



Securing America's
Future Energy

Issue Brief

Commission on Autonomous Vehicle Testing and Safety
A project of Securing America's Future Energy

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Letter from the Commission

Alongside many members of industry and the general public, we share a sense of great excitement regarding the advances in mobility that are anticipated over the coming years and decades. Society is standing at the starting line of the era of autonomous vehicles (AVs), which may foster as great a change in society as the invention of the automobile itself. While any time of transition presents challenges, we and many others are excited at the potential for autonomous vehicles to reduce the toll of motor vehicle accidents, increase mobility access for underserved populations, contribute to economic growth opportunities, and expedite the transition away from petroleum fuels in the transportation sector. **Our goal is to promote the safety of the American public by recommending best practices for AV technology testing and early deployment.**

We are not naïve or overly sanguine about the challenges of AV deployment. There will inevitably be setbacks and challenges on the road to widespread adoption. We have formed as a group to anticipate the challenges between now and when the technology is broadly embraced and available. Our background is diverse—we are five individuals with broad experience in assuring the critical safety of complex systems, not just in the automotive sector, but in aviation and the nuclear industry as well. Our goal is to minimize complications in AV testing and deployment and encourage dialogue within industry to hasten the journey to acceptance and societal benefit.

The rapid emergence of a new technology that represents a discontinuity with the current automotive products stresses our society's existing safety institutions and trust in automotive technology. In particular, the committee has identified a risk that society will be slow to accept the new technology, and that our regulatory systems will not evolve in concert with the pace of innovation. **At such a juncture, the role of industry is crucial in providing leadership for society and government.**

We see our role as facilitating industry leadership during the next crucial years by creating a road map of key issues that must be addressed. Our aim is promote a focused dialogue amongst developers of AV technology that attempts to preempt public concerns and more effectively address inevitable regulatory questions.

This report should be seen as the beginning of such a dialogue. We have outlined thoughts to foster industry action, and we welcome further engagement opportunities to go into greater depth on the critical issues we are presenting.

Finally, we would like to thank Robbie Diamond and the staff of Securing America's Future Energy (SAFE) for sponsoring and facilitating our work.

Major General, USAF (ret.), Mark Rosenker, Chairman
Admiral, USN (ret.), Dennis Blair
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Commission on Autonomous Vehicle Testing and Safety

Mission Statement

The development of autonomous vehicle technology serves the public interest. However, risks to the public during the maturation of the technology must be closely managed. Based on extensive study and experience, the Commission on Autonomous Vehicle Testing and Safety presents the following best practices for industry and other parties for the early deployment of autonomous vehicles in real-world conditions.

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Introduction

Autonomous Vehicles

This report comes during a period of the most rapid change in automotive technology since the invention of the internal combustion engine. Autonomous vehicles (AV) technology “is essentially here” and industry is preparing for deployment of these vehicles in the next several years.¹ The recent progression of AVs from concept to deployment has taken the public—and many in the industry—by surprise, and there is concern that a clear road map does not yet exist for how the technology will develop and deploy.²

A Note on AV Levels

Automated vehicle technologies exist on a spectrum. The primary focus of this report are autonomous vehicle technologies defined by the Society of Automotive Engineers (SAE) standard as Level 3-5; vehicles with this level of technology been designated by the federal government as Highly Automated Vehicles (HAVs). There is a particular focus on a technology deployment pathway which culminates in automation that is not predicated on the presence of a backup driver, reflecting the ambitions of many (but not all) developers to achieve at least level 4 automation. A primer on the SAE levels can be found here: https://www.sae.org/misc/pdfs/automated_driving.pdf

This report makes recommendations on several public policy and safety issues that have the potential to slow or halt the deployment of AVs. The objective is to identify safe and clear pathways for our society to move from today’s diverse and individual AV testing and deployment activities along a well understood, documented and publicly supported development trajectory, which will foster widespread acceptance and adoption of commercially available technology.

AVs have many exciting and potentially transformative advantages, including enhanced mobility for the elderly and handicapped, improvements in the speed and efficiency of transportation, and meaningful reduction in oil use in the transportation sector. But perhaps the greatest immediate benefit to society is dramatic improvements in motor vehicle safety. Vehicles have become incrementally safer since the 1960s through invention, development, and deployment of improved collision avoidance and injury mitigation technologies (see Figure 1). However, these developments have not eliminated the root cause of 94% of motor vehicle collisions—driver error. Autonomous vehicles have the promise to eliminate the observational errors made by drivers who are distracted, incapacitated, inattentive, or who make erroneous judgments that lead to collisions and often fatalities.

¹ Alex Davies, “Obama: The Feds Must Guarantee Self-Driving Cars Work for Everybody,” *Wired*, October 12, 2016.

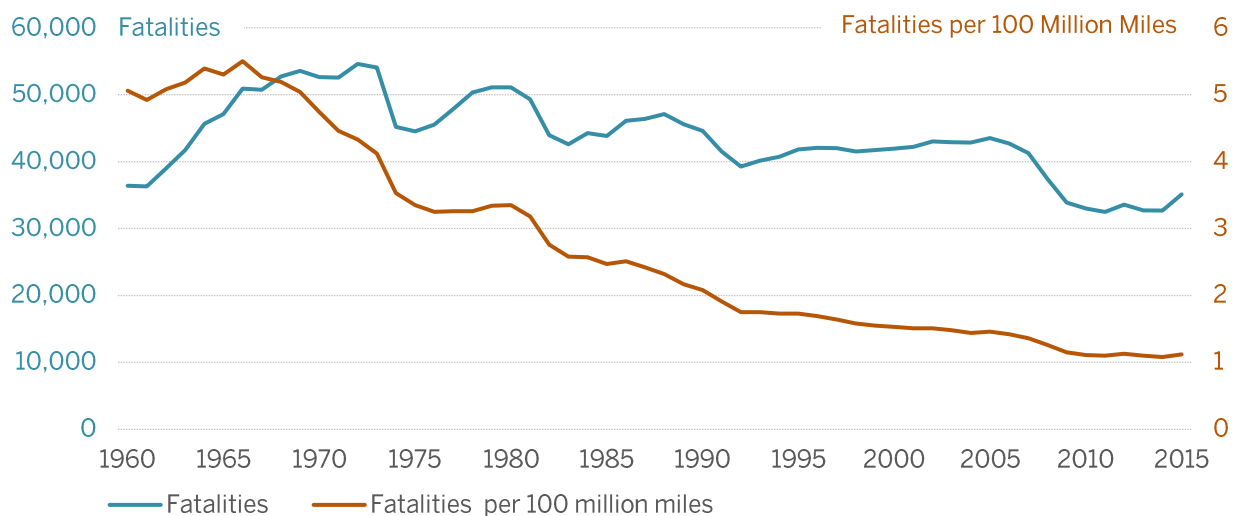
² European Road Transport Research Advisory Council (ERTRAC), *Automated Driving Roadmap*, July 7, 2015.

Despite this, the public has expressed instinctive and reasonable safety concerns about turning over control of a vehicle to a computer. Motorists and passengers must be convinced by demonstrations, data, and personal experience that AVs are safer than human drivers. The recommendations in this report provide a path for AV developers and government regulators towards earning this critical public confidence and support.

Safety Progress

In recent decades, automotive safety has generally improved and fatalities have trended steadily downward with the number of roadway deaths declining by almost 50%—though the last two years have seen a sharp reversal of this overall positive trend.³ Despite the overall positive momentum, the human toll of vehicle collision remains high. In 2015, 35,092 people lost their lives on U.S. roadways, with an estimated 2.44 million injured in 6.3 million reported crashes. Drunk driving is a factor in 41% of crashes, distraction in 10%, and fatigue in 2.5%. Importantly, each of these driver failures can be addressed in AV controls.⁴ The commercialization of AV technology and, eventually, fully autonomous vehicles promises to reduce collisions and mitigate human error, potentially saving countless lives.

FIGURE 1 · U.S. Road Fatality Rate, 1960 - 2015



Source: U.S. Department of Transportation

Technological and Regulatory Progress

The private sector is committing vast resources to the development of AV technologies, and the activities of non-traditional companies like Tesla, Google and Apple and various smaller entrepreneurs have received considerable publicity. Traditional automobile manufacturers are actively developing AVs, although some of these players envision a slower, more

³ NHTSA, "Traffic Safety Facts Research Note - 2015 Motor Vehicle Crashes: Overview," August 2016.

⁴ Nidhi Kalra, "Testimony: Shaping the Future of Autonomous Vehicles," Rand Corporation, November 16, 2016.

iterative deployment. A focus on autonomous technology is growing in the trucking sector, where business models and safety considerations may contribute to a more rapid uptake.^{5 6}

Federal and state governments have stepped up regulatory activities in response. At present, nine states have enacted legislation related to autonomous vehicles and the governors of two others have issued executive orders. Dozens of other states are considering but have not yet adopted such legislation.⁷ The federal government has taken several steps in the area, most notably releasing the Federal Automated Vehicle Policy on September 20, 2016.⁸ Industry and observers have applauded the positive signal sent by federal endorsement of AV technology, but have also criticized some areas of the policy.⁹

The private sector deserves credit for the tremendous progress it has made on the development of AV technology. Twenty companies have met the requirements to test AVs on California's roads, and millions of miles have already been driven in California and other states. Numerous early deployment projects are ongoing elsewhere in the U.S. and across the globe, some in which members of the public are allowed to ride in AVs as passengers.¹⁰

Potential Obstacles

The critical threats to the deployment of autonomous vehicles are public acceptance risk and regulatory risk.¹¹

Public Acceptance Risk: It is expected that once a certain technological threshold is met, autonomous vehicles will be safer than human drivers. However, it is impossible to eliminate all accidents. As we have seen so far with crashes involving autonomous and semi-autonomous vehicles, the publicity from individual crashes can outweigh the impact of dry statistics on public opinion concerning safety and reliability, especially when there is a fatality. The Commission is concerned whether public support for AVs, which public opinion polls show is currently mixed, can survive the inevitable negative attention that will stem from early accidents as the technology continues to improve.

A survey in mid-2016 showed that just 32% of Americans believe autonomous vehicles will improve their driving experience, while almost 50% believe the opposite. Only 35% believe that autonomy will increase safety; older respondents expressed even greater levels of skepticism. Another poll found that a majority believed that cars should always require a driver.¹² A survey conducted by AAA (March 2016) found that 75% of individuals report feeling "afraid" to ride in an autonomous vehicle.¹³ While some have found greater

⁵ Transport Topics, "ATA President Chris Spear: Autonomous Trucks Will Continue to Need Drivers," December 6, 2016.

⁶ The findings of this report apply to automation in all vehicle segments including trucking, but some of the unique aspects of both the technology and business model in the commercial and off-road sectors would benefit from additional attention that is beyond the scope of the current report.

⁷ National Conference of State Legislatures, "Autonomous - Self-Driving Vehicles Legislation," November 11, 2016.

⁸ Department of Transportation, "Federal Automated Vehicles Policy," Anthony Foxx, November 22, 2016.

⁹ Numerous submissions to NHTSA docket on AV policy: https://www.regulations.gov/document?D=NHTSA_FRDOC_0001-1693

¹⁰ State of California Department of Motor Vehicles, "Testing of Autonomous Vehicles," December 8, 2016.

¹¹ AT121: The Alliance for Transportation Innovation, "A NATIONAL STRATEGIC FRAMEWORK TO ADVANCE LIFE-SAVING SELF-DRIVING VEHICLES," 2016.

¹² Matt Piotrowski, "It's Not Yet Clear How Americans Feel About Driverless Cars," The Fuse, October 13, 2016.

¹³ Erin Stepp, "Three-Quarters of Americans 'Afraid' to Ride in a Self-Driving Vehicle," AAA, March 1, 2016.

enthusiasm,¹⁴ public opinion could quickly turn against this important innovation, despite its tremendous potential to improve roadway safety.

Additionally, according to independent polling and experience, there is considerable confusion about AV technology on the part of the public and a lack of confidence that developers and regulators will safely deliver and manage AV technology.

Regulatory Risk: Regulation of emerging technology is always challenging, but autonomous vehicles face two exceptional obstacles. The first is that vehicles are regulated by a complex network of national, state, and local laws. The second is that AVs function based on highly sophisticated computer algorithms, or software. These technologies stress current regulatory frameworks, which are designed to test and approve more limited safety technologies such as seatbelts, airbags, or basic collision warning systems. The broad deployment of AVs will depend on finding new approaches to the verification and certification of safety.

Safety assurance will present a challenge to regulators and create a major roadblock in the regulatory process. Manufacturers must not only achieve an acceptable level of safety, but also convince regulators, users, and the public at large.

Role of the Commission

In many ways, the goals of minimizing public opposition and regulatory risk are synergistic. It is the Commission's view that an ongoing industry dialogue on the best ways to benchmark, measure, and improve safety will ultimately promote public acceptance of AV technologies.

Additionally, the novelty of AV technology means there is a significant asymmetry of knowledge among regulators, industry, and the general public. As the party responsible for building the technology, industry is ultimately accountable for educating regulators and customers on the state of the technology, and the steps being taken to ensure it is deployed in a safe and responsible fashion.

Contributing to the complexity of this challenge are the high levels of proprietary information involved in developing AV systems and current level of fragmentation of the industry. According to the financial research company CB Insights, there were 33 companies working on self-driving cars as of August 2016.¹⁵ These companies are engaged in intense competition with one another, but without cooperation in helping formulate a progressive, pro-innovation regulatory framework, consumer demand for AV products may be slowed and/or minimized.

We urge AV providers and researchers to reach agreement and ultimately coalesce around common standards, metrics, and commitments to specific safety protocols in advance of widespread commercialization, as it is during the current nascent development period that the technology is most at risk.

¹⁴ Ashley Halsey and Michael Laris, "Are you ready to try a driverless car? 70 percent of Americans say yes," Washington Post, October 6, 2016.

¹⁵ CB Insights, "33 Corporations Working On Autonomous Vehicles," CB Insights Blog, August 11, 2016.

Summary of Recommendations

This report is divided into two sections. The first set of recommendations are centered on creating transparent processes to increase public confidence in AV development, testing, and early deployment. The second set of recommendations establish a pre-regulatory agenda that we believe would be beneficial for industry to adopt and promote.

Part I. **Assuring Public Confidence**

1. The Commission recommends that AV providers move to on road testing and deployment only once confident that the vehicle's performance is as safe as the average human driver, accounting for backup drivers, speed restrictions, geofencing and other safety measures.
2. The Commission encourages AV providers to create safety milestones for AV development. The Commission further encourages public disclosure of achieved milestones and accompanying validation.
3. The Commission encourages developers to deploy redundant layers of technology to increase safety beyond any minimum required standard.
4. The Commission encourages developers to clearly define and effectively communicate autonomous features, including their limitations.

Part II. **Steps Toward an Industry-Driven Regulatory Framework**

5. The Commission encourages AV providers to formally collaborate through a technical data consortium to accelerate AV learning and safety through shared, anonymized information.
6. The Commission recommends that industry formulate objective, practical, quantitative metrics for measuring AV safety.
7. The Commission recommends that any future framework for regulating AVs rest on a modern foundation reflecting the advanced software-driven nature of vehicle automation.

Part I: Assuring Public Confidence

Recommendation: The Commission recommends that AV providers move to on road testing and deployment only once confident that the vehicle's performance is as safe as the average human driver, accounting for backup drivers, speed restrictions, geofencing and other safety measures.

There should be a minimum safety performance benchmark before AVs operate on public roads for testing or early deployment purposes. The Commission recommends the safety benchmark be set at the level of an average human driver. Exceeding this level of performance would represent a net benefit to society. Importantly, such a standard for AVs represents a public commitment to ensuring a reasonable level of safety performance during development stages, which will help foster public acceptance.

The average human driver is far from perfect, as seen through the incident rates below in Figure 1. Society already allows young drivers behind the wheel even though teen drivers ages 16 to 19 are nearly three times more likely than drivers aged 20 and older to be involved in a fatal crash.¹⁶ Similarly, it is reasonable that AV performance be evaluated within the context of current road safety. Holding this new technology to an unreasonable standard may delay deployment, mass adoption, and the resultant safety benefits.

FIGURE 1 · Fatality, Injury, Property Damage, and Collision Data, 2015

Occurrence	Frequency (2015)	Miles Between Incidents
Fatal Crash	1.02 per 100 million miles	97 million
Injury-causing crash	55 per 100 million miles	1.8 million
All reported collisions	201 per 100 million miles	500,000
Any collision (including estimated unreported)	~400-500 per 100 million miles	~200,000

Note: Figures describe how common crashes of a particular severity are. We counted a single crash with multiple casualties as a single event.
Source: NHTSA, *2015 Motor Vehicle Crashes: Overview, August 2016*.

Determining whether a given AV meets the benchmark will require the formation of metrics to measure its performance level. A broader discussion on the creation of necessary metrics is addressed later in Recommendation 6.

Additionally, a single, high-level benchmark for AVs may be insufficient to determine whether a given AV system meets the benchmark. AVs are likely to operate in multiple driving domains.¹⁷ A domain is a set of driving conditions, including weather, road type, and time of day. For example, urban driving and freeway driving represent distinct domains. A

¹⁶ Center for Disease Control, "Injury Prevention & Control: Motor Vehicle Safety."

¹⁷ Note: This is similar to the concept of an operational design domain (ODD) outlined in NHTSA's *Federal Automated Vehicles Policy*.

separate benchmark may be required for trucks and other heavy duty applications with their distinct risk and accident profiles.¹⁸

While setting the safety benchmark should be the product of a broader conversation, the Commission suggests that AVs should meet the safety performance of the average human driver in any domain in which it operates. This will require: 1) defining a set of domains, and 2) benchmarking human performance in each domain.

Defining a set of domains will be challenging. The number of driving domains should be limited, as having too many segmentations will make it impossible to gather meaningful or useful data in each domain. However, too few segmentations will make it difficult for providers to meaningfully assess AV performance. While identifying a full spectrum of domains for driving is beyond the scope of this paper, as an illustration, Figures 2 and 3 below show the apportionment of 2015 fatal crashes by road type and weather condition. Building on these figures will require collecting and analyzing the necessary data to segment driving domains and define a safety benchmark in each.

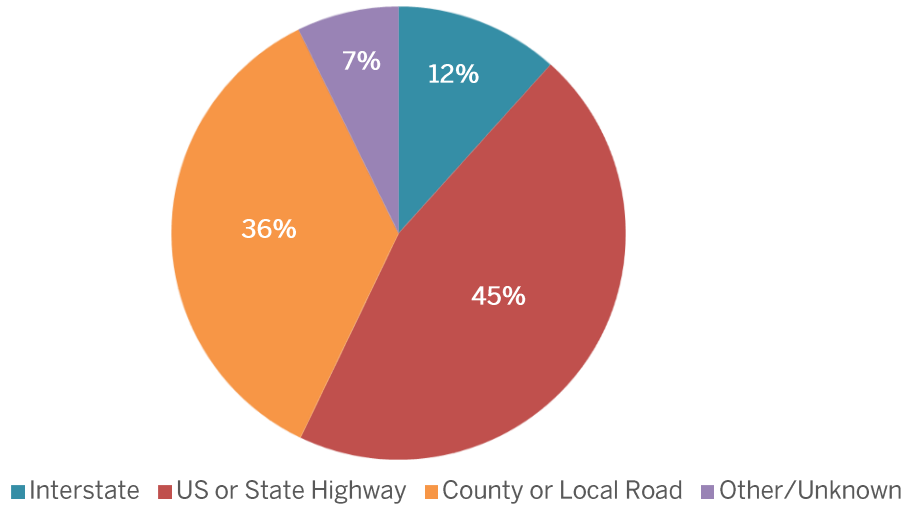
After consideration, the Commission chose not to distinguish between AV testing and early deployment. To operate on a public road, whether it is a test model or commercially available vehicle, an AV should meet the benchmark. During early stage testing, safety may be provided by backup drivers or other safety measures such as geofencing, speed limitations, etc. However, it should be understood that the presence of a backup driver does not mean that the benchmark is met—as a backup driver, even if properly trained, cannot necessarily compensate for immature AV technology. As AVs mature and more providers experiment with members of the public as passengers in an AV, deployment will likely progress on a continuum where developers slowly increase public exposure while gradually increasing autonomous operation.

The Commission also urges AV providers to keep relevant regulatory bodies apprised of their progress and intention to test or deploy AVs on public roads. This is consistent with NHTSA's *Federal Automated Vehicles Policy*, which requests 4 months advance notice before active public road testing begins on a new automated feature.¹⁹ Ideally, state and local authorities should be engaged and kept abreast of provider intentions in order to facilitate local acceptance.

¹⁸ IIHS Highway Loss Data Institute, "Large trucks."

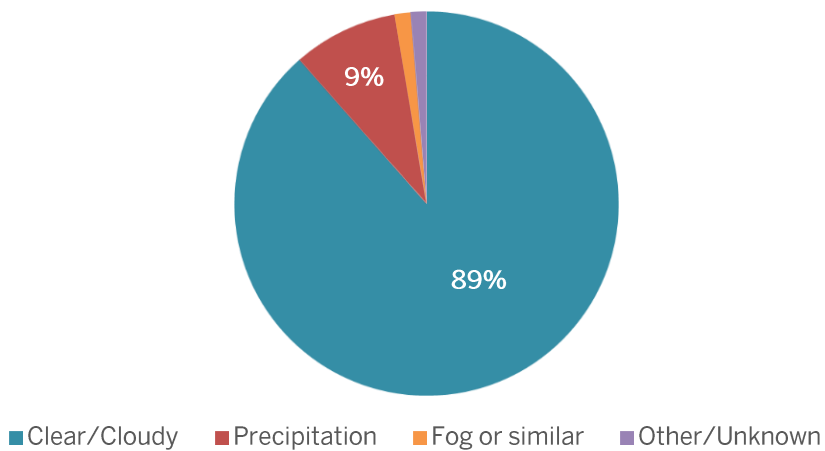
¹⁹ NHTSA, *Federal Automated Vehicles Policy*, September 2016, at 16.

FIGURE 2 · Road Fatality Distribution by Road Type, 2015



Source: U.S. Department of Transportation

FIGURE 3 · Road Fatality Distribution by Weather Conditions, 2015



Source: U.S. Department of Transportation

Recommendation: The Commission encourages AV providers to create safety milestones for AV development. The Commission further encourages public disclosure of achieved milestones and accompanying validation.

Many AV providers have already begun active testing in the United States on public roads. In California alone, at least twenty different companies have procured licenses to test vehicles or AV systems.²⁰ Each provider is employing a proprietary approach towards not only the technology that is being installed into the vehicle, but how they are preparing the vehicles for testing and early deployment. Some providers are testing mainly on freeways (especially in trucking applications), others in urban areas, and others still on dedicated or

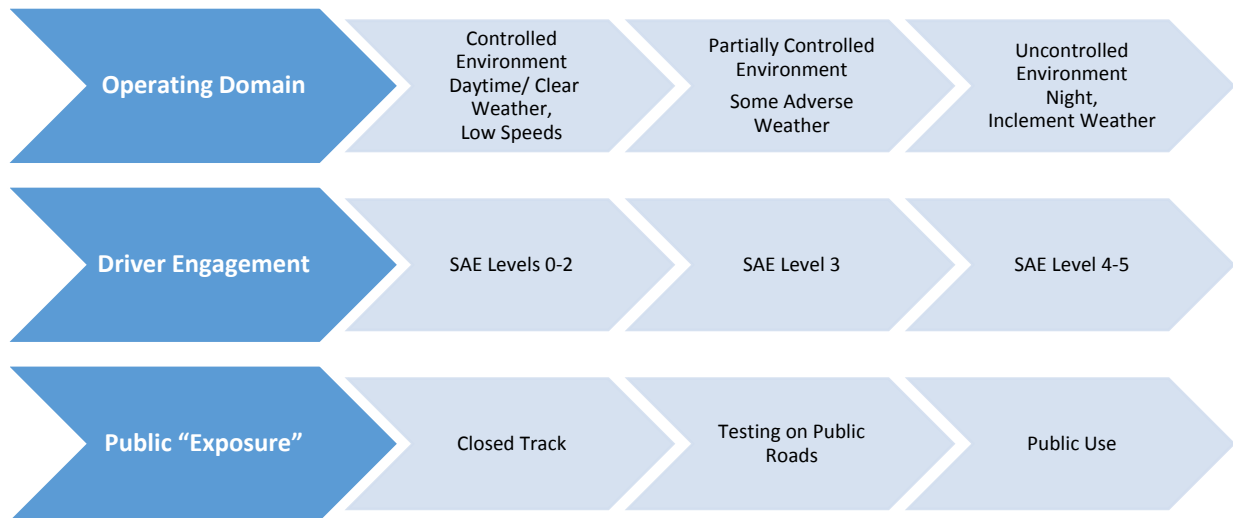
²⁰ See, e.g., Megan Guess, "Automakers balk at California's proposed self-driving car rules," ars Technica, October 20, 2016.

fixed routes using only low-speed vehicles. Some AV testing activity consists of deploying Advanced Driver Assistance (ADAS) features on existing vehicle platforms already available for sale to the public, while others are testing fully autonomous vehicles on test tracks with no public exposure.

In short, the term “AV testing” can refer to a very broad range of activity. This creates some confusion among the general public, which may not differentiate between testing activities. The public may conflate setbacks that occur with certain types of higher risk or advanced AV activities with a negative outlook for the entire AV enterprise.

The Commission suggests the development of a hierarchical system to classify AV testing and development. This would work, for example, with providers testing limited functionalities, only on test tracks, with backup drivers, or in well-defined geo-fenced areas. Over time, providers would increase the scope of autonomous activity, test or deploy in a broader area, or begin to operate with fewer backup or redundant safety measures (e.g. no backup driver). This would culminate in the deployment of autonomous features on publicly available vehicles. The Commission encourages each AV provider to create a roadmap for progressing from their current state of AV testing to significant public deployment. An illustrative example of such a roadmap can be found below in Figure 4.

FIGURE 4 · Example Safety Milestones for Selected Criteria



The Commission recommends each AV provider establish “safety milestones” on their roadmaps. For example, a milestone may represent moving from a controlled and closed-track testing environment to a geo-fenced area on public roads, or expanding a geo-fenced area. Another example of a milestone would be when a company removes a backup driver from the vehicle. This format logically suggests, for example, that when a provider wishes to add new functionality to an AV, it should first test this functionality on a test track. The number of milestones, and method in which achievement of a milestone is validated would be internally determined by each AV provider. Progression to the next milestone should only proceed once a reasonable level of safety assurance has been reached.

Developers may wish to formulate milestone plans internally to protect confidential business information. The Commission wishes to highlight the benefits of a more transparent approach. After a milestone is achieved, the Commission suggests information sharing among developers to advance the industry's safety accomplishments and, by extension, boost public confidence. Additionally, a transparent dialogue—or a semi-public conversation partially shielded through a consortium—can drive standardization of safety milestones.

A major positive impact of publicizing some aspects of this safety roadmap is that it could help the public differentiate between the many types of AVs (e.g. low-speed shuttle vs. Level 3 functionality for an existing vehicle) and will not conflate negative incidents that are only relevant to one technology category. It will also communicate to the public that developers are proceeding deliberately and in a logical, ordered fashion.

Recommendation: The Commission encourages developers to deploy redundant layers of technology to increase safety beyond any minimum required standard.

Safety is the single most important consideration during the early days of autonomous vehicle testing and deployment, not only to protect the public, but also to prevent backlash or regulatory overreaction in response to crashes or other incidents. The Commission is confident that AVs will ultimately have a very positive impact on improving the overall safety of U.S. roadways, thus it is essential that early negative incidents do not derail AV deployment and delay the tremendous benefits that stand to be gained through widespread adoption of this technology. Therefore, the Commission recommends that AV providers and regulators work to ensure that a broad range of backup safety technologies are available and readily deployed on AVs. Redundant technology should be installed wherever possible across the technology stack, including on sensors, actuators, code, and communication features. Public education campaigns that explain the use of redundant safety technologies can also help reassure consumers who are concerned about the reliability of AVs.

The coming decades are likely to see a mixed fleet, in which autonomous or semi-autonomous vehicles mingle on roadways alongside vehicles without these features. To maintain safety when sharing the road with less predictable human drivers, the Commission specifically recommends that AVs include redundant systems for essential driving tasks to protect against failure. This may require additional sensors, communication channels, and braking or steering mechanisms. Redundancy should preserve the vehicle's ability to navigate safely or effectively in the event of a partial system failure—even if only with limited functionality.²¹

External connectivity is another potential source of safety redundancy. While other connected safety technologies exist and are expected to be developed for commercial use, the most prominent example of a supplemental status monitoring mechanism is vehicle-to-vehicle (V2V) communication. V2V communication "use(s) on-board dedicated short-range radio communication (DSRC) devices to transmit messages about a vehicle's location, speed, heading, control status, and other information to other vehicles and receive the

²¹ The Brake Report, "The Future of Autonomous Vehicles and Redundancy," February 24, 2016

same information from the vehicles within the local area network.”²² The possibility also exists for further developing vehicle-to-everything (V2X) communication to ensure that an AV is able to talk to infrastructure, pedestrians with cell phones, or dedicated safety transceivers. Other technologies that do not depend on DSRC are possible as well. The Commission encourages regulators to enable rather than hinder these technologies to abet the safe deployment of AVs in the near future.

Recommendation: The Commission encourages developers to clearly define and effectively communicate autonomous features, including their limitations.

The pace of AV development is increasing. NHTSA recently adopted the Society of Automotive Engineers’ (SAE) definitions for AVs, which divides all vehicles into six levels of autonomy based on functionality.

Adopting standardized definitions is an important first step in improving public understanding of AVs, but much work remains to be done. Marketing efforts by AV providers can play a role, although companies advertising driver-assist features may have, on occasion, inadvertently created misperceptions about the state of the technology. Imperfect understanding of AV technology by early adopters presents safety risks to both users of the vehicles and members of the general public.

The Commission believes it necessary for industry to provide comprehensive use instructions, appropriate training materials, and adequate notice to users regarding the limitations of all autonomous or semi-autonomous features and systems. These instructions should be made available to all appropriate regulators as well as the user community. AV providers should implement a mechanism, perhaps through a user agreement, by which the user community acknowledges they have received and understand these instructions before use.

The mechanism for communicating instructions and information on capabilities and limitations of autonomous systems will need to vary based on future consumer interaction with AVs. Whether autonomous features are purchased at a dealership point, installed through wireless over-the-air (OTA) updates,²³ or experienced through a carsharing or ridesharing platform, AV providers should use appropriate measures to verify that critical information reaches the consumer.

Industry has already found that explaining and marketing such a complex technology has contributed to confusion among users and has the potential to adversely impact safety. For example, Tesla has faced scrutiny in both the United States and China over the use of the term “Autopilot” following highly-publicized collisions in both countries.²⁴ Mercedes-Benz withdrew an advertisement introducing its E-class Sedan as “a self-driving car” following complaints by consumer groups.²⁵

²² NHTSA, “Vehicle-to-Vehicle Communications: Readiness of V2V Technology for Application,” August 2014, at xiv.

²³ Note: For the foreseeable future, the dealer network will play a key role in educating consumers about their vehicle’s capabilities. The Commission does not address the role of dealerships because the scope of the report ends before the stage of broad deployment—when the role of the dealer in educating consumers is likely to become significant.

²⁴ See, e.g., Associated Press, “Tesla’s autopilot system under scrutiny in fatal China crash,” Fox News, September 15, 2016.

²⁵ See, e.g., “Pete Bigelow, “Mercedes-Benz Pulls E-class Ad over Autonomous Confusion,” Car and Driver, July 29, 2016.

Marketing campaigns alone may never fully convey the meaning and significance of SAE levels to the public, but it will be imperative that users or passengers in AVs understand what their vehicle can and cannot do.

Part II: Steps Toward an Industry-Driven Regulatory Framework

The Commission is concerned that an unfavorable regulatory environment will be created if AV providers fail to lead in either informing regulators of developments, or implementing the structures and mechanisms necessary for safety assurance. In this section, the Commission presents a voluntary agenda that can be executed by industry. The agenda will not only lead to more rapid learning and safer AVs over the long term, but will lay the groundwork for a mature regulatory framework that would be more likely to facilitate AV deployment and acceptance.

Recommendation: The Commission encourages AV providers to formally collaborate through a technical data consortium to accelerate AV learning and safety through shared, anonymized information.

Emerging technologies present challenges for regulators because of information asymmetry—meaning that while the private sector fully understands the implications and limitations of the technology it is producing, regulators may have a less complete picture. When an emerging technology is safety-critical it is imperative for industry to proactively formalize safety assurance strategies, not just for the sake of the public, but also to protect the nascent technology against regulations that, while well-intentioned, do not reflect a complete understanding of the technology.

The fragmentation of the AV industry augments this challenge, with many companies working in largely parallel efforts to develop the technology with minimal information sharing or coordination, fearing that cooperation risks a loss of competitive advantage. The early stage of development means, inevitably, that the lack of sharing will lead to companies spending considerable effort and resources in duplicative efforts. To the extent that open information can accelerate safety without compromising trade secrets, sharing of key scenarios and anonymized sensor data should proceed on an opt-in basis.

Shared, anonymized information could rapidly advance development of the technology using a key advantage available to the AV industry—the capability for developers to utilize vast amounts of data for “fleet learning.” For example, any experience gained from one vehicle can be applied across the entire fleet through small changes in algorithms or software code.

Similarly, “stress testing” of core AV software offers the promise of partially validating a system’s performance and identifying weak spots, potential flaws, or unintended consequences before testing or broad deployment on public roads. In “stress testing,” developers can directly evaluate their software in any environment or domain, and in any specific or challenging scenario. Such tests enable developers to confirm the software reacts correctly to the stress condition and to any potential threats.

The potential benefits of implementing collaborative software at the core of AV safety development cannot be overstated. However, given the enormous financial stakes,

companies are expected to consider any data collected from their AV systems proprietary, and resist sharing data that may even slightly degrade their individual short-term competitive advantage.

We recognize the importance of encouraging companies to expend resources for autonomous technology development, as well as the role of preserving intellectual property and trade secrets in incentivizing investment. At the same time, having many different companies working on the same technological ground, making the same mistakes, and not coordinating on standards is a clear impediment to the broader advancement of the technology. Accordingly, we note the recent proposal to reward companies that share information in the public interest.²⁶

Consortium opportunities include: 1) Accelerating safety learning by making actionable AV test data more broadly available to participants, 2) minimizing standards incompatibilities and enabling participants to self-analyze and validate their own platforms, 3) increasing pre-competitive research, and 4) advancing safety assurance through AV software simulation. Formation of more than one consortium may be necessary. Taking these steps will allow developers to better assure the safety of their own products, and understand the relative safety of their system against industry benchmarks.

There is precedent in other industries for the establishment of similar consortia. Examples include the auto industry, which has formed the Automotive Information Sharing and Analysis Center (Auto-ISAC) to respond to cybersecurity threats. In addition to other prominent ISACs,²⁷ the Institute for Nuclear Power Operations (INPO) serves as a model. The INPO is funded by industry to “establish performance objectives, criteria and guidelines... and provide assistance to help nuclear power plants continually improve their performance.”²⁸

Ultimately, industry must decide the mechanics and extent of information sharing. However, broad industry participation in any consortium or other collaborative mechanism is likely to increase prospects for success among all participants. Ideally, leadership should be independent and possess the necessary technical expertise and experience to execute the mission. Institutional models could resemble the Collision Avoidance Metrics partnership (CAPM), the National Safety Council, the Air Bag and Seat Belt Safety Campaign, the American Coalition for Traffic Safety (ACTS), and the Transportation Research Board.

We anticipate Congress will monitor developments in this area, and could charter such a consortium as an expression of public policy intent and influence.

Recommendation: The Commission recommends that industry formulate objective, practical, quantitative metrics for measuring AV safety.

²⁶ Paul Brubaker, “Statement before the Subcommittee on Transportation, Housing and Related Agencies, Committee on Appropriations,” 2016.

²⁷ Information Sharing and Analysis Organizations, “Information Sharing Groups,” 2016.

²⁸ Institute of Nuclear Power Operations, “About Us,” 2015.

Federal Motor Vehicle Safety Standards (FMVSS) are the regulations specifying design, construction, performance, and durability requirement of American vehicles and their safety components. Currently, automakers must self-certify that their vehicles are FMVSS compliant. In the case of AVs, safety will be tied to the performance and robustness of the underlying software, which is not yet addressed by the FMVSS. Additionally, the key enabling technology for AVs will be software-based and dynamic, which presents a challenge in regulating them using descriptive standards such as the FMVSS.

The Commission places great importance on developing the capability to quantitatively assess the safety of an autonomous vehicle. However, this task presents several challenges for developers and regulators, and many outstanding questions remain. The first is how best to quantify the robustness of the software to system failures or attack, whether from incorrect decision making, software crashes, or hacking. As explained earlier, serious collisions are rare events for an individual vehicle, and fatal collisions are rarer still. Because of these low accident rates, some claim that AVs must drive for billions of miles without negative incident to robustly prove a level of safety greater than the average human driver.²⁹ To avoid this impossible standard, there must be other internal metrics for developers to understand when their technology has proven sufficiently reliable to justify release and possible commercialization. Metrics must be generalizable enough to be capable of assessing the broad range of AV functionality that will develop (e.g. highway driving, urban driving, trucking). As an example, the FAA has recently increased efforts to harmonize operating metrics and data across aviation segments to allow individual operators to benchmark performance across the industry.³⁰

As an illustrative experience, California required that AVs tested on its roads report miles between “disengagements,” which is defined as when a human driver must manually take over the car because of safety concerns. While capturing some information about the state of autonomous technology, the broad definition of “disengagements” limited its utility as a metric, as it allows companies to choose and report different interpretations. Additionally, variations in the disengagement rate are driven by factors aside from the maturity of the autonomous technology, such as the choice of testing conditions and whether the autonomous vehicle is learning new operational maneuvers. Disengagements do not necessarily mean that the AV would have crashed had the safety driver not taken over, and developers may seek to “game” the disengagement statistic by altering the threshold for when a backup driver would resume control. For these reasons, the “disengagement” metric is inadequate to measure AV safety performance, and the formation of a more robust metric ranks as one of the most important R&D tasks to advance AV safety.

An independent industry based group, perhaps building upon the work accomplished by the consortium proposed in recommendation 5, could be commissioned to formulate objective metrics. Other key resources will include research entities such as the DOT’s Volpe Center and associated University Technology Centers.

²⁹ Nidhi Kalra and Susan M. Paddock, “How Many Miles of Driving Would It Take to Demonstrate Autonomous Vehicle Reliability?,” 2016.

³⁰ FAA, “Operational Metrics.”

Recommendation: The Commission recommends that any future framework for regulating AVs rest on a modern foundation reflecting the advanced software-driven nature of vehicle automation.

The recently issued Federal Automated Vehicle Policy Guidance states that “if a vehicle is compliant within the existing FMVSS [Federal Motor Vehicle Safety Standards] regulatory framework and maintains a conventional vehicle design, there is currently no specific federal legal barrier to an HAV [autonomous vehicle] being offered for sale.”³¹ This statement underscores the entirely new task of regulating AVs.

Vehicle regulators face a certain Catch-22 in that by the time a new technology is ready to be standardized, it has often already achieved significant market penetration. This phenomenon is illustrated by a 2011 NHTSA decision to issue a standard requiring curtain airbags to be installed in all new vehicles—at the point that this regulation was created, the devices were already present in 91% of new vehicles.³²

The challenge of regulating immature technologies stems from the fact that specifications and design only stabilize as a technology matures. AV technology is rapidly changing, and advanced artificial intelligence systems that are relatively immature are now playing a large role in AV development. Technological advancements such as these also represent a workforce issue. Regulatory bodies and compliance teams will need considerably more input from experts in artificial intelligence, robotics, and other skills that have not traditionally been important subject matters for automotive regulation. Therefore, the challenges that already exist with airbags and other preventative safety measures will be magnified ten-fold as they apply to autonomous vehicle technology.

Several states have attempted to quantify performance standards for AVs and establish a methodology for testing them. As mentioned previously, many of these efforts have been flawed. The fundamental difference in technological approaches employed by different AV teams, sensor suites, aspirational levels of automation, and areas where automation is being pursued all present a challenge to a unifying and objective regulatory scheme. We believe that industry may be the only actor capable of developing the tools and data sets that will prove necessary for AV regulation.

In the case of AVs, innovation does not stand in opposition to safety; innovation is necessary to provide a realizable level of safety. Regulators will have an important role as a watchdog: while we believe that such occurrences will be rare, it is the role of government to be vigilant against the irresponsible deployment of AVs. However, a balance must be struck, as the imposition of high barriers to entry could delay AVs and ultimately harm the public interest. As such, we recommend that governments retain a flexible framework to allow for these technologies to mature and contribute to public safety.

³¹ NHTSA, “Federal Automated Vehicle Policy,” 2016.

³² Stephen Zoepf, “Automotive Features: Mass Impact and Deployment Characterization,” Massachusetts Institute of Technology, May 13, 2011.

Conclusion

The surface transportation system in the United States is the largest and most dynamic in the world, serving as a pillar of the nation's economy. However, the system in its current form is not without costs. As we've watched a digital revolution transform our society and give rise to the seamless flow of information in ways that have upended our way of life, the fundamentals of our transportation system have remained unchanged since the middle of the 20th century—the physical movement of people and goods remains slow, dangerous, frustrating, inaccessible to large swaths of the population, and singularly fueled by oil.

In the Commission's view, autonomous vehicles have the potential to solve these complex challenges. Regarding transportation safety, AVs could eradicate most of the over six million accidents that occur on U.S. roads every year and the resulting 2 million injuries and nearly \$1 trillion in economic and social cost. Most of the 35,000 deaths that occur annually could be prevented by eliminating human error, which contributes to over 94% of accidents.

AVs can solve another challenge facing our society—lack of transportation access for underserved populations. More than 50 million Americans suffer from a disability which impairs their mobility, while a growing number of older Americans are gradually losing their ability to drive. New transportation options will not only enrich their lives, but help our economy grow as they gain access to the workforce and local economies.

Furthermore, autonomous vehicles can precipitate a shift away from oil, which currently holds a monopoly over our transportation system. Oil dependence exacts a tremendous toll on American economic and national security, costing 5-6% of our GDP every year. This dependence burdens the U.S. military by forcing it to patrol global oil flows, constrains the country's foreign policy options, and sends billions of dollars directly to countries that share neither our interests nor our values. Every day, the United States consumes one-fifth of global oil supply thanks to the thirst of our massive transportation system, which is 92% powered by petroleum. Autonomous vehicles will reduce this dependence by improving vehicle efficiency, creating opportunities for lightweighting, and will streamline the driving process. Additionally, the majority of self-driving cars are likely to be electric vehicles, diversifying our mobility system away from a single, highly volatile global commodity.

The opportunities for this technology are tremendous, but none of these problems will be solved without establishing public trust in the safety of AV technology. Only 35% of Americans currently understand that autonomous vehicles will improve roadway safety, 71% of older Americans have expressed that they are 'worried' about driverless cars, and 45% of millennials say they would 'never' use an autonomous ride-sharing service. Furthermore, in the early stages of technological deployment small accidents can have an outsized risk on public perception.

The Commission on Autonomous Vehicle Testing and Safety's goal is that these recommendations will spark a critical dialogue between industry, regulators, and the public—one which enables AV developers to prevent accidents and establish a foundation of trust, while proactively contributing to an innovation-first regulatory framework that is

capable of keeping pace with this dynamic industry. We look forward to continuing to work with all stakeholders across the AV value chain to advance this technology and help achieve the staggering potential benefits.

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Securing America's Future Energy (SAFE) is an action-oriented, nonpartisan organization that aims to reduce America's dependence on oil. Near-total dependence on petroleum in the transportation sector undermines the nation's economic and national security, and constrains U.S. foreign policy. To combat these threats, SAFE advocates for expanded domestic production of U.S. oil and gas resources, continued improvements in vehicle fuel efficiency, and transportation sector innovations including electric vehicles, natural gas trucks, and autonomous vehicles. In 2006, SAFE joined with General P.X. Kelley (Ret.), 28th Commandant of the U.S. Marine Corps, and Frederick W. Smith, Chairman, President, and CEO of FedEx Corporation, to form the Energy Security Leadership Council (ESLC), a group of business and former military leaders committed to reducing the United States' dependence on oil. Today, the ESLC is co-chaired by Frederick W. Smith and General James T. Conway (Ret), 34th Commandant of the U.S. Marine Corps.