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AUTONOMOUS VEHICLES: PROBLEMS AND PRINCIPLES FOR FUTURE REGULATION

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INTRODUCTION

An array of emerging scientific and technological innovations promises to reshape contemporary society. The healthcare, financial, and agricultural sectors, among others, stand to be transformed by innovations in areas such as nanotechnology,[1] information technology,[2] and biotech-

[1] *See* Vincent Mangematin & Steve Walsh, *The Future of Nanotechnologies*, 32 TECHNOVATION 157, 157 (2012) ("[N]anotechnologies promise greater and more equal access to knowledge and information; new therapeutic interventions; improved environmental monitoring; greater safety and security; expanded communication capacities and many other industrial and societal applications."); Hailmichael Teshome Demissie, *Taming Matter for the Welfare of Humanity: Regulating Nanotechnology*, *in* REGULATING TECHNOLOGIES: LEGAL FUTURES, REGULATORY FRAMES AND TECHNOLOGICAL FIXES 327–40 (Roger Brownsword & Karen Yeung eds., 2008) (describing the "transformative potential" of nanotechnology).

[2] *See* Sagarmay Deb, *Information Technology, Its Impact on Society and Its Future*, 4 ADVANCES IN COMPUTING 25, 25–29 (2014) (discussing the past and potential future impacts

nology.[3] In addition to their transformative potential, these innovations are notable for the unprecedented rate at which they have emerged and continue to evolve.[4] As a growing body of literature observes, such technologies pose unique challenges to U.S. legal institutions, outrunning the normal pace of legal change and placing pressure on regulators to creatively deal with their rise.[5] This tension between innovation and the law is forcing regulators,

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of information technologies on business, medicine, education, and government); *see also* Monroe E. Price, *The Newness of New Technologies*, 22 CARDOZO L. REV. 1885, 1886 (2001) (speculating that innovations in "satellite [technologies], the Internet, and other information technologies will lead to the greatest revolution in information since the invention of the printing press").

[3] *See* Ronald Evens & Kenneth Kaitin, *The Evolution of Biotechnology and its Impact on Health Care*, 34 HEALTH AFFAIRS 210, 218 (2015) (observing that biotechnology has and will continue to produce a "continuing stream of novel medicines" which will have an "extraordinary impact" on health care); STEWART BRAND, THE CLOCK OF THE LONG NOW: TIME AND RESPONSIBILITY 13–14 (2000) (arguing that biological knowledge grows at an "exponential" rate and is transforming the "agriculture, nutrition, and healthcare" industries).

[4] *See* Braden Allenby, *The Dynamics of Emerging Technology Systems*, *in* INNOVATIVE GOVERNANCE MODELS FOR EMERGING TECHNOLOGIES 19–43 (Gary E. Marchant et al. ed., 2013) (arguing that the evolutionary pace and complexity of new emerging technologies, including nanotechnologies, biotechnologies, and information technologies, are unprecedented); RAY KURZWEIL, THE SINGULARITY IS NEAR (2005) (documenting the accelerating rate of technological change); DEREK J. DE SOLLA PRICE, LITTLE SCIENCE, BIG SCIENCE…AND BEYOND (1986) (arguing that the number of "important discoveries" has doubled every 20 years); Gordon E. Moore, *Progress in Digital Integrated Electronics*, TECH. DIGEST, 1975, at 11–13 (arguing that computing power doubles every 18-24 months); *see also* Rita Gunther McGrath, *The Pace of Technology Adoption is Speeding Up*, HARV. BUS. REV. (Nov. 25, 2013), https://hbr.org/2013/11/the-pace-of-technology-adoption-is-speeding-up [https://perma.cc/7DZW-WU5L] (summarizing several empirical analyses of the increasing rates of introduction and adoption of new technologies); Ilkka Tuomi, *Kurzweil, Moore, and Accelerating Change* 1–9 (Inst. for Prospective Tech. Studies, Working Paper, 2003), http://meaningprocessing.com/personalPages/tuomi/articles/Kurzweil.pdf (same).

[5] *See* INNOVATIVE GOVERNANCE MODELS FOR EMERGING TECHNOLOGIES (Gary E. Marchant et al. eds., 2013) (collecting essays on the incongruous rate at which the law and some emerging technologies evolve); THE GROWING GAP BETWEEN EMERGING TECHNOLOGIES AND LEGAL-ETHICAL OVERSIGHT (Gary E. Marchant et al. eds., 2011) (same); REGULATING TECHNOLOGIES: LEGAL FUTURES, REGULATORY FRAMES AND TECHNOLOGICAL FIXES (Roger Brownsword & Karen Yeung eds., 2008) (same); *see also* U.S. OFFICE OF TECH. ASSESSMENT, OTA-CIT-302, INTELLECTUAL PROPERTY RIGHTS IN AN AGE OF ELECTRONICS AND INFORMATION 3 (1986) ("Once a relatively slow and ponderous process, technological change is now outpacing the legal structure that governs the system . . . ."); Richard S. Whitt, *Adaptive Policymaking: Evolving and Applying Emergent Solutions for U.S. Commun-ications Policy*, 61 FED. COMM. L.J. 483, 497–98 (2009) ("[M]arket sectors featuring rapid and dynamic technological change . . . challenge the policymaker's ability to predict, control, and manage the system's behavior."); David Rejeski, *The Next Small Thing*, 21 ENVTL. F. 42, 45 (2004) ("We have moved into . . . a . . . world dominated by rapid improvements in products, processes, and organizations, all moving at rates

policymakers, and scholars to consider whether and how the law should respond to rapidly emerging technologies—a challenge centered on the need to simultaneously balance both public safety and the promotion of tantalizing social, economic, and environmental benefits.[6]

One of the most promising innovations in this cohort of rapidly emerging and potentially transformative technologies is autonomous vehicles.[7] It is widely agreed that autonomous vehicles have the potential to revolutionize personal and commercial transportation.[8] In particular, autonomous vehicles

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that exceed the ability of our traditional governing institutions to adapt or shape outcomes. If you think that any existing regulatory framework can keep pace with this rate of change, think again."); John H. Pearson, *Regulating in the Face of Technological Advance: Who Makes These Calls Anyway?*, 13 NOTRE DAME J.L. ETHICS & PUB. POL'Y 1, 1–2 (1999) (suggesting that technological advances are now "so fast and furious that they raise severe doubts about how and if the legal and governmental structures of western democracy . . . can respond").

[6] *See* Gregory N. Mandel, *Regulating Emerging Technologies*, 1 L. INNOVATION & TECH. 75, 75 (2009) ("The challenge is how to simultaneously leverage a promising innovation's anticipated benefits while guarding against its potential risks . . . ."); Christopher Bosso, *The Enduring Embrace: The Regulatory* Ancien Régime *and Governance of Nanomaterials in the U.S.*, 9 NANOTECHNOLOGY L. & BUS. 381, 381 (2013) (framing the regulation of technological innovations as the challenge of balancing potential benefits against potential risks and negative impacts); Albert C. Lin, *Size Matters: Regulating Nanotechnology*, 31 HARV. ENVTL. L. REV. 350, 375 (2007) (describing in similar terms "the challenge" of regulating nanotechnology as that of "address[ing] health and environmental concerns without crippling [a] promising industry").

[7] As used in this article, the term "autonomous vehicle" refers to fully autonomous vehicles, or autonomous vehicles which require no active human control. *See generally* SOCIETY OF AUTOMOTIVE ENGINEERS, TAXONOMY AND DEFINITIONS FOR TERMS RELATED TO ON-ROAD MOTOR VEHICLE AUTOMATED DRIVING SYSTEMS (2016) (outlining a taxonomy for motor vehicle automation). Although intermediate levels of automation are already available in the marketplace, *see* Kersten Heineke et al., *Self-Driving Car Technology: When Will the Robots Hit the Road?*, MCKINSEY & CO. (May 17, 2017), https://www.mckinsey.com/industries/automotive-and-assembly/our-insights/self-driving-car-technology-when-will-the-robots-hit-the-road [https://perma.cc/5UX2-JWXE], full automation poses the greatest challenge to existing regulatory structures because it eliminates an historical constant: human drivers; *see generally* Bryant Walker Smith, *Automated Vehicles are Probably Legal in the United States*, 1 TEX. A&M L. REV. 411, 412 (2014) (discussing comprehensively the challenge of regulating autonomous vehicles under existing domestic and international law).

[8] *See, e.g.*, NAT'L HIGHWAY TRAFFIC SAFETY ADMIN., FEDERAL AUTOMATED VEHICLES POLICY 5 (2016) [hereinafter NHTSA POLICY 2016] ("The development of advanced automated vehicle . . . technologies . . . may prove to be the greatest personal transportation revolution since the popularization of the personal automobile nearly a century ago."); JAMES A. ANDERSON ET AL., RAND CORP., AUTONOMOUS VEHICLE TECHNOLOGIES: A GUIDE FOR POLICYMAKERS xiii (2016) [hereinafter RAND REPORT] ("Autonomous vehicle (AV) technology offers the possibility of fundamentally changing transportation."); ENO CTR. FOR TRANSP., PREPARING A NATION FOR AUTONOMOUS VEHICLES: OPPORTUNITIES, BARRIERS AND POLICY RECOMMENDATIONS 1 (2013) [hereinafter ENO REPORT] ("AVs have the potential to fundamentally alter transportation systems . . . .").

promise to deliver significant social, economic, and environmental benefits to both consumers and businesses. These benefits include a drastic reduction in the number traffic fatalities and injuries, significant gains in individual productivity, unprecedented mobility for the elderly and disabled populations, greater flexibility in urban planning, and a reduction in harmful vehicle emissions.[9] As automobile manufacturers and technology firms race closer to the technological viability of fully autonomous vehicles, the hypothesized benefits of these vehicles are closer than ever to becoming a reality.[10]

Nevertheless, the widespread adoption of autonomous vehicles is far from guaranteed. One significant potential obstacle is the legal environment within which they must continue to develop and operate. Although regulation can help to facilitate the commercial success of emerging technologies,[11] as well as manage their potential risks,[12] it also has potential drawbacks.[13] In the context of autonomous vehicles, attempts to overcome the incongruous rates at which the law and automation technologies evolve may lead to suboptimal outcomes.[14] Indeed, the most common responses to this "pacing problem"[15] generate their own impediments to the widespread commercial adopt of autonomous vehicle technologies.[16] The challenge of regulating autonomous vehicles, as such, is to identify a regulatory approach which addresses the tension between innovation and regulation in a way which maximizes potential benefits and minimizes

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[9] *See infra* Part I.A (discussing the potential benefits of autonomous vehicles).

[10] *See* RAND REPORT, *supra* note 8, at 74 ("Efforts of the last 15 years, first by universities and then by industry, have brought this technology to near readiness.").

[11] *See, e.g.*, Larry Downes, *The Right and Wrong Way to Regulate Self-Driving Cars*, HARV. BUS. REV. (Dec. 6, 2016), https://hbr.org/2016/12/the-right-and-wrong-ways-to-regulate-self-driving-cars [https://perma.cc/3JK8-4TX5] ("Done correctly, an evolving legal system can encourage optimal investment in technologies that will increase social welfare, public safety, and sustainable energy consumption, as well as positively impact labor markets, land use, public health, and more.").

[12] *See, e.g.*, WORLD COMM'N ON THE ETHICS OF SCIENTIFIC KNOWLEDGE AND TECH., THE PRECAUTIONARY PRINCIPLE, 7–53 (2005), http://unesdoc.unesco.org/images/0013/001395/139578e.pdf [https://perma.cc/3JK8-4TX5] (defending the role of regulation in minimizing risks to public health and safety in the face of scientific and technological uncertainty).

[13] *See, e.g.*, NAT'L HIGHWAY TRAFFIC SAFETY ADMIN., PRELIMINARY STATEMENT OF POLICY CONCERNING AUTOMATED VEHICLES 10 (2013) [hereinafter NHTSA POLICY 2013] ("[T]he agency recognizes that premature regulation can run the risk of putting the brakes on the evolution toward increasingly better vehicle safety technologies.").

[14] *See infra* Part II.B (analyzing the impacts of different regulatory approaches on the commercial success of their target technologies, including autonomous vehicles).

[15] Gary E. Marchant, *The Growing Gap Between Emerging Technologies and the Law*, *in* THE GROWING GAP BETWEEN EMERGING TECHNOLOGIES AND LEGAL-ETHICAL OVERSIGHT 23 (Gary E. Marchant et al. eds., 2011) (coining the phrase "pacing problem").

[16] *See infra* Part II.B (arguing further that traditional approaches to managing the pacing problem may directly or indirectly deprive society of the benefits of autonomous vehicles).

potential risks. In this article, I directly address that challenge and offer a novel approach to the regulation of autonomous vehicles informed by the principles of planned adaptive regulation.

In Part I, I briefly summarize the most significant anticipated benefits of autonomous vehicles and outline the regulatory environment within which autonomous vehicles currently operate. In Part II, I closely examine the unique regulatory challenge posed by rapidly evolving technologies like autonomous vehicles and identify three common responses to that challenge. In doing so, I draw on Part I to illustrate each response in the context of autonomous vehicle regulation and describe the way in which each could hamper the adoption of autonomous vehicle technologies. Finally, in Part III, I offer an approach to the regulation of autonomous vehicles which aims to address the shortcomings of existing regulatory approaches and adds to the nascent literature on adaptive regulation. I argue that any system for regulating autonomous vehicles must directly address the limited reactive and adaptive capabilities of U.S. legal institutions, rather than circumvent these limitations by attempting to perfect regulatory frameworks ex ante. To operationalize this evolutionary paradigm, I propose a new approach informed by the principles of planned adaptive regulation.

I. THE POTENTIAL BENEFITS AND CURRENT REGULATION OF AUTONOMOUS VEHICLES

The potential benefits of autonomous vehicles are substantial.[17] As former Transportation Secretary Anthony Foxx remarked in 2016, "[t]he development of advanced automated vehicle . . . technologies . . . may prove to be the greatest personal transportation revolution since the popularization of the personal automobile nearly a century ago."[18] Although the technology for full automation continues to develop,[19] widespread commercial adoption of autonomous vehicle technology promises to deliver a wide range of social, economic, and environmental benefits.[20] The precise magnitude of these benefits is difficult to predict, but existing research suggests that the net

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[17] *See generally* Tracy Hresko Pearl, *Fast & Furious: The Misregulation of Driverless Cars*, 73 N.Y.U. ANN. SURV. AM. L. 19, 35–43 (2017) (providing a detailed discussion of the likely benefits of autonomous vehicles).

[18] NHTSA POLICY 2016, *supra* note 8, at 5.

[19] *See* TODD LITMAN, VICTORIA TRANSP. POLICY INST., AUTONOMOUS VEHICLE IMPLEMENTATION PREDICTIONS 10–13 (2018) (describing the limits of existing autonomous vehicle technology and deployment).

[20] *See generally* RAND REPORT, *supra* note 8, at 9–36 (providing an overview of the likely benefits of autonomous vehicles); Pearl, *supra* note 17, at 35–43 (same).

impact of autonomous vehicles will be significant.[21] In this Part, I briefly summarize the most significant of these predicted benefits and describe the regulatory environment within which autonomous vehicle technology must continue to develop and operate.

A. The Potential Benefits of Autonomous Vehicles

1. Transportation Safety

The most notable predicted benefit of autonomous vehicle technology is a substantial reduction in the human and economic toll of traffic accidents.[22] In 2016, there were more than 7.2 million reported vehicle accidents resulting in 3.14 million injured people and over 37,000 deaths.[23] According to the National Highway Transportation Safety Administration (NHTSA), 94 percent of all vehicle crashes are attributable to human error.[24] These sources of error include, but are not limited to, "driving too fast,

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[21] *See, e.g.*, Morgan Stanley, *Autonomous Cars: Self-Driving the New Auto Industry Paradigm, Blue Paper* (2013) (discussing economic benefits); Daniel J. Fagant & Kara M. Kockelman, *The Travel and Environmental Implications of Shared Autonomous Vehicles, Using Agent-Based Model Scenarios*, 40 TRANSP. RESEARCH PART C 1, 8–10 (2013) (discussing environmental benefits); Pearl, *supra* note 17, at 35–39 (discussing public health benefits). The realization of these benefits will not necessarily have a perfectly linear correlation with the market saturation of autonomous vehicles. Instead, the majority of benefits may not be realized until autonomous vehicles constitute a certain minimum percentage of the overall vehicle population. Similarly, autonomous vehicles may impose new costs, such as displacing existing institutions, services, and jobs. On balance, however, the benefits of autonomous vehicles are likely to far outweigh their costs. *See* MORGAN STANLEY, *supra* note 21, at 7 (estimating total net economic benefits of more than $1.3 trillion annually in the U.S. and $5.6 trillion annually across the globe once autonomous vehicles reach peak market penetration).

[22] In its 2016 policy statement, NHTSA hailed autonomous vehicle technology as a "potentially unprecedented advance in safety on U.S. roads and highways." NHTSA POLICY 2016, *supra* note 8, at 5.

[23] NAT'L CTR. FOR STATISTICS AND ANALYSIS, NAT'L HIGHWAY TRAFFIC SAFETY ADMIN., 2016 MOTOR VEHICLE CRASHES: OVERVIEW 1 (2017), https://crashstats.nhtsa.dot.gov/Api/Public/Publication/812456 [https://perma.cc/FA5C-PN9H]; *Traffic Safety Facts Annual Report Tables: National Statistics*, NAT'L HIGHWAY TRAFFIC SAFETY ADMIN., https://cdan.nhtsa.gov/tsftables/National%20Statistics.pdf [https://perma.cc/5ENQ-9XQZ].

[24] *Automated Vehicles for Safety*, NAT'L HIGHWAY TRAFFIC SAFETY ADMIN., https://www.nhtsa.gov/technology-innovation/automated-vehicles [https://perma.cc/2WVR-DJPX] (last visited Aug. 18, 2018). In addition, "[e]ven when the critical reason behind a crash is attributed to the vehicle, roadway or environment, additional human factors . . . are regularly found to have contributed to the crash occurrence and/or injury severity." ENO REPORT, *supra* note 8, at 3.

misjudging other drivers' behaviors, alcohol impairment, distraction, and fatigue."[25] Indeed, impairment, distractions, and fatigue alone account for over 50 percent of all fatal crashes.[26] The use of autonomous vehicles could significantly reduce the incidence of such crashes, as vehicles with no human operators are never drunk, distracted, fatigued, or otherwise susceptible to human failings.[27] In addition, any reduction in accidents would offer significant economic benefits in the form of fewer hospital stays, days of work missed, lives lost, and instances of property damage, among other savings.[28] In 2015 alone, vehicle crashes cost the U.S. economy $300 billion, or 2 percent of Gross Domestic Product (GDP), meaning that even a 25 percent reduction in accidents could save nearly $100 billion annually.[29]

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[25] *Shaping the Future of Autonomous Vehicles: How Policymakers Can Promote Safety, Mobility, and Efficiency in an Uncertain World: Hearing Before the Subcomm. on Transp., Housing and Urban Dev., and Related Agencies of the S. Comm. on Appropriations*, 114th Cong. 2 (2016) (statement of Nidhi Kalra, Senior Info. Scientist, RAND Corp.) [hereinafter Kalra Testimony] (citations omitted).

[26] *Id.* (adding together all crash data due to drunk, distracted, or fatigued drivers).

[27] *See* Neal Katyal, *Disruptive Technologies and the Law*, 102 GEO. L.J. 1685, 1688 (2014) (estimating that 90 percent market penetration would prevent over 4 million crashes annually). Indeed, "most autonomous vehicle researchers agree that fully autonomous vehicles can drastically improve highway safety." Pearl, *supra* note 17, at 38 n.122 (providing a comprehensive review of research to this effect); *see also* Press Release, Nat'l Highway Traffic Safety Admin., U.S. DOT, National Safety Council Launch 'Road to Zero' Coalition to End Roadway Fatalities (Oct. 5, 2016), https://www.transportation.gov/briefing-room/us-dot-national-safety-council-launch-road-zero-coalition-end-roadway-fatalities [https://perma.cc/HD3U-B2XN] ("With the rapid introduction of automated vehicles . . . the Department believes it is now increasingly likely that the vision of zero road deaths and serious injuries can be achieved in the next 30 years."). Autonomous vehicles could also improve the avoidance of others, such as pedestrians, who are still prone to human error. *Cf.* RAND REPORT, *supra* note 8, at 16 n.3 (noting further that "49 percent of pedestrians killed by motor vehicles are under the influence of alcohol" and that "38 percent of cyclists killed by motor vehicles are under the influence of alcohol"). Still, autonomous vehicles might not eliminate all accidents. For instance, "inclement weather and complex driving environments pose challenges for autonomous vehicles, as well as for human drivers, and autonomous vehicles might perform worse than human drivers in some cases. There is also the potential for autonomous vehicles to pose new and serious crash risks—for example, crashes resulting from cyberattacks." Kalra Testimony, *supra* note 25, at 2–3 (citations omitted).

[28] *See* ENO REPORT, *supra* note 8, at 8; *see also* NHTSA POLICY 2013, *supra* note 13, at 1 ("Preventing significant numbers of crashes will, in addition to relieving the enormous emotional toll on families, also greatly reduce the enormous related societal costs . . . that total in the hundreds of billions of dollars each year.").

[29] ENO REPORT, *supra* note 8, at 3–4; *see also* Adam Ozimek, *The Massive Economic Benefits of Self-Driving Cars*, FORBES (Nov. 8, 2014), http://www.forbes.com/sites/modeledbehavior/2014/11/08/the-massive-economic-benefits-of-self-driving-cars/#127de25b68d9 [https://perma.cc/2C3M-TK5L] (estimating in the alternative that all crashes combined cost the U.S. economy a total of $543 billion annually).

2. Access to Transportation

Another important potential benefit of autonomous vehicle technology is increased mobility for populations currently unable or not permitted to operate traditional vehicles. These populations include older citizens, the disabled, people too young to drive, and others without a driver's license.[30] As Clyde Terry, Chair of the National Council on Disability, recently testified before Congress, "a lack of reliable and accessible transportation remains one of the biggest deterrents to employment and community involvement" for members of these populations.[31] In turn, the widespread use of autonomous vehicles could dramatically increase the mobility of a wide range of people unable to operate traditional vehicles and have a transformative effect on their productivity, social wellbeing, and physical and mental health.[32] Similarly, any increased freedom and independence experienced by such populations could translate into gains in the productivity and wellbeing of caretakers, guardians, and family members.

3. Traffic Congestion and Land Use

In addition to making transportation safer and more accessible, autonomous vehicles could reduce congestion and change the way in which cities are planned. There are two ways in which autonomous vehicles could reduce congestion. First, although autonomous vehicles may lead to an increase in overall vehicle miles traveled,[33] they have the potential to "support higher vehicle throughput rates on existing roads."[34] In particular,

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[30] RAND REPORT, *supra* note 8, at 16–17.
[31] *Hands Off: The Future of Self-Driving Cars: Hearing Before the S. Comm. on Science, Tech., & Transp.*, 114th Cong. 1, 4 (2016) (statement of Clyde Terry, Chair, Nat'l Council on Disability).
[32] Kalra Testimony, *supra* note 25, at 6–8; *see also* NAT'L COUNCIL ON DISABILITY, SELF-DRIVING CARS: MAPPING ACCESS TO A TECHNOLOGY REVOLUTION 11 (2015), http://www.ncd.gov/sites/default/files/NCD_AutomatedVehiclesReport_508-PDF.pdf ("AVs will change the world for everyone, but the most dramatic impact could be for people with disabilities and people who are aging . . . . AVs can become an essential component of their independence, economic development, and well-being."); *cf.* RAND REPORT, *supra* note 8, at xv ("Some of these [benefits] are currently provided by mass transit or paratransit agencies, but each of these alternatives has significant disadvantages. Mass transit generally requires fixed routes that may not serve people where they live and work [and] [p]aratransit services are expensive because they require a trained, salaried, human driver.").
[33] *See* RAND REPORT, *supra* note 8, at 17–21.
[34] *Id.* at 21. Throughput rate is a measurement of the total number of vehicles moving between point A and point B within a given period of time. *Id.*

autonomous vehicles' ability to "constantly monitor surrounding traffic and respond with finely tuned braking and acceleration adjustments should enable [them] to travel safely at higher speeds and with reduced headway (space) between each vehicle."[35] Second, autonomous vehicles have the potential to drastically reduce congestion stemming from traffic accidents.[36] According to one estimate, accident-related congestion accounts for 25 percent of all congestion delays.[37] In turn, because autonomous vehicles have the potential to prevent the vast majority of accidents, they could "eliminat[e] an appreciable share of all traffic delays."[38] These reductions would also carry weighty economic implications, as congestion is estimated to cost the U.S. over $160 billion annually.[39]

A reduction in congestion and other changes in vehicle behavior could also positively impact existing patterns of land use. This impact would fall into two categories. First, autonomous vehicles could significantly reduce the amount of space devoted to vehicle parking within crowded urban areas.[40] The proximity of a vehicle owner to the parking place of an autonomous vehicle is far less relevant since autonomous vehicles could park themselves in remote locations and appear at a desired location upon request.[41] As population density in urban areas continues to skyrocket,[42] parking lots and

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[35] *Id.*

[36] *Id.*

[37] *Id.* at 23.

[38] *Id.*

[39] David Schrank et al., *2015 Urban Mobility Scorecard*, TEX. A&M TRANSP. INST. 1 (2015). This figure includes additional expenses (e.g., fuel) and opportunity costs (e.g., lost productivity). *Id.* Another estimate places the cost at closer to $100 billion annually. *See* Adeel Lari et. al., *Self-Driving Vehicles and Policy Implications: Current Status of Autonomous Vehicle Development and Minnesota Policy Implications*, 16 MINN. J.L. SCI. & TECH. 735, 752 (2015) ("Increases in capacity ultimately mean more convenient travel and reductions in congestion, which currently costs Americans $100 billion in wasted fuel and lost time, according to some reports.").

[40] *See* David Levinson, *Climbing Mount Next: The Effects of Autonomous Vehicles on Society*, 16 MINN. J.L. SCI. & TECH. 787, 805 (2015) (describing how autonomous vehicles would allow parking spaces to be "repurposed").

[41] *See id.* ("Autonomous vehicles can drop off their passenger at the front door, and then park themselves in far less space than drivers currently require (or move on to their next passenger), and that space need not be so close to the most valuable urban areas.").

[42] The United Nations (UN) estimates that, in 2010, a staggering 82 percent of the U.S. population already lived in urban areas. DEP'T OF ECON. AND SOC. AFFAIRS, UNITED NATIONS, WORLD URBANIZATION PROSPECTS 133 (2011), http://www.un.org/en/development/desa/population/publications/pdf/urbanization/WUP2011_Report.pdf. It is further projected that "84.4 percent of Americans will live in urban areas [by 2020], with more than 28 percent living in urban areas of more than five million people." CTR. FOR AUTOMOTIVE RES., SELF-DRIVING CARS: THE NEXT REVOLUTION 8 (2012) (citation omitted).

garages are projected to occupy increasingly valuable urban space, leading to "urban dead zones."[43] In some U.S. cities, "parking lots cover more than a third of the land area, becoming the single most salient feature of our built environment."[44] Autonomous vehicles offer an opportunity to repurpose such space for more socially and economically productive uses.[45] Second, because autonomous vehicles allow their owners to engage in other activities while riding, individuals and firms may be more willing to "locate further away from the urban core."[46] This would help to alleviate urban crowding and make more affordable peripheral housing accessible and practical for those who cannot afford urban housing.[47]

4. Energy and Emissions

Finally, autonomous vehicle technology has the potential to reduce both energy consumption and pollution. Several factors could improve fuel economy in autonomous vehicles relative to traditional vehicles. These factors include efficiencies gained through smoother acceleration and deceleration, reduced distance between vehicles, and increased roadway capacity.[48] In addition, given their potential to virtually eliminate traffic accidents, autonomous vehicles could be lighter than conventional vehicles, shedding the materials necessary to meet rigorous crash-test standards.[49] Less obviously, autonomous vehicles may also help to reduce emissions by

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[43] CTR. FOR AUTOMOTIVE RES., *supra* note 42, at 8.

[44] ERAN BEN-JOSEPH, RETHINKING A LOT: THE DESIGN AND CULTURE OF PARKING xi (2012).

[45] *See, e.g.*, ENO REPORT, *supra* note 8, at 20 (estimating that each autonomous vehicle will save $250 in annual parking costs).

[46] RAND REPORT, *supra* note 8, at 26.

[47] *See id.* at 27 ("AVs could support even greater dispersion of low-density development along the outskirts of major metropolitan areas given the ability of owners to engage in other activities as vehicles pilot themselves.").

[48] *See* Levinson, *supra* note 40, at 796–97 ("Because they are safer, autonomous vehicles can have shorter headways."), 805–06 ("Fuel costs on the other hand should be lower, as autonomous vehicles are likely to be more efficient, both due to less congestion and to more optimized driving styles . . . ."); ENO REPORT, *supra* note 8, at 4–5 ("Under various levels of AV adoption congestion savings due to ACC measures and traffic monitoring systems could smooth traffic flows by seeking to minimize accelerations and braking in freeway traffic."); CTR. FOR AUTOMOTIVE RES., *supra* note 42, at 26, 31 ("A transportation system composed of self-driving vehicles would decrease energy consumption in at least three primary ways: more efficient driving; lighter, more fuel-efficient vehicles; and efficient infrastructure.").

[49] Kalra Testimony, *supra* note 25, at 11. This benefit would, of course, require near universal adoption of autonomous vehicle technology as crash risks would persist so long as human drivers remain on the road.

enabling the use of alternative fuels.[50] For example, "if the decrease in frequency of crashes allows lighter vehicles, many of the range issues that have limited the use of electric and other alternative vehicles [would be] diminished."[51] Similarly, the ability of autonomous vehicles to drop off passengers and then drive to refuel themselves could "permit a viable system with fewer refueling stations than would otherwise be required."[52]

B. The Current Regulatory Environment for Autonomous Vehicles

The legal environment within which autonomous vehicles and their associated benefits must continue to develop remains in a nascent stage. It is generally accepted that, absent specific laws or regulations to the contrary, autonomous vehicles are legal in the United States.[53] Although well over half of all states have enacted legislation or issued executive orders related to autonomous vehicles, only a fraction of these laws impose or authorize the creation of binding regulatory mandates.[54] Similarly, the federal government, acting through NHTSA, has taken a laissez-faire approach and declined to initiate any rulemakings in the area of autonomous vehicle design or

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[50] *See* RAND REPORT, *supra* note 8, at 33–36 (considering how autonomous vehicles may "enable and accelerate specific competitive aspects of alternative vehicles and fuels").

[51] *Id.* at xvi.

[52] *Id.* at xvi–xvii. One recent study even showed that sharing electronic autonomous vehicles could reduce greenhouse gas emissions 87–94 percent by 2030 relative to current conventional vehicles. Jeffery B. Greenblatt & Samveg Saxena, *Autonomous Taxis Could Greatly Reduce Greenhouse-Gas Emissions of US Light-Duty Vehicles*, 5 NATURE CLIMATE CHANGE 860, 860–62 (2015). *But see* RAND REPORT, *supra* note 8, at xvii ("[D]ecreases in the cost of driving, and additions to the pool of vehicle users (e.g., elderly, disabled, and those under 16)[,] are likely to result in an increase in overall [vehicle miles traveled]. While it seems likely that the decline in fuel consumption and emissions would outweigh any such increase, it is uncertain.").

[53] *See* NHTSA POLICY 2016, *supra* note 8, at 11 ("[I]f a vehicle is compliant within the existing FMVSS regulatory framework and maintains a conventional vehicle design, there is currently no specific federal legal barrier to . . . being offered for sale."); NAT'L HIGHWAY TRANSP. ADMIN., *Understanding NHTSA's Regulatory Tools* 2 (2016) ("It is important to note that NHTSA does not prohibit the introduction of new motor vehicles or motor vehicle technologies into the vehicle fleet, provided those vehicles and technologies meet existing FMVSS."); *see also* Smith, *supra* note 7, at 516 (conducting an extensive review of existing domestic and international law and concluding that autonomous vehicles are most likely legal in the United States).

[54] *See Autonomous Vehicles: Self-Driving Vehicle Legislation*, NAT'L CONF. OF STATE LEGISLATURES (Aug. 27, 2018) [hereinafter NCSL List], http://www.ncsl.org/research/transportation/autonomous-vehicles-self-driving-vehicles-enacted-legislation.aspx#Enacted%20Autonomous%20Vehicle%20Legislation [https://perma.cc/T37B-3MGU] (listing and providing a searchable interface of all proposed and enacted state autonomous vehicle legislation).

performance.[55] There is, effectively, a blank canvas just starting to be filled by federal and state regulators. In the following section, I briefly describe the most recent slate of federal regulatory proposals and summarize the regulatory actions taken at the state level.

1. Federal Regulation

The federal government has maintained a permissive posture toward autonomous vehicle technology.[56] In addition to voicing its support and aspirations for the widespread commercial adoption of autonomous vehicle technology,[57] NHTSA has refrained from mandating technology-specific design features and performance standards.[58] In its most recent policy

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[55] *See generally* NAT'L HIGHWAY TRAFFIC SAFETY ADMIN., AUTOMATED DRIVING SYSTEMS 2.0: *A VISION FOR SAFETY* ii (2017) [hereinafter NHTSA POLICY 2017] (offering non-binding guidance to industry and state actors); NHTSA POLICY 2016, *supra* note 8 (same); NHTSA POLICY 2013, *supra* note 13 (same).

[56] NHTSA is responsible for regulating vehicle safety and performance. 49 U.S.C. § 30111 ("The Secretary of Transportation shall prescribe motor vehicle safety standards."); 49 U.S.C. § 30102(a)(9) ("'[M]otor vehicle safety' means the performance of a motor vehicle or motor vehicle equipment in a way that protects the public against unreasonable risk of accidents occurring because of the design, construction, or performance of a motor vehicle, and against unreasonable risk of death or injury in an accident, and includes nonoperational safety of a motor vehicle."); 49 U.S.C. § 30102(a)(10) ("'[M]otor vehicle safety standard' means a minimum standard for motor vehicle or motor vehicle equipment performance."). Traditionally, states have been responsible for regulating other aspects of vehicle operation. *See* Stephen P. Wood et al., *The Potential Regulatory Challenges of Increasingly Autonomous Motor Vehicles*, 52 SANTA CLARA L. REV. 1423, 1435 (2012) ("[NHTSA] does not regulate the actions of vehicle owners, the operation of motor vehicles on public roads, or the maintenance and repair of vehicles-in-use."); *see also* NHTSA POLICY 2017, *supra* note 55, at 20 ("State[ ] responsibilities [include] . . . licensing human drivers and registering motors vehicles in their jurisdictions; enacting and enforcing traffic laws and regulations; conducting safety inspections . . . ; [and] regulating motor vehicle insurance and liability."). Although the distinction between the vehicle and its driver is increasingly blurred in the context of autonomous vehicles, NHTSA has signaled its intent to maintain exclusive control over vehicle design and performance. *Id*. ("DOT strongly encourages States to allow DOT alone to regulate the safety design and performance aspects of ADS technology. If a State does pursue ADS performance-related regulations, that State should consult with NHTSA.").

[57] *See, e.g.*, NHTSA POLICY 2017, *supra* note 55, at ii ("[A]utomated vehicle technologies possess the potential to save thousands of lives, as well as reduce congestion, enhance mobility, and improve productivity. The Federal Government wants to ensure it does not impede progress with unnecessary or unintended barriers to innovation."); NHTSA POLICY 2016, *supra* note 8, at 6 ("Recognizing [their] great potential, this Policy sets out an ambitious approach to accelerate the [autonomous vehicle] revolution."); NHTSA POLICY 2013, *supra* note 13, at 1 (reflecting a similar sentiment).

[58] *See* NHTSA POLICY 2017, *supra* note 55, at ii, 2 (reaffirming NHTSA's commitment to a "nonregulatory approach" to autonomous vehicle safety and offering "recommendations and

statement,[59] the agency offered a "nonregulatory approach" to autonomous vehicle safety.[60] To that end, the document outlined 12 vehicle performance guidelines for industry participants to "consider" as they develop, test, and deploy autonomous vehicles on public roadways.[61] The guidelines cover broad categories such as "system safety," "human machine interface," and "crashworthiness."[62] Although NHTSA encouraged industry participants to submit a "Safety Self-Assessment" describing their treatment of each guideline, it emphasized that doing so is "entirely voluntary" and that there is no "compliance or enforcement mechanism" for its recommendations.[63] In short, the policy statement signaled to industry participants that they are free to engage in "testing [and] deployment" without any pre-approval from the agency.[64]

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suggestions" to industry and state actors); NHTSA POLICY 2016, *supra* note 8, at 6, 11 (emphasizing NHTSA's use of "agency guidance rather than . . . rulemaking" and that, although elements of the guidance may become binding in the future, it is "not [presently] mandatory"); *see also* William J. Kohler & Alex Colbert-Taylor, *Current Law and Potential Legal Issues Pertaining to Automated, Autonomous, and Connected Vehicles*, 31 SANTA CLARA HIGH TECH. L.J. 99, 105 (2015) ("[T]he U.S. federal government has not attempted to regulate autonomous motor vehicles as such.").

59 The prior policy statements were published in 2013 and 2016. *See* NHTSA POLICY 2016, *supra* note 8 (updating the 2013 policy); NHTSA POLICY 2013, *supra* note 13 (articulating the first federal policy).

60 NHTSA POLICY 2017, *supra* note 55, at ii.

61 *Id.* at 2.

62 *Id.* at 5, 10, 12.

63 *Id.* at 2, 16. Although the new guidance does not materially change any existing elements of federal policy toward autonomous vehicles—a policy which has always been premised on voluntary compliance—it does change the trajectory of that policy. In 2016, for example, NHTSA looked poised to mandate autonomous vehicle-specific safety standards and the submission of self-assessments. *See* NHTSA POLICY 2016, *supra* note 8, at 100 (identifying as "next steps" the mandatory "submission of [a] Safety Assessment" and promulgation of "a new FMVSS"). The new guidance, however, makes clear that NHTSA does not intend to pursue either measure. The new guidance also abandons four proposed changes to NHTSA's statutory authorities and internal processes, including a pre-market approval process. *See id.* at 63-82 (describing "regulatory tools and authorities . . . [with] potential to facilitate the expeditious and safe introduction of [automated vehicles]"). The 2017 guidance thus sends a clear message that NHTSA intends to act as an aggregator of best practices and post-market safety net, not a hands-on participant in the pre-market design process.

64 NHTSA POLICY 2017, *supra* note 55, at 16 ("NHTSA does not require that entities provide submissions nor are they required to delay testing or deployment. Assessments are not subject to Federal approval."); *see also* Adam Thierer & Jennifer Huddleston Skees, *Big Questions About NHTSA's "Soft Law" Driverless Cars Guidance*, PLAIN TEXT (Sept. 13, 2017), https://readplaintext.com/big-questions-about-nhtsas-soft-law-driverless-cars-guidance-e9da327a7522 [https://perma.cc/KMQ8-ZYMQ] ("[T]he agency had previously hinted that it might consider a 'pre-market approval approach—used either in conjunction with or as a replacement for DOT's

The lack of technology-specific regulations, however, does not mean that autonomous vehicles are unregulated at the federal level. To the contrary, NHTSA has been careful to remind manufacturers that they must comply with existing mandates applicable to conventional vehicles.[65] Under the National Traffic and Motor Vehicle Safety Act,[66] the agency uses notice and comment rulemaking to create design, construction, and performance standards, known as Federal Motor Vehicle Safety Standards (FMVSS), applicable to all motor vehicles.[67] A manufacturer must self-certify compliance with each applicable standard absent a specific exemption from the agency.[68] Although NHTSA lacks the authority to pre-approve or block new vehicle designs or technologies before they come to market, it may test commercially available vehicles and pursue enforcement actions if a vehicle fails to meet an applicable FMVSS.[69] In addition, NHTSA may order a vehicle or equipment recall if it identifies a "defect" posing an "unreasonable risk to safety."[70] This authority applies "notwithstanding the

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existing self-certification and compliance testing process.' But that suggestion has now been abandoned . . . .").

[65] *See* NHTSA POLICY 2017, *supra* note 55, at 3 ("NHTSA has broad enforcement authority to address existing and new automotive technologies and equipment."); NHTSA POLICY 2016, *supra* note 8, at 7 ("NHTSA will continue to exercise its available regulatory authority over [autonomous vehicles] using its existing regulatory tools . . . ."); NHTSA Enforcement Guidance Bulletin 2016–02: Safety-Related Defects and Automated Safety Technologies, 81 Fed. Reg. 65,706 (Sept. 23, 2016) [hereinafter NHTSA Enforcement Bulletin] ("[T]his Guidance aims to increase awareness of NHTSA's enforcement authority over motor vehicle equipment in all of its various forms.").

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

[67] *See* 49 U.S.C. § 30111 ("The Secretary of Transportation shall prescribe motor vehicle safety standards."); 49 C.F.R. § 553 (2017) (listing procedures for adopting rules); *see also* NHTSA POLICY 2016, *supra* note 8, at 49 ("Notice-and-comment rulemaking is the tool the Agency uses to adopt new standards, modify existing standards, or repeal an existing standard."). The FMVSS are codified at 49 C.F.R. §§ 571.101–571.500.

[68] *See* 49 U.S.C. § 30115 (describing the self-certification process); 49 U.S.C. §§ 30113-30114 (describing the circumstances under which temporary exemptions may be granted). In addition to exemptions, the public may also request a letter of interpretation from NHTSA. *See* NAT'L HIGHWAY TRANSPORTATION ADMIN., *Understanding NHTSA's Regulatory Tools* 2–3 (2016). Interpretation letters and rulings on exemptions have "historically . . . taken several months to several years" for the agency to issue. NHTSA POLICY 2016, *supra* note 8, at 49.

[69] *See* 49 U.S.C. § 30112(a); *see also* NHTSA Enforcement Bulletin, *supra* note 65, at 65,707 (stating that NHTSA's enforcement authority under the National Traffic Safety and Motor Vehicle Act "includes investigations, administrative proceedings, civil penalties, and other civil enforcement actions").

[70] NHTSA Enforcement Bulletin, *supra* note 65, at 65, 707–08 (explaining how NHTSA determines whether a defect exists and, if so, whether it poses an unreasonable risk to safety); *see also* 49 U.S.C. § 30102(a)(3) (defining "defect," in a circular fashion, as any "defect in performance, construction, a component, or material of a motor vehicle or motor vehicle equipment"); 49 U.S.C. § 30102(a)(9) (defining "motor vehicle safety" as an "unreasonable

presence or absence of an FMVSS."[71] Thus, as applied to autonomous vehicles, NHTSA has the authority to create and enforce FMVSS and, separately, to recall vehicles that otherwise pose an "unreasonable risk to safety."[72]

As of the time of this writing, Congress is also considering two pieces of autonomous vehicle legislation.[73] Under both, lawmakers would largely codify the existing federal policy on autonomous vehicles. The SELF DRIVE Act, which already passed in the House of Representatives, gives NHTSA 1 year to issue a "rule-making and safety priority plan" outlining, "as necessary," any technology-specific amendments and additions to the FMVSS.[74] The AV START Act, currently pending in the Senate, would require one-time recommendations within 5 years from a "Highly Automated Vehicles Technical Committee," after which NHTSA would have 1 year to consider and promulgate any technology-specific amendments or additions to the FMVSS.[75] In the interim, both proposals would allow vehicle testing to move forward and authorize NHTSA to grant manufacturers at least 80,000 exemptions from existing FMVSS.[76] The bills would also require manufacturers to submit some version of the "Voluntary Safety Self-Assessment" described in NHTSA's 2017 policy statement, though prohibit any adverse action based thereupon.[77] Notably, neither

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risk of accidents" or "unreasonable risk of death or injury in an accident"); 49 U.S.C. § 30118(b) (requiring a recall if NHTSA identifies a "defect related to motor vehicle safety").

[71] NHTSA Enforcement Bulletin, *supra* note 65, at 65,707 (citing United States v. Chrysler Corp., 158 F.3d 1350, 1351 (D.C. Cir. 1998)). Notably, NHTSA's recall authority does not authorize it to order immediate mitigation measures by the manufacturer. *See* 49 U.S.C. §§ 30118, 30120 (describing the recall authority).

[72] *See* NHTSA POLICY 2017, *supra* note 55, at 20 (explaining that NHTSA is authorized to "enforc[e] compliance with FMVSSs" and oversee the "recall and remedy of . . . safety-related vehicle defects" for autonomous vehicles); NHTSA POLICY 2016, *supra* note 8, at 48 (stating that NHTSA will treat autonomous vehicles like conventional vehicles and "pursue[] enforcement actions when the Agency finds either a non-compliance [with FMVSS] or a defect posing an unreasonable risk to safety"); NHTSA Enforcement Bulletin, *supra* note 65, at 65,708 (same).

[73] *See* SELF DRIVE Act, H.R. 3388, 115th Cong. (2017) (regulating "the safety of highly automated vehicles"); AV START Act, S. 1885, 115th Cong. (2017) (supporting "the development of highly automated vehicle safety technologies"). For a side-by-side comparison of the two pieces of legislation, see *Section-by-Section Comparison of House and Senate Autonomous Vehicle Bills*, ENO CTR. FOR TRANSP. (Oct. 6, 2017), https://www.enotrans.org/wp-content/uploads/2017/10/AV-Bill-SBS-Senate-Reported.pdf?x43122.

[74] H.R. 3388, 115th Cong. § 4 (2017).

[75] S. 1885, 115th Cong. §§ 10(d)(3), 11(b) (2017). The bill would require a more expedient review and resolution of any conflicts between existing FMVSS and autonomous vehicle technologies. *See id.* § 4.

[76] *See* H.R. 3388, 115th Cong. § 6 (2017) (providing for up to 100,000 exemptions); S. 1885, 115th Cong. § 6 (2017) (providing for up to 80,000 exemptions).

[77] *See* H.R. 3388, 115th Cong. § 4 (2017) (directing NHTSA to promulgate a rule requiring submission of "safety assessment certifications" and, in the interim, mandating submission

law would change the process by which the agency establishes or revises its rules governing vehicle design and performance. NHTSA's recall authority would also remain untouched. Although increasing the number of exemptions could make the system more flexible, FMVSS exemptions operate on a case-by-case basis.

2. State Regulation

Most states have also taken a hands-off approach to regulating the safety and operation of autonomous vehicles. Although 35 states and the District of Columbia have enacted legislation or issued an executive order related to autonomous vehicles,[78] many of these laws simply call for the study of autonomous vehicles,[79] establish advisory committees,[80] or consider narrow applications of automated technology.[81] Only a fraction of the enacted state laws impose specific regulatory mandates,[82] instruct state agencies to promulgate

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of the Safety Self-Assessment contemplated by the agency's 2017 policy statement); S. 1885, 115th Cong. § 9 (2017) (requiring a "safety evaluation report" and describing its content).

[78] *See* NCSL List, *supra* note 54 (listing proposed and enacted autonomous vehicle laws by state).

[79] *See* H.R. 1065, 64th Leg. Assemb. (N.D. 2015) (commissioning a study about the benefits of automated motor vehicles and requesting recommendations for policy changes); Exec. Order No. 18-04 (Minn. 2018) (establishing an "Advisory Council" to "study, assess, and prepare for the transformation and opportunities associated with the widespread adoption of automated and connected vehicles" and "develop recommendations for changes in state law, rules, and policies").

[80] *See* H.B. 4063, 79th Leg. Assemb., Reg. Sess. (Or. 2018) (establishing a task force on autonomous vehicles); H. 494, 2017 Leg., Reg. Sess. (Vt. 2017) (convening a meeting of automated vehicle experts); Exec. Order No. 2018-01 (Idaho 2018) (creating the "Autonomous and Connected Vehicle Testing and Deployment Committee"); Exec. Order 245 (Wis. 2018) (forming the "Steering Committee on Autonomous and Connected Vehicle testing and Deployment" to review current laws and identify areas for improvement).

[81] *See, e.g.*, S.B. 125, 2018 Leg., Reg. Sess. (Ala. 2018) (addressing the platooning of autonomous trucks); H.B. 1290, 120th Gen Assemb., 2d Reg. Sess. (Ind. 2018) (same); S.B. 116, 2018 Leg., Reg. Sess. (Ky. 2018) (same); H.B. 1343, 2018 Leg., Reg. Sess. (Miss. 2018) (same); H.B. 1754, 91st Gen. Assemb., Reg. Sess. (Ark. 2017) (same); H. 3289, 122d Gen. Assemb. (S.C. 2017) (same); H.B. 373, 61st Leg., Gen. Sess. (Utah 2015) (same).

[82] *See* A.B. 9508, 241st Leg., Reg. Sess. (N.Y. 2018) (requiring, for example, "that a natural person holding a valid license for the operation of the motor vehicle's class be present within such vehicle for the duration of the time it is operated on public highways"); Exec. Order No. 2018-04K (Ohio 2018) (requiring, for example, "a designated operator" for all autonomous vehicles in the state); S.B. 260, 2017 Leg., Reg. Sess. (Conn. 2017) (requiring, for example, that any autonomous test vehicle be operated by a person "seated in the driver's seat" and "capable of taking immediate manual control"); Council 19-643, Council Period 20 (D.C. 2013) (mandating that autonomous vehicles comply with traffic laws, possess a manual override feature, and have a driver present); Exec. Order No. 17-02 (Wash. 2017) (outlining different requirements for autonomous vehicles based on whether or not human operators are present); Exec. Order No. 572 (Mass. 2016) (requiring, for example, that autonomous test vehicles have "a human being . . . in the driver's seat"); *see also* A.B. 69, 79th Leg., Reg. Sess. (Nev. 2017) (allowing for the operation

such mandates,[83] or expressly authorize autonomous vehicle operation.[84] These laws, at least as they pertain to vehicle design and operation, can be divided into roughly three categories: (1) laws which mandate specific design features and limit the operation of autonomous vehicles,[85] (2) laws which limit the operation of autonomous vehicles but do not mandate specific design features,[86] and (3) laws which expressly authorize the operation of autonomous vehicles with varying degrees of oversight.[87] Notably, as at the federal level,

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of fully autonomous vehicles, but imposing strict design requirements on partially automated vehicles). Some of the laws regarding autonomous truck platoons, listed *supra* note 81, also include specific regulatory mandates. *See, e.g.*, S.B. 116, 2018 Leg., Reg. Sess. (Ky. 2018) ("An appropriately endorsed driver who holds a valid commercial driver's license shall be present behind the wheel of each commercial motor vehicle in a platoon.").

[83] *See* H.P. 1204, 128th Leg., 2d Reg. Sess. (Me. 2018) (instructing the Commissioner of Transportation to promulgate rules governing autonomous vehicle testing and empowering her to prohibit any testing which she deems a threat to public safety); Exec. Order No. 572 (Mass. 2016) (instructing the Department of Transportation to "issue guidance" to allow for the safe testing of automated vehicles). Some of the laws regarding autonomous truck platoons, listed *supra* note 81, also delegate regulatory authority. *See, e.g.*, S.B. 116, 2018 Leg., Reg. Sess. (Ky. 2018) (directing the Kentucky Department of Vehicle Regulation to "promulgate administrative regulations . . . set[ting] forth procedures for platooning, including required elements of a platooning plan").

[84] *See* L.B. 989, 105th Leg., 2d Reg. Sess. (Neb. 2018) (authorizing cities to conduct pilot projects to test autonomous vehicles); S.B. 2205, 85th Leg., Reg. Sess. (Tex. 2017) ("A political subdivision of this state or a state agency may not impose a . . . regulation related to the operation of an automated motor vehicle or automated driving system."); S.B. 17-213, 71st Gen. Assemb., 1st Reg. Sess. (Colo. 2017) (authorizing persons to use "automated driving system[s]"); S.B. 219, 154th Gen. Assemb., 1st Reg. Sess. (Ga. 2017) (allowing persons to "operate a fully autonomous vehicle with the automated driving system engaged without a human driver being present in the vehicle"); H.B. 791, 100th Gen. Assemb., Reg. Sess. (Ill. 2017) (forbidding local governments from "prohibiting the use of Automated Driving System equipped vehicles"); S.B. 995, 98th Leg. (Mich. 2016) (allowing operation of autonomous vehicles without a human driver present); S.B. 0598, 109th Gen. Assemb., Reg. Sess. (Tenn. 2015) (same); H.B. 1207, 2012 Leg., Reg. Sess. (Fla. 2012) ("A person who possesses a valid driver license may operate an autonomous vehicle in autonomous mode."); Exec. Order No. 2018-04 (Ariz. 2018) (allowing "operation of self-driving vehicles . . . with, or without, a person present"); H.B. 469, 2017 Leg., Reg. Sess. (N.C. 2017) (authorizing "the operation of fully autonomous motor vehicles" by persons without a driver's license).

[85] *See infra* notes 88–92 and accompanying text (listing and detailing this first category of laws, including those from Connecticut, New York, Massachusetts, Nevada, and the District of Columbia).

[86] *See infra* notes 93–97 and accompanying text (listing and detailing this second category of laws, including those from Maine, Washington, and Ohio).

[87] *See infra* notes 97–102 and accompanying text (listing and detailing this third category of laws, including those from California, Colorado, Georgia, Nebraska, North Carolina, Texas, Arizona, Michigan, Florida, and Tennessee).

no state has altered the way in which it approaches motor vehicle regulation, leaving the processes by which state legislatures and agencies establish and revise the rules governing autonomous vehicles unchanged from those applicable to traditional vehicles.

The first category of laws includes Connecticut, New York, Massachusetts, Nevada, and the District of Columbia. Although the testing of autonomous vehicles is permitted in each locality, all but Nevada mandate that a licensed human driver be present and capable of taking manual control of an autonomous vehicle at all times.[88] This mandate effectively requires that every autonomous vehicle be equipped with a steering wheel, accelerator, and brake pedal.[89] Nevada permits the unrestricted testing and deployment of fully autonomous vehicles without a human driver, but requires that all other automated vehicle designs contain an "accessible" means to "engage and disengage the automated driving system," an indicator of whether the automated driving system is engaged, and a system to alert the human operator if "a failure of the automated driving system occurs."[90] Connecticut, New York, and Massachusetts further limit who may test an autonomous vehicle[91] and under what circumstances.[92]

[88] *See* CONN. GEN. STAT. § 13a-260(d)(1) (requiring that a human operator "be seated in the driver's seat" and "capable of taking immediate manual control"); D.C. CODE § 50-2352(2) (requiring that a human driver be "seated in the control seat of the vehicle while in operation [and be] prepared to take control of the autonomous vehicle at any moment"); A.B. 9508, part H § 1, 241st Leg., Reg. Sess. (N.Y. 2018) (enacted) (requiring that a "natural person . . . be present within [the] vehicle for the duration of the time it is operated on public highways"); Exec. Order No. 572 § 4 (Mass. 2016) (requiring a "human being" be seated in "the driver's seat or other location in the vehicle" where she "can take immediate control of the vehicle if necessary").

[89] These design features are explicitly required under D.C. law and implicitly required under Connecticut, New York, and Massachusetts law.

[90] NEV. REV. STAT. § 482A.080(2)(a)–(b).

[91] *See* CONN. GEN. STAT. § 13a-260(d)(1)(D) (limiting vehicle operators to an "employee, independent contractor or other person designated and trained by the autonomous vehicle tester");A.B. 9508, part H § 1, 241st Leg., Reg. Sess. (N.Y. 2018) (enacted) (requiring vehicle operators to hold a valid driver's license); Exec. Order No. 572 § 2 (Mass. 2016) (limiting testing of autonomous vehicles to "companies in the [autonomous vehicle] sector"). Until recently, the District of Columbia also limited who could test autonomous vehicles. *See* D.C. MUN. REGS. tit. 18, § 114 (repealed 2018) (limiting vehicle operators to those who hold a special autonomous vehicle license).

[92] *See* CONN. GEN. STAT. § 13a-260(c) (restricting testing to agreed upon "locations and routes"); A.B. 9508, part H § 1, 241st Leg., Reg. Sess. (N.Y. 2018) (enacted) (requiring "demonstrations and tests shall only take place . . . in a form and manner prescribed by the superintendent of the New York state police"); Exec. Order No. 572 § 4 (Mass. 2016) (requiring a demonstration that the vehicle can be "operated without undue risk to public safety").

The second category of laws is limited to Maine, Washington, and Ohio. Maine restricts autonomous vehicle operation to "pilot projects" pre-approved by a Highly Automated Vehicles Advisory Committee.[93] The duration of each project is limited and approval contingent on a cost-benefit analysis conducted by the Advisory Committee.[94] Similarly, an executive order issued by Governor John Kasich of Ohio limits autonomous vehicle operation to "testing and pilot programs" and requires registration with the Department of Transportation prior to operation.[95] The state also requires that companies submit a safety self-evaluation and designate "an employee, contractor, or agent" to "actively monitor the [autonomous] vehicle at all times."[96] Finally, Washington permits the operation of autonomous vehicles which are "capable" of complying with "relevant" state motor vehicle laws, but only as part of a "pilot program" and by "entities that that are developing autonomous vehicle technology equipment."[97]

The final category of laws includes California, Colorado, Georgia, Nebraska, North Carolina, Texas, Arizona, Michigan, Florida, and Tennessee. In all ten states, the testing and deployment of fully autonomous vehicles is expressly permitted and members of the public may operate or facilitate the operation of an automated vehicle.[98] Tennessee, Colorado, North Carolina, and

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[93] Exec. Order No. 2018–001 at 3 (Me. 2018).

[94] *See id.* (instructing the committee to "assess the purpose(s) of proposed Pilot Projects, including their benefits for the traveling public and their value for the advancement of HAV technologies in the State of Maine" and to weigh these factors against "public safety").

[95] Exec. Order No. 2018–04K §§ 1, 3 (Ohio 2018).

[96] *Id.* §§ 5–6.

[97] Exec. Order No. 17–02 at 2–3 (Wash. 2017).

[98] *See* COLO. REV. STAT. § 42-4-242(1) (2017) ("A person may use an automated driving system to drive a motor vehicle or to control a function of a motor vehicle . . . ."); FLA. STAT. § 316.85 (2018) ("A person who possesses a valid driver license may operate an autonomous vehicle in autonomous mode on roads in this state if the vehicle is equipped with autonomous technology . . . ."); GA. CODE ANN. § 40-8-11(a) (2018) ("A person may operate a fully autonomous vehicle with the automated driving system engaged without a human driver being present in the vehicle . . . ."); MICH. COMP. LAWS § 257.665b(3)(a) (2018) (permitting a "motor vehicle manufacturer" to make available on-demand autonomous motor vehicles for members of the public); NEB. REV. STAT. § 60–3302 (2018) ("A driverless-capable vehicle may operate on the public roads of this state without a conventional human driver physically present in the vehicle . . . ."); N.C. GEN. STAT. § 20-401(h) (2018) ("A person may operate a fully autonomous vehicle . . . .");TENN. CODE ANN. §§ 55–30–103 (2018) ("An ADS-operated vehicle may drive or operate on streets and highways in this state with the ADS engaged without a human driver physically present in the vehicle . . . ."); TEX. TRANSP. CODE § 545.454 (a) (2017) ("An automated motor vehicle may operate in this state with the automated driving system engaged, regardless of whether a human operator is physically present in the vehicle."); Exec. Order No. 2018-04 § 3 (Ariz. 2018) ("Testing or operation of vehicles on public roads . . . shall be allowed . . . ."); CAL. CODE REGS. tit. 13,

Texas even prohibit cities and municipalities from banning or limiting the use of autonomous vehicles within their boundaries.[99] All but Florida, Colorado, Nebraska, and Texas require that vehicle owners notify state regulators prior to operating on public roads,[100] and all but Florida mandate that vehicles comply with existing state and federal regulations.[101] Interestingly, despite

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§ 228.00 (2018) (allowing autonomous vehicles to be "deployed on public roads in California").

[99] TENN. CODE ANN. § 55-8-202(a) (2018); COLO. REV. STAT. § 42–4–110(b) (2018); N.C. GEN. STAT. § 20-401(i) (2018); TEX. TRANSP. CODE § 545.452(b) (2017).

[100] *See* GA. CODE ANN. § 40-8-11(a)(5) (2018) (requiring that each vehicle be "registered" and be "identified on such registration as a fully autonomous vehicle"); MICH. COMP. LAWS § 257.665b(3)(a) (2018) ("The motor vehicle manufacturer may commence a SAVE project at any time after it notifies the department that it has self-certified as provided in subsection (1)."); N.C. GEN. STAT. § 20-401(h)(5) (2018) (requiring that each vehicle be "registered" and "identified on the registration and registration card as a fully autonomous vehicle"); TENN. CODE ANN. §§ 55-30-103 (2018) ("In order for a manufacturer to participate in a SAVE project, it must submit a letter to the department prior to operating any ADS-operated vehicles on the public roads or highways."); Ariz. Exec. Order No. 2018–04 § 3 (requiring that each owner of an autonomous vehicle, "prior to commencing testing or operation, . . . submit[ ] a written statement to the Arizona Department of Transportation" self-certifying compliance with the executive order); CAL. CODE REGS. tit. 13, § 228.06(a) (2018) ("[A]n autonomous vehicle shall not be deployed on any public road in California until the manufacturer has submitted and the department has approved an Application for a Permit to Deploy Autonomous Vehicles on Public Streets . . . .").

[101] *See* COLO. REV. STAT. § 42-4-242(1) (2017) (requiring that each vehicle be "capable of complying with every state and federal law that applies to the function that the system is operating"); GA. CODE ANN. § 40-8-11(a)(1) (2018) (requiring that each vehicle be "capable of being operated in compliance with [the rules of the road] and has been, at the time of its manufacture, certified by the manufacturer as being in compliance with applicable federal motor vehicle safety standards"); MICH. COMP. LAWS § 257.665b(1)(c)-(d) (2018) (requiring that each vehicle comply "with all applicable state and federal laws" and be "capable of being operated in compliance with applicable traffic and motor vehicle laws of this state"); NEB. REV. STAT. § 60-3303(2) (2018) ("The automated driving system feature, while engaged, shall be designed to operate . . . in compliance with the Nebraska Rules of the Road . . . ."); TENN. CODE ANN. §§ 55-30-103(1) (2018) (requiring that each vehicle comply with "all applicable state and federal laws" and be "capable of being operated in compliance with applicable traffic and motor vehicle laws of this state"); TEX. TRANSP. CODE § 545.454(b)(1), (3) (2017) (requiring that each vehicle be "capable of operating in compliance with applicable traffic and motor vehicle laws of this state" and "equipped with an automated driving system in compliance with applicable federal law and federal motor vehicle safety standards"); Ariz. Exec. Order No. 2018-04 § 3(a), (c) (requiring that each vehicle comply with "all applicable federal law and federal motor vehicle safety standards," as well as be "capable of complying with all applicable [state] traffic and motor vehicle safety laws and regulations"); CAL. CODE REGS. tit. 13, § 228.06(8)–(9) (2018) ("[T]he manufacturer shall certify that the autonomous technology meets Federal Motor Vehicle Safety Standards [and] . . . that the autonomous technology is designed to detect and respond to roadway situations

mandating compliance with existing state laws, only Michigan, Colorado, and Texas expressly clarify that autonomous vehicles are deemed to satisfy all traffic and motor vehicle laws which reference the presence of a driver or physical acts performed by a driver.[102]

II. The Challenge of Regulating Autonomous Vehicles and Other Rapidly Evolving Technologies

Despite the potential economic, social, and environmental benefits outlined in Part I, autonomous vehicles face a number of obstacles to widespread commercial adoption. One of the most significant sources of potential friction is the evolving legal and regulatory environment within which autonomous vehicles must continue to develop and operate. Although regulation can help to facilitate the commercial success of emerging technologies, as well as manage potential risks, it also has potential drawbacks.[103] In discussing the ways in which the present and future regulation of autonomous vehicles may impede their development, this Part proceeds in two sections. In the first, I outline the inherent challenge of regulating rapidly evolving technologies like autonomous vehicles and divide common regulatory responses to this challenge into three categories. In doing so, I draw on Part I of the article to highlight how all three responses are reflected in both existing and proposed state and federal approaches to regulating autonomous vehicles. In the second section, I then analyze the potential barriers to commercial adoption of new technologies inherent in

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in compliance with all provisions of the California Vehicle Code and local regulation applicable to the performance of the dynamic driving task in the vehicle's operational design domain . . . .").

[102] *See* MICH. COMP. LAWS § 257.665b(4) (2018) ("When engaged, an automated driving system or any remote or expert-controlled assist activity shall be considered the driver or operator of the vehicle for purposes of determining conformance to any applicable traffic or motor vehicle laws and shall be deemed to satisfy electronically all physical acts required by a driver or operator of the vehicle."); COLO. REV. STAT. § 42-4-242(1) (2017) ("Any provision . . . that by its nature regulates a human driver . . . does not apply to an automated driving system, except for laws regulating the physical driving of a vehicle."); NEB. REV. STAT. § 60-3306 (2018) ("[T]he Nebraska Rules of the Road shall not be construed as requiring a conventional human driver to operate a driverless-capable vehicle that is being operated by an automated driving system, and the automated driving system of such vehicle, when engaged, shall be deemed to fulfill any physical acts required of a conventional human driver to perform the dynamic driving task."); TEX. TRANSP. CODE § 545.453(a)(1)–(2) (2017) (clarifying that "the automated driving system is considered to be licensed to operate the vehicle" and that "the owner of the automated driving system is considered the operator of the automated motor vehicle solely for the purpose of assessing compliance with applicable traffic or motor vehicle laws").

[103] *See supra* notes 11-13 (highlighting the potential benefits and drawbacks of regulation).

each regulatory response and consider the ways in which employing each type of approach could adversely impact autonomous vehicles.

A. The Pacing Problem and Potential Regulatory Responses to the Problem

One of the main challenges of regulating emerging technologies like autonomous vehicles is the incongruous rates at which law and technology sometimes evolve. The following section describes both the inherent obstacles to adaptation of new and existing regulations to rapid technological change and the way in which uncertainty and the inertia of U.S. legal institutions give rise to three common regulatory responses: precaution, inaction, and proactivity.

1. Why U.S. Legal Institutions Struggle to Keep Up with New Technologies

A growing body of literature explores the difficulties faced by regulatory frameworks as they attempt to evolve concurrently with the technologies which they target.[104] This phenomenon, labeled by one commentator as the "pacing problem,"[105] captures the recurring tension between the limited reactive and adaptive capacity of U.S. legal institutions and the increasingly fluid nature of emerging technologies.[106] At the heart of this tension are several characteristics of traditional sources of regulation—legislatures, administrative agencies, and courts—which can make it difficult, if not impossible, for the law to keep pace with rapidly changing technologies.[107]

a. Legislatures

The limited reactive and adaptive capacity of U.S. legal institutions is particularly pronounced in the legislative process. Legislatures are the most

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[104] *See supra* notes 4-6 (surveying this literature).

[105] Marchant, *supra* note 15. Other scholars have described this same problem using different labels and metaphors, but Professor Marchant's account is the most recent and salient. *See, e.g.*, ROGER BROWNSWORD, RIGHTS, REGULATION AND THE TECHNOLOGICAL REVOLUTION 160–61 (2008) (defining the problem as one of "regulatory connection"); Michael Kirby, *Medical Technology and New Frontiers of Family Law*, 1 AUSTL. J. FAM. L. 196, 212 (1987) (describing the law as a tortoise and technology as a hare). It also provides the jumping off point for this analysis.

[106] *See supra* notes 4–5 (describing the accelerating rate of technological change and the increasingly limited capacity of legal institutions to adapt and shape outcomes).

[107] This is not to suggest that U.S. legal institutions can never and do not ever keep pace with technological change; rather, it is meant to highlight the features of U.S. legal institutions which can and frequently do create gaps. In addition, some commentators have suggested that the speed at which technology is currently evolving is more rapid than at previous moments in history.

powerful and fundamental lawmaking unit within the U.S. political system. Congress and state legislatures possess a wide range of tools with which to regulate new and emerging technologies, including the delegation of regulatory authority to administrative bodies,[108] the creation of specialized courts,[109] and the passage of new legislation.[110] Nevertheless, despite these inherent capabilities, the rate at which legislatures operate is constrained both by design and political circumstance.

At the federal level, constitutional and statutory language impose a number of structural and procedural requirements which deliberately "slow legislative decision making and distance it from the immediacy of legislators' and various constituencies' passions and desires."[111] Article I of the U.S. Constitution, for example, requires that proposed legislation be debated and approved by both houses of Congress,[112] after which any approved legislation must be presented to the president for his signature or veto.[113] As James Madison and Alexander Hamilton outlined in *The Federalist Papers*, these

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[108] *See* Mistretta v. United States, 488 U.S. 361, 372–73 (1989) (reaffirming congressional power to delegate rulemaking authority to agencies if there is an "intelligible principle" upon which an agency may base its actions); *Separation of Powers—Delegation of Legislative Power*, NAT'L CONF. OF STATE LEGISLATURES, http://www.ncsl.org/research/about-state-legislatures/delegation-of-legislative-power.aspx [https://perma.cc/HYZ5-CHXF] (describing state approaches to legislative delegations of authority).

[109] *See* U.S. CONST. art. III, § 1 (providing that the "judicial Power" of the United States shall be "vested in one supreme Court, and in such inferior Courts as the Congress may from time to time ordain and establish"); U.S. CONST. art. I, § 8 ("Congress shall have Power to . . . constitute Tribunals inferior to the supreme Court . . . ."); Markus B. Zimmer, *Overview of Specialized Courts*, INT'L J. FOR CT. ADMIN., 1, 1, 7–13 (2009) (discussing specialized state and federal courts).

[110] *See* U.S. CONST. art. I, §§ 1, 8 (vesting "[a]ll legislative Powers . . . in a Congress" and enumerating its powers).

[111] Eric Lane, *Men Are Not Angels: The Realpolitik of Direct Democracy and What We Can Do About It*, 34 WILLAMETTE L. REV. 579, 598-99 (1998); *see also* Ittai Bar-Siman-Tov, *The Puzzling Resistance to Judicial Review of the Legislative Process*, 91 B.U. L. REV. 1915, 1933 (2011) ("One of the important purposes of procedural rules such as bicameral passage, discussion in committee, and three readings is precisely to slow down the legislative process and to make legislation an arduous and deliberate process. These rules ensure, *inter alia*, that laws will not change too frequently or too hastily . . . .") (footnotes omitted); John O. McGinnis & Michael B. Rappaport, *Our Supermajoritarian Constitution*, 80 TEX. L. REV. 703, 771 (2002) ("[T]he Framers saw that bicameralism had the potential to reduce the influence of excessive political passion and the power of special-interest groups, thereby improving the quality of legislation.").

[112] U.S. CONST. art. I, § 7, cl. 2.

[113] *Id.*; *see also* McGinnis & Rappaport, *supra* note 111, at 715 ("The President's veto power has the effect of making the President a third legislative house, turning our system into one of tricameralism.").

features of the lawmaking process are designed as a deliberate anchor against precipitous change.[114] In addition, internal rules of congressional procedure—such as the requirement that proposed legislation be reviewed in committee[115] and that all legislation be read three times prior to passage[116]—serve a similar purpose.[117] Many of these same structural and procedural constraints are reflected in state legislative processes.[118]

In addition to the designed constraints on legislative efficiency, political circumstance also places a check on the reactive and adaptive capacity of legislatures. Congress and state legislatures are often faced with more issues than time or resources allow them to address.[119] As Professor John W. Kingdon famously argued, policy issues are unlikely to receive attention outside of brief "policy windows" when political feasibility, social urgency, and mature policy solutions combine to allow for legislative action.[120] Although the combination of these factors permits new laws to be enacted or old laws to be adapted during an open window, it may be years before political conditions allow lawmakers to revisit the same issue during a new window.[121] Moreover, the potential inability of a single political party to control the presidency and both houses of Congress simultaneously may create even larger gaps between these windows. There is already anecdotal evidence to this effect, as the three most recent terms of Congress, both characterized by significant political discord between and within the legislative and executive branches, each produced fewer laws than any other term since 1948, when congressional productivity was first measured.[122]

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[114] *See* THE FEDERALIST NO. 62, at 378 (James Madison) (Clinton Rossiter ed., 1961) ("To trace the mischievous effects of a mutable government would fill a volume.").
[115] *See* Standing Rules of the Senate, R. XVII(3)(a); Rules of the House of Representatives, R. XII(2)(a).
[116] *See* Standing Rules of the Senate, R. XIV(2); Rules of the House of Representatives, R. XVI(8)(a)-(c).
[117] *See* Jacob E. Gersen & Eric A. Posner, *Timing Rules and Legal Institutions*, 121 HARV. L. REV. 543, 552-57 (2007) (describing the "significant effect[]" internal rules of procedure have on the pace of legislative action).
[118] *See, e.g.*, *How a Bill Becomes Law: Michigan Legislature*, MICH. LEGISLATIVE SERV. BUREAU, http://www.legislature.mi.gov/publications/howbillbecomeslaw.pdf (last visited March 3, 2017) (describing the procedural requirements for Michigan state laws, including that each bill be read three times and reviewed in committee prior to becoming law).
[119] *See* Gary E. Marchant et al., *What Does the History of Technology Regulation Teach Us About Nano Oversight?*, 37 J.L. MED. & ETHICS 724, 726 (2009) ("Congress is handcuffed by the synergistic effect of an impossibly large number of important issues needing attention mixed with partisan gridlock, making prompt action on any but the most urgent or symbolic issues unlikely.").
[120] *See generally* JOHN W. KINGDON, AGENDAS, ALTERNATIVES, AND PUBLIC POLICIES (1984).
[121] *Id.*
[122] *See* Ezra Klein, *Goodbye and Good Riddance, 112th Congress*, WASH. POST: WONKBLOG (Jan. 4, 2013), https://www.washingtonpost.com/news/wonk/wp/2013/01/04/goodbye-and-good

b. Administrative Agencies

Although administrative agencies ostensibly operate with greater efficiency and flexibility than legislatures,[123] they also face potential obstacles to enacting or adjusting regulations in response to rapid technological change. These obstacles can be divided into three categories. First, the authority delegated to an agency by a legislature may be a poor fit for the task of regulating an emerging technology where a technology or problem was unanticipated by the legislature. An outdated organic statute could limit or delay an agency's regulatory response to certain aspects of a new technology or prevent an agency from regulating the new technology altogether.[124] In the field of biotechnology, for example, commentators have observed that it is unclear whether any agency has authority to regulate genetically modified animals containing genes from other species and not intended for human consumption.[125] As outlined in the previous section, amendment of an agency's statutory authority can be a slow process, especially in a politically polarized climate.[126]

Second, if an agency does have the authority to regulate a new technology, powerful stakeholders may nevertheless capture the agency and attempt to prevent effective regulation.[127] The problem of regulatory capture is

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-riddance-112th-congress/ [https://perma.cc/WE25-6SQE] (noting that the 112th Congress passed the fewest laws of "any Congress on record"); *Statistics and Historical Comparison*, GOVTRACK, https://www.govtrack.us/congress/bills/statistics [https://perma.cc/2XR4-98V5] (last visited Aug. 22, 2017) (listing the number of laws enacted by each session of Congress and showing that the past three have enacted the fewest laws since tracking began in 1948). This trend may change, however, after the most recent election, when Republicans took control of the presidency and both houses of Congress. This anomaly itself represents a potential policy window.

[123] *Cf.* 5 U.S.C. § 553(b)-(c) (2012) (allowing, on its face, for agencies to promulgate binding rules after three easy steps: (1) notice, (2) comment, and (3) publication of "a concise general statement of [a rule's] basis and purpose").

[124] *See* Mandel, *supra* note 6, at 84 ("Statutes and regulations, almost by definition, are designed to handle regulatory concerns existing at the time of promulgation. It is not surprising that emerging technologies often exacerbate regulatory gaps or introduce new concerns that create new regulatory lacunae."); Lyria Bennett Moses, *Understanding Legal Responses to Technological Change: The Example of* In Vitro *Fertilization*, 6 MINN. J.L. SCI. & TECH. 505, 577 (providing examples).

[125] Mandel, *supra* note 6, at 84–85; *see also* Gregory N. Mandel, *Gaps, Inexperience, Inconsistencies, and Overlaps: Crisis in the Regulation of Genetically Modified Plants and Animals*, 45 WM. & MARY L. REV. 2167, 2230-36 (2004) (discussing the gaps in federal agencies' authority to regulate genetically modified products).

[126] *See supra* pp. 21–23.

[127] *See generally* George J. Stigler, *The Theory of Economic Regulation*, 2 BELL J. ECON. & MGMT. SCI. 3 (1971); *see also* Lawrence G. Baxter, *"Capture" in Financial Regulation: Can We Channel it Toward the Common Good?*, 21 CORNELL J.L. & PUB. POL'Y 175, 176-88 (2011) (unpacking the different forms of capture).

well documented.[128] In the context of emerging technologies, an incumbent industry benefiting from an existing regulatory scheme or hoping to handicap a new technology may use its clout to prevent an agency from effectively regulating the new technology, or at least from doing so in a manner that necessarily prioritizes the public interest.[129] Similarly, powerful business interests invested in developing new technologies, such as Google or Uber in the case of autonomous vehicles, may attempt to prevent new regulations designed to promote safety, but which impose significant costs or disadvantage specific forms of a technology.

Finally, even if an agency has the ability and will to regulate a new technology, the actual process of enacting or amending contested rules is often slow. A typical federal rule takes one to two years from the time an agency issues a notice of proposed rulemaking to the time it is published in the *Federal Register*.[130] Some agencies take longer.[131] This is largely the result of statutory,[132] judicial,[133] and executive branch-imposed[134] procedural require-

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[128] *See, e.g.*, John Abraham & Rachel Ballinger, *Science, Politics, and Health in the Brave New World of Pharmaceutical Carcinogenic Risk Assessment: Technical Progress or Cycle of Regulatory Capture?* 75 SOC. SCI. & MED. 1433, 1434 (examining capture in public health regulation); Wendy Wagner et al., *Rulemaking in the Shade: An Empirical Study of EPA's Air Toxic Emission Standards*, 63 ADMIN. L. REV. 99, 105–109 (2011) (documenting capture in the context of environmental regulations); Daniel C. Hardy, *Regulatory Capture in Banking* 4-6 (Int'l Monetary Fund, Working Paper No. 34, 2006) (discussing capture within banking regulation).

[129] *See* Whitt, *supra* note 5, at 553 (describing this problem in the context of efforts by the Federal Communications Commission to regulate emerging communications technologies).

[130] Jason Webb Yackee & Susan Webb Yackee, *Testing the Ossification Thesis: An Empirical Examination of Federal Regulatory Volume and Speed, 1950-1990*, 80 GEO. WASH. L. REV. 1414, 1456-58 (2012).

[131] *See, e.g.*, Cass R. Sunstein, *Problems with Rules*, 83 CAL. L. REV. 953, 1015 (1995) (finding the EPA usually takes over three years to comply with all procedural requirements).

[132] *See* 5 U.S.C. § 553 (containing the procedural requirements applicable to the informal rulemaking process); *see also* 5 U.S.C. §§ 556-557 (containing the procedural requirements applicable to the less frequently used formal rulemaking process).

[133] *See, e.g.*, Fertilizer Inst. v. EPA, 935 F.2d 1303, 1311 (D.C. Cir.1991) (requiring that final rules be a logical outgrowth of proposed rules); U.S. v. Nova Scotia Food Products Corp. 568 F.2d 240, 252 (2d Cir. 1977) (requiring that agencies disclose the "basic data relied upon" and answer, as part of its concise general statement, all "vital questions" raised in public comments). Since *Vermont Yankee* held that courts are "generally not free to impose . . . additional procedural requirements" beyond those provided for in Section 553, the paper hearing requirement and logical outgrowth test are both, ostensibly, interpretations of requirements contained in Section 553. Vermont Yankee Nuclear Power Corp. v. Natural Resources Defense Council, Inc., 435 U.S. 519, 524 (1978).

[134] *See, e.g.*, Exec. Order No. 12,866, 58 Fed. Reg. 190 (Sept. 30, 1993) (requiring, among other things, that "significant regulatory actions" undergo a cost-benefit review by the Office of Information and Regulatory Affairs).

ments. In addition, some argue that regulatory processes at the federal and state level have slowed, or "ossified," significantly over the past forty years.[135] In the U.S., regulatory agencies are required to undertake a number of analytical requirements to support regulatory decisions. These requirements are imposed by the legislative,[136] judicial,[137] and executive branches.[138] Although a growing body of empirical research challenges the ossification thesis,[139] "[a]dministrative law scholars appear almost universally to accept that pre-enforcement review of regulations at NHTSA," the federal agency responsible for regulating autonomous vehicles, "has led to a decline in new regulations."[140]

c. Courts

The adaptive and reactive capacity of U.S. courts is also limited.[141] Three features help to account for this limited capacity. First, federal and state

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[135] *See* Thomas O. McGarity, *Some Thoughts on "Deossifying" the Rulemaking Process*, 41 DUKE L.J. 1385, 1385 (1992) (arguing that "[a]n assortment of analytical requirements . . . imposed on the simple rulemaking model, and evolving judicial doctrines . . . [requiring] agencies to take greater pains to ensure that the technical bases for rules are capable of withstanding judicial scrutiny" have caused the rulemaking process to "become increasingly rigid and burdensome"); *see also* JERRY L. MASHAW, GREED, CHAOS, AND GOVERNANCE: USING PUBLIC CHOICE TO IMPROVE PUBLIC LAW 161 (1997) ("The past decade's case study literature on the performance of America's administrative agencies details an agency-by-agency retreat from rulemaking.").

[136] *See supra* note 132 (describing the procedural requirements applicable to formal and informal rulemaking).

[137] *See supra* note 133 (describing the paper hearing requirement and logical outgrowth test).

[138] *See supra* note 134 (describing the cost-benefit review required of significant regulatory actions).

[139] *See, e.g.*, Yackee & Yackee, *supra* note 130, at 1445–63 (finding that "evidence that ossification generally is either a serious or widespread problem is mixed at best, and appears relatively weak overall"); Cary Coglianese, *Empirical Analysis and Administrative Law*, 2002 U. ILL. L. REV. 1111, 1125–31 (concluding that "regulatory agencies have not abandoned their use of rulemaking").

[140] Coglianese, *supra* note 139, at 1126–27 (citing JERRY L. MASHAW & DAVID L. HARFST, THE STRUGGLE FOR AUTO SAFETY (1990)); *see also* MASHAW, *supra* note 135; Robert Glicksman & Christopher H. Schroeder, *EPA and the Courts: Twenty Years of Law and Politics*, 54 LAW & CONTEMP. PROBS. 249, 249 n.2 (1991); McGarity, *supra* note 135, at 1412 (noting how judicial review has hampered NHTSA's willingness to promulgate new rules); Richard J. Pierce, Jr., *Two Problems in Administrative Law: Political Polarity on the District of Columbia Circuit and Judicial Deterrence of Agency Rulemaking*, 1988 DUKE L.J. 300, 311 (1988) (explaining that "NHTSA has abandoned almost completely its efforts to establish policy through rulemaking"). *But see* Coglianese, *supra* note 139, at 1127–29 (questioning the empirical validity of such claims).

[141] This is not to say that courts and judges are incapable of adapting to technological change. *Cf.* Paul Martin & Patrick Schmidt, *Courts During Periods of Rapid Technological Change: Comparative Perspectives on Freedom of Speech in the Digital Era* 29 (Aug. 28, 2003)

courts are part of the common law tradition. In contrast to a civil law system, which relies on a comprehensive set of codified rules to guide the reasoning of judges, the common law system builds on prior judicial decisions in analogous cases to supply legal rules.[142] Despite creating predictability and stability, the reliance on precedent and analogical reasoning places a check on rapid change in the legal system.[143] As one commentator notes, the common law system is "grounded in the notion of slow, evolutionary adaptation . . . in a case-by-case format."[144] Although there is room for judges to adjust the law to new conditions by distinguishing or overruling precedent,[145] the process of revising existing legal doctrines or developing new doctrines is slow and piecemeal.[146] If one court–whether at the federal or state level–decides to adjust the law in response to a new technology, there is no guarantee that courts in other states or regions will do the same, and the rate at which other courts react could vary throughout the country.

(unpublished paper presented at the Annual Meeting of the American Political Science Association) (on file with author) (finding that courts, despite reoccurring challenges, may find ways adapt to technological change, if only as a matter of necessity). The issue here, however, is that the speed at which they do so can have potentially deleterious effects on the development of a new technology.

[142] *See generally* Joseph Dainow, *The Civil Law and Common Law: Some Points of Comparison*, 15 AM. J. COMP. L. 419 (1967) (providing a comparative overview of the common law and civil law systems). This is not to say that common law courts do not also rely on statutes – they do. *Id.* at 425–27. But common law courts deal primarily with precedent. *Id.* at 427.

[143] *See* Oona A. Hathaway, *Path Dependence in the Law: The Course and Pattern of Legal Change in a Common Law System*, 86 IOWA L. REV. 601, 625–26 (2001) ("The system of stare decisis . . . creates an explicitly path-dependent process in which later decisions rely on, and are constrained by, earlier decisions.").

[144] Martin & Schmidt, *supra* note 141, at 14. *But see* Monroe E. Price & John F. Duffy, *Technological Change and Doctrinal Persistence: Telecommunications Reform in Congress and the Court*, 97 COLUM. L. REV. 976, 1009 (1997) ("Counterintuitively, technological change may . . . be more likely to lead to extensive . . . changes in the courts . . . .").

[145] *See* Dainow, *supra* note 142, at 425 ("[A] judge [can] 'distinguish' [a] previous decision and leave its application limited to the specific fact situation which it control[s] . . . . The latter two techniques, distinguishing and overruling, ma[k]e room for flexibility and permit[] adjustment to new conditions."); *see also* Hathaway, *supra* note 143, at 647 ("The law evolves gradually over time, drawing on an existing stock of precedent, punctuated by periods of rapid adaptation.").

[146] *See* Lyria Bennett Moses, *Adapting the Law to Technological Change: A Comparison of Common Law and Legislation*, 26 U. NEW S. WHALES L.J. 394, 395 (2003) (noting that, although the common law "constantly adapts to technological change," it is "slow, piecemeal and unable to reach an optimal solution to every problem on its own"). Moreover, fears about legitimacy may prevent judges from moving too far afield of prior decisions. *See* Martin & Schmidt, *supra* note 141, at 14.

Second, when courts apply and interpret statutes, they are virtually powerless to modify or discard outdated statutory rules.[147] Where a statute is poorly suited to a new technology or otherwise obsolete, only the legislature can revise or repeal the rule. Although the various tools of statutory interpretation allow judges some flexibility in applying existing law, courts are, at least as a formal matter, powerless to adapt a statute to new technologies.[148] These limitations, combined with the slow pace of legislative change, has prompted one prominent commentator, Guido Calabresi, to suggest that courts should "treat statutory rules in the same way as they do common law rules, effectively repealing them when they fail to achieve their purposes or no longer fit in the legal landscape in light of changing conditions."[149]

Finally, even when courts do attempt to adapt the law to technological change, the civil litigation process can be slow and protracted.[150] It can take years for a single case to progress from the filing of a complaint at the trial level to a final appellate decision.[151] In recent years, civil cases filed in federal district court have taken an average of thirty months, or two and a half years, to receive final appellate action.[152] This figure is only an average, and cases involving multiple interested parties and complex new technologies may take even longer to litigate given the importance of an outcome to the commercial success of a

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[147] See *infra* Part II.B for a discussion of the ways in which a statute might be outdated; *cf. also* Lyria Bennett Moses, *Recurring Dilemmas: The Law's Race to Keep Up with Technological Change*, 2007 U. ILL. J.L. TECH. & POL'Y 239, 247–69 (offering a typology of the different ways in which statutory rules can become outdated).

[148] *See* U.S. CONST. art. I, § 1 (vesting "[a]ll legislative Powers" in Congress); *see also* Robert Weisberg, *The Calabresian Judicial Artist: Statutes and the New Legal Process*, 35 STAN. L. REV. 213, 217 (1983) (noting that "our jurisprudence treats the legislative command as a uniquely imperative form of legal authority from which judges, at least presumptively, can do no more than mechanically deduce right answers for specific cases"); Moses, *supra* note 146, 412 (arguing that statutory obsolesce is "unlikely to be solved by judicial interpretation" and that only a legislature "can act to change [an outdated] rule").

[149] Moses, *supra* note 147, at 281 (paraphrasing the thesis put forth in GUIDO CALABRESI, A COMMON LAW FOR THE AGE OF STATUTES (1982)).

[150] *See generally* Michael Heise, *Justice Delayed: An Empirical Analysis of Civil Case Disposition Time*, 50 CASE W. RES. L. REV. 813, 834–35 (2000) (conducting an empirical analysis of the disposition time for civil cases that reach a jury trial in state court); Theodore Eisenberg et al., *Litigation Outcomes in State and Federal Courts: A Statistical Portrait*, 19 SEATTLE U. L. REV., 433, 434–45 (1996) (comparing federal and state civil trials).

[151] *See* Heise, *supra* note 150, at 834–35 (finding that the mean civil case disposition time in state court from filing to jury verdict is more than 30 months); ADMIN. OFFICE OF THE U.S. COURTS, ANNUAL REPORT OF THE DIRECTOR: JUDICIAL BUSINESS OF THE UNITED STATES COURTS tbl.B-4A (2017), http://www.uscourts.gov/sites/default/files/data_tables/jb_b4a_0930.2017.pdf (finding that the median civil case disposition time in federal court from filing to final order on appeal is more than 30 months).

[152] ADMIN. OFFICE OF THE U.S. COURTS, *supra* note 151, tbl.B4-A.

new technology and the non-specialized nature of most state and federal courts. The slow pace at which individual cases often advance through the court system only serves to exacerbate the systemic and jurisdictional checks discussed above. Indeed, when the developmental path of a technology is highly uncertain, as is the case with autonomous vehicles, "a judicial opinion could be outdated before it is even decided even at the time it is issued."[153]

2. Potential Regulatory Responses to Uncertainty and the Pacing Problem

The slow rate at which traditional regulatory institutions often respond and adapt to technological change, as well as the perceived risks and uncertainties of emerging technologies, gives rise to three common regulatory responses. These responses—precaution, inaction, and proactivity—reflect fundamentally different understandings of regulation's role in the emergence of novel technologies like autonomous vehicles. All three responses, however, are implicitly informed by an underlying uncertainty with respect to the ability of traditional legal institutions to effectively react and adapt to rapid changes in technology. Although the regulation of autonomous vehicles remains in a nascent stage, features of all three responses are discernable in the current regulation at the state and federal level, and are likely to inform future regulation.

a. Attempt to Slow Technological Development

The most conservative regulatory response to rapid technological change is to slow the development of a new technology. This approach, often referred to as the "precautionary principle," is commonly reduced to the phrase "better safe than sorry."[154] The precautionary principle operates on the

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[153] Marchant, *supra* note 15, at 24.

[154] Stephen G. Wood et al., *Whither the Precautionary Principle? An American Assessment from an Administrative Law Perspective*, 54 AM. J. COMP. L. 581, 581 (2006). There is no single manifestation of the precautionary principle and not every manifestation requires completely halting the development of a technology. *See generally* Per Sandin, *Dimensions of the Precautionary Principle*, 5 HUM. & ECOLOGICAL RISK ASSESSMENT 889 (1999) (arguing that there are several different formulations of the precautionary principle). The basic premise of the principle, however, remains consistent across these different manifestations. Moreover, although the precautionary principle first emerged in the context of environmental regulation, it has since been applied in a number of other contexts. *See* Chang-fa Lo, *Risks, Scientific Uncertainty and the Approach of Applying Precautionary Principle*, 28 J. MED. & L. 283, 289 (2009) (noting that the precautionary principle has also been applied to "genetically modified organisms ('GMOS'), human rights, planetary defense, terrorist attacks, and tourism").

assumption that it is best to limit or halt the commercial adoption of an emerging technology until it is explicitly shown to be safe or sufficient information exists to calibrate a proportionate regulatory response.[155] As one commentator notes, this approach "seeks to create a 'speed bump' that can slow the pace of rapidly developing technologies whose risks are uncertain and regulatory frameworks incomplete."[156] In particular, by restraining the rate at which a new technology can take root and evolve, proponents believe that the precautionary principle provides regulators with additional time and information to design and enact regulatory frameworks, as well as reduces the likelihood that such frameworks will need to be amended based on new information regarding the risks or trajectory of an emerging technology.[157]

Although rarely framed as a direct response to the pacing problem, application of the precautionary principle is a common regulatory reaction to the scientific and developmental uncertainty which accompanies many new technologies.[158] In U.S. domestic law, the precautionary principle is reflected in both environmental and health regulations.[159] The U.S. Food and Drug Administration, for example, requires pharmaceutical companies to demonstrate the efficacy and safety of new drugs and medical devices before they can enter

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[155] Sarah E. Light, *Precautionary Federalism and the Sharing Economy*, 66 EMORY L.J. 333, 337 (2017) ("At its heart, the precautionary principle tells us that it is better to be safe than sorry in the face of significant risk of irreversible harm, even if we are uncertain about the magnitude of the risk.").

[156] Gary E. Marchant, *Addressing the Pacing Problem*, *in* THE GROWING GAP BETWEEN EMERGING TECHNOLOGIES AND LEGAL-ETHICAL OVERSIGHT 200 (Gary E. Marchant et al. eds., 2011).

[157] *See* Light, *supra* note 155, at 363 (arguing that the precautionary principle serves an information forcing function); *cf. also* Han Somsen, *Cloning Trojan Horses: Precautionary Regulation of Reproductive Technology*, *in* REGULATING TECHNOLOGIES: LEGAL FUTURES, REGULATORY FRAMES AND TECHNOLOGICAL FIXES 228–29 (Roger Brownsword & Karen Yeung eds., 2008) (observing that the precautionary principle is "not so much a principle that urges regulators to stray on the side of caution . . . , as a procedural principle that instructs [regulators] to take account of all relevant knowledge in circumstances of scientific uncertainty and ignorance").

[158] *See* James Cameron, *The Precautionary Principle*, in TRADE, ENVIRONMENT AND THE MILLENNIUM 250 (Gary P. Sampson & W. Bradnee Chambers eds., 1999) ("[N]o country has so fully adopted the essence of the precautionary principle in domestic law as the United States."); CASS R. SUNSTEIN, LAWS OF FEAR: BEYOND THE PRECAUTIONARY PRINCIPLE 15 (2005) (observing that the precautionary principle "enjoys widespread international support" and "has been a staple of regulatory policy for several decades"); Wood et al., *supra* note 154, at 585 ("[T]he regulatory policies embodied in the precautionary principle . . . have played, play and will continue to play a significant role in American law.").

[159] *See generally* DIAHANNA LYNCH & DAVID VOGEL, COUNCIL ON FOREIGN RELATIONS, THE REGULATION OF GMOS IN EUROPE AND THE UNITED STATES: A CASE-STUDY OF CONTEMPORARY EUROPEAN REGULATORY POLITICS (2001), http://www.cfr.org/agricultural-policy/regulation-gmos-europe-united-states-case-study-contemporary-european-regulatory-politics/p8688 (discussing the precautionary principle in U.S. law).

the market.[160] Similarly, the Clean Air Act requires the Environmental Protection Agency (EPA) to apply "an adequate margin of safety" in setting emission limits for hazardous pollutants.[161] European law also draws heavily on the precautionary principle to address legal and scientific uncertainty.[162] In response to the emergence of genetically modified foods, for instance, the European Commission has permitted only certain varieties to enter Europe and requires labeling for those which are on the market.[163]

In the context of autonomous vehicles, some states have already responded to the emergence of driverless technology by attempting to slow its development. As discussed in Part I, several states require that a human driver be present in an autonomous vehicle during operation and effectively require that all autonomous vehicles feature a steering wheel, brake pedal, and accelerator.[164] Similarly, other states only allow the operation of autonomous vehicles for testing purposes and prohibit or limit commercial applications.[165] Although no longer federal policy, NHTSA previously urged states to both prohibit the "operation of autonomous vehicles for purposes other than testing" and require that a human driver be present and capable of taking control over an autonomous vehicle.[166] These laws, in essentially slowing the development of autonomous vehicles by mandating technically unnecessary features or simply limiting their operation, attempt to render autonomous vehicle technology a stationary target more amenable to the limited reactive and adaptive capabilities of regulatory institutions. That is, rather than accelerating the rate at which the institutions overseeing autonomous vehicles operate, laws in some states are slowing or manipulating the rate at which autonomous vehicle technology can be adopted so that regulatory institutions have an opportunity to keep pace.

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[160] *See* 21 U.S.C. § 360e (requiring pre-market approval of new medical devices based on a showing that the device is "safe and effective"); 21 C.F.R. § 314 (same for new drugs).
[161] 42 U.S.C. § 7409(b)(1).
[162] *See* LYNCH & VOGEL, *supra* note 159, at 22 (observing that the precautionary principle "has become increasingly influential in Europe").
[163] *See* Emily Marden, *Risk and Regulation: U.S. Regulatory Policy on Genetically Modified Food and Agriculture*, 44 B.C. L. REV. 733, 735 (2003) ("[T]he European Commission has taken a precautionary approach toward [genetically modified foods], and has permitted only limited varieties of GM species to be introduced in Europe.").
[164] *See supra* notes 88–89 and accompanying text (listing these states). In its 2016 policy statement, NHTSA also proposed a "pre-market approval" system, wherein the agency would have prohibited "the manufacture, introduction into commerce, offer for sale and sale" of autonomous vehicles without agency approval based on "the safety of [a] vehicle's performance." NHTSA POLICY 2016, *supra* note 8, at 72. The agency subsequently abandoned that proposal in its 2017 policy statement.
[165] *See supra* notes 93–97 and accompanying text (listing and describing the laws in these states).
[166] NHTSA POLICY 2013, *supra* note 13, at 10.

b. Avoid Amending Existing Regulations or Enacting New Regulations

A second response to rapid technological change is to limit or refrain from regulating a new technology.[167] This approach, labeled "permissionless innovation" by one commentator,[168] views regulation as a potential impediment to the development of emerging technologies.[169] It maintains that because regulatory institutions struggle to reverse or even revise prior actions, regulators should refrain from acting until market failures demand intervention or conclusive proof exists that a technology causes harm.[170] In contrast to the precautionary principle, permissionless innovation places its faith in market forces and existing legal frameworks to maximize the success and safety of new technologies.[171] Although new regulations or adjustments may sometimes be warranted,[172] proponents of the approach assume that attempting to regulate through lethargic or otherwise flawed legal institutions

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[167] *Cf.* Michael Kirby, *New Frontier: Regulating Technology by Law and 'Code'*, *in* REGULATING TECHNOLOGIES: LEGAL FUTURES, REGULATORY FRAMES AND TECHNOLOGICAL FIXES 375 (Roger Brownsword & Karen Yeung eds., 2008) ("[A] failure to provide law to deal with . . . [new] technologies is not socially neutral. Effectively, to do nothing is often to make a decision.").

[168] ADAM THIERER, PERMISSIONLESS INNOVATION: THE CONTINUING CASE FOR COMPREHENSIVE TECHNOLOGICAL FREEDOM 1 (2016), http://permissionlessinnovation.org/wp-content/uploads/2016/03/Thierer_Permissionless_web.pdf.

[169] *See generally id.* at 8–12 (summarizing this approach); *see also* Adam Thierer, *Technopanics, Threat Inflation, and the Danger of an Information Technology Precautionary Principle*, 14 MINN. J.L. SCI. & TECH. 309, 352–56 (2013) (describing further the premises on which this approach rests).

[170] *See* KENNETH A. OYE ET AL., ON BELIEFS AND REGIMES: JUSTIFICATION, CAUSAL KNOWLEDGE, AND MEASURES OF COMPLIANCE 15 (2005) (discussing the range of work which challenges the precautionary principle and describing this work's general presumption that "[r]egulators should not act until after there is conclusive proof of harms, because regulatory actions are often irreversible").

[171] *See, e.g.*, Marc Scribner, *Self-Driving Regulation: Pro-Market Policies Key to Automated Vehicle Innovation* 1 (Competitive Enter. Inst. Working Paper No. 192, 2014), https://cei.org/sites/default/files/Marc%20Scribner%20-%20Self-Driving%20Regulation.pdf ("[R]egulatory and legislative intervention . . . poses great risks to the development of [new] technolog[ies]. . . . [L]aws and regulations that narrow the scope of permissible development, testing, and operational functionality risk locking in inferior technology, delaying adoption, and increasing prices faced by consumers.").

[172] *See, e.g.*, Adam Thierer & Ryan Hagemann, *Removing Roadblocks to Intelligent Vehicles and Driverless Cars* 13 (Mercatus Ctr. Working Paper, 2014), https://www.mercatus.org/system/files/Thierer-Intelligent-Vehicles.pdf ("To the extent that more serious problems develop or persist, public policy can always be adjusted to address those issues after careful evaluation of the costs and benefits of proposed rules.").

will impose greater costs than benefits.[173] As one commentator argues, "[u]nless a compelling case can be made that an invention poses a serious immediate threat to public well-being, innovation should be allowed to continue unabated."[174]

This combination of inaction and legalization is frequently proposed as a response to rapid technological change.[175] A good example is early efforts to regulate the Internet.[176] In his 1997 *Framework for Global Electronic Commerce*, for instance, President Clinton articulated a largely hands-off approach to regulating Internet technologies.[177] His skepticism of regulatory intervention was based in large part on concerns about the incongruous rates at which the Internet and regulatory systems could develop.[178]As the President warned, since "[b]usiness models must evolve rapidly to keep pace with the break-neck speed of [technological change], government attempts to regulate are likely to be outmoded by the time they are finally enacted, especially to the extent such regulations are technology-specific."[179] Thus, instead of attempting to slow or otherwise manage the development of information technology, President Clinton recommended

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[173] *See, e.g.*, Daniel Sarewitz, *Anticipatory Governance of Emerging Technologies*, *in* THE GROWING GAP BETWEEN EMERGING TECHNOLOGIES AND LEGAL-ETHICAL OVERSIGHT 98 (Gary E. Marchant et al. eds., 2011) ("[T]he alignment of technological innovation with the ideologies of the marketplace . . . tell us that the appropriate measures of technological value are monetary[ ] and [that] the appropriate mode of intervention is hands-off."); *cf.* JOEL MOKYR, LEVER OF RICHES: TECHNOLOGICAL CREATIVITY AND ECONOMIC PROGRESS 16 (1990) ("Technological progress is like a fragile and vulnerable plant, whose flourishing is not only dependent on the appropriate surroundings and climate, but whose life is almost always short. It is highly sensitive . . . and can easily be arrested by relatively small external changes.").

[174] Thierer & Hagemann, *supra* note 172, at 10.

[175] *See* Demissie, *Taming Matter for the Welfare of Humanity: Regulating Nanotechnology*, *in* REGULATING TECHNOLOGIES: LEGAL FUTURES, REGULATORY FRAMES AND TECHNOLOGICAL FIXES 340 (Roger Brownsword & Karen Yeung eds., 2008) (noting the popularity of this approach and describing it as "regulatory vogue"); Gregory N. Mandel, *History Lessons for a General Theory of Law and Technology*, 8 MINN. J.L. SCI. & TECH. 551, 564 (2007) ("[T]here often appears to be an inclination to handle new technology disputes under existing rules."); Lin, *supra* note 6, at 380 (observing that many "new technologies . . . develop and come to market with little or no government oversight").

[176] *See* THIERER, *supra* note 168, at 14–15 (arguing that the Clinton administration's "market-oriented vision for cyberspace governance" is a prototypical example of permissionless innovation).

[177] *See* William J. Clinton & Albert Gore Jr., *A Framework for Global Electronic Commerce* (July 1, 1997), https://clinton4.nara.gov/WH/New/Commerce/read.html (describing a "non-regulatory, market-oriented approach")

[178] *See id.* (cautioning that the Internet's "explosive" growth could pose "significant logistical and technological challenges" to regulators).

[179] *Id.*

that states and federal agencies "refrain from imposing new and unnecessary regulations . . . on commercial activities that take place via the Internet."[180]

Inaction and simple legalization have also been the most common regulatory responses to autonomous vehicle technology. As described in Part I, most states have refrained from prohibiting or strictly controlling the development and operation of autonomous vehicles.[181] Since the operation of autonomous vehicles is generally presumed to be legal in every state without an explicit prohibition, most states have effectively—if not formally—legalized their operation.[182] The federal government, moreover, acting through NHTSA, has carefully limited its regulatory activities.[183] Although the agency has published non-binding best practices for industry participants[184] and is currently considering ways to remove barriers to autonomous vehicle technologies in existing FMVSS,[185] it has mostly remained a passive observer.[186] This paucity of state and federal action is no accident and, in some cases, is framed as a direct response to the pacing problem.[187] As autonomous vehicle developers, scholars,

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[180] *Id.*

[181] *See supra* Part I.B.2 (surveying state laws).

[182] *See* Smith, *supra* note 7 (explaining this presumption); *see also* Thad Moore, *As Self-Driving Cars Come to More States, Regulators Take a Back Seat*, WASH. POST (Aug. 29, 2015), https://www.washingtonpost.com/business/ economy/as-self-driving-cars-come-to-more-states-regulators-take-a-back-seat/2015/08/28/7a29413e-474f-11e5-8ab4-c73967a14 3d3_story.html [https://perma.cc/L8MB-FJ5K] (reporting that, based on the strength of this presumption, manufacturers have been taking prototypes on cross-country trips through states without autonomous vehicle laws).

[183] *See supra* Part I.B.1 (describing the federal response to autonomous vehicles); *see also* Kohler & Colbert-Taylor, *supra* note 58, at 105 ("[T]he U.S. federal government has not attempted to regulate autonomous motor vehicles as such . . . ."); RAND REPORT, *supra* note 8, at 103 ("There are currently no federal regulations related specifically to [autonomous vehicle] technologies.").

[184] NHTSA POLICY 2017, *supra* note 55, at 1-18; NHTSA POLICY 2016, *supra* note 8, at 11–36.

[185] *See* Removing Regulatory Barriers for Vehicles with Automated Driving Systems, 83 Fed. Reg. 2607 (Jan. 18, 2018) (seeking public comment on "regulatory barriers in the existing [FMVSS]").

[186] Although the two bills currently pending in Congress, H.R. 3388 and S. 1885, encourage NHTSA to consider creating some technology-specific regulations, they would mostly codify the agency's existing hands-off approach and leave in place the legal framework governing conventional vehicles. *See supra* Part I.B.1 (discussing the main components of both bills).

[187] *See, e.g.*, NHTSA POLICY 2017, *supra* note 55, at ii, 1 ("The Federal Government wants to ensure it does not impede progress with unnecessary or unintended barriers to innovation. . . . As automated driving technologies evolve at a rapid pace, . . . [e]ach entity is free to be creative and innovative when developing the best method for its system to appropriately mitigate the safety risks associated with their approach."); NHTSA POLICY 2013, *supra* note

and lawmakers continue to raise concerns about whether existing regulatory machinery can keep pace with autonomous vehicle technology, inaction and simple legalization are likely to remain popular responses.

c. Attempt to Regulate into the Future

A third response to rapid technological change is to enact future-facing regulations that attempt to anticipate or otherwise shape the development of an emerging technology. Proponents of this response acknowledge the limitations of regulatory institutions but view regulation as an important element in the success and safety of new innovations.[188] They maintain that, because regulatory institutions struggle to react and adapt to rapid changes in emerging technologies, regulators must design frameworks which anticipate, or attempt to guide, their ongoing and future development.[189] In particular, the approach assumes that regulators must minimize the probability that regulations enacted in response to a new technology will need to be revised or revisited in the future.[190] Although there is no uniform theory of how to avoid such revisions, the two most prominent approaches are to (1) mandate specific characteristics or forms of a technology[191] and (2) draft technology-neutral

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13, at 10 ("Because . . . the technical specifications for . . . automated systems are still in flux, the agency believes that regulation of the technical performance of automated vehicles is premature at this time."); *see also* Moore, *supra* note 182 (discussing the lack of autonomous vehicle legislation and its relationship to many state lawmakers' concerns about stifling autonomous vehicle technology as it continues to evolve).

[188] *See, e.g.*, Karni Chagal-Feferkorn, *The Reasonable Algorithm*, 2018 U. ILL. J.L. TECH. & POL'Y 111, 129–30 (2018) (proposing a technology-neutral standard for regulating algorithms so as to avoid "the need to constantly update laws and regulations" and arguing that appropriate regulation "could have a positive effect on innovation[,] . . . create proper incentives for the efficient use of humans and algorithms, and . . . allow victims of harm caused by algorithms to stand on equal ground in terms of recovery").

[189] *See* Brad A. Greenberg, *Rethinking Technology Neutrality*, 100 MINN. L. REV. 1495, 1521 (2016) ("To avoid being made obsolete by technological changes, a law needs to anticipate innovations; it can do so through prescience or . . . provisions that enable flexible application."); Michael Birnhack, *Reverse Engineering Information Privacy Law*, 15 YALE J. L. & TECH. 24, 38–39 (2013) ("Given that the law cannot anticipate new technologies in detail, and once we acknowledge that technology does develop and change faster than the pace of the legislative process, the preference for a law that will last for longer than the present moment is clear.").

[190] *See* Michael A. Geist, *Is There a There There? Toward Greater Certainty for Internet Jurisdiction*, 16 BERKELEY TECH. L.J. 1345, 1359 (2001) (describing the need to establish "effective and enduring" regulations); *see also* S. Rep. No. 102-294, at 36 (1992) (designing copyright rules to spare "Congress from having to revisit this issue almost annually in order to keep pace with the rapidly changing technological world").

[191] *See* Greenberg, *supra* note 189, at 1523 (identifying this as one of the two forms of future-facing regulations); Justin R. Pidot, *Governance and Uncertainty*, 37 CARDOZO L. REV. 113, 131

laws which focus on achieving a particular state of the world rather than a particular state of a technology.[192]

A future-facing approach to the regulation of emerging technologies is perhaps the most natural and deliberate response to the pacing problem. As such, regulators have operationalized this principle in a wide range of technological contexts over the past forty years.[193] In an attempt to "future-proof" copyright law, for example, Congress enacted a technology-neutral regulatory framework in 1976.[194] Whereas earlier frameworks conditioned the protection of original works on the form or medium in which they were fixed, the Copyright Act of 1976 extended protection to works "fixed in any tangible medium of expression."[195] In making this change, lawmakers sought to uncouple "the scope of an author's rights" from specific technologies and eliminate the need for future revisions based on "unknown and unforeseen technologies."[196] Instead of "forc[ing] the law to struggle" with rapid changes or requiring regular updates to copyright law, lawmakers aimed to craft a framework "adaptable to technological advances."[197]

(2015) (same); *cf.* Jaegul Lee et al., Innovation and Technology Policy: Lessons from Emission Control and Safety Technologies in the U.S. Automobile Industry 7-8 (April 2007) (working paper prepared for the Sloan Industry Studies Conference) (reviewing the use of technology forcing regulations mandating adoption of "specific technologies or technological pathways").

[192] *See* Greenberg, *supra* note 189, at 1512–13 ("Rather than force the law to struggle with new technologies, and in the interest of sparing legislators the time-consuming effort of frequent revisions, technology neutrality attempts to avoid ossification by making a statute more adaptable to technological advances."); Geist, *supra* note 190, at 1359 ("Technology neutral . . . refers to statutory tests or guidelines that do not depend upon a specific development or state of technology, but rather are based on core principles that can be adapted to changing technologies.").

[193] *See, e.g.*, Stephanie K. Pell & Christopher Soghoian, *Can You See Me Now? Toward Reasonable Standards for Law Enforcement Access to Location Data that Congress Could Enact*, 27 BERKELEY TECH. L. J. 117, 117 (2012) (proposing a technology-neutral "legislative model for law enforcement access standards and downstream privacy protections for location information"); Orin S. Kerr, *Applying the Fourth Amendment to the Internet: A General Approach*, 62 STAN. L. REV. 1005, 1015–17 (2010) (positing that courts have applied the Fourth Amendment in a technology-neutral manner); Geist, *supra* note 190, at 1345–46 (recommending a technology-neutral jurisdictional test for cases involving predominantly Internet-based contacts); Nicholas W. Allard & Theresa Lauerhass, *Debalkanize the Telecommunications Marketplace*, 28 CAL. W. L. REV. 231, 231 (1992) (examining the need for a technology-neutral implementation of telecommunications policies).

[194] Greenberg, *supra* note 189, at 1517; Copyright Act of 1976, Pub. L. No. 94–533, 90 Stat. 2541 (codified at scattered sections of title 17 of the United States Code).

[195] 17 U.S.C. § 102(a).

[196] Greenberg, *supra* note 189, at 1517 n.93 (quoting STAFF OF THE H. COMM. ON THE JUDICIARY, 89TH CONG., COPYRIGHT LAW REVISION, PART 6: SUPPLEMENTARY REP. OF THE REGISTER OF COPYRIGHTS ON THE GENERAL REVISION OF THE U.S. COPYRIGHT LAW 18 (Comm. Print 1965)).

[197] *Id.* at 1513.

Despite its intuitive appeal, states have largely avoided future-facing regulations in the autonomous vehicle context. The vast majority of states make no attempt to shape or anticipate the development of autonomous vehicle technology, limiting themselves to logistical management of product testing or affirmative declarations that autonomous vehicles are legal under existing law.[198] The federal government, by contrast, has relied at least in part on NHTSA's technology-neutral recall authority as it seeks to avoid more prescriptive actions.[199] As discussed in Part I, that recall authority, as applied to vehicle and equipment defects, allows the agency to order a recall if it finds an "unreasonable risk to safety."[200] The "unreasonable risk" standard is part of the National Traffic and Motor Vehicle Safety Act, a law originally enacted in 1966, but it remains central to the work of federal regulators.[201] Although NHTSA's policy has been to refrain from mandating the use or design of specific autonomous vehicle technologies, and it has yet to order any recalls, the agency appears confident that it can ensure autonomous vehicle safety based predominantly on this technology-neutral authority and without taking prescriptive actions in the future.[202]

B. Obstacles Created by Regulatory Responses to the Pacing Problem

The preceding section outlined the inherent challenge of regulating rapidly evolving technologies like autonomous vehicles and described three categories of common regulatory responses to this challenge. Although the aim

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[198] *See supra* Part I.B.2 (noting the presumption that autonomous vehicles are legal and explaining that very few states address specific aspects of autonomous vehicle design). Although state laws requiring a steering wheel, brake pedal, and accelerator could be viewed as attempts to shape the development of autonomous vehicle technology, their motivation appears to be more in line with the precautionary principle.

[199] *See supra* Part I.B.1 (describing the current federal policy on autonomous vehicles).

[200] *See supra* notes 70–72 and accompanying text (detailing NHTSA's recall authority)

[201] *See generally* NAT'L HIGHWAY TRANSP. SAFETY ADMIN., UNDERSTANDING NHTSA'S REGULATORY TOOLS 2–4 (2016), https://www.nhtsa.gov/sites/nhtsa.dot.gov/files/documents/understanding_nhtsas_current_regulatory_tools-tag.pdf (providing an overview of the regulatory tools, including determinations and remediations of unreasonable risks to safety, available to NHTSA under the National Traffic and Motor Vehicle Safety Act).

[202] NHTSA POLICY 2017, *supra* note 55, at 3 ("NHTSA has broad enforcement authority to address existing and new automotive technologies and equipment. . . . Specifically, NHTSA's enforcement authority concerning safety-related defects in motor vehicles and motor vehicle equipment extends and applies equally to current and emerging ADSs."); NHTSA Enforcement Bulletin, *supra* note 65, at 65, 708 ("NHTSA's enforcement authority concerning safety-related defects in motor vehicles and motor vehicle equipment extends and applies equally to current and emerging automated safety technologies. This includes fully automated (self-driving) vehicles.").

of all three responses is to overcome the inertia of regulatory institutions and facilitate the safe and widespread adoption of beneficial new technologies, each has potential drawbacks. As lawmakers, scholars, and market participants consider how to realize the benefits of autonomous vehicles, it is not only important to identify the inherent limitations of existing regulatory processes, but also to appreciate any shortcomings in perceived solutions to these problems. In the following section, I outline these shortcomings, describing the legal and social barriers to the successful development of rapidly evolving technologies generated by each response to the pacing problem and the ways in which these barriers could negatively impact the development of autonomous vehicles.[203]

1. Potential Drawbacks of Failing to Regulate

The most basic response to the pacing problem is to do nothing—leave existing laws in place and refrain from enacting new laws. Although there is a seductive simplicity and certain advantages to taking a hands-off approach to regulating rapidly evolving technologies,[204] the failure to amend existing laws or enact new laws can create both regulatory uncertainty for market participants and low public confidence in the safety of new technologies.

a. Regulatory Uncertainty

As new technologies give rise to novel "forms of conduct" and new "activities and relationships," existing laws "may not operate as effectively as they did in the past."[205] The disconnect between existing law and innovation can generate significant regulatory uncertainty for market participants.[206] This uncertainty can take at least three forms: (1) potential prohibitions on a new technology, (2) application of ambiguous legal terms and concepts to a new technology, and (3) superfluous rules governing the design or use of a new technology.[207]

[203] The purpose of this section is not to establish that these regulatory responses have no utility or are never appropriate; rather, its purpose is to emphasize that perceived solutions to the pacing problem can themselves create obstacles to the commercial success of emerging technologies.
[204] *Cf.* Demissie, *supra* note 1, at 340 (describing inaction and deregulation as "regulatory vogue").
[205] Lyria Bennett Moses, *Agents of Change: How the Law 'Copes' with Technological Change*, 20 GRIFFITH L. REV. 763, 767 (2011); *see also* Mandel, *supra* note 175, at 568 ("[I]t should be anticipated that preexisting legal regimes may run into problems when being used to govern technology that did not exist when the regimes were created.").
[206] *See generally* Moses, *supra* note 147, at 253-57 (discussing the problem of legal uncertainty as it relates to new technologies).
[207] As should be obvious from the following subsection, these categories are not mutually exclusive and frequently overlap. The subsection, moreover, is not intended as an exhaustive

i. Prohibitions in Existing Laws

First, existing laws may prohibit the production, sale, or specific uses of an emerging technology. In most cases, such prohibitions are inadvertent and result from technological developments which could have never been anticipated when lawmakers drafted the relevant statute or regulation.[208] In particular, a new relationship, activity, or type of conduct made possible by an emerging technology may "fall within a rule despite being irrelevant to [its] goals."[209] Notwithstanding the inadvertent nature of these prohibitions, failing to amend existing laws or enact new laws can leave developers, retailers, and users of new technologies in a precarious position. Indeed, as long as outdated rules remain in force, market participants must depend on the enforcement discretion of federal and state agencies, creating an unstable and potentially inconsistent legal environment for all parties.[210]

A classic example of existing law impeding the adoption of a new technology is the traditional common law rule that land is owned *usque ad coelum*, or infinitely upwards.[211] In the pre-aviation era, this rule stood for the intuitive proposition that a land owner is entitled to the exclusive use of any air space above his property.[212] However, as aviation technologies started to

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analysis of every type of uncertainty; it aims, instead, to highlight several of the most disruptive types of uncertainty arising from inaction.

[208] *See, e.g.*, Act of Mar. 25, ch. 600, 1991 Va. Acts 1111 (amending VA. CODE § 32.1-289.1 (1991), which was intended to prohibit the sale of organs, so that women could sell ova for in vitro fertilization, the donation of which was technologically impossible when the law was originally passed); *see also* Moses, *supra* note 146, at 400-01 (discussing more generally inadvertent prohibitions in the context of over and under-inclusive laws); Moses, *supra* note 147, at 260-64 (discussing issues with statutory ambiguities resulting in under or over-inclusiveness of prohibitions applied to technological developments and providing relevant examples in ADA designations, railroad owner liabilities, and computer and internet related complications).

[209] *See* Moses, *supra* note 147, at 260 ("New artifacts, activities, and relationships may fall within a rule despite being irrelevant to their goals . . . .").

[210] *See* Mandel, *supra* note 175, at 564–65 (describing such problems in the context of biotechnology and nanotechnology).

[211] *See* Moses, *supra* note 146, at 399 (offering this example); *see also* Lora D. Lashbrook, *The "Ad Coelum" Maxim As Applied to Aviation Law*, 21 NOTRE DAME LAWYER 143, 146–7, 154 (1946) (applying the *ad coelum* doctrine to commercial air travel in the United States).

[212] *See, e.g.*, Portsmouth Co. v. United States, 260 U.S. 327, 329–30 (1922) (finding that the plaintiff had an arguable claim to trespass for shooting a bullet across the land of another); Hannabalson v. Sessions, 90 N.W. 93, 94–95 (Iowa 1902) (affirming the vitality of *usque ad coelum* in a claim involving the thrusting of an arm across the property of another); Cumberland Tel. & Tel. Co. v. Barnes, 30 Ky. L. Rptr. 1290, 1291–92 (Ky. App. 1907) (finding an unlawful trespass by defendant for extending boards from a telephone pole across the land of another); *see also* Lashbrook, *supra* note 211, at 143–46 (summarizing the doctrine's historical development); Moses, *supra* note 146, at 399 (same).

emerge, the doctrine threatened to complicate efforts to commercialize air travel, as it would have effectively prohibited the operation of balloons and airplanes since every flight over private land risked being prosecuted as a trespass.[213] Although courts eventually stepped in to circumscribe the doctrine and allow commercial aviation to move forward,[214] early participants faced legal uncertainty as a result of the unanticipated intersection between property law and aviation technologies.[215] Without judicial intervention—a possibility only in the common law context—new aviation technologies could have remained grounded.

Although less pronounced, developers of autonomous vehicles also face uncertainty with respect to performance standards and the legality of general and specific applications of their products.[216] At the international level, for example, the 1949 Geneva Convention on Road Traffic, to which the U.S. is a party, requires every vehicle to have a "driver" who is "at all times . . . able to control [it]."[217] Although an intuitive requirement with respect to the safe

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[213] *See* MICHAEL HELLER, THE GRIDLOCK ECONOMY: HOW TOO MUCH OWNERSHIP WRECKS MARKETS, STOPS INNOVATION, AND COST LIVES 28 (2008) (observing if the doctrine was enforced literally "then crossing each [air] column without permission [would have been] a trespass").

[214] *See* United States v. Causby, 328 U.S. 256, 260–61 (1946) (holding that the *ad coelum* doctrine "has no place in the modern world"); *see also* Johnson v. Curtiss N.W. Airplane Co., 1928 U.S. Av. Rep. 42 (Minn. D. Ct. 1923) (finding the common law principle inapplicable to aviation because "[m]odern progress and great public interests should not be blocked by unnecessary legal refinements"); Commonwealth v. Nevin, 1928 U. S. Av. Rep. 39, 41 (Pa. D. & C.2d 1922) (refusing to apply trespass law where the law did not clearly contemplate airplane travel); Roger F. Williams, *The Existence of the Right to Flight*, 79 U. PA. L. REV. 729, 738–40 (1931) (discussing prior cases involving trespass across property by airplanes to support the proposition that there exists a right to flight across private property).

[215] Indeed, legal scholars vigorously debated the extent of property rights in air space and whether airplanes could operate without some exercise of a state's power of eminent domain or police power. *See generally* Arthur L. Newman, *Aviation Law and the Constitution*, 39 YALE L.J. 1113, 1127–29 (1930) (summarizing the conflict between property rights and aviation and the legal arguments made during litigation of trespass claims).

[216] *See, e.g.*, ANITA KIM ET AL., NAT'L HIGHWAY TRANSPORTATION ADMIN., REVIEW OF FEDERAL MOTOR VEHICLE SAFETY STANDARDS (FMVSS) FOR AUTOMATED VEHICLES 8-21 (2016) (identifying FMVSS which "may pose challenges to the introduction of automated vehicles"); Letter from Chris Urmson, Director, Google Self-Driving Car Project, to Paul A. Hemmersbaugh, Chief Counsel, NHTSA (Nov. 12, 2015) [hereinafter Google Letter] (on file with the author) (requesting NHTSA interpretations on a number of FMVSS which could render all or part of Google's autonomous vehicle design illegal); *see also* NHTSA POLICY 2016, *supra* note 8, at 48-52 (suggesting that existing vehicle safety standards may prohibit some autonomous vehicle technologies, or at least create this perception among market participants, by noting the importance of agency interpretation letters and the need to issue such interpretations and exemptions on an expedited basis).

[217] Geneva Convention on Road Traffic art. 8, Sept. 19, 1949, 3 U.S.T. 3008, 125 U.N.T.S. 3.

operation of traditional vehicles, such a mandate could prevent the lawful use of autonomous vehicles, at least to the extent that no human is able to intervene in the automated vehicle's operation.[218] Similarly, at the federal level, compliance with many FMVSS is contingent upon the presence of a human "driver" and controls like a steering wheel.[219] Vehicle codes in several states also outlaw the operation of a vehicle without "one hand" remaining on the steering mechanism.[220] These rules, clearly designed with traditional vehicles in mind, have the potential to impede the development of fully automated vehicles, which specifically aim to eliminate active human control over vehicle movements.[221] Although regulators are unlikely to enforce such prohibitions, leaving these laws on the books creates additional risk and uncertainty for investors in autonomous vehicle technologies.

ii. Ambiguous Terms and Concepts in Existing Laws

Second, new technologies may also reveal "latent ambiguities" in the terms and concepts contained in existing laws.[222] Such ambiguities often arise "where new technology or new forms of conduct do not fit easily into existing conceptual and legal categories."[223] A word or idea may have had a straight-

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[218] *But see* Smith, *supra* note 7, at 433-41 (concluding that, at least under international law, "the term 'driver' is probably flexible"); Removing Regulatory Barriers for Vehicles with Automated Driving Systems, 83 Fed. Reg. 2607 (Jan. 18, 2018) (seeking public comment on ways to remove "regulatory barriers in the existing [FMVSS]"); *infra* pp. 45–46 (discussing whether computers might qualify as drivers).

[219] *See* ANITA KIM ET AL., *supra* note 216, at 1–2, 10–11 ("If manufacturers want to sell vehicles only intended for automated operation, with no way for human occupants to drive the vehicle, they are likely to have difficulty certifying to requirements for a foot-actuated service brake control (517.135), a designated seating position for the driver (571.207), a steering wheel (a requirement for completing tests specified in 571.126), and certain controls and displays."); *see also* Removing Regulatory Barriers for Vehicles with Automated Driving Systems, 83 Fed. Reg. 2607 (Jan. 18, 2018) (further describing "regulatory barriers in the existing [FMVSS]").

[220] *See, e.g.*, N.Y. VEH. & TRAF. LAW § 1226 (detailing the requirements for handling a steering mechanism); MASS. GEN. LAWS ch. 90, § 13 (specifying the requirements for operating a vehicle).

[221] State laws requiring minimum spacing between vehicles could also complicate efforts to use autonomous vehicles in tightly grouped platoons. *See* Smith, *supra* note 7, app. 1 at 518-21 (listing and analyzing such laws).

[222] LAWRENCE LESSIG, CODE: VERSION 2.0 at 25-26, 155-56 (2006); *see also* Mandel, *supra* note 175, at 553 ("[W]here [a] new issue arises as a result of technological change, . . . old categories may no longer apply."); Moses, *supra* note 147, at 257 ("Some legal categories and concepts become ambiguous in light of technological change.").

[223] Moses, *supra* note 146, at 396.

forward meaning or application in its original context, but technological innovations, among other developments, may allow for multiple, often competing ways of interpreting or applying the same words and concepts.[224] A good example is the shifting definition of what it means to be a person's lawful "mother."[225] Traditionally, a mother was "the woman who bore a child and contributed to its genetic identity."[226] With the development of *in vitro* fertilization, however, the mother of a child could be at least two people: the woman who provides the ovum and the woman who serves as the surrogate.[227] Although innocuous on its face, this ambiguity has generated significant uncertainty in states with laws granting custody of child to its "mother," as the term could reasonably apply to both the donor and the surrogate.[228]

The same types of ambiguities are present in the laws governing traditional vehicles. A particularly important ambiguity involves the terms "driver" and "operator." As described above, the Geneva Convention requires that a "driver" be able to control a vehicle at all times.[229] Many federal and state regulations also impose specific obligations on the "driver" or "operator" of a vehicle.[230] When natural persons were the only entities physically controlling vehicles, the meaning of these terms was generally clear.[231] As applied to autonomous vehicles, however, the terms are ambiguous.[232] In particular, it is not always clear whether a "driver" or "operator" of a vehicle also encompasses the computer which controls an

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[224] *See* Lessig, *supra* note 222, at 25 (describing this problem).
[225] *See generally* Michael H. Shapiro, *Lawyers, Judges and Bioethics*, 5 S. CAL. INTERDISC. L.J. 113 (1997).
[226] Moses, *supra* note 147, at 257.
[227] *Id.*
[228] *See, e.g.*, Johnson v. Calvert, 851 P.2d 776 (Cal. 1993) (addressing the question of whether the donor or surrogate was the "natural mother" of a child born through *in vitro* fertilization under California law). Of course, not every custody statute leaves the term "mother" undefined and many states have amended their laws to include a definition of the term. *See* Susan L. Crockin & Gary A. Debele, *Ethical Issues in Assisted Reproduction: A Primer for Family Law Attorneys*, 27 ETHICAL ISSUES IN ASSISTED REPRODUCTION 289, 340-43 (2015) (surveying the law around sperm and egg donation).
[229] *See* Convention on Road Traffic, *supra* note 217.
[230] *See* ANITA KIM ET AL., *supra* note 216, at 3-4, 17-25 (identifying every use of "driver" and "operator" in the FMVSS); Smith, *supra* note 7, at 464 n.307 (listing state and federal regulations).
[231] But not always. *See, e.g.*, Fairman v. Mors, 130 P.2d 448, 450-51 (Cal. Ct. App. 1942) (holding that, under California law, "a[n] automobile incapable of moving under its own power is not 'driven' by any of its occupants when being towed by another automobile").
[232] *Cf.* ANITA KIM ET AL., *supra* note 216, at 18 ("[L]anguage throughout the FMVSS is clear in a world where all vehicles require a human driver for manual control, but the meaning of the term 'driver' could become less certain or different when considered in the context of vehicles with increasingly automated capabilities.").

autonomous vehicle.[233] The uncertainty generated by this ambiguity is further compounded by the varying statutory and common law definitions of the terms, each of which could lead to slightly different results.[234] In some states, for example, the driver of an autonomous vehicle could be the computer; in others it could be the owner; still in others it could be the person who summoned or started the vehicle.[235] When making investment decisions, individuals and firms may struggle with this ambiguity, unsure of the liabilities they could incur or the ways in which an autonomous vehicle could be lawfully used.

iii. Superfluous Requirements and Limitations in Existing Laws

Finally, existing laws may impose unnecessary limitations or requirements on the design or use of a new technology. Like the prohibitions discussed above, these superfluous mandates are generally the result of unforeseeable technological developments.[236] In particular, a new relationship, activity, or type of conduct made possible by an emerging technology may fall within the scope of an existing rule despite being irrelevant to its goals.[237] Consider the following scenario. A hypothetical city ordinance prohibits the use of motorcycles in a park frequented by birdwatchers because motorcycles are loud and would scare away the birds. Ten years after the ordinance is passed, engineers develop a new technology which allows motorcyclists to operate their vehicles silently. If the ordinance remained unchanged, motorcycles would still be excluded from the park, even though doing so would no longer serve the purpose of the ordinance. This overbreadth would mean that the new technology would itself be legal, but its utility and potential benefits could be substantially limited, at least in so far as one intended benefit of the technology was to open more public spaces to motorcyclists.

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[233] *See, e.g.*, Google Letter, *supra* note 216 (seeking clarification on this matter under FMVSS); *see also* Smith, *supra* note 7, at 463–80 (considering this question under a range of existing state laws).
[234] *See* Smith, *supra* note 7, at 464 n.307 (listing virtually every different state, federal, and international law definition of "driver" and "operator").
[235] *See* Smith, *supra* note 7, at 476–80 (exploring these possibilities); *see also* Jack Karsten & Darrell West, *The State of Self-Driving Car Laws Across the U.S.*, BROOKINGS (May 1, 2018), https://www.brookings.edu/blog/techtank/2018/05/01/the-state-of-self-driving-car-laws-across-the-u-s/ [https://perma.cc/THW9-LJMB] ("[I]ndividual states . . . differ on basics like the definition of 'vehicle operator.' Tennessee SB 151 points to the autonomous driving system (ADS), while Texas SB 2205 designates a 'natural person' riding in the vehicle. Meanwhile, Georgia SB 219 identifies the operator as the person who causes the ADS to engage, which might happen remotely in a vehicle fleet.").
[236] *See* Moses, *supra* note 147, at 260-64 (discussing superfluous mandates in the context of over-inclusive rules resulting from technologic change).
[237] *Id.*

In most states, these same types of unnecessary limitations and requirements are imposed on autonomous vehicles. The aim of state vehicle codes, for instance, is to maximize the safety of vehicle operators and pedestrians. To that end, all states prohibit individuals from either "driving," "operating" or "being in control" of a motor vehicle while intoxicated.[238] These laws make sense if a natural person is the one actually controlling the vehicle. If a natural person is only a passenger in a fully automated vehicle, however, it makes far less sense to prohibit that person from riding in the vehicle while intoxicated. Nevertheless, the vehicle codes in some states may still categorize the human passenger in an autonomous vehicle as its "driver" or "operator."[239] In such states, simply riding in an autonomous vehicle while intoxicated would likely constitute the unlawful act of intoxicated driving. Thus, to the extent that one purpose of autonomous vehicles is to increase mobility while improving public safety, these laws would add legal uncertainty for investors and undermine at least one potential benefit of the technology.[240]

b. Reduced Public Confidence in Safety

In addition to legal uncertainty, regulatory inaction can also undermine public confidence in the safety of a new technology. The importance of public confidence cannot be overstated.[241] If consumers are unwilling to purchase or

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[238] *See* James O. Pearson, Jr., *What Constitutes Driving, Operating, or Being in Control of Motor Vehicle for Purposes of Driving While Intoxicated Statute or Ordinance*, 93 A.L.R. 3d 7 (1979) (compiling drunk-driving laws).

[239] *See supra* notes 232-35 and accompanying text.

[240] The same is true of distracted driving laws, which could prevent autonomous vehicle passengers from engaging in productive activities while on the road. *See, e.g.*, OKLA. STAT. tit. 47, § 11-901b ("The operator of every vehicle, while driving, shall devote their full time and attention to such driving."); GA. CODE § 40-6-241 (prohibiting drivers from "engag[ing] in any actions which [would] distract [the] driver from the safe operation of [a] vehicle"); ARK. CODE § 27-51-104 (prohibiting any person from "driv[ing] or operat[ing] any vehicle in such a careless manner as to evidence a failure to keep a proper lookout for other traffic, vehicular or otherwise, or in such a manner as to evidence a failure to maintain proper control").

[241] *See* Barack Obama, *Self-Driving, Yes, But Also Safe*, PITTSBURGH POST-GAZETTE, Sept. 19, 2016, http://www.post-gazette.com/opinion/Op-Ed/2016/09/19/Barack-Obama-Self-driving-yes-but-also-safe/stories/201609200027 [https://perma.cc/RH35-7XXX] ("The quickest way to slam the brakes on innovation is for the public to lose confidence in the safety of new technologies."); Gregory N. Mandel, *Emerging Technology Governance*, *in* INNOVATIVE GOVERNANCE MODELS FOR EMERGING TECHNOLOGIES 60 (Gary E. Marchant et al. eds., 2013) ("[P]ublic confidence in an emerging technology and its governance is critical to the success of the technology."); Douglas J. Sylvester et al., *Not Again! Public Perception, Regulation, and Nanotechnology*, 3 REG. & GOVERNANCE 165, 168 (2009) ("[P]ublic opinion is crucial to the success and integration of new technologies. If the public turns against a technology, its likelihood of success (however defined)

use a new technology due to concerns about safety—whether justified or not—then the potential benefits of a new technology are virtually guaranteed to remain unrealized.[242] Importantly, the degree to which a technology is regulated relates to public confidence in at least two ways. First, to the extent that imposing minimum safety standards on a new technology actually reduces the probability of harmful events, the regulated technology is likely to be perceived as safer.[243] Since most people first hear about a new technology through the media,[244] highly publicized incidents involving the technology could cause people to overestimate its risks.[245] Second, a growing body of research suggests that public confidence in unfamiliar technologies depends at least in part on their level of regulation.[246] This may be especially true in the wake of high-profile accidents involving such technologies.[247]

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is greatly reduced."); Lynn L. Bergeson, *Avoid Mistakes of the Past: Develop Nano Responsibly*, 22 ENVTL. L. F. 41, 41 (2005) (arguing that "the public's perception of safety is essential" and that "no emerging technology will survive without broad public support").

[242] *Cf.* Lin, *supra* note 6, at 378 ("[P]ublic mistrust and suspicion . . . can ultimately hamper even beneficial uses of a new technology.").

[243] *Cf.* Matthew T. Wansley, *Regulation of Emerging Risks*, 69 VAND. L. REV. 401, 471 (2016) ("Federal regulation [can] significantly reduce the risk of reverse entrenchment by controlling experimentation and ensuring that all firms take sufficient care to avoid [harmful events] that could impede public acceptance [of new technologies].").

[244] *See, e.g.*, JANE MACOUBRIE, WOODROW WILSON INT'L CTR. FOR SCHOLARS, INFORMED PUBLIC PERCEPTIONS OF NANOTECHNOLOGY AND TRUST IN GOVERNMENT 8 (2005) (finding respondents most likely to have heard of nanotechnology a media source first).

[245] *See* W. Kip Viscusi, *Alarmist Decisions with Divergent Risk Information*, 107 ECON. J. 1657, 1668 (1997) (finding that that consumers often misperceive the risks they face and overemphasize information claiming high risks); Cass R. Sunstein, *Probability Neglect: Emotions, Worst Cases, and Law*, 112 YALE L.J. 61, 82 (2002) ("[V]ivid images and concrete pictures of disaster can 'crowd out' other kinds of thoughts, including the crucial thought that the probability of a disaster is really small."); Sylvester et al., *supra* note 241, at 175 ("As the media and interest groups emphasize certain risks, the images they create can overwhelm objective information.").

[246] *See, e.g.*, MACOUBRIE, *supra* note 244, at 19 (finding this to be true in the context of nanotechnology); Christian Gollier & Nicholas Treich, *Decision-Making Under Scientific Uncertainty*, 27 J. RISK & UNCERTAINTY 77, 97 (2003) (discussing some of the empirical research); *see also* Marchant et al., *supra* note 119, at 725 ("[I]t seems that the establishment of a regulatory scheme is a prerequisite for maintaining public trust, providing another rationale for adoption of regulation beyond the substantive need for such provisions."); Moses, *supra* note 124, at 526 ("Sometimes, the mere exercise of centralized control can allay public fears as to the direction the technology might otherwise take."); William Birnbauer, *Nano Could be a Huge Future Health Crisis*, THE AGE (Oct. 30, 2005), https://www.theage.com.au/national/nano-could-be-a-huge-future-health-crisis-20051030-ge1561.html (arguing in the context of nanotechnology that "[t]he early introduction and explanation of regulation reduces the risk that public concern will prevent acceptance" of a technology).

[247] *Cf.* MACOUBRIE, *supra* note 244, at 10 (finding that public perceptions of nanotechnology, which tend to favor greater regulation, also correlate to concerns about past high-profile

There is already data to suggest that consumers harbor serious concerns about the safety of autonomous vehicles and their lack of oversight.[248] According to a recent study, only one in four U.S. consumers would trust an autonomous vehicle to transport them as a passenger.[249] These misgivings were on full display following several crashes involving fully and partially automated vehicles in 2017 and 2018.[250] As one commentator rushed to note following an accident involving a Tesla vehicle, "[t]he race . . . to develop self-driving cars has been fueled by the belief that computers can operate a vehicle more safely than human drivers, but that view is now in question."[251] Consistent with that reaction, consumer trust in autonomous vehicle safety has slipped in the wake of these incidents[252] and a number of commentators and politicians have called for

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"environmental . . . and human health errors"); *cf. also* notes 252–53 (discussing the paucity of autonomous vehicle regulations, the drop in consumer confidence following high-profile accidents involving autonomous vehicles, and the subsequent calls for greater regulation).

[248] *See generally* ADVOCATES FOR HIGHWAY & AUTO SAFETY, CARAVAN PUBLIC OPINION POLL: DRIVERLESS CARS (2018) (surveying consumer attitudes toward autonomous vehicles and finding that significant segments of the U.S. population are skeptical of autonomous vehicle safety); *Fact Sheet: Vehicle Technology Survey – Phase IIIB*, AAA (May 22, 2018), https://publicaffairsresources.aaa.biz/download/10980/ (same); WORLD ECON. FORUM, SELF-DRIVING VEHICLES IN AN URBAN CONTEXT (2015); BRANDON SCHOETTLE & MICHAEL SIVAK, UNIV. OF MICH. TRANSP. RESEARCH INST., A SURVEY OF PUBLIC OPINION ABOUT AUTONOMOUS AND SELF-DRIVING VEHICLES IN THE U.S., U.K., AND AUSTRALIA (2014); *see also* Nikhil Menon, Consumer Perception and Anticipated Adoption of Autonomous Vehicle Technology: Results from Multi-Population Survey 6-10 (Oct. 27, 2015) (unpublished M.A. thesis, University of South Florida) (on file with author) (summarizing much of the empirical research on consumer attitudes toward autonomous vehicles).

[249] *See* Craig Giffi et al., *The Race to Autonomous Driving: Winning American Consumers' Trust*, 20 DELOITTE REV. 74, 85 (finding 74% of U.S. consumers believe that autonomous vehicles are unsafe); *Fact Sheet: Vehicle Technology Survey– Phase IIIB*, *supra* note 248 (same); ADVOCATES FOR HIGHWAY & AUTO SAFETY, *supra* note 248, at 2 (finding the same for 64% of consumers).

[250] *See, e.g.*, Paul Eistenstein, *Fatal Crash Could Pull Plug on Autonomous Vehicle Testing on Public Roads*, NBC NEWS (Mar. 20, 2018), https://www.nbcnews.com/business/autos/fatal-crash-could-pull-plug-autonomous-vehicle-testing-public-roads-n858151 [https://perma.cc/4Z8B-4JRD] (reporting on consumer, industry, and lawmaker reactions to these incidents).

[251] Bill Vlasic & Neal E. Boudette, *Self-Driving Tesla Was Involved in Fatal Crash, U.S. Says*, N.Y. TIMES (June 30, 2016), http://www.nytimes.com/2016/07/01/business/self-driving-tesla-fatal-crash-investigation.html.

[252] *Compare Fact Sheet: Vehicle Technology Survey – Phase IIIB*, *supra* note 248, at 1 (finding that, in April 2018, 73% of U.S. consumers "would be afraid to ride in a fully self-driving vehicle") *with Fact Sheet: Vehicle Technology Survey – Phase III*, AAA (Jan. 24, 2018), https://publicaffairsresources.aaa.biz/download/9852/ (finding that, in December 2017, 63% of U.S. consumers "would be afraid to ride in a fully self-driving vehicle"); *see also* Andrew J. Hawkins, *Self-Driving Car Crashes Put a Dent in Consumer Trust, Poll Says*, The VERGE (May 22, 2018), https://www.theverge.com/2018/5/22/17380374/self-driving-car-crash-consumer-trust-poll-aaa (reporting on the drop in consumer confidence).

increased government oversight.[253] In the autonomous vehicle industry, where success is dependent on convincing people to switch from active driving to passive riding, doubts about vehicle safety could pose a serious threat to widespread commercial adoption.[254]

Indeed, as illustrated throughout history, a single incident involving a new technology can undermine years of development and marketing.[255] The infamous explosion that destroyed the Hindenburg in 1937 is perhaps the most vivid example, but other high profile incidents involving nuclear power,[256] genetically modified foods,[257] and gene therapy[258] have spurred similar levels of public angst and industry collapse. As one scholar observes, "each of these incidents sparked subsequent official investigations and media

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[253] *See, e.g.*, Ross Marchand, *Put Driverless Cars Back in the Slow Lane*, REALCLEARPOLICY (Feb. 15, 2018), https://www.realclearpolicy.com/articles/2018/02/15/put_driverless_cars_back_in_the_slow_lane_110511.html ("In light of these data, policymakers must press for more safety before permitting driverless vehicles on the open road without human testers."); Sam Thielman, *'Someone is Going to Die': Experts Warn Lawmakers Over Self-Driving Cars*, THE GUARDIAN (Mar. 15, 2016), https://www.theguardian.com/technology/2016/mar/15/self-driving-cars-danger-senate-general-motors-google ("The robot car revolution hit a speed bump . . . as senators and tech experts sounded stern warnings about the potentially fatal risks of self-driving cars.").

[254] *See* Wansley, *supra* note 243, at 470 (arguing that "early, high profile collisions" could "turn public sentiment against" autonomous vehicles and impede their development); *see also* Sven A. Beiker, *Legal Aspects of Autonomous Driving*, 52 SANTA CLARA L. REV. 1145, 1152 (2012) ("It is unclear how . . . the public will react to accidents involving robotic cars. Overreaction is a clear danger, even if it could be shown that a transition to autonomous vehicles leads to far fewer traffic-related deaths.").

[255] *See* Marchant et al., *supra* note 119, at 725 ("[A] single incident gone awry [can] undermin[e] years of careful planning and building of regulatory system."); *see also* CALESTOUS JUMA, INNOVATION AND ITS ENEMIES: WHY PEOPLE RESIST NEW TECHNOLOGIES (2016) (discussing examples of resistance to new technologies).

[256] *See* JOHN D. GRAHAM, THE HERITAGE FOUND., THE PERILS OF THE PRECAUTIONARY PRINCIPLE: LESSONS FROM THE AMERICAN AND EUROPEAN EXPERIENCE 3 (2004) (suggesting that there has been "a de facto moratorium on construction of nuclear power plants" in the United States since the accident at Three Mile Island); *see also* J. V. REES, HOSTAGES OF EACH OTHER: THE TRANSFORMATION OF NUCLEAR SAFETY SINCE THREE MILE ISLAND (1994) (examining the Three Mile Island nuclear accident and its impact on the nuclear power industry).

[257] *See* Mandel, *supra* note 241, at 47-48 ("The early stages of genetically modified food development in the United States provides a poster-child example of how significant public concern over a technology—and the perception that it is not being managed properly—can thwart technological development.").

[258] Rick Weiss & Deborah Nelson, *Gene Therapy's Troubling Crossroads: A Death Raises Questions of Ethics, Profit, Science*, WASH. POST (Dec. 31, 1999), http://www.washingtonpost.com/wp-srv/WPcap/1999-12/31/055r-123199-idx.html (exploring the death of a participant in a gene therapy clinical trial).

scrutiny that revealed significant flaws and failures in the regulatory system," the results of which "severely undermined public trust in both the technology at issue . . . and the regulatory programs responsible for the oversight of that technology."[259] It is true that taking regulatory action does not guarantee that a new technology will escape negative publicity or scrutiny of its oversight; however, common sense suggests that inaction increases both the probability of accidents and the severity of public fallout.

2. Potential Drawbacks of Regulatory Action

Despite the potential drawbacks of responding to the pacing problem through inaction, responses based on regulatory *action* can also have a number of drawbacks. As described above, there are, broadly speaking, two potential affirmative responses to the pacing problem: a precautionary approach and a future-facing approach. The future-facing approach can be further broken down into regulations which mandate specific characteristics or forms of a technology and regulations which are technology neutral. I address the drawbacks of each in turn.

a. Precautionary Principle: Forgone Benefits and Stunted Innovation

The aim of a regulatory approach informed by the precautionary principle is to temporarily slow or halt the development of a new technology until it is explicitly proven safe.[260] As a response to the pacing problem, a precautionary approach provides regulators with additional time and information to design and enact regulatory regimes which are calibrated to the idiosyncrasies of unfamiliar new technologies.[261] Although information about the risks and applications of an emerging technology are important considerations when drafting regulations, and regulators may otherwise struggle to effectively manage such risks in a timely manner, there are two major drawbacks to artificially constraining the rate at which a new technology can develop.[262]

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[259] Marchant et al., *supra* note 119, at 725.
[260] *See supra* notes 154-57 and accompanying text.
[261] *Id*.
[262] For a comprehensive summary of precautionary principle critiques, see Wood et al., *supra* note 154, at 589–607. Two additional problems worth noting are the lack of a consensus definition of the precautionary principle, *see* Jonathan B. Wiener, *Precaution in a Multi-Risk World*, *in* HUMAN AND ECOLOGICAL RISK ASSESSMENT: THEORY AND PRACTICE 1513 (Dennis J. Paustenbach ed., 2002) (recognizing that there is no single definition for the precautionary principle and that existing definitions are "varied" and "often vague"), and disagreements over

First, using law to slow or halt the development of a new technology forces consumers to forgo its potential benefits.[263] This is a seemingly obvious consideration, but the "benefits of [new] activities are commonly ignored when [precautionary] regulation is contemplated."[264] In the case of autonomous vehicles, for example, regulators in California recently considered an indefinite moratorium on the private sale and commercial use of autonomous vehicles.[265] Although they ultimately decided against it, the move would have allowed regulators to collect additional information and extend the lifespan of their initial rules. At the same time, however, preventing the sale of autonomous vehicles, or even simply mandating that a licensed driver always be present in "the driver seat of the vehicle,"[266] would have prevented the public from realizing many of the potential benefits of autonomous vehicles.[267] Some of the forgone benefits, such as any reduction in the number of traffic fatalities attributable to human error, would have been easily quantifiable, while others, such as increased mobility and independence for the elderly and disabled, would have been much harder to quantify.

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what constitutes an acceptable level of risk, *see* Julian Morris, *Defining the Precautionary Principle*, *in* RETHINKING RISK AND THE PRECAUTIONARY PRINCIPLE 1-19 (Julian Morris ed., 2000) (distinguishing between "strong" and "weak" versions of the precautionary principle).

[263] *See* Frank B. Cross, *Paradoxical Perils of the Precautionary Principle*, 53 WASH. & LEE L. REV. 851, 882-98 (1996) (arguing that the forgone benefits of new technologies are a significant cost of taking a precautionary approach); *see also* Henry I. Miller & Gregory Conko, *Precaution Without Principle*, 19 NATURE BIOTECH. 302, 302 (2001) ("What is missing from the precautionary calculus is an acknowledgment that even when technologies introduce new risks, most confer net benefits; that is, their use reduces many other, far more serious hazards.").

[264] Cross, *supra* note 263, at 882.

[265] *See* CAL. CODE REGS. tit. 13, § 227.68 (proposed Dec. 16, 2015), https://www.dmv.ca.gov/portal/wcm/connect/ed6f78fe-fe38-4100-b5c21656f555e841/AVExpressTerms.pdf?MOD=AJPERES.

[266] *See* CAL. CODE REGS. tit. 13, § 227.52(a)(5) (proposed Dec. 16, 2015) (requiring the presence of "an operator," defined as a person "sitting in the driver seat of the vehicle," at all times).

[267] *See* Caleb Watney & Marc Scribner, *Slowing Down Driverless Cars Would be a Fatal Mistake*, TECHDIRT (Mar. 2, 2018), https://www.techdirt.com/articles/20180302/10045039339/slowing-down-driverless-cars-would-be-fatal-mistake.shtml ("As a society, we can't afford to wait until we are 100-percent certain that driverless cars are statistically safer than humans before letting them on the roads."); Ian Adams, *Thoughtless Bureaucrats and Driverless Cars*, CITY JOURNAL (Mar. 4, 2016), http://www.city-journal.org/html/thoughtless-bureaucrats-and-driverless-cars-14289.html ("Why would the state pursue policies to discourage the adoption of vehicles that, by virtually all accounts, would be orders of magnitude safer than traditionally operated vehicles?"). Indeed, one study estimates that it would take tens or even hundreds of years to log sufficient miles on closed courses to adequately assess the safety of the vehicles when compared to conventional vehicles. *See* NIDHI KALRA & SUSAN M. PADDOCK, DRIVING TO SAFETY: HOW MANY MILES OF DRIVING WOULD IT TAKE TO DEMONSTRATE AUTONOMOUS VEHICLE RELIABILITY? 10-11 (2016).

In addition, blocking or slowing the emergence of a new technology may prevent the technology from achieving commercial viability or lead to a stunted version of the technology.[268] Although the precautionary principle does not aim to ban all new technologies in perpetuity, constraining the development of a new technology in its nascent stages may nevertheless preclude the type of "experimentation and failure" necessary to develop an optimal product.[269] Moreover, to the extent that a technology is excluded from the marketplace or a stunted version is introduced, developers may struggle to establish a viable consumer base.[270] The requirement in some states, for instance, that autonomous vehicles contain a licensed driver at all times, as well as the numerous references to the "driver" or "operator" in existing FMVSS, could channel innovation away from full automation—the technology with the greatest potential benefit—and eliminate a sizable portion of the consumer base for autonomous vehicles, including elderly and disabled persons without drivers licenses and autonomous ridesharing companies.[271]

b. Future-Facing Mandates: Choosing the Wrong Path for a New Technology

Second, future-facing mandates designed to minimize regulatory revision, such as technology-specific designs or safety standards, also have the potential to stunt the development of an emerging technology.[272] Although attempting to anticipate or shape the evolution of a new technology

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[268] *See* Thierer, *supra* note 169, at 362-63; *cf. also* Cross, *supra* note 263, at 898-907 (describing how taking too many precautions may lead to a stunted and less safe version of a new technology).

[269] THIERER, *supra* note 168, at 27; *see also* GRAHAM, *supra* note 256, at 3 ("By its very nature, technological innovation occurs through a process of trial-and-error and refinement, and this process could be disrupted by an inflexible version of the precautionary principle."); Demissie, *supra* note 1, at 343 ("[T]he precautionary principle cannot ensure safety without hindering innovation and development.").

[270] *Cf.* THIERER, *supra* note 168, at 28 (arguing that, "[i]n practical terms, the precautionary principle results in . . . lower-quality goods, higher prices, diminished economic growth, and a decline in the overall standard of living").

[271] *See supra* note 88 (listing state laws requiring the presence of a licensed human driver); ANITA KIM ET AL., *supra* note 216, at 3-4, 17-25 (identifying every use of the terms "driver" and "operator" in the FMVSS).

[272] *See* Lyria Bennett Moses, *Sui Generis Rules*, *in* THE GROWING GAP BETWEEN EMERGING TECHNOLOGIES AND LEGAL-ETHICAL OVERSIGHT 86-87 (2011) (providing an overview of potential problems with laws which "assume a particular state of technology"). *But cf.* ORG. FOR ECON. COOPERATION & DEV., AUTOMATED AND AUTONOMOUS DRIVING: REGULATION UNDER UNCERTAINTY 27 (2015) [hereinafter OECD REPORT] (noting that "[p]roactive policy, including specific rules, can provide companies the legal clarity they need to make investment and deployment decisions").

is a natural response to the limited reactive and adaptive capabilities of regulatory institutions, it requires a level of foresight virtually impossible for lawmakers and regulators to achieve.[273] "It is an unhappy fact of life," Grant Gilmore famously wrote, "that, while we can know the past only imperfectly, we know the future not at all."[274] The consequences of wrongly forecasting the evolution of a new technology, or attempting to shape its development based on incomplete information or faulty assumptions, can be significant.[275] A future-facing regulation, for example, can "lock in one pathway to [adoption of a technology] over . . . potentially better one[s]" or "freeze unrealistic expectations—high or low—into the law,"[276] resulting in an inferior technology forged by forces external to the market.[277]

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[273] *See* Cass R. Sunstein, *Problems with Rules*, 83 CAL. L. REV. 953, 993 (1995) ("Those who issue a rule cannot know the full range of situations to which the rule will be applied, and in the new circumstances, the rule may be hopelessly outmoded."); Eugene Volokh, *Technology and the Future of Law*, 47 STAN. L. REV. 1375, 1375-76 (1995) (identifying four failures of technological prediction); Grant Gilmore, *On Statutory Obsolescence*, 39 U. COLO. L. REV. 461, 467 (1967) ("Our best informed guesses about what is going to happen next have an uncomfortable habit of missing the mark completely."); Sarewitz, *supra* note 173, at 97 (providing that, "efforts to predict technological pathways as an input into decision-making have been failures, and often absurd failures at that"); *see also* Obama, *supra* note 241 ("Government sometimes gets it wrong when it comes to rapidly changing technologies.").

[274] Gilmore, *supra* note 273, at 467. As former Secretary of Defense Donald Rumsfeld observed: "[T]here are known knowns; there are things we know we know. We also know there are known unknowns; that is to say we know there are some things we do not know. But there are also unknown unknowns -- the ones we don't know we don't know. . .[I]t is the latter category that tends to be the difficult ones." Donald Rumsfeld, Remarks at Department of Defense News Briefing (Feb. 12, 2002), http://archive.defense.gov/Transcripts/Transcript.aspx?TranscriptID=2636.

[275] *See* Moses, *supra* note 272, at 87 ("Rules that assume a particular technological framework are not only potentially distorting from a legal perspective, but they may distort technology as well. Potential avenues for technological change may remain unexplored in order to remain within the technological paradigm assumed beneficial by a law. Alternatively, technology may be redesigned in socially and economically unproductive ways in order to avoid the application of onerous regulation."); *see also* Jonathan B. Wiener, *The Regulation of Technology and the Technology of Regulation*, 26 TECH. IN SOC'Y 483, 489 (2004) ("Technology requirements, intended to force industry . . . to upgrade, may foster the diffusion of existing technology across industry, but ironically may stagnate innovation of new technologies by specifying a particular technology and giving no incentives for further improvements.").

[276] OECD REPORT, *supra* note 272, at 6.

[277] *See* Scribner, *supra* note 171, at 1 (contending that, "laws and regulations that narrow the scope of permissible development, testing, and operational functionality risk locking in inferior technology, delaying adoption, and increasing prices faced by consumers"); *see also* Birnhack, *supra* note 189, at 43 ("[A] legislative endorsement of one particular technology might cause a technological lock-in: the chosen technology will be used even if there are superior technologies.

The risks of future-facing regulatory mandates are particularly acute in the context of autonomous vehicles.[278] There are multiple competing manifestations of the technology currently under development[279] and numerous visions for how autonomous vehicles should be introduced to consumers.[280] It would be virtually impossible for state or federal regulators to determine which pathway would be best or to predict the precise pathway along which autonomous vehicles will actually develop.[281] The autonomous vehicle industry, recognizing this fact, has protested vocally against regulations which purport to do just that.[282] "It's really hard to try and

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Once a technology is implemented and widely used, there are costs of switching to other technologies . . . . If the switching costs are higher than the perceived benefit, a technological lock-in would occur, even though the locked-in technology is inferior to newer ones.").

[278] *See* NHTSA POLICY 2016, *supra* note 8, at 79 (recognizing that, "given the speed and extent of [technological] evolution, even the most performance-oriented and forward-looking [autonomous vehicle] testing protocols rapidly could become out-of-date, ineffectual and even obstructive").

[279] *See* RAND REPORT, *supra* note 8, at 58-72 (describing the range of autonomous vehicle technologies and configurations currently available and under development); RICHARD T. BAKER & JASON WAGNER, POLICY PATHWAYS TO VEHICLE AUTOMATION 431 (2013) (same); *see also* Bryant Walker Smith, *How Governments Can Promote Automated Driving*, 47 N.M. L. REV. 99 (2017) (arguing that there are at least three different technological pathways to fully automated vehicles).

[280] *See, e.g.*, BAKER & WAGNER, *supra* note 279, at 431-36 (compiling the competing visions of several industry representatives); Eva Fraedrich & Sven Beiker, *Transition Pathways to Fully Automated Driving and Its Implications for the Sociotechnical System of Automobility*, 3 EUR. J. FUTURES RESEARCH 1, 5-11 (describing three possible "sociotechnical transition scenarios"); CTR. FOR AUTOMOTIVE RESEARCH, SELF-DRIVING CARS: THE NEXT REVOLUTION 16-17 (2012) (describing three "possible adoption scenarios").

[281] *See* Jeff Wise, *How to Make Self-Driving Cars Safe*, HEWLETT PACKARD ENTERPRISE (July 11, 2017), https://www.hpe.com/us/en/insights/articles/autonomous-vehicles-need-regulation-but-who-designs-the-standards-1707.html ("It's important to recognize that we're very much in early days; there's a lot we don't know; and whatever predictions we might make, they're probably going to be completely wrong . . . ."); Alexander Hars, *Five Guiding Principles for Autonomous Vehicle Policy*, DRIVERLESS-FUTURE.COM (Oct. 20, 2014), http://www.driverless-future.com/?p=683 ("There are so many paths that this technology can take, so many changes in many different areas of business and society, so many proponents and possibly opponents that it is hard to be right about the path of technology and – consequently – of law."); Mark Scribner, *Driverless Cars Are on the Way: Here's How Not to Regulate Them*, WASH. POST (Nov. 2, 2012), https://www.washingtonpost.com/opinions/driverless-cars-are-on-the-way-heres-how-not-to-regulate-them/2012/11/02/a5337880-21f1-11e2-ac85-e669876c6a24_story.html?utm_term=.8543436a5d58 ("[N]o one knows precisely how autonomous vehicle technology will develop or be adopted by consumers . . . .").

[282] *See, e.g.*, Alex Davies, *Self-Driving Cars are Legal, But Real Rules Would be Nice*, WIRED (May 15, 2015) https://www.wired.com/2015/05/self-driving-cars-legal-real-rules-nice/ (quoting industry representatives on their strong concerns with respect to the impact of future-facing regulations); *see also* Moore, *supra* note 182 ("Fearing that the technology's

anticipate how the technology might be used in the future and write laws for every eventuality," Google recently stated through a spokesperson, and "[w]e think policymakers should learn about the technology and see how people want to use it first before putting a ceiling on innovation."[283] As one commentator argues, future-facing mandates which "narrow the scope of permissible development, testing, and operational functionality" of autonomous vehicles risk "locking in inferior technology, delaying adoption, and increasing prices faced by consumers."[284]

c. Technology-Neutral Laws: Linear Innovation and High Compliance Costs

Finally, technology-neutral regulation, which rejects the rigid specificity of future-facing mandates, can also create barriers to the emergence of new technologies. Technology-neutral laws are designed to be independent of any particular technological context and use "broad, open-textured" language to increase the flexibility of regulations and avoid future revisions based on technological advances.[285] Like future-facing mandates, the aim of technology-neutral laws—to minimize reliance on the rulemaking machinery of regulatory institutions—is an intuitive response to the pacing problem. Despite its intuitive appeal, however, reliance on technological neutrality can stymie the development of emerging technologies in two important ways.

First, although such rules purport to be untethered from specific technologies and sufficiently flexible to handle future developments, technology-neutral laws are still constrained by the unpredictable nature of innovation.[286] "In the abstract," Brad Greenberg argues, "legislators can say

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development could be stifled, Google has lobbied state lawmakers nationwide not to advance any bills, even if they seem innocuous."). As an Audi spokesperson remarked in the article: "We see a danger of actions taken too early to govern piloted driving 10 to 20 years into the future. Such laws would have little application to initial levels of piloted driving that will emerge over the next few years. They could also jeopardize robust research needs." Davies, *supra* note 282.

[283] Davies, *supra* note 282.

[284] Scribner, *supra* note 171, at 1; *see also* NHTSA POLICY 2016, *supra* note 8, at 79 ("The greater the amount of detail that is included in [autonomous vehicle] testing protocols to maximize safety performance or address risks believed to be associated with current HAVs, the greater the likelihood that detail might limit the use of future technologies.").

[285] Greenberg, *supra* note 189, at 1513.

[286] *See* Moses, *supra* note 124, at 578 ("Language cannot be completely technology-neutral; it is impossible to draft legislation with sufficient precision and clarity that addresses every possible future technical variation.").

that they want an unknown B to be treated like a known A."[287] However, until the "nature and capabilities of B are understood—until legislators have some appreciation for how the law will affect B, and the attendant welfare costs and benefits—it is impossible to evaluate the extent to which the law actually should treat B like A."[288] Moreover, when lawmakers and regulators draft new rules, they "[do] so from the vantage point of contemporary technological limitations . . . [and] with extant technology in mind."[289] Thus, Greenberg continues, "[l]ike the nineteenth-century farmer who imagines a sharper plow but is unable to foresee the combustion engine, [regulators] imagine linear advances from extant technology."[290] This can lead not only to obsolescence, a problem in its own right, but laws which are poorly tailored to future technologies or inadvertently discourage radical innovation.

Second, technology-neutral laws can generate high compliance costs for market participants. When applied to new technologies, the inherently vague and flexible terms of technology-neutral laws may prove ambiguous or have an unclear purpose, scope, or effect.[291] In particular, given the lack of specificity in such laws, the task of finding purpose or meaning in their terms and providing guidance to market participants often falls to the courts.[292] In areas of law heavily reliant on technology-neutral rules, however, this lack of specificity has led to inconsistent and confusing results.[293] Where technology-neutral laws produce uncertainty with respect to the scope or effect of a regulation, market participants must expend additional resources on regulatory compliance and evaluating the risks of investment; some developers may even respond to this uncertainty by exiting the market or deferring investment.[294] In the context of autonomous vehicles,

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[287] Greenberg, *supra* note 189, at 1526.
[288] *Id.*
[289] *Id.* at 1527.
[290] *Id.*
[291] *Cf. id.* at 1524-43 (describing these problems in the context of copyright law); *cf. also* Moses, *supra* note 147, at 276-77 ("[I]t is often impossible to draft a rule that will be both operationally effective and immune from problems related to technological change.").
[292] *See, e.g.*, Paul M. Janicke, *On the Cause of Unpredictability of Federal Circuit Decisions in Patent Cases*, 3 NW. J. TECH. & INTELL. PROP. 93, 94 (2005) ("Patent statutes in the United States have always been written in broad terms, leaving it to the courts to fill in details as cases arise."); Greenberg, *supra* note 189, at 1524-43 (describing the extensive litigation stemming from problems of definition, scope, and consistency in copyright law).
[293] *See, e.g.*, Janicke, *supra* note 292, at 95-96 (arguing that technology-neutral language in patent law "can hardly be expected to lead to predictability in the outcomes of court resolution of the issues").
[294] *See* Birnhack, *supra* note 189, at 44 ("[T]he open-ended nature of a technology-neutral legislation might have a chilling effect on developers of technology. Not knowing in advance

where NHTSA has fallen back on its technology-neutral recall authority as the primary mechanism for ensuring safety, industry participants have warned that there is little clarity as to how the "unreasonable risk" standard might apply to their products.[295] At a moment when clarity is at a premium for industry participants and consumers, reliance on technology-neutral laws and regulations could lead to significant uncertainty for all parties.[296]

III. RETHINKING THE REGULATION OF AUTONOMOUS VEHICLES AND OTHER RAPIDLY EVOLVING TECHNOLOGIES

The previous Part outlined three common responses to the pacing problem, illustrated how these responses have manifested themselves in the context of autonomous vehicle regulation, and described the obstacles created by each to the widespread commercial adoption of rapidly evolving technologies like autonomous vehicles. In essence, regulators of autonomous vehicles and other emerging technologies face a maddening catch-22. On the one hand, the less they regulate or the broader they phrase regulations, the more disconnected law may become from its target or the less clarity and certainty enjoyed by regulated entities and consumers.[297] On the other hand, the more certainty and confidence regulators attempt to provide entities and consumers, the more likely it is that regulations will become outdated, generate future ambiguities and uncertainty, or pigeonhole a developing technology.[298] In both cases, if regulators block or slow a technology until its likely developmental path and risks are fully understood,

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how the law might address their technology, they might refrain from pursuing it, perhaps to the detriment of all. Details and specification can provide certainty.").

295 *See, e.g.*, Ryan Hagemann, Niskanen Ctr., Comments Submitted to the National Highway Transportation Safety Administration in the Matter of: Federal Automated Vehicle Policy *NHTSA-2016-0090* at 7 (Nov. 21, 2016), https://niskanencenter.org/wp-content/uploads/2016/11/CommentsAutonomousVehicleStandardsNHTSA.pdf (offering examples and concluding that "a great deal of clarification will be needed for outlining the specifics of when a recall order would be justified in the case of autonomous vehicles"); *see also* Skees, *supra* note 64 (arguing that NHTSA's 2017 policy statement "lacks a clear interpretation for either innovators or other policymakers. This may . . . increase regulatory uncertainty that stifles development").

296 *Cf.* Mike Ramsey, *Autonomous Vehicles Fall into the Trough of Disillusionment*, FORBES (Aug. 14, 2018), https://www.forbes.com/sites/enroute/2018/08/14/autonomous-vehicles-fall-into-the-trough-of-disillusionment-but-thats-good/#20034c9a7b5a [https://perma.cc/UGF5-V88X] (reporting on Audi's announcement that it would not sell its most advance automated technology in the U.S. because of a "lack of clarity on regulations").

297 *See supra* Part II.B, sections (1)(a)(ii) & (2)(c).

298 *See supra* Part II.B, sections (1)(a)(i), (1)(a)(iii), & (2)(b).

then its benefits—including any life-saving applications—will remain unrealized or diluted.[299] The challenge of this final Part, therefore, is to offer an approach to the regulation of autonomous vehicles which balances (1) the realization of autonomous vehicles' potential benefits, (2) the need for public confidence in their safety, and (3) the potential pitfalls of future-facing regulations.

A common attribute of the present and proposed regulatory responses to autonomous vehicles is their overwhelming focus on identifying, ex ante, the optimal substance for the rules governing autonomous vehicles.[300] On its face, this is a reasonable reaction to a new regulatory challenge and the substance of regulations—whether prohibition, inaction, or something in-between—is arguably the most important aspect of any regulatory framework. At the same time, however, focusing excessively on substance distracts from the root, underlying source of the regulatory challenge facing autonomous vehicles: their rapid evolution and the limited reactive and adaptive capabilities of U.S. legal institutions.[301] Whether deliberately or subconsciously, regulators and commentators have approached autonomous vehicle regulation as if there is a single, optimal regulatory path waiting to be discovered, and it is their responsibility, ex ante, to identify that path and implement a corresponding framework (albeit at varying rates).[302] Nevertheless, as described in the first half of Part II, the pacing problem is

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[299] *See supra* Part II.B, section (2)(a).

[300] Whether that means deciding to refrain from enacting or promulgating new laws and regulations, relying on precautionary regulation, or employing specific future-facing regulations. Moreover, inaction is, in some cases, simply a way of buying time to draft an optimal regulation. *See, e.g.*, NHTSA POLICY 2013, *supra* note 13, at 10 ("Because . . . the technical specifications for . . . automated systems are still in flux, the agency believes that regulation of the technical performance of automated vehicles is premature at this time.")

[301] *See supra* Part II.A (discussing the lethargy of legislatures, agencies, and courts based on a combination of political and procedural constraints); *cf.* Warren E. Walker et al., *Adaptive Policies, Policy Analysis, and Policy-Making*, 128 EUR. J. OPERATIONAL RES. 282, 283 (2001) ("For very complex systems whose behavior we cannot predict . . . . it is appropriate to separate the process by which policies are specified, assessed, chosen, and implemented from the policies themselves.").

[302] California is a particularly poignant example, with the Department of Motor Vehicles toiling over a final set of regulations for nearly 6 years. *See* Russ Mitchell, *California Regulations for Driverless Cars Stall as Other States Speed Ahead*, L.A. TIMES (Jan. 26, 2017), http://www.latimes.com/business/autos/la-fi-hy-driverless-regulations-california-20170126-story.html (describing the California DMV's rulemaking process for autonomous vehicles) [https://perma.cc/8B4A-UF5H]; *see also Driverless Testing and Public Use Rules for Autonomous Vehicles Approved*, CAL. DEP'T OF MOTOR VEHICLES (Feb. 26, 2018), https://www.dmv.ca.gov/portal/dmv/detail/pubs/newsrel/2018/2018_17 [https://perma.cc/W2NC-XEK5] (announcing the DMV's approval of new regulations on autonomous technology).

largely a function of institutional limitations related to the *process* of crafting and enacting regulations,[303] and the existing substantive responses to this problem, particularly in the autonomous vehicle context, suffer from deficiencies equal to or greater than those characterizing the underlying problem.[304]These shortcomings suggest that a new approach to regulating under the conditions of deep uncertainty created by the rapid evolution of autonomous vehicle technology is needed.[305] There are, no doubt, more and less effective ways of regulating autonomous vehicles, but it is virtually impossible, early in the life of a rapidly evolving technology, to identify both an optimal regulatory approach and establish an enduring framework, all in one shot.[306] Instead, it makes far more sense to approach regulation in this context as an iterative process, with the first regulations of autonomous vehicles as an initial step, rather than the ultimate goal. In other words, the approach to regulating autonomous vehicles must shift from one informed by

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[303] *See supra* Part II.A.

[304] *See supra* Part II.B. There may very well be an "optimal" regulatory path, and it is my hope that adaptive regulation can be used to eventually find that path, but it is foolhardy to believe that, in the context of a paradigm shifting and rapidly evolving technology, such a path can be identified from the start.

[305] Annacoos Wiersema, discussing the pacing problem more generally, pointedly summarized the challenge facing autonomous vehicles: "[W]e live in a complex society where laws designed for particular purposes can have unanticipated consequences, where bureaucracy is too slow and cumbersome to respond quickly and efficiently enough to those consequences, and where the traditional structure of top-down lawmaking is under siege as too rigid, too hierarchical, and too contentious to achieve its goals. The world we live in, as legal writers spanning a range of fields tell us, requires new forms of governance." Annecoos Wiersema, *A Train Without Tracks: Rethinking the Place of Law and Goals in Environmental and Natural Resources Law*, 38 ENVTL. L. 1239, 1241 (2008).

[306] A growing body of literature examining other rapidly evolving technologies recognizes as much. *See, e.g.*, Warren E. Walker et al., *Addressing Deep Uncertainty Using Adaptive Policies: Introduction to Section 2*, 77 TECH. FORECASTING & SOC. CHANGE 917, 919 (2010) ("It is clear from experience that a static policy designed for a best estimate future is unlikely to survive in a complex and dynamic policy setting."); Lawrence E. McCray et al., *Planned Adaptation in Risk Regulation: An Initial Survey of U.S. Environmental, Health, and Safety Regulation*, 77 TECH. FORECASTING & SOC. CHANGE 951, 952 (2010) ("Over time, things change. Science evolves, technology advances, and implementation costs migrate, so assumptions that were once reasonable can become much less supportable. When this occurs, the delivered benefits of a policy decision and its actual social costs may fall substantially out of the intended balance."); Warren E. Walker et al., *supra* note 301, at 282-83 ("For very complex systems whose behavior we cannot predict, policies based on best estimate models can prove to be very fragile against unexpected events that happen all the time. . . . Such policies are best for a future that most certainly will not occur, and have implications for the future that actually occurs that are typically not examined in the course of policy design and analysis or even revisited as that future unfold.")

the traditional paradigm emphasizing "static optimization" to one informed by an "evolutionary paradigm" focused on adaptability.[307] Such an iterative model of regulation would depend upon federal and state regulatory institutions "designed from the outset to expect, anticipate, and be able to . . . recalibrate [regulations] quickly" in response to rapid technological change and new information about risks, benefits, and the effects of existing rules.[308]

The most promising mechanism to keep autonomous vehicle regulation "yoked to an evolving knowledge base," and avoid the significant social and technological pitfalls of regulatory inaction and prohibition, is planned adaptive regulation.[309] Although there is no single agreed upon definition of planned adaptive regulation,[310] a planned adaptive approach is generally characterized by two fundamental attributes: (1) "a prior commitment, planned early in the policy's design, to subject the policy to periodic re-evaluation and potential revision," and (2) "a systemic effort or mechanism planned early in the policy's design, to monitor and synthesize new information for use in the re-evaluations."[311] In turn, planned adaptive regulation "requires institutional-

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[307] *See* Barbra A. Cherry & Joannes M. Bauer, *Adaptive Regulation Contours of a Policy Model for the Internet Economy* 26 (2004) (unpublished manuscript) (on file with author). As Walker et al. observe, consistent with my discussion of future-facing regulations in Part II, "[a] static policy that is crafted to be robust under a range of plausible futures is a better starting point, but is still not likely to perform under conditions of deep uncertainty." Walker et al., *supra* note 306, at 919.

[308] Marchant, *supra* note 156, at 202.

[309] McCray et al., *supra* note 306, at 952. As Marchant explains, "[a]doptive governance derives from the concept of adaptive management first developed in the context of ecology to experiment with different policy approaches that are simultaneously undertaken with active monitoring, assessment, and adjustment." Marchant, *supra* note 156, at 202 (citing Adaptive Environmental Assessment and Management and introducing the concept of adaptive management); *see also* Kai N. Lee & Jody Lawrence, *Adaptive Management: Learning from the Columbia River Basin Fish and Wildlife Program*, 16 ENVTL. L. 431, 442 n.45 (1986) (tracing the term "adaptive management" to Holling's book). A growing literature advocates for analogous planned adaptive approaches to regulation in other contexts, including drug therapy, climate change, and biotechnology. *See generally* H-G Eichler et al., *Adaptive Licensing: Taking the Next Step in the Evolution of Drug Approval*, 91 CLINICAL PHARMACOLOGY & THERAPEUTICS 426 (2012) (drug therapy); Alejandro E. Camacho, *Adapting Governance to Climate Change: Managing Uncertainty Through A Learning Infrastructure*, 59 EMORY L.J. 1 (2009) (climate change); Kenneth Oye et al., *On Revision of the Coordinated Framework for the Regulation of Biotechnology* 1 (Mar. 22, 2016) (White Paper prepared for the Biotechnology Working Group of the U.S. Emerging Technologies Interagency Policy Coordination Committee) (on file with the author) (biotechnology). In each of these contexts, regulators face a similar tradeoff between potentially lifesaving technologies, risks to public safety, and the need for continued consumer confidence in rapidly evolving and foreign technologies.

[310] Walker et al. *supra* note 306, at 922.

[311] INT'L RISK GOV. CTR., CONFERENCE REPORT: PLANNING ADAPTIVE RISK REGULATION app. 2 at 26 (2016). A planned adaptive approach to regulation, while flexible in its own

ization of monitoring-adjustment frameworks that allow incremental policy and decision adjustments," ex post, "where performance results can be evaluated and the new information can be fed back into the ongoing regulatory process."[312] A carefully conceived "framework for altering course, rapidly and frequently if conditions warrant," is thus an "essential ingredient[]"of a planned adaptive approach to regulation in any context.[313]

In the context of autonomous vehicles, a planned adaptive approach to design and operation would consist of four general dimensions: (1) initial regulation, (2) intensive data collection, (3) independent assessment and recommendations, and (4) agency consideration of recommendations and adjustment.[314] The first dimension, initial regulation, would not represent a significant departure from the present notice and comment process and would largely mirror the process in which NHTSA and select state departments of transportation are currently engaged.[315] The aim of initial regulations,

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way, is distinct from "flexible regulation," as used in the administrative law literature. *See, e.g.*, Lori S. Bennear & Cary Coglianese, *Flexible Approaches to Environmental Regulation* 1 (Univ. of Pa. Law Sch., Pub. Law Research Paper No. 12-05, 2012). Whereas the term "flexibility" is often used in reference to regulatory commands, targets, consequences, and sources, *id.*, the flexibility envisioned in this article is one step removed from these categories and relates to flexibility in the process of reaching regulatory decisions—flexibility in reaching a desired command, target, consequence, or even source of regulation. Within that framework, a chosen regulation may be flexible in the traditional sense, e.g. by using a general duty of care or a principle-based model, but is not necessarily so.

[312] J.B. Ruhl, *Regulation by Adaptive Management—Is It Possible?*, 7 MINN. J.L. SCI. & TECH. 21, 30 (2005). This would, of course, require legislation exempting agencies from the APA and analogous state statutes or amendment of the APA. *See supra* notes 306-11 and accompanying text.

[313] Ruhl, *supra* note 312, at 30. In the context of environmental regulation, at least one scholar has laid out a more detailed eight-part protocol: "(1) definition of the problem, (2) determination of goals and objectives for management, (3) determination of the baseline, (4) development of conceptual models, (5) selection of future actions, (6) implementation and management actions, (7) monitoring, and (8) evaluation and return to step (1)." Robin Craig & J.B. Ruhl, *Designing Administrative Law for Adaptive Management*, 67 VAND. L. REV. 1, 7 (2014).

[314] This framework, and the following discussion of the framework, are only a starting point and present the broadest outline of what an adaptive approach to autonomous vehicle regulation might look like. The aim is not to provide a detailed blueprint for regulatory action, but rather to highlight the need for a planned adaptive approach, its advantages over extant and proposed approaches to regulating autonomous vehicles, and the core features of any such framework. For a more comprehensive discussion of proposed mechanisms for implementing a planned adaptive regulatory system, see generally Craig & Ruhl, *supra* note 313; J.B. Ruhl, *General Principles for Resilience and Adaptive Capacity in Legal Systems – With Applications to Climate Change Adaptation*, 89 N.C.L. REV. 1373 (2011); Camacho, *supra* note 309; Cherry & Bauer, *supra* note 307; Walker et al., *supra* note 301.

[315] *See supra* note 67 and accompanying text (describing the process by which NHTSA enacts rules).

however, would be to establish a relatively permissive legal environment constrained only by minimum safety standards. As adaptive regulation is premised on system feedback and adjustment, placing significant restrictions on the design and operation of autonomous vehicles could prematurely foreclose certain paths for technological development and data collection, fostering many of the same problems associated with a precautionary approach and technology-specific rules.[316] Nevertheless, because regulation is an important bulwark against unsafe technologies, and serves a signaling function to consumers, autonomous vehicle manufacturers would need to provide evidence reasonably suggesting that any proposed design or use is at least as safe as traditional driving technology.[317]

The second dimension, intensive data collection, would require autonomous vehicle manufacturers to gather and report data on all vehicle testing, sales, and performance at regular intervals.[318] In addition, relevant federal and state agencies would be responsible for collecting data related to consumer experience, as well as the economic and social impacts of autonomous vehicles.[319] This reporting and collection of data is essential to an adaptive regulatory framework, as any decision to retain, reverse, or otherwise alter existing regulations must be empirically driven and based on quantifiable costs,

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[316] *See supra* Part II.B, section (2)(a).

[317] *See* NIDHI KALRA & SUSAN M. PADDOCK, *supra* note 267, at 10-11 (proposing a similar standard). This would generally track NHTSA's standard for granting FMVSS exemptions but would not place a cap on autonomous vehicle deployment and could be used as a pre-market requirement. *See* 49 U.S.C. § 30113 (allowing for an exemption if, inter alia, the applicant demonstrate that the safety level of its feature or vehicle "at least equals the safety level of the standard"). On its face, the "at least as safe" standard seems like a burdensome requirement analogous to a diluted precautionary approach. However, given the high rate of traffic accidents and their overwhelming attribution to human error, *see supra* note 24, this standard would be easy to satisfy. In addition, while initial regulations are important, they carry far less weight in an adaptive system, except to the extent that they foreclose certain future technological and regulatory opportunities. As such, it makes sense, at least initially, to start with a permissive standard.

[318] In its most recent policy statement, NHTSA outlined a much more modest and voluntary vision of data collection with respect to limited categories of information. *See* NHTSA POLICY 2017, *supra* note 55, at 16 ("Entities engaged in ADS testing and deployment may demonstrate how they address—via industry best practices, their own best practices, or other appropriate methods– the safety elements contained in the Voluntary Guidance by publishing a Voluntary Safety Self-Assessment."). The bills currently pending in Congress also contemplate some form of institutionalized data collection, though they provide few details on its scope, content, and frequency. *See* H.R. 3388, 115th Cong. § 4 (2017); S. 1885, 115th Cong. § 9 (2017).

[319] This is not an exhaustive list of categories and agencies, within the boundaries of the law, should be free to mandate reporting and engage in all data collection necessary to assess regulatory performance.

benefits, and risks. As such, because any adaptive regulatory framework is dependent upon an effective feedback loop in the interval between regulation and revision, regulators and stakeholders would need to place a premium on designing effective surveillance and research mechanisms. Although the types of reported and collected data would likely vary depending on the specific subject of regulation (e.g. vehicle design or operation)—and may themselves evolve over time as technology changes—the aim would always be to facilitate back-end assessment of regulatory and technological impact.

The third dimension, independent assessment and recommendations based on compiled data, is perhaps the most important. The assessment and adjustment of existing regulations is at the heart of any adaptive system.[320] At the outset of each cycle of data collection and assessment, regulators, working alone or with industry participants and the public, would identify principles or objectives against which performance could be assessed.[321] These objectives would then guide each scheduled assessment, as well any unilateral emergency actions by the agency. In the context of autonomous vehicles, however, the mere act of assessment would be insufficient—it is equally important that this assessment be conducted by an outside body composed of industry stakeholders.[322] Since adaptive regulation is a resource-intensive approach

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[320] *See* Craig & Ruhl, *supra* note 313, at 18 (identifying "monitoring, assessment, and feedback" as common attributes of the different branches of adaptive management theory).

[321] *See* Walker et al., *supra* note 306, at 920 ("[P]olicymakers and stakeholders, through monitoring and corrective actions, . . . try to keep the system headed toward [its] original goals."). A major point of tension between a planned adaptive approach to regulation and traditional administrative law theory is the value of public participation. *See* Craig & Ruhl, *supra* note 313, at 28, 30 ("One of the critical values enshrined in contemporary administrative law is public participation. . . . [A]daptive management threatens, or at least is perceived to threaten, the promotion of public participation in traditional administrative law."). The initial articulation of goals and values guiding the evaluation of each iteration of a regulatory system, however, offers an important opportunity for public participation in the regulatory process. *See* Lawrence Susskind et al., *A Critical Assessment of Collaborative Adaptive Management in Practice*, 49 J. APPLIED ECOLOGY 47, 49-50 (2012) (pointing to the setup phase of adaptive regulation as a promising moment for public participation). Indeed, formulation of the plan itself is clearly a moment which lends itself to public input. As Craig & Ruhl note, the requirement that agencies "engage in periodic evaluations of their progress toward preidentified goals, and hence that they periodically comprehensively adjust the management measures that they are employing, provides . . . perfect moments for recurring, rather than continual, public participation." Craig & Ruhl, *supra* note 313, at 43.

[322] The use of "deliberate organizational separation is a common feature" of existing regulatory regimes reflecting a planned adaptive approach. McCray et al., *supra* note 306, at 958. In particular, the "learning" function (reassessing the relevant evidence) is often isolated from the "changing" function (deciding whether and how to re-craft the rule). *See id.* ("[T]he National Transportation Safety Board assesses crash evidence, but works at some distance from the licensing process at the Federal Aviation Administration, and for air pollution standards the

which relies on continuous monitoring, experimentation, and assessment, as well as potentially steep compliance costs,[323] it is critical that regulators engage industry stakeholders in the process of reaching regulatory decisions.[324] This co-ownership over the regulatory process would not only introduce greater predictability into the system for targeted entities, but allow targeted entities to contribute their expertise and present their positions in a transparent manner.[325] The expertise of industry stakeholders is particularly vital in the context of autonomous vehicles, where the technology has developed at such a rapid rate that significant informational and technical asymmetries exist between stakeholders and the agencies tasked with overseeing them.[326]

The final dimension, adjustment, would require agencies to consider the assessment and recommendation of the outside committee and make adjustments as deemed necessary. Although the agency would be required to consider any outside recommendations, such recommendations would be precatory and any adjustments ultimately guided by the principles or objectives identified in the planned framework.[327] This separation of the "assessment" and "changing" functions is a common attribute of existing adaptive systems[328] and, by placing decision making power with the agency, increases the likelihood of

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science assessment is conducted in a unit that operates at some organizational distance from EPA's air pollution policy office.").

[323] *See infra* notes 316-17 and accompanying text (discussing costs as a potential drawback).

[324] This process of outside review and recommendation most closely resembles the review mechanism for ambient air quality standards carried out by the EPA pursuant to the Clean Air Act, under which an independent Clean Air Scientific Advisory Committee reviews data compiled by the EPA and issues a subsequent recommendation to the EPA Administrator for consideration. *See* McCray et al., *supra* note 306, at 954 (describing this arrangement).

[325] Indeed, under notice and comment regimes, some work suggests that the majority of industry lobbying occurs behind closed doors, before a notice of proposed rulemaking is ever published. *See, e.g.*, Kimberly D. Krawiec, *Don't 'Screw Joe the Plumber': The Sausage Making of Financial Reform*, 55 ARIZ. L. REV. 53, 59 (2013) (finding that financial industry lobbyists succeeded in swaying "agencies to adopt favorable definitions, interpretations, and exemptions [of the Volcker Rule] prior to the NPRM."). The use of an industry advisory board, in contrast, could channel industry positions into the open, as the views of regulated entities would be based on publicly available data and clearly represented in their published recommendations to the agency.

[326] *See* Matt McFarland, *How Can We Make Sure That Driverless Cars Are Safe?*, L.A. TIMES (Dec. 22, 2015), http://www.latimes.com/business/technology/la-fi-1222-thedownload-driverless-car-safety-20151222-story.html (describing state and federal regulators as "lacking expertise in the rapidly emerging field").

[327] *See* Craig & Ruhl, *supra* note 313, at 52 ("These goals and objectives provide the overall measures against which both the agency and the courts can measure progress in the adaptive management process.").

[328] *See supra* note 322.

reaching socially optimal outcomes.[329] Moreover, although business must play a central role in autonomous vehicle regulation, questions remain about the efficacy of self-regulation and its viability in the context of emerging technologies.[330]

There are, without a doubt, clear institutional and legal obstacles to implementing a system of planned adaptive regulation for autonomous vehicles at both the state and federal level.[331] These obstacles would not only require changes to the procedures governing agency rulemaking and amendment,[332] but also shifts in the way regulators, stakeholders, and courts view the regulatory process.[333] As one commentator notes, agencies "have not often been rewarded for flexibility, openness, and their willingness to experiment, monitor, and adapt."[334] As such, for adaptive regulation of autonomous vehicles to succeed, "legislatures must empower [administrative agencies] to do it, interest groups must let them do it, and the courts must resist the temptation to second-guess when [agencies] do in fact do it."[335] It would, in short, require "substantial change" in existing structures and assumptions underpinning administrative law.[336] This paradigm shift is

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[329] *Cf.* Cary Coglianese, *Engaging Business in the Regulation of Nanotechnology* 1, 32 (Univ. of Pa. Law Sch., Pub. Law Research Paper No. 12-12, 2010) ("Just as James Madison said that government would not be needed if men were angels, regulation of some kind would not be needed if businesses already acted in socially optimal ways . . . .").

[330] *See, e.g.,* Bennear & Coglianese, *supra* note 311, at 25-29 (describing the mixed results of existing and past self-regulatory regimes). In addition, self-regulation could create a further democratic deficit.

[331] *See generally* 5 U.S.C. §§ 551-559 (mandating the procedures federal administrative agencies must follow when considering, issuing, and revising rules).

[332] This includes procedures related to the notice and comment process, *see* 5 U.S.C. § 553, amendment of existing regulations, *see* 5 U.S.C. § 553, and judicial review, *see* 5 U.S.C. § 704.

[333] *See* Ruhl, *supra* note 313, at 53-54 ("Legislatures, interest groups, and courts have become acculturated to a 'front-end' style of command-and-control regulation that has dominated for decades.").

[334] R. Edward Grumbine, *Reflections on "What is Ecosystem Management?"*, 11 CONSERVATION BIOLOGY 41, 45 (1997).

[335] Ruhl, *supra* note 312, at 31.

[336] *Id.* at 31. *See also* Warren T. Coleman, *Legal Barriers to the Restoration of Aquatic Systems and the Utilization of Adaptive Management*, 23 VT. L. REV. 177, 197 (1998) ("In order for agencies to be free to use adaptive management, the legal framework for decision-making . . . must explicitly recognize the flexibility needed to manage adaptively, yet still provide a degree of finality to those parties affected by resource management decisions. Solving this puzzle will require broader change rather than piecemeal legislation or legal maneuvering within the existing legal framework."). *But see* Timothy H. Profeta, *Managing Without a Balance: Environmental Regulation in Light of Ecological Advances*, 7 DUKE ENVTL. L. & POL'Y J. 71, 96 (1996) ("As long as an adaptive management [project]

certainly attainable, and some existing regulatory frameworks at the federal level incorporate aspects of planned adaptive regulation, but it would not occur naturally.[337] Indeed, scholarship like this article will play an essential role in highlighting the need for a shift by laying bare the shortcomings in existing regulatory processes and the responses to these shortcomings.

Importantly, an increased emphasis on regulatory process—that is, adaptability—over ex ante regulatory substance improves on common responses to the pacing problem in two important ways. First, an adaptive approach offers a middle ground between inaction and prohibition. Although regulators may determine that autonomous vehicles are best governed with a light touch, the potential safety risks associated with the technology and fallout from highly visible accidents make it critical that some form of government regulation guarantee minimum levels of safety and, just as importantly, sow consumer confidence in the technology.[338] At the same time, embracing the opposite extreme and slowing the development of autonomous vehicles in response to potential risks would be equally crude and forgo significant benefits due to comparably small or unproven costs.[339] The use of a planned adaptive approach has the potential to occupy a productive compromise between both extremes.

Second, given the desirability of some form of regulatory response, an adaptive approach also offers clear advantages over future-facing and technology-neutral laws. In particular, adaptive regulation avoids the pitfalls of static mandates by responding to, rather than locking in or implicitly anticipating, specific evolutions in autonomous vehicle technology. Instead of making an educated guess as to the most likely or desirable developmental path of autonomous vehicle technology, an adaptive approach allows for adjustment based on real-world data, active debate, and changes in the market or society. Moreover, although broadly worded technology-neutral rules may be warranted based on the observed effects of prior regulations or some aspect of future autonomous vehicle technology, regulators in a planned adaptive system can offer greater clarity and specificity in their rules given their iterative nature. In other words, there is no need to "future proof" laws because, if warranted, they can always be revisited.

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is approved pursuant to the Administrative Procedure Act, then each individual manipulation in the management plan should not violate due process.").

[337] *See* McCray et al., *supra* note 306, at 954-56 (describing existing programs of planned adaptation, including regulation of ambient air standards, commercial air transportation safety, and post-market drug safety). For a full discussion of the legal obstacles facing an adaptive approach to regulation, see generally Craig & Ruhl, *supra* note 313, at 26-38.

[338] *See supra* Part II.B, section (1)(b).

[339] *See supra* Part II.B, section (2)(a).

This is not to suggest that, as applied to autonomous vehicles, adaptive regulation is without its flaws.[340] An adaptive approach has the potential to impose significant new costs on both administrative agencies and industry stakeholders.[341] These costs would stem from both the mandated collection and assessment of data, as well as greater compliance costs related to the potential unpredictability of future revision.[342] In addition, scheduled revision and the initial identification of goals could create a series of lobbying opportunities by industry stakeholders, potentially adding to the already significant risk of regulatory capture.[343] There is also a chance, as mentioned above, that agency officials would be reluctant to implement such a system due to institutional inertia, a preference for the status quo, or concerns about agency credibility.[344]

Although these concerns deserve attention, most can be mitigated or resolved. Industry involvement in the collection and analysis of impact data, for example, should make any changes based thereupon reasonably foreseeable and allow ample time for planning during the collection process. In addition, given the potential prevalence of backroom lobbying under notice and comment regimes, the use of an industry advisory board could actually channel otherwise opaque industry positions into the open, as industry views would be based on publicly available data and expounded in published recommendations. Still, more work is needed to understand the potential impacts and industry reception of planned adaptive regulation as applied to autonomous vehicles. What appears clear, however, is that a planned adaptive approach offers regulators the best opportunity to balance safety, public confidence, and the realization of autonomous vehicles' many potential benefits in an increasingly fluid technological environment.

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[340] Nor is adaptive regulation desirable in every aspect of autonomous vehicle regulation. The definition of what it means to be a driver, as discussed in Part II, or how humans are licensed in autonomous vehicles, won't need to be constantly adapted—they do not necessarily depend on the details of the technology.

[341] *See* Eric Biber, *Adaptive Management and the Future of Environmental Law*, 46 AKRON L. REV. 933, 945-951 (detailing the potential costs of planned adaptive regulation); *see also* HOLLY DOREMUS ET AL., CTR. FOR PROGRESSIVE REFORM, MAKING GOOD USE OF ADAPTIVE MANAGEMENT 1, 5 (2011) (suggesting that planned adaptive regulation "requires more resources than conventional [regulation], because doing it right requires taking the time to carefully analyze the system at the outset, monitor the results, and periodically reassess and revise"). These analyses, however, do not appear to consider any countervailing cost savings which might result from an adaptive approach.

[342] *See* Biber, *supra* note 341, at 945-51.

[343] *See* Charles K. Whitehead, *The Goldilocks Approach: Financial Risk and Staged Regulation*, 97 CORNELL L. REV. 1267, 1305 (2012) (making this point in the context of staging and sunsetting provisions).

[344] *See* McCray et al., *supra* note 306, at 957 (discussing why administrative agencies may be reluctant to embrace adaptive management).

CONCLUSION

The rise of autonomous vehicles promises significant social, economic, and environmental benefits. At the same time, their rapid emergence and evolution pose a unique challenge to the federal and state regulators tasked with ensuring their safe and successful adoption. In particular, as with a growing number of new technologies, autonomous vehicles strain the reactive and adaptive capabilities of U.S. legal institutions. At the heart of this tension are several characteristics of traditional sources of regulation—legislatures, agencies, and courts—which make it difficult, if not impossible, for the law to keep pace with new technologies. Although regulators have attempted to address this pacing problem in a number of ways, including through inaction, precaution, and proactivity, these responses suffer from shortcomings equal to or greater than those caused by the underlying defect. This problem has placed lawmakers in a difficult position and increases the risk that autonomous vehicles will fail to achieve widespread adoption.

To address this quandary and maximize the benefits of autonomous vehicles, I have argued that lawmakers should draw on the principles of planned adaptive regulation. A planned adaptive approach to regulating autonomous vehicle operation and design would require the institutionalization of monitoring-adjustment frameworks which allow for incremental policy adjustments. Although this would be a sharp departure from traditional static models of regulation and could impose new costs on agencies and regulated entities, it offers significant advantages over static systems. Most importantly, rather than attempting to treat the pacing problem's symptoms through ex ante "best guess" regulation, a planned adaptive approach directly targets its root causes through institutional reforms. More work is needed to understand the potential impacts and reception of planned adaptive regulation, as well as to detail the mechanics of implementing such a system. Nevertheless, this article offers the first comprehensive analysis of the full scope and implications of the pacing problem and, based on that analysis, the outline for a corresponding regulatory solution in the context of autonomous vehicles.