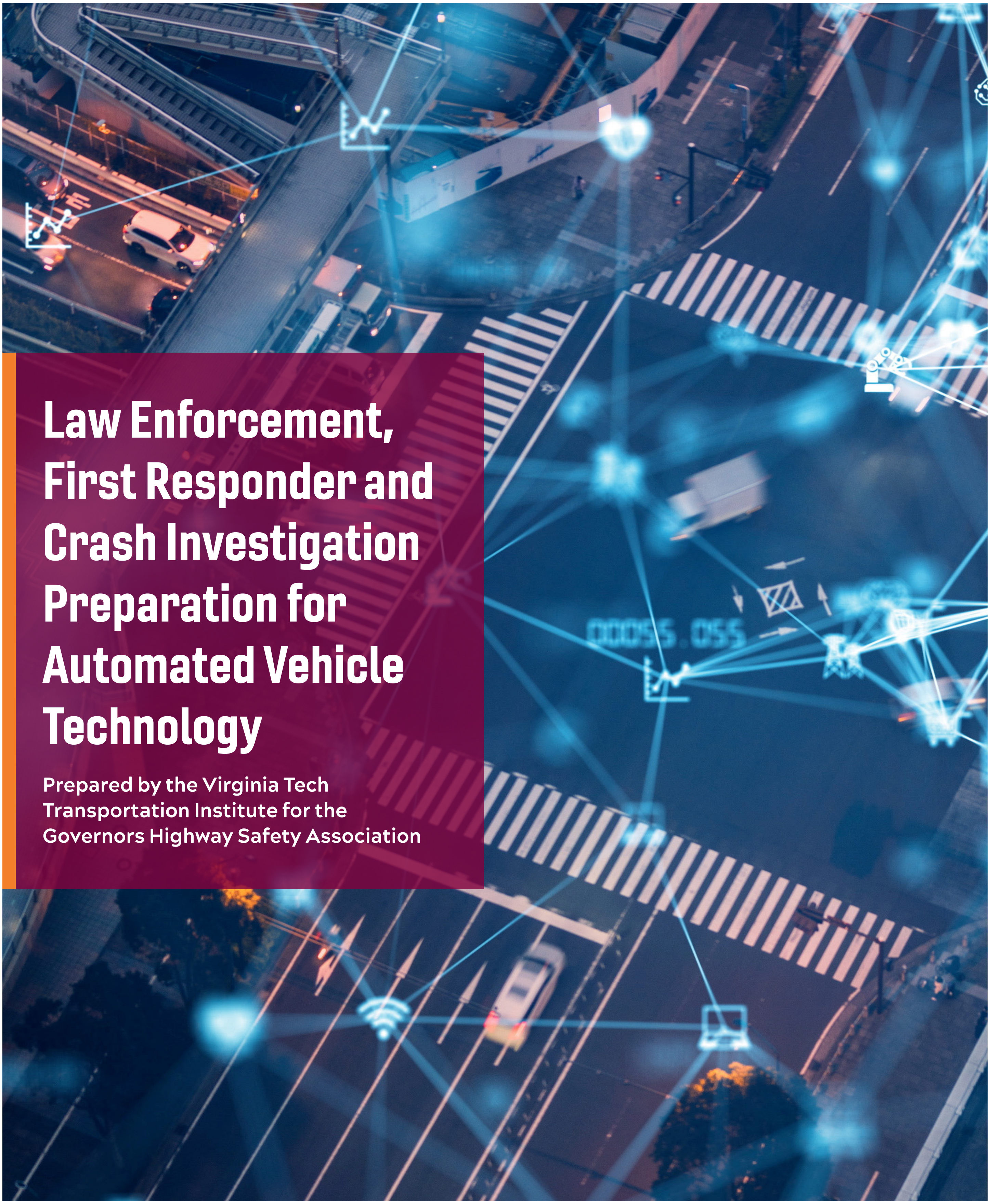


Law Enforcement, First Responder and Crash Investigation Preparation for Automated Vehicle Technology

Prepared by the Virginia Tech Transportation Institute for the Governors Highway Safety Association

VIRGINIA TECH TRANSPORTATION INSTITUTE

GHSA
Governors Highway Safety Association®
The States' Voice on Highway Safety

State Farm®

ACKNOWLEDGEMENTS

This report was prepared by Tammy Trimble, Ph.D., and Travis Terry, Ph.D., with the Virginia Tech Transportation Institute, for the Governors Highway Safety Association (GHSA) as a result of the association's ongoing focus on the safety implications of automated vehicles. The authors conducted discussions with first responders, law enforcement officials, crash reconstructionists, government administrators, automakers, insurance professionals and advocates.

Editorial direction and review were provided by GHSA staff.

This report was made possible by a grant from State Farm®.

Creative by Winking Fish.

TABLE OF CONTENTS

Executive Summary

Building upon previous (e.g., Terry et al., 2018, 2021; Goodison et al., 2020; Automated Vehicle Safety Consortium, 2020) and current efforts seeking to identify strategies for integrating Automated Driving System (ADS)-equipped vehicles into the U.S. fleet without significant disruption to first responder protocols, this research project sought to distill and summarize progress to inform and educate stakeholders on ADS-related technologies. This effort was conducted in three parts.

Part one included a literature review that introduced Advanced Driver Assistance System (ADAS) and Automated Driving System (ADS) technologies by describing their most recent and current states and forecasted near-term future deployments and outlooks. Part two included discussions with government administrators, first responder and law enforcement organizations, automakers, crash reconstruction organizations, and insurance and safety advocates. These discussions explored and documented general training needs for public safety service providers as well as training channels and potential barriers. By reaching out to a wide range of stakeholders, the researchers were able to identify areas where training was most needed. Additionally, stakeholders were asked to detail effective methods of presenting training materials as well as barriers to information dissemination.

Part three involved synthesizing the key findings from parts one and two to formulate a curriculum development strategy. Each recommended topic is meant to provide guidance to public safety providers along with anticipated learning outcomes. When developing this curriculum, organizations should take into consideration the background materials and resources as well as curriculum considerations included in this report along with state and local safety protocols and procedures for nuanced training situations. The recommended curriculum topics include:

- Understanding the differences between and capabilities of ADAS- and ADS-equipped vehicles
- Identifying ADS technologies on the road today
- Understanding governmental responsibilities regarding vehicle oversight
- Anticipating ADAS- and ADS-equipped vehicle deployment
- Interacting with ADS-equipped vehicles
- Understanding and accessing data

These recommendations are presented with the understanding that ADAS and ADS technologies are continuously evolving, and materials must be agile to accommodate future changes. The proposed curriculum recommendations provide a knowledge base surrounding ADAS- and ADS-equipped vehicle deployment for law enforcement officials, first responders and crash investigators, and identify appropriate training channels and potential barriers to training and information dissemination in a practical manner.

1. Introduction

The automated technologies currently integrated into vehicles, and those planned for future integration, are intended to reduce driver input and lessen the potential for human error. The rollout of these advanced technologies will be iterative – highways will be shared by conventional and advanced automated vehicles for years to come. This process slowly adds to the complexities faced by first responders who must interact with all types of vehicles in the performance of their duties.

1.1. PROJECT OBJECTIVES AND APPROACH

Building upon previous (e.g., Terry et al., 2018, 2021; Goodison et al., 2020; Automated Vehicle Safety Consortium, 2020) and current efforts to identify strategies for integrating Automated Driving System (ADS)-equipped vehicles into the U.S. fleet without significant disruption to first responder protocols, this research sought to distill and summarize progress to inform and educate stakeholders on ADS- and Advanced Driver Assistance Systems (ADAS)-related technologies. The project was conducted in three parts.

Part one included a literature review that introduced ADAS and ADS technologies by describing their most recent and current states and forecasted near-term future deployments and expectancies. The literature review also described what is encompassed under the term "public safety" as it relates to this research effort and provided examples of previous research addressing first responders and the impact automation will have on their routine tasks. In addition, the review document included summaries of recent policies and recommended best practices for public safety providers, delved into crash reconstruction and crash reporting methods, and identified opportunities for the inclusion and tracking of rapidly changing technologies within those fields.

Part two included discussions with government administrators, first responder and law enforcement organizations, automakers, crash reconstruction organizations, and insurance and safety advocates. These discussions explored and documented general training needs for public safety providers as well as training channels and potential barriers. By reaching out to a wide range of stakeholders, the researchers were able to identify areas where training was most needed. Additionally, stakeholders were asked to detail effective methods for presenting training materials as well as barriers to information dissemination.

Part three involved synthesizing the key findings from parts one and two to formulate a curriculum suited for outreach and education. These recommendations are presented with the understanding that ADAS and ADS technologies are rapidly advancing, and materials must be agile to accommodate future changes. The proposed curriculum recommendations provide a knowledge base surrounding ADAS- and ADS-equipped vehicle deployment for law enforcement officials, first responders and crash investigators, and identify appropriate training channels for and potential barriers to training and information dissemination in a practical manner.

1.2. DEFINING PUBLIC SAFETY STAKEHOLDERS

This research focuses on public safety providers in law enforcement, any entity considered a first responder, and crash scene investigators, and includes administrative personnel as well as rank and file officers. The term "first responder" typically includes frontline or patrol officers who commonly interact with civilian drivers (such as during traffic stops) and respond to incidents and also fire and rescue teams, emergency medical service (EMS) providers, and safety service patrols. Crash investigators are not considered first responders but must be familiar with the technological concepts and capabilities of crash-involved vehicles to accurately conduct reconstructions and assign liability. Additionally, the crash reporting and citation forms used by law enforcement or investigators must be able to account for ADAS- or ADS-equipped vehicles involved in a crash, so accurate data are recorded.

1.3. UNDERSTANDING EMERGING VEHICLE TECHNOLOGIES

The rapid advancement of vehicle technology is changing the role of the human driver. In conventional vehicles, the human driver has full control over the driving task, but as vehicle technologies evolve, some drivers will transition to a fallback ready role. This shift will result in changes to common scenarios where public safety providers typically engage with humans who occupy the driver's seat. In fact, in the future, some vehicles may render the term "driver's seat" obsolete.

Currently, there are two vehicle automation categories: ADAS and ADS. The major distinction between the two is that a vehicle can possess many different ADAS features, such as forward collision warning (FCW), automatic emergency braking (AEB) or curve speed warning systems. These systems may work independently of one another and share the same sensors or cameras to function properly. A single vehicle may have all or some of these systems depending on standard and optional packages available at purchase. An ADS, on the other hand, is defined by the role of the driver and the automated systems that operate the vehicle. These are classified into six levels of automation and are detailed in section 1.3.2. of this document below.

1.3.1. Automated Driving Assistance Systems (ADAS)

ADAS are designed to make the driving task easier for humans and reduce crashes and save lives by intervening automatically when certain parameters are met. These are known as active safety systems (SAE International, 2021a; SAE International, 2021b; Sinclair, 2021). AEB, which will cause the vehicle to slow or stop when an urgent action is warranted, is one example of this type of active system. Other well-known ADAS are considered "warning" systems and include FCW, lane departure warning (LDW), lane keeping assistance (LKA), blind spot warning (BSW), and rear cross traffic warning (RCTW) (Hourdos, 2019; Sinclair, 2021).

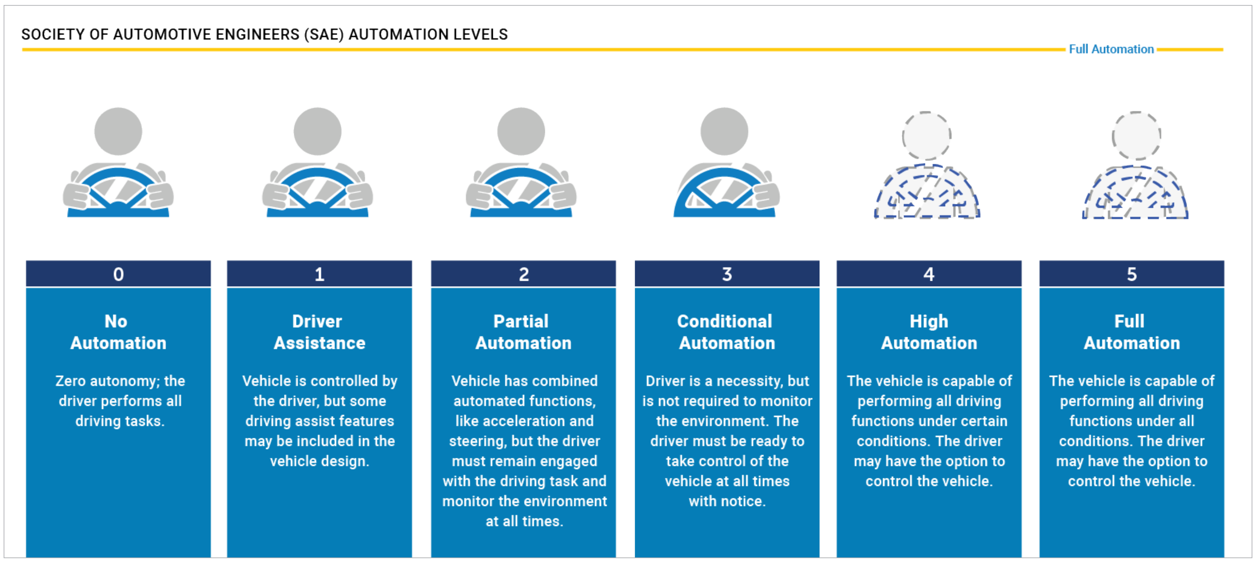
1.3.2. Automated Driving System (ADS)

ADS have the collective ability for hardware and software to perform a dynamic driving task on a sustained basis. There are six levels of automation, defined in SAE J3016, that categorize the role of the human driver, as shown in Figure 1. Levels 0, 1 and 2 are often referred to as conventional vehicles, or vehicles where humans have most of the responsibility for the driving task. Levels 3, 4 and 5 are referred to as ADS and in

vehicles equipped with an ADS at these levels, the role of the human driver is greatly reduced (level 3) or removed completely (levels 4 and 5) (SAE International, 2021b).

It is important to note that manufacturers decide the level of vehicle automation. For example, one manufacturer may design a level 4 vehicle that gives humans the ability to turn level 4 capability on or off, while another may restrict that ability. Such differences are expected, especially between private and fleet-owned and operated ADS-equipped vehicles.

Figure 1: SAE Automation Levels
(as described by the National Highway Traffic Safety Administration)



1.3.3. State of the Technology

Throughout this document, references to ADAS and ADS are consistent with industry norms. The acceptance and use of consistent terminology are key components to increasing knowledge about this topic.

Unlike ADS, terminology for ADAS features is not consistent across manufacturers. A clear example of this is Adaptive Cruise Control (ACC). ACC allows a driver to select a speed and a following distance and the vehicle will maintain those parameters. If a slower vehicle is encountered, ACC will adjust the speed and distance automatically, requiring no action from the driver. A traditional cruise control feature would require the driver to manually adjust the speed or cancel cruise control altogether and adjust speed and distance manually to the slower vehicle. ACC is now available in all newer vehicles as part of the standard package of ADAS features; however, it is referred to by a plethora of marketing terms including Smart Cruise Control, Intelligent Cruise Control, Adaptive Cruise Control with Queue Assist, Dynamic Radar Cruise Control, Distronic Plus, and Traffic Aware Cruise Control.

To assist consumers in understanding the purpose or function of their vehicles' features, the National Safety Council maintains the website mycardoeswhat.org. AAA has provided manufacturers with naming convention guidelines and encourages consistent use of terminology across features to bolster understanding of the numerous advanced systems and their functions (2019). Marketing terms help sell consumers on a product's abilities, but ultimately burden first responders and crash investigators, who must quickly synthesize the details of an incident to make proper judgements.

The findings and recommendations included in this document provide first responders, crash investigators and other relevant stakeholders guidance that may be used to develop effective curricula that will help them transition their operational policies to account for the widespread adoption of future ADAS and ADS technologies. Supplemental background information is provided in the Appendices.

2. Curriculum Development Considerations

A series of discussions were held with public safety providers and stakeholders, including government administrators, automakers and technology developers, and insurance and safety advocates. The following summarizes the key takeaways from these discussions and serves as a helpful reference for those developing curricula for public safety providers.

2.1. WHY IS TRAINING NEEDED?

From 2011 to 2020, a total of 498 line-of-duty deaths involving law enforcement officers were the result of motor vehicle-related incidents (struck by and crashes; National Law Enforcement Memorial Fund, 2021). Emerging technologies such as ADAS- and ADS-equipped vehicles have the potential to make roadways safer for all drivers, especially law enforcement and other public safety providers who spend hours behind the wheel and face increased crash risks when responding to emergency calls. Yet, public safety providers' understanding of how ADAS- and ADS-equipped vehicles currently do and will operate in and respond to situations is limited. Many safety providers are working in areas with limited or no vehicles with ADS and have yet to be exposed to these technologies via training or conferences. Often, exposure is limited to Internet videos or television news coverage, resulting in incomplete knowledge or misunderstanding regarding these technologies (for example, thinking that "self-driving" cars currently exist). As a result, the following questions persist among public safety providers (Terry et al., 2018):

- How will we disable an ADS-equipped vehicle, investigate an abandoned vehicle or perform stabilization or extrication?
- How do we know the ADS-equipped vehicle has sensed or detected the presence of an emergency vehicle that is responding to an incident or the presence of a first responder who is conducting traffic direction and control?
- How do we determine ownership of an ADS-equipped vehicle? How is responsibility assigned at an incident or when conducting a traffic stop?

The events of the past year have highlighted the demands facing public service personnel. For example, police officers are responsible for maintaining public order and safety; enforcing laws; and preventing, detecting and investigating criminal activity. Depending on their jurisdiction and job assignment, interacting with vehicles may consume a small percentage of their time. Because of the challenging nature of their jobs, training designed to reduce the uncertainty and temper expectations surrounding ADAS- and ADS-equipped vehicles is desired. Basic training specific to ADAS- and ADS-equipped vehicles in combination with first responder interaction plans will answer questions such as these, allowing public safety personnel to focus their attention on the other demands of their job.

Moving forward it is important that developers of ADAS and ADS understand the needs of public safety providers. At the same time, public safety providers must be prepared to accept potential changes to how they carry out certain tasks. Together, automakers, technology developers and public safety providers must

communicate and coordinate, so that the rapid evolution of automated technology creates opportunities for increasing safety while decreasing uncertainty and misunderstandings.

2.2. WHAT TRAINING SHOULD BE PROVIDED?

There is significant misunderstanding among both the general public and public safety providers about the capabilities of ADAS- and ADS-equipped vehicles. Curriculum development efforts must start with the creation of a common set of definitions and expectations about ADAS and ADS capabilities. While the SAE J3016 definitions (Figure 1) should be employed to the fullest extent possible, additional resources, such as AAA's naming convention guidelines, could also be used to provide common and more understandable terminologies.

There is also a need to know what types of interactions public safety providers may have with ADAS and ADS while conducting their day-to-day duties. Terry et al. (2018) defined three types of interactions that first responders have with civilian vehicles: direct, indirect and informational, which are outlined in detail in Appendix B. Providing an understanding of these interaction types and the associated scenarios will help to reduce first responder uncertainty with these systems.

For some, ADS-related encounters may be commonplace due to current deployments in their jurisdictions. For others, ADS-related encounters may be rare or non-existent for many years. However, training on related technologies, like electric and hybrid vehicles, may have nearer-term impacts. Stakeholders interviewed for this research pointed to the need for battery-related training, such as that provided by Underwriters Laboratory and the resources compiled by the National Fire Protection Association.

Data needs were a common theme during the stakeholder discussions but were especially prevalent in the context of crash reporting and reconstruction. Data availability varies across vehicle models and situations. Training is needed to provide a better understanding of what data are available, how that data can be accessed (e.g., via the crash data recorder or a dealership service system, with or without a warrant or other legal permissions), and how that data may be interpreted. In some cases, to complete a crash reconstruction, the vehicle manufacturer may need to be consulted to understand what data are included and available.

2.3. WHERE SHOULD TRAINING BE PROVIDED?

Public safety providers have many job-related responsibilities that require specialized training, so ADAS- and ADS-related training will account for a small percentage of their training demands. Therefore, incorporating this information into existing training programs was suggested.

To ensure that all safety providers receive the same basic level of training, suggested delivery methods included academy training and/or roll call trainings. For example, most states offer Traffic Incident Management System (TIMS) training throughout the year, which could include ADAS- and ADS-related issues. Others suggested including these technologies in annual crash investigation training or, in the case of battery safety training, in conjunction with first aid training.

The ability to reach a large number of individuals through stakeholder conferences was also suggested. For example, the Crash Academy and EDR [Electronic Data Recorder] Summit is dedicated to users of EDR tools and other in-vehicle data. On a smaller scale, division updates, like those provided to volunteers on topics like hazardous materials or operator safety, allow for targeted training on the most relevant ADAS and ADS topics. Information sharing can extend beyond the conference as participants convey what they learned to their co-workers upon returning home. Also, by recording a conference session, the materials may be repurposed for webinars, expanding a training session's reach.

2.4. WHEN SHOULD TRAINING BE PROVIDED?

When a first responder may encounter ADAS- and ADS-equipped vehicles varies greatly depending on where they live and work. For example, in the short-term, Silicon Valley, California; the Capital Beltway of Virginia/Maryland; and the Phoenix, Arizona regions are more likely than more rural regions to see test deployments of ADS-equipped vehicles and market saturation of high-end, level 2+ ADAS-equipped vehicles. However, as ADAS features become more prevalent and technologies begin to proliferate, the relevance to public safety providers across the nation will increase. The AV Test Initiative (see Appendix C.3.3), in combination with outreach from manufacturers, can help educate public safety providers and the public about technology deployment and piloting in specific areas. Basic training, meant to clarify any misconceptions or misinformation, should be provided in the near-term. This training should be updated and repeated as technologies evolve. Training on specific deployments should be conducted in conjunction with public safety liaison teams prior to launch.

2.5. WHO SHOULD PROVIDE TRAINING-RELATED INFORMATION?

Many organizations were identified as potential training providers and/or sources of training materials:

- **Accreditation organizations:** The Commission on Accreditation for Law Enforcement Agencies, Inc. (CALEA), Commission on Accreditation of Allied Health Education Programs (CAAHEP), Committee on Accreditation of Educational Programs for the Emergency Medical Services Professionals, International Association of Directors of Law Enforcement Standards and Training (IADLEST)
- **Membership organizations:** Representing a wide-range of public safety providers through professional memberships that are able to offer peer-to-peer training, including AAMVA and GHSA as well as law-, fire-, EMS-, and crash reconstruction-specific organizations
- **State and local precincts and departments:** Including state Traffic Incident Management System (TIMS) working groups and State Highway Safety Offices
- **Standards organizations:** SAE International (including the SAE Automated Vehicle Safety Consortium), the International Organization for Standardization (ISO International), the National Fire Protection Association, and Underwriters Laboratories
- **Federal government initiatives:** The AV Test Initiative and other Department of Transportation webpages that may serve as an information clearinghouse

- **Academic institutions:** Those with existing training programs such as the University of North Florida's Institute for Policy Training and Management (IPTM) and Northwest University's Center for Public Safety (NUCPS) as well as those actively engaged in the testing and development of ADAS- and ADS-equipped vehicle systems including Virginia Tech and the University of Michigan

These entities were identified due to their current or potential role in providing training opportunities. Regardless of who is providing the training, it must meet the participants' needs. For example, EMS officials placed a greater emphasis on training that would count toward continuing education credits than other stakeholders. Additionally, deployment- or technology-specific training provided by an automaker or technology developer was seen as supplementing basic training provided by one of the organizations listed above.

2.6. HOW SHOULD TRAINING BE PROVIDED?

Overwhelmingly, stakeholders suggested that training be short, easy to comprehend and highly illustrated with pictures and/or videos to help public safety providers understand what to expect from technology applications. Training materials also must be engaging and convey how the public safety providers' jobs will be made easier and/or safer. This may mean providing different training based on the various roles within an agency. In addition, just as technologies are continuously evolving, so too should training materials. Rules and procedures should be viewed as living documents; they should provide current guidance while allowing for flexibility as technology evolves.

Suggested training approaches included the following:

- **Modular approach:** Start with the information that public safety providers need to know to keep road users safe and build to more advanced topics.
- **Blended training:** Use a combination of online and in-person training. Online asynchronous training will allow information to be shared with a wider range of public safety providers at times that are convenient to them. Targeted outreach can be used to share information on hot topics with leadership. Peer-to-peer training can occur at the local level, via special training sessions or shift or roll-call briefings.
- **Experiential training:** Provide hands-on training in collaboration with a technology developer to give individuals a chance to see firsthand the capabilities associated with a particular technology or deployment. Shorter videos (5-10 minutes) or a series of videos with high production value could serve as a surrogate to hands-on experiential training.

In addition to these approaches, the following opportunities for sharing information were identified:

- **A daily dispatch:** To share lessons learned in short, digestible snippets.
- **Weekly or monthly bulletins or email updates:** To share longer messages and include links to additional information.
- **Roll call/shift trainings:** Approximately 15-minute trainings that could consist of a short lecture, a 5- to 10-minute video with high production value and/or a one-page handout. Roll call trainings provide opportunities for public safety officers to ask questions and raise concerns that can be incorporated into future trainings to promote increased understanding.

2.7. BARRIERS TO EFFECTIVE TRAINING

Many barriers to effective training were noted. A significant barrier that was echoed throughout the stakeholder discussions was that with so many competing training demands, it can be difficult to know what training is needed in the short-term. Further, these needs are not uniform across the country and can vary based on anticipated technology deployment in a region. Those seeking training may find a limited number of training courses available or even a limited amount of available information on new and emerging technologies.

Once training is developed, it may be quickly outdated due to the rapid advancement of technology. Training also needs to have relevancy and immediacy to the trainee – without these two factors, any training may be met with resistance. Similarly, if the trainer or training provider is not viewed as a credible source of information, the training may not be well received.

Budgetary constraints also should be considered. Training is expensive – an agency is not just paying for the person to attend the training, but also for another person to perform the trainee's job while they are unavailable (i.e., the backfill). In rural areas, budgetary constraints may be significant, as travel to and from in-person training can be expensive. Since personnel are needed to provide coverage at all times, not all personnel will be able to attend the same training.

While email and newsletter bulletin updates were identified as information delivery methods, stakeholders also pointed out these documents can easily be ignored.

2.8. OPPORTUNITIES MOVING FORWARD

The gaps in training are discussed elsewhere in this document; however, two opportunities that emerged from the stakeholder discussions merit specific attention.

2.8.1. Identification of Departmental Champions

While it is important to train public safety providers on what to expect when interacting with an ADS-equipped vehicle (for example, when directing traffic), it is unrealistic to think that every public safety provider will have the capacity to become an ADAS or ADS subject matter expert. Rather, it is likely that, similar to drug recognition experts and crash reconstructionists, there will be officers who are specialists in this technology. These departmental champions may already be engaged with technology-related issues (e.g., a member of a highway safety committee) or, especially in smaller departments, simply have an interest in being the point-of-contact regarding ADAS and ADS technologies. Once trained, these individuals could provide peer-to-peer training within and outside their respective organizations.

2.8.2. Public Private Partnerships

Public safety provider liaison teams play an important role in the deployment of ADS technologies. These liaison teams interact with officials where technologies are deploying. These teams can help fill first responder knowledge gaps about ADS-equipped vehicle applications. Critical to filling this gap are the first responder interaction plans as described in the AVSC Best Practice for First Responder Interactions with Fleet-Man-

aged ADS-DVs (AVSC, 2020). The plans should be developed in dialogue with end user groups. Doing so will ensure that potential regional scenarios and/or concerns are considered and that questions are adequately answered. Additionally, collaborations between liaison teams and the crash reconstruction community can help provide a better understanding regarding data availability and associated technology application-specific training. Liaison teams can also facilitate hands-on training opportunities prior to a regional deployment.

3. Potential Curriculum Recommendations

Several training topics emerged during the stakeholder discussion and are presented as curriculum recommendations. Each recommended topic included below is meant to provide guidance to public safety providers about the training topics to be conveyed, along with anticipated learning outcomes. In developing the curriculum to accompany these recommendations, organizations should take into consideration the materials, resources and curriculum considerations discussed in this report Additionally, organizations will need to ensure the training that is developed takes into account their own state and local safety protocols and procedures for nuanced training situations.

3.1. UNDERSTANDING THE DIFFERENCES AND CAPABILITIES BETWEEN ADAS AND ADS TECHNOLOGIES

It is important that individuals understand ADAS and ADS technologies at a foundational level. Information to be covered should include an overview of ADAS and ADS, particularly the definitions and acronyms, which are not widely understood.

This module should provide individuals with the ability to define the characteristics of ADAS and ADS and list ways that ADAS and ADS capabilities vary.

3.2. IDENTIFYING ADAS TECHNOLOGIES ON THE ROAD TODAY

Given the competing training demands and workplace responsibilities of public safety providers, knowing when to provide training can be challenging. While the purpose of the first module is to provide a general understanding of the differences between ADAS and ADS, this module explores ADAS technologies in greater detail. As these vehicles are presently on the road, it is more likely that public safety providers will encounter an ADAS-equipped vehicle.

This module should provide individuals with the ability to list and describe basic ADAS features.

3.3. UNDERSTANDING GOVERNMENTAL RESPONSIBILITIES REGARDING VEHICLE OVERSIGHT

Vehicle oversight responsibilities at each level of government and potential expectations associated with those responsibilities are not always clear to front-line public safety providers. This module clarifies the responsibilities of federal government agencies (i.e., responsible for vehicle safety via the Federal Motor Vehicle Safety Standards) and state government agencies (i.e., responsible for the safety of the driver, driver licensing, and the enforcement of traffic laws). This module should be supplemented with relevant state and

local enforcement authority related to ADAS- and ADS-equipped vehicles (e.g., those ADS-equipped vehicles associated with non-roadway-based delivery operations).

This module should provide individuals with the ability to list and describe federal and state responsibilities regarding ADAS- and ADS-equipped vehicles.

3.4. ANTICIPATING ADAS- AND ADS-EQUIPPED VEHICLE DEPLOYMENT

This module serves to reassure individuals that, much like previous one-time novel technologies such as seat belts, air bags and cruise control, vehicles equipped with ADAS and ADS will gradually be introduced and are tools for safer travel for all roadway users. For those departments purchasing vehicles equipped with ADAS technologies, individuals should be trained on the features in their vehicles to clarify any misconceptions about their capabilities. Tools such as the U.S. DOT's AV Test Initiative (see Appendix C.3) may be consulted to check for the potential presence of ADS-equipped vehicles in their region.

This module should provide individuals with the ability to explain the features and associated capabilities included on departmental vehicles and identify any potential ADS-equipped vehicle deployments in their region.

3.5. INTERACTING WITH ADS-EQUIPPED VEHICLES

One of the common concerns encountered during this and previous research efforts (Terry, 2018), is a desire to know how and when public safety providers may interact with ADS-equipped civilian vehicles. It is important to first provide a foundational understanding of the types of interactions with ADS-equipped vehicles that should be expected (Terry, 2018; AVSC, 2020). Next, overviews of interactions with ADS-equipped vehicles specific to the operations of each public safety provider group should be provided (i.e., those interactions discussed in Appendix B). This understanding should then be supplemented with information from relevant first responder interaction plans specific to ADS-equipped vehicle operations. When possible, hands-on training opportunities should be provided.

This module should provide individuals with the ability to define the three types of interactions that first responders have with ADS-equipped civilian vehicles (direct, indirect, and informational), identify cross-cutting scenarios involving shared first responder interactions and operation specific interactions with ADS-equipped vehicles (Appendix B), and list any unique interactions as identified in first responder interaction plans.

3.6. UNDERSTANDING AND ACCESSING DATA

Data availability varies across vehicle models and situations. This module should provide an understanding of what data are available, how that data can be accessed (e.g., via the crash data recorder or a dealership service system, with or without a warrant or other legal permissions), and how that data may be interpreted (e.g., to confirm physical evidence).

This module should provide public safety responders the ability to articulate situations when a warrant may be necessary and complete a crash reconstruction using sample data.

Modules such as these, coupled with AVSC Best Practices, are expected to form a strong foundational knowledge that will provide public safety personnel confidence in their interactions with ADAS- and ADS-equipped vehicles.

4. Conclusion

ADAS- and ADS-specific training for public safety providers will help reduce uncertainty and misconceptions regarding these technologies and identify how providers may interact with them in the field. Through interviews with stakeholders, six curriculum topics, ranging from basic to more advanced information, emerged:

1. Understanding the differences between and capabilities of ADAS- and ADS-equipped vehicles
2. Identifying ADS technologies on the road today
3. Understanding governmental responsibilities regarding vehicle oversight
4. Anticipating ADAS- and ADS-equipped vehicle deployment
5. Interacting with ADS-equipped vehicles
6. Understanding and accessing data

These recommendations are presented with the understanding that ADAS and ADS technologies are continuously evolving, and training materials must be agile to accommodate future changes. The proposed curriculum recommendations provide a knowledge base surrounding ADAS- and ADS-equipped vehicle deployment for public safety providers, and identify appropriate training channels and potential barriers to training and information dissemination in a practical manner.

5. References

Ahmed-Zaid, F., Bai, F., Bai, S., Basnayake, C., Bellur, B., Brovold, S., . . . VanSickle, S. (2011). Vehicle safety communications - Applications (VSC-A) final report (DOT HS 811 492A). https://www.nhtsa.gov/sites/nhtsa.dot.gov/files/811492a.pdf

Ahrens, M., & Evarts, B. (2017). Fire department roadway and vehicle incidents. National Fire Protection Association. https://www.nfpa.org/News-and-Research/Data-research-and-tools/Emergency-Responders/Fire-Department-Roadway-and-Vehicle-Incidents

AAA. (2019). Advanced driver assistance technology names: AAA's recommendation for common naming of advanced safety systems. https://www.aaa.com/AAA/common/AAR/files/ADAS-Technology-Names-Research-Report.pdf

American Association of Motor Vehicle Administrators (2021, May). Automated delivery vehicles and devices. https://www.aamva.org/AutomatedDeliveryVehiclesAndDevicesWhitepaper-May2021/

American Association of Motor Vehicle Administrators (2020, September). Safe testing and deployment of vehicles equipped with automated driving systems guidelines, Edition 2. https://www.aamva.org/SafeTestingandDeploymentOfVehiclesEquippedwithADSGuidelines/

American Association of Motor Vehicle Administrators, Automated Vehicles Subcommittee (2019, August). Guidelines for testing drivers in vehicles with advanced driver assistance systems. https://www.aamva.org/GuidelinesforTestingDriversinVehicles with ADAS_ Final/

Anderson, J. M., Kalra, N., Stanley, K. D., & Morikawa, J. (2017). Rethinking insurance and liability in the transformative age of autonomous vehicles. RAND Corporation. https://www.rand.org/content/dam/rand/pubs/conf_proceedings/CF300/CF383/RAND_CF383.pdf

Arizona Department of Transportation. (2021, Jan.). Arizona traffic crash report forms instruction manual (12th Ed.). https://apps.azdot.gov/files/highway%20safety% 20improvement%20program/arizona-crash-forms-instruction-manual.pdf

Automated Vehicle Safety Consortium. (2020). Best practice for first responder interactions with fleet-managed automated driving system-dedicated vehicles (ADS-DVs). https://avsc.sae-itc.org/principle-5-5471WV-45187C7.html

Brewer, J., Koopmann, J., & Najm, W. G. (2011). System capability assessment of cooperative intersection collision avoidance system for violations (CICAS-V) (Report No. DOT HS 811 499). National Highway Traffic Safety Administration. https://www.nhtsa.gov/ DOT/NHTSA/NVS/Crash%20Avoidance/Technical%20Publications/2011/811499.pdf

Burt, M., Zimmer, R. E., Zink, G. J., Valentine, D. A., & Knox, W. J. J. (2014). Transit safety retrofit package development: Architecture and design specifications (Report No. FHWA-JPO-14-119). Federal Highway Administration. https://rosap.ntl.bts.gov/view/ dot/3455

California Title 13, Division 1, Chapter 1 Article 3.7 – Testing of Autonomous Vehicles (2019). https://www.dmv.ca.gov/portal/uploads/2020/06/Adopted-Regulatory-Text-2019.pdf

Casualty Actuarial Society. (2018). Automated vehicles and the insurance industry. A pathway to safety: The case for collaboration. https://www.casact.org/pubs/forum/18spforum/ CompleteSpring2018.pdf

Colorado Department of Transportation (n.d.). DR3447: The new state of the Colorado Traffic Crash Report Form. https://www.codot.gov/about/committees/strac/dr3447

Florida Department of Highway Safety and Motor Vehicles (2019, February). Uniform traffic crash report manual (HSMV 90010S). https://www.flhsmv.gov/pdf/courts/crash/ CrashManualComplete.pdf

General Motors. (2018). 2018 Self-driving safety report. http://www.gm.com/content/dam/gm/en_us/english/self-driving/gmsafetyreport.pdf

Goodison, S. E., Barnum, J. D., Vermeer, M. J. D., Woods, D., Lloyd-Dotta, T., & Jackson, B. A. (2020). Autonomous road vehicles and law enforcement: Identifying high-priority needs for law enforcement interactions with autonomous vehicles within the next five years (Document No. *RR-A108-4*). RAND Corporation. https://www.rand.org/pubs/research_reports/RRA108-4.html

Gotsch, S. (2019). Crash course: I own my car, I drive my car, I fix my car. CCC Information Services. https://collisionweek.com/wp-content/uploads/2019/03/2019-0313-FINAL-3.12-Crash-Course-2019.pdf

Gregg, A. (2019). Autonomous police vehicles: The impact on law enforcement (0704-0188). [MA in Security Studies, Naval Postgraduate School]. http://hdl.handle.net/10945/62255

Hourdos, J. (2019). How locals need to prepare for the future of V2V/V2I connected vehicles (Final Report 2019-35). Minnesota Department of Transportation. http://www.dot.state.mn.us/research/reports/2019/201935.pdf

Kansas Department of Transportation. (2019). Law enforcement crash reporting information. https://www.ksdot.org/burtransplan/prodinfo/lawinfo.asp

Khalkhali, M. (2020). Liability & insurance panel at the Autonomous Vehicle Legal Summit. In My notes from BLG's inaugural AV Legal Summit, Feb 20, 2020. medium.com.

Krafcik, J. (2020, Oct. 8). Waymo is opening its fully driverless service to the general public in Phoenix. Waymo One [Blog post]. https://blog.waymo.com/2020/10/waymo-is-opening-its-fully-driverless.html

Lamb. E. (2021, July 16). DOT officials offer overview of automated vehicle testing. *Transport Topics*. https://www.ttnews.com/articles/dot-officials-offer-overview-automated-vehicle-testing

Lebeau, P. (2018, Dec. 5). Waymo starts commercial ride-share service. CNBC. https://www.cnbc.com/2018/12/05/waymo-starts-commercial-ride-share-service.html

Lee, J. D., McGehee, D. V., Brown, T. L., & Marshall, D. C. (2008). Rear-end crash avoidance system (RECAS) algorithms and alerting strategies: Effects of adaptive cruise control and alert modality on driver performance (DOT HS 810 981). National Highway Traffic Safety Administration. https://www.nhtsa.gov/sites/nhtsa.dot.gov/files/810981.pdf

Lee, S.E., Knipling, R.R., DeHart, M.C., Perez, M.A., Holbrook, G.T., Brown, S.B., Stone, S.R., & Olson, R.L. (2004). Vehicle-based countermeasures for signal and stop sign violations: Task 1. Intersection control violation crash analyses; Task 2. Top-level system and human factors requirements (DOT HS 809 716). National Highway Traffic Safety Administration. http://www.nhtsa.gov/DOT/NHTSA/NRD/Multimedia/PDFs/Crash%20 Avoidance/2004/809-716.pdf

Lyakina, M., Heaphy, W., Konecny, V., & Kliestik, T. (2019). Algorithmic governance and technological guidance of connected and autonomous vehicle use: Regulatory policies, traffic liability rules, and ethical dilemmas. *Contemporary Readings in Law & Social Justice, 11*(2), 7. https://doi.org/10.22381/CRLSJ11220192

Mackie, T. (2018). Proving liability for highly and fully automated vehicle accidents in Australia. *Computer Law & Security Review, 34*(6), 18. https://www.sciencedirect.com/science/article/abs/pii/S026736491830356X

Marinik, A., Bishop, R., Fitchett, V., Morgan, J. F., Trimble, T. E., & Blanco, M. (2014). Human factors evaluation of level 2 and level 3 automated driving concepts: Concepts of operation (DOT-HS-812-044). National Highway Traffic Safety Administration. https://www.nhtsa.gov/sites/nhtsa.gov/files/812044_hf-evaluation-levels-2-3-automated-driving-concepts-f-operation.pdf

Maryland State Police. (2017). Automated crash reporting system: Field reference guide. https://www.nhtsa.gov/sites/nhtsa.dot.gov/files/documents/acrsfieldreference.pdf

Michigan Department of State Police (2018). UD-10 traffic crash report instruction manual. http://www.michigan.gov/crash

National Academies of Sciences, Engineering, and Medicine (2018). Implications of connected and automated driving systems. The National Academies Press. https://doi.org/10.17226/25296

National Fire Protection Association. (2017). Standard for technical rescue personnel professional qualifications. https://www.nfpa.org/codes-and-standards/all-codes-and-standards/list-of-codes-and-standards/detail?code=1006

National Highway Traffic Safety Administration. (n.d.-a). Automated vehicles for safety. https://www.nhtsa.gov/technology-innovation/automated-vehicles-safety

National Highway Traffic Safety Administration. (n.d.-b). AV TEST initiative: Test tracking tool. Automated Vehicle Transparency and Engagement for Safe Testing Initiative. https://www.nhtsa.gov/automated-vehicles-safety/av-test-initiative-tracking-tool

National Highway Traffic Safety Administration. (n.d.-c). Pedestrian automatic emergency braking. *Safety Technology.* https://www.nhtsa.gov/equipment/driver-assistance-technologies#collision-intervention-30656

National Highway Traffic Safety Administration. (n.d.-d). Vehicle-to-vehicle communication technology. https://www.nhtsa.gov/technology-innovation/vehicle-vehicle-communication

National Highway Traffic Safety Administration. (2011). USDOT connected vehicle research program vehicle-to-vehicle safety application research plan (DOT HS 811 373). https://www.nhtsa.gov/sites/nhtsa.dot.gov/files/811373.pdf

National Highway Traffic Safety Administration. (2017). MMUCC Guideline: Model Minimum Uniform Crash Criteria. 5th. https://www.nhtsa.gov/mmucc-1

National Highway Traffic Safety Administration. (2019). NHTSA announces update to historic AEB commitment by 20 Automakers [Press release]. https://www.nhtsa.gov/press-releases/nhtsa-announces-update-historic-aeb-commitment-20-automakers

National Highway Traffic Safety Administration. (2016). Federal automated vehicles policy. https://www.transportation.gov/AV/federal-automated-vehicles-policy-september-2016

National Highway Traffic Safety Administration (2021). Standing General Order 2021-01 incident reporting for Automated Driving Systems (ADS) and Level 2 Advanced Driver Assistance Systems (ADAS). https://www.nhtsa.gov/sites/nhtsa.gov/files/2021-06/Standing_General_Order_2021_01-digital-06292021.pdf

National Highway Traffic Safety Administration. (2020). U.S. Transportation Secretary Elaine L. Chao announces first participants in new automated vehicle initiative web pilot to improve safety, testing, public engagement [Press release]. https://www.nhtsa.gov/press-releases/participants-automated-vehicle-transparency-and-engagement-for-safe-testing-initiative

National Law Enforcement Memorial Fund (2019). Causes of law enforcement deaths. https://nleomf.org/facts-figures/causes-of-law-enforcement-deaths

National Safety Council. (2020). Mycardoeswhat.org [Website]. https://mycardoeswhat.org/

New Mexico Department of Transportation Traffic Records Bureau. (2019, May). Uniform crash report instruction manual. http://nmtrafficrecords.com/wp-content/uploads/Uniform-Crash-Report-Manual-2019-Final-3-2020.pdf

New Mexico Department of Transportation. (2021). New Mexico uniform crash report. http://nmtrafficrecords.com/resources/new-mexico-uniform-crash-report-2/

Ohio Department of Public Safety. (2019). Ohio crash report procedure manual (HSY 7010 6/19 [760-1337]). https://publicsafety.ohio.gov/static/HSY7010.pdf

Pennsylvania Department of. Transportation. (2020, Sept.). Police officers crash report manual. https://www.penndot.gov/TravelInPA/Safety/Documents/Pub153.pdf

Ptolemus Consulting Group. (2017). Autonomous vehicle global study. https://www.ptolemus.com/research/theautonomousvehicleglobalstudy2017/

SAE International (2021a). J3063_202103: Active safety systems terms & definitions. https://www.sae.org/standards/content/j3063_202103/

SAE International. (2021b). J3016_202104: Taxonomy and definitions for terms related to driving automation systems for on-road motor vehicles. https://www.sae.org/standards/content/j3016_202104/

SAE International. (2020). J3018_202012: Safety-relevant guidance for on-road testing of prototype Automated Driving System (ADS)-operated vehicles. https://www.sae.org/standards/content/j3018_202012/

SAE International. (2018). J3016_201806: Taxonomy and definitions for terms related to driving automation systems for on-road motor vehicles. https://www.sae.org/standards/content/j3016_201806/

Sinclair, S. (2021, Jan. 5). Guide to cars with advanced safety systems. https://www.consumerreports.org/car-safety/cars-with-advanced-safety-systems/

Stephens, D. R., Timcho, T. J., Young, E., Klein, R. A., & Schroeder, J. L. (2013, Mar.). Accelerated Vehicle-to-Infrastructure (V2I) Safety Applications Concept of Operations Document. (Report No. FHWA-JPO-13-060). Federal Highway Administration. https://rosap.ntl.bts.gov/view/dot/26500

Sweet, D. (2012). *Vehicle Extrication: Levels I & II: Principles and Practice.* Jones & Bartlett Learning. https://publish.jblearning.com/index.php?mod=jbbrowse&act=book_details&id=77

Tate, J. (2017). Trickle-down car tech. https://autonxt.net/trickle-down-car-tech/

Terry, T., Trimble, T., Buchanan-King, M., Blanco, M., Fitchett V., & Chaka, M. (2021). In pursuit of emergency procedures for automated driving system-involved scenarios. *SAE Intl. J CAV, 4*(2):151-160. https://doi.org/10.4271/12-04-02-0012.

Terry, T., Trimble, T. E., Blanco, M., Fitzsimmons, E. J., Fitchett, V. L., & Chaka, M. (2018). An examination of emergency response scenarios for ADS. Crash Avoidance Metrics Partners LLC. https://www.campllc.org/publications/

Voelk, T. (2020, October 8, 2020). New safety features in cars (or just new to you). *New York Times*. https://www.nytimes.com/2020/10/08/business/new-car-safety-features.html

Waymo. (2018). Emergency response supplement. Fully self-driving my 2017 Pacifica. 1.0. https://www.documentcloud.org/documents/4457998-Waymo-Emergency-Response-Supplement.html

Winston, C. (2020). Autonomous vehicles could improve policing, public safety, and much more. https://www.brookings.edu/blog/techtank/2020/08/25/autonomous-vehicles-could-improve-policing-public-safety-and-much-more/

Woods, J. B. (2019). Autonomous vehicles and police de-escalation. *Northwestern University Law Review, 114*(74). https://scholarlycommons.law.northwestern.edu/cgi/viewcontent .cgi?article=1272&context=nulr_online

Yoshida, J. (2020). Lack of ADAS benchmarks is haunting car industry. *Automotive Designline.* https://www.eetimes.com/lack-of-adas-benchmarks-is-haunting-car-industry/

Appendix A. Current and Future State of ADAS and ADS Technologies

A.1. CURRENT STATE OF ADAS TECHNOLOGIES

ADAS technologies are at varying states of maturity and while many of the technologies have become standard in newer vehicles, like FCW and AEB, others like lane departure warning (LDW) remain mostly optional (Sinclair, 2021). In some cases, Original Equipment Manufacturers (OEMs) will agree on the inclusion of a system as a standard feature if all indications point to a strong safety benefit. In the case of AEB systems, manufacturers agreed to equip all passenger vehicles with low-speed AEB that includes FCW by September 1, 2022. As of December 2019, four manufacturers had already met that voluntary commitment (National Highway Traffic Safety Administration [NHTSA], 2019).

The incorporation of an ADAS feature into a vehicle, whether standard or non-standard, does not guarantee maturity or robustness. The testing of ADAS features is not regulated and there are no standards for performance. NHTSA, as of the last update in 2019, has developed working drafts for confirmation tests on a number of ADAS features, including blind spot detection warnings, active park assist systems, intersection safety assist systems, pedestrian AEBs, opposing traffic safety assist, and traffic jam assist (n.d.-a). While OEMs submit their ADAS technologies to rigorous internal tests, should a federal testing standard and conformance criteria be developed, testing will need to pass external criteria as well.

ADS technology can be broken into subset classifications based on their purpose. Driver Awareness Assistance Features (DAAF) enhance a driver's awareness around the vehicle during driving. Safety warning systems (SWS) provide warnings to drivers to alert them to hazardous or potentially dangerous events ahead. Active Safety Intervention Systems (ASIS) actively intervene in the driving task to perform braking, acceleration or steering actions to avoid a hazardous event. Driving Automation Support Features (DASF) can perform part of the driving task on a sustained basis given there is human supervision and readiness to reassume operation at any time. DAAF, SWS and ASIS systems are all level 0 features that enhance the ability of a human driver to perform the driving task; these systems do not perform any automated tasks. DASF features can be level 1 or level 2, depending on the technology. The most common ADAS features are described in detail in Table 1. There are many and they continue to grow into an acronym-heavy list of features, levels and classifications that result in greater complexity for first responders and their interactions with vehicles.

Table 1: ADAS Features, Descriptions, Levels and System Classifications

Feature	Brief Description	Level	Classification
Adaptive cruise control (ACC)	Adjusts vehicle speed by detecting speed of leading vehicle (Lee et al., 2008).	1	DASF
Automatic emergency braking (AEB)	Intervenes or stops the vehicle to avoid a collision based on calculation of trajectories (Marinik et al., 2014).	0	ASIS
Blindspot monitoring system (BMS)	Provides alert to driver if vehicle is detected in blind spot (NHTSA, 2011; Ahmed-Zaid et al., 2011).	0	SWS/DAAF
Cooperative intersection collision avoidance system (CICAS)	Provides alert to driver of vehicle approaching intersection of an impending collision (Brewer et al., 2011; Hourdos, 2019; NHTSA, 2011).	0	SWS
Curve speed warning (CSW)	Provides alert to driver of vehicle approaching a curve that current speed is unsafe for the curve (Burt et al., 2014; Stephens et al., 2012).	0	SWS
Do not pass warning (DNPW)	Provides alert to driver to avoid a head-on collision due to passing maneuvers (Ahmed-Zaid et al., 2011; NHTSA, 2011; NHTSA, n.d.-d).	0	SWS
Emergency electronic brake lights (EEBL)	Provides alert to braking ahead in traffic string (Ahmed-Zaid et al., 2011; Burt et al., 2014; NHTSA, 2011; NHTSA, n.d.-d).	0	SWS/DAAF
Forward collision warning (FCW)	Provides alert to driver to take action to avoid or mitigate a rear-end collision (Ahmed-Zaid et al., 2011; Burt et al., 2014; NHTSA, 2011; NHTSA, n.d.-d).	0	SWS
Lane departure warning (LDW)	Provides alert to driver that their vehicle has left the lane of travel or provides warning to driver when leaving lane of travel is dangerous (Hourdos, 2019; NHTSA, 2011).	0	SWS

Feature	Brief Description	Level	Classification
Lane keep assist (LKA)	Maintains the center position of the lane with electronically controlled steering (Hourdos, 2019; SAE International, 2021b).	0	ASIS
Left-turn assist (LTA)	Provides warning to drivers when it is unsafe to make a left turn into an intersection (NHTSA, n.d.-d).	0	DAAF
Patrial driving automation-highway assistance	Uses combination of other ADAS systems to conduct driving task until issues occur or the operational design domain (ODD) is changed (Marinik et al., 2014; SAE International, 2021b)	2	DASF
Pedestrian Automatic Emergency Braking (PAEB)	Provides automatic braking when pedestrians are detected in the forward path of the vehicle and trajectory calculations estimate a crash (NHTSA, n.d.-c)	0	ASIS
Red light violation warning (RLVW)	Provides alert to drivers that current trajectory will result in a red light violation (Hourdos, 2019; Stephens et al., 2012).	0	SWS
Reduced speed/work zone warning (RSWZ)	Provides alert to drivers to take action (reduce speed, change lanes, remain in lane, or stop) within a work zone (Marinik et al., 2014).	0	SWS
Stop sign gap assist (SGGA)	Assists driver determine sufficient gap in vehicle string for entering an intersection (Stephens et al., 2012).	0	DAAF
Stop sign violation warning (SSVW)	Alerts drivers their trajectory will result in a stop sign violation (Lee et al., 2004).	0	SWS/DAAF
Traffic jam assist (TJA)	Provides full control of driving in congested conditions with driver supervision (Marinik et al., 2014).	2	DASF
Traffic sign recognition (TSR)	Identifies and displays upcoming traffic signs to driver (Hourdos, 2019).	0	SWS

A.2. BARRIERS FOR ADOPTION

Barriers for widespread adoption of ADAS features include cost, the slow "trickling down" of features from high-end models and lack of technical standards. LiDAR is the prime example of a technology or system hardware that is restrictive due to its current price. As is typical with most new technologies, the price is expected to drop significantly over time.

Often due to the cost of newer technologies, advanced features are reserved for the high-end models in a manufacturer's fleet. Over time, as factors such as consumer demand, safety regulations and reduced cost of implementation call for and allow it, these new technologies "trickle down" to other models. This can occur slowly in contrast to the rate of modern technology innovation especially within the automated sector (Tate, 2017; Voelk, 2020).

Many ADAS technologies, such as those that rely on infrastructure, necessitate the collaboration of multiple entities, including technology developers, automobile manufacturers, departments of transportation (DOTs) and infrastructure owners and operators. While cooperation on technology development and testing can occur relatively quickly, benchmarking and peer reviewed standards for safety metrics are less common and often vague (Khalkhali, 2020; Yoshida, 2020). Combined with the lack of standard nomenclature for ADAS, features that fail to meet certain performance requirements could lead to market confusion as expectations among consumers regarding what the various technologies are actually designed for become misaligned (Yoshida, 2020).

A.3. CURRENT STATE OF ADS TECHNOLOGY

Many vehicles on the road today are level 0 and possess no automated driving features. However, level 1 and 2 vehicles are steadily becoming more prevalent on U.S. roadways as more ADAS features become standardized (Gotsch, 2019). A global study from 2017 predicted level 2 vehicles would make up over 70% of all passenger car sales by 2025 and estimated that level 3 vehicles would be on the market that same year (Ptolemus Consulting Group, 2017).

Currently, level 5 capable vehicles do not exist, but level 4 vehicles have seen limited testing on public roadways. Waymo has been piloting a robo-taxi service, Waymo One, in Phoenix, AZ since 2018. This ride-hailing shuttle is available to the public 24-hours a day but is limited to Phoenix and the surrounding area (Lebeau, 2018). Waymo placed a safety driver in the cockpit at the beginning of the program and then phased these drivers out as the public gained more confidence in the system. In 2020, Waymo estimated that 5 to 10% of their rides in 2020 were fully driverless and are expected to be 100% driverless in the near term (Krafcik, 2020).

Law enforcement, perhaps reflecting a larger sentiment of the public, are less optimistic about the timeframe for widespread deployment. In one study, participating law enforcement officers were generally aware of geofenced deployments with shuttles and robo-taxis, but also indicated they largely did not anticipate there would be many – if any – examples of level 4 vehicles operating as a fleet or available for personal use in the next five years (Goodison et al., 2020).

As ADS-equipped vehicles with level 4 and 5 capabilities are gradually integrated into the nation's transportation system, the concept of ownership may also evolve. An expected benefit of an autonomous future includes more efficient land use reducing the need for parking, as ADS-equipped vehicles, at least initially, will be third-party owned and fleet operated (National Academies of Sciences, 2018). Gotsch (2019) predicts that as mobility options such as ride-hailing become more common, the concept of ownership will change as will the traditional concepts of new and used vehicles and the need for service, repair and rental services.

The ultimate benefit of the future ADS-equipped vehicle is the elimination of most crashes that result from human error. ADAS features are precursor technologies to ADS and are already showing promise for crash reduction and overcoming human error due to distraction or inattention. In addition to crashes, violations of traffic safety laws are expected to be greatly reduced requiring less need for enforcement. Traffic stops in general may become less necessary as licensure requirements may be eliminated and DUI laws reformed (Goodison et al., 2020; Winston, 2020; Woods, 2019). The manpower required for investigations of hit-and-run offenses and other traffic violations may be greatly reduced over time as well (Winston, 2020; Woods, 2019). In the future, due to the complex nature of the technologies in vehicles, first responders may require IT experience as part of their practical skillset (Gregg, 2019). Based on current deployment trends, these developments are not expected to be realized for some time.

A ride-hailing world where many vehicles are no longer owned or operated by people, but rather by companies and corporations, raises the question of how law enforcement, crash investigators and insurance companies will treat liability. Currently, liability is assigned based on a negligence system that basically seeks to answer which party could have done the most to prevent the incident. Many jurisdictions often rely on the judgement of on-scene law enforcement to assign fault when responding to a crash or completing a crash report. Financial accountability is then attributed to that party. It is expected that the liability system of the future will primarily be directed at manufacturers. However, exceptions to that assumption include a necessary discernment between auto liability and product liability. Discussions on this topic are necessary before widespread deployments can be efficiently managed, and there are organizations, such as the Casualty Actuarial Society, who have put forth a case for collaboration on the topic of insurance and liability sooner rather than later (2018). Guidance will need to be provided to law enforcement and crash investigators regarding how to attribute fault where no drivers are in control of the involved vehicles.

While advancements toward higher levels of automation continue and many common interactions between public safety providers and civilian vehicles are reduced, opportunities for improving the safety of those safety providers increase. ADS technology can only mitigate transportation related conflicts and crashes and cannot affect natural or man-made disasters or health-related instances that require a medical response. Therefore, continued research to identify opportunities where the safety of public safety providers and first responders will be maintained or increased is imperative as new technologies are developed and deployed.

Appendix B. Public Safety Providers Interactions Research

To identify areas where technology developers and public safety providers align or misalign, it is important to understand the general requirements for tasks where interactions between first responders and vehicles are most common. Traditionally, it has been rare for OEMs to consult with first responders or public safety experts before bringing a new vehicle technology or concept to market, but the rise of advanced vehicle technologies makes this increasingly necessary. The deployment of electric and hybrid-electric vehicles has introduced unique hazards to first responders, mainly fire and rescue teams, who may need to cut through a vehicle to extricate an occupant. Electric and hybrid-electric vehicles have different schematics for wiring than conventional vehicles, meaning certain areas of a vehicle, such as an A or B pillar, which fire and rescue teams would previously sever to gain access to the interior, are now considered dangerous. Some manufacturers, such as Waymo, for example, issued supplementary first responder guides that indicated where the vehicle's electricity was routed and instructions for disabling it (2018).

Regarding ADS technologies, several companies have recognized the need to involve public safety providers earlier in the development process. In addition to recognizing the need to educate first responders on how ADS-equipped vehicles will be expected to behave and interact (General Motors, 2018), the Crash Avoidance Metrics Partnership (CAMP) LLC has committed to funding research on the topic of first responder safety and identifying areas for improving safety through ADS development (Terry et al., 2018).

In cooperation with CAMP LLC, the Virginia Tech Transportation Institute (VTTI) and the University of Massachusetts Transportation Center (UMassSafe) collaborated on an exploratory study to identify common scenarios where first responders interacted with today's vehicles. The researchers conducted focus groups and interviews with 79 first responders from across the U.S. and Canada. First, researchers sought insight on the multiple ways a first responder may conduct a task, including all variations in traffic direction and control operations along with the impacts of weather. Questions also focused on learning what resources and/or trainings were used to determine how a task or operation is carried out. The second half of the discussions focused on how an ADS-equipped vehicle operating in driverless mode could impact each interaction subtask and identified opportunities for augmenting first responder safety.

A similar effort sponsored by the National Institute of Justice, published in 2020, focused on identifying and prioritizing the needs for law enforcement specific interactions with ADS-equipped vehicles within the next five years. The identified needs centered on cybersecurity; the cost and benefits of vehicle-to-vehicle communication options; stakeholder collaboration; and considerations for standard procedures, guidelines and training (Goodison et al., 2020).

B.1. INTERACTION TYPES AND DEFINITIONS

Terry et al. (2018) defined three types of interactions that first responders have with civilian vehicles: direct, indirect and informational. Categorizing the type of interaction allowed the researchers to create intuitive task analysis maps that illustrated the flow of information in each task and subtask.

A direct interaction is defined as any interaction where a first responder must come in physical contact with another vehicle. Examples provided include a law enforcement officer feeling the hood of an abandoned vehicle to test if the engine was running recently or a member of a fire and rescue team using a tool to cut through a vehicle's I-beam to extricate an occupant. It is generally uncommon that a task requires a first responder to come in physical contact with another vehicle.

An indirect interaction is defined as any attempt from a first responder to contact or communicate with another vehicle without physical contact. This includes the use of lights and sirens to warn vehicles in the vicinity that a first responder is en route to an emergency, or the use of hand signals, gestures and/or eye-contact to communicate with and signal a driver through an area when conducting manual traffic direction and control. Indirect interactions are common and occur primarily when a first responder needs to get the attention of a single motorist or all motorists in the vicinity

An informational interaction occurs when a first responder obtains information, either via documentation or visual affirmation, from a civilian vehicle or driver. Examples of informational interactions include the simple act of a law enforcement officer visually noting the vehicle's license plate number, a driver handing their driver's license and vehicle registration to an officer, or when a first responder attempts to determine the number of occupants in a vehicle prior to a crash to identify any occupants who may have been ejected.

B.2. SHARED FIRST RESPONDER INTERACTIONS

Terry et al. (2018) interviewed first responders from law enforcement, fire and rescue and EMS domains to determine key scenarios where first responders interacted the most with civilian vehicles. Three scenarios shared among the three domains were identified, although there are differences in how each domain may approach those scenarios:

- **Emergency response to an incident**: Any scenario where an emergency vehicle is traveling in an active emergency mode (with lights and sirens activated).
- **Securing an incident scene:** Any scenario where a first responder arrives to an incident scene and establishes a protocol to protect the involved parties from additional harm.
- **Traffic direction and control:** Any scenario where public safety personnel must manually (without the assistance of traffic lights or signs) direct or guide vehicles to a preferred travelway.

B.3. LAW ENFORCEMENT INTERACTIONS

Law enforcement and civilian vehicle interactions are expected to evolve as fleet owned and operated ADS-equipped vehicles are deployed. The study conducted by Terry et al. (2018) analyzed the following law enforcement specific scenarios for their interactions with civilian vehicles:

- **Traffic stops and checkpoints:** A scenario where a law enforcement officer intends to place a vehicle and driver in temporary detention to investigate a crime or violation.
- **Investigating abandoned or unattended vehicles:** A scenario where a law enforcement officer identifies a vehicle without occupants located in a restricted area for an amount of time dictated by ordinance or where the vehicle without occupants is located in an otherwise suspicious area. Note that other public safety personnel, such as a towing company or a safety service patrol representative may also be the first to process an abandoned or unattended vehicle; however, those industries were not represented in this study.

Goodison et al. (2020) focused their workshop discussions on traffic stops, collisions, emergencies such as detours and evacuations, and tangential interactions, such as when an ADS-equipped vehicle is evidence in an investigation. Similar to Terry et al. (2018), that study found that law enforcement prioritizes the need to distinguish and identify an ADS-equipped vehicle. The overlap of ADS-deployment with conventional vehicles on the highway system will present challenges for law enforcement, and all first responders, regarding what to expect during interactions. The ability to delineate between vehicles with varying capabilities is crucial.

Cybersecurity is also a concern for law enforcement. Law enforcement officials participating in workshops identified cybersecurity threats as a potential ADS-equipped vehicle vulnerability. Participants worry their sirens or lights could be replicated and that ADS-equipped vehicles would be at risk of hacking (Goodison et al., 2020). The methods and technology needed to facilitate communication between first responders and ADS-equipped vehicles – such as what is needed to perform a traffic stop – have not yet been defined.

B.4. FIRE AND RESCUE INTERACTIONS

Fire and rescue departments are often dispatched to roadway incidents as a precaution. Sixty-seven percent of roadway incident response involves fire and rescue services, with 21% of those incidents also requiring EMS. Much less frequent (1%) are incidents that necessitate occupant removal or extrication from a vehicle (Ahrens & Evarts, 2017). The most common direct interactions fire and rescue teams have with vehicles are during stabilization and extrication procedures. Stabilization of the vehicle is essential before extrication can be performed, so the two operations were grouped together in the research by Terry et al. (2018). They are defined as:

- **Stabilization:** The process of immobilizing a vehicle to prevent movement and create a safe environment for first responders and potential occupants (National Fire Protection Association, 2017; Sweet, 2012).

- **Extrication:** The process of removing a trapped occupant from a vehicle or machinery. Extrication is often an involved process that requires disentanglement by means of spreading, cutting and/or removing pieces and parts of a vehicle (Sweet, 2012).

B.5. CRASH REPORTING AND RECONSTRUCTION

Given the sheer number of crash reporting forms used across the U.S., a universal crash reporting system is unlikely in the near term. Nonetheless, the need to capture accurate vehicle data is essential. The data generated by ADAS- and ADS-equipped vehicles and their interactions with other vehicles will impact how the public and first responders think about and approach these new technologies. The tools used to detail scenarios where the technology-equipped vehicles perform unexpectedly and the metrics used to calculate safety performance should be concise (Wishart et al., 2020). The resulting crash reporting data combined with the vehicle data may be used to inform ongoing improvement of ADAS by the ADS development and transportation engineering communities.

B.5.1. Model Minimum Uniform Crash Reporting Criteria (MMUCC)

The August 2017 update to the Model Minimum Uniform Crash Criteria (MMUCC) included guidance for recording ADS data on crash reports and incorporated the SAE definitions. The template includes fields for law enforcement to indicate the ADS features engaged at the time of the crash (NHTSA, 2017). It is important to note that not all agencies and jurisdictions use the MMUCC, as these are voluntary guidelines used to describe a motor vehicle crash.

Table 2. Terms and Definitions Used in MMUCC (NHTSA, 2017)

Term	Definition (SAE J3016)
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.
Driver Assistance	Driver assistance system of either steering or acceleration/deceleration using information about the driving environment and with the expectation that the human driver will perform all remaining aspects of the dynamic driving task.
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 will perform all remaining aspects of the dynamic driving task.

Term	Definition (SAE J3016)
Conditional Automation	The driving mode-specific performance by an automated driving system of all aspects of the dynamic driving task with the expectation the human driver will respond appropriately to a request to intervene.
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.
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.
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	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	A notification by the ADS to a human driver that they should promptly begin or resume performance of the dynamic driving task.

In addition to the definitions, the MMUCC includes the following subfields (Figure 2) used to denote whether a crash-involved vehicle possesses an automation system(s).

Figure 2: MMUCC excerpt – DV1. Motor Vehicle Automated Driving System(s) Subfield 1

Attribute Values:

Subfield 1 **Automation System or Systems in Vehicle** **Select 1**

01 No
02 Yes
99 Unknown

Subfield 2 (Figure 3) requests information regarding the vehicle's associated level of automation. Available fields include those defined in Figure 3, as well as the option for level of automation unknown and a general "Unknown" option; the distinction between the two "unknowns" is unclear.

Figure 3: MMUCC Excerpt – DV1. Motor Vehicle Automated Driving System(s) Subfield 2

Subfield 2 **Automation System Levels in Vehicle** — **Select 1-5**

00 No Automation
01 Driver Assistance
02 Partial Automation
03 Conditional Automation
04 High Automation
05 Full Automation
06 Automation Level Unknown
99 Unknown

Subfield 3 (Figure 4) differs from Subfield 2 in that it inquires specifically about the levels of automation engaged at the time of the crash. Subfield 2 inquires only about the automated features the vehicle(s) in the crash possess or that are engageable. Below Subfield 3, the MMUCC provides the following rationale, "As motor vehicles become increasingly automated, States will have the ability to measure how the different levels of vehicle automation affect traffic safety."

Figure 4: MMUCC Excerpt – DMV1. Motor Vehicle Automated Driving System(s) Subfield 3

Subfield 3 **Automation System Levels Engaged at Time of Crash** — **Select 1-5**

00 No Automation
01 Driver Assistance
02 Partial Automation
03 Conditional Automation
04 High Automation
05 Full Automation
06 Automation Level Unknown
99 Unknown

Rationale As motor vehicles become increasingly automated, States will have the ability to measure how the different levels of vehicle automation affects traffic safety.

B.5.2. State-specific Crash Reporting Requirements

Of the 51,247 vehicles included in the 2019 Fatality Analysis Reporting System (FARS) dataset, only 29 crashes are coded as "ADS present." Looking more closely at crash reporting requirements across the country, several states were identified as attempting to track ADS-equipped vehicles via their crash reports. Though a state may not specifically record the involvement of ADS-equipped vehicles on its crash report, the information may still be captured. For example, the California Traffic Collision Report (CHP 555) does not specifically record the involvement of ADS-equipped vehicles; however, California does require additional reporting requirements for manufacturers testing automated vehicles within their state. Manufacturers are required to report any collision involving an ADS-equipped vehicle that resulted in property damage, bodily injury or death within 10 days of the incident (Title 13, Division 1, Chapter 1, Article 3.7 – Testing of Autonomous Vehicles). Other states, such as Florida, do not explicitly ask whether the vehicle is ADS-equipped, but depending on crash variables, this information may be captured on the crash report (e.g., as another source of distraction inside the vehicle; Florida Department of Highway Safety and Motor Vehicles, 2019).

With the advent of new technologies, there may be a need to update existing crash reporting forms to avoid confusion. For example, Maryland's crash report includes a driverless variable. However, the explanation for this variable indicates that the vehicle in question is a motor vehicle moving on its own with no human control, for example, when a vehicle is left in gear as opposed to park (Maryland State Police, 2017, p. 80).

Table 3. Examples of State Efforts to Track Involvement of ADS-equipped Vehicles Via State Crash Reports

State	Instruction	Clarification Provided
Arizona	Check if the vehicle has some level of automation. Check if the operator had full or partial control at the time of the crash. An option is also provided for indicating if it is unknown whether the vehicle had some type of automation at the time of the crash.	Instructions provide a definition of partial and full automation and examples.
Colorado	Enter the code that best describes the level of autonomy that the vehicle has. An option is also provided for indicating if it is unknown whether the vehicle had some type of automation at the time of the crash. The report also notes whether or not the driver surrendered control of the vehicle.	Instructions provide definitions ranging from no automation through full automation and are based on a press release announcing the USDOT's adoption of SAE International's level of automation (2018). Guidance is also offered in terms of which codes may be used when control options are surrendered.

State	Instruction	Clarification Provided
Kansas	For autonomous vehicle crashes, the person in the driver's seat is to be recorded as the driver. If the person is not in the driver's seat, it is coded as a driverless vehicle. Autonomous (self-driving) vehicles are also to be noted in the crash scenario.	For driverless vehicles, the owner information is to be recorded. The operator (not seated in the driver's seat) is included as a passenger (Kansas Department of Transportation, 2019).
Michigan	Indicate yes or no if the vehicle is equipped with an automation system(s). Record the highest level from no automation, to automation level unknown, to automation unknown. Record the highest level of automation that was engaged by the vehicle at the time of the crash.	Automation system level definitions from no automation through full automation are provided. Additional definitions are provided for the dynamic driving task, driving mode, and request to intervene. The SAE International automation system level tables are also included.
New Mexico	The New Mexico Uniform Crash Report Instruction Manual provides definitions of motor vehicle automated driving systems (New Mexico Department of Transportation Traffic Records Bureau, 2019).	Automation system level definitions from no automation through full automation are provided. Additional definitions are provided for the dynamic driving task, driving mode and request to intervene.
Ohio	Indicate the autonomous mode the vehicle was operating in at the time of the motor vehicle crash (yes, no, other/unknown). If yes is marked indicating that any part of the driving task was being performed by an autonomous system, enter the autonomous mode level the vehicle was operating in at the time of the motor vehicle crash (Ohio Department of Public Safety, 2019).	Automation system level definitions from no automation through full automation are provided. Additional definitions are provided for the dynamic driving task, driving mode, and request to intervene. The SAE International automation system level tables are also included.
Pennsylvania	Note the level of vehicle automation from no automation to partial or full automation to unknown automation level.	Partial automation is explained as meaning "…there are driver assist functions available at the time of the crash such as blind spot detection, lane departure warning, adaptive cruise control, collision avoidance braking, etc." (PennDOT, 2020, p. 10)

Appendix C. Policies and Recommended Practices for First Responders

At present, ADAS and ADS policies and recommended practices for first responders are in their infancy. The documents described in this Appendix are vague but do establish a framework to build on as the technology matures. In general, it is recommended that first responders and public safety agencies are aware, educated and prepared. Resources such as the AV TEST initiative (described below) and the National Safety Council's website mycardoeswhat.org can serve to bolster first responder and public awareness and education.

C.1. NHTSA FEDERAL AUTOMATED VEHICLE POLICY

An early step in the effort to establish a framework for future rulemaking was the "Federal Automated Vehicle Policy" published by NHTSA in 2016. As of February 2021, much of the terminology used in that initial effort is outdated, as uses of the term Highly Automated Vehicle (HAV) in place of ADS are common throughout. The Model State Policy section confirms that states will continue to retain responsibilities regarding licensure and registration, enforcing traffic laws and maintaining vehicle insurance and liability protocols. These topics have since been discussed more widely and are expected to endure change. At the time, NHTSA was aware that the complexity and novelty of new innovations likely outpaced their ability to conduct regulatory processes (2016).

Considerations for first responders, specifically law enforcement, centered on encouraging public safety personnel to understand how ADS may affect their duties. In short, as automation capabilities evolve, drivers may become more distracted. NHTSA encouraged states to work together to develop a consistent regulatory scheme to limit distraction in vehicles that provided less than "full self-driving capabilities." Additionally, states were also encouraged to consider how allocating liability among ADS owners, operators, passengers and manufacturers would occur (NHTSA, 2016).

The question of liability has been explored via discussion platforms (Anderson et al., 2017; Khalkhali, 2020) and scientific literature (Lyakina et al., 2019; Mackie, 2018; Lee et al., 2008). Currently, without fully understanding or being familiar with the nature of ADS-equipped vehicles and their technologies, it may be more difficult determining who is ultimately liable for any damages resulting from a crash than which vehicle is at fault.

C.2. NHTSA STANDING GENERAL ORDER

On June 29, 2021, NHTSA issued a "standing general order" requiring manufacturers and operators of vehicles equipped with level 2 ADAS or levels 3-5 ADS to report crashes (NHTSA, 2021). Acting NHTSA Administrator Dr. Steven Cliff noted, "that action will improve both safety and transparency by providing the agency with critical and timely data that will also be made available to the public" (Lamb, 2021). This new standing general order will have an immediate impact on those performing crash investigations.

C.3. AV TEST INITIATIVE

The Automated Vehicle Transparency and Engagement for Safe Testing (AV TEST) initiative is a formal platform for the government to share information on the testing of automated vehicles. At its inception in June 2020, nine companies and eight states signed on as participants (NHTSA, 2020). The program has grown since then, with a total of 21 states and 31 companies now participating (NHTSA, n.d.-b).

The initiative is essentially a publicly accessed tool that can be used to gather up-to-date information on automated vehicle pilots and testing being conducted across the country. The goal is to increase public awareness of ADS on-road testing, safety precautions and the principles guiding the testing. The initiative also fosters collaboration between the government and private stakeholders to ensure safe development and integration (NHTSA, 2020). Over time, NHTSA expects to expand the number of volunteer companies and states who contribute to the initiative. NHTSA also plans to host public meetings and panel discussions centered on educating the public and stakeholders as automated vehicle technology continues to evolve (n.d.-b).

C.4. SAE AUTOMATED VEHICLE SAFETY CONSORTIUM (AVSC)

The SAE Automated Vehicle Safety Consortium (AVSC) is made up of members who are actively involved in pilot testing automated vehicles with the goal of promoting their safe deployment. The consortium has developed ADS best practices and recommendations that can be accessed via avsc.sae-itc.org and are listed below:

- AVSC Best Practice for First Responder Interactions with Fleet-Managed Automated Driving System-Dedicated Vehicles (ADS-DVs) (2020)
- ACSV Best Practice for Data Collection for Automated Driving System Dedicated Vehicles to Support Event Analysis (2020)
- AVSC Best Practice for Passenger-Initiated Emergency Trip Interruption (2020)
- AVSC Best Practice for Describing an Operational Design Domain: Conceptual Framework and Lexicon (2019)
- AVSC Best Practice for Safety Operator Selection, Training, and Oversight Procedures for Automated Vehicles Under Test (2019)

The most recent, AVSC Best Practice for First Responder Interactions with Fleet-Managed Automated Driving System-Dedicated Vehicles (ADS-DVs) (AVSC, 2020) primarily leverages the interactions in research previously referenced by Terry et al. (2018). The term "dedicated vehicles" is adopted from SAEJ 3016 and refers to an ADS that does not have human controls. An ADS-equipped vehicle, regardless of level, will possess human controls onboard where an ADS-DV will not and is considered truly driverless (SAE International, 2021b). The consortium presents a framework for agencies to develop first responder interaction plans as a proactive step for establishing protocols, procedures and plans for interactions with ADS-DVs.

The AVSC defines first responder as law enforcement, fire and rescue, EMS, roadway response, and towing and recovery. The role of an ADS-DV fleet operator and a Good Samaritan are accounted for here as well. The fleet operator provides technical, operational, emergency or customer support assistance for the fleet and excludes any privately owned entity. A Good Samaritan is not considered a first responder by

definition but is any individual who is first to respond or be on scene and provide aide or assistance until public safety authorities arrive. An individual can be considered a Good Samaritan based on intent and regardless of training.

The AVSC best practice document specifies the base needs an interaction plan will require, such as a description of the operational design domain, including road type, geographical area, weather conditions, time of day, and speed range. An interaction plan should incorporate instructions, descriptions and considerations addressing disabling or de-powering, accessing required documentation, extricating passengers, safe towing, determining passenger presence, pulling over and releasing a vehicle, obtaining fleet operator contact information, and other considerations such as issues that may arise based on jurisdictional boundaries or statutes (AVSC, 2020).

C.5. AMERICAN ASSOCIATION OF MOTOR VEHICLE ADMINISTRATORS (AAMVA)

AAMVA's Autonomous Vehicle Subcommittee monitors the development, testing and piloting of automated devices and provides additional guidance. Of particular interest are the following documents that can be accessed via aamva.org and are listed below:

- Safe Testing and Deployment of Vehicles Equipped with Automated Driving Systems Guidelines, Edition 2 (2020)
- Automated Delivery Vehicles and Devices (2021)
- Guidelines for Testing Drivers in Vehicles with Advanced Driver Assistance Systems (2021)