AAMVA Automated Vehicles Activities
January 2017

The American Association of Motor Vehicle Administrators (AAMVA) has taken an active role in working with key stakeholders to share information, to work collaboratively and to develop guidance related to autonomous vehicles. The AAMVA community continues to be engaged in the development and testing of this technology as it emerges as one of the most significant safety and mobility innovations since the advent of the motor vehicle. Several states have acted to encourage development of highly automated vehicles and are eager to work with industry to support automated vehicle testing and deployment.

AAMVA has had two working groups dedicated to gathering, organizing and share information with the AAMVA community related to the development, design, testing, use and regulation of autonomous vehicles and other emerging vehicle technology. This includes the Autonomous Vehicles Information Sharing Group made up to 80 representative from jurisdictions, law enforcement, federal agencies, vehicle manufactures, industry and other stakeholders who meet virtually to hear presentation from experts and briefings on relevant reports and studies. This group's efforts led to the launch of the AAMVA AV Information Library: http://www.aamva.org/Autonomous-Vehicle-Information-Library/

AAMVA's other key effort is the partnership with NHTSA to create the Autonomous Vehicle Working Group. This group of 18 jurisdictional experts from the US and Canada were brought together to focus on the specific impacts of automation on the work our members do on Vehicles, Drivers and Law Enforcement and to develop guidance for those disciplines. This is the body that provided input to NHTSA in the drafting of the Model State Policy that is now one section of the Federal Automated Vehicle Policy.

In addition, many AAMVA members and staff are involved in multiple projects as expert resources and are speaking at many meetings, conferences and workshops on the regulation of highly automated vehicles. This includes working with the Uniform Law Commission on their project to draft model legislation for self-driving vehicles and TRB Project NCHRP 20-102(7), which is seeking to provide state DOTs and motor vehicle departments with guidance and resources to assist with the legal changes that will result from the roll out of connected and automated vehicles.

Connected Vehicle and Autonomous Vehicle Activities

The concept of Connected Vehicles combining with autonomous vehicles to achieve "Connected Automation" represents a potentially revolutionizing change to surface transportation as we know it. While the benefits seem very promising, the challenges facing the infrastructure owners and operators are also significant. AASHTO has been active in this arena for a number of years and since 2014 AASHTO has increased its focus and led or co-led several Connected and Automated Vehicle (CAV) activities to help ease the entry of state and local DOTs into CAV deployments, including:

- The creation of the Vehicle to Infrastructure Deployment Coalition (V2I DC),
- The revitalization of the CAV Executive Leadership Team (CAV ELT),
- Conducting three regional Autonomous Vehicle policy workshops throughout the country with AAMVA; and
- Funding an AASHTO-led large scale 5 year NCHRP research project to establish a CAV Road Map.

These and other CAV related AASHTO activities are summarized in the paragraphs below. Details on all activities can be found at the web links provided below. The web links below link directly to the National Operations Center of Excellence website (http://www.transportationops.org), which serves as a "one-stop-shop" for accessing information about AASHTO, ITS America, and ITE joint CAV activities. Similarly, the AASHTO Subcommittee on Transportation Systems Management and Operations (STSMO) CAV Working Group information can also be found at the STSMO website: http://stsmo.transportation.org/Pages/default.aspx.

AASHTO Autonomous Vehicle Policy Workshops

Beginning in 2015, AASHTO led a series of Autonomous Vehicles Policy workshops in locations throughout the United States. The objectives of the AV Policy workshops were to: raise awareness of policy issues for various national, state and local organizations and agencies; identify and refine near term urgent or important policy issues for further study, collaboration or advocacy; and determine future form of any follow-on automated vehicle public policy forum. Details on the workshops can be found at: http://stsmo.transportation.org/Pages/default.aspx

Vehicle to Infrastructure Deployment Coalition (V2I DC)

In 2015, with USDOT support, AASHTO collaborated with ITE and ITS America to establish the Vehicle to Infrastructure Deployment Coalition (V2I DC). The V2I DC is now a single point of reference for stakeholders to meet and discuss V2I deployment related issues. The overall focus of the V2I DC is to help accelerate deployment of V2I applications related to intersections, end of queue warning systems, work zone management, and curve warning systems. The V2I DC is organized into five Technical Working Groups (TWGs), and membership is open to anyone wishing to participate. Additional details on the activities of each TWG, progress of the V2I DC, technical reports, and the business plan can be found at the Coalition's website: http://www.transportationops.org/V2I/V2I-overview .

Connected and Automated Vehicle Executive Leadership Team (CAV-ELT)

In 2004 AASHTO established an Executive Leadership Team that convened twice a year to discuss the Connected Vehicle programs progress, challenges and issues that need insights from the infrastructure Community, the automobile industry and the USDOT. ***The group was reconvened in 2016*** with an expanded role to address automated vehicles (AV) as well as connected vehicles (CV), and to promote the convergence of AV and CV to create "connected automated vehicles (CAV). The group focus is on policy level issues and programmatic level efforts that members can perform to help accelerate deployment of CAV. Membership includes the Directors of more than 20 state and local DOTs, Executives from all of the large automotive manufacturers from the US, Europe and Asia. USDOT representation includes NHTSA, FHWA and the ITS Joint Program Office. The CAV-ELT is an AASHTO led effort, supported by ITE, ITS America, TRB, USDOT, and the Original Equipment Manufacturers (OEMs). The CAV ELT met in Detroit, MI on April 22, 2016 and seven policy perspectives statements have been prioritized for development. A summary report is available at: http://stsmo.transportation.org/Pages/connected_vehicles_new.aspx. Additional details of the CAV ELT and the V2I DC are available at: http://www.transportationops.org/V2I/V2I-overview .

AASHTO STSMO Connected and Automated Vehicle Working Group (CAV WG)

The AASHTO SCOH Subcommittee on Transportation Systems Management and Operations (STSMO) includes a Connected and Automated Vehicle Working Group (CAV WG). The CAV WG provides a forum for state DOTs to share their connected and automated vehicle advancements, challenges, and experiences with the goal of helping all states prepare for CAV deployment. Membership consists of roughly 30 members, who meet monthly by webinar and in-person with STSMO meetings. An AV task force was established under the AASHTO Standing Committee on Planning. Details on STSMO activities can be found on the AASHTO STSMO website at: http://stsmo.transportation.org/Pages/default.aspx.

2015 FHWA Vehicle to Infrastructure Deployment Guidance and Products

In 2015 FHWA released Vehicle to Infrastructure (V2I) Guidance to assist FHWA staff and transportation system owners and operators as they deploy V2I technology. An update to the V2I Guidance is expected in 2017. The current Guidance is available at http://stsmo.transportation.org/Documents/V2I_DeploymentGuidanceDraftv9.pdf.

NCHRP 20-102: Impacts of Connected and Automated Vehicles on State and Local Transportation Agencies

NCHRP Project 20-24(98) developed a draft research roadmap for addressing CAV issues. The NCHRP 20-102 project is responsible for maintaining this roadmap and performing tasks defined in the roadmap. The objectives of NCHRP 20-102 are to: identify critical issues associated with CAV that state and local transportation agencies and AASHTO will face; conduct research to address those issues; and conduct technology transfer and information exchange activities. Details can be found at the TRB/NCHRP website at: http://apps.trb.org/cmsfeed/TRBNetProjectDisplay.asp?ProjectID=3824.

Connected Vehicle Field Infrastructure Near-Term Analysis Tools

Since 2014, AASHTO has led an effort to develop a suite of tools to assist state and local DOTs as they consider and plan for V2I infrastructure deployment. These tools, which include an *Application Prioritization Tool, a Life Cycle Cost Model (LCCM), and an Infrastructure Planning Tool* have been developed in accordance with the Connected Vehicle Regional Implementation Architecture (CVRIA) and build on the V2I Footprint Analysis results.

Connected Vehicle Field Infrastructure Footprint Analysis

AASHTO, with the support of the United States Department of Transportation (USDOT) and Transport Canada, has undertaken a Connected Vehicle Field Infrastructure Footprint Analysis to provide supporting information to agency decision-makers. AASHTO's work in this analysis has been performed through its Connected Vehicle Deployment Coalition, a group comprising representatives from a number of state and local transportation agencies, and the findings and recommendations in this report represent the opinions of this AASHTO community. The final report is available at http://stsmo.transportation.org/Documents/AASHTO%20Final%20Report%20_v1.1.pdf.

Connected Vehicle Pooled Fund Program

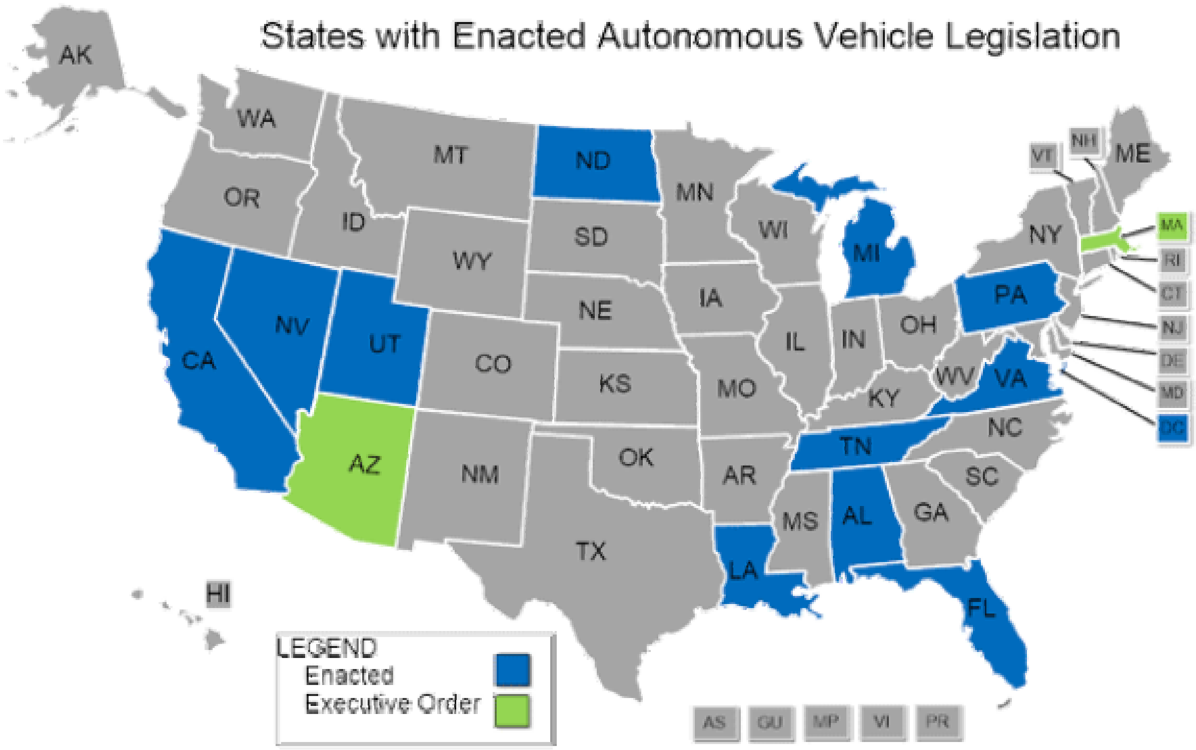
The AASHTO Strategic Plan and Field Infrastructure Footprint Analysis identified the need for infrastructure providers to conduct research to develop applications that will make full use of the CV environment. With this background, the pooled fund study entitled "Program to Support the Development and Deployment of Connected Vehicle Applications" was created by a group of state and local transportation agencies and FHWA to conduct the work necessary for infrastructure providers to play a leading role in advancing the Connected Vehicle systems. http://www.cts.virginia.edu/cvpfs/

CV 101 Webinar

AASHTO hosted a webinar in September 2014 where the Federal Highway Administration gave a presentation on Connected Vehicles 101. Topics included introduction to the connected vehicle environment, connected vehicle applications, connected vehicle testing and deployment, and policy and institutional issues.
http://stsmo.transportation.org/Pages/SSOM-Webinars.aspx

State DOT CEO Leadership Forum: A Focus on Transportation Futures

A state DOT CEO forum was held at 2014 ITS World Congress in Detroit, Michigan. A Final Report is available at:
http://stsmo.transportation.org/Documents/FR1_NCHRP%202024%28100%29_CEOs%20at%20ITS%20WC_FINAL.pdf


States with Enacted Autonomous Vehicle Legislation
AK
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NV
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Executive Order

SAE INTERNATIONAL

AUTOMATED DRIVING

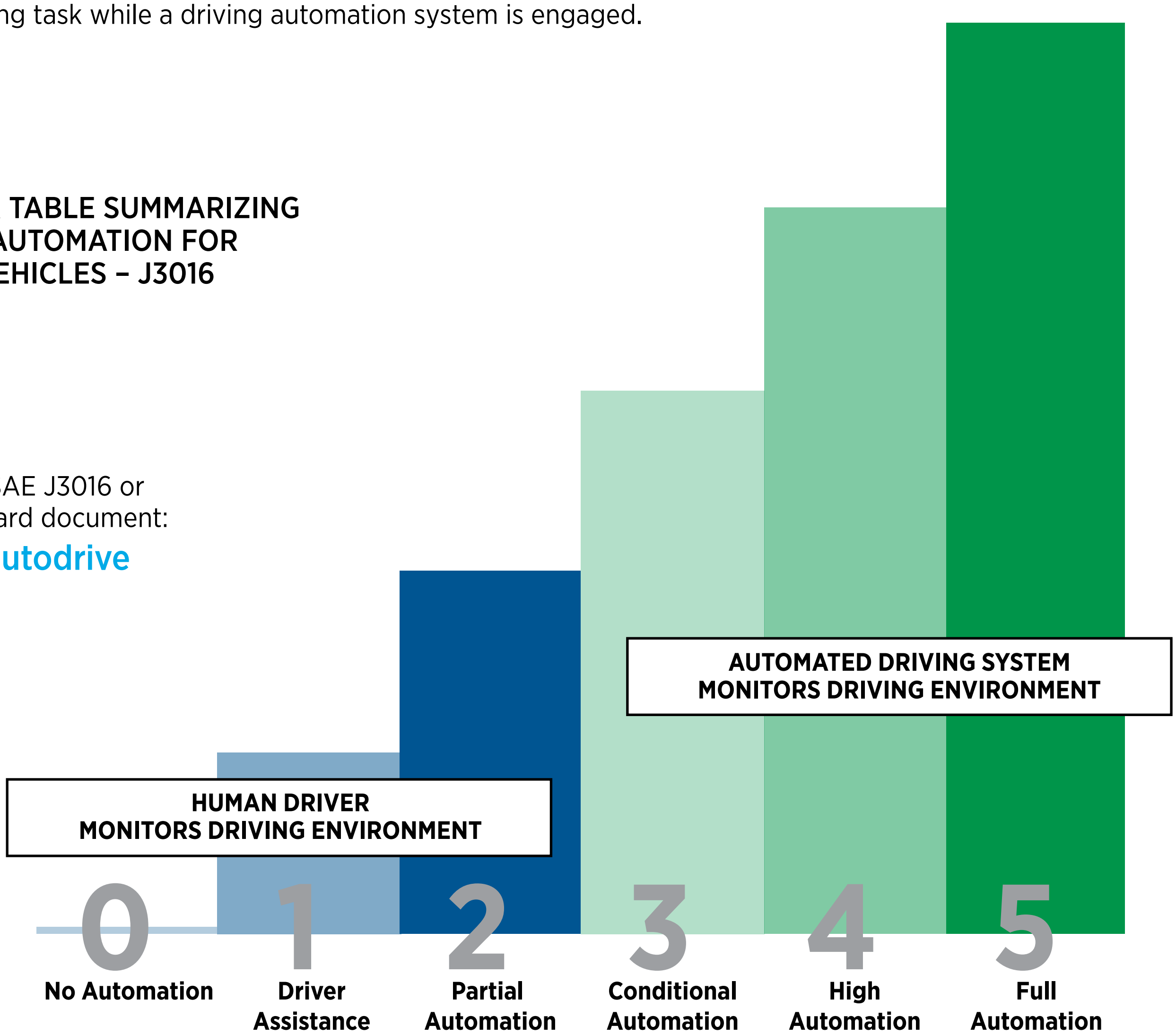
LEVELS OF DRIVING AUTOMATION ARE DEFINED IN NEW SAE INTERNATIONAL STANDARD J3016

With the goal of providing common terminology for automated driving, SAE International's new standard J3016: **Taxonomy and Definitions for Terms Related to On-Road Motor Vehicle Automated Driving Systems**, delivers a harmonized classification system and supporting definitions that:

- Identify six levels of driving automation from "no automation" to "full automation".
- Base definitions and levels on functional aspects of technology.
- Describe categorical distinctions for a step-wise progression through the levels.
- Are consistent with current industry practice.
- Eliminate confusion and are useful across numerous disciplines (engineering, legal, media, and public discourse).
- Educate a wider community by clarifying for each level what role (if any) drivers have in performing the dynamic driving task while a driving automation system is engaged.

OVER FOR A TABLE SUMMARIZING LEVELS OF AUTOMATION FOR ON-ROAD VEHICLES – J3016

Learn more about SAE J3016 or purchase the standard document:
www.sae.org/autodrive



SUMMARY OF SAE INTERNATIONAL'S LEVELS OF DRIVING AUTOMATION FOR ON-ROAD VEHICLES

Issued January 2014, **SAE international's J3016** provides a common taxonomy and definitions for automated driving in order to simplify communication and facilitate collaboration within technical and policy domains. It defines more than a **dozen key terms**, including those italicized below, and provides **full descriptions and examples** for each level.

The report's **six levels of driving automation** span from *no automation* to *full automation*. A **key distinction** is between level 2, where the *human driver* performs part of the *dynamic driving task*, and level 3, where the *automated driving system* performs the entire *dynamic driving task*.

These levels are **descriptive** rather than normative and **technical** rather than legal. They imply **no particular order** of market introduction. Elements indicate **minimum** rather than maximum system capabilities for each level. A particular vehicle may have multiple driving automation features such that it could operate at **different levels** depending upon the feature(s) that are engaged.

System refers to the driver assistance system, combination of driver assistance systems, or *automated driving system*. **Excluded** are **warning and momentary intervention systems**, which do not automate any part of the *dynamic driving task* on a sustained basis and therefore do not change the *human driver's* role in performing the *dynamic driving* task.

SAE level	Name	Narrative Definition	Execution of Steering and Acceleration/ Deceleration	*Monitoring* of Driving Environment	Fallback Performance of *Dynamic Driving Task*	System Capability *(Driving Modes)*
***Human driver* monitors the driving environment**						
0	**No Automation**	the full-time performance by the *human driver* of all aspects of the *dynamic driving task*, even when enhanced by warning or intervention systems	Human driver	Human driver	Human driver	n/a
1	**Driver Assistance**	the *driving mode*-specific execution by a driver assistance system of either steering or acceleration/deceleration using information about the driving environment and with the expectation that the *human driver* perform all remaining aspects of the *dynamic driving task*	Human driver and system	Human driver	Human driver	Some driving modes
2	**Partial Automation**	the *driving mode*-specific execution by one or more driver assistance systems of both steering and acceleration/ deceleration using information about the driving environment and with the expectation that the *human driver* perform all remaining aspects of the *dynamic driving task*	**System**	Human driver	Human driver	Some driving modes
***Automated driving system* ("system") monitors the driving environment**						
3	**Conditional Automation**	the *driving mode*-specific performance by an *automated driving system* of all aspects of the dynamic driving task with the expectation that the *human driver* will respond appropriately to a *request to intervene*	System	**System**	Human driver	Some driving modes
4	**High Automation**	the *driving mode*-specific performance by an automated driving system of all aspects of the *dynamic driving task*, even if a *human driver* does not respond appropriately to a *request to intervene*	System	System	**System**	Some driving modes
5	**Full Automation**	the full-time performance by an *automated driving system* of all aspects of the *dynamic driving task* under all roadway and environmental conditions that can be managed by a *human driver*	System	System	System	**All driving modes**

Key definitions in J3016 include (among others):

Dynamic driving task includes the operational (steering, braking, accelerating, monitoring the vehicle and roadway) and tactical (responding to events, determining when to change lanes, turn, use signals, etc.) aspects of the driving task, but not the strategic (determining destinations and waypoints) aspect of the driving task.

Driving mode is a type of driving scenario with characteristic *dynamic driving task* requirements (e.g., expressway merging, high speed cruising, low speed traffic jam, closed-campus operations, etc.).

Request to intervene is notification by the *automated driving system* to a *human driver* that s/he should promptly begin or resume performance of the *dynamic driving task*.

Contact: SAE INTERNATIONAL +1.724.776.4841 • Global Ground Vehicle Standards +1.248.273.2455 • Asia+86.21.61577368

NCHRP 20-102 [Active]

Impacts of Connected Vehicles and Automated Vehicles on State and Local Transportation Agencies--Task-Order Support

Project Data	
Funds:	**$2,000,000 ($1M each from FY 2015 & FY 2016)**
Staff Responsibility:	**B. Ray Derr**
Research Agency:	**Booz Allen Hamilton, Kimley-Horn and Associates, Texas A&M Transportation Institute, Virginia Tech Transportation Institute**
Principal Investigator:	**Christopher Hill, Douglas Gettman, Christopher Poe, Myra Blanco (respectively)**

RESEARCH OBJECTIVES

The objectives of NCHRP Project 20-102 are to (1) identify critical issues associated with connected vehicles and automated vehicles that state and local transportation agencies and AASHTO will face, (2) conduct research to address those issues, and (3) conduct related technology transfer and information exchange activities.

NCHRP Project 20-24(98) has developed a **draft research roadmap** for addressing CV/AV issues. The panel for NCHRP Project 20-102 is responsible for maintaining this roadmap and will be selecting tasks from it to carry out. Tasks may be rescoped, added, or deleted from the roadmap at the discretion of the panel. Tasks currently underway are listed at the bottom of this page and the NCHRP 20-102 panel will be meeting in July 2015 to select additional projects.

BACKGROUND

Connected vehicle technologies are being developed to enable safe, interoperable networked wireless communications among vehicles (V2V), the infrastructure (V2I), and travelers' personal communication devices (V2X). These technologies are intended to reduce highway crashes; provide data for assessing the performance of the transportation system; provide continual access to accurate information on the operation of the system to travelers; and reduce unnecessary stops, delays, and emissions.

Automated vehicle technologies are also under development that will significantly change fundamental planning, design, and operational characteristics for the road network. Some industry leaders expect that Level 4 vehicle automation (under NHTSA and SAE definitions) will be available on the market by 2018. Fully autonomous, driverless vehicles (SAE Level 5 automation) could be on the market by 2025.

For Level 5 automation, "the vehicle is designed to perform all safety-critical driving functions and monitor roadway conditions for an entire trip. Such a design anticipates that the driver will provide destination or navigation input, but is not expected to be available for control at any time during the trip." (NHTSA, Preliminary Statement of Policy Concerning Automated Vehicles) Level 4 automation is essentially the same as Level 5, without any driver supervision (e.g., there is no expectation that the driver will be engaged), over a limited driving domain. These vehicles may be safer than current models.

Connected vehicles and automated vehicles are essentially different technologies, though some of the challenges they present to transportation agencies will be similar. These two technologies may converge or diverge from each other based largely on developments in the private sector (e.g., vehicle manufacturers, third-party vendors). While some actors envision a completely autonomous vehicle that does not require communication with other entities, others see serendipities between the two technologies. This project will address both technologies (including the combination) under the umbrella term of CV/AV. The individual tasks that compose the project will clearly identify which technologies are to be addressed.

TASK-ORDER SUPPORT

A request for statements of qualifications was active from December 11, 2014 to January 29, 2015. Four task-order contracts have been executed. For the individual tasks selected by the NCHRP Project 20-102 panel (listed below), the selected task-order contractors will be asked to submit competitive proposals that will be evaluated by a separate panel for each task. These task panels will also oversee the contractor's work.

During the course of the contract, task-order contractors will be expected to submit quarterly progress reports that include: (1) brief status reports on tasks currently underway (including a table of milestones and deliverables, significant findings, a description of any problems encountered, and recommended solutions to such problems); (2) summary of significant events in the CV and AV industries that may affect the research roadmap; and (3) recommendations for updates to the research roadmap.

The NCHRP will decide in Summer 2017 whether to readvertise for task-order contractors or to extend the ones that are in place.

LISTING OF TASKS

20-102(01) **Policy and Planning Actions to Internalize Societal Impacts of CV and AV Systems into Market Decisions**

20-102(02) **Impacts of Regulations and Policies on CV and AV Technology Introduction in Transit Operations**

20-102(03) **Challenges to CV and AV Application in Truck Freight Operations**

20-102(05) **Strategic Communications Plan for NCHRP Project 20-102**

20-102(06) **Road Markings for Machine Vision**

20-102(07) **Implications of Automation for Motor Vehicle Codes**

20-102(08) **Dedicating Lanes for Priority or Exclusive Use by CVs and AVs**

20-102(09) **Providing Support to the Introduction of CV/AV Impacts into Regional Transportation Planning and Modeling Tools**

20-102(10) **Cybersecurity Implications of CV/AV Technologies on State and Local Transportation Agencies**

20-102(11) **Summary of Existing Studies on the Effects of CV/AV on Travel Demand**

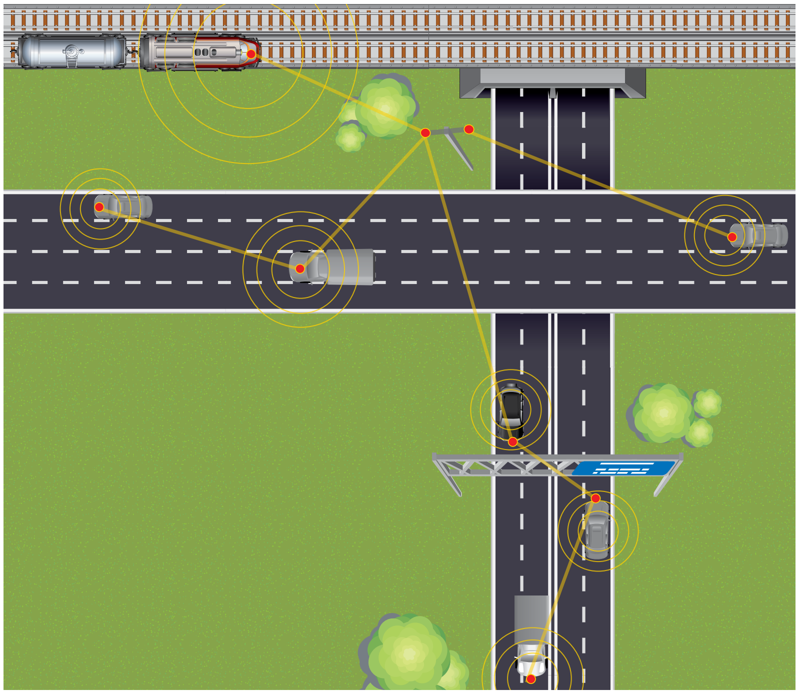
20-102(12) **Business Models to Facilitate Deployment of CV Infrastructure to Support AV Operations**

20-102(13) **Planning Data Needs and Collection Techniques for CV/AV Applications**

20-102(14) **Data Management Strategies for CV/AV Applications for Operations**

To create a link to this page, use this URL: http://apps.trb.org/cmsfeed/TRBNetProjectDisplay.asp?ProjectID=3824

TTI's Capabilities in Connected Transportation



CV/AV TTI Vision

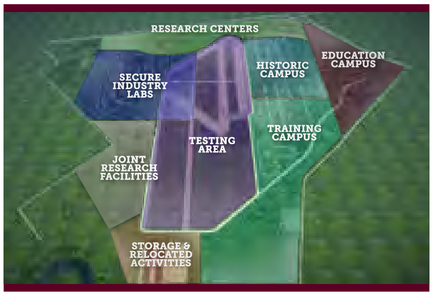
The Texas A&M Transportation Institute (TTI) shares an industry vision where no vehicles collide and people can use connected and automated transportation to transform how they live, work and interact with their environment. To achieve this vision, research, development and testing are needed on how vehicles, users and transportation infrastructure all work together.

While automated vehicles are emerging and connected vehicle research is progressing, TTI believes the most significant gains in safety and mobility will occur at the nexus of these areas. TTI is creating a world-class research environment on the Texas A&M University campus where researchers can collaborate, new transportation paradigms can be created, and future mobility and safety can be showcased.

RELLIS Campus

In December 2018, TTI is scheduled to move to the newly developed Texas A&M University System RELLIS Campus, a high-tech, multi-institutional research, testing and workforce development campus in close proximity to Texas A&M University. TTI already has several facilities located at the 2,000-acre campus, including a full-service safety proving grounds facility; an environmental and emissions facility; and a sediment and erosion control laboratory. In addition, the new Center for Infrastructure Renewal, a collaboration among TTI, the Texas A&M Engineering Experiment Station and the private sector, is being constructed next door to TTI's new State Headquarters Building. This research, testing and training facility is expected to reduce the cost and extend the life of infrastructure with new, better materials and construction methods.

CV/AV Test Beds



RELLIS Campus CV/AV Test Bed

TTI is developing a connected and automated transportation test bed at the Texas A&M University System RELLIS Campus in Bryan, Texas. The test bed will be used to develop and test connected and automated vehicle (CV/AV) applications and human-machine interfaces using vehicle-to-infrastructure (V2I) and infrastructure-to-vehicle communication in a controlled environment. The test bed will leverage other automated vehicle expertise across the University in ground, aerial and subterranean applications.

Connected Work Zone

TTI is deploying CV technology along the I-35 corridor to improve safety and mobility through work zones by providing in-vehicle devices to freight companies to receive work zone infrastructure data on lane closure location, capacity reduction, queue lengths and delay to assist in pre-trip and en-route planning for logistics.

Sponsor: Texas Department of Transportation and U.S. Department of Transportation

Transit, Bicycle and Pedestrian Safety

TTI developed a Concept of Operations Plan for designing, testing, piloting, demonstrating and deploying CV/AV technology hardware and applications to reduce and eliminate crashes involving transit, bicyclists and pedestrians. A pilot test was also conducted of the Mobileye Shield + collision avoidance system on a Texas A&M University bus in Phase I of the project. In Phase II, TTI is designing, developing and piloting a Smart Intersection/Smart Bus application with buses automatically communicating with smart traffic signals to provide visual and audio warnings to bicyclists and pedestrians. A smartphone app is also being designed, developed and piloted for bicyclists and pedestrians at the Smart Intersection.

Sponsor: Texas Department of Transportation

Physical Infrastructure

New Technologies and Approaches for Asset Management

Combining geo-coded machine vision technology with crowdsourcing strategies, TTI has developed and is prototyping a new method for highway agencies to obtain data on their assets and keep the data current with relatively minimal effort. TTI is installing custom-made machine vision systems in TxDOT fleet vehicles. The systems will require no input from the driver and collect the necessary data in an automated manner. Specific assets are automatically identified, geo-coded and provided a condition rating. These data are pushed to a cloud service where analytics are provided, and the data are returned to a dashboard where agencies can access real-time asset information to make more timely and cost-effective decisions with their limited maintenance budgets.

Sponsor: Texas Department of Transportation

Establishing Highway Infrastructure Criteria for Machine Vision

As vehicle technology continues to expand into new areas, a need is developing to synchronize vehicle technology capabilities with traditional physical highway infrastructure. One of the most heavily used elements of the physical infrastructure space on a highway is pavement markings. Many new vehicles use cameras and machine vision algorithms to detect and read pavement markings to provide features such as lane departure warning and lane-keeping assistance. TTI is leading a research project that is designed to develop pavement marking criteria that will provide reliable detection with in-vehicle camera systems. The results will be used by agencies interested in specifying and maintaining their highways to a level that will provide reliable machine vision detection.

Sponsor: National Cooperative Highway Research Program

Sensor-Enhanced Pavement Markings

TTI is developing and testing sensor-enhanced pavement markings to provide enhanced detection when machine vision begins to fail, such as in low sun positions or inclement weather, to provide a redundant detection alternative for vehicle technologies.

Sponsor: Virginia Department of Transportation

CV Applications

TTI researchers have developed the concept of operations and system requirements for the development of wrong way driving and mitigation applications for CVs. TTI researchers led the development of the Intelligent Network Flow Optimization bundle of CV applications, including the Q-WARN and Speed-Harm. A small-scale demonstration was conducted in Seattle to demonstrate the feasibility of using CV data to implement these applications. In addition, TTI is working with the Collision Avoidance Metrics Partnership (CAMP) to develop and test eco approach and departure applications to minimize fuel consumption and reduce vehicle emissions at signalized intersections.

Evaluation of CV Applications

TTI researchers have developed a platform to facilitate FHWA to evaluate CV applications and technologies in a realistic manner using advanced hardware-in-the-loop simulation techniques. The simulation model, VISSIM, was integrated with CV hardware and with ns-3, a communication simulation model.

CV Pilot Deployment and Program Evaluation

TTI was recently selected by FHWA to lead the national evaluation of the CV Pilot Deployments. Teaming with partners, such as Kittleson & Associates, Inc., Gannett Fleming, Rand Corporation, Cadmus and JMC Rota, TTI is leading the national evaluation of the three CV pilot sites (Tampa, New York City, and Wyoming). This evaluation could also be extended to include evaluations of the Smart City and AMTCD grants.

Signal Phase and Timing

TTI researchers led the development of an interface between traffic signal controllers and roadside equipment to enable communication of real-time traffic signal status and timing to CVs. Researchers then designed and developed an open source platform, Integrated Vehicle to Infrastructure Platform, to facilitate development and deployment of infrastructure-based CV applications. This platform is being improved to generate and broadcast conflict-free Infrastructure-to-Vehicle (I2V) required messages to improve intersection safety and mobility.

CV Standards

As part of the development of intersection and freeway operations-related CV applications, TTI researchers provided feedback to the standards committees working on updating the CV and traffic signal controller standards including SAE J2735, NTCIP 1202 and related standards. TTI researchers are also involved in a number of committees working on updating these standards.

Wrong-Way Driving Detection and Mitigation Research

Developed concept of operations and requirements for a CV test bed for wrong-way driving applications. Developing a proof-of-concept CV wrong-way driving detection and management system at the Texas A&M System's RELLIS Campus.

Sponsor: Texas Department of Transportation

Vehicle Automation

Commercial Truck Platooning

Created a first-of-its-kind comprehensive freight platooning demonstration in Texas to build upon past and current platooning development projects and demonstrate the safety and fuel savings benefits that can be achieved by applying vehicle automation to freight truck platoons.

Sponsor: Texas Department of Transportation

CV/AV Policy

Transportation Policy Research Center (PRC)

The emergence of CV/AV technology presents significant implications for policy makers. The TTI PRC is working to better understand those implications and inform the decision making that will influence how automated travel can come about in a way that best serves the public interest. The *Revolutionizing our Roadways* series outlines the PRC's work in the following specific areas.

Completed Research Reports

(tti.tamu.edu/policy/technology)

The Challenges and Benefits of Making Automated Vehicles a Reality

Policy Considerations for Automated Vehicle Testing in Texas

Cybersecurity Considerations for Connected and Automated Vehicle Policy

Data Privacy Considerations

Liability Issues

Travel Behavior Impacts of Automated Vehicles

Implications of Automated Vehicle Crash Scenarios

In Progress Research

Vehicle Telematics as a Platform for Road User Fees

Mobility Effects of Connected and Automated Vehicles

CV/AV Planning

Transportation Planning Implications of Automated Vehicles on Texas Highways
Assess how to effectively incorporate transformative CV/AV technologies in transportation planning to assist in the decision making process.

Sponsor: Texas Department of Transportation

Policy and Planning Actions to Internalize Societal Impacts of CV/AV Systems into Market Decisions
Generate information for state and local governments about policy/planning actions that can be taken to stimulate the development of markets for CV/AV systems for all modes, providing the ability to internalize societal costs and benefits in industry market decisions.

Sponsor: National Cooperative Highway Research Program

Providing Support to the Introduction of CV/AV Impacts into Regional Transportation Planning and Modeling Tools
Develop guidelines for the implementation of travel forecasting models that address travel behavior and system performance changes resulting from CV/AV technology.

Sponsor: National Cooperative Highway Research Program

Preparing for the Connected Airport and the Internet of Things
Develop an evidence-based primer for airport operators and stakeholders on the Internet of Things within the airport environment.

Sponsor: Airport Cooperative Research Program

Deploying CV/AV: Scenarios and Roadmap
Developed CV/AV deployment scenarios, use the scenarios to determine future roadway infrastructure requirements, and developed a strategic roadmap for addressing the implications of CV/AV futures.

Human Factors

Driver Cognitive Load and Distraction Due to Multimodal Infotainment System Interaction
Conducted a closed-course study to evaluate the extent to which popular multimodal infotainment systems requiring driver input may negatively impact behavior, cognitive load, and the subsequent impact on driving safety.

Sponsor: Honda Research Institute

Monitoring, Assessing and Acting on Driver and Vehicle States to Enhance Safety
Developed and evaluated a vehicle-based countermeasure that detects unsafe vehicle operational parameters and driver stress states and directly assists the driver and vehicle to improve overall safety.

Sponsor: Toyota Economic Loss Settlement

TTI's Mission

To identify and solve transportation problems through research, to transfer technology and knowledge, and to develop diverse human resources to meet the transportation challenges of tomorrow.

Contact

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tti.tamu.edu

FACT SHEET: FEDERAL AUTOMATED VEHICLES POLICY OVERVIEW

The Federal Automated Vehicles Policy sets out a proactive safety approach that will bring lifesaving technologies to the roads safely while providing innovators the space they need to develop new solutions. The Policy is rooted in DOT's view that automated vehicles hold enormous potential benefits for safety, mobility and sustainability.

The primary focus of the policy is on highly automated vehicles (HAVs), or those in which the vehicle can take full control of the driving task in at least some circumstances. Portions of the policy also apply to lower levels of automation, including some of the driver-assistance systems already being deployed by automakers today.

Components of the Policy

- Vehicle Performance Guidance for Automated Vehicles: The guidance for manufacturers, developers and other organizations outlines a 15 point "Safety Assessment" for the safe design, development, testing and deployment of automated vehicles.
- Model State Policy: This section presents a clear distinction between Federal and State responsibilities for regulation of HAVs, and suggests recommended policy areas for states to consider with a goal of generating a consistent national framework for the testing and deployment of highly automated vehicles.
- Current Regulatory Tools: This discussion outlines DOT's current regulatory tools that can be used to accelerate the safe development of HAVs, such as interpreting current rules to allow for greater flexibility in design and providing limited exemptions to allow for testing of nontraditional vehicle designs in a more timely fashion.
- Modern Regulatory Tools: This discussion identifies potential new regulatory tools and statutory authorities that may aid the safe and efficient deployment of new lifesaving technologies.

Policy Development and Public Comment

The Policy is a product of significant public input, including two public meetings and an open public docket. The Policy will be updated annually to ensure it remains relevant and timely, and will continue to be shaped by public comment, industry feedback and real-world experience. DOT is seeking public comment on the entire policy at www.transportation.gov/AV.

Most of the Policy is effective on the date of its publication. However, certain elements involving data and information collection will be effective upon the completion of a Paperwork Reduction Act (PRA) review and process.

The policy outlines a series of next steps that the agency will take to solicit additional public input and to implement the components. The next steps include public workshops, stakeholder engagement, expert review, work plans to implement Policy components, possible rulemakings, and education efforts.

EXECUTIVE SUMMARY

For the last 50 years, the U.S. Department of Transportation (DOT) has been committed to saving lives and improving safety and efficiency in every way Americans move—by planes, trains, automobiles, bicycles, foot, and more. DOT, through the National Highway Traffic Safety Administration (NHTSA), has carried out that mission on U.S. roadways in part by consistently embracing new technologies that make driving, riding, biking, and walking safer. Twentieth century automobile technologies (such as seat belts, air bags, child seats, and antilock brakes)—developed in the private sector and brought to the nation's driving public through NHTSA's safety programs and regulatory authority—are responsible for saving hundreds of thousands of lives.[1]

Today, the automobile industry is on the cusp of a technological transformation that holds promise to catalyze an unprecedented advance in safety on U.S. roads and highways. 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.

For DOT, the excitement around highly automated vehicles (HAVs) starts with safety. Two numbers exemplify the need. First, 35,092 people died on U.S. roadways in 2015 alone. Second, 94 percent of crashes can be tied to a human choice or error.[2] An important promise of HAVs is to address and mitigate that overwhelming majority of crashes. Whether through technology that corrects for human mistakes, or through technology that takes over the full driving responsibility, automated driving innovations could dramatically decrease the number of crashes tied to human choices and behavior. HAVs also hold a learning advantage over humans. While a human driver may repeat the same mistakes as millions before them, an HAV can benefit from the data and experience drawn from thousands of other vehicles on the road. DOT is also encouraged about the potential for HAV systems to use other complementary sensor technologies such as vehicle-to-vehicle (V2V) and vehicle-to-infrastructure (V2I) capabilities to improve system performance. These sensor technologies have their own potential to reduce the number and severity of crashes, and the inclusion of V2V and V2I capabilities could augment the safety and performance of HAV systems.

The benefits don't stop with safety. Innovations have the potential to transform personal mobility and open doors to people and communities—people with disabilities, aging populations, communities where car ownership is prohibitively expensive, or those who prefer not to drive or own a car—that today have limited or impractical options. Cities will reconsider how space is utilized and how public transit is provided. Infrastructure capacity could be increased without pouring a single new truck load of concrete. HAVs may also have the potential to save energy and reduce air pollution from transportation through efficiency and by supporting vehicle electrification.

Recognizing this great potential, this Policy sets out an ambitious approach to accelerate the HAV revolution. The remarkable speed with which increasingly complex HAVs are evolving challenges DOT to take new approaches that ensure these technologies are safely introduced (i.e., do not introduce significant new safety risks), provide safety benefits today, and achieve their full safety potential in the future. To meet this challenge, we must rapidly build our expertise and knowledge to keep pace with developments, expand our regulatory capability, and increase our speed of execution.

This Policy is an important early step in that effort. We are issuing this Policy as agency guidance rather than in a rulemaking in order to speed the delivery of an initial regulatory framework and best practices to guide manufacturers and other entities in the safe design, development, testing, and deployment of HAVs. In the following pages, we divide the task of facilitating the safe introduction and deployment of HAVs into four sections:

- Vehicle Performance Guidance for Automated Vehicles
- Model State Policy
- NHTSA's Current Regulatory Tools
- New Tools and Authorities

1. Vehicle Performance Guidance for Automated Vehicles

The Vehicle Performance Guidance for Automated Vehicles (or "Guidance") section outlines best practices for the safe pre-deployment design, development and testing of HAVs prior to commercial sale or operation on public roads. This Guidance defines "deployment" as the operation of an HAV by members of the public who are not the employees or agents of the designer, developer, or manufacturer of that HAV.

This Guidance is intended to be an initial step to further guide the safe testing and deployment of HAVs. It sets DOT's expectations of industry by providing reasonable practices and procedures that manufacturers, suppliers, and other entities should follow in the immediate short term to test and deploy HAVs. The data generated from these activities should be shared in a way that allows government, industry, and the public to increase their learning and understanding as technology evolves but protects legitimate privacy and competitive interests.

2. Model State Policy

Today, a motorist can drive across state lines without a worry more complicated than, "did the speed limit change?" The integration of HAVs should not change that ability. Similarly, a manufacturer should be able to focus on developing a single HAV fleet rather than 50 different versions to meet individual state requirements.

State governments play an important role in facilitating HAVs, ensuring they are safely deployed, and promoting their life-saving benefits. The Model State Policy confirms that States retain their traditional responsibilities for vehicle licensing and registration, traffic laws and enforcement, and motor vehicle insurance and liability regimes. Since 2014, DOT has partnered with the American Association of Motor Vehicle Administrators (AAMVA) to explore HAV policies. This collaboration was one of the bases for the Model State Policy framework presented here and identifies where new issues fit within the existing federal/state structure. The shared objective is to ensure the establishment of a consistent national framework rather than a patchwork of incompatible laws.

3. NHTSA's Current Regulatory Tools

NHTSA will continue to exercise its available regulatory authority over HAVs using its existing regulatory tools: interpretations, exemptions, notice-and-comment rulemaking, and defects and enforcement authority. NHTSA has the authority to identify safety defects, allowing the Agency to recall vehicles or equipment that pose an unreasonable risk to safety even when there is no applicable Federal Motor Vehicle Safety Standard (FMVSS).

To aid regulated entities and the public in understanding the use of these tools (including the introduction of new HAVs), NHTSA has prepared a new information and guidance document. This document provides instructions, practical guidance, and assistance to entities seeking to employ those tools. Furthermore, NHTSA has streamlined its review process and is committing to issuing simple HAV-related interpretations in 60 days, and ruling on simple HAV-related exemption requests in six months.[3] NHTSA will publish the section—which has wider application beyond HAVs—in the Federal Register for public review, comment and use.

4. New Tools and Authorities

The more effective use of NHTSA's existing regulatory tools will help to expedite the safe introduction and regulation of new HAVs. However, because today's governing statutes and regulations were developed when HAVs were only a remote notion, those tools may not be sufficient to ensure that HAVs are introduced safely, and to realize the full safety promise of new technologies. The speed with which HAVs are advancing, combined with the complexity and novelty of these innovations, threatens to outpace the Agency's conventional regulatory processes and capabilities.

This challenge requires DOT to examine whether the way DOT has addressed safety for the last 50 years should be expanded to realize the safety potential of automated vehicles over the next 50 years.

Therefore, this section identifies potential new tools, authorities and regulatory structures that could aid the safe and appropriately expeditious deployment of new technologies by enabling the Agency to be more nimble and flexible. There will always be an important role for standards and testing protocols based on careful scientific research and developed through the give-and-take of an open public process. It is likely that additional regulatory tools along with new expertise and research will be needed to allow the Agency to more quickly address safety challenges and speed the responsible deployment of lifesaving technology.

Public Comment

Although most of this Policy is effective immediately upon publication, DOT is also seeking public comment on the entire Policy. While the Agency sought input from various stakeholders during the development of the Policy, it recognizes that not all interested people had a full opportunity to provide such input. Moreover, while this Policy is intended as a starting point that provides needed initial guidance to industry, government, and consumers, it will necessarily evolve over time to meet the changing needs and demands of improved safety and technology. Accordingly, DOT expects and intends this Policy and its guidance to be iterative, changing based on public comment; the experience of the agency, manufacturers, suppliers, consumers, and others; and further technological innovation. DOT intends to revise and refine the Policy periodically to reflect such experience, innovation, and public input. Although it would not be practical to set a specific time for the next iteration, DOT expects to issue the first revised, follow-on Policy sometime within the next year, and at roughly annual intervals thereafter.

A critical input to the continuing development of this HAV Policy is the public notice-and-comment process. Along with this initial Policy, NHTSA is issuing a Request for Comment (RFC) on the Policy, which is available at www.nhtsa.gov/AV, or in the docket for this Policy, NHTSA-2016-0090. That RFC will be open for sixty (60) days. NHTSA will analyze the public comments received during that period and address significant comments in the next revision of this Policy.

Conclusion

The content of this Policy is the product of significant input from stakeholders across the spectrum of voices from the traveling public, traffic safety professionals, researchers, industry, government, the disabled community and others. As technology develops, more data becomes available and new ideas are brought forth, DOT will adapt and supplement this Policy. Within the next year, DOT intends to produce an updated version of this Policy incorporating new data, lessons learned from experience with applying this guidance, and stakeholder input.

New vehicle technologies developed in the 20th century—from seat belts to air bags to child seats—were once controversial. But after having saved hundreds of thousands of American lives, they are now considered indispensable. Advanced technologies developed in the first part of the 21st century—like automatic emergency braking and lane departure warnings—are already making U.S. roads safer. How many more lives might be saved today and in the future with highly automated vehicles? DOT is committed to finding out.

Note on "Levels of Automation"

There are multiple definitions for various levels of automation and for some time there has been need for standardization to aid clarity and consistency. Therefore, this Policy adopts the SAE International (SAE) definitions for levels of automation. The SAE definitions divide vehicles into levels based on "who does what, when."[4] Generally:

- At SAE Level 0, the human driver does everything;
- At SAE Level 1, an automated system on the vehicle can *sometimes assist* the human driver conduct *some parts of* the driving task;
- At SAE Level 2, an automated system on the vehicle can *actually conduct* some parts of the driving task, while the human continues to monitor the driving environment and performs the rest of the driving task;
- At SAE Level 3, an automated system can both actually conduct some parts of the driving task and monitor the driving environment *in some instances*, but the human driver must be ready to take back control when the automated system requests;
- At SAE Level 4, an automated system can conduct the driving task and monitor the driving environment, and the human need not take back control, but the automated system can operate only in certain environments and under certain conditions; and
- At SAE Level 5, the automated system can perform all driving tasks, under all conditions that a human driver could perform them.

Using the SAE levels, DOT draws a distinction between Levels 0-2 and 3-5 based on whether the human operator or the automated system is primarily responsible for monitoring the driving environment. Throughout this Policy the term "highly automated vehicle" (HAV) represents SAE Levels 3-5 vehicles with automated systems that *are responsible for monitoring the driving environment.*

An automated vehicle system is a combination of hardware and software (both remote and on-board) that performs a driving function, with or without a human actively monitoring the driving environment. A vehicle has a separate automated vehicle system for each Operational Design Domain such that a SAE Level 2, 3 or 4 vehicle could have one or multiple systems, one for each ODD (e.g., freeway driving, self-parking, geofenced urban driving). SAE Level 5 vehicles have a single automated vehicle system that performs under all conditions. This Policy defines "HAV systems" as automated vehicle systems that are capable of monitoring the driving environment as defined by SAE J3016. HAV systems are SAE Level 3 and higher by definition.[5]

NHTSA expects manufacturers and entities to classify their HAV system(s) as described in SAE J3016. Examples and the application of classifying HAV systems to the SAE levels of automation can be seen in the paper "Key Considerations in the Development of Driving Automation Systems."[6]

Note on Effective Dates of This Policy

As discussed above, most of this Policy is effective on the date of its publication. However, certain elements involving data and information collection will be effective upon the completion of a Paperwork Reduction Act review and process. Those elements are the Safety Assessment for HAV Manufacturers and Other Entities and the Safety Assessment for L2 Systems described in Section I, Vehicle Performance Guidance for Automated Vehicles.

U.S. Department of Transportation

VEHICLE-TO-VEHICLE
COMMUNICATION TECHNOLOGY

NHTSA ISSUES NOTICE OF PROPOSED RULEMAKING AND RESEARCH REPORT ON VEHICLE-TO-VEHICLE COMMUNICATIONS

The U.S. Department of Transportation's National Highway Traffic Safety Administration has issued a Notice of Proposed Rulemaking (NPRM) to mandate vehicle-to-vehicle (V2V) communication technology for new light vehicles in the United States.

What is V2V?

First and foremost, V2V technology is about crash prevention. Approximately 94 percent of crashes involve human error; V2V allows vehicles to effectively recognize collision situations, or threats, earlier and better than a human driver can.

V2V is a crash avoidance technology that relies on communication of information between nearby vehicles to warn drivers about potentially dangerous situations that could lead to crashes. For example, V2V could help warn a driver that a vehicle ahead is braking and they need to slow down, or let a driver know that it is not safe to proceed through an intersection because another car, unseen by the driver, is quickly approaching.

How does V2V work?

V2V communications systems use dedicated short-range communications (DSRC) technology to exchange basic data with other vehicles about factors such as location, speed, direction and braking status. V2V devices use this information from other vehicles to determine if a warning to the vehicle's driver is needed to help prevent a crash.

What is in the rulemaking proposal?

The proposed rulemaking is the culmination of more than a decade of work in partnership with others in the U.S. Department of Transportation (DOT), the automotive industry, State and local transportation departments, and academic institutions to prove out and develop consensus standards that support a coordinated, national deployment of V2V technology. This is the first proposed mandate of V2V technology worldwide.

NHTSA's NPRM consists of a proposal to mandate V2V technology in all new light vehicles by utilizing the radio transmission protocols and spectrum bandwidth collectively known as dedicated short-range communications (DSRC). The agency is proposing to require that all V2V devices must "speak the same language" through a standard technology. The agency is also proposing that privacy and security measures are employed in any V2V device.

The NPRM follows NHTSA's previously issued advance notice of proposed rulemaking (ANPRM) and research report, "Vehicle-to-Vehicle Communications: Readiness of V2V Technology for Application," in August 2014, and directly supports Secretary Foxx's announcement on February 3, 2014, that the Department would work on a regulatory proposal to require V2V devices in new vehicles.

What are the advantages of V2V?

V2V messages using DSRC technology would have a range of approximately 300 meters, which exceeds the capabilities of systems with ultrasonic sensors, cameras, and radar, allowing greater capability and time to warn drivers. In addition, these radio messages can "see" around corners or "through" other vehicles, addressing scenarios such as those, for example, where an oncoming vehicle emerges from behind a truck or from a blind alley. In those situations, V2V communications can detect the threat much sooner than radar or camera sensors can.

V2V technology can also be combined with existing on-vehicle sensors, such as radar and cameras, to provide even greater benefits than either approach alone. This combined approach could also augment system accuracy becoming a foundation for realizing the safe deployment of automated vehicles on our Nation's roadways. For more detailed information on how NHTSA believes the various levels of vehicle automation will help reduce crashes and how on-board systems may someday work cooperatively with V2V technology, see NHTSA's Preliminary Statement of Policy on Vehicle Automation (May 2013).

V2V devices can be installed directly in vehicles when the vehicles are originally manufactured, after initial manufacture via an "aftermarket" installation, or could potentially be carried into vehicles by drivers in the form of a hand-held device (and perhaps, eventually, even as a function on a smartphone).

What data is exchanged?

The data, known as the "basic safety message" (BSM), is exchanged between vehicles and contains vehicle dynamics information such as heading, speed, and location. The BSM is updated and broadcast up to 10 times per second to surrounding vehicles. The information is received by other vehicles equipped with V2V devices and processed to determine collision threats. Based on that information, if required, a warning could be issued to drivers to take appropriate action to avoid an imminent crash.

What is V2V's potential to address vehicle crashes?

V2V can enable a number of different safety "applications" that help drivers with different aspects of driving, like warning drivers about stopped vehicles in the road ahead, vehicles speeding unexpectedly through intersections, vehicles in blind spots, and more.

The agency's analysis of two potential applications, "intersection movement assist" (IMA) and "left turn assist" (LTA), indicated there could be an average 50-percent reduction in crashes, injuries, and fatalities just through these two applications.

Applied to the full national vehicle fleet, this could potentially reduce 400,000 to 600,000 crashes, prevent 190,000 to 270,000 injuries and save 780 to 1,080 lives each year once fully deployed. The addition of other V2V and vehicle-to-infrastructure (V2I) safety applications would save even more lives. Taken together, all of these applications could eliminate or reduce the severity of up to 80 percent of non-impaired-driving crashes.


Source: U.S. DOT

What vehicles are affected by this NPRM?

The NPRM applies to light-duty vehicles (passenger cars and trucks). However, NHTSA believes that V2V technology also holds great promise for medium- and heavy-duty trucks and buses, and working with industry, the Agency is continuing research to adapt the technology for these vehicles.

What are dedicated short-range communications?

Dedicated short-range communications (DSRC) are two-way, wireless communications permitting secure and fast messaging needed for safety applications, where "short range" is approximately 300 meters depending on the surrounding environment. These communications occur in a 75 MHz band of the 5.9 GHz spectrum, which has been allocated by the FCC for use by Intelligent Transportations Systems (ITS) vehicle safety and mobility applications. This band affords a relatively clean operating environment with very few pre-existing users, allowing for relatively unimpeded and interference-free communication zone.

What are the practical applications enabled by V2V?

V2V can enable warnings that are not currently available to drivers and that might not otherwise be available without V2V. Some of the potential applications of V2V technology include:

Intersection Movement Assist

Intersection Movement Assist (IMA) warns the driver when it is not safe to enter an intersection because of high potential for colliding with one or more vehicles.

Left Turn Assist

Left Turn Assist (LTA) warns the driver there is high probability they will collide with an oncoming vehicle when making a left turn. This is especially critical when the driver's line-of-sight is blocked by a vehicle also making a left turn from the opposite direction.

Emergency Electronic Brake Light

An Emergency Electronic Brake Light (EEBL) warns the driver to be prepared to take action when a V2V-equipped vehicle traveling in the same direction but not in the driver's line-of-sight decelerates quickly. V2V would allow the driver to "see through" vehicles or poor weather conditions to know that traffic ahead may be coming to an abrupt stop.

Forward Collision Warning

Forward Collision Warning (FCW) alerts the driver of the risk of an impending rear-end collision with another vehicle ahead in traffic in the same lane and direction of travel.

Blind Spot Warning and Lane Change Warning

Blind Spot Warning (BSW) notifies the driver when a vehicle in an adjacent lane is positioned in the driver's "blind spot" zone. If the driver were to attempt a lane change, Lane Change Warning (LCW) warns the driver of a vehicle's presence during a lane change attempt if another vehicle is present in or approaching the "blind-spot" zone.

Do Not Pass Warning

Do Not Pass Warning (DNPW) tells the driver that it is not safe to pass a slower-moving vehicle because vehicles are approaching from the opposite direction in the passing lane.

How are V2V and automated vehicle technologies related?

V2V and automated vehicle technologies are distinct technologies, which each carry significant safety potential. It is the Department's view that these technologies are highly complementary to each other, and when deployed in concert will have significant safety benefits. Vehicles that contain automated driving functions—such as automated emergency braking and adaptive cruise control—generally rely on an on-board suite of sensors, such as radar and cameras. V2V offers an additional source of data inputs, which could help these automated technologies better avoid or mitigate crashes.

V2V expands sensing performance beyond what is achievable by "line-of-sight" sensors (e.g., LIDAR, radar, cameras). With V2V, a vehicle gains capabilities like "seeing" around corners, buildings or trucks, and many vehicles ahead or behind. V2V has a larger effective sensing range than conventional sensors, providing additional lead time for decision algorithms, which is essential for higher levels of automation. V2V packs a rich set of "vehicle performance and status" information directly from the source, which enables automation algorithms to "know" what surrounding vehicles are doing and not have to guess or estimate what they may be doing.

Is V2V a "must have" for highly automated vehicles?

Our discussions with both traditional automotive and "high-tech" companies involved in development of highly automated vehicles suggests that within a given operational design domain (ODD) as specified for a particular product model, safe operation of such automated vehicles is possible without V2V. However, industry stakeholders also agree that, if available, they would utilize V2V information to enhance their systems, and even further, it would not be possible to optimize the benefits of automated vehicles without V2V.

When the proposed V2V mandate becomes a Final Rule, the technology will be required on all new light-duty vehicles—including highly automated passenger vehicles.

Will V2V be vulnerable to cyber-attacks?

Vehicle cybersecurity is a high priority for NHTSA. In October 2016, NHTSA issued proposed guidance for improving motor vehicle cybersecurity. The V2V NPRM promotes cybersecurity protection to ensure that V2V technologies are safeguarded from unauthorized access. The current proposed design for the V2V system employs a security level of at least 128-bit encryption and is NIST compliant.

The proposed rulemaking remains consistent with the security approach detailed in NHTSA's V2V research report, where NHTSA and industry research partners developed a security system design based on the widely and successfully applied public key infrastructure, employing digital certificates. The system design consists of three primary components:

1. A message authentication proposal designed to enhance confidence in the authenticity of V2V messages and secure the exchange of safety data;
2. V2V devices, which broadcast and receive safety messages and ensure that each incoming message is checked to detect and avoid misbehavior; and
3. A misbehavior reporting requirement to share signatures misconfigured, or malicious vehicles enabling other vehicles to block V2V messages from misbehaving vehicles.

In addition, the Agency is also seeking comments on potential alternative approaches to security and looks forward to receiving comments on both the proposal and the alternatives presented in the NPRM.

Will drivers' privacy be at risk when V2V is deployed?

By design, the V2V system will not collect, broadcast, or share information linked or linkable, as a practical matter, to individuals or their vehicles. V2V-enabled vehicles exchange only generic safety information. The system is designed to operate without using any personal information about specific vehicles or drivers.

How does the public submit comments?

To submit comments on the ANPRM and research report, visit www.regulations.gov and enter Docket No. NHTSA-2016-0126, or visit www.safercar.gov/v2v. Comments will be accepted for 90 days; late comments will be considered to the extent practicable.

What are the next steps?

NHTSA will review the submitted comments and adjust the proposal as appropriate before issuing a final rule.

U.S. Department of Transportation
National Highway Traffic Safety Administration

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Self-Driving Cars: Driving Into the Future

The promise of self-driving cars is that they will see better than humans, never get lost, and almost never crash. Easier said than done.

By Jeff Plungis

February 28, 2017

In what was once an industrial-age foundry along the Allegheny River in Pittsburgh, Carnegie Mellon University has created a long-standing hub for the development of autonomous vehicle technology—the National Robotics Engineering Center.

The university's pioneering work with the government's Defense Advanced Research Projects Agency dates back to 1984 and has led to the creation of many of the vehicles that occupy the facility today.

The building's high bay has a crane capable of lifting 10 tons, and the huge open space is littered with prototypes with names like Crusher (an unmanned military ground vehicle), Chimp (a robot with thumbs that can grasp tools), and Boss (a 2007 Chevy Tahoe modified to drive itself).

Some of the center's major clients—including NASA, Caterpillar, Ford Motor Co., John Deere, and multiple arms of the Defense Department—are underwriters of advanced autonomous vehicle technology.

Although much of this technology was originally intended for the battlefield, it has become increasingly clear in recent years that self-driving cars and trucks—animated by computer code—will be sharing the roads with ordinary drivers in the near future. And in places like Mountain View, Calif., Pittsburgh, and Phoenix, this is already happening in the form of on-the-road testing. Pittsburgh was also the place Uber chose to launch its prototype test fleet of self-driving taxis last year.

More on Self-Driving Cars

- How Safe Is Safe Enough?
- What Manufacturers Have in Store
- From Human to Machine: Levels of Automation
- Guide to Self-Driving Cars

Philip Koopman is a computer and electrical engineering professor at Carnegie Mellon who often spots Uber's self-driving taxis while riding a bus downtown. These days, his job at NREC is to stress-test the software that guides the center's self-driving car prototypes. He and his team of computer wizards throw dilemmas at the vehicles in the form of confounding nuggets of code.

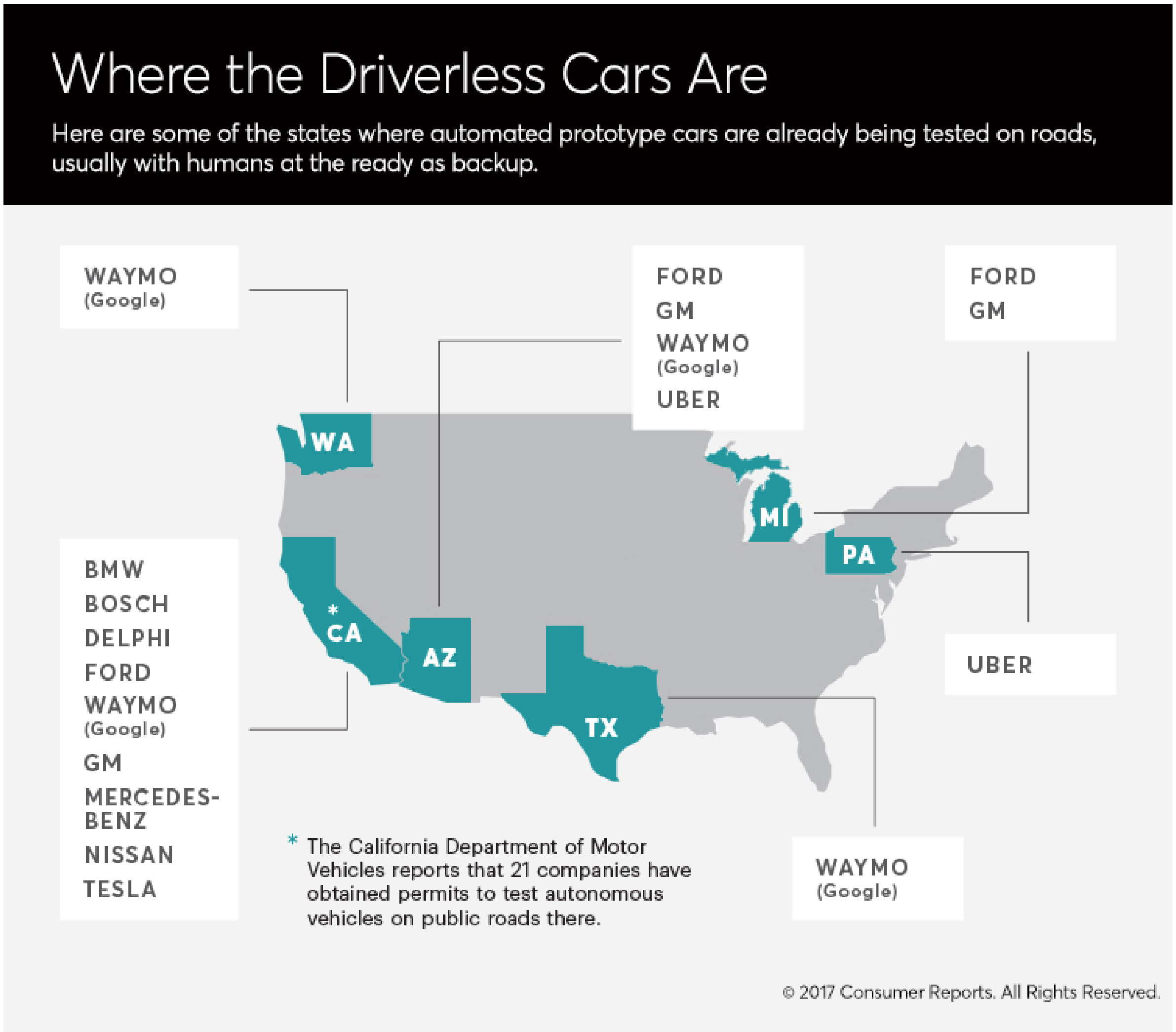
One day they might try to ensure a programmed speed limit holds steady in self-driving mode. On another, they'll corrupt map data to see how the vehicles respond. Do the cars stop entirely, or crash? Or act confused?

Sometimes Koopman's team's experiments are simulated inside the enormous facility. Other times they work around the country at their clients' testing facilities, riding alongside vehicles they are trying to befuddle.

It's a lopsided competition, for sure. "We've broken everything we've touched," says Koopman.

Although that sounds like bad news, Koopman's crew prefers to interpret the failures it causes as counterintuitive moments of progress for the evolution of machine-driven vehicles.

This kind of work takes time, Koopman says, and is important, especially when you're dealing with "a shiny toy that can kill people."



Are We There Yet?

Fully self-driving technology is at a critical juncture in its development. For a few years now, test fleets have been operating on public roads, and, for the most part, those fleets have coexisted fairly well with human drivers and pedestrians. That alone can seem like such a miracle of modern engineering that people might assume the full deployment of self-driving cars is all but inevitable, and near-term.

Most experts consulted for this story tend to agree that, technologically, we are about 85 to 90 percent of the way to perfecting the hardware, guidance systems, and software to make vehicles that can reliably and safely drive themselves. Almost all of the fully autonomous vehicles currently allowed on public roads are still under the direct supervision of human pilots, and they're only driving on roads that have been heavily studied and mapped in three dimensions.

Ford Motor Co. executive vice president Raj Nair says you get to 90 percent automation pretty quickly once you understand the technology you need. “It takes a lot, lot longer to get to 96 or 97,” he says. “You have a curve, and those last few percentage points are really difficult.”

Almost every time auto executives talk about the promise of self-driving cars, they cite the National Highway Traffic Safety Administration statistic that shows human error is the “critical reason” for all but 6 percent of car crashes.

But that’s kind of misleading, says Nair. “If you look at it in terms of fatal accidents and miles driven, humans are actually very reliable machines. We need to create an even more reliable machine.”

Some of the gnarliest issues are still to be solved. There are technical hurdles for the industry to overcome, like perfecting the sensors that enable cars to “see” in all conditions. There are legal questions, such as whether a car company will accept liability when the driver is its software. Ethical challenges may prove even harder. Should a self-driving car swerve to avoid a young child, risking the life of its owner-occupant? And for every real-life situation researchers like Koopman and his team identify, there are likely hundreds and thousands of others no one has yet thought of.

As daunting as that sounds, there has been a lot of progress in the technological foundation of autonomous driving in the last few years. And even more hype. So how long will it take to get from test cars to real-world autonomous vehicles?

Most industry analysts believe it will take many more years—even decades—before they replace human-driven cars in significant numbers. Market forecaster Moody’s projects they won’t be a majority of active cars before 2045.

Still, driverless technology is one of the major trends in the auto world, along with the rise of electric vehicles, the growth of ride sharing, and increasing Internet connectivity.

It seems an autos revolution is upon us.

Mike Ableson, the vice president of global strategy at General Motors, says GM expects to see more industry change over the next five years than in the last 50. “We’ve solved a lot of the really hard problems as far as the environment we operate in,” he says of reaching the threshold of full driving automation. “There’s not a lot of fundamental invention that's got to go on. It's more development and refinement and validation."

For all the uncertainty, there's a good deal of agreement on the biggest technical issues that still need to be solved, which boil down to three main areas: sensor technology (for "seeing" the road and any potential obstacles), mapping (for spatial orientation), and software (for thinking and problem-solving).

1. Sensor Technology

Just like a human driver uses eyes to see the road ahead and transfers visual data to the brain, an automated vehicle will have to use a combination of sensors to transmit data about the nearby environment to its computer processors. Think how much safer a human driver would be if she had eight eyes, not two.

Prototype vehicles today are equipped with bulky equipment on the roof, where it's easier for sensors to get a 360-degree view of the vicinity. All that gear is basically a collection of two different types of sensors. First is an array of cameras, which takes in the same type of visual information that the human eye does—only in multiple directions at the same time—then feeds that information to a computer. With enough cameras, blind spots are eliminated. Narrower-range cameras can clearly see distances beyond human vision. Wide-angle cameras offer superior peripheral vision.

Mobileye, a company based in Israel that develops cameras, hardware, and software for much of the auto industry, is marketing systems that use eight cameras spaced around the vehicle, along with chips and software to process that visual data.

The second type of object-detecting sensors includes radar and lidar. They use radio waves or light pulses to scan the road ahead for potential obstacles. This can work in tandem with cameras, leveraging the strengths and weaknesses of each technology. Researchers and automakers are still working out what combination of sensors creates the best balance of capability, complexity, and cost.

Human vision at night is limited, reduced to whatever headlights can illuminate. Meanwhile, some sensors, such as lidar, and more traditional radar, don't need light to see, according to Michael Jellen, president and chief operating officer of Velodyne LiDAR, a leading industry supplier.

“Driving into the sunrise or sunset, of course, night driving—these are all extremely tough challenges for anything that’s not lidar-based,” Jellen says.

Radar is adept at calculating speed and distance. But it still has some limitations, including not being able to distinguish whether an upcoming obstacle is a living thing or a similarly sized rock, or whether a traffic light is red or green.

Lidar has been perhaps the most exotic, costly, and important technological piece of the self-driving puzzle. Pulsating lasers bounce off surrounding objects to generate a three-dimensional map. The third dimension is key because it gives the car the depth perception we humans naturally have, which is necessary to avoid crashes. Lidar systems are accurate, but cost as much as $7,500 per car. And they can be easily flummoxed by commonly occurring events such as rain and snow.

Some newer vehicles, such as the 2017 Cadillac CTS, are already equipped with a radio technology known as vehicle-to-vehicle or vehicle-to-infrastructure, which lets vehicles communicate with the infrastructure around them or directly with other cars on the road. An Audi system on some Q7 and A4 models already communicates with certain “smart stoplights” and tells drivers the seconds until a light will turn green.

Federal safety regulators see enormous potential safety benefits to V2V and V2I technologies, and have proposed that all cars eventually come with V2V equipment, enabling cars to talk to one another by broadcasting a stream of speed, acceleration, location, and braking information.

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2. Mapping

Right now, GPS systems can pinpoint locations of phones and cars to within about 2 meters roughly 95 percent of the time. That's accurate enough to navigate in traffic, but not good enough to let the car drive on its own.

That's why researchers and carmakers are embarking on a massive endeavor to create high-definition 3D maps of the nation's roads. Some of this mapping is already under way in cities where self-driving fleets and research vehicles have scanned roads using lidar.

These high-definition maps have been shown to be accurate to within a few centimeters. They can help self-driving cars navigate when conditions make it difficult for sensors to see the road. And they can assist self-driving cars in cutting through the chaos while merging onto a highway entrance ramp, joining a traffic circle, or traversing a bridge.

Ford's test vehicles, for example, scan every road they drive to pinpoint locations of trees, fire hydrants, buildings, stop signs, and traffic lights—anything within 200 meters of the moving car. Once roads—and larger areas such as towns and cities—are fully mapped, cars will know whether a crosswalk exists even when painted lines are worn thin or covered by snow.

Some companies have begun crowdsourcing the job of gathering data for 3D maps instead of doing it all themselves. Newer-model cars already have built-in cameras for active-safety systems such as automatic braking and lane-change assist that are generating huge amounts of this kind of data.

Even temporary construction zones, potholes, and sinkholes could be identified and marked very quickly with crowdsourcing of real-time conditions, says Jim Zizelman, a vice president for electronics and safety at Delphi, an automotive and technology company.

This is one reason companies like Tesla are willing to roll out cars equipped with autonomous-vehicle hardware before having corresponding software written. By using the cars' cameras to record data about accidents and near misses, Tesla says it can evolve and validate self-driving technology before activating it.

Other companies like Mobileye are planning a similar effort to gather data from the nearly 14 million newer-model cars already using their sensors for other semi-autonomous features.

One of the challenges of 3D maps using lidar is that they'll need storage and processing powers well beyond what could fit in a car today. The crowd-sourced maps would transmit data 100,000 times faster than the 3D maps using lidar, says Zizelman, and they'll be continually updated.

3. Software

Today's self-driving cars are sometimes described like teenagers: relatively safe in limited situations, not nearly as safe as an experienced human driver.

Programming cars to make them safe enough to be let loose on busy roads requires painstaking programming of real-life situations, machine learning, and artificial intelligence so that they can recognize what's happening in every conceivable circumstance. They have to process their environment and make safe decisions even about things they're encountering for the first time.

There are essentially two ways to train a vehicle to anticipate the unexpected: Program in every possible eventuality, or teach a vehicle to learn and think for itself.

The system has to be one that sees pedestrians, bicyclists, and lanes and understands driver behavior, says Ford's Nair. "It's not just recognizing there's a vehicle in front of it," he says, explaining that it learns through driving experience, like people do.

A lot of the progress has come via analysis of test cars on actual roads and in programmed simulations of road driving. Programmers have worked out a lot of the basics of ordinary driving.

The trick is getting those rare situations, ones that might occur only once in a lifetime, written into code.

Researchers scan for weird incidents among the millions of test-car miles. This has yielded oddities, such as the Google car that stopped cold while a woman in an electric wheelchair did circles in the road ahead. She was chasing a duck with a broom. The poor car had never seen anything like it.

Ford's test fleet of self-driving Fusion sedans are all learning from each other at the same time, Nair says. When one vehicle encounters a situation and a software engineer figures out a solution, it is then learned by every other self-driving car Ford owns, he says.

It's a daunting task imagining and writing all that code, then testing it in labs and on roads. "We're trying to replicate your brain," Nair says. The auto industry seems unfazed that the human brain, which works so well to process data it absorbs, evolved over millions of years. It won't take anywhere near that long to get a functional computer brain for self-driving cars, Nair says, because engineers will rely on experimenting and testing, and not random genetic mutation.

"Mother Nature, as good as she is, does a lot of work by accident," Nair says. "If something doesn't work, we can make a design change right away."

The challenge might be easier if self-driving cars only had to worry about other predictable self-driving cars. But that won't be the case. They'll be sharing the road with unpredictable human drivers for decades, at least.

That's where [Waymo](), a new company that was formerly Google's self-driving car project, believes it has an edge. With deep roots in software, it has experimented with machine learning in projects like Google Translate and Google Photos. "To navigate city streets, we've had to train our software to be able to understand and predict how drivers and other users of the road will behave," says Johnny Luu, a spokesman for Waymo.

Ford's recent partnership with a small visual-software company echoes the industry's growing interest in artificial intelligence. Nirenberg Neuroscience, a New York-based company founded by Weill Cornell Medical College professor Sheila Nirenberg, has developed software meant to mimic the code transmitted from the human eye to the brain. Nirenberg's research is already helping robots recognize objects, read faces, and navigate complex situations. Her company has also developed a "bionic eye" to restore sight to patients with degenerative retinal diseases.

Ford hopes to use its partnership with Nirenberg to bring humanlike intelligence to driverless cars.

Nirenberg says she figured out that the human eye transmits to the brain only what it needs to know. The key to the artificial intelligence she's developing is how to be just as effective working with a much smaller amount of data.

Evolution built that editing process over millions of years, Nirenberg told CR. "I figured out what evolution did and turned it into equations." It's nearly impossible to map all circumstances in all weather conditions, she says. Humans didn't evolve with highly detailed maps in their heads. We can function in places we've never been before because our brains focus only on what they need to know at the moment.

Likewise, cars must be able to respond to something on the fly, to handle the unexpected, she says."You want the flexibility to be like we are; you don't have to know everything."

Editor's Note: This article also appeared in the April 2017 issue of Consumer Reports magazine.
