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Regulating Driving Automation Safety

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REGULATING DRIVING AUTOMATION SAFETY

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ABSTRACT

Over forty thousand people die in motor vehicle crashes in the United States each year, and over two million are injured. The careful deployment of driving automation systems could prevent many of these deaths and injuries, but only if it is accompanied by effective regulation. Conventional vehicle safety standards are inadequate because they can only test how technology performs in a controlled environment. To assess the safety of a driving automation system, regulators must observe how it performs in a range of unpredictable, real world edge cases. The National Highway Traffic Safety Administration (NHTSA) is trying to adapt by experimenting with a novel regulatory strategy. Instead of setting standards, the agency is using its statutory powers in unprecedented ways—ordering automation developers to report crashes daily and directing rapid recalls that require changes to defective software. NHTSA is betting that intense monitoring and the credible threat of recalls will push developers to prioritize safety. This Article argues that NHTSA's experimental strategy could be transformed into effective safety regulation. Regulators should (1) require that all new vehicles be equipped with telematics that can send safety data and receive software updates over the air; (2) mandate universal crash reporting; and (3) use recalls to force developers of driving automation systems that create unreasonable risks to restrict where their systems can operate until they can develop safer code.

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INTRODUCTION

Over a half century ago, there was a moment when ending the bloodshed on the highways seemed possible. In 1966, Congress unanimously passed the National Traffic and Motor Vehicle Safety Act.[1] Its purpose was to "reduce traffic accidents and deaths and injuries resulting from traffic accidents."[2] The Safety Act created a new agency, which became the National Highway Traffic Safety Administration (NHTSA), and gave it the power to set safety standards for vehicles and equipment.[3] The architects of the Safety Act intended for NHTSA to use rulemaking to force automakers to develop safer technology.[4] They hoped to "channel the creative energies and vast technology of the automobile industry into a vigorous and competitive effort to improve the safety of vehicles."[5]

For several years, NHTSA exercised that rulemaking power. It crafted many of the regulations that became the Federal Motor Vehicle Safety Standards (FMVSSs).[6] But, as Jerry Mashaw and David Harfst have explained in their definitive history of NHTSA, the honeymoon ended quickly.[7] In the 1970s, judicial decisions curtailed the agency's rulemaking. The Sixth Circuit held that each standard must allow for compliance to be measured by an "objective" test, which would produce identical results if duplicated.[8] Then the Ninth Circuit held that, before NHTSA could enforce a standard, it needed to show that it was "practicable" based on evidence from vehicles "in use" on the roads.[9] These

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[1] National Traffic and Motor Vehicle Safety Act of 1966, Pub. L. No. 89-563, 80 Stat. 718 (codified as amended at 49 U.S.C. §§ 30101–83); B<small>ILL</small> C<small>ANIS</small>, C<small>ONG</small>. R<small>SCH</small>. S<small>ERV</small>., R46398, M<small>OTOR</small> V<small>EHICLE</small> S<small>AFETY</small>: I<small>SSUES FOR</small> C<small>ONGRESS</small> 2 (2020) (noting that the Motor Vehicle Safety Act of 1966 was approved unanimously).

[2] 49 U.S.C. § 30101.

[3] *Id.* § 30111(a). NHTSA was briefly known as the National Highway Transportation Safety Bureau. J<small>ERRY</small> L. M<small>ASHAW</small> & D<small>AVID</small> L. H<small>ARFST</small>, T<small>HE</small> S<small>TRUGGLE FOR</small> A<small>UTO</small> S<small>AFETY</small> 6 (1990).

[4] *See* M<small>ASHAW</small> & H<small>ARFST</small>, *supra* note 3, at 62–63 (explaining that, during hearings on the Safety Act, there was a "political consensus" in favor of forcing automakers to develop safer technology).

[5] S. R<small>EP</small>. N<small>O</small>. 1301, at 1 (1966), *reprinted in* U.S.C.C.A.N. 2709.

[6] *See* M<small>ASHAW</small> & H<small>ARFST</small>, *supra* note 3, at 69–80 (describing NHTSA's rulemaking in the late 1960s and early 1970s); Jerry L. Mashaw & David L. Harfst, *From Command and Control to Collaboration and Deference: The Transformation of Auto Safety Regulation*, 34 Y<small>ALE</small> J. R<small>EG</small>. 167, 176–80 (2017).

[7] See Mashaw & Harfst, *supra* note 6, at 87–103 (recounting NHTSA's judicial losses in the 1970s).

[8] Chrysler Corp. v. U.S. Dep't of Transp., 472 F.2d 659, 676 (6th Cir. 1972).

[9] PACCAR, Inc. v. Nat'l Highway Traffic Safety Admin., 573 F.2d 632, 635, 643 (9th Cir. 1978).

decisions made the agency reluctant to try to force automakers to develop new technology.[10]

When rulemaking met resistance, NHTSA turned to recalls. The Safety Act had granted the agency power to determine that a vehicle or equipment was defective and compel the manufacturer to order a recall.[11] In 1974, Congress amended the Safety Act to strengthen the recall power by increasing fines, imposing new reporting obligations, and authorizing subpoenas.[12] The courts facilitated recalls by holding that NHTSA did not need to prove the cause of a defect as long as the vehicle or equipment failed in practice.[13] As the pace of rulemaking declined, the frequency of recalls rose.[14] But recalls had a limited impact on safety because they let automakers set the standards to which they would be held.[15] More recently, NHTSA has returned to rulemaking but with diminished ambitions. It has aimed to diffuse existing safety technology across the industry rather than force the development of new technology.[16]

In the first few decades after the Safety Act, the roads got safer. From 1966 to 2011, the rate of traffic fatalities per 100 million vehicle miles traveled (VMT) declined from 5.50 to 1.10.[17] NHTSA's vehicle safety regulations contributed to the decline, and so did improvements in road design, emergency medicine, and driver behavior.[18] In the last decade, though, the fatality rate stagnated.[19] After the pandemic, it started to increase, and, in In 2021, it reached 1.37.[20] The trend line looks grim.

Yet for the first time since the 1960s, radical progress in road safety seems possible. Recent advances in sensors, computing, and software have enabled the

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[10] MASHAW & HARFST, *supra* note 3, at 173–80.

[11] *See* 49 U.S.C. § 30118(b) (authorizing the Secretary of Transportation to make defect determinations); *id.* § 30120(a)(1) (prescribing defect remedies, including recalls).

[12] *See* Motor Vehicle and Schoolbus Safety Amends. of 1974, Pub. L. No. 93-492, 88 Stat. 1470, 1478, 1480 (codified at 15 U.S.C. §§ 1398, 1402, 1409); *see also* MASHAW & HARFST, *supra* note 3, at 121–35 (describing the recall provisions of the 1974 amendments).

[13] *See* United States v. Gen. Motors Corp., 518 F.2d 420, 427 (D.C. Cir. 1975) ("[T]he Government may discharge its burden of establishing a defect by showing a significant number of failures without making any showing of cause.").

[14] *See* Mashaw & Harfst, *supra* note 6, at 182–87.

[15] *See id.* at 251–54 (evaluating evidence on the costs and benefits of recalls).

[16] *See id.* at 216–24 (describing NHTSA's rulemaking in the 2000s and early 2010s).

[17] NAT'L HIGHWAY TRAFFIC SAFETY ADMIN., DOT HS 813 527, TRAFFIC SAFETY FACTS 2021, at 13 (2023) [hereinafter TRAFFIC SAFETY FACTS], https://crashstats.nhtsa.dot.gov/Api/Public/ViewPublication/813527.

[18] NAT'L HIGHWAY TRAFFIC SAFETY ADMIN., DOT HS 812 069, LIVES SAVED BY VEHICLE SAFETY TECHNOLOGIES AND ASSOCIATED FEDERAL MOTOR VEHICLE SAFETY STANDARDS, 1960 TO 2012, at x (2015).

[19] *See* TRAFFIC SAFETY FACTS, *supra* note 17, at 13.

[20] *Id.*

development of driving automation technology.[21] The careful deployment of driving automation could greatly reduce the frequency and severity of crashes. Since the invention of automobile, automotive safety technology has been designed to make *vehicles* safer. Automation has the potential to make *driving* safer. But that potential will only be realized if regulators force developers to prioritize safety.

To understand the potential risks and benefits of driving automation, it is critical to distinguish among different kinds of technology. A little jargon can help. The basic unit of regulation is a *driving automation system*—a combination of sensors, computers, and software that can perform at least some of the subtasks of driving on a sustained basis.[22] A driving automation system that can perform the entire driving task—in other words, drive without human supervision—is called an *Automated Driving System (ADS).[23]* There are three important kinds of driving automation systems on the road today.[24]

A *Level 2 system* (*L2 system*) can perform some—but not all—driving subtasks under the active supervision of a human driver.[25] An L2 system is a driver assistance technology. It is *not* an ADS. A typical L2 system can keep a vehicle centered in its lane and maintain a fixed headway behind the vehicle ahead. But the driver must keep their eyes on the road, detect objects and events that the system misses, and disengage the system when necessary.

A *Level 4 Automated Driving System* (*L4 ADS*) can drive a vehicle on its own.[26] L4 ADS-equipped vehicles are sometimes called "self-driving cars," "driverless cars," or "autonomous vehicles." But for the purpose of regulation, the driver is the ADS. Every person in the vehicle is a passenger. And the vehicle need not carry a passenger at all.

A *Level 3 Automated Driving System* (*L3 ADS*) has capabilities in between an L2 system and an L4 ADS. An L3 ADS can drive a vehicle in some conditions but relies on a person as a fallback—a "fallback-ready user."[27] The fallback-

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[21]   *See* discussion *infra* Part I.B.
[22]   *See* SAE INT'L, SURFACE VEHICLE RECOMMENDED PRACTICE J3016 30–32 (2021).
[23]   *See id.* at 6.
[24]   The SAE taxonomy also includes two other kinds of driving automation systems—L1 and L5. *See id.* at 30–32. L1 features, such as a standalone adaptive cruise control, can either steer or accelerate and brake but not both. *See id.* at 30; *see also infra* Part I.B. An L5 ADS is an L4 ADS with no ODD restrictions. *See* SAE INT'L, *supra* note **Error! Bookmark not defined.**, at 32. No such system exists today.
[25]   *See id.* at 31.
[26]   *See id.*
[27]   *See id.*

ready user does not need to have their eyes on the road. But they must be receptive to a message from the ADS to resume driving.

These three kinds of systems are being deployed in different ways. L2 systems are widely available. More than half of model year 2023 vehicles come equipped with an L2 system, such as Ford BlueCruise, GM Super Cruise, or Tesla Autopilot.[28] L4 ADSs, by contrast, are not designed for individually-owned vehicles.[29] Instead, companies like Waymo (an Alphabet subsidiary) and Cruise (a GM subsidiary) are developing L4 ADS-equipped robotaxis.[30] Other companies are developing L4 ADSs for small package delivery vehicles or trucks.[31] L3 ADSs, like L2 systems, are designed for individually-owned vehicles, but so far they are more limited in scope. The only L3 ADS available in the United States is Mercedes Drive Pilot, a traffic jam assist feature.[32]

Each of these kinds of systems raises distinct safety issues. L2 systems present an urgent problem for regulators. While it is possible that they could make drivers safer, there is mounting evidence that they create serious safety risks.[33] Drivers using these systems are prone to become complacent and miss objects and events that the systems cannot manage safely. In the last several years, L2 systems—particularly Tesla Autopilot—have contributed to a series of fatal crashes.[34]

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[28] *See* Mike Monticello, *Ford's BlueCruise Ousts GM's Super Cruise as CR's Top-Rated Active Driving Assistance System*, CONSUMER REPORTS (May 8, 2023), https://www.consumerreports.org/cars/car-safety/active-driving-assistance-systems-review-a2103632203/.

[29] Keith Barry, *No, You Cannot Buy a Self-Driving Car Today*, CONSUMER REPORTS (Nov. 7, 2022), http://www.consumerreports.org/cars/autonomous-driving/no-you-cannot-buy-a-self-driving-car-today-a4355089516/.

[30] Ricardo Cano, *Driverless Taxi Service from Cruise and Waymo to Hit S.F. Streets*, S.F. CHRON. (Aug. 11, 2023, 6:03 PM), https://www.sfchronicle.com/sf/article/cruise-waymo-s-f-24-hour-driverless-taxi-service-18285010.php.

[31] *See, e.g.*, NURO, DELIVERING SAFETY (2021), https://nuro.sfo3.digitaloceanspaces.com/nuro-vssa-2022.pdf; AURORA, SAFETY REPORT (2022), https://info.aurora.tech/hubfs/Website%20Public%20Files/Q4_Safety_VSSA%202022_digital_r2.pdf.

[32] *See* Daniel Golson, *We Put Our Blind Faith in Mercedes-Benz's First-of-its-Kind Autonomous Drive Pilot Feature*, VERGE (Sept. 27, 2023, 8:00 AM), https://www.theverge.com/2023/9/27/23892154/mercedes-benz-drive-pilot-autonomous-level-3-test.

[33] *See infra* Part I.C.1.

[34] *See* NAT'L TRANSP. SAFETY BD., COLLISION BETWEEN A SPORT UTILITY VEHICLE OPERATING WITH PARTIAL DRIVING AUTOMATION AND A CRASH ATTENUATOR ix–x, 26–29, 58 (2018) [hereinafter NTSB MOUNTAIN VIEW REPORT], https://www.ntsb.gov/investigations/AccidentReports/Reports/HAR2001.pdf (discussing Tesla Autopilot's contribution to fatal crashes in Williston, Florida; Culver City, California; Delray Beach, Florida; and Mountain View, California).

L4 ADSs create more favorable risk-risk tradeoffs. They could make driving radically safer.[35] They will never drive drunk, drowsy, or distracted. They can be programmed to follow speed limits, obey stop signs and traffic lights, maintain a safe headway, and yield the right of way. An L4 ADS developer can learn from the experience of a fleet of vehicles and improve its system's performance over time. For now, though, L4 ADSs are still struggling with common driving scenarios.[36] They can move in unpredictable ways that contribute to crashes.[37] There has only been one fatal crash involving an L4 ADS, but there likely will be more serious crashes as they are deployed more widely.[38]

The safety risks of L3 ADSs are less well understood. Experts are skeptical that it is safe for an ADS to rely on a person with their eyes off the road as a fallback.[39] But since the only available L3 ADS is designed for low speed travel on highways, there is no evidence on how L3 ADSs designed for more challenging conditions might perform.

Assessing driving automation safety is a hard problem. A driving automation system does not perform a discrete function like a brake does. Its performance cannot be assessed by a duplicable test in a controlled environment, like measuring how many feet it takes to bring a vehicle to a stop on a track. With an L2 system, regulators need to assess how the system interacts with diverse and fallible human drivers. With an L4 ADS, regulators need to assess the driving of an artificial intelligence. With an L3 ADS, regulators need to assess *both* the ADS's driving and its interaction with the fallback-ready user. Each of these

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[35] *See infra* Part I.C.2.

[36] *See* Matt McFarland, *Waymo's Self-Driving Taxi Struggles with Left Turns and Puddles. But It's Still Winning Over Some Arizona Riders*, CNN (Oct. 13, 2021, 11:08 AM), https://www.cnn.com/2021/10/12/tech/waymo-one-year/index.html.

[37] There is a rich debate on how tort and product liability law will and should respond to crashes involving ADSs. For an overview of the issues, see generally Bryant Walker Smith, *Automated Driving and Product Liability*, 2017 MICH. ST. L. REV. 1 (2017). For reform proposals, see Kenneth S. Abraham & Robert L. Rabin, *Automated Vehicles and Manufacturer Responsibility for Accidents: A New Legal Regime for a New Era*, 105 VA. L. REV. 127, 145–71 (2019); Mark A. Geistfeld, *A Roadmap for Autonomous Vehicles: State Tort Liability, Automobile Insurance, and Federal Safety Regulation*, 105 CALIF. L. REV. 1611, 1632–60 (2017); David C. Vladeck, *Machines Without Principals: Liability Rules and Artificial Intelligence*, 89 WASH. L. REV. 117, 141–50 (2014); and Matthew Wansley, *The End of Accidents*, 55 U.C. DAVIS L. REV. 269, 313–35 (2021).

[38] *See* NAT'L TRANSP. SAFETY BD., COLLISION BETWEEN VEHICLE CONTROLLED BY DEVELOPMENTAL AUTOMATED DRIVING SYSTEM AND PEDESTRIAN 14–19 (2018) [hereinafter NTSB TEMPE REPORT], https://www.ntsb.gov/investigations/accidentreports/reports/har1903.pdf (discussing the contribution of Uber's ADS to the only fatal crash involving an ADS-equipped vehicle).

[39] *See* PHILIP KOOPMAN, HOW SAFE IS SAFE ENOUGH?: MEASURING AND PREDICTING AUTONOMOUS VEHICLE SAFETY 23–25 (2022).

systems may have vulnerabilities that are only revealed in "edge cases"—rare situations that require the system to behave differently than it behaves in similar situations.[40] The system may outperform unassisted drivers in normal conditions but make dangerous errors in edge cases.

A further complication is that driving automation systems are only designed to be used in limited operational design domains (ODDs). An ODD may include "environmental, geographical, and time-of-day restrictions" and the "presence or absence of certain traffic or roadway characteristics."[41] Most L2 systems are designed for access-controlled highways.[42] Many L4 ADSs are restricted to lower speed roads in dense, urban areas.[43] The first L3 ADS is designed only for highway traffic jams.[44] In each case, the ODD affects the system's safety risk profile.[45] Accordingly, any comparison between a driving automation system and unassisted drivers must carefully account for its ODD.

For most of the last decade, NHTSA struggled with how to regulate driving automation safety. The agency was ill-equipped for the challenge. NHTSA had some experience regulating active safety features that momentarily automate parts of driving, such as automatic emergency braking and electronic stability control.[46] But it lacked the expertise to evaluate the sophisticated software at the core of an ADS.[47] And the agency expressed concern that the rapid pace of technological change could quickly make any standards it set obsolete.[48]

NHTSA also faced legal obstacles to more proactive regulation. The difficulty of assessing driving automation safety would have made it hard to quantify the benefits of any proposed standard. The courts' insistence on objective tests and evidence from technologies "in use" would have complicated rulemaking.

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[40] For examples, see *id.* at 39–52.

[41] SAE INT'L, *supra* note **Error! Bookmark not defined.**, at 17.

[42] *See* Monticello, *supra* note 28.

[43] *Id.*

[44] *See* Golson, *supra* note 32.

[45] *See* KOOPMAN, *supra* note 39, at 66–67.

[46] Mashaw & Harfst, *supra* note 6, at 259–60 (automatic emergency breaking); *id.* at 219–21 (electronic stability control).

[47] *See* NAT'L HIGHWAY TRAFFIC SAFETY ADMIN., FEDERAL AUTOMATED VEHICLES POLICY 6 (2016) [hereinafter AV 1.0], https://www.transportation.gov/sites/dot.gov/files/docs/AV%20policy%20guidance%20PDF.pdf ("[W]e must rapidly build our expertise and knowledge to keep pace with developments.").

[48] *See id.* at 8 ("The speed with which [driving automation systems] are advancing, combined with the complexity and novelty of these innovations, threatens to outpace the Agency's conventional regulatory processes and capabilities.").

Faced with these constraints, NHTSA took a passive approach. It issued a few non-binding policy statements, asked ADS developers to self-certify their systems' safety, and otherwise ceded regulation to the states.[49] At the request of ADS developers, the agency used its powers of interpretation, exemption, and amendment to adapt the FMVSSs for vehicles without human controls, like steering wheels or brake pedals.[50] Even then, NHTSA stuck to its core expertise of conventional vehicle safety—it carefully avoided taking any position on the safety of the underlying ADS. The only time NHTSA deviated from this passive approach was when it confronted a startup that planned to sell a hastily developed L2 system directly to consumers.[51]

Then crashes started happening. In 2016, a Tesla equipped with its L2 system Autopilot crashed into a tractor-trailer crossing its path, killing the Tesla's driver.[52] NHTSA issued a report that largely exonerated Tesla.[53] The National Transportation Safety Board (NTSB), however, issued a dueling report on the same crash that was more critical of Tesla.[54] In 2018, an SUV equipped with Uber's L4 ADS struck and killed a pedestrian.[55] The NTSB criticized NHTSA and state regulators for inadequate scrutiny of ADS testing.[56] More serious crashes involving Tesla Autopilot emerged. In one fatal crash, a Tesla with Autopilot engaged drove itself into a metal lane divider while its driver played a video game.[57] The NTSB escalated its criticism on NHTSA, slamming the agency's "hands-off approach."[58]

In 2021, NHTSA changed direction. The new administration, the criticism from the NTSB, and the increasing public scrutiny of Autopilot crashes may all have contributed to the change. But NHTSA did not return to rulemaking. Instead, the agency started to experiment with using its investigative and recall

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[49] *See infra* Part II.A.

[50] *See infra* Part II.A.4.

[51] *See infra* Part II.A.3.

[52] Nat'l Transp. Safety Bd., Collision Between a Car Operating With Automated Vehicle Control Systems and a Tractor-Semitrailer Truck 1–2 (2017) [hereinafter NTSB Williston Report], https://www.ntsb.gov/investigations/accidentreports/reports/har1702.pdf.

[53] *See* Nat'l Highway Traffic Safety Admin., PE 16-007 Close Resume 11–12 (2017) [hereinafter ODI Williston Report], https://static.nhtsa.gov/odi/inv/2016/INCLA-PE16007-7876.PDF (concluding that Tesla Autopilot was not defective).

[54] *See* NTSB Williston Report, *supra* note 52, at 41 (finding that Tesla Autopilot lacked "an effective method of ensuring driver engagement").

[55] NTSB Tempe Report, *supra* note 38, at 1–2, 5.

[56] *See id.* at 58 (criticizing Arizona's "lack of a safety-focused application-approval process" and NHTSA's "inadequate safety self-assessment process").

[57] NTSB Mountain View Report, *supra* note 34, at 1–3, 19, 19 n.27.

[58] *Id.* at 65.

powers in novel ways. It issued an unprecedented standing general order (SGO) to automation developers to report serious crashes involving their systems within one day of the crash.[59] Then it released the data it collected to the public, inviting wider scrutiny of driving automation safety.[60]

NHTSA used its recall power to demand changes to defective driving automation software. In January 2022, the agency made Tesla recall an L2 feature that performed rolling stops.[61] The recall was unusually fast and cheap. Tesla simply cut the feature from its code and sent an over-the-air software update to its vehicles.[62] About two months later, NHTSA made the startup Pony.ai recall its L4 ADS after it drove an unoccupied vehicle into a median and hit a traffic sign.[63]

NHTSA made Cruise recall its L4 ADS three times—each time after a troubling crash.. In the first, a Cruise robotaxi stopped in the middle of an intersection while attempting to turn left and got hit by an oncoming car.[64] In the second, a Cruise robotaxi slammed into the back of an articulated transit bus.[65] In the third, a conventional vehicle hit a pedestrian and the force of the collision propelled her in front of a nearby Cruise robotaxi.[66] The ADS misinterpreted the situation and attempted to pull over, dragging the pedestrian forward.[67] In each

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[59] *See* NAT'L HIGHWAY TRAFFIC SAFETY ADMIN., IN RE FIRST AMENDED STANDING GENERAL ORDER 2021-01: INCIDENT REPORTING FOR AUTOMATED DRIVING SYSTEMS (ADS) AND LEVEL 2 ADVANCED DRIVER ASSISTANCE SYSTEMS (ADAS) 13–15 (2021) [hereinafter SGO], https://www.nhtsa.gov/sites/nhtsa.gov/files/2021-08/First_Amended_SGO_2021_01_Final.pdf.

[60] *See* NAT'L HIGHWAY TRAFFIC SAFETY ADMIN., DOT HS 813 324, SUMMARY REPORT: STANDING GENERAL ORDER ON CRASH REPORTING FOR AUTOMATED DRIVING SYSTEMS 4–7 (2022) [hereinafter ADS REPORT], https://www.nhtsa.gov/sites/nhtsa.gov/files/2022-06/ADS-SGO-Report-June-2022.pdf; NAT'L HIGHWAY TRAFFIC SAFETY ADMIN., DOT HS 813 324, SUMMARY REPORT: STANDING GENERAL ORDER ON CRASH REPORTING FOR LEVEL 2 ADVANCED DRIVER ASSISTANCE SYSTEMS 5–8 (2022) [hereinafter L2 REPORT], https://www.nhtsa.gov/sites/nhtsa.gov/files/2022-06/ADAS-L2-SGO-Report-June-2022.pdf.

[61] *See* NAT'L HIGHWAY TRAFFIC SAFETY ADMIN., PART 573 SAFETY RECALL REPORT 22V-037, at 1–4 (2022) [hereinafter ROLLING STOP RECALL], https://static.nhtsa.gov/odi/rcl/2022/RCLRPT-22V037-4462.PDF.

[62] *See id.* at 4.

[63] *See* NAT'L HIGHWAY TRAFFIC SAFETY ADMIN., PART 573 SAFETY RECALL REPORT 22E-016, at 1–3 (2022) [hereinafter PONY.AI RECALL], https://static.nhtsa.gov/odi/rcl/2022/RCLRPT-22E016-6814.PDF.

[64] *See* NAT'L HIGHWAY TRAFFIC SAFETY ADMIN., PART 573 SAFETY RECALL REPORT 22E-072, at 2–3 (2022) [hereinafter CRUISE UNPROTECTED LEFT RECALL], https://static.nhtsa.gov/odi/rcl/2022/RCLRPT-22E072-8020.PDF.

[65] *See* NAT'L HIGHWAY TRAFFIC SAFETY ADMIN., PART 573 SAFETY RECALL REPORT 23E-029, at 2–3 (2023) [hereinafter CRUISE MUNI BUS RECALL], https://static.nhtsa.gov/odi/rcl/2023/RCLRPT-23E029-4270.PDF.

[66] *See* NAT'L HIGHWAY TRAFFIC SAFETY ADMIN., PART 573 SAFETY RECALL REPORT 23E-086, at 3 (2023) [hereinafter CRUISE PEDESTRIAN CRASH RECALL], https://static.nhtsa.gov/odi/rcl/2023/RCLRPT-23E086-7725.PDF.

[67] *See id.*

of these recalls, Cruise agreed to make changes to its ADS software to avoid similar collisions in the future.

NHTSA has also opened two other investigations into Cruise's ADS, which are still ongoing. One is examining rear-end collisions in which the Cruise ADS braked hard unexpectedly and incidents in which Cruise's vehicles became immobilized on public streets.[68] The other is probing complaints that Cruise robotaxis have not exercised appropriate caution around pedestrians.[69]

NHTSA's most important driving automation recall involved Tesla Autopilot. In 2021, the agency announced that it was investigating a series of crashes in which Tesla vehicles with Autopilot engaged collided with first responder vehicles.[70] In 2022, it broadened the investigation and made clear that it would consider whether Autopilot's design contributed to foreseeable misuse by drivers.[71] In December 2023, NHTSA made Tesla recall Autopilot with an over-the-air software update that strengthened its driver monitoring system and alerted the driver when the system was leaving its ODD.[72] But the agency stopped short of requiring Tesla to restrict Autopilot so that it could not be engaged outside its ODD.[73]

In this Article, I argue that NHTSA's experimental approach to regulating driving automation safety could transform road safety regulation. NHTSA now has access to more timely information about crashes than ever before.[74] When a driving automation system is involved in a serious crash, the agency should hear within a day.[75] The recall power, once the weaker of NHTSA's statutory authorities, can become the primary instrument of regulation. Though recalls have little impact on safety when technology is stagnant, they can create

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[68] *See* NAT'L HIGHWAY TRAFFIC SAFETY ADMIN., PE 22-014 OPEN RESUME 1–2 (2022) [hereinafter CRUISE HARD BRAKING INVESTIGATION], https://static.nhtsa.gov/odi/inv/2022/INOA-PE22014-4871.PDF.

[69] *See* NAT'L HIGHWAY TRAFFIC SAFETY ADMIN., PE 23-018 OPEN RESUME 1–2 (2023) [hereinafter CRUISE PEDESTRIAN SAFETY INVESTIGATION], https://static.nhtsa.gov/odi/inv/2023/INOA-PE23018-11587.PDF.

[70] *See* NAT'L HIGHWAY TRAFFIC SAFETY ADMIN., PE 21-020 OPEN RESUME 1–2 (2021) [hereinafter AUTOPILOT PRELIMINARY EVALUATION], https://static.nhtsa.gov/odi/inv/2021/INOA-PE21020-1893.PDF.

[71] *See* NAT'L HIGHWAY TRAFFIC SAFETY ADMIN., EA 22-002 OPEN RESUME 4 (2022) [hereinafter AUTOPILOT ENGINEERING ANALYSIS], https://static.nhtsa.gov/odi/inv/2022/INOA-EA22002-3184.PDF (stating that the investigation will evaluate whether Tesla Autopilot "may exacerbate human factors or behavioral safety risks by undermining the effectiveness of the driver's supervision").

[72] *See* NAT'L HIGHWAY TRAFFIC SAFETY ADMIN., PART 573 SAFETY RECALL REPORT 23V-838, at 5 (2023) [hereinafter AUTOPILOT RECALL], https://static.nhtsa.gov/odi/rcl/2023/RCLRPT-23V838-8276.PDF.

[73] *See id.*

[74] *See infra* Part IV.B (detailing universal crash reporting).

[75] SGO, *supra* note 59, at 13–15.

powerful incentives in periods of rapid innovation. NHTSA can commit to forcing recalls of technology that creates unreasonable risks and thereby align automakers' economic interests with safety. To be sure, the new approach is fledgling. NHTSA's unconventional use of its investigative and recall powers has yet to be tested in court. And the modest changes that NHTSA accepted in the Tesla Autopilot recall suggests that the agency is still hesitant to pick a fight. But it is clear that NHTSA now has the opportunity to push innovation towards safety in a way that the architects of the Safety Act could only have dreamed.

This Article provides a three-step plan to turn NHTSA's experiment into effective regulation of driving automation safety.[76] First, NHTSA should set a standard that requires every new vehicle to be equipped with telematics that can transmit safety data and receive over-the-air updates. Second, it should expand the SGO to require that automakers report *all* serious crashes they learn about from their vehicle's telematics—not just crashes involving driving automation. Third, NHTSA should adopt a "fix-or-restrict" recall policy. When crash data suggests that a driving automation system is creating an unreasonable risk to safety, NHTSA should give the automaker a choice: fix the software or restrict the system's ODD to avoid the risk. These three steps would encourage the deployment of driving automation while mitigating the risks it creates. And none of the steps require legislation or a change in case law. NHTSA has the powers it needs.

The Article proceeds in four Parts. Part I explains how driving automation systems work and the safety issues they raise. Parts II and III analyze the history of NHTSA's regulation of driving automation safety. Part II shows how the agency took a passive approach for most of the last decade. Then Part III shows how NHTSA changed course and started to experiment with a novel regulatory strategy in the last three years. Part IV details the plan to transform the experimental strategy into effective safety regulation.

I. THE CHALLENGE OF DRIVING AUTOMATION

Regulating driving automation safety would be challenging even for an agency with no legal constraints and plentiful resources. Driving automation systems create high stakes risk-risk tradeoffs. Their net safety impact cannot be

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[76] For a proposal that would integrate federal regulation of ADS-equipped vehicles with state tort law, see Mark A. Geistfeld, *The Regulatory Sweet Spot for Autonomous Vehicles*, 53 WAKE FOREST L. REV. 337, 341–61 (2018).

determined on a test track or by a computer simulation.[77] And automation developers are continuously updating their systems, so past performance may not predict future performance.[78] To make progress, regulators must understand the differences among driving automation systems, assess their risks and benefits with limited data, and learn to react quickly as new data emerges.

A. History

Early driving automation systems evolved like traditional automotive technologies. The incumbent automakers developed new features that incrementally improved on existing features.[79] They added them to their existing models and marketed them to their existing customers.[80] In the 1990s, Toyota and Mercedes introduced adaptive cruise control.[81] Then in the 2000s, the automakers started to roll out lane centering assistance.[82] The combination of those two features created the modern L2 system.[83]

L4 ADSs have a different origin story. They were not born in Detroit.[84] They grew out of the U.S. military's interest in mobile robots.[85] In 2004, the Defense Advanced Research Projects Agency (DARPA) hosted a race for robotic vehicles called the Grand Challenge.[86] DARPA offered a $1 million prize for the first vehicle that could complete a course in the Mojave Desert.[87] Teams from UC Berkeley, Caltech, Carnegie Mellon, and other leading robotics labs entered the competition.[88] But none of the teams won the prize because none of their vehicles could complete the course.[89]

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[77]   *See infra* Part I.C.5.

[78]   *See infra* Part I.C.5.

[79]   Keith Barry, *Big Bets and Broken Promises: A Timeline of Tesla's Self-Driving Aspirations*, CONSUMER REPORTS (Nov. 11, 2021), https://www.consumerreports.org/autonomous-driving/timeline-of-tesla-self-driving-aspirations-a9686689375/.

[80]   *See id.*

[81]   *Id.*

[82]   *Id.*

[83]   *See* Monticello, *supra* note 28.

[84]   Both government and industry have been researching automated transportation since the late 1950's. For a brief history of earlier developments, see RODNEY K. LAY ET AL., THE UNITED STATES DEPARTMENT OF TRANSPORTATION STATUS' REPORT ON THE AUTOMATED HIGHWAY SYSTEM PROGRAM app. A, at 1–4 (1996).

[85]   *See* DEF. ADVANCED RSCH. PROJECTS AGENCY, GRAND CHALLENGE 2004 FINAL REPORT 2 (2004), https://www.esd.whs.mil/Portals/54/Documents/FOID/Reading%20Room/DARPA/15-F-0059_GC_2004_FINAL_RPT_7-30-2004.pdf ("[Department of Defense] missions require autonomous ground vehicles . . . .").

[86]   *Id.*

[87]   *Id.* at 2, 7.

[88]   *See id.* at 6.

[89]   *Id.* at 9.

DARPA did not give up after the disappointing results. In 2005, it hosted a second Grand Challenge on a similar desert course with a $2 million prize.[90] In the intervening year, the technology had progressed rapidly.[91] In the second Grand Challenge, some of the vehicles reached the finish.[92] Then in 2007, DARPA hosted the Urban Challenge, a race on a course designed to resemble city streets.[93] The vehicles competing in the Urban Challenge had to navigate intersections and interact with other vehicles, while complying with California traffic law.[94] Some of them succeeded.[95]

Silicon Valley watched the DARPA Challenges with interest. Google co-founders Sergey Brin and Larry Page attended the second DARPA Grand Challenge in disguises.[96] Over the next few years, Google assembled a team of engineers who had worked on the DARPA Challenges to explore whether ADS technology could be commercialized.[97] In 2010, Google's automated driving program, Project Chauffeur, was introduced to the public.[98]

In the early years of the last decade, Google and the automakers differed on how to develop the technology. In 2013, Google let some of its employees drive vehicles equipped with a prototype L2 system.[99] The company told the employees that they had to continuously supervise the system, but video revealed that they were "napping, putting on makeup and fiddling with their phones as the vehicles traveled up to 56 mph."[100] Google became concerned that

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[90] *See* DEF. ADVANCED RSCH. PROJECTS AGENCY, REPORT TO CONGRESS: DARPA PRIZE AUTHORITY 1, 3–11   (2006), https://www.grandchallenge.org/grandchallenge/docs/Grand_Challenge_2005_Report_to_Congress.pdf.

[91] *See id.*

[92] *Id.* at 8.

[93] *See* DEF. ADVANCED RSCH. PROJECTS AGENCY, DARPA URBAN CHALLENGE: FISCAL YEAR 2007 ANNUAL   REPORT   3–4   (2008), https://www.grandchallenge.org/grandchallenge/docs/DDRE_Prize_Report_FY07.pdf.

[94] *Id.*

[95] *Id.*

[96] Arjun Kharpal, *Google's Larry Page Disguised Himself During a Driverless Car Race to Hire the Founder of His Moonshot Lab*, CNBC, https://www.cnbc.com/2017/05/11/google-larry-page-moonshot-lab.html (July 31, 2017, 7:49 AM).

[97] *See* LAWRENCE D. BURNS & CHRISTOPHER SHULGAN, AUTONOMY 167–70 (2018) (describing the formation of Project Chauffeur).

[98] *Id.*; John Markoff, *Google Cars Drive Themselves, in Traffic*, N.Y. TIMES (Oct. 9, 2010), https://www.nytimes.com/2010/10/10/science/10google.html.

[99] *See* Paresh Dave, *Google Ditched Autopilot Driving Feature After Test User Napped Behind Wheel*, REUTERS (Oct. 31, 2017, 3:09 AM), https://www.reuters.com/article/us-alphabet-autos-self-driving/google-ditched-autopilot-driving-feature-after-test-user-napped-behind-wheel-idUSKBN1D00MD?il=0.

[100] *Id.*

its employees were losing situational awareness, so it stopped the experiment.[101] Since then, Google has focused on developing an L4 ADS and argued that humans should be taken out of the loop entirely.[102]

The automakers preferred a more incremental approach.[103] They envisioned that L2 systems would gradually develop more capabilities and evolve into L3 ADSs and eventually L4 ADSs.[104] This divergence between Google and the automakers reflected differences in their engineering cultures. Google excelled at building software and saw driving automation as a software problem.[105] The automakers took pride in building vehicles and saw driving automation as another vehicle feature.[106] They were also interested in different business models. Google's executives, who were witnessing the rise of Uber and Lyft, envisioned selling rides in robotaxis.[107] The automakers wanted to continue selling cars to individual owners.[108]

By the mid-2010s, some of the automakers came around to Google's vision. Leading automakers formed new companies to develop L4 ADSs, including Argo (Ford and Volkswagen), Cruise (GM and Honda), and Motional (Hyundai).[109] Google's Project Chauffeur spun off into its own company, Waymo.[110] Other companies started developing ADSs too, including Apple, Aurora, BMW, Mercedes-Benz, Toyota, and Zoox (Amazon).[111] Both Uber and Lyft tried to develop L4 ADSs, but after their respective IPOs, they sold their programs under pressure from cost-conscious investors.[112]

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[101]   *Id.*

[102]   *Id.*

[103]   *See* BURNS & SHULGAN, *supra* note 97, at 199–201 (describing the automakers' early skepticism towards ADSs).

[104]   *See id.* at 272 ("[A]utomakers were coming around to the idea that autonomous technology was something they'd get around to . . . eventually. We'll just keep adding safety equipment to our cars, they assumed, and . . . eventually you won't even have to drive the darn things." (first alteration in original)).

[105]   *See id.* at 196–97, 241, 257.

[106]   *Id.*

[107]   *See id.* at 263–69 (describing Google's interest in the robotaxi business model).

[108]   *See id.* at 272–73 (describing the automakers' initial skepticism and gradually increasing openness to the robotaxi business model).

[109]   *See Voluntary Safety Self-Assessment*, NAT'L HIGHWAY TRAFFIC SAFETY ADMIN., https://www.nhtsa.gov/automated-driving-systems/voluntary-safety-self-assessment (last visited Jan. 14, 2024) (providing links to each ADS developer's voluntary safety self-assessment).

[110]   *See About*, WAYMO, https://waymo.com/about/#story (last visited Jan. 14, 2024).

[111]   *See Voluntary Safety Self-Assessment*, *supra* note 109.

[112]   *See* Lizette Chapman & Dana Hull, *Uber Sells Self-Driving Unit to Aurora, Takes Startup Stake*, BLOOMBERG (Dec. 7, 2020, 5:58 PM), https://www.bloomberg.com/news/articles/2020-12-07/uber-sells-self-driving-unit-to-aurora-takes-stake-in-startup; *Woven Planet, a Subsidiary of Toyota, to Acquire Lyft's Self-*

For most of the 2010s, L4 ADS testing was limited in scale and scope. Every ADS-equipped vehicle driving on the public roads had a test driver behind the steering wheel.[113] ADS developers limited their testing to small, geofenced areas in or near warm weather cities like Las Vegas, Phoenix, and San Francisco.[114] They also restricted their systems' ODDs in other ways. Most L4 ADSs avoided highways, and some took circuitous routes to avoid challenging intersections.[115]

The development of L4 ADSs took longer than many in the industry predicted.[116] Some developers, like Argo, shut down.[117] But other developers gradually made progress. In 2017, Waymo started testing its L4 ADS on public roads in Chandler, Arizona without a test driver.[118] In 2020, Cruise started testing without a test driver in San Francisco.[119] In August 2023, California regulators approved Waymo's and Cruise's applications to charge fares to passengers in robotaxis at all hours.[120]

Waymo is currently operating commercial robotaxi services in San Francisco and Phoenix.[121] Cruise is not currently operating a robotaxi service because California regulators suspended the company's permit to test without a test driver after it misled regulators about a serious crash in October 2023.[122]

Driving Car Division, LYFT (Apr. 26, 2021), https://investor.lyft.com/news-and-events/news-details/2021/Woven-Planet-a-subsidiary-of-Toyota-to-acquire-Lyfts-self-driving-car-division.

[113] Andrew J. Hawkins, *Waymo is First to Put Fully Self-Driving Cars on US Roads Without a Safety Driver: Going Level 4 in Arizona*, VERGE (Nov. 7, 2017, 11:00 AM), https://www.theverge.com/2017/11/7/16615290/waymo-self-driving-safety-driver-chandler-autonomous.

[114] *See* Cade Metz, *The Costly Pursuit of Self-Driving Cars Continues On. And On. And On.*, N.Y. TIMES (May 24, 2021), https://www.nytimes.com/2021/05/24/technology/self-driving-cars-wait.html (describing the state of ADS testing in 2021).

[115] *See* McFarland, *supra* note 36 (describing passengers' complaints about Waymo's robotaxis' circuitous routes).

[116] *See* Metz, *supra* note 114.

[117] Kirsten Korosec, *Ford, VW-Backed Argo AI Is Shutting Down*, TECHCRUNCH (Oct. 26, 2022, 2:49 PM), https://techcrunch.com/2022/10/26/ford-vw-backed-argo-ai-is-shutting-down.

[118] Hawkins, *supra* note 113.

[119] Kirsten Korosec, *Cruise Begins Driverless Testing in San Francisco*, TECHCRUNCH (Dec. 9, 2020, 1:43 PM), https://techcrunch.com/2020/12/09/cruise-begins-driverless-testing-in-san-francisco/.

[120] Cano, *supra* note 30.

[121] *See* Andrew J. Hawkins, *Waymo's Robotaxis Are Now Available to Tens of Thousands of People Across All of San Francisco*, VERGE (Oct. 10, 2023, 11:20 AM), https://www.theverge.com/2023/10/10/23911190/waymo-robotaxi-san-francisco-customers-waitlist.

[122] Will Feuer & Ryan Felton, *GM's Cruise Pauses All Driverless Operations After California Crackdown*, WALL ST. J. (Oct. 27, 2023, 11:01 AM), https://www.wsj.com/business/autos/gms-cruise-pauses-all-driverless-operations-after-california-crackdown-a8878ce9.

At the same time, L2 systems have become widely available.[123] And in 2023, Nevada and California approved the first L3 ADS in the United States, Mercedes Drive Pilot.[124] BMW is planning to offer a similar L3 traffic jam assist feature, Personal Pilot, in Germany in 2024.[125] So now each of these three different kinds of driving automation systems are in use on public roads.

B. Technology

Each driving automation system is a combination of sensors, computers, and software.[126] The sensors—typically lidar, radar, and video cameras—collect data about objects in the vehicle's environment.[127] The software decides where and how the vehicle will move in light of that information. Then the system executes the motion by sending signals to the steering, throttle, or brakes.[128] But despite the structural similarities, these systems vary greatly in capabilities.

The engineering community—through SAE (formerly the Society of Automotive Engineers)—has developed a taxonomy for driving automation systems.[129] NHTSA's policy statements and some state legislation and regulation have adopted it.[130] The SAE taxonomy classifies systems into different "levels" of automation.[131] It divides the task of driving a vehicle into subtasks: steering, acceleration/braking, and object and event detection and response.[132] And then it assigns each driving automation system to a level based on the subtasks it can perform and its ODD.[133]

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[123] *See* Monticello, *supra* note 28.

[124] *See* Golson, *supra* note 32.

[125] Christophe Koenig, *Level 3 Highly Automated Driving Available in the New BMW 7 Series from Next Spring.*, BMW GROUP (Nov. 10, 2023), https://www.press.bmwgroup.com/global/article/detail/T0438214EN/level-3-highly-automated-driving-available-in-the-new-bmw-7-series-from-next-spring.

[126] *See* SAE INT'L, *supra* note 22.

[127] Lidar detects nearby objects by emitting laser beams and measuring the time it takes for the beams to return to the sensor. Ekim Yurtsever et al., *A Survey of Autonomous Driving: Common Practices and Emerging Technologies*, 8 IEEE ACCESS 58443, 58448–49 (2020). Radar does the same with radio waves. *Id.* at 58448. The two sensors are complimentary. Radar can see farther than lidar, but lidar is generally more accurate at short ranges. *Id.* at 58448–49. Video cameras add the ability to see color. *Id.* at 58447.

[128] *See id.* at 58443.

[129] SAE INT'L, *supra* note **Error! Bookmark not defined.**.

[130] *See* SGO, *supra* note 59, at 6–8 (defining different levels of automation systems by reference to SAE J3016).

[131] *See* SAE INT'L, *supra* note 22, at 30–32.

[132] *See id.* at 9.

[133] *See id.* at 24.

The most basic form of driving automation system, a *Level 1 system* (or L1 system), can *either* steer *or* accelerate and brake.[134] For example, a standalone adaptive cruise control feature—the kind that has been available since the 1990s—is an L1 system. In recent years, though, L1 features are increasingly being integrated into L2 systems.

1. L2 Systems

An L2 system can *both* steer *and* accelerate or brake simultaneously.[135] A typical L2 system combines two L1 features, adaptive cruise control and lane centering assistance.[136]

Adaptive cruise control is like cruise control that has learned how to follow the vehicle ahead.[137] It maintains a pre-set speed when the lane is clear, but it will also accelerate or brake in response to the motion of the vehicle ahead to maintain a safe headway.[138] The system's sensors detect when the vehicle ahead slows down or speeds up, and the software sends a signal to the brakes or the throttle to respond accordingly.[139]

Lane centering assistance keeps the vehicle in the middle of its lane by nudging the steering.[140] The system's video cameras detect the lane markings, and the software plans a trajectory between them and sends a signal to the steering to execute it.[141] The combination of adaptive cruise control and lane centering assistance makes driving feel less effortful but also creates the risk of complacency.

L2 systems rely critically on the active supervision of a driver. They do not perform all of the "object and event detection and response" subtask.[142] For example, an L2 system may not be able to predict when a vehicle in an adjacent lane will cut into its lane or when a vehicle ahead will cut out of its lane,

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[134] *See id.* at 30.

[135] *See id.* at 31.

[136] Monticello, *supra* note 28.

[137] *See* Keith Barry, *Guide to Adaptive Cruise Control*, CONSUMER REPORTS, https://www.consumerreports.org/cars/car-safety/guide-to-adaptive-cruise-control-a9154580873/ (May 9, 2022).

[138] *See id.*

[139] *See id.*

[140] Keith Barry, *Guide to Lane Departure Warning & Lane Keeping Assist*, CONSUMER REPORTS, https://www.consumerreports.org/cars/car-safety/lane-departure-warning-lane-keeping-assist-guide-a7087080070/ (May 9, 2022).

[141] *See id.*

[142] *See* SAE INT'L, *supra* note 22, at 9, 25.

revealing a stopped car immediately ahead.[143] The driver is expected to keep their eyes on the road, recognize situations that the system cannot handle, and disengage the system when necessary.[144]

L2 systems have limited ODDs. Most are designed for access-controlled highways.[145] And many are designed for highway driving in one lane.[146] Some advanced L2 systems can perform more sophisticated driving maneuvers. For example, some automakers are developing L2 features that can perform automatic lane changes.[147] But even these features require that the driver supervises the system while it executes the lane change.[148]

2. L4 ADSs

An L4 ADS can perform the entire driving task.[149] An L4 ADS-equipped vehicle is truly self-driving. The most important difference in capability between an L4 ADS and an L2 system is that the ADS's decision-making software is powerful enough to perform object and event detection and response. An L4 ADS has specialized software for mapping, localization, perception, behavior prediction, and planning.[150]

The ADS's mapping software facilitates navigation by helping the ADS anticipate where travel lanes and stationary objects are located. ADSs being developed today rely heavily on pre-programmed digital maps.[151] These maps are accurate down to a few centimeters.[152] The maps encode information about the rules of the road, such as speed limits and lane directions.[153]

The localization software enables the ADS to pinpoint its position on the map.[154] An ADS uses specialized sensors for localization that are more robust

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[143] This is a point that NHTSA emphasized in a report that largely exonerated Tesla Autopilot after a fatal crash. *See infra* Part II.B.1; ODI WILLISTON REPORT, *supra* note 53, at 8–9.

[144] SAE INT'L, *supra* note 22, at 9, 28.

[145] *See* Monticello, *supra* note 28.

[146] *See id.*

[147] *See* Jordan Golson, *GM's Super Cruise Getting Fully Automatic, Hands-Free Lane Changes and More for 2022*, VERGE (July 23, 2021, 12:01 AM), https://www.theverge.com/2021/7/23/22589285/gm-super-cruise-automatic-lane-change-gmc-chevy-silverado.

[148] *Id.*

[149] SAE INT'L, *supra* note 22, at 31–32.

[150] Yurtsever et al., *supra* note 127, at 58443.

[151] *Id.* at 58450.

[152] *Id.* at 58451.

[153] *See id.* at 58449.

[154] *Id.* at 58450.

than a conventional GPS. For example, a sensor called an inertial measurement unit is able to function even where a GPS signal would be degraded, like in a tunnel or a concrete canyon.[155]

The perception software generates a continuously updated, 360-degree image of the vehicle's environment. It fuses data from the vehicle's sensors—lidars, radars, and cameras.[156] It detects objects and determines their location, size, and shape.[157] It classifies the objects into categories, such as "vehicle," "cyclist," or "pedestrian."[158] And then it tracks the objects as they move.[159]

The behavior prediction software enables the ADS to anticipate where and how objects will move.[160] Over very short time spans, an object's future position can be predicted from its present position, direction, speed, and acceleration using basic physics. For longer time spans, though, predictions are less about physics and more about psychology.[161] The behavior prediction software uses an object's classification to draw inferences about its likely path.[162] Drivers, cyclists, and pedestrians behave differently. Motorcyclists often drive between lanes, but 18-wheelers rarely try it. Behavior prediction can be maddeningly complex—consider children, deer, and debris falling off a truck.[163]

The planning software charts a path for the vehicle.[164] It integrates the mapping software's view of available lanes, the localization software's view of the vehicle's position, the perception software's view of nearby objects, and the behavior prediction software's view of the objects' future paths.[165] Then, the planning software selects a trajectory that aims to advance the vehicle towards its destination while avoiding collisions.[166]

The control software executes the path that the planning software has chosen.[167] It breaks down the selected trajectory into a sequence of commands

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[155]   *Id.*
[156]   *Id.* at 58447–48.
[157]   *Id.* at 58447, 58451.
[158]   *Id.* at 58451.
[159]   *Id.* at 58456.
[160]   *Id.*
[161]   *Id.* at 58457–58.
[162]   *Id.* at 58458–59.
[163]   *Id.* at 58445.
[164]   *Id.* at 58459–60.
[165]   *Id.* at 58449, 58456–57.
[166]   *Id.* at 58460.
[167]   *Id.*

to steer, brake, or accelerate.[168] Then it sends signals to the vehicle's mechanical systems to execute them.[169]

L4 ADSs are developed through a process that combines computer simulations, closed-course testing, and on-road testing.[170] First, the code is tested in simulations.[171] These simulations are based on traffic scenarios that the ADS has encountered in on-road testing and other fictional-but-realistic scenarios developed by engineers or by algorithms.[172] Second, if the code passes the simulations, it is deployed on a small number of vehicles in a closed-course environment.[173] Closed-course testing shows how the code will perform in the physical world, while reducing the risk to bystanders if it proves dangerous.[174] Third, if the code passes closed-course testing, it is uploaded to vehicles in the ADS developer's fleet for on-road testing.[175]

The development process is iterative.[176] An ADS developer can learn from the experience of all of the vehicles on which its ADS deployed. Each vehicle in an ADS developer's fleet creates a digital log of its travels.[177] When one of those vehicles encounters a traffic scenario that the ADS cannot navigate safely, the developer's engineers are tasked with developing code that can handle it.[178] The proposed fix then undergoes simulation, closed-course testing, and on-road testing.[179] Once a fix survives the development process, it is incorporated into the next version of the ADS. The iterative process is not perfect. New code can inject new faults that simulations fail to detect.[180] But over time, the software should become safer. Newly developed L4 ADSs start with tightly restricted ODDs.[181] As they learn to navigate more traffic scenarios safely, their ODD restrictions are gradually relaxed.[182]

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[168]   *Id.*

[169]   *Id.*

[170]   WAYMO, WAYMO SAFETY REPORT 22 (2021), https://storage.googleapis.com/waymo-uploads/files/documents/safety/2021-12-waymo-safety-report.pdf.

[171]   *See id.*

[172]   *See id.* 22–23.

[173]   *Id.* at 22.

[174]   *Id.* at 26.

[175]   *Id.* at 22.

[176]   *See id.* at 27.

[177]   *See id.* at 18.

[178]   *Id.*

[179]   *See id.* at 22.

[180]   *See* KOOPMAN, *supra* note 39, at 82–83.

[181]   *See* Yurtsever et al., *supra* note 127, at 58445.

[182]   *See, e.g.*, WAYMO, *supra* note 170, at 16 (detailing Waymo's plans for ODD expansion once the ADS "system's capabilities grow and are validated").

3. L3 ADSs

An L3 ADS can perform all driving subtasks *except* that it relies on a person—the fallback-ready user—as a fallback.[183] The fallback-ready user is *not* expected to continuously supervise the system.[184] But they must be "receptive" to requests to intervene from the system, and they must also notice other vehicle failures that the system might not notice, such as a sudden tire blowout.[185] If the fallback-ready user receives a request to intervene or notices a vehicle system failure, they are expected to resume driving or to bring the vehicle to a "minimal risk condition" by, for example, pulling over to the shoulder.[186]

The only L3 ADS available today, Mercedes Drive Pilot, is a highway traffic jam assistance feature. It can be engaged only on access-controlled highways and only at speeds under 40 mph.[187] The other announced L3 ADS, BMW Personal Pilot, is also a traffic jam assist.[188] Its ODD is similar, except that it can be engaged at night.[189] Both Drive Pilot and Personal Pilot require a person in the driver's seat to serve as the fallback-ready user.[190] But neither system requires the fallback-ready user to keep their eyes on the road.[191] Both Mercedes and BMW envision fallback-ready users watching videos on their vehicle's center console while the L3 ADS drives.[192]

4. Telematics

The introduction of driving automation systems has started to change the relationship between the automaker and the vehicle. Automakers have traditionally installed the final version of a vehicle's features before selling it to the customer. Some automakers are interacting with their driving automation systems differently. They are outfitting their vehicles with telematics—technology that transmits data over the air to remote locations.[193]

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[183] *See* SAE INT'L, *supra* note 22, at 31. The SAE taxonomy also envisions an alternative in which there is a remote fallback-ready user. *See id.* at 22.

[184] *Id.* at 31.

[185] *See id.*

[186] *Id.*

[187] Golson, *supra* note 32.

[188] Koenig, *supra* note 125.

[189] *Id.*

[190] *See* Golson, *supra* note 32; Koenig, *supra* note 125.

[191] *See* Golson, *supra* note 32; Koenig, *supra* note 125.

[192] *See* Golson, *supra* note 32; Koenig, *supra* note 125. Anyone who often gets stuck in traffic jams long enough to watch videos should probably rethink their commute.

[193] *See* Subir Halder et al., *Secure OTA Software Updates in Connected Vehicles: A Survey*, 178 COMPUT. NETWORKS 1, 3–4 (2020).

Telematics enable two-way communication between an automaker and its vehicles. The automaker can program its vehicles to send back performance data, which can be used for quality control.[194] The automaker can also send software updates to the vehicle, which can improve existing software features or add new ones.[195] The vehicle owner does not need to visit a dealership for repairs or replacement parts. To be sure, a driving automation system does not require a vehicle to have telematics, but the potential for refining software through over-the-air updates makes adding telematics attractive. Indeed, telematics may prove critical to keeping driving automation systems reasonably safe.

C. Safety

Each kind of driving automation system raises different safety issues. For an L2 system, is the risk of complacency mitigated? For an L4 ADS, is the artificial intelligence mishandling situations that a human driver would navigate safely? For an L3 ADS, is the fallback-ready user reliably fallback-ready?

1. L2 Systems

L2 systems are designed for convenience, not safety. It is possible that they could make driving safer.[196] For example, adaptive cruise control could maintain a safe headway more consistently than a driver would, which might avoid some rear-end collisions. Likewise, lane centering could reduce the risk that a vehicle drifts into an adjacent lane, which might avoid some side-swipe collisions. Drivers might also be less tempted to speed while an L2 system is engaged.

But safety experts are skeptical that L2 systems provide much *marginal* benefit over widely available "active safety" features.[197] Some active safety features alert the driver to potential hazards.[198] For example, forward collision warning alerts a driver that the vehicle is moving too close to the vehicle

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[194]   *Id.*

[195]   *See id.* (explaining the mechanics of an over-the-air update).

[196]   *See* Alexandra S. Mueller et al., *Addressing Driver Disengagement and Proper System Use: Human Factors Recommendations for Level 2 Driving Automation Design*, 15 J. COGNITIVE ENG'G & DECISION MAKING 3, 4 (2021).

[197]   *See id.* at 3–4; *see also* KOOPMAN, *supra* note 40, at 34–35 ("[A]ctive safety approaches might ultimately prove to be safer . . . due to their more natural fit to human strengths and computer weaknesses.").

[198]   Active safety features perform a driving subtask momentarily. *See* SAE INT'L, *supra* note 22, at 6 (defining "active safety system"). They are not considered automation because they do not perform a driving task on "a sustained basis." *Id.* at 4.

ahead.[199] Lane departure warning alerts a driver that the vehicle is about to cross into an adjacent lane.[200] Other active safety features briefly take control of the vehicle in an emergency. Electronic stability control applies the brakes when it detects a loss of traction. Automatic emergency braking applies the brakes when it detects that a collision is imminent.[201]

The advantage of active safety features over L2 systems is that, since they are only activated when a hazard is imminent, they do not create a risk of complacency. A rigorous analysis of the safety benefits of any L2 system should compare the performance of its component features to a relevant active safety feature.[202] For example, the safety benefits of active cruise control should be compared to the combination of forward collision warning and automatic emergency braking. Lane centering should be compared to lane departure warning.

The safety risks of L2 systems are more clearly established than the potential benefits. Human factors researchers have learned that automation creates a paradox: "[t]he more sophisticated and reliable the driving automation is, the harder it is for drivers to maintain the necessary vigilance to monitor the vehicle interface and roadway to detect vehicle notifications and hazards."[203] The automation paradox explains why L2 systems are more controversial than standalone L1 adaptive cruise control features. Drivers who do not need to frequently adjust the steering wheel are more easily lulled into complacency. They can lose situational awareness—an understanding of the other road users and objects in the vehicle's surroundings.[204]

The *New York Times* columnist Farhad Manjoo inadvertently illustrated the danger of automation complacency in an essay praising Super Cruise, the L2 system on his Cadillac Escalade.[205] Manjoo wrote that, while Super Cruise is

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[199] *See* KELLY FUNKHOUSER, CONSUMER REPORTS GUIDE TO ADAS USABILITY 32 (2022), https://data.consumerreports.org/reports/crs-guide-to-adas-usability (listing currently available forward collision warning features).

[200] *See id.* at 39 (listing currently available lane departure warning features).

[201] *See id.* at 32 (listing currently available automatic emergency braking features).

[202] *See* KOOPMAN, *supra* note 40, at 70–71.

[203] *See* Mueller et al., *supra* note 196, at 4.

[204] *See* Francesco N. Biondi et al., *80 MPH and Out-of-the-Loop: Effects of Real-World Semi-Automated Driving on Driver Workload and Arousal*, 62 PROC. HUM. FACTORS & ERGONOMICS SOC'Y 1878, 1879–81 (2018) (finding that drivers scored worse on a peripheral detection task and showed lower physiological arousal when driving with Autopilot engaged).

[205] Farhad Manjoo, *Help. I've Fallen for That Cadillac Escalade.*, N.Y. TIMES (Feb. 4, 2022), https://www.nytimes.com/2022/02/04/opinion/self-driving-car-escalade.html.

engaged, "you can let your eye wander across the scenery and your mind contemplate the mundane and the profound."[206] He claimed that "[i]t's not that you're completely distracted—even lost in thought, you can keep situational awareness of the road ahead."[207] But Manjoo seemed to neglect the possibility that he could have lost situational awareness without realizing it.

An L2 system developer can mitigate the risk that drivers will misuse its system by reminding them about its limitations. But some developers send mixed messages: an owner's manual filled with detailed warnings that few drivers read and advertising that exaggerates their systems' capabilities and undermines those warnings. For example, Tesla's Owner's Manual contains detailed warnings about Autopilot's limitations.[208] But Tesla's marketing sends a different message. Researchers have found that the name "Autopilot" leads consumers to overestimate the system's capabilities.[209] This is why state legislators and regulators are starting to crack down on misleading marketing.[210]

An L2 system developer can also reduce the risk that drivers will misuse its system by coupling it with a "driver monitoring" system. Research suggests that the most effective driver monitoring systems combine information about the driver's eye gaze or head orientation, their steering input, how long it takes the driver to respond to warnings, and the length of the trip.[211] Some L2 systems use infrared cameras to monitor the driver's eyes, but others rely solely on steering input.[212]

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[206] *Id.*

[207] *Id.*

[208] TESLA, MODEL 3: OWNER'S MANUAL 87–88 (2023), https://www.tesla.com/ownersmanual/model3/en_us/Owners_Manual.pdf.

[209] *See* Eric R. Teoh, *What's in a Name? Drivers' Perceptions of the Use of Five SAE Level 2 Driving Automation Systems*, 72 J. SAFETY RSCH. 145, 147 (2020) (finding that respondents were more likely to believe that certain risky behaviors were "safe" while an L2 system was engaged if it was named "Autopilot"); *see also* Hillary Abraham et al., *What's in a Name: Vehicle Technology Branding & Consumer Expectations for Automation*, 9 PROC. 9TH ACM INT'L CONF. AUTO. USER INTERFACES & INTERACTIVE VEHICULAR APPLICATIONS 226, 229–33 (2017) (finding that consumers' beliefs about L2 system capabilities are sensitive to terms like "cruise," "assist," and "autopilot").

[210] In 2022, California regulators brought an administrative action against Tesla, alleging that the company made "untrue or misleading" statements by calling its system "Autopilot" and suggesting that it could operate without human intervention. Accusation at 2, *In re* Tesla Inc., No. 21-02188 (Office Admin. Hearing July 28, 2022). Later that year, California enacted a statute that prohibits naming or describing in marketing materials "any partial driving automation feature" with "language that implies or would otherwise lead a reasonable person to believe, that the feature allows the vehicle to function as an autonomous vehicle." S.B. 1398, 2022 Cal. Legis. Serv. Ch. 308 (West) (amending CAL. VEH. CODE § 24011.5(b)).

[211] Mueller et al., *supra* note 196, at 6.

[212] *See, e.g.*, Monticello, *supra* note 28.

A driver monitoring system can include a "driver management" system that aims to keep the driver focused on the driving task though a series of warnings. The warnings can escalate if the driver fails to respond—first visual, next tactile, and then auditory.[213] If none of those warnings work, the vehicle can perform "pulse braking"—braking that is rapid and brief enough to catch the driver's attention but does not create a significant risk of getting rear-ended.[214] If drivers repeatedly fail to respond to warnings, the driver management system can prevent them from using the system for the rest of the trip.[215]

The automakers face difficult choices in developing driver monitoring and driver management systems. Drivers might find warnings annoying and resist being "managed." Some drivers, like Manjoo, want to let their eyes wander across the scenery, and some automakers are tempted to sell that experience. Recent safety research has found that one way to keep drivers engaged is to let them share control of the steering with the lane centering feature.[216] Under shared control, the driver can adjust the steering slightly without disengaging lane centering. The benefit of shared control is that the driver does not feel penalized for interacting with the system they are supervising.

An L2 system developer can also reduce the risk that its system will be misused by designing it to automatically enforce its ODD.[217] Some L2 systems, like GM Super Cruise, can only be engaged on pre-mapped highways, and they will automatically disengage when they leave those highways.[218] Other L2 systems, though, like Tesla Autopilot, rely on the driver to recognize when the system is leaving its ODD and disengage it.[219] That creates the risk that the driver will deliberately engage the system, or inadvertently forget to disengage it, on a road that it cannot navigate safely.[220]

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[213]   *See* Mueller et al., *supra* note 196, at 12.

[214]   *Id.* at 11–12.

[215]   *Id.* at 13.

[216]   *See id.* at 14–15.

[217]   *See id.* at 19–20.

[218]   *See* Monticello, *supra* note 28.

[219]   *See id.*

[220]   L2 system developers that let their systems be engaged outside their ODDs may lack the digital maps that their systems would need to enforce ODD restrictions. ADS developers reduce the cost of mapping by deploying their robotaxis only in small, geofenced areas, but automakers do not want to sell an L2 system that can only operate in certain parts of San Francisco.

2. L4 ADSs

L4 ADSs create more favorable risk-risk tradeoffs. They will avoid certain kinds of crashes because they will not make certain kinds of common human errors. They will not drive drunk, drowsy, or distracted. They can be programmed to observe speed limits, obey stop signs and traffic lights, maintain a safe headway, and yield the right of way. They can also be designed to drive defensively. They can learn to sense when vulnerable road users are present and give them more space.[221]

At the same time, though, L4 ADSs will make errors that human drivers would not make. ADSs are still struggling with many edge cases.[222] For example, robotaxis in San Francisco have collided with a semi-trailer making a wide turn,[223] collided with a fire truck en route to an emergency call,[224] narrowly avoided colliding with a light rail train,[225] and gotten stuck in wet concrete.[226] Each of these situations is common enough that a competent human driver would handle them safely.

Many L4 ADS crashes follow a pattern: the ADS encounters another vehicle, the driver of that vehicle makes an error, and the ADS responds in a way that fails to avoid a crash.[227] Or the ADS moves in a way that a nearby driver did not expect, and the two vehicles crash.[228] As ADSs are deployed at scale, these crashes may become more common.

Most L4 ADS developers are using test drivers during on-road testing to mitigate safety risks.[229] A test driver sits in the driver's seat of an ADS-equipped

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[221] *See generally* Wansley, *supra* note 37, at 290–92 (considering how ADSs might improve on human driver safety performance).

[222] *See infra* notes 223–26 and accompanying text.

[223] Liz Lindqwister, *Semitruck Crashes into Cruise Robotaxi in San Francisco*, S.F. STANDARD (Aug. 7, 2023, 4:39 PM), https://sfstandard.com/2023/08/07/semi-truck-crashes-into-cruise-robotaxi-in-san-francisco/.

[224] Rohan Goswami, *Cruise Robotaxi Gets in Accident with San Francisco Fire Truck, One Injured*, CNBC (Aug. 18, 2023, 3:43 PM), https://www.cnbc.com/2023/08/18/cruise-self-driving-car-in-san-francisco-fire-truck-crash-one-injured.html.

[225] *See* Paresh Dave, *Dashcam Footage Shows Driverless Cars Clogging San Francisco*, WIRED (Apr. 10, 2023, 7:00 AM), https://www.wired.com/story/dashcam-footage-shows-driverless-cars-cruise-waymo-clogging-san-francisco/.

[226] Michael Levenson, *A Driverless Car Gets Stuck in Wet Concrete in San Francisco*, N.Y. TIMES (Aug. 17, 2023), https://www.nytimes.com/2023/08/17/us/driverless-car-accident-sf.html.

[227] *See* Wansley, *supra* note 37, at 295–304 (reviewing data on ADS crashes).

[228] *See id.* at 303.

[229] *See, e.g.*, MATTHEW SCHWALL ET AL., WAYMO PUBLIC ROAD SAFETY PERFORMANCE DATA 2 (2020), https://arxiv.org/pdf/2011.00038.

vehicle and continually supervises the ADS.[230] The test driver is expected to decide when to disengage the ADS and resume driving.[231] In a sense, the driver treats the L4 ADS like an L2 system. The presence of a test driver helps with edge cases but reintroduces the risk of automation complacency. Companies testing ADSs with a test driver need to manage that risk with training, supervision, and driver monitoring.[232]

3. L3 ADSs

L3 ADSs have complex risk profiles. When an L3 ADS is driving, its risk profile resembles an L4 ADS. There will be some edge cases that the system cannot manage safely, and sometimes those edge cases will result in crashes. When an L3 ADS requests that the fallback-ready user intervene, its risk profile resembles an L2 system. The fallback-ready user may not always be fallback-ready, and sometimes a botched fallback will result in crashes. In fact, the risk that the fallback-ready user of an L3 ADS loses situational awareness is even greater than it would be for the driver of an L2 system because they are not expected to supervise the system.[233] This is why safety researchers familiar with the automation paradox are wary of L3 ADSs.[234]

L3 ADS developers argue that they can make the fallback safe. Mercedes Drive Pilot has an automated backup system to mitigate the consequences of a failed fallback. Mercedes claims that, if the fallback-ready user "fails to take back control even after increasingly urgent prompting . . . the system brakes the vehicle to a standstill in a controlled manner while engaging the hazard warning lights."[235] But, of course, it is not always safe to stop in the middle of a traffic lane. And the risks of a delayed or failed fallback will increase if L3 ADSs are deployed at higher speeds.

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[230] *Id.*

[231] *Id.*

[232] *See* KOOPMAN, *supra* note 39, at 32 ("[I]t is possible that intended vehicle behaviors will malfunction in ways that an ordinary driver would not expect. Additional skill and vigilance are required for a test driver to supervise dangerous failures . . . .").

[233] In fact, SAE suggests that the fallback-ready user may have as little as "several seconds" to respond to a request to intervene. *See id.* at 17.

[234] *See id.* at 23–25 (arguing that safe L3 ADSs will require L2-style driver monitoring systems or very limited ODDs).

[235] *Mercedes-Benz World's First Automotive Company to Certify SAE Level 3 System or U.S. Market*, MERCEDES-BENZ: MEDIA NEWSROOM USA (Jan. 26, 2023), https://media.mbusa.com/releases/release-1972539e60b30e8816b4ea4b6302f67e-mercedes-benz-worlds-first-automotive-company-to-certify-sae-level-3-system-for-us-market.

4. Regulatory Arbitrage

Since each kind of driving automation system creates distinct safety risks, many states have used the SAE taxonomy in legislation and regulation. For example, California requires companies testing vehicles equipped with L3 or L4 ADSs to apply for a permit, report crashes and disengagements, and, at least initially, test with a professional test driver behind the wheel.[236] One risk of codifying the SAE's levels is that they are defined by the manufacturer's "design intention."[237] If regulators are not willing to second guess manufacturers' characterizations of their design intention, there is an opportunity for regulatory arbitrage.

In 2020, Tesla introduced a new set of features called "Full Self-Driving beta," which extends Autopilot's ODD beyond access-controlled highways.[238] One feature is designed to guide a vehicle from "on-ramp to off-ramp" and automatically exit a highway.[239] Another feature "[i]dentifies stop signs and traffic lights and automatically slows [the] car to a stop on approach" with the driver's "active supervision."[240] These features' claimed capabilities and ODD resemble an L4 ADS.[241] And the name "Full Self-Driving" fits an L4 ADS too. Tesla, however, claims that Full Self-Driving beta is an L2 system.[242] The company has argued to California regulators that Full Self-Driving beta should not be subject to ADS regulations because it "is not designed such that a driver can rely on an alert to draw his attention to a situation requiring response."[243]

Tesla's argument misunderstands the purpose of safety regulation. Full Self-Driving beta's inability to alert drivers to all situations it cannot handle explains why is not yet a safe L4 ADS. It is not an argument for why the system should be treated as an L2 system. Regulation should categorize technologies by their risk profiles. Full Self-Driving beta's unusual combination of limited object and

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[236] *See* CAL. CODE REGS. tit. 13, § 227 (2022).

[237] SAE INT'L, *supra* note 22, at 36.

[238] Andrew J. Hawkins, *Tesla's "Full Self-Driving" Software is Starting to Roll Out to Select Customers*, VERGE (Oct. 21, 2020, 6:47 PM), https://www.theverge.com/2020/10/21/21527577/tesla-full-self-driving-autopilot-beta-software-update.

[239] *Autopilot and Full Self-Driving Capability*, TESLA, https://www.tesla.com/support/autopilot (last visited Jan. 14, 2024).

[240] *Id.*

[241] *See* William H. Widen & Philip Koopman, *Autonomous Vehicle Regulation & Trust: The Impact of Failures to Comply with Standards*, 27 U.C.L.A. J.L. & TECH. 169, 180–84 (2022) (comparing Full Self Driving's capabilities to SAE's definition of an ADS).

[242] *See id.* at 178.

[243] Letter from Eric C. Williams, Assoc. Gen. Couns. Regul., Tesla, to Miguel Acosta, Chief, Autonomous Vehicles Branch, Cal. Dep't of Motor Vehicles (Nov. 20, 2022).

event detection and response capabilities and a broad ODD that includes intersections *increases* the risk of a crash relative to both conventional L2 systems and mature L4 ADSs.

5. Safety Assessment

Since driving automation systems have the potential to both increase and reduce safety risks, regulators need to assess each system's net safety impact. That assessment, though, will not be easy. Regulators generally assess the safety of a vehicle or equipment by testing it in a controlled environment or analyzing real world crash data. But neither controlled testing nor currently available data can reliably measure performance in edge cases. And for driving automation systems, safety performance in edge cases is critical.

Consider the choices that NHTSA faces. The agency could build a closed-course track designed to test vehicles equipped with driving automation systems in difficult driving conditions. Some regulators have taken this approach. Singapore uses a closed-course test as part of its ADS regulations.[244] But a closed-course assessment would create a dilemma. If developers were told how the course would be designed, it would be trivial for them to program their system to navigate it safely. If developers were not told in advance, they would have a good argument that the test was not "objective."[245] Even if the case law were interpreted to permit a blind test, a closed-course track could only feasibly test a small sample of the edge cases that the technology would encounter in real world driving.

NHTSA could instead develop a series of computer simulations designed to test how the system performs in a larger set of traffic scenarios. Simulations can test performance over many more miles than real-world testing.[246] They can also be designed to include more edge cases than would be encountered in an equivalent number of real-world miles.[247] And simulations enable testing of scenarios that might be dangerous on a closed-course track. This is why ADS

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[244] *See Autonomous Vehicles*, SING. LAND TRANSP. AUTH., https://www.lta.gov.sg/content/ltagov/en/industry_innovations/technologies/autonomous_vehicles.html (last visited Jan. 14, 2024) (describing regulatory requirements for ADSs, including a successful demonstration in a closed-course environment).

[245] For a discussion of the relevant case law, see *supra* notes 8–13 and accompanying text.

[246] *See* WAYMO, *supra* note 170, at 15.

[247] Even in simulation, it can be difficult to identify a sufficient number of edge cases. The industry has developed a common list as a starting point, and naturalistic data from human driven vehicle fleets can help. *See* KOOPMAN, *supra* note 39, at 88–89.

developers rely heavily on simulation to perform their internal safety assessments.[248]

The disadvantage of simulation as a regulatory (rather than internal) safety assessment is that the simulation must be validated. And a large part of how developers validate their simulations is through on-road testing.[249] If simulation were used as a regulatory tool, the developer of a system that failed a simulation test could argue that the simulation did not accurately reflect how the system would have performed in the real world. Even worse, the developer might be able to argue that designing its system to behave in a way that would pass the simulation could make it less safe in the real world. These arguments would be difficult to resolve. At its root, the problem of simulation as a regulatory tool is that artificial intelligence is not yet very good at predicting real-world behavior.

NHTSA could avoid the validation problem by assessing driving automation safety with real world crash data.[250] But relying on crash data would introduce other complications. The assessment would require assembling two datasets.[251] The first dataset would measure the safety performance of the driving automation system.[252] It would need to include enough miles of driving to capture performance in edge cases. The second dataset would measure the performance of human drivers—ideally drivers using vehicles with the latest active safety features.[253] It would need to include an equally large number of miles driven in a similar ODD.

The number of miles that a driving automation system would need to drive to enable a meaningful comparison depends on the kind of crash data being collected. NHTSA possesses reliable data on fatal crashes, but they are (thankfully) too rare to be useful. A RAND study calculates that an ADS would need to travel 8.8 billion miles "to demonstrate with 95% confidence their failure

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[248]   *See id.* at 87–88.

[249]   *See id.*

[250]   Of course, the net crash rate is not the only relevant metric. For example, NHTSA should also consider whether a driving automation system transfers risks to vulnerable road users. *See* Philip Koopman & William H. Widen, Breaking the Tyranny of Net Risk Metrics for Automated Vehicle Safety 7–8 (Nov. 15, 2023) (unpublished manuscript), https://papers.ssrn.com/sol3/papers.cfm?abstract_id=4634179.

[251]   *See* Noah Goodall, *Normalizing Crash Risk of Partially Automated Vehicles Under Sparse Data*, 16 J. TRANSP. SAFETY & SEC. 1, 5–6 (2024) (comparing Tesla's reported Autopilot crash data to naturalistic data).

[252]   *See id.* at 5.

[253]   *See id.* at 6.

rate to within 20% of the true rate of" the average driver.[254] Data on less severe crashes are plagued by reporting problems.[255] Many non-fatal crashes are not reported to the police or are reported but not recorded in police records.[256] One NHTSA study estimates that 24.3% of non-fatal injury crashes and 59.7% of property damage only crashes are not reflected in police records.[257]

Another challenge is assembling a comparison dataset that reflects the driving automation system's ODD. This is critical because a system's ODD affects its risk profile.[258] For L2 systems that are designed to operate only on access-controlled highways, accounting for the ODD might be manageable.[259] But the definition of an L4 ADS's ODD can be more complex. For example, an ADS might be restricted to operating in certain neighborhoods in Miami on roads with a speed limit below 35 mph, and only in dry weather. The ODD might exclude intersections with "unprotected" left turns—that is, left turns without a dedicated turn signal. It would be hard to find data with that level of granularity. A comparison would need to account for variations in intersection complexity, speed limit, and weather.

The frequent updating of L4 ADS software adds a further complication. A software update might fix previously observed failures but inject new ones.[260] In general, NHTSA should aim to compare the performance of vehicles equipped with a specific version of the software. But each version might not be in use on enough vehicles for enough miles to generate enough data for a meaningful comparison.

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[254] NIDHI KALRA & SUSAN M. PADDOCK, DRIVING TO SAFETY: HOW MANY MILES OF DRIVING WOULD IT TAKE TO DEMONSTRATE AUTONOMOUS VEHICLE RELIABILITY 10 (2016), https://www.rand.org/content/dam/rand/pubs/research_reports/RR1400/RR1478/RAND_RR1478.pdf.

[255] *See, e.g.*, LAWRENCE BLINCOE ET AL., NAT'L HIGHWAY TRAFFIC SAFETY ADMIN., THE ECONOMIC AND SOCIETAL IMPACT OF MOTOR VEHICLE CRASHES, 2010 (REVISED) 2, 13 (2015), https://crashstats.nhtsa.dot.gov/Api/Public/ViewPublication/812013 ("Approximately 60[%] of property-damage-only crashes and 24[%] of all injury crashes are not reported to the police.").

[256] *See* NAT'L HIGHWAY TRAFFIC SAFETY ADMIN., DOT HS 812 013, THE ECONOMIC AND SOCIETAL IMPACT OF MOTOR VEHICLE CRASHES, 2010 121–43 (2015 ed.), https://crashstats.nhtsa.dot.gov/Api/Public/ViewPublication/812013 (discussing reporting problems in the non-fatal crash data).

[257] *Id.* at 139, 141.

[258] *See* KOOPMAN, *supra* note 39, at 66–67.

[259] *See* Goodall, *supra* note 251, at 7–9 (adjusting Tesla Autopilot crash data to account for its ODD).

[260] *See* KOOPMAN, *supra* note 39, at 82–83 ("[A]ny change to the software—no matter how small—can in principle (and often does) introduce new defects."). This point will not be lost on anyone who has edited a law review article.

To be sure, the complexities of assessing driving automation safety will not be relevant for all regulatory decisions. A driving automation system may be involved in enough crashes over a small number of miles that regulators can be confident that it is creating an unreasonable safety risk without further testing. A system might also crash in a way that provides *qualitative* evidence of safety risks. For example, if an ADS-equipped vehicle drives into oncoming traffic, regulators should immediately investigate.[261] But most driving automation systems should pass these low bars, which will force regulators to confront the more complex questions of assessing safety. Indeed, the difficulty of assessing driving automation safety may partially explain NHTSA's initial hesitance to regulate.

II. THE PASSIVE YEARS (2013–2020)

For most of the last decade, NHTSA took a passive approach to regulating driving automation safety. It asked ADS developers to voluntarily assess the safety of their own systems, and it adapted the FMVSSs to facilitate the development of vehicles without human controls. But it mostly left regulation to the states. Then a series of fatal crashes involving Tesla Autopilot and a fatal crash involving Uber's ADS increased scrutiny of driving automation safety. In the aftermath of those crashes, the NTSB waged a public campaign to pressure NHTSA to take more action.

A. Elements of the Passive Approach

NHTSA's passive approach to regulating driving automation safety had multiple causes. The Safety Act does not require automakers to seek NHTSA's approval before they introduce new vehicles or equipment. It just requires them to self-certify that the new technology complies with existing FMVSSs.[262] Therefore, NHTSA did not need to affirmatively approve driving automation systems as long as developers tested them on FMVSS-compliant vehicles.

NHTSA would likely have struggled to regulate if it had tried. NHTSA's engineers had little experience with the sophisticated software that powered ADSs.[263] And the industry had yet to converge on standards that NHTSA could

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[261] *See infra* Part III.B.2 (explaining how the obviously unsafe behavior of Pony.ai's ADS led NHTSA to demand a recall).

[262] 49 U.S.C. § 30115(a).

[263] *See* AV 1.0, *supra* note 47, at 6.

enforce.[264] These institutional constraints combined with the administrative law burdens that had curtailed rulemaking for decades. Any standard that NHTSA set would have needed to pass cost-benefit analysis.[265] Then it would have been subject to judicial review.[266] The difficulty of assessing driving automation safety would have made it hard to quantify a standard's benefits. And any standard that survived the rulemaking process might have quickly become obsolete.

In 2020, NHTSA described the problem this way:

> Based on the current state of ADS development, it is probably too soon to make any decisions about the extent to which new FMVSS might be needed to address particular aspects of the safety performance of these systems. ADS are, generally, in the development stages, and market-ready, mature ADS do not yet exist. Accordingly, there do not exist meaningful data about the on-road experience of these systems that can be analyzed to determine the safety need that potentially should be addressed, e.g., which aspects of performance are in need of regulation, what would be reasonable, practicable, or appropriate for regulation, or the minimum thresholds for performance, much less how to regulate such performance.[267]

Given these obstacles to regulation, it is not surprising that NHTSA decided to wait.

1. Policy Statements

Over the last decade, NHTSA issued a series of non-binding policy statements on automated driving. In 2013, the agency issued what it called its "Preliminary Statement." The Statement embraced the "enormous safety potential" of ADSs and promised that NHTSA would "help states implement

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[264] In 2020—at the end of the passive years—NHTSA stated that "[v]arious companies and organizations have begun efforts to develop a framework or at least portions of one." Framework for Automated Driving System Safety, 85 Fed. Reg. 78058, 78062, 78064 (Dec. 3, 2020).

[265] Regulations that have an annual economic effect of $100 million or more are subject to cost-benefit analysis review by the Office of Management and Budget. *See* Exec. Order No. 12,866, 58 Fed. Reg. 51735 (Oct. 4, 1993); Exec. Order No. 13,563, 76 Fed. Reg. 3821 (Jan. 21, 2011).

[266] The Safety Act provides that any person adversely affected by a standard may petition for review in a federal court of appeals. 49 U.S.C. § 30161(a). The reviewing court asks whether, in promulgating the standard, the agency complied with both the Safety Act and the Administrative Procedure Act. Chrysler Corp. v. U.S. Dep't of Transp., 472 F.2d 659, 670 (6th Cir. 1972).

[267] *See* Framework for Automated Driving System Safety, 85 Fed. Reg. 78058, 78062 (Dec. 3, 2020).

this technology safely so that its full benefits can be realized."[268] It provided an automation taxonomy, a description of the agency's research plan, and set of recommendations for states considering regulating ADSs.[269]

In 2016, NHTSA published a more substantial policy statement, which later became known as "AV 1.0." It provided "vehicle performance guidance" on fifteen issues related to ADS safety.[270] The issues ranged from technical safety topics like cybersecurity and validation methods to policy considerations like consumer education and privacy.[271] There was even a whimsical discussion of "ethical considerations" seemingly inspired by the trolley problem.[272]

The vehicle performance guidance was abstract and qualitative. For example, one section listed a series of driving maneuvers that an ADS should be able to perform, such as "Detect and Respond to Lane Changes" and "Navigate Roundabouts."[273] The list was specific enough that one could imagine it forming the basis for minimum performance standards.[274] But it came with a disclaimer: "The full list of behavioral competencies a particular [ADS] would be expected to demonstrate and routinely perform will depend on the [ADS], its ODD, and the fall back method."[275] It added that "as DOT develops more experience and expertise with [ADSs], NHTSA may promulgate specific performance tests and standards."[276]

AV 1.0 asked each ADS developer to submit a "Safety Assessment" letter to NHTSA that would explain how their system would address each of the fifteen safety issues.[277] The agency stated that submitting the letters was voluntary but suggested that they might eventually become mandatory.[278] NHTSA also floated

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[268] NAT'L HIGHWAY TRAFFIC SAFETY ADMIN., PRELIMINARY STATEMENT OF POLICY CONCERNING AUTOMATED VEHICLES 1 (2013) [hereinafter PRELIMINARY STATEMENT], https://www.nhtsa.gov/staticfiles/rulemaking/pdf/Automated_Vehicles_Policy.pdf.

[269] *See id*. at 3–14.

[270] AV 1.0, *supra* note 47, at 11–36.

[271] *Id.*

[272] *Id.* at 26–27. For a skeptical take on the relevance of the trolley problem to ADSs, see Bryant Walker Smith, *The Trolley and the Pinto: Cost-Benefit Analysis in Automated Driving and Other Cyber-Physical Systems*, 4 TEX. A&M L. REV. 197, 200–01 (2017).

[273] AV 1.0, *supra* note 47, at 29.

[274] *See id.* at 28–29.

[275] *Id.* at 29.

[276] *Id.* at 27.

[277] *Id.* at 15–17.

[278] *Id.* at 15.

some interesting ideas for how it could regulate ADS safety—including a pre-market approval system—but left it unclear whether it would pursue them.[279]

The possibility that the ideas raised in AV 1.0 would develop into regulation evaporated two months after its publication, when Donald Trump was elected President. The new Secretary of Transportation, Elaine Chao, said she would prioritize removing barriers to innovation.[280] In 2017, NHTSA published a new policy statement, AV 2.0, with a more industry-friendly tone.[281] AV 2.0 revisited the issues raised in AV 1.0's vehicle performance guidance but presented them as "best practices" for the industry.[282] It preserved AV 1.0's request that companies submit Safety Assessment letters but rebranded them as "Voluntary Safety Self-Assessments" or VSSAs.[283]

Most of the ADS developers did eventually submit VSSAs.[284] Some of them offer useful primers on the basics of ADS technology. But they are primarily marketing documents. None of them offer information that would be useful to a regulator attempting to assess the ADS's safety. This outcome was entirely predictable. A company that disclosed interesting information about its safety practices or safety performance might attract regulatory attention or educate its competitors.

2. ADS Federalism

NHTSA's policy statements encouraged states to regulate ADS testing within their jurisdictions. The Preliminary Statement recommended that states require ADS developers to test their systems with a test driver behind the wheel and report crashes and disengagements.[285] AV 1.0 included a Model State Policy, which recommended that states develop an application process for ADS testing and mandate crash reporting.[286]

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[279] *Id.* at 68–82.

[280] *See* Aarian Marshall, *The Next Transportation Secretary Seems Pretty Down with Self-Driving Cars*, WIRED (Jan. 11, 2017, 5:33 PM), https://www.wired.com/2017/01/elaine-chao-confirmation-hearing.

[281] *See* NAT'L HIGHWAY TRAFFIC SAFETY ADMIN., AUTOMATED DRIVING SYSTEMS 2.0, at 5–15 (2017), https://www.nhtsa.gov/sites/nhtsa.gov/files/documents/13069a-ads2.0_090617_v9a_tag.pdf.

[282] *Id.*

[283] *Id.* at 16.

[284] *See Voluntary Safety Self-Assessment*, *supra* note 109 (listing the VSSAs).

[285] PRELIMINARY STATEMENT, *supra* note 268, at 12.

[286] AV 1.0, *supra* note 47, at 39–43.

AV 1.0 also articulated NHTSA's view on the division of responsibilities between state and federal regulators in more detail.[287] Federal regulators would stick to high-level vehicle safety—setting standards, enforcing compliance, issuing recalls, and providing vehicle performance guidance.[288] States would retain control over driver safety—licensing drivers, regulating insurance, enforcing the traffic laws—as well as vehicle registration and safety inspections.[289] NHTSA's delineation of responsibility avoided the hard issue of who should regulate ADS safety, which effectively left it to the states.

States took divergent approaches to regulating ADS testing. California, the most popular state for ADS testing, required developers to submit an application to its Department of Motor Vehicles (DMV).[290] Companies approved to test were required to report how many miles their ADS-equipped vehicles drove and any crashes in which they were involved.[291] They also had to report "disengagements"—defined as incidents in which a test driver took over manual control from the ADS because "a failure of the autonomous technology" was detected or "the safe operation of the vehicle" required it.[292]

Other states took a more laissez-faire approach. Arizona, another popular choice for ADS testing, was typical.[293] It required no application and no reporting of miles, crashes, or disengagements.[294] It simply required the developer to submit a plan for how law enforcement officers could interact with the vehicle.[295] A third group of states adopted some, but not all, of the California model. For example, Pennsylvania—home to a cluster of ADS testing near Carnegie Mellon—required an application and crash reporting, but no disengagement reporting.[296] It could be argued that the divergence in state

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[287] *Id.* at 38.

[288] *Id.*

[289] *Id.*

[290] CAL. CODE REGS. tit. 13, § 227.18(a) (2022).

[291] *Id.* §§ 227.48, 227.50.

[292] *Id.* § 227.50.

[293] Ottzvia Zappala, *Car Companies Come to Arizona to Test Their Vehicles. Here's Why*, ARIZ. REPUBLIC (Dec. 25, 2017, 6:00 AM), https://www.azcentral.com/story/money/business/tech/2017/12/25/car-companies-come-arizona-test-their-vehicles-heres-why/965235001/.

[294] *See* ARIZ. REV. STAT. ANN. § 28-9702(C) (2021).

[295] *Id.* § 28-9702(C)(1).

[296] *See* PA. DEP'T OF TRANSP., AUTOMATED VEHICLE TESTING GUIDANCE 2, 7 (2018), https://www.penndot.pa.gov/ProjectAndPrograms/ResearchandTesting/Autonomous%20_Vehicles/Documents/PennDOT%20HAV%20Testing%20Guidance.pdf.

regulations created a race-to-the-bottom.[297] Some companies moved their ADS testing operations to Arizona.[298] But most companies continued to test in California notwithstanding its more stringent regulations.[299]

California's crash report database became the most important source of ADS safety data during the 2010s.[300] The California DMV may have lacked the expertise to do much with the data, but it published the reports on the internet so that others could use them. The transparency of the crash report database created an incentive to test safely that was more immediate than liability risk. ADS developers had to report even minor crashes, and they could expect that curious journalists and savvy investors would read the reports.

California's disengagement regulation proved to be counterproductive. Each year, the California DMV would release each company's disengagement reports.[301] After each release, the media would run stories comparing the ADS developers by their reported disengagement rate per mile.[302] These comparisons were often misleading because the reported disengagement rate was manipulable. The regulation did not clearly define which disengagements were reportable, so each company could use whatever definition served its interests. Even if every company had used the same definition, the disengagement rates would still have been misleading because they were not adjusted for ODD.[303] Even worse, the regulation created a perverse incentive for companies to encourage their test drivers to try not to disengage the ADS even when they felt unsafe.[304]

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[297] For a critique of the race-to-the-bottom theory, see Richard L. Revesz, *Rehabilitating Interstate Competition: Rethinking the "Race-to-the-Bottom" Rationale for Federal Environmental Regulation*, 67 N.Y.U. L. REV. 1210, 1213–27 (1992).

[298] Cecilia Kang, *Where Self-Driving Cars Go to Learn*, N.Y. TIMES, Nov. 11, 2017, at 1, 4.

[299] *See* Russ Mitchell, *Totally Driverless Cars Could Be Allowed on California Roads by June 2018*, L.A. TIMES (Oct. 11, 2017, 11:15 AM), https://www.latimes.com/business/autos/la-fi-hy-dmv-driverless-california-20171011-story.html (noting that forty-two companies held permits to test in California).

[300] *See* CAL. DEP'T MOTOR VEHICLES, AUTONOMOUS VEHICLE COLLISION REPORTS, https://www.dmv.ca.gov/portal/vehicle-industry-services/autonomous-vehicles/autonomous-vehicle-collision-reports (last updated Dec. 7, 2023).

[301] *See* CAL. DEP'T MOTOR VEHICLES, DISENGAGEMENT REPORTS, https://www.dmv.ca.gov/portal/vehicle-industry-services/autonomous-vehicles/disengagement-reports (last visited Jan. 14, 2024).

[302] *See* Andrew J. Hawkins, *Everyone Hates California's Self-driving Car Reports*, VERGE (Feb. 26, 2020, 3:06 PM), https://www.theverge.com/2020/2/26/21142685/california-dmv-self-driving-car-disengagement-report-data.

[303] *See id.*

[304] Junko Yoshida, *Disengagements: Wrong Metric for AV Testing*, EE TIMES (Apr. 10, 2019), https://www.eetimes.com/disengagements-wrong-metric-for-av-testing (paraphrasing Phil Koopman's argument that the disengagement reporting regulation "tends to subtly encourage test operators to minimize their interventions").

NHTSA's delegation of ADS safety regulation to the states can be defended as an experiment in the laboratories of democracy. NHTSA would eventually mandate crash reporting but not disengagement reporting.[305] The experience of state regulations may have informed that decision. Crashes are a better safety metric than disengagements. Crashes are easier to define, and the only incentive that crash reporting creates is to avoid crashes. For almost a decade, though, NHTSA's approach led to the odd result that the primary regulator of an industry worth tens of billions of dollars was the California DMV.

3. Comma.ai Special Order

NHTSA made one exception to its practice of not regulating driving automation safety in the 2010s. In September 2016, George Hotz, a brash, twentysomething engineer, announced that his startup Comma.ai would soon start selling an L2 system, the Comma One, directly to consumers.[306] The Comma One was designed to support certain late model year Honda Civics that were already equipped with a similar L2 system.[307] It was a small device, not much larger than a mobile phone, with a display screen and a camera.[308] It was meant to be installed in place of the driver's rearview mirror.[309] The Comma One used its camera and the Honda-installed radar to sense its surroundings, Comma.ai's software to plan its motion, and the Honda-installed controls to execute the motion.[310]

Why would anyone want to buy a L2 kit for a vehicle already equipped with a similar system? Hotz claimed that Honda's system was just "[not] very good" and that the Comma One would provide better performance.[311] He tried to preempt questions about the Comma One's legality by calling it an "aftermarket upgrade."[312] He argued that, because the Comma One "provides no new

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[305] *See* SGO, *supra* note 59, at 2.

[306] Darrell Etherington & Romain Dillet, *Comma.ai Will Ship a $999 Autonomous Driving Add-on by the End of This Year*, TECHCRUNCH (Sept. 13, 2016, 5:10 PM), https://techcrunch.com/2016/09/13/comma-ai-will-ship-a-999-autonomous-driving-add-on-by-the-end-of-this-year.

[307] Andrew J. Hawkins, *George Hotz is on a hacker Crusade Against the 'Scam' of Self-Driving Cars*, VERGE (Jul. 13, 2019, 9:00 AM), https://www.theverge.com/2018/7/13/17561484/george-hotz-comma-ai-self-driving-car-scam-diy-kit.

[308] *Id.*

[309] *Id.*

[310] Etherington & Dillet, *supra* note 306.

[311] George Hotz, *On the Safety and Legality of the Comma One*, WE ARE COMMA.AI (Oct. 20, 2016, 5:04 PM), https://commaai.blogspot.com/2016/10/on-safety-and-legality-of-comma-one.html.

[312] *Id.*

functionality," it "should be legal everywhere the Honda systems are."[313] Hotz also exaggerated the Comma One's capabilities, claiming that drivers could travel from "Mountain View to San Francisco without touching the wheel."[314]

NHTSA used its investigative powers to crack down on Comma.ai. The Safety Act provides that the Secretary of Transportation may "require, by general or special order, any person to file reports or answers to specific questions, including reports or answers under oath."[315] In October 2016, NHTSA issued a special order to Comma.ai.[316] In a letter attached to the order, the agency's chief counsel wrote that the Comma One was "replacement motor vehicle equipment" and that Comma.ai was therefore "a manufacturer of motor vehicle equipment subject to the requirements of" the Safety Act.[317] He urged Comma.ai "to delay selling or deploying [its] product on the public roadways unless and until [it could] ensure that it is safe."[318] He warned that "there is a high likelihood that some drivers will use [the] product in a manner that exceeds its intended purpose," which creates a safety risk to other road users.[319]

The special order required Hotz to respond under oath to a set of questions.[320] NHTSA asked for detail on how the Comma One would be installed, how it differed from Honda's system, how a driver would use it, what its ODD would be, and how Comma.ai had determined that it would operate safely within its ODD.[321] NHTSA also asked whether installing the Comma One would affect a vehicle's compliance with the FMVSSs, including Standard 111, which requires rearview mirrors.[322]

One day after NHTSA issued the special order, Hotz announced that he was cancelling the Comma One.[323] He tweeted that he "[w]ould much rather spend

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[313]   *Id.*

[314]   Etherington & Dillet, *supra* note 306.

[315]   49 U.S.C. § 30166(g)(1)(A).

[316]   Darrell Etherington, *Comma.ai Cancels the Comma One Following NHTSA Letter*, TECHCRUNCH (Oct. 28, 2016, 9:34 AM), https://techcrunch.com/2016/10/28/comma-ai-cancels-the-comma-one-following-nhtsa-letter.

[317]   Letter from Paul A. Hemmersbaugh, Chief Couns., Nat'l Highway Traffic Safety Admin., to George Hotz, President, Comma.ai 8–9 (Oct. 27, 2016).

[318]   *Id.*

[319]   *Id.* at 1–2.

[320]   Etherington, *supra* note 316.

[321]   Special Order Directed to Comma.ai, U.S. Dep't of Transp. & Nat'l Highway Traffic Safety Admin. from Paul A. Hemmersbaugh, Chief Counsel, Nat'l Highway Traffic Safety Admin., to George Hotz, President, Comma.ai 8–9 (Oct. 27, 2016).

[322]   *Id.* at 10.

[323]   Etherington, *supra* note 316.

[his] life building amazing tech than dealing with regulators and lawyers."[324] The special order reflected NHTSA's approach to driving automation safety. The agency did not attempt to assess whether the Comma One was safe. Instead, it asked Comma.ai to explain how *Comma.ai* had assessed the Comma One's safety.[325] Comma.ai, a small startup with no lawyers, could not pass that basic test and gave up.[326] More sophisticated companies had no trouble self-certifying their safety.

4. Novel Vehicle Designs

While NHTSA avoided regulating driving automation safety, it took action to facilitate the development of ADS-equipped vehicles with unconventional designs. Most ADS developers built their test platforms by taking FMVSS-compliant vehicles and adding sensors and computers.[327] These modifications generally did not take the vehicles out of FMVSS compliance. Some ADS developers, though, sought to design vehicles without human controls or with unconventional seating configurations.[328] These designs did not comply with the FMVSSs, so the developers needed NHTSA to approve them. NHTSA used its powers of interpretation, exemption, and amendment cautiously, accommodating the new vehicles only when it could avoid taking a position on the safety of the underlying ADS.

In 2015, Google asked NHTSA to interpret the FMVSSs to allow an ADS-equipped vehicle that lacked a "brake pedal, steering wheel, accelerator pedal, and certain controls and displays."[329] Specifically, Google asked the agency to treat its ADS as the vehicle's "driver" and to deem certain standards requiring human controls to be inapplicable or satisfied by the ADS.[330] NHTSA agreed that the ADS could be considered the "driver" of the vehicle, but it rejected most

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[324] comma (@comma_ai), X [formerly TWITTER] (Oct. 28, 2016, 7:02 AM), https://twitter.com/comma_ai/status/791958385348321284 ("Would much rather spend my life building amazing tech than dealing with regulators and lawyers. It isn't worth it. -GH 2/3").

[325] Special Order Directed to Comma.ai, *supra* note 321, at 10.

[326] Comma (@comma_ai), X [formerly TWITTER] (Oct. 28, 2016, 7:02 AM), https://twitter.com/comma_ai/status/791958385348321284.

[327] *See* WAYMO, *supra* note 170, at 21.

[328] *See id.*

[329] Letter from Chris Urmson, Dir., Self-Driving Car Project, Google, Inc., to Paul A. Hemmersbaugh, Chief Counsel, Nat'l Highway Traffic Safety Admin. 2 (Nov. 12, 2015) (on file with author).

[330] *Id.* at 7–9.

of Google's proposals for the standards on human controls.[331] The agency emphasized that it could not deem a standard met without a procedure to test that the ADS met the standard.[332] It explained that some of the issues that Google had raised "are not susceptible to interpretation and must be resolved through rulemaking."[333] But it added that other issues "may be resolved on an interim basis" through a petition for an exemption.[334]

Two ADS developers accepted NHTSA's invitation to petition for an exemption. In January 2018, Cruise petitioned for an exemption for an ADS-equipped electric Chevrolet Bolt without human controls.[335] The Safety Act gave NHTSA two ways to grant Cruise an exemption. The agency could find that the exemption would facilitate the development of a new safety feature that was "at least equal to the safety level of the standard."[336] Or, since the Bolt met the definition of a "low emission-vehicle," it could find that that the exemption "would not unreasonably lower" the safety of the vehicle.[337] Cruise's petition created a dilemma for NHTSA. The agency had told ADS developers to seek exemptions. But it could not properly assess Cruise's claims about the safety of its ADS. It had no "objective" test to measure the Bolt's compliance with the standards. NHTSA requested comment on the petition but took no action.[338] In 2020, Cruise withdrew the Bolt petition and pledged to file a new petition later for its next generation vehicle.[339]

In October 2018, the automated delivery startup Nuro petitioned for an exemption for its ADS-equipped vehicle, the R2X.[340] The R2X was a small,

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[331] Letter from Paul A. Hemmersbaugh, Chief Counsel, Nat'l Highway Traffic Safety Admin., to Chris Urmson, Dir., Self-Driving Car Project, Google, Inc. (Feb. 4, 2016), https://www.nhtsa.gov/interpretations/google-compiled-response-12-nov-15-interp-request-4-feb-16-final.

[332] *Id.*

[333] *Id.*

[334] *Id.*

[335] *See* Safety Petition from General Motors, LLC to Nat'l Highway Traffic Safety Admin. 3, 5, 7 (Jan. 11, 2018), https://www.regulations.gov/document/NHTSA-2019-0016-0002.

[336] 49 U.S.C. § 30113(b)(3)(B)(ii).

[337] *Id.* § 30113(b)(3)(B)(iii).

[338] Receipt of Petition for Temporary Exemption from Various Requirements of the Safety Standards for an All-Electric Vehicle with an Automated Driving System, from Nat'l Highway Traffic Safety Admin. to General Motors, LLC, 84 Fed. Reg. 10182 (Mar. 19, 2019), https://www.govinfo.gov/content/pkg/FR-2019-03-19/pdf/2019-05119.pdf.

[339] Jane Lanhee Lee et al., *Cruise, GM to Seek U.S. Okay for Self-driving Vehicle Without Pedal, Steering Wheel*, REUTERS (Oct. 21, 2020, 2:02 PM), https://www.reuters.com/article/us-autonomous-cruise-nhtsa/cruise-gm-to-seek-u-s-okay-for-self-driving-vehicle-without-pedal-steering-wheel-idUSKBN2762SP.

[340] Petition for Exemption from Certain Provisions of Federal Motor Vehicle Safety Standard, No. 500, from Dave Ferguson, President and Co-Founder, Nuro, Inc., to The Honorable Heidi King, Office of the

short, "driverless and passengerless" vehicle for carrying packages.[341] It had a top speed of less than 25 mph, which meant that it met the regulatory definition of a "low-speed vehicle."[342] Low-speed vehicles only need to comply with a single standard—Standard 500.[343] Nuro sought exemptions from parts of Standard 500 that required exterior mirrors, windshields with specific glazing materials, and unobstructed rear visibility.[344] NHTSA granted the petition.[345] The agency found that the R2X's non-compliance would not lower the safety of the vehicle.[346] In fact, it suggested that the R2X might be safer without exterior mirrors.[347] NHTSA attached conditions to the exemption, including a requirement that Nuro report any crashes within 24 hours and "any incidents in which the R2X has experienced a sustained acceleration of at least 0.7g on any axis for at least 150 ms."[348]

In 2022, NHTSA amended the FMVSSs that regulate occupant protection to accommodate vehicles without human controls.[349] For passenger vehicles, the amendment essentially treats the seat formerly known as the driver's seat as if it were a front passenger seat.[350] For "occupant-less vehicles," the new amendment effectively eliminates the occupant protection standards.[351] The amendment could facilitate the deployment of robotaxis without human controls and delivery-only vehicles like the R2X. More radical design changes still require exemptions. In 2023, NHTSA announced that it was investigating Amazon-backed Zoox to examine its self-certification of a seemingly non-compliant ADS-equipped vehicle, in which passengers face each other in a "campfire" configuration.[352]

Administrator, Nat'l Highway Traffic Safety Admin. (Oct. 19, 2018) [hereinafter Nuro Petition for Exemption], https://www.regulations.gov/document/NHTSA-2019-0017-0002.

[341] *Id.* at 3.

[342] *Id.*

[343] Nuro, Inc.; Grant of Temporary Exemption for a Low-Speed Vehicle with an Automated Driving System, 85 Fed. Reg. 7826, 7828 (Feb. 11, 2020).

[344] Nuro Petition for Exemption, *supra* note 340, at 2.

[345] *See* Nuro, Inc., Grant of Temporary Exemption for a Low-Speed Vehicle with an Automated Driving System, *supra* note 343, at 7826.

[346] *Id.* at 7827.

[347] *Id.* at 7832.

[348] *Id.* at 7841–42.

[349] *See* Occupant Protection for Vehicles with Automated Driving Systems, 87 Fed. Reg. 18560 (Mar. 30, 2022) (codified at 49 C.F.R. pt. 571).

[350] *See id.* at 18566.

[351] *See id.*

[352] *See* NAT'L HIGHWAY TRAFFIC SAFETY ADMIN., AQ 23-001 RESUME (2023), https://static.nhtsa.gov/odi/inv/2023/INOA-AQ23001-2603.PDF; David Shepardson, *U.S. Opens Probe into*

NHTSA's approach to novel vehicle designs exemplifies its more general approach to regulation in the early years of automation. The agency was willing to modify existing standards to accommodate ADSs only when it did not need to decide thorny issues of ADS safety.

B. NTSB's War on NHTSA

NHTSA's passive approach to regulating driving automation safety attracted a high-profile critic—its sister agency, the National Transportation Safety Board. Unlike NHTSA, the NTSB has no power to make rules or issue recalls.[353] Its mission is to "establish the facts, circumstances, and cause or probable cause of" significant crashes.[354] The NTSB can make recommendations to the Secretary of Transportation, but the Secretary may refuse to carry them out.[355] The NTSB's strongest power is its megaphone, which it used with increasing volume to criticize NHTSA.

1. Williston Tesla Crash

On May 7, 2016, a Tesla Model S with Autopilot engaged collided with a tractor-trailer near Williston, Florida.[356] The crash happened at 4:36 PM on a clear, dry afternoon.[357] The Tesla was traveling straight in the right lane of eastbound US Highway 27A, a four lane divided road with a wide grass median.[358] The tractor-trailer was coming from the westbound side, making an unprotected left across the eastbound lanes onto a side road.[359] The Tesla struck the right side of the trailer at 74 mph.[360] The underside of the trailer sheared off the Tesla's roof and killed the Tesla's driver, Joshua Brown.[361]

Amazon's Zoox Robotaxi Self-Certification, REUTERS (Mar. 6, 2023, 1:52 PM), https://www.reuters.com/legal/us-opens-probe-into-amazons-zoox-robotaxi-self-certification-2023-03-06/.

[353] *See* 49 U.S.C. § 1135(a) (outlining the NTSB's authority to make recommendations).

[354] *Id.* § 1131(a)(1).

[355] *See id.* § 1135(a).

[356] *See* NTSB WILLISTON REPORT, *supra* note 52, at 1.

[357] *Id.* at 1, 5.

[358] *Id.* at 1, 3.

[359] *Id.* at 1.

[360] *Id.*

[361] *Id.*; *see also* David Shepardson, *Tesla Driver in Fatal 'Autopilot' Crash Got Numerous Warnings: U.S. Government*, REUTERS (June 19, 2017, 5:36 PM), https://www.reuters.com/article/us-tesla-crash-idUSKBN19A2XC.

Figure 1: Williston Crash Scene (NTSB 2017)

Brown had engaged Autopilot for 37 minutes of his 41 minute trip that morning.[362] Autopilot's driver monitoring system was designed to send a warning if the driver did not interact with the steering wheel for a certain period of time.[363] The system would start with a visual warning, but if the driver did not respond, it would escalate to an audio warning. Seven times during Brown's trip that morning, the instrument panel displayed a visual warning that read "Hold Steering Wheel."[364] On six of those occasions, the system escalated to an audio warning before he touched the steering wheel.[365]

The evidence suggests that Brown did not notice the tractor-trailer. He did not brake or take control of the steering wheel.[366] He last interacted with Autopilot one minute and fifty-one seconds before the crash, when he set the

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[362] NTSB WILLISTON REPORT, *supra* note 52, at 14.
[363] *Id.*
[364] *Id.*
[365] *Id.*
[366] *Id.* at 15.

cruise control speed to 74 mph.[367] Autopilot did not detect the tractor-trailer crossing the Tesla's path either.[368]

After the crash, NHTSA's Office of Defects Investigation (ODI) opened an investigation to "examine the design and performance" of Autopilot.[369] It subpoenaed Tesla for data on the Williston crash and other crashes involving Autopilot.[370] ODI's investigation revealed other cases in which Teslas with Autopilot engaged had crashed in situations that the system was not designed to handle.[371] They had crashed when other traffic crossed their lanes, cut into their lanes, or cut out of their lanes.[372] Some of these crashes happened outside of Autopilot's ODD, including "city traffic, highway entrance/exit ramps, construction zones, in heavy rain, and road junctions/intersections."[373] ODI also found that, in some of the other Tesla crashes, the driver appeared distracted or confused about whether Autopilot was engaged.[374]

ODI's report did not blame Tesla for the crashes. Instead, ODI argued that L2 systems developed by Tesla's competitors were not designed to handle to cut-ins, cut-outs, or cross-traffic either.[375] It conceded that the information Tesla provided to drivers was "perhaps not as specific as it could be."[376] But it determined that the Autopilot crashes did not amount to a defect because they were "isolated events that involved different sets of contributing factors."[377]

After the Williston crash, Tesla made changes to Autopilot's driver monitoring system. Tesla shortened the period of time a driver could go without touching the steering wheel before receiving a warning.[378] It also added a new driver management system called "Autopilot strikeout," which disables

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[367] *Id.* The Tesla's forward collision warning did not send an alert, and its automatic emergency braking system did not activate. *Id.* at 41.

[368] *Id.* at 15. Some experts blame Tesla's decision not to equip its vehicles with lidar. *See* Brad Templeton, *Elon Musk's War on LIDAR: Who Is Right and Why Do They Think That?*, FORBES (May 6, 2019, 10:00 AM), https://www.forbes.com/sites/bradtempleton/2019/05/06/elon-musks-war-on-lidar-who-is-right-and-why-do-they-think-that ("A LIDAR system would have detected the truck crossing the road that killed Tesla driver Joshua Brown in Florida when Autopilot sent his car under it.").

[369] ODI WILLISTON REPORT, *supra* note 53, at 1.

[370] *Id.* at 8.

[371] *Id.*

[372] *Id.*

[373] *Id.* at 9.

[374] *Id.*

[375] *See id.* at 8–9 (pointing to specific warnings in BMW and Volvo owner's manuals).

[376] *Id.* at 11.

[377] *Id.* at 9.

[378] *Id.* at 7.

Autopilot for the remainder of the trip "if the driver fails to respond to the alerts adequately."[379] ODI suggested that it was satisfied with these changes, and it concluded that Autopilot was not defective. [380]

The most controversial part of ODI's report was a paragraph that attempted to address the net impact of Autopilot on crash rates. ODI explained that it "analyzed mileage and airbag deployment data supplied by Tesla . . . to calculate crash rates by miles travelled prior to and after Autopilot installation."[381] According to the calculation, "the Tesla vehicles crash rate dropped by almost 40 percent" after Autopilot was installed.[382] The report offered no further detail on how ODI performed the calculation.[383] Randy Whitfield, an independent consultant, later obtained the underlying data through a FOIA request and published a report that disputed ODI's conclusions.[384] Tesla took the ODI report as an exoneration. Elon Musk called it "very positive."[385]

The NTSB issued its own report on the Williston crash several months later. The report largely accepted ODI's account of the facts.[386] But it was much more critical of Tesla Autopilot than ODI had been. The NTSB determined that the probable cause of the crash was "the truck driver's failure to yield the right of way to the car, combined with the car driver's inattention due to overreliance on vehicle automation, which resulted in the car driver's lack of reaction to the presence of the truck."[387] The NTSB also found that the design of Tesla Autopilot contributed to Brown's complacency by "permit[ing] his prolonged disengagement from the driving task."[388]

The NTSB recommended that L2 system developers improve their driver monitoring capabilities and prevent their systems from being engaged outside their ODDs.[389] It also recommended that NHTSA develop standard data parameters to assess driving automation safety, mandate that developers report

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[379] *Id.*

[380] *Id.* at 11–12.

[381] *Id.* at 10.

[382] *Id.*

[383] *See id.*

[384] Edward Niedermeyer, *NHTSA's Flawed Autopilot Safety Study Unmasked*, THE DRIVE (July 15, 2019, 8:17 AM), https://www.thedrive.com/tech/26455/nhtsas-flawed-autopilot-safety-study-unmasked.

[385] Elon Musk (@elonmusk), X [formerly TWITTER] (Jan. 19, 2017, 12:09 PM), https://twitter.com/elonmusk/status/822128741228756992?lang=en.

[386] *See* NTSB WILLISTON REPORT, *supra* note 52.

[387] *Id.* at vi.

[388] *Id.*

[389] *Id.* at 43.

crashes, and require that L2 systems be designed to prevent engagement outside their ODDs.[390] NHTSA did not act immediately on any of the recommendations.[391] But the issues that the NTSB raised became the focus of debates about driving automation safety.

2. Tempe Uber Crash

On March 18, 2018, a Volvo XC90 SUV equipped with Uber's ADS struck and killed Elaine Herzberg in Tempe, Arizona.[392] The crash happened at 9:58 PM on a dry evening.[393] The SUV was driving northbound in the right lane of Mill Avenue, a multi-lane suburban boulevard with a wide median.[394] Herzberg was walking her bike across the street, moving from west to east.[395] When she reached the right lane, the SUV hit her at 39 mph.[396] She died from the impact.[397] An Uber test driver, Rafaela Vasquez, was seated in the driver's seat of the SUV.[398] In the seconds before the crash, Vasquez was looking down towards the center console, where she was streaming a show on her mobile phone.[399] She did not touch the wheel until 0.02 seconds before impact.[400]

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[390] *Id.*

[391] *See* NTSB Mountain View Report, *supra* note 34, at 60–61.

[392] *See* NTSB TEMPE REPORT, *supra* note 38, at v, 1; *see also* Kate Conger, *Driver Charged in Uber's Fatal 2018 Autonomous Car Crash*, N.Y. TIMES (Sept. 15, 2020), https://www.nytimes.com/2020/09/15/technology/uber-autonomous-crash-driver-charged.html.

[393] NTSB TEMPE REPORT, *supra* note 38, at 1, 3.

[394] *Id.* at v, 4.

[395] *Id.* at v.

[396] *Id.* at 2.

[397] *Id.* at v.

[398] *Id.* at 1; *see also* Conger, *supra* note 392.

[399] NTSB TEMPE REPORT, *supra* note 38, at 1.

[400] *Id.* at v.

Figure 2: Tempe Crash Scene (NTSB 2019)
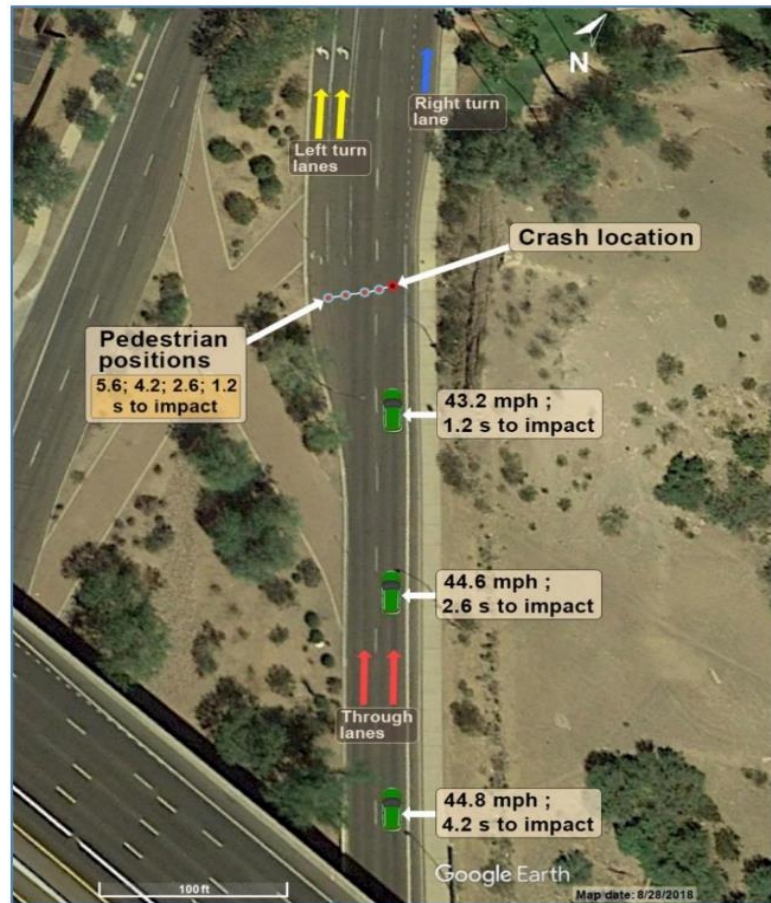
The NTSB found that the ADS detected Herzberg 5.6 seconds before impact.[401] The perception software initially classified her as a vehicle, then an unknown object, and then a bicyclist.[402] The ADS continued to track her, but did not make any predictions about her future path.[403] By the time it recognized that a collision was imminent—1.2 seconds before the crash—"the situation exceeded the response specifications of the ADS braking system to avoid the

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[401]   *Id.*
[402]   *Id.* at 1.
[403]   *Id.*

collision."[404] In that situation, the ADS was designed to rely on the test driver to take control.[405]

The NTSB determined that the probable cause of the crash was Vasquez's failure "to monitor the driving environment and the operation of the [ADS] because she was visually distracted" by her phone.[406] It also found that Uber's "inadequate safety risk assessment procedures," "ineffective oversight" of test drivers, and "lack of adequate mechanisms for addressing operators' automation complacency" contributed to the crash.[407]

The NTSB's recommendations after the Tempe crash were less concrete than its recommendations after the Williston crash. The NTSB simply asked NHTSA to require ADS developers to submit VSSAs, "[e]stablish a process for the ongoing evaluation of" the VSSAs, and "determine whether the plans include appropriate safeguards for testing a developmental [ADS] on public roads, including adequate monitoring of [test driver] engagement."[408] The Board's recommendations suggest that it was envisioning that the VSSAs would look different than the marketing documents that the developers submitted.

The NTSB gave similarly vague advice to Arizona regulators. It recommended that they require companies testing ADSs to submit an application with a risk management plan and that they convene an expert task force to evaluate the applications.[409] Even the NTSB—an agency more enthusiastic about regulation than the Trump-era NHTSA—had no answer to the hard problem of assessing ADS safety other than expressing hope that outside experts could solve it.

State regulators agreed with the NTSB that Uber's ADS testing program had taken unreasonable risks. Arizona and California took actions that effectively banned Uber from testing its ADS on their public roads.[410] Uber resumed public

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[404] *Id.*

[405] *Id.*

[406] *Id.* at v.

[407] *Id.* at v–vi. The NTSB listed as further contributing factors Herzberg's decision to cross the street outside of a crosswalk and Arizona's "insufficient oversight of automated vehicle testing." *Id.* at vi.

[408] *Id.* at viii.

[409] *Id.* at ix.

[410] *See* Melissa Daniels, *Arizona Governor Suspends Uber from Autonomous Testing*, ASSOCIATED PRESS (Mar. 26, 2018, 10:01 PM), https://apnews.com/article/0ae96a5b23a542e39da252c4267ec3a5; Letter from Brian G. Soublet, Chief Counsel, Cal. Dep't Motor Vehicles, to Austin Heyworth, Uber Advanced Tech. Ctr., LLC (Mar. 27, 2018) (on file with author) (explaining that Uber's testing permit was expiring and it would need to address the crash if and when it reapplied).

road testing in December 2018.[411] But its reputation never recovered, and Uber sold its ADS program in 2020.[412]

3. Mountain View Tesla Crash

On March 23, 2018, a Tesla Model X SUV with Autopilot engaged crashed in Mountain View, California and killed its driver, Walter Huang.[413] The crash happened at 9:27 AM on a clear day.[414] The Tesla was driving southbound on US Highway 101, an access-controlled highway, in the second lane from the left.[415] Shortly before the crash site, the left lane split from the other lanes to become an exit lane. There was a paved area called a "gore" between the lanes. At the end of the gore was a "crash attenuator," the front end of a metal lane divider between the exit lane and the main roadway.[416] As the Tesla SUV approached the lane divide, it drifted into the gore.[417] Then it struck the attenuator at just over 70 mph.[418] Huang died a few hours later from blunt force injuries that he sustained in the crash.[419]

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[411] David Shepardson, *Uber Resuming Self-Driving Car Testing in Pennsylvania*, REUTERS (Dec. 20, 2018, 8:03 AM), https://www.reuters.com/article/us-uber-selfdriving/uber-resuming-self-driving-car-testing-in-pennsylvania-idUSKCN1OJ1OD.

[412] *See* Chapman & Hull, *supra* note 112.

[413] *See* NTSB MOUNTAIN VIEW REPORT, *supra* note 34, at ix; *see also* Brad Templeton, *STSB Releases Report On 2018 Fatal Silicon Valley Tesla Autopilot Crash*, FORBES (Feb. 13, 2020, 8:10 AM), https://www.forbes.com/sites/bradtempleton/2020/02/13/ntsb-releases-report-on-2018-fatal-silicon-valley-tesla-autopilot-crash.

[414] NTSB MOUNTAIN VIEW REPORT, *supra* note 34, at ix, 26.
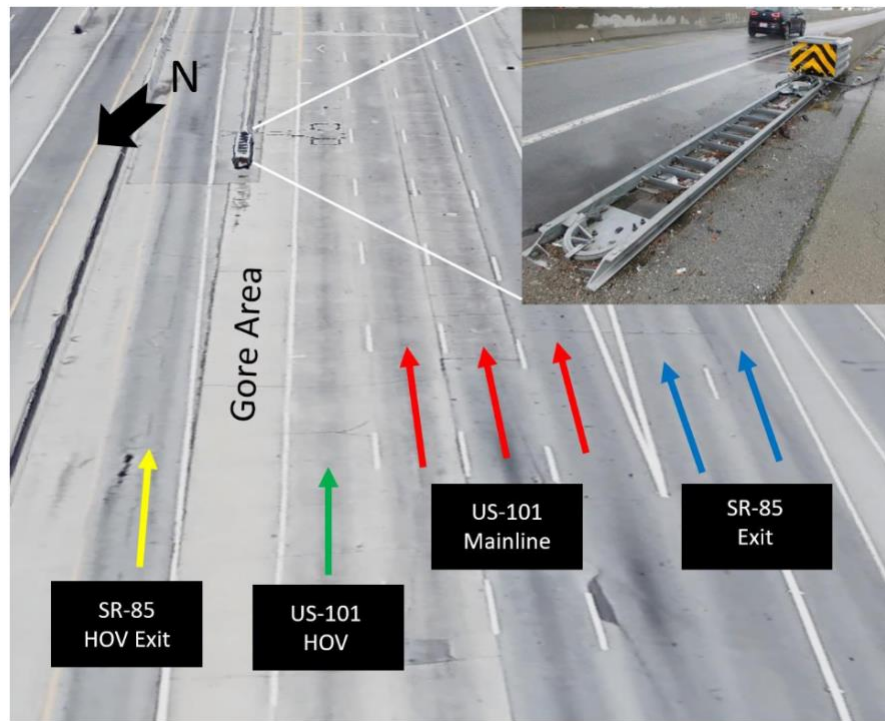
[415] *Id.* at ix.

[416] *See infra* Fig. 3.

[417] NTSB MOUNTAIN VIEW REPORT, *supra* note 34, at ix.

[418] *Id.*

[419] *Id.* at 3. The impact rotated the Tesla counterclockwise into an adjacent lane, where it got hit by a Mazda and an Audi. *Id.* at ix. The driver of the Audi was not injured, and the driver of the Mazda suffered minor injuries. *Id.*

Figure 3: Mountain View Crash Scene (NTSB 2020)

Autopilot was engaged before and during the crash.[420] Huang had set the cruise control speed to 75 mph.[421] From ten to six seconds before the crash, the Tesla was traveling at a slightly slower speed—sixty-four to sixty-six mph—to maintain a safe headway.[422] About six seconds before the crash, Autopilot started to steer the vehicle left into the gore.[423] About four seconds before the crash, it started to accelerate because it no longer detected a vehicle ahead.[424] The Autopilot did not change the collision course it had set, and it rammed the vehicle straight into the attenuator.[425]

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[420] *Id.* at 5.
[421] *Id.*
[422] *Id.*
[423] *Id.* at 6.
[424] *Id.*
[425] *Id.*

The crash happened on Huang's morning commute.[426] He was playing a video game around the time of the crash, and he had also played video games while driving every morning that week.[427] Autopilot gave Huang two visual warnings and one audio warning to keep his hands on the wheel during the drive.[428] Investigators learned from interviews with Huang's family and a friend that Huang had complained about Autopilot driving him towards the same gore before.[429] In fact, data from the system showed that, in the month leading up to the crash, Autopilot had twice steered Huang's vehicle towards the gore.[430] In both of those cases, Huang had manually corrected the steering.[431]

The NTSB did not conclusively resolve why Autopilot drove the Tesla into the gore. It suggested that the system failed to detect the lane marking between its lane and the gore because it was worn at the time of the crash.[432] Tesla engineers, in correspondence with the NTSB, "surmised that the [lane centering] system likely momentarily lost its lane line prediction and/or identified a stronger lane line on the left side of the gore."[433] Accordingly, the NTSB determined that the probable cause of the crash was "the Tesla Autopilot system steering the sport utility vehicle into a highway gore area due to system limitations, and the driver's lack of response due to distraction likely from a cell phone game application and overreliance on the Autopilot."[434]

The NTSB's report excoriated Tesla. The Board argued that the fatal Mountain View crash was just one of a series of crashes caused by known limitations of Tesla Autopilot.[435] It noted that Autopilot had played a similar role in the fatal Williston crash, a crash between a Tesla and a fire truck in Culver City, California, and another fatal crash between a Tesla and tractor-trailer in Delray Beach, Florida.[436]

Then the NTSB pinned blame on NHTSA. The Board claimed that NHTSA's "failure to ensure that vehicle manufacturers of [L2 systems] are incorporating appropriate system safeguards to limit operation of these systems to [their

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[426] *Id.* at 21.
[427] *Id.* at 19, 33.
[428] *Id.* at 20.
[429] *Id.* at 20–21.
[430] *Id.* at 21.
[431] *Id.*
[432] *Id.* at 21–22.
[433] *Id.* at 32.
[434] *Id.* at 58.
[435] *Id.* at 43, 52.
[436] *Id.* at 26–29.

ODDs] compromises safety."[437] It argued that NHTSA's approach to regulating driving automation safety was "misguided" because it relied on "waiting for problems to occur rather than addressing safety issues proactively."[438]

The NTSB report reiterated its recommendations from the Williston crash report on safety data, crash reporting, and automatic enforcement of ODD restrictions.[439] Then it asked NHTSA to set standards for driver monitoring systems and to require that L2 system developers meet those standards.[440] It also called for NHTSA to investigate Tesla Autopilot to determine if its "operating limitations, the foreseeability of driver misuse, and the ability to operate the vehicles outside the intended ODD pose an unreasonable risk to safety."[441]

The NTSB continued its campaign against NHTSA after the Mountain View crash. In December 2020, NHTSA published an advanced notice of proposed rulemaking that sought comment on how the agency should develop a "framework" for ADS safety.[442] On February 1, 2021, just days after the start of the Biden Administration, the NTSB sent a letter in response to the request for comments.[443] It used the opportunity to reiterate its previous objections and criticize the agency's approach to driving automation safety.[444]

The NTSB explained that NHTSA had said that it planned to ensure driving automation safety "through its enforcement authority and a surveillance program aimed at identifying safety-related trends in design or performance defects, and not through regulations."[445] The NTSB countered that NHTSA should address safety issues proactively.[446] Even if recalls were the answer, the Board wrote, "[t]o date, NHTSA has shown no indication that it is prepared to respond effectively and in a timely manner to potential [driving automation] safety-related defects."[447]

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[437]   *Id.* at xiii.

[438]   *Id.* at 65.

[439]   *Id.* at 60–61; *see also* NTSB WILLISTON REPORT, *supra* note 52, at 43.

[440]   NTSB MOUNTAIN VIEW REPORT, *supra* note 34, at 59.

[441]   *Id.* at 52.

[442]   *See* Framework for Automated Driving System Safety, 85 Fed. Reg. 78058 (Dec. 3, 2020).

[443]   *See* Letter from Robert L. Sumwalt, III, Chairman, Nat'l Transp. Safety Bd., to U.S. Dep't of Transp. 1–2 (Feb. 1, 2021) (on file with author).

[444]   *See id.*

[445]   *Id.* at 8.

[446]   *Id.*

[447]   *Id.* at 9.

The NTSB was right to point out that, if Tesla had implemented a better driver monitoring system after the Williston crash, it could have prevented the death of Walter Huang and likely others. But the NTSB's perspective is colored by its distance from the rulemaking process. Its recommendations are not subjected to cost-benefit analysis and judicial review. When technology changes, it can quickly change its recommendations in response. NHTSA, by contrast, must contend with cost-benefit analysis, judicial review, and the time and resource demands of the rulemaking process. Those constraints may not justify NHTSA's initial reluctance to regulate driving automation safety, but they help to explain it.

III. THE EXPERIMENTAL STRATEGY (2021–PRESENT)

Starting in 2021, NHTSA dramatically changed its approach to driving automation safety. It issued an unprecedented standing general order that required certain crashes involving driving automation systems to be reported within a day. Then it started to use its recall authority to make developers fix defective driving automation software.

A. Crash Reporting

In October 2021, President Biden appointed Steven Cliff, a former California environmental regulator, as NHTSA's Administrator.[448] Under Cliff, NHTSA started to regulate driving automation safety. But it did not follow the NTSB's recommendation to return to rulemaking. Instead, it started to use its investigative and recall powers in unprecedented ways.[449] Cliff explained in an interview that, when he started the job, he was surprised to discover that the agency had no data on crashes involving automation.[450] That would soon change.

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[448] David Shepardson, *Biden to Tap No. 2 Official to Head U.S. Auto Safety Agency*, REUTERS (Oct. 20, 2021, 12:21 AM), https://www.reuters.com/business/autos-transportation/exclusive-biden-tap-no-2-official-head-us-auto-safety-agency-source-2021-10-19/.

[449] Tom Krisher, *New NHTSA Chief: Agency to Scrutinize Auto-driver Technology*, ASSOCIATED PRESS (June 29, 2022, 6:52 PM), https://apnews.com/article/technology-government-and-politics-892ac7de98e90682808e09a0734ddcec.

[450] *Id.*

1. *Standing General Order*

In June 2021, NHTSA issued a standing general order (SGO) mandating reporting for certain crashes involving driving automation systems.[451] NHTSA invoked its statutory authority to "require, by general or special order, any person to file reports or answers to specific questions"—the same provision it used for its special order to Comma.ai.[452] NHTSA explained that it would use the crash reports to evaluate whether vehicle manufacturers "are meeting their statutory obligations to ensure that their vehicles and equipment are free of defects."[453] The SGO is directed to all "vehicle and equipment manufacturers and operators of" L2 systems and ADSs.[454] It covers crashes on publicly accessible roads in the United States in which an L2 system or an ADS was engaged at the moment of the crash or during the last 30 seconds before the crash.[455]

The SGO's reporting mandate depends on the severity of the crash and the level of automation.[456] A crash involving either an L2 system or an ADS that "results in any individual being transported to a hospital for medical treatment, a fatality, a vehicle tow-away, or an air bag deployment or involves a vulnerable road user" must be reported within one day.[457] A crash involving an ADS that does not meet these severity criteria must be reported by the fifteenth day of the month following the month of the crash.[458] In effect, the SGO mandates crash reporting for severe crashes involving L2 systems and *all* crashes involving ADSs.[459]

The SGO does not impose any affirmative duty to seek out information about crashes.[460] It only requires companies to report crashes "of which [they] receive notice."[461] Notice is defined broadly to include "vehicle reports, test reports, crash reports, media reports, consumer or customer reports, claims, demands,

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[451] SGO, *supra* note 59, at 1–2.

[452] *Id.* at 5; *see also* Special Order Directed to Comma.ai, *supra* note 321, at 3–4.

[453] SGO, *supra* note 59, at 4–5.

[454] *Id.* at 2.

[455] *Id.* at 5, 14–15.

[456] Developers must also report crashes in which their system "contributes or is alleged to contribute (by steering, braking, acceleration, or other operational performance) to another vehicle's physical impact with another road user or property" even if the automation system-equipped vehicle was not impacted. *Id.* at 6.

[457] *Id.* at 13–14. A more detailed crash report must be filed within ten days. *Id.* at 13.

[458] *Id.* at 14.

[459] *Id.* at 13–15.

[460] *See id.* at 10 (detailing the NHTSA requirement to submit reports on a prospective basis).

[461] *Id.* at 10.

and lawsuits."[462] In practice, though, notice depends on the company's technology. ADS developers almost always have access to crash data because they can physically retrieve it when their vehicles return to the garage. L2 system developers only have reliable access to crash data if their vehicles are equipped with telematics. Otherwise, they lose access to data once their vehicles leave the dealership.

2. SGO Data

Starting in June 2022, NHTSA has been periodically releasing the data it collects under the SGO.[463] The data show both the tremendous potential of rapid, reliable crash reporting and the sorry state of telematics on most vehicles with L2 systems.

The most recent ADS data show 534 crashes.[464] None of the crashes were fatal. NHTSA asks reporting companies to characterize the severity of the injuries. Of the 534 crashes, 457 had no injury, 43 had a minor injury, 9 had a moderate injury, 4 had a serious injury, and in 21 crashes the injury status was unknown.[465] ADS developers were most likely to learn about crashes through telematics or field reports.[466]

The number of crashes each company reported varied greatly. Waymo reported 234 crashes.[467] The other companies that have reported more than 20 crashes are Cruise, Zoox, and the shuttle operator Transdev.[468] The report does not attempt to normalize the ADS data for miles driven or ODD. So the total number of crashes that an ADS developer reports reveals more about how many miles it is driving and where it is driving than it does about its safety. Without normalization, it is impossible to compare crash rates, which limits the inferences that can be drawn.

For example, the report shows that ADS-equipped vehicles are about twice as likely to incur damage in the rear than in the front.[469] Are ADSs driving too slowly or stopping unpredictably in a way that increases their likelihood of being

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[462] *Id.* at 8–9.
[463] *See* Standing General Order on Crash Reporting, NAT'L HIGHWAY TRAFFIC SAFETY ADMIN., https://www.nhtsa.gov/laws-regulations/standing-general-order-crash-reporting (last updated Jan. 16, 2024).
[464] *Id.*
[465] *Id.*
[466] ADS REPORT, *supra* note 60.
[467] Standing General Order on Crash Reporting, *supra* note 464.
[468] *Id.*
[469] ADS REPORT, *supra* note 60.

rear-ended? A study of the California crash data—which can be normalized for miles because California mandates miles reporting—found that ADS-equipped vehicles were more than four times as likely to be rear-ended than conventional vehicles.[470] But the study also found that the disparity is reduced significantly when the data is adjusted to account for the ADS's ODD.[471] Even after adjustment, however, ADS-equipped vehicles are still more likely to be rear-ended when they are stopped.[472] To enable inferences like these, NHTSA would need to collect data on how many miles each ADS developer has driven during the relevant time period.

Still, the SGO ADS data provide important insights into ADS safety. The mere fact that there were only a small number of crashes with more than minor injuries is significant for policymaking. Journalists can follow up on those few serious crashes, and regulators can learn about the causes of those crashes. The SGO also effectively ends the race-to-the-bottom in crash regulations. ADS developers cannot avoid scrutiny by moving their testing to Arizona. This is particularly important for the regulation of automated trucking. Many ADS-equipped trucks are being tested in states without useful crash reporting.[473]

The L2 data are less illuminating than the ADS data. This is in part because L2 system developers are only required to report severe crashes. The larger problem, though, is that most vehicles equipped with L2 systems are not also equipped with state-of-the-art telematics. The data show 1318 crashes, 1084 of which were reported by Tesla and 108 by Honda.[474] The numbers for other automakers are almost certainly too low, considering that L2 systems have become common on new vehicles.[475] It is implausible that only Tesla's and Honda's systems were involved in a significant number of serious crashes.

The data on how L2 system developers learned about crashes makes this clear. Over 70% of reported crashes became known to the company through

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[470] *See* Noah J. Goodall, *Comparison of Automated Vehicle Struck-from-behind Crash Rates with National Rates Using Naturalistic Data*, 154 ACCIDENT ANALYSIS & PREVENTION 1, 3, 5 (2021) (finding that ADS-equipped vehicles were struck from behind at a rate of 17.2 per million VMT compared with a rate of 3.6 per million VMT for conventional vehicles).

[471] *See id.* at 5–7.

[472] *See id.* at 7.

[473] *See* Mark Harris, *Behind the Scenes of Waymo's Worst Automated Truck Crash*, TECHCRUNCH (July 1, 2022, 2:43 PM), https://techcrunch.com/2022/07/01/behind-the-scenes-of-waymos-worst-automated-truck-crash/.

[474] Standing General Order on Crash Reporting, *supra* note 464.

[475] *See* Monticello, *supra* note 28.

telematics.[476] Almost all of these telematics-enabled reports were filed by Tesla.[477] The data suggest that other L2 system developers are not equipping their vehicles with useful telematics, so they are not learning when their systems are involved in a crash.[478]

The L2 data also lack critical information on the severity of injuries. The data show that 29 crashes were fatal, 94 involved non-fatal injuries, and another 98 involved no injuries.[479] But for 1097 crashes, the injuries, if any, were listed as "unknown."[480] It is likely that many of these crashes involved injuries because the SGO only requires L2 crashes to be reported if they meet severity criteria. The severity criteria that are not about injuries—a vehicle tow-away, an airbag deployment, and the presence of a vulnerable road user—are positively correlated with injuries.

Despite these limitations, the SGO provides critical information. When a crash report suggests that a driving automation system is creating an unreasonable safety risk, NHTSA can respond quickly.

B. A New Kind of Recall

NHTSA's primary tool for responding to emerging safety risks is a recall investigation. The Safety Act empowers the Secretary of Transportation to determine that a vehicle or equipment is defective.[481] A defect determination can be based on a violation of one of the FMVSSs, but it does not need to be. In fact, NHTSA has said that "the vast majority of recalls" are issued for defects unrelated to the FMVSSs.[482] To establish a defect, the government just needs to show that the vehicle or equipment creates an unreasonable risk of a crash or an "unreasonable risk of death or injury" in a crash.[483] A defect determination triggers a recall.[484]

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[476] Standing General Order on Crash Reporting, *supra* note 464.

[477] *Id.*

[478] *See* ADS REPORT, *supra* note 60.

[479] *Id.*

[480] *Id.*

[481] 49 U.S.C. § 30118(b)(1).

[482] Framework for Automated Driving System Safety, 85 Fed. Reg. 78058, 78068 n.63 (Dec. 3, 2020).

[483] *See* United States v. Gen. Motors Corp., 518 F.2d 420, 432, 442 n.112 (D.C. Cir. 1975). The defect at issue in that case involved an unreasonable risk of accidents, but the court suggested that an unreasonable risk of death or injury in an accident would also suffice. *See id.* at 432, 442 n.112.

[484] *See id.*

ODI oversees the recall process. ODI collects data on potential safety concerns from consumer complaints, media reports, and litigation filings.[485] Some of this data comes from NHTSA's Early Warning Reporting program, which requires automakers to report any insurance claims or consumer complaints that allege a defect.[486] ODI reviews the submitted data and determines whether the incidents are severe and frequent enough to justify a defect investigation.[487]

Most defect investigations end with an "influenced recall," which resembles a litigation settlement.[488] ODI and the automaker come to an agreement on a defect determination. Then the automaker voluntarily files a report identifying the defect and describing its plan to remedy it.[489] If the automaker does not act voluntarily, NHTSA can make its own defect determination and ask the Attorney General to seek an injunction to compel a recall.[490] Once a vehicle has been found to be defective, the manufacturer has the option to repair it, replace it with an equivalent vehicle, or refund the purchase price.[491] In the last two decades, recalls are estimated to have cost about $4 billion each year.[492]

Recalls of driving automation systems can be faster and cheaper.[493] The SGO will alert ODI rapidly. The defects will usually involve software, not hardware. NHTSA can task the developer with creating code that fixes the defect if it has not done so already. The new code can be transmitted over the air to all the vehicles equipped with the system. This kind of recall is not hypothetical. Indeed, they have already happened.[494]

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[485] *See* NAT'L HIGHWAY TRAFFIC SAFETY ADMIN., DOT HS 812 984, RISK-BASED PROCESSES FOR SAFETY DEFECT ANALYSIS AND MANAGEMENT OF RECALLS 4, 6 (2020) [hereinafter RECALL PROCESS] (on file with author).

[486] *See* 49 U.S.C. § 30166(m).

[487] *See* RECALL PROCESS, *supra* note 485, at 7–8.

[488] *Id.* at 10.

[489] *Id.*

[490] *See* 49 U.S.C. § 30163(a)(2)(A).

[491] *Id.* § 30120(a)(1)(A).

[492] *See* Mashaw & Harfst, *supra* note 6, at 251–52.

[493] Mashaw and Harfst anticipated that recalls would become more important as automation increased. *See id.* at 277 ("As more and more decisions are committed to digital systems, more and more crashes will be prima facie evidence of equipment failures that might justify a defects investigation and, potentially, a recall.").

[494] Recalls of software defects on conventional vehicles have become increasingly common in the last several years. *See* Halder et al., *supra* note 193 (listing examples). Some of these recalls have been over-the-air. *See* Emma Himes, Note, *NHTSA Up in the Clouds: The Formal Recall Process & Over-the-Air Software Updates*, 28 MICH. TECH. L. REV. 153, 168 (2021) (describing an over-the-air update to software on Mercedes vehicles that provided the vehicle's location to emergency responders).

1. Tesla Rolling Stop Recall

In October 2020, Tesla sent an over-the-air software update to vehicles with Full Self-Driving beta.[495] The update included a new feature that could perform an automated rolling stop at certain intersections.[496] Tesla drivers were asked on their display to choose between three modes of operation—Chill, Average, or Assertive.[497] They were told that if they picked either Average or Assertive, the feature might perform a rolling stop.[498]

Tesla's system would only perform a rolling stop under certain conditions. The vehicle needed to be traveling at a speed below 5.6 mph.[499] It needed to be approaching an "all-way stop intersection," where each road leading to the intersection had a speed limit of 30 mph or less.[500] It also needed to detect no "relevant" moving cars, pedestrians, or cyclists nearby and have "sufficient visibility" in the intersection.[501] If all these conditions were met, the vehicle would "travel through the all-way-stop intersection at a speed from 0.1 mph up to 5.6 mph without first coming to a complete stop."[502]

In January 2022, NHTSA met with Tesla about the rolling stop feature.[503] As a result of those conversations, Tesla agreed to recall it.[504] Tesla filed a recall report in which it conceded that "[e]ntering an all-way-stop intersection without coming to a complete stop may increase the risk of collision."[505] Tesla insisted, though, that it was not aware of any collisions, injuries, or fatalities related to the rolling stops.[506] The recall was easy to implement. Tesla simply sent another over-the-air software update that disabled the rolling stop feature and also promised to disable the feature in future software releases.[507] No Tesla owner

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[495] *See* ROLLING STOP RECALL, *supra* note 61, at 1, 3.

[496] *See id.* at 3.

[497] Emma Roth, *Tesla's 'Full Self-Driving' Beta Has an 'Assertive' Driving Mode That 'May Perform Rolling Stops'*, VERGE (Jan. 9, 2022, 7:12 PM), https://www.theverge.com/2022/1/9/22875382/tesla-full-self-driving-beta-assertive-profile.

[498] *See* ROLLING STOP RECALL, *supra* note 61, at 2.

[499] *Id.*

[500] *Id.* at 2–3.

[501] *Id.*

[502] *Id.* at 3.

[503] *Id.*

[504] *Id.*

[505] *Id.* at 2.

[506] *Id.* at 4.

[507] *Id.*

needed to take any affirmative step to complete the recall.[508] The decision was made on January 20, and the update was scheduled for early February.[509]

Tesla's report downplayed the safety risk. It did not provide any explanation for the defect determination other than the cursory statement that rolling stops "may increase the risk of collision."[510] But both NHTSA and Tesla knew that rolling stops are illegal. They could have predicted that a court would find an automated law-breaking feature to be defective. NHTSA had effectively avoided the hard problem of assessing driving automation safety again. At the time, it seemed possible that the brazenness of the rolling stop feature would limit the precedential value of the recall.

Still, the recall attracted some criticism. Brad Templeton, an early advisor to Google's ADS program, decried what he perceived as NHTSA's expansion of its regulatory authority.[511] He argued that NHTSA was attempting to enforce the traffic law—traditionally a state responsibility—rather than regulate vehicle safety.[512] He pointed out that Tesla owners had to affirmatively select the rolling stop setting.[513] He asked: "Does NHTSA have the power to force a recall of any car that can go faster than 85 mph to put a speed governor on it[?]"[514] In fact, activists tried and failed to persuade Congress to mandate speed governors in the 1970s.[515] But the politics of safety regulation may be changing, especially when regulation targets corporate software, not human drivers.

2. *Pony.ai Recall*

Another recall, less than a year later, removed any doubt about whether the rolling stop recall was anomalous. This recall involved Pony.ai, a Chinese startup developing an ADS.[516] Pony.ai was a small operation, but it had attracted

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[508]   *See id.*

[509]   *Id.* at 3.

[510]   *Id.* at 2.

[511]   Brad Templeton, *Feds Make Tesla Remove 'Rolling Stops.' It's A Terrible Decision*, FORBES (Feb. 1, 2022, 3:14 PM), https://www.forbes.com/sites/bradtempleton/2022/02/01/feds-make-tesla-remove-rolling-stops-its-a-terrible-decision/?sh=5fdda3aa2111.

[512]   *Id.*

[513]   *Id.*

[514]   *Id.*

[515]   *See* Mashaw & Harfst, *supra* note 6, at 119. In 2017, the NTSB called for NHTSA to "incentivize" the adoption of "intelligent speed adaptation" systems, which use geolocation to detect the speed limit and then either warn the driver they are approaching the limit or make it physically difficult or impossible to exceed the limit. *See* NAT'L TRANSP. SAFETY BD., REDUCING SPEEDING-RELATED CRASHES INVOLVING PASSENGER VEHICLES 43–44, 56 (2017), https://www.ntsb.gov/safety/safety-studies/documents/ss1701.pdf.

[516]   *See* PONY.AI RECALL, *supra* note 63, at 1.

funding from Toyota and the Chinese arm of the prestigious venture capital fund Sequoia.[517] It had been testing its ADS on public roads in California, using Hyundai Konas.[518] In May 2021, Pony.ai had become one of a small number of ADS developers to receive a permit from the California DMV to test its system without a test driver.[519]

On October 28, 2021, a Hyundai equipped with Pony.ai's ADS crashed in Fremont, California while it was driving without a test driver.[520] The ADS turned right onto a multi-lane suburban boulevard and then attempted to merge into the left lane.[521] Instead, it ran into the median and crashed into a traffic sign.[522] The vehicle suffered "moderate" damage to the front and undercarriage.[523] The crash immediately raised questions about Pony.ai's safety. As we have seen, most of the known vulnerabilities of ADSs relate to the difficulty of predicting and responding to the behavior of other road users. ADSs should not crash into stationary objects. Pony.ai's ADS looked like a drunk driver. A few weeks after the crash, the California DMV suspended Pony.ai's permit to operate without a test driver.[524]

NHTSA learned about the crash through a report that Pony.ai filed under the SGO.[525] ODI opened an investigation, and Pony.ai agreed to declare a defect.[526] In its recall report, Pony.ai explained that its ADS was running a "geolocation diagnostic check" right before the crash.[527] An error in its ADS software led to a "geolocation mismatch," and the mismatch caused the diagnostic check to shut down the ADS.[528] Then, "[l]ess than 2 ½ seconds after the ADS shutdown, the

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[517] Yilei Sun & Brenda Goh, *Toyota-backed Startup Pony.ai Raises $267 Million in Latest Fundraising*, REUTERS (Nov. 6, 2020, 2:05 AM), https://www.reuters.com/article/us-pony-ai-autonomous/toyota-backed-startup-pony-ai-raises-267-million-in-latest-fundraising-idUSKBN27M0QW.

[518] Press Release, Cal. Dep't Motor Vehicles, DMV Authorizes Pony.ai to Test Driverless Vehicles in Fremont, Milpitas and Irvine (May 21, 2021), https://www.dmv.ca.gov/portal/news-and-media/dmv-authorizes-pony-ai-to-test-driverless-vehicles-in-fremont-milpitas-and-irvine/.

[519] *Id.*

[520] PONY.AI, INC. REPORT OF TRAFFIC COLLISION INVOLVING AN AUTONOMOUS VEHICLE TO STATE OF CAL. DEP'T OF MOTOR VEHICLES (2021), https://www.dmv.ca.gov/portal/file/pony-ai_102821-pdf.

[521] *Id.*

[522] *Id.*

[523] *Id.*

[524] Rita Liao, *California Suspends Pony.ai Driverless Test Permit After Crash*, TECHCRUNCH (Dec. 14, 2021, 9:00 AM), https://techcrunch.com/2021/12/14/pony-ai-suspension-driverless-pilot-california/.

[525] PONY.AI RECALL, *supra* note 63, at 2.

[526] *Id.*

[527] *Id.*

[528] *Id.*

vehicle's momentum caused it to collide with a street sign on the median."[529] As with the Tesla rolling stop recall, the Pony.ai recall was cheap and quick. Pony.ai corrected the error in its code on the day of the crash, and it updated the software on all its ADS-equipped vehicles the day after.[530] In February 2022, NHTSA "advised Pony.ai that it believed Pony.ai's ADS had a safety defect," and Pony.ai filed its recall report the next month.[531]

NHTSA's response to the Pony.ai crash illustrates how the SGO and the recall power work together to expedite safety fixes. A vehicle crashes while its driving automation system is engaged. The developer reports it under the SGO. If ODI suspects that the crash involves a safety defect, it can ask follow-up questions. If ODI determines that the system is defective, it can ask the developer to declare a defect and issue a recall. The developer can create code that fixes the defect, if it has not done so already. Then it can add the corrected code to every vehicle equipped with its system, possibly over the air.

The Pony.ai recall was still only an incremental step for NHTSA. As a small Chinese startup, Pony.ai had little political power. The behavior of Pony.ai's ADS—driving onto a median and crashing into a sign—was *qualitatively* unsafe. NHTSA did not need to analyze a large set of system performance data. But less than a year later, NHTSA would confront a powerful domestic automaker over a crash in which the system's safety performance was more ambiguous.

3. Cruise Recalls

On June 3, 2022, a vehicle equipped with Cruise's ADS collided with a Toyota Prius.[532] The crash happened at the intersection of Geary Boulevard and Spruce Street in San Francisco around 11:00 PM.[533] The Cruise ADS was attempting to make an unprotected left turn from eastbound Geary, across three lanes of westbound traffic, to head north on Spruce.[534] The Prius was heading

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[529] *Id.*

[530] *Id.* at 2–3.

[531] *Id.* at 1, 3.

[532] *See* CRUISE LLC, REPORT OF TRAFFIC COLLISION INVOLVING AN AUTONOMOUS VEHICLE TO STATE OF CAL. DEP'T OF MOTOR VEHICLES (2022), https://www.dmv.ca.gov/portal/file/cruise_060322-pdf.

[533] *See id.*

[534] *See id.*

westbound on Geary in the right lane, which was a dedicated lane for taxis, buses and right turns.[535] It was traveling at about 40 mph in a 25 mph zone.[536]

Figure 4: Geary Boulevard & Spruce Street (Google Maps)

According to Cruise, the ADS predicted that the Prius would turn right at the intersection to head north on Spruce Street—the same direction it was heading.[537] To avoid a collision, the ADS braked and came to a stop in the middle of the intersection. But the ADS made the wrong prediction.[538] The Prius "suddenly moved out of the right-turn lane and proceeded straight through the intersection."[539] It collided with the right rear panel of the Cruise vehicle.[540] One of the three passengers in the Cruise vehicle was taken to the hospital with "non-life threatening injuries," and two passengers in the Prius were treated at the

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535   *See id.*
536   *Id.*
537   CRUISE UNPROTECTED LEFT RECALL, *supra* note 64, at 2.
538   *Id.*
539   *Id.*
540   *Id.*

scene for their injuries.[541] Cruise claims that a police report found that the Prius was the "party at most fault" for the collision because it was traveling straight in a right turn only lane and speeding.[542]

Cruise reported the crash to NHTSA under the SGO.[543] ODI opened an investigation. In August, Cruise declared a defect and issued a recall.[544] In the recall report, Cruise offered a defense of its software's actions, arguing that the ADS "had to decide between two different risk scenarios and chose the one with the least potential for a serious collision" at the time, before the oncoming vehicle's sudden change of direction.[545] Nevertheless, Cruise grudgingly conceded that its ADS was defective because, when making an unprotected left, it may "not have correctly predicted" or "been sufficiently reactive" to "the sudden path change of a road user violating demarcated lane usage and operating at excessive speed."[546] After the crash, Cruise briefly "disabl[ed] unprotected left turns from the fleet" and "reduc[ed] the ODD to a smaller geofence."[547] Then it updated its ADS software with a version that could handle the Geary crash scenario safely, and its ADS-equipped vehicles started taking unprotected left turns again.[548]

Cruise offered a superficially plausible defense of its ADS's behavior. The Prius had been speeding and went straight through an intersection from a right turn only lane.[549] But at the moment of the crash, the Prius arguably had the right-of-way.[550] It was heading straight, and the Cruise ADS was making a left against oncoming traffic.[551] An experienced driver would know that other drivers often speed and ignore lane restrictions. An ADS needs to anticipate these common human errors and prevent them from leading to crashes.

The next Cruise recall involved a crash with no human error. On March 23, 2023, a Cruise robotaxi rear-ended an "articulated" bus—that is, a bus with two

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[541] Pete Bigelow, *Cruise Passenger Was Taken to Hospital Following Self-Driving Crash*, AUTO. NEWS (July 18, 2022, 8:20 PM), https://www.autonews.com/mobility-report/cruise-passenger-was-taken-hospital-following-self-driving-crash.

[542] CRUISE UNPROTECTED LEFT RECALL, *supra* note 64, at 3.

[543] *Id.*

[544] *Id.*

[545] *Id.*

[546] *Id.*

[547] *Id.* at 3.

[548] *See id.*

[549] *Id.* at 2.

[550] *Id.*

[551] *Id.*

rigid sections connected with a soft, accordion-like joint—operated by the San Francisco Municipal Transit Authority (Muni).[552] According to Cruise, "the ADS initially perceived both sections of the bus," but when the bus pulled out of a bus stop and into the ADS's lane of travel, "the rear section of the bus obstructed the front section."[553] When the bus decelerated, the "ADS inaccurately determined that the bus was continuing to move forward in traffic based on the anticipated behavior of the front section of the bus," and braked too late to avoid a collision.[554] Cruise claimed it fixed the issue with a software update two days after the crash.[555]

The Cruise ADS's error was concerning because the SGO data show that, while it is common for ADS-equipped vehicles to get rear-ended, it is rare for them to rear-end another vehicle.[556] Cruise's report emphasized "the anomalous nature of the issue" and called the crash a "singular incident."[557] But articulated Muni buses are a common sight on the streets of San Francisco. An ADS driving on those streets must be able to interact with them safely. Cruise's explanation makes it sound like the ADS made a tracking error or a behavior prediction error, but it does not explain why the ADS could not identify the large, metal bus directly in front of it. An attentive driver, or a simple automatic emergency braking system, would have been able to avoid the crash.

Several months later, the Cruise ADS made a much more serious error. On October 2, 2023, at 9:35 PM, a Cruise robotaxi stopped at a stoplight in the right southbound lane of Fifth Street at its intersection with Market Street in San Francisco.[558] A conventional vehicle was stopped in the left lane.[559] When the light turned green, both vehicles entered the intersection.[560] The conventional vehicle hit a pedestrian walking along a crosswalk, and the force of the collision propelled the pedestrian in front of the robotaxi.[561] According to Cruise, the ADS

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[552]   CRUISE MUNI BUS RECALL, *supra* note 65, at 2.

[553]   *Id.*

[554]   *Id.*

[555]   *Id.*

[556]   *See* ADS REPORT, *supra* note 60.

[557]   CRUISE MUNI BUS RECALL, *supra* note 65, at 3.

[558]   Jordan Parker & Nora Mishanec, *Driver Hits Woman in S.F., Then Cruise Driverless Car Runs Her Over; Photo Shows Victim Trapped*, S.F. CHRONICLE (Oct. 3, 2023, 3:52 PM), https://www.sfchronicle.com/bayarea/article/woman-run-autonomous-vehicle-san-francisco-18403044.php.

[559]   *Id.*

[560]   *Id.*

[561]   *Id.*

"biased to the right and braked aggressively," but it was too late.[562] The robotaxi ran over the pedestrian and came to a stop with her pinned underneath.[563]

Then it got worse. According to Cruise, its ADS has a "Collision Detection Subsystem" that determines how to respond after a crash.[564] How the ADS responds depends on the other road users involved, the location of the impact, and the perceived severity of the impact.[565] In this case, the ADS "inaccurately characterized the collision as a lateral collision" and attempted to pulled over with the pedestrian still pinned underneath, dragging her twenty feet.[566] She suffered serious injuries from the crash and was hospitalized.[567]

Cruise tried to cover up the dragging. The day after the crash, Cruise met with NHTSA and state officials to share data.[568] In an email before the meeting, Cruise neglected to mention that its robotaxi had dragged the pedestrian after stopping.[569] And according to regulators who attended the meeting, Cruise only showed them the video of the initial impact between its robotaxi and the pedestrian, not the dragging in the aftermath.[570] When the full story emerged, the California DMV suspended Cruise's license to operate without a test driver.[571] Cruise stopped operating without a test driver in other cities as well.[572] The company hired an outside law firm to investigate the crash and its aftermath.[573] Cruise CEO Kyle Vogt resigned.[574] Cruise recalled its ADS with a software fix that, it said, would have keep a vehicle stationary after a similar collision.[575]

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[562] CRUISE PEDESTRIAN CRASH RECALL, *supra* note 66, at 2.

[563] Parker & Mishanec, *supra* note 558.

[564] CRUISE PEDESTRIAN CRASH RECALL, *supra* note 66, at 2.

[565] *Id.*

[566] *Id.*; *see* Ricardo Cano & St. John Barned-Smith, *Inside the Cruise Crash that Got the Robotaxis Pulled from S.F. Was There A Coverup?*, S.F. CHRONICLE (Oct. 25, 2023, 1:59 PM), https://www.sfchronicle.com/sf/article/s-f-cruise-robotaxis-cover-up-18445876.php.

[567] *See* Cano & Barned-Smith, *supra* note 566. The pedestrian's name was not released. *Id.*

[568] CAL. DEP'T MOTOR VEHIC., ORDER OF SUSPENSION 1 (2023) [hereinafter CRUISE SUSPENSION], https://s3.documentcloud.org/documents/24080715/gm-cruise-order-of-suspension-driverless-testing.pdf.

[569] Aaron Gordon, *Cruise Exec Omitted Pedestrian Dragging in Summary of Self-Driving Car Incident to California DMV, Email Shows*, VICE (Nov. 17, 2023, 7:46 PM), https://www.vice.com/en/article/wxjbx5/cruise-exec-omitted-pedestrian-dragging-in-summary-of-self-driving-car-incident-to-california-dmv-email-shows.

[570] CRUISE SUSPENSION, *supra* note 568, at 1.

[571] *See id.*

[572] *See* Yiwen Lu & Tripp Mickle, *Cruise's C.E.O. Quits as the Driverless Carmaker Aims to Rebuild Trust*, N.Y. TIMES (Nov. 19, 2023), https://www.nytimes.com/2023/11/19/technology/cruise-ceo-kyle-vogt-quits.html.

[573] *Id.*

[574] *Id.*

[575] CRUISE PEDESTRIAN CRASH RECALL, *supra* note 66, at 4.

A skeptic might ask what the Cruise recalls accomplished. After all, ADS developers have strong reputational and liability incentives to reassess their systems after a serious crash, create code that would avoid similar crashes in the future, and implement fixes through software updates. Cruise likely would have made the fixes anyway. There are an infinite number of edge cases that an ADS can encounter. The fixes that Cruise implemented after the recalls will not prevent all crashes involving unprotected lefts and articulated buses, and they will not always ensure that the ADS makes the right decision in the aftermath of a collision. NHTSA cannot solve the hard problems of ADS safety simply by requiring developers to issue recalls after every serious crash that their ADSs could have handled better.[576]

NHTSA's recall strategy makes more sense when understood as a long-term monitoring program. A defect investigation lets NHTSA kick the tires. The agency acquires detailed information about the capabilities and limitations of the driving automation system in question and its developer's safety practices. For example, after the Geary crash, Cruise, by its own account, met with NHTSA repeatedly and shared analysis of the crash, its ADS's behavior, and its mitigation measures.[577]

Recall investigations give NHTSA options. If ODI decides that a system does not create an unreasonable risk to safety, the investigation ends. If ODI decides that the system does create an unreasonable risk, it lets the developer propose a fix. If ODI is satisfied with the fix, the developer implements it, declares a defect, and files a report. If ODI is not satisfied with the fix, it can take more aggressive action. Recall reports are published, so other driving automation developers, Congress, and the public know that NHTSA is watching. If a pattern of similar crashes emerges over time, the agency will have a paper trail to justify further action. If a developer decides that NHTSA is abusing the recall power, it can force the government to sue and let the courts sort it out.

4. Cruise Investigations

NHTSA has also opened two broader investigations of Cruise's ADS, and both are still ongoing. In December 2022—after the Geary crash but before the

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[576] *See* Brad Templeton, *Cruise 'Recalls' Robotaxis After Crash, But the Recall Is the Wrong Mechanism*, FORBES (Sept. 14, 2022, 2:13 PM), https://www.forbes.com/sites/bradtempleton/2022/09/14/cruise-recalls-robotaxis-after-crash-but-the-recall-is-the-wrong-mechanism/?sh=67ac5afb4a2b ("The recall process is involved and bureaucratic, and definitely can't be used for every software update, even updates that fix a safety problem.").

[577] CRUISE UNPROTECTED LEFT RECALL, *supra* note 64, at 3.

Muni crash—ODI announced that it would investigate two different kinds of incidents arising out of Cruise's operations in San Francisco. First, ODI is reviewing three "hard braking" crashes that Cruise reported in the SGO.[578] In each case, the Cruise ADS braked suddenly "in response to another road user that was quickly approaching from the rear," and "the other road user subsequently struck the rear of the ADS-equipped vehicle."[579] Second, ODI is reviewing reports that Cruise vehicles have become immobilized on public roads.[580] These incidents are dangerous, ODI says, because they "may strand vehicle passengers in unsafe locations," "cause other road users to make abrupt or unsafe maneuvers," or obstruct the path of emergency vehicles.[581]

In October 2023, ODI stated that it had "received reports of incidents in which [the Cruise ADS] may not have exercised appropriate caution around pedestrians in the roadway."[582] According to ODI, "[t]hese reports involve ADS equipped vehicles encroaching on pedestrians present in or entering roadways, including pedestrian crosswalks, in the proximity of the intended travel path of the vehicles."[583] Therefore, ODI stated that it would open a *fifth* investigation of Cruise's ADS to "determine the scope and severity of the potential problem, including causal factors that may relate to ADS driving policies and performance around pedestrians, and to fully assess the potential safety risks."[584]

Taken together, these broader defect investigations cover many of the important questions in ADS safety. The incidents involving immobilized vehicles may stem from a problem with Cruise's communications infrastructure. But the other issues may prove more difficult to resolve. We know that ADS-equipped vehicles are rear-ended often.[585] That may be because they are more conservative about avoiding collisions ahead. It is possible that the complex tradeoffs involved cannot be managed with a simple software fix. Close interactions between pedestrians and ADS-equipped vehicles are also common. In the crash at Fifth and Market, it was clear that the Cruise ADS made a serious error when it tried to pull over with the pedestrian pinned underneath. But in routine interactions with pedestrians in dense cities, however, the appropriate level of assertiveness might not always be clear.

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[578]   *Id.*

[579]   *Id.*

[580]   *Id.*

[581]   *Id.* at 1–2.

[582]   CRUISE PEDESTRIAN SAFETY INVESTIGATION, *supra* note 69.

[583]   *Id.*

[584]   *Id.*

[585]   *See* ADS REPORT, *supra* note 60; *see also* Goodall, *supra* note 470, at 1.

NHTSA has the time to study these issues carefully and make sure Cruise gets them right. Waymo and the other L4 ADS companies that have not yet been subject to a recall should be watching. NHTSA is now in the business of regulating ADS safety. The remaining question is how.

5. Tesla Autopilot Recall

NHTSA's regulation of L2 safety has also progressed. In 2021, ODI opened an investigation of Tesla Autopilot focused on eleven crashes between Teslas and first responder vehicles.[586] In most of these crashes, the collision happened while the first responder vehicle was attending to a pre-existing crash scene.[587] ODI stated that the investigation would include both the eleven crashes it had identified and "other similar crashes."[588] ODI said it would assess Autopilot's ability to perform object and event detection and response, its ODD, and its driver monitoring system.[589]

In 2022, ODI escalated the investigation from a "preliminary evaluation" to an "engineering analysis."[590] ODI explained that, during preliminary evaluation, it had uncovered six additional Tesla Autopilot crashes involving first responder vehicles or road maintenance vehicles.[591] In the crashes it studied, ODI estimated that, on average, the first responder scene would have been visible to the driver eight seconds before impact.[592] But the drivers did not take effective evasive action, and, on average, Autopilot only "aborted vehicle control" about one second before the impact.[593]

As part of the same investigation, ODI also reviewed another 106 crashes involving Autopilot.[594] It found that drivers were not paying sufficient attention in about half of those crashes, and Autopilot was operating outside of its ODD in about a quarter of the crashes.[595] ODI explained that the engineering analysis would "explore the degree to which Autopilot . . . may exacerbate human factors or behavioral safety risks by undermining the effectiveness of the driver's

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[586] AUTOPILOT PRELIMINARY EVALUATION, *supra* note 70, at 1.

[587] *Id.*

[588] *Id.*

[589] *Id.*

[590] AUTOPILOT ENGINEERING ANALYSIS, *supra* note 71, at 1.

[591] *Id.* at 2. In one case, investigators learned about the crash because Tesla reported it under the SGO. *Id.*

[592] *Id.* at 3. In most of the crashes, Tesla's forward collision warning had activated, and, in about half, the automatic emergency braking system had too. *Id.* at 2.

[593] *Id.*

[594] *Id.* at 3.

[595] *Id.*

supervision."[596] It would also assess Tesla's "vehicle control authority, driver engagement technologies, and related human factors considerations."[597]

In its statement escalating the investigation, ODI suggested that its thinking on L2 system safety had evolved since the Williston crash.[598] It noted that "[a] driver's use or misuse of vehicle components, or operation of a vehicle in an unintended manner does not necessarily preclude a system defect."[599] Then it added: "This is particularly the case if the driver behavior in question is foreseeable in light of the system's design or operation."[600] The statement could have been ghostwritten by the NTSB.

In December 2023, almost two-and-half years after the investigation began, Tesla agreed to recall Autopilot. Tesla conceded that the system may increase the risk of a collision if drivers "are unprepared to intervene, fail to recognize when the [system] is canceled or not engaged, and/or fail to recognize when the [system] is operating in situations where its functionality may be limited."[601] To remedy the defect, Tesla sent an over-the-air software update "increasing the prominence of visual alerts on the user interface," "simplifying engagement and disengagement," and adding "checks" when the driver uses the system "outside controlled access highways" or "when approaching traffic controls."[602] Telsa also noted that the exact changes would depend on the vehicle's hardware, which means that Tesla was not willing to install driver-facing cabin cameras on vehicles that did not already have them.[603]

The recall appeared to be a compromise. The changes to the driver monitoring system are modest. According to Tesla's software release notes, they included "increasing the text size" of driver monitoring alerts and presenting them in "a more prominent position."[604] Tesla also said it would strengthen its driver management system by suspending drivers from using Autopilot for a week if the system has to force them to disengage five times.[605] And Tesla "increased the strictness of driver attentiveness requirements" when a driver uses

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[596]   *Id.* at 1.

[597]   *Id.*

[598]   *Id.*

[599]   *Id.* at 3.

[600]   *Id.*

[601]   AUTOPILOT RECALL, *supra* note 69, at 3.

[602]   *Id.* at 5.

[603]   *See id.*

[604]   Fred Lambert, *Tesla Explains New Autopilot Nag Forced by the NHTSA Recall*, ELECTREK (Dec. 15, 2023, 10:59 AM), https://electrek.co/2023/12/15/tesla-explains-autopilot-nag-forced-nhtsa-recall/.

[605]   *Id.*

Autopilot near traffic lights and stop signs, but it did not restrict Autopilot from being used off of access-controlled highways.[606]

NHTSA claims that its decision not to restrict Autopilot to its ODD was based on feasibility, not politics. According to *The Washington Post*, "NHTSA said it would be too complex and resource-intensive to verify that systems such as Tesla Autopilot are used within the ODD. It also expressed doubt that doing so would fix the problem."[607] But we know that GM Super Cruise cannot be engaged outside of access-controlled highways.[608] And we know that when Ford BlueCruise is used off the highway, drivers must keep their hands on the wheel.[609] So it is not clear why Tesla cannot keep up with their rivals in Detroit.

The saving grace of the Autopilot recall is that NHTSA kept the investigation open "to support an evaluation of the effectiveness of the remedies deployed by Tesla."[610] Thanks to the SGO and Tesla's telematics, NHTSA will be able to monitor how crash rates change for the over two million vehicles subject to the recall. If crashes due to foreseeable misuse persist, NHTSA can demand more radical changes. The regulation of driving automation safety is just beginning.

IV. A PLAN FOR DRIVING AUTOMATION SAFETY

This Part proposes a plan to transform NHTSA's experimental strategy into effective safety regulation. The plan relies only on existing statutory authority, and it works within the constraints of existing case law. The plan has three parts. First, NHTSA should mandate that all newly manufactured vehicles come equipped with telematics that can transmit basic safety data to and receive over-the-air software updates from the manufacturer. Second, it should expand the SGO into a universal crash report order. Third, when crash data shows that a driving automation system creates an unreasonable risk to safety, NHTSA should give the developer a choice—fix the defect or restrict the system's ODD.

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[606] *Id.*

[607] Faiz Siddiqui & Trisha Thadani, *Recalling Almost Every Tesla in America Won't Fix Safety Issues, Experts Say*, WASH. POST (Dec. 16, 2023, 6:49 AM), https://www.washingtonpost.com/technology/2023/12/16/tesla-autopilot-recall/.

[608] Monticello, *supra* note 28.

[609] *Id.*

[610] Letter from Alex Ansley, Chief, Recall Mgmt. Div., Nat'l Highway Traffic Safety Admin., to Jacky Lam, Tesla 2 (Dec. 12, 2023).

A. *Telematics Standard*

NHTSA should set a standard requiring that new vehicles come equipped with state-of-the-art telematics. The telematics standard would bolster safety regulation in two ways. First, it would ensure that automakers are collecting crash data from their vehicles, so they could send rapid, accurate crash reports to NHTSA. Second, it would reduce the time and expense of software recalls by enabling automakers to fix defects through over-the-air updates.

The telematics standard would need to specify the data elements that the telematics must be able to transmit. At a minimum, these elements would include the vehicle's position, direction, speed, and acceleration shortly before and after a crash, and whether a driving automation system or active safety features were engaged at the time.[611] It would also need to specify what kind of software must be able to receive over-the-air updates.

The telematics standard would be practicable. Tesla has shown the feasibility of equipping vehicles with telematics and using them to transmit performance data and over-the-air updates.[612] Some other automakers are moving to equip their vehicles with telematics too.[613] But most automakers are not there yet, as the SGO data revealed.[614] As it has often done recently, NHTSA can use its rulemaking power to accelerate automakers' development timelines.[615] Beyond regulatory compliance, automakers should be using telematics for their own quality control and research and development.[616]

The test for compliance would also be objective. The telematics standard would be a performance standard, not a design standard. Automakers could

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[611] For an example of a standard specifying data elements, see Event Data Recorders, 87 Fed. Reg. 37289, 37299 (proposed June 22, 2022) (to be codified at 49 C.F.R. pt. 563).

[612] *See supra* Part III.A.2.

[613] *See* Keith Barry, *Automakers Embrace Over-the-Air Updates, But Can We Trust Digital Car Repair?*, CONSUMER REPS. (Apr. 20, 2018), https://www.consumerreports.org/automotive-technology/automakers-embrace-over-the-air-updates-can-we-trust-digital-car-repair.

[614] *See* L2 REPORT, *supra* note 60 (showing few reports sourced from telematics by automakers other than Tesla).

[615] *See, e.g.*, Mashaw & Harfst, *supra* note 6, at 220 (explaining how Standard 126 on electronic stability control accelerated the deployment of a new safety technology).

[616] The data that telematics collect could also be valuable for other purposes. For example, Tesla offers owners of its vehicles the option to purchase insurance directly from Tesla and uses the data it collects on the driver's performance for underwriting. *See Tesla Insurance*, TESLA, https://www.tesla.com/support/insurance (last visited Jan. 14, 2024). Unfortunately, Tesla has bungled the execution. *See* Steve Stecklow et al., *Tesla Launched Its Own Car Insurance. These Drivers Say It's a Lemon.*, REUTERS (Nov. 21, 2023, 11:00 AM), https://www.reuters.com/investigates/special-report/tesla-insurance/.

choose their own sensors, computers, software, and communication protocol. They would simply need to certify that their telematics could send and receive data under realistic use conditions, which NHTSA could define.

The telematics standard could build on NHTSA's existing rule on event data recorders (EDRs). An EDR, sometimes called a "black box," is a device installed in a vehicle that logs vehicle performance data and can be retrieved by investigators after a crash.[617] NHTSA does not directly require that vehicles contain EDRs. Instead, it requires that, if a vehicle is equipped with an EDR, the device must meet basic requirements, including a requirement to record certain data elements.[618] The rule is practically significant because most late model vehicles—including an estimated 99.5% of model year 2021 vehicles—contain EDRs.[619] The difference between an EDR and telematics is how and when they transmit information. An EDR must be physically retrieved after a crash.[620] Telematics would transmit data about crashes faster over the air.[621]

It might seem more efficient for NHTSA to mandate that telematics send crash data directly to the agency rather than indirectly through the automaker. But the indirect strategy is easier to implement. If NHTSA were to mandate that telematics transmit data directly to the agency, it would need to select one communications technology and require all automakers to adopt it, even if they were already implementing a different technology. With the indirect strategy, NHTSA can set a performance standard for telematics and let automakers comply with whatever technology they choose.

NHTSA will need to craft the telematics standard with sensitivity to privacy concerns. Telematics will enable an automaker to track its vehicles, just as a mobile phone company can track its phones. The main difference between the two is that, unlike mobile phones, vehicles usually do not follow their drivers or passengers inside a building. NHTSA cannot mandate telematics and also prevent automakers from gaining the technological ability to track their vehicles, but it can regulate how they use location data. The telematics standard should list the permissible uses of telematics data—crash reporting, quality control, and

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[617]   *See* Event Data Recorders, 87 Fed. Reg. 37290 (proposed June 22, 2022) (to be codified at 49 C.F.R. pt. 563) (describing EDR technology).

[618]   *Id.*

[619]   *Id.*

[620]   *See id.*

[621]   *See* Subir Halder et al., *Secure OTA Software Updates in Connected Vehicles: A Survey*, 178 COMPUT. NETWORKS 1, 3–4 (2020).

research and development—and specifically prohibit the use of personally identifiable data for other purposes.

The most difficult issue for telematics is cybersecurity. Vehicles that can receive over-the-air updates are vulnerable to hacking.[622] There is no doubt that the industry needs to develop effective countermeasures. It is less clear how countermeasures should be regulated. NHTSA's response to cybersecurity risks to date has focused on disseminating best practices.[623] The agency seems to be betting that automakers, or their insurers, have sufficiently strong incentives to take care absent regulation. A telematics mandate may require more stringent cybersecurity regulations.

B. Universal Crash Reporting

Once the telematics standard becomes effective, NHTSA should implement a universal crash report order. It should require automakers to report all crashes that meet severity criteria within one day of receiving data from the vehicle's telematics. The order should specify that automakers need to report to NHTSA the same data elements that the telematics standard requires them to collect from their vehicles.

NHTSA would not need to create an affirmative duty for automakers to seek out crash data, because the telematics standard would ensure they already possessed it. The order should be designed to include serious non-fatal crashes. The severity criteria should be quantitative, so they cannot be gamed.[624] NHTSA should also require automakers to send a short survey to the vehicle owner after any reportable crash to ask about injuries and property damage.

NHTSA has the statutory authority to issue a universal crash report order. It could use the authority to "require, by general or special order, any person to file reports or answers to specific questions"—the same one it used for the SGO.[625] Alternatively, it could rely on the TREAD Act—the statute that created the Early Warning Reporting program—which gives the Secretary of Transportation a

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[622]   *Id.* at 5.

[623]   *See generally* NAT'L HIGHWAY TRAFFIC SAFETY ADMIN., CYBERSECURITY BEST PRACTICES FOR MODERN VEHICLES (2016).

[624]   NHTSA imposed an acceleration-based reporting standard in its conditions on the Nuro exemption. *See* Nuro, Inc.; Grant of Temporary Exemption for a Low-Speed Vehicle with an Automated Driving System, 85 Fed. Reg. 7826, 7841–42 (Feb. 11, 2020). A quantitative standard may need to be supplemented with a requirement to report crashes involving vulnerable road users when the impact of those crashes would otherwise fall below the standard.

[625]   49 U.S.C. § 30166(g)(1)(A).

sweeping grant of authority to require manufacturers to report information that "may assist in the identification of defects related to motor vehicle safety."[626]

The universal crash report order would invigorate safety regulation. It would disclose incidents that should trigger defect investigations. It would illuminate patterns that could inform rulemaking and legislation. It would facilitate safety research in industry, government, and academia. And it would achieve these goals without creating perverse incentives. NHTSA currently learns about emerging safety risks through the Early Warning Reporting program and the SGO. But neither system is comprehensive, and only the SGO is fast.[627]

Why should crash reporting apply to vehicles that are not equipped with driving automation systems? There are three reasons for universal reporting. First, it would facilitate the regulation of driving automation safety by providing baseline safety performance data on conventional vehicles. This baseline data may prove crucial for making the kind of ODD-sensitive comparisons necessary to assess driving automation systems. Second, it would facilitate the regulation of conventional vehicle safety. NHTSA would no longer miss an important crash because it was not reported to insurers and did not lead to a consumer complaint. Third, it would reduce the risk that the SGO misleads the public into thinking that ADSs are especially dangerous, simply because crashes involving ADSs are more likely to be reported.

NHTSA should also require automakers to report, on a periodic basis, the total miles driven by each of their vehicle models by model year. Driving automation developers should report the total miles driven while their systems were engaged. NHTSA could use the miles data to normalize the crash data. In some cases, the reported crash-per-mile rate would need to be adjusted for ODD and possibly the age distribution of drivers.[628] The agency might sometimes need to subpoena an automaker for data to help with the adjustments, especially if the system's ODD was not transparent. When NHTSA releases the miles data to the public, it should provide clear warnings about how the unadjusted crash-per-mile rate can be misleading. There is a risk that ADSs will appear especially dangerous simply because they are driving in urban areas.

The miles reporting requirement would not create perverse incentives for conventional vehicles. Automakers cannot control how many miles their

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[626] *Id.* § 30166(m)(3)(B).

[627] *See* RECALL PROCESS, *supra* note 485.

[628] *See* Goodall, *supra* note 251, at 5–8 (calculating Tesla Autopilot crash rates by adjusting for ODD and driver age).

vehicles drive after they leave the dealership. For L2 system developers, the miles reporting requirement might create the salutary incentive to limit the system's ODD to conditions in which it is less likely to be involved in crashes. For ADS developers, there is some risk of a perverse incentive. Most ADSs have driven only a modest number of miles, so their crash-per-mile rate is sensitive to small increases in the total number of miles driven. ADS developers might be tempted to have vehicles equipped with their systems rack up dumb miles on empty roads. But as ADSs are deployed at scale, gaming will become infeasible, and the benefits of calculating crash rates will outweigh the risk that developers will try to game the metric.

C. Fix-or-Restrict Recall Policy

With a telematics standard and universal crash report order in place, NHTSA should adopt a fix-or-restrict policy for recalls involving driving automation. When ODI finds that a driving automation system is defective under certain conditions, it should give the developer a choice. Fix the defect—that is, develop new code that reduces the identified risk to a reasonable level. Or restrict the system's ODD so that it cannot operate in the conditions in which the risk materialized. Then the developer could send an over-the-air update to its systems that implements the fix or the restriction. The fix-or-restrict policy requires three steps—finding a defect, negotiating the fix or restriction, and monitoring compliance.

First, ODI needs to determine that the driving automation system is defective. As the courts have explained, a vehicle or equipment is defective if it creates an "unreasonable risk" to safety.[629] The unreasonableness of a risk is weighed against a baseline set by comparable vehicles or equipment.[630] The universal crash report order would help ODI determine when a vehicle, equipment, or driving automation system creates an unreasonable risk. When regulators spot a troubling pattern, they could quickly access current crash data on comparable vehicles. If the suspect system crashes more often while operating in comparable conditions, ODI could open a defect investigation. The ability to compare technology to a baseline is important for all recalls, but it is

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[629] *See* United States v. Gen. Motors Corp., 518 F.2d 420, 432 (D.C. Cir. 1975) (indicating that the definition of "motor vehicle safety" suggests the performance of motor vehicles in a way that protects the public from the "unreasonable risk" of defects).

[630] *See* United States v. Gen. Motors Corp., 841 F.2d 400, 416 (D.C. Cir. 1988) (endorsing the District Court's reasoning that the GM models' brakes were not defective because they were not more prone to premature lockup than comparable models).

critical for recalls involving driving automation systems because of their vulnerability in edge cases. The comparison might show that, although the system reduces net crashes, it increases crashes in certain conditions. This creates the possibility of a more surgical recall.

Second, if ODI determines that the driving automation system is defective, it can give the developer the choice of developing a fix or restricting the system's ODD. The rolling stop, Pony.ai, and Cruise recalls showed the value of the fix option. Tesla simply disabled the rolling stop feature.[631] Pony.ai fixed what appeared to be a simple bug.[632] Cruise claims that its software updates remedied the more complex issues that caused the Geary crash, the Muni bus crash, and the ADS's decision to pull over with a pedestrian pinned underneath the vehicle in the Fifth and Market crash.[633] But these were easy cases. NHTSA stopped short using the "restrict" option in the Autopilot recall. It has never restricted a driving automation system's ODD.

Suppose, though, that ODI gathers enough data to prove that Teslas with Autopilot engaged crash in intersections with cross-traffic more than similarly situated vehicles, with or without L2 systems. ODI could tell Tesla that, until it develops software that can reliably detect cross-traffic, it must restrict its system so that it can only be engaged on roads without cross-traffic, like access-controlled highways. If Tesla could not implement the restriction, ODI could recall Autopilot altogether. Either way, reliable crash data would deprive Tesla of the defense that Tesla owners who crashed their vehicles were misusing Autopilot. If drivers using Autopilot are significantly more likely to crash than drivers using other L2 systems in similar conditions, then the foreseeable misuse of Autopilot is creating an unreasonable risk to safety.

The fix-or-restrict recall illustrates how automation does not just create new risks for regulation to address—it creates new regulatory tools. It is not feasible to restrict the ODD of conventional vehicles. If NHTSA were to determine that the brakes on Honda Civics were prone to fail at high speeds, it would be impractical to give Honda the option of restricting its vehicles from operating at high speeds. The cost of installing an aftermarket speed governor on each of the affected vehicles might outweigh the benefits, and drivers likely would not agree

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[631]   ROLLING STOP RECALL, *supra* note 61, at 4.

[632]   PONY.AI RECALL, *supra* note 63, at 2.

[633]   *See* CRUISE UNPROTECTED LEFT RECALL, *supra* note 64, at 3; CRUISE MUNI BUS RECALL, *supra* note 65, at 3; CRUISE PEDESTRIAN CRASH RECALL, *supra* note 66, at 4.

to have it installed. But a simple over-the-air update would easily restrict the speed of a driving automation system.

Third, after the developer implements a fix or a restriction through an over-the-air update, NHTSA can use the crash data to monitor compliance. Monitoring is critical because at the time a fix or a restriction is implemented, the agency will be relying on the developer's good faith. For example, the developer might present results from a simulation that indicate that the new code would be able to safely navigate the scenarios in which earlier versions of the system crashed. Or it might claim that the new code would avoid those scenarios altogether because of newly added restrictions on its ODD. With the universal crash report order, NHTSA would be able to watch as data rolls in and learn whether vehicles equipped with the same system crashed again in similar circumstances. The ease of ex post monitoring will give the developer an ex ante incentive to be honest.

The most important advantage of the fix-and-restrict recall policy is its ability to adapt as technology improves. When ODI restricts a driving automation system's ODD in a recall, it should keep open the option of revisiting the restriction when a fix is developed. A restriction open to revision would encourage the developer to prioritize building safer software.

The fix-or-restrict recall policy has the same goal as the NTSB's proposal to require L2 system developers to prevent their systems from being engaged outside their ODDs.[634] But it is easier to implement. If NHTSA were to adopt the NTSB's proposal, developers might respond by defining their systems' ODDs broadly. If NHTSA disagreed with a developer's definition, it might struggle to show that the developer was wrong about the capabilities of its own system. The fix-or-restrict policy avoids the definitional debate. NHTSA would let developers set their own systems' ODDs. If and when data shows that the system creates an unreasonable risk under certain conditions, NHTSA could impose a restriction.

The restrict option might require L2 system developers to compensate vehicle owners. Some consumers choose to buy vehicles because of their L2 features, and others pay separately for those features. For example, Tesla is currently charging its vehicle owners $12,000 for access to Full Self-Driving.[635]

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[634] *See* NTSB WILLISTON REPORT, *supra* note 52, at 43.

[635] Lora Kolodny, *Elon Musk Says Tesla Will Raise Price of "Full Self-Driving" Driver Assistance to $12,000*, CNBC, https://www.cnbc.com/2022/01/07/elon-musk-says-tesla-will-raise-price-of-fsd-to-12000-in-us.html (Jan. 9, 2022, 7:06 PM).

If NHTSA were to force Tesla to restrict its system's ODD, Tesla owners would have a plausible claim that Tesla had breached its contract. In a conventional recall, when a manufacturer cannot repair the vehicle, it must replace it with an equivalent vehicle or refund the purchase price.[636] For a recall that imposes an ODD restriction, a better remedy might be to refund some or all of the (express or implied) price of the L2 system. The potential financial loss from an ODD restriction would encourage L2 system developers to set their systems' ODDs more conservatively.

One might object that the fix-or-restrict recall policy would enmesh NHTSA too deeply in the technical and business decision-making of the automakers. But NHTSA's need to demonstrate that a driving automation system creates an "unreasonable risk" to safety would limit overreach. In 1988, the D.C. Circuit held that the mere fact that a vehicle model was involved in crashes does not justify a recall when there is evidence that comparable vehicles were just as likely to be involved in crashes.[637] Courts will be able to interpret the defect standard more strictly once NHTSA has better data on crashes. A telematics standard and a universal crash report order would make arguments about safety risk easier to resolve and make the unreasonable risk standard a stronger check on overreach.

It is also important to keep in mind the alternative. Uber's fatal crash led state regulators to take its ADS off the road.[638] The Cruise ADS's error in the Fifth and Market crash—and the attempted cover-up—caused the company to lose its permit.[639] Tesla has yet to face serious consequences for Autopilot crashes beyond the recall, but it is being investigated by the California DMV and sued by crash victims and their families.[640] We may not tolerate crashes involving driving automation systems as much as we tolerate conventional vehicle crashes. The best strategy for promoting the sustainable deployment of driving automation may be for NHTSA to use its recall power to ensure that driving automation systems are only deployed when they are sufficiently safe.

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[636] 49 U.S.C. § 30120(a)(1)(A).

[637] United States v. Gen. Motors Corp., 841 F.2d 400, 415–16 (D.C. Cir. 1988).

[638] *See* Daniels, *supra* note 410.

[639] *See* CRUISE SUSPENSION, *supra* note 568, at 1.

[640] *See* Russ Mitchell, *The DMV Said it Would Investigate Tesla Over Self-Driving Claims. Then, Crickets*, L.A. TIMES (May 26, 2022, 5:00 AM), https://www.latimes.com/business/story/2022-05-26/dmv-tesla-year-long-slow-walk; Neal E. Boudette, *Tesla Says Autopilot Makes Its Cars Safer. Crash Victims Say It Kills.*, N.Y. TIMES, https://www.nytimes.com/2021/07/05/business/tesla-autopilot-lawsuits-safety.html (Sept. 1, 2021).

D. Driver Monitoring Revisited

Whether NHTSA should set substantive safety standards for driving automation in the near term is a more difficult question. There is a good case that NHTSA should set a minimum standard for driver monitoring for L2 systems. A better driver monitoring system might have led Joshua Brown to avoid the tractor-trailer, Rafaela Vasquez to avoid Elaine Herzberg, and Walter Huang to avoid the crash attenuator. But it would be hard to craft a standard that is substantial enough to impact safety, flexible enough to avoid rapid obsolescence, and well-supported enough to survive cost-benefit analysis and judicial review.

Suppose that NHTSA tried to set a performance standard. The performance it would want to measure is the system's ability to keep the driver attentive. Driver attentiveness cannot be measured directly. Safety researchers rely on indirect measurements like eye gaze or head orientation.[641] Drivers might vary greatly in how they respond to a monitoring system, which would complicate the design of any objective test. In 1972, the Sixth Circuit struck down NHTSA's passive restraint standard on the ground that the agency had left itself too much discretion by not specifying the stiffness of a crash dummy.[642] How could NHTSA develop a test that would produce identical results when applied to a diverse population of warm-blooded humans?

Now suppose instead that NHTSA set a design standard. For example, it could mandate that L2 systems include technology that warns the driver whenever they look away from the road for a certain interval. If NHTSA could define the technology specifically enough, it could avoid the problem of developing an objective performance test. But it would risk freezing the existing state of driver monitoring technology and discouraging investment in improving it. Human factors engineers might be more likely to discover more effective or less intrusive means to keep a driver's attention if the industry is allowed to experiment.

The better strategy might be for NHTSA to craft a flexible performance standard and then argue that the antiquated precedents need to be adapted for the automated age. The agency, though, still seems haunted by its old demons. In an interview, then-Administrator Cliff "cautioned that while he believes federal standards are needed to regulate driver [assistance] technology, he wants to

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[641] Mueller et al., *supra* note 196, at 6.

[642] *See* Chrysler Corp. v. Dep't of Transp., 472 F.2d 659, 675–76, 678 (6th Cir. 1972).

avoid rushing to embrace new rules that might potentially end up compromising safety."[643] Cliff explained: "Any time we put a regulation on the books, we have to define not only what standard that technology needs to be held to, but we need to have an objective way to measure the performance of the system . . . ."[644] It is telling that even Cliff, an energetic outsider, internalized NHTSA's cautious approach to regulation and the case law.

Whatever standard NHTSA develops would also have to confront the L3 problem. In an L3 ADS, the fallback-ready user is not expected to continuously supervise the system.[645] If NHTSA were to apply the same driver monitoring standard to L2 systems and L3 ADSs, it would erase the difference in the subjective experience of using those technologies, even though they differ in functionality. If NHTSA were to apply a different standard for L3 ADSs, L2 system developers might try to characterize their systems as L3 ADSs, thereby rendering the standard irrelevant.

Ultimately, NHTSA may find that the recall power can solve the driver monitoring problem indirectly. If the agency determines that an L2 system has created an unreasonable risk and that better driver monitoring might mitigate that risk, the agency could offer the developer the option of improving its driver monitoring system. The general approach that NHTSA took in the Tesla Autopilot recall may have been right, even though the changes it required did not go far enough. Remedying clearly deficient driver monitoring systems through recalls would let the rest of the industry continue to experiment with developing better driver monitoring technology. The recall power may prove to be the right tool for the automated age.

CONCLUSION

The architects of the Safety Act believed that the auto industry of their time was not devoting sufficient resources to safety innovation. They hoped that NHTSA would set standards that would force the industry to develop safer technology. But the industry had strong incentives to obstruct new standards. The automakers could protect their profits by convincing the agency or the courts that reaching a higher level of safety was not feasible.

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[643] Krisher, *supra* note 450.

[644] *Id.*

[645] *See* SAE INT'L, *supra* note 22, at 31.

In the automated age, these incentives have become more complicated. Automakers and tech companies are racing to bring driving automation systems to market. They have spent tens of billions of dollars on research and development. Safety regulation no longer needs to compel innovation. Instead, it should *align* innovation with safety. Achieving that goal will require more subtle tools.

NHTSA should use its investigative powers to monitor new technology as it comes to market. If a driving automation system has a positive net impact on safety, NHTSA should let the experiment continue. If it creates unreasonable risks, NHTSA should tell the developer to go back to the lab and design safer software. Developers should learn that the easiest way to avoid regulation is to prioritize safety in development. In that way, NHTSA can finally realize its mission to channel the creative energies and vast technology of the automobile industry into a vigorous and competitive effort to improve the safety of vehicles.