this same formula to R2X would project that 100% of these crashes could be avoided.

Ability to Verify Compliance with the Standard

Previously, the Department has interpreted "driver" and "operator" in FMVSS No. 111 as referring to the self-driving system in cases of autonomous vehicles.[15] However, in its letter to Google, the Department noted the need for a testing procedure to satisfy itself that the images provided to the self-driving system meet the requirements for field of view, image size, timing, and durability. As noted above, R2X is capable of full operation by an authorized operator located outside the vehicle, equipped with all necessary visualization and control equipment, including displays. For the purposes of verifying the field of view, R2X is capable of simultaneously broadcasting the precise image called for in FMVSS No. 111 — with the timing and nature of display requirements articulated in the standard — to the remote operator. Because that image would be broadcast directly from the vehicle, it provides a reliable means of external verification that all field of view and image size requirements are met.

The rear visibility standard prescribes a testing procedure to ensure the field of view and image response time requirements are met. These procedures contain several elements that assume a vehicle with human occupants and do not contemplate a driverless electric vehicle, including:

- In the testing procedures for the field of view requirement, the requirements for vehicle conditions relating to the fuel tank, driver's seating position, and steering wheel (S14.1.2.2, S14.1.2.5, S14.1.7)
- In the testing procedure for the image response time test, the requirements for opening the driver's door and activating the starting system with the key (S14.2)

For the purpose of enabling the Department to verify that R2X's system does not unreasonably lower the safety level of the vehicle, Nuro has designed a test procedure that applies the standard's terms to the context of an electric vehicle designed to contain no passengers, as follows:

- R2X lacks a fuel tank. However, it contains an electric battery that may be fully charged prior to the test. For the purposes of subsection S14.1.2.2, Nuro's test procedure will regard the fuel as electric charge, and intends to conduct this test with a full battery, affording a functionally identical testing environment.
- The "driver's seating position" referred to in S14.1.2.5 is the seating position of the remote operator.
- R2X lacks a steering wheel; however, it is capable of conducting the field of view test consistent with the testing state (parallel wheels) called for in the test — therefore, Nuro's test procedure regards "steering wheel" as referring to the mechanical system orienting the wheels for the purpose of manipulating the wheels' angle perpendicular to the road. This is consistent with all other drive-by-wire cars, which use values sent by telematics to the power steering system as a replacement for the mechanical linkages of

[15] Interpretation to Mr. Chris Urmson of Google, Feb. 2016 ("we agree that the information required by the provisions of FMVSS No. 111 that must be provided to the 'driver' or 'operator' may be provided to the SDS [Self-Driving System]"); *see also*, USDOT, Automated Vehicles 3.0: Preparing for the Future of Transportation, Oct. 2018 ("the Department will interpret . . . the definitions of "driver" and "operator" to recognize that such terms do not refer exclusively to a human, but may in fact include an automated system.")

a traditional steering wheel. Nuro's approach provides for an identical testing environment as prescribed in the field of view test.

- Similarly, R2X does not possess a "driver's door" or "passenger doors," but does have cargo compartments that serve as the principal means of accessing the vehicle's interior. The standard's test procedure, which specifies opening and closing said doors, is designed to simulate the mix of atmospheric conditions the vehicle will undergo when the vehicle interior is subject to the environment of the exterior, to ensure that exposure does not limit performance. R2X is capable of undergoing a test providing the same operational conditions with respect to any and all doors. Therefore Nuro regards the testing procedure as referring to the principal vehicle doors designed for regular access to the vehicle's interior compartment(s), providing for an identical testing environment as prescribed in the image response test.

This test procedure provides the Department with the ability to verify that R2X's autonomy and sensing systems do not unreasonably lower the safety of the vehicle compared to a traditional rear visibility procedure, and therefore Nuro requests an exemption from the elements of the requirements in FMVSS No. 111 discussed above.

6. A Temporary Exemption Would Facilitate the Development or Field Evaluation of the Vehicle

Nuro's self-driving technology has been subject to extensive testing, and operation on public roads represents the next step in the development and testing of R2X. Prior to the testing of the custom chassis seen in R2X, Nuro developed its custom hardware and software for sensing and automation on a fleet of traditional passenger vehicles. These vehicles were equipped with identical sensors and software ultimately included in R2X, but due to their status as traditional passenger vehicles, were already certified as fully FMVSS compliant and approved by the relevant states for autonomous testing on public roads. With these vehicles in near continuous operation for the last year, Nuro has been able to test our technology in real-world situations, a range of roadway environments, and in various adverse conditions. In addition to on-road testing of these light-duty test vehicles, Nuro has conducted further testing in simulated environments to conduct twenty-fold more testing of this technology under a range of circumstances.

The prototype model for the custom, purpose-built chassis for which Nuro seeks FMVSS exemption in this petition has itself also been extensively tested in the company's private testing facility in California. Designed to simulate the conditions of neighborhood driving in urban and suburban areas, this private testing has provided Nuro with the opportunity to measure the custom vehicle's performance, informed by the data and improvement of the on-road tests, but in a more controlled setting. Combined, these two methods of operation — passenger-vehicle data collection with a safety driver, and custom-vehicle testing in a closed, non-public environment — have led to continual improvement in the performance of the vehicle's systems.

However, Nuro has nearly exhausted the safety gains that can accrue from closed-environment testing of its custom vehicle and passenger-vehicle data collection. As recognized by the Department's recent guidance on autonomous vehicles, on-road testing is important to

autonomous vehicle development.[16] Autonomous vehicle technology learns from the experience of encountering diverse situations: R2X implements world-leading computer vision powered by advanced machine learning — capable of continual improvement. Testing on public roads will expose R2X to a greater variety of real-world situations than can be achieved in simulation or use of other FMVSS-compliant hardware platforms, and would enable R2X's performance to continually improve. Relying on passenger-vehicle data collection, while a valuable tool for improving the safety of the autonomy system, is also not a sufficient substitute for public road testing with R2X; by testing on public roads, Nuro also will get valuable insight into how to safely navigate the response of other road users to R2X's unique design, and how best to maximize the safety advantage of R2X's narrower width and improved maneuverability. For R2X's performance to continually improve, it is critical to test the vehicle in a suitable, controlled, yet public environment.

To facilitate the development and field evaluation of R2X, this exemption is required. Without the exemption, Nuro would be required to add extraneous equipment during public roads testing that increases pedestrian strike risk, adds mass, and worsens the impact of collisions. A temporary exemption would enable safer and easier field evaluation and development of R2X.

Looking ahead, if approved for these exemptions and, subsequently, testing on public roads, Nuro would take a highly incremental and controlled approach to deployment. To begin, any area designated for public-road testing would be extensively evaluated for optimal environmental conditions, then thoroughly mapped by state-of-the-art technology to ensure the entirety of the operational environment is well-understood and internalized by the autonomy system. Consistent with the SAE definition of Level 4 automation, at no point would the vehicle operate outside of this controlled, evaluated, and mapped environment. Any early on-road tests would occur with human-manned professional safety drivers with override abilities supervising the vehicle for any anomalies in behavior.

For Nuro's R2X to have the opportunity to provide the range of substantial public environmental, safety, and economic benefits articulated herein, the company will require the ability to test on public roads, and therefore requests with this exemption petition the ability to produce a very safe vehicle.

7. A Statement Whether, at the End of the Exemption Period, the Manufacturer Intends to Conform with the Standard

If approved, Nuro requests that NHTSA grant this exemption for a period of twenty-four (24) months from the date of issuance, the period during which we anticipate conducting initial testing and limited-scale internal and consumer pilots of this hardware and the service it is designed to support. This proposed sunset acknowledges the rapid pace of technological innovation and the need for relevant authorities to periodically evaluate the continued public safety interest and appropriateness of granted exemptions. We further anticipate that in that timeframe, Congress may grant the Department different authorities or guidance with respect to the treatment of ADSs on public roads within the United States. We also anticipate the

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[16] *See* USDOT, *Automated Vehicles 3.0*, p. 1 ("On-road testing and early deployments are important to improving automated vehicle performance and allowing them to reach their full performance potential. Careful real-world testing allows developers to identify and rapidly fix system shortcomings, not just on individual vehicles but across fleets.").

Department will have further elaborated on other ADS guidelines or regulations. Likewise, Nuro's design process allows for rapid prototyping, and by the end of this period, Nuro will be working on a new model vehicle. Given this fast moving environment, it is too early to determine whether R2X will be produced after the end of the exemption period or whether future models of the vehicle will also require exemptions from FMVSS No. 500. Nuro will reevaluate conforming with the standard in advance of the expiration of this exemption, subject to the laws and regulations in effect at that time.

8. A Statement That Not More Than 2,500 Exempted Vehicles Will be Sold in the United States in Any 12-month Period For Which an Exemption May Be Granted

Not more than 2,500 exempted vehicles will be sold in the United States in any 12-month period for which an exemption may be granted.

9. If the Applicant Is Presently Manufacturing a Vehicle Conforming to the Standard, the Results of Tests Conducted to Substantiate Certification to the Standard

Nuro has built a prototype vehicle conforming to the elements of FMVSS No. 500 that are the subject of this exemption petition. This vehicle will be equipped with mirrors, for which testing is not required by the standard. It will also feature a windshield; Nuro will rely on the manufacturer's certification that it satisfies the glazing requirements, as permitted by the FMVSS. The rear visibility requirement is not applicable to this vehicle based on the date of manufacture and the phase-in schedule of the standard.

10. The Results of Any Tests Conducted on the Vehicle that Demonstrate its Failure to Meet the Standard, Expressed as Comparative Performance Levels;

This provision does not apply to this exemption petition because it is not possible to express the differences between the vehicle and the standard in comparative performance levels.

10. Conclusion

Thank you for your consideration of this petition. We are prepared to respond to any questions from you or the public regarding these requests. If you have any questions, please do not hesitate to reach out to us.

Respectfully,

David Ferguson
President
Nuro, Inc.