



**Ghost Locomotion Inc**

[www.driveghost.com](http://www.driveghost.com)

September 27, 2021

Submitted via Regulations.gov

Michael Regan  
Administrator, Environmental Protection Agency

Stephen S. Cliff, Ph.D.  
Acting Administrator, National Highway Traffic Safety Administration

Re: Comments to Docket ID Nos. EPA-HQ-OAR-2021-0208 and NHTSA 2021-0053

Dear Administrator Regan and Acting Administrator Cliff:

The vision of an electric consumer vehicle mass market is within sight. The proposed standards, combined with the President's Executive Order and automakers' electric vehicle commitments, make it possible for the majority of new light-duty vehicles offered for sale in the United States soon to be electrically driven.

As automakers roll out increasingly electric fleets, they will also be equipping these cars with more autonomous capabilities. Although higher-level autonomous driving may affect various of the regulatory elements analyzed in the proposals, scant attention is given to the impact that a progressively more autonomous fleet may have on these analyses.

It is axiomatic that well-designed autonomous driving systems can operate more quickly and more accurately than human drivers, and are not subject to fatigue, distraction or other driving impairments. The safety promise of an autonomous future will begin when Level 4 autonomous systems are deployed for personal transportation.<sup>1</sup> Level 4 systems will not abdicate responsibility to the driver at the last minute nor defer to a driver with slower

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<sup>1</sup> The Levels of Autonomy are defined by SAE J3016\_202104.

computational abilities and response times, but instead will retain responsibility for making driving and fallback decisions.

The marriage of electrification and autonomy, however, is endangered. Current systems generally operate either only semi-autonomously or with such compute complexity that use of the ADAS or ADS systems shrinks the available power supply in electric vehicles, substantially diminishing the available battery range. According to one industry analyst: “In general, most assisted driving system developers agree that battery electric AVs will lose about 40-50% of the range available from the base vehicle.”<sup>2</sup> Yet, emerging ADS technology can solve this dilemma and conserve battery power with more efficient algorithms and general purpose sensors, requiring substantially less computing power.

To meet the aggressive goals for EV deployment, the EV market will need to extend beyond consumers who choose them solely or mostly for environmental reasons. They must also meet the growing consumer demand for autonomy – with drivers able to safely rely on the autonomous system for highway driving. If autonomous operation unduly limits range, electric vehicles will be less consumer-friendly and less likely to proliferate at a pace necessary to meet the current EV goals. High-level autonomy free of additional range anxiety will likely spur demand for electric vehicles.

Ghost Locomotion Inc. (“Ghost”) appreciates the opportunity to provide input into how technology, such as that being developed by Ghost, will affect the driving environment envisioned in the proposals.<sup>3</sup> A high-autonomy and low-compute system can:

- Provide autonomy without undue battery drain, particularly if coupled with a credit system such as that proposed by Ghost below.
- Reduce fatalities even beyond those expected due to the rebound effect and mass reduction; and
- Allow consumers to redirect time typically spent driving and put it towards other productive use.

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<sup>2</sup> See <https://carbuzz.com/news/autonomous-driving-will-massively-impact-range>.

<sup>3</sup> Ghost’s founders have a history of successfully developing highly secure software systems. CEO John Hayes previously founded Pure Storage to store and protect critical customer data for Fortune 500 companies. Pure Storage is now publicly listed on the New York Stock Exchange. CTO Volkmar Uhlig architected the L4 Pistachio Microkernel, which protects biometric data on billions of Apple and Android devices worldwide. Ghost was founded in 2017 and, in addition to its primary location in Mountain View, California, includes a software formal verification team in Sydney, Australia and a radar development team near Dallas, Texas.

## Ghost Technology

Ghost is developing a unique Level 4 autonomous driving system. Ghost technology is centered around a revolutionary approach to crash avoidance. The Ghost approach tracks the motion of clusters of pixels in a scene to determine the relative distance and velocity of the object to the vehicle. Based on this information, and other information collected about the environment, Ghost technology makes next step driving decisions.

Unlike other systems, the Ghost approach is not dependent on a pre-set classification of images and is not subject to the error conditions of mis- or not recognizing objects. The Ghost system does not need to know what an object is in order not to hit it. As a result, it can manage many of the edge cases other systems cannot.

## Preserving Battery Range

Current systems offer either high autonomy or low power draw, but not both. The Ghost system uses more efficient algorithms and general purpose sensors. The resulting compute efficiency requires significantly less energy than robotic-based and/or other compute-intense systems now in use. More efficient autonomous driving capability protects battery range, an essential precursor for a successful marriage between electric drive and autonomy.

That the market for autonomous and electric vehicles will grow together is clear.<sup>4</sup> One estimate projects that 7% of the total automotive market will have autonomous capability by 2023, and that more than half the total market will have Level 3 and higher capability by 2030.<sup>5</sup> At the same time, the proposed regulations support the President's vision and automakers' commitments to substantially expand their electric-drive offerings by 2030. Autonomy and electric vehicles offer a 1-2 punch, encouraging consumers to modernize their vehicles, accelerating both the safety benefits offered by autonomy and the environmental benefits offered by electric power.

The technology paths, however, are not necessarily compatible. Operating in autonomous mode can strain the power supply and result in a significant drain in available range. Tesla, for example, has estimated an approximate 25% range reduction when operating in driver-assist

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<sup>4</sup> Steps such as the recent enactment of SB 500 in California – mandating that future Level 3-5 autonomous driving systems be installed only on electric vehicles – represent this movement. Other states are likely to follow California's path. Market analysts, moreover, opine that the pace of vehicle development and refresh may become shorter with electric vehicles than what has become traditional with regard to ICE vehicles. See Robinet (IHS Markit), "Preparing for the new, faster EV product cadence," SAE International (Aug. 30, 2021). See also <https://www.ucsus.org/about/news/california-bill-requires-all-new-self-driving-vehicles-be-zero-emission-2030>.

<sup>5</sup> See <https://techcrunch.com/2021/05/24/light-is-the-key-to-long-range-fully-autonomous-evs/>.

mode.<sup>6</sup> A study by Nature Energy suggests that, with regard to certain LiDar systems, aerodynamic drag can also contribute to battery drain, particularly for suburban driving.<sup>7</sup>

The agencies should consider ensuring that electric vehicle range is maintained through a credit program aimed at encouraging low-compute and high-autonomy systems. The credits could be expressed similarly to how the agencies value off-cycle credits or alternatively could be applied through a multiplier. The program could, for example, offer credits for higher-level autonomous systems operating at 120 watts or below, with additional credit opportunities should the systems be able to operate at wattages below that level (e.g., 75 watts or 50 watts). To reflect how systems are used in the real world, wattage should be measured when the system is operating with full redundancy, and not when redundancies are in standby mode.

Such a credit program would acknowledge the impending linkage between autonomous and electric vehicles and support systems that allow consumers to take advantage of autonomy without losing benefits associated with their electric vehicles. By recognizing and potentially encouraging systems that draw less power the agencies can help catalyze a driving environment devoid of both motor vehicle fatalities and motor vehicle emissions.

An advanced AV credit system would be consistent with the agencies' proposed consideration of expanding the off-cycle credit program.<sup>8</sup> Flexibility and opportunities for credits can spur technological innovation, new investments, and greater deployment of EVs. Indeed, CARB's Zero Emission Vehicle (ZEV) program has played a key role in Tesla's success.<sup>9</sup>

### Fewer Fatalities

Ghost's breakthrough approach to crash avoidance has the potential to substantially reduce crash occurrence on highways, including those attributed to mass reduction and those associated with the rebound effect resulting from better fuel efficiency.<sup>10</sup>

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<sup>6</sup> *Id.*

<sup>7</sup> See [https://www.nature.com/articles/s41560-020-0644-3.epdf?sharing\\_token=-2h1AonBifDqx83jK3qlHdRgN0jAjlWel9jnR3ZoTv0PkV4h-0BfuDxTt20euiNiwgJB6g8CLgd2HJNRMDTCS8\\_8JcBgF0-pv7-mboFgY-h88dzdolgR95UKVmkCdlw2hfjGxCUzDwlWphvJ5ecSDurTdn-t4gEFdDq8Le\\_8BcntFFo1h9arXsOtQfTjkgSBdelM2H\\_hHPNj0YprRaW1w%3D%3D](https://www.nature.com/articles/s41560-020-0644-3.epdf?sharing_token=-2h1AonBifDqx83jK3qlHdRgN0jAjlWel9jnR3ZoTv0PkV4h-0BfuDxTt20euiNiwgJB6g8CLgd2HJNRMDTCS8_8JcBgF0-pv7-mboFgY-h88dzdolgR95UKVmkCdlw2hfjGxCUzDwlWphvJ5ecSDurTdn-t4gEFdDq8Le_8BcntFFo1h9arXsOtQfTjkgSBdelM2H_hHPNj0YprRaW1w%3D%3D), cited in *Id.*

<sup>8</sup> See 86 Fed. Reg. at 43, 762-67 (Aug. 10, 2021)

<sup>9</sup> See, e.g., <https://www.cnbc.com/2021/05/18/tesla-electric-vehicle-regulatory-credits-explained.html>

<sup>10</sup> Mass reduction can increase or reduce safety risk, depending on whether weight is removed from smaller/lighter vehicles (increasing crash incompatibility) or from larger/heavier vehicles (reducing crash incompatibility). The rebound effect results in higher risk exposure by virtue of more time spent traveling on the

Much of the benefit tied to autonomous driving results from minimizing human error. Ghost believes that crash avoidance is more than a by-product of autonomy. It is an essential capability and necessary foundation for any autonomous driving system, just as the central nervous system in humans is designed to instantly react and move the body out of harm's way when an object is rapidly approaching. It is indeed the missing link to the success of autonomous driving systems.

The data is clear that driver assistance features or additional sensors alone cannot solve our motor vehicle safety problems. More comprehensive crash avoidance must be deployed to avert the vast majority of motor vehicle fatalities. In a 2019 article updating an earlier study, researchers at Carnegie Mellon University suggested that if all light duty vehicles in the fleet were equipped with three current driver assistance systems – forward collision warnings, lane departure warning and blind spot alert – it “could prevent or reduce the severity of as many as 1.6 million crashes, including 7200 fatal crashes,” with the highest reduction for fatal crashes associated with Lane Departure Warning.<sup>11</sup> While that is substantial progress, with more than 35,000 motor vehicle fatalities annually, it is not alone sufficient to meet the safety need.

The safety impact analyses in the proposals point largely to crash protection considerations. The additional fatalities estimated are largely due to the increased on-road exposure and/or possible crash incompatibility due to mass reduction in certain vehicles. As more advanced crash avoidance systems deploy into the fleet, the relationship between exposure and crash risk may need to be reconsidered and adjusted. Trailblazing crash avoidance will upend this dynamic, minimizing risk associated with exposure and also reducing any impacts from mass reduction or longer vehicle retention.

### **Productive Time Recouped**

The agencies have long recognized time as a significant private benefit. The proposals monetize the productive time recaptured as part of the cost/benefit analyses.

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roadways. NHTSA estimates that the proposed standards will result in an additional 1822 fatalities: 115 associated with mass reduction, 584 due to the increased exposure arising from the rebound effect of consumers driving more in response to better fuel efficiency, and 1123 attributed to delays in vehicle turnover mostly associated with the increased cost of the new motor vehicles and the fewer safety features incorporated into older ones. (NHTSA NPRM, 86 Fed. Reg. 49602, 49742 (Sept. 3, 2021). For its part, EPA estimates an additional 2288 fatalities, with 1952 (about 85%) associated with increased driving and the remainder with increased fatality risk. (EPA NPRM, 86 Fed. Reg. 43726, 43793 (Aug. 10, 2021).

<sup>11</sup> (Khan, Harper, Hendrickson, Samaras, “Net-societal and net-private benefits of some existing vehicle crash avoidance technologies,” Accident Analysis and Prevention (Feb. 2019) (<https://doi.org/10.1016/j.aap.2019.02.003> (p. 7).

NHTSA estimates these savings by calculating the amount of refueling time avoided—including the time it takes to find, refuel, and pay—and multiplying it by DOT’s “value of time of travel savings estimate.” EPA similarly considers “the costs of time spent refueling . . . calculated as the total amount of time the driver of a typical vehicle would spend refueling multiplied by the value of their time. If less time is spent refueling vehicles under the proposed standards, then a refueling time savings would be incurred.”<sup>12</sup>

Level 4 autonomy represents another opportunity to recapture time. With Level 4 operation, the autonomous driving system operates all aspects of the dynamic driving task within its Operational Design Domain and retains responsibility to manage unexpected or emergent conditions. Only with Level 4/5 operation is a driver able to focus their attention on a task other than driving. With education and experience, consumers will increasingly demand the ability to redirect their commuting time and put it to use in other productive ways. This evolution is likely to occur during the time frame encompassing the useful life of the vehicles subject to the proposals, and while it may be too speculative at this point to quantify the value of the time saved, the agencies should nonetheless recognize this as a benefit of Level 4/5 autonomy.

### **The Energy Efficiency Gap**

According to NHTSA’s proposal, automakers maintain that consumers tend to value the benefits of better fuel economy over a period of approximately 30 months, even though the actual benefits may extend further.

Ghost maintains that consumers will value the benefits of autonomous driving for much longer, and indeed for as long as the autonomous driving system is able to be updated and remain competitive within the market. A critical aspect of software-centric autonomous driving will be its ability to update the software systems on an ongoing basis. The speed with which the systems can be updated means that the reliability and performance of these systems can be regularly enhanced. As a result, while consumers may not readily recognize the longer-term financial benefits of a more fuel-efficient vehicle, they should continue to acknowledge the ongoing benefits of a self-learning and self-improving autonomous driving system.

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<sup>12</sup> See NHTSA Draft Technical Support Document, pp. 388 and 415-416; EPA NPRM, pp. 204). Recaptured time does not include time that is otherwise recouped – such as using the restroom or buying snacks at the gas stations. Nor does it include routine trips to the gas station (e.g., every Sunday evening) because that time has already been institutionalized into the consumer’s regular activities. This analysis may become more complex with regard to electric vehicles, as some owners can charge at home overnight, others at shopping malls or grocery stores, and yet others may need to take the time to charge at other publicly available stations.

## Conclusion

The advent of reliable, safe, and low-compute Level 4 autonomous driving will have a profound impact on how consumers in the United States use their vehicles. In the coming decades, vehicles are likely to be both electrically driven and autonomous. The result should be fewer crashes, less congestion, and more time recouped. It is possible to achieve these results without unduly draining battery range – thus allowing for a fully compatible electric and autonomous future which can not only eviscerate motor vehicle emissions but motor vehicle fatalities as well.

We would welcome the opportunity to meet with and brief your staff on these issues. In the meantime, please contact me at [jackie@gh.st](mailto:jackie@gh.st) with any questions.

Sincerely,

A handwritten signature in cursive script that reads "Jackie Glassman".

Jacqueline Glassman  
General Counsel, Ghost Locomotion Inc.