PRODUCTS LIABILITY FOR SOFTWARE DEFECTS IN DRIVERLESS CARS

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ABSTRACT

The cars of my childhood were unsafe at any speed. American automobiles were designed for looks, not safety. Automobiles of the 1950s and 1960s were sold without padded dashboards, antilock brakes, airbags, traction control, or even seatbelts. The first federal motor vehicle safety standards led to collapsible steering columns by the late 1960s. Today's automobiles are safer than ever, yet 40,000 Americans are killed annually in automobile accidents. Ninety-four percent of all automobile accidents are caused by human error. America's automobile industry is in the process of making a paradigmatic shift to connected vehicles controlled by software, not humans. Key enablers of fully autonomous vehicles are software and advances in machine learning. Autonomous vehicles ("AVs") travel from their point of departure to their point of destination without human intervention controlled by software, cameras, and Light Detection and Ranging ("LiDAR"). This Article proposes extending products liability to defective software components in AVs. Under this proposed reform, software creators that supply components to driverless vehicles or AVs will be strictly liable for injuries or deaths attributable to dangerously defective code. The software industry currently deploys contract law to disclaim all meaningful warranties and cap damages in their licensing agreements. Under a product liability regime, software warranties can no longer be disclaimed nor liability limited. Extending products liability to defective software incorporated within AVs will ensure that manufacturers, distributors, suppliers, retailers, and other parties involved in the production of AVs will be held accountable for the costs of injuries and deaths caused by defective AV software components. Product liability must evolve to address software failure caused by errors in algorithms to protect the occupants of AVs and others using the roadway, including bicyclists and pedestrians.

I. INTRODUCTION

A fully autonomous vehicle will not have a steering wheel or brake pedal and will operate in multitudinous driving conditions without human intervention.[1] Autonomous vehicles ("AVs") must navigate in "unpredictable

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[1] Tiffany Y. Gruenberg, *Self-Driving Cars Will Likely Increase Product Liability Litigation*, NAT'L L. REV. (Jan. 22, 2019), https://www.natlawreview.com/article/self-driving-cars-will-likely-increase-product-liability-litigation [https://perma.cc/FWX9-L5E6].

and varied environments."[2] "Autonomous vehicles are smart vehicles with autonomous driving technologies for which the smart vehicles reach destinations by themselves even when drivers do not directly operate steering wheels, accelerator pedals, brakes, and the like."[3] "When full automation mode is engaged, the software takes over the functions and decisions associated with driving without a need for human input."[4] "The automotive industry is undergoing a paradigm change towards connected and autonomous vehicles."[5] AVs "use[] some combination of 'cameras, radar systems, lasers (for example, LiDAR), and Global Positioning System (GPS) units' to gather information about the environment and make decisions about when and how to steer, accelerate, and brake."[6]

Part I of this Article presents an overview of the epidemic of injury and death caused by conventional automobiles. Next, Part II defines and describes software defects in AVs that will likely cause injury or deaths as these vehicles are deployed. This part of the Article examines different levels of automation, as well as an overview of the major players in the driverless car industry. Part III proposes that products liability be extended to defective software components in AVs causing injuries and deaths. Products liability holds accountable manufacturers, distributors, suppliers, retailers, and everyone else in the chain of distribution for placing a defective product into the stream of commerce. Dangerously defective driverless cars are the latest iteration of products liability's role as an early response system for remediating products deemed unsafe for their unforeseeable environment of use.

II. DEATH BY DRIVER DISTRACTION

A. DRIVER-RELATED ERRORS & AUTOMOBILE ACCIDENTS

A National Highway Traffic Administration ("NHTSA") report suggests that emerging Information Technology Services ("ITS") could reduce the one million collisions that occur annually, resulting in a "$25.6 billion economic savings per year."[7]

> The lifetime economic cost of these crashes is over $150 billion annually. The share borne by taxpayers is staggering: the public pays 13[%] of the cost of injuries treated in an emergency department;

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[2] Ben Dickson, *The Predictions Were Wrong: Self-Driving Cars Have a Long Way to Go*, PC MAG. (Feb. 11, 2019), https://www.pcmag.com/news/the-predictions-were-wrong-self-driving-cars-have-a-long-way-to-go [https://perma.cc/F99R-TBXD].

[3] *Researchers Submit Patent Application, "Operation Control Method of Foldable Pedal Apparatus", for Approval (USPTO 20220324420), Hyundai Motor Company*, DAILY ASIA BUSINESS (Nov. 2, 2022), 2022 WLNR 35045883.

[4] Alejandro Monarrez, *Autonomous Vehicle Manufacturers: Applying A Common Carrier Liability Scheme to Autonomous Vehicle Manufacturers—and Why Elon Musk Will Be Haunted by His Words*, 43 SEATTLE UNIV. L. REV. 1, 5 (2020).

[5] EUR. UNION AGENCY FOR CYBERSECURITY, ENISA GOOD PRACTICES FOR SECURITY OF SMART CARS 5 (2019), https://www.enisa.europa.eu/publications/smart-cars/at_download/fullReport [https://perma.cc/5MAP-KFUZ].

[6] Tracy Hresko Pearl, *Compensation at the Crossroads: Autonomous Vehicles & Alternative Victim Compensation Schemes*, 60 WM. & MARY L. REV. 1827, 1835 (2019).

[7] *NHTSA 2020 Report: People Saving People: On the Road to a Healthier Future*, NAT'L HIGHWAY TRAFFIC SAFETY ADMIN. (Sept. 1997), https://one.nhtsa.gov/nhtsa/whatis/planning/2020Report/2020report.html [https://perma.cc/NC6R-M5EN].

> 26[%] of the cost of injuries requiring hospitalization; and 48[%] of the cost of injuries treated in a rehabilitation hospital.[8]

The "NHTSA projects that an estimated 42,915 people died in motor vehicle traffic crashes [in 2021], a 10.5% increase from the 38,824 fatalities in 2020. The projection is the highest number of fatalities since 2005 and the largest annual percentage increase in the Fatality Analysis Reporting System's history."[9]

NHTSA concluded that the critical reason for automobile accidents was driver error in 94% percent of the cases it studied over a two-year period.[10] NHTSA explains that distracted driving includes not only:

> cell phone use and texting, but distracted driving also includes other activities such as eating, talking to other passengers, or adjusting the radio or climate controls. A distraction-affected crash is any crash in which a driver was identified as distracted at the time of the crash. …
>
> In 2018, there were 2,841 people killed and an estimated additional 400,000 people injured in motor vehicle crashes involving distracted drivers.[11]

Distracted driving is the chief cause of most automobile accidents: 8% of all fatal crashes in 2020 were distraction-related, resulting in 3,142 lives lost, an increase of 9.9% over 2018 when 2,858 lives were lost due to distracted driving.[12]

"Eight percent of fatal crashes, 15 percent of injury crashes, and 14 percent of all police-reported motor vehicle traffic crashes in 2018 were reported as distraction-affected crashes."[13] About 400,000 were injured and 2,841 killed because of distraction-affected crashes.[14]

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[8] *Id.*

[9] *Newly Released Estimates Show Traffic Fatalities Reached a 16-Year High in 2021*, NAT'L HIGHWAY TRAFFIC SAFETY ADMIN. (May 22, 2022), https://www.nhtsa.gov/press-releases/early-estimate-2021-traffic-fatalities [https://perma.cc/Q68J-YLT7].

[10] NAT'L HIGHWAY TRAFFIC SAFETY ADMIN., CRITICAL REASONS FOR CRASHES INVESTIGATED IN THE NATIONAL MOTOR VEHICLE CRASH CAUSATION SURVEY 1 (2015), https://crashstats.nhtsa.dot.gov/Api/Public/ViewPublication/812115 [https://perma.cc/38ZU-XZWS] ("The National Motor Vehicle Crash Causation Survey (NMVCCS), conducted from 2005 to 2007, was aimed at collecting on-scene information about the events and associated factors leading up to crashes involving light vehicles. Several facets of crash occurrence were investigated during data collection, namely the precrash movement, critical pre-crash event, critical reason, and the associated factors. A weighted sample of 5,470 crashes was investigated over a period of two and a half years, which represents an estimated 2,189,000 crashes nationwide. About 4,031,000 vehicles, 3,945,000 drivers, and 1,982,000 passengers were estimated to have been involved in these crashes.").

[11] NAT'L HIGHWAY TRAFFIC SAFETY ADMIN.'S NAT'L CTR. FOR STAT. & ANALYSIS, RESEARCH NOTE: DISTRACTED DRIVING 2018 1 (2020), https://crashstats.nhtsa.dot.gov/Api/Public/Publication/812926 [https://perma.cc/3GW9-H53H].

[12] NAT'L HIGHWAY TRAFFIC SAFETY ADMIN.'S NAT'L CTR. FOR STAT. & ANALYSIS, RESEARCH NOTE: DISTRACTED DRIVING 2020 2 tbl.1 (2022), https://crashstats.nhtsa.dot.gov/Api/Public/ViewPublication/813309 [https://perma.cc/A5UF-UYAL].

[13] NAT'L HIGHWAY TRAFFIC SAFETY ADMIN.'S NAT'L CTR. FOR STAT. & ANALYSIS, *supra* note 11, at 1.

[14] *Id.*

"About 1 in 5 of the people who died in crashes involving a distracted driver in 2019 were not in vehicles—they were walking, riding their bikes, or otherwise outside a vehicle."[15]

"Distracted driving crashes are under-reported and the [National Safety Council] estimates that cell phone use alone accounted for 27% of 2015 car crashes."[16]

A 2021 survey concluded that the problem of distracted driving is widespread:

> 36.4% of participants completely agree that using a mobile device hinders your ability to drive, yet 36% admit to engaging in activities with a cellphone while driving.
>
> Less than half of participants completely agree that texting and driving is just as dangerous as drinking and driving, despite numerous studies proving both activities limit your capacity for awareness and focus.
>
> Only 4.1% of participants' ages 25–34 claimed they felt a high degree of pressure to respond to text messages while driving. In total, 12.1% of respondents in that age group felt any pressure to answer a text at all.
>
> 17.9% of the age group 18–24 felt the most pressure to respond to a text while driving. Interestingly, it is also this age group that is most often in accidents.[17]

At this point in time, human error causes most automobile accidents as opposed to defects in automotive design. In the future, as driverless cars are introduced, that ratio will change. In terms of driverless cars, humans at the wheel will no longer be making mistakes. However, software engineers may defectively design software components that lead to accidents.[18] There must be accountability for dangerously defective software defects.

B. Autonomous Vehicles Will Eliminate Human Error

A fully autonomous vehicle (AV) will not have a steering wheel or brake pedal and will operate in multitudinous driving conditions without human intervention.[19] AVs deploy artificial intelligence ("AI"), sensors, and big data in order to "adapt to changing circumstances and handle complex situations as a substitute for human judgement, as the latter would no longer be needed

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[15] *Distracted Driving*, Ctr. for Disease Control and Prevention, https://www.cdc.gov/transportationsafety/distracted_driving/index.html [https://perma.cc/3CGW-83JW] (last visited Sept. 15, 2022).

[16] *Learn the Facts About Distracted Driving*, End Distracted Driving, https://www.enddd.org/the-facts-about-distracted-driving/?gclid=CjwKCAjwzMeFBhBwEiwAzwS8zL31tCAwexyIlsWwpSXyrG05qtr76PW3ncpVacB5Tu8Ob-J7QVRuZBoCw5sQAvD_BwE [https://perma.cc/T4K5-LWE5] (last visited Sept. 16, 2022).

[17] *Distracted Driving Statistics in 2022*, Zebra, https://www.thezebra.com/resources/research/distracted-driving-statistics/#statistics-2021 [https://perma.cc/UCJ5-R5W3] (July 7, 2022).

[18] Bad software design in AVs is inevitable given the difficult work situation of software engineers. Software engineers report that the industry can be stressful, and they are pressured to moonlight. *See* Jenna Gyimesi, *The 5 Worst Things About My Job as a Software Engineer,* Bus. Insider (Nov. 25, 2022), www.businessinsider.com/software-engineer-5-worst-things-about-job-2022-11 [https://perma.cc/DAW6-UZ7R].

[19] Gruenberg, *supra* note 1.

for conventional vehicle operations such as lane-changing, parking, collision avoidance and braking."[20]AVs will navigate in difficult-to-access locations as well as "unpredictable and varied environments."[21]

Despite these challenges, Arizona, California, Colorado, Florida, Georgia, Iowa, Kansas, Nebraska, Nevada, New Hampshire, North Carolina, North Dakota, Tennessee, Texas, Utah, and West Virginia have authorized the full employment of automated vehicles.[22] Alabama, Arkansas, and Louisiana limit deployment to commercial vehicles. Connecticut, District of Columbia, Hawaii, Illinois, Maine, Massachusetts, New Mexico, New York, Ohio, Vermont, Virginia, and Washington permit AVs to be tested on their roads.[23] "Michigan authorizes testing of any 'automated motor vehicle' and deployment of 'on-demand automated motor vehicle networks.' "[24] Pennsylvania requires a licensed human driver if a "highly automated vehicle" is being tested.[25]

Fully autonomous vehicles will have total automation where the vehicle travels from its point of departure to its point of destination without human intervention.[26] By 2040, fully autonomous vehicles will often be seen on America's highways.[27] Fully automated vehicles will inevitably get into car accidents because of software bugs or hardware failure, even if driver error is eliminated.[28] If no one is driving AVs, who would become liable in a situation where the software malfunctions and causes the vehicle to veer off and strike a pedestrian, a telephone pole, or a conventional automobile? If a person summons a self-driving car and is not driving, is there any legal responsibility on the part of the consumer for malfunctioning software that proximately causes an accident?

Aside from these risks, there is a concern that accidents could be caused by cybercriminals hacking into a car's systems, overriding the settings, speeding it up, or shifting it into reverse, thus endangering the car's

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[20] Araz Taeihagh & Hazel Si Min Lim, *Governing Autonomous Vehicles: Emerging Responses for Safety, Liability, Privacy, Cybersecurity, and Industry Risks*, 39 TRANSP. REV. 103 (2019).

[21] Dickson, *supra* note 2.

[22] *Autonomous Vehicle Laws*, INS. INST. FOR HIGHWAY SAFETY, HIGHWAY LOSS DATA INST. (June 2022), https://www.iihs.org/topics/advanced-driver-assistance/autonomous-vehicle-laws#fn2 [https://perma.cc/86HG-FQWS].

[23] *Id.*

[24] *Id.* at n.12.

[25] *Id.* at n.18.

[26] *See* NAT'L HIGHWAY TRAFFIC SAFETY ADMIN., HIGHLY AUTOMATED OR "SELF-DRIVING" VEHICLES 2, https://www.nhtsa.gov/sites/nhtsa.gov/files/documents/14269-overview_of_automated_vehicle_technology_042319_v1b.pdf [https://perma.cc/3R52-ADCM] [hereinafter HIGHLY AUTOMATED OR "SELF-DRIVING" VEHICLES].

[27] Jeffrey K. Gurney, *Crashing into the Unknown: An Examination of Crash-Optimization Algorithms Through the Two Lanes of Ethics and Law*, 79 ALB. L. REV. 183, 189 (2016).

[28] Lance Eliot, *Essential Stats for Justifying and Comparing Self-Driving Cars to Humans at the Wheel*, FORBES (May 30, 2019 11:18 AM), https://www.forbes.com/sites/lanceeliot/2019/05/30/essential-stats-for-justifying-and-comparing-self-driving-cars-to-humans-at-the-wheel/?sh=28273fcd46ed [https://perma.cc/W2KU-EYE2]:

> We are going to have autonomous cars that get into car accidents, which can happen because something goes awry in the autonomous car (like encountering an AI software bug or hardware fault that is not otherwise caught), or because the car breaks down in some manner (remember, it's still a car, composed of mechanical [art and vulnerable to wear-and-tear on its parts), or due to say a pedestrian that unexpectedly leaps in front of an autonomous car for which the physics prevents the driverless car from avoiding the pedestrian and so on.

occupants and pedestrians.[29] When the accidents involve highly automated vehicles ("HAVs"), "potentially liable parties may include HAV manufacturers, developers of HAV software and algorithms, and owners or manufacturers of roadside infrastructure communicating with HAVs. Thus, as HAVs are deployed on the roads, there will be a shift in the defendants in [a] typical motor vehicle case."[30]

Higher levels of automation, referred to as automated driving systems, remove the human driver from the chain of events that can lead to a crash.[31] The definitions of AVs are relatively uniform but there are variations among states.[32] "Autonomous cars . . . are operated by a complex computer system consisting of cameras, laser sensors, GPS software, and a multitude of other mechanisms that create a 3-D image of the world around the vehicle."[33] These vehicles improve computer vision and enhance the perception system by using cameras, software, and radar, as well as building highly detailed maps of the environment so the vehicle may process its surroundings. AVs "are likely to improve safety and decrease the number of crashes, traffic fatalities, and serious injuries on U.S. roadways."[34]

C. SAE International Levels of Autonomy Based on Driver Control

The terms "autonomous vehicle," "driverless vehicle," and "robot car," refer to connected and automated vehicles ("AVs"). On January 11, 2021, the U.S. Department of Transportation released the Automated Vehicles Comprehensive Plan ("AVCP"), a "robust multimodal strategy to promote collaboration and transparency, modernize the regulatory environment, and prepare the transportation system for the safe integration of Automated

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[29] Julie Goodrich, *Driving Miss Daisy: An Autonomous Chauffeur System*, 51 Hous. L. Rev. 265, 282–83 (2013) ("Breaching an autonomous vehicle's entry points may do more than just release data; a hacker could potentially take control of the vehicle and cause it to drive to a certain location."); Neal Katyal, *Disruptive Technologies and the Law*, 102 Geo. L.J. 1685, 1689 (2014) ("Self-driving vehicles would also open the country up to a number of new security concerns. Hackers could tamper with autonomous driving software; terrorists could infiltrate the central transportation system.").

[30] Terésa J. Farris & Charles P. Kindregan III, § 1:42 *Application of Tort Law to Autonomous Vehicles*, *in* 11 Massachusetts Practice, Motor Vehicle Law And Practice (5th ed., June 2022 update).

[31] *Automated Vehicles for Safety*, Nat'l Highway Traffic Safety Admin., [https://perma.cc/6BSY-L396] (last visited Nov. 11, 2022).

[32] Jordan Fowler, *Trailblazing an Industry: The Potential Effects and Defects of Autonomous Vehicles and the Need for Legislation in Texas,* 49 Tex. Tech. L. Rev. 903 (2017) ("Although the definition of 'autonomous technology' is relatively uniform, states have somewhat different definitions for what constitutes an 'autonomous vehicle.'").

[33] Sophia H. Duffy & Jamie P. Hopkins, *Sit, Stay, Drive: The Future of Autonomous Car Liability*, 16 SMU Sci. & Tech. L. Rev. 453 (2013).

[34] U.S. Dep't of Transp., Doc. No. NHTSA-2016-0040, National Highway Traffic Safety Administration (NHTSA) Enforcement Guidance Bulletin 2016-02: Safety-Related Defects and Automated Safety Technologies (2016), https://www.transportation.gov/AV/nhtsa-guidance-2016-02-safety-related-defects-and-automated-safety [https://perma.cc/B35U-V3QQ]; *see also Automated Vehicles for Safety*, *supra* note 31:

> Automated vehicles' potential to save lives and reduce injuries is rooted in one critical and tragic fact: 94% of serious crashes are due to human error. Automated vehicles have the potential to remove human error from the crash equation, which will help protect drivers and passengers, as well as bicyclists and pedestrians.

Driving Systems ("ADS")."[35] The automotive industry recognizes graduated standards for measuring the level of automated driving.[36] SAE International argues that the term "self-driving" is imprecise and "can vary based on unstated assumptions about the meaning of driving and driver."[37] SAE International also notes that AVs depend on "communication and/or cooperation with outside entities" to gather and transmit data.[38] SAE International's taxonomy of the increasing levels of driving automation is widely used by stakeholders in the AV technology industry.[39]

The SAE International taxonomy defines the term "motor vehicle driving automation systems" as "systems that perform part or all of the entire dynamic driving task ("DDT") on a sustained basis."[40] SAE International defines the term "on-road" as "publicly accessible roadways (including parking areas and private campuses that permit public access) that collectively serve users of vehicles of all classes and driving automation levels (including no driving automation), as well as motorcyclists, pedal cyclists, and pedestrians."[41]

SAE International describes advanced driver assistance systems ("ADAS")—vehicles capable of driving partially automated—as having achieved Level 2 automation on a 0–5 scale.[42] The SAE International J3016 Technical Standards Committee set forth SAE International's six driving levels and they are defined as follows:

> *Level 0 (Driver Only)*—No automation; the human driver is responsible for all driving tasks.
>
> *Level 1 (Assisted)*—The automated system on the vehicle can assist the human driver within the defined use cases (i.e., operating environments and conditions) of the driving task.
>
> *Level 2 (Partial Automation)*—The automated system on the vehicle conducts multiple parts of the driving task. The human continues to

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[35] *U.S. Department of Transportation Releases Automated Vehicles Comprehensive Plan*, U.S. DEP'T OF TRANSP., (Jan. 11, 2021), https://www.transportation.gov/briefing-room/us-department-transportation-releases-automated-vehicles-comprehensive-plan [https://perma.cc/4BP4-JKVZ].

[36] Jianqiang Wang, Heye Huang, Keqiang Li & Jun Li, *Towards the Unified Principles for Level 5 Autonomous Vehicles*, 7 ENG'G 1313 (2021).

[37] SAE On-Road Automated Vehicle Standards Comm., *Taxonomy and Definitions for Terms Related to Driving Automation Systems for On-Road Motor Vehicles*, SAE INT'L (2016), http://106.38.59.21:8080/userfiles/5e7584d8e30147ef84cb72f9c4e29124/files/teckSolution/2019/10/SAE_J3016_AutomatedDrivingSystems_2016.pdf.

[38] Michael L. Slack, *Automation in Transportation, 2018 Emerging Technology: Legal Issues Involving Autonomous Vehicles*, ADVANCED INTELL. PROP. L. 8 (2018).

[39] *See* Jennifer Shuttleworth, *SAE Standards News: J3016 Automated-Driving Graphic Update*, SAE INT'L (Jan. 7, 2019), https://www.sae.org/news/2019/01/sae-updates-j3016-automated-driving-graphic [https://perma.cc/T8JR-8X52]:

> SAE International recently unveiled a new visual Table (below, and in gallery) that is designed to clarify and simplify its J3016 'Levels of Driving Automation' standard for consumers. The J3016 standard defines six levels of driving automation, from SAE Level Zero (no automation) to SAE Level 5 (full vehicle autonomy). It serves as the industry's most-cited reference for automated-vehicle (AV) capabilities.

[40] *Taxonomy and Definitions for Terms Related to Driving Automation Systems for On-Road Motor Vehicles J3016_201806,* SAE INT'L (June 15, 2018), https://www.sae.org/standards/content/j3016_201806/ [https://perma.cc/7RKZ-XGKA] [hereinafter *Taxonomy and Definitions for Terms*].

[41] *Id.*

[42] SAE On-Road Automated Vehicle Standards Comm., *supra* note 37, at 19 (The Society of Automotive Engineers uses the term "driving automation system or technology.").

monitor the driving environment and perform the remaining driving tasks.

Level 3 (Conditional Automation)—The automated system conducts multiple parts of the driving task and monitors the driving environment within the defined use cases. The human driver must always be ready to take back control when the automated system requests.

Level 4 (High Automation)—The automated system conducts the driving task and monitors the driving environment within the defined use cases. The human need not take back control when operating in these defined use cases. The human driver assumes control outside of the defined use cases.

Level 5 (Full Automation)—The automated system performs all driving tasks within all use cases that a human driver could perform them.[43]

Most traditional vehicles today "feature levels 1 or 2 automation: cruise control, electronic stability control, forward-collision warning, automated emergency braking, and self-parking. The Audi 8 was the first production car to reach [L]evel-3 automation."[44] Most semi-autonomous vehicles available for purchase on the market today are SAE International Level 2 or Level 3 AVs, including Tesla's AV.[45] The AV manufacturers "testing AVs on public roads are either from traditional vehicle manufacturers (i.e., Toyota, Nissan, and General Motor), or technology companies (i.e., Google, Uber, and Baidu)."[46] AVs with the capability to transfer human passengers and perform all driving tasks at any time under any circumstance with no human supervision are classified at level 5.[47]

The leading "players operating in the global autonomous car market are Daimler AG, General Motors, Volkswagen Group, Ford Motor Company, BMW AG, Robert Bosch GMBH, Denso Corporation, Renault-Nissan-Mitsubishi Alliance, AB Volvo, Tesla Inc., and Toyota Motor Corporation."[48] Tesla's vehicles logged more hours on the road than any of its competitors:

[A] total of 3 billion miles on Autopilot as of April 2020—up from a cumulative 1 billion miles it reported in late 2018. This is well ahead

[43] U.S. DEP'T OF ENERGY, U.S. ENERGY INFO. ADMIN., STUDY OF THE POTENTIAL ENERGY CONSUMPTION IMPACTS OF CONNECTED AND AUTOMATED VEHICLES, (Mar. 2017), https://www.eia.gov/analysis/studies/transportation/automated/pdf/automated_vehicles.pdf [https://perma.cc/MZ6M-HWGK].

[44] Brad Anderson, *How Will Autonomous Cars Affect Insurance?* READWRITE, (May 12, 2020), https://readwrite.com/how-will-autonomous-cars-affect-insurance/#:~:text=Insurance%20Rates%20Will%20Drop,across%20five%20levels%20of%20automation [https://perma.cc/LT7S-VVWZ].

[45] Matt O'Brien, *Google, Tesla, Others Wait for DMV's Self-Driving Rules*, SAN JOSE MERCURY NEWS (Aug. 12, 2016, 1:31 AM), http://www.mercurynews.com/business/ci_29027362/google-tesla-others-wait-dmvs-self-drivingrules [https://perma.cc/TG8C-LV3D].

[46] Song Wang & Zhixia Li, *Exploring the Mechanism of Crashes with Automated Vehicles Using Statistical Modeling Approaches*, PLOS ONE, (Mar. 28, 2019), https://journals.plos.org/plosone/article/file?id=10.1371/journal.pone.0214550&type=printable [https://perma.cc/88RZ-DC4X].

[47] *Id.*

[48] Panchali Mallik Tripathi, *Google's Robot Car Project to Drive Innovation in Autonomous Car Technology*, GE SPATIAL WORLD, (Aug. 14, 2019), https://www.geospatialworld.net/blogs/googles- robot -car-project-to-drive-innovation/ [https://perma.cc/S23D-K4AL].

> of its nearest rival, Waymo (backed by Alphabet), which reported that its test vehicles had logged 20 million miles on public roads as of January.[49]

"Tesla's total autonomous miles logged has grown exponentially from 0.1 billion in May 2016 to an estimated 1.88 billion as of October 2019."[50] "Tesla overtook Toyota to become the world's biggest carmaker by market capitalisation. The maker of electric vehicles has seen its share price rev up from $225 a year ago to $1,120, giving it a value of more than $205 [billion]. It has yet to turn an annual profit."[51]

Over the last fifteen years, Audi, Volkswagen, BMW, Toyota, and Subaru have installed laser-based adaptive cruise control systems in varying vehicle types.[52] U.S. car manufacturers have already incorporated semi-autonomous systems into their vehicles. These systems enable the vehicle to drive "independently" for a portion of the driver's journey. However, manufacturers have not yet designed vehicles that are capable of total automation where the vehicle travels from its point of departure to its point of destination without human intervention.[53] Mainstream vehicles in 2021 are predominately at Level 2 automation:

> In relation to cars in 2022, most mainstream carmakers are focused on[] Level 2 autonomy. This level allows the vehicle to take over most steering, acceleration[,] and braking functions, but still requires that the driver remain fully attentive to the driving situation and be able to intervene at any moment. It is not driverless, fully autonomous driving, like robotaxis from Waymo or Cruise (that are now testing in California).
>
> That means, today, autopilot really means 'assisted driving' and not 'self-driving' since the driver still has to be alert and attentive at all times. It will not be until Level 4 or Level 5 fully autonomous cars hit the roads that the true promise of full self-driving will be a reality. Currently, that's not expected to happen until 2022 (although the team at Tesla is pushing hard to do so as soon as possible, as announced at Tesla Autonomy Day, since all new cars sold with Hardware 3 are much more powerful).[54]
>
> In 2022, the analyst expects many [Original Equipment Manufacturers (OEMs)] to offer L2+ hands-off driving systems in mass-market vehicles in the United States, Canada, Japan, China, and Korea, while Europe remains at L2 [Level 2] hands-on driving. We anticipate only

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[49] Trefis Team, *Tesla: King Of [Self-Driving] Cars?*, TREFIS (July 3, 2020), https://www.trefis.com/stock/tsla/articles/492591/has-tesla-built-an-insurmountable-lead-in-self-driving-software/2020-07-02 [https://perma.cc/96WY-GYCR].

[50] *Id.*

[51] *Business This Week*, ECONOMIST: THE WORLD THIS WEEK (July 4, 2020), https://www.economist.com/the-world-this-week/2020/07/04/business-this-week [https://perma.cc/2N5Y-SV3A].

[52] Aaron M. Cargain & Tad A. Devlin, *What Road Lies Ahead for Autonomous Vehicles?*, 36 WESTLAW J. AUTO., no. 5, Sept. 2016, at 2.

[53] HIGHLY AUTOMATED OR "SELF-DRIVING" VEHICLES, *supra* note 26, at 1.

[54] *Cars With Autopilot in 2021*, AUTOPILOT REV., https://www.autopilotreview.com/cars-with-autopilot-self-driving/ [https://perma.cc/57JG-SD5Y] (last visited Oct. 13, 2022).

> a few premium OEMs to launch L3 [Level 3] piloted driving features in their flagship models due to the low value proposition.[55]

KPMG predicts "that all vehicles produced in the UK by 2027 will have at least L3 technologies embedded in them" and a quarter of all vehicles will be fully automated by 2030.[56] By 2026, eight million cars will be on the road "with some level of autonomous vehicle technology."[57] The automotive software market is "projected to reach USD 37.0 billion by 2025 from USD 16.9 billion in 2020, at a CAGR of 16.9%."[58] Fully automated vehicles are not found "on the public roads of Europe . . . [and e]ven Level 3 vehicles are rarely seen."[59] " 'Autonomous technology' means technology that has the capability to drive a vehicle without the active physical control by or monitoring of a human operator."[60] Autonomous tech developers who "were aiming for Level 5 just a few years ago" have since revealed "slashed budgets, scaled-down goals and a much more skeptical tech landscape."[61] Level 5 optimism was displaced by Level 5 skepticism. This optimism,

> largely ended two years ago, was fueled by a belief that getting from Level 3 to Level 5 would take just as many years as it took to get from Level 1 to Level 3—a fallacy called out at the time by relatively few skeptics—and was to a great extent boosted by prototypes that *seemed* to be able to drive in complex traffic without disengaging or crashing into anything, "proven" by YouTube videos posted by their developers.[62]

D. AVs Will Eliminate Human Error

AVs will strike human error as a cause of traffic accidents, as there is no human input once "the software takes over the functions and decisions associated with driving."[63] Removing human error will dramatically reduce the risk of car accidents. By 2040, the expected impact of AVs on the

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[55] *Global Advanced Driver Assistance Systems (ADAS) and Autonomous Driving (AD) Industry Outlook Report 2022: AD Function-on-Demand, Enabling Software*, BUS. WIRE (May 27, 2022, 12:18 PM), https://www.businesswire.com/news/home/20220527005353/en/Global-Advanced-Driver-Assistance-Systems-ADAS-and-Autonomous-Driving-AD-Industry-Outlook-Report-2022-AD-Function-on-Demand-Enabling-Software-Tools-for-AD-Development-Chip-Shortage-Impact-on-AD---ResearchAndMarkets.com [https://perma.cc/CA69-3G4C].

[56] KPMG, CONNECTED AND AUTONOMOUS VEHICLES – THE UK ECONOMIC OPPORTUNITY 9 (2015), https://www.smmt.co.uk/wp-content/uploads/sites/2/CRT036586F-Connected-and-Autonomous-Vehicles-%E2%80%93-The-UK-Economic-Opportu...1.pdf [https://perma.cc/J6PA-7QWU].

[57] IMERIT, DATA ANNOTATION FOR AUTONOMOUS VEHICLE DEVELOPMENT 2 (2020), https://imerit.net/wp-content/uploads/2020/06/Data-Annotation-For-Autonomous-Vehicle-Development.pdf?x45067 [https://perma.cc/74ZV-QMEJ].

[58] *$30+ Billion Worldwide Automotive Software Industry to 2025 - Featuring Blackberry, Nvidia & Microsoft Among Others*, PRNEWSWIRE (June 3, 2020, 4:16 PM), https://www.prnewswire.com/news-releases/30-billion-worldwide-automotive-software-industry-to-2025---featuring-blackberry-nvidia--microsoft-among-others-301070143.html [https://perma.cc/H45Y-TYSQ].

[59] Ken Oliphant, *Liability for Road Accidents Caused by Driverless Cars*, SING. COMP. L. REV. 190 (2019).

[60] CAL. VEH. CODE § 38750 (LexisNexis 2022).

[61] Jay Ramey, *Here's Why Our Gleaming Self-Driving Future Has Been Delayed Indefinitely,* AUTOWEEK (June 8, 2020), https://www.autoweek.com/news/technology/a32782600/why-level-5-autonomous-driving-has-not-happened/ [https://perma.cc/R75H-LTHW].

[62] *Id*.

[63] Alejandro Monarrez, *Autonomous Vehicle Manufacturers: Applying a Common Carrier Liability Scheme to Autonomous Vehicle Manufacturers—and Why Elon Musk Will Be Haunted by His Words*, 43 SEATTLE UNIV. L. REV. 1 (2020).

insurance industry suggests that accident frequency could be cut by eighty percent.[64] Eliminating the human operator will prevent accidents caused by reckless driving, drunk driving, and other human errors.[65] Fully autonomous taxis will be the first fully autonomous vehicles:

> Consumers will purchase rides rather than vehicles. Almost every major company in the industry is either pursuing this business model or has invested in other companies that are pursuing it. . . . Uber spent years trying to develop a robotaxi in house, but it never recovered from a fatal crash in 2018. . . . The industry has converged on the robotaxi model for both economic and technological reasons. The economic advantage of robotaxis over individually-owned AVs is higher utilization rates. Most individually-owned vehicles are lightly utilized. They sit and depreciate in driveways, garages, or parking lots for about 90% of the day. In recent years, new business models have emerged to increase vehicle utilization rates. Car-sharing networks, like Zipcar, allow multiple drivers to use the same car at different times in one day. But car-sharing networks must manage demand carefully, because their cars sit idle between rides. Taxis generally have higher utilization rates than individually-owned vehicles, but they're still limited by the schedule of the human driver. For an AV, when one trip ends, the AV can drive autonomously to where the next trip will begin. An operator of a robotaxi fleet seeking to maximize profits will optimize routes to increase utilization rates.[66]

AVs will have "a 360-degree field of vision, they will have a faster reaction time, and they will not fall asleep."[67] AVs "are expected to dramatically decrease accidents and make roads safer, given that 94% of grave accidents are due to human error, while at the same time reduce significantly traffic congestion, driving costs and CO2 emissions."[68] AVs will likely help "to improve safety for vehicle operators and occupants, pedestrians, bicyclists, motorcyclists, and other travelers sharing the road."[69] The United Kingdom summarized the following benefits of AVs:

> The potential benefits of the technology in the UK are vast. We want to see the technology make transport greener, cheaper and more efficient; to better connect rural communities, giving everyone better

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[64] Mark A. Geistfeld, *A Roadmap for Autonomous Vehicles: State Tort Liability, Automobile Insurance and Federal Safety Regulation*, 105 CALIF. L. REV. 1611, 1615 (2017).

[65] *Self-Driving Cars in the EU: From Science Fiction to Reality,* EUR. PARLIAMENT (Jan. 14, 2019, 5:41 PM), https://www.europarl.europa.eu/news/en/headlines/economy/20190110STO23102/self-driving-cars-in-the-eu-from-science-fiction-to-reality [https://perma.cc/AX88-B6JP]:

> Human error is involved in about 95% of all road traffic accidents in the EU, and in 2017 alone, 25,000 people died on the European Union's roads. Driverless cars and lorries can drastically reduce these figures and safety, while new digital technologies can also reduce traffic congestion, and emissions of greenhouse gases and pollutants.

[66] Matthew Wansley, *The End of Accidents*, 55 U.C. DAVIS L. REV. 269, 285, 287–88 (2021) (citations omitted).

[67] Robert W. Peterson, *New Technology—Old Law: Autonomous Vehicles and California's Insurance Framework*, 52 SANTA CLARA L. REV. 1341 (2012).

[68] Michael Chatzipanagiotis & George Leloudas, *Automated Vehicles and Third-Party Liability: A European Perspective*, 2020 U. ILL. J.L. TECH. & POL'Y 109 (2020).

[69] U.S. DEP'T. OF TRANSPORTATION, PREPARING FOR THE FUTURE OF TRANSPORTATION: AUTOMATED VEHICLE 3.0 (2018), https://www.transportation.gov/av/3 [https://perma.cc/5SZS-AH4U].

> access to education, to work or simply to seeing friends and family more often; to call an end to urban congestion, with traffic lights and vehicles speaking to each other to keep traffic flowing; and to make our roads safer, reducing human errors that can lead to accidents. As well as providing improved transport for all, we believe that AV technology could also deliver huge economic benefits. The market in the UK could be worth between £52 billion and £62 billion by 2035, capturing around 6 per cent of the £907 billion global market, creating tens of thousands of jobs.[70]

The overall social-welfare benefits of vehicles that crash less frequently will be significant, both for the United States and globally, and purchasers of AVs will feel many of these benefits.[71] Driver-related factors such as impaired driving, distraction and speeding, or illegal maneuvers account for 94% of all motor-vehicle crashes.[72] While AVs will not eliminate car accidents, they will significantly reduce the number of incidents by eliminating the variable of human error.[73] Assuming that the software works perfectly, automated vehicles will be involved in accidents because they share the road with human-driven vehicles. The Smart Mobility, or Transport 5.0 software, will lead to greater safety outcomes through various tools.

> Safety outcomes arrived at through smart mobility include a reduction in road fatalities through both a reduction in numbers of cars on roads but also through advanced driver assistance systems present in autonomous and semi-autonomous vehicles that warn drivers of potential hazards, and automatic braking in emergency situations. Vehicle to Everything [sic] technology present in smart cars also automatically contacts an ambulance in the case of a crash, with traffic light patterns changing to facilitate the ambulance.[74]

In this formative era of self-driving cars, studies demonstrate AVs have a higher rate of accidents compared to human-driven cars, but the injuries

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[70] *Innovation Is Great: Connected and Automated Vehicles*, GOV'T OF U.K. (2020), https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/929352/innovation-is-great-connected-and-automated-vehicles-booklet.pdf [https://perma.cc/8T6R-QWZN].

[71] JAMES M. ANDERSON, NIDHI KALRA, KARLYN D. STANLEY, PAUL SORENSON, CONSTANTINE SAMARAS & OLUWATOBI A. OLUWATOLA, RAND CORP., AUTONOMOUS VEHICLE TECHNOLOGY: A GUIDE FOR POLICYMAKERS 62 (2016), https://www.rand.org/content/dam/rand/pubs/research_reports/RR400/RR443-2/RAND_RR443-2.pdf [https://perma.cc/5NY3-CA3W].

[72] *Id.*; *see also* U.S. NAT'L HIGHWAY TRAFFIC SAFETY ADMIN., CRITICAL REASONS FOR CRASHES INVESTIGATED IN THE NATIONAL MOTOR VEHICLE CRASH CAUSATION SURVEY, (Feb. 2015), https://perma.cc/XVV2-AD94. (The National Motor Vehicle Crash Causation Survey (NMVCCS), which was conducted between 2005 and 2007, found that "the critical reason for the pre-crash event (i.e., the immediate reason for the critical event . . . the last failure in the causal chain of events leading up to the crash)" was attributed to the vehicle in only two percent of crashes and to the environment in an additional two percent of crashes. Driver recognition error, such as inattention or distraction, accounts for forty-one percent of driver-related crashes. Driver decision error, such as misjudgment, accounts for thirty-three percent of driver-related crashes.).

[73] Bernard Marr, *5 Ways Self-Driving Cars Could Make Our World (and Our Lives) Better,* FORBES (July 17, 2020, 12:24 AM), https://www.forbes.com/sites/bernardmarr/2020/07/17/5-ways-self-driving-cars-could-make-our-world-and-our-lives-better/?sh=75c9dbfb42a3 [https://perma.cc/G5HN-2LVC] ("While there have been some high-profile cases of autonomous vehicles being involved in tragic fatal accidents, data suggests that self-driving cars will ultimately make our roads safer."); *see* Jean-François Bonnefon, Azim Shariff & Iyad Rahwan, *The Social Dilemma of Autonomous Vehicles*, 352 SCI. 1573 (2016) (despite the numerous advantages of AVs, "[n]ot all crashes will be avoided").

[74] *Transport 5.0*, AGENDANI (Mar. 2021), https://www.agendani.com/transport-5-0/ [https://perma.cc/GRL9-RRWQ].

are less serious. On average, there are 9.1 self-driving car accidents per million miles driven, while the same rate is 4.1 crashes per million miles for human-driven vehicles.[75] The developers of AVs contend that self-driving cars will ultimately be safer than conventional vehicles.[76] Bob Luz, a former General Motors Vice Chairman stated: "The autonomous car doesn't drink, doesn't do drugs, doesn't text while driving, and doesn't get road rage. Autonomous cars don't race other autonomous cars, and they don't go to sleep."[77]

III. SOFTWARE DEFECTS IN AUTONOMOUS AUTOMOBILES

A. SOFTWARE COMPONENTS IN TRADITIONAL AUTOMOBILES

Traditional vehicles are equipped with networked electronic components and systems under the control of software. These components currently do not make autonomous decisions or operate the vehicle independently as distinguished from software-powered systems that are designed to replace some or all functions performed by a human operator. "The modern vehicle is a computer—actually dozens to more than 100 computers—containing more than 100 million lines of code that control everything from the infotainment system to safety systems like steering, acceleration and brakes."[78]

Software solutions "enhance safety, performance and the overall driving experience. There is a wide range of automotive software including entertainment, safety[,] and navigation software, among others."[79] "The latest automotive innovations, including intuitive infotainment, self-driving abilities, and electrification, depend less on mechanical ingenuity than on software quality, execution, and integration."[80] New generation vehicles are composed of five or more domains, together comprising hundreds of functional components in the car and in the cloud that cover:

> everything from infotainment and ADAS to mapping, telematics, and third-party applications. . . . Typical OEMs constructing this architecture interact with a multitude of software providers to build various capabilities; in the process, they fill their vehicles with a broad set of development languages, operating systems, and software

75 Maria Martin, *24 Self-Driving Car Statistics & Facts*, CARSURANCE (Feb. 20, 2022), https://carsurance.net/insights/self-driving-car-statistics/ [https://perma.cc/FB6W-6BJ3].

76 Tom Vanderbilt, *Autonomous Cars: How Safe Is Safe Enough?*, CAR AND DRIVER (Oct. 3, 2017), https://www.caranddriver.com/features/a15080598/autonomous-cars-how-safe-is-safe-enough-feature/ [https://perma.cc/8PHA-A959].

77 *Torts of the Future: Addressing the Liability and Regulatory Implications of Emerging Technologies*, U.S. CHAMBER INST. FOR LEGAL REFORM (Mar. 2017), https://instituteforlegalreform.com/wp-content/uploads/2020/10/Torts_of_the_Future.pdf [https://perma.cc/KMF8-TRJS].

78 Taylor Armerding, *Connected Cars Need Better Connection to Cybersecurity*, FORBES, (Feb. 6, 2019, 8:54 AM), https://www.forbes.com/sites/taylorarmerding/2019/02/06/connected-cars-need-better-connection-to-cybersecurity [https://perma.cc/R3X5-X5UN].

79 Alex Wilson, *Type of Software Used In Automobile Industry*, MEDIUM (July 26, 2017), https://medium.com/@jktechnosoft/type-of-software-used-in-automobile-industry-a4516f8ad5b3 [https://perma.cc/H7MM-UZGS].

80 Ryan Fletcher, Abhijit Mahindroo, Nick Santhanam & Andreas Tschiesner, *The Case for an End-to-End Automotive-Software Platform*, MCKINSEY & CO. (Jan. 16, 2020), https://www.mckinsey.com/industries/automotive-and-assembly/our-insights/the-case-for-an-end-to-end-automotive-software-platform.

structures. This piecemeal approach is common among industry leaders because no single software platform on the market can meet all cross-system needs.[81]

The speed at which information must be processed while driving, coupled with the large number of data inputs, necessitates the use of powerful processing chips. NVIDIA, a company known for making videogame graphics cards, is creating chips for AVs. They have also created software to process data inputs.[82]

B. SOFTWARE TECHNOLOGIES IN AUTONOMOUS VEHICLES

Software plays an even more central role in AVs. Vehicles use software "to collect and process information about the surrounding environment."[83] Self-driving technologies, such as automatic lane stabilization, speed adjustments, and self-parking are software-driven components already deployed in conventional vehicles.[84]

These vehicles use a combination of "'cameras, radar systems, lasers (for example, LiDAR), and [GPS] units' to gather information about the environment and make decisions about when and how to steer, accelerate, and brake."[85] AVs deploy AI, sensors, and big data to "adapt to changing circumstances and handle complex situations as a substitute for human judgement, as the latter would no longer be needed for conventional vehicle operations such as lane-changing, parking, collision avoidance and braking."[86]

AVs have a 360-degree field of vision, a faster reaction time, and will not fall asleep.[87] The progress made by AVs is due to "the recent advances in AI, and in particular in ML [machine learning]."[88] Machine learning ("ML") "is a type of [AI], . . . which algorithms use historical data as input to predict new output values."[89] Autonomous technologies include "5G, AI, Mobile Edge Computing, IoT [Internet of Things], data analytics, and smart building integration."[90]

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[81] *Id.*

[82] *Solutions for Self-Driving Cars and Autonomous Vehicles*, NVIDIA CORP., https://www.nvidia.com/en-us/self-driving-cars/ [https://perma.cc/ECS9-GPRA] (last visited Sept. 1, 2022).

[83] Kyle J. Barringer, *Code Bound and Down . . . A Long Way to Go and a Short Time to Get There: Autonomous Vehicle Legislation in Illinois*, 38 S. ILL. U. L.J. 121, 122 (2013).

[84] Erica Rutner, *Semi-Autonomous Vehicle Litigation: Minimizing the Class Action Risks in Advance*, 26 No. 04 WESTLAW J. DERIVATIVES 13 (Jan. 9, 2020).

[85] Pearl, *supra* note 6.

[86] Taeihagh & Lim, *supra* note 20.

[87] Peterson, *supra* note 67, at 1343.

[88] *Cybersecurity Challenges in the Uptake of Artificial Intelligence in Autonomous Driving*, EUR. UNION AGENCY FOR CYBERSECURITY 14 (2021), https://www.enisa.europa.eu/publications/enisa-jrc-cybersecurity-challenges-in-the-uptake-of-artificial-intelligence-in-autonomous-driving/@@download/fullReport.

[89] Azamat Abdoullaev, *What Is the State-of-the-Art & Future of Artificial Intelligence?* BBN TIMES (June 29, 2021), https://www.bbntimes.com/technology/what-is-the-state-of-the-art-future-of-artificial-intelligence [https://perma.cc/792M-5J95].

[90] *$172.3 Bn Autonomous Vehicle Market by Autonomy Level, Vehicle Powertrain, Components, and Supporting Tech —Global Forecast to 2024—ResearchAndMarkets.com*, BUS. WIRE (Mar. 8, 2019), https://www.businesswire.com/news/home/20190308005206/en/172.3-Bn-Autonomous-Vehicle-Market-by-Autonomy-Level-Vehicle-Powertrain-Components-and-Supporting-Tech---Global-Forecast-to-2024---ResearchAndMarkets.com [https://perma.cc/MJ9V-HSDJ].

AV makers must "ensure that their software and firmware is secure," a challenge "which is made more complex with the connectivity of an IoT system in which one vulnerability could open up the system to further threats."[91] An AV "depends on communication and/or cooperation with outside entities" for purposes of gathering and transmitting data.[92]

Although some autonomous cars might be considered autonomous if the car is capable of functioning "independently and self-sufficiently,"[93] most vernacular-deemed "autonomous" vehicles "depend on communication and/or cooperation with outside entities,"[94] and thus, "should be considered cooperative rather than autonomous."[95]

Software developers "use a process called 'deep learning' to teach the autonomous vehicle systems how to respond to new or unexpected events by entering large amounts of exemplary data into the systems' algorithms."[96]

> Machine-learning systems, which are excellent at pattern-matching, are terrible at extrapolation—transferring what they have learned from one domain into another. For example, they can identify a snowman on the side of the road as a potential pedestrian, but can't tell that it's actually an inanimate object that's highly unlikely to cross the road.[97]

"Some artificial agents may be unpredictable in principle, and many will be unpredictable in practice."[98] As AI systems are capable of learning on their own, it may not always be possible for deployers of AI to predict outcomes.[99]

Autonomous automobiles incorporate intelligent software algorithms in LiDAR, localization systems, advanced driver assistance systems, power electronics, battery systems, ADAS sensors, and control platforms.[100]

1. Advanced Driver Assistance System ("ADAS")

ADAS, which are an important first step to fully autonomous vehicles, deploy electronic systems that assist the driver with the primary focus on "collision avoidance technologies (for example, lane departure warning and blind-spot applications) and driver aids, such as night vision, driver alertness and adaptive cruise control."[101] ADAS applies to: "Seat belt reminders, Intelligent Speed Adaptation (ISA), Stability Electronic Control (ESP), Anti-

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[91] Michael Aminzade, *Autonomous Cars: The Cybersecurity Issues Facing the Industry*, VERDICT (Apr. 29, 2020), https://www.verdict.co.uk/autonomous-car-cybersecurity/ [https://perma.cc/P5QU-9B55].

[92] *Taxonomy and Definitions for Terms*, *supra* note 40, at 28.

[93] *Id.*

[94] *Id.*

[95] *Id.*

[96] Weride Corp. v. Huang, 379 F. Supp. 3d 834, 841 (N.D. Cal. 2019).

[97] Christopher Mims, *Self-Driving Cars Could Be Decades Away, No Matter What Elon Musk Said*, WALL ST. J. (June 5, 2021), https://www.wsj.com/articles/self-driving-cars-could-be-decades-away-no-matter-what-elon-musk-said-11622865615 [https://perma.cc/JLL7-FMHB].

[98] Pinchas Huberman, *Tort Law, Corrective Justice and the Problem of Autonomous-Machine-Caused Harm*, 34 CAN. J. L. & JURIS. 105, 112 n. 52 (2021) (quoting Peter M. Asaro).

[99] *Id.* at 2-3.

[100] Delphi Auto. PLC v. Absmeier, No. 15-cv-13966, 2016 U.S. Dist. LEXIS 38212, at *16–17 (E.D. Mich. Mar. 24, 2016).

[101] *Advanced Driver Assistance Systems (ADAS)*, GARTNER, https://www.gartner.com/en/information-technology/glossary/advanced-driver-assistance-systems-adass [https://perma.cc/UE68-WJ7U] (last visited Sept. 1, 2022).

lock braking system (ABS), Emergency Autonomous Braking System (AEB), Lane control systems, Alcohol blocking systems, Cross-traffic alert, Blind spot control, Facial Monitoring to Detect Fatigue, Parking sensors, and Automatic parking systems."[102] "[ADAS] and [AV] systems use cameras and other sensors, together with object classifiers, to detect specific objects in an environment of a vehicle navigating a road."[103]

The NHTSA denotes available driving automation systems as the ADAS.[104] A driving automation system is classified within the ADAS definition if the system can "simultaneously control lateral lane-keeping movements and longitudinal vehicle following distances" and "can execute steering and acceleration/deceleration tasks."[105] Broadly, lateral control refers to automated lane keeping, lane changing, and other lateral movements.[106] Longitudinal control refers to adaptive cruise-control systems that are capable of accelerating or decelerating the vehicle.[107] Longitudinal systems include automated detection of obstructions in front of the vehicle.[108] "The ability of preconfigured classifiers, as a single solution, to deal with the infinitesimal variety and detail of road environments and its surroundings and its often dynamic nature (moving vehicles, shadows, [and so forth]) is, however, limited and is sensitive to errors."[109]

The driver's intervention is required when the ADAS does not recognize or respond to a hazard.[110] Autonomous vehicles use sensor inputs to interpret both the driving and road environment.

> AVs combine data from all their sensor inputs to obtain an accurate understanding of their environment. LiDAR images are combined with radar velocity information to form a model of objects and their trajectories in the environment. This information is further combined with camera information, GPS information and the stored map database to accurately determine the position of the vehicle and other

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[102] *That's ADAS, the Artificial Brain That Takes Care of Our Lives Inside Cars*, NOTICIAS FINANCIERAS (May 29, 2021), 2021 WLNR 17336346.

[103] *Researchers Submit Patent Application, "Systems and Methods for Augmenting Upright Object Detection", for Approval (USPTO 20210073557)*, TRANSP. DAILY NEWS (Apr. 1, 2021), 2021 WLNR 10616845.

[104] NAT'L TRANSP. SAFETY BD., HIGHWAY ACCIDENT BRIEF: REAR-END COLLISION BETWEEN A CAR OPERATING WITH ADVANCED DRIVER ASSISTANCE SYSTEMS AND A STATIONARY FIRE TRUCK, CULVER CITY, CALIFORNIA, JANUARY 22, 2018, 6 (Aug. 22, 2019), https://www.ntsb.gov/investigations/AccidentReports/Reports/HAB1907.pdf [https://perma.cc/E4JT-GZ32].

[105] NAT'L TRANSP. SAFETY BD., HIGHWAY ACCIDENT REPORT: COLLISION BETWEEN A CAR OPERATING WITH AUTOMATED VEHICLE CONTROL SYSTEMS AND A TRACTOR-SEMITRAILER TRUCK NEAR WILLISTON, FLORIDA, MAY 7, 2016, 27 (Sept. 12, 2017), https://www.ntsb.gov/investigations/accidentreports/reports/har1702.pdf [https://perma.cc/M6P9-9NRC].

[106] NAT'L HIGHWAY TRAFFIC SAFETY ADMIN., NATURALISTIC STUDY OF LEVEL 2 DRIVING AUTOMATION FUNCTIONS, 4 (Nov. 2018), https://www.nhtsa.gov/sites/nhtsa.dot.gov/files/documents/812642_naturalistic-study-of-level-2-driving-automation-functions.pdf [https://perma.cc/CYZ3-376B].

[107] NAT'L TRANSP. SAFETY BD., *supra* note 104.

[108] *Id.*

[109] TRANSP. DAILY NEWS, *supra* note 103.

[110] Rob Stumpf, *Autopilot Blamed for Tesla's Crash into Overturned Truck: Keep Your Hands on the Wheel and Your Eyes on the Road*, THE DRIVE (June 16, 2020, 10:07 AM), https://www.thedrive.com/news/33789/autopilot-blamed-for-teslas-crash-into-overturned-truck [https://perma.cc/329Q-FP2Y].

> objects in the environment. Interpreting the environment requires recognizing objects in the environment using computer vision.[111]

Using technology that may include onboard video cameras, radar, and ultrasonic sensing, these semi-autonomous vehicles mark the start of a new automotive generation. General Motors Cruise AV can "see the environment around it, in 360 degrees, day and night. It is designed to identify pedestrians in a crosswalk, or an object darting suddenly into its path, and to respond accordingly. It can maneuver through construction cones, yield to emergency vehicles[,] and react to avoid collisions."[112]

2. LiDAR

LiDAR stands for "Light Detection and Ranging" and uses light in the form of a pulse to detect distances.[113] AVs deploy a combination of "cameras, radar systems, lasers (for example, LiDAR), and GPS units to gather information about the environment and make decisions about when and how to steer, accelerate, and brake."[114]By taking into account other information from the systems, LiDAR maps out the surrounding area three-dimensionally.[115]

> An autonomous vehicle (driverless vehicle) uses various sensors to navigate through a path. In addition, various techniques are used to detect obstacles in the surroundings of the autonomous vehicle. The autonomous vehicle senses the environment with the help of sensors such as laser, Light Detection and Ranging (LiDAR), computer vision, camera, and the like. The autonomous vehicle has a central control unit that helps the autonomous vehicle to traverse a path to reach a destination location from a source location.[116]

> LiDAR has an energy source that emits pulsed laser light and sensors that detect the reflected light and form a 3D representation of objects in the environment. LiDAR can produce higher resolution images than radar in general. . . . Most autonomous car manufacturers use LiDAR with the notable exception of Tesla.[117]

Researchers at Cornell University replicated LiDAR's effectiveness by simply using two cameras on either side of the windshield.[118] GMC incorporates next-generation LiDAR in its self-driving vehicles.[119]

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[111] Gary Marchant & Rida Bazzi, *Autonomous Vehicles and Products Liability: What Will Juries Do?*, 26 B.U. J. SCI. & TECH. L. 67, 75 (2020).

[112] *2018 Self-Driving Safety Report*, GEN. MOTORS, https://www.gm.com/content/dam/company/docs/us/en/gmcom/gmsafetyreport.pdf.

[113] *What Is Lidar?*, NAT'L OCEAN SERV., NAT'L OCEANIC & ATMOSPHERIC ADMIN., U.S. DEP'T. OF COM., https://oceanservice.noaa.gov/facts/LiDAR.html [https://perma.cc/BBN8-2HCX].

[114] Pearl, *supra* note 6.

[115] *Id.*

[116] *Patent Issued for Method and System for Detecting Obstacles by Autonomous Vehicles in Real-Time (USPTO 10,671,862)*, COMPUT. BUS. DAILY (June 15, 2020), 2020 WLNR 16661530.

[117] Marchant & Bazzi, *supra* note 111, at 74.

[118] Steve Crowe, *Researchers Back Tesla's Non-LIDAR Approach to Self-Driving Cars*, ROBOT REP. (Apr. 25, 2019), https://www.therobotreport.com/researchers-back-teslas-non-lidar-approach-to-self-driving-cars/ [https://perma.cc/9M4M-9DDQ].

[119] *GM Advances Self-Driving Vehicle Deployment with Acquisition of LIDAR Developer,* GEN. MOTORS: NEWSROOM, https://media.gm.com/media/us/en/gm/news.detail.html/content/Pages/news/us/en/2017/oct/1009-lidar1.html [https://perma.cc/PK7G-UV32].

3. Radar

"Radar is complementary to LiDAR because it uses electromagnetic pulse measurements and can see solid objects that have low light reflectivity . . . . Cameras are also complementary to LiDAR because they measure the light intensity reflected off or emitted."[120] "For 3D LiDAR sensors, the PCD contains the x, y, z coordinates and the intensity information of the obstacles within the scene or surroundings. For AD applications, LiDAR sensors with 64- or 128- channels are commonly employed to generate laser images (or point cloud data) in high resolution."[121]

"LiDARs are typically useful over a shorter range than other sensors—the Velodyne provides data up to 120 meters away, depending on the reflectivity of the object."[122] The field of AV technology includes technologies such as radar, Delphi's Radar, and Camera System ("RACam").[123] RACam "integrates radar sensing, data fusion, and vision sensing in a single system, thus enabling adaptive cruise control, autonomous braking, forward collision warning, and a lane departure system for obstacles on the road."[124]

4. Sensors

Computer software is what enables AVs to operate in complex environments; LiDAR, radar, and other software applications help driverless cars detect objects in their path.

> [S]ensors are installed in automobiles to regulate the temperature inside the vehicles and optimize the energy consumption by the vehicles. Moreover, the driverless cars which are the next big thing in the automotive business space will further augment the smart-sensors

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[120] GEN. MOTORS, *supra* note 112.

[121] De Jong Yeong, Gustavo Velasco-Hernandez, John Barry & Joseph Walsh, *Sensor and Sensor Fusion Technology in Autonomous Vehicles: A Review,* 21 SENSORS 2140 (2021) https://www.ncbi.nlm.nih.gov/pmc/articles/PMC8003231/ [https://perma.cc/C33R-YAZ8].

[122] ANDERSON ET AL., *supra* note 71.

[123] *See* ES Admin, *Delphi RACam Wins International Award for Automotive Innovation; Delphi Integrates Radar, Vision and Sensor Fusion in Single Module,* ELEC. SPECIFIER (Oct. 27, 2011), https://www.electronicspecifier.com/products/sensors/delphi-racam-wins-international-award-for-automotive-innovation [https://perma.cc/4AYZ-8QC7] (defining the Delphi RaCam as a product that:

> integrates radar sensing, vision sensing and substantial computing power in a single, compact module to enable a suite of advanced driver assistance systems including full speed range adaptive cruise control, adaptive headlamp control, traffic sign recognition, forward collision warning, pedestrian detection and autonomous braking, which automatically slows the vehicle to a stop in situations where the driver does not react to a hazard ahead. The Delphi RACam is significantly less expensive, lighter and smaller than non-integrated systems. The single-box system allows the vehicle to appropriately respond to a hazard–such as automatically braking for another vehicle or a pedestrian–when the driver doesn't, and its innovative design has resulted in a module small enough to be positioned on the windscreen side of the rear view mirror. Though separate radar systems are traditionally mounted behind the vehicle's front grille, RACam's size makes it possible to locate the radar away from crush zone, helping to reduce repair costs following a frontal impact.

[124] *Technavio Announces Top Five Vendors in the Global Anti-Collision Sensors Market*, BUS. WIRE (Jan. 26, 2016, 11:00 AM), https://www.businesswire.com/news/home/20160126005020/en/Technavio-Announces-Top-Five-Vendors-in-the-Global-Anti-Collision-Sensors-Market [https://perma.cc/9F5N-WUTD].

industry, attributed to the technology's pivotal role in making these cars truly intelligent.[125]

> For an autonomous vehicle to stay in a lane, the localization requirements are in the order of decimeters. GPS alone is insufficient and does not meet these requirements. In today's production-grade autonomous vehicles, critical sensors include radar, sonar, and cameras. Long-range vehicle detection typically requires radar, while nearby car detection can be solved with sonar. Radar works reasonably well for detecting vehicles, but has difficulty distinguishing between different metal objects and thus can register false positives on objects such as tin cans, mailbox, etc. Also, radar provides little orientation information and has a higher variance on the lateral position of objects, making the localization difficult on sharp bends. The utility of sonar is both compromised at high speeds and, even at slow speeds, is limited to a working distance of about two meters.[126]

Anti-collision sensors are used in automobiles, industrial vehicles, and other machines. "These anti-collision sensors are used in different technologies including radar, sonar or ultrasound to detect objects on the path of moving vehicles and to reduce the severity of a collision."[127] Tesla describes its autopilot system as making sense:

> of all of this data, a new onboard computer with over 40 times the computing power of the previous generation runs the new Tesla-developed neural net for vision, sonar and radar processing software. Together, this system provides a view of the world that a driver alone cannot access, seeing in every direction simultaneously, and on wavelengths that go far beyond the human senses.[128]

"The Nissan Leaf is the only manufacturer to develop an Autonomous Emergency Steering ("AES") system." It "is fitted with sensors—'five laser scanners, three millimeter-wave radars and one camera'—that scan the area around the vehicle, looking for 'escape zones' that the vehicle could move into during an attempt to avoid a crash."[129] "The fact is, even humans don't

[125] *Smart Sensor Market Growth Projection by 2024: Atmel Corporation, Analog Devices, Inc., Eaton Corporation PLC, Honeywell International, NXP Semiconductors,* SBWIRE (May 12, 2020), 2020 WLNR 13303982.

[126] Henry H. Perritt, Jr., *The 21st Century Cowboy: Robots on the Range*, 43 U. ARK. LITTLE ROCK L. REV. 149, 170–71 (2020).

[127] *Anti-Collision Sensors Market 2019–2027, Credence Research | Size, Share Forecast*, NEWSTEX BLOGS (July 24, 2019), https://www.transparencymarketresearch.com/collision-avoidance-sensors-market.html [https://perma.cc/9YPZ-J8TP].

[128] *All Tesla Cars Being Produced Now Have Full Self-Driving Hardware*, TESLA (Oct. 19, 2016), https://www.tesla.com/blog/all-tesla-cars-being-produced-now-have-full-self-driving-hardware [https://perma.cc/6UWD-FGQW].

[129] Goodrich, *supra* note 29, at 273.

understand humans all the time."[130] "For AI developers, they are struggling with getting autonomous cars to gauge what human drivers do."[131]

> The sensors are installed in automobiles to regulate the temperature inside the vehicles and optimize the energy consumption by the vehicles. Moreover, the driverless cars which are the next big thing in the automotive business space will further augment the smart sensors industry, attributed to the technology's pivotal role in making these cars truly intelligent.[132]

AVs also "use audio sensors to detect emergency sirens and other environmental sounds."[133] Moreover, "the information collected with the sensors in [AVs], including the actual path ahead, traffic jams, and any obstacles on the road, can also be shared between cars that are connected through M2M technology."[134] Autonomous cars use "sensor fusion of the GPS with vehicle motion sensors such as an inertial measurement unit ("IMU"), vehicle odometers, and steering angle sensors" to localize for the environment.[135]

5. Cameras

Two-dimensional cameras are now used in conventional luxury cars.[136] Autonomous vehicles deploy 3-D cameras whose "image sensors automatically detect objects, classify them, and determine the distances between them and the vehicle. For example, the cameras can easily identify other cars, pedestrians, cyclists, traffic signs and signals, road markings, bridges, and guardrails."[137] Tesla's advanced senor coverage includes "eight cameras and powerful vision processing provide 360 degrees of visibility at up to 250 meters of range."[138] Twelve updated ultrasonic sensors complement this vision, allowing for detection of both hard and soft objects at nearly twice the distance of the prior system. A forward-facing radar with enhanced processing provides additional data about the world on a redundant wavelength that is able to see through heavy rain, fog, dust and even the car ahead.

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[130] Aarian Marshall, *Teaching Self-Driving Cars to Watch for Unpredictable Humans*, WIRED (Dec. 4, 2019), https://www.wired.com/story/teaching-self-driving-cars-watch-unpredictable-humans/ [https://perma.cc/5LXA-T9EK].

[131] Lance Eliot, *Human Drivers Bullying Self-Driving Cars: Unlawful or Fair Game?*, FORBES (June 4, 2019), https://www.forbes.com/sites/lanceeliot/2019/06/04/human-drivers-bullying-self-driving-cars-unlawful-or-fair-game/#4013a38249ee [https://perma.cc/X87B-NBEP].

[132] *Smart Sensor Market Growth Projection by 2024: Atmel Corporation, Analog Devices, Inc., Eaton Corporation PLC, Honeywell International, NXP Semiconductors,* SBWIRE: BLOG (May 12, 2020), 2020 WLNR 13303982.

[133] Marchant & Bazzi, *supra* note 111, at 74.

[134] Sandra Khvoynitskaya, *3 Types of Autonomous Vehicle Sensors in Self-Driving Cars*, ITRANSITION (Feb. 11, 2020), https://www.itransition.com/blog/autonomous-vehicle-sensors [https:// perma.cc/7T8G-GFYU].

[135] Kichun Jo & Myoungho Sunwoo, *Development of Localisation and Mapping Software for Autonomous Cars*, 13 IET INTELL.TRANSP. SYS. 406, 407 (Feb. 2019).

[136] Gert Rudolph & Uwe Voelzke, *Three Sensor Types Drive Autonomous Vehicles*, FIERCE ELECS. (Nov. 10, 2017), https://www.fierceelectronics.com/components/three-sensor-types-drive-autonomous-vehicles [https://perma.cc/45R3-32ET].

[137] Khvoynitskaya, *supra* note 134.

[138] TESLA, Advanced Sensor Coverage, *Autopilot*, www.tesla.com/autopilot [https://perma.cc/P9Z2-TSZF].

Mobileye vision-based systems (cameras and software) are incorporated into modern automobiles,[139] while AI-based camera perception software is incorporated into ADAS as well as AVs.[140]

6. Vision-Based Navigation

Vision-based navigation of AVs depends upon a "deep neural network (DNN) based system[] in which the controller obtains input from sensors/detectors" and uses this data to "produce[] a vehicle control output, such as a steering wheel angle to navigate the vehicle safely in a roadway traffic environment."[141] "RoboSense LiDAR has been designed and developed under the roadside perception needs of the V2I (Vehicle-to-Infrastructure) system, which enables [AVs] to sense every traffic participant, ensuring traffic safety and efficiency, as well as information services applications."[142]

Before Waymo Driver begins operating in a new area it uses a "map [of] the territory with incredible detail, from lane markers to stop signs to curbs and crosswalks . . . [and] uses these highly detailed custom maps, matched with real-time sensor data, to determine its exact road location at all times.[143] Loading this data in beforehand would make it less reliant on vision-based navigation.[144]

> WaveSense uses the ground-penetrating radar to send an electromagnetic pulse up to [three] metres below the ground, and then measures reflections from objects like rocks, pipes, and roots and changes in soil properties to build a highly accurate map of the subsurface strata. As the vehicle drives along the road, WaveSense scans the ground below it approximately 126 times per second and then compares the data to the onboard image database, allowing the vehicle to determine its exact position down to a few centimetres. According to the company, the tests have shown the technology to be

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[139] *See About*, MOBILEYE, https://www.mobileye.com/about/ [https://perma.cc/WD9H-JYEL] (last visited Oct. 14, 2022) (Mobileye, an Intel company, was launched in 1999, has developed a range of software products that is deployed on a proprietary family of computer chips named EyeQ®. Mobileye is the leading supplier of software that enables Advanced Driver Assist Systems (ADAS), with more than 25 automaker partners including some of the world's largest. Beyond ADAS, Mobileye technology has rapidly evolved to also support the three pillars of Autonomous Driving – Sensing, Mapping, and Driving Policy. As a result of this broad and well-advanced product offering, Mobileye has achieved a partnership to develop production-ready Fully Autonomous Vehicles with BMW and Intel, with production launch planned for 2021, and another partnership with the Tier-1 supplier Delphi for a "turnkey" system to be productized starting from 2019 with customer OEMs.).

[140] Lynn Walford, *Autonomous and Self-Driving Vehicle News: Venti Technologies, IIHS, Velodyne, Guidehouse, AEye & StradVision*, AUTO CONNECTED CAR NEWS (June 14, 2020), https://www.autoconnectedcar.com/2020/06/autonomous-and-self-driving-vehicle-news-venti-technologies-iihs-velodyne-guidehouse-aeye-stradvision/ [https://perma.cc/L4E9-DJ3D].

[141] Mhafuzul Islam, Mashrur Chowdury, Hongda Li & Hongxin Hu, *Vision-Based Navigation of Autonomous Vehicle in Roadway Environments with Unexpected Hazards*, 2673 TRANSP. RSCH. REC. 494, 494 (2019).

[142] *RoboSense LiDAR and DT Mobile to Develop V2I Solution for Smart City,* MARKETLINE INDUS. NEWSWIRE (May 26, 2020) ("[LiDAR] perception technology provider RoboSense has partnered with the Chinese communication equipment manufacturer DT Mobile for the deployment of the first vehicle-to-infrastructure (V2I) solution for the smart city.").

[143] *Waymo Driver,* WAYMO, https://waymo.com/waymo-driver/ [https://perma.cc/5CYT-EEE3] (last visited Sept. 16, 2022).

[144] *See id.*

accurate and reliable at standard highway speeds (up to 105 kilometres per hour), even during the night and in snowstorm conditions.[145]

A problem with the GPS and vehicle sensor fusion is that drift errors can occur because of GPS signal failures (for example, in urban canyons and tunnels). Other problems can occur, such as multipath errors and low-frequency noise of the processed position data.[146] Another common issue with GPS is "when someone uses a radio transmitter to send a counterfeit GPS signal to a receiver antenna to counter a legitimate GPS satellite signal."[147] In these situations, "GPS spoofing allows hackers to interfere with navigation systems without operators realizing it. The fake GPS feeds cause drivers, ship captains, and other operators to go off course without any coercion."[148] But "AV systems today predominantly use Multi-Sensor Fusion ("MSF") algorithms that are generally believed to have the potential to practically defeat GPS spoofing . . . [by] reject[ing] other input sources."[149]

7. Electronic Control Units

An electronic control unit ("ECU") "is a device responsible for overseeing, regulating and altering the operation of a car's electronic systems. Each of a car's electronic features, such as an anti-lock braking system or electronic fuel injection setup, will typically be controlled by an ECU."[150] An ECU typically consists of a black-box assembly with an embedded microprocessor, memory, firmware, network connection, and circuitry for carrying out its function.[151] "Each ECU typically contains a dedicated chip that runs its own software or firmware, and requires power and data connections to operate."[152] "Modern automobiles consist of an increasing number of ECUs connected by a sophisticated network communications bus that is more and more commonly using Ethernet."[153] An automotive engineer explains how ECUs are electronic devices with several inputs:

> The data from these inputs is assessed by the ECU and compared against stored on-board data. The ECU then decides what needs to happen to ensure the system in question functions properly and issues

[145] *'Sensor Fusion': Next-Gen Autonomous Vehicles Could Function in All Weather Conditions*, RICHARD VAN HOOIJDONK BLOG (Feb. 27, 2019), https://blog.richardvanhooijdonk.com/en/sensor-fusion-next-gen-autonomous-vehicles-could-function-in-all-weather-conditions/ [https://perma.cc/4BGX-U2K3].

[146] *Id.*

[147] *GPS Spoofing 101: What is GPS Spoofing*, MCAFEE: BLOG (Aug. 25, 2020), https://www.mcafee.com/blogs/consumer/what-is-gps-spoofing [https://perma.cc/S6N8-MAYP].

[148] *Id.*

[149] Junjie Shen, Zeyuan Chen & Qi Alfred Chen, *Drift with Devil: Security of Multi-Sensor Fusion Based Localization in High-Level Autonomous Driving Under GPS Spoofing,* PROC. 29TH USENIX SEC. SYMP. 1, 1 (2020), https://www.junjieshen.com/assets/pdf/pub/sec20-fusion-ripper.pdf [https://perma.cc/QW4E-PWQJ].

[150] Lewis Kingston, *What Is an Electronic Control Unit? PH Explains*, PISTONHEADS (Mar. 27, 2018), https://www.pistonheads.com/news/features/what-is-an-electronic-control-unit-ph-explains/37771 [https://perma.cc/292S-E4EE].

[151] Erika Barron-Delgado, *Automotive Software Defects on the Rise*, DZONE (Aug. 29, 2016), https://dzone.com/articles/automotive-software-defects-on-the-rise [https://perma.cc/Q35X-X5FU].

[152] Mobility Insider, *What Is an Electronic Control Unit?*, APTIV (Apr. 16, 2020), https://www.aptiv.com/en/insights/article/what-is-an-electronic-control-unit [https://perma.cc/BQ37-3D PK].

[153] Alan Zeichick, *Automotive Software Engineering Defects on the Rise*, PARASOFT (Aug. 25, 2016), https://www.parasoft.com/blog/automotive-software-engineering-defects-on-the-rise/ [https://perma.cc/A92W-6A4G].

> new commands to suit. These outputs then alter the operation of the system, delivering the desired effect. For example, modern electronic fuel injection systems are controlled by ECUs. Data, including temperature, engine speed and accelerator position is fed into the ECU. The ECU then compares the data against on-board tables that tell it what the engine ideally needs, and alters the behaviour of the fuel injectors and in many cases the ignition system to deliver the best performance.[154]

The ECU was the first computer to be incorporated within automobiles.[155] "ECU's have become a standard device on most cars since the late 1970s when they became necessary due to increasingly stringent government emission standards."[156] To perform safely, ECU devices must communicate in real-time through a "controller area network, or 'CAN bus,' by sending each other digital messages called 'CAN packets.' "[157] The CAN is a serial communication bus designed for robust and flexible performance in harsh environments, and particularly for industrial and automotive applications.[158]

> Originally invented by Bosch and later codified into the ISO11898-1 standard, CAN defines the data link and physical layer of the Open Systems Interconnection (OSI) model, providing a low-level networking solution for high-speed in-vehicle communications. In particular, CAN was developed to reduce cable wiring, so the separate electronic control units (ECUs) inside a vehicle could communicate with only a single pair of wires.[159]

"At the vehicular level, the hardware involves sensors to detect various pertinent data which in turn is fed into an Electronic Control Unit (ECU)."[160] The CAN bus protocol enables communications between ECUs:

> In an automotive CAN bus system, ECUs can be the engine control unit, airbags, audio system [and so forth.] A modern car may have up to 70 ECUs and each of them may have information that needs to be shared with other parts of the network. The CAN bus system enables

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[154] Kingston, *supra* note 150.

[155] *Computer Chips Inside Cars*, CHIPS ETC, https://www.chipsetc.com/computer-chips-inside-the-car.html [https://perma.cc/C77V-TPHF] (last visited Sept. 16, 2022):

> The first use of a computer in a car was simply for the purpose of engine control. Automotive manufactures began introducing early versions of computer-controlled systems to perform one specific function; in 1968, Volkswagen introduced the first vehicle with a computer controlled electronic fuel injection (EFI) system - the D-Jetronic, a transistorized electronic module manufactured by Bosch. It was offered as standard equipment on their Type-3 models.

[156] *Id.*

[157] Cahen v. Toyota Motor Corp., 147 F. Supp. 3d 955, 958 (N.D. Cal. 2015).

[158] Stephen St. Michael, *Introduction to CAN (Controller Area Network)*, ALL ABOUT CIRCUITS (Feb. 19, 2019), https://www.allaboutcircuits.com/technical-articles/introduction-to-can-controller-area-network/ [https://perma.cc/58S5-A7J5].

[159] *Id.*

[160] *Method for Protection of Children, Seniors and Pets from Vehicular Heatstroke in Hot Vehicles*, JUSTIA PATENTS (Aug. 16, 2019) https://patents.justia.com/patent/11049383 [https://perma.cc/NQ3V-N5CN].

each ECU to communicate with all other ECUs without complex dedicated wiring.[161]

The lack of dedicated wiring between ECUs allows features such as electronic gearbox control to be added via software alone.[162]

Common types of ECU:

Engine control module: Also known as an engine control unit. Responsible for assessing the load of the engine and tuning the ignition, fuel delivery and more to deliver optimum performance and economy.

Transmission control module: These control the way, and when, an automatic gearbox shifts. Besides being fed with sensor data from the transmission itself, TCMs may also take data from the engine control unit to deliver more suitable, precise shifts.

Suspension control module: Sometimes dubbed a ride control module and common in active, adjustable or air suspension set-ups. These adjust the suspension to suit the current driving conditions, or work to maintain the correct ride height.

Body control module: This unit is typically responsible for controlling the car's myriad electrical access, comforts and security features. Common features it controls include door locks, electric windows and climate systems.

Telematics control module: Typically offers internet and phone connectivity for the car's on-board services. May also include a GPS receiver for navigation services.[163]

Controller Area Network (CAN) is a serial network information technology that facilitates the passing of information between Electronic Control Units (ECUs, also known as nodes). Developed by BOSCH in 1986 to circumvent challenges in harness-connected systems and provide improved message handling in automobiles, the CAN interface allows broadcast communication between all connected ECUs within a vehicle's integrated electronic system through distributed control and decentralized measuring equipment.[164]

In particular, "CAN was developed to reduce cable wiring, so the separate electronic control units (ECUs) inside a vehicle could communicate with only a single pair of wires."[165] The ECU reports "a complete history of Driver, Fuel, Engine, Emissions, Transmission, and Diagnostic engine reporting."[166] The CAN bus protocol enables communications between

[161] Martin Falch, *CAN Bus Explained—A Simple Intro [2022]*, CSS ELECS., https://www.csselectronics.com/pages/can-bus-simple-intro-tutorial [https://perma.cc/SS5C-BZZK] (last visited Sept. 16, 2022).

[162] *See id*.

[163] Kingston, *supra* note 150.

[164] Hannah M. Boland et al., *An Overview of CAN-BUS Development, Utilization, and Future Potential in Serial Network Messaging for Off-Road Mobile Equipment*, *in* TECH. IN AGRIC. 1, 1 (Fiaz Ahmad ed., 2021).

[165] St. Michael, *supra* note 158.

[166] *GeoSpace Labs Releases ELD Version 5.0 Which Includes Safety Diagnostics, Emission Reporting, and FMCSA Emergency Declaration 2020-002 Support*, PR NEWSWIRE (Mar. 17, 2020, 8:38

ECUs incorporated in AVs. The CAN bus protocol history is summarized in the following timeline:

Pre CAN:	Car ECUs relied on complex point-to-point wiring
1986:	Bosch developed the CAN protocol as a solution
1991:	Bosch published CAN 2.0 (CAN 2.0A: 11 bit, 2.0B: 29 bit)
1993:	CAN is adopted as international standard (ISO 11898)
2003:	ISO 11898 becomes a standard series (11898-1, 11898-2, . . .)
2012:	Bosch released the CAN FD 1.0 (flexible data rate)
2015:	The CAN FD protocol is standardized (ISO 11898-1)
2016:	The physical CAN layer for data-rates up to 5 Mbit/s standardized in ISO 11898-2[167]

Today, the CAN protocol is standard in practically all conventional vehicles—cars, trucks, buses, tractors, ships, planes—as well as EV batteries, industrial machinery, and more.[168] Efficient algorithms have created new practical applications in the AI market. The most notable trend in AI includes the development of AVs. A large number of open-source projects deploy AI to address different aspects of mobility.[169] MIT researchers combined human input with AI "to produce a model that pinpoints situations where the system most likely needs more information about how to act correctly."[170]

8. 5G Technology & Data Transfer

5G enables "data transfer among AI algorithms, sensors, and mechanical parts to navigate self-driving or autonomous vehicles."[171] "Apart from vehicle-to-vehicle communication, interaction with traffic systems is possible with 5G technology, which enables data transmission beforehand to achieve practical navigation for certain road conditions."[172] For an AV to operate safely, it must take into account the information coming in from its several cameras and radar in order to map out an area while moving at a high speed.

AM) https://www.prnewswire.com/news-releases/geospace-labs-releases-eld-version-5-0-which-includes-safety-diagnostics-emission-reporting-and-fmcsa-emergency-declaration-2020-002-support-301025318.html [https://perma.cc/GZ2F-J4MV].

[167] Falch, *supra* note 161.

[168] *Id.*

[169] Kalyan C. Kankanala, *Intellectual Property, Open Source and Intelligent Automobiles*, BANANAIP (July 2, 2019), https://www.bananaip.com/ip-news-center/intellectual-property-open-source-and-intelligent-automobiles/ [https://perma.cc/JNK4-9P8M].

[170] Rob Matheson, *Identifying Artificial Intelligence "Blind Spots"*, MIT NEWS (Jan. 24, 2019), http://news.mit.edu/2019/artificial-intelligence-blind-spots-0124 [https://perma.cc/RG9N-NNHL].

[171] *5G Integration in IIoT Systems Accelerates Industry 4.0 in the Wake of Pandemic, Says Frost & Sullivan*, PR NEWSWIRE (May 26, 2020), https://www.prnewswire.com/in/news-releases/5g-integration-in-iiot-systems-accelerates-industry-4-0-in-the-wake-of-pandemic-says-frost-amp-sullivan-872924266.html [https://perma.cc/U9HW-UZDW].

[172] *Id.*

To facilitate the necessary computing speed, many experts believe that we must first upgrade to a 5G network. "Handling, processing, and analyzing this amount of data requires a much faster network than the existing 4G technology."[173] The technology exists to synchronize self-driving cars with local traffic lights and signs. Although this is not common yet, this would enable more confidence in AVs by giving pedestrians some assurance that the car is properly processing its surrounding conditions.[174]

C. An Overview of Software Defects in Autonomous Vehicles

Software defects are responsible for many conventional automotive recalls. "From 2005 to 2012, there were 32 automotive recalls that included software fixes affecting 3.6 million vehicles. In the next 3.5 years—from 2012 through June 2015—there were 63 recalls associated with a software component affecting 6.4 million cars. In half the time, the impact of software defects nearly doubled."[175] "Recalls involving software-related defects reached record levels in 2018."[176]

1. Software Defects in AVs

"More U.S. vehicles in 2018 were affected by . . . software-based defects than the previous five years combined."[177] "As more sophisticated electronic components and systems continue to be integrated into more vehicles," an elevated level of software-based defects will continue.[178] "LYNX MOSA.ic is a software framework for building and integrating complex multi-core safety- or security-critical systems using independent application modules."[179] Lynx Software Technologies highlighted its software development framework for,

> rapidly building robust, comprehensible software architectures by partitioning and isolating safety-critical software components from non-critical elements on modern, multi-core processors and system-on-a-chip devices, as required in the fast-moving automotive industry. The Lynx MOSA.ic demonstration illustrates the isolation and protection of a safety-critical, real-time OS processing active, autonomous driving commands and control from non-critical in-

[173] Ralf Llanasas, *5G's Important Role in Autonomous Car Technology*, MACH. DESIGN (Mar. 11, 2019), https://www.machinedesign.com/mechanical-motion-systems/article/21837614/5gs-important-role-in-autonomous-car-technology.

[174] Beth Daley, *Linking Self-Driving Cars to Traffic Signals Might Help Pedestrians Give Them the Green Light*, THE CONVERSATION (Apr. 21, 2020), https://theconversation.com/linking-self-driving-cars-to-traffic-signals-might-help-pedestrians-give-them-the-green-light-132952 [https://perma.cc/V3U6-NUKF].

[175] Erika Barron-Delgado, *Automotive Software Defects on the Rise*, DZONE (Aug. 29, 2016), https://dzone.com/articles/automotive-software-defects-on-the-rise [https://perma.cc/DH9H-YZWC].

[176] Neil Steinkamp, Robert Levine & Raymond Roth, III, *2019 Automotive Defect & Recall Report* 1, 70, STOUT (2019), https://www.stout.com/en/insights/report/2019-automotive-defect-and-recall-report [https://perma.cc/4QVD-L3UC].

[177] *Id.* at 95.

[178] *Id.* at 70.

[179] *LYNX MOSA.ic*, LYNX SOFTWARE TECHS., https://www.lynx.com/products/lynx-mosaic-modular-development-framework [https://perma.cc/ZR33-S5N4] (last visited Sept. 16, 2022).

> vehicle entertainment software components, providing a high-assurance, safe and secure software architecture.[180]

"If a defect of software for controlling the sensors occurs during autonomous driving or if software hacking occurs during autonomous driving, safety of the user present in a vehicle may not be guaranteed."[181] The NHTSA "recalled Hyundai Nexo and Sonata vehicles with Remote Parking Assist over a software glitch" where the vehicles failed to stop if the software malfunctioned.[182] Tesla recalled over 134,000 vehicles for faulty screens, the main interface that drivers use in order to operate and execute the cars functions.[183] General Motors recalled more than 810,000 vehicles mostly pickup trucks because of two software-related defects.

One of these defects is a software error in the vehicles' electronic brake control module that could disable the vehicle's electronic stability control and anti-lock braking control systems. According to the NHTSA, if that happens, the vehicle's diagnostics will not illuminate some malfunction warning lights. That recall affects 464,000 2019 Chevrolet Silverado 1500 and GMC Sierra 1500 vehicles, and it also includes less than 1,000 2019 Cadillac CT6 models.

The other recall is specifically aimed at 350,000 2019-20 Chevrolet Silverado 1500 and GMC Sierra 1500 trucks. That recall involves the possibility of a failing of the electrical connection between the battery cable and alternator that could cause the vehicle to stall, increasing the possibility of a crash. The problem could also lead to electrical arcing, which could generate enough heat to damage surrounding material and possibly cause a fire. GM said that the battery positive cable rings might have been made with too much glue that could be the cause of the problem.[184]

These latent defects in software can be fixed by updates but must be discovered before passengers are injured or killed. New risks arise from "[a]utomated control, information, entertainment and navigation systems and smart connectivity features (such as Bluetooth and Wi-Fi) are soft targets for hackers wanting to sell information to competitors, and compromising

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[180] *Drive World and ESC 2019 to Feature Leading Companies Propelling Electronics Forward,* BLOOMBERG L.P. (Aug. 15, 2019), https://www.bloomberg.com/press-releases/2019-08-15/drive-world-and-esc-2019-to-feature-leading-companies-propelling-electronics-forward [https://perma.cc/EG5Q-ZHFG].

[181] News Reporter-Staff News Editor at Daily Asia Business, *Researchers Submit Patent Application, "Vehicle Control Device Provided In Vehicle And Method For Controlling Vehicle", for Approval (USPTO 20190217868)*, NEWSRX LLC (Aug. 7, 2019).

[182] GILBERT SHAR, NHTSA RECALLS HYUNDAI NEXOS & SONATAS OVER AUTONOMOUS PARKING FEATURE (Apr. 21, 2020), 2020 WLNR 11248433:

> Hyundai Motor America (Hyundai) is recalling certain 2020 Nexo and Sonata vehicles. The Remote Smart Parking Assist (RSPA) software may fail to prevent vehicle movement upon detection of an RSPA system malfunction. Consequence: Unintended vehicle movement increases the risk of a crash. Remedy: Hyundai will notify owners, and dealers will reprogram the RSPA software, free of charge. The recall is expected to begin June 4, 2020.

[183] Keith Barry, *Tesla Recalls over 134,000 Vehicles for Faulty Screens*, CONSUMER REPS. (Feb. 2, 2021), https://www.consumerreports.org/car-recalls-defects/tesla-recalls-model-s-model-x-for-faulty-screens [https://perma.cc/V56K-TWW5].

[184] Ben Miller, *General Motors Recalling More Than 810,000 Vehicles*, THE BUS. J., (Dec. 20, 2019), https://www.bizjournals.com/losangeles/news/2019/12/20/general-motors-recalling-more-than-810-000.html.

vehicle control in order to obtain ransoms."[185] A Federal Trade Commission ("FTC") workshop identified potential problems of security with smart devices:

> [U]nauthorized persons might exploit security vulnerabilities to create risks to physical safety in some cases. One participant described how he was able to hack remotely into two different connected insulin pumps and change their settings so that they no longer delivered medicine. Another participant discussed a set of experiments where an attacker could gain "access to the car's internal computer network without ever physically touching the car."[186]

Many of the risk factors of AVs are from vulnerabilities in software components in contrast to the failure of physical components in traditional vehicles. These include:

> *Hardware and software failures.* Complex electronic systems often fail due to false sensors, distorted signals and software errors. Self-driving vehicles will have failures that contribute to crashes; the question is their frequency compared with human drivers.
>
> *Malicious hacking.* Self-driving technologies can be manipulated for amusement or crime.
>
> *Increased risk-taking.* When travelers feel safer they tend to take additional risks, called *offsetting behavior* or *risk compensation*. For example, autonomous vehicles passengers may reduce seatbelt use, and other road users may be less cautious, described as "over-trusting" technology.
>
> *Platooning risks.* Many potential benefits, such as reduced congestion and pollution emissions, require *platooning* (vehicles operating close together at high speeds on dedicated lanes), which can introduce new risks, such as human drivers joining platoons and increased crashes severity.
>
> *Increased total vehicle travel.* By improving convenience and comfort[,] autonomous vehicles may increase total vehicle travel and therefore crash exposure.
>
> *Additional risks to non-auto travelers.* Autonomous vehicles may have difficulty detecting and accommodating pedestrians, bicyclists and motorcycles.

185 Haroun Khwaja, *Connected Cars, Autonomous Vehicles and Legal Potholes*, AL TAMIMI & CO. (Oct. 2018) https://www.tamimi.com/law-update-articles/connected-cars-autonomous-vehicles-and-legal-potholes/ [https://perma.cc/C8RG-CUHJ].

186 FTC STAFF, FTC STAFF REPORT: INTERNET OF THINGS: PRIVACY & SECURITY IN A CONNECTED WORLD 12 (2015) https://www.ftc.gov/system/files/documents/reports/federal-trade-commission-staff-report-november-2013-workshop-entitled-internet-things-privacy/150127iotrpt.pdf [https://perma.cc/35BM-9HFL].

> *Reduced investment in conventional safety strategies.* The prospect of autonomous vehicles may reduce future efforts to improve driver safety.[187]

Software malfunctions are often latent and may emerge at any point in the life of an AV:

> Software, however, is not like tires or cars. Tires and cars have a distinctly limited usable life. At the end of the product's life, the product and whatever defect it may have had pass away. If a defect does not manifest itself in that time span, the buyer has gotten what he bargained for. Software's useful life, however, is indefinite. Even though the defect is not manifest today, perhaps because the user is not using the data compression feature, it may manifest itself tomorrow.[188]

D. Testing to Detect and Correct Software Defects

"Software testing is the process of evaluating and verifying that a software product or application does what it is supposed to do. The benefits of testing include preventing bugs, reducing development costs[,] and improving performance."[189] To test for "defects," software engineers determine whether the software is consistent with the requirements and documentation.

> One way to define 'defects' is to think about how testers identify them. Testers often start looking for defects by reading a requirements document, then examining the software to determine whether it meets the requirements. Requirements documents are usually written by some combination of the development team and the business stakeholders to explicitly state the business value that the software must present to the users. Any team member can refer to the requirements document to determine whether the software is working correctly. Sometimes the specification is called an oracle because it acts as one possible source of truth.
>
> The requirements documentation is a useful way to identify defects. Any place where the software is different from the specification might be a bug. And[] it may be tempting to define 'defect' as 'any software behavior that is not described by the requirements document.' However, most experienced software testers recognize that there will be defects that fall outside of the expected behavior defined by the documentation. These are generally recognized using other types of information or rules of thumb.[190]

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[187] Todd Litman, *Autonomous Vehicle Implementation Predictions: Implications for Transport Planning*, VICTORIA TRANSP. POL'Y INST. 13 (Sept. 16, 2022), https://www.vtpi.org/avip.pdf [https://perma.cc/H4WM-QM3D] (citations omitted).

[188] Microsoft v. Manning, 914 S.W.2d 602, 609 (Tex. Ct. App. 1995).

[189] *What Is Software Testing?*, IBM, https://www.ibm.com/topics/software-testing [https://perma.cc/AX5K-C87Z] (last visited Sept. 5, 2022).

[190] Tom Alexander, *What Is a Software Defect*, SMARTBEAR (May 26, 2018), https://smartbear.com/blog/what-is-software-defect/ [https://perma.cc/QA5Z-WL4A].

IBM sets forth the different types of software testing.

> *Acceptance testing*: Verifying whether the whole system works as intended.
>
> *Integration testing*: Ensuring that software components or functions operate together.
>
> *Unit testing*: Validating that each software unit performs as expected. A unit is the smallest testable component of an application.
>
> *Functional testing*: Checking functions by emulating business scenarios, based on functional requirements. Black-box testing is a common way to verify functions.
>
> *Performance testing*: Testing how the software performs under different workloads.
>
> *Load testing*, for example, is used to evaluate performance under real-life load conditions.
>
> *Regression testing*: Checking whether new features break or degrade functionality. Sanity testing can be used to verify menus, functions and commands at the surface level, when there is no time for a full regression test.
>
> *Stress testing*: Testing how much strain the system can take before it fails. Considered to be a type of non-functional testing.
>
> *Usability testing*: Validating how well a customer can use a system or web application to complete a task.[191]

E. DATA ON DISENGAGEMENTS

In 2020, autonomous-vehicle makers reported 3,696 disengagements, instances where human drivers must take control of their AV, to the California DMV.[192] California "manufacturers who are testing autonomous vehicles need to report any collision that resulted in property damage, bodily injury, or death within 10 days of the incident."[193] "As of May 20, 2021, the DMV has received 308 Autonomous Vehicle Collision Reports."[194] California's Department of Motor Vehicles ("DMV") requires that,

> [a]utonomous vehicle manufacturers that are testing vehicles in the Autonomous Vehicle Tester (AVT) Program and AVT Driverless Program . . . submit annual reports to share how often their vehicles disengaged from autonomous mode during tests (whether because of

[191] IBM, *supra* note 189.

[192] *2020 Autonomous Vehicle Disengagement Reports (CSV)*, CAL. DEP'T MOTOR VEHICLES, https://www.dmv.ca.gov/portal/file/2020-autonomous-vehicle-disengagement-reports-csv (last visited Sept. 5, 2022).

[193] *Autonomous Vehicle Collision Reports*, CAL. DEP'T MOTOR VEHICLES, https://www.dmv.ca.gov/portal/vehicle-industry-services/autonomous-vehicles/autonomous-vehicle-collision-reports [https://perma.cc/W37B-GRP9] (last visited Sept. 5, 2022).

[194] *Id.*

technology failure or situations requiring the test driver/operator to take manual control of the vehicle to operate safely).[195]

Each disengagement report gives a brief description of facts leading to the disengagement.[196] In 2020, for example, AImotive—an AV maker—reported 114 disengagements to the California DMV, noting that each event occurred during a test drive on the freeway. A number of them occurred when "[d]uring an exit/merge the test vehicle was going the 'correct' speed as posted by road signs, but was going too slow or too fast given the traffic and road conditions."[197] Apple reported more varied reasons for its 129 disengagements while their autonomous vehicles were operating on streets: (1) motion control health check caused software kickout, (2) hardware diagnostic caused software kickout, (3) incorrect prediction led to undesirable motion plan, (4) sensor data mismatch caused software kickout, (5) safety driver performed improper robotic mode engagement, (6) undesirable motion plan violating traffic signal, (7) reduced visibility of a vehicle due to an undesirable motion plan, (8) hardware diagnostic detected hardware health issue, (9) system issue interrupted driving algorithm, (10) undesirable motion plan violating keep-clear zone, (11) incorrect prediction of parked vehicle caused undesirable motion plan, (12) safety driver discomfort due to selected motion plan, and (13) incorrect perception of traffic signal led to undesirable motion plan.[198]

Software failure is frequently listed as the cause in California's 2020 DMV disengagement reports. Examples include planning module failure due to mapping or software issues; planning discrepancies, including failure to yield other actors, poor lane change in contested target lane, and incorrect behavior at traffic light; disengagement for unwanted maneuver of the vehicle in merging situations, failing to detect an object correctly, and planning discrepancies while generating an appropriate trajectory; software kickout; and software crashed and needed to be rebooted, among other reasons, triggered an emergency stop.[199]

A content analysis of the California DMV data reveals that many disengagements were due to software malfunctioning, mismatches, creating unsafe motion plans, interrupted software, or incorrect predictions or perceptions. The California DMV found safety driver error to play a less significant role in disengagements than software or hardware diagnostic issues. Lyft's 122 disengagement reports for 2020 listed the following four reasons for disengagements: (1) a perception discrepancy for which a component of the vehicle's perception system failed to detect an object correctly, (2) an unwanted maneuver of the vehicle caused by a planning discrepancy while generating an appropriate trajectory, (3) an unwanted

[195] *Disengagement Reports*, CAL. DEP'T OF MOTOR VEHICLES, https://www.dmv.ca.gov/portal/vehicle-industry-services/autonomous-vehicles/disengagement-reports [https://perma.cc/L7Z3-S3RW] (last visited Sept. 5, 2022).

[196] *2020 Autonomous Vehicle Disengagement Reports (CSV)*, *supra* note 192.

[197] *Id.* (rows 1–114 on Excel Sheets of California Department of Motor Vehicles' 2020 Disengagement Reports).

[198] *Id.* (rows 115–244 on Excel Sheets of California Department of Motor Vehicles' 2020 Disengagement Reports).

[199] *Id.* (rows 1–3696 on Excel Sheets of California Department of Motor Vehicles' 2020 Disengagement Reports).

maneuver of the vehicle caused by map discrepancy, and (4) a software fault due to a potential performance issue with a software component of the self-driving system (including third party software components).[200]

Lyft's data also demonstrates that defective, malfunctioning, or discrepant software was the leading cause of disengagement. The next section will further explain the role of software defects in AV disengagements and accidents.

F. STUDIES OF SOFTWARE MALFUNCTION IN AUTONOMOUS VEHICLES

Baidu Apollo and Autoware, leading software systems for AVs, "have been used by large companies and governments (e.g., Lincoln, Volvo, Ford, Intel, Hitachi, LG, and the US Department of Transportation)."[201] Researchers developed a taxonomy for errors in AV systems, identifying thirteen root causes, twenty symptoms, and eighteen categories for 499 bugs in automated vehicles.[202] The root causes of AV bugs identified were as followed:

- *Incorrect algorithm implementation (Alg)*: The implementation of the algorithm's logic is incorrect and cannot be fixed by addressing only one of the other root causes.
- *Incorrect numerical computation (Num)*: This root cause involves incorrect numerical calculations, values, or usage.
- *Incorrect assignment (Assi)*: One or more variables is incorrectly assigned or initialized.
- *Missing condition checks (MCC)*: A necessary conditional statement is missing.
- *Data*: The data structure is incorrectly defined, pointers to a data structure are misused, or types are converted incorrectly.
- *Misuse of an external interface (Exter-API)*: This cause involves misuse of interfaces of other systems or libraries (e.g., deprecated methods, incorrect parameter settings, etc.)
- *Misuse of an internal interface (Inter-API)*: This cause involves misuse of interfaces of other components—such as mismatched calling sequences; violating the contract of inheritance; and incorrect opening, reading, and writing.
- *Incorrect condition logic (ICL)*: This occurs due to incorrect conditional expressions.

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[200] *Id.* (rows 455–577 on Excel Sheets of California Department of Motor Vehicles' 2020 Disengagement Reports).

[201] Joshua Garcia, Yang Feng, Junjie Shen, Sumaya Almanee, Yuan Xia & Qi Alfred Chen, *A Comprehensive Study of Autonomous Vehicle Bugs,* ICSE 2020 TECH. PAPERS at 385 (May 2020), https://dl.acm.org/doi/pdf/10.1145/3377811.3380397 [https://perma.cc/ZN4D-TU4V].

[202] *Id.*

- *Concurrency (Conc)*: This cause involves misuse of concurrency oriented structures (e.g., locks, critical regions, threads, etc.).
- *Memory (Mem)*: This cause involves misuse of memory (e.g., Improper memory allocation or de-allocation).
- *Invalid Documentation (Doc)*: This cause involves incorrect manuals, tutorials, code comments, and text that is not executed by the AV system.
- *Incorrect configuration (Config)*: This cause involves modifications to files for compilation, build, compatibility, and installation (e.g., incorrect parameters in Docker configuration files).
- *Other (OT)* causes occur highly infrequently and do not fall into any one of the above categories.[203]

The overwhelming number of AV defects or malfunctions are caused by software failure. The chief symptoms of software failure in driverless cars include:

- *Crashes* terminate an AV system or component improperly.
- *Hangs* are characterized by an AV system or component becoming unable to respond to inputs while its process remains running.
- *Build* errors prevent correct compilation, building, or installation of an AV system or component.
- *Display and GUI (DGUI)* errors show erroneous output on a GUI, visualization, or the HMI of the AV system.
- *Camera (Cam)* errors prevent image capture by an AV camera.
- *Stop and parking (Stop)* errors refer to the incorrect behaviors occurring when the AV attempts to stop or park the vehicle (e.g., sudden stops at inappropriate times, failure to stop in emergency situations, and parking outside of the intended parking space).
- *Lane Positioning and Navigating (LPN)* errors involve incorrect behaviors shown in lane positioning and navigating (e.g., failing to merge properly into a lane and failing to stay in the same lane).
- *Speed and Velocity Control (SVC)* symptoms involve incorrect behaviors related to the control of vehicle speed and velocity (e.g., failure to enforce the planned velocity and failing to follow another vehicle at high speed).

[203] *Id.* at 387–88.

- *Traffic Light Processing (TLP)* errors represent any incorrect behaviors involving handling of traffic lights.
- *Launch (Lau)* symptoms occur when an AV system or component fails to start.
- *Turning (Turn)* symptoms occur when an AV behaves incorrectly when making or attempting to make a turn (e.g., turning at the wrong angle and problems with turn signals).
- *Trajectory (Traj)* symptoms involve incorrect trajectory prediction results (e.g., incorrect trajectory angles or predicted paths).
- *IO* errors involve incorrect behaviors when performing inputs or outputs to files or devices.
- *Localization (LOC)* errors refer to incorrect behaviors related with multi-sensor fusion-based localization and may manifest as incorrect information on a vehicle's map.
- *Security & safety (SS)* symptoms involve behaviors affecting security or privacy properties (e.g., confidentiality, integrity, or availability), damage to the vehicle, or injury to its passengers.
- *Obstacle Processing (OP)* errors occur when AVs incorrectly process detected obstacles on the road (e.g., failure to correctly estimate distance from an object).
- *Logic* errors represent incorrect behaviors that do not terminate the program or fit into the aforementioned symptom categories.
- *Documentation (Doc)* symptoms include any errors in documentation including manuals, tutorial, code comments, and other text intended for human rather than machine consumption.
- *Unreported (UN)* symptoms cannot be identified by reading issue discussions or descriptions, source code, or issue labels.
- *Other (OT)* symptoms occur highly infrequently and do not fit into the above categories.[204]

The research team found that "build errors, crashes, logic errors, and GUI errors are among the most frequently occurring domain-independent errors in AV systems amounting to 16.23% of bugs for build errors, 10.62% for crashes, 11.42% for logic errors, and 7.82% for GUI errors."[205]

Nevertheless, the research team found that "[b]ugs reported with explicit safety or security symptoms occur highly infrequently."[206] Incorrect algorithms were by far the most common root cause of AV failures:

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[204] *Id.* at 388.
[205] *Id.* at 390.
[206] *Id.*

> Unsurprisingly, that cause resulted in a wide variety of symptoms, producing 16 out of 20 of the symptoms in our classification scheme. This root cause results in many symptoms directly affecting the correct driving of a vehicle (i.e., lane positioning and navigation, speed and velocity control, traffic-light processing, stopping and parking, vehicle turning and trajectory, localization, and obstacle processing). Symptoms especially affected by incorrect algorithm implementations include lane positioning and navigation (17 occurrences), speed and velocity control (15 occurrences), and trajectory (19 occurrences). This indicates that implementing such algorithms has a high complexity compared to other aspects of AV driving. Other symptoms that occur frequently due to incorrect algorithm implementations include crashes (12 occurrences), display and GUI errors (15 occurrences), and logic errors (23 occurrences). Given that many lines of code (i.e., 104 lines of code on average) often need to be added or modified to fix AV bugs arising due to incorrect algorithm implementations, a wide variety of AV-specific and safety-critical bugs are likely to be inapplicable for state-of-the-art fault localization and automatic program-repair techniques.[207]

The study concluded that software "[c]rash bugs occur throughout critical AV components—especially Perception, Localization, and Planning—making them susceptible to more dangerous secondary effects."[208] "In the case of software law, there has been a forty-year 'legal lag' between the rises of software as a separate industry" and the development of specialized liability standards focusing on software defects.[209] "Commentators have suggested, or perhaps even assumed, that software that is part of a hardware product (such as software embedded in an automobile braking system) may be subject to a product liability lawsuit if defects in the software render the product defective in its operation and a personal injury results."[210]

G. Security Vulnerabilities in AVs

One hundred and twenty-five million conventional vehicles will be connected to the Internet by the end of 2022, which creates a large-scale risk of hacking into the software and taking control of these vehicles remotely.[211] A Ponemon Institute survey of global automotive manufacturers and suppliers concluded, "that 84 percent of automotive professionals have concerns that their organizations' cybersecurity practices are not keeping pace with evolving technologies."[212] "Few companies—just 10%—have an established cybersecurity team. Less than a third of organizations (31%)

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[207] *Id.* at 391.
[208] *Id*. at 393.
[209] Michael L. Rustad & Maria Vittoria Onufrio, *The Exportability of the Principles of Software: Lost in Translation?*, 2 Hastings Sci. & Tech. L. J. 25, 29 (2010).
[210] Jeffrey D. Neuburger & Maureen E. Garde, *Information Security Vulnerabilities: Should We Litigate or Mitigate?* 7 Andrews Telecomm. Indus. Litig. Rep. 11, 5 (2004).
[211] Sarah Archer, Could Your Car Be Hacked Next? How Hackers Do It and Steps to Protect Yourself (Feb. 3, 2020), 2020 WLNR 3374050.
[212] Lynn Walford, Automotive Cybersecurity: Practices, RISC-V, Sensors, Argus Cybersecurity, NVIDIA (Aug. 11, 2019), 2019 WLNR 4353777.

educate their developers on secure coding methods. Fewer than half (44%) impose cybersecurity requirements on suppliers and other third parties."[213] "In 2015, 1.4 million vehicles were affected by the first and only cybersecurity-related recall issued by Fiat Chrysler."[214] As the Acting Administrator of the NHTSA testified,

> NHTSA would be responsible for anything that impacts the safe operation of vehicles, while the Federal Trade Commission would be responsible for privacy issues. He described cyber vulnerabilities as a "dynamic and evolving threat" but said NHTSA would treat software problems the same as hardware issues and could recall vehicles for software vulnerabilities, as it did in 2015 with the recall of 1.4 million vehicles.[215]

Inadequate security has the potential of allowing criminals to exploit software vulnerabilities and perpetrate an extensive number of cybercrimes, including:

> - [H]acking cars for ransom before allowing the user either in or out of the car. This can happen when the car is parked or driving.
> - Terrorists hijacking the network and taking control [of] a transport system in an area. Hacking a network can cause major crashes by disabling the light-detecting and ranging sensors, leading to endless confusion.
> - Hacking the car's operating system remotely to intentionally destroy the car could harm the user financially.
> - As with any other hacking scenario, hacking into an autonomous car could expose much of [one's] personal data—including [one's] destination. With this information, someone could track the user with an aim toward robbery or assault. If hackers can gain access to the controls of the vehicle, it could also be possible to redirect the vehicle to a more convenient location for either scenario.
> - As the technology evolves, driverless cars can turn on any smart device in your home, be it the TV, heater, garage door, or front gate, and everything programmable in the home. Hackers could use these features to gain access to [one's] home.[216]

Further, a University of Michigan study "suggests that cybersecurity is one of the primary concerns consumers have regarding the [AVs]. In addition to fear of losing control of the vehicle due to hacking, citizens are concerned

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[213] Taylor Armerding, *Connected Cars Need Better Connection to Cybersecurity*, FORBES (Feb. 6, 2019, 8:54 AM), https://www.forbes.com/sites/taylorarmerding/2019/02/06/connected-cars-need-better-connection-to-cybersecurity/#156341aa6040 [https://perma.cc/66A7-VJ7D].

[214] ARCHER, *supra* note 211.

[215] CYBERSECURITY POL'Y REP., CYBER ISSUES CAN PROMPT RECALLS OF AUTOMATED VEHICLES, SENATORS TOLD (Nov. 21, 2019), 2019 WLNR 35146231.

[216] Rilind Elezaj, *Autonomous Cars: Safety Opportunity or Cybersecurity Threat?*, MACH. DESIGN (July 16, 2019), https://www.machinedesign.com/mechanical-motion-systems/article/21837958/autonomous-cars-safety-opportunity-or-cybersecurity-threat [https://perma.cc/NSK5-QHAX].

that access to driving patterns and location will create an invasion of privacy."[217]

H. SOFTWARE'S ROLE IN THE FIRST AV ACCIDENTS

Computer programmers write software code in a human-readable language such as Visual Basic, C, and C++. AVs are susceptible to bugs in computer software that is safety-critical "possibly leading to severe injuries to passengers or even death."[218] The first AV car death occurred when a self-driving Uber Technologies test vehicle ran into Elaine Herzberg, killing her as she was crossing a road.[219] The AV's

> automated driving system initially struggled to correctly identify 49-year-old Elaine Herzberg on the side of the road. But once it did, it still was not able to predict that the pedestrian would cross in front of the vehicle, and it failed to execute the correct evasive maneuver to avoid striking the woman crossing the highway.[220]

A major problem with AVs is not the possibility of the vehicle missing something on the road, but of the software incorrectly identifying something important.[221] In Williston, Florida, a Tesla Model 3 AV misidentified a white trailer in the road as the sky and did not apply the brake, killing the vehicle's driver.[222]

Human drivers may rely too much on autopilot and not assess road conditions.[223] In the Uber AV accident, "[a]n initial investigation by . . . police indicated that the pedestrian [hit by the AV] might have been at fault. According to that report, Herzberg appears to have come 'from the shadows,' stepping off the median into the roadway, and ending up in the path of the car while jaywalking across the street."[224] The "car's sensors detected the pedestrian, who was crossing the street with a bicycle, but Uber's software

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[217] Melissa L. Griffin, *Steering (or Not) Through the Social and Legal Implications of Autonomous Vehicles*, 11 J. BUS. ENTREPRENEURSHIP & L. 81, 99 (2018).

[218] Garcia et al., *supra* note 201, at 385.

[219] Sam Levin & Julia Carrie Wong, *Self-Driving Uber Kills Arizona Woman in First Fatal Crash Involving Pedestrian*, THE GUARDIAN (Mar. 19, 2018, 6:48 PM), https://www.theguardian.com/technology/2018/mar/19/uber-self-driving-car-kills-woman-arizona-tempe [https://perma.cc/97DX-6NCE].

[220] LYN WALFORD, AUTONOMOUS AND SELF-DRIVING VEHICLE NEWS: FORD, ARGO.AI, VOLKSWAGEN, IIHS, OTTO MOTORS & FORTELLIX (June 8, 2020), 2020 WLNR 15936840.

[221] NEWSRX, PATENT ISSUED FOR SYSTEMS AND METHODS FOR APPLYING MAPS TO IMPROVE OBJECT TRACKING, LANE-ASSIGNMENT AND CLASSIFICATION (Dec. 3, 2020) 2020 WLNR 34515869:

> Autonomous and semi-autonomous vehicles require highly accurate perception of objects to object tracks. The perception of object tracks can be subject to perspective distortions. This results in incorrect lane identification of objects. In addition, the sensor data from the vehicle sensors may contain significant noise thus, further reducing the accuracy for making lane assignments of perceived objects. Such discrepancies are problematic because autonomous vehicles, in particular, require proper identification of parked vehicles adjacent to roadways as well as stationary vehicles on the roadways.

[222] Danny Yadron & Dan Tynan, *Tesla Driver Dies in First Fatal Crash While Using Autopilot Mode*, THE GUARDIAN (Jun. 30, 2016, 7:14 PM), https://www.theguardian.com/technology/2016/jun/30/tesla-autopilot-death-self-driving-car-elon-musk [https://perma.cc/4ZXU-9A7D].

[223] Lewis Tingler, *Recent Self Driving Car Crash Shares Similarities to Williston Crash of 2016,* WCJB (May 16, 2019, 11:00 AM), https://www.wcjb.com/content/news/NTSB-issues-final-report-on-fatal-autonomous-Tesla-crash-from-2016-510023551.html [https://perma.cc/U9RE-YHXT].

[224] Ian Bogost, *Can You Sue a Robocar?*, THE ATLANTIC (Mar. 20, 2018), https://www.theatlantic.com/technology/archive/2018/03/can-you-sue-a-robocar/556007 [https://perma.cc/G933-ZFHW].

decided it didn't need to react right away. That's a result of how the software was tuned."[225] The human backup driver of the Uber AV "was streaming the television show 'The Voice' on her phone and looking downward just before fatally striking a pedestrian and could have avoided the pedestrian had she been paying attention."[226] An accident reconstruction revealed the following cause of the accident:

> Regarding the Uber self-driving car, it was found that the emergency braking maneuvers were disabled [while] a computer as stated by the National Transportation Safety Board was controlling the car. The sensors on the Volvo XC-90 SUV spotted the woman but because of the disabled emergency braking features the car did not apply the brakes and the human backup driver in the car was not warned[;] hence, [the driver] did not intervene in time. It was found that the car was traveling at 43 [miles per hour] and needed to break 1.3 seconds before impact.[227]

"Three motorists have died while operating Tesla vehicles in self-driving mode, which Tesla calls Autopilot. Tesla improved its system after a vehicle crashed into a semi-truck crossing a highway in 2016."[228] In March of 2020, a Tesla Model S collided with a semi-truck in Florida while on autopilot, killing the Tesla driver.[229] There has also been at least one pedestrian death from a Tesla. The driver of a Tesla sport-utility Model X crashed in Mountain View, California, killing 38-year-old Apple software engineer Wei Huang; the driver had "received several visual warnings and one audible hands-on warning earlier in the drive and the driver's hands were not detected on the wheel for six seconds prior to the collision."[230]

"The driver had about five seconds and 150 meters of unobstructed view of the concrete divider . . . but the vehicle logs show that no action was taken."[231] Vehicle-to-vehicle communication ("V2V") may cause significant software issues. It relies on Dedicated Short Range Communications ("DSRC") to share data with nearby vehicles such as speed and direction. In theory, this should prevent any collisions because the real-time data communicated from the car is more accurate than the cameras and sensors. This process could also be extended to phone apps to let pedestrians and bikers transmit the data. A fully autonomous vehicle could be greatly

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[225] Brad Templeton, *Uber Reported to Have Made an Error Tuning Perception System*, BRAD IDEAS (May 17, 2018, 5:51 PM), https://ideas.4brad.com/uber-reported-have-made-error-tuning-perception-system [https://perma.cc/6Z24-YFMA].

[226] Tom Krishner & Jacques Billeaud, *Police: Backup Driver in Fatal Uber Crash Was Distracted*, ASSOCIATED PRESS (June 22, 2018), https://apnews.com/44ab48ed026f46f99a16eb9fd9165736 [https://perma.cc/P353-E8WV].

[227] Meriame Berboucha, *Uber Self-Driving Car Crash: What Really Happened*, FORBES (May 28, 2018, 10:08 AM), https://www.forbes.com/sites/meriameberboucha/2018/05/28/uber-self-driving-car-crash-what-really-happened/?sh=6dca7d154dc4 [https://perma.cc/5Y3G-NBNK].

[228] Jim Sams, *InsurTechs Push for Front Row Seat in New World of Autonomous Technology*, CLAIMS J. (Aug. 19, 2019), https://www.claimsjournal.com/news/national/2019/08/19/292603.htm [https://perma.cc/U2ZW-Y3B5].

[229] Andrew J. Hawkins, *Tesla's Autopilot Was Engaged When Model 3 Crashed into Truck, Report States*, THE VERGE (May 16, 2019, 10:34 AM), https://www.theverge.com/2019/5/16/18627766/tesla-autopilot-fatal-crash-delray-florida-ntsb-model-3 [https://perma.cc/KX9R-GSS2].

[230] *Tesla Car That Crashed and Killed Driver Was Running on Autopilot, Firm Says*, THE GUARDIAN (Mar. 31, 2018, 2:40 PM), https://www.theguardian.com/technology/2018/mar/31/tesla-car-crash-autopilot-mountain-view [https://perma.cc/3RR5-BKU9].

[231] *Id*.

enhanced by having connectivity to other vehicles as an input instead of relying on its cameras and sensors.[232]

In Taiwan, the driver of a Tesla suffered no injury when his car struck an overturned truck.[233] The Tesla Autopilot was on and the software failed to detect the truck.[234] When it crashed, no airbags were deployed.[235] In 2020, Volkswagen delayed the rollout of its ID.3 model due to software issues.[236] The company said it had "massive software" issues because of the company building the technology "too quickly," thus leading to malfunctions.[237] The next section proposes extending products liability to AV accidents caused by software malfunction.

IV. PRODUCTS LIABILITY FOR AUTONOMOUS VEHICLES

A. PRODUCTS LIABILITY AS SUING FOR SAFETY

Product liability is the liability of manufacturers, processors, distributors, and sellers of products for personal injury, death, or property damage under diverse theories that include negligence, strict liability, and breach of warranty.[238] Products liability law governs liability for the sale or other commercial transfer of a product, which causes physical harm because it is defective or its properties are falsely represented.[239] The manufacturers, component part makers, distributors, and retailers of AVs will be the primary defendants in products liability litigation. "Products liability lies in the borderland between the law of contracts and of torts, reallocating the cost of injuries to those who supply dangerously defective 'goods or products for the use of others.' "[240] Prior to the development of products liability, there was an epidemic of excessive preventable dangers in vehicle design:

> Those who documented crash sites from the 1920s to the 1960s recorded with numbing frequency victims' eyes impaled on jutting dashboard knobs, necks broken by rigid steering columns, jagged

[232] Huei Peng, *Saving Lives by Letting Cars Talk to Each Other*, THE CONVERSATION (Sep. 11, 2016, 9:41 PM), https://theconversation.com/saving-lives-by-letting-cars-talk-to-each-other-59221 [https://perma.cc/2CRM-MEPA].

[233] Anirudh Sk, *Question on Tesla Autopilot as Model 3 Crashes into a Truck at 110 Kmph on Highway*, NEWS18 (June 3, 2020, 1:07 PM), https://www.news18.com/news/auto/question-on-tesla-autopilot-as-model-3-crashes-into-a-truck-at-110-kmph-on-highway-watch-video-2650639.html [https://perma.cc/3C9E-Q94G].

[234] *Id*.

[235] *Id*.

[236] Sean O'Kane, *VW's First Mass-market EV Suffers Delay Thanks to Software Struggles,* THE VERGE (June 11, 2020, 4:07 PM), https://www.theverge.com/2020/6/11/21288572/volkswagen-id3-ev-delay-software-vw-herbert-diess [https://perma.cc/VX53-AGKQ] ("Volkswagen is delaying the release of certain versions of the all-electric ID 3 because the car's software isn't ready, confirming months of reports from German outlets like *Sueddeutsche Zeitung* and Manager Magazine about the company's struggle to bring its first mass-produced electric vehicle to market.").

[237] Verdi Ogewell, *Volkswagen Solves "Massive Software Problems" for New Electric Car, and Is on Track Industrially and in PLM*, ENGINEERING.COM (June 8, 2020), https://www.engineering.com/PLMERP/ArticleID/20379/Volkswagen-Solves-Massive-Software-Problems-for-New-Electric-Car-and-is-On-Track-Industrially-and-in-PLM.aspx [https://perma.cc/VX53-AGKQ].

[238] THOMAS H. KOENIG & MICHAEL L. RUSTAD, IN DEFENSE OF TORT LAW 35, 51–59 (2001).

[239] DAVID G. OWEN, PRODUCTS LIABILITY LAW: HORNBOOK SERIES 1 (3d ed. 2015).

[240] Thomas H. Koenig & Michael L. Rustad, *Reconceptualizing the BP Oil Spill as Parens Patriae Products Liability*, 49 HOUS. L. REV. 291, 345 (2012).

> "glass collars" where heads had burst through windshields, severed arms from rollovers, and on and on without legal solutions in sight.[241]

In the past fifty years, products liability has addressed defects in traditional vehicles, leading to significant safety improvements.[242] One commentator noted that several safety improvements had been instituted because of products liability lawsuits, including: "(1) shielding gas tanks; (2) strengthening automobile frames; (3) requiring the installation of airbags; . . . (4) improving tire tread through more fastidious reporting requirements;" and (5) "strengthened standards for roof strength."[243]

B. The Justification for Strict Products Liability to AVs

1. Strict Products Liability

Strict liability differs from negligence in that it "eliminates the necessity for the injured party to prove that the manufacturer of the product which caused injury was negligent."[244] "Ordinarily, strict liability, which was developed to ease a claimant's burden of proof, requires proof of fewer elements than negligence, making a positive verdict on the latter difficult to explain if strict liability cannot be found."[245] To prevail in a strict products liability action, a plaintiff must prove: (1) a defect made the vehicle unreasonably dangerous; (2) the defect was present when the vehicle was delivered to the owner; (3) the vehicle maker manufactured or sold a car with a defect; (4) the passenger or bystander sustained bodily or economic damages proximately caused by the defect in the vehicle; and (5) the car was being used in a reasonable, foreseeable manner at the time of the accident and the occupant did not override safety features that would have prevented the accident.

"The term 'strict' is used because it removes the issue of manufacturer negligence from consideration, and instead is based on consumer expectations that products should not be unreasonably dangerous."[246] In a concurring opinion in the 1944 case of *Escola v. Coca Cola Bottling Co.*,[247] Justice Roger Traynor of the California Supreme Court stated the public policy basis for strict liability when he argued that a manufacturer "incurs an absolute liability" for placing a product on the market, knowing it will be used without inspection, when that article "proves to have a defect that causes injury."[248] Justice Traynor stated, "public policy demands that responsibility be fixed wherever it will most effectively reduce the hazards to life and health inherent in defective products that reach the market."[249]

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[241] Bryan H. Choi, *Crashworthy Code* 94 WASH. L. REV. 39, 45 (2019).

[242] Aaron Ezroj, *Product Liability After Unintended Acceleration: How Automotive Litigation Has Evolved*, 26 LOY. CONSUMER L. REV. 470, 490 (2014).

[243] *Id.*

[244] Brown v. Super. Ct., 751 P.2d 470, 474 (Cal. 1988).

[245] Trejo v. Johnson & Johnson, 220 Cal. Rptr. 3d 127, 140 (Ct. App. 2017) (quoting 1 DAVID G. OWEN & MARY J. DAVIS, OWEN & DAVIS ON PRODUCTS LIABILITY § 5:29 n.25 (4th ed. 2016)).

[246] John Villasenor, *Products Liability and Driverless Cars: Issues and Guiding Principles for Legislation*, BROOKINGS INST. (Apr. 24, 2014), https://www.brookings.edu/research/products-liability-and-driverless-cars-issues-and-guiding-principles-for-legislation/ [https://perma.cc/8HJ6-UJMB].

[247] Escola v. Coca Cola Bottling Co. of Fresno, 150 P.2d 436 (Cal. 1944).

[248] *Id.* at 440 (Traynor, J., concurring).

[249] *Id.*

Nineteen years later in 1963, California became the first jurisdiction to recognize strict liability in *Greenman v. Yuba Power Products, Inc.*[250] Greenman, the plaintiff, was injured when a piece of wood on which he was working flew from the lathe of his Shopsmith, a combination power tool that is usable as a saw, drill, and wood lathe. To establish the manufacturer's liability, it was sufficient for the plaintiff to prove that he was injured because of a defect in the design and manufacture—of which plaintiff was not aware—while using the Shopsmith in the way it was intended to be used.[251]

In *Greenman*, Justice Traynor stated, "[a] manufacturer is strictly liable in tort when an article he places on the market, knowing that it is to be used without inspection for defects, proves to have a defect that causes injury to a human being."[252] "Subsequently, [the Greenman principle] was incorporated in section 402A of the Restatement Second of Torts, and adopted by a majority of American jurisdictions."[253] Section 402A of the Restatement (Second) of Torts has been adopted by most states and follows *Greenman* in holding a manufacturer strictly liable for harm to a person or property caused by "any product in a defective condition unreasonably dangerous to the user."[254]

A product may be found defective in design if the product failed "to perform as safely as an ordinary consumer would expect when used in an intended or reasonably foreseeable manner.[255] Under the "consumer expectation" test, a plaintiff must prove by a preponderance of the evidence that:

> (1) The defendant's connection with the product, such as manufacturer, distributor, or seller; (2) that the design of the product that injured the plaintiff was the same as the design of the product when it left the defendant's possession; (3) that the product failed to perform as safely as an ordinary consumer of that product would have expected; (4) that the design of the product was a proximate cause of the plaintiff's injuries; (5) that the product was used in a manner reasonably foreseeable by the defendant; and (6) the nature and extent of the plaintiff's injuries.[256]

Strict products liability places "the burden of compensating victims of unreasonably dangerous products . . . on the manufacturers . . . , who are most able to protect against the risk of harm, and not on the consumer injured by the product."[257] The chief policy justification for strict liability is to place

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[250] Greenman v. Yuba Power Prods., Inc., 377 P.2d 897 (Cal. 1963).
[251] *Id.* at 898.
[252] *Id.* at 900.
[253] Daly v. Gen. Motors Corp., 575 P.2d 1162, 1166 (Cal. 1978).

> We, ourselves, were perhaps the first court to give the new principle judicial sanction. In Greenman v. Yuba Power Prods., Inc., 59 Cal. 2d 57 (1963), confronted with injury to an ultimate consumer caused by a defective power tool, we fastened strict liability on a manufacturer who placed on the market a defective product even though both privity and notice of breach of warranty were lacking.

[254] RESTATEMENT (SECOND) OF TORTS § 402A(1) (AM. L. INST. 1965).
[255] Soule v. Gen. Motors Corp., 882 P.2d 298, 303 (Cal. 1994).
[256] MICHAEL PAUL THOMAS, ZAIDA ANGULO MCGHEE, BRIAN D. KAHN, STACY L. LA SCALA, CAL. CIV. PRAC. TORTS § 24:26 (May 2021 Update).
[257] Aubin v. Union Carbide Corp., 177 So. 3d 489, 510 (Fla. 2015).

the loss caused by defective products on those who create the risks and reap the profits by placing such products in the stream of commerce.[258] A cause of action under strict liability "cover[s] the sale of any product which, if it should prove to be defective, may be expected to cause physical harm to the consumer or his property."[259]

2. Extending Strict Products Liability to Autonomous Vehicles

Fully autonomous vehicles will not be fully deployed for decades. When AVs are widely deployed, courts should apply products liability rules to defective software deployed in autonomous cars so that vehicle manufacturers, distributors, suppliers, retailers, and anyone in the chain of distribution will become liable for placing a defective product into the stream of commerce, which could then result in injury or death to a consumer or bystander.[260] By removing human error from the automobile accident equation, automobile accidents of the future will be disproportionately caused by defective software components and systems. The Brookings Institution argues for applying the well-established products liability to AVs:

> The legal precedents established over the last half a century of products liability litigation will provide manufacturers of autonomous vehicle technology with a very strong set of incentives to make their products as safe as possible. In the overwhelming majority of cases, they will succeed. However, despite these efforts, there will inevitably be some accidents attributable in whole or in part to defects in future vehicle automation systems. While this will raise complex new liability questions, there is no reason to expect that the legal system will be unable to resolve them.[261]

Under a products liability regime, AV makers are liable for the final product (i.e., the vehicle) in accidents resulting from a software defect in the vehicle.[262] An autonomous car manufacturer is in a better position than a passenger to foresee the uses, misuses, and potential harms of driverless cars.[263] Products liability actions, arising out of injuries or deaths, generally result from defectively designed components. Due to far-reaching consequences within the economy, products liability is the most practically important field to protect consumers.[264]

AVs are evolving rapidly, but the legal system has not yet assigned responsibility for personal injury or deaths caused by defective software components.[265] Historically, courts have been resistant to recognize products

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[258] Cassidy v. China Vitamins, LLC, 120 N.E.3d 959, 967 (Ill. 2018).

[259] *See* RESTATEMENT (SECOND) OF TORTS § 402A cmt. b (AM. L. INST. 1965).

[260] *Id.*

[261] John Villasenor, *Products Liability and Driverless Cars: Issues and Guiding Principles for Legislation*, BROOKINGS INST. (Apr. 24, 2014), https://www.brookings.edu/research/products-liability-and-driverless-cars-issues-and-guiding-principles-for-legislation/ [https://perma.cc/XXS2-JB8C].

[262] Goodrich, *supra* note 29, at 281 (quoting Gary E. Marchant & Rachel A. Lindor, *The Coming Collision Between Autonomous Vehicles and the Liability System*, 52 SANTA CLARA L. REV. 1321 (2012)).

[263] Adam D. Thierer and Ryan Hagemann, *Removing Roadblocks to Intelligent Vehicles and Driverless Cars*, 5 WAKE FOREST J. L. & POL'Y 339 (2015).

[264] MARK GEISTFELD, PRINCIPLES OF PRODUCTS LIABILITY (Foundation Press, 2d ed. 2011).

[265] Choi, *supra* note 241, at 42:

> Courts uniformly dismiss claims of software defect, often because there is no physical injury at stake, but also for a broad range of other disqualifying reasons. And even when the plaintiff

liability for defective software; instead, they generally tend to enforce contractual limits on liability.[266] While products liability does not yet apply to software, "this is sure to change. As software becomes more involved in the operation of machinery the greater the chance a court will apply products liability someday to software."[267] Imposing strict liability on AV manufacturers for defects they cause will encourage safety in design and production. The diffusion of this cost in the purchase price of individual units should be acceptable to the user if "it results in added assurance of protection."[268]

Extending products liability to defective software components will prevent AV makers from contractually shifting the risks of defective software to users. No longer will the software industry be able to use warranty disclaimers and caps on damages to eliminate their responsibility for marketing dangerously defective code. Strict product liability "was developed to ease a claimant's burden of proof, requires proof of fewer elements than negligence, making a positive verdict on the latter difficult to explain if strict liability cannot be found."[269]

Strict products liability places incentives on software designers who will presumably do more testing, data analysis, and inspection to correct software hazards in the laboratory rather than in a post-accident reconstruction.[270] AV accident prevention is far superior to accident compensation. A fence at the top of the cliff is superior to an ambulance in the valley below.

Applying products liability to AVs will involve many of the same issues as in other automobile products liability litigation. As with other automobile products cases, all entities that supply components are potentially liable, but "[t]he delineation of liability will be more complicated where a number of parties (e.g., automotive manufacturer, hardware vendor, software licensor[,] and mobile network operator) are involved in the creation of the technology

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> alleges an eligible injury, it remains exceedingly difficult to prove whether the software caused the injury, and whether that cause was due to some defect intrinsic to the software.

[266] DAVID G. OWEN & MARY J. DAVIS, 2 OWEN & DAVIS ON PRODUCTS LIABILITY § 17:30 (4th ed., May 2021 Update):

> Whether manufacturers of computer software should be subject to products liability for personal injuries caused by defective software is an intriguing question. While commentators widely favor the application of products liability theories in such situations, the case law so far is limited to commercial contexts involving claims for economic loss without physical harm.

See also Michael L. Rustad & Thomas H. Koenig, *Cybertorts and Legal Lag: An Empirical Analysis*, 13 S. CAL. INTERDISC. L.J. 77, 135 (2003) ("Courts have yet to extend products liability theories to bad software, computer viruses, or web sites with inadequate security or defective design.").

[267] L. J. KUTTEN & FREDERIC M. WILF, 3 COMPUTER SOFTWARE § 12:45 (2021).

[268] Fasolas v. Bobcat of N.Y., Inc., 33 N.Y.3d 421, 429 (Ct. App. 2019) (quoting Codling v. Paglia, 32 N.Y.2d 330 (Ct. App. 1973)).

[269] Trejo v. Johnson & Johnson, 220 Cal. Rptr. 3d 127, 140 (Ct. App. 2017).

[270] Smith v. Home Light & Power Co., 734 P.2d 1051 (Colo. 1987) ("Principles of modern strict products liability law evolved in part to motivate manufacturers to use information that they can obtain through design, testing, data analysis and inspection to correct hazards in products and thereby combat the massive problem of accidents resulting from defective products") (quoting Palmer v. A.H. Robins Co., 684 P.2d 187 (Colo. 1984)). Therefore, strict products liability under § 402A:

> does not rest upon negligence principles, but rather is premised on the concept of enterprise liability for casting a defective product into the stream of commerce . . . . Thus, the focus is upon the nature of the product, and the consumer's reasonable expectations with regard to that product, rather than on the conduct, either of the manufacturer or of the person injured because of the product. Jackson v. Harsco Corp., 673 P.2d 363 (Colo. 1983) (citations omitted).

and/or provision of the various components and services required for operation of the vehicle."[271] Extending products liability to defective software components in AVs, which directly result in injury or death, brings common sense to the common law.

C. Types of Defects in Autonomous Vehicle Products Liability Actions

To prevail in an AV products liability action, a plaintiff must show that an autonomous vehicle contained a defect that is the direct cause of the plaintiff's injury or death. Section 2 of the Restatement (Third) of Torts: Products Liability requires a product defect to be determined "at the time of sale or distribution."[272] The Restatement (Third) of Torts: Products Liability recognizes three paradigmatic types of defects in products litigation: (1) manufacturing defects; (2) design defects; and (3) the failure to warn or inadequate warnings.[273]

1. Manufacturing Defects in AVs

A product has a manufacturing defect when it deviates from its intended design even though all possible care was exercised in its preparation and marketing. To establish a prima facie case of products liability "predicated on manufacturing defect, a plaintiff must prove that the product did not perform as intended and that the product was defective when it left the manufacturer's control."[274]

> To plead and prove a manufacturing flaw under either negligence or strict liability, the plaintiff must show that a specific product unit was defective as a result of 'some mishap in the manufacturing process itself, improper workmanship, or because defective materials were used in construction,' and that the defect was the cause of plaintiff's injury.[275]

A party injured because "a manufacturer fails to warn purchasers of a foreseeable danger in connection with the use of an HAV" would have a product liability cause of action.[276]

A manufacturing defect for autonomous vehicles exists "when the product departs from its intended design even though all possible care was exercised in the preparation and marketing of the product."[277] The unintended manufacturing defects generally occur during production.

> Manufacturing defects, flaws or irregularities in products arising from errors in production, give rise to the most basic type of products

[271] Khwaja, *supra* note 185.
[272] Restatement (Third) of Torts: Prods. Liab. § 2 (Am. L. Inst. 1998).
[273] *Id*.
[274] Wesp v. Carl Zeiss, Inc., 11 A.D.3d 965, 968 (N.Y. App. Div. 2004) (reversing summary judgment of products liability action based upon manufacturing defect in case where surgical nurse was injured while moving a 600-pound surgical microscope and floor stand unit at the hospital where she worked).
[275] Colon ex rel. Molina v. BIC USA, Inc., 199 F. Supp. 2d 53, 85 (S.D.N.Y. 2001) (quoting Caprara v. Chrysler Corp., 52 N.Y.2d 114 (Ct. App. 1981)). Manufacturing defects tend to occur on the assembly line, during construction, or in packaging an item.
[276] 11 Terésa J. Farris & Charles P. Kindregan III, Mass. Prac., Motor Vehicle Law And Practice § 1:42 (5th ed. 2021).
[277] Restatement (Third) of Torts: Prods. Liab. § 2(a) (Am. L. Inst. 1998).

> liability claim. The misalignment of a punch press may result in a jagged burr along a product's metal edge; the maladjustment of a nut on a bolt may interfere with a machine's operation; and the failure to prevent foreign matter from entering food or drink may cause its contamination. Tire failures frequently are the result of defective manufacturing.
>
> For example, a rash of failures of Bridgestone/Firestone tires on Ford Explorers probably resulted in part from various irregularities in the production process . . . . If such a product escapes the manufacturer's quality controls, its flawed condition may lead to its failure during use, to an accident, and possibly to an injury to the user or another.[278]

"A manufacturing defect differs from a design defect in that the former occurs in only a small percentage of units in a product line."[279] A Brooking Institution AV researcher gave the following hypothetical of a manufacturing defect in the context of an AV case:

> Consider a manufacturer of fully autonomous vehicles that usually ships its cars with well-tested, market-ready automatic braking software. However, suppose that in one instance it accidentally ships one vehicle with a prototype version of the software containing a flaw not present in the market-ready version. If the vehicle becomes involved in an accident attributable to the flaw, a person injured in the accident could file a claim for damages arising from this manufacturing defect. A manufacturer can be found strictly liable for dangerous manufacturing defects, even if it has exercised "all possible care" in preparing the product.[280]

A "manufacturing defect involves an unintended condition or abnormality in a product and can be identified in most cases by comparing the allegedly defective product with other products in the same line."[281] "Typically, manufacturing defects occur in only a small percentage of units in a product line."[282] In 2018, for example, there were missing spot welds in the B-pillar area of 293 Subaru Ascents.[283] A recall was issued for 471 Honda Clarity vehicles because their "fuel cell control units may cause loss of power."[284] In 2018, three Rolls-Royce Ghosts were recalled because head airbags were not fully activated.[285]

An example of a manufacturing defect is a failure in a single AV, such as the problem that aluminum shrinks when cooled "significantly while a steel bolt shrinks to a lesser extent and as such a fastener joining these materials

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278 David Owen, *Manufacturing Defects*, 53 S. CAL. L. REV. 851, 852-53 (2002).

279 Blue v. Env't Eng'g Inc., 215 Ill. 2d 78, 89 (2005).

280 John Villasenor, *Products Liability and Driverless Cars: Issues and Guiding Principles for Legislation*, BROOKINGS INST. (Apr. 24, 2014), https://www.brookings.edu/research/products-liability-and-driverless-cars-issues-and-guiding-principles-for-legislation/ [https://perma.cc/V3TM-RFZD].

281 Kevin R. Boyle, *The Expanding Post-Sale Duty of a Manufacturer: Does a Manufacturer Have a Duty to Retrofit Its Products?*, 38 ARIZ. L. REV. 1033 (1996).

282 RESTATEMENT (THIRD) OF TORTS: PRODS. LIAB. § 1 cmt. a (AM. L. INST. 1998).

283 STOUT, 2019 AUTOMOTIVE DEFECT AND RECALL REPORT 32 (2019), https://www.stout.com/en/insights/report/2019-automotive-defect-and-recall-report [https://perma.cc/63UH-9E5C].

284 *Id.*

285 *Id.*

will loosen with decreasing temperature. When the same joint is heated, the aluminum expands more than the steel bolt and the joint can become over tight stretching or even breaking the bolt."[286] Thermal cycling and vibration is a cause of fatigue and the bolt's failure.[287] An example of manufacturing defects in a conventional truck is the failure of connecting rod bushings that "cause engine failure that can result in a sudden loss of power with an inability to restart."[288] The Restatement (Third) states that,

> A product is defective when, at the time of sale or distribution, it contains a manufacturing defect, is defective in design, or is defective because of inadequate instructions or warnings. A product . . . contains a manufacturing defect when the product departs from its intended design even though all possible care was exercised in the preparation and marketing of the product.[289]

Plaintiffs in manufacturing cases must prove by a preponderance of the evidence that the manufacturer's AV or driverless car equipment failed to function because of some deviation from the carmaker's intended design for the vehicle.[290] A manufacturer can be found liable for dangerous manufacturing defects, even if it has exercised all possible care in preparing the product.[291] A plaintiff injured by an AV may use the malfunction doctrine, whereby the plaintiff can demonstrate a manufacturing defect without necessarily proving how it was defective, by showing that: (1) the product malfunctioned; (2) the malfunction occurred during proper use; and (3) the product had been altered or misused in a manner that probably caused the malfunction. A manufacturer can be found strictly liable for dangerous manufacturing defects even if it has exercised all possible care in preparing the product.

2. Failure to Warn of Known Defects or Inadequate Warnings

In conventional products liability litigation, the manufacturer's failure to warn or to give adequate warnings for safe use are frequently asserted claims.[292] The owner's manual for Tesla's Model S gives warnings or instructions for safe operation of the autopilot that is designed to "reduce

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[286] *Researchers Submit Patent Application, "Thermally Stabilized Fastener System and Method," for Approval (USPTO 20200149577) Patent Application*, CHEM. & CHEMISTRY BUS. DAILY, June 1, 2020, 2020 WLNR 15284555.

[287] *Id.*

[288] GOV'T OF CAN, RECALL DETAILS TRANSPORT CANADA RECALL # 2020-198 (Nov. 10, 2020):

> On certain trucks, the connecting rod bushings could fail due to a manufacturing defect. This could cause an engine failure that can result in a sudden loss of power with an inability to restart. Safety Risk: A sudden loss of engine power could increase the risk of a crash. Additionally, a stalled vehicle could also increase the risk of crash. Corrective Actions: The company will notify owners by mail. The corrective actions for this recall are under development.

[289] RESTATEMENT (THIRD) OF TORTS: PRODS. LIABILITY § 2(a) (AM. L. INST. 2012).

[290] Jeffrey K. Gurney, *Sue My Car Not Me: Products Liability and Accidents Involving Autonomous Vehicles*, 2013 U. ILL. J.L. TECH. & POL'Y 247 (2013).

[291] JOHN VILLASENOR, BROOKINGS, PRODUCT LIABILITY AND DRIVERLESS CARS: ISSUES AND GUIDING PRINCIPLES FOR LEGISLATION (2014), https://www.brookings.edu/wp-content/uploads/2016/06/Products_Liability_and_Driverless_Cars.pdf [https://perma.cc/X96B-R455].

[292] Michael Rustad, *In Defense of Punitive Damages in Products Liability: Testing Anecdotes with Empirical Data*, 78 IOWA L. REV. 1 (1992) (noting that three out of every four punitive damage awards in products liability actions between 1965 and 1990 were for the failure to warn of known dangers and post-marketing failures to remedy known dangers).

driver workload."[293] Tesla's owner's manual also describes the "limitations" of autopilot, explaining that poor visibility, bright light, weather damage, things mounted on the car like a bike rack, wrappings or excess paint, narrow or winding roads, bumper issues, things that create ultrasonic waves, and extreme temperatures can all cause the autopilot "to be unable to function as intended."[294] It mentions that this list is not exhaustive and that the driver is still responsible.[295] Tesla updates its software over the internet and thus its vehicles do not need to be returned to the dealership for safety improvements.

In AV cases, as in conventional automobile cases, a vehicle may be properly designed and manufactured but considered defective if "an intended use of the product is dangerous, but the manufacturer did not provide sufficient warning or instruction."[296] Failure to warn is not a theory that meshes well for AVs, as the driver is generally passive.[297] Because the human is not the operator, it is unclear what passengers should do in the face of a warning for a known hazard.

In conventional vehicle cases, the warning is calculated so the driver can reduce the radius of the risk by taking precautions that are not relevant in AV operation. Conventional vehicles with backup cameras will usually display a message that they should not be relied upon by the human driver. The more complicated issue is that passengers of AVs have no way of opting out except by exiting the vehicle. The duty to warn applies to material risks and includes the obligation to give users adequate instructions for safe use and warnings of the material risks or dangers of improper use.[298]

The manufacturer's duty to warn is "against dangers resulting from foreseeable uses about which it knew or should have known, and . . . failure to do so was the proximate cause of the harm."[299] "An act cannot be the 'substantial cause' if the injury would have occurred regardless of the content of a defendant's warning."[300] Plaintiffs in a products liability action may also assert a claim of failure-to-warn theory based upon (1) informing buyers of hidden dangers and (2) instructing buyers on how to safely use a product.[301] Section 2 of the Restatement (Third) of Torts: Products Liability requires a

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[293] *Model S Owner's Manual*, TESLA (May 24, 2020), https://www.tesla.com/ownersmanual/models/en_us [https://perma.cc/32ZQ-Q2L7].
[294] *Id.*
[295] *Id.*
[296] Burton v. E.I. du Pont de Nemours and Co., 994 F.3d 791, 822 (7th Cir. 2021).
[297] Alfred R. Cowger, Jr., *Liability Considerations When Autonomous Vehicles Choose the Accident Victim*, 19 J. HIGH TECH. L. 1, 17 (2018):

> Even if the open-and-obvious doctrine does not act as a bar to a failure to warn claim, the failure-to-warn doctrine will still be inapplicable because the warning will not affect either the owner or occupant of the vehicle or the product operation itself. Before a warning can be questioned for adequacy, it must be shown that the warning would have altered a user's interaction with the product. However, in the case of a truly autonomous vehicle, any use of the product is completely passive. If a vehicle is operating autonomously, no warning will have any effect on the owner or user of the vehicle.

[298] Ryan J. Duplechin, *The Emerging Intersection of Products Liability, Cybersecurity, and Autonomous Vehicles*, 85 TENN. L. REV. 803, 821 (2018).
[299] Fuentes v. Scag Power Equip.-Div. of Metalcraft of Mayville, Inc., No. 2:17-cv-825 (DRH)(AKT), 2019 WL 3804735, at *7 (E.D.N.Y. Aug. 13, 2019).
[300] *Id.* (citing Sorto-Romero v. Delta Int'l Mach. Corp., No. 05-CV-5172 (SJF) (AKT), 2007 WL 2816191, at *11 (E.D.N.Y. Sept. 24, 2007) (citations omitted).
[301] Gurney, *supra* note 290, at 264.

product defect to be determined "at the time of sale or distribution."[302] The Restatement (Third) defines failure to warn or instruct as defective,

> because of inadequate instructions or warnings when the foreseeable risks of harm posed by the product could have been reduced or avoided by the provision of reasonable instructions or warnings by the seller or other distributor, or a predecessor in the commercial chain of distribution, and the omission of the instructions or warnings renders the product not reasonably safe.[303]

Similarly, Section 2(C) imposes a negligence-like standard in failure to warn cases.[304]

A product is defective if "the foreseeable risks of harm posed by the product could have been reduced or avoided by the provision of reasonable instructions or warnings by the seller."[305] In *Air & Liquid Systems Corp. v. DeVries*,[306] the U.S. Supreme Court stated how products liability rightly assumes that "the product manufacturer will often be in a better position than the parts manufacturer to warn of the danger from the integrated product."[307] The Court conceptualized a product makers' duty to warn in a maritime tort action as follows:

> [A] product manufacturer has a duty to warn when (i) its product requires incorporation of a part, (ii) the manufacturer knows or has reason to know that the integrated product is likely to be dangerous for its intended uses, and (iii) the manufacturer has no reason to believe that the product's users will realize that danger.[308]

"[T]he manufacturer is under a duty to provide adequate warning of those dangers that are reasonably foreseeable . . . . If the product is distributed without adequate warnings, then even if the benefits of the product outweigh the risks, an unreasonably dangerous product remains so, and the manufacturer is strictly liable to those who are foreseeably endangered."[309] "The interaction between software and hardware in automated vehicles raises interesting questions. Does a manufacturer that claims continued ownership of the software adopt a heightened duty to update, as well as potential liability from failure to warn?"[310] The 2016 Tesla Model S involved in the first fatal autonomous car crash had numerous warnings in the owner's manual.

> The Driver Assistance section includes 52 individual warnings and six cautions. Then, there is the "catch-all" informing the driver of ultimate responsibility: "Never depend on these components to keep you safe.

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[302] RESTATEMENT (THIRD) OF TORTS: PRODS. LIABILITY §2 (AM. L. INST. 1998).
[303] *Id*. at § 2(c).
[304] *Id.*
[305] *Id.*
[306] Air & Liquid Sys. Corp. v. DeVries, 139 S. Ct. 986, 994 (2019).
[307] *Id.*
[308] *Id.* at 955.
[309] Jackson v. Johns-Manville Sales Corp., 727 F.2d 506, 516 (5th Cir. 1984).
[310] Damien A. Riehl, *Car Minus Driver: Autonomous Vehicle Regulation, Liability, and Policy,* BENCH & BAR MINN., Nov. 2016, at 25-26 (available on Westlaw Secondary Sources).

It is the driver's responsibility to stay alert, drive safely, and be in control of the vehicle at all times."[311]

One of the consequences of the autonomous vehicles making decisions rather than humans is the need to adapt the rules of products liability:

> Product manufacturers have a legal duty to carefully design their products in a way that reasonably foresees risks of injury to those using their product reasonably. If little or no driver interaction is required with driverless cars, a myriad of conditions or combination of conditions could combine to cause an accident—even if it involves a foreseeable human operator panicking and interfering with the vehicle's automation. Consumers may even begin to rely too much on these early autonomous vehicles, leading to collisions resulting from inattentiveness.[312]

In *Air & Liquid Systems*, the U.S. Supreme Court explained that products manufacturers must warn or instruct about their products. [313] By placing the product on the market, the seller represents to the public that the product is fit; and the seller intends and expects that the product will be purchased and consumed in reliance upon that representation. The intermediary is no more than a conduit; a mechanical device through which the good sold reaches the consumer. The costs of accidents should be placed on the party best able to determine whether there are means to prevent that accident. When those means are less expensive than the costs of such accidents, responsibility for implementing them should be placed on the party best able to do so.

"A manufacturer must anticipate foreseeable misuse and also consider the particular hazard. When a product presents a serious risk of harm, the manufacturer must warn in a manner likely to catch the user's attention."[314] In autonomous vehicle cases, misuse by humans will not often be a defense asserted by the AV manufacturer or AV software component designer.

Thus, a plaintiff may argue that an auto-manufacturer either (1) had to warn consumers of any dangers they may face while using driverless car technology or (2) failed to instruct consumers on how to operate the driverless car. Manufacturers will attempt to minimize their exposure of failure-to-warn claims by requiring driverless car operators to watch an instructional video or partake in a driver's education class before purchasing said vehicle.[315]

A manufacturer is not subject to liability if the consumer used the vehicle in an unforeseeable way, as it was impossible for the manufacturer to know of the danger and thus warn the consumer.[316] It would be relatively easy to warn the occupants of autonomous vehicles of known dangers with a screen

[311] Faez Roger, *A Look at the Semi-Autonomous Road Ahead*, SME ADVISOR MIDDLE EAST, Jan. 30, 2017, 2017 WLNR 2977618.
[312] Gary Wickert, *Subrogating Automated Driving Systems and Autonomous Vehicle Failures*, CLAIMSJOURNAL.COM, (Dec. 28, 2021), 2021 WLNR 42173570.
[313] Air & Liquid Sys. Corp. v. DeVries, 139 S. Ct. 986, 997 (2019).
[314] Delery v. Prudential Ins. Co. of Am., 643 So. 2d 807, 814 (La. Ct. App. 1994).
[315] Gurney, *supra* note 290, at 265.
[316] Kyle Colonna, *Autonomous Cars and Tort Liability*, 4 J.L. TECH. & INTERNET 81, 106, 107 (2012).

displayed in the car. The occupants would have to acknowledge that they read the warnings before the vehicle could be operated.

In a strict liability failure-to-warn claim, a plaintiff must prove that the defendant's product was unreasonably dangerous and that the plaintiff was injured as a result or because of the defendant's failure to warn.[317] In contrast, "[a] negligent failure to warn claim requires proof of those two elements and proof of an additional element—that the defendant had a duty to warn of dangers known to it or dangers that, in the exercise of reasonable care, should have been known to it, and breached that duty."[318]

Section 4 of the Restatement (Third) explains the connection between liability for defective design and inadequate instructions or warnings:

> (a) a product's noncompliance with an applicable product safety statute or administrative regulation renders the product defective with respect to the risks sought to be reduced by the statute or regulation; and (b) a product's compliance with an applicable product safety statute or administrative regulation is properly considered in determining whether the product is defective with respect to the risks sought to be reduced by the statute or regulation, but such compliance does not preclude as a matter of law a finding of product defect.[319]

"A manufacturer must anticipate foreseeable misuse and also consider the particular hazard. When a product presents a serious risk of harm, the manufacturer must warn in a manner likely to catch the user's attention."[320] The duty to warn, like a design defect determination, depends upon the environment of use. In a failure-to-warn case, the reasonable manufacturer must warn when it knows of the product's harmful character. Under a manufacturer's duty to warn, there are two elements: informing buyers of hidden dangers and instructing buyers on how to safely use the products.

Knowledge of the danger about the product is a component of both claims.[321] The economist Ronald Coase coined the term "the least cost avoiders" meaning that the "efficient outcome requires looking at who has the lower cost of reducing or eliminating the externality."[322] In conventional vehicle crash cases, either the maker or the driver can avoid accidents. Giuseppe Dari-Mattiacci and Nuno Garoupa note that,

> When accidents can be avoided by either of two parties, it seems obvious to place liability on the least cost avoider, that is, the party who could have prevented the accident at the lowest cost. This approach is unanimously recognized as desirable, because not only

[317] Phipps v. Gen. Motors Corp., 363 A.2d 955, 958 (Md. 1976) (discussing the elements of a strict liability products liability action); Mazda Motor of Am. v. Rogowski, 659 A.2d 391, 394 (Md. Ct. Spec. App. 1995) (explaining that a product is defective if the seller fails to warn about latent defects when the failure will "cause the product to be unreasonably dangerous as marketed").

[318] Mack Trucks, Inc. v. Coates, No. 2709, 2018 Md. App. LEXIS 458 at *20 (Md. Ct. Spec. App. May 11, 2018).

[319] RESTATEMENT (THIRD) OF TORTS: PRODS. LIABILITY §4 (AM. L. INST. 1998).

[320] Delery v. Prudential Ins. Co. of Am., 643 So. 2d 807, 814 (La. Ct. App. 1994).

[321] Owens-Ill., Inc. v. Zenobia, 601 A.2d 633, 641 (Md. 1992) (holding that the knowledge component of an action for negligent failure to warn is applicable to a strict liability action).

[322] David R. Henderson, *Economic Lessons From COVID-19: What the Pandemic Has Re-Taught Us About the Perils of Planning, the Power of Incentives, and the Complexities of Externalities,* REASON MAG., June 2021, at 28, 31.

> does it induce parties to prevent accidents but it also forestalls wasteful care-taking by the party with the highest costs of care or, even worse, care-taking by both parties.[323]

The software designer is the least cost avoider given the complexity of the software in an AV that a reasonable consumer will neither understand nor be in a position to correct.

3. Design Defects

Section 2 of the Restatement (Third) defines a "design defect" as one that occurs when the foreseeable risks of harm posed by a product could have been reduced or avoided by the adoption of a "reasonable alternative design."[324] The definition replaces Section 402A of the Restatement (Second)'s "consumer expectation" test with the "risk/utility test."[325]

"A design defect . . . exists when the product is built in accordance with its intended specifications, but the design itself is inherently defective."[326] Doctrinal differences have evolved over what test to use in determining whether a product is defectively designed. Courts have adopted the risk-utility test, which weighs the product's risks against its benefits without a special requirement for a showing of an alternative reasonable design. If the product's utility, as designed, outweighs its risks, it is not defective.[327]

A Brookings Institution report on AVs noted that a case for design defect could theoretically be based upon a carmaker's failure to adequately instruct drivers that, under Level Two, they are responsible for monitoring the roadway and safe operation and they are expected to be available for control at all times and on short notice.

> Suppose that an autonomous vehicle manufacturer markets a vehicle that it claims has NHTSA level two automation. But what does "short notice" mean? Consider an accident that occurs because a human driver does not take over control of the autonomous vehicle quickly enough. In a products liability lawsuit, an injured party would likely argue that the autonomous vehicle had a design defect, because it should have been designed to provide the driver with more advanced warning. The manufacturer of the system might counter by arguing 1) that the system did provide sufficient advanced warning, and 2) that providing even more warning would necessitate adding very costly new sensors to the vehicle that would only increase the warning time

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[323] Giuseppe Dari-Mattiacci & Nuno Garoupa, *Least-Cost Avoidance: The Tragedy of Common Safety*, 25 J.L. ECON. & ORG. 235, 325–26 (2007).

[324] RESTATEMENT (THIRD) OF TORTS: PRODS. LIABILITY §2(b) (AM. L. INST. 1998).

[325] *Id.* (explaining that a product is defective in design when the foreseeable risks of harm posed by the product could have been reduced or avoided by the adoption of a reasonable alternative design by the seller or other distributor, or a predecessor in the commercial chain of distribution, and the omission of the alternative design renders the product not reasonably safe).

[326] McCabe v. Am. Honda Motor Co., 123 Cal. Rptr. 2d 303, 309 (Ct. App. 2002).

[327] *See* Ruwantissa Abeyratne, *The Deepwater Horizon Disaster--Some Liability Issues*, 35 TUL. MAR. L.J. 125, 134 (2010) (distinguishing the risk-utility test adopted by several jurisdictions from the reasonable standards test, which considers the adoption of a reasonable alternate design).

> so marginally as to make no practical difference in the time available to a driver to react.[328]

As in conventional vehicle cases, crashworthiness involves a separate and distinctive injury than those caused by the initial collision and should be recoverable.

> Any design defect not causing the accident would not subject the manufacturer to liability for the entire damage, but the manufacturer should be liable for that portion of the damage or injury caused by the defective design over and above the damage or injury that probably would have occurred as a result of the impact or collision absent the defective design.[329]

The burden of proving crashworthiness or enhanced injuries will be great because of the superior design of autonomous vehicles.[330] Crashworthiness will not be a significantly different formulation in AV accident cases because the physical components of driverless vehicles will be substantially similar to conventional vehicles.

a. *Consumer Expectation Test*

"The 'consumer expectation test' permits a plaintiff to prove design defect by demonstrating that 'the product failed to perform as safely as an ordinary consumer would expect when used in an intended or reasonably foreseeable manner.' "[331] This design defect test assumes that the manufacturer establishes consumers' expectations for a particular product in the form of advertising and other pitches determining purchasing decisions. Section 402A of the Restatement (Second) of Torts generally holds a manufacturer strictly liable for harm to a person or property caused by "any product in a defective condition unreasonably dangerous to the user."[332] A comment to section 402A states: "The rule is one of strict liability, making the seller subject to liability to the user or consumer even though he has exercised all possible care in the preparation and sale of the product."[333] The consumer expectation test does not mesh well with autonomous vehicles because of their complexity.[334] Under the consumer expectations test, a court will need to determine what expectations a reasonable consumer would have of an autonomous vehicle.

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[328] VILLASENOR, *supra* note 291, at 9.

[329] Davis v. Daimler Chrysler Corp., No. HHDX04CV065015721S, 2009 WL 323428, at *2 (Conn. Super. Ct. Jan. 12, 2009).

[330] Jeremy Levy, *No Need to Reinvent the Wheel: Why Existing Liability Law Does Not Need to Be Preemptively Altered to Cope with the Debut of the Driverless Car*, 9 J. BUS. ENTREPRENEURSHIP & L. 355, 382 (2016):

> Unless flaws unrelated to the driverless technology are present, applying the crashworthy test to driverless cars is unrealistic. Already possessing the newest safety and crash-avoidance systems, driverless car manufactures would likely use the defense that the devices used in their driverless car are cutting-edge technology, and a safer device does not yet exist, or was not available at the time of manufacture.

[331] Cruz v. Mathenge, No. B286067, 2019 Cal. App. Unpub. LEXIS 1332, at *36 (Feb. 26, 2019) (citing Barker v. Lull Eng'g Co., 573 P.2d 443 (Cal. 1978)).

[332] RESTATEMENT (SECOND) OF TORTS §402A (AM. L. INST. 1965).

[333] *Id.* at §402A, cmt. a.

[334] Gurney, *supra* note 290, at 260–62.

> The initial argument is simple—self-driving vehicles should drive themselves without mishap, although such an expectation may be unrealistic based on new and developing technology. On the one hand, self-driving technology is incredibly complex and so there is an argument that the test cannot be utilized because reasonable consumers might not expect perfection. However, if allowed and the facts can be proven, then this test may well be a potential avenue for recovery.[335]

Driverless car operators necessarily expect the vehicle to operate on its own, but when a driverless car deviates from the consumer's expectations and results in an accident, then a consumer expectations jurisdiction may allow the plaintiff to utilize the test.[336] However, the consumer expectation test is not well suited for AV design defect cases because relatively few consumers will have any understanding of how driverless cars work. The consumer expectation test focuses on what consumers expect when a product is used in foreseeable way.[337] It is unclear what the ordinary consumer expectation would be for autonomous vehicles (AVs). "Will the 'ordinary consumer' expect less from autonomous vehicles while the technology is in its infancy?"[338] Courts have been reluctant to apply the consumer expectation test to traditional

b. Risk-Utility Test

Plaintiffs may establish defective design alternatively through a consumer expectation or a risk utility test.[339] Under the consumer expectation test, "the plaintiff demonstrates that the product failed to perform as safely as an ordinary consumer would expect when used in an intended or reasonably foreseeable manner."[340] Under the risk-utility test, a product is defectively designed "[i]f the plaintiff proves that the product's design proximately caused his injury and the defendant fails to prove, in light of the relevant factors discussed above, that on balance the benefits of the challenged design outweigh the risk of danger inherent in such design."[341] automobiles and autonomous technology is more complex.[342]

In contrast, a court applying the risk/utility test will determine whether the maker of the AV should have designed the AV to function under

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335 Roy Alan Cohen, *Self-Driving Technology and Autonomous Vehicles: A Whole New World for Potential Product Liability Discussion*, 82 DEF. C. J. 328 (2015).

336 Gurney, *supra* note 290, at 261.

337 Brent Steinberg, *Autonomous Vehicles and Transportation Network Companies*, *in* FLORIDA BAR, FLORIDA AUTOMOBILE INSURANCE LAW § 9.2(F)(6)(c) (2020):

> Florida adheres to the "consumer expectations test," as set forth in the S[econd] R[estatement] for product liability claims, premised upon an alleged design defect. That test "considers whether a product is unreasonably dangerous in design because it failed to perform as safely as an ordinary consumer would expect when used as intended or in a reasonably foreseeable manner." (quoting Aubin v. Union Carbide Corp., 177 So. 3d 489, 510 (Fla. 2015)).

338 *Id.* (citation omitted).

339 Barker v. Lull Eng'g Co., 573 P.2d 443, 457–58 (Cal. 1978).

340 *Id.* at 457.

341 *Id.* at 457–58.

342 Jeffrey K. Gurney, *Sue My Car Not Me: Products Liability and Accidents Involving Autonomous Vehicles*, 2013 U. ILL. J.L. TECH. & POL'Y 247, 261 (2013).

conditions that are more rigorous.[343] Under such a test, a product's design is defective if the costs of avoiding a particular hazard are foreseeably less than the resulting safety benefits. The burden is on the AV software designer to demonstrate that its product is reasonably designed with sufficient redundancy to function in complex driving conditions. The risk-utility test is a cost benefit test that will be easier to apply to driverless cars than the consumer expectation test.

c. Restatement (Third) Risk Utility Test Requiring Alternative Design

In 1997, the American Law Institute (ALI) approved the Restatement (Third) of Torts: Products Liability.[344] The Restatement (Third) created a third test representing a retreat from strict liability, thereby making it more difficult for plaintiffs to prevail.[345] The Restatement (Third) of Torts: Products Liability defines a "design defect" as that which occurs when the foreseeable risks of harm posed by the product could have been reduced or avoided by the adoption of a "reasonable alternative design."[346] A product is defective if "the foreseeable risks of harm posed by the product could have been reduced or avoided by the provision of reasonable instructions or warnings by the seller."[347]

Even though the Restatement (Third)'s risk-utility test is conceptualized as strict liability, it is, in fact, a retreat to negligence, a variant of Judge Learned Hand's famous balancing test.[348] Strict liability "focuses on the nature of the defendant's product, whereas liability in negligence 'hinges in large part on the defendant's conduct under circumstances involving a foreseeable risk of harm.' "[349] The Restatement (Third)'s emphasis on the foreseeable risks of harm posed by the product incorporates fault-based negligence "that belies a strict liability basis."[350]

A number of courts have declined to adopt the Restatement (Third)'s requirement that plaintiffs prove a reasonable alternative design.[351] A

[343] RESTATEMENT (THIRD) OF TORTS: PRODS. LIAB. § 2(D) (AM. L. INST. 1998) (adopting the Restatement (Third) require the plaintiff to prove a reasonable alternative design as an absolute requirement for liability).

[344] RESTATEMENT (THIRD) OF TORTS: PRODS. LIABILITY (AM. L. INST. 1998).

[345] Michael L. Rustad & Thomas H. Koenig, *The Tort of Negligent Enablement of Cybercrime*, 20 BERKELEY TECH. L.J. 1553 (2005) ("It seems unlikely that the courts adopting the Restatement will be receptive to stretching product liability concepts to software, digital information, and other intangibles.").

[346] RESTATEMENT (THIRD) OF TORTS: PRODS. LIAB. § 2(b) (AM L. INST. 1998).

[347] *Id.* at §2(c).

[348] Learned Hand's famous formula was devised in United States v. Carroll Towing Co., 159 F.2d 169, 173 (2d Cir. 1947):

> Since there are occasions when every vessel will break from her moorings, and since, if she does, she becomes a menace to those about her; the owner's duty, as in other similar situations, to provide against resulting injuries is a function of three variables: (1) The probability that she will break away; (2) the gravity of the resulting injury, if she does; (3) the burden of adequate precautions. Possibly, it serves to bring this notion into relief to state it in algebraic terms: if the probability be called P; the injury, L; and the burden, B; liability depends upon whether B is less than L multiplied by P: i.e., whether B less than PL.

[349] Burton v. E.I. du Pont de Nemours & Co., Inc., 994 F.3d 791, 818 (7th Cir. 2021).

[350] THOMAS GALLIGAN JR., PHOEBE HADDON, FRANK L. MARAIST, FRANK MCCLELLAN, MICHAEL L. RUSTAD, NICHOLAS TERRY AND STEPHANIE M. WILDMAN, TORT LAW: CASES PERSPECTIVES AND PROBLEMS (New York, New York: LexisNexis 2007).

[351] The Connecticut Supreme Court in Potter v. Chicago Pneumatic Tool Co., 694 A.2d 1319, 1331 (Conn. 1996), found (1) six jurisdictions affirmatively state that a plaintiff need not show a feasible alternative design in order to establish a manufacturer's liability for design defect; (2) sixteen jurisdictions hold that a feasible alternative design is merely one of several factors that the jury may consider in

majority of U.S. jurisdictions do not require the plaintiff to demonstrate a reasonable alternative design to prevail in a risk-utility test for design defect.[352] The Wisconsin Supreme Court rejected the Restatement (Third)'s requirement that the plaintiff demonstrates a reasonable alternative design as reallocating costs to the plaintiff rather than the defendant manufacturer: "Where a manufacturer places a defective and unreasonably dangerous product into the stream of commerce, the manufacturer, not the injured consumer, should bear the costs of the risks posed by the product. Because 2(b) unduly obstructs this equitable principle, we refuse to adopt 2(b) into Wisconsin law."[353]

4. Malfunction as Circumstantial Proof of Defect

Expanding the concept of a defect to include "product malfunction" will alleviate a difficult burden of proof for plaintiffs seeking recovery for injury or damages caused by AVs. Some states already allow plaintiffs to apply the malfunction theory in product liability cases where it is too difficult to prove a defect.[354] Malfunction theory is an alternative to "circumstantially prove

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determining whether a product design is defective; (3) three jurisdictions require the defendant, not the plaintiff, to prove that the product was not defective; and (4) eight jurisdictions require that the plaintiff prove a feasible alternative design in order to establish a prima facie case of design defect.

[352] In Delaney v. Deere & Co., 999 P.2d 930, 945–46 (Kan. 2000), the Supreme Court of Kansas rejected the Restatement (Third)'s requirement that plaintiffs show a reasonable alternative:

> In rejecting Comment l, we agree that as the foreword to the Third Restatement makes clear, the new Restatement "goes beyond the law." Hazard, Foreword to Restatement (Third) of Torts, xv, xvi (1997). Rather than simply taking a photograph of the law of the field, the Third Restatement goes beyond this to create a framework for products liability. We have examined Comment l and find it wanting. The adoption of Comment l necessarily involves the adoption of the reasonable alternative design standard and an exclusive risk/utility analysis of that reasonable alternative design to determine whether the subject product is defective.

This is contrary to the law in Kansas. While the Third Restatement was intended to restate the law as decided by state courts and state legislatures, various courts have criticized its discussion of strict products liability, emphasizing that it "goes beyond the law" because "[r]ather than simply taking a photograph of the law of the field," the Third Restatement attempts to create a framework for strict products liability by urging the adoption of the reasonable alternative design standard and an exclusive risk/utility analysis, notwithstanding that the majority of jurisdictions in this country do not require a reasonable alternative design in strict products liability actions.

See also Potter v. Chicago Pneumatic Tool Co., A.2d 1319, 1331 (Conn. 1996) ("[O]ur independent review of the prevailing common law reveals that the majority of jurisdictions do not impose upon plaintiffs an absolute requirement to prove a feasible alternative design."). The Connecticut Supreme Court's survey of jurisdictions concluded that only "eight jurisdictions require that the plaintiff prove a feasible alternative design in order to establish a prima facie case of design defect." *See generally* John Vargo, *The Emperor's New Clothes: The American Law Institute Adorns a 'New Cloth' for Section 402A Products Liability Design Defects—A Survey of the States Reveals a Different Weave*, 26 UNIV. MEM. L. REV. 493 (1996) (arguing that the Restatement (Third)'s reasonable alternative design requirement is not followed by most jurisdictions); Frank J. Vandall, *The Restatement (Third) of Torts: Products Liability Section 2(b): The Reasonable Alternative Design Requirement*, 61 TENN. L. REV. 1407, 1428 (1994) ('The centerpiece of the Restatement (Third) of Torts: Products Liability is the requirement that the plaintiff present evidence of a reasonable alternative design as part of her prima facie case. This requirement is not supported by the majority of the jurisdictions that have considered the question.').

[353] Green v. Smith & Nephew AHP, Inc., 629 N.W.2d 727, 801-02 (Wis. 2001):

> In sum, the Sumnicht factors must be understood and applied in light of the consumer-contemplation test. Instead of abrogating or redefining Wisconsin's products liability standard, Sumnicht reiterated this state's devotion to the consumer-contemplation test: Wisconsin strict products liability law applies the consumer-contemplation test and only the consumer-contemplation test in all strict products liability cases.

[354] *See* Pitts v. Genie Indus. Inc., 921 N.W.2d 597 (Neb. 2019) (showing the Nebraska Supreme Court elected to expand the doctrine of strict products liability by adopting the malfunction theory of strict

that a product is defective by showing evidence of a malfunction and eliminating abnormal use or reasonable, secondary causes for the malfunction."[355]

A plaintiff injured by an autonomous vehicle may utilize the malfunction doctrine, whereby they can demonstrate a manufacturing defect, without necessarily proving how it was defective by showing: (1) the product malfunctioned, (2) the malfunction occurred during proper use, and (3) the product had been altered or misused in a manner that probably caused the malfunction.[356] A manufacturer can be found strictly liable for dangerous manufacturing defects even if it has exercised all possible care in preparing the product.[357] Malfunction theory may help plaintiffs in cases where dangerously defective software components in AVs caused injury or death.

> Consider a programming error or bug in the software that causes the operating system to crash, in turn causing the vehicle to crash. In these cases, the plaintiff would not have to identify the specific coding error and could instead prove defective design solely based on the manner in which the operating system misperformed. According to the *Restatement (Third) of Torts*, product performance is a sufficient substitute for direct proof of defect when it "was of a kind that ordinarily occurs as a result of product defect; and . . . was not, in the particular case, solely the result of causes other than a product defect existing at the time of sale or distribution." Because the defect in these cases is inferred from the product misperformance, the *Restatement (Third)* calls such performance a "malfunction," a usage adopted by some courts and commentators. . . . Based on this definition, a malfunction would occur if a coding error caused the operating system to crash, resulting in a crash of the autonomous vehicle. The coding error prevented the operating system from performing its manifestly intended function of executing the dynamic driving task, subjecting the manufacturer to liability for the crash.[358]

The plaintiff will have the burden to show that an AV failed or caused harm or injury because of a manufacturing defect.[359] Plaintiffs in some

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products liability from the Restatement (Third) § 3); Dubas v. Clark Equip. Co., 532 F. Supp. 3d 819, 826 (D. Neb. 2021):

> The malfunction theory allows plaintiffs to recover by providing circumstantial evidence when there is no direct evidence of a specific design defect. This expansion of strict-products-liability doctrine suggests that the Nebraska Supreme Court is likely in favor of a flexible approach in order to increase the opportunities for plaintiffs to recover under theories of product liability. This aligns with the Court's general policy of permitting strict products liability claims, which is to "exonerat[e] a claimant from what is frequently an insurmountable burden of proof" in products-liability actions. (citations omitted).

[355] Gus Sara, *Examination of the Product Does Not Stop a Pennsylvania Court from Applying the Malfunction Theory*, JD SUPRA (May 21, 2021), https://www.jdsupra.com/legalnews/examination-of-the-product-does-not-934071 [https://perma.cc/8A4C-FQYT].

[356] Gurney, *supra* note 290, at 259.

[357] VILLASENOR, *supra* note 291, at 9.

[358] Geistfeld, *supra* note 64, at 1634.

[359] Owen, *supra* note 278, at 855:

> Manufacturing defect claims possess certain advantages for plaintiffs over claims involving design and warnings defects. First, the defendant is less likely to invest as much in defending a manufacturing defect claim since it challenges only a single product unit rather than the entire line of products. In addition, and quite unlike design and warnings cases, the liability standards for manufacturing defects – departure from intended design and product malfunction – are still

jurisdictions may use circumstantial evidence to prove a product malfunctioned.

> Under this approach, plaintiffs would only have to show that "(1) the product malfunctioned, (2) the malfunction occurred during proper use, and (3) the product had not been altered or misused in a manner that probably caused the malfunction." For example, a court found Toyota's vehicle at fault by applying the principles of *res ipsa loquitor* regarding an alleged sudden acceleration claim against Toyota when there was no traceable record plaintiffs could find from the defective vehicle. Courts might not always accept this theory, and they may disallow "plaintiffs or juries to rely on guess, conjecture, or speculation." But, manufacturers should be wary of the uncertainty and lack of clarity surrounding their potential liability.[360]

The Department of Transportation will need to "[m]odernize regulations as existing Federal regulations and standards may pose challenges to the widespread integration of automated vehicles."[361] The federal government will also help provide best practices and encourage voluntary technical standards, and "will pursue strategies to address regulatory gaps or unnecessary challenges that inhibit a safe and reasonable path to full commercial integration."[362] "As of May 2019, fourteen companies had released Voluntary Safety Self-Assessments detailing how they will incorporate safety into their design and testing of automated driving systems."[363]

Driverless carmakers have a duty of care when it comes to installing, updating, or adjusting software so that it is reasonably fit for its environment of use. In October 2019, the NHTSA investigated "a claim that Tesla should have recalled Model S sedans and Model X SUVs that were given a software update meant to prevent battery fires," which allegedly "reduced the range of affected vehicles."[364] A California law firm alleged that "drivers saw the range of their Teslas fall by 25 miles or more after Tesla released two battery management software updates beginning in May 2019. "NHTSA estimates 2,000 Model S and Model X vehicles were affected."[365]

The NHTSA also investigated a complaint from a driver of a 2015 Tesla S 85D. The driver recounted that his car was locked when "moments later the vehicle started accelerating forward towards the street and crashed into a parked car."[366] "Another complaint said a Tesla driver in Andover,

explicitly "strict." Moreover, manufacturing defect cases may be immune from certain types of defenses applicable to other types of cases.

[360] Sunghyo Kim, *Crashed Software: Assessing Product Liability for Software Defects in Automated Vehicles*, 16 DUKE L. & TECH. REV. 300, 305 (2018) (citations omitted).

[361] U.S. DEP'T. OF TRANS., *supra* note 69.

[362] *Id.*

[363] NAT'L SCI. & TECH. COUNCIL, EXEC. OFFICE OF THE PRESIDENT, THE NATIONAL ARTIFICIAL INTELLIGENCE RESEARCH AND DEVELOPMENT STRATEGIC PLAN: 2019 UPDATE (June 2019).

[364] Mark Matousek, *NHTSA is Investigating a Claim That a Tesla Software Update Meant to Prevent Battery Fires Hurt the Range of Some Model S and Model X Vehicles*, BUS. INSIDER (Oct. 4, 2019).

[365] Ryan Beene, *NHTSA Evaluating Complaint About Alleged Flaw in Tesla Cars*, INDUS. WK. (Oct. 4, 2019).

[366] David Shepardson, *U.S. Will Look at Sudden Acceleration Complaints Involving 500,000 Tesla Vehicles*, REUTERS, (Jan. 17, 2020).

Massachusetts was approaching her garage door 'when the car suddenly lurched forward' and 'went through the garage door destroying two garage doors.' The Tesla stopped when it hit the garage's concrete wall."[367]

A California court did allow a design defect claim to go forward in a case involving the Tesla Model X in *Izzetov v. Tesla Inc*.[368] The plaintiffs' product liability case arose out of an injury which was suffered when her "finger became caught in the vehicle's door-locking mechanism" while she was attempting to get into her Model X Tesla.[369] The court described the Tesla Model X's rear doors as being powered by electric motors that had a "falcon wing design opening upwards."[370]

> These doors open upwards. In contrast, the front doors, much like on a conventional vehicle, are hinged at the front and open outwards. These front doors, however, have electric motors built-in such that the doors can open and close with minimal physical effort. When activated, these front doors can automatically open between 20 to 45 degrees (the breadth depends on whether any obstacles are detected by the sensors). Once a person "presses" the exterior door handle, the door will open. However, if the electric door motor senses resistance, an "ice breaker" deploys. The ice breaker senses external pressure to the door (like an ice formation between the door and the body-mounted seals) and "breaks" any resistance to help the door motor open the door. The icebreaker is rectangular, with a hollow center. The icebreaker is supposed to retract back into the frame of the door after it is deployed.[371]

The court described how the accident occurred; one of the plaintiffs, a child, pressed the front door handle in order to open the right front door, which caused the door to open approximately 20 degrees, resulting in her hand becoming trapped in the ice breaker.

> Plaintiff MMI proceeded to manually open the door by pulling the back edge of the front doorframe towards her. The ice breaker was at Plaintiff MMI's hand height as she reached out to touch the door. As Plaintiff MMI placed her hand on the back edge of the door frame, her finger was placed in the hollow space of the ice breaker, which had not safely retracted into the doorframe. Once her finger was in the ice breaker, the ice breaker began to automatically retract. As a result, Plaintiff MMI's finger was trapped inside the ice breaker. Plaintiff MMI's finger allegedly became embedded inside the Tesla's metal door frame. Plaintiff Izzetov tried to release his daughter's finger, but could not. Ultimately, emergency services had to use special metal-cutting equipment to cut through the Tesla's doorframe and ice-breaker to release Plaintiff MMI's finger from the door. It took responders two hours to free Plaintiff MMI's finger.[372]

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[367] *Id.*

[368] Izzetov v. Tesla Inc., No. 5:19-cv-03734-EJD, 2020 U.S. Dist. LEXIS 60261 (N.D. Cal. Apr. 6, 2020).

[369] *Id.* at *2.

[370] *Id.*

[371] *Id.* at *2–*3 (citations omitted).

[372] *Id.* at *3–*4 (citations omitted).

The court refused to dismiss the plaintiff's claim, which said that the Tesla Model X was defectively designed and unreasonably dangerous,

> because it was designed, manufactured and sold with a Locking Mechanism and Latch that malfunctions, including during the Incident. Tesla manufactured, distributed, and sold the Tesla Model X, the product contained a manufacturing defect when it left Tesla's possession, the plaintiffs were harmed and a substantial factor in causing such harm was the product's defect.
>
> From the allegation that the Tesla was manufactured with a malfunctioning part, the Court can draw the reasonable inference that Defendant allegedly manufactured a car with a design defect. Hence, at present, Plaintiffs' allegations that the car was defective are sufficient to support Plaintiffs' design defect claim.[373]

D. Difficulties of Applying Strict Liability to Software

1. The Overdeterrence Problem

Applying strict product liability to driverless vehicles may create too much liability on the automaker, deterring manufacturers from developing new autonomous automobiles. Strict liability may also deter insurance companies from offering insurance policies to cover these vehicles, given that they will be liable for all accidents caused by the vehicle.[374] It is the manufacturer, not the driver, who will be liable in most autonomous vehicle products liability cases.[375] In traditional car accident cases, the driver is liable in most instances and the manufacturer is liable only if it was likely that a product defect contributed to the accident.

2. Conceptualizing Software as a Defective Product

"In this era of mobile software applications, it is difficult to fathom that the term 'software' was not even part of the popular lexicon prior to 1970. Back then, software was neither separately priced nor marketed, but was included with the hardware in a turnkey computer system."[376] Courts have been reluctant to extend products liability to software because it is intangible.[377] "To date, there have been no reported cases holding a software manufacturer strictly liable for defects in the software."[378] The courts have

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[373] *Id.* at *11 (citations omitted).

[374] Duffy & Hopkins, *supra* note 33, at 473.

[375] *See* Greg Walden, *Driverless Cars Crash into the Trolley Problem,* CORP. COUNSEL BUS. J. (Sept. 6, 2018), http://www.ccbjournal.com/articles/driverless-cars-crash-trolley-problem https://perma.cc/CF67-D4BR].

[376] Michael L. Rustad & Maria Vittoria Onufrio, *Reconceptualizing Consumer Terms of Use for a Globalized Knowledge Economy*, 14 UNIV. PA. J. BUS. L. 1085 (2012).

[377] Gurney, *supra* note 290, at 258–59; Duplechin, *supra* note 298, at 821; Rustad & Koenig, *supra* note 345, at 1567, 1579 n.139; Michael Scott, *Tort Liability for Vendors of Insecure Software: Has the Time Finally Come?*, 67 MD. L. REV. 425 (2008) ("To date, there are no reported decisions in the United States holding a software vendor liable under a strict [products] liability theory.").

[378] *See* Frances E. Zollers, Andrew McMullin, Sandra N. Hurd & Peter Shears, *No More Soft Landings for Software: Liability for Defects in an Industry That Has Come of Age,* 21 SANTA CLARA COMPUT. & HIGH TECH. L.J. 745 (2005).

classified software under contract law rather than products liability as applied to intangibles and services.[379]

3. Weighing Operators' Fault

The software industry contends that it is unfair to impose product liability on them as "software is a highly complex product, often misused or modified by consumers."[380] It is likely that the operator's insurance carrier will be liable if the autonomous vehicle is at fault.[381] As autonomous vehicles go mainstream, new liability rules will become necessary in order to address who is liable if the vehicle—while engaged in automated mode—gets into an accident because of operator fault. An example of operator fault would be the failure of the operator to be in the driver's seat.[382]

Operators sometimes continue driving their conventional vehicles after getting into fender benders without consequence. Operators who continue driving their autonomous vehicles after a minor accident will create excessive preventable dangers because a key sensor could be damaged by a slight collision. Another major difference between traditional and autonomous vehicle cases is that drivers will be less likely to be liable for accidents. The more autonomous the vehicle, the less likely it will be that a human operator is the cause of the accident; more likely, the vehicle's malfunctioning software will have been at fault. However, in one scenario, operators may still be held responsible:

> [A] company that rents a fleet of autonomous vehicles or uses them like Uber or Lyft. If there's an accident, the driver of the non-autonomous car may sue the company that has the fleet as well as the manufacturer. And the operator could file a third-party complaint against the manufacturer or vice versa.[383]

During the transition to fully autonomous vehicles, there may well be driver liability raised by the following questions:

> Did the human override the computer? Was the human paying attention--and to a sufficient degree? Did the computer properly alert the human? Did the computer notify the human early enough? Did the computer misinterpret data? The fact-specific queries and aggregate

[379] In the past, products liability law has drawn a bright-line distinction between injuries caused by tangible and intangible products. Generally, computer code has been thought of as a "service" and not considered a "product." However, this notion is shifting as software is increasingly implemented into physical machinery, such as the modern connected automobile.

[380] Steve Lohr, *Product Liability Lawsuits Are New Threat to Microsoft*, N.Y. TIMES (Oct. 6, 2003), https://www.nytimes.com/2003/10/06/business/product-liability-lawsuits-are-new-threat-to-microsoft.html [https://perma.cc/B3GR-UAJV].

[381] Colorado, Pennsylvania and Virginia are the only states that have no requirement of liability insurance for autonomous vehicles, while the insurance issue is not addressed in Hawaii. *Autonomous Vehicle Laws,* IIHS-HLDI, (Sept. 2022), https://www.iihs.org/topics/advanced-driver-assistance/autonomous-vehicle-laws https://perma.cc/7JZK-KLZP].

[382] *Id.* Alabama, California, Kansas, Louisiana, Maine, Tennessee, and Texas have no requirement that a human operator be in an autonomous vehicle that is driving in automated mode. Arizona, Arkansas, Florida, Georgia, Iowa, Nebraska, Nevada, New Hampshire, New Mexico, North Carolina, North Dakota, and Pennsylvania determine whether a human operator is necessary by the automated level of the vehicle. Florida's autonomous vehicle statute states: "A vehicle that does not require a human to take over driving (Level 4 or Level 5 of the SAE Levels of Driving Automation) does not require a human to be in the vehicle." Colorado and Virginia have not addressed the requirement of a human operator. *Id.*

[383] Walden, *supra* note 375.

test cases to determine liability will likely be crafted by insurers, litigators, and regulators.[384]

Assigning liability to the owner of a driverless vehicle is problematic unless, at the time of purchase, owners agree to assume the risk of all harm regardless of the cause. "The underlying idea of the assumption of risk defense is that a user has fully consented to incur a risk which he or she fully comprehends."[385] The typical consumer will seldom understand autonomous vehicles or software components, and will be unlikely to override software settings. The defense of assumption of risk includes the following key points: "(1) consent or acquiescence in (2) an appreciated or known (3) risk."[386] "Express assumption of risk would arise where a person expressly contracts with another not to sue for any future injuries which may be caused by that person's negligence."[387] Both primary and secondary assumption of risk assume that the plaintiff is assuming a known risk, which is unlikely given the complexity of software deployed in AVs.

> In cases involving "primary assumption of risk"—where, by virtue of the nature of the activity and the parties' relationship to the activity, the defendant owes no legal duty to protect the plaintiff from the particular risk of harm that caused the injury—the doctrine of assumption of risk continues to operate as a complete bar to the plaintiff's recovery. In cases involving "secondary assumption of risk"—where the defendant does owe a duty of care to the plaintiff, but the plaintiff proceeds to encounter a known risk imposed by the defendant's breach of duty—the doctrine is merged into the comparative fault scheme, and the trier of fact, in apportioning the loss resulting from the injury, may consider the relative responsibility of the parties.[388]

The Restatement (Third) of Torts represents a retreat from strict liability making it more difficult for plaintiffs to prevail.[389] The Restatement (Third) limits strict liability to manufacturing defect cases, which impose negligence-based standards in design, and warning cases. If a product's utility, as designed, outweighs its risks, the product's design is not defective. The American Law Institute approved the Restatement (Third) of Products Liability in 1997, which replaces the Restatement (Second)'s strict products liability with negligence-based standards in design and failure to warn cases.[390] Section 1 of the Restatement (Third) of Torts: Products Liability makes each seller in the chain of distribution liable if there is proof that the product was sold with a defect.[391]

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[384] Riehl, *supra* note 310.
[385] DAVID OWEN & MARY J. DAVIS, OWEN & DAVIS ON PRODUCTS LIABILITY § 13:13 Assumption of Risk (4th ed. May 2022).
[386] Anderson v. Ceccardi, 451 N.E.2d 780, 782 (Ohio 1983).
[387] *Id.* at 783.
[388] Knight v. Jewett, 834 P.2d 696, 707–08 (Cal. 1992).
[389] Rustad & Koenig, *supra* note 345, at 1577 ("It seems unlikely that the courts adopting the Restatement will be receptive to stretching product liability concepts to software, digital information, and other intangibles.").
[390] *See* RESTATEMENT (THIRD) OF TORTS: PRODS. LIABILITY § 2.
[391] *Id.* § 1.

A cause of action under strict liability "cover[s] the sale of any product which, if it should prove to be defective, may be expected to cause physical harm to the consumer or his property."[392] For driverless cars, the manufacturer is the "adequate risk bearer."[393] With the safety concerns that accompany the introduction of driverless vehicles, it is desirable to incentivize the manufacturers of these vehicles to make improvements in safety design.[394] A concern with shifting liability to vehicle manufacturers is that their liability exposure may pose as a disincentive to manufacture AVs, thus reducing the production of automated vehicles.[395] The plaintiff need only establish that a defect in software proximately caused injury or damage to recover in strict products liability.[396]

Plaintiffs face barriers to products liability suits because they must impeach the design of a complex AV. Expert testimony will be necessary to demonstrate that an AV line of vehicles has a design defect and that there is a reasonable alternative design.[397] Requiring the plaintiff to hire an expert witness to testify about an alternative design may exceed any cost of repairing the driverless vehicle.[398] However, if a manufacturer uses a subsequent update in the vehicle's algorithm (or a safety update), then a plaintiff may rely on such behavior as evidence of a reasonable alternative design,[399] but Federal Rule of Evidence 407 prohibits the introduction of subsequent remedial measures by a manufacturer in federal courts.[400]

A Brookings Institution Report notes that AV makers will be held liable if these vehicles are tested only on dry roads when the braking systems are not reliable on wet roads: "He or she could argue that his or her injuries were directly attributable to the manufacturer's negligent failure to anticipate driving in wet conditions as a reasonably foreseeable use of a car equipped with the fully automated braking system."[401] Software innovation will likely result in new technologies for risk reduction:

> [W]hen the technologies become cheap enough, it becomes plausible to claim that a manufacturer is negligent for designing a deadly machine that fails to inexpensively surveil its operator for signs of dangerous driving and to inexpensively report the operator's dangerous driving to the authorities.[402]

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[392] *See* RESTATEMENT (SECOND) OF TORTS § 402A cmt. b (AM. L. INST. 1965).

[393] Melinda Florina Lohmann, *Liability Issues Concerning Self-Driving Vehicles*, 7 EUR. J. RISK REG. 335, 338 (2016).

[394] *Id.*

[395] *Id.*

[396] *See generally* Diane B. Lawrence, *Strict Liability, Computer Software and Medicine: Public Policy at the Crossroads*, 23 TORT & INS. L.J. (1987).

[397] *Id.*; Steven Wittenberg, *Automated Vehicles: Strict Products Liability, Negligence Liability and Proliferation*, ILL. BUS. J. (Jan. 7, 2016), https://publish.illinois.edu/illinoisblj/2016/01/07/automated-vehicles-strict-products-liability-negligence-liability-and-proliferation/ [https://perma.cc/4G7N-LC4W].

[398] Gurney, *supra* note 290, at 266.

[399] *Id.*

[400] *Id.*; *see also* FED. R. EVID. 407.

[401] JOHN VILLASENOR, BROOKINGS INSTITUTION, PRODS. LIAB. AND DRIVERLESS CARS: ISSUES AND GUIDING PRINCIPLES FOR LEGIS., EXEC. SUMMARY (Apr. 2014).

[402] Eugene Volokh, *Tort Law vs. Privacy*, 114 COLUM. L. REV. 879, 885 (2014).

E. PROOF OF A DEFECT IN DRIVERLESS CAR CASES

Driverless car accidents caused by defective software components or design defects in physical components create products liability for manufacturers and those sellers or other intermediaries within the chain of distribution.[403] The general standard for products liability is that the product be fit for its environment of use. The proof of a defect is the *sine qua non* of an autonomous vehicle defective products liability claim.[404] Section 1 of the Restatement (Third): Products Liability makes each seller in the chain of distribution liable if there is proof that the product was sold with a defect.[405] Two major issues need to be addressed when applying products liability to products that incorporate artificial intelligence:

> The first is how to apply the law of products liability on the assumption that any liability concern with the machine is the result of human (but not driver) error—that is, a design or manufacturing defect, an information defect, or a failure to instruct humans on the safe and appropriate use of the product. . . . [T]he application of these reasonably settled principles is a straightforward one, and there is no justification for treating even autonomous thinking machines differently than any other machine or tool a human may use, except, perhaps, holding them to a higher standard of care.
>
> The second question comes into play if, and only if, fully autonomous machines cause injury in ways wholly untraceable and unattributable to the hand of man. . . . It is fair to assume that, if driver-less cars become the norm, there will be accidents, perhaps few and far between, that cannot fairly be attributed to a design, manufacturing, or programming defect. . . . Tort law is ordinarily unwilling to let people injured through no fault of their own bear costs imposed by others. Therefore, the question then becomes, "Who pays?" The only feasible approach, it would seem, would be to infer a defect of some kind on the theory that the accident itself is proof of defect, even if there is compelling evidence that cuts against a defect theory. There is precedent for courts making such an inference, which is simply a restatement of *res ipsa loquitor.*[406]

AVs pose unique risk factors from failed sensors, software defects, and hardware failure in addition to traditional product failures such as tire blowouts, steering column failure, or fuel tank explosions.[407] Aside from the

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[403] *See* Jack Boeglin, *The Costs of Self-Driving Cars: Reconciling Freedom and Privacy with Tort Liability in Autonomous Vehicle Regulation*, 17 YALE J.L. & TECH. 171, 186 n. 66 (2015).

[404] MARSHALL S. SHAPO, 1 SHAPO ON THE LAW OF PRODUCTS LIABILITY (New York, New York: Wolters Kluwer Law and Business, 2013 at §8.01 at 8-5 (Significance of Defect).

[405] RESTATEMENT (THIRD) OF TORTS: PRODS. LIABILITY § 1 (AM. L. INST.1998).

[406] David C. Vladeck, *Machines Without Principals: Liability Rules and Artificial Intelligence*, 89 WASH. L. REV. 117, 127–28 (2014) (citations omitted).

[407] *See* Lance Eliot, *Essential Stats for Justifying and Comparing Self-Driving Cars to Humans at the Wheel*, FORBES (May 30, 2019, 11:18 AM), https://www.forbes.com/sites/lanceeliot/2019/05/30/essential-stats-for-justifying-and-comparing-self-driving-cars-to-humans-at-the-wheel/#2e80f28746 ed [https://perma.cc/RQ7E-63N4]:

> We are going to have autonomous cars that get into car accidents, which can happen because something goes awry in the autonomous car (like encountering an AI software bug or hardware fault that is not otherwise caught), or because the car breaks down in some manner (remember,

risks posed within the car itself, there is also a huge concern about the ability of an outsider to hack into the car's system. A cybercriminal, for example, could override its settings to speed up the car or shift it into reverse, remotely endangering the car's occupants or unwary pedestrians. Ransomware extortionists may use malware to disable cars' safety devices or lock passengers into vehicles, thus immobilizing them in isolated settings.

The primary feature distinguishing the autonomous vehicle from the non-autonomous vehicle is the AV's control system and software, not physical components, and these will account for many defects or malfunctions.

> Control systems typically consist of LiDAR arrays and sensors, which the vehicle uses to "see" its surroundings. The impressions from these systems are used by onboard computers to make driving decisions, which are communicated to the vehicle for execution.
>
> It's not unrealistic, therefore, to assume that the first product liability cases involving driverless vehicles will focus on defects in the LiDAR systems' manufacturing (such as weak mounting brackets), design (such as sensor placement resulting in "blind spots"), or instructions and warnings (such as a clear explanation of conditions in which the LiDAR may fail).
>
> Software defects pose a potentially fertile ground for autonomous vehicle product liability lawsuits. For instance, software designs that depend on inadequate sensor data (either in terms of content or transmission speed) or that fail to perform safe ordinary driving maneuvers may quickly become the subject of litigation. Inadequate pattern recognition, collision avoidance algorithms, or human-computer coordination may also lead to lawsuits.[408]

F. Expert Witnesses in Software Product Liability

"Expert witnesses will be necessary to explain these technologies to fact finders. Data recording features in autonomous and semi-autonomous vehicles may provide for more robust crash-reconstruction modeling."[409] At a 2018 conference, a panel of lawyers concluded, "there were only a limited number of expert witnesses who could make sense of automotive software code. Many judges are overwhelmed by such testimony, the lawyers said, and increasingly appoint technical advisers to guide them in discovery decisions."[410] According to a defense counsel, "plaintiffs would need to focus on three primary issues in their discovery: the reliability of the sensors

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it's still a car, composed of mechanical and vulnerable to wear-and-tear on its parts), or due to say a pedestrian that unexpectedly leaps in front of an autonomous car for which the physics prevents the driverless car from avoiding the pedestrian, and so on.

[408] Dani Alexis Ryskamp, *Product Liability Law for Self-Driving Cars*, Expert Inst. (Aug. 27, 2021), https://www.expertinstitute.com/resources/insights/product-liability-law-for-self-driving-cars [https://perma.cc/D45V-7V5J].

[409] Jeffrey Soble & Katlin Cravatta, *NTSB Preliminary Report Reminds That Driver Error Persists*, Foley & Lardner LLP (June 7, 2018), https://www.foley.com/en/insights/publications/2018/06/ntsb-preliminary-report-reminds-that-driver-error [https://perma.cc/KLP6-VJD6].

[410] Tina Belton, *Self-Driving Issues Dominate Product Liability Conference*, Reuters Legal (Apr. 6, 2018, 2:27 PM), https://www.reuters.com/article/products-conference/self-driving-issues-dominate-product-liability-conference-idUSL2N1RJ225 [https://perma.cc/JY7G-AWDL].

feeding autonomous vehicle software, the software itself and the security of the system against hacking attacks."[411]

The court's role is a gatekeeper of expert testimony to ensure "that an expert's testimony both rests on a reliable foundation and is relevant to the task at hand."[412] One possible way to determine software or mechanical failure in AVs is to require them to contain Event Data Recorders, as they do with airplanes, in order to help expert witnesses understand mechanical or software failures.[413] Presumably, most expert witnesses will be software engineers in AV accident cases in the future.

G. Defenses in AV Products Liability Actions

1. Disregarding Manufacturer's Instructions

The earliest known accident involving an AV was caused in large part by the driver's disregard of instructions relating to safe operation.[414] The National Transportation Safety Board (NTSB) concluded:

> [T]he probable cause of the Williston, Florida, 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. Contributing to the car driver's overreliance on the vehicle automation was its operational design, which permitted his prolonged disengagement from the driving task and his use of the automation in ways inconsistent with guidance and warnings from the manufacturer.[415]

In the traditional products liability context, a primary misuse defense often arises from disregard of instructions that have a clear safety component.

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411 *Id*.

412 Daubert v. Merrell Dow Pharm., Inc., 509 U.S. 579, 580 (1993).

413 Klaus Böhm, Tibor Jubjatko, Daniel Paul & Hans-Georg Schweiger, *New Developments on EDR (Event Data Recorder) for Automated Vehicles*, DEGRYTER.COM (Mar. 8, 2020), https://www.degruyter.com/document/doi/10.1515/eng-2020-0007/html [https://perma.cc/WK5Z-79 Q Y]:

> Since 2006, NHTSA has defined with the regulation "49 CFR Part 563" uniform requirements for the accuracy, collection, storage, survivability, and retrievability of vehicle-specific crash event data in vehicles equipped with an event data recorder (EDR) This EDR functionality is generally implemented in the airbag control unit. The regulation "49 CFR Part 563" applies only to the vehicle categories M1 and N1. As a result, heavy trucks, buses, motorcycles, agricultural and forestry vehicles, trailers or special purpose vehicles are not required to be equipped with an EDR. The US EDR records the vehicle data listed in "49 CFR Part 563.7", which are useful for accident investigations and the evaluation of restraint systems. The regulation further requires that an accident analyst must be able to retrieve the data of an EDR without the support of the vehicle manufacturer using a "commercially available tool/ device" As the regulation of the US EDR has been in force since 2006 no data elements important for the investigation of accidents involving automated, connected or electrified vehicles are taken into account. In addition, many accidents involving pedestrians and cyclists in particular, are not recognized as significant events for data storage activation because of insufficient trigger criteria.

414 NAT'L TRANSP. SAFETY. BD., ACCIDENT REPORT: COLLISION BETWEEN A CAR OPERATING WITH AUTOMATED VEHICLE CONTROL SYSTEMS AND A TRACTOR-SEMITRAILER TRUCK NEAR WILLISTON, FLORIDA (May 7, 2016), https://www.ntsb.gov/investigations/AccidentReports/Reports/HAR1702.pdf [https://perma.cc/X5EF-PKJF].

415 *Id.* at vi.

The NTSB described the accident setting as follows:

> At 4:36 p.m. eastern daylight time on Saturday, May 7, 2016, a 2015 Tesla Model S 70D car, traveling eastbound on US Highway 27A (US-27A), west of Williston, Florida, struck a refrigerated semitrailer powered by a 2014 Freightliner Cascadia truck-tractor. At the time of the collision, the truck was making a left turn from westbound US-27A across the two eastbound travel lanes onto NE 140th Court, a local paved road. The car struck the right side of the semitrailer, crossed underneath it, and then went off the right roadside at a shallow angle. The impact with the underside of the semitrailer sheared off the roof of the car.
>
> After leaving the roadway, the car continued through a drainage culvert and two wire fences. It then struck and broke a utility pole, rotated counterclockwise, and came to rest perpendicular to the highway in the front yard of a private residence. Meanwhile, the truck continued across the intersection and came to a stop on NE 140th Court, south of a retail business located on the intersection corner.
>
> The driver and sole occupant of the car died in the crash; the commercial truck driver was not injured.
>
> System performance data downloaded from the car indicated that the driver was operating it using the Traffic-Aware Cruise Control and Autosteer lane-keeping systems, which are automated vehicle control systems within Tesla's Autopilot suite.[416]

The National Transportation Safety Board stated that the probable cause of the Williston, Florida 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."[417] Further, the car's "operational design, which permitted [the driver's] prolonged disengagement from the driving task and his use of the automation in ways inconsistent with guidance and warnings from the manufacturer," contributed to the driver's "overreliance on vehicle automation."[418]

The Tesla car involved in the Williston, Florida crash was equipped with a Level 2 automated driving system, which "provide[d] lateral control (lane-keeping or steering) and longitudinal control (adaptive cruise control or acceleration/deceleration). When operating a Level 2 vehicle, the driver is responsible for monitoring the driving environment."[419] The driver's disregard of the instruction to monitor the driving environment would likely constitute contributory negligence, the assumption of risk, or the basis for a misuse defense.

Another driver did not suffer injury even though his Tesla, set to Autopilot, drove into an unoccupied parked fire truck. The report states:

[416] *Id.*
[417] *Id.*
[418] *Id.*
[419] *Id.* at 24.

> [T]he Tesla was following a vehicle for an extended period at a speed of around 21 miles per hour (33.8 kph) when the vehicle ahead changed lanes seconds before the crash. After the vehicle in front shifted, the Tesla began accelerating toward the driver-set cruise control speed of 80 mph (129 kph) and hit the parked fire truck while going 30.9 mph. The system did not detect the driver's hands on the wheel for the final 3 minutes and 41 seconds of the crash.[420]

Tesla advises drivers to not take their hands off the steering wheel while the car is being steered by Autopilot. However, that did not stop a foolhardy British man from attempting to operate his Tesla on Autopilot while seated in the passenger seat.[421] This recklessness reveals that technological safety improvements may be negated by human audaciousness.

2. Misuse Defense

The widespread deployment of AVs will largely eliminate defenses of product misuse, contributory negligence, and the assumption of risk.[422] Misuse is traditionally a leading defense in products liability cases involving human drivers. Manufacturers are required to anticipate reasonably foreseeable misuses of their product but need not take precautions against every misuse. Manufacturers will often try to defend themselves by claiming that a product was not used normally or as it was intended.[423] "Where the injuries arise from an abuse or misuse of product that was not reasonably foreseeable, the law does not hold manufacturers responsible in tort."[424]

The closely related defenses of contributory negligence and assumption of risk will also be largely stricken from the automobile products liability landscape because human drivers will not be part of the liability equation. The human factor in accidents will be greatly reduced as human driven cars are replaced with robocars.

> Human drivers cause accidents due to a variety of reasons. Some are distracted by their phones while driving, others drive for long distances and get overly fatigued, some over-speed while in a hurry, and others just have total disregard for road safety rules. AVs are immune to all these limitations.[425]

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[420] David Shepardson, *Tesla Autopilot Engaged in 2018 California Crash; Driver's Hands Off Wheel: NTSB*, REUTERS, Sept. 3, 2019, https://www.reuters.com/article/us-tesla-crash/tesla-autopilot-engaged-in-2018-california-crash-drivers-hands-off-wheel-ntsb-idUSKCN1VO22E [https://perma.cc/R2TM-PDBR].

[421] Yonette Joseph, *He Drove a Tesla on Autopilot from the Passenger Seat. The Court Was Not Amused.*, N.Y. TIMES (Apr. 29, 2018), https://www.nytimes.com/2018/04/29/world/europe/uk-autopilot-driver-no-hands.html [https://perma.cc/8CQK-JN5Q].

[422] Theo Calvin, *Preparing for the Unexpected Future of Autonomous Mobility,* FROG (June 2018), http://www.dot.state.mn.us/automated/docs/frog_preparing_for_the_unexpected_future_of_autonomous_mobility.pdf [https://perma.cc/4Y89-XXNJ].

[423] Stephen M. Copenhaver, *When Do Manufacturers Need to Anticipate Misuses – and Abuses – of Their Products?*, ARENTFOX SCHIFF (Apr. 18, 2018), https://www.afslaw.com/perspectives/product-liability-mass-torts-blog/when-do-manufacturers-need-anticipate-misuses-and [https://perma.cc/EV6K-KNSQ].

[424] *Id.*

[425] Elezaj, *supra* note 216.

3. Seat-Belt Defense

The seat belt defense reduces the amount of recoverable damages for a plaintiff, given that the extent of an accident could have been minimized had the person been wearing a seat belt.[426] The Florida Supreme Court described the seat belt defense as,

> an attempt to prove that the non-use of a functional and available restraint system by the plaintiff either caused or measurably worsened the plaintiff's injuries that resulted from the defendant's actions, and based on that non-use (even though the non-use preceded and did not cause or contribute to the accident), the plaintiff's recoverable damages should be barred or reduced.[427]

If the failure to wear an available seat belt contributes to injuries suffered by a passenger in an autonomous vehicle, the AV maker should be able to introduce evidence that such a failure constitutes comparative negligence, reducing the plaintiff's recovery if the defendant can prove injuries would be mitigated if the AV passenger had worn their seat belt. One possible solution to eliminate this seat belt defense is through not having the AV operate until the seat belts are fastened properly for the driver and all passengers.

H. Economic Loss Rule

The economic loss rule (ELR) draws a sharp line of demarcation between torts and contracts. If a court determines whether a tort resulted in purely "economic loss," the plaintiff's action is contractual rather than a tort. In autonomous products liability litigation, the ELR "bars recovery in tort where the loss is purely economic, that is, direct economic loss to the product itself as opposed to personal injury or damages to other property."[428] The ELR is a court-created doctrine, which restricts the plaintiff to contract remedies if the only damages suffered are economic losses.[429]

"The economic loss rule adopted by most courts is a barrier to tort recovery for Internet-related security breaches."[430] "Under the majority rule, a plaintiff may recover economic losses for negligence only when there is accompanying physical damage to person or property."[431] The ELR will prevent the plaintiff in an AV products liability suit from pursuing a tort remedy where only economic losses were caused by a defective product.[432]

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[426] *See* Colo. Rev. Stat. § 42-4-237. Evidence of seat belt non-use "shall be admissible to mitigate damages with respect to any person who was involved in a motor accident and who seeks in any subsequent litigation to recover damages for injuries resulting from the accident."

[427] Ridley v. Safety Kleen Corp., 693 So. 2d 934, 938 (Fla. 1996).

[428] MICHAEL L. RUSTAD, GLOBAL INTERNET LAW HORNBOOK 726 (3d ed. 2020).

[429] *See* Indem. Ins. Co. of N. Am. v. Am. Aviation, Inc., 891 So. 2d 532, 536 (Fla. 2004).

[430] Michael L. Rustad, *Private Enforcement of Cybercrime on the Electronic Frontier*, 11 S. CAL. INTERDISC. L.J. 63, 113 (2001).

[431] Ann O'Brien, *Limited Recovery Rule as a Dam: Preventing a Flood of Litigation for Negligent Infliction of Pure Economic Loss*, 31 ARIZ. L. REV. 959, 959 (1989).

[432] *See Indem. Ins. Co. of N. Am.*, 891 So. 2d at 537–38 ("In contrast to the contractual privity economic loss rule, which developed to protect the integrity of the contract, the products liability economic loss rule developed to protect manufacturers from liability for economic damages caused by a defective product beyond those damages provided for by warranty law.").

I. POLICIES SUPPORTING AV PRODUCTS LIABILITY

Products liability will also likely focus on security breaches created by software design defects.[433] The biggest threat to AVs, for example, is their vulnerability to security hacks.[434] Breaching an AV's entry points may do more than just release data; a hacker could potentially take control of the vehicle and cause it to drive to a certain location.[435]

Driverless cars collect enormous amounts of personal data, sometimes without users' knowledge or consent. "[A] connected L5 automated vehicle could produce about 4,000 GB of data per day, much of it deemed personal."[436] In determining liability involving AVs, Event Data Recorders ("EDRs") will play a crucial role in providing information leading to the accident occurrence and its cause; however, the use of EDRs implicates data privacy and protection concerns.[437] "Finally, in the case of an accident, an [EDR] is of vital importance to reconstruct the events to the lawyers."[438] "The global automotive event data recorder (EDR) market is expected to post a CAGR [Compound Annual Growth Rate] nearly 6% during the period 2019–2023."[439]

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[433] *See* Andy Greenberg, *Securing Driverless Cars from Hackers Is Hard. Ask the Ex-Uber Guy Who Protects Them,* WIRED, (Apr. 12, 2017, 7:00 AM), https://www.wired.com/2017/04/ubers-former-top-hacker-securing-autonomous-cars-really-hard-problem [https://perma.cc/A8WG-LT2S]; Andy Green berg, *Hackers Remotely Kill a Jeep on the Highway—with Me in It,* WIRED, (July 21, 2015, 6:00 AM), https://www.wired.com/2015/07/hackers-remotely-kill-jeep-highway [https://perma.cc/3VKG-XE N3].

[434] *See* Rob Toews, The Biggest Threat Facing Connected Autonomous Vehicles Is Cybersecurity, TECHCRUNCH, (Aug. 25, 2016, 7:00 AM), https://techcrunch.com/2016/08/25/the-biggest-threat-facing-connected-autonomous-vehicles-is-cybersecurity [https://perma.cc/R7BV-W6VY]; Greenberg, *supra* note 433; Jack Stewart, *Why Self-Driving Cars Need Superhuman Senses*, WIRED (Sept. 11, 2017, 9:00 AM), https://www.wired.com/story/why-self-driving-cars-need-superhuman-senses [https://perma.cc/XTD5-RCSS]; Nicole Perlroth, *Electronic Setups of Driverless Cars Vulnerable to Hackers,* N.Y. TIMES (June 7, 2017), https://www.nytimes.com/2017/06/07/technology/electronic-setups-of-driverless-cars-vulnerable-to-hackers.html?mcubz=1 [https://perma.cc/FFK9-5MAZ]; Danielle Muoio, *Self-Driving Cars Are Prone to Hacks—and Automakers Are Barely Talking About It,* BUS. INSIDER (Dec. 15, 2016, 9:04 AM), http://www.businessinsider.com/driverless-cars-hacking-ricks-2016-12 [https://perma.cc/M96 W-T8K5]; Ashiq Ja, *Security Nightmare of Driverless Cars*, TRIPWIRE(Oct. 25, 2015), https://www .tripwire.com/state-of-security/security-data-protection/cyber-security/security-nightmare-of-driverless-cars [https://perma.cc/7YFN-2TA6]; Michael Ballaban, *Mercedes, Google, Volvo To Accept Liability When Their Autonomous Cars Screw Up*, JALOPNIK (Oct. 7, 2015, 11:47 AM), http://jalopnik. com/mercedes-google-volvo-to-accept-liability-when-their-1735170893 [https://perma.cc/7T7C-3LWF] ; Kirsten Korosec, *Volvo CEO: We Will Accept All Liability When Our Cars Are in Autonomous Mode*, FORTUNE (Oct. 7, 2015, 12:34 PM), http://fortune.com/2015/10/07/ volvo-liability-self-driving-cars [https://perma.cc/N2L2-3WTL]; Hanley Chew, *Privacy and Security in the Age of the Driverless Car*, IP WATCHDOG (Sept. 5, 2016, 8:30 AM), http://www.ipwatchdog.com/2016/09/05/ privacy-security-driverless-car/id=72540 [https://perma.cc/7RYY-MWAT]; Dave Gershgorn, *Instead of Hacking Self-Driving Cars, Researchers Are Trying to Hack the World They See,* QUARTZ (July 18, 2017), https://qz.com/1031233/instead-of-hacking-self-driving-cars-researchers-are-trying-to-hack-the-world-they-see [https://perma.cc/AT9L-UKM2].

[435] *See* Katyal, *supra* note 29 ("Self-driving vehicles would also open the country up to a number of new security concerns. Hackers could tamper with autonomous driving software; terrorists could infiltrate the central transportation system.").

[436] Peter Els, *Mobility and the GDPR: An Important but Uneasy Partnership*, AUTO. IQ (Oct. 26, 2018), https://www.automotive-iq.com/autonomous-drive/articles/mobility-and-the-gdpr-an-important-but-uneasy-partnership [https://perma.cc/F95D-M5Z8].

[437] Melinda Florina Lohmann, *Liability Issues Concerning Self-Driving Vehicles*, 7 EUR. J. RISK REGUL. 335, 339 (2016).

[438] Andrea Martinesco, Mariana Netto, Arthur Miranda Neto & Victor H. Etgens, *A Note on Accidents Involving Autonomous Vehicles: Interdependence of Event Data Recorder, Human-Vehicle Cooperation and Legal Aspects,* 5 IFAC PAPERSONLINE 407, 407 (2019).

[439] *Global Automotive Event Data Recorder (EDR) Market 2019–2023: Development of Autonomous Vehicles to Boost Demand: Technavio*, BUS. WIRE (Oct. 14, 2019, 06:25 AM), https://www.businesswire .com/news/home/20191014005293/en/Global-Automotive-Event-Data-Recorder-EDR-Market-2019-

The extent of harm that digital technologies may cause has changed significantly, requiring policy makers to rethink the allocation of responsibility among related parties.

> In the past, strict products liability has not tended to apply to the designers, manufacturers, and/or retailers of digital products. This is because the impacts from the failures of these products have been limited to mostly economic damages, such as the inconvenient need to reboot a device or restore data from a backup. In the future, failures of increasingly ubiquitous IoT devices are likely to have more serious consequences such as damage to property, personal harm, or even death. This significant change in harms calls for policy makers to consider the allocation of responsibility for the harms. This different assignment of liability will affect the business models of companies that design, manufacture, and sell these technologies; the insurance market; and, ultimately, the trajectory of technological change.[440]

1. Liability on the Least Cost Avoider

The manufacturer is the least cost avoider for defective autonomous cars because one party can only avoid the harm. "The prospect of assigning all AV liability to manufacturers has theoretical appeal: after all, the manufacturer of the self-driving software is presumably the only party capable of controlling or improving the safety of the vehicle."[441] This would benefit AV consumers and all other parties sharing the roads with these vehicles. The occupants of AVs and those who share the road with them (pedestrians, bicyclists, and others) suffer from information asymmetries. The AV manufacturer, the software suppliers, and producers of other components know far more about driverless cars than the average consumer. Manufacturers of AVs and their components should be "bound by product liability law for defects regarding design, construction and instruction" because they are the "adequate risk bearer."[442]

The least cost avoider approach places liability on the party who will incur the least cost and is thus in the best position to remediate defects in products.[443] "The question for the court reduces to a search for the cheapest

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2023-Development-of-Autonomous-Vehicles-to-Boost-Growth-Technavio [https://perma.cc/LRL4-KX53]. *See generally* Rick Wayman, *Compound Annual Growth Rate: What You Should Know,* INVESTOPEDIA (May 16, 2022), https://www.investopedia.com/investing/compound-annual-growth-rate-what-you-should-know [https://perma.cc/T4XD-YE5L] (explaining that a "compound annual growth rate, or CAGR, is the mean annual growth rate of an investment over a specified period of time longer than one year.").

440 Benjamin C. Dean, *An Exploration of Strict Products Liability and the Internet of Things*, CTR. FOR DEMOCRACY & TECH. 1 (Apr. 2018), https://cdt.org/files/2018/04/2018-04-16-IoT-Strict-Products-Liability-FNL.pdf [https://perma.cc/5GA4-P2J9].

441 Gordon Anderson & Austin Brown, *Product Liability Is the Wrong Standard for Self-Driving Cars*, UC DAVIS: INST. OF TRANSP. STUD. (Apr. 2, 2019), https://its.ucdavis.edu/blog-post/product-liability-is-the-wrong-standard-for-self-driving-cars/ [https://perma.cc/2PV5-7KUN].

442 Lohmann, *supra* note 437.

443 *See generally* GUIDO CALABRESI, THE COSTS OF ACCIDENTS: A LEGAL AND ECONOMIC ANALYSIS, 135–73 (1970) (advocating apportionment of risk to the least cost avoider); Nat'l Union Fire Ins. Co. of Pittsburgh v. Riggs Nat'l Bank of Wash., D.C., 5 F.3d 554, 557 (D.C. Cir. 1993) (Silberman, Ct. J., concurring) ("Placing liability with the least-cost avoider increases the incentive for that party to adopt preventive measures" that will "have the greatest marginal effect on preventing the loss.").

cost avoider."[444] The cheapest cost avoider has been defined as "an arbitrary initial bearer of accident costs [that] would (in the absence of transaction and information costs) find it most worthwhile to "bribe" to obtain that modification of behavior which would lessen accident costs most."[445] Product liability in a defective AV case will likely be based upon a claim that personal injury, death, or property damage was caused by a manufacturing defect, design defect, or manufacturer's failure to warn of a known danger. The California Supreme Court adopted strict liability "to insure that the costs of injuries resulting from defective products are borne by the manufacturer that put such products on the market rather than by the injured persons who are powerless to protect themselves."[446] Defective or malfunctioning object recognition software, for example, can

> wrongly identify an object on the road and cause an accident involving injuries and material damage. As with the risks to fundamental rights, these risks can be caused by flaws in the design of the AI technology, be related to problems with the availability and quality of data or to other problems stemming from machine learning. While some of these risks are not limited to products and services that rely on AI, the use of AI may increase or aggravate the risks.[447]

As software is increasingly being deployed in connected cars, drones, and other products that can result in serious harm or death, it is time to make software makers accountable for products liability.

> In the past, strict products liability has not tended to apply to the designers, manufacturers, and/or retailers of digital products. This is because the impacts from the failures of these products have been limited to mostly economic damages, such as the inconvenient need to reboot a device or restore data from a backup. In the future, failures of increasingly ubiquitous IoT devices are likely to have more serious consequences such as damage to property, personal harm, or even death. This significant change in harms calls for policy makers to consider the allocation of responsibility for the harms. This different assignment of liability will affect the business models of companies that design, manufacture, and sell these technologies; the insurance market; and, ultimately, the trajectory of technological change.[448]

2. Spreading the Cost of Injury

The court in *Vandermark v. Ford Motor Co*. ruled that retailers were subject to strict products liability because they "are an integral part of the overall producing and marketing enterprise that should bear the cost of injuries."[449] The Fifth Circuit in *Putnam v. Erie City Manufacturing Co*. noted that "the manufacturer or assembler placing its product in the market

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[444] S*ee, e.g.*, Guido Calabresi & Jon T. Hirschoff, *Toward a Test for Strict Liability in Torts*, 81 YALE L.J. 1055, 1060 (1972).
[445] *Id.* at 1060 n.19.
[446] Greenman v. Yuba Power Prod. Inc., 377 P.2d 897, 901 (Cal. 1963).
[447] EUR. COMM'N, WHITE PAPER ON ARTIFICIAL INTELLIGENCE—A EUROPEAN APPROACH TO EXCELLENCE AND TRUST 12 (2020).
[448] Dean, *supra* note 440.
[449] Vandermark v. Ford Motor Co., 391 P.2d 168, 171 (Cal. 1964).

place should bear, with its greater capacity to spread the cost, the burden of society's desire to protect the public from injury."[450] Products liability emphasizes risk spreading and collective goals, such as the minimization of costs associated with defective products.[451] The public policies underlying products liability are loss-spreading, deterrence, and burden of proof considerations.[452]

Products liability ensures "that the costs of injuries resulting from defective products are borne by the manufacturers that put such products on the market rather than by the injured persons who are powerless to protect themselves."[453] "Strict liability is premised on the theory that certain activities, such as hazardous waste disposal, are likely to result in some injury to the environment. Liability is, therefore, imposed upon those who economically benefit from the activity and who are in the best position to reduce or eliminate the attendant risks."[454] The idea of cost spreading is that the price of a product reflects the risk and cost of injury from defects in the product.[455] Justice Roger Traynor's concurring opinion in *Escola v. Coca Cola* stated,

> Those who suffer injury from defective products are unprepared to meet its consequences. The cost of an injury and the loss of time or health may be an overwhelming misfortune to the person injured, and a needless one, for the risk of injury can be insured by the manufacturer and distributed among the public as a cost of doing business.[456]

3. Relieve Plaintiff the Burden of Proving Defendant's Negligence

A California court stated that strict liability is "a 'short cut' to liability where negligence may be present but is difficult to prove."[457] The second policy of strict products liability is to relieve the injured plaintiff of having to prove the manufacturer's negligence.[458] Imposing strict liability relieves

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[450] Putnam v. Erie City Mfg. Co., 338 F.2d 911, 914 (5th Cir. 1964).

[451] Michael L. Rustad & Thomas H. Koenig, *The Tort of Negligent Enablement of Cybercrime*, 20 BERKELEY TECH. L. J. 1553, 1568 (2005):

> Software vendors, not computer users, are in the best position to design software that deters cyber-intruders. Software defects should be detected by software engineers before a product's release. Furthermore, software vendors can bundle together tools to prevent foreseeable cybercrimes. For example, vendors possess technology to track antivirus software and to warn users if their protection is not installed or properly updated. The social costs associated with hackers, viruses, and cybercrimes will not decrease until the software industry is held accountable for marketing products with known design defects. Constructing a duty of care to produce secure software will provide vendors and other stakeholders' incentives to implement, install, and update safe and reliable products and services.

[452] PROSSER AND KEETON ON THE LAW OF TORTS § 98, at 692–93 (W. Page Keeton et al. eds., 1984) (discussing public policies underlying products liability).

[453] Jackson v. Johns-Manville Sales Corp., 727 F.2d 506, 525 (5th Cir. 1984) (quoting State Stove Mfg. Co. v. Hodges, 189 So. 2d 113, 120 (Miss. 1966)) (discussing policy objectives of strict liability in reallocating the cost of injury to the responsible manufacturer).

[454] Joseph DiBenedetto, *Generator Liability Under the Common Law and Federal and State Statutes*, 39 BUS. LAW. 611, 620 (1984).

[455] Parker v. St. Vincent Hospital, 122 N.M. 39, 43 (1996).

[456] Escola v. Coca Cola Bottling Co. of Fresno, 150 P.2d 436, 441 (Cal. 1944) (Traynor, J. concurring).

[457] Bostick v. Flex Equip. Co., 54 Cal. Rptr. 3d 28, 35 (Ct. App. 2007).

[458] *Parker*, 122 N.M. at 43.

plaintiffs from the burden of proving ordinary negligence, which is likely but difficult to prove.[459]

> This rationale can also support liability of *distributors* for manufacturing defects because of the difficulty that may arise in determining whether the defect arose at the time of manufacture or during handling in the distribution chain. It has little force, however, when applied to non-manufacturer liability for design defects. The fact that it is easier to prove a product is defectively designed than to prove that there was negligence in designing the product has a perverse effect in that context because ordinarily there is no possibility that a distributor other than the manufacturer created a design defect.[460]

The products liability of "nonmanufacturing sellers in the distributive chain is strict. It is no defense that they acted reasonably and did not discover a defect in the product, be it from manufacturing, design, or failure to warn."[461]

4. Holding the Full Chain of Supply Accountable

Strict liability imposes this liability on every seller of the product, i.e., manufacturers, wholesalers, retailers, and any other party involved in the product's chain of distribution, in order to ensure that a plaintiff will have a meaningful remedy. Section 402A of the Restatement (Second) of Torts protects consumers by acting "as a deterrent and a method of allocating the risk of loss among those best equipped to deal with it."[462] "[S]uppliers who otherwise might not be liable because of a passive role in the chain of supply should be encouraged to select reputable and responsible manufacturers who generally design and construct safe products and who generally accept financial responsibility for injuries caused by their defective products."[463] Strict liability holds the entire chain of distribution accountable, thus creating incentives "to select reputable and responsible [partners] who generally design and construct safe products and who generally accept financial responsibility for injuries caused by their defective products."[464]

5. Fairness in Holding Software Vendors Liable

"[T]he policy behind strict products liability is greater than simple plaintiff compensation . . . it implicates the public policy that the cost of defective products be borne by the manufacturers who put such products on the market."[465]

> The rationale underlying this liability is threefold: (1) the public interest in human life and safety demands broad protection against the sale of defective products; (2) the manufacturer solicits and invites the

[459] *Id*. at 44.
[460] *Id*. at 43 (emphasis in original) (citations omitted).
[461] Bylsma v. R.C. Willey, 416 P.3d 595, 612 (Utah 2017).
[462] *Id.* at 613.
[463] *Parker*, 122 N.M. at 44.
[464] Brooks v. Beech Aircraft Corp., 902 P.2d 54, 59 (N.M.1995).
[465] Mendoza v. Gen. Motors LLC, 2018 WL 1960563 at *3 (E.D. Cal. Apr. 26, 2018).

> use of his products by representing that they are safe and suitable for use; and (3) the losses caused by defectively dangerous products should be borne by those who have created the risks and reaped the profits by placing the products into commerce.[466]

The chief justification for creating the strict products liability doctrine was "to insure that the costs of injuries resulting from defective products are borne by the manufacturers that put such products on the market rather than by the injured persons who are powerless to protect themselves."[467]

The court's recognition of product liability for defective AVs rests on a fundamental law and economics principle: the vehicle manufacturer is in a superior position to know when its automobile is suitably designed and safely made for its intended purpose. Imposing strict liability on AV manufacturers for defects they produce will encourage safety in design and production. The diffusion of this cost in the purchase price of individual units should be acceptable to the user if "it results in added assurance of protection."[468] The rationale for holding AV makers liable is based on the economic benefit that the manufacturer derives from the vehicles it sells.[469]

> A sense of fairness is subjective, although advances in the common law often arise from careful analysis of one's sense of fairness in order to identify the essential elements. . . . 'At the heart of this judgment [that liability should be imposed] lies the conclusion that although the manufacturer has provided a valuable service by supplying the public with a product that it wants or needs, it is more fair that the cost of an unreasonable risk of harm lie with the product and its possibly innocent manufacturer than it is to visit the entire loss upon the often unsuspecting consumer who has relied upon the expertise of the manufacturer when selecting the injury-producing product.'[470]

6. Suing for Safety

Manufacturers should be responsible for the final product (i.e., the AV) as well as for actions involving driverless cars where the indication is that something went wrong with a collision avoidance system or there was a situation that the vehicle's software was not prepared to address.[471] With the safety concerns that accompany the introduction of driverless vehicles, it is desirable to incentivize manufacturers of these vehicles to make improvements in safety design.[472] Some courts argue that "imposing strict products liability may cause manufacturers to take more care in designing and manufacturing a product and in the warnings they give to consumers

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[466] Cassidy v. China Vitamins LLC, 120 N.E.3d 959, 967–68 (Ill. 2018).

[467] Greenman v. Yuba Power Prod. Inc., 377 P.2d 897, 901 (Cal. 1963).

[468] Fasolas v. Bobcat of N.Y., Inc., 128 N.E.3d 627, 632 (N.Y. 2019) (quoting Codling v. Paglia, 32 298 N.E.2d 622, 628 (N.Y. 1973)).

[469] Kyle Colonna, *Autonomous Cars and Tort Liability*, 4 CASE W. RES. J.L. TECH. & THE INTERNET 81, 105 (2012).

[470] Parker v. St. Vincent Hosp., 122 N.M. 39, 45 (1996) (quoting Brooks v. Beech Aircraft Corp., 902 P.2d 54 (1995)) (citations omitted).

[471] Goodrich, *supra* note 29, at 281 (2013) (quoting Gary E. Marchant & Rachel A. Lindnor, *The Coming Collision Between an Autonomous Vehicle and the Liability System*, 52 SANTA CLARA L. REV. 1321, 1323, 1328–29 (2013)).

[472] *Id.*

about using that product."[473] Debugging throughout helps catch any syntax errors or gaps in logic sooner rather than later.[474] " Software failure is often caused by human error in application programming.[475]

AV makers, for example, will have incentives to do adequate testing in order to avoid incorrect algorithmic, numerical, and variable assignment.[476] AV software component makers will take more care in programming the software to fill in missing condition checks, calibrate the correct defining of data, and insure correct condition logic.

The law of products liability will ensure that AVs are safer just "as it handled seat belts, air bags, and cruise control."[477] Tort law is 'public law in disguise' because of its emphasis on larger societal interests "outside and beyond the interests of the immediate parties to the litigation."[478] Tort law fulfills multiple functions in that there are contextual aspects to every tort case based upon "public policy, social welfare, law making, or judicial legislation."[479] Strict products liability has a larger societal purpose in driving dangerously defective products from the marketplace. "An error does not become a mistake unless you refuse to correct it."[480]

Products liability has resulted in improved automobile design and recalls. The 1950s and 1960s were not happy days when it came to automotive safety. Ralph Nader's *Unsafe at Any Speed* documented how Corvairs turned into everyday deadly objects.[481] Rear-engine Corvairs would suddenly lurch off the road "where centrifugal forces came into play."[482] The lightweight, rear-engineered automobile would go out of control and flip over because of defects in its cheap, swing-axle suspension.[483]

Prior to the advent of products liability, the American automobile industry did not believe that safety sold. Steering wheels tattooed drivers with imprints of sharp emblems. Steering wheel columns impaled drivers. Unpadded dashboards and the sharp edges of ashtrays took out eyes and caused head and facial injuries. Automobiles of the 1960s, even hardtop sedans, "crumpled like a Japanese lantern" in foreseeable rollover

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[473] *Parker*, 122 N.M. at 45.

[474] Valinda Chan, *10 Steps to Solving a Programming Problem*, CODEBURST.IO (Aug. 1, 2017), https://codeburst.io/10-steps-to-solving-a-programming-problem-8a32d1e96d74.

[475] Aaron Continelli, *How to Identify and Prevent Software Failure Risks*, TECHSLING WEBLOG (Feb. 15, 2017), https://www.techsling.com/identify-prevent-software-failure-risks/ [https://perma.cc/MM28-4U5Q] ("[T]he number one cause of software failure is human error in application programming. This failure happens during the coding process, often due to oversights in the software development lifecycle. A programmer may fail to consider extreme or unusual user inputs; [sic] which may cause system bugs when the software is deployed, and users begin using the software in ways the programmer didn't anticipate.").

[476] *Ways to Avoid Common Coding Errors and Become a Better Programmer*, CODESLAW, https://codeslaw.com/blog/5-ways-to-avoid-common-coding-errors-become-a-better-programmer-1008227 ("The more often you test your code without interrupting your workflow, the easier it will be to write error-free code.").

[477] Andrew P. Garza, Note, *"Look Ma, No Hands!": Wrinkles and Wrecks in the Age of Autonomous Vehicles*, 46 NEW ENG. L. REV. 581, 581 (2012).

[478] *See* Leon Green, *Tort Law Public Law in Disguise*, 38 TEX. L. REV. 1, 2 (1959).

[479] *Id.*

[480] England v. Simmons, 728 P.2d 1137, 1149 (Wyo. 1986) (J. Urbigkit, dissenting) (citing Thomas F. Lambert Jr., *Suing for Safety*, 19(11) TRIAL 48 (November 1983)).

[481] RALPH NADER, UNSAFE AT ANY SPEED (1965).

[482] *Id.* at 22.

[483] *Id*. at 24.

accidents.[484] Cadillac fins impaled pedestrians. Nader noted how the fins on Cadillacs "bore an uncanny resemblance to the tail of the stegosaurus, a dinosaur that had two sharp rearward-projecting horns."[485]

Despite this history, not all courts believe the imposition of strict products liability will lead to safer design. A New Mexico court of appeal stated that the New Mexico Supreme Court was reluctant "to rely on this policy objective [and has] skepticism about whether imposition of strict products liability actually causes manufacturers to exercise more care in such matters as product design."[486]

7. Private Enforcement for Public Purpose

The software industry has operated in a liability-free zone since its inception. "Operating within a 'legislative void', the courts have consistently construed software licenses in a manner that allows software vendors to disclaim almost all liability for software defects."[487] As a prominent security expert stated, "there are no real consequences for having bad security."[488] In the past, software makers disclaimed all liability when their software failed in an era where it was rare for software to be linked to physical injury or death.

> As the software industry ventures from purely cyber systems toward cyber-physical systems such as self-driving cars, delivery drones, and networked medical devices, anticipation has been building that the rules for cyber-physical liability will be different. Traditional software does not kill, at least not without opportunity for human intervention. But when code controls physical systems directly, code crashes will cause physical crashes. "Common sense" suggests courts would "revolt" at the idea of "killer bots."[489]

Software publishers releasing dangerously insecure code should shoulder the costs of enabling foreseeable computer intruders. For the software industry to incur liability for negligently causing harm, the vendor must owe a duty of care to its licensees. Judicial opinions in negligence cases demonstrate that determinations of no duty are rare. A company will have a duty where its conduct poses preventable risks to others. Such a duty may arise from a company's failure to anticipate tortious or criminal acts of others, although "courts are reluctant to impose a duty to anticipate the criminal or tortious conduct of third parties."[490]

Courts have not yet extended applying products liability to computer software,[491] but the law must evolve to address emerging risks and dangers. Legal standards for autonomous vehicles may gradually evolve toward the

[484] *Id*. at 107.
[485] *Id*. at 182.
[486] Parker v. St. Vincent Hosp., 122 N.M. 39, 45 (1996).
[487] Jane Chong, *Bad Code: The Whole Series*, LAWFARE INST. (Nov. 4, 2013, 12:46 PM), https://www.lawfareblog.com/bad-code-whole-series [https://perma.cc/7R62-T2KH].
[488] *Id.*
[489] Choi, *supra* note 241, at 43 (citations omitted).
[490] Rustad & Koenig, *supra* note 345, at 1571.
[491] *See* Chong, *supra* note 487.

common law governing traditional automobiles and other technologies.[492] Law has been "highly adaptive to the many new technologies that have emerged in recent decades, and . . . will be quite capable of adapting to emerging autonomous vehicle technologies as the need arises."[493] Extending products liability to driverless cars will ensure that these vehicles are safer, just as the tort system created incentives for "seat belts, air bags, and cruise control."[494]

V. CONCLUSION

Products liability assesses whether a defect makes a vehicle "unreasonably dangerous," whether it was hidden from the user, and the causal connection between the defect and the injuries. This Article has proposed extending products liability to defective AVs so that those who are injured in a car accident caused by defective software component parts may recover from autonomous carmakers as well as software creators. Extending products liability to AVs will eliminate the de facto liability shield protecting software programmers from the consequences of producing dangerously defective software. Principles of products liability law must evolve to create incentives so that manufacturers will promptly use design, testing, data analysis, and inspection to correct hazards in products and combat the massive problem of accidents that are caused by defective products.[495]

While AVs may still be subject to disengagements and accidents, most disengagements and accidents are causally connected by defective software design. Extending strict products liability to include malfunctioning software which is incorporated into AVs will ensure that manufacturers, distributors, suppliers, retailers, and other parties involved in the production and manufacturing of these vehicles will be held accountable for manufacturing vehicles with known software defects into the stream of commerce. To achieve this, products liability must evolve to address software failure in order to protect the occupants of both conventional and autonomous vehicles, as well as surrounding bicyclists and pedestrians. Strict products liability action against autonomous carmakers and those who supply component parts is necessary so that the industry pays the true costs of deploying defective software components in driverless cars.

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492 Adam D. Thierer & Ryan Hagemann, *Removing Roadblocks to Intelligent Vehicles and Driverless Cars*, WAKE FOREST J.L. & POL'Y.

493 *Id.*

494 Garza, *supra* note 477, at 595.

495 Smith v. Home Light & Power Co., 734 P.2d 1051, 1053 (Colo. 1987) ("Principles of modern strict products liability law evolved in part to motivate manufacturers to use information that they can obtain through design, testing, data analysis and inspection to correct hazards in products and thereby combat the massive problem of accidents resulting from defective products.") (citation omitted). Therefore, strict products liability under § 402A,

> does not rest upon negligence principles, but rather is premised on the concept of enterprise liability for casting a defective product into the stream of commerce. Thus, the focus is upon the nature of the product, and the consumer's reasonable expectations with regard to that product, rather than on the conduct, either of the manufacturer or of the person injured because of the product.

Jackson v. Harsco Corp., 673 P.2d 363, 365 (Colo. 1983) (citations omitted).