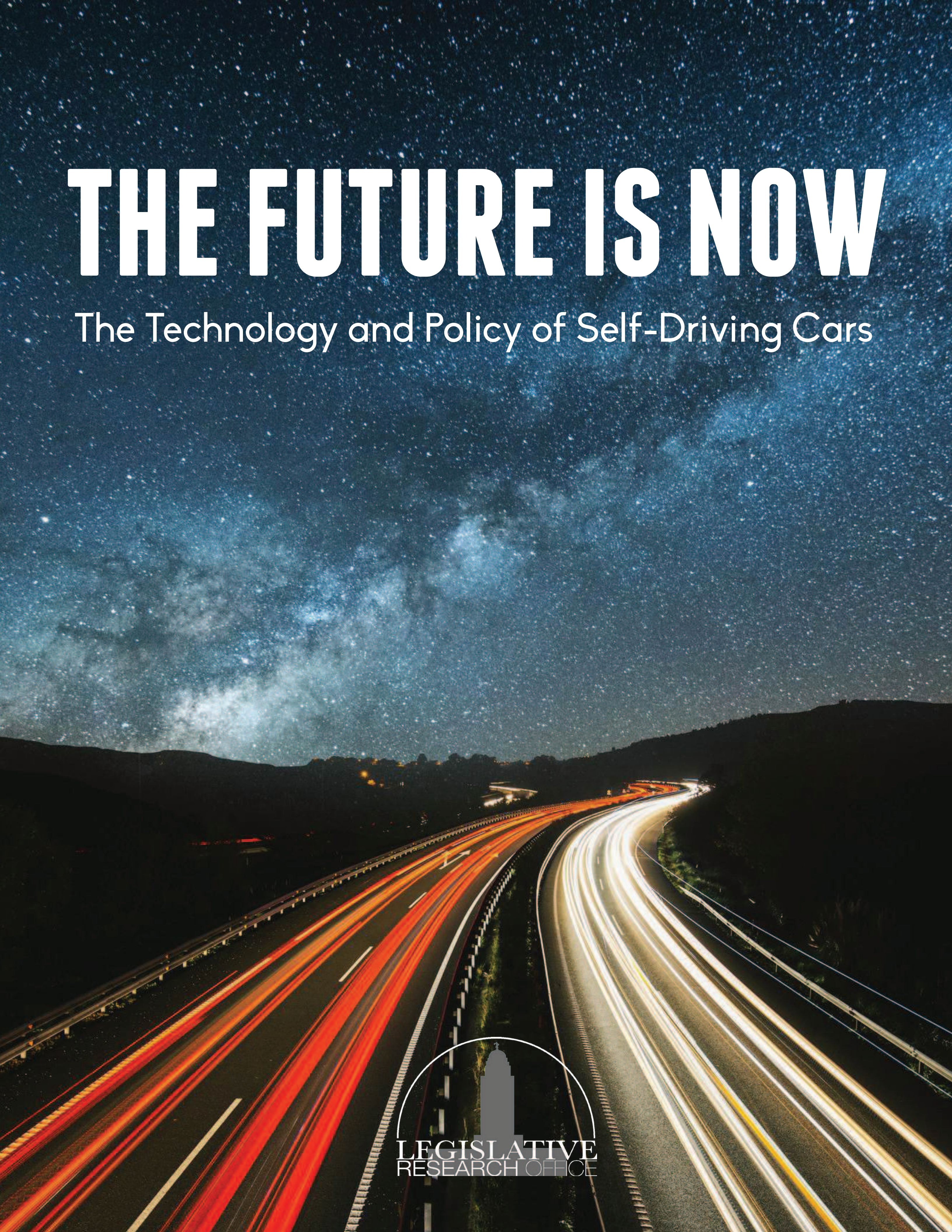
THE FUTURE IS NOW

The Technology and Policy of Self-Driving Cars



LEGISLATIVE RESEARCH OFFICE

The Future is Now

The technology and policy of self-driving cars

A Legislative Research Office Backgrounder

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Imagine being able to drive to work if you are legally blind, to the grocery if you are frail elderly, or to school if you are too young for a license. Perhaps your concerns run to cutting traffic fatalities or reducing energy consumption and curbing pollution, or managing road congestion and putting parking lots to better land use.

All of these outcomes and more are cited as the upside of autonomous vehicle (AV) technology.

All major automakers are engaged in AV research, as are auto upstarts Tesla and Uber, and tech innovators Bosch and Google, whose vehicles have test-driven hundreds of thousands of miles. Even computer giant Intel became a player with the 2017 purchase of an Israeli company making software used in AV technology systems.

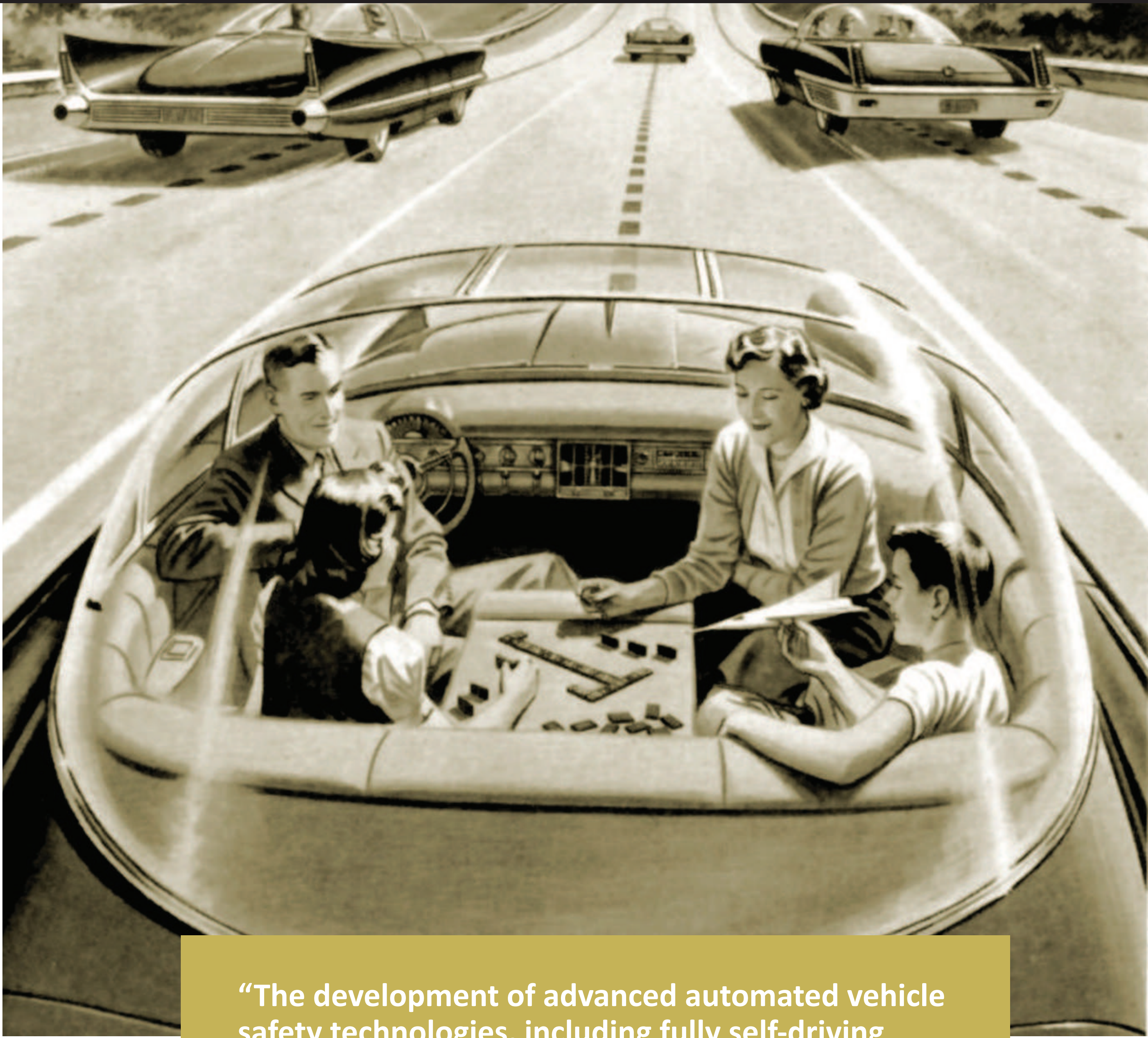
Full-scale commercial introduction is anticipated within five to 20 years.[1] Google executives say they will be ready in a year. In the meantime, varying levels of automation are in development, under production, and on the roads.

With such potential, AVs stand to alter how society views disability, uses its time, develops infrastructure, and provides jobs. The potential for how this technology will alter our lives is mind-boggling. Policymakers must be prepared for the changes ahead to take advantage of the touted benefits and to ameliorate the inevitable disruptions.

This Backgrounder summarizes the status of the industry and technology, federal involvement, and legislative action taken by the states to date.

A note about nomenclature: "Self-driving," "driverless," "autonomous vehicles," "automated driving systems" are all terms (and there are probably many others) used in the literature, policy manuals, statutes, and other materials to refer to vehicles that do not require a human driver. For consistency, this Backgrounder uses the term "autonomous vehicle" or AV, for short, when referring to fully autonomous vehicles.

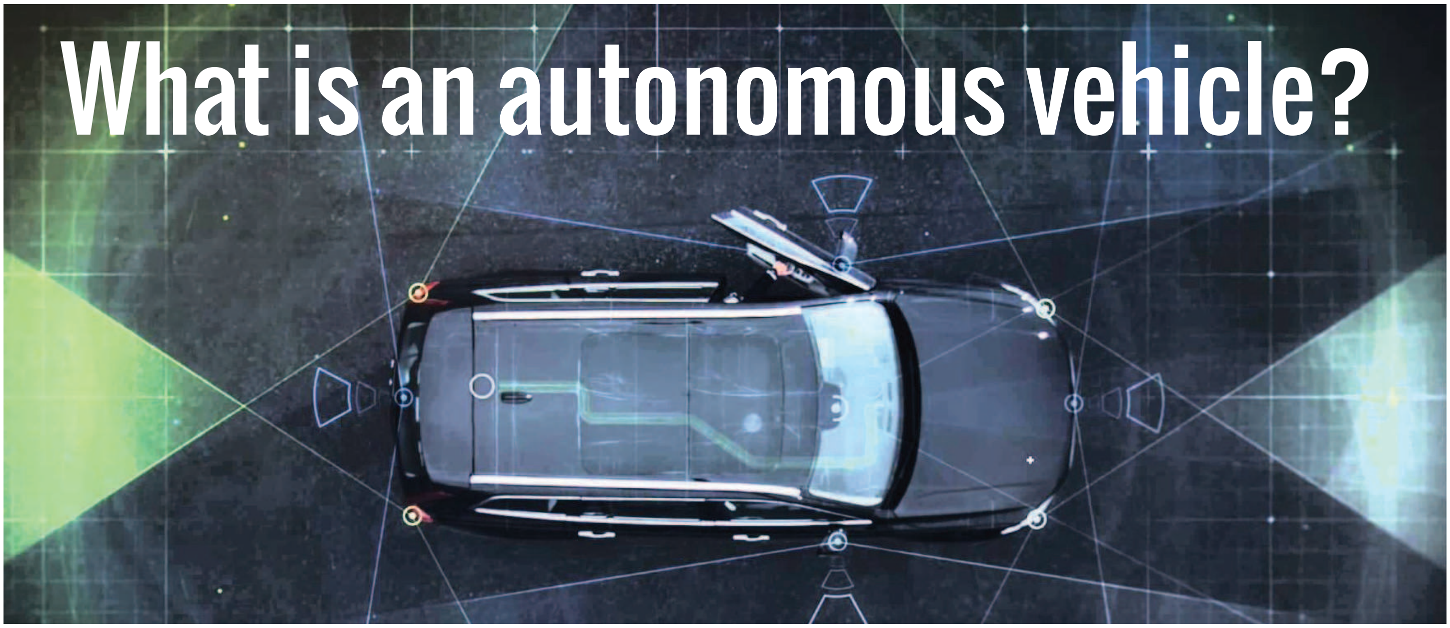
And, a caveat: Summarizing the status of AVs is like trying to catch a speeding bullet in your softball mitt—just too fast and dangerous. Developments in this field are rapid. Pertinent to legislative interest, actions in other states and the federal government are also beginning to move quickly, especially as Congress considers legislation that may hasten AV deployment but usurp states' ability to regulate the vehicles. For the most current information on what is happening in particular states and at the federal level, please contact the Legislative Research Office.



"The development of advanced automated vehicle safety technologies, including fully self-driving cars, may prove to be the greatest personal transportation revolution since the popularization of the personal automobile nearly a century ago."[2]

-U.S. Dept. of Transportation

What is an autonomous vehicle?



As anyone who has recently bought an automobile knows, aspects of automated technology are available that help drivers parallel park and alert drivers to the presence of other vehicles in their blind spots.

As helpful as the assistive technologies are proving, the big buzz is about fully autonomous vehicles.

In an effort to clarify how a car that brakes automatically in an emergency differs from what is on the automotive horizon, SAE International[3] issued a standard that defines six levels of driving automation for on-road motor vehicles, from none (level 0) to full automation (level 5). These are technical, not legal, definitions. Nonetheless, the National Highway Transportation Safety Administration (NHTSA), the nation's primary federal regulator of vehicle safety, adopted the SAE standard in its *Federal Automated Vehicles Policy*, issued in 2016.

Briefly, the SAE levels[4] are:

Level 0—No automation.

Level 1—Driver assistance.

Level 2—Partial automation.

Level 3—Conditional automation.

Level 4—High automation.

Level 5—Full automation.

Level 0 are the autos on the road now, including those enhanced with warning or intervention systems. The human driver is in complete control of the driving environment at all times.

At levels 1 and 2, the human driver remains in full control of cars that have some degree of automation. Level 1 vehicles have automated either the steering or the accelerating/decelerating functions, while Level 2 vehicles have both of these systems automated. The human driver performs all other driving tasks. Tesla's Autopilot, which provides assists to change speed and lanes, is considered a Level 2 vehicle.

At levels 3 and 4, vehicles have gradually increasing levels of automation, with automated driving systems monitoring some aspects of the driving environment. Level 3 vehicles have systems (changing lanes, responding to unexpected incidents on the road) that take over the driving responsibility under certain conditions, with the expectation the human driver retakes control when the system requests it. Level 4 vehicles have automated all aspects of the dynamic driving task and can respond to situations without human intervention, but still allow for the human driver to take control of the driving task.

Level 5 vehicles are capable of fully autonomous operation. This means the full-time operation by an automated driving system of all aspects of driving under all roadway and environmental conditions. An example of a Level 5 auto is Google's SDC.

As states begin to regulate AVs, many of them are specifically excluding those active safety systems or operator assistance systems that are increasingly becoming standard on traditional motor vehicles. Such systems include electronic blind spot assistance, crash avoidance, parking assistance, or lane departure notification.

As whiz-bang as these assistive technologies seem to long-time drivers, fully autonomous driving technology is light years beyond this. Ultimately, AV technology is not assisting human drivers, it is replacing them.

From science fiction to science fact

At right: Stanley, the autonomous car that won the 2005 DARPA Grand Challenge. It was designed by Stanford University in cooperation with Volkswagen.

The 1939 New York World's Fair featured a display by General Motors that first introduced the concept that became the Interstate Highway System and also envisioned a future of driverless, electric automobiles. Advances in computing technology in the mid-1980s allowed engineers to proceed with developing systems that had been the stuff of imagination in prior decades. Advances since then can be divided into three phases.

Phase I, from 1980 to 2003, laid the foundational research done by university-based researchers, often in partnership with transportation agencies and automakers.

Phase II, from 2003 to 2007, was known as the U.S. Defense Advanced Research Projects Agency (DARPA) challenge period, and saw accelerated AV advancements.[5]

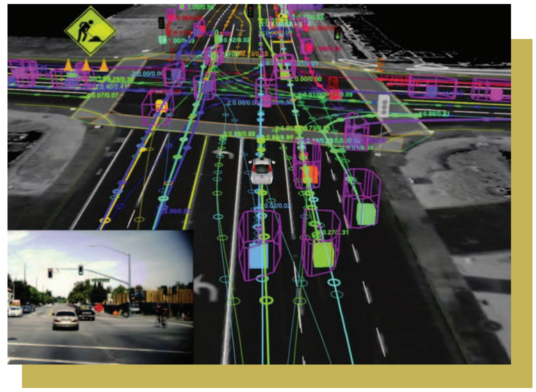
The "big bang" of AV technology occurred in November 2007.

In 2007, DARPA invited the nation's best and brightest to bring their technology to a challenge race in the Southern California desert. The 2007 race was the third and final of DARPA's "grand challenges," which are credited with accelerating AV technology and igniting public imagination. The final challenge simulated a 60-mile urban course in which competitors had to obey traffic laws and navigate alongside other autonomous and traditional vehicles. (The challenge was won by a team from Carnegie Mellon University driving a Chevrolet Tahoe named "Boss.")

"A handful of companies immediately saw amazing potential in all this, and they began hiring everybody they could from academia,'' said a DARPA-challenge participant. "But that's the great part of this story. An idea emerged from outside of the traditional auto industry, and companies like Google with their fast-moving and creative culture got it. And as a result, the idea took flight far faster than it would have otherwise."[6]

How Autonomous Cars See the Road

Autonomous vehicles combine data from many different sources — including cameras, radar, and LIDAR — to navigate through the world.



Camera
Takes images of the road that are interpreted by a computer. Limited by what the camera can "see."

Radar
Radio waves are sent out and bounced off objects. Can work in all weather but cannot differentiate objects.

LiDAR
Light pulses are sent out and reflected off objects. Can define lines on the road and works in the dark.

AV technology is now in Phase III. Partnerships have solidified between the researchers and the automakers and commercial development is proceeding.

To propel a vehicle down the road, without a driver, requires vehicles be able to (1) gather information from the driving environment, (2) process the information received, and (3) react to that information. Every time. Flawlessly.

AVs must read street signs, but possess the programming to disobey traffic rules to avoid crashes or road construction. AVs must be able to assess driving conditions, adjusting to traffic or weather or a child darting into the street. The technology must also be sensitive to individual concerns about privacy and fears about being hacked while driving.

How are researchers and manufacturers doing this?

- Radar sensors. Spaced around the vehicle, radar sensors process low-resolution data used to track the position of large objects at long range.
- Video cameras. These read traffic lights and road signs and monitor obstacles. The cameras are usually centrally mounted between the rear view mirror and the front windscreen for basic functions and at the wheel-arch level for surround view applications.
- LIDAR sensors. These sensors detect the edge of the road and lane markings by bouncing pulses of light off the car's surroundings.
- Ultrasonic sensors. Located all around the vehicle at bumper level, these detect the position of curbs and nearby vehicles while parking.
- Processing computers. Dozens of processing stations, equipped with graphical processors and multi-core computers, analyze input from various sensors to control steering, acceleration, and braking.

The roles for government

The National Highway Transportation Safety Administration's (NHTSA) *Federal Automated Vehicles Policy* (policy) serves as the federal government's AV development road map.

Issued as guidance, not rulemaking, the policy presents vehicle performance guidance for the industry, suggests a model state policy, describes the current regulatory tools available to the federal government, and looks ahead to what rules and laws may need changing to facilitate fully autonomous vehicles.

The policy reiterates the expectation that the traditional roles of the federal government and the states in regulating motor vehicles will not significantly change for AVs. Therefore, NHTSA sets and enforces the Federal Motor Vehicle Safety Standards (FMVSS) for new motor vehicles and motor vehicle equipment; investigates and manages recalls; and issues industry guidance and rulemaking.

States license drivers and register motor vehicles; enact and enforce traffic laws; conduct safety inspections; and regulate motor vehicle insurance and liability.

While the Department of Transportation and NHTSA play the prominent federal roles, other agencies are also players.

Because AVs will need to "communicate" with one another and with the surrounding transportation infrastructure, the Federal Communications Commission (FCC) has a policy role in the development of a dedicated short-range communications (DSRC) spectrum for vehicles and infrastructure. DSRC is essential for AV development because it can be integrated with radar, LIDAR sensors, and GPS navigation systems AVs use to network with other vehicles and their surroundings.

Cybersecurity is an ongoing AV safety concern, bringing agencies such as the FBI and Homeland Security into the mix.

Congress is also beginning to act.

In advance of a June 2017 hearing, a bipartisan group of U.S. senators, including the chair of the Senate Commerce, Science and Transportation Committee, released a set of six principles for AV legislation. The principles are:

- Prioritize safety;
- Promote innovation and reduce regulatory roadblocks;
- Remain tech neutral to avoid favoring one business model over another;
- Reinforce the separate regulatory roles of federal and state governments;
- Strengthen cybersecurity; and
- Educate the public as to the differences between conventional and autonomous vehicles.

On September 5, 2017, the House passed the SELF Drive Act (H.R. 3388). The bill includes four main sections: expansion of federal preemption; updates to the FMVSS; AV exemptions from the FMVSS (considered important to expedite AV testing under real-road conditions); and creation of a federal AV advisory council. Significantly, H.R. 3388 proposes to expand sole federal jurisdiction beyond the traditional role of motor vehicle safety to include motor vehicle operations and would prohibit states from regulating the operator of an AV.

The state of the states

> *A two-year NHTSA study from 2005 to 2007 estimated that 94 percent of the accidents on U.S. roadways are due to human error.*

As of August 2017, 20 states and the District of Columbia have enacted laws addressing some aspect of AV technology.[7] Additionally, governors in Arizona, Massachusetts, Washington, and Wisconsin issued executive orders giving support for developing and testing AV technology.

State enactments differ in scope.

While states such as Nevada, California, and Florida are aggressively pursuing an AV presence, others are testing the waters with studies (e.g., Alabama, Connecticut, North Dakota, Utah, and Vermont) or amending statutes to eventually accommodate a driverless future (e.g., Louisiana, Pennsylvania, and Virginia).

Among the states looking to encourage commercial AV applications, Arkansas, Florida, Georgia, and South Carolina have authorized driver-assistive truck platooning systems on the state's streets and highways. Driver-assistive truck platooning technology allows two or more trucks to drive semi-autonomously, very closely, in convoys controlled by the lead vehicle through wireless communication.[8]

However, a lack of legislative action does not indicate a lack of AV activity within a state. Given concerns about overregulating an industry dependent on innovation and cutting edge technology, states such as Washington, with its tech-savvy population and geographic diversity, draw AV developers by not inhibiting development with rules and regulations.

Following are brief summaries from some of the states considered to be in the forefront of AV development and testing.

A demo of a driver-assistive truck platoon designed by Volvo.

California

The state is no stranger to AV technology. The historic DARPA challenges described on page 4 took place in Southern California, and Google famously entered the fray with a test drive in the Bay Area. But the Legislature did not adopt legislation until 2012, expressing the state's intent to encourage AV development, testing, and operation, while ensuring such activities are done safely.

The law gives the Department of Motor Vehicles (department) authority to develop regulations governing testing and, ultimately, public use of AVs on California roadways. Regulations for testing became effective in September 2014, and draft regulations for public use are currently under review.

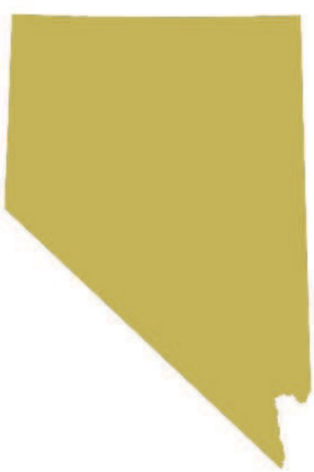
California authorizes operating AVs on public roads for testing purposes by a driver who meets certain statutory requirements, including that the driver be in the driver's seat and capable of immediately assuming manual control of the vehicle. Use on public roads for other than testing is barred until a manufacturer submits an application to the department certifying the vehicle meets certain requirements, including Federal Safety Standards and performance requirements.

The department must notify the Legislature when it receives and when it approves any application from a manufacturer for an AV capable of operating without the presence of a driver in the vehicle.

In 2016, the Legislature approved a pilot project authorizing the Contra Costa Transportation Authority to test AVs that do not have a driver seated in the driver's seat and are not equipped with a steering wheel, a brake pedal, or an accelerator. Testing must be conducted at specified locations, and the AV must operate at speeds of less than 35 miles per hour.

Nevada

The Legislature initially authorized its Department of Transportation (DOT) in 2011 to adopt regulations guiding the operation and testing of AVs on Nevada highways, including requirements for insurance and minimum safety standards. In 2013, the Legislature refined its law, providing more statutory specificity and revising definitions. The DOT continues to be responsible for promulgating regulations. However, the law requires AVs to meet all federal standards and regulations applicable to motor vehicles before being registered in Nevada. Additionally, AVs cannot be tested or operated on Nevada highways unless they are:



- Equipped with a means to engage and disengage the autonomous technology which is easily accessible to the human operator;
- Equipped with a visual indicator located inside the AV which indicates when autonomous technology is operating the AV;
- Equipped with a means to alert the human operator to take manual control of the AV if a failure of the autonomous technology has been detected and the failure affects the ability of the autonomous technology to operate safely; and
- Capable of being operated in compliance with the applicable motor vehicle laws and traffic laws of Nevada.

Nevada is also home to the first American city—Las Vegas—to carry passengers via an autonomous shuttle bus. The pilot project operated briefly in January 2017, running a driverless bus on a three-block route. The bus topped out with a maximum speed of 16 mph and was monitored by an on-board operator for safety.

Michigan

The state considered home to the U.S. auto industry recognized AVs with two bills passed in 2013, but moved into the forefront of AV legislation with a package of bills signed in 2016. As did other early passage states, Michigan first authorized testing on the state's roads by individuals working in the industry. Unless AVs were being operated on a closed course, the law required a human driver be in the vehicle.

Laws passed in 2016 opened the state's roads to testing driverless vehicles and authorized initiatives to test networks of self-driving cars that can pick up passengers on demand. Further, the laws provided for creating mobility research centers to test automated technology and the Michigan Council on Future Mobility to make recommendations on statewide policy.

In partnership with industry, the University of Michigan built a $6.5 million track for testing AVs in real-world urban and suburban conditions.

Florida

Florida adopted legislation in 2012 that authorized testing. The law contained provisions common to other states, that is, proof of insurance prior to testing in the state, an exemption to liability for the vehicle's original manufacturer, and a definition of AVs. The law also required the Department of Highway Safety and Motor Vehicles to submit a report to the Legislature recommending additional legislative or regulatory action relating to testing and operating AVs.

In 2016, legislators amended the law to permit operating AVs on public roads by individuals with a valid driver's license and eliminated the requirement that operation be limited to testing. The law also eliminated the requirement that a driver be present in the vehicle and provided that transportation planning include "consideration of infrastructure and technological improvements necessary to accommodate advances in vehicle technology, such as autonomous technology and other developments."

Legislation passed in 2016 authorized a study on the use and safe operation of "driver-assistive truck platooning technology" followed by a pilot project.

Tennessee

Initially, Tennessee simply prohibited political subdivisions from enacting local ordinances or resolutions prohibiting the use of motor vehicles within their jurisdictions solely because the vehicles are equipped with autonomous technology.

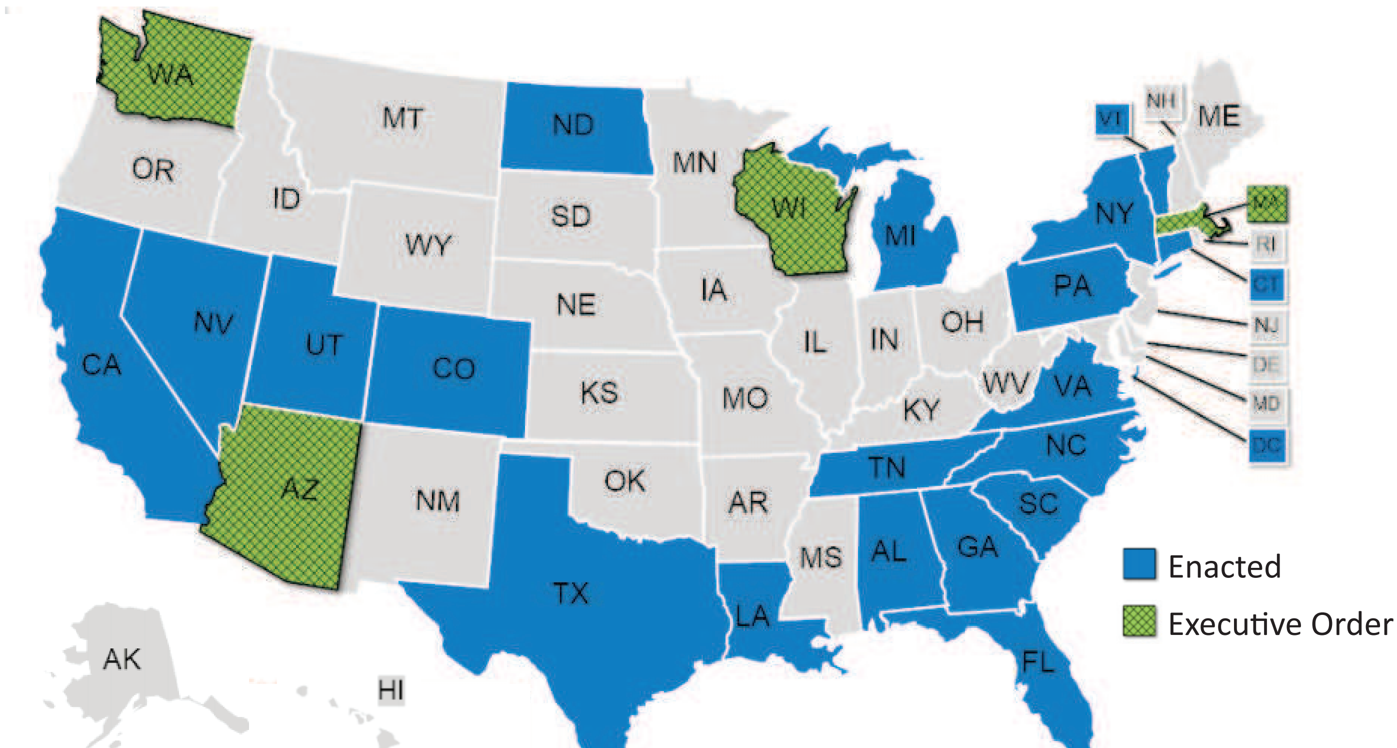
In 2016, the Legislature passed comprehensive AV legislation authorizing testing on the state's roads and highways by manufacturers certified by the Department of Safety. Tennessee defines "no-operator-required autonomous vehicles" and "operator-required autonomous vehicles" and specifies requirements each must meet in order to be tested, leased, or sold in Tennessee.

Notably, Tennessee also imposes a use tax on AVs operated on public highways based on the vehicles' number of axles. Proceeds from the tax are split between the state's general fund, highway fund, and the county highway fund.

Additionally, Tennessee provides for "fleet service providers" – defined as persons or entities that own, lease, or operate one or more AVs for commercial or public use – and authorizes them to operate AVs certified by the Department of Safety.

In 2017, the state authorized the operation of trucks in a platoon provided that the operator gives notice to the state departments of Transportation and Safety.

States with Enacted Autonomous Vehicle Legislation



Source: NCSL

The Boston Consulting Group estimates that the global market for partially and fully autonomous vehicles will reach ***$42 billion*** *by 2025, expanding to* **$77 billion** *by 2035.*

AV Proving Grounds

The U.S. Department of Transportation designated 10 proving ground pilot sites to encourage AV technology testing and information sharing. The proving ground designees are:

- City of Pittsburgh and the Thomas D. Larson Pennsylvania Transportation Institute
- Texas AV Proving Grounds Partnership
- U.S. Army Aberdeen Test Center (Maryland)
- Center for Mobility at Willow Run (Michigan)
- Contra Costa Transportation Authority & GoMentum Station (California)
- San Diego Association of Governments
- Iowa City Area Development Group
- University of Wisconsin-Madison
- Central Florida Automated Vehicle Partners
- North Carolina Turnpike Authority

Nebraska and other states

Legislation dealing with autonomous technology has steadily increased since the first proposals passed. The National Conference of State Legislatures (NCSL) reports 33 states introduced legislation in 2017, up from 20 in 2016. All told, since 2012, 41 states and the District of Columbia have considered some form of AV legislation.

Nebraska joined those numbers in 2017 with its first proposal, LB 627. The bill would have provided definitions for “autonomous motor vehicle” and “autonomous technology.” Significantly, LB 627 would have allowed anyone with a valid operator’s license to operate an autonomous motor vehicle on Nebraska highways. For purposes of the Nebraska Rules of the Road, LB 627 would have provided that a person was deemed to be the operator of an autonomous motor vehicle when the person causes the motor vehicle’s autonomous technology to engage, regardless of whether the person is physically present in the vehicle.

AVs in Nebraska would have been required to meet all applicable federal standards and regulations and all state motor vehicle laws and regulations. The bill was a big leap forward—few states authorize persons not involved in testing AVs to be able to operate them simply by possessing a valid operator’s license—and did not advance from the Transportation and Telecommunications Committee.

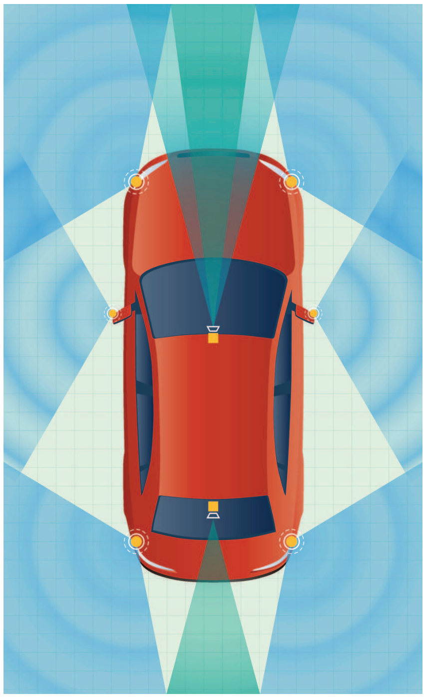
In the meantime, an interim study resolution (LR 215) proposes to study the feasibility of a pilot project to allow a city of the primary class to operate autonomous shuttles. Lincoln had sought a federal grant to operate driverless shuttles in its downtown. The grant did not go through, but city officials say they are seeking private and University of Nebraska partners to move a version of the plan.

State Policy Considerations

Nebraska and other states face numerous policy considerations.[9]

- *Evaluate current laws and regulations, addressing impediments to safe testing and deployment of AVs, and updating terminology to prepare for a driverless future.*

States have traditionally and historically regulated motor vehicles in the areas of traffic law and safety, insurance and liability, and registration and licensing of both cars and drivers. Motor vehicle law is predicated on a human driver. If nothing else, states must examine the terminology used in existing statutes to adapt it to a driverless future. For example, what does it mean to be an "operator" of an AV? Who is charged with obeying the speed limit and traffic lights? What about insurance, when the occupants of a vehicle are not responsible for the driving of that vehicle?



The AV industry's diverse cast of characters—from the legend carmakers to Silicon Valley to small upstarts—are developing and testing the technology at a breath-taking pace. This suggests that regulation should remain technology neutral and not favor (inadvertently or otherwise) one company or developer over another. Therefore, it matters how to statutorily define terms such as "manufacturer" so as not to stifle the emergence of new players.

- *Maintain roadways and infrastructure for current use, but build with an eye to the future.*

To the extent possible, states are encouraged to plan and build roadways for the future. Infrastructure investments must meet today's needs, but policymakers must also look to what will serve a very different transportation system in the future. While improved pavement, road markings, and other infrastructure repairs serve both current and future needs, other considerations could include incorporating some form of dedicated short range communications technology by which AVs communicate with each other and the infrastructure around them.

- *Be aware of what other states are doing. Take what works and leave the rest. But ultimately a patchwork of regulations serves neither efficacy nor safety.*

Eventually, a uniform system of state laws will benefit AV technology as it moves from testing to commercial availability. NHTSA, which has included a model state policy in its 2016 report, recommends that states "may wish to experiment with different policies and approaches to consistent standards, and in that way contribute to the development of the best approaches and policies to achieve consistent regulatory objectives." The goal need not be total uniformity across state lines, but "sufficient consistency of laws and policies to avoid a patchwork of inconsistent state laws that could impede innovation and the expeditious and widespread distribution of safety enhancing automated vehicle technologies."[10]

- *Remember the driving public.*

Proponents have made a case for the great advancements posed by this pending transportation revolution. However, policymakers must look at a broader picture.

Change is stressful. In the short run at least, there will be economic winners and losers. Policymakers can expect and plan for economic disruptions as industries dramatically change and they can also reimagine a regulatory framework and a transportation network. But, keeping public trust while navigating these changes will be equally important.

For an in-depth look at the issue, we recommend the following reports:

- *Federal Automated Vehicles Policy, Accelerating the Next Revolution in Roadway Safety,* the National Highway Traffic Safety Administration, September 2016.
- *The Autonomous Vehicle Revolution, Fostering Innovation with Smart Regulation,* Center for the Study of the Presidency & Congress, March 2017.
- *Autonomous Vehicle Technology, A Guide for Policymakers,* Rand Corp., 2016.
- National Conference of State Legislatures, Autonomous Vehicles webpage.

END NOTES

1. *Autonomous Vehicle Technology, A Guide for Policymakers*, Anderson, Kalra, Stanley, Sorensen, Samaras, Oluwatola, Rand Corp., 2016.

2. *Federal Automated Vehicles Policy, Accelerating the Next Revolution in Roadway Safety*, National Highway Traffic Safety Administration, U.S. Department of Transportation, September 2016.

3. SAE, originally the Society of Automotive Engineers International describes itself as a global association of engineers and related technical experts in the aerospace, automotive, and commercial-vehicle industries.

4. A full description of the SAE levels of automation can be found at *http://standards.sae.org/j3016_201401/*

5. *Autonomous Vehicle Technology, A Guide for Policymakers,* 2016 Rand Corp.

6. *The Big Bang of autonomous driving*, December 19, 2016, *www.autonews.com.*

7. The states are Alabama, Arkansas, California, Colorado, Connecticut, Florida, Georgia, Louisiana, Michigan, New York, Nevada, North Carolina, North Dakota, Pennsylvania, South Carolina, Tennessee, Texas, Utah, Virginia, and Vermont.

8. Some observers expect the first operational roll out of AVs will be commercial, including truck platooning and AVs operating on a set course in an urban environment, similar to trolleys and street cars of a bygone era. States wishing to authorize truck platooning must, at a minimum, change laws prohibiting tailgating.

9. The following agencies or entities were used as sources to compile the policy suggestions: The National Highway Traffic Safety Administration, the Center for the Study of the Presidency and Congress, and the Rand Corp.

10. *Federal Automated Vehicles Policy, Accelerating the Next Revolution in Roadway Safety,* NHTSA, September 2016.

IMAGE CREDITS

1. DARPA
2. Google
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6. Tesla
7. Volvo