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Foreign Investment in Advanced Vehicle Technology

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Contents

1 | An Evolving Industry

The mobility landscape is on the cusp of a revolution centered around automation, connectivity, and electrification (ACE). That revolution is driven by innovative automakers, suppliers, and technology companies that pour time, talent, and money into research and development (R&D) for the technology fundamental to ACE vehicles. The United States is home to a range of factors that make it a premier destination for R&D central to ACE vehicles. Within the United States, 14 automobile manufacturers—10 of which are foreign headquartered—assemble, sell, and export vehicles. Those automakers work hand-in-glove with countless U.S. suppliers and, increasingly, cutting-edge technology companies. Some of the world's leading academic and research institutions in robotics, imaging, navigation, artificial intelligence, propulsion, and other fields at the heart of ACE vehicles call the United States home.

The benefits of ACE technology are enormous. Automobile crashes just in the United States were estimated to have an $836 billion societal cost in 2010 alone.[1] Autonomous systems would quell the accident rate, 94 percent of which are attributable to human error.[2] Computers and sensors, the guts and brains of ACE vehicles, cannot get drunk or otherwise impaired and do not suffer from lapses in focus, sleep deprivation, or get distracted. Smarter vehicles could also reduce traffic congestion and create new mobility options to the roughly 50 million Americans over 65 and the over 50 million Americans that have a disability.[3]

The more than $125 billion automakers invested in R&D in 2018 indicates the industry recognizes the promise of ACE technology. That the auto industry is willing to invest more than the software and aerospace defense industries in R&D despite slowing auto sales around the world suggests that the auto industry views ACE technology as integral

1. U.S. Department of Transportation National Highway Traffic Safety Administration, *The Economic and Societal Impact Of Motor Vehicle Crashes, 2010 (Revised)* (Washington, DC: National Highway Traffic Safety Administration, 2015), https://crashstats.nhtsa.dot.gov/Api/Public/ViewPublication/812013.
2. U.S. Department of Transportation National Highway Traffic Safety Administration, *Traffic Safety Fact: Critical Reasons for Crashes Investigated in the National Motor Vehicle Crash Causation Survey* (Washington, DC: NHTSA, 2015), https://crashstats.nhtsa.dot.gov/Api/Public/ViewPublication/812115.
3. Mihele Bertoncello and Dominik Wee, "Ten ways autonomous driving could redefine the automotive world," McKinsey & Company, June 2015, https://www.mckinsey.com/industries/automotive-and-assembly/our-insights/ten-ways-autonomous-driving-could-redefine-the-automotive-world; Henry Claypool, Amitai Bin-Nun, Jeffrey Gerlach, *Self-Driving Cars: The Impact on People with Disabilities* (Boston, MA: Ruderman Family Foundation, 2017), https://rudermanfoundation.org/white_papers/self-driving-cars-the-impact-on-people-with-disabilities/.

to the future of the industry.[4] However, much of that investment is unlikely to payoff for the industry in the short-term. The combination of technology requirements, regulatory certainty, and consumer acceptance necessary for ACE vehicles to make up the majority of the automobile fleet in the U.S., let alone around the world, will take decades to come together. In light of these challenges, traditional competitors and new entrants within and outside the auto industry are forming strategic partnerships.

Partnerships have traditionally been inherent to the automotive industry. Original equipment manufacturers (OEMs), suppliers throughout supply chains, and dealers seamlessly deliver vehicles to consumers and commercial customers. Now faced with a seismic shift within industry, players that have typically been rivals are forming strategic partnerships to tackle technical challenges that no one company could take on by itself. A partnership between General Motors, Honda, SoftBank (an unordinary partner in the auto space), and Cruise Automation (a GM subsidiary devoted to self-driving cars) would have raised eyebrows a decade ago. But that type of collaboration is becoming more commonplace as major auto companies, investors flush with capital, and tech companies team up to take on what the founder of Cruise has dubbed "the ultimate engineering challenge."[5] These types of partnerships drive innovation beyond what any one company can do alone; expand opportunities for innovation, investment, and growth across the auto industry and throughout technology sectors; and, crucially, are enabled by the attractiveness of the United States as a destination for investment by foreign and domestic companies alike.

The case for ACE research, development, and deployment is clear. R&D into smarter vehicles has already paid off for consumers. Advanced safety features and advanced driver-assistance systems (ADAS) such as blind-spot detection, collision warnings, and automatic emergency braking are becoming increasingly common in vehicles produced in the last two decades.[6] Even with those advances, there is still much more work to be done until fully autonomous vehicles are ready for public use, let alone make up most of the U.S. auto fleet. ADAS are classified by the Society of Automotive Engineers and the National Highway Traffic Safety Administration (NHTSA) as Level 0 to Level 1 automation, while a Level 5 vehicle is capable of "performing all driving functions under all conditions." Most estimates put widespread adoption of Level 5 autonomous vehicles (AVs), which will require a suite of ACE technology, as decades away. The benefits of "smarter" vehicles, however, (i.e., fewer accidents, reduced congestion, and more accessible mobility) do not all require Level 5 vehicles.

At Levels 3 and above of automation, significant positive externalities would begin to arise. AVs would lead to fewer automotive accidents because those vehicles would be equipped to intervene in emergencies that humans may not otherwise react to.

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4. Grep Ip, "'Peak Car' is Holding Back the Global Economy," Wall Street Journal, October 29, 2019, https://www.wsj.com/articles/auto-sectors-struggles-threaten-global-growth-11571830251.
Peter Holley, "Honda and GM partner for 'ultimate engineering challenge' — a new
5. Peter Holley, "Honda and GM partner for 'ultimate engineering challenge' — a new autonomous vehicle," *Washington Post*, October 3, 2019, https://www.washingtonpost.com/technology/2018/10/03/honda-gm-partner-ultimate-engineering-challenge-new-autonomous-vehicle/.
6. "AAA Recommends Common Naming for ADAS Technology," AAA, January 2019, https://newsroom.aaa.com/2019/01/common-naming-for-adas-technology/.

A highly autonomous driving environment could also lead to improved infrastructure performance. A Milken Institute study suggests that highways carrying only AVs could accommodate two to three times as many vehicles.[7] The vehicles would be able to interact with each other more smoothly by driving closer together and reacting in sync, which would also have effects that would decrease congestion. However, the impacts on congestion at this level of automation are currently disputed. Some argue that automation would lead to an increase in the number of vehicles on the road, which could worsen congestion.

In some instances, AVs could also cause increased fleet utilization if ridesharing grows alongside AV ubiquity. The average U.S. vehicle sits idle for 95 percent of the time. Fully autonomous vehicles could operate at almost all hours, leading to a transportation system that is cheaper and more efficient than taxis. Studies have found that a single shared AV could replace roughly 10 privately owned vehicles, although the impact on traffic congestion, average travel time, and total vehicle miles traveled remains murky.[8] A study on the Boston metro area found that a fleet composed of 30 percent autonomous mobility-on-demand vehicles and 38 percent of personal vehicles and personal AVs would reduce the total vehicles on the road by 15 percent, reduce travel time by 4.3 percent across the entire region, but increase travel time in downtown Boston by 5.5 percent.[9] A study on the Austin area comes to similar conclusions. One shared AV in Austin could take 10 privately owned vehicles off the road, but the vehicle miles traveled is expected to increase. An OECD simulation found that just 3 percent of Lisbon's current vehicle fleet would be required to service the transportation needs of the city if those vehicles were sharable and autonomous.[10]

Foreign and domestic companies, research institutions, and governments have been historically intertwined in automotive innovation. Foreign automakers have been responsible for developing and applying driver assistance systems that are increasingly common in all vehicles. Work done at MIT and by NASA on embedded systems for the Apollo Program laid the groundwork for advanced safety features and ADAS, while foreign automakers led the charge in many cases in deploying those features in vehicles.[11]

Backup cameras were first commercially deployed by Toyota in 1991. Now, NHTSA requires backup cameras in all autos sold in the United States that were built after May 2018. Lane departure warning systems appeared first on commercial trucks in Europe

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7. Robert Atkinson, *The Coming Transportation Revolution* (Milken Institute, 2014), https://assets1c.milkeninstitute.org/assets/Publication/MIReview/PDF/78-87-MR64.pdf
8. Susan Shaheen and Nelson Chan, *Mobility and the Sharing Economy: Impacts Synopsis* (Berkeley, CA: Transportation Sustainability Research Center, University of California, 2015), http://innovativemobility.org/wp-content/uploads/Innovative-Mobility-Industry-Outlook_SM-Spring-2015.pdf.
9. World Economic Forum, Reshaping Urban Mobility with Autonomous Vehicles: Lessons from the City of Boston (Geneva: World Economic Forum, 2018), http://www3.weforum.org/docs/WEF_Reshaping_Urban_Mobility_with_Autonomous_Vehicles_2018.pdf.
10. OECD International Transport Forum, *Shared Mobility: Innovation for Liveable Cities 2016* (Paris: OECD International Transport Forum, 2016), https://www.itf-oecd.org/sites/default/files/docs/shared-mobility-liveable-cities.pdf.
11. Adnan Shaout, Dominic Colella, and S. Awad, "Advanced Driver Assistance Systems – Past, Present and Future," The University of Michigan Dearborn, Electrical and Computer Engineering Department published in 2011 Seventh International Computer Engineering Conference(IEEE, 2012), https://www.researchgate.net/profile/Adnan_Shaout/publication/261166846_shaout_colella_awad-advanced_driver_assistance/links/00b7d5335ac2c16418000000/shaout-colella-awad-advanced-driver-assistance.pdf.

in 2000, then passenger vehicles in Japan produced by Nissan and Toyota in 2001 and 2002 and did not come to North America until 2004 via Infiniti. Adaptive cruise control was first deployed by Toyota in Lexus sedans in the late 1990s. Autonomous parking assist systems were first made widely available in the Toyota Prius in 2003. Honda and Mercedes debuted emergency brake assist systems in 2003. NHTSA estimates that emergency braking will be standard in 99 percent of U.S. autos by 2022.[12] Blind-spot monitoring was first installed in commercial vehicles by Volvo in 2005. Pre-crash systems were introduced by Toyota and Honda in the mid-2000s and adopted by Ford and others in the late 2000s. Blind-spot detection was introduced by Volvo in 2007 and then Ford. In 2011, Infiniti was the first to make a system that assisted in steering if an object is detected in a blind spot commercially available.

More recently, foreign companies have invested in U.S. firms—startups and growing enterprises working on core ACE vehicle technologies—and are partnering with U.S. automakers to develop the next generation of vehicles. Foreign and domestic automakers are leveraging U.S. strengths in their efforts to research and develop the next generation of vehicles and underlying technology. Those strengths include the robust and competitive U.S. auto market, its strong innovative software ecosystem, a rewarding intellectual property regime, and a regulatory environment that is relatively friendly towards AV R&D.

Despite the benefits promised by the ACE vehicles, speedbumps remain that could slow their arrival in the United States and undermine the country's position as a leader in ACE innovation and R&D. Such speedbumps include regulatory uncertainty at the federal level on the one hand and the danger of over-regulation that stymies innovation and testing, on the other hand. Further reduction in government support for cutting-edge R&D is another speedbump that should be avoided. Lack of public acceptance of AVs would slow research, development, and deployment of next-generation vehicles. Perhaps the most obstructive speedbumps come in the form of policies that aim to prop up domestic automakers at the expense of foreign automakers, which would jeopardize the innovative capacity of domestic and foreign firms alike. Viewing foreign and domestic companies' R&D efforts in the United States as distinct, as the Trump administration has suggested is the case, would sabotage the position of the United States as a top destination for global ACE vehicle R&D. Placing foreign and domestic firms into separate baskets would make the entire auto industry and the United States as a whole less globally competitive at a crucial moment in the automotive industry's evolution. Policy certainty and stability is king when it comes to multi-million-dollar investments that will take years to recoup.

12. U.S. Department of Transportation, National Highway Traffic Safety Administration, "10 automakers equipped most of their 2018 vehicles with automatic emergency braking," Press Release, March 13, 2019, https://www.nhtsa.gov/press-releases/10-automakers-equipped-most-their-2018-vehicles-automatic-emergency-braking.

2 | The United States in Pole Position

ACE vehicles are a marriage of a traditional mechanical vehicle with cutting-edge digital and internet-enabled technology: cameras, lidar, radar, and chips to enable machine learning, navigation, and the software that undergirds those tools. Testing this technology, a fundamental aspect of R&D, requires a flexible regulatory environment that welcomes innovation and risks while balancing safety concerns. The United States has a slew of competitive advantages in the foundations of the technological fusion required to research, develop, and manufacture ACE vehicles. "Centers of excellence" in many of the areas necessary for ACE vehicles to come to life exist within the United States. An open investment policy and a business-friendly regulatory environment enable the collaboration between industries and between foreign and domestic companies that is necessary to build the ecosystem of innovation that drives further investment into ACE vehicles. Cooperation between automotive companies and technology companies is eased by the deep roots each industry has in the United States, the agglomeration advantage of a relatively large amount of skilled engineering and information and communications technology (ICT) labor, and flush venture capital players.[13] The United States invests a higher share of GDP into ICT capital assets, which includes software, IT equipment, and communications equipment, than other major auto-producing countries.[14] The United States fares less well when it comes to ICT and total business expenditure on R&D intensities, trailing the established auto bases of South Korea, Japan, and Germany, and emerging auto competitor China.[15]

While U.S. auto companies and U.S. tech companies are major players in the drive for ACE vehicles, growing cooperation between those industries is not limited to U.S. auto companies working with U.S. tech companies. There is a range of partnerships among foreign and domestic auto companies and parts suppliers, technology companies, and ride-hailing companies. The technological complexity and diversity of industries involved in ACE vehicles demand that research, development, and deployment be a deeply international process.

13. Robert Atkinson and Caleb Foote, *How the Shift to IT-Enabled Vehicles Plays to America's Competitive Strengths* (Information Technology & Innovation Foundation, 2018), http://www2.itif.org/2018-it-vehicles-competitive-strength.pdf.
14. OECD, *OECD Digital Economy Outlook 2017* (Paris: OECD, 2017), https://www.oecd.org/internet/oecd-digital-economy-outlook-2017-9789264276284-en.htm. U.S. ICT investment was 3.1 percent of its GDP in 2015, trailing the Czech Republic, Switzerland, Sweden, the Netherlands, New Zealand, France, and Austria.
15. Ibid. Total business expenditures on R&D in the United States was 1.96 percent of its GDP that year, of which ICT manufacturing R&D made up .33 percent and ICT services R&D made up .34 percent.

Automakers, parts suppliers, and technology companies, both U.S. and foreign, are pumping increasing funds into R&D for the next generation of vehicles. This is reflected in R&D numbers by auto and tech companies headquartered in and outside of the United States. In 2018, automakers spent close to $100 billion on R&D globally. Seven of the top 25 R&D spenders, excluding governments, were automakers, five of which are headquartered outside of the United States. In the United States, automakers invested nearly $20 billion in R&D in 2017, which supports about 80 R&D domestic facilities and roughly 60,000 jobs.[16]

International automakers, like their U.S. counterparts, research, develop, and manufacture vehicles in the United States for U.S. consumers and to export abroad. Foreign automakers have invested almost $82 billion in the United States, employ over 125 thousand Americans, and operate almost 500 facilities.[17] They accounted for almost half of all vehicles (except heavy trucks) produced in the United States in 2018 and about half of U.S. vehicle exports. Those companies, like their U.S. counterparts, feed the U.S. innovation ecosystem by creating demand for a range of top-notch manufacturing employees and now increasingly software engineers. Those companies, like their U.S. counterparts, partner with cutting-edge U.S. start-ups and explore new scientific frontiers with U.S. universities and national labs.

And the United States' intellectual property protections and regulatory environment make it an ideal place to invest, take risks, and reap rewards. Although there is no federal framework for AVs, the Department of Transportation (DOT) has released voluntary guidelines for the development and deployment of AVs.[18] The Preparing for the Future of Transportation: Automated Vehicles 3.0 document presents voluntary guidelines for the development and safe deployment of AVs with the aim of balancing safety with incentivizing innovation.[19] Importantly, the DOT has committed to reconsidering how it currently thinks about safety and design regulations for vehicles. The NHTSA is considering changes to safety regulations on the design of vehicles to account for unnecessary features in Level 4 or 5 vehicles, such as steering wheels and brake pedals. DOT is also considering changes to regulations on traffic control systems and public transportation. The document does not provide strict rules to be enforced but rather outlines the Department's goals and gives an indication to where formal regulation will be heading. The DOT's report also offers guidelines for states and localities, encouraging them to remove barriers and improve interoperability. Despite the guidelines, the lack of a federal framework for AV development generates policy uncertainty that may erode U.S. advantages.

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16. Raymond M. Wolfe, "Business R&D Performed in the United States Reached $356 Billion in 2015," National Science Foundation, August 22, 2017, https://www.nsf.gov/statistics/2017/nsf17320/; Alliance of Automobile Manufacturers, *Comments of the Alliance of Automobile Manufacturers on the Section 232 National Security Investigation of Imports of Automobiles, Including Cars, SUVs, Vans and Light Trucks, and Automotive Parts* (Auto Alliance), https://autoalliance.org/wp-content/uploads/2018/06/Alliance_Comments_On_Section232.pdf.
17. Global Automakers and Here for America, *Section 232 Automobile and Automotive Parts Imports Investigation To Determine the Effects on U.S. National Security of Imports of Automobiles, Including Cars, SUVs, Vans and Light Trucks, and Automotive Parts June 27, 2018* (GlobalAutomakers and Her for America, 2018), https://www.globalautomakers.org/Association%20of%20Global%20Automakers%20Automotive%20232%20Comments%206-27_2.pdf.
18. Andrew Hawkins, "US will rewrite safety rules to permit fully driverless cars on public roads," The Verge, October 4, 2018, https://www.theverge.com/2018/10/4/17936576/self-driving-car-av-guidelines-3-nhtsa-elaine-chao.
19. U.S. Department of Transportation, *Preparing for the Future of Transportation: Automated Vehicle 3.0* (Washington, DC: U.S. Department of Transportation, 2018), https://www.transportation.gov/av/3.

Several countries are ahead of the United States in policy preparedness for AVs. However, the United States is still the leader in innovation and investment by foreign and domestic companies in technology development. Based on a study by KMPG International, the United States ranks third, behind Singapore and the Netherlands, in overall preparedness to adopt AVs.[20] The United States leads the ranking in technology and innovation but falls slightly behind in infrastructure and policy preparation.

Singapore is a leader in AV development.[21] It has hosted testing grounds since 2017 and an autonomous ridesharing service, NuTonomy, since 2016. In 2017, Singapore also introduced a series of autonomous vehicle rules, including a change to recognize that motor vehicles do not require drivers. However, Singapore rules still require that a safety driver be in the vehicle for emergencies. Singapore plans to enact more permanent regulations within the next five years.

The European Union is working on the Cooperative-Intelligent Transportation Systems (CIT-S) which would cause newly built vehicles, motorways, and road signs to be fitted with technology to send messages across vehicles.[22] This increased connectivity aims to increase road safety. However, the European Union has not yet adopted overarching regulations on AVs. Individual European countries are working on their own AV policies.[23] The United Kingdom has set up a government department dedicated to AVs and is working on legislation to allow them to be tested on public roads. Germany has passed legislation which would account for the use of AVs in existing automotive safety legislation. Permits for autonomous testing in Germany have been handled on a city level. France is working on legislation to allow AVs on public roads in 2019.

The French government has also provided 40 million euros to help subsidize autonomous technology development.

China lags behind the United States and European Union in preparedness for AVs. Complicated signage and the lack of fully standardized light systems make integration of AVs difficult. Several Chinese companies, such as Baidu and Pony.ai are working on AVs, and while China is still behind the United States in AV innovation, the gap is beginning to close.[24] The Chinese government has also been working on technology standards and industry guidelines for AVs. Beijing and other cities have issued permits for testing on public roads.[25]

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20. KPMG International, *Autonomous Vehicles Readiness Index* (KPMG International, 2018), https://assets.kpmg/content/dam/kpmg/tw/pdf/2018/03/KPMG-Autonomous-Vehicle-Readiness-Index.pdf.
21. Cristina Lago and Charlotte Trueman, "How Singapore is driving the development of autonomous vehicles," CIO, January 24, 2019, https://www.cio.com/article/3294207/how-singapore-is-driving-the-development-of-autonomous-vehicles.html.
22. "Cooperative Intelligent Transport to be deployed on EU roads," Government Europa, March 13, 2019, https://www.governmenteuropa.eu/cooperative-intelligent-transport/92556/.
23. "The state of autonomous legislation in Europe," Autovista Group, February 28, 2019, https://autovistagroup.com/news-and-insights/state-autonomous-legislation-europe.
24. Celia Chen, "China lagging US in autonomous driving but gap is narrowing, says start-up Pony.ai," *South China Morning Post*, July 17, 2018, https://www.scmp.com/tech/start-ups/article/2155491/china-lagging-us-autonomous-driving-gap-narrowing-says-start-ponyai.
25. Kyle Wiggers, " Baidu's autonomous cars have driven more than 1 million miles across 13 cities in China," VentureBeat, July 2, 2019, https://venturebeat.com/2019/07/02/baidus-autonomous-cars-have-driven-more-than-1-million-miles-across-13-cities-in-china/.

In the United States, state and local governments have adopted their own laws and regulations in the absence of a federal framework. Thirty states have adopted their own AV legislation, and governors of 11 states have issued executive orders on the matter.[26] Overall, the various actions of the states generally encourage the development of AVs. Many states have created permit systems to allow the testing of AVs, but rules vary largely across states. California, Arizona, and Nevada all allow testing without a safety driver in the vehicle, a privilege offered in few other locations around the world.[27]

Fifty percent of large cities have or are exploring plans to integrate AVs into their long-term transportation plans.[28] However, while many larger cities have begun planning, many small and mid-size cities are not yet taking steps in preparation. One paper estimated that less than 5 percent of cities had a "clear plan" for AVs.[29] The National League of Cities released a policy preparation guide to help cities prepare for rapid escalation of AV technology.[30] The blueprint focuses on policies that prioritize efficiency and equity during the adoption of AVs.

Mcity, Luminar, and Aptiv: Institutional and Technical R&D Case Studies

The University of Michigan's Mcity fully leverages the U.S. business environment that encourages industry, academia, and government to collaborate on ACE vehicles. The first proving ground designed in partnership with DOT and built specifically for ACE vehicle testing, Mcity is a public-private partnership that provides companies and researchers the opportunity to test emerging technology in labs and on the road. The Michigan Economic Development Corporation, Michigan DOT, City of Ann Arbor, U.S. DOT, and U.S. Department of Energy are involved in work done at Mcity, along with private companies and the University of Michigan. Research funded by Mcity utilizes the intellectual capital of the University of Michigan to work on a range of issues, from legal questions to road-testing autonomous safety solutions to researching strategies for growing consumer acceptance of AVs. Industry partners from a variety of sectors are engaged at Mcity, from auto titans like GM, Honda, Toyota, and Denso to rising high-tech mobility parts companies like Aptiv and telecommunications giants like Verizon.

R&D into lidar (light detection and ranging) in the United States showcase the international nature of CAV supply chains and R&D. Lidar is considered by many in the ACE arena to be integral to ACE vehicles. Lidar, usually sitting atop a vehicle, is used to generate a 3-D map of a vehicle's surrounding by shooting and receiving the reflection of millions of laser beams

26. National Conference of State Legislatures, "Autonomous Vehicles | Self-Driving Vehicles Enacted Legislation," http://www.ncsl.org/research/transportation/autonomous-vehicles-self-driving-vehicles-enacted-legislation.aspx.
27. Jack Karsten and 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/.
28. Brooks Rainwater and Nicole Dupuis, "Cities Have Taken the Lead in Regulating Driverless Vehicles," City Lab, October 23, 2018, https://www.citylab.com/perspective/2018/10/cities-lead-regulation-driverless-vehicles/573325/.
29. Laura Bliss, "Why Aren't Cities Getting Ready for Autonomous Vehicles," City Lab, May 30, 2019, https://www.citylab.com/transportation/2019/05/autonomous-vehicles-city-regulations-traffic-self-driving-car/590440/.
30. "Blueprint for Autonomous Urbanism: Second Edition," National Association of City Transportation Officials, https://nacto.org/publication/bau2/.

per second. Difficult to manufacture and expensive, additional improvements in technology are needed before deployment at scale. Lidar consists of a laser, light scanner, photodetector, processor, computing unit, and specialized GPS receiver.

Most lidar firms operate in complex supply chains with centers in the United States, Europe, Japan, and South Korea. Much of the final manufacturing and development of these products occurs in California, where many of the startups focused on lidar are centered. Several other companies focused on automotive lidar also exist in Canada, Europe, China, Japan, and Israel. Costs for lidar remain high due to the constant investment in innovation and changes to the product.

Luminar, an AV sensor and software vehicle company with offices in Palo Alto, Orlando, and Colorado Springs, works with 12 of the top 15 auto companies on AV development. A number of Luminar's partners are foreign companies, including Volvo, Toyota via the Toyota Research Institute, and the Autonomous Intelligent Driving (AID) unit of Audi, which is owned by the Volkswagen Group. Supported by foreign and domestic investment, Luminar's lidar technology has made its way from the United States to the streets of Hamburg in five Volkswagen vehicles approved for road testing in the German city with Level 4 automation enabled—a landmark test in Germany. A similar story has played out with Velodyne, another American lidar company with mobility partners on every continent (except Antarctica).

Aptiv is another player in the CAV space that operates on a global scale. The company integrates lidar and other sensors with software, connectivity technology, data computation, and machine learning to provide new mobility solutions. It employs over 160,000 workers in 44 countries at manufacturing sights and research centers. Headquartered in Dublin, Aptiv operates more facilities in the United States than any other continent. Its U.S. facilities stretch from tech hotspots like Mountain View and Boston to classic automotive sites like Warren, Ohio, and Detroit.

Driver's Ed. for Machines

For the imaging from lidars, cameras, and radars to be useful, AVs must be equipped with software to process the information. Machine learning technology is key to process the flood of information picked up by an AV's various sensors. That information includes signage, road markings, other vehicles, pedestrians, weather conditions, and more. How to make sense of that data and drive accordingly is second nature for humans, who have a lifetime of experience to apply when behind the wheel. Humans can instantly recognize a slew of variables on the road—a stop sign, yellow light, pedestrian about to cross the street, braking vehicle, or animal in the road—and act accordingly. Getting self-driving vehicles to interpret those variables and make decisions as a human driver would—or make even safer decisions—is a monumental challenge. A vehicle's sensors are often referred to as its nervous system, while the computational power to make sense of the data picked up by those sensors and make decisions is referred to as the vehicle's brain.

Machine learning in this area requires both software engineering, hardware know-how, and on-the-ground testing where vehicles move through various scenarios and learn to make decisions. The willingness of some states, such as California and Arizona, to let companies test AVs on public roads is an enormous attraction for companies foreign and domestic in the AV space. On the technical side, the United States is an AI leader based on a range of metrics.[31] It is home to over 1,000 companies focused on artificial intelligence, including global leaders like Google (which has its own AV play in Waymo), Facebook, Amazon, Microsoft, and IBM. The United States is flush with venture capital cash and talent in the AI space as well, is a long-time leader in the hardware that powers machine learning and leads in other areas.[32]

The United States is dominating the autonomous vehicle AI space. Prior to 2015, AV firms made up less than 5 percent of total investment in AI start-ups. By mid-2018, AV firms accounted for 30 percent of total investment in AI start-ups, with 80 percent of that funding going to U.S. companies.[33] Toyota is one of many companies that has embraced—and in turn supports—the fusion of the U.S. AI ecosystem with the classic automotive excellence found in the United States. Toyota operates a venture capital arm, Toyota AI Ventures, as a subsidiary of Toyota Research Institute, which is devoted to applying AI to vehicles. Toyota AI Ventures has invested in a range of cutting-edge U.S. firms, most of which are tackling the challenges at the core of ACE vehicles.

Despite the innovation, significant investment, and excitement surrounding ACE vehicles, the race to electrified and connected vehicles with Level 4 automation (highly automated vehicles capable of performing all driving tasks under certain conditions, with the option for human override) and above is still in an early phase. Governments are only beginning to grapple with how to regulate AVs, businesses with few small exceptions remain squarely focused on R&D and limited deployment of vehicles that exhibit Level 3 conditional automation, and the general public remains wary of AVs. The United States has time to address those challenges. The competitive advantages discussed above have given it a lead over competitors as the premier destination for ACE vehicle R&D. Further, the average vehicle age in the United States is over 11 years, which provides the private sector and government ample time to prepare for the automated, connected, and electric future of mobility. As in any long-distance race, endurance, stability, situational awareness, and a well-thought-out game plan are keys to success.

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31. Daniel Castro, Michael McLaughlin, and Eline Chivot, “Who Is Winning the AI Race: China, the EU or the United States?” Center for Data Innovation, August 19, 2019, https://www.datainnovation.org/2019/08/who-is-winning-the-ai-race-china-the-eu-or-the-united-states/.
32. OECD, “Private Equity Investment in Artificial Investment,” *OECD Going Digital Policy Note*, December 2018, https://www.oecd.org/going-digital/ai/private-equity-investment-in-artificial-intelligence.pdf.
33. Ibid

3 | Challenges and Recommendations

While the United States is already an attractive place for foreign and domestic companies alike to research, develop, test, and even deploy ACE vehicles, a number of speedbumps remain that if left unaddressed or mishandled could risk the United States' position as a global leader in ACE development. The following list of challenges is not exhaustive, nor are the recommendations the only right answers to the challenges presented. Rather, this section is intended to highlight some of the many significant issues government and businesses should have on their radar as ACE vehicles continue to develop and approach wide-scale commercial deployment.

Generally, the United States should focus on policies that increase opportunities for cooperation and competition among foreign and domestic companies, and it should not adopt policies that restrict trade, investment, and collaboration among industry stakeholders.

Tariffs

THE ISSUE:

In May, the Trump administration concluded in its Section 232 investigation that U.S. imports of automobiles and auto parts pose a threat to U.S. national security.[34] Domestic and foreign automakers argue that imports do not pose a risk to U.S. national security and that tariffs or other restrictions would do more to harm than help the industry.[35] The automakers strongly oppose trade restrictions on automobiles and parts. The administration found that rising automotive imports alongside "protected foreign markets" in the European Union and Japan have cut into domestic automakers' revenue and therefore, their ability to invest in R&D. According to the administration:

> Sales revenue enables R&D expenditures that are necessary for long-term automotive technological superiority, and automotive technological superiority is essential for the national defense. The lag in R&D expenditures by American-owned

34. White House, "Adjusting Imports of Automobiles and Automobile Parts Into the United States," Presidential Proclamation, May 17, 2019, https://www.whitehouse.gov/presidential-actions/adjusting-imports-automobiles-automobile-parts-united-states/.
35. "Section 232 National Security Investigation of Imports of Automobiles and Automotive Parts Hearing Panel," July 19, 2018, https://www.regulations.gov/contentStreamer?documentId=DOC-2018-0002-2299&contentType=pdf.

> producers is weakening innovation and, accordingly, threatening to impair our national security.[36]

Under that basis, the Secretary of Commerce concluded that automobile and parts imports threaten U.S. national security; however, the president has not exercised his authority provided under Section 232 of the Trade Expansion Act of 1962 to restrict imports. Regardless, the administration made clear that it believes investment and the innovation contribution from U.S.-owned automotive companies is more valuable than that of foreign automakers. Further, linking automobile R&D and production to national security does not inherently mean that restricting imports would be advantageous for U.S. national security or that more capacity is required to meet defense needs. In addition, the overwhelming majority of U.S. auto imports come from allies such as Canada, Mexico, Japan, South Korea, and the European Union. The administration's rhetoric and reasoning alone can have a chilling effect on foreign automakers and companies considering investment in the United States.[37]

Ironically, tariffs would likely damage both domestic and foreign auto companies, choke revenue for R&D, and encourage the entire industry to shift at least some R&D and production outside of the United States.[38] Imports of motor vehicles and parts from the European Union and Japan amounted to almost $120 billion in 2018, which is about one-third of all U.S. auto and parts imports. Vehicles produced in the United States for domestic consumption or export abroad rely on foreign parts and global value chains to maintain a competitive position in the global market. Foreign retaliation would put further pressure on automakers in the United States. Higher prices of autos assembled in the United States as a result of tariffs would discourage domestic sales and make U.S.-assembled autos less globally competitive. Lower demand due to higher vehicle prices would result in less production, fewer jobs, and less revenue for R&D.

Tariffs on components necessary for ACE vehicles, such as batteries, sensors and other lidar components, and chips, would deter R&D in the automotive and tech sectors. Tariffs on parts that make up the nervous system and brain of AVs ignore the reality that those parts rely on software—usually developed in the United States or at least in part—to have any real utility or value. Sensors and chips have limited utility without cutting-edge software to instruct and teach AVs how to interpret and react to data gathered. Tariffs used in a bid to protect the United States' ability to competitively manufacture certain AV parts do not play to the U.S. strengths outlined above—its high rate of graduates in the information technology space and its lead in software engineering, semiconductor technology, and artificial intelligence. Competitive access to parts integral to ACE vehicles up and down the value chain allows the United States to exploit its own competitive advantages. Cutting off access would minimize those advantages. Tariffs on ACE components would also complicate the ability of automakers and retailers to keep vehicle prices relatively constant despite customers' expectation that new features continue to be added to vehicles. Tariffs could make strategic partnerships between U.S. and foreign automakers and other players in the ACE vehicle space untenable as well.

In short, tariffs would put the United States' position as a global leader in ACE vehicle innovation at risk.

RECOMMENDATIONS:

- **The administration should make clear that it will not impose or threaten tariffs or quotas** via Section 232 on automobiles and parts, including those necessary for ACE vehicle R&D.
- **If foreign investment raises national security risks, the administration should use carefully tailored, narrow tools to negate those risks, including the Committee on Foreign Investment in the United States.**

Export Controls and Investment Restrictions

THE ISSUE:

The Department of Commerce is in the process of reviewing a range of technologies for export controls, some of which are at the heart of ACE vehicles. Separate from the export control effort, the administration has linked automotive R&D to national security, writing that "the rapid application of commercial breakthroughs in automobile technology is necessary for the United States to retain competitive military advantage and meet new defense requirements."[39]

Unilateral U.S. controls that unintentionally capture civilian applications of emerging technologies could frustrate R&D in the United States and risk offshoring R&D to environments where technology and information sharing across borders is less constrained. Unilateral controls on technologies that can be researched, developed, deployed, and acquired outside the United States would also do little to slow the uptake of those technologies by adversaries. Broad export controls could also limit the amount and quality of human capital companies in the United States can attract for R&D. Engineers and software developers are increasingly sought after as the economy increasingly becomes digitized. Export controls that limit or complicate the ability of companies in the United States to attract the best and the brightest will result in top global talent being siphoned away to Europe, Japan, China, and elsewhere.

Technologies under review for control by the Department of Commerce include artificial intelligence and machine learning, a broad category that includes areas that ACE vehicles will rely on and where U.S. and foreign companies are cooperating on and competing against each other, such as computer vision, expert systems, speech and audio processing, natural language processing, cloud technologies, and AI chipsets. Other broad categories being considered for export controls that ACE vehicles will rely on include position, navigation, and timing technology; microprocessor technology; advanced computing technology; data analytics technology; and logistics technology.

The nature of these technologies makes export controls, particularly unilateral controls, complicated. The technologies themselves are not inherently connected to national security; in fact, many of them share roots within academia and open-source research. National security implications arise via the application of the technology—military platforms enabled or augmented by AI; military logistics made more efficient with AI; unpiloted military intelligence, surveillance, and reconnaissance systems that make use of autonomous navigation and computer vision; and AI-assisted data processing to parse foreign capabilities or targets.

39. Ibid., 35.

In addition to dual-use applications, these technologies and their research, development, and deployment in the automotive sector are not "made in America," and they are not developed by only U.S. companies. Nor are these technologies worked on only by Americans, even in the United States. Foreign talent, investment, and corporate buy-in to develop these technologies within the United States could be put at risk by onerous export controls that limit civilian applications of emerging technologies along with military applications. In the near term, overly broad export controls on emerging and foundation technologies could limit U.S. exports of cutting-edge parts and vehicles, deter international R&D within U.S. companies and among partnerships between U.S. companies and foreign companies, and limit access to human capital—all while boosting the competitiveness of companies abroad.

RECOMMENDATIONS:

- **U.S. regulators should identify discrete products, rather than systems technology, to control.** Those products should exhibit a specific national security dimension. The administration should continue to emphasize end-use in export control decision-making to avoid capturing entire systems or technologies.
- **Consideration of license applications for controlled items should follow the Department of Commerce's established end-user-based approach rather than providing for blanket denials.**
- **The administration should work with existing multilateral export control regimes to ensure they are up to date with respect to emerging and foundational technologies and that member nations are developing parallel policies.**
- **The administration should continue to pursue and implement policies to guard against technology transfer to foreign adversaries**, such as those required by the Foreign Investment Risk Review Modernization Act's updates to the Committee on Foreign Investment in the United States.
- **The administration should ensure that companies have adequate time and recourse to ensure new controls do not adversely impact** international research collaboration **by limiting retention and hiring of foreign nationals.**

Positive Foreign Cooperation

The development of ACE vehicles is not only happening in the United States. Just as the United States is grappling with how to adapt its regulatory framework to advances in technology and automation, other major markets are doing so as well. From technical standards, data protection, cybersecurity standards, design requirements, performance standards, certification standards, and more, the risk of international regulatory fragmentation threatens the United States' ability to transition from a leader in ACE vehicle R&D to a leader in ACE vehicle exports. U.S. automakers claim the inability to bridge regulatory gaps has impeded traditional U.S. automobile exports to key markets, including the European Union, South Korea, and Japan. Given the nascent nature of AV technology and the United States' potential to become a major manufacturing hub for ACE vehicles, the United States should engage with global automakers and trading partners sooner rather than later to develop common standards. Although international standards cannot be set before national standards, early engagement will make mutual recognition discussions less painful in the future.

RECOMMENDATIONS:

- **The United States should negotiate acceptance of U.S. autonomous vehicle safety standards and certification procedures in free trade agreements** and update existing free trade agreements to do so.
- **The United States should establish autonomous vehicle regulatory cooperation working groups** with governments of major export markets and at relevant international institutions.
- **U.S. stakeholders should engage with international standard-setting bodies working on ACE vehicles, including the Society of Automobile Engineers (SAE International) and the International Organization for Standardization.**

Clear Regulatory Guidelines

THE ISSUE:

The primary way in which the government can help stimulate innovation and investment in AVs in the United States is to improve the regulatory framework under which automakers and tech companies operate. Despite the relative attractiveness of the U.S. regulatory environment for ACE vehicle R&D, the lack of clear and modernized federal regulation for ACE vehicles risks slowing R&D and deployment in the United States. Traditionally, federal and state authority over vehicle regulations has been clearly delineated. The federal government, through DOT and National Highway Traffic Safety Administration (NHTSA), has jurisdiction over vehicle safety, which includes vehicle performance and design features regulated in part through the Federal Motor Vehicle Safety Standards (FMVSS). States maintain authority over driver licensing, vehicle registration, insurance, inspections, and traffic laws. As vehicles become increasingly autonomous, they will decreasingly fit within traditional policy frameworks.

As with any nascent technology, overregulation can be fatal, something that DOT has acknowledged by taking a light-touch approach in the AV space driven in large part by voluntary guidance.[40] Regulation is slow and can be inflexible, while technological advances tend to be quick and unpredictable. However, the lack of baseline, updated regulation for AVs at the federal level leaves open the possibility that states will create a patchwork of regulations that stymies R&D and deployment and dissuades investment in the United States. Indeed 30 states have already adopted legislation on AVs. The prospect of all 50 states adopting unique and potentially incompatible regulations in areas including safety, design, performance, certification, and testing is a nightmare scenario for AV developers and manufacturers. Automakers are interested in building vehicles that can be sold nationally and internationally, not vehicles that qualify for sale in individual states. Multiple state standards would make economies of scale—a crucial factor in vehicle manufacturing—within the United States impossible to achieve as vehicles would have to be built or programmed to meet certain state specifications. Perhaps most importantly, conflicting state regulations could slow testing on public roads across the United States, which is pivotal for data gathering, safety improvement, and consumer acceptance.

40. U.S. Department of Transportation, *Preparing for the Future of Transportation: Automated Vehicle 3.0*.

State regulations of AVs generally fall into one of three categories: friendly, cautious, and prohibited. States with friendly legislation tend to allow the testing and operation of AVs on public roads without permits and without the requirement of safety drivers. Such states include Michigan, Colorado, and Florida. While friendly states have differing requirements for traffic laws and insurance, they represent some of the least restrictive legal frameworks. These states do not require manufacturers to jump through hoops for permits, and they allow for companies to test and ultimately operate Level 4 or 5 AVs without a driver. Michigan was one of the first states to enact comprehensive legislation on AVs in 2016. The Michigan framework permits AVs to operate on public roads without drivers and allows for commercial self-driving car services like Uber and Lyft.

Many other states more cautiously allow for AVs. These states allow for the testing of AVs but require companies to obtain permits before launching and typically require safety drivers to be present in the vehicle. Such states include California, Arizona, and Arkansas. California has been a leader and a hub for AV development, but the state remains cautious about regulation. California requires various permit processes for testing of AVs, including separate permits for vehicles testing with a driver, without a driver, and for the deployment of fully autonomous vehicles.[41] While this system is comprehensive and prepared for various scenarios of AVs, the extensive permit process prevents the state from being fully friendly to AV development. Arizona has recently updated its AV requirements, which has changed it from a friendly location to a cautious one.[42] In 2015, Arizona governor Doug Ducey signed an executive order which allowed for AV testing without permits, including for vehicles with no driver present. However, in 2018, the governor signed an updated order which requires new licensing and permits for AVs in the state and updated safety and traffic measures.[43]

Several remaining states have no legislation or executive orders regarding AVs. This creates a gray zone in which AVs are not banned but not governed by any laws. In effect, AVs are not tested in those states. Some of these states, such as New Jersey, have created task forces or introduced legislation concerning AVs.[44]

RECOMMENDATIONS:

- **Congress should pass legislation to create an enforceable federal framework for autonomous vehicle safety and design.** The SELF DRIVE Act and AV Start Act should serve as starting points.[45] Legislation should at a minimum mandate that:
    - The federal government has sole authority over regulations pertaining to the design, construction, and performance of AVs or driving systems.
    - OEMs are required to certify the safety of AVs before public testing or deployment, including through data sharing with DOT, and DOT should establish new safety

41. "Autonomous Vehicles in California," State of California Department of Motor Vehicles, https://www.dmv.ca.gov/portal/dmv/detail/vr/autonomous/bkgd.
42. Mallory Locklear, "Arizona no longer requires safety drivers in autonomous vehicles," Engadget, March 2, 2018, https://www.engadget.com/2018/03/02/arizona-no-safety-drivers-autonomous-vehicles/.
43. Office of Governor Doug Ducey, "Governor Ducey Updates Autonomous Vehicle Executive Order," News Release, March 1, 2018, https://azgovernor.gov/governor/news/2018/03/governor-ducey-updates-autonomous-vehicle-executive-order.
44. Automotive Fleet Staff, "New Jersey Forming Autonomous Vehicle Task Force," *Automotive Fleet*, February 5, 2019, https://www.automotive-fleet.com/324480/new-jersey-forming-autonomous-vehicle-task-force.
45. See, S.1885, AV Start Act, and H.R. 3388, SELF DRIVE Act.

standards for AVs.

- Data sharing requirements should be narrowly tailored to data that is relevant to NHTSA's safety mandate. Safety checks should include facets unique to AVs, including system safety, data recording, cybersecurity, automation detection, law applicability, crashworthiness, post-crash behavior, capabilities and limitations of autonomous systems, and human-machine interface capabilities. Similar safety assessments are currently voluntary as per DOT guidance.
- NHTSA has requested feedback from stakeholders on which categories of data ought to be provided by companies to participate in a national pilot program to enable facilitation, monitoring, and research on the testing and development of driving automation.[46] Those categories should serve as a starting point for discussions and rulemaking on business to government data sharing.

- DOT should update FMVSS to accommodate autonomous and highly automated vehicles. Examples include not requiring typical human interface vehicle components like steering wheels, pedals, and mirrors, while requiring clear indicators on the outside of the vehicle that autonomous driving is in effect. These updates would not make AVs less safe than traditional vehicles but would recognize the innovative opportunities of the autonomous systems in vehicle design and performance. DOT should emphasize performance over design.
- DOT should expand the number and duration of exemptions to FMVSS provided to automakers. DOT may currently only provide exemptions to 2,500 vehicles with a two-year duration. Expanded exemptions would allow a greater number and variety of vehicles to be tested and deployed from a greater number of automakers and other players. More vehicles being tested for a longer duration on public roads would be a boon to R&D, provide DOT and state regulators data required to advance appropriate rulemaking, and put more AVs on the road to showcase safety and other benefits in order to build public support.
- DOT or other government agencies cannot require premarket government testing or approval of each AV model prior to sale. The current system of OEM self-certification for compliance with FMVSS is a distinct advantage for U.S. automobile production and R&D. By contrast, the European Union via the United Nations Economic Commission for Europe (UNECE) Regulations and Japan have adopted a "type approval" process carried out by EU member states and the Japanese government. Maintaining self-certification would provide automakers in the United States a less onerous pathway to testing and deployment. As vehicles become more reliant on software, consistent patching that would invariably impact performance standards would be incompatible with requiring premarket government testing and approval. Self-certification of AVs is necessary to prevent regulatory bottlenecks, which would hamper innovation and commercialization by putting AVs at a regulatory disadvantage compared to traditional vehicles.[47]

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46. National Highway Traffic Safety Administration, Department of Transportation, "Pilot Program for Collaborative Research on Motor Vehicles With High or Full Driving Automation," Federal Register 83, no. 196 (October 10, 2018): 50872, https://www.federalregister.gov/documents/2018/10/10/2018-21919/pilot-program-for-collaborative-research-on-motor-vehicles-with-high-or-full-driving-automation.
47. Maxmillian Agerholzer III et al., *The Autonomous Vehicle Revolution: Fostering Innovation with Smart Regulation*

- OEMs are required to submit and implement cybersecurity protection plans for vehicles sold in the United States.
- A technical advisory committee composed of business, labor, environmental, and consumer groups, as well as academia and state and local government representatives be established to advise future rulemaking on ACE vehicles.

- **Congress should earmark funding for additional Automated Driving System Demonstration Grants.** In 2019, DOT awarded $60 million in federal grant funding to 8 out of 73 applicants—indicating a high level of interest in the grant program.[48] The recipients include universities, state DOTs, and cities. Grant-funded projects will strengthen DOT's ability to gather critical safety data to guide rulemaking and will encourage cooperation among state, local, and private stakeholders. Federal grants provide an avenue for DOT to seed projects in areas not addressed by private R&D. Federal resources set aside exclusively for AV R&D showcase government support for AV technology, R&D, and deployment.

Consumer Acceptance

THE ISSUE:

Consumers tend to believe that AVs are inevitable.[49] However, that does not translate into a desire to surrender control and travel to AVs. Absent demand for next-generation vehicles, R&D will have little payoff. Further, educating drivers about their vehicle's capabilities is necessary to fully reap the benefits of new technology.[50] A 2017 Pew survey found that 56 percent of respondents would not personally want to ride in a driverless vehicle, although 65 percent of people expect to see them on the road in the next 10 to 50 years.[51] The public widely agrees on the need for safety regulations such as human override (87 percent), designated traffic lanes (83 percent), and restricted areas like school zones (69 percent). An April 2018 Gallup poll found that 52 percent of U.S. respondents would never want to use a driverless car and that 78 percent of respondents enjoy driving "a great deal" or "a moderate amount," suggesting that the capabilities of Level 4 AVs are inconsistent with consumer preferences at this point.[52] In a 2019 U.S. online Reuters/Ipsos poll, 64 percent of respondents disagreed with buying a self-driving car, and 67 percent agreed that self-driving cars should be held to higher standards than traditional ones. A July 2014 cross-national study found 69 percent of respondents expect fully automated driving to capture 50 percent market share by 2050.[53] Respondents from developed countries were least comfortable with the potential for vehicles to transmit data.

(Washington, DC: Center for the Study of the Presidency and Congress, 2017), https://www.aamva.org/AutonomousVehRevolution-FosteringSmartRegs/.

48. "Automated Driving System Demonstration Grants," U.S. Department of Transportation, updated September 18, 2019, https://www.transportation.gov/av/grants.

49. John Gramlich, "Americans had concerns about self-driving cars before fatal Arizona accident," Pew Research Center, March 21, 2018, https://www.pewresearch.org/fact-tank/2018/03/21/americans-had-concerns-about-self-driving-cars-before-fatal-arizona-accident/.

50. AAA, "Drivers Rely Too Heavily on New Vehicle Safety Technologies In Spite of Limitations," News release, 2018, https://newsroom.aaa.com/2018/09/drivers-rely-heavily-new-vehicle-safety-technologies/.

51. Ibid., 49.

52. Megan Brenan, "Driverless Cars Are a Tough Sell to Americans," Gallup, May 15, 2018, https://news.gallup.com/poll/234416/driverless-cars-tough-sell-americans.aspx.

53. M. Kyriakidis, R> Happee, and J.C.F. de Winter, "Public opinion on automated driving: Results of an international questionnaire among 5000 respondents," T*ransportation Research Part F: Traffic Psychology and Behaviour 32* (July 2015): 127-140, https://www.sciencedirect.com/science/article/abs/pii/S1369847815000777?via%3Dihub.

A 2019 AAA study provides some insights into how best to acclimate consumers to the idea of AVs.[54] While 71 percent of respondents remain fearful of riding in fully autonomous vehicles, exposure to limited AV capabilities—such as advanced driver assistance programs—reliably improves consumer comfort with driverless technology. Also, the limited application of AVs appeals to a greater portion of respondents, with 53 percent approving of low-speed vehicles, such as airport people movers, and 44 percent approving of courier vehicles being automated.

The 2018 Deloitte Global Automotive Consumer Study suggests that consumers are already getting on board with self-driving vehicles.[55] In 2017, 74 percent of U.S. consumers doubted AV safety; in 2018, that figure plummeted to 47 percent. The study observed the same trend in all countries surveyed. Safety concerns aside, affordability is another major factor affecting consumer preferences regarding AVs. Consumers are generally unwilling to pay significant additional sums for next-gen vehicles; with steady gas prices, four out of five U.S. consumers plan on their next purchase being a traditional gasoline or diesel engine car. This study bears good news for traditional U.S. carmakers with strong brand recognition. 63 percent of U.S. consumers said they would prefer to ride in an AV offered by a trusted brand rather than by a new AV company or an existing tech company.

Cybersecurity and data privacy concerns could also arise as autonomous and connected vehicles move towards commercialization. Consumers may be wary of stepping into an automobile that they suspect could be hacked to dangerous effect. A 2018 Morning Consult poll found that 67 percent of adults surveyed are concerned about cyber threats to AVs.[56] Only 5 percent of adults were not at all concerned, and 15 percent did not have an opinion. Citizens may also be uncomfortable with automakers and technology companies gathering personal data, such as travel patterns. In a separate 2018 poll administered by Solace, 48 percent of respondents were not aware that connected vehicles can store personal identifiable information, compared to 38 percent who were aware and 15 percent who answered, "I don't know."[57]

The inherently networked nature of next generation-vehicles—the need to always be online and maintain connections with nearby vehicles, infrastructure, and passengers' devices—makes cybersecurity vulnerabilities and data privacy questions inevitable. NHTSA and the Federal Trade Commission, the federal agency tasked with protecting consumer privacy and personal data, have ongoing conversations with manufacturers and other stakeholders on consumer data privacy; however, federal guidelines have not been established.[58] On the cybersecurity front, NHTSA promotes a risk-based, "multi-layered approach to cybersecurity by focusing on a vehicle's entry points, both wireless and wired, which could be potentially

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54. AAA, "Three in Four American Remain Afraid of Fully Self-Driving Vehicles," March 14, 2019, News release, https://newsroom.aaa.com/2019/03/americans-fear-self-driving-cars-survey/
55. Craig Giffi et al., "A reality check on advanced vehicle technologies," *Deloitte Insights*, 2017, https://www2.deloitte.com/content/dam/insights/us/articles/4400_a-reality-check-on-advanced-vehicle-technologies/4400_reality-check-advanced-vehicle-technologies.pdf.
56. Morning Consult, "Morning Consult National Tracking Poll #180108, January 11-16, 2018: Crosstabulation Results,"2018, https://morningconsult.com/wp-content/uploads/2018/01/Brands-Full-Results-180108-crosstabs.pdf.
57. "Connected Car Drivers: A Survey on Attitudes, Use and Trust" Solace, 2018, https://solace.com/use-cases/industries/connected-car-survey/.
58. "Vehicle Data Privacy," National Highway Traffic Safety Administration, https://www.nhtsa.gov/technology-innovation/vehicle-data-privacy.

vulnerable to a cyberattack."[59] A layered approach includes rapid detection of on-road cybersecurity incidents, vehicle systems redundancy and resiliency to mitigate the impact of attacks, and intelligence and information sharing within the industry to raise awareness of vulnerabilities and share best practices. It is clear that these issues will have to be addressed if widespread consumer acceptance is to be achieved.

When it comes to electric vehicles (EVs), public perception of EVs remains skewed although it appears to be improving. A 2019 AAA poll reflected poor public knowledge of but strong interest in EVs.[60] 59 percent of respondents remain concerned about EVs' range in stop-and-go or highway traffic. In reality, they perform better than traditional automobiles due to battery charging during deceleration. On the bright side, concerns about charging port availability and price burdens decreased from 2017 levels. Also, only 4 in 10 respondents predicted widespread adoption of EVs by 2029, a striking comparison to more optimistic predictions of AV adoption from other studies.

RECOMMENDATIONS:

- **Government, consumer groups, and private sector stakeholders should collaborate on a broad public education campaign** regarding the safety and other benefits enabled by AVs. Such a campaign should include clear communication of vehicle safety standards for AVs.
- **Industry and government should provide the public across the country opportunities to experience** traveling in AVs through live demonstrations.
- **Cities and other localities should provide clear signage and notification** if AVs can operate on public roads.
- **Businesses should clearly communicate to consumers how personal identifiable consumer data collected** via AV travel will be stored, processed, and handled.

59. "Vehicle Cybersecurity," National Highway Traffic Safety Administration, https://www.nhtsa.gov/technology-innovation/vehicle-cybersecurity.
60. AAA, "Why Aren't Americans Plugging in to Electric Vehicles?" News release, May 9, 2019, https://newsroom.aaa.com/2019/05/why-arent-americans-plugging-in-to-electric-vehicles/.

4 | The Checkered Flag

There are countless advantages in the responsible research, development, and deployment of autonomous, connected, and electric vehicles. From environmental sustainability to reduced vehicle accidents, from less traffic congestion to new accessible mobility options across society, the commercialization of AVs will revolutionize how people commute. Even prior to commercialization, R&D of autonomous systems, vehicle connectivity, and electrification will lead to technological advances applicable beyond the automotive industry. The country that leads in the development of ACE vehicles will capture a key first-mover advantage in commercialization and, in doing so, maintain its position as a hub of automotive and technology innovation and production.

The United States is at the center of the ACE vehicle revolution. No other country possesses the combination of talent and tradition across the range of industries necessary to develop ACE vehicles along with relatively open and friendly investment, trade, and regulatory policies. Those factors enable organic, positive-sum partnerships between and among foreign and domestic auto companies and technology companies necessary to take on the monumental challenges posed by ACE vehicle development and commercialization. The United States' domestic competitive advantages in the ACE vehicle space encourage stakeholders to research, develop, and test technology in the United States with an eye towards commercialization. An open trade and investment policy encourages foreign direct investment in the United States, which has been instrumental in growing the footprint of foreign automakers, parts companies, and technology companies. The foreign footprint in the United States encourages competition and feeds collaboration, generates jobs for U.S. workers, and, in doing so, bolsters a robust innovation ecosystem that benefits foreign and domestic companies and consumers alike. Similarly, access to foreign parts, technology, talent, and capital makes U.S. companies more competitive within the United States and globally.

The United States should build on those advantages, not squander them. Policies that make it more difficult for foreign and domestic companies to utilize the United States' assets—either in cooperation or competition—would dull the U.S. innovative edge in ACE vehicle development. Similarly, policies that provide a leg up to domestic companies at the expense of foreign companies would fracture the innovative ACE vehicle R&D ecosystem that has naturally formed in the United States. Tariffs, broad investment restrictions, onerous export controls, and other policies aimed at protecting U.S. companies from foreign competition will do more damage to the competitiveness of those companies and the North American automotive and technology sectors overall than they will help.

Instead of creating barriers between foreign and domestic companies, the United States should take steps to generate certainty and predictability for all businesses in the U.S. ACE vehicle space. ACE vehicle R&D has already had disruptive effects on many levels, and the eventual commercialization of ACE vehicles promises more disruption across society. The United States should focus on harnessing and guiding that disruption to generate positive outcomes for businesses and consumers. Policymakers should update laws and regulations to accommodate and encourage the responsible development and timely commercialization of ACE vehicles. Businesses and governments should undertake a concerted effort to educate the public on the vast benefits promised by ACE vehicles. Most importantly, the United States should ensure that it is pursuing policies that allow storied automakers and ambitious, cutting-edge technologies to collaborate and compete, regardless of the location of their headquarters. Setting down a path with that vision will ensure the United States continues to lead in ACE vehicle research, development, and commercialization.

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