United States Government Accountability Office

Report to Congressional Committees

November 2017

AUTOMATED VEHICLES

Comprehensive Plan Could Help DOT Address Challenges

Accessible Version

GAO-18-132

GAO Highlights

Highlights of GAO-18-132, a report to congressional committees

November 2017

AUTOMATED VEHICLES

Comprehensive Plan Could Help DOT Address Challenges

Why GAO Did This Study

Automated vehicles potentially promise transformative benefits in safety, mobility, and other areas. However, the successful development of these vehicles and technologies may pose a range of challenges for policymakers to confront. DOT is the lead federal agency for vehicle safety and road infrastructure.

Recent legislation included a provision for GAO to review automated vehicle policy and DOT's readiness to address challenges. This report addresses: (1) what selected stakeholders and literature identify as potential safety and infrastructure challenges automated vehicles pose for policymakers and (2) DOT's efforts in response to these challenges. GAO reviewed selected literature and interviewed 27 selected stakeholders to identify policy challenges and views on DOT's efforts. GAO judgmentally selected these stakeholders—including state transportation officials, academic experts, and industry representatives—to obtain a wide-range of perspectives and expertise. The results are non-generalizable. GAO also reviewed DOT's policy and program documentation and interviewed agency officials. GAO compared DOT's efforts with leading planning principles identified in prior GAO work and federal internal control standards.

What GAO Recommends

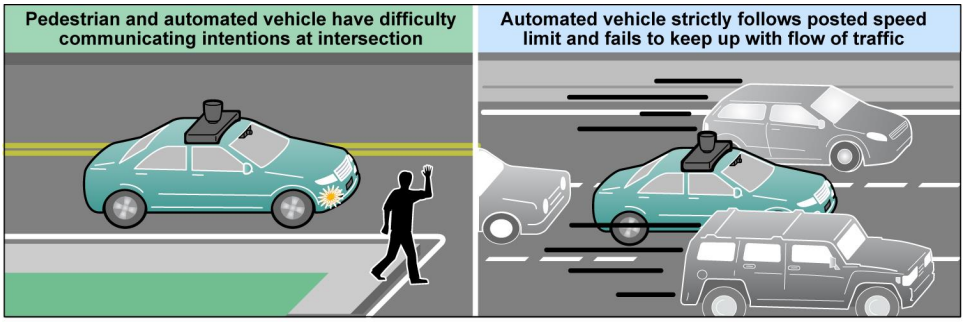
GAO recommends that DOT develop a comprehensive plan to better manage departmental initiatives related to automated vehicles. DOT concurred with the recommendation.

View GAO-18-132. For more information, contact David Wise at (202) 512-2834 or wised@gao.gov.

What GAO Found

Automated cars and light-duty trucks—from vehicles already on the road equipped with driver assistance technologies to fully driverless cars still in development—pose safety and infrastructure challenges for policymakers, according to literature GAO reviewed and stakeholders GAO interviewed. For example, policymakers will need to decide if the current approach to vehicle testing and standards is sufficient to ensure adequate vehicle safety, according to many stakeholders GAO interviewed. Further, policymakers may want to address how automated vehicles interact with other road users (see figure below). Likewise, automated vehicles may require infrastructure changes, and policymakers will need to decide what changes to pursue, while also providing for conventional vehicles since many stakeholders expect conventional vehicles to remain on the roads for decades.

Examples of Potential Driving Scenarios That Could Pose Challenges



Source: GAO. | GAO-18-132

The U.S. Department of Transportation (DOT) has made efforts to respond to some of these challenges. For example, DOT's National Highway Traffic Safety Administration has conducted defect investigations and pursued recalls of some driver-assistance technologies. In September 2017, DOT issued new voluntary guidance that provides technical assistance for states and suggests a framework for industry-led safety testing.

However, DOT does not have a comprehensive plan that sets clear goals, that establishes when and how it will act, or that indicates how it will monitor progress. According to officials, DOT recently formed a group to lead policy development in the future, but has not announced a detailed timeframe or scope of work. Without a comprehensive plan, it is unclear whether DOT's efforts are adequately tackling automated vehicle challenges. DOT has an opportunity to enhance federal leadership on automated vehicle challenges and a comprehensive plan could be a first step toward doing so.

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Abbreviations

ADS	automated driving systems
DOT	U.S. Department of Transportation
FAST Act	Fixing America's Surface Transportation Act
FAVP	*Federal Automated Vehicles Policy*
FHWA	Federal Highway Administration
GPS	Global Positioning System
JPO	Intelligent Transportation Systems–Joint Program Office
LIDAR	light detection and ranging (sensors)
NHTSA	National Highway Traffic Safety Administration
V2X	vehicle-to-everything

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November 30, 2017

The Honorable John Thune
Chairman
The Honorable Bill Nelson
Ranking Member
Committee on Commerce, Science, and Transportation
United States Senate

The Honorable Bill Shuster
Chairman
The Honorable Peter A. DeFazio
Ranking Member
Committee on Transportation and Infrastructure
House of Representatives

The Honorable Lamar S. Smith
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The Honorable Eddie Bernice Johnson
Ranking Member
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House of Representatives

Automated vehicles, from those that assist drivers with some driving tasks to fully self-driving cars, promise transformative benefits such as reducing crashes and fatalities, easing congestion, and increasing mobility. The U.S. Department of Transportation (DOT) has calculated that 94 percent of crashes can be tied to a human choice or error, and many observers believe that automated vehicle technologies could reduce or eliminate these errors.[1] For example, technologies that automatically slow or stop a vehicle when it predicts a forward collision can mitigate accidents due to inattentive driving and save lives. Further, fully self-driving vehicles could reduce traffic congestion through more efficient operations or make time in the car less onerous by freeing drivers from some or all driving responsibilities. Moreover, people with physical limitations that prevent them from operating a vehicle may find that driverless vehicles provide them with greater mobility. DOT has stated that automated vehicle

[1]S. Singh, Critical Reasons for Crashes Investigated in the National Motor Vehicle Crash Causation Survey *Traffic Safety Facts*, Crash Stats. Report No. DOT HS 812 115. (Washington, D.C.: National Highway Traffic Safety Administration, February 2015).

technologies, including fully self-driving cars, may prove to be the greatest personal transportation revolution since the popularization of the personal automobile a century ago.[2]

Automakers and technology firms are investing heavily to develop and deploy automated vehicles. Already, automated technologies are changing cars and light trucks, as well as other vehicles. For example, automated parking and adaptive cruise control are available on cars for sale today. However, for these benefits to be realized, policymakers must confront an array of challenges now, as technologies are developed and tested and in the future as vehicles become widely available. Some of these challenges include vehicle safety and infrastructure development.

Within DOT, the National Highway Traffic Safety Administration (NHTSA) leads federal efforts to improve car and light-duty truck safety, among other responsibilities, and the Federal Highway Administration (FHWA) governs multiple infrastructure programs. In September 2017, NHTSA released *Automated Driving Systems 2.0: A Vision for Safety* to provide manufacturers, state governments, other entities, and stakeholders with testing and deployment guidance.[3] State and local governments also have roles and responsibilities to play in planning, building, and maintaining infrastructure; licensing drivers; registering vehicles; and enforcement, and more. Industry observers predict initial deployments of automated vehicles in limited situations—such as geographically constrained areas or only for hired rides—but expect broader usage in the future.

The Fixing America's Surface Transportation Act (FAST Act), signed into law in December 2015, includes a provision for GAO to review automated vehicle policy and DOT's readiness to address challenges related to the eventual implementation of this technology.[4] In this report we examine: (1) what selected stakeholders and literature identify as potential safety and infrastructure challenges posed by automated cars and light trucks

[2]NHTSA, *Federal Automated Vehicles Policy: Accelerating the Next Revolution in Roadway Safety* (September 2016).The *Federal Automated Vehicles Policy (FAVP)* established an initial foundation and framework for DOT's actions related to vehicle automation.

[3]NHTSA, *Automated Driving Systems 2.0: A Vision for Safety,* (Washington, D.C.: September 2017), which replaced the *FAVP*.

[4]Pub.L. No.114-94, title VI, § 6025, 129 Stat. 1312, 1586 (2015).

that policymakers face; and (2) DOT's efforts to respond to these challenges.

To identify and describe safety and infrastructure challenges posed by vehicle automation, including vehicle safety, roadway operations and design, among other areas, we reviewed literature on this topic and interviewed 27 selected stakeholders. To identify recent, pertinent literature, we searched bibliographic databases, including Transportation Research International Documentation and Scopus for literature from 2014 or later. We identified scholarly and trade citations using search terms related to automated vehicle concepts and policies. Books, journal articles, government reports, and industry and think-tank publications were considered, among other types of literature. We determined that selected works were credible based on factors including the demonstrated expertise of the author or source and recommendations from experts.

We also selected stakeholders to interview, including representatives of 10 companies and industry groups; 7 governmental organizations (e.g., representatives of state governments or national associations); 6 academics; and 4 safety organizations. We selected these people and entities to interview based on considerations such as recent engagement with relevant topics (e.g., publication of articles or significant investments in automated technology), recognized expertise; and institutional relevance to identified challenges (e.g., we interviewed groups that represent the automotive industry, state transportation officials, and so forth). We conducted these interviews prior to the release of NHTSA's *A Vision for Safety* in September 2017, so stakeholders were not able to comment on it. To cover the wide range of topics pertinent to automated vehicles, our selections of literature and interviews reflect a range of perspectives, topics, and areas of expertise. We relied on the information gathered through these selections collectively to develop categorizations and descriptions of automated vehicle challenges. We analyzed the content of our interviews and literature review to identify policy challenges and themes that could be the basis for these categorizations. When appropriate, we indicate whether the challenges we summarize were identified by some, many, or most of the interviewees or works of literature, but frequency may not necessarily be indicative of the relative

importance of a challenge or consensus, or lack thereof.[5] The results of our literature review and interviews are non-generalizable. However, we determined that our selection methodologies were appropriate for our design and objectives and that these methodologies would generate valid and reliable evidence to support our work. See appendix I for citations of literature reviewed and a list of entities we interviewed. Further, to describe the extent of state legislative activities related to automated vehicles, we used a database maintained by the National Council of State Legislatures. We did not independently perform a data reliability assessment of these data.

To examine DOT's efforts to respond to the challenges we identified, we reviewed relevant DOT laws, regulations, and agency guidance and interviewed DOT officials and the selected stakeholders described above. We assessed DOT's efforts compared to sound-planning practices that we identified through a review of relevant literature, prior GAO work, and the *Standards for Internal Control in the Federal Government*.[6] We identified prior GAO reports where we defined a number of desirable characteristics of an effective, results-oriented plan or components of sound-planning practices.[7] We selected the specific planning practices we used as criteria by determining which were most applicable to DOT's recent efforts to incorporate automated vehicles in its policies and programs. We focused on NHTSA, FHWA, and the Office of the Secretary of Transportation because they have led many of DOT's automated vehicle efforts to date.

We conducted this performance audit from November 2016 to November 2017 in accordance with generally accepted government auditing

[5]To describe the frequency of stakeholder views, we use "some" when 2 to 6 stakeholders indicated a shared viewpoint, "several" for 7 to 11, "many" for 12 to 16, and "most" for 17 to 21 in situations in which all 27 interviews were applicable.

[6]GAO, *Standards for Internal Control in the Federal Government*, GAO-14-704G (Washington, D.C.: September 2014), contains the internal control standards to be followed by executive agencies in establishing and maintaining systems of internal control as required by 31 U.S.C. § 3512 (c), (d).

[7]In past reports, we have identified best practices in planning. For example, see GAO, *Executive Guide: Effectively Implementing the Government Performance and Results Act,* GAO/GGD-96-118 (Washington, D.C.: June 1, 1996); GAO, *Combating Terrorism: Evaluation of Selected Characteristics in National Strategies Related to Terrorism,* GAO-04-408T (Washington, D.C.: Feb. 3, 2004); and GAO, *Veterans' Health Care: Proper Plan Needed to Modernize System for Paying Community Providers,* GAO-16-353 (Washington, D.C.: May 11, 2016).

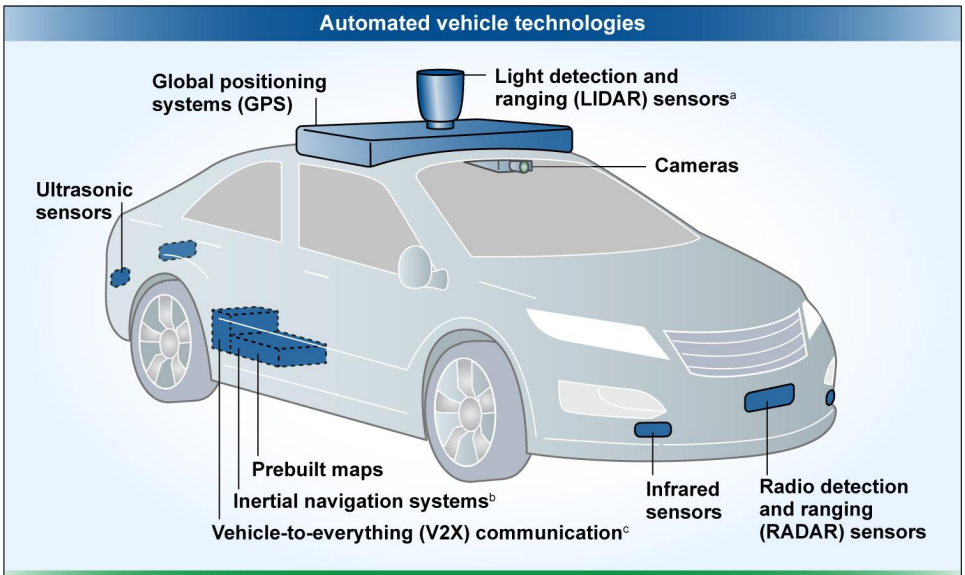
standards. Those standards require that we plan and perform the audit to obtain sufficient, appropriate evidence to provide a reasonable basis for our findings and conclusions based on our audit objectives. We believe that the evidence obtained provides a reasonable basis for our findings and conclusions based on our audit objectives.

Background

Automated Vehicles

Automated vehicles can perform certain driving tasks without human input. They encompass a diverse range of automated technologies ranging from relatively simple driver assistance systems to fully self-driving vehicles. Certain automated features, like adaptive cruise control, can adjust vehicle speed in relation to other objects on the road and are currently available on various car models. Over the next several years, auto makers expect to market vehicles capable of fully operating without the aid of a human driver under certain conditions. DOT has adopted a framework for automated driving developed by SAE International, which categorizes the levels of automation into 6 levels (See fig. 1).

Figure 1: Levels of Driving Automation Used by Department of Transportation



Levels of driving automation adopted by Department of Transportation

Level	Name	Definition
0	No automation	Human driver controls all aspects of dynamic driving tasks, even when enhanced by warning system
1	Driver assistance	Automation controls one vehicle function (e.g., steering or speed)
2	Partial automation	Automation controls both steering and speed with driver responsible for monitoring and immediate reengagement
3	Conditional automation	Automation controls both steering and speed and monitors environment; driver may be notified to reengage
4	High automation	Automation performs all aspects of dynamic driving tasks in some driving modes; driver not required to reengage
5	Full automation	Automation performs all aspects of dynamic driving tasks under all roadway and environmental conditions

Sources: GAO and GAO analysis based on U.S. Department of Transportation information. | GAO-18-132

[a]LIDAR is a technology that uses laser remote sensing to map the vehicle's surroundings.

[b]Inertial navigation systems consist of gyroscopes and accelerometers to constantly track the vehicle's position and help improve the accuracy of the GPS

[c]V2X encompasses communication between other vehicles or other permanently installed infrastructure.

Vehicles with Level 0, 1, and 2 technologies, as outlined in figure 1, are already available for private ownership and currently operate on public roadways. Level 0 encompasses conventional vehicles where a human driver controls all aspects of driving. Systems that warn drivers of safety hazards, such as forward collision warning, but do not take control away from the driver are not considered automated. Level 1 technologies incorporate automatic control over one major driving function, such as

steering or speed, and examples include adaptive cruise control and technology that provides assistance keeping within a lane. With Level 2 the automated systems can control both steering and lane positioning in certain conditions, though the human driver must maintain situational awareness to ensure safe functioning.

In the September 2017 *Vision for Safety*, NHTSA categorizes vehicles with Level 3, 4, and 5 technologies as Automated Driving Systems (ADSs).[8] Vehicles with ADS are still in development, and automakers and technology firms are actively testing them, sometimes on public roads. With Level 3 autonomy, the system can take full control of the vehicle in certain conditions. However, it may not be able to navigate all driving scenarios, in which case it would pass control back to the human driver who must maintain situational awareness to ensure safe functioning. With Level 4, automation controls all aspects of driving in certain driving conditions and environments, and with Level 5 the vehicle can operate fully, in any condition or environment, without a human driver or occupant. Some automakers have indicated their intention to release Level 4 vehicles for use in defined scenarios, such as select commuter roads or in a ride-sharing platform as early as 2021.[9]

DOT has long-standing activities aimed at advancing connected vehicle technologies. Connected technologies allow vehicles to communicate with other vehicles (vehicle-to-vehicle), roadway infrastructure (vehicle-to-infrastructure), and personal communication devices.[10] These

[8]NHTSA's 2016 *FAVP* referred to Levels 3–5 vehicles as "Highly-Automated Vehicles." Throughout this report, we adopt DOT's current terminology where appropriate, but use the term "automated vehicles" to refer to vehicles at any level of automation. The 2017 *Vision for Safety* focuses specifically on Levels 3–5 vehicles, whereas the 2016 FAVP applied to Levels 2–5 vehicles.

[9]We did not assess the likelihood to which industry forecasts are accurate.

[10]See GAO, *Intelligent Transportation Systems: Vehicle-to-Infrastructure Technologies Expected to Offer Benefits, but Deployment Challenges Exist,* GAO-15-775 (Washington, D.C.; Sept. 15, 2015) and GAO, *Intelligent Transportation Systems: Vehicle-to-Vehicle Technologies Expected to Offer Safety Benefits, but a Variety of Deployment Challenges Exist,* GAO-14-13 (Washington, D.C.: Nov. 1, 2013). Vehicle-to-vehicle systems rely on in-vehicle equipment that transmits data between vehicles, enabling applications that can warn drivers of road conditions and hazards. Vehicle-to-infrastructure systems transmit data between vehicles and roadway infrastructure, such as signage and signal lights. These technologies typically communicate using Dedicated Short Range Communications, a technology similar to Wi-Fi that offers a link through which vehicles and infrastructure can transmit messages over a range of about 300 to 500 meters. Currently, these technologies are still being tested and are available on select models.

technologies could complement automated technologies, and DOT has indicated that connected vehicle technologies could be critical to the success of automated vehicles' safety. For example, connected technologies could help automated vehicles maintain or improve situational awareness by communicating traffic control messages that camera and radar-based crash avoidance technologies may not be able to detect because of obstructions such as buildings or fog. DOT's research and other efforts related to connected vehicles historically have been largely independent of vehicle automation, but recent departmental efforts have sought to study the potential interactions and synergies between the two concepts.

Government Roles

As the lead federal department responsible for vehicle safety and roadway infrastructure programs, DOT is responsible for coordinating automated vehicle policy at the federal level.[11] Through its various offices and modal administrations, DOT executes a broad range of responsibilities for promoting safe and efficient transportation. NHTSA and FHWA are the primary operating administrations within DOT that oversee vehicle safety and infrastructure issues,[12] while the Office of the Under Secretary for Policy and the Office of the Assistant Secretary for Research and Technology coordinate policy and research efforts, respectively.

NHTSA—NHTSA is responsible for enhancing the safety of vehicles, including automated vehicles, and does so through several different means that include: developing and enforcing Federal Motor Vehicle Safety Standards, promoting safety, leading defect and crash investigations, and identifying safety trends and countermeasures.

[11]Other federal agencies, such as the Federal Communications Commission and National Transportation Safety Board have roles that intersect with automated vehicles. For example the Federal Communications Commission monitors radiofrequency spectrum, which automated or connected vehicles may use for wireless communications. The National Transportation Safety Board has authority to investigate major highway accidents, and this authority extends to accidents involving automated vehicles.

[12]The Federal Motor Carrier Safety Administration, Federal Transit Administration, and Federal Railroad Administration are also DOT administrations that have various roles that relate to safety and infrastructure. The Federal Motor Carrier Safety Administration also has a role on the operations side for commercial vehicles. However, such responsibilities are not covered in this report.

- The Federal Motor Vehicle Safety Standards are minimum safety requirements under which manufacturers of motor vehicles and motor vehicle equipment self-certify conformance. NHTSA does not pre-approve vehicles and equipment before they enter the marketplace.
- NHTSA's New Car Assessment Program promotes safety through a 5-star Safety Ratings Program, which evaluates new vehicles for crash worthiness and rollover protection beyond what is required by the vehicle standards as well as recognizing vehicles equipped with certain crash avoidance technologies, such as forward collision warning systems.
- NHTSA can require a recall of vehicles or equipment deemed to pose an unreasonable risk to motor vehicle safety, and this authority extends to automated vehicle technologies. NHTSA identifies possible vehicle defects by gathering data from consumer complaints, manufacturer information, and other sources to decide whether an investigation should be initiated and if a recall is warranted.[13]
- NHTSA tracks and monitors safety trends by collecting vehicle safety data through its administration of the Fatality Analysis Reporting System, which records annual statistics on fatal motor vehicle crashes. NHTSA's Special Crash Investigations teams also help collect data on unique vehicle crashes and publish summaries of incidents to aid the automotive safety community in identifying issues and improving the performance of advanced safety systems.

FHWA—FHWA is responsible for improving mobility and ensuring the safety of the country's highways through funding, research, and guidance. FHWA administers the federal-aid highway program, which distributes approximately $40 billion per year to states for infrastructure projects to build and maintain highways, roads, and bridges. FHWA also provides guidance on transportation planning, roadway design, operations, and other areas to support state and local transportation agencies, which own most of the nation's roads. FHWA also has been a proponent of advancing vehicle-to-infrastructure and vehicle-to-vehicle communication technologies.

[13]Vehicle manufacturers also have a responsibility to report and conduct recalls of defective technologies independent of direction to do so from the federal government. See GAO, *Auto Safety: NHTSA Has Options to Improve Safety Defect Recall Process*, GAO-11-603 (Washington, D.C.: June 15, 2011).

Policy and Research—The Office of the Under Secretary for Policy is the focal point for developing and coordinating DOT's automated vehicle policies. Likewise, the Intelligent Transportation Systems–Joint Program Office (JPO) within the Office of Assistant Secretary for Research and Technology is responsible for advancing research and other advanced technology efforts throughout DOT. NHTSA and FHWA manage research, development, and technology programs as well.

State, regional, and local governments also have responsibilities for automated vehicles. For example, state departments of transportation oversee the construction and maintenance of state and interstate highways, while state police departments enforce traffic laws, such as speed limits. States are also responsible for registering vehicles, licensing drivers, educating drivers, and regulating auto insurance. Regional governments have a variety of long-range infrastructure planning responsibilities. At the local level, towns and cities are responsible for infrastructure planning, construction, and maintenance; enforcement of traffic laws; and emergency services.

Selected Stakeholders and Literature Cite Many Challenges Automated Vehicles Present for Policymakers

Challenges policymakers face include assuring that automated vehicles are safe and interact with other road users predictably, adapting road and other infrastructure to these vehicles, and addressing questions about how data generated by automated vehicles can be used. These challenges could spur shifts in the roles and responsibilities of different levels of government. Also, given the rapid pace at which automated technologies are developing, policymakers face uncertainties in timing their actions.

Policymakers Face Challenges Posed by Automated Vehicles across a Wide Range of Areas

According to literature we reviewed and stakeholders we spoke to, automated vehicles pose challenges to federal, state, and local-level policymakers across a wide range of areas and addressing these challenges will be important if society is to realize the potential benefits of these vehicles. Specifically, based on our literature review and stakeholder interviews, we found that the challenges facing policymakers can be categorized into four major topical areas: vehicle safety assurance, vehicle behavior, infrastructure adaptation, and data protection and use.

- *Safety assurance:* Policymakers will need to determine if the current, established approach to vehicle safety assurance is sufficient or if modifications or changes are needed, according to many stakeholders we interviewed and literature we reviewed. Manufacturers have long had the primary responsibility for safety testing of their vehicles and, according to the companies developing automated vehicles that we interviewed, will continue to focus on safety as they develop automated technologies.[14] Policymakers also have a role in safety assurance through activities like crash testing and safety ratings. Across the range of different types of stakeholders we interviewed, stakeholders consistently indicated that the complexity of automated technologies and the difficulties in demonstrating their safety are a challenge for existing public-sector safety programs. Some stakeholders and literature suggested that policymakers may wish to examine alternative approaches, including third-party testing and

[14]Vehicle developers face a host of challenges in testing their technologies, according to DOT, stakeholders, and relevant literature. Developers must determine that their technologies function properly (e.g., can stay on the road, follow traffic laws, and avoid hazards). According to the literature we reviewed, vehicle developers are likely to need a combination of on-road testing, simulations, and other techniques to validate their technology functions as intended. For example, one study estimates that millions of on-road testing miles could be needed to prove that automated vehicles perform safely; so many, in fact, that the study concludes on-road testing alone may not be practical. Of particular concern might be situations that are atypical and may not be routinely experienced in on-road testing, but may actually be sometimes or commonly experienced by drivers (e.g., a child running into the street or a work zone). See Nidhi Kalra and Susan Paddock, "Driving to Safety: How many miles of driving would it take to demonstrate autonomous vehicle reliability?*" Transportation Research Part A 94* (2016) 182-193 and Philip Koopman and Michael Wagner, *Challenges in Autonomous Vehicle Testing and Validation*, SAE World Congress, 2016-01-0128/16AE-0265.

establishing common testing standards. Other stakeholders—notably vehicle developers—advocated for maintaining the current structure.

NHTSA's Federal Motor Vehicle Safety Standards do not include specific requirements for ADS performance.[15] Across the range of stakeholders we interviewed, there was broad agreement that the current vehicle standards are likely to need some modifications to allow for automated technologies to be fully incorporated into vehicle design. For example, some stakeholders told us that current standards could impede vehicle development because, for example, the standards assume the presence of a human driver. As reported by the Congressional Research Service, revising the Federal Motor Vehicle Safety Standards can take years.[16] Views differed on what approach NHTSA should take to update the standards. For example, one safety organization we interviewed advocated the development of functional safety standards that explicitly define required aspects of vehicle performance. Alternatively, some companies and industry groups advocated increasing the number of vehicles NHTSA has authority to exempt from these standards to handle situations where current standards are not relevant for automated vehicles while maintaining the basic approach of the current standards.[17]

Policymakers have regulatory and enforcement tools to assure that vehicles on the road are safe, but these tools may need to be modified or enhanced to address automated vehicles, according to stakeholders we interviewed and our literature review. For example, we have previously found that NHTSA faces challenges in conducting defect investigations because of the difficulty in keeping up with changing technologies, among other things. Such challenges might

[15]All vehicles, including automated vehicles, must meet these standards to be sold in the United States.

[16]Congressional Research Service, *Issues with Federal Motor Vehicle Safety Standards,* 7-5700 (Washington, D.C.: March 2017).

[17]Vehicle developers can request a temporary exemption from NHTSA from existing Federal Motor Vehicle Safety Standards if the manufacturer can make a sufficient showing to NHTSA that the exemption is necessary for research, testing, investigations, demonstrations, training, competitive racing events, show, or display. Vehicles exempted for testing purposes cannot be sold following the conclusion of testing. Currently, the Secretary of Transportation may temporarily exempt up to 2,500 vehicles from certain motor vehicle standards annually, if he or she deems it appropriate. Exemptions can last up to 3 years and renewals up to 2 years.

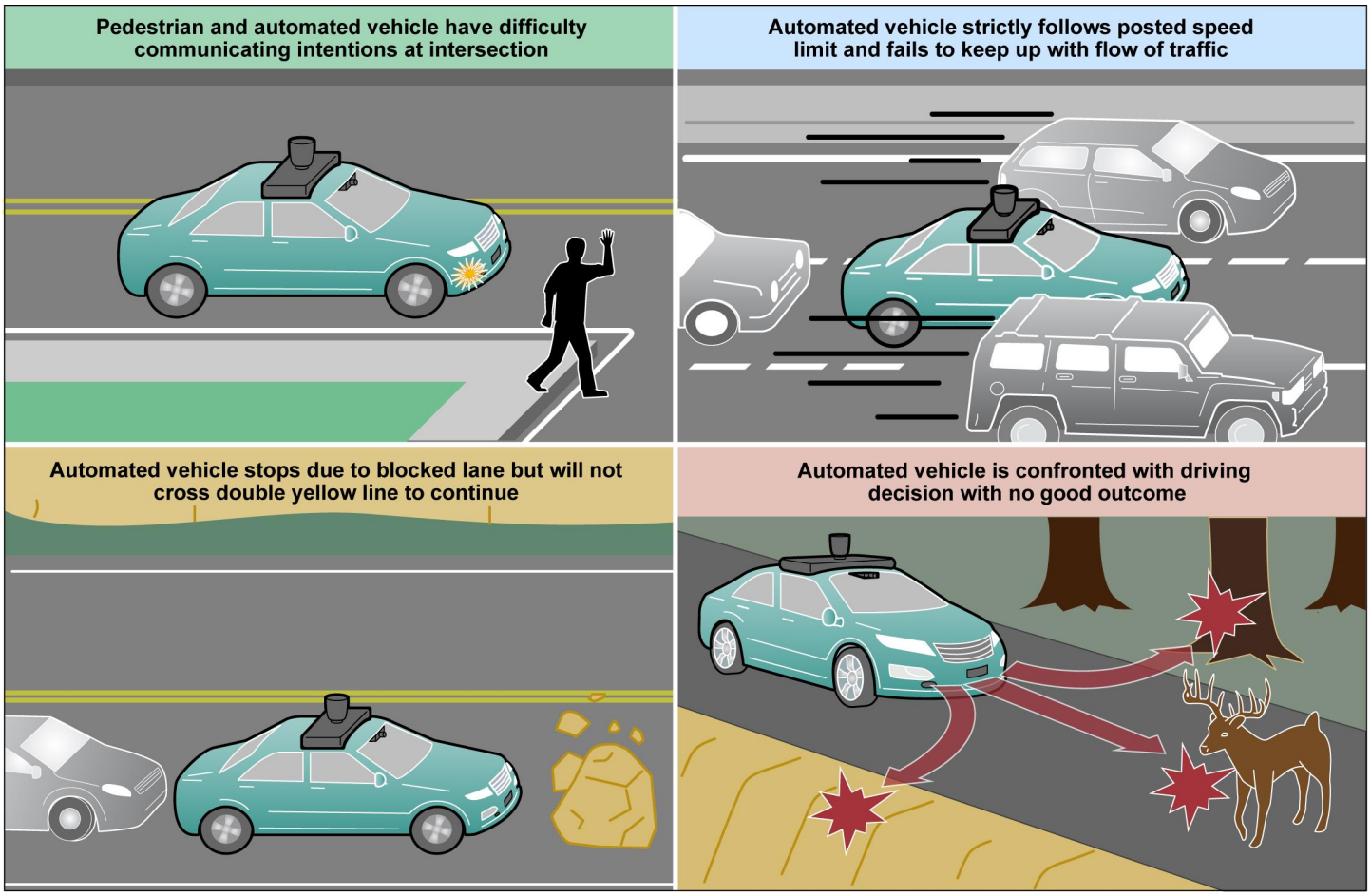
result in difficulty determining when recalls are warranted.[18] As with vehicle safety testing, some stakeholders indicated that defect investigations may become increasingly challenging given that automated technologies are vastly more complex than conventional vehicles. A few stakeholders we interviewed mentioned that it could be difficult for investigators to inspect increasingly complex technologies that, in some cases, "make" decisions that cannot be explained after the fact. For example, the underlying basis for a specific decision made by some artificial intelligence technologies might be unknowable or untraceable, making assignment of fault difficult or impossible for investigators.

- *Vehicle behavior:* Stakeholders and literature we reviewed identified challenges with how automated vehicles operate in the world. For example, DOT has identified the importance of automated vehicles' ability to operate in the traffic conditions the vehicles encounter, including following laws and etiquette in responding to other vehicles and other road users such as pedestrians and law enforcement.[19] As such, policymakers may want to address how developers handle these questions. Some stakeholders noted that public input would help developers better decide how their vehicles interpret and respond to the formal and informal rules of the road and interact with other road users, such as conventional vehicles, pedestrians, and cyclists. See figure 2. For example, policy decisions could include how much, if any, allowance ADSs should be given to selectively break traffic laws when the circumstances might call for it (e.g., should an automated vehicle speed to keep up with freeway traffic flow or cross double yellow lines to avoid a hazard or work zone?). DOT officials noted that automated vehicle technologies have a particularly difficult time handling work zones, pedestrians, cyclists, and other vulnerable road users. Moreover, there may be some situations in which an automated system is confronted with a situation in which there is no good outcome. However, some stakeholders we interviewed stated that moral dilemma questions are likely to be exceedingly rare.

[18]GAO, *Vehicle Safety: Enhanced Project Management of New Information Technology Could Help Improve NHTSA's Oversight of Safety Defects*, GAO-16-312 (Washington, D.C.: Feb. 24, 2016).

[19]In DOT's 2016 *Federal Automated Vehicle Policy,* now replaced by *A Vision for Safety,* DOT uses "vehicle behavioral competencies" to refer to the ability of an automated vehicles to operate in the traffic conditions that it will regularly encounter, including keeping the vehicle in the lane, obeying traffic laws, following reasonable etiquette, and responding to other vehicles, road users, or commonly encountered hazards.

Figure 2: Examples of Potential Driving Scenarios That Could Pose Policy Challenges Related to Automated Vehicles



Source: GAO. | GAO-18-132

Policymakers also may have some role in educating the public about what behaviors to expect from automated vehicles, according to stakeholders and literature. While several stakeholders we interviewed agreed that the industry ought to have a sizable role in educating the public on the capabilities of the vehicles they sell, there could also be a public-sector role. For example, the public sector could help passengers understand if a system is not capable of safely operating at night or in poor weather conditions—decisions traditionally made by human drivers based on their judgment and experience and, at times, limited information about changing weather and road conditions—before they attempt to use it in those domains.

Law enforcement and emergency responders will need knowledge and procedures for handling automated vehicles on the road and at accident scenes. According to some stakeholders we spoke to and literature addressing state and local government responsibilities, policymakers will have a role in developing these procedures and educating public safety personnel. For example, one stakeholder commented that law enforcement will need protocols to pull over automated vehicles when warranted and, at a crash scene, procedures to retrieve vehicle data to aid crash investigations and analysis. Because these protocols and procedures will need to work across a range of vehicle makes and models, some standardization will be needed, according to another stakeholder.

- *Infrastructure adaptation:* Automated vehicles may necessitate changes in roadway designs, land use, and other public infrastructure, but, based on literature we reviewed, DOT officials, and many stakeholders we interviewed, infrastructure will need to continue to serve conventional vehicles for decades to come. As a result, some stakeholders do not expect that fundamental changes in infrastructure design due to automation are likely to be widespread in the near-term. The vehicle developers we interviewed all stated that they are currently pursuing automation approaches that are designed to work on infrastructure as it currently exists, noting that a technology is not commercially viable if it requires perfectly designed and maintained roads. Nevertheless, several stakeholders highlighted the importance of well-maintained roads and consistent lane markings and signage for automated and conventional vehicles alike.[20] DOT officials added that local ownership of the majority of U.S. roads complicates implementation of infrastructure changes because of the increased number of stakeholders involved.

  Though highly uncertain, more substantial infrastructure adaptations could be justified in the long-term if ADSs become common, according to some stakeholders and literature. For example, highway capacity of existing roadways may increase if automated vehicles are able to safely follow one another more closely than conventional vehicles, according to officials we interviewed representing state transportation agencies. Likewise, as postulated in one study we reviewed, if driverless ride hailing becomes the norm, fewer on- and

[20]DOT officials added that infrastructure adaptations and challenges may differ in urban and rural areas and that rural fatalities comprise about half of all roadway fatalities.

off-street parking spaces may be needed, allowing for these spaces to be repurposed for other uses. Further, land-use could change in more fundamental ways than just parking availability, either by encouraging more density (because ride-hailing works best in denser areas) or less (because longer trips become less onerous in an automated vehicle, increasing people's willingness to undertake long commutes).[21]

Additionally, automated vehicles may benefit from complementary new technologies including vehicle-to-infrastructure and vehicle-to-vehicle communications. For example, these technologies could warn drivers and vehicles of potentially dangerous road conditions ahead. However, as we have previously reported, for these communication technologies to work, public sector regulators and industry will need to establish standards, provide wireless spectrum, and deploy equipment.[22] Officials representing state transportation agencies indicated that they are convening multiple groups to address topics such as these to facilitate connected- and automated-vehicle deployment.

- *Data:* Automated vehicles also raise questions for policymakers about data privacy, ownership, and access that, according to some stakeholders we interviewed, will need to be addressed. In each of these areas, as we have previously found, the public has needs for data to inform crash and defect investigations and safety analysis and transparency about consumer privacy protection.[23] One academic we interviewed noted that state data privacy protections are typically based on the type of technology in use, not the nature or sensitivity of data, and are regulated by multiple entities. There is no comprehensive federal privacy law, but rather federal statutes and regulations are generally tailored to specific purposes, situations, and

[21]Automated vehicles could have implications for vehicle registration and other revenue streams that support infrastructure. Also, if automation accelerates transitions to electric vehicles, as some studies predict, then current revenue challenges for the Highway Trust Fund—which is the principle mechanism for funding federal highway and transit programs—could be exacerbated because the Highway Trust Fund is largely funded through federal fuel tax revenues. Furthermore, changes in vehicle ownership and use could have workforce and energy implications.

[22]See GAO-14-13 and GAO-15-775.

[23]See GAO-16-312 and GAO, *Vehicle Data Privacy, Industry and Federal Efforts Under Way, but DOT Needs to Define Its Role,* GAO-17-656 (Washington, D.C.: July 28, 2017).

types of information.[24] Data protections are also determined by individual disclosure agreements from manufacturers and, where applicable, state laws. Furthermore, the large volumes of data automated vehicles are expected to collect also raise questions about data ownership and access. For example, automated vehicle data could provide investigators with new sources of data on facts and circumstances of motor vehicle crashes. However, for these uses to become a reality, clarification about who owns and who has access to these data is needed, according to some of the stakeholders we interviewed. DOT officials indicated that they expect existing data privacy policies and disclosure agreements to apply to automated vehicles. Additionally, data standards may be needed across vehicles so information collected from different vehicles can be compared, according to a safety organization we interviewed.

Federal, State, and Local Government Responsibilities May Shift in Response to Challenges

In addition to challenges related to specific areas, policymakers at the federal, state, and local levels may face challenges related to shifts in their traditional roles and responsibilities. According to some stakeholders we interviewed, there is a need for each level of government to examine current practices and, where necessary, make adjustments. Also, the literature we reviewed calls on states, regions, and local governments to prepare for automation.[25] For example, an official with one state transportation agency indicated that there is a grey area about the state's role in regulating Level 4 and Level 5 vehicles which would be controlled by software and could theoretically operate without a state licensed driver in the vehicle. This official wondered what kind of regulatory framework and division of state and federal responsibility is needed to ensure safety. An official with another state transportation agency noted that this state's vehicle code is silent on automation and that the state is working to fill this gap with new rules that balance state and federal roles. Likewise, as we have previously reported, NHTSA has not fully defined its roles and

[24]The Federal Trade Commission is the lead federal agency in the area of consumer data privacy and security, providing guidance and education to consumers and industry and wielding enforcement authority to ensure that manufacturers and other stakeholders adhere to the data privacy and security commitments that they make to consumers.

[25]Some historical roles may remain relatively constant, but the nature of regulatory activities may change. For example, states may continue regulating auto insurance markets even as the increased safety of automated vehicles could shrink the industry.

responsibilities in the event of a cyberattack, to which automated vehicles could be vulnerable.[26]

Some states have instituted, or considered, new laws and regulations. Several stakeholders we interviewed expressed concerns that meeting different state requirements for testing and deployment could hinder safety testing and automated vehicle development. Officials with safety organizations and state transportation agencies consistently agreed that states should avoid enacting conflicting vehicle regulations, but held differing views on the best path for regulating automated vehicle safety. DOT has indicated that states will retain their traditional responsibilities, such as licensing, and stated the department's vehicle safety objective is a shared national framework rather than a "patchwork" of state laws. To date, many states have considered automated vehicle legislation.[27] According to the National Council of State Legislators, at least 41 states have considered some kind of automated vehicle-related legislation, such as requiring the state-licensing agency to study if automated vehicle regulations are needed, and 21 states passed legislation related to automated vehicles. Additionally, Governors of five states have issued executive orders related to automated vehicles.[28]

[26]GAO, *Vehicle Cybersecurity: DOT and Industry Have Efforts Under Way, but DOT Needs to Define Its Role in Responding to a Real-world Attack*, GAO-16-350 (Washington, D.C.: March 24, 2016). As of May 2017, NHTSA had taken steps to define its roles and responsibilities to address cybersecurity and plans to continue to improve its response and coordination plan in fiscal year 2018.

[27]In addition, Congress is considering legislation that would preempt states from regulating automated vehicle design and safety. Legislation was passed by the House of Representatives on September 6, 2017, that includes a preemption provision. H.R 3388,.115th Cong. (2017). Another automated vehicle bill, S. 1885, 115th Cong. (2017), was passed by the Senate Committee on Commerce, Science, and Transportation on October 4, 2017, and it also contains a preemption provision.

[28]Moreover, according to the National Council of State Legislators, state legislative activity in this area has increased in recent years with legislation introduced in 33 states in 2017, 20 states in 2016, 16 states in 2015, 12 states in 2014, 9 states and Washington, D.C. in 2013, and 6 states in 2012. See National Council of State Legislatures, *Self-Driving Vehicles Enacted Legislation,* accessed November 16, 2017, http://www.ncsl.org/research/transportation/autonomous-vehicles-self-driving-vehicles-enacted-legislation.aspx. We did not independently validate these numbers.

Policymakers Face Challenges in Timing Actions

In addition to determining what policy actions should be taken and by whom, policymakers also face challenges in deciding when to do so. Automated technologies are rapidly changing, and consequently, it can be unclear when policymakers, regulators, or oversight bodies should act. For example, many stakeholders agreed that changes to the Federal Motor Vehicle Safety Standards are needed, but views differed about when such a revision is needed because premature actions could potentially hinder innovation. Likewise, regional government officials noted that making significant investment to adapt infrastructure for automated vehicles was difficult because it is hard to know when such investments should be made. For example, uncertainties about vehicle-to-infrastructure standards create a risk that early investments by states or municipalities could prove to be in the wrong technologies, according to state transportation officials we interviewed. DOT officials also emphasized the importance of timing actions, noting, for example, that imposing vehicle standards too soon could constrain technology development and that well-timed standards can provide stability which may encourage industry investments.

Pilot programs can provide an incremental approach to addressing these uncertainties. For example, the City of Pittsburgh uses information gained from pilot programs to better understand emerging automated vehicle technologies, how the city should adapt its role in response, and when actions are needed to advance public-interest goals, such as equity and accessibility. Strategies such as this provide decision makers with a basis for decisions today about infrastructure needs decades in the future, but represent something of a departure from more traditional infrastructure planning approaches, according to some state, regional, and local officials we interviewed.

DOT Has Made Efforts to Address Challenges Posed by Automated Vehicles but Does Not Have a Comprehensive Plan

DOT has begun to address the challenges posed by automated vehicles by (1) issuing and revising departmental policies and guidance on vehicle safety and oversight; (2) revising programs to address automated-vehicle-related research requirements and to advance new technologies; and (3) conducting internal management efforts such as workforce initiatives.

While these early efforts represent progress, we found that DOT does not have a comprehensive plan that sets clear goals related to automated vehicles, that establishes when and how it will act to support those goals, or that identifies performance measures to monitor and gauge results. In the absence of such a comprehensive plan, as DOT, NHTSA, and FHWA undertake these complex efforts, it is not clear that they are well-positioned to fully address the challenges posed by automation.

DOT Has Undertaken a Range of Initial Efforts to Respond to Various Automated Vehicle Challenges

Policy, Guidance, and Oversight Efforts

As of October 2017, DOT has developed and published several policies that start to address the challenges we previously discussed related to vehicle safety assurance and oversight, federal versus state roles, and infrastructure adaptation. According to DOT officials, DOT is first seeking to identify or determine best practices for automated vehicles as an incremental step in order to avoid issuing regulations prematurely that are unable to keep pace with rapidly advancing technologies. Thus far, DOTs activities include the following:

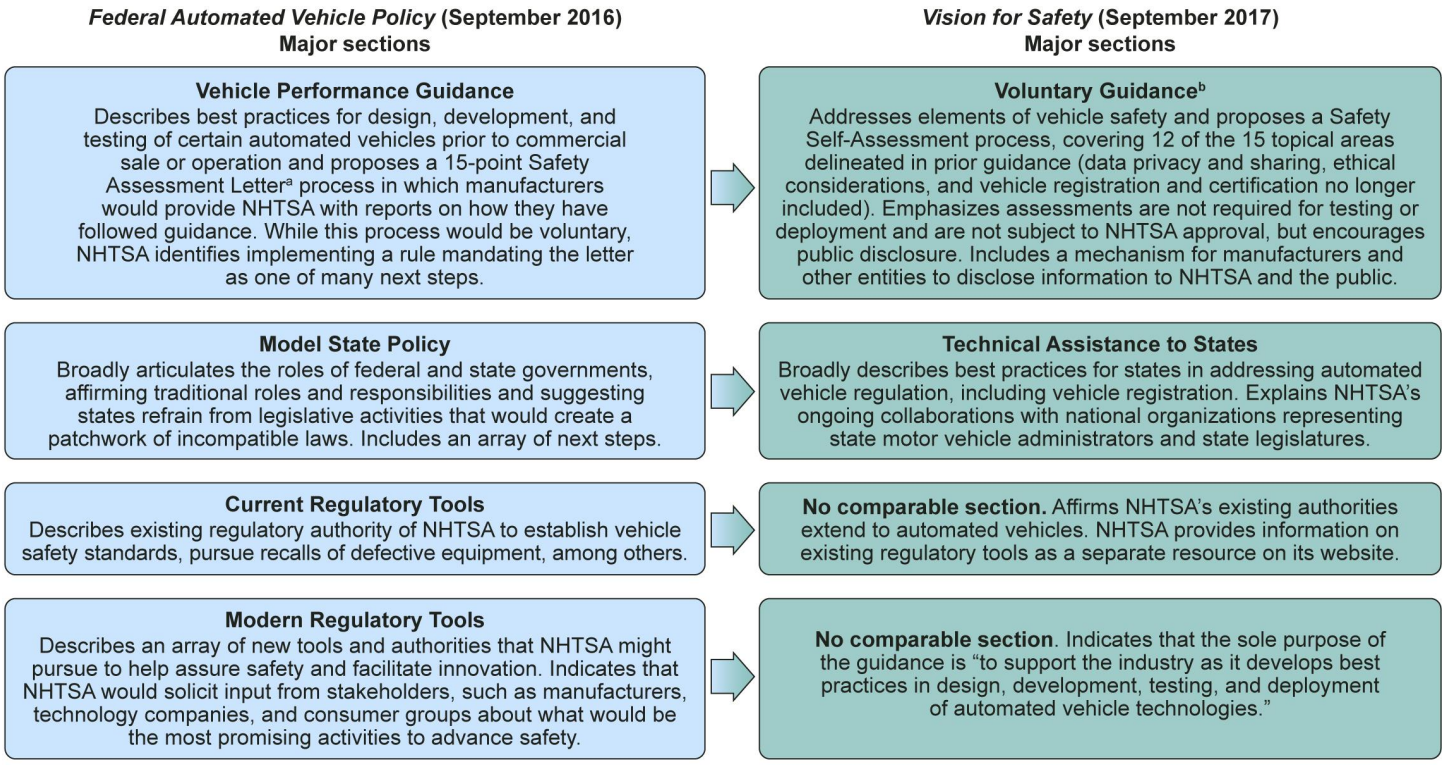
- *Publishing Voluntary Guidance.* In 2016, NHTSA issued the *Federal Automated Vehicles Policy* (*FAVP*), which discussed policy ideas in four areas: (1) vehicle safety assurance; (2) model state policy; (3) current regulatory tools; and (4) modern regulatory tools (see fig. 3). DOT officials described the *FAVP* as an initial step toward establishing a regulatory framework for automated vehicle safety assurance and performance. The policy stated that the rapid development of complex, automated vehicle technologies called on DOT to take new approaches to ensure these technologies achieve their safety potential and do not introduce new safety risks. Stakeholders we spoke to broadly agreed that issuing the *FAVP* was a positive first step for DOT, but most stakeholders said that details in the *FAVP* needed clarification. For example, 7 of the 10 companies and industry groups we interviewed indicated that NHTSA's idea for manufacturers to voluntarily submit a 15-point certification, called a "Safety Assessment Letter" and a major aspect of the *FAVP*'s section on vehicle safety assurance, needed more detail and a few indicated

that the lack of detail created uncertainties in their own planning.[29] DOT held public meetings on the *FAVP* and solicited written comments.

In September 2017, NHTSA issued *A Vision for Safety*, which sought to address stakeholder comments on the 2016 *FAVP* and incorporate current policy priorities. This document states that DOT's role is to encourage the development of safe automated vehicle technologies through a flexible, nimble non-regulatory framework. Like the *FAVP*, the new guidance includes a voluntary, manufacturer-led safety self-assessment and addresses the division of federal and state responsibilities. For example, it discusses roles and responsibilities of states and the federal government (e.g., licensing drivers versus setting vehicle standards, respectively) and emphasizes that automated vehicles should not change these general areas of responsibility. However, DOT officials described it as a new policy direction (see fig. 3).

[29]NHTSA did not receive any Safety Assessment Letters following the publication of the *FAVP* and the issuance of *A Vision for Safety*, which replaced it.

Figure 3: Comparison of National Highway Traffic Safety Administration's (NHTSA) *Federal Automated Vehicle Policy* (2016) and *Vision for Safety* (2017)



Source: GAO analysis of DOT documentation. | GAO-18-132

[a]The Safety Assessment Letter suggested by NHTSA would cover the following areas: data recording and sharing; privacy; system safety; vehicle cybersecurity; human machine interface; crashworthiness; consumer education and training; registration and certification; post-crash behavior; federal, state, and local laws; ethical considerations; operational design domain (i.e., the conditions in which an automated vehicle is designed to work); object and event detection and response; fall back (i.e., what the automated vehicle will do if a system fails); and validation methods.

[b]The *Vision for Safety* focuses on vehicles and technologies that either do not require a driver or in which a driver is not required to monitor the driving environment (SAE International Level 3–5), and not "partial automation," which requires constant driver engagement (SAE International Level 2).

The *Vision for Safety* also makes some changes in the safety assessment by manufacturers, eliminates some sections of the original *FAVP*, and creates a resource document separate from the guidance. First, a Voluntary Safety Self-Assessment replaces the *FAVP*'s Safety Assessment Letter as the proposed mechanism for motor vehicle and motor vehicle equipment developers to demonstrate their approach to ADS safety. This assessment remains voluntary and the new guidance more clearly indicates that ADSs are not subject to NHTSA approval prior to testing or deployment. Further, three topical areas that the *FAVP* suggested vehicle developers

discuss in the Safety Assessment Letter—data privacy and sharing, ethical considerations, and vehicle registration—are not included in the Voluntary Safety Self-Assessment.[30] Second, unlike the *FAVP*, the *Vision for Safety* does not discuss NHTSA's current regulatory tools, options for how new regulatory tools might help address challenges, or list specific "next steps" that DOT intends to take in the different areas the guidance addresses. According to officials, DOT is beginning work on the third version, dubbed the "*FAVP* 3.0," that will be available in 2018 and include multimodal topics such as transit and commercial trucking. However, DOT has not announced specific milestones or a detailed scope of work for this effort.

- *Exercising Safety Oversight Authority*. As discussed earlier, DOT has a multi-faceted approach to safety oversight that includes setting federal vehicle safety standards, conducting investigations, and pursuing recalls of noncompliant or defective equipment. DOT has taken some steps to apply this approach to automated vehicles. For example, DOT's 2016 Enforcement Guidance Bulletin reinforced that NHTSA's authority to investigate and require the recall of defective equipment extends to automated vehicle technologies. NHTSA has exercised that authority and conducted investigations of Level 0, 1, and 2 vehicles equipped with features such as automatic emergency braking and adaptive cruise control. As a result of these investigations, NHTSA has pursued recalls of some Level 1 automated equipment, but not for Level 2.[31] NHTSA also identified

[30]*A Vision for Safety* briefly mentions privacy and ethical considerations in an endnote, which directs readers to NHTSA's website for a more thorough discussion. In October 2017, Waymo released *On the Road to Fully Self-Driving*, a report that describes the company's processes relevant to the 12 topical areas included in *A Vision for Safety*.

[31]For instance, NHTSA investigated incidents alleging that the adaptive cruise control, a Level 1 technology, on 2015 Ford F-150s falsely identified objects in the vehicle's path, causing unwanted severe brake application. This investigation led to a recall of over 30,000 vehicles. NHTSA has conducted a preliminary evaluation of a fatal crash involving a 2015 Tesla Model S categorized as a Level 2 automated vehicle. NHTSA determined that a safety-related defect trend had not been identified and closed its preliminary evaluation, noting that it was not making a determination that no safety-related defect existed. The National Transportation Safety Board also investigated this crash and determined that the vehicle's automation permitted the car driver's overreliance on the automation, noting its design allowed prolonged disengagement from the driving task and enabled the driver to use it in ways inconsistent with manufacturer guidance and warnings. See National Transportation Safety Board, *Collision between a Car Operating with Automated Vehicle Control Systems and a Tractor-Semitrailer Truck Near Williston, Florida, May 7, 2016,* Accident Report, NTSB/HAR-17/02, (Washington, D.C.: Sept. 12, 2017).

various potential areas for revision within the Federal Motor Vehicle Safety Standards and is continuing to study the needs for changes to these standards.[32] However, DOT has not specified what changes to exemption authorities are needed or established a time table for when a new rulemaking proposal will be initiated.

- *Exploring Infrastructure Modernization*. DOT has begun responding to the challenges it faces in adapting both highway and vehicle communication infrastructure by drafting guidance and proposing new rules, but is still investigating the best ways to execute such proposals. For example, FHWA issued draft *Vehicle-to-Infrastructure Deployment* guidance[33] designed to assist DOT staff and infrastructure owners at the federal,[34] state, and local levels in planning for and deploying this technology and ensuring its effective operation. According to FHWA officials, they are currently working on a final version of the guidance, but could not provide a publication date. FHWA officials also acknowledged that existing roadway signage and traffic control guidance would likely need to be updated. As a result, the office responsible for publishing this guidance has begun exploring this issue.[35] Additionally, in 2016 NHTSA issued a Notice of Proposed Rulemaking to require vehicle-to-vehicle communications on all new light vehicles models.[36] This rulemaking seeks to equip all new passenger vehicles with interoperable vehicle-to-vehicle communications capability that could facilitate the

[32]For instance, DOT's Volpe Center conducted a study which sought to identify aspects of the Federal Motor Vehicle Safety Standards that could be affected by automated vehicles. Anita Kim, et al, *Review of Federal Motor Vehicle Safety Standards (FMVSS) for Automated Vehicles; Identifying potential barriers and challenges for the certification of automated vehicles using existing FMVSS*, Preliminary Report, Technology Innovation and Policy Division, John A. Volpe National Transportation Systems Center, Prepared for Intelligent Transportation Systems Joint Program Office; National Highway Traffic Safety Administration (Washington, D.C.: March, 2016).

[33]FHWA's vehicle-to-infrastructure guidance was originally estimated to be published in September 2015. FHWA initially issued it in January 2017, but the new DOT administration has decided to review it.

[34]FHWA operates the Office of Federal Lands Highway to assist federal infrastructure owners which include the National Park Service, Bureau of Indian Affairs, Tribal Governments, and the Department of Defense.

[35]The Manual on Uniform Traffic Control Devices contains the national standards for all roadway signage and traffic control infrastructure.

[36]The effective date for manufacturers to implement this requirement would be 2 model years after the final rule is adopted, with a 3 year phase-in period to accommodate vehicle manufacturer's production cycles.

development and deployment of safety applications. However, some of the stakeholders we interviewed noted that different forms of wireless communication are already available to facilitate vehicle-to vehicle communications. Mandating one type of wireless communications could create issues if other, more advanced communication technologies arise, according to these stakeholders. DOT is reviewing comments to the notice, and no communication standard has been established.

Research and Technology Efforts

DOT has begun to focus its research more on automated vehicles, has revised programs to incorporate automated vehicle technologies, and advance its deployment. While JPO has a central role in coordinating research across modes, NHTSA and FHWA also lead many research efforts. DOT's research to date has mainly focused on Level 1 and 2 technologies. For example, many of FHWA's and JPO's studies focus on things such as adaptive cruise control and speed harmonization, both Level 1 technologies. NHTSA's research includes some studies of Level 2 crash avoidance technology and related effect on human factors. One of NHTSA's more advanced research areas focuses on the challenge of how humans and machines interface when operating Level 2 and 3 automated systems. Moreover, DOT has revised programs aimed at the deployment of advanced technologies to include automated vehicle technologies and has also begun to include some automated vehicle technologies as part of its New Car Assessment Program (see table 1).

Table 1: DOT's Activities to Advance the Deployment of Smart Infrastructure and Automated Vehicle Technologies

	Program	Description
Promoting Smart Infrastructure	Smart City Challenge	Competition held by DOT in 2016 for cities to develop smart infrastructure projects with the goal of moving people and goods more efficiently. The winner received a $40 million federal grant to deploy its ideas.
	Advanced Transportation and Congestion Management Technologies Deployment Program	A DOT program that collectively offers $60 million worth of competitive grants for applicants to deploy infrastructure projects with advanced technologies. Projects that include automated technologies or that accommodate automated vehicles can be eligible for funding, though it is not a requirement for the program.
Promoting Automated Technologies	New Car Assessment Program	NHTSA program that develops safety ratings for all vehicle models based on a scale of 1 to 5 stars. Automatic emergency braking will become one of the program's recommended safety features, beginning with all 2018 models. Other automated features, such as lane-keeping support, are under consideration for inclusion.

Source: GAO analysis of Department of Transportation information. | GAO-18-132.

Internal Management Efforts

DOT has made efforts to use existing mechanisms to coordinate internally to respond to automation challenges. These efforts include considering automated vehicles in strategic and workforce planning, as well as using internal workgroups, as follows:

- *Starting to Incorporate Automation into Strategic Planning*: At the departmental level and through its various administrations, DOT has taken preliminary steps toward incorporating automated vehicles into its strategic planning. At the departmental level, DOT's 2014-2018 strategic plan briefly identifies automated vehicles as a safety research area and includes as a priority "leading the conversation on vehicle-to-vehicle technology," which reflects the department's focus thus far on vehicle communication technologies.[37] NHTSA's 2016-2020 strategic plan includes objectives related to ADSs, such as providing leadership for the safe deployment of automated vehicles. The plan discusses how these vehicles could reinforce NHTSA's overall mission of saving lives, preventing injury, and reducing economic costs due to traffic crashes. FHWA's and JPO's strategic plans also acknowledge how automation could fit into their overall visions and missions. Conversely, FHWA issued a 2016 plan identifying priorities for the department's pedestrian and bicycle initiatives and investments, but it does not discuss how the risks posed to pedestrians and cyclists by automated vehicle technologies would be addressed.[38]
- *Beginning to Explore Workforce Adaptations*: DOT officials and some stakeholders we interviewed described the difficulty DOT faces in reshaping its workforce in light of emergent demands on the department as automated vehicles become more prevalent. One

[37]The plan includes additional strategies including: (1) encouraging the deployment of effective advanced vehicle automation technologies such as advanced braking systems, and (2) continuing research and implementation of vehicle-to-vehicle and vehicle-to-infrastructure technologies. See U.S. Department of Transportation, *Transportation for a New Generation, Strategic Plan Fiscal Years 2014–18.* DOT's draft strategic plan for 2018-22, circulated for public comment in October 2017 and expected to be finalized by February 2018, indicates the department will work with public and private stakeholders to advance the development and adoption of automated technologies and ensure their safety. See *U.S. Department of Transportation Strategic Plan for FY 2018-2022, Draft for Public Comment, October 19, 2017.*

[38]See U.S. Department of Transportation, Federal Highway Administration, *Strategic Agenda for Pedestrian and Bicycle Transportation* (Washington, D.C.: September 2016).

reason, they said, is that DOT competes with high-paying technology firms to acquire new talent. For example, some stakeholders expressed concern that NHTSA does not have the resources necessary to meet the challenges it faces in regulating the safety of and overseeing automated vehicles because, in part, it is difficult for DOT to find and hire staff with the right software and automotive expertise. DOT officials also said that, while recruiting budgets were small, they have—on a limited basis—attempted to reach more potential college recruits by sponsoring a symposium designed to increase potential candidates' awareness of DOT. In addition, in 2016 DOT brought in its first Chief Innovation Officer on detail to help foster a culture of innovation. This individual was a member of the team that developed the *FAVP*, but is no longer with DOT, and other NHTSA staff led the development of *A Vision for Safety*.

- *Establishing Internal Working Groups*: DOT has created and used different internal working groups to help address automation challenges. For example, JPO facilitates weekly executive-level meetings to coordinate automated vehicle projects and policy initiatives across the department and a bi-weekly meeting to coordinate automation research. Likewise, to coordinate all ongoing research efforts internally, FHWA's Research Oversight Committee holds monthly meetings among the various offices within the administration. In addition, FHWA has established an automated vehicle working group that is taking steps to develop a vision statement to guide FHWA's role related to automated vehicles. In other instances, DOT created working groups for specific projects; however, the working groups end when the project is finished. For instance, NHTSA created the Vehicle Innovation Team to support the development of the *FAVP*. According to DOT officials, the team stopped meeting formally following the 2016 release of the *FAVP*, though individuals continue to work together on implementation and next steps. According to NHTSA officials, NHTSA has created another team to review key policy issues stakeholders raised in public comments headed by the Associate Administrator for Vehicle Safety Research. DOT officials also indicated that after the appointment of a new Deputy Assistant Secretary of Transportation Policy in the summer of 2017, the Office of the Under Secretary for Policy formed an Automation Policy Working Group to develop and coordinate automated vehicle policy department-wide, including the "*FAVP* 3.0" mentioned previously.

DOT Does Not Have a Comprehensive Plan to Further Address Challenges

While DOT has made initial efforts to issue or update policies, revise programs, and coordinate its research related to automated vehicles, it has done so without the benefit of a comprehensive plan to guide these efforts. This lack of comprehensive planning is inconsistent with leading principles on sound planning we have identified in our prior work; these principles call for developing robust, comprehensive plans to achieve agency goals.[39] When facing major challenges similar to those posed by automated vehicles, leading practices call for agencies to develop robust, comprehensive plans.[40] Successful comprehensive plans include principles that progress logically from conception to implementation, such as: (1) what the plan is trying to achieve and how it will achieve those results, with goals and objectives linked to prioritized activities; and (2) milestones and performance measures to monitor and gauge those results.[41] Comprehensive planning is also consistent with federal internal control standards, which call for agencies to identify timeframes for achieving defined objectives and to assess their progress toward meeting their objectives.[42]

As described previously, strategic plans for DOT, NHTSA, and FHWA include automation in discussions of vehicle safety, but these plans do not have the details that would be found in a comprehensive plan. Specifically, DOT issued a departmental strategic plan that calls for encouraging automated vehicle technologies and continuing research and implementation of vehicle-to-vehicle and vehicle- to-infrastructure

[39]For example, see GAO/GGD-96-118 and GAO, *Veterans' Health Care: Proper Plan Needed to Modernize System for Paying Community Providers*, GAO-16-353 (Washington, D.C.: May 11, 2016).

[40]GAO-16-353.

[41]For key characteristics of sound planning that reflect a comprehensive approach to program management, see GAO, *Combating Terrorism: Evaluation of Selected Characteristics in National Strategies Related to Terrorism,* GAO-04-408T (Washington, D.C.: Feb. 3, 2004) and GAO, *Health Care Quality: HHS Should Set Priorities and Comprehensively Plan Its Efforts to Better Align Health Quality Measures*, GAO-17-5 (Washington, D.C.: Oct. 13, 2016).

[42]GAO, *Standards for Internal Control in the Federal Government*, GAO-14-704G (Washington, D.C.: September 2014).

technologies.[43] Likewise, NHTSA, FHWA, and JPO have strategic plans that contain high-level goals and objectives, some of which include automated vehicles. However, as expected of strategic plans, these are broad frameworks for accountability and oversight rather than comprehensive plans that systematically outline and prioritize the specific efforts needed to achieve the department's goals and objectives. For example, NHTSA's 2016–2020 strategic plan includes five high-level strategic goals, one of which is automated vehicles.[44] To achieve this goal, the plan calls for NHTSA to "provide national leadership for the safe deployment of automated vehicles," among other objectives. However, the plan does not define what national leadership would entail nor delineate priorities, implementation details, or a method to monitor results. Moreover, while DOT officials indicated that automated vehicles could pose a particular risk for pedestrians and cyclists, FHWA does not include automation in its plan for pedestrian and cyclist safety, even though the plan sets priorities, outlines efforts FHWA will make to achieve its goals, and establishes timelines that can be used to monitor progress.

The automation policy and guidance documents DOT has issued, such as the *FAVP* and *A Vision for Safety*, are also not comprehensive plans that explain how DOT will prioritize its efforts in this area and monitor results. The *FAV*P was meant to speed the delivery of an initial regulatory framework and best practices and was a first step towards making some elements of the guidance mandatory and binding through future regulatory actions. The *Vision for Safety* articulates DOT's new non-regulatory policy direction which emphasizes voluntary industry actions and promoting best practices. However, neither document specified how NHTSA would prioritize its efforts, when various internal working groups would meet milestones, or what performance measures would be used to track progress. For example, the *FAVP*'s next steps included "Publish Safety Assessment Template" and "Mandate Safety Assessment," but the steps were not prioritized and did not include milestones.[45] Moreover, *A*

[43]DOT's Strategic Plan for fiscal years 2014-2018 includes a strategic goal aimed at improving safety by reducing transportation-related fatalities and injuries. The draft strategic plan for 2018-2022 indicates that automation is a part of the department's strategy to improve safety and encourage innovation.

[44]U.S. Department of Transportation, *The Road Ahead: National Highway Traffic Safety Administration Strategic Plan 2016-2020*, DOT HS 812 343 (Washington, D.C.: October 2016).

[45]NHTSA did not complete either of these steps prior to issuing *A Vision for Safety*, which replaced the *FAVP*.

Vision for Safety did not include any next steps. Without a comprehensive plan, DOT also lacks a mechanism to monitor the results of its efforts. For example, as discussed earlier, NHTSA has identified various potential areas for revision within the Federal Motor Vehicle Safety Standards. Such changes involve numerous steps and could take many years to accomplish. However, as NHTSA continues to study the need for changes to these standards, it has not specified milestones or performance measures for the efforts it would need to complete to make such a determination about the standards.

DOT has changed its policy direction under new leadership and is in the early stages of detailing this new, non-regulatory and voluntary vision, according to officials, and does not have a comprehensive plan for its current efforts. After releasing the *FAVP* in September 2016, NHTSA solicited and reviewed public comments and developed potential responses to the comments through the first half of 2017. However, following the change in administrations, DOT was without some permanent key senior leadership, including a NHTSA administrator, and NHTSA did not take any public steps to further clarify the guidance after January 2017. Many of the stakeholders we interviewed said that the absence of senior leaders or NHTSA clarifications created uncertainty about the direction of DOT's automated vehicle policy. As noted above, in June 2017, DOT's policy efforts coalesced under the leadership of the new Automation Policy Working Group, according to DOT officials, to start work on DOT's next policy. This effort is just beginning and not fully detailed, but DOT documentation describing this effort indicates it will result in a "coordinated, comprehensive plan" to support safe automated vehicle development and deployment. However, this documentation does not indicate that it will include goals, milestones, or monitoring, key principles of comprehensive planning that have been lacking from DOT's recent guidance and strategic plans.

At present, it is unclear whether DOT's initial efforts are appropriately tackling automated vehicle challenges and making sufficient progress toward achieving high-priority goals. This could lead to delays in the deployment of life-saving technologies or, conversely, unsafe technologies making it into vehicles. A comprehensive plan would also help provide industry, governmental, and safety stakeholders with details about DOT's efforts so they can appropriately plan their own efforts.

Conclusions

Automated vehicle technologies are quickly evolving, and as a result, DOT has been and likely will continue to face emerging safety and infrastructure challenges. It is too soon to know if DOT's current efforts, as articulated in *A Vision for Safety*, will successfully address the challenges automated vehicles pose. As DOT refines and advances its efforts, it has the opportunity to incorporate leading principles of comprehensive planning. A comprehensive plan would help DOT manage its efforts to oversee and advance the safe development, testing, and deployment of automated vehicle technology. In addition, a comprehensive plan could help DOT make decisions about whether and how to respond to different automated vehicle technology challenges as they arise. Without a comprehensive plan, DOT may miss the opportunity to organize, prioritize, and clearly monitor the progress of its many efforts across NHTSA, FHWA, and the Office of the Secretary, and other administrations as appropriate.

Recommendation for Executive Action

The Secretary of Transportation should develop and implement a comprehensive plan to better manage departmental initiatives related to automated vehicles. This plan should include leading principles such as goals, priorities, steps to achieve results, milestones, and performance measures to track progress. (Recommendation 1)

Agency Comments

We provided a draft of this report to DOT for review and comment. In its comments, reproduced in appendix II, DOT concurred with the recommendation and indicated that it would be premature to publish a comprehensive plan at this time, but would pursue an iterative framework to manage DOT's activities to address automated vehicle challenges. We believe this approach could address our recommendation provided this framework incorporates leading principles of comprehensive planning. DOT also provided technical comments which we incorporated as appropriate.

We are sending copies of this report to the Secretary of the Department of Transportation, and interested congressional requesters. In addition,

the report will be available at no charge on the GAO website at http://www.gao.gov. If you or your staff have any questions about this report, please contact me at (202) 512-2834 or wised@gao.gov. Contact points for our Offices of Congressional Relations and Public Affairs may be found on the last page of this report. GAO staff who made major contributions to this report are listed in appendix III.

David Wise
Director, Physical Infrastructure Issues

Appendix I: Literature Reviewed and Selected Stakeholders Interviewed

Literature Reviewed

Anderson, James, et al. *Autonomous Vehicle Technology, A Guide for Policymakers*. Santa Monica, CA: RAND Corporation, 2016.

DiClemente, Jonathan, et al., *Autonomous Car Policy Report*. Pittsburgh, PA: Carnegie Mellon University, May 2014.

Glancy, Dorthy J., et al. "A Look at the Legal Environment for Driverless Vehicles." *Legal Research Digest 69*. Washington, D.C.: National Cooperative Highway Research Program, Feb. 2016.

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Selected Stakeholders Interviewed

Table 2 lists the stakeholders we interviewed for this work.

Table 2: Organization, Type, and Description of Selected Stakeholders

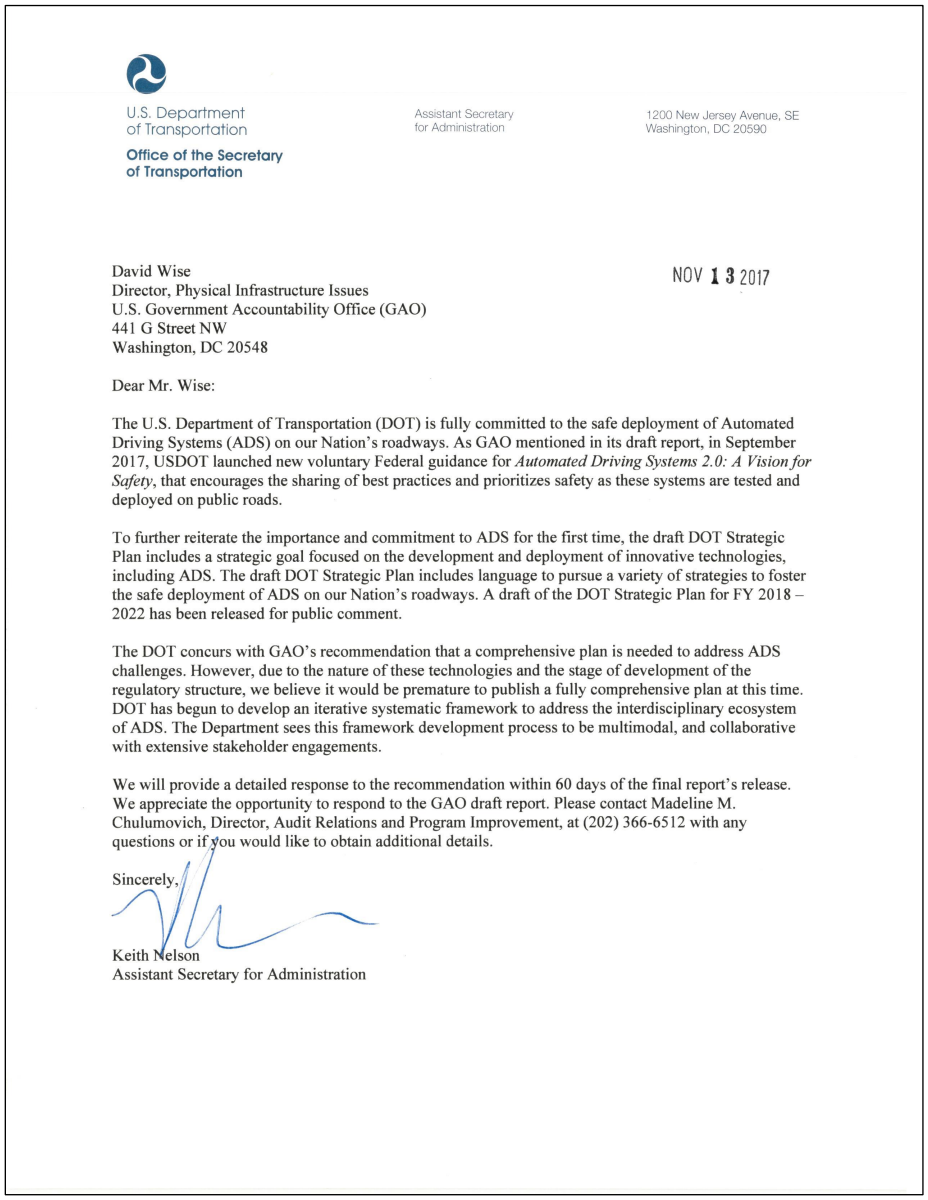
	Organization	Description
Companies and industry groups	Alliance of Automobile Manufacturers	An advocacy group for the auto industry representing 12 companies that account for 70 percent of all car and light truck sales in the U.S.
	Automotive Information Sharing and Analysis Center	Created by the auto industry to promote collaborative cyber-security efforts, the group has established and maintained a set of best practices.
	Delphi Automotive	High-technology company that develops and sells automated and connected vehicle technologies.
	Ford Motor Company	Plans to design and operate Level 4 automated vehicles without steering wheels, or gas or brake pedals for use in commercial mobility services such as ride sharing and ride hailing within limited areas.
	General Motors	Has been testing Chevrolet Bolt EV automated vehicles equipped with self-driving technology on public roads in San Francisco, CA and Scottsdale, AZ, since June 2016 and in Warren, MI. since Jan. 2017.
	Mercedes-Benz	Developing software and algorithms for an automated driving system through a partnership designed to bring Level 4 and 5 cars to urban roads.
	QNX Software Systems	Subsidiary of Blackberry, developing a software platform for automotive safety applications such as digital instrument clusters, heads-up displays, and advanced driver-assistance systems.

	Organization	Description
	SAE International	International standards organization that defined automated driving terms and identified six levels of driving automation, from no automation to full automation, later adapted by the National Highway Traffic Safety Administration.
	Tesla	Auto maker all of whose electric vehicles come standard with automated features that are updated through over-the-air software upgrades.
	Waymo	Technology company working to commercialize self-driving technology, currently testing nearly 60 automated vehicles on public roads in 4 U.S. cities.
State, regional, and local governmental organizations or associations	American Association of Motor Vehicle Administrators	Nonprofit organization developing model programs in motor vehicle administration, law enforcement, and highway safety.
State, regional, and local governmental organizations or associations	American Association of State Highway and Transportation Officials	Nonprofit organization working to foster the development, operation, and maintenance of an integrated national transportation system.
	California Department of Motor Vehicles	California Vehicle Code Section 38750 requires the department to adopt regulations governing both the testing and public use of automated vehicles on California roadways.
	City of Pittsburgh, Mayor's Office	City plans to use self-driving technology and adaptive traffic signals to improve safety and increase mobility.
	City of San Francisco • Mayor's Office • Municipal Transportation Agency (SFMTA)	City plans to use shared, electric vehicles—eventually fully automated ones—as well as collision avoidance technology and connected vehicles to enhance safety.
	Pennsylvania Department of Transportation (PennDOT)	Convened an Autonomous Vehicle Policy Task Force to promote the advancement of technology while ensuring public safety.
	• Regional Transportation Commission of Southern Nevada • Nevada Department of Transportation	• The commission is a regional entity that oversees public transportation, traffic management, roadway design and construction funding, and transportation planning for Southern Nevada. • The department works to provide, operate, and preserve a transportation system that enhances safety, quality of life and economic development through innovation, environmental stewardship, and a dedicated workforce.
Safety organizations	Governors Highway Safety Association	Nonprofit organization representing state and territorial highway safety offices that implement federal grant programs to address behavioral highway safety issues.
	Insurance Institute for Highway Safety	Independent, nonprofit scientific and educational organization dedicated to reducing the losses—deaths, injuries and property damage—from crashes on the nation's roads.
	National Transportation Safety Board	Independent federal agency that investigates accidents, determines their probable cause, and recommends ways to prevent them from happening again.

	Organization	Description
	Safety Research and Strategies	Provides fact-based research and analysis on injuries associated with product hazards ranging from motor vehicles to consumer and industrial products to medical devices.
Academics	California Partners for Advanced Transportation Technology (University of California, Berkeley)	We interviewed Steven Shladover, Program Manager and Research Engineer at Partners for Advanced Transportation Technology, a research and development program that has been a leader in intelligent transportation systems research since its founding in 1986.
	Center for Automotive Research (Stanford University)	We interviewed Chris Gerdes, Professor of Mechanical Engineering, who studies how cars move, how humans drive, and how to design automated vehicles. He served as the U.S. Dept. of Transportation's first Chief Innovation Officer from Feb. 2016 to Jan. 2017 and was part of the team that developed the *Federal Automated Vehicles Policy*.
	Santa Clara University School of Law	We interviewed Dorothy Glancy, a Law Professor at SCU since 1975, who is nationally known for her extensive work in the area of privacy and transportation law.
	Technologies for Safe and Efficient Transportation (Carnegie Mellon University)	We interviewed Raj Rajkumar, Technologies for Safe and Efficient Transportation Director and Electrical and Computer Engineering Professor. His work is primarily in cyber-physical systems, such as automated driving and vehicular networks, and wireless/sensor networks.
Academics	Traffic21 (Carnegie Mellon University)	We interviewed Chris Hendrickson, Engineering Professor and Director of Traffic 21, which was founded to identify, refine, and deploy intelligent transportation system projects to Pittsburgh.
	University of South Carolina School of Law	We interviewed Bryant Walker Smith, Law Professor at the University of South Carolina, and Affiliate Scholar at Stanford Law School's Center for Internet and Society.

Source: GAO. | GAO-18-132.

Appendix II: Comments from the Department of Transportation



U.S. Department of Transportation
Office of the Secretary of Transportation

Assistant Secretary for Administration

1200 New Jersey Avenue, SE
Washington, DC 20590

David Wise
Director, Physical Infrastructure Issues
U.S. Government Accountability Office (GAO)
441 G Street NW
Washington, DC 20548

NOV 13 2017

Dear Mr. Wise:

The U.S. Department of Transportation (DOT) is fully committed to the safe deployment of Automated Driving Systems (ADS) on our Nation's roadways. As GAO mentioned in its draft report, in September 2017, USDOT launched new voluntary Federal guidance for *Automated Driving Systems 2.0: A Vision for Safety*, that encourages the sharing of best practices and prioritizes safety as these systems are tested and deployed on public roads.

To further reiterate the importance and commitment to ADS for the first time, the draft DOT Strategic Plan includes a strategic goal focused on the development and deployment of innovative technologies, including ADS. The draft DOT Strategic Plan includes language to pursue a variety of strategies to foster the safe deployment of ADS on our Nation's roadways. A draft of the DOT Strategic Plan for FY 2018 – 2022 has been released for public comment.

The DOT concurs with GAO's recommendation that a comprehensive plan is needed to address ADS challenges. However, due to the nature of these technologies and the stage of development of the regulatory structure, we believe it would be premature to publish a fully comprehensive plan at this time. DOT has begun to develop an iterative systematic framework to address the interdisciplinary ecosystem of ADS. The Department sees this framework development process to be multimodal, and collaborative with extensive stakeholder engagements.

We will provide a detailed response to the recommendation within 60 days of the final report's release. We appreciate the opportunity to respond to the GAO draft report. Please contact Madeline M. Chulumovich, Director, Audit Relations and Program Improvement, at (202) 366-6512 with any questions or if you would like to obtain additional details.

Sincerely,

Keith Nelson
Assistant Secretary for Administration

Appendix III: GAO Contact and Staff Acknowledgments

GAO Contact

David Wise, (202) 512-2834 or wised@gao.gov

Staff Acknowledgments

In addition to the individual named above, Cathy Colwell (Assistant Director); John Stambaugh (Analyst in Charge); Jenny Chanley; Leia Dickerson; Gary Guggolz; Terence Lam; Josh Ormond; Cheryl Peterson; Patrick Tierney; and Michelle Weathers made key contributions to this report.

Appendix IV: Accessible Data

Agency Comment Letter

Text of Appendix II: Comments from the Department of Transportation

NOV 13, 2017

David Wise

Director, Physical Infrastructure Issues

U.S. Government Accountability Office (GAO) 44l G Street NW

Washington, DC 20548

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Sincerely,

Keith Nelson

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Intelligent Transportation Systems: Urban and Rural Transit Providers Reported Benefits but Face Deployment Challenges. GAO-16-638. Washington, D.C.: June 21, 2016.

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Vehicle Safety

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